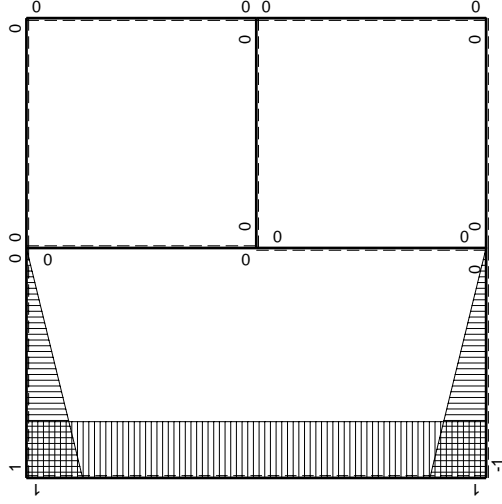


Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJdx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	$-Fb/EJ$	0	0	0	0+0	0	
CB b	0	$2Fx$	$Fb/EJ$	0	0	0			
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1			
DE b	$1-x/b$	$1/2Fb-Fx$	0	$1/2Fb-3/2Fx+Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/12+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fb-Fx$	0	$-1/2Fx+Fx^2/b$	0	$x^2/b^2$			
EF b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
FE b	0	$1/2qx^2$	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-1/4Fb+3/4Fx-1/2qx^2$	0	0	0	0	0+0	0	
BH b	0	$-1/4Fx+1/2qx^2$	0	0	0	0			
HE b	0	$1/4Fb-1/4Fx$	0	0	0	0	0+0	0	
EH b	0	$-1/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/8Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-3/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

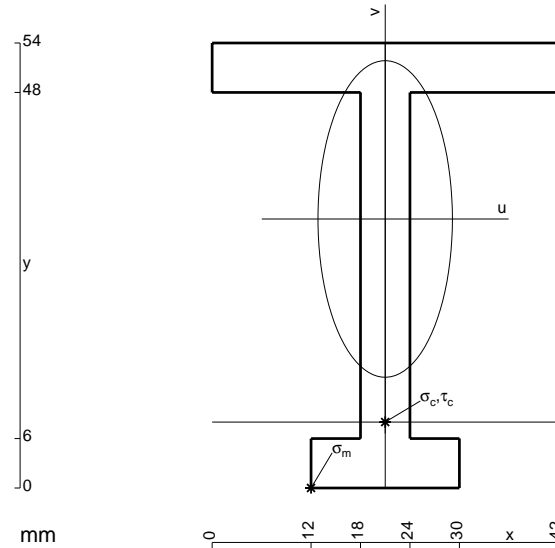
$$= (b - 1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - 3/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 3/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

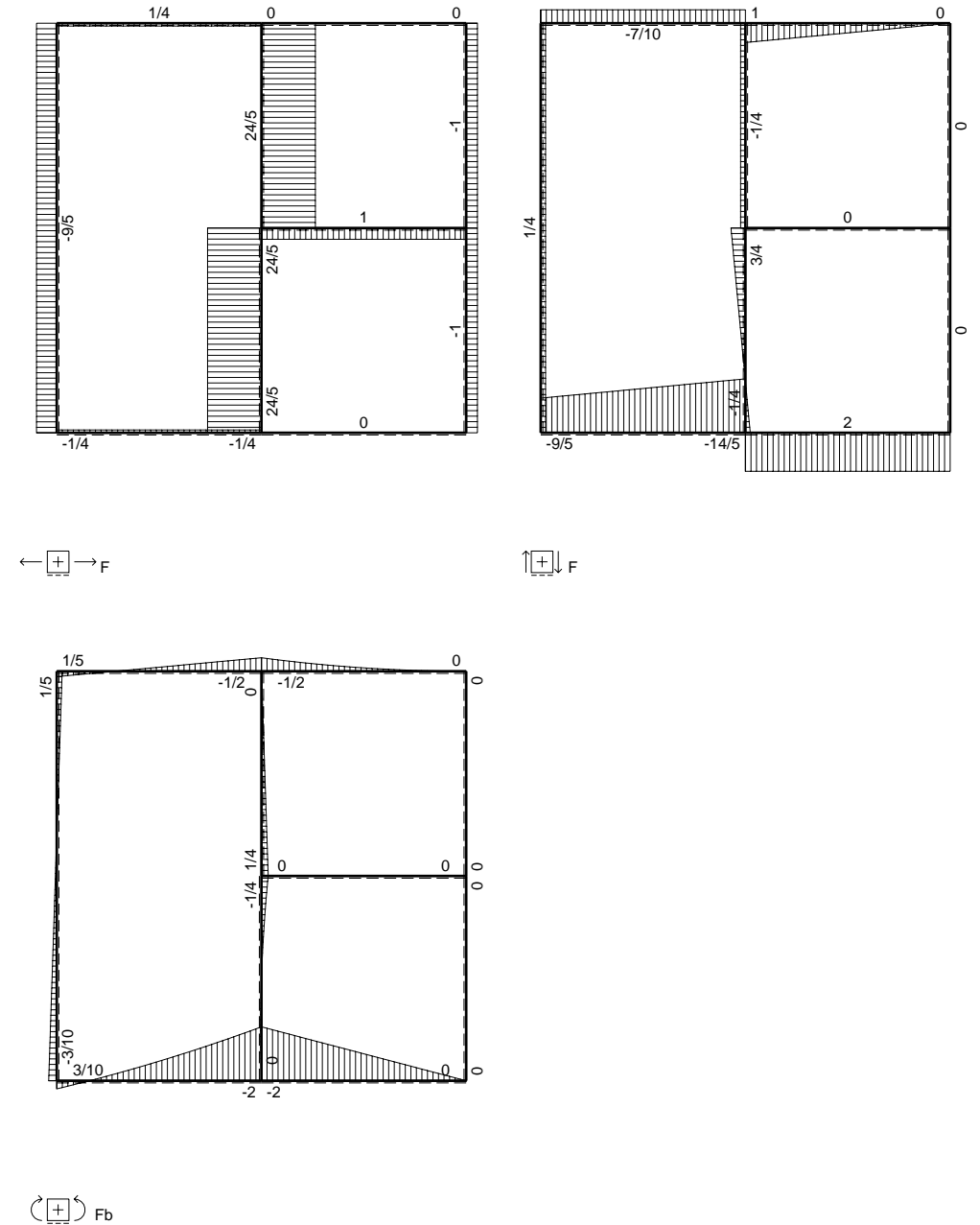
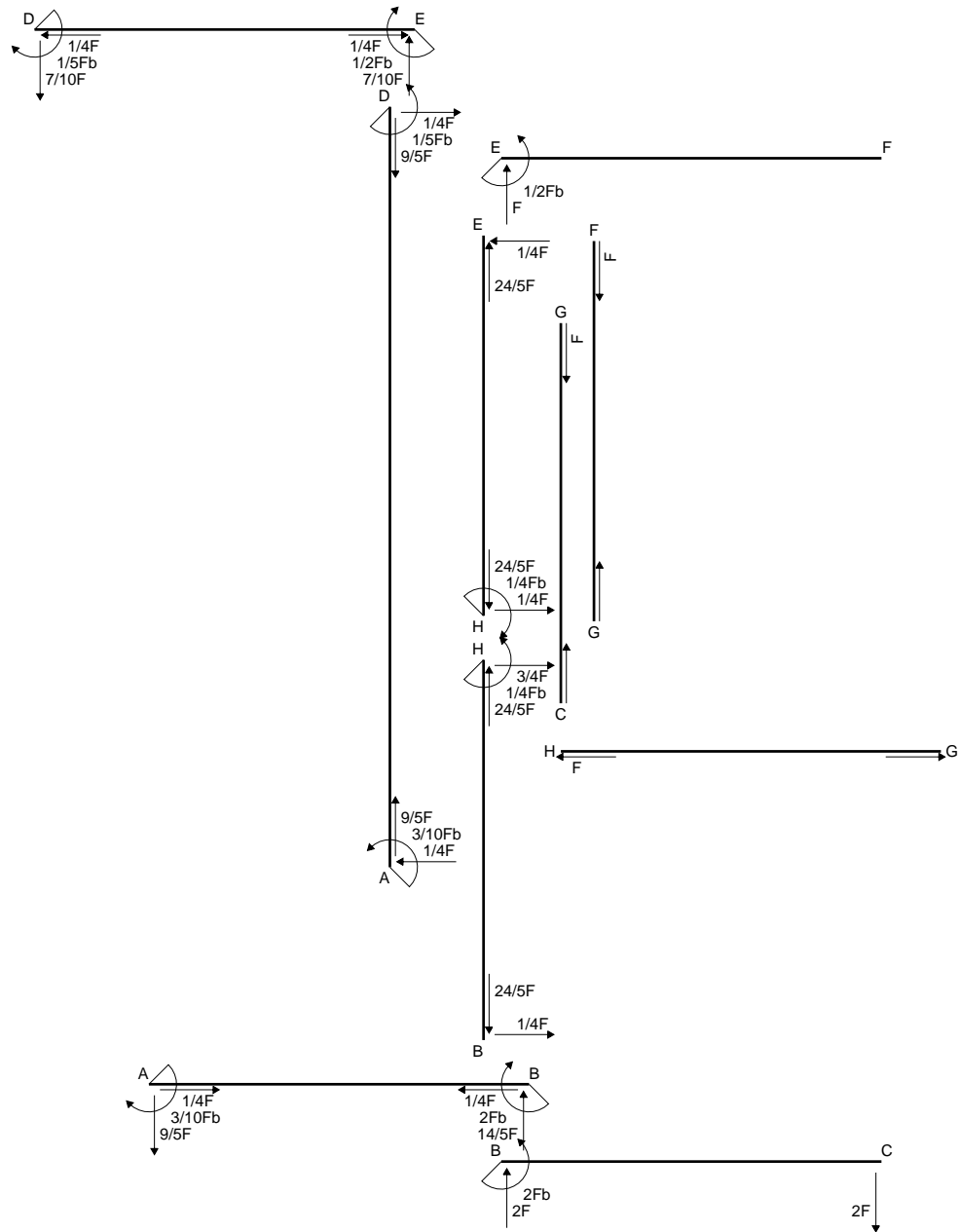
$$= (1/2 b - 3/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$

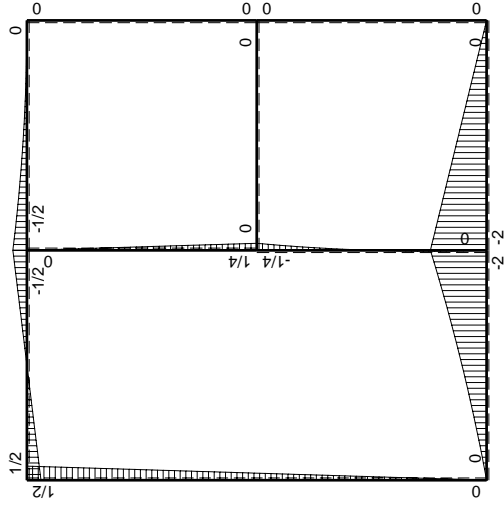
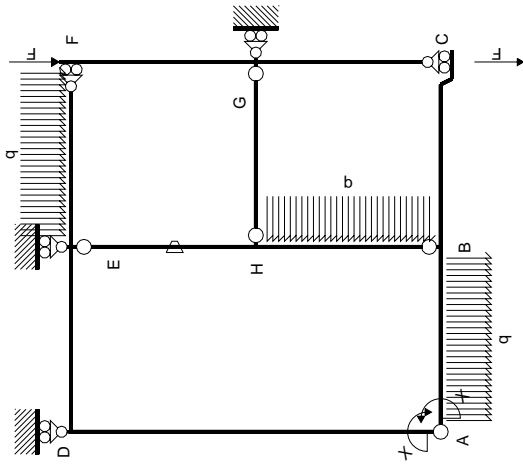
$$L_{ED}^{xo} = \int_0^b (-1/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$



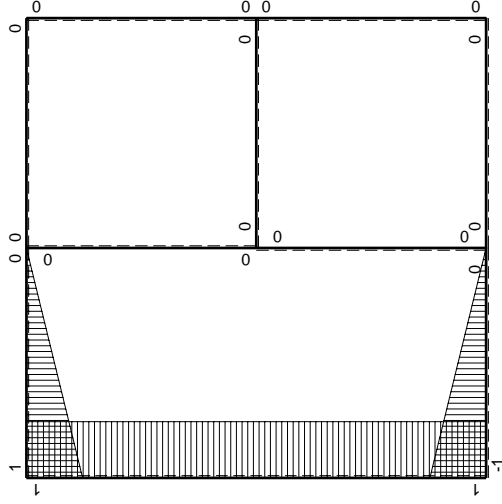
$A = 612. \text{ mm}^2$   
 $J_u = 225968. \text{ mm}^4$   
 $J_v = 40716. \text{ mm}^4$   
 $y_g = 32.65 \text{ mm}$   
 $T_y = 2740. \text{ N}$   
 $M_x = -1452200. \text{ Nmm}$   
 $x_m = 12. \text{ mm}$   
 $u_m = -9. \text{ mm}$   
 $v_m = -32.65 \text{ mm}$   
 $\sigma_m = -Mv/J_u = -209.8 \text{ N/mm}^2$   
 $x_c = 21. \text{ mm}$   
 $y_c = 8. \text{ mm}$   
 $v_c = -24.65 \text{ mm}$   
 $\sigma_c = -Mv/J_u = -158.4 \text{ N/mm}^2$   
 $\tau_c = 7.093 \text{ N/mm}^2$   
 $\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 158.9 \text{ N/mm}^2$   
 $S = 3510. \text{ mm}^3$





Schema di calcolo iperstatico

M<sub>0</sub> flessione da carichi assegnati



M<sub>x</sub> flessione da iperstatica X=1

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0
CB b	0	$2Fx$	0	0	0	0		
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1		
DE b	$1-x/b$	$1/2Fb-Fx$	0	$1/2Fb-3/2Fx+Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/12+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$1/2Fb-Fx$	0	$-1/2Fx+Fx^2/b$	0	$x^2/b^2$		
EF b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0
FE b	0	$1/2qx^2$	0	0	0	0		
FG b	0	0	0	0	0	0	0+0	0
GF b	0	0	0	0	0	0		
GC b	0	0	0	0	0	0	0+0	0
CG b	0	0	0	0	0	0		
HG b	0	0	0	0	0	0	0+0	0
GH b	0	0	0	0	0	0		
HB b	0	$-1/4Fb+3/4Fx-1/2qx^2$	0	0	0	0	0+0	0
BH b	0	$-1/4Fx+1/2qx^2$	0	0	0	0		
HE b	0	$1/4Fb-1/4Fx$	$-Fb/EJ$	0	0	0	0+0	0
EH b	0	$-1/4Fx$	$Fb/EJ$	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$7/8Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$-3/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

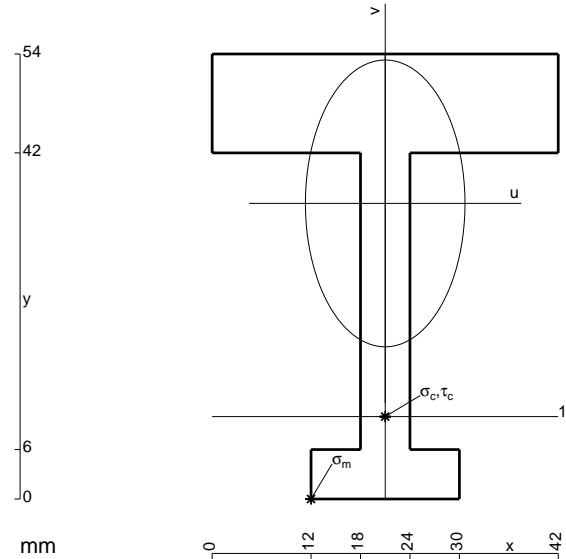
$$= (b - 1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - 3/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 3/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/2 b - 3/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$

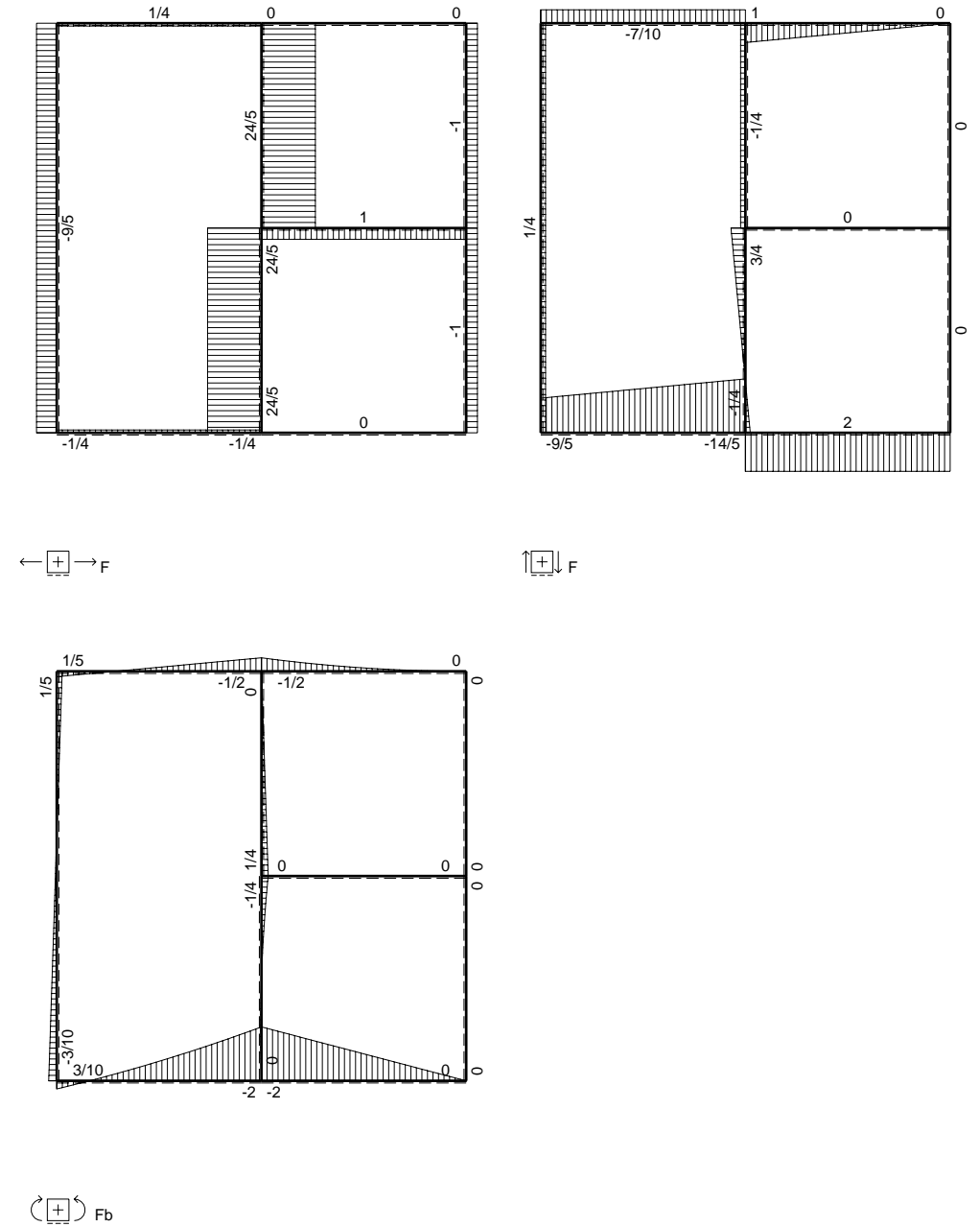
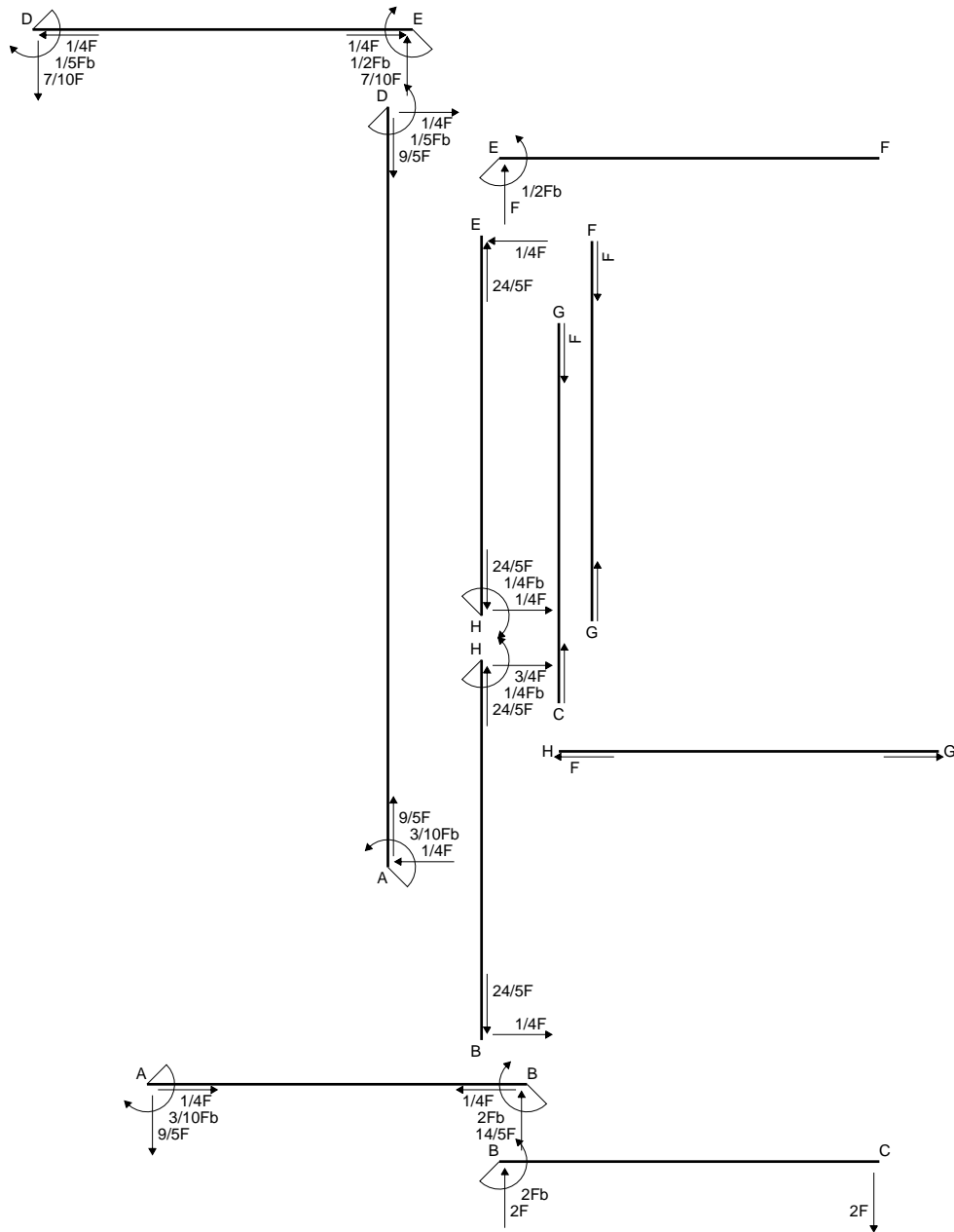
$$L_{ED}^{xo} = \int_0^b (-1/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

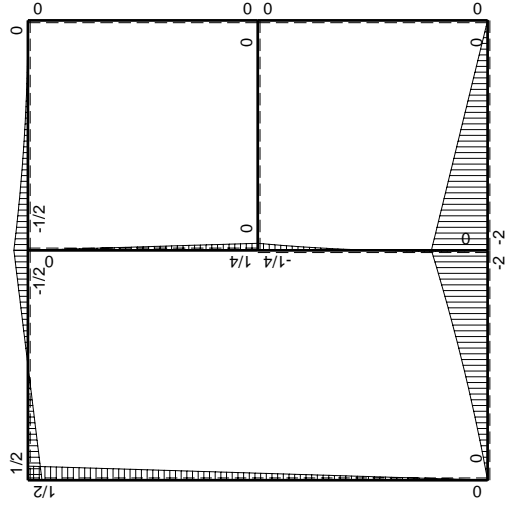
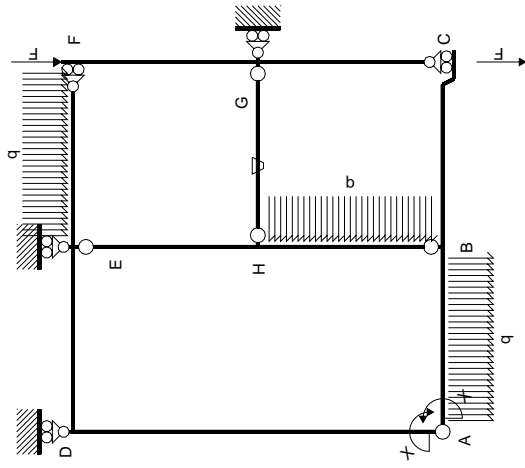
$$= (-1/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$



- A = 828. mm<sup>2</sup>
- J<sub>u</sub> = 250978. mm<sup>4</sup>
- J<sub>v</sub> = 77652. mm<sup>4</sup>
- y<sub>g</sub> = 35.87 mm
- T<sub>y</sub> = 2640. N
- M<sub>x</sub> = -1531200. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -9. mm
- v<sub>m</sub> = -35.87 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -218.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 10. mm
- v<sub>c</sub> = -25.87 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -157.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.396 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 158.3 N/mm<sup>2</sup>
- S = 4219. mm<sup>3</sup>

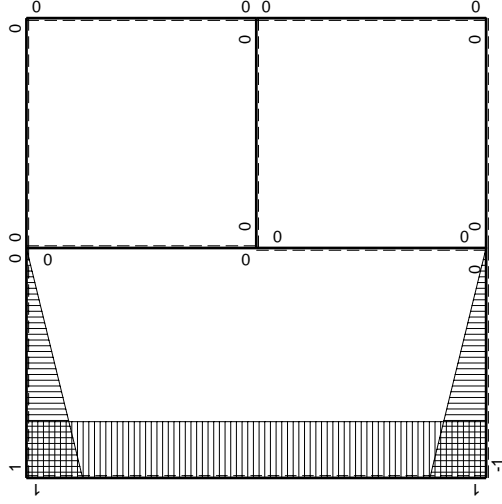






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJdx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1			
DE b	$1-x/b$	$1/2Fb-Fx$	0	$1/2Fb-3/2Fx+Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/12+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fb-Fx$	0	$-1/2Fx+Fx^2/b$	0	$x^2/b^2$			
EF b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
FE b	0	$1/2qx^2$	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
GH b	0	0	$Fb/EJ$	0	0	0			
HB b	0	$-1/4Fb+3/4Fx-1/2qx^2$	0	0	0	0	0+0	0	
BH b	0	$-1/4Fx+1/2qx^2$	0	0	0	0			
HE b	0	$1/4Fb-1/4Fx$	0	0	0	0	0+0	0	
EH b	0	$-1/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/8Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-3/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

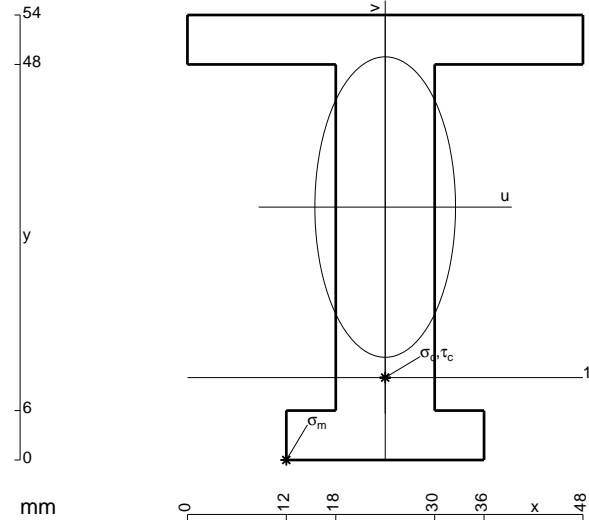
$$= (b - 1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - 3/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 3/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

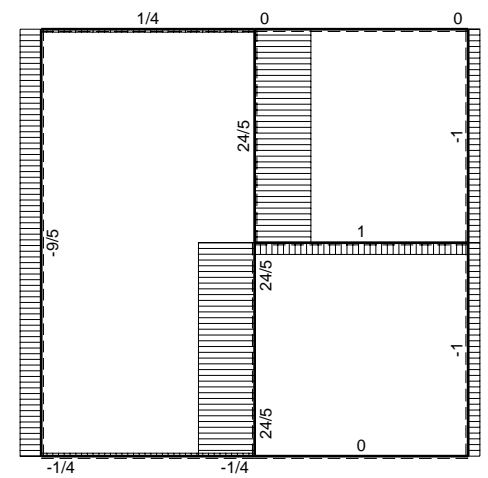
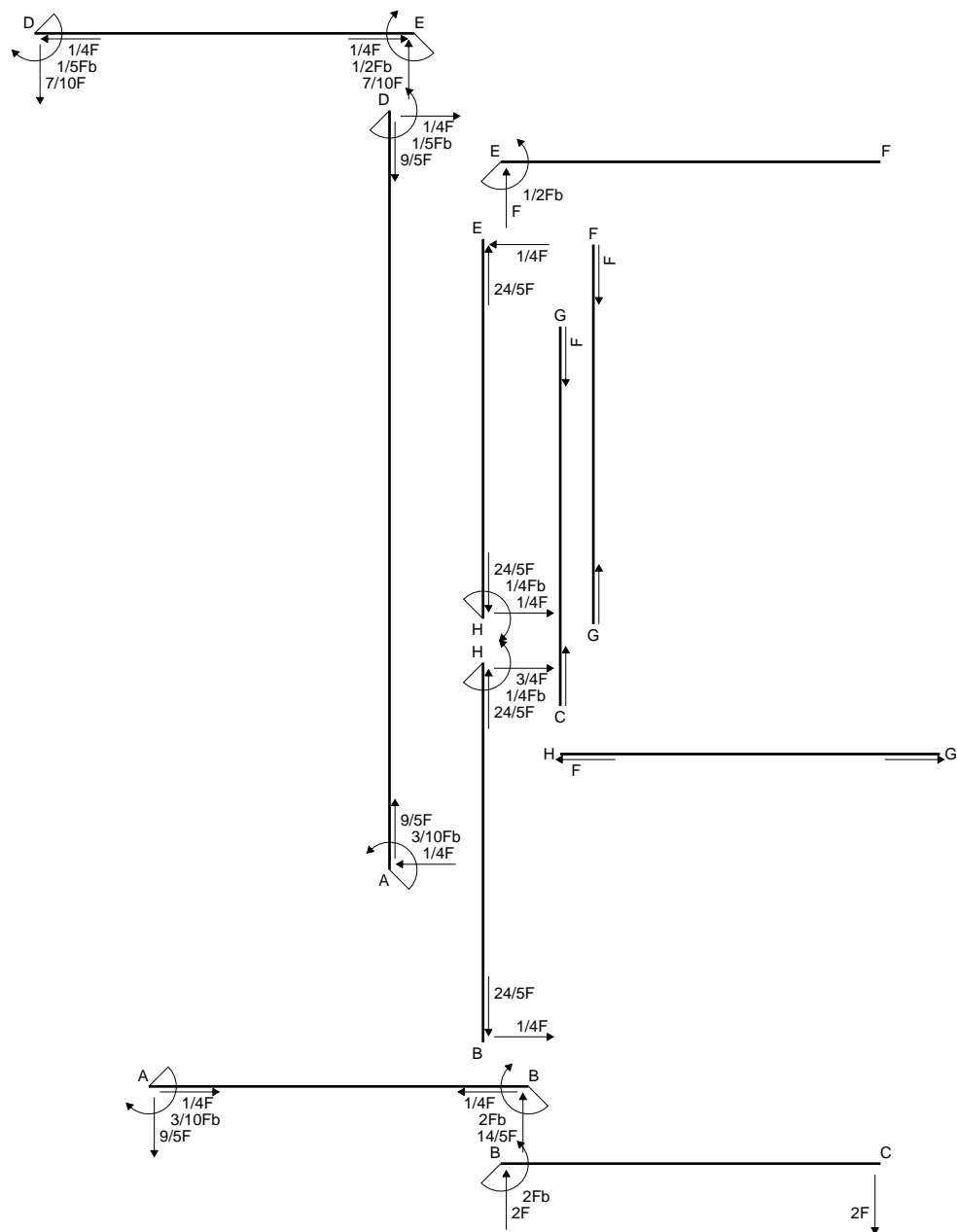
$$= (1/2 b - 3/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (-1/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

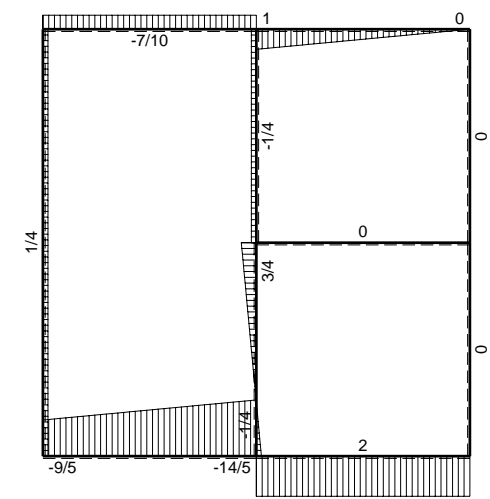
$$= (-1/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$



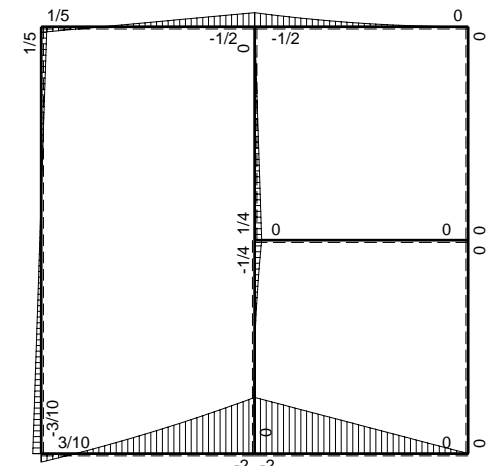
- A = 936. mm<sup>2</sup>
- J<sub>u</sub> = 311455. mm<sup>4</sup>
- J<sub>v</sub> = 68256. mm<sup>4</sup>
- y<sub>g</sub> = 30.69 mm
- T<sub>y</sub> = 3700. N
- M<sub>x</sub> = -2331000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -12. mm
- v<sub>m</sub> = -30.69 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -229.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 10. mm
- v<sub>c</sub> = -20.69 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -154.9 N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.026 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 155.1 N/mm<sup>2</sup>
- S = 5077. mm<sup>3</sup>



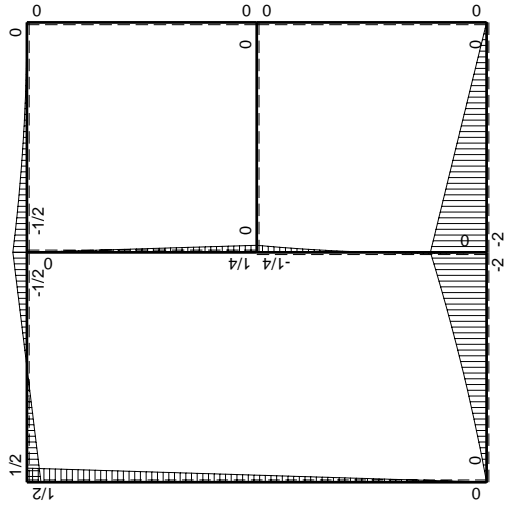
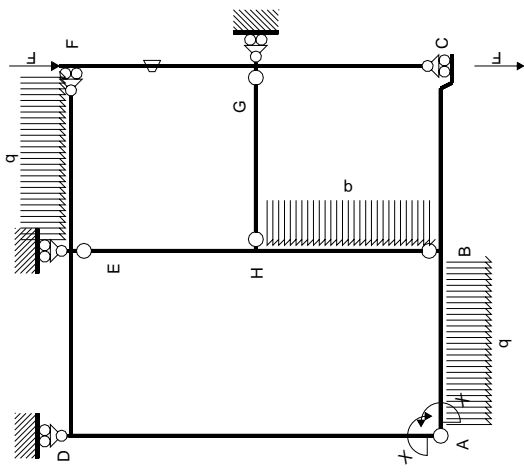
← (+) → F



↑ (+) ↓ F

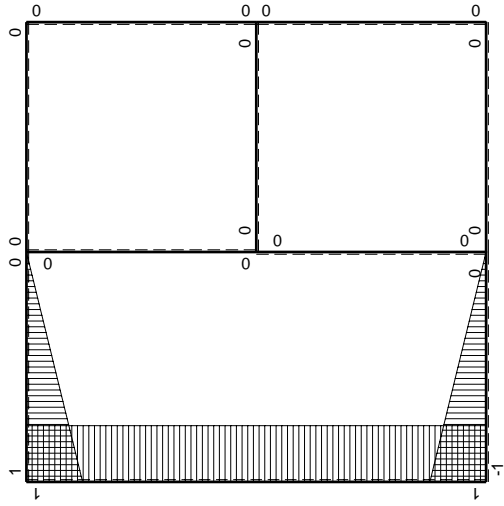


⊕ (+) ⊖ F<sub>b</sub>



Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1			
DE b	$1-x/b$	$1/2Fb-Fx$	0	$1/2Fb-3/2Fx+Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/12+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fb-Fx$	0	$-1/2Fx+Fx^2/b$	0	$x^2/b^2$			
EF b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
FE b	0	$1/2qx^2$	0	0	0	0			
FG b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
GF b	0	0	$Fb/EJ$	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-1/4Fb+3/4Fx-1/2qx^2$	0	0	0	0	0+0	0	
BH b	0	$-1/4Fx+1/2qx^2$	0	0	0	0			
HE b	0	$1/4Fb-1/4Fx$	0	0	0	0	0+0	0	
EH b	0	$-1/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/8Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-3/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

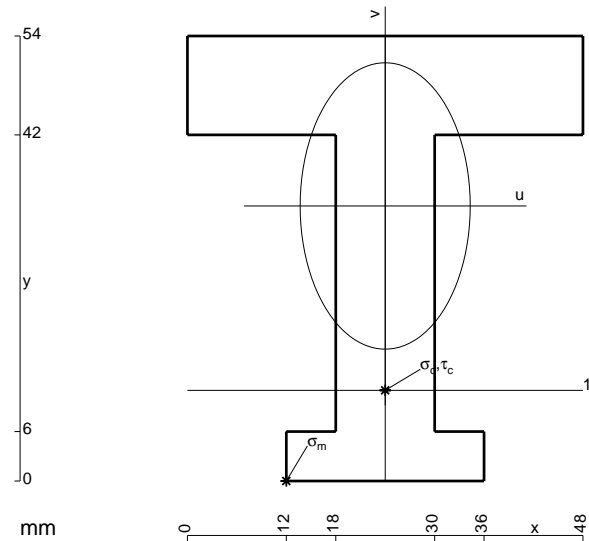
$$= (b - 1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - 3/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 3/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/2 b - 3/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$

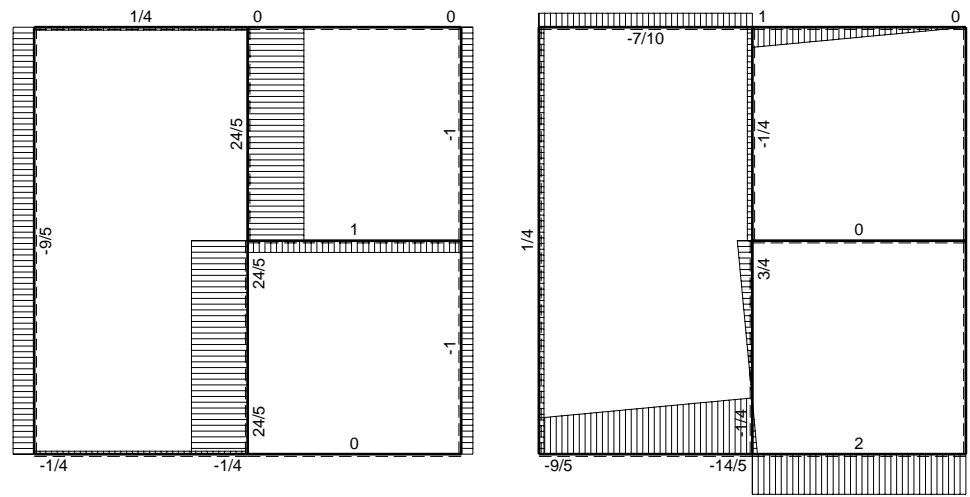
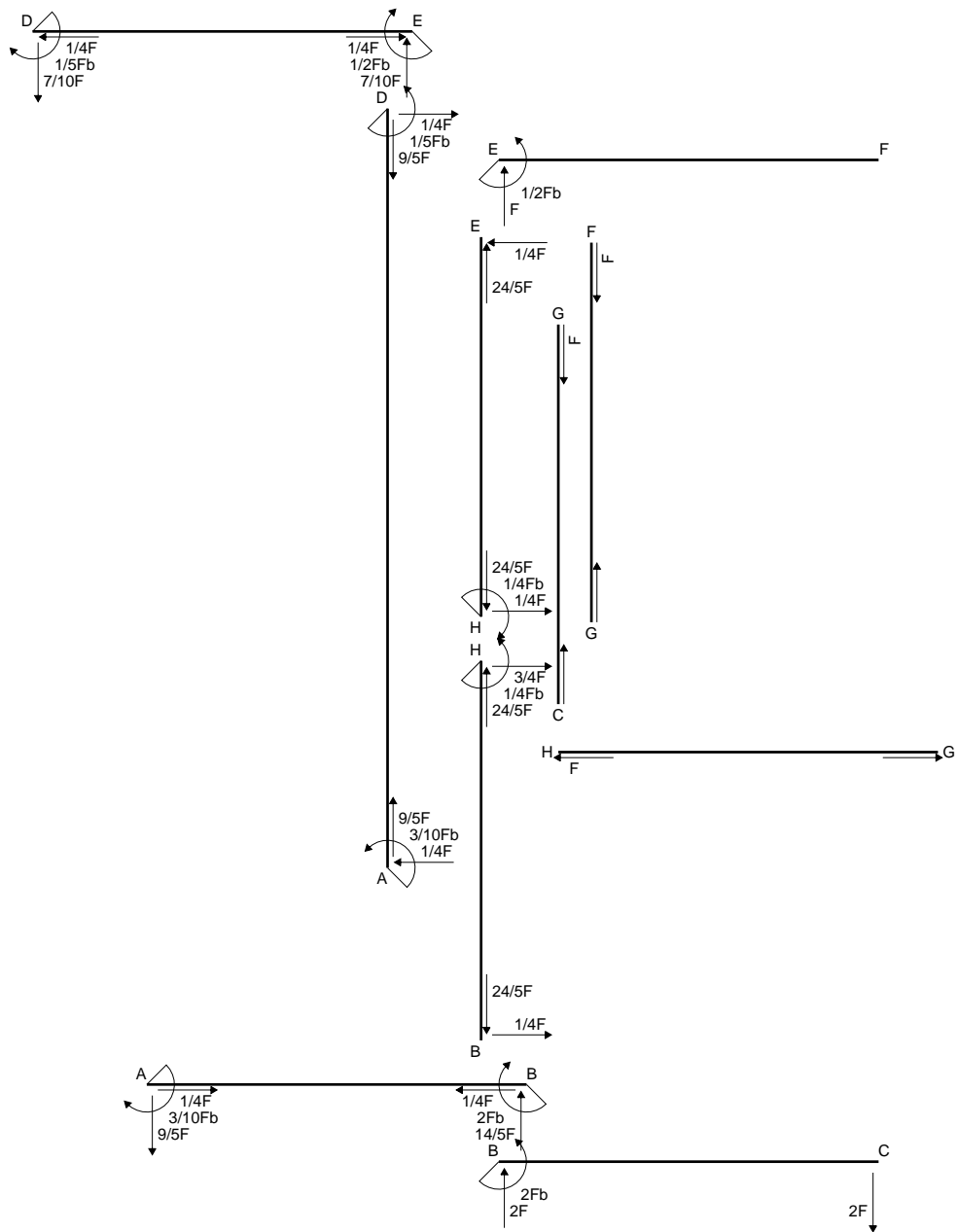
$$L_{ED}^{xo} = \int_0^b (-1/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$



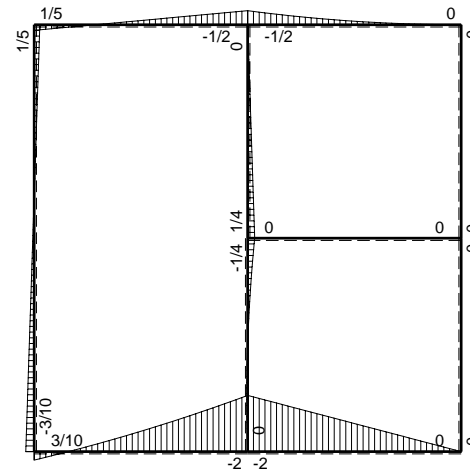
- A = 1152. mm<sup>2</sup>
- J<sub>u</sub> = 348030. mm<sup>4</sup>
- J<sub>v</sub> = 122688. mm<sup>4</sup>
- y<sub>g</sub> = 33.38 mm
- T<sub>y</sub> = 3680. N
- M<sub>x</sub> = -2502400. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -12. mm
- v<sub>m</sub> = -33.38 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -240. N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 11. mm
- v<sub>c</sub> = -22.38 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -160.9 N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.169 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 161.1 N/mm<sup>2</sup>
- S = 5867. mm<sup>3</sup>



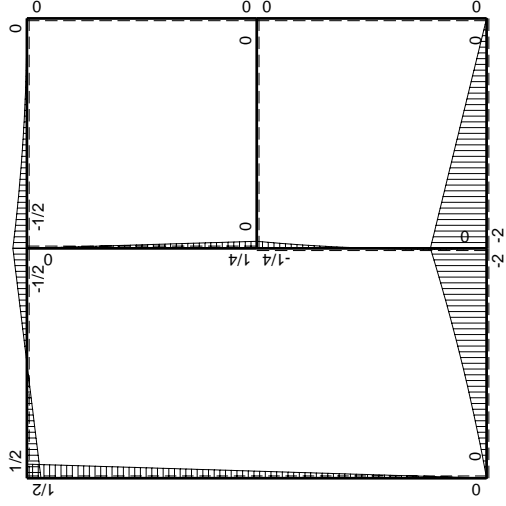
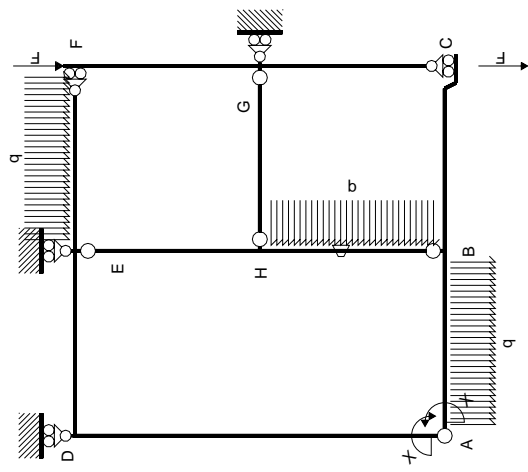


← ⊕ → F

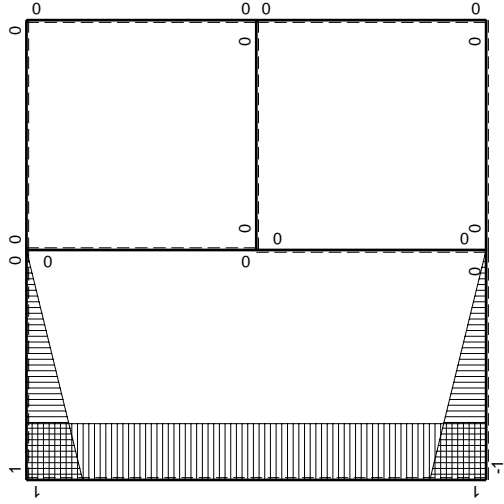
↑ ⊕ ↓ F



⊕ ⊖ Fb



Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati

$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int X M_x M_x/EJdx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1			
DE b	$1-x/b$	$1/2Fb-Fx$	0	$1/2Fb-3/2Fx+Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/12+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fb-Fx$	0	$-1/2Fx+Fx^2/b$	0	$x^2/b^2$			
EF b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
FE b	0	$1/2qx^2$	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-1/4Fb+3/4Fx-1/2qx^2$	$-Fb/EJ$	0	0	0	0+0	0	
BH b	0	$-1/4Fx+1/2qx^2$	$Fb/EJ$	0	0	0			
HE b	0	$1/4Fb-1/4Fx$	0	0	0	0	0+0	0	
EH b	0	$-1/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/8Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-3/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

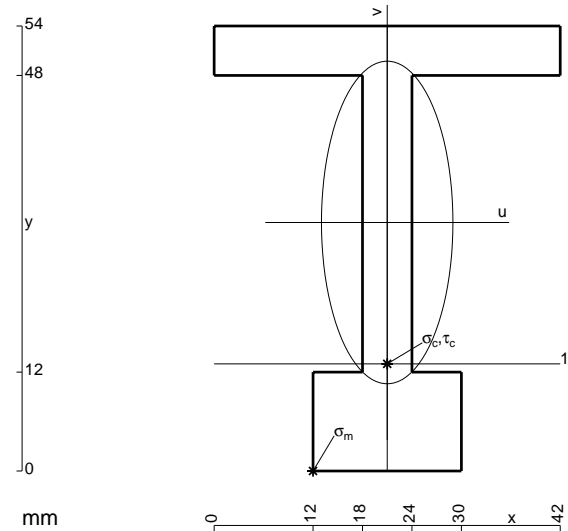
$$= (b - 1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - 3/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 3/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

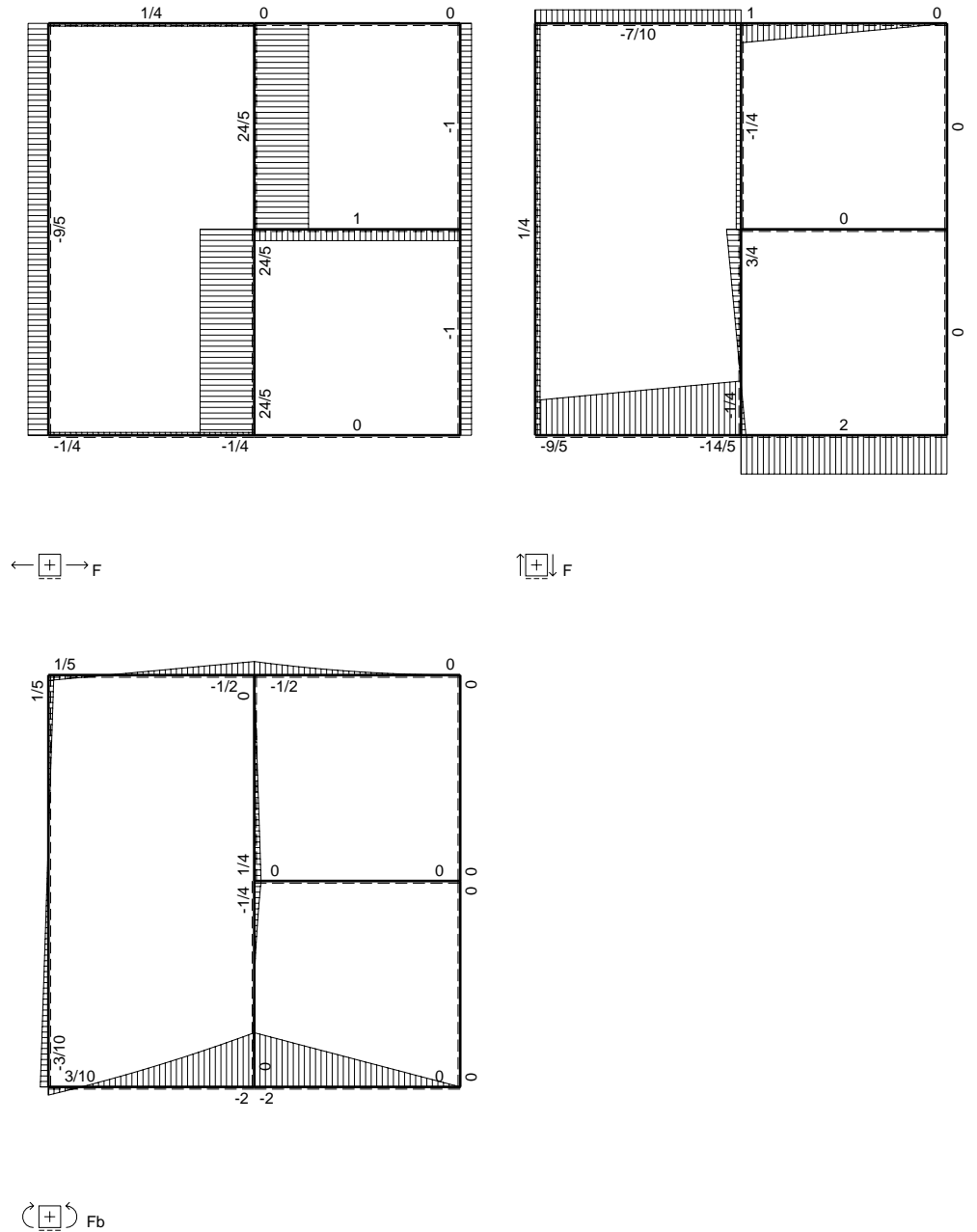
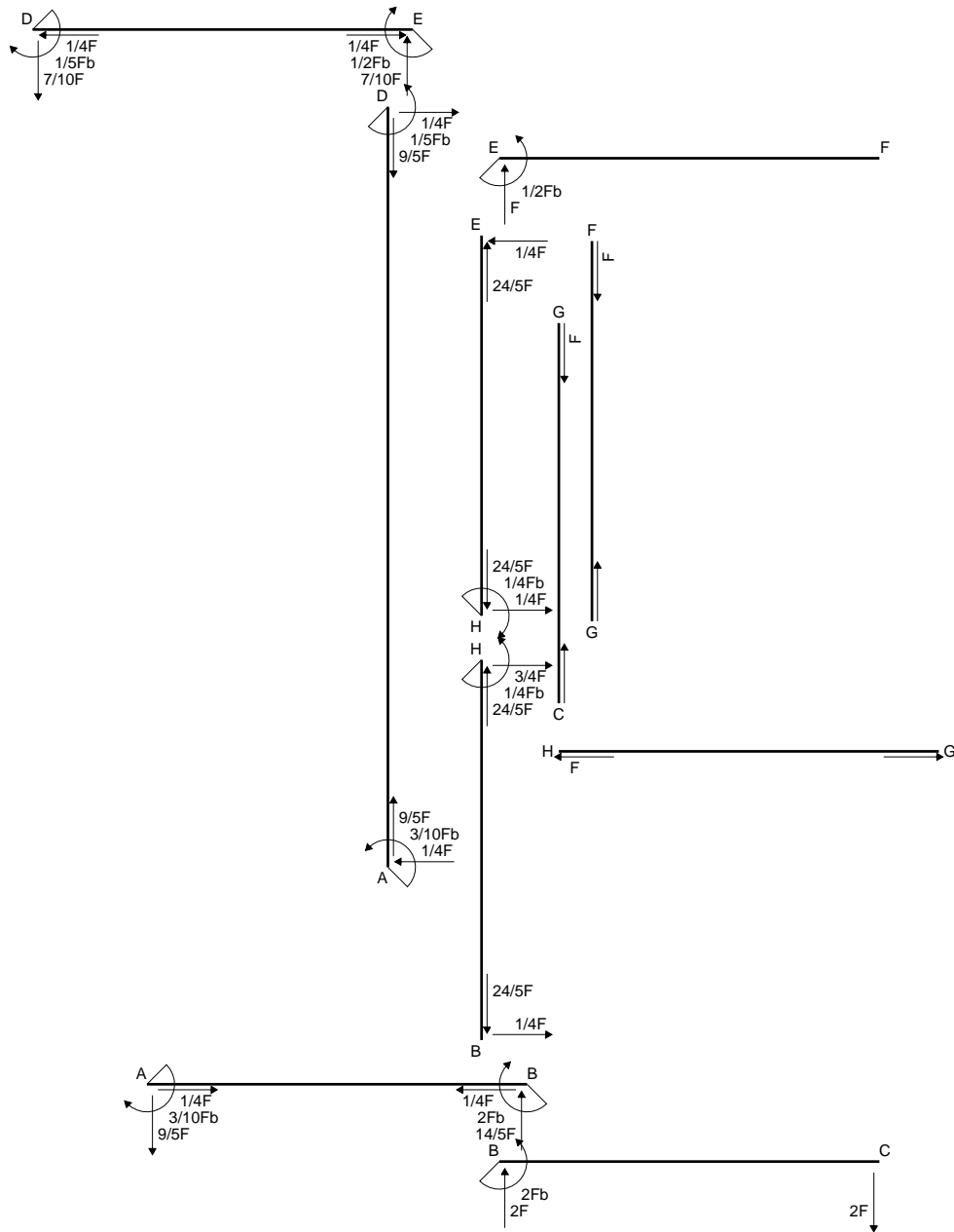
$$= (1/2 b - 3/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$

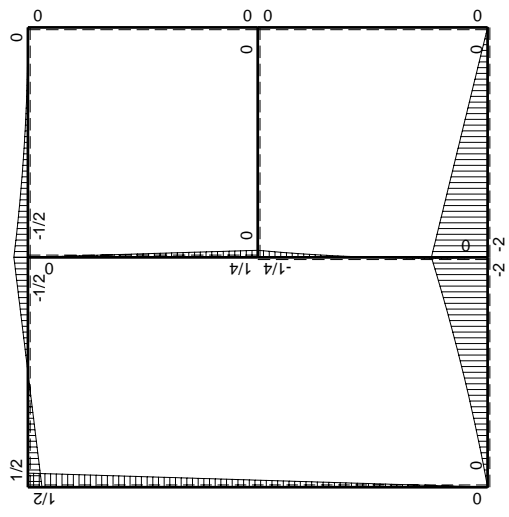
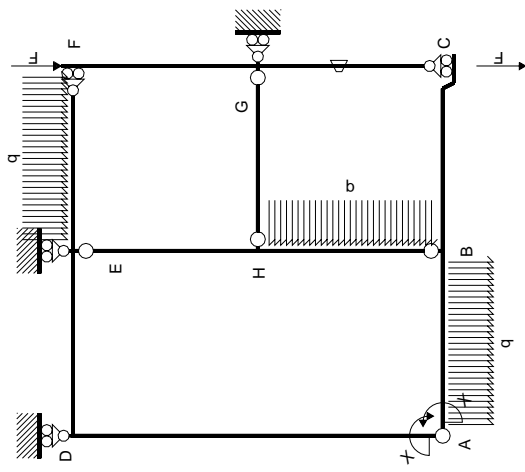
$$L_{ED}^{xo} = \int_0^b (-1/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$



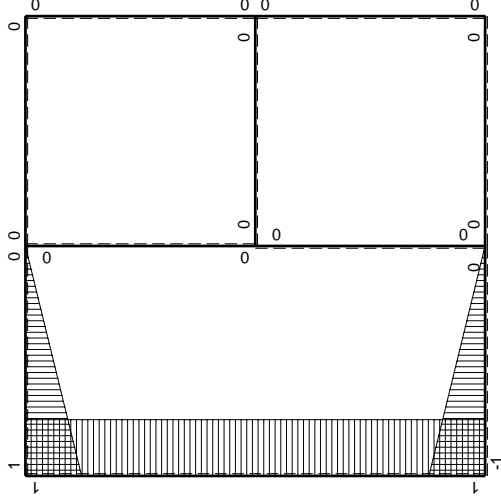
$A = 684. \text{ mm}^2$   
 $J_u = 262207. \text{ mm}^4$   
 $J_v = 43524. \text{ mm}^4$   
 $y_g = 30.16 \text{ mm}$   
 $T_y = 2380. \text{ N}$   
 $M_x = -1737400. \text{ Nmm}$   
 $x_m = 12. \text{ mm}$   
 $u_m = -9. \text{ mm}$   
 $v_m = -30.16 \text{ mm}$   
 $\sigma_m = -Mv/J_u = -199.8 \text{ N/mm}^2$   
 $x_c = 21. \text{ mm}$   
 $y_c = 13. \text{ mm}$   
 $v_c = -17.16 \text{ mm}$   
 $\sigma_c = -Mv/J_u = -113.7 \text{ N/mm}^2$   
 $\tau_c = 8.054 \text{ N/mm}^2$   
 $\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 114.5 \text{ N/mm}^2$   
 $S = 5324. \text{ mm}^3$





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJdx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1			
DE b	$1-x/b$	$1/2Fb-Fx$	0	$1/2Fb-3/2Fx+Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/12+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fb-Fx$	0	$-1/2Fx+Fx^2/b$	0	$x^2/b^2$			
EF b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
FE b	0	$1/2qx^2$	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
CG b	0	0	$Fb/EJ$	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-1/4Fb+3/4Fx-1/2qx^2$	0	0	0	0	0+0	0	
BH b	0	$-1/4Fx+1/2qx^2$	0	0	0	0			
HE b	0	$1/4Fb-1/4Fx$	0	0	0	0	0+0	0	
EH b	0	$-1/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/8Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-3/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

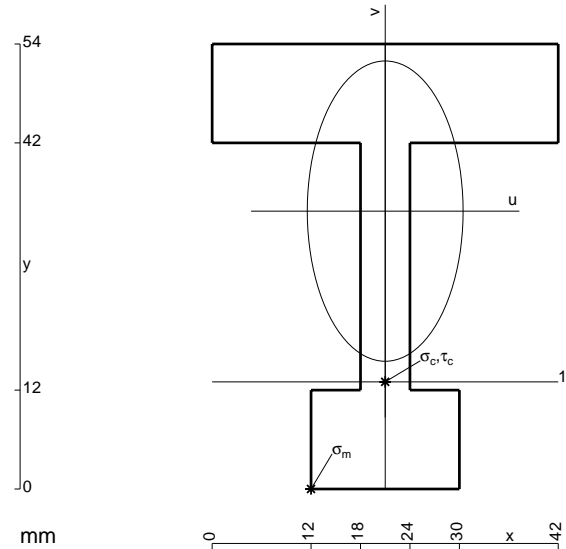
$$= (b - 1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - 3/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 3/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/2 b - 3/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$

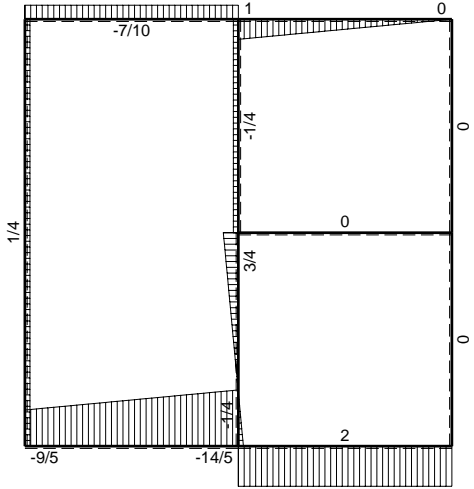
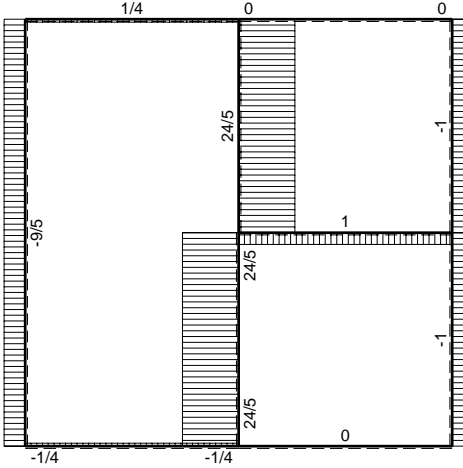
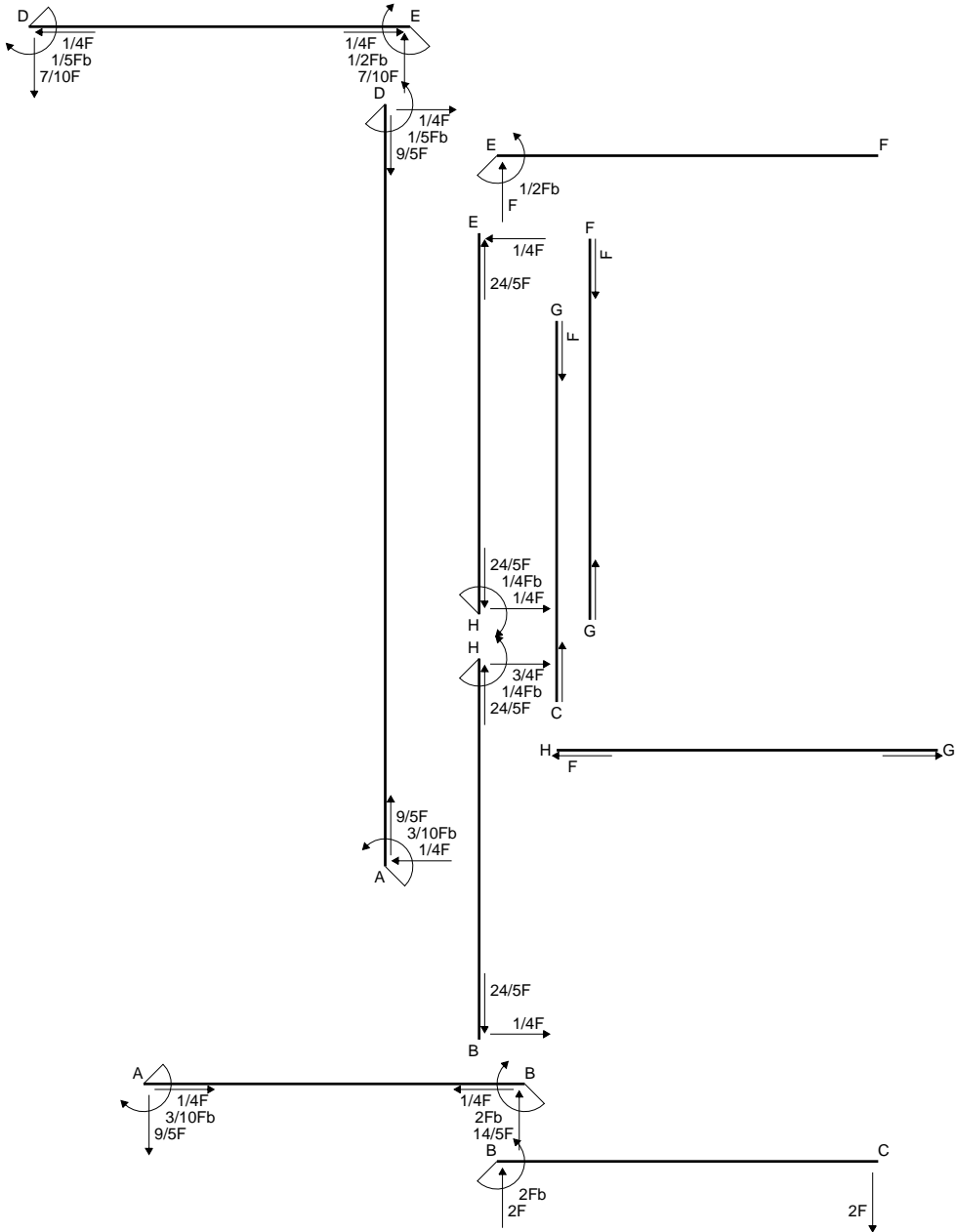
$$L_{ED}^{xo} = \int_0^b (-1/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$



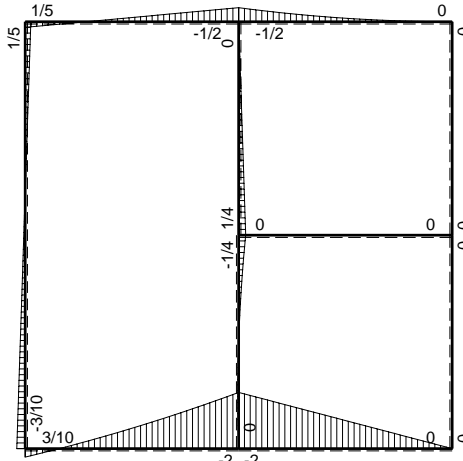
- A = 900. mm<sup>2</sup>
- J<sub>u</sub> = 299017. mm<sup>4</sup>
- J<sub>v</sub> = 80460. mm<sup>4</sup>
- y<sub>g</sub> = 33.72 mm
- T<sub>y</sub> = 2380. N
- M<sub>x</sub> = -1856400. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -9. mm
- v<sub>m</sub> = -33.72 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -209.3 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 13. mm
- v<sub>c</sub> = -20.72 mm
- σ<sub>c</sub> = -Mv/J<sub>v</sub> = -128.6 N/mm<sup>2</sup>
- τ<sub>c</sub> = 8.112 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 129.4 N/mm<sup>2</sup>
- S = 6115. mm<sup>3</sup>



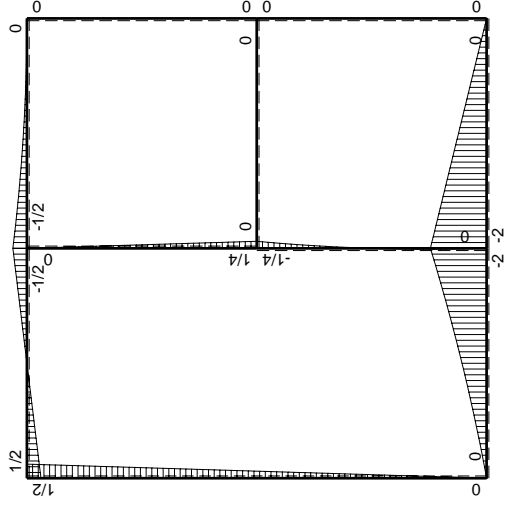
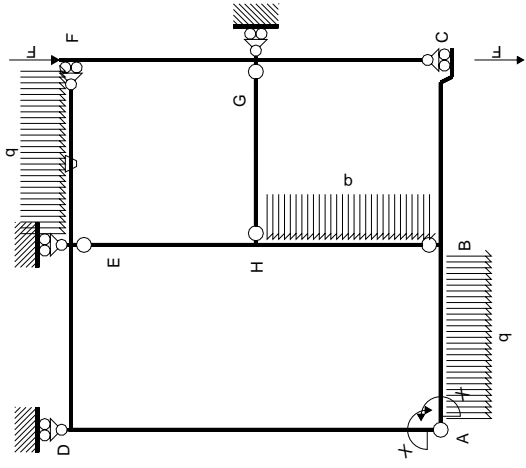


← ⊕ → F

↑ ⊕ ↓ F

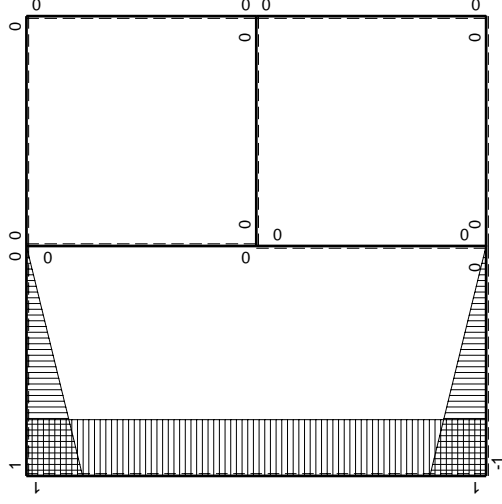


⊕ ⊖ Fb



Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJdx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1			
DE b	$1-x/b$	$1/2Fb-Fx$	0	$1/2Fb-3/2Fx+Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/12+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fb-Fx$	0	$-1/2Fx+Fx^2/b$	0	$x^2/b^2$			
EF b	0	$-1/2Fb+Fx-1/2qx^2$	$-Fb/EJ$	0	0	0	0+0	0	
FE b	0	$1/2qx^2$	$Fb/EJ$	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-1/4Fb+3/4Fx-1/2qx^2$	0	0	0	0	0+0	0	
BH b	0	$-1/4Fx+1/2qx^2$	0	0	0	0			
HE b	0	$1/4Fb-1/4Fx$	0	0	0	0	0+0	0	
EH b	0	$-1/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/8Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-3/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{x_0} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{x_0} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{x_0} = \int_0^{2b} (1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{x_0} = \int_0^{2b} (1/2 - 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

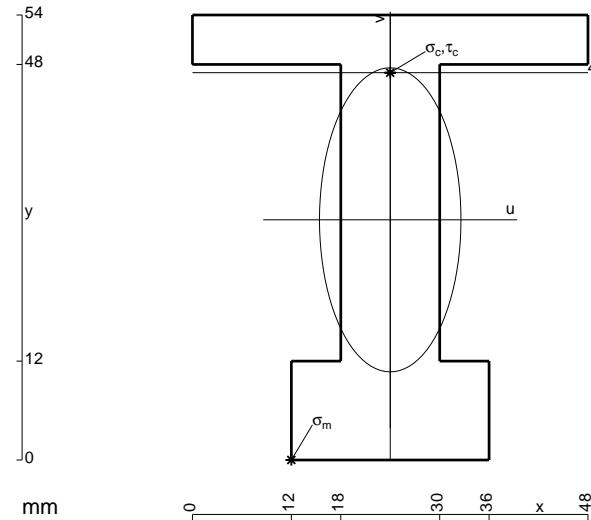
$$= (b - 1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{x_0} = \int_0^b (1/2 - 3/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 3/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

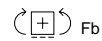
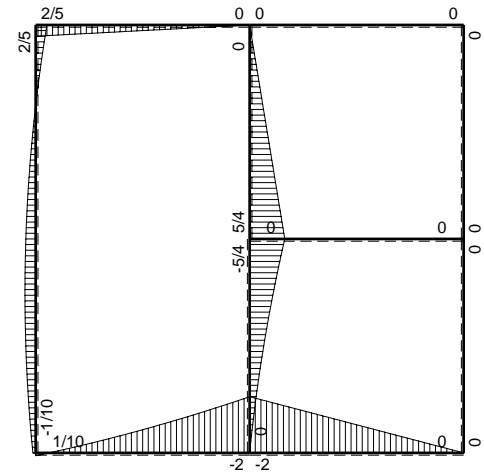
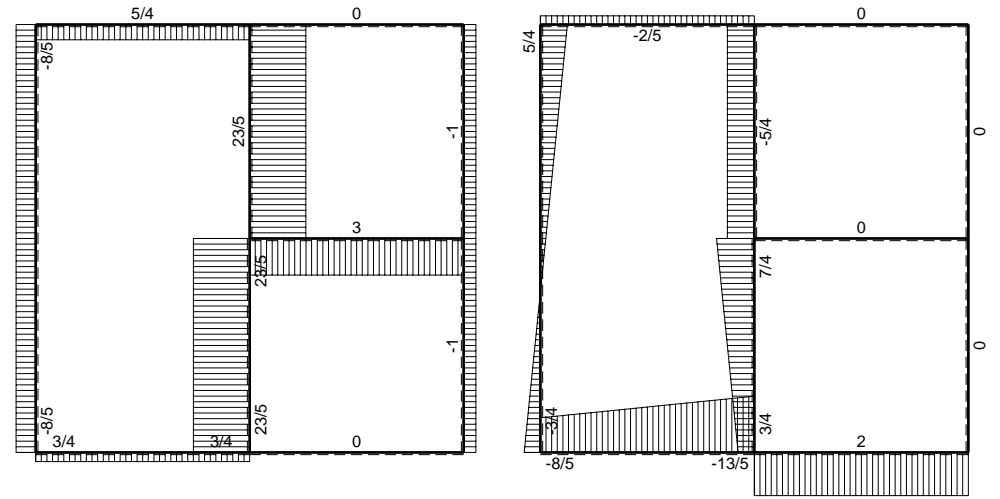
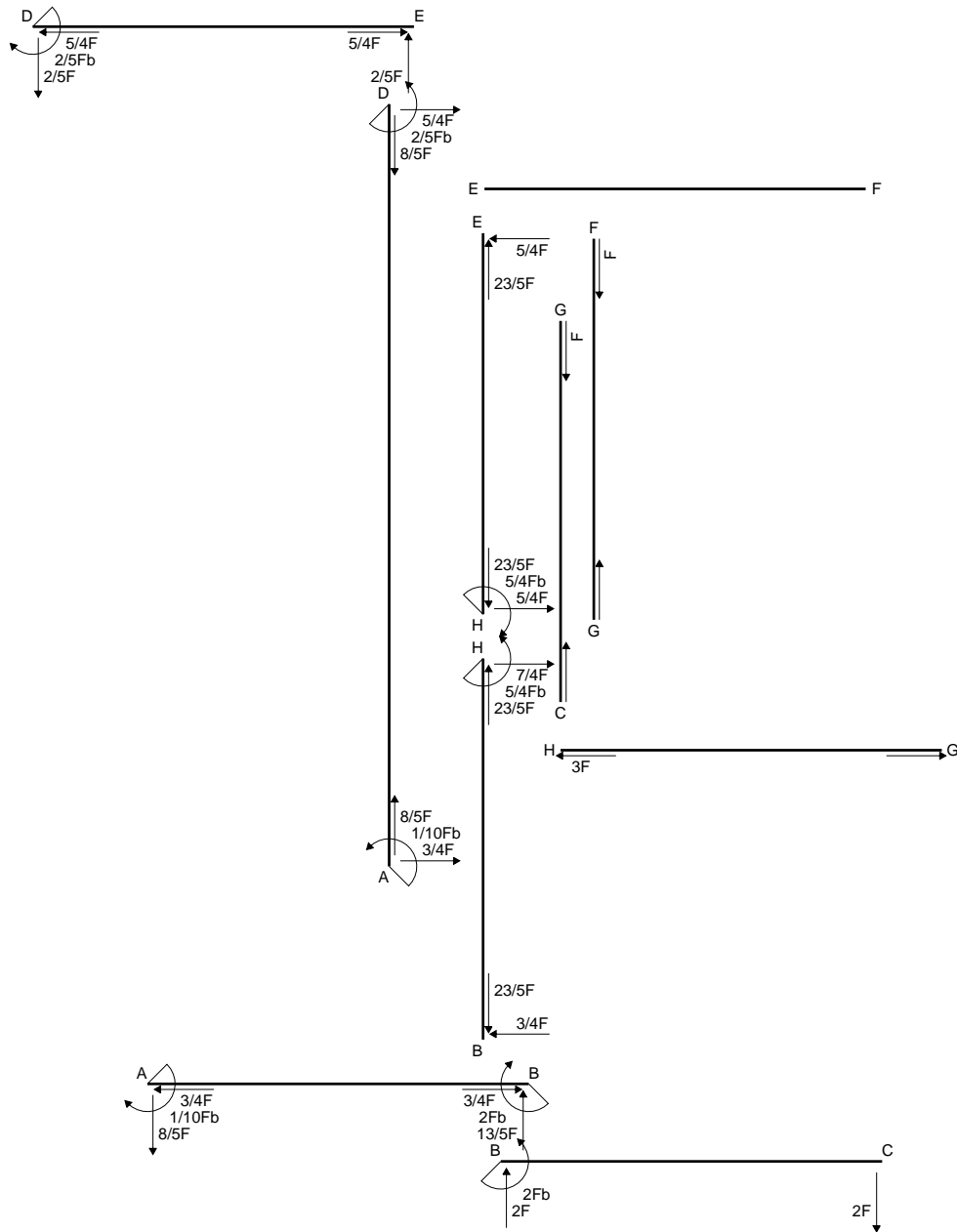
$$= (1/2 b - 3/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$

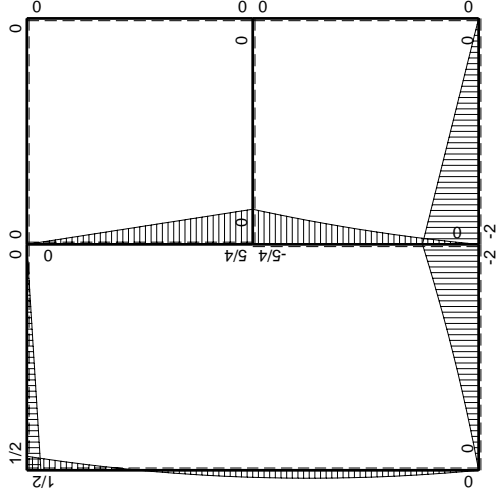
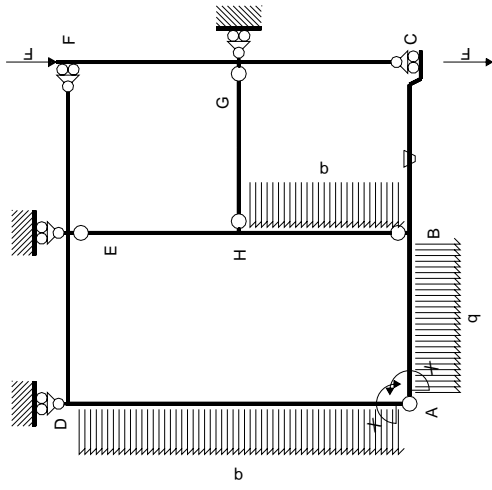
$$L_{ED}^{x_0} = \int_0^b (-1/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$



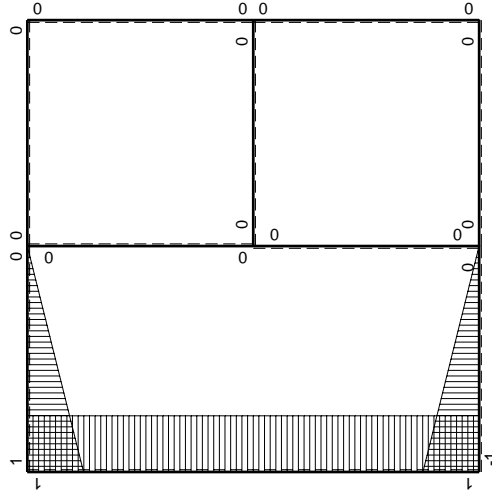
- A = 1008. mm<sup>2</sup>
- J<sub>u</sub> = 343131. mm<sup>4</sup>
- J<sub>v</sub> = 74304. mm<sup>4</sup>
- y<sub>g</sub> = 29.14 mm
- T<sub>y</sub> = 3120. N
- M<sub>x</sub> = -2589600. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -12. mm
- v<sub>m</sub> = -29.14 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -219.9 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 47. mm
- v<sub>c</sub> = 17.86 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 134.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.937 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 135. N/mm<sup>2</sup>
- S = 6515. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJdx$
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-2Fb+2Fx$	$-Fb/EJ$	0	0	0	0+0	0
CB b	0	$2Fx$	$Fb/EJ$	0	0	0		
AD 2b	1	$-3/4Fx+1/2qx^2$	0	$-3/4Fx+1/2Fx^2/b$	0	1	$(-1/6+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$-1/2Fb+5/4Fx-1/2qx^2$	0	$1/2Fb-5/4Fx+1/2Fx^2/b$	0	1		
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$		
EF b	0	0	0	0	0	0	0+0	0
FE b	0	0	0	0	0	0		
FG b	0	0	0	0	0	0	0+0	0
GF b	0	0	0	0	0	0		
GC b	0	0	0	0	0	0	0+0	0
CG b	0	0	0	0	0	0		
HG b	0	0	0	0	0	0	0+0	0
GH b	0	0	0	0	0	0		
HB b	0	$-5/4Fb+7/4Fx-1/2qx^2$	0	0	0	0	0+0	0
BH b	0	$3/4Fx+1/2qx^2$	0	0	0	0		
HE b	0	$5/4Fb-5/4Fx$	0	0	0	0	0+0	0
EH b	0	$-5/4Fx$	0	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-3/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-3/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 5/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

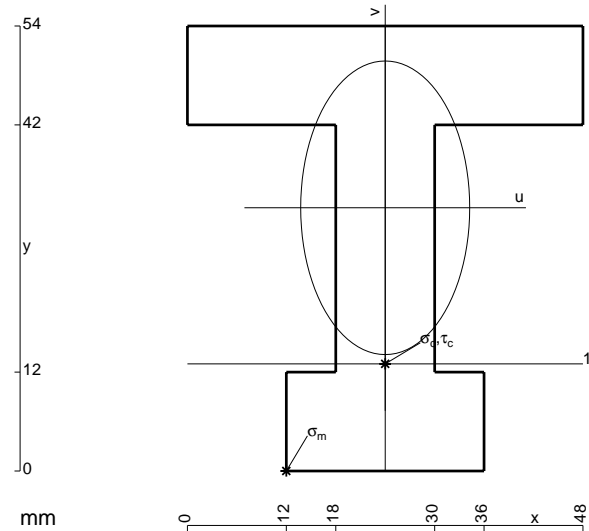
$$= (b - 5/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/2 b - 1/2 b + 1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$



$$A = 1224. \text{ mm}^2$$

$$J_u = 388508. \text{ mm}^4$$

$$J_v = 128736. \text{ mm}^4$$

$$y_g = 31.94 \text{ mm}$$

$$T_y = 3160. \text{ N}$$

$$M_x = -2780800. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -12. \text{ mm}$$

$$v_m = -31.94 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -228.6 \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 13. \text{ mm}$$

$$v_c = -18.94 \text{ mm}$$

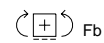
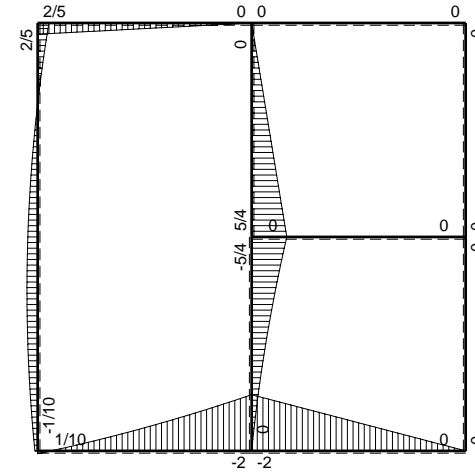
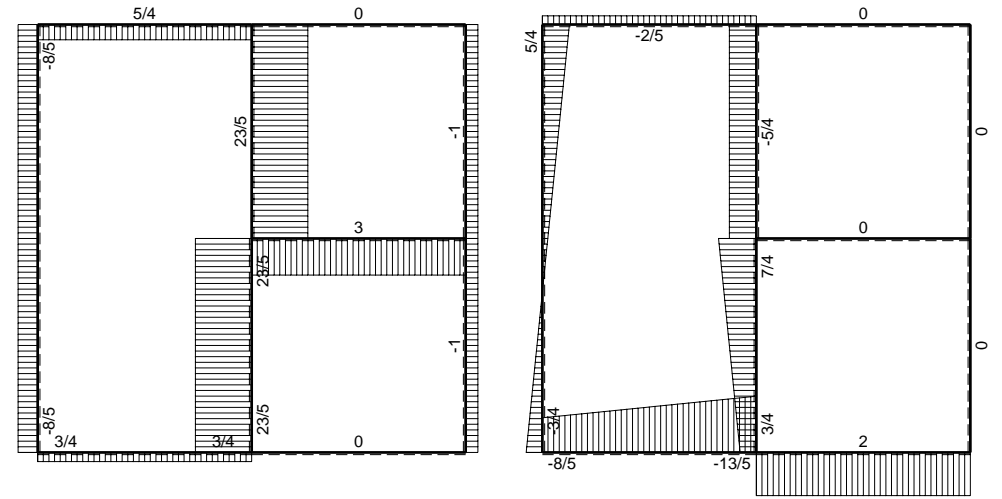
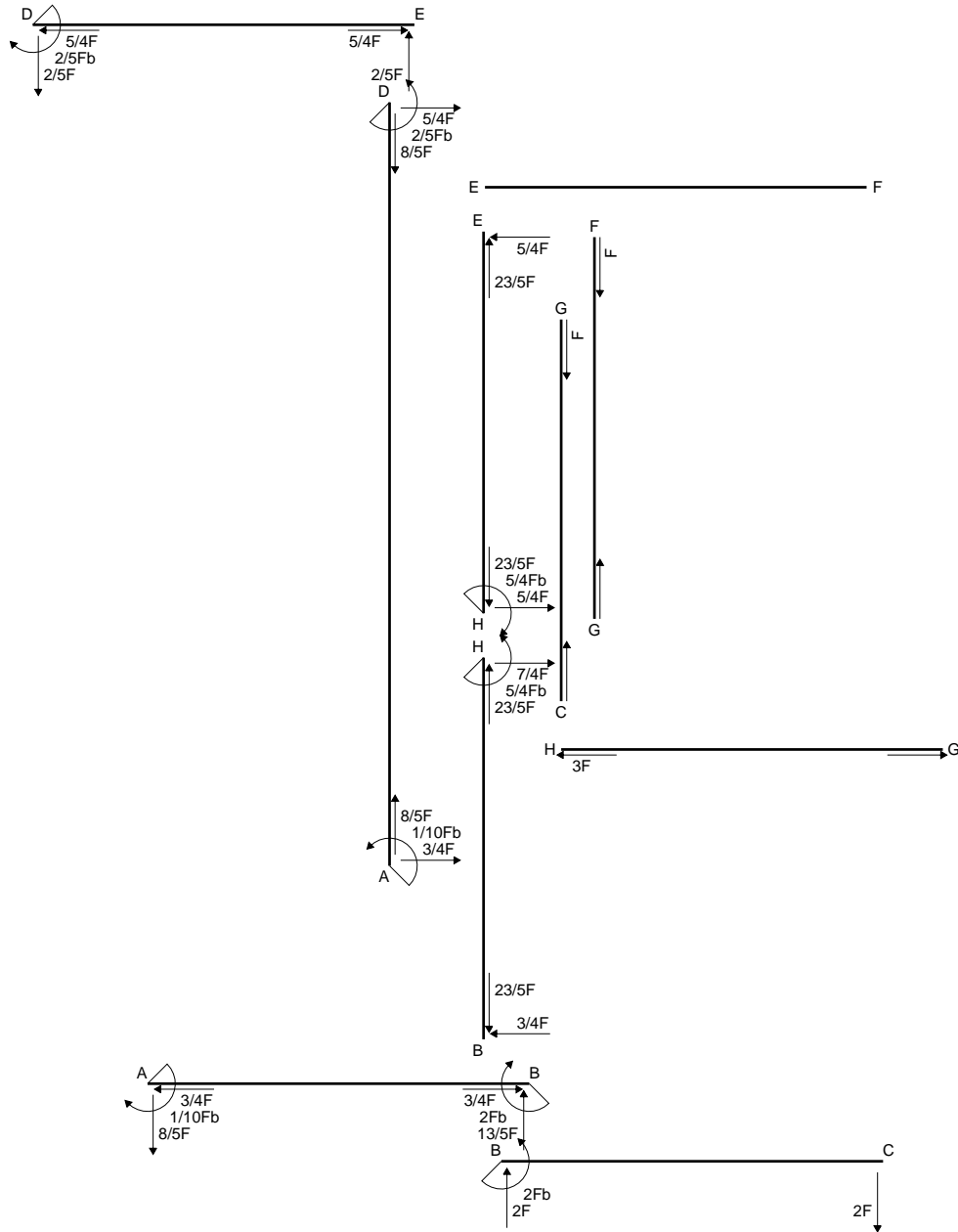
$$\sigma_c = -Mv/J_u = -135.6 \text{ N/mm}^2$$

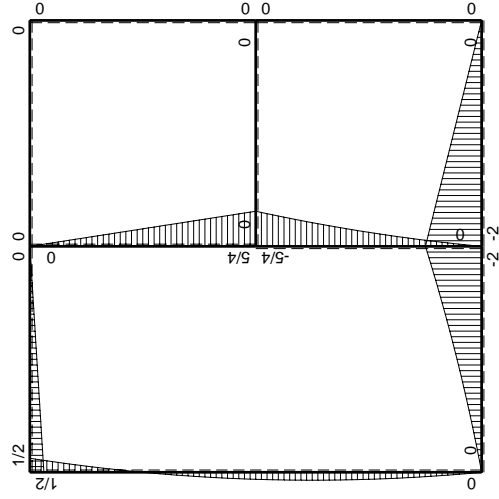
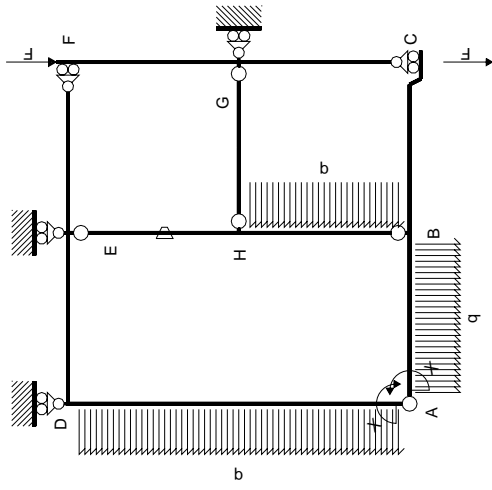
$$\tau_c = 5.222 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 135.9 \text{ N/mm}^2$$

$$S = 7704. \text{ mm}^3$$

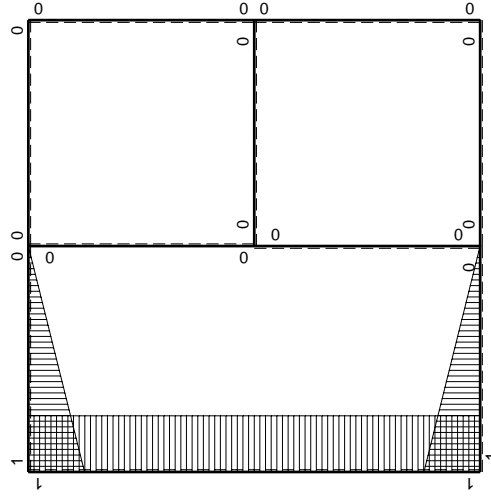






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0
CB b	0	$2Fx$	0	0	0	0		
AD 2b	1	$-3/4Fx+1/2qx^2$	0	$-3/4Fx+1/2Fx^2/b$	0	1	$(-1/6+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$-1/2Fb+5/4Fx-1/2qx^2$	0	$1/2Fb-5/4Fx+1/2Fx^2/b$	0	1		
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$		
EF b	0	0	0	0	0	0	0+0	0
FE b	0	0	0	0	0	0		
FG b	0	0	0	0	0	0	0+0	0
GF b	0	0	0	0	0	0		
GC b	0	0	0	0	0	0	0+0	0
CG b	0	0	0	0	0	0		
HG b	0	0	0	0	0	0	0+0	0
GH b	0	0	0	0	0	0		
HB b	0	$-5/4Fb+7/4Fx-1/2qx^2$	0	0	0	0	0+0	0
BH b	0	$3/4Fx+1/2qx^2$	0	0	0	0		
HE b	0	$5/4Fb-5/4Fx$	$-Fb/EJ$	0	0	0	0+0	0
EH b	0	$-5/4Fx$	$Fb/EJ$	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-3/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-3/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 5/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

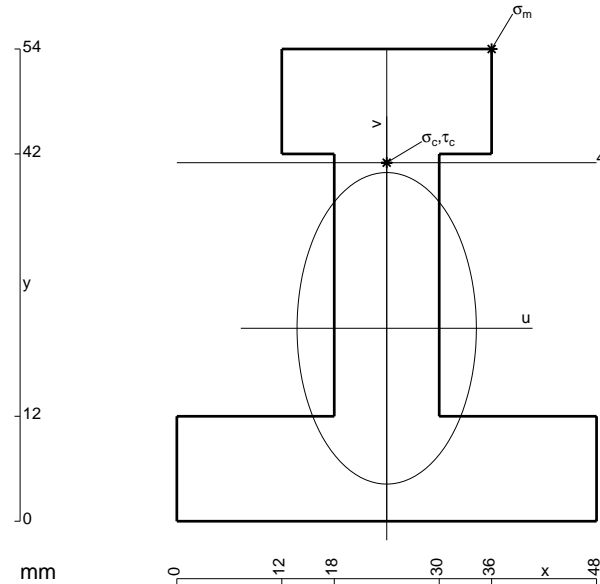
$$= (b - 5/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

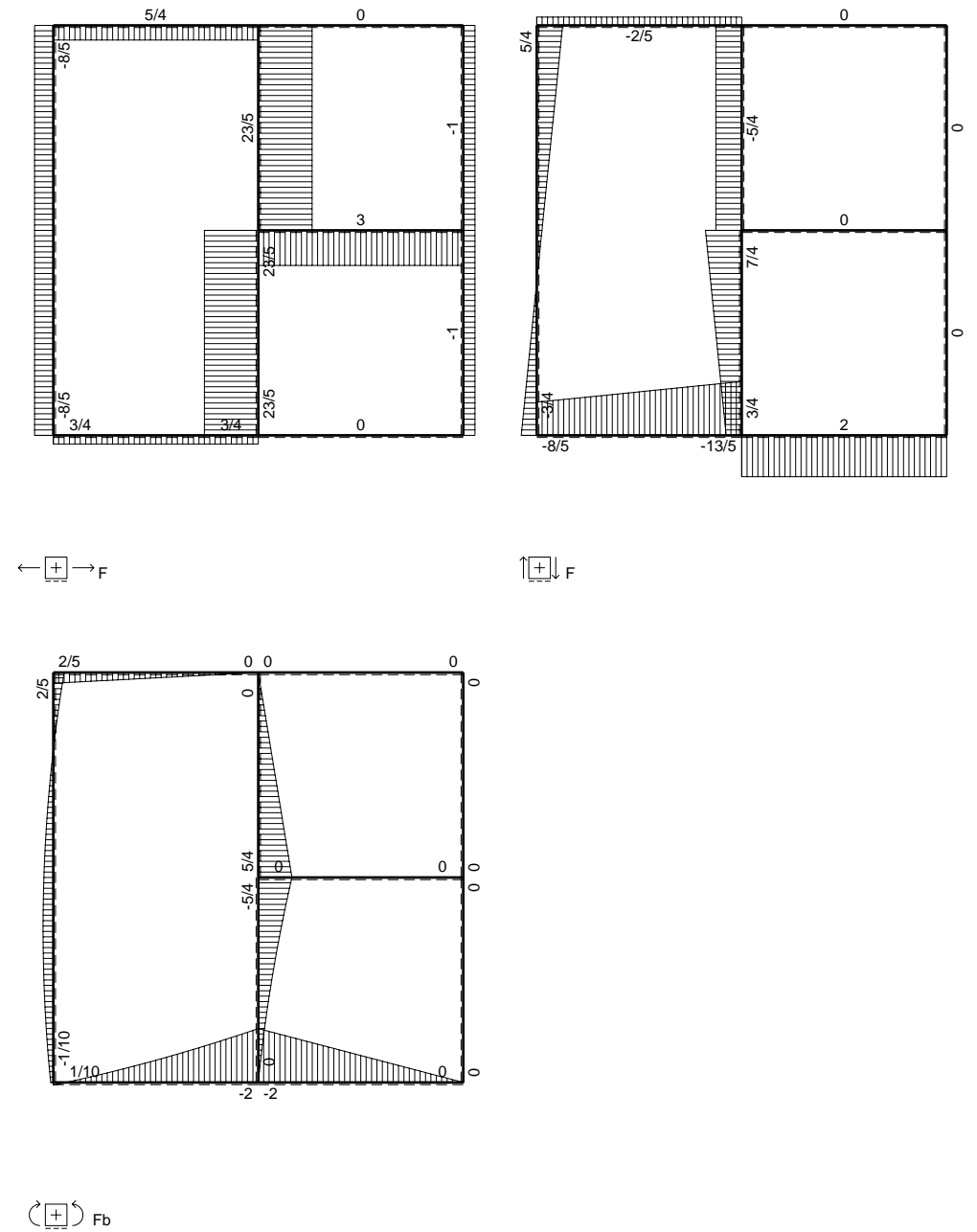
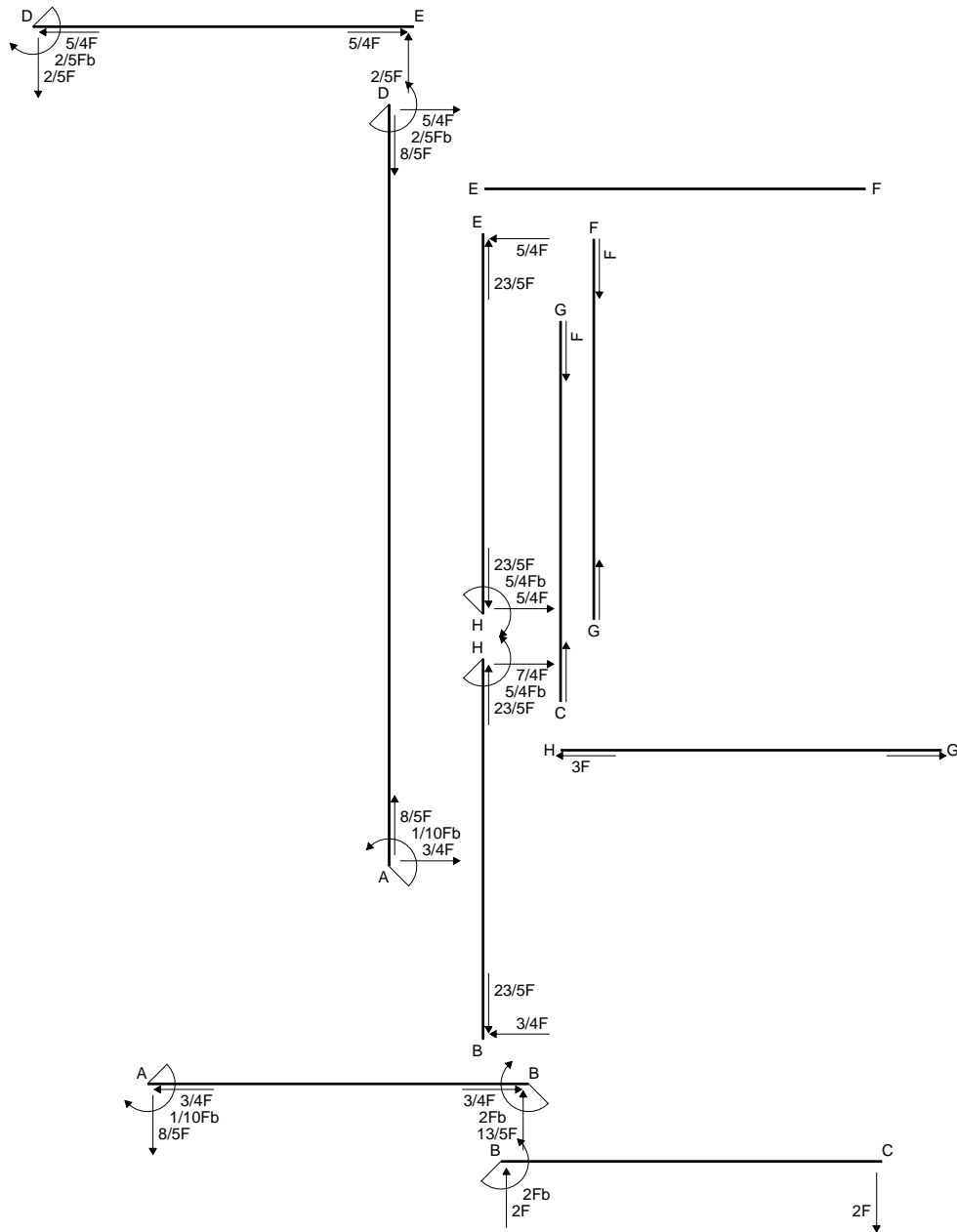
$$= (1/2 b - 1/2 b + 1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$

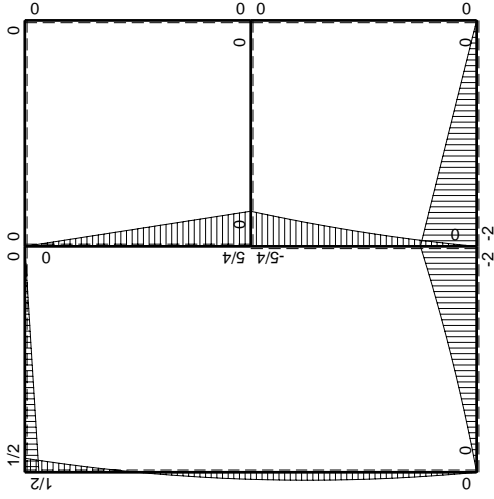
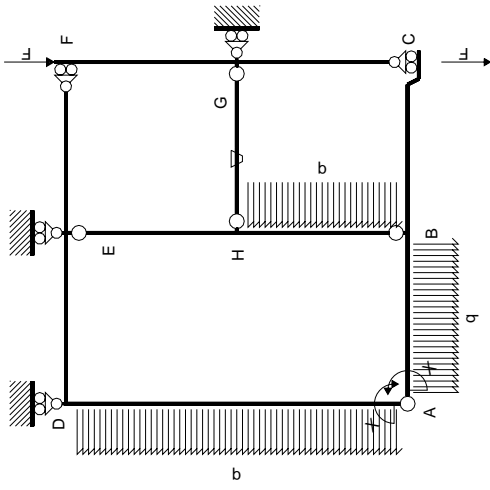
$$L_{ED}^{xo} = \int_0^b (1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$



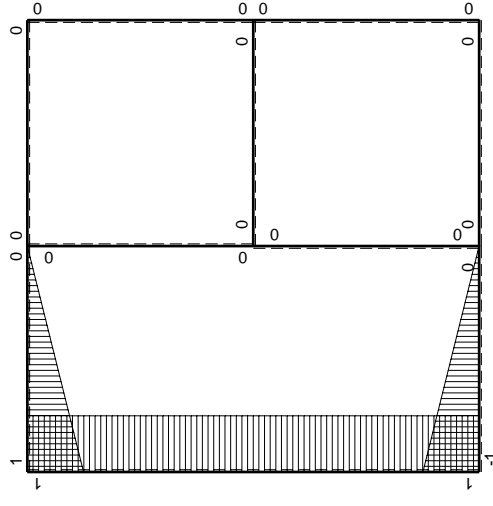
- A = 1224. mm<sup>2</sup>
- J<sub>u</sub> = 388508. mm<sup>4</sup>
- J<sub>v</sub> = 128736. mm<sup>4</sup>
- y<sub>g</sub> = 22.06 mm
- T<sub>y</sub> = 3120. N
- M<sub>x</sub> = -2901600. Nmm
- x<sub>m</sub> = 36. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 12. mm
- v<sub>m</sub> = 31.94 mm
- σ<sub>m</sub> = -M<sub>v</sub>/J<sub>u</sub> = 238.6 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 41. mm
- v<sub>c</sub> = 18.94 mm
- σ<sub>c</sub> = -M<sub>v</sub>/J<sub>u</sub> = 141.5 N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.156 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 141.7 N/mm<sup>2</sup>
- S = 7704. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJdx$
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0
CB b	0	$2Fx$	0	0	0	0		
AD 2b	1	$-3/4Fx+1/2qx^2$	0	$-3/4Fx+1/2Fx^2/b$	0	1	$(-1/6+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$-1/2Fb+5/4Fx-1/2qx^2$	0	$1/2Fb-5/4Fx+1/2Fx^2/b$	0	1		
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$		
EF b	0	0	0	0	0	0	0+0	0
FE b	0	0	0	0	0	0		
FG b	0	0	0	0	0	0	0+0	0
GF b	0	0	0	0	0	0		
GC b	0	0	0	0	0	0	0+0	0
CG b	0	0	0	0	0	0		
HG b	0	0	$-Fb/EJ$	0	0	0	0+0	0
GH b	0	0	$Fb/EJ$	0	0	0		
HB b	0	$-5/4Fb+7/4Fx-1/2qx^2$	0	0	0	0	0+0	0
BH b	0	$3/4Fx+1/2qx^2$	0	0	0	0		
HE b	0	$5/4Fb-5/4Fx$	0	0	0	0	0+0	0
EH b	0	$-5/4Fx$	0	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-3/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-3/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 5/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

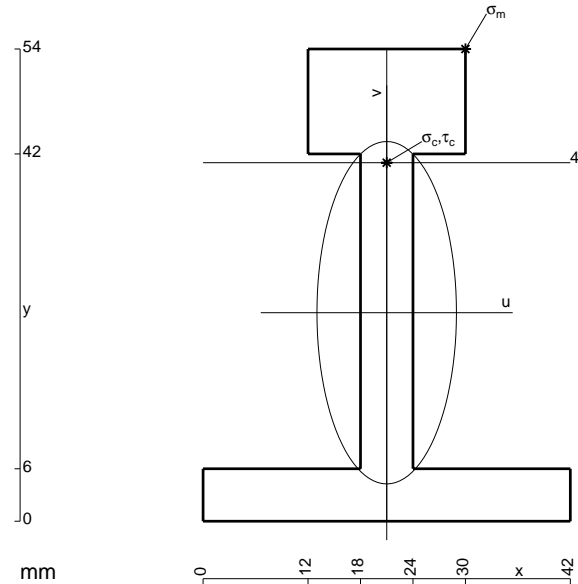
$$= (b - 5/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/2 b - 1/2 b + 1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$

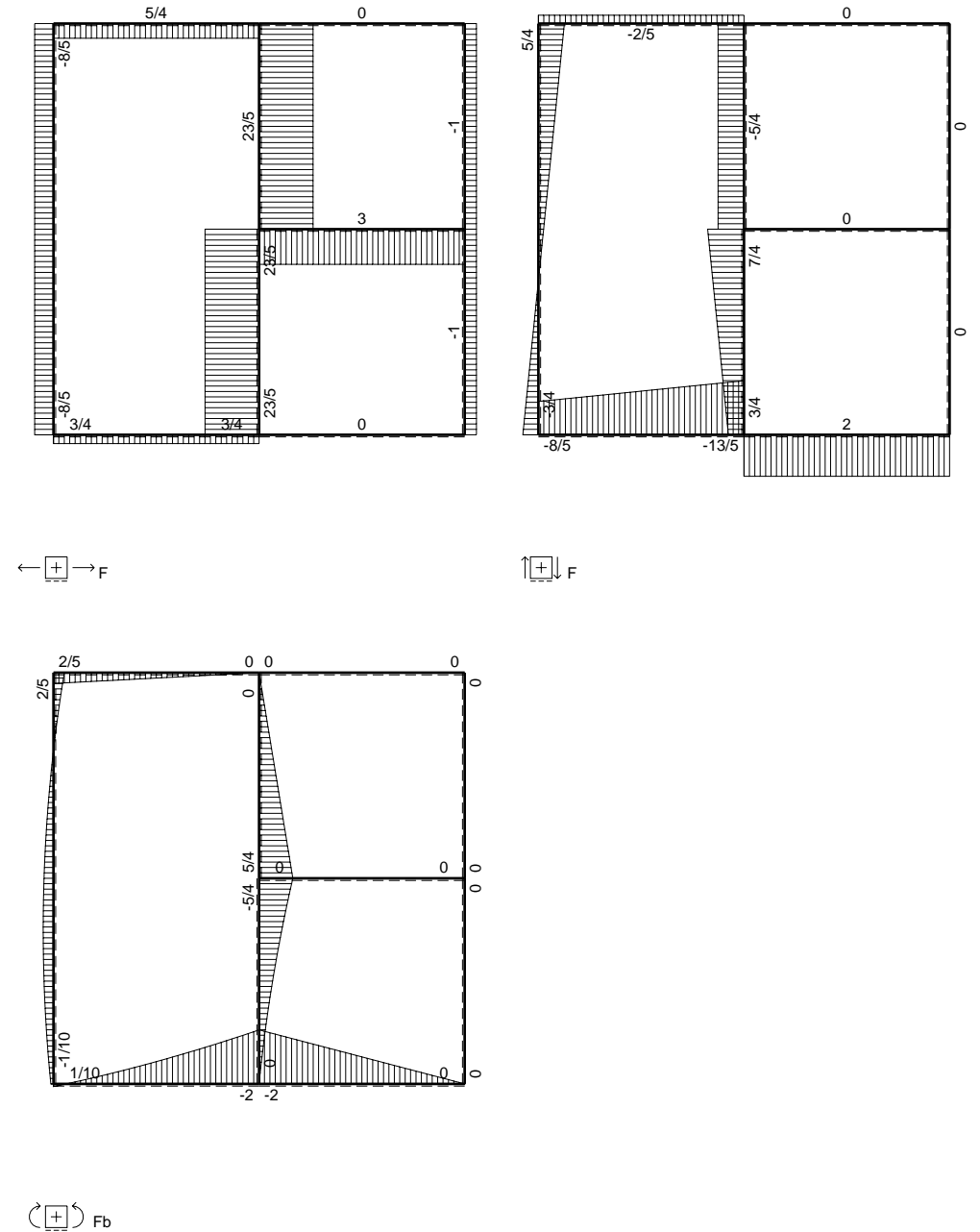
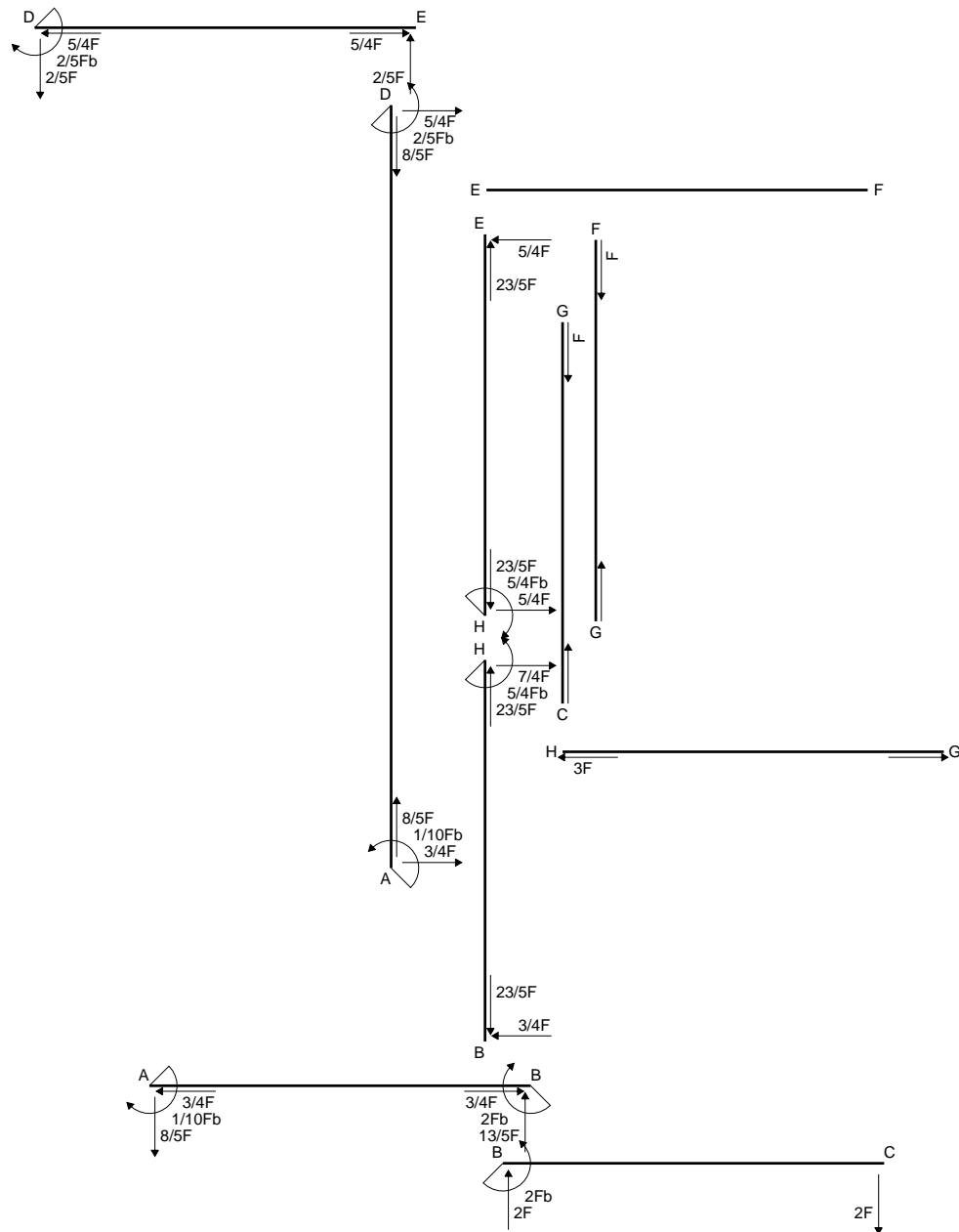
$$L_{ED}^{xo} = \int_0^b (1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

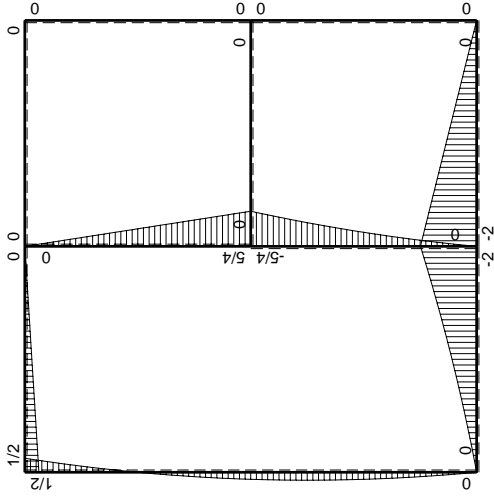
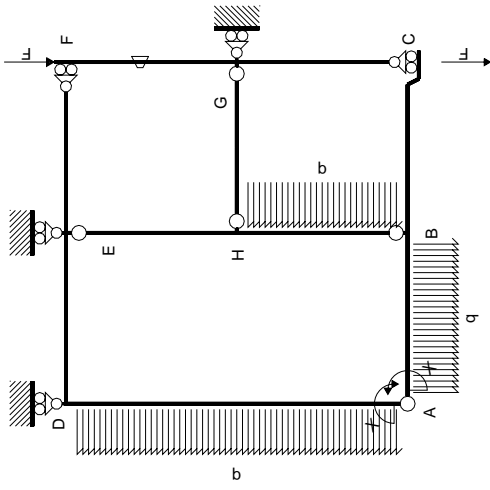
$$= (1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$



$A = 684. \text{ mm}^2$   
 $J_u = 262207. \text{ mm}^4$   
 $J_v = 43524. \text{ mm}^4$   
 $y_g = 23.84 \text{ mm}$   
 $T_y = 3540. \text{ N}$   
 $M_x = -1734600. \text{ Nmm}$   
 $x_m = 30. \text{ mm}$   
 $y_m = 54. \text{ mm}$   
 $u_m = 9. \text{ mm}$   
 $v_m = 30.16 \text{ mm}$   
 $\sigma_m = -Mv/J_u = 199.5 \text{ N/mm}^2$   
 $x_c = 21. \text{ mm}$   
 $y_c = 41. \text{ mm}$   
 $v_c = 17.16 \text{ mm}$   
 $\sigma_c = -Mv/J_u = 113.5 \text{ N/mm}^2$   
 $\tau_c = 11.98 \text{ N/mm}^2$   
 $\sigma_o = \sqrt{\sigma^2 + 3\tau^2} = 115.4 \text{ N/mm}^2$   
 $S = 5324. \text{ mm}^3$

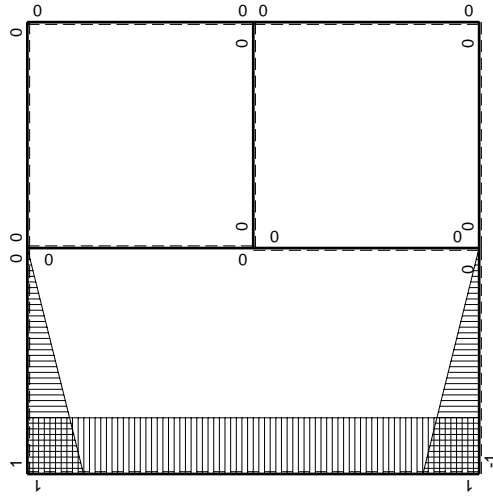






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJdx$
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0
CB b	0	$2Fx$	0	0	0	0		
AD 2b	1	$-3/4Fx+1/2qx^2$	0	$-3/4Fx+1/2Fx^2/b$	0	1	$(-1/6+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$-1/2Fb+5/4Fx-1/2qx^2$	0	$1/2Fb-5/4Fx+1/2Fx^2/b$	0	1		
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$		
EF b	0	0	0	0	0	0	0+0	0
FE b	0	0	0	0	0	0		
FG b	0	0	$-Fb/EJ$	0	0	0	0+0	0
GF b	0	0	$Fb/EJ$	0	0	0		
GC b	0	0	0	0	0	0	0+0	0
CG b	0	0	0	0	0	0		
HG b	0	0	0	0	0	0	0+0	0
GH b	0	0	0	0	0	0		
HB b	0	$-5/4Fb+7/4Fx-1/2qx^2$	0	0	0	0	0+0	0
BH b	0	$3/4Fx+1/2qx^2$	0	0	0	0		
HE b	0	$5/4Fb-5/4Fx$	0	0	0	0	0+0	0
EH b	0	$-5/4Fx$	0	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{x_0} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{x_0} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{x_0} = \int_0^{2b} (-3/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-3/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DA}^{x_0} = \int_0^{2b} (1/2 - 5/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

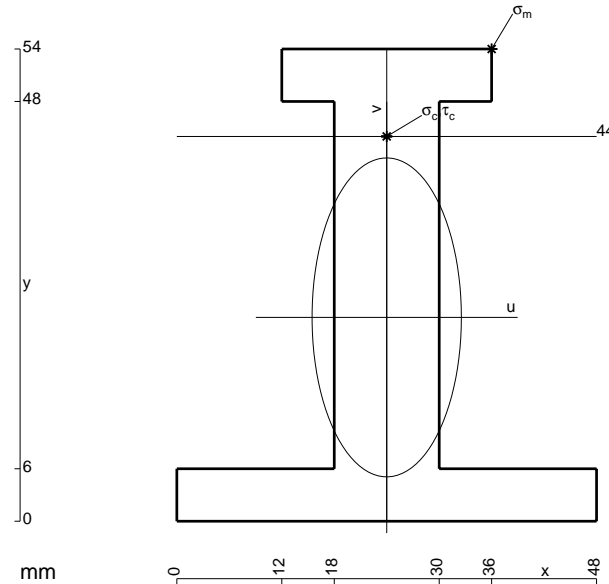
$$= (b - 5/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DE}^{x_0} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

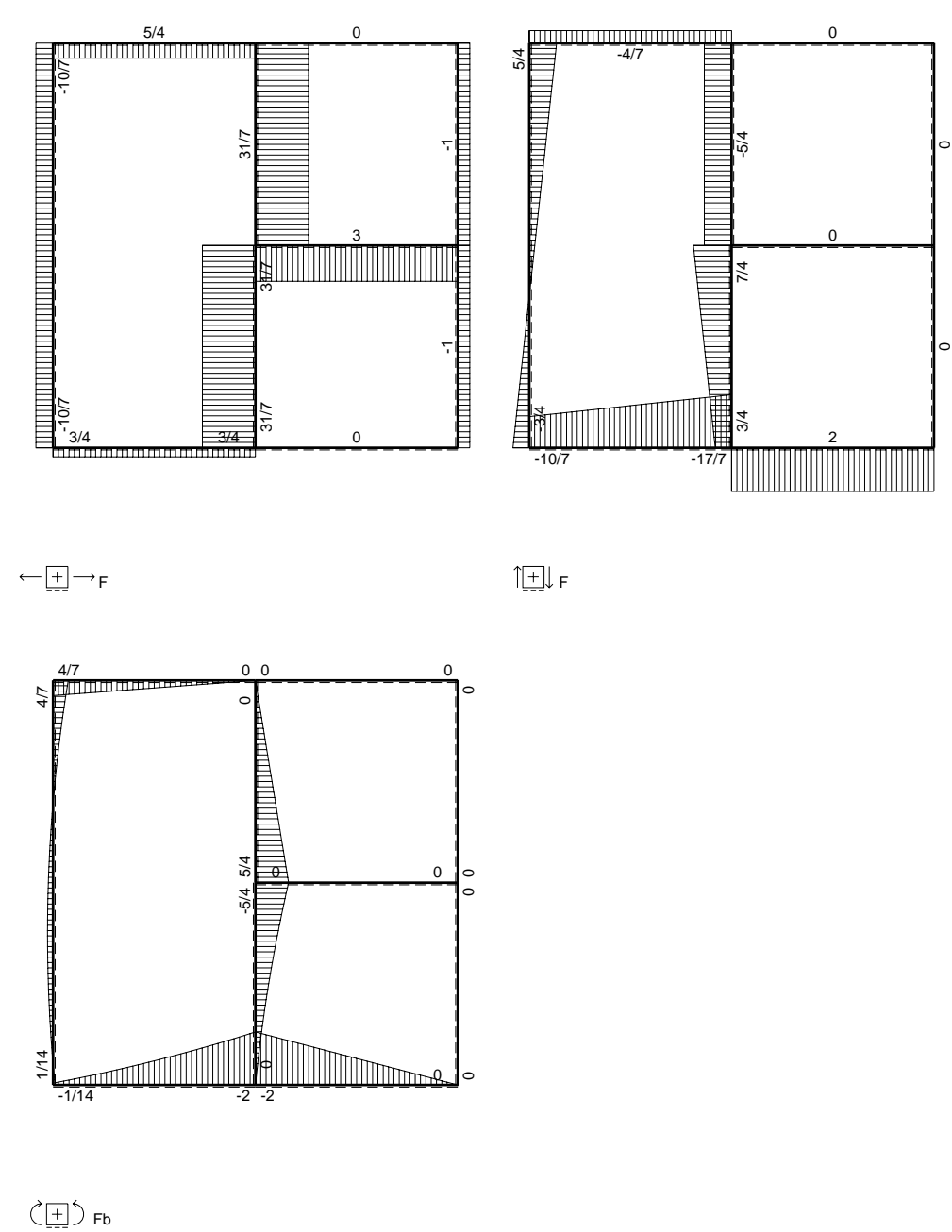
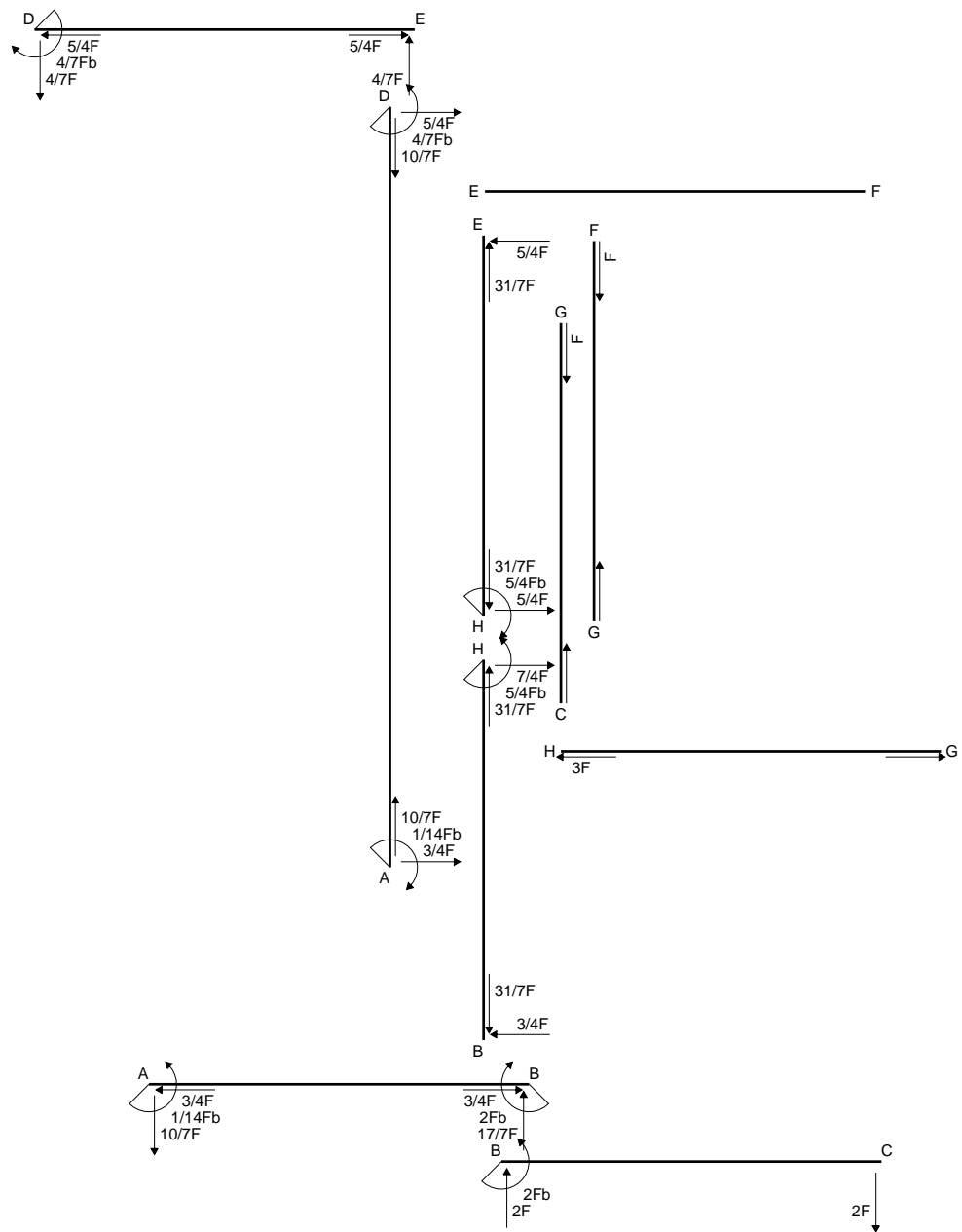
$$= (1/2 b - 1/2 b + 1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$

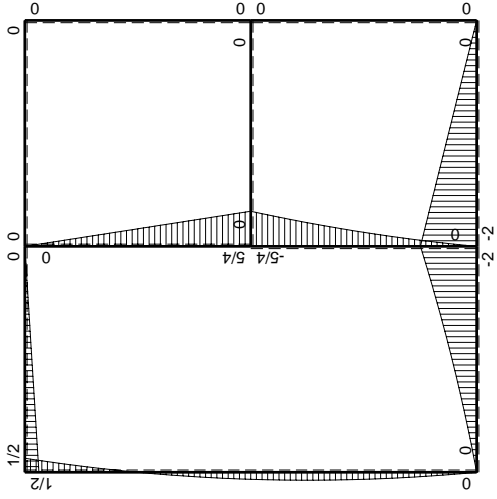
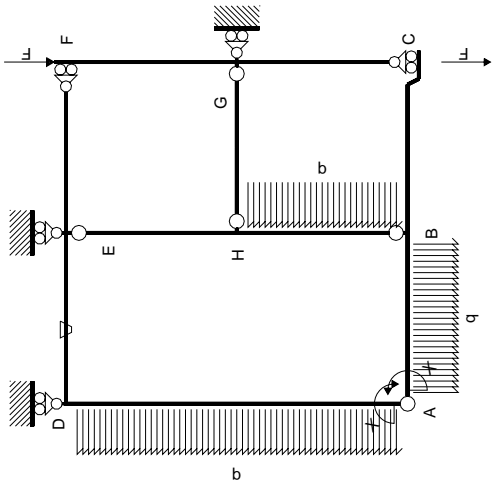
$$L_{ED}^{x_0} = \int_0^b (1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$



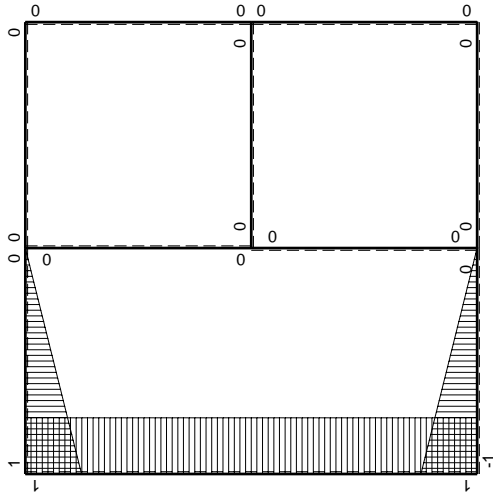
- A = 936. mm<sup>2</sup>
- J<sub>u</sub> = 311455. mm<sup>4</sup>
- J<sub>v</sub> = 68256. mm<sup>4</sup>
- y<sub>g</sub> = 23.31 mm
- T<sub>y</sub> = 4020. N
- M<sub>x</sub> = -2130600. Nmm
- x<sub>m</sub> = 36. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 12. mm
- v<sub>m</sub> = 30.69 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 210. N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 44. mm
- v<sub>c</sub> = 20.69 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 141.6 N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.461 N/mm<sup>2</sup>
- σ<sub>σ</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 141.9 N/mm<sup>2</sup>
- S = 5077. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x / EJ dx$
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0
CB b	0	$2Fx$	0	0	0	0		
AD 2b	1	$-3/4Fx+1/2qx^2$	0	$-3/4Fx+1/2Fx^2/b$	0	1	$(-1/6+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$-1/2Fb+5/4Fx-1/2qx^2$	0	$1/2Fb-5/4Fx+1/2Fx^2/b$	0	1		
DE b	$1-x/b$	$1/2Fb-1/2Fx$	$-Fb/EJ$	$1/2Fb-Fx+1/2Fx^2/b$	$-Fb/EJ+Fx/EJ$	$1-2x/b+x^2/b^2$	$(1/6-1/2)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$-1/2Fx$	$Fb/EJ$	$1/2Fx^2/b$	$-Fx/EJ$	$x^2/b^2$		
EF b	0	0	0	0	0	0	0+0	0
FE b	0	0	0	0	0	0		
FG b	0	0	0	0	0	0	0+0	0
GF b	0	0	0	0	0	0		
GC b	0	0	0	0	0	0	0+0	0
CG b	0	0	0	0	0	0		
HG b	0	0	0	0	0	0	0+0	0
GH b	0	0	0	0	0	0		
HB b	0	$-5/4Fb+7/4Fx-1/2qx^2$	0	0	0	0	0+0	0
BH b	0	$3/4Fx+1/2qx^2$	0	0	0	0		
HE b	0	$5/4Fb-5/4Fx$	0	0	0	0	0+0	0
EH b	0	$-5/4Fx$	0	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$-5/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$1/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-3/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-3/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 5/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (b - 5/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

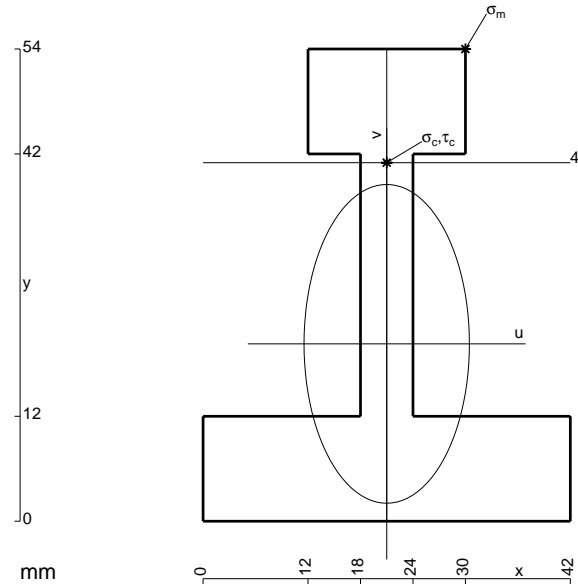
$$L_{DE}^{xo} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx + \int_0^b (-1 + x/b) \cdot \theta \, dx$$

$$= \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ + \left[ -x + 1/2 x^2/b \right]_0^b \cdot \theta$$

$$= (1/2 b - 1/2 b + 1/6 b) \cdot Fb \cdot 1/EJ + (-b + 1/2 b) \cdot \theta = -1/3 \cdot Fb^2/EJ$$

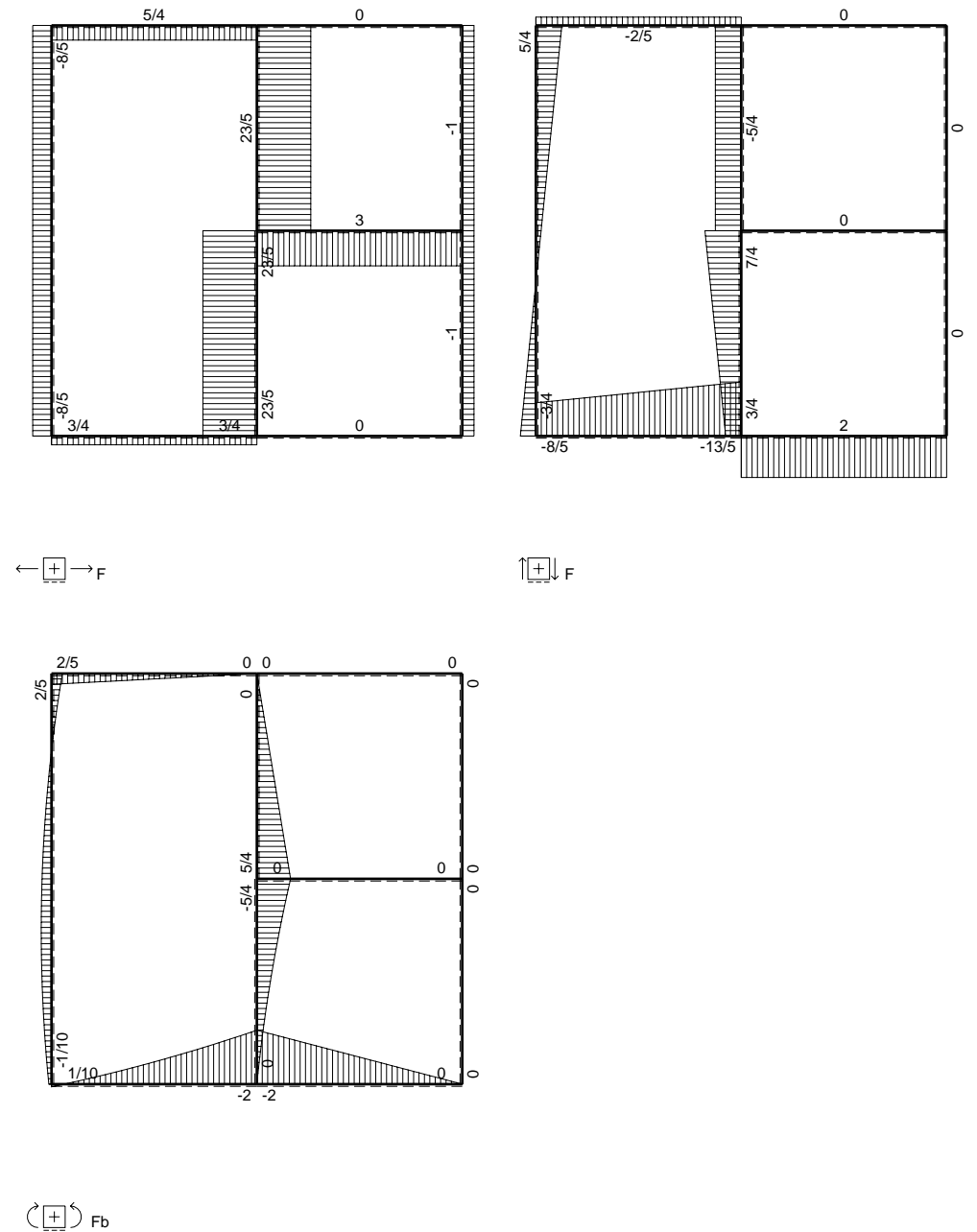
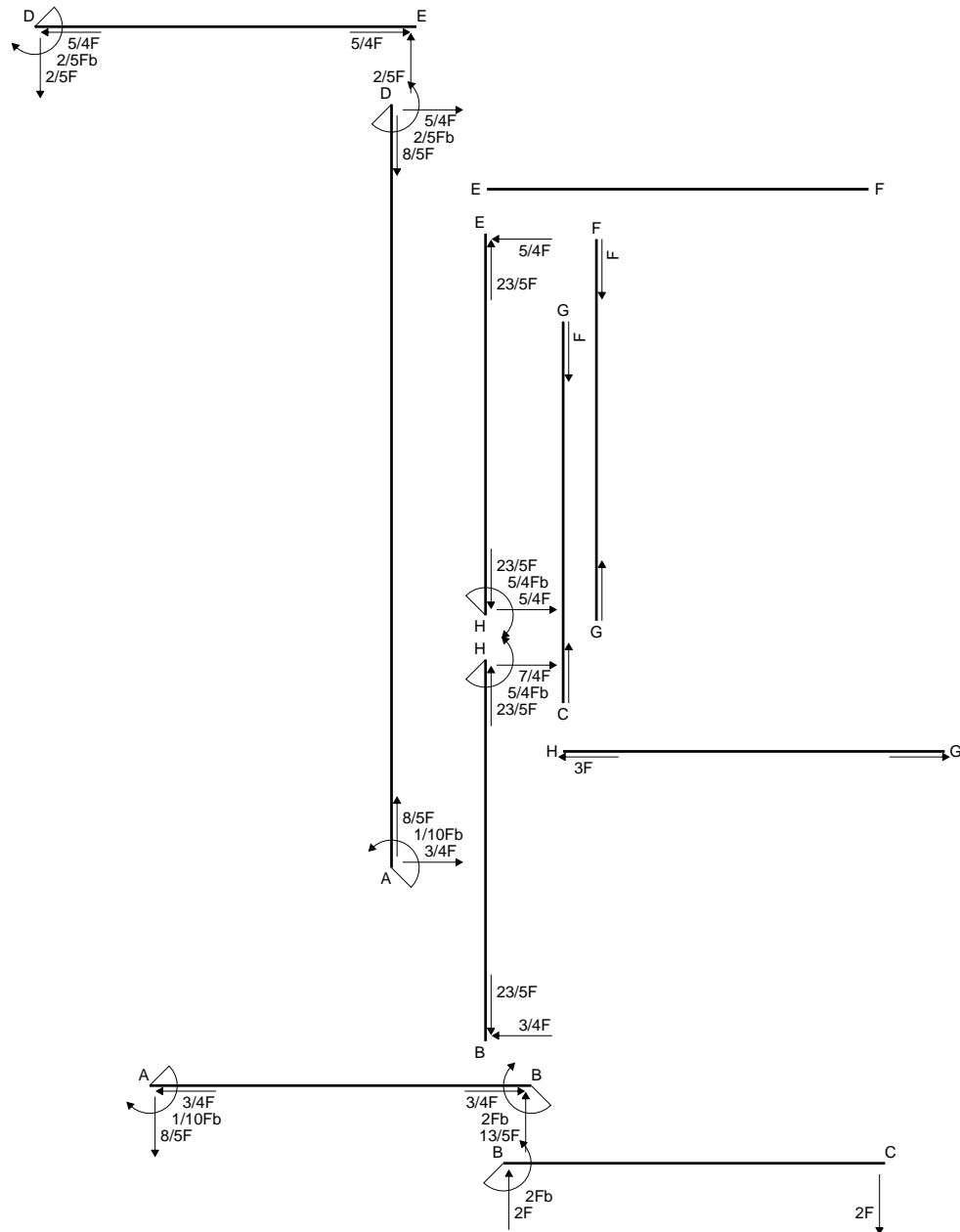
$$L_{ED}^{xo} = \int_0^b (1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx + \int_0^b (x/b) \cdot \theta \, dx = \left[ 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ + \left[ 1/2 x^2/b \right]_0^b \cdot \theta$$

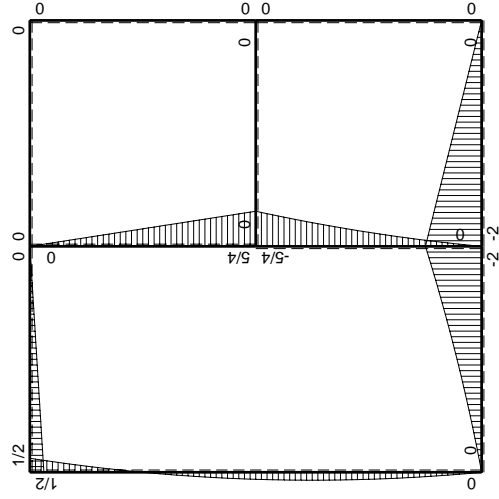
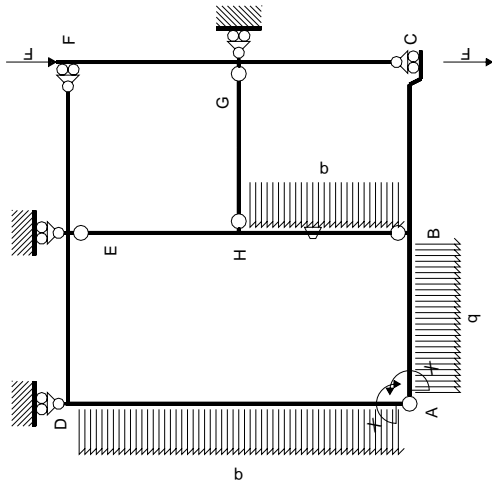
$$= (1/6 b) \cdot Fb \cdot 1/EJ + (1/2 b) \cdot \theta = -1/3 \cdot Fb^2/EJ$$



$A = 900. \text{ mm}^2$   
 $J_u = 299017. \text{ mm}^4$   
 $J_v = 80460. \text{ mm}^4$   
 $y_g = 20.28 \text{ mm}$   
 $T_y = 3360. \text{ N}$   
 $M_x = -1948800. \text{ Nmm}$   
 $x_m = 30. \text{ mm}$   
 $y_m = 54. \text{ mm}$   
 $u_m = 9. \text{ mm}$   
 $v_m = 33.72 \text{ mm}$   
 $\sigma_m = -Mv/J_u = 219.8 \text{ N/mm}^2$   
 $x_c = 21. \text{ mm}$   
 $y_c = 41. \text{ mm}$   
 $v_c = 20.72 \text{ mm}$   
 $\sigma_c = -Mv/J_u = 135. \text{ N/mm}^2$   
 $\tau_c = 11.45 \text{ N/mm}^2$   
 $\sigma_\varrho = \sqrt{\sigma^2 + 3\tau^2} = 136.5 \text{ N/mm}^2$   
 $S = 6115. \text{ mm}^3$

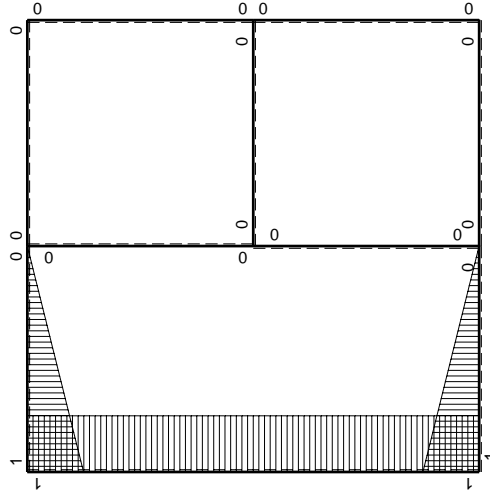






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0
CB b	0	$2Fx$	0	0	0	0		
AD 2b	1	$-3/4Fx+1/2qx^2$	0	$-3/4Fx+1/2Fx^2/b$	0	1	$(-1/6+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$-1/2Fb+5/4Fx-1/2qx^2$	0	$1/2Fb-5/4Fx+1/2Fx^2/b$	0	1		
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$		
EF b	0	0	0	0	0	0	0+0	0
FE b	0	0	0	0	0	0		
FG b	0	0	0	0	0	0	0+0	0
GF b	0	0	0	0	0	0		
GC b	0	0	0	0	0	0	0+0	0
CG b	0	0	0	0	0	0		
HG b	0	0	0	0	0	0	0+0	0
GH b	0	0	0	0	0	0		
HB b	0	$-5/4Fb+7/4Fx-1/2qx^2$	$-Fb/EJ$	0	0	0	0+0	0
BH b	0	$3/4Fx+1/2qx^2$	$Fb/EJ$	0	0	0		
HE b	0	$5/4Fb-5/4Fx$	0	0	0	0	0+0	0
EH b	0	$-5/4Fx$	0	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-3/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-3/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 5/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

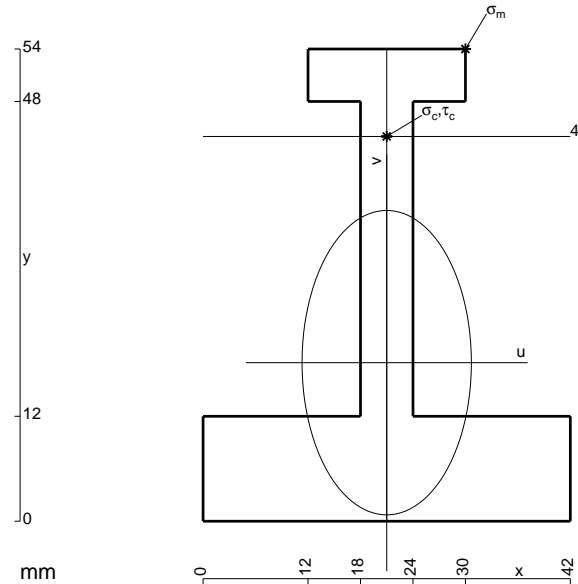
$$= (b - 5/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

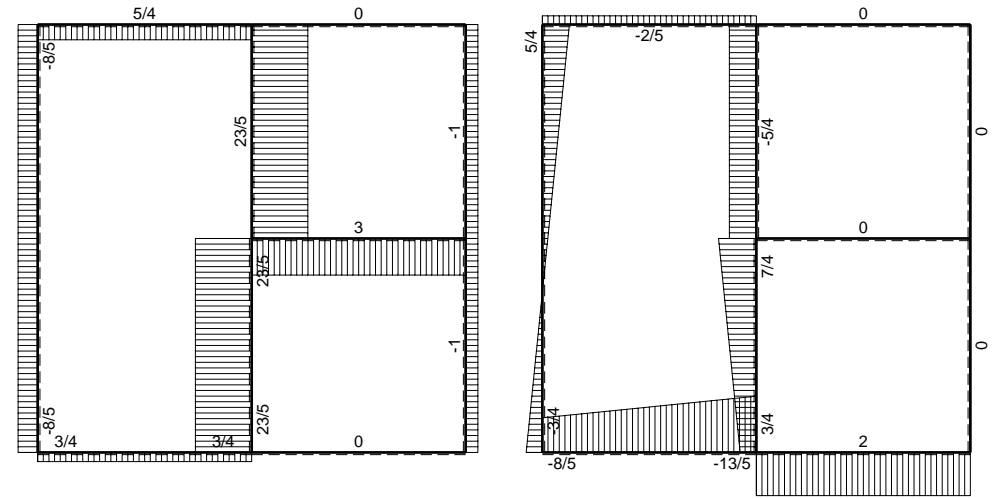
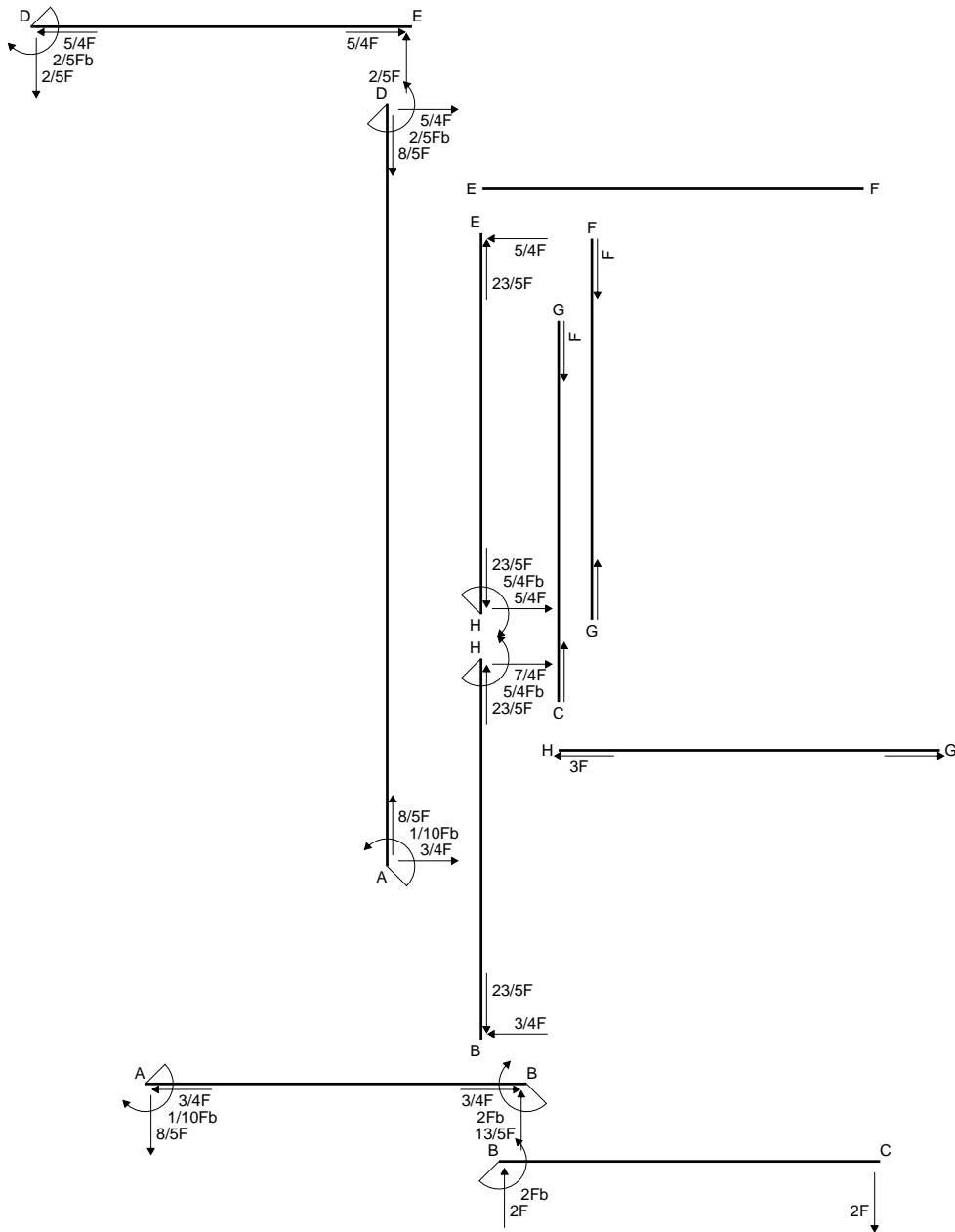
$$= (1/2 b - 1/2 b + 1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$

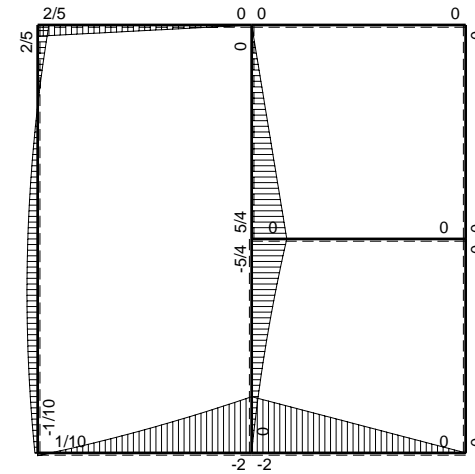


- A = 828. mm<sup>2</sup>
- J<sub>u</sub> = 250978. mm<sup>4</sup>
- J<sub>v</sub> = 77652. mm<sup>4</sup>
- y<sub>g</sub> = 18.13 mm
- T<sub>y</sub> = 2540. N
- M<sub>x</sub> = -1600200. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 9. mm
- v<sub>m</sub> = 35.87 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 228.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 44. mm
- v<sub>c</sub> = 25.87 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 164.9 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.116 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 165.4 N/mm<sup>2</sup>
- S = 4219. mm<sup>3</sup>

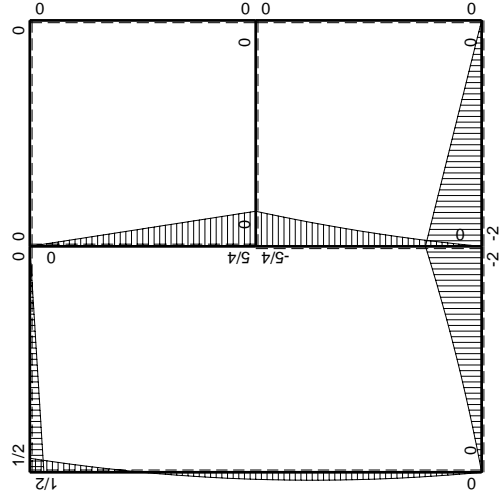
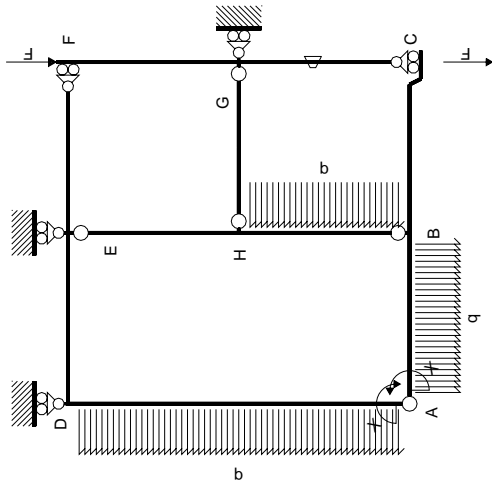


← (+) → F

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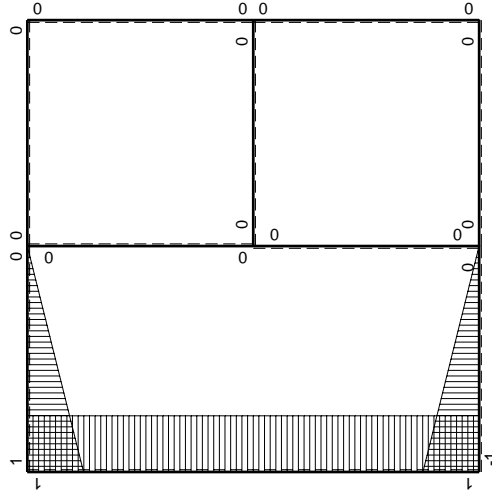


⊕ ⊖ Fb



Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0
CB b	0	$2Fx$	0	0	0	0		
AD 2b	1	$-3/4Fx+1/2qx^2$	0	$-3/4Fx+1/2Fx^2/b$	0	1	$(-1/6+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$-1/2Fb+5/4Fx-1/2qx^2$	0	$1/2Fb-5/4Fx+1/2Fx^2/b$	0	1		
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$		
EF b	0	0	0	0	0	0	0+0	0
FE b	0	0	0	0	0	0		
FG b	0	0	0	0	0	0	0+0	0
GF b	0	0	0	0	0	0		
GC b	0	0	$-Fb/EJ$	0	0	0	0+0	0
CG b	0	0	$Fb/EJ$	0	0	0		
HG b	0	0	0	0	0	0	0+0	0
GH b	0	0	0	0	0	0		
HB b	0	$-5/4Fb+7/4Fx-1/2qx^2$	0	0	0	0	0+0	0
BH b	0	$3/4Fx+1/2qx^2$	0	0	0	0		
HE b	0	$5/4Fb-5/4Fx$	0	0	0	0	0+0	0
EH b	0	$-5/4Fx$	0	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{x_0} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{x_0} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{x_0} = \int_0^{2b} (-3/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-3/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DA}^{x_0} = \int_0^{2b} (1/2 - 5/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

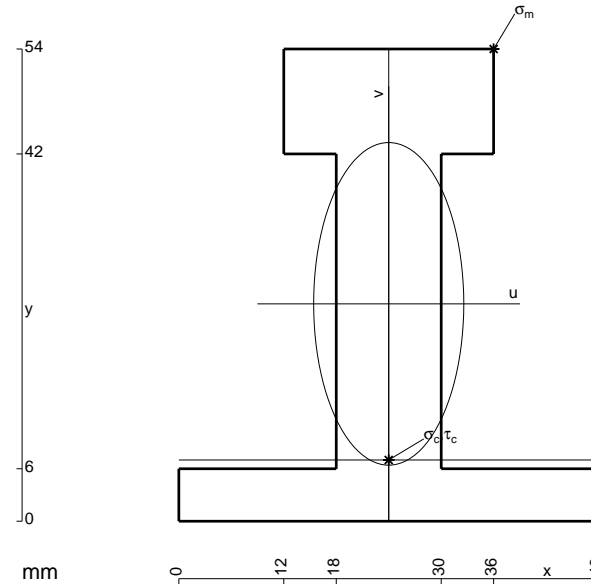
$$= (b - 5/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DE}^{x_0} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/2 b - 1/2 b + 1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$

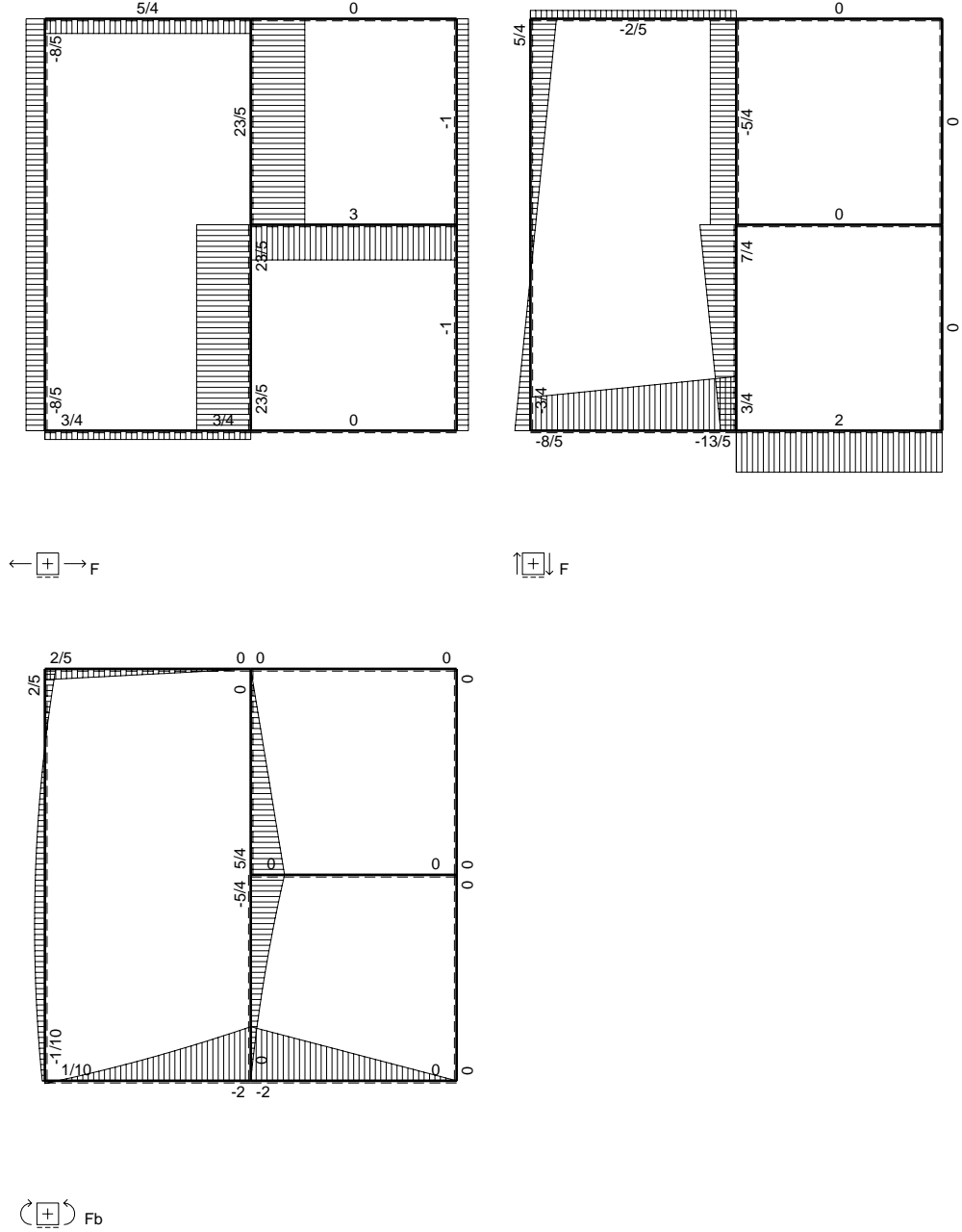
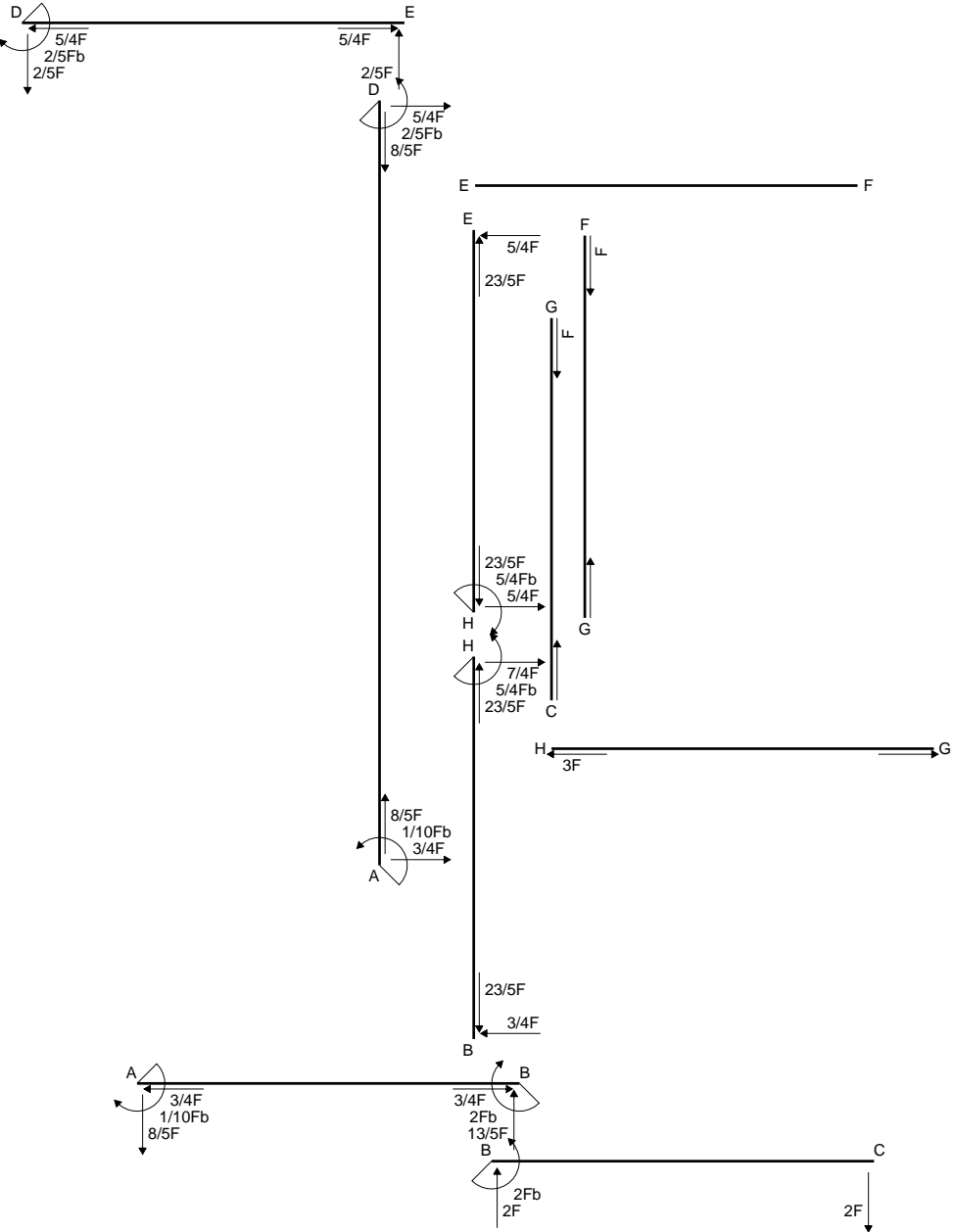
$$L_{ED}^{x_0} = \int_0^b (1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

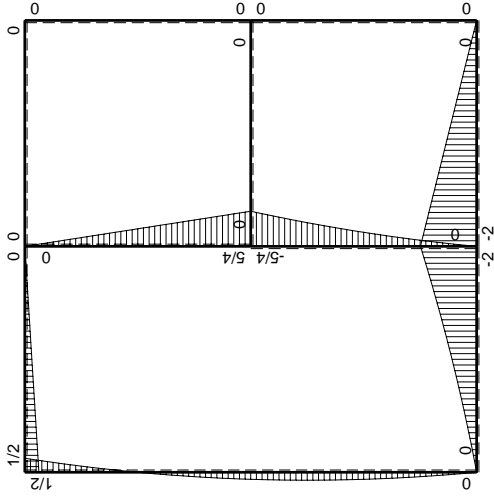
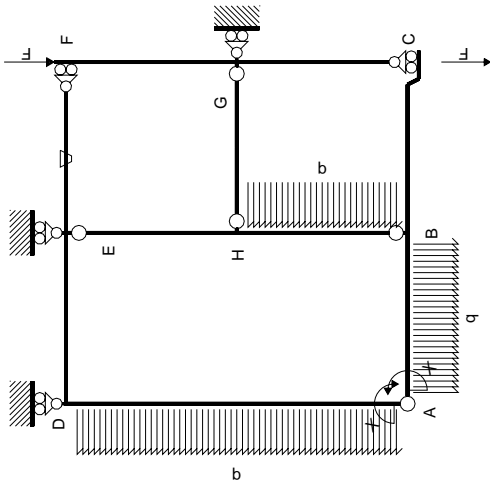
$$= (1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$



- A = 1008. mm<sup>2</sup>
- J<sub>u</sub> = 343131. mm<sup>4</sup>
- J<sub>v</sub> = 74304. mm<sup>4</sup>
- y<sub>g</sub> = 24.86 mm
- T<sub>y</sub> = 4140. N
- M<sub>x</sub> = -2815200. Nmm
- x<sub>m</sub> = 36. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 12. mm
- v<sub>m</sub> = 29.14 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 239.1 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 7. mm
- v<sub>c</sub> = -17.86 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -146.5 N/mm<sup>2</sup>
- τ<sub>c</sub> = 6.551 N/mm<sup>2</sup>
- σ<sub>σ</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 146.9 N/mm<sup>2</sup>
- S = 6515. mm<sup>3</sup>

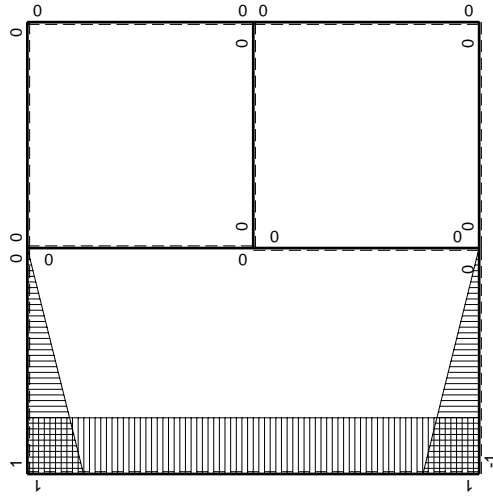






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJdx$
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0
CB b	0	$2Fx$	0	0	0	0		
AD 2b	1	$-3/4Fx+1/2qx^2$	0	$-3/4Fx+1/2Fx^2/b$	0	1	$(-1/6+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$-1/2Fb+5/4Fx-1/2qx^2$	0	$1/2Fb-5/4Fx+1/2Fx^2/b$	0	1		
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$		
EF b	0	0	$-Fb/EJ$	0	0	0	0+0	0
FE b	0	0	$Fb/EJ$	0	0	0		
FG b	0	0	0	0	0	0	0+0	0
GF b	0	0	0	0	0	0		
GC b	0	0	0	0	0	0	0+0	0
CG b	0	0	0	0	0	0		
HG b	0	0	0	0	0	0	0+0	0
GH b	0	0	0	0	0	0		
HB b	0	$-5/4Fb+7/4Fx-1/2qx^2$	0	0	0	0	0+0	0
BH b	0	$3/4Fx+1/2qx^2$	0	0	0	0		
HE b	0	$5/4Fb-5/4Fx$	0	0	0	0	0+0	0
EH b	0	$-5/4Fx$	0	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-3/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-3/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 5/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

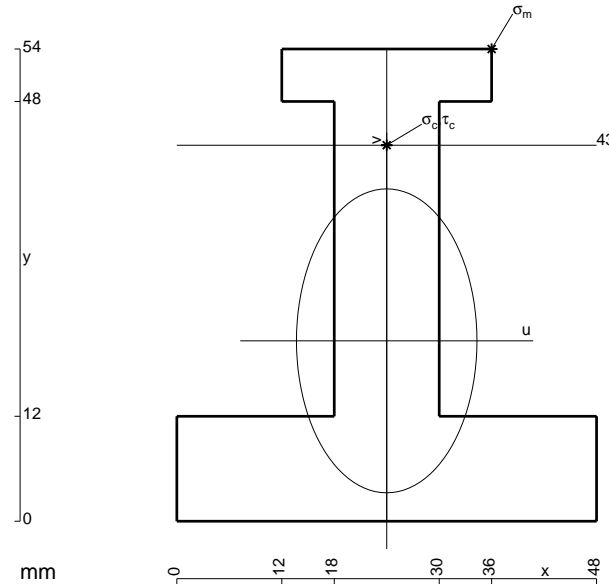
$$= (b - 5/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

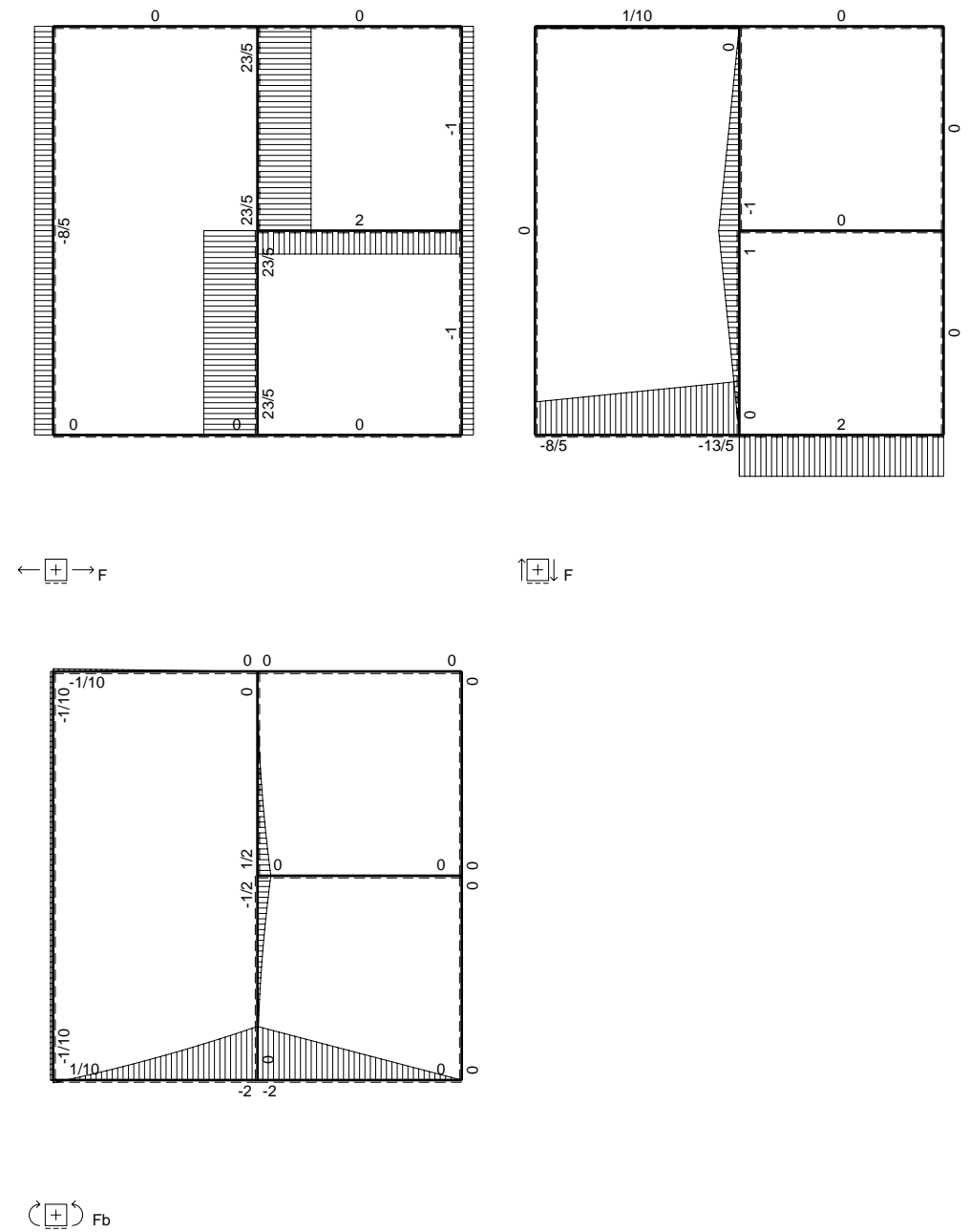
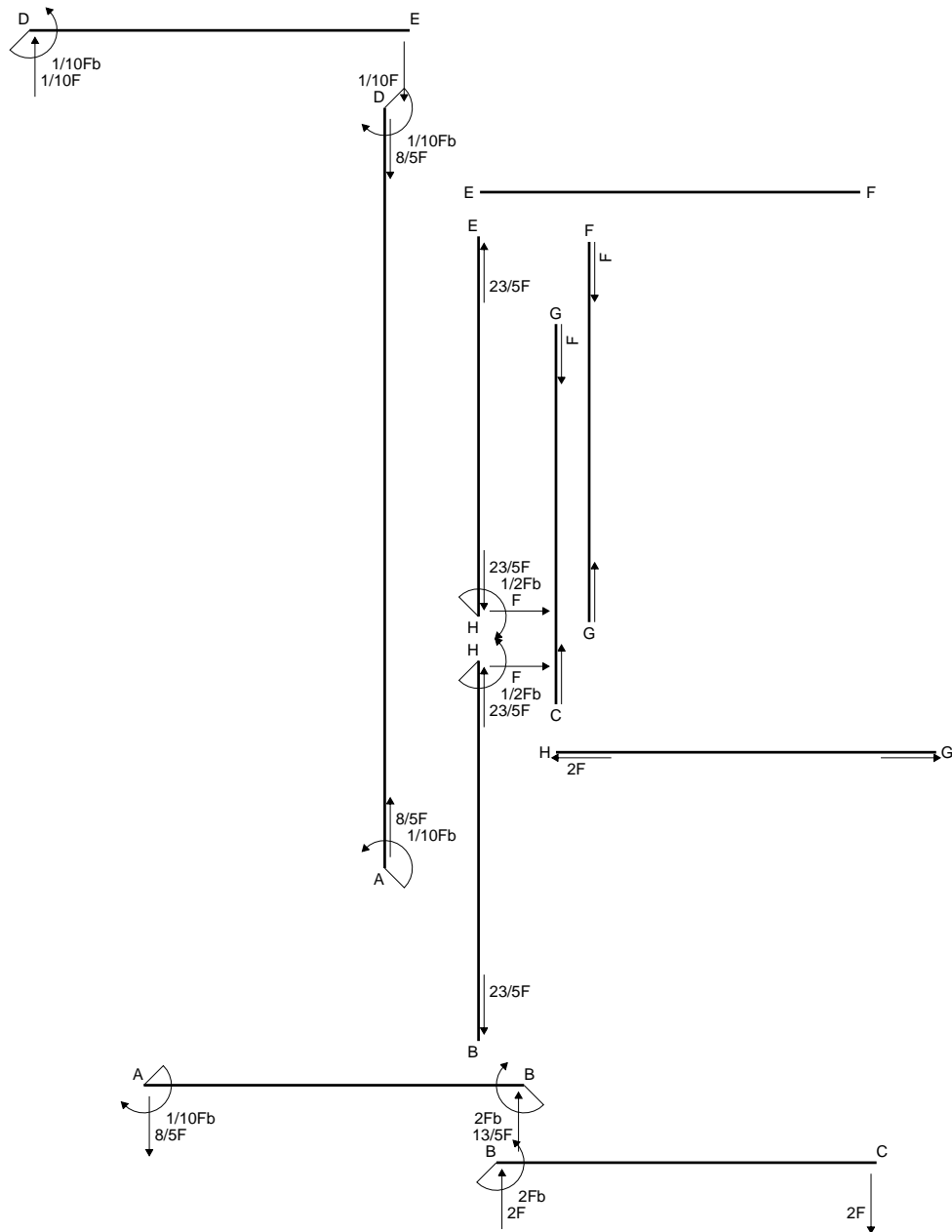
$$= (1/2 b - 1/2 b + 1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$

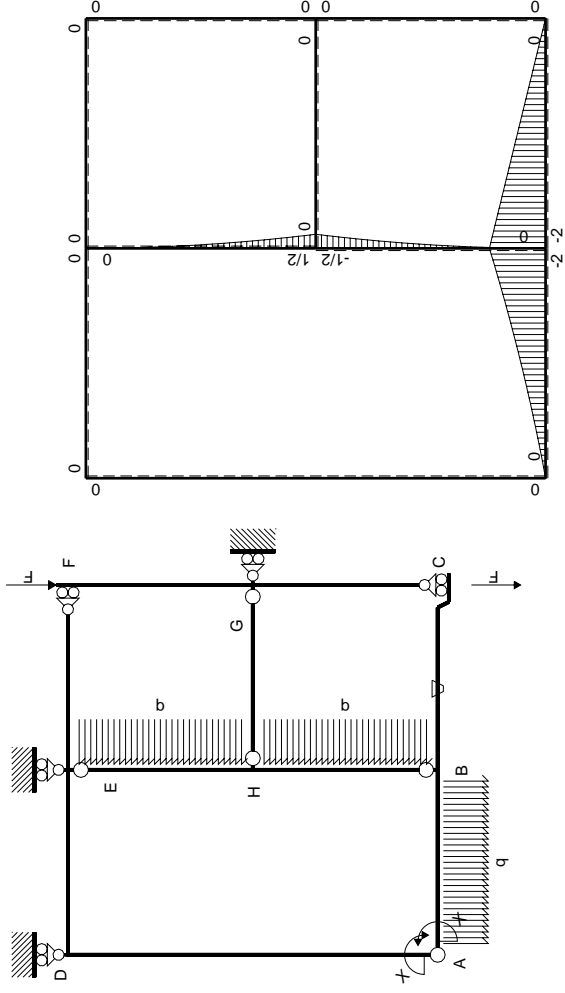
$$L_{ED}^{xo} = \int_0^b (1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$



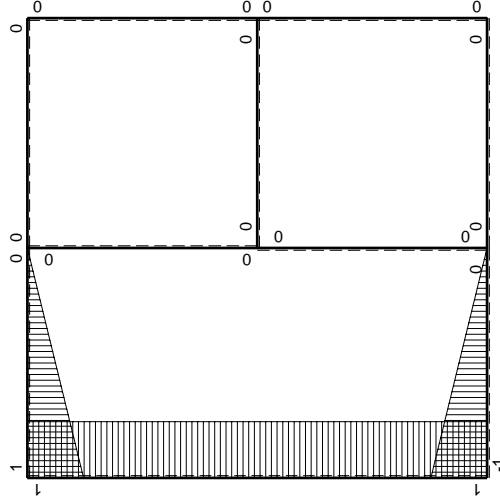
- A = 1152. mm<sup>2</sup>
- J<sub>u</sub> = 348030. mm<sup>4</sup>
- J<sub>v</sub> = 122688. mm<sup>4</sup>
- y<sub>g</sub> = 20.63 mm
- T<sub>y</sub> = 2840. N
- M<sub>x</sub> = -2073200. Nmm
- x<sub>m</sub> = 36. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 12. mm
- v<sub>m</sub> = 33.38 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 198.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 43. mm
- v<sub>c</sub> = 22.38 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 133.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.989 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 133.5 N/mm<sup>2</sup>
- S = 5867. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	$-Fb/EJ$	0	0	0	0+0	0	
CB b	0	$2Fx$	$Fb/EJ$	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
BH b	0	$1/2qx^2$	0	0	0	0			
HE b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0+0	0	
EH b	0	$-1/2qx^2$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

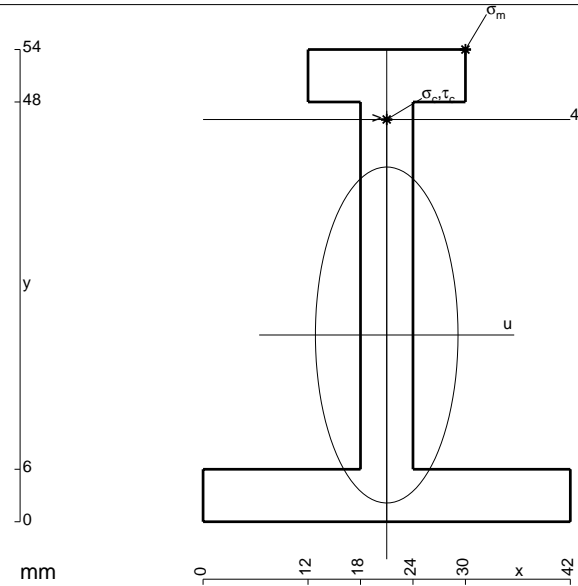
$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

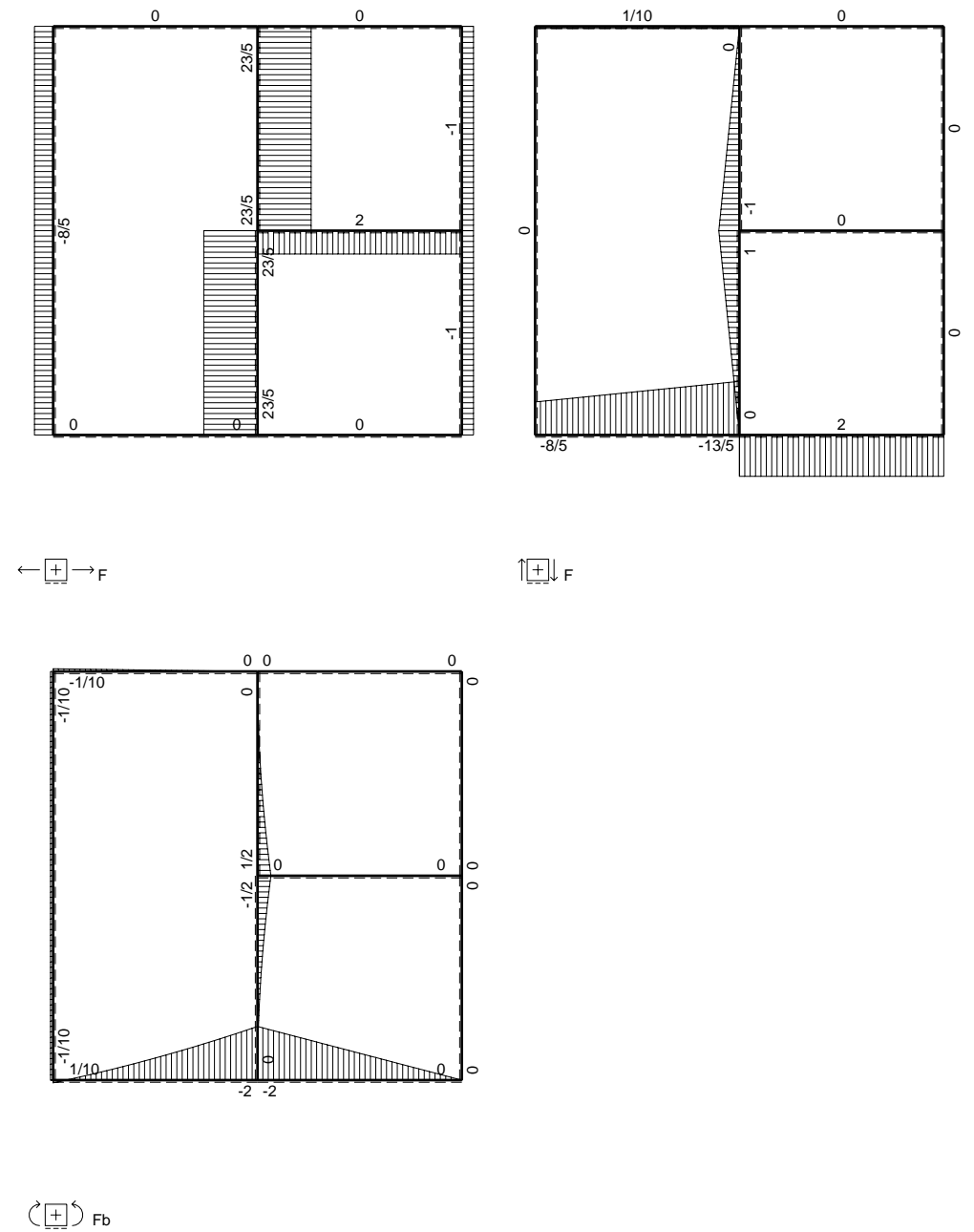
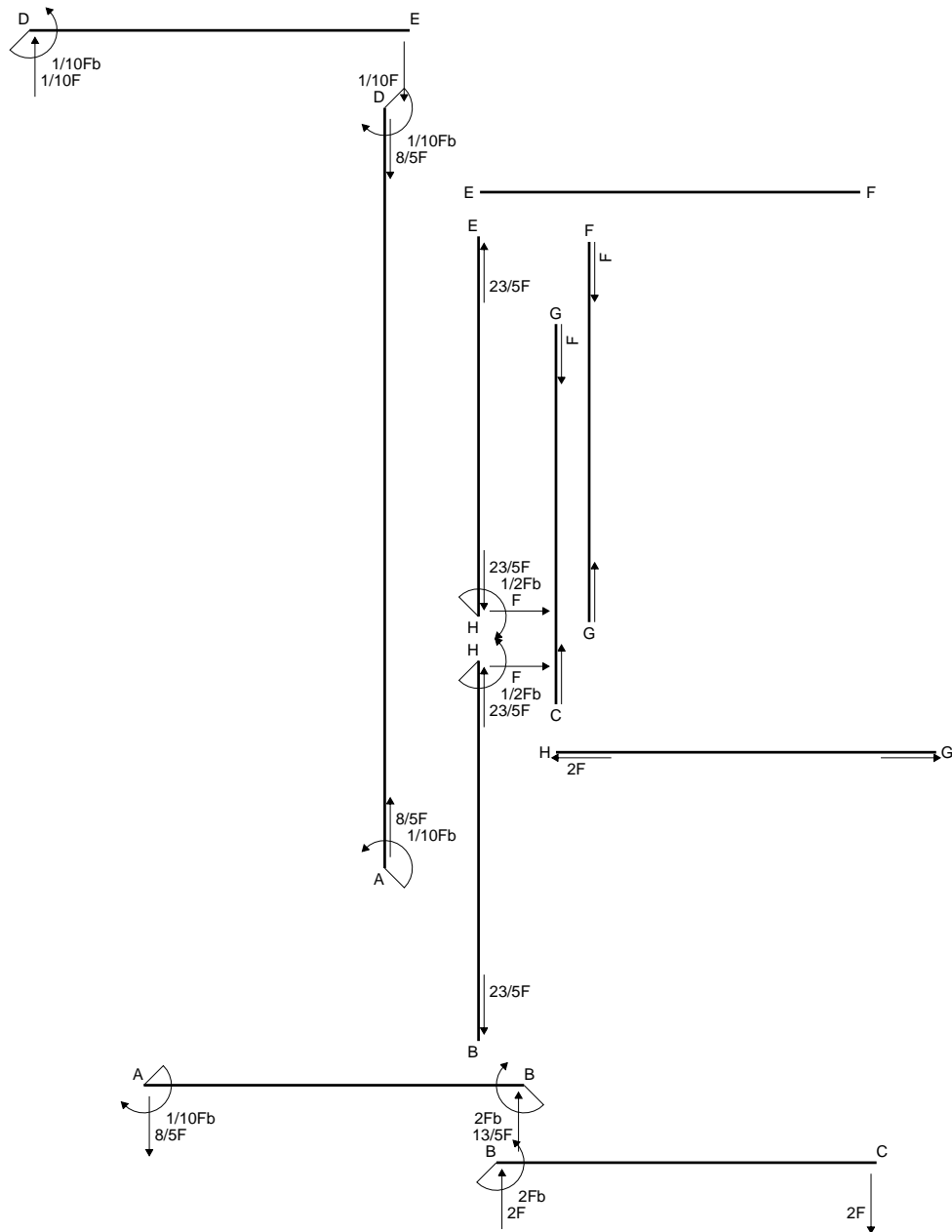
$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

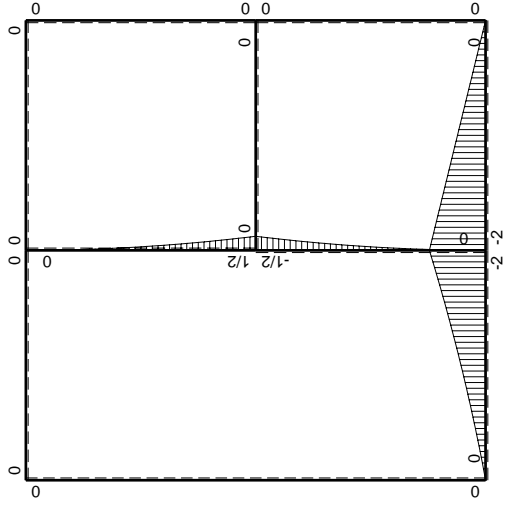
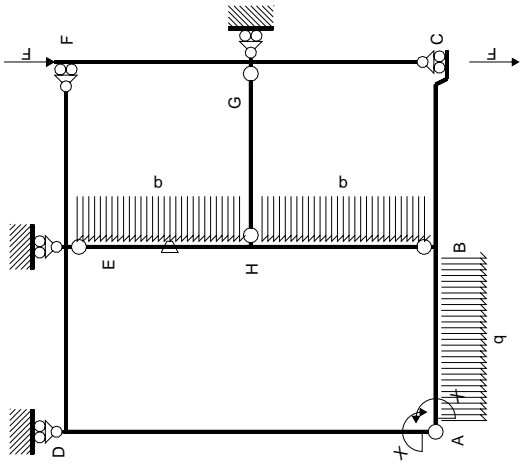
$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$



- A = 612. mm<sup>2</sup>
- J<sub>u</sub> = 225968. mm<sup>4</sup>
- J<sub>v</sub> = 40716. mm<sup>4</sup>
- y<sub>g</sub> = 21.35 mm
- T<sub>y</sub> = 1860. N
- M<sub>x</sub> = -1450800. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 9. mm
- v<sub>m</sub> = 32.65 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 209.6 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 46. mm
- v<sub>c</sub> = 24.65 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 158.2 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.815 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 158.5 N/mm<sup>2</sup>
- S = 3510. mm<sup>3</sup>

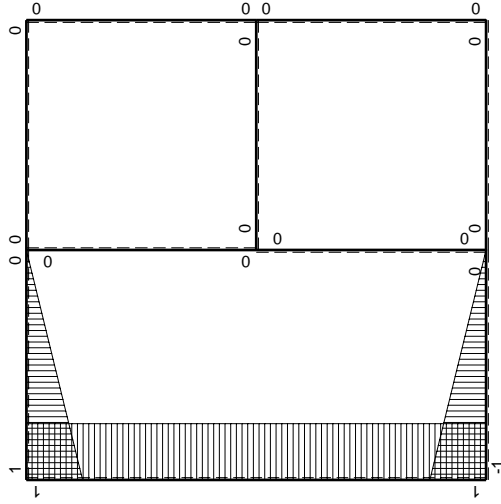






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
BH b	0	$1/2qx^2$	0	0	0	0			
HE b	0	$1/2Fb-Fx+1/2qx^2$	$-Fb/EJ$	0	0	0	0+0	0	
EH b	0	$-1/2qx^2$	$Fb/EJ$	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (-2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (-2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

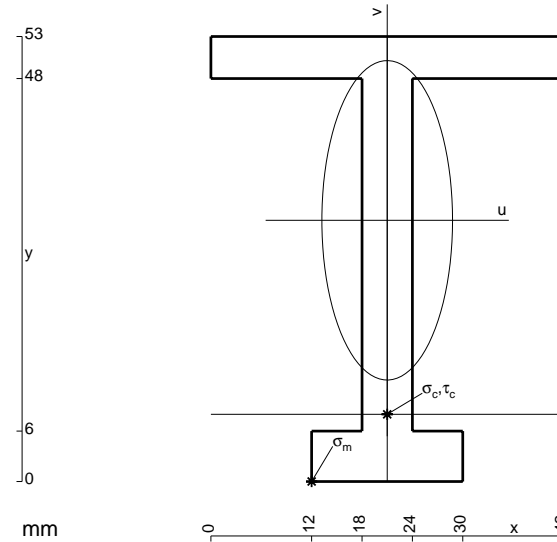
$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

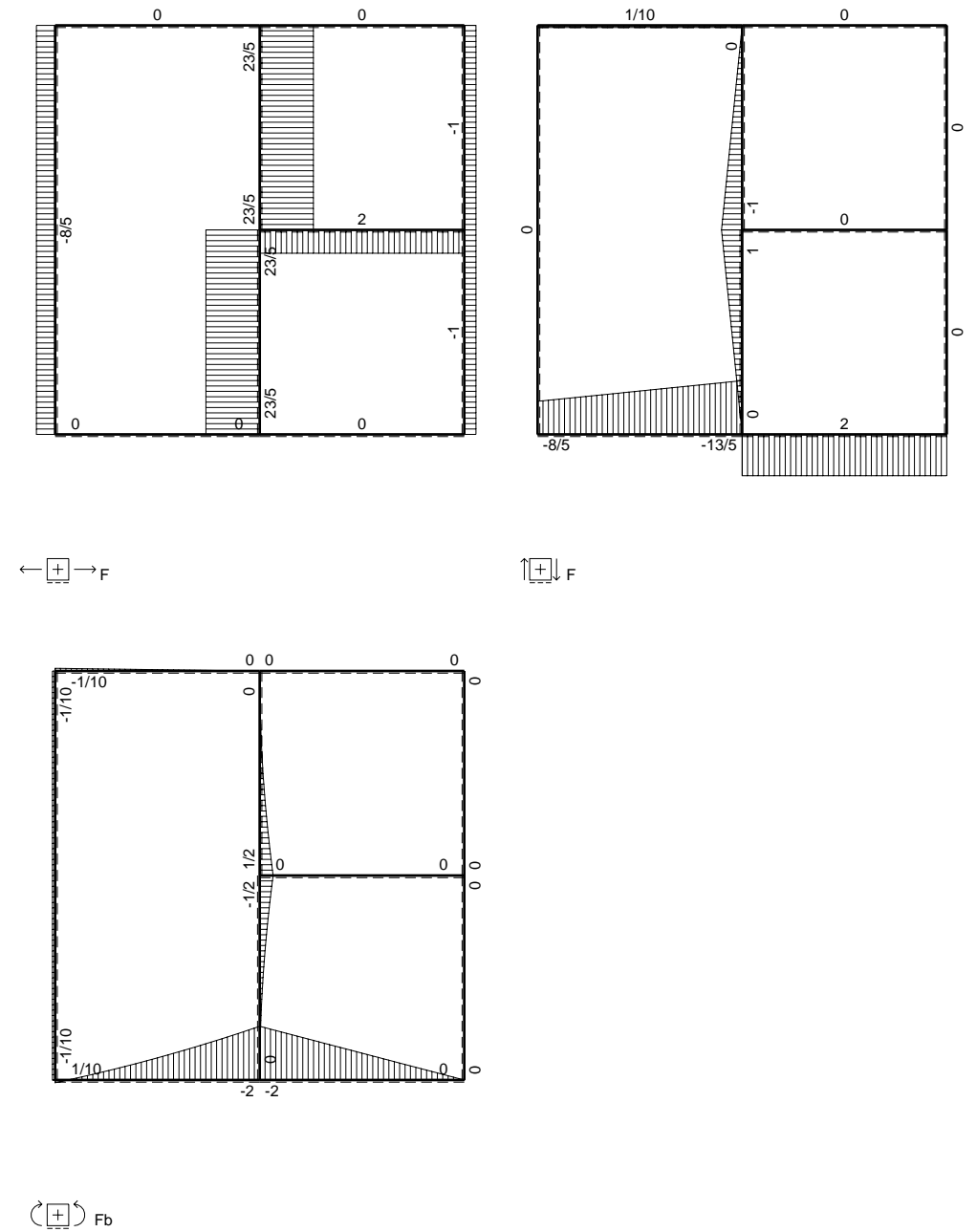
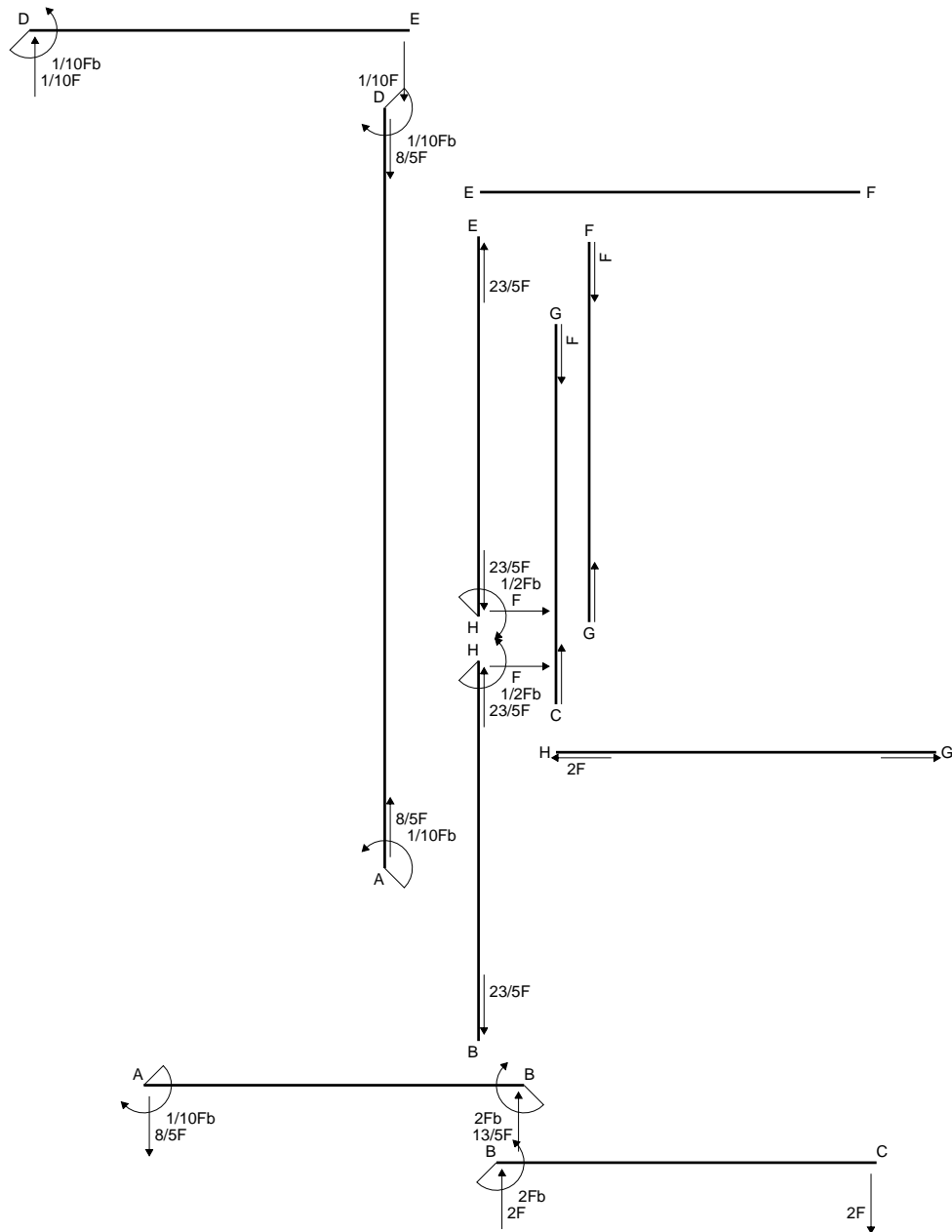
$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

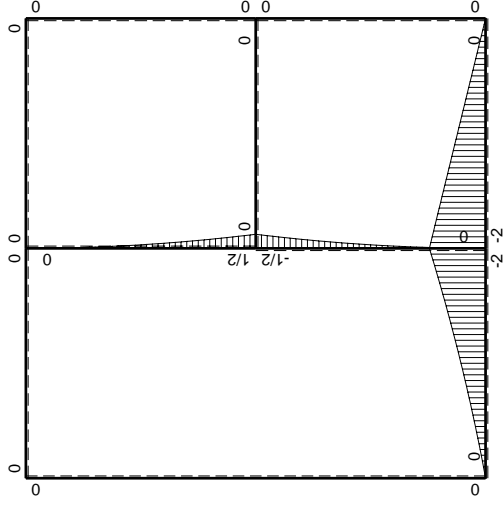
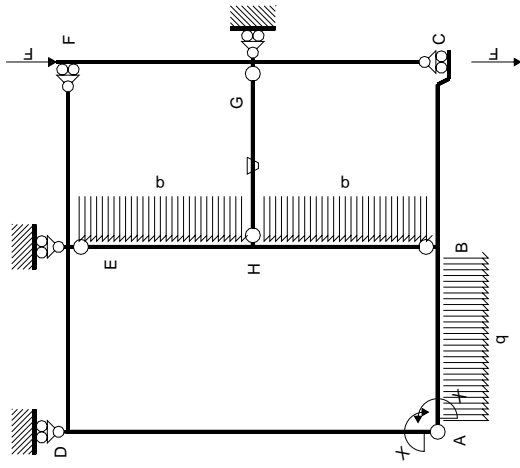
$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$



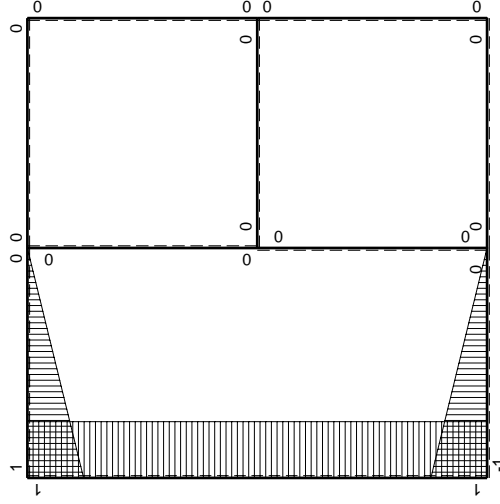
- A = 570. mm<sup>2</sup>
- J<sub>u</sub> = 206355. mm<sup>4</sup>
- J<sub>v</sub> = 34542. mm<sup>4</sup>
- y<sub>g</sub> = 31.11 mm
- T<sub>y</sub> = 1800. N
- M<sub>x</sub> = -1458000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -9. mm
- v<sub>m</sub> = -31.11 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -219.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 8. mm
- v<sub>c</sub> = -23.11 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -163.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.834 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 163.5 N/mm<sup>2</sup>
- S = 3325. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
GH b	0	0	$Fb/EJ$	0	0	0			
HB b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
BH b	0	$1/2qx^2$	0	0	0	0			
HE b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0+0	0	
EH b	0	$-1/2qx^2$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

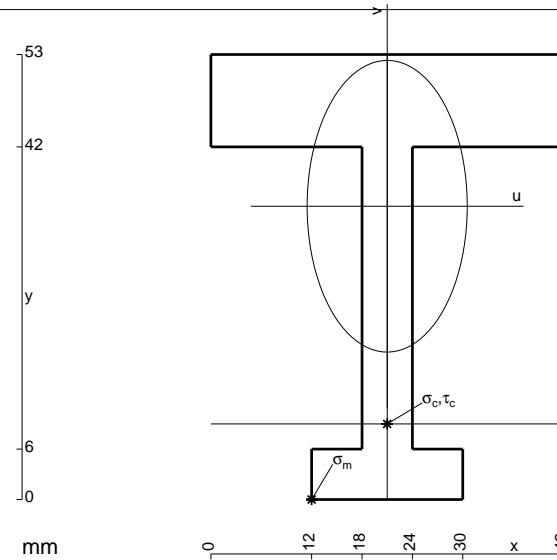
$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

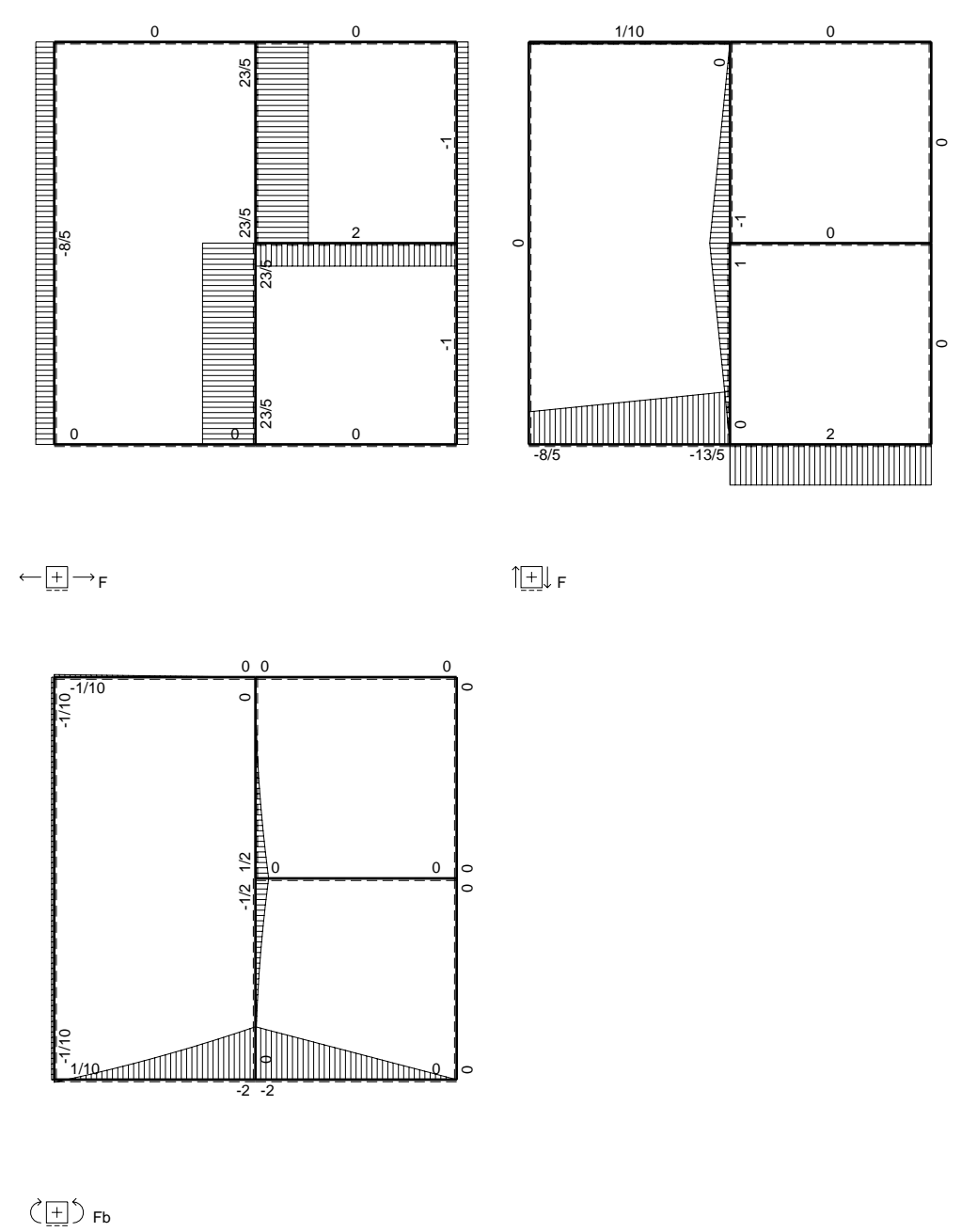
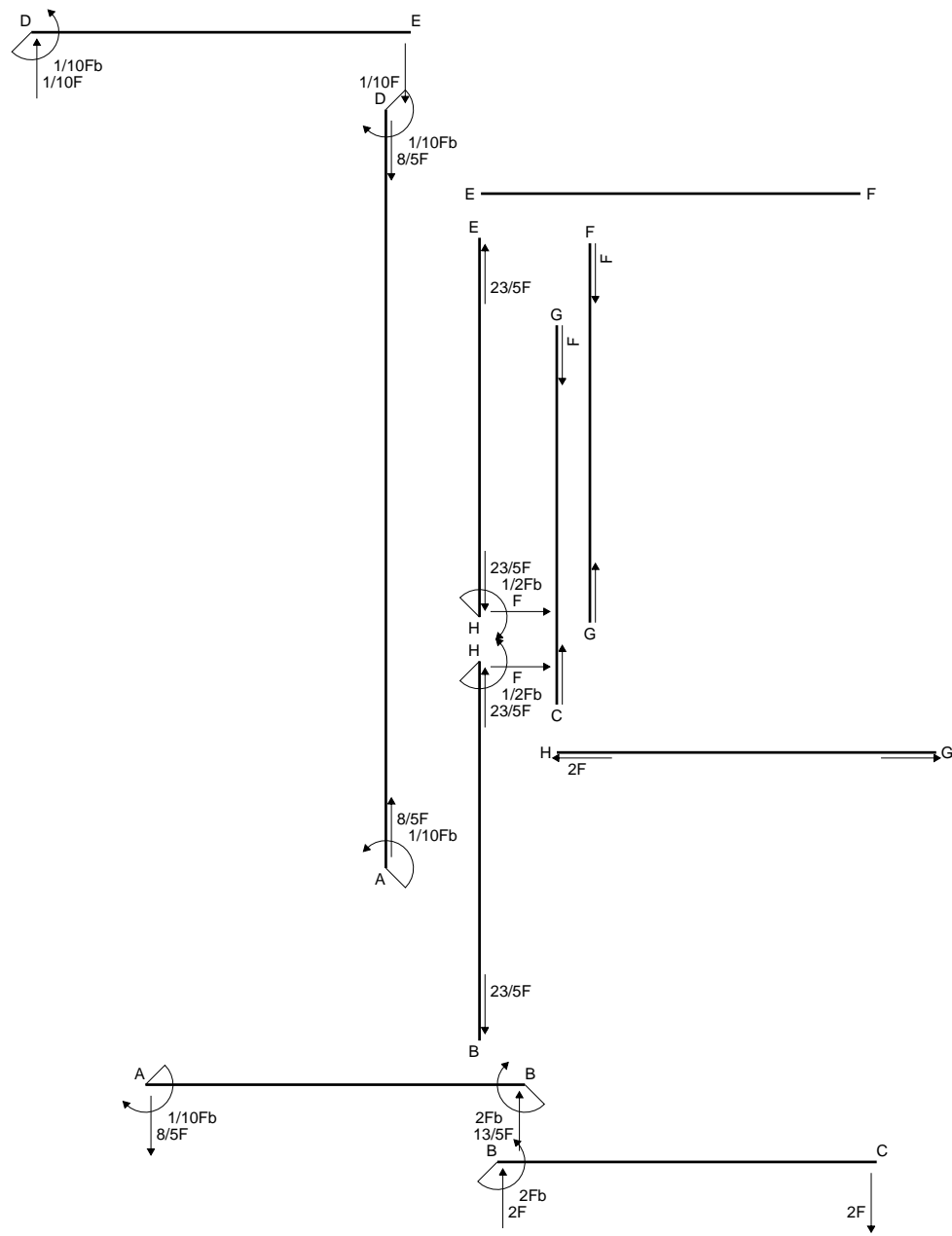
$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

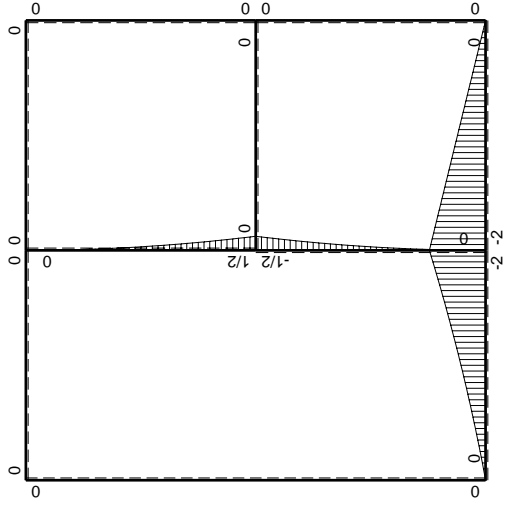
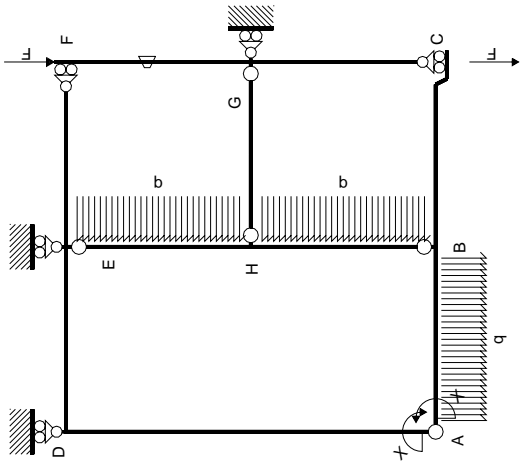
$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$



- A = 786. mm<sup>2</sup>
- J<sub>u</sub> = 237222. mm<sup>4</sup>
- J<sub>v</sub> = 71478. mm<sup>4</sup>
- y<sub>g</sub> = 34.93 mm
- T<sub>y</sub> = 1800. N
- M<sub>x</sub> = -1548000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -9. mm
- v<sub>m</sub> = -34.93 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -227.9 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 9. mm
- v<sub>c</sub> = -25.93 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -169.2 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.985 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 169.4 N/mm<sup>2</sup>
- S = 3942. mm<sup>3</sup>

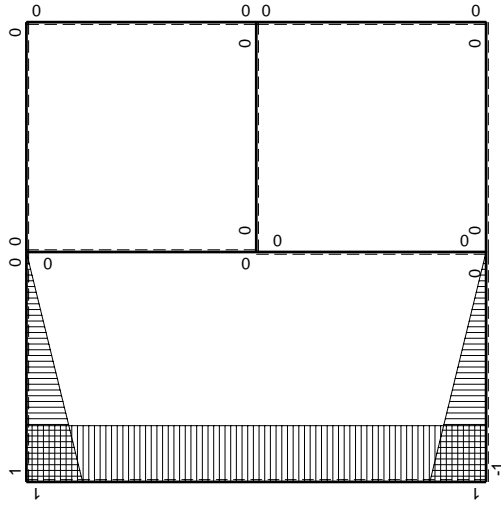






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
GF b	0	0	$Fb/EJ$	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
BH b	0	$1/2qx^2$	0	0	0	0			
HE b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0+0	0	
EH b	0	$-1/2qx^2$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (-2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (-2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

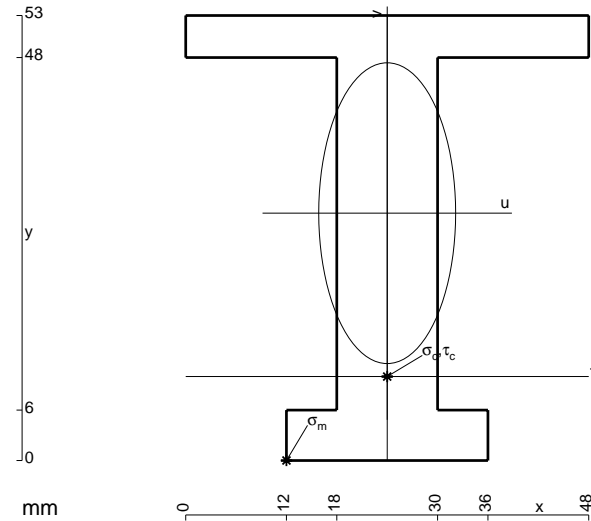
$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

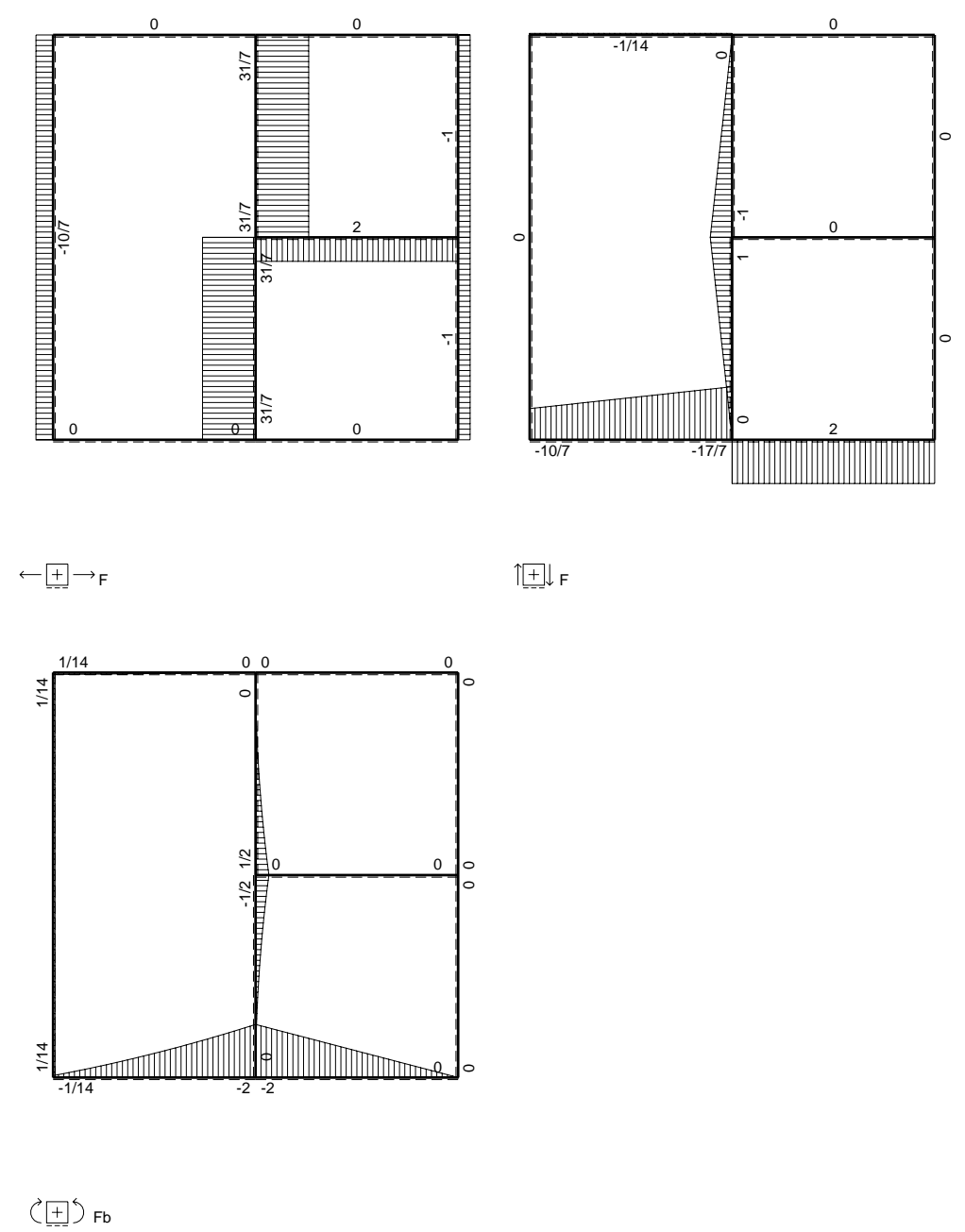
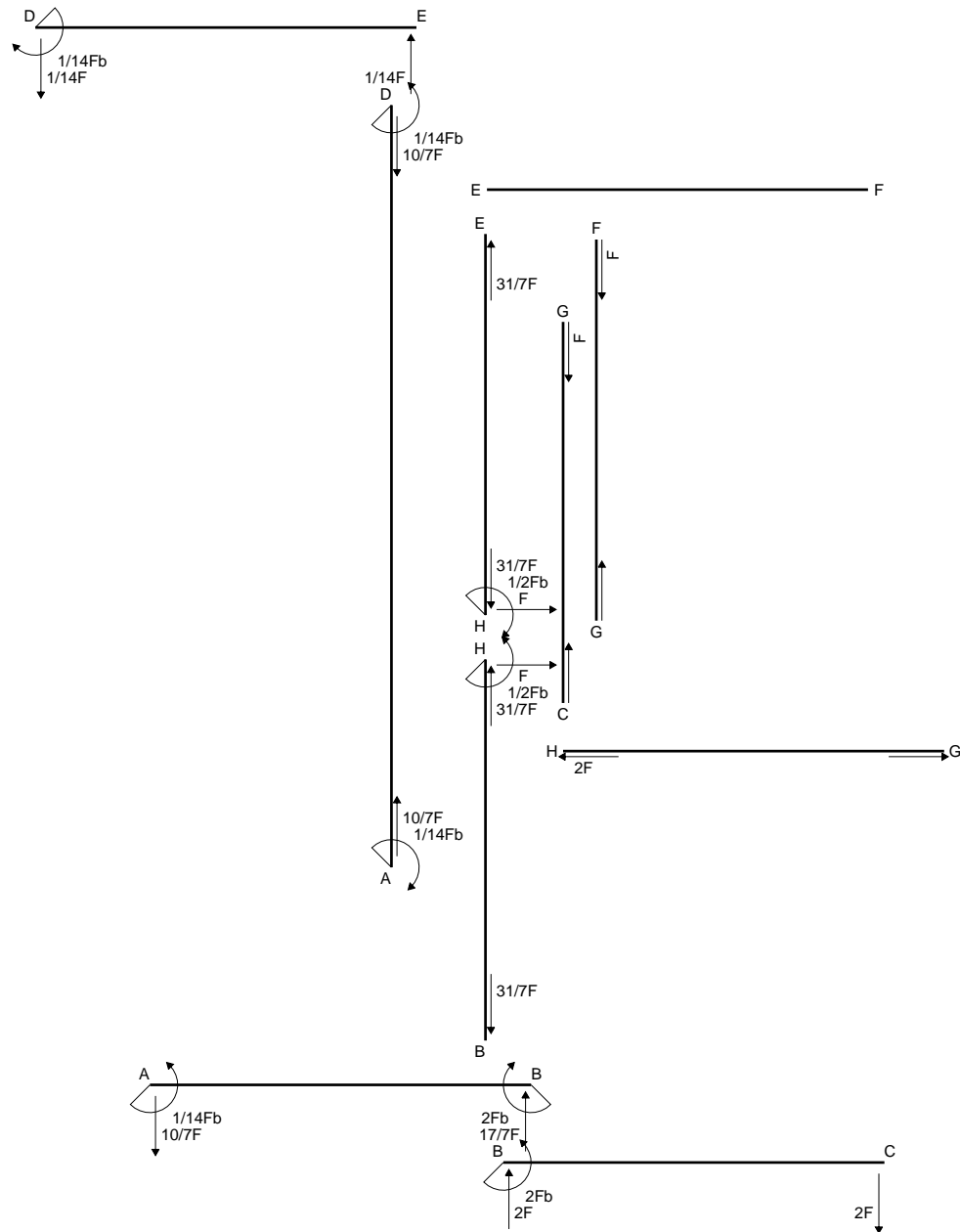
$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

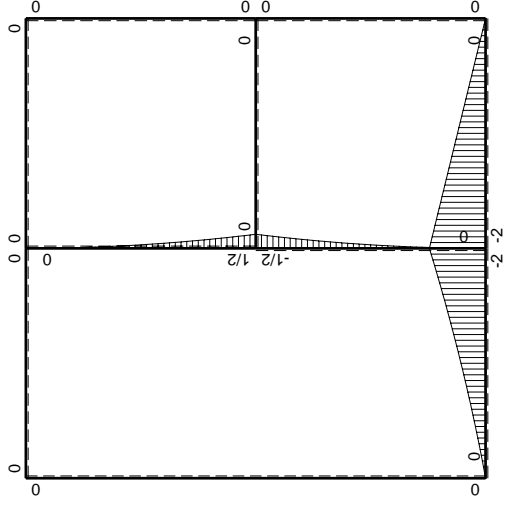
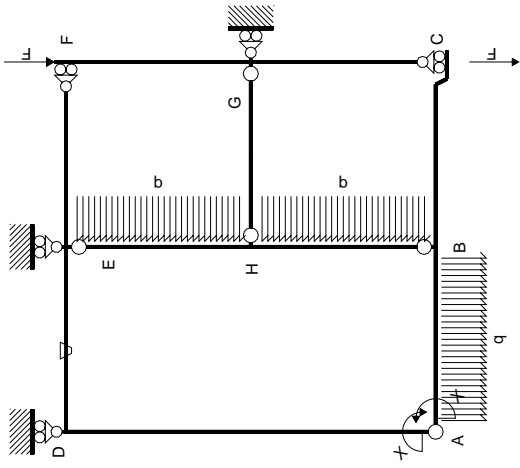
$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$



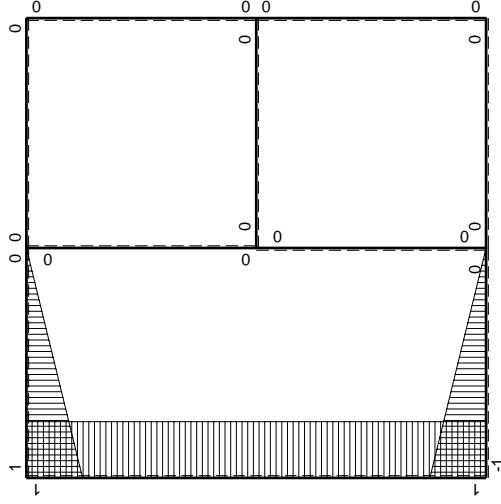
- A = 888. mm<sup>2</sup>
- J<sub>u</sub> = 285133. mm<sup>4</sup>
- J<sub>v</sub> = 59040. mm<sup>4</sup>
- y<sub>g</sub> = 29.46 mm
- T<sub>y</sub> = 2540. N
- M<sub>x</sub> = -2311400. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -12. mm
- v<sub>m</sub> = -29.46 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -238.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 10. mm
- v<sub>c</sub> = -19.46 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -157.7 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.593 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 157.9 N/mm<sup>2</sup>
- S = 4840. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_1$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	2Xb/EJ	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	$-Fb/EJ$	0	$-Fb/EJ+Fx/EJ$	$1-2x/b+x^2/b^2$	$(0-1/2)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	0	$Fb/EJ$	0	$-Fx/EJ$	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
BH b	0	$1/2qx^2$	0	0	0	0			
HE b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0+0	0	
EH b	0	$-1/2qx^2$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$-5/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$1/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ}$$

$$= (b - b + 1/3 b) \frac{1}{EJ} = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx = \left[ 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ}$$

$$= (1/3 b) \frac{1}{EJ} = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

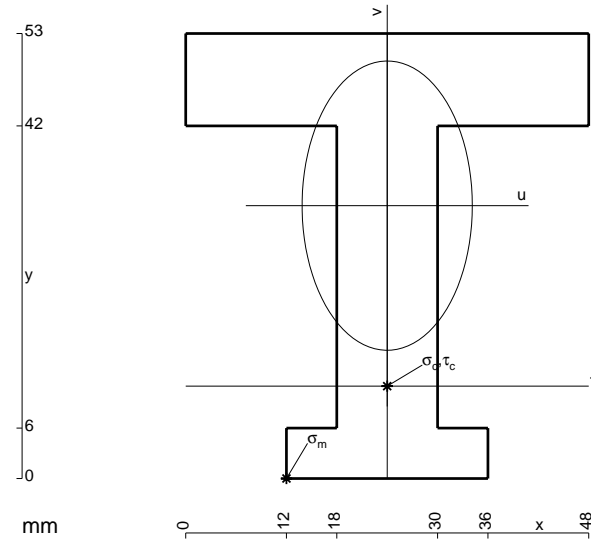
$$= (b - 5/6 b + 1/8 b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (-1 + x/b) \theta dx = \left[ -x + 1/2 x^2/b \right]_0^b \theta$$

$$= (-b + 1/2 b) \theta = -1/2 \cdot Fb^2/EJ$$

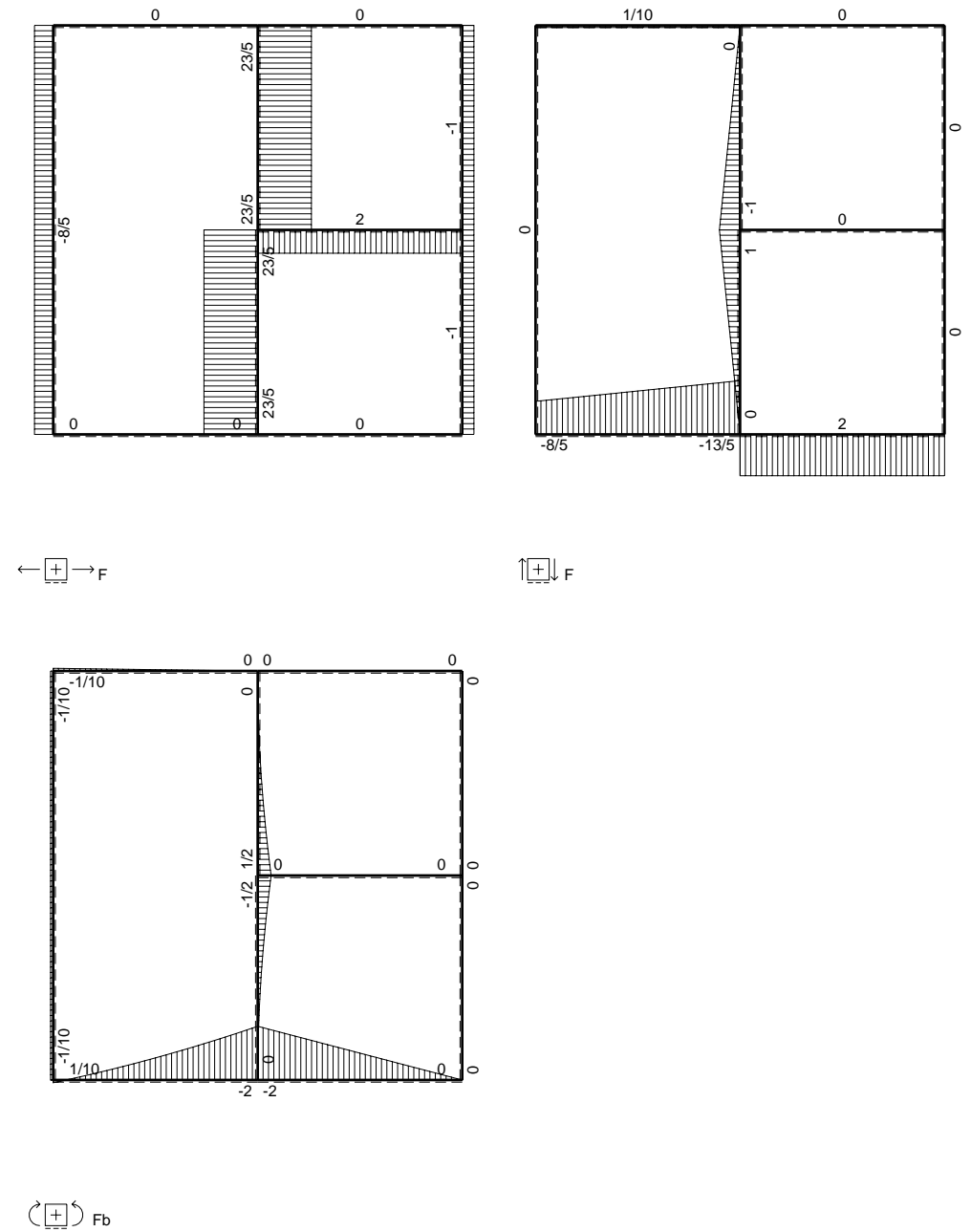
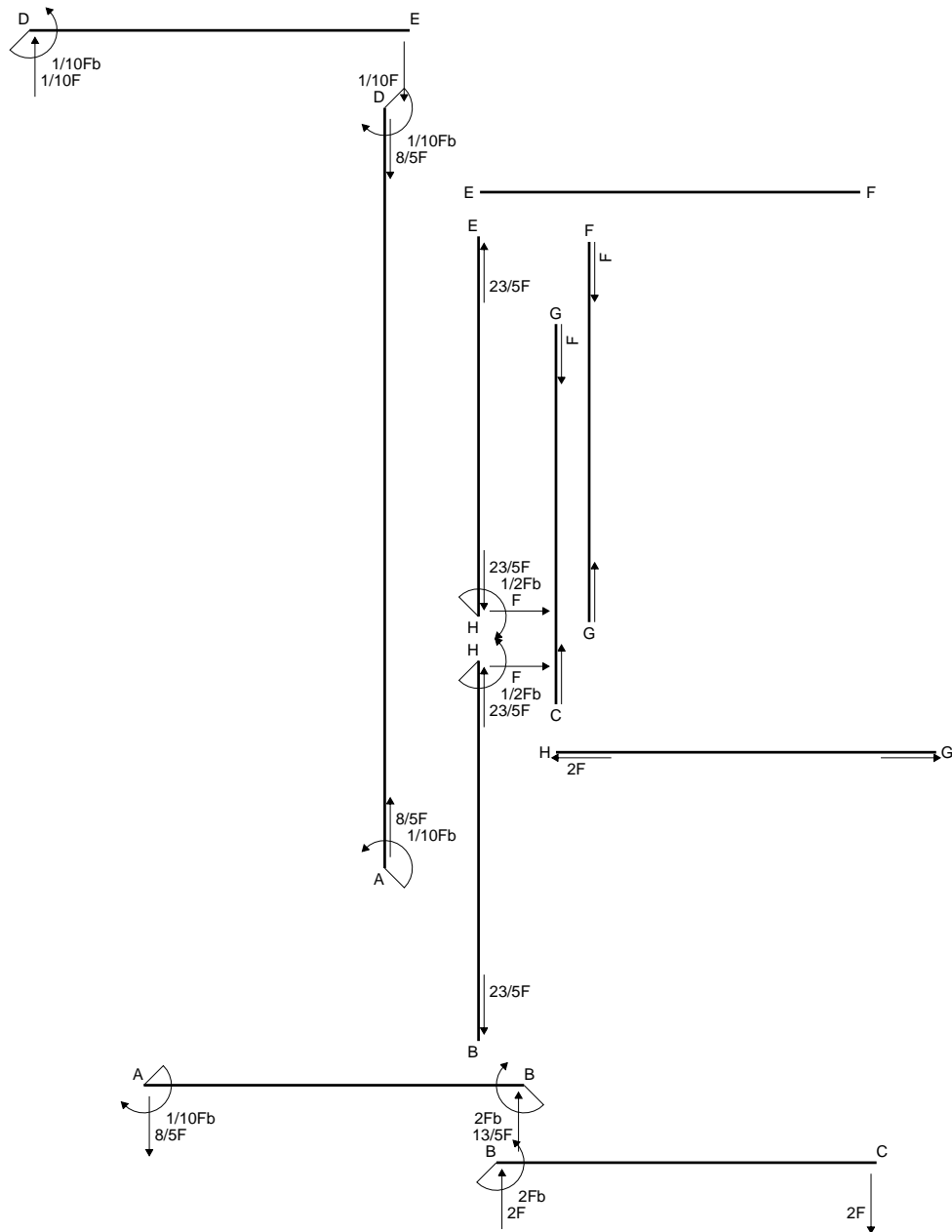
$$L_{ED}^{xo} = \int_0^b (x/b) \theta dx = \left[ 1/2 x^2/b \right]_0^b \theta$$

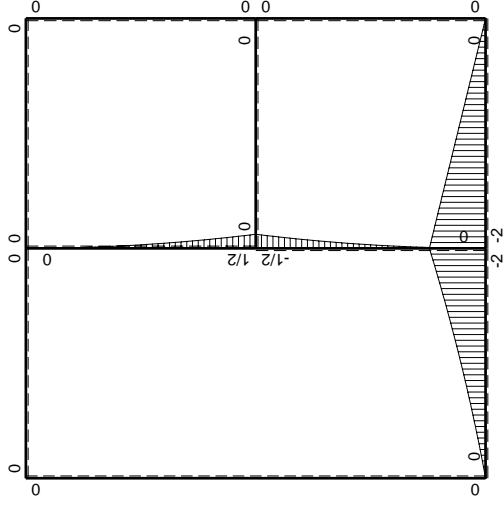
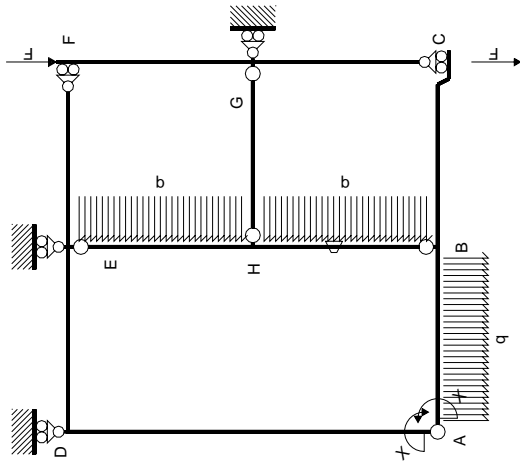
$$= (1/2 b) \theta = -1/2 \cdot Fb^2/EJ$$



- A = 1104. mm<sup>2</sup>
- J<sub>u</sub> = 327740. mm<sup>4</sup>
- J<sub>v</sub> = 113472. mm<sup>4</sup>
- y<sub>g</sub> = 32.5 mm
- T<sub>y</sub> = 4200. N
- M<sub>x</sub> = -2016000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -12. mm
- v<sub>m</sub> = -32.5 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -199.9 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 11. mm
- v<sub>c</sub> = -21.5 mm
- σ<sub>c</sub> = -Mv/J<sub>v</sub> = -132.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 6.074 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 132.7 N/mm<sup>2</sup>
- S = 5688. mm<sup>3</sup>

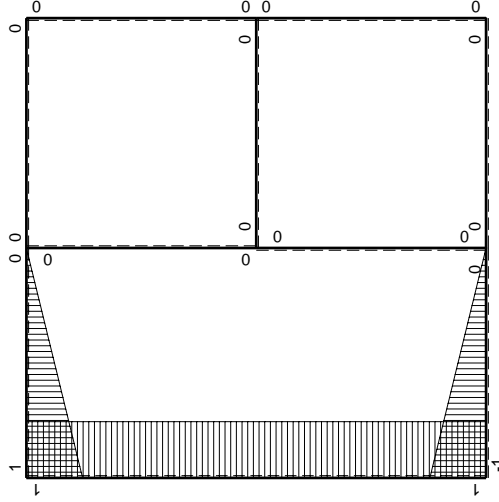






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-1/2Fb+Fx-1/2qx^2$	$-Fb/EJ$	0	0	0	0+0	0	
BH b	0	$1/2qx^2$	$Fb/EJ$	0	0	0			
HE b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0+0	0	
EH b	0	$-1/2qx^2$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

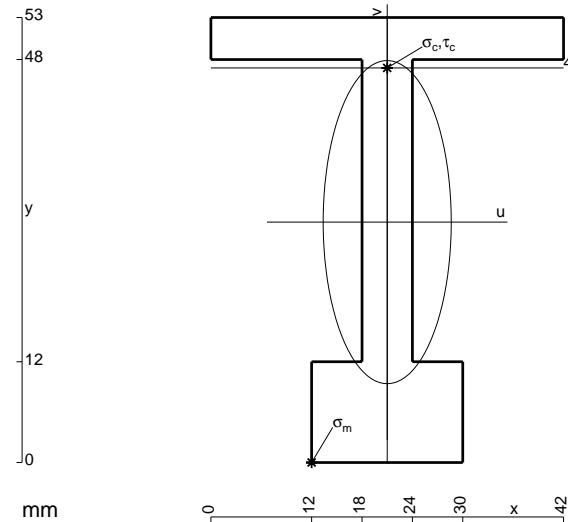
$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

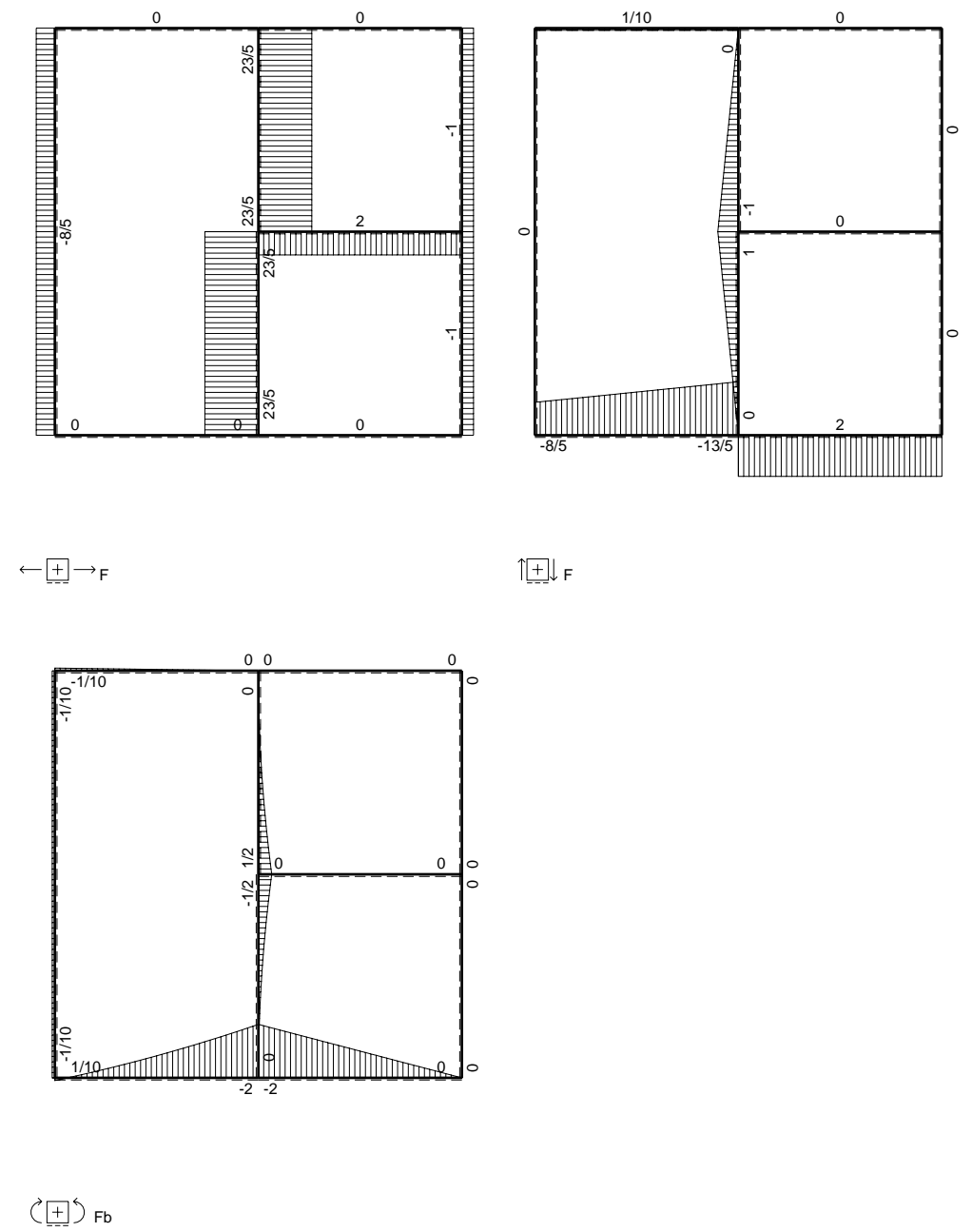
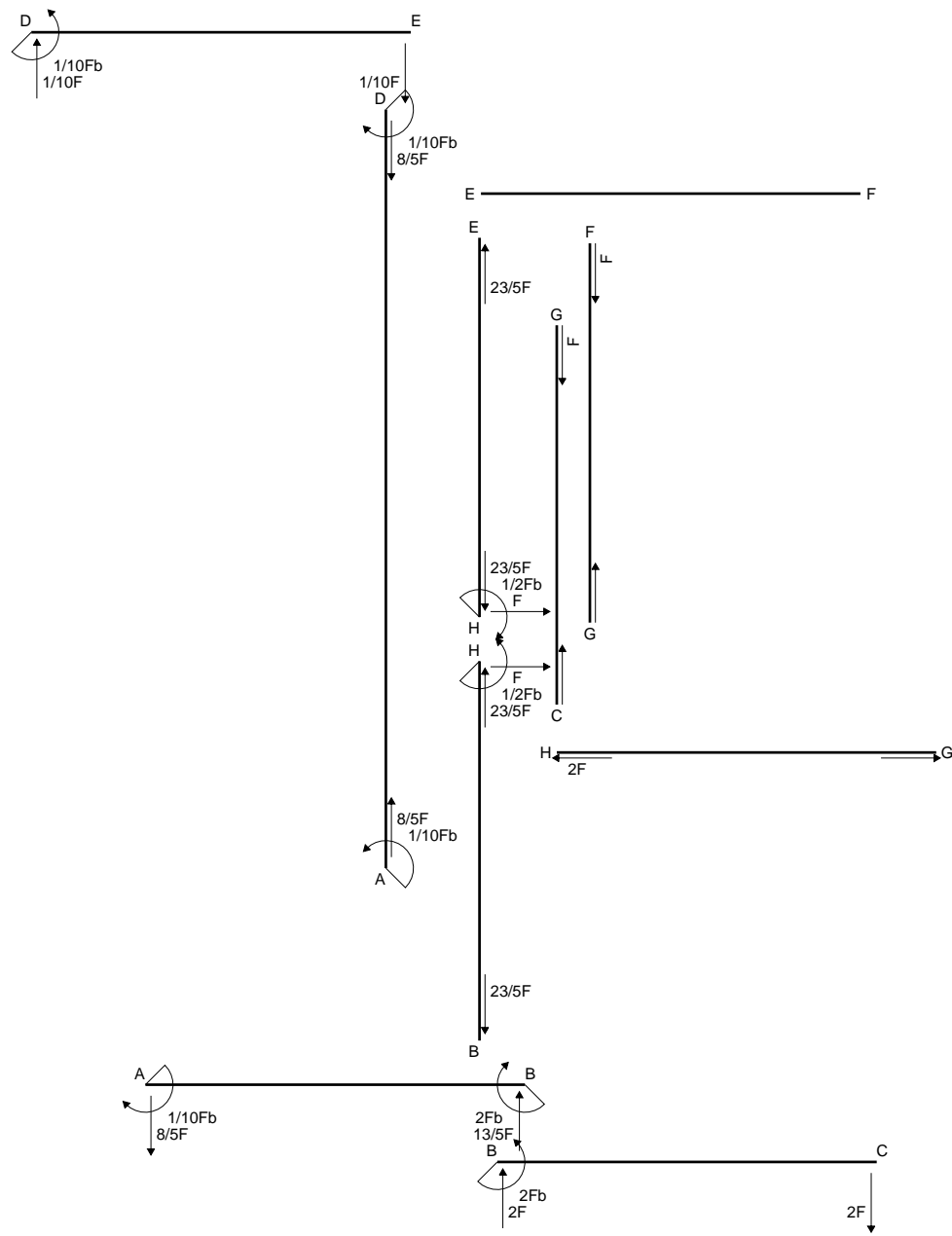
$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

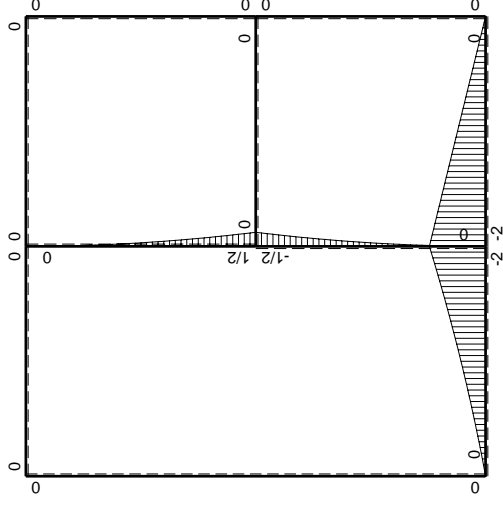
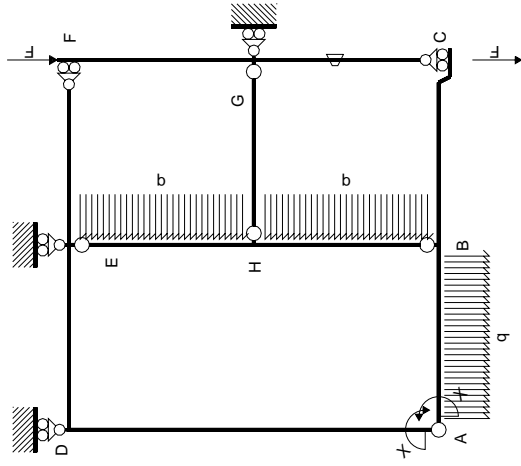
$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$



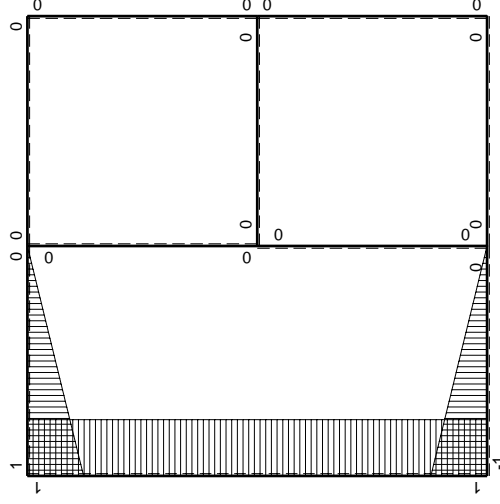
- A = 642. mm<sup>2</sup>
- J<sub>u</sub> = 237823. mm<sup>4</sup>
- J<sub>v</sub> = 37350. mm<sup>4</sup>
- y<sub>g</sub> = 28.63 mm
- T<sub>y</sub> = 3340. N
- M<sub>x</sub> = -1736800. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -9. mm
- v<sub>m</sub> = -28.63 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -209.1 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 47. mm
- v<sub>c</sub> = 18.37 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 134.1 N/mm<sup>2</sup>
- τ<sub>c</sub> = 11.01 N/mm<sup>2</sup>
- σ<sub>o</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 135.5 N/mm<sup>2</sup>
- S = 4706. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
CG b	0	0	$Fb/EJ$	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
BH b	0	$1/2qx^2$	0	0	0	0			
HE b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0+0	0	
EH b	0	$-1/2qx^2$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

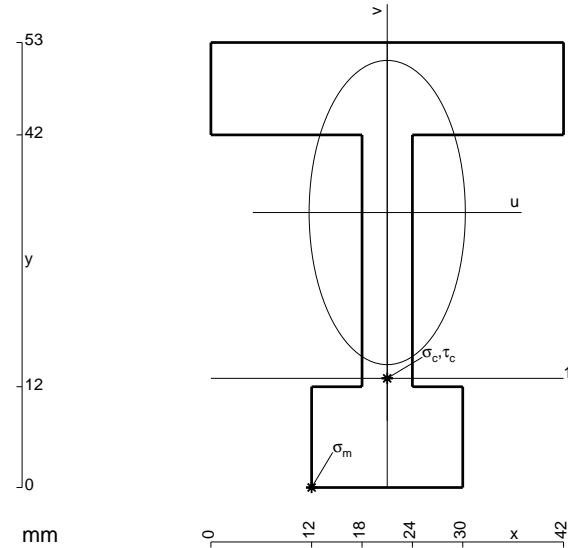
$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

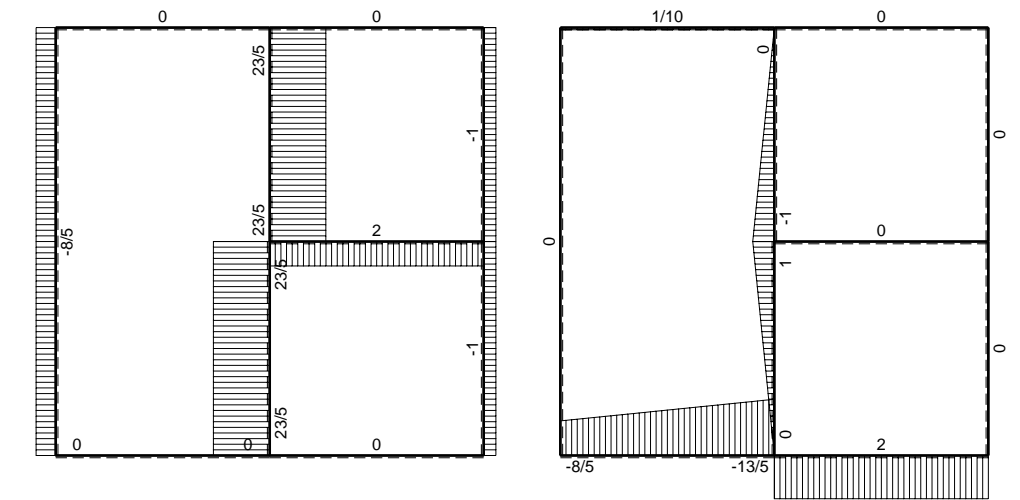
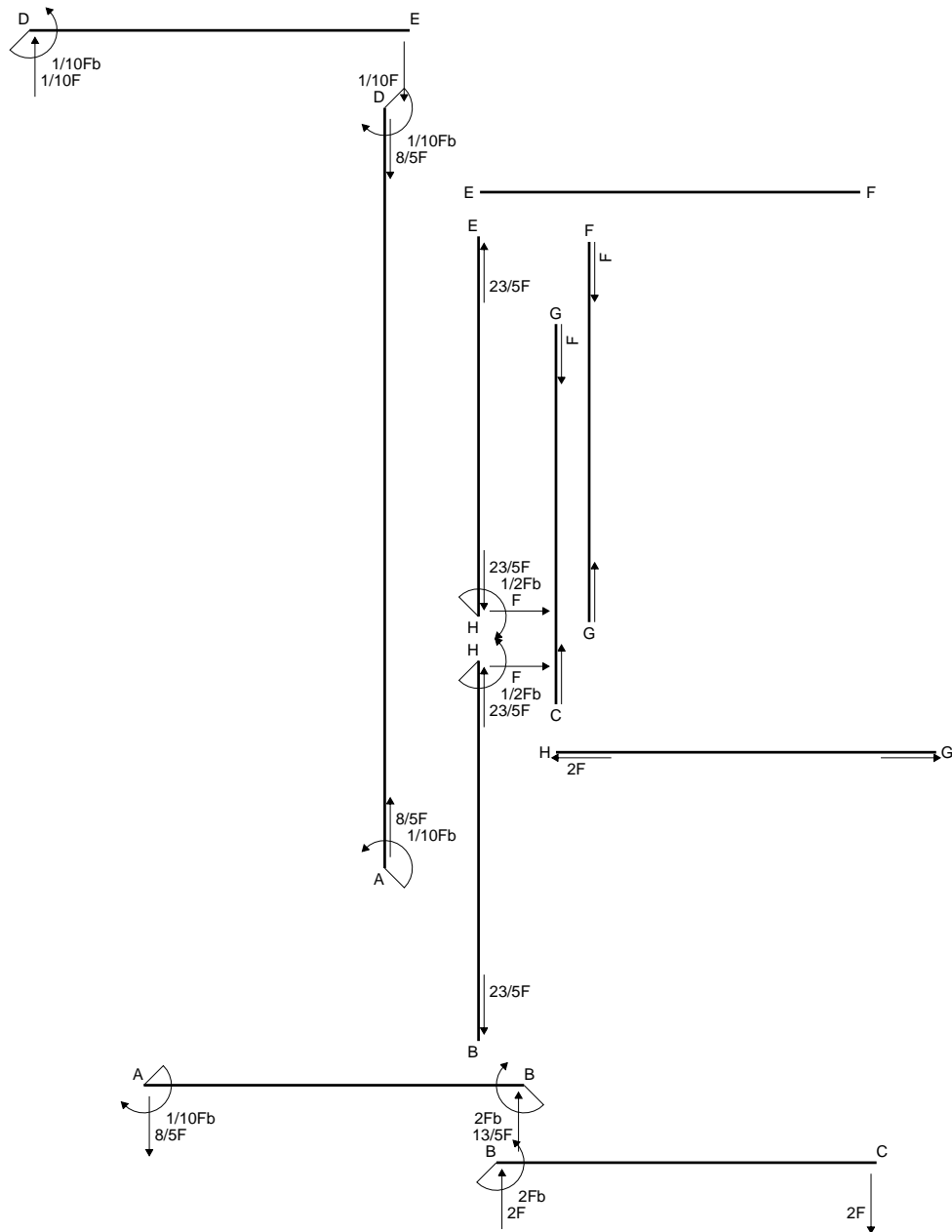
$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$



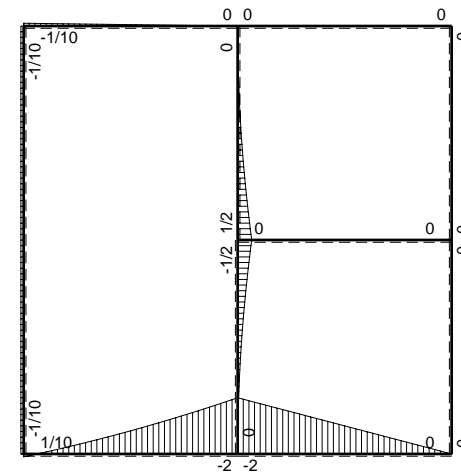
- A = 858. mm<sup>2</sup>
- J<sub>u</sub> = 281777. mm<sup>4</sup>
- J<sub>v</sub> = 74286. mm<sup>4</sup>
- y<sub>g</sub> = 32.75 mm
- T<sub>y</sub> = 3320. N
- M<sub>x</sub> = -1892400. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -9. mm
- v<sub>m</sub> = -32.75 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -220. N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 13. mm
- v<sub>c</sub> = -19.75 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -132.7 N/mm<sup>2</sup>
- τ<sub>c</sub> = 11.59 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 134.2 N/mm<sup>2</sup>
- S = 5900. mm<sup>3</sup>



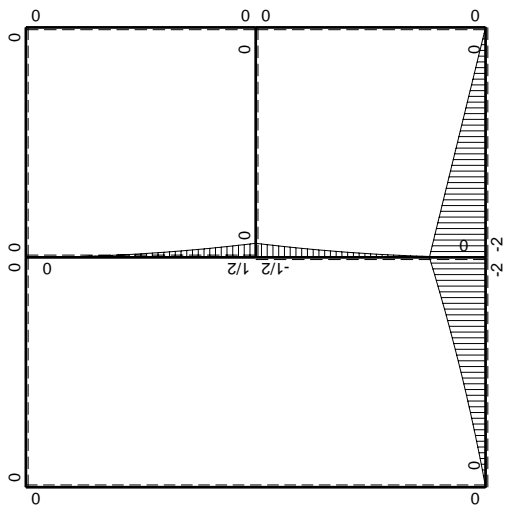
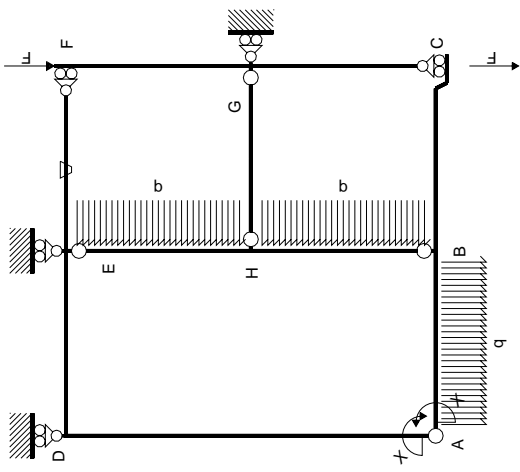


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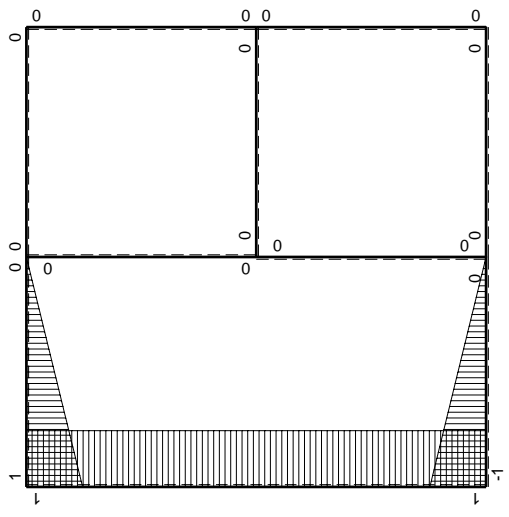


⊕ ⊖ F<sub>b</sub>



Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_X$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
FE b	0	0	$Fb/EJ$	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
BH b	0	$1/2qx^2$	0	0	0	0			
HE b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0+0	0	
EH b	0	$-1/2qx^2$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

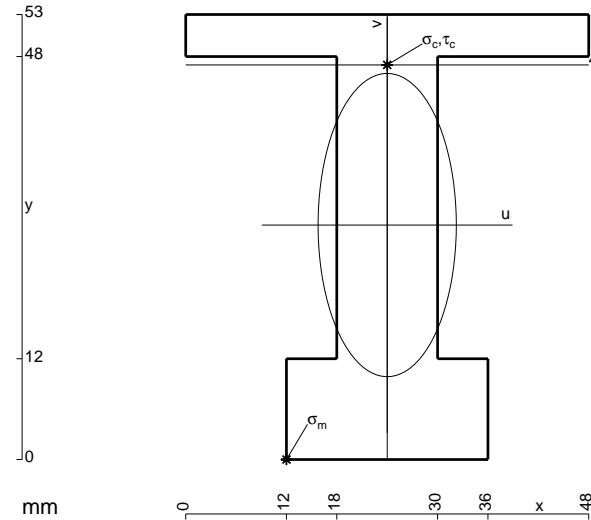
$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

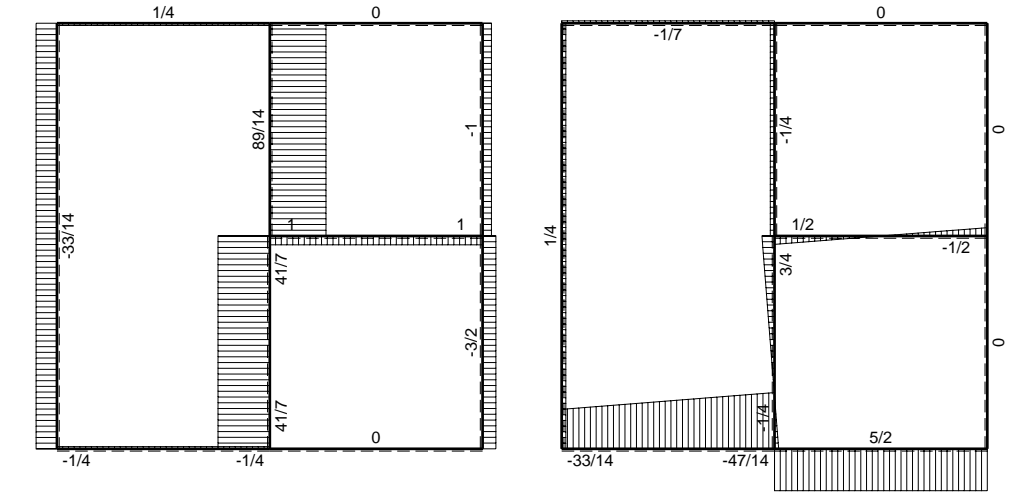
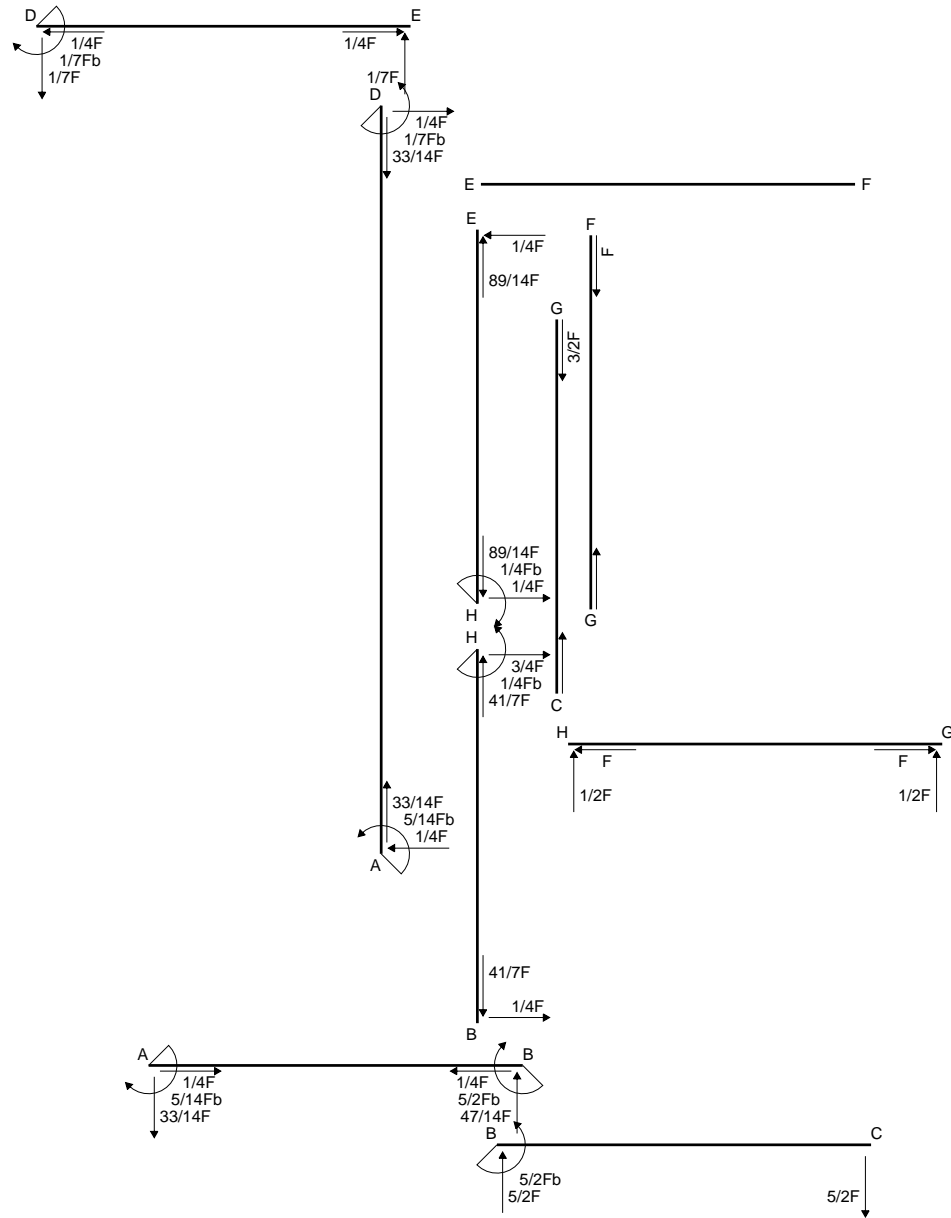
$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

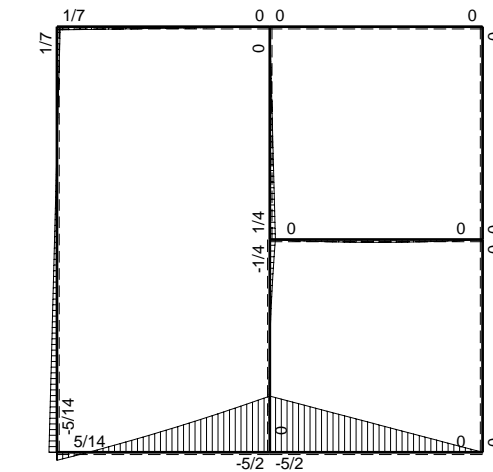


- A = 960. mm<sup>2</sup>
- J<sub>u</sub> = 313227. mm<sup>4</sup>
- J<sub>v</sub> = 65088. mm<sup>4</sup>
- y<sub>g</sub> = 27.92 mm
- T<sub>y</sub> = 4160. N
- M<sub>x</sub> = -2579200. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -12. mm
- v<sub>m</sub> = -27.92 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -229.9 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 47. mm
- v<sub>c</sub> = 19.08 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 157.1 N/mm<sup>2</sup>
- τ<sub>c</sub> = 6.256 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 157.4 N/mm<sup>2</sup>
- S = 5653. mm<sup>3</sup>

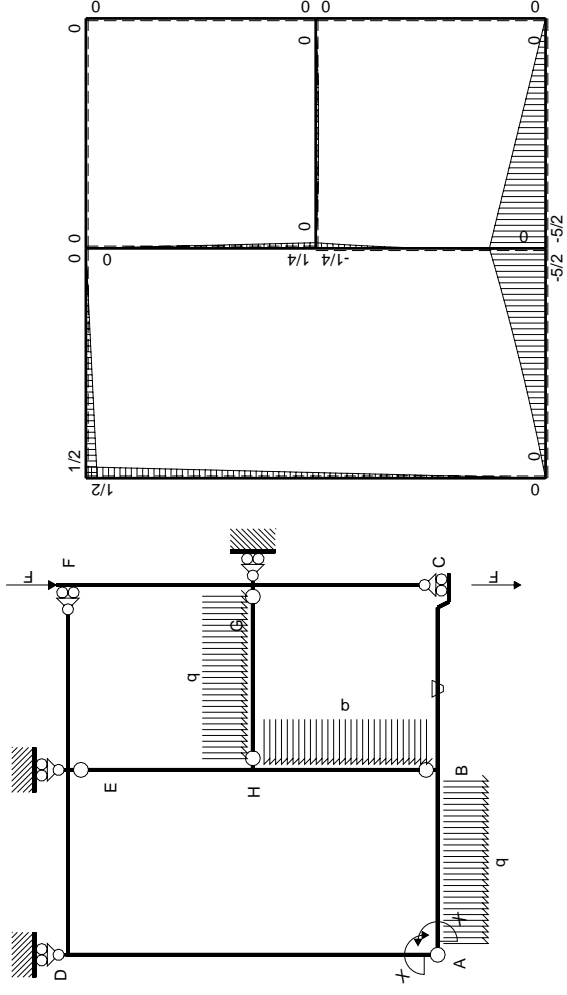


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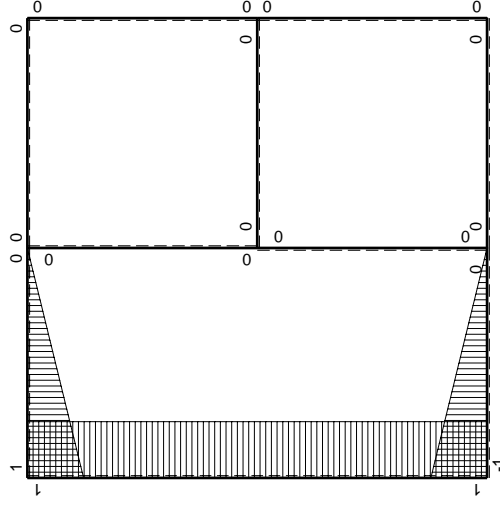


⊕ ⊖ Fb



Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$
AB b	$-1+x/b$	$-2Fx-1/2qx^2$	0	$2Fx-3/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(3/8+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$5/2Fb-3Fx+1/2qx^2$	0	$5/2Fx-3Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-5/2Fb+5/2Fx$	$-Fb/EJ$	0	0	0	0+0	0
CB b	0	$5/2Fx$	$Fb/EJ$	0	0	0		
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1		
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$		
EF b	0	0	0	0	0	0	0+0	0
FE b	0	0	0	0	0	0		
FG b	0	0	0	0	0	0	0+0	0
GF b	0	0	0	0	0	0		
GC b	0	0	0	0	0	0	0+0	0
CG b	0	0	0	0	0	0		
HG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0
GH b	0	$-1/2Fx+1/2qx^2$	0	0	0	0		
HB b	0	$-1/4Fb+3/4Fx-1/2qx^2$	0	0	0	0	0+0	0
BH b	0	$-1/4Fx+1/2qx^2$	0	0	0	0		
HE b	0	$1/4Fb-1/4Fx$	0	0	0	0	0+0	0
EH b	0	$-1/4Fx$	0	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$25/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$-5/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (2x/b - 3/2 x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 1/2 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 1/2 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (5/2 x/b - 3 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 5/4 x^2/b - x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (5/4 b - b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

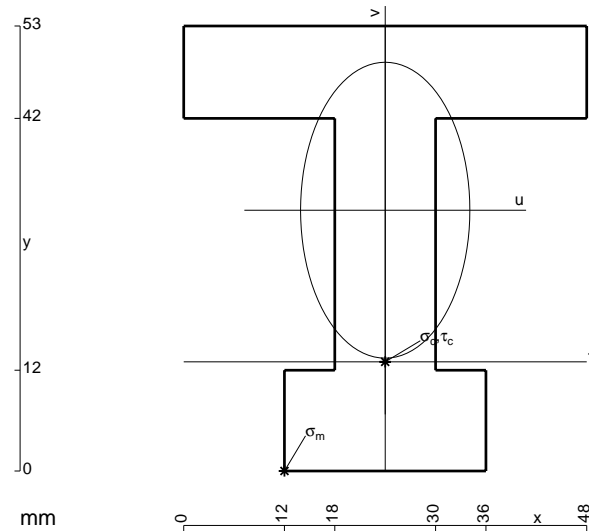
$$= (b - 1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/2 b - 1/2 b + 1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$

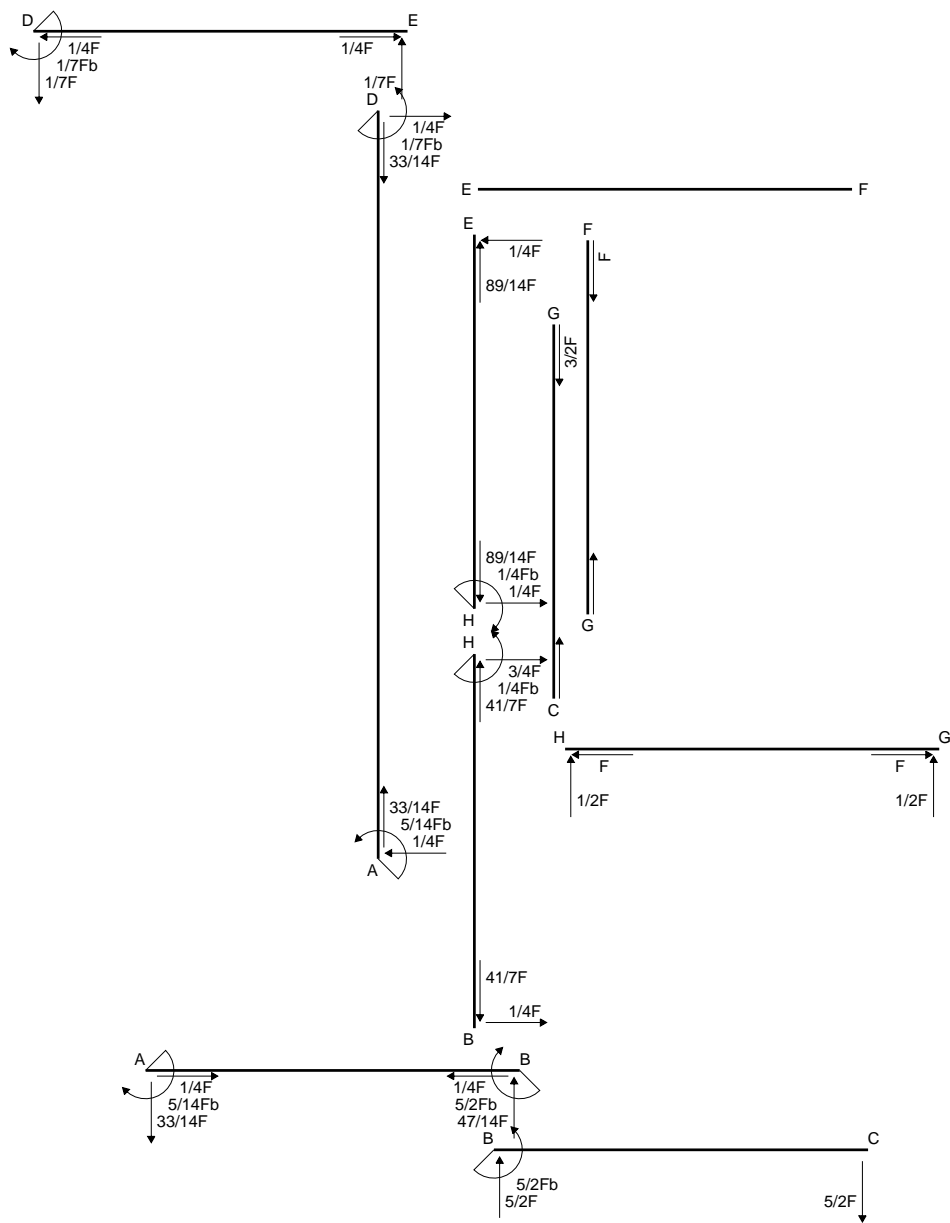
$$L_{ED}^{xo} = \int_0^b (1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

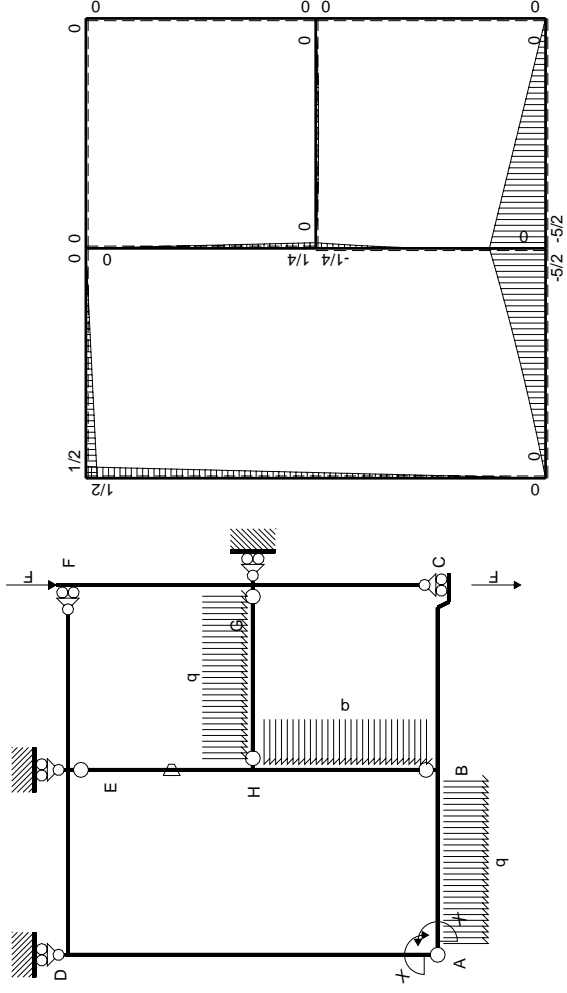
$$= (1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$



- A = 1176. mm<sup>2</sup>
- J<sub>u</sub> = 365284. mm<sup>4</sup>
- J<sub>v</sub> = 119520. mm<sup>4</sup>
- y<sub>g</sub> = 31.06 mm
- T<sub>y</sub> = 4200. N
- M<sub>x</sub> = -2814000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -12. mm
- v<sub>m</sub> = -31.06 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -239.3 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 13. mm
- v<sub>c</sub> = -18.06 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -139.1 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.129 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 139.7 N/mm<sup>2</sup>
- S = 7440. mm<sup>3</sup>

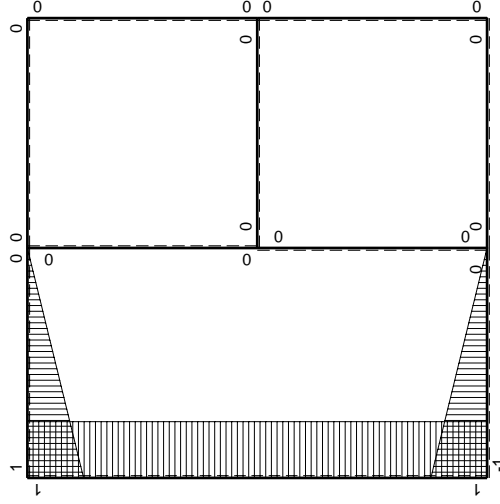






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$
AB b	$-1+x/b$	$-2Fx-1/2qx^2$	0	$2Fx-3/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(3/8+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$5/2Fb-3Fx+1/2qx^2$	0	$5/2Fx-3Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-5/2Fb+5/2Fx$	0	0	0	0	0+0	0
CB b	0	$5/2Fx$	0	0	0	0		
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1		
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$		
EF b	0	0	0	0	0	0	0+0	0
FE b	0	0	0	0	0	0		
FG b	0	0	0	0	0	0	0+0	0
GF b	0	0	0	0	0	0		
GC b	0	0	0	0	0	0	0+0	0
CG b	0	0	0	0	0	0		
HG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0
GH b	0	$-1/2Fx+1/2qx^2$	0	0	0	0		
HB b	0	$-1/4Fb+3/4Fx-1/2qx^2$	0	0	0	0	0+0	0
BH b	0	$-1/4Fx+1/2qx^2$	0	0	0	0		
HE b	0	$1/4Fb-1/4Fx$	$-Fb/EJ$	0	0	0	0+0	0
EH b	0	$-1/4Fx$	$Fb/EJ$	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$25/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$-5/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (2x/b - 3/2 x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 1/2 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 1/2 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (5/2 x/b - 3 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 5/4 x^2/b - x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (5/4 b - b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

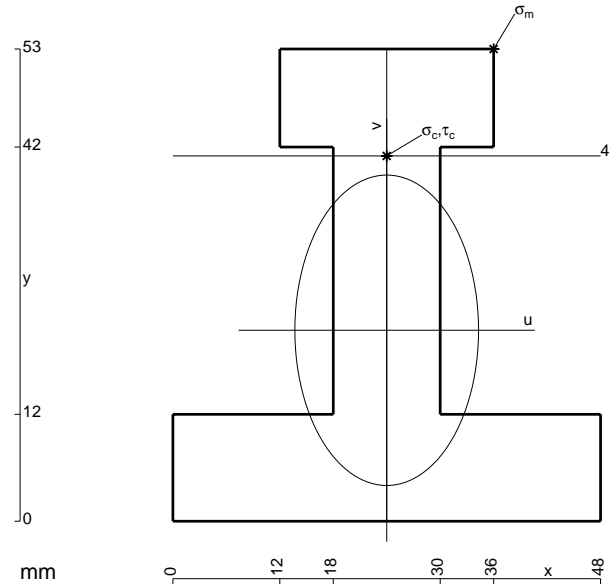
$$= (b - 1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

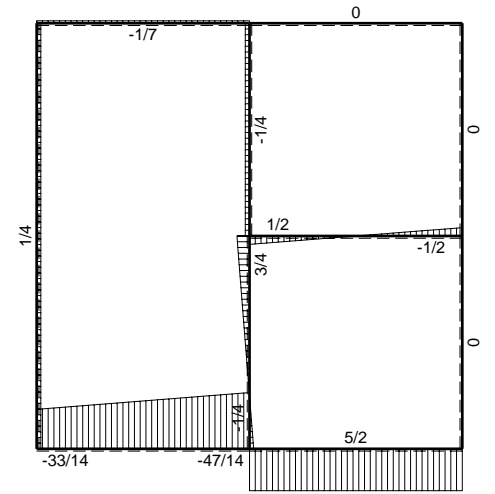
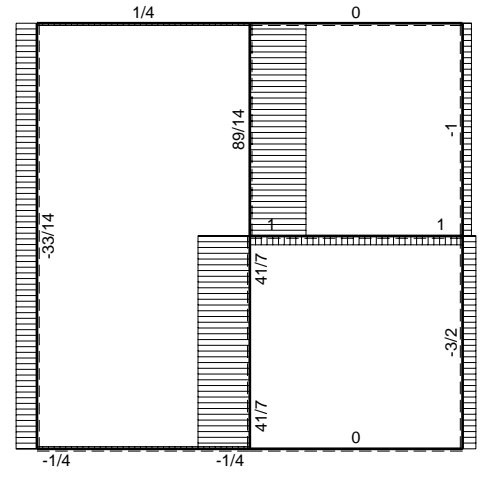
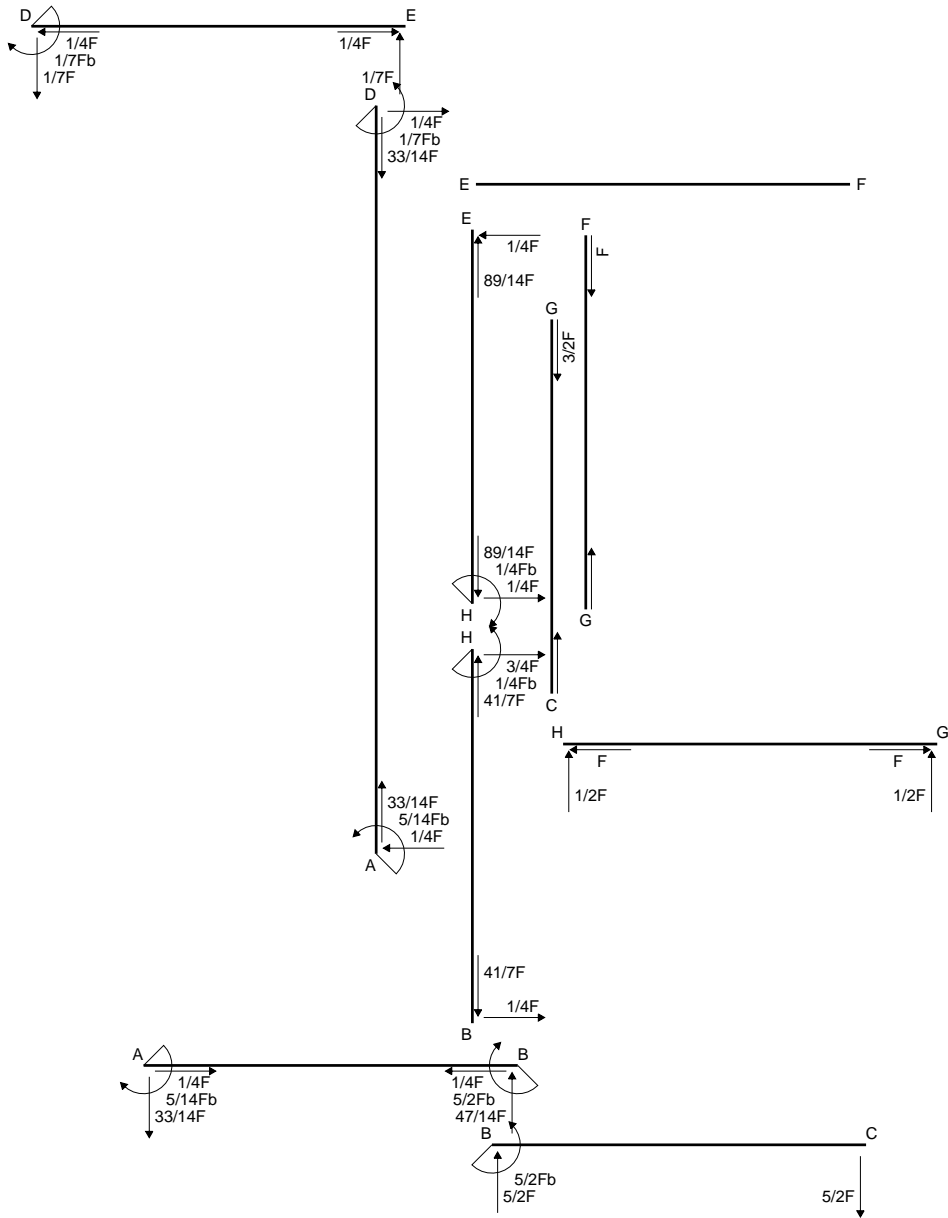
$$= (1/2 b - 1/2 b + 1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$

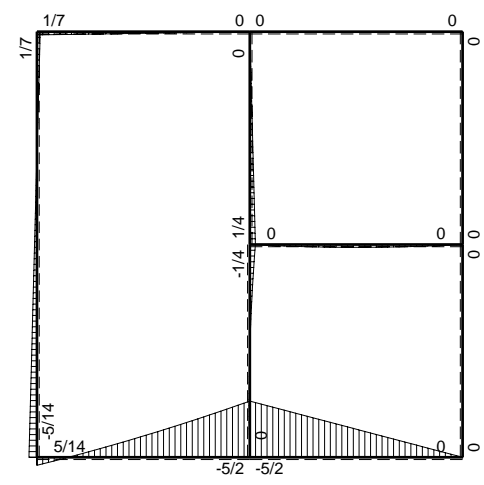


- A = 1200. mm<sup>2</sup>
- J<sub>u</sub> = 364306. mm<sup>4</sup>
- J<sub>v</sub> = 127584. mm<sup>4</sup>
- y<sub>g</sub> = 21.43 mm
- T<sub>y</sub> = 3200. N
- M<sub>x</sub> = -2304000. Nmm
- x<sub>m</sub> = 36. mm
- y<sub>m</sub> = 53. mm
- u<sub>m</sub> = 12. mm
- v<sub>m</sub> = 31.57 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 199.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 41. mm
- v<sub>c</sub> = 19.57 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 123.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.214 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 124.1 N/mm<sup>2</sup>
- S = 7123. mm<sup>3</sup>

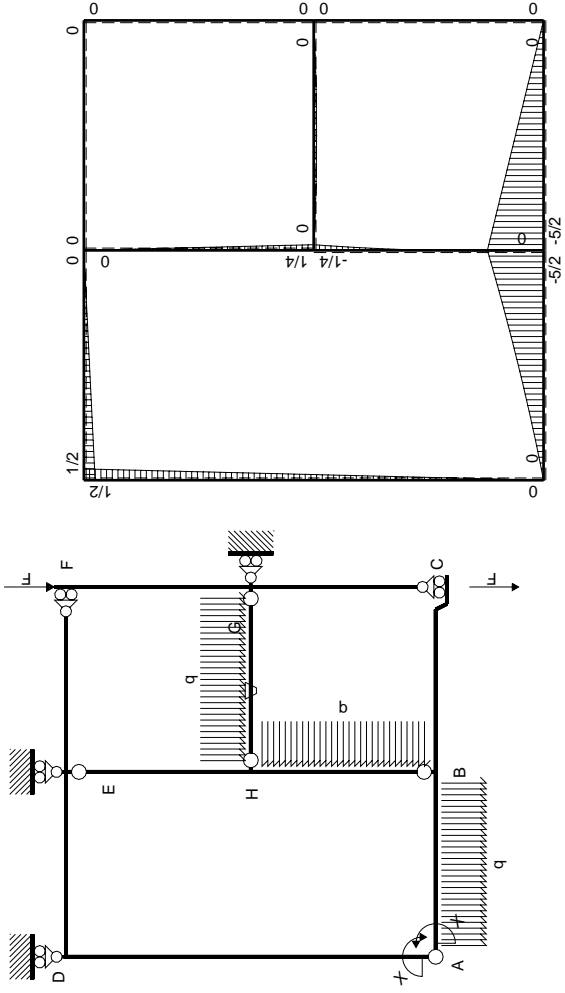


← ⊕ → F

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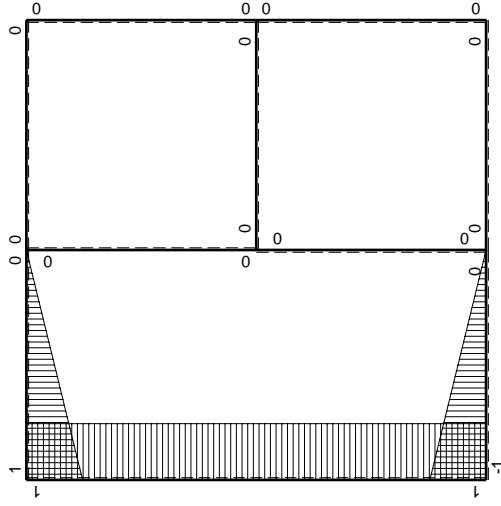


⊕ ⊖ Fb



Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x / EJ dx$
AB b	$-1+x/b$	$-2Fx-1/2qx^2$	0	$2Fx-3/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(3/8+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$5/2Fb-3Fx+1/2qx^2$	0	$5/2Fx-3Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-5/2Fb+5/2Fx$	0	0	0	0	0+0	0
CB b	0	$5/2Fx$	0	0	0	0		
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1		
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$		
EF b	0	0	0	0	0	0	0+0	0
FE b	0	0	0	0	0	0		
FG b	0	0	0	0	0	0	0+0	0
GF b	0	0	0	0	0	0		
GC b	0	0	0	0	0	0	0+0	0
CG b	0	0	0	0	0	0		
HG b	0	$1/2Fx-1/2qx^2$	$-Fb/EJ$	0	0	0	0+0	0
GH b	0	$-1/2Fx+1/2qx^2$	$Fb/EJ$	0	0	0		
HB b	0	$-1/4Fb+3/4Fx-1/2qx^2$	0	0	0	0	0+0	0
BH b	0	$-1/4Fx+1/2qx^2$	0	0	0	0		
HE b	0	$1/4Fb-1/4Fx$	0	0	0	0	0+0	0
EH b	0	$-1/4Fx$	0	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$25/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$-5/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (2x/b - 3/2 x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 1/2 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 1/2 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (5/2 x/b - 3 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 5/4 x^2/b - x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (5/4 b - b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

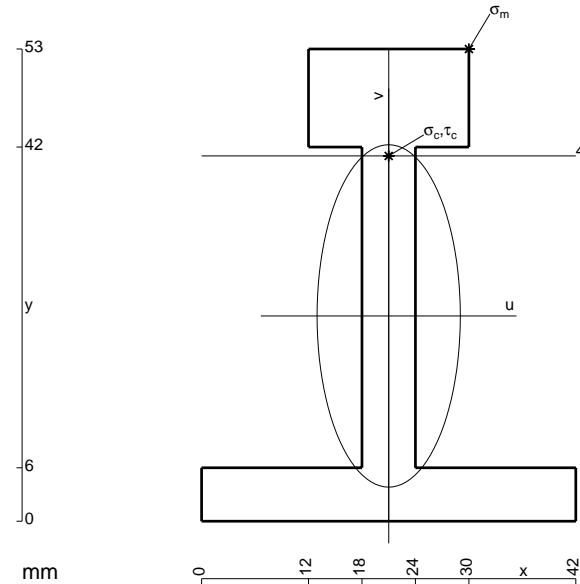
$$= (b - 1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/2 b - 1/2 b + 1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

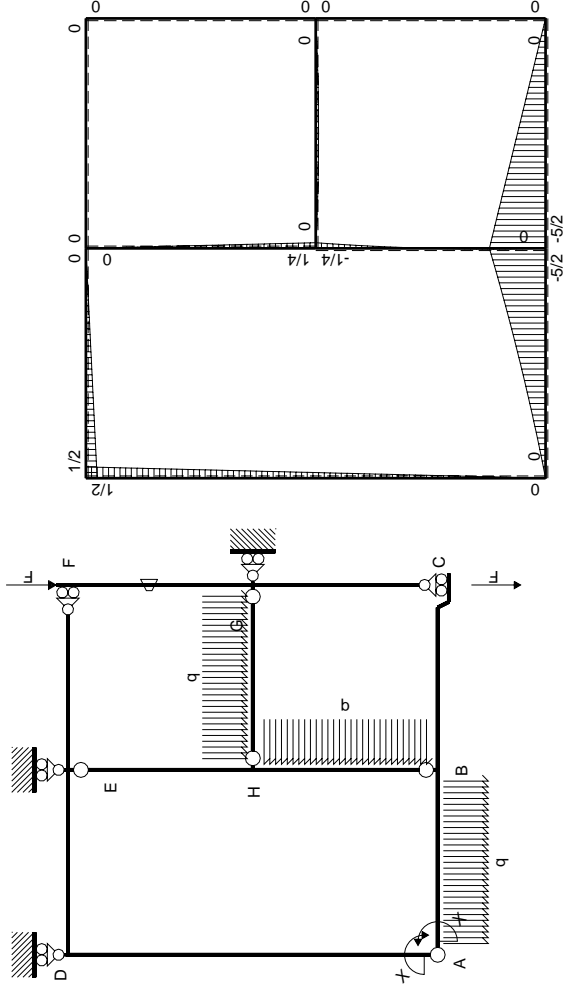
$$= (1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$



- A = 666. mm<sup>2</sup>
- J<sub>u</sub> = 245945. mm<sup>4</sup>
- J<sub>v</sub> = 43038. mm<sup>4</sup>
- y<sub>g</sub> = 23.04 mm
- T<sub>y</sub> = 2250. N
- M<sub>x</sub> = -1710000. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 53. mm
- u<sub>m</sub> = 9. mm
- v<sub>m</sub> = 29.96 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 208.3 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 41. mm
- v<sub>c</sub> = 17.96 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 124.9 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.553 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 125.6 N/mm<sup>2</sup>
- S = 4954. mm<sup>3</sup>

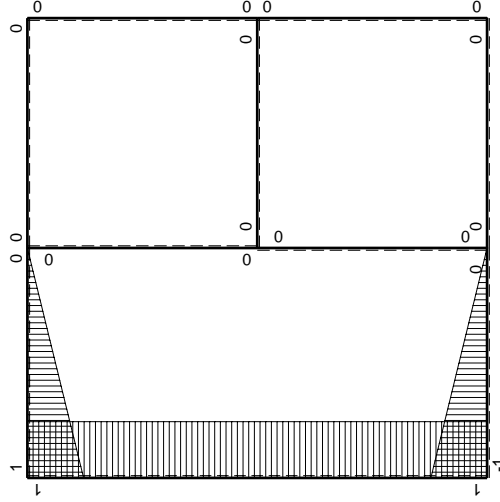






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-2Fx-1/2qx^2$	0	$2Fx-3/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(3/8+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$5/2Fb-3Fx+1/2qx^2$	0	$5/2Fx-3Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-5/2Fb+5/2Fx$	0	0	0	0	0+0	0	
CB b	0	$5/2Fx$	0	0	0	0			
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1			
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
GF b	0	0	$Fb/EJ$	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
GH b	0	$-1/2Fx+1/2qx^2$	0	0	0	0			
HB b	0	$-1/4Fb+3/4Fx-1/2qx^2$	0	0	0	0	0+0	0	
BH b	0	$-1/4Fx+1/2qx^2$	0	0	0	0			
HE b	0	$1/4Fb-1/4Fx$	0	0	0	0	0+0	0	
EH b	0	$-1/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$25/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-5/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (2x/b - 3/2 x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 1/2 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 1/2 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (5/2 x/b - 3 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 5/4 x^2/b - x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (5/4 b - b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

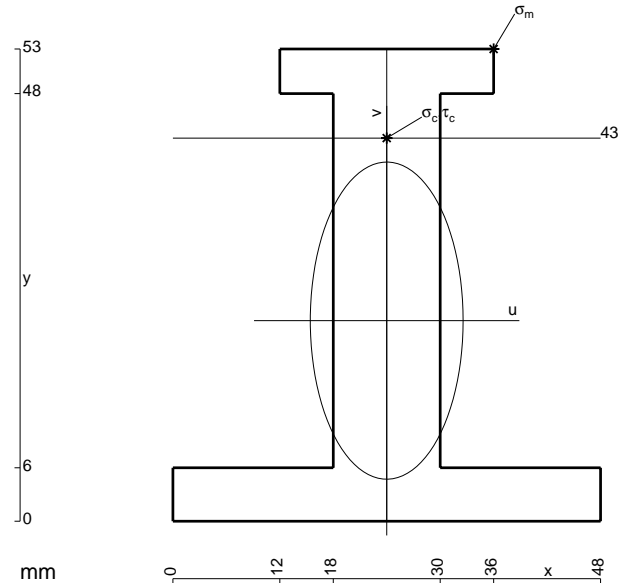
$$= (b - 1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/2 b - 1/2 b + 1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$

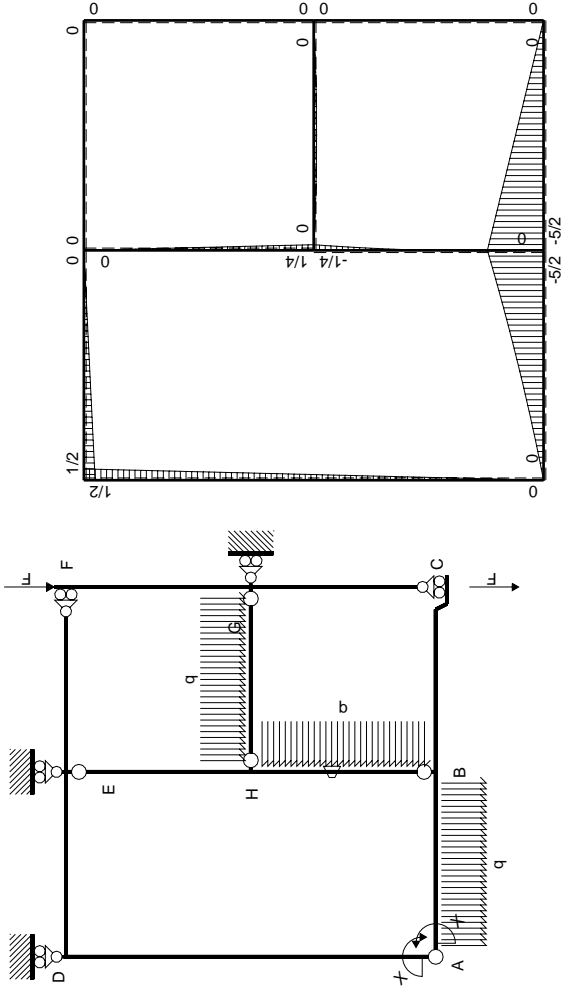
$$L_{ED}^{xo} = \int_0^b (1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$



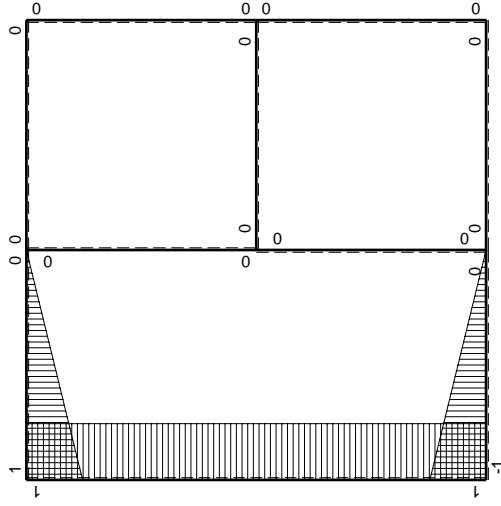
- A = 912. mm<sup>2</sup>
- J<sub>u</sub> = 289000. mm<sup>4</sup>
- J<sub>v</sub> = 67104. mm<sup>4</sup>
- y<sub>g</sub> = 22.51 mm
- T<sub>y</sub> = 2550. N
- M<sub>x</sub> = -2065500. Nmm
- x<sub>m</sub> = 36. mm
- y<sub>m</sub> = 53. mm
- u<sub>m</sub> = 12. mm
- v<sub>m</sub> = 30.49 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 217.9 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 43. mm
- v<sub>c</sub> = 20.49 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 146.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.484 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 146.5 N/mm<sup>2</sup>
- S = 4738. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$
AB b	$-1+x/b$	$-2Fx-1/2qx^2$	0	$2Fx-3/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(3/8+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$5/2Fb-3Fx+1/2qx^2$	0	$5/2Fx-3Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-5/2Fb+5/2Fx$	0	0	0	0	0+0	0
CB b	0	$5/2Fx$	0	0	0	0		
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1		
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$		
EF b	0	0	0	0	0	0	0+0	0
FE b	0	0	0	0	0	0		
FG b	0	0	0	0	0	0	0+0	0
GF b	0	0	0	0	0	0		
GC b	0	0	0	0	0	0	0+0	0
CG b	0	0	0	0	0	0		
HG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0
GH b	0	$-1/2Fx+1/2qx^2$	0	0	0	0		
HB b	0	$-1/4Fb+3/4Fx-1/2qx^2$	$-Fb/EJ$	0	0	0	0+0	0
BH b	0	$-1/4Fx+1/2qx^2$	$Fb/EJ$	0	0	0		
HE b	0	$1/4Fb-1/4Fx$	0	0	0	0	0+0	0
EH b	0	$-1/4Fx$	0	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$25/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$-5/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx + 1 \cdot 1 \cdot \frac{1}{4} \frac{b}{EJ} = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ} + 1 \cdot 1 \cdot \frac{1}{4} \frac{b}{EJ}$$

$$= (b - b + 1/3 b) \frac{1}{EJ} + 1 \cdot 1 \cdot \frac{1}{4} \frac{b}{EJ} = 7/12 \frac{b}{EJ}$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx + 1 \cdot 1 \cdot \frac{1}{4} \frac{b}{EJ} = \left[ 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ} + 1 \cdot 1 \cdot \frac{1}{4} \frac{b}{EJ}$$

$$= (1/3 b) \frac{1}{EJ} + 1 \cdot 1 \cdot \frac{1}{4} \frac{b}{EJ} = 7/12 \frac{b}{EJ}$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \frac{b}{EJ}$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \frac{b}{EJ}$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ}$$

$$= (b - b + 1/3 b) \frac{1}{EJ} = 1/3 \frac{b}{EJ}$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx = \left[ 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ}$$

$$= (1/3 b) \frac{1}{EJ} = 1/3 \frac{b}{EJ}$$

$$L_{AB}^{xo} = \int_0^b (2x/b - 3/2 x^2/b^2 - 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= \left[ x^2/b - 1/2 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= (b - 1/2 b - 1/8 b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ} = 3/8 \frac{Fb^2}{EJ}$$

$$L_{BA}^{xo} = \int_0^b (5/2 x/b - 3 x^2/b^2 + 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= \left[ 5/4 x^2/b - x^3/b^2 + 1/8 x^4/b^3 \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= (5/4 b - b + 1/8 b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ} = 3/8 \frac{Fb^2}{EJ}$$

$$L_{AD}^{xo} = \int_0^{2b} (1/4 x/b) Fb \frac{1}{EJ} dx = \left[ 1/8 x^2/b \right]_0^{2b} Fb \frac{1}{EJ}$$

$$= (1/2 b) Fb \frac{1}{EJ} = 1/2 \frac{Fb^2}{EJ}$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 1/4 x/b) Fb \frac{1}{EJ} dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} Fb \frac{1}{EJ}$$

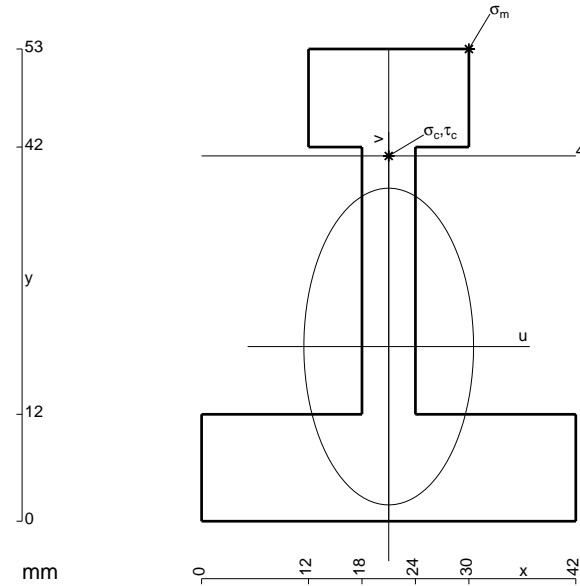
$$= (b - 1/2 b) Fb \frac{1}{EJ} = 1/2 \frac{Fb^2}{EJ}$$

$$L_{DE}^{xo} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) Fb \frac{1}{EJ} dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b Fb \frac{1}{EJ}$$

$$= (1/2 b - 1/2 b + 1/6 b) Fb \frac{1}{EJ} = 1/6 \frac{Fb^2}{EJ}$$

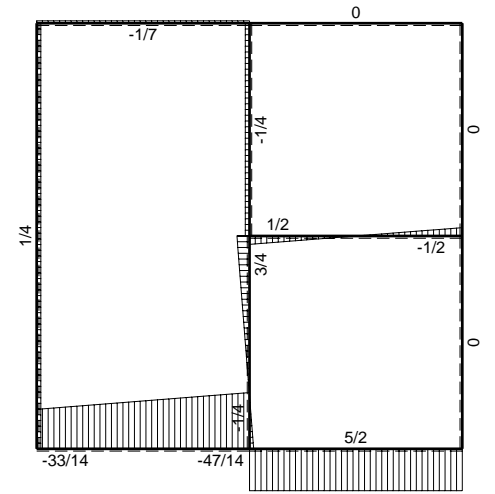
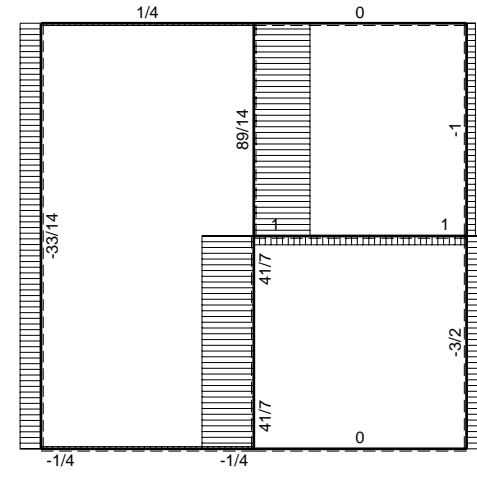
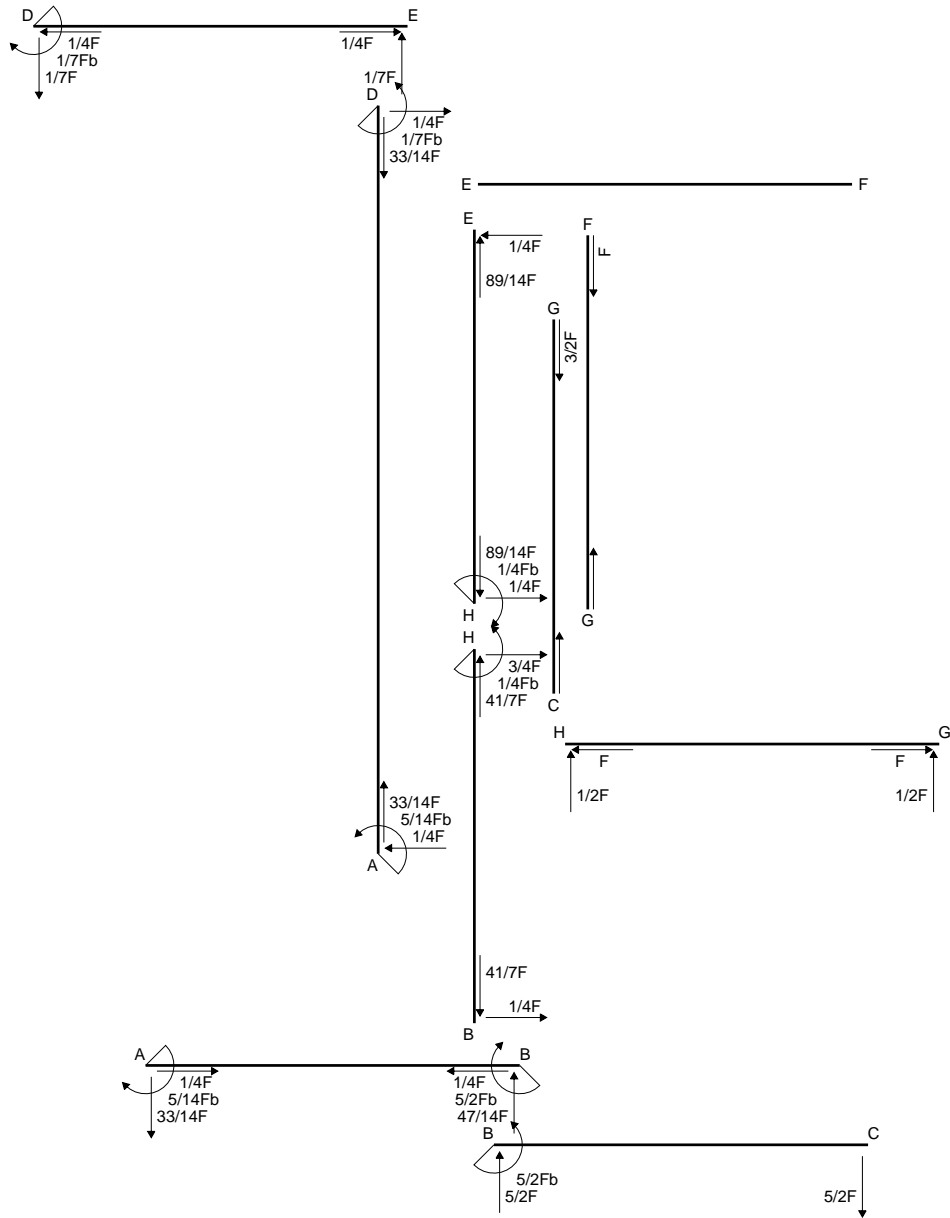
$$L_{ED}^{xo} = \int_0^b (1/2 x^2/b^2) Fb \frac{1}{EJ} dx = \left[ 1/6 x^3/b^2 \right]_0^b Fb \frac{1}{EJ}$$

$$= (1/6 b) Fb \frac{1}{EJ} = 1/6 \frac{Fb^2}{EJ}$$



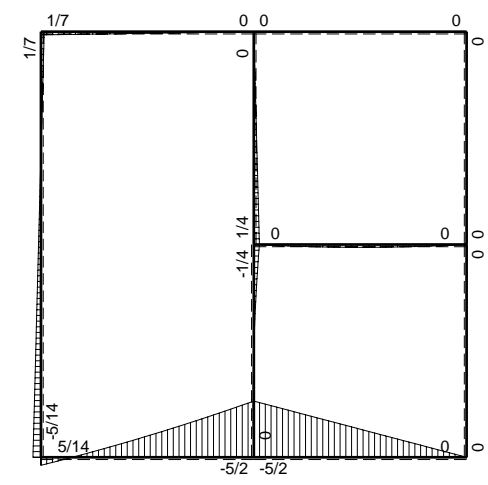
- A = 882. mm<sup>2</sup>
- J<sub>u</sub> = 278746. mm<sup>4</sup>
- J<sub>v</sub> = 79974. mm<sup>4</sup>
- y<sub>g</sub> = 19.6 mm
- T<sub>y</sub> = 2225. N
- M<sub>x</sub> = -1913500. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 53. mm
- u<sub>m</sub> = 9. mm
- v<sub>m</sub> = 33.4 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 229.3 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 41. mm
- v<sub>c</sub> = 21.4 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 146.9 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.523 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 147.5 N/mm<sup>2</sup>
- S = 5655. mm<sup>3</sup>



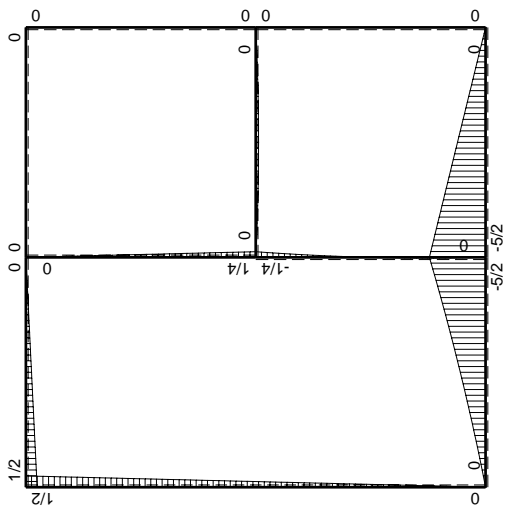
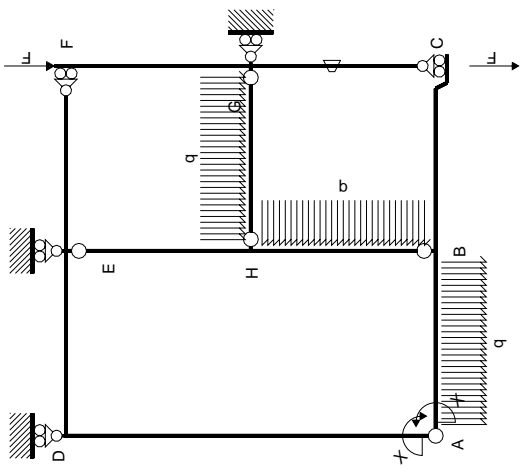


← ⊕ → F

↑ ⊕ ↓ F

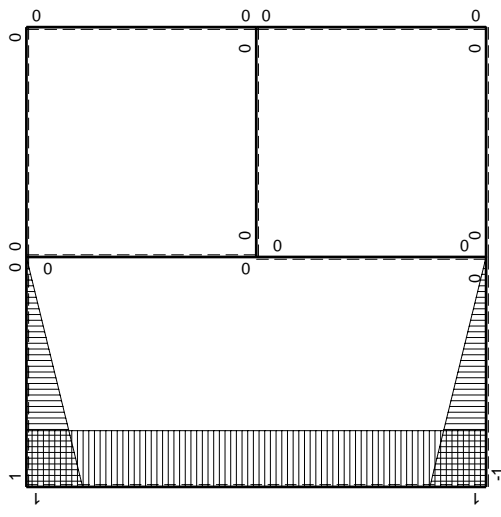


⊕ ⊖ F<sub>b</sub>



Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-2Fx-1/2qx^2$	0	$2Fx-3/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(3/8+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$5/2Fb-3Fx+1/2qx^2$	0	$5/2Fx-3Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-5/2Fb+5/2Fx$	0	0	0	0	0+0	0	
CB b	0	$5/2Fx$	0	0	0	0			
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1			
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
CG b	0	0	$Fb/EJ$	0	0	0			
HG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
GH b	0	$-1/2Fx+1/2qx^2$	0	0	0	0			
HB b	0	$-1/4Fb+3/4Fx-1/2qx^2$	0	0	0	0	0+0	0	
BH b	0	$-1/4Fx+1/2qx^2$	0	0	0	0			
HE b	0	$1/4Fb-1/4Fx$	0	0	0	0	0+0	0	
EH b	0	$-1/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$25/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-5/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (2x/b - 3/2 x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 1/2 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 1/2 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (5/2 x/b - 3 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 5/4 x^2/b - x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (5/4 b - b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

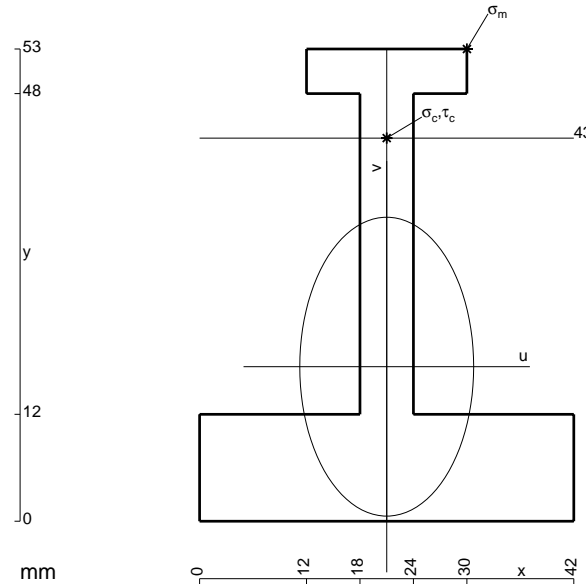
$$= (b - 1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

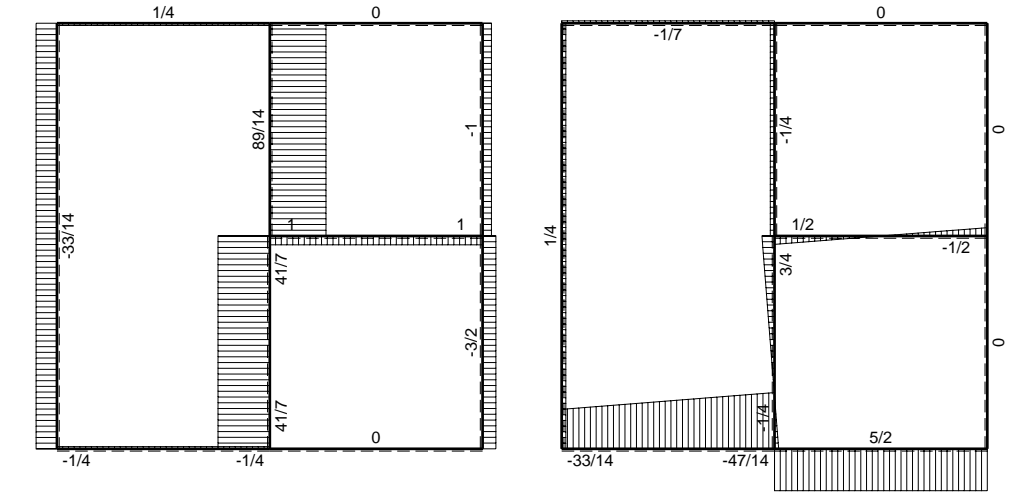
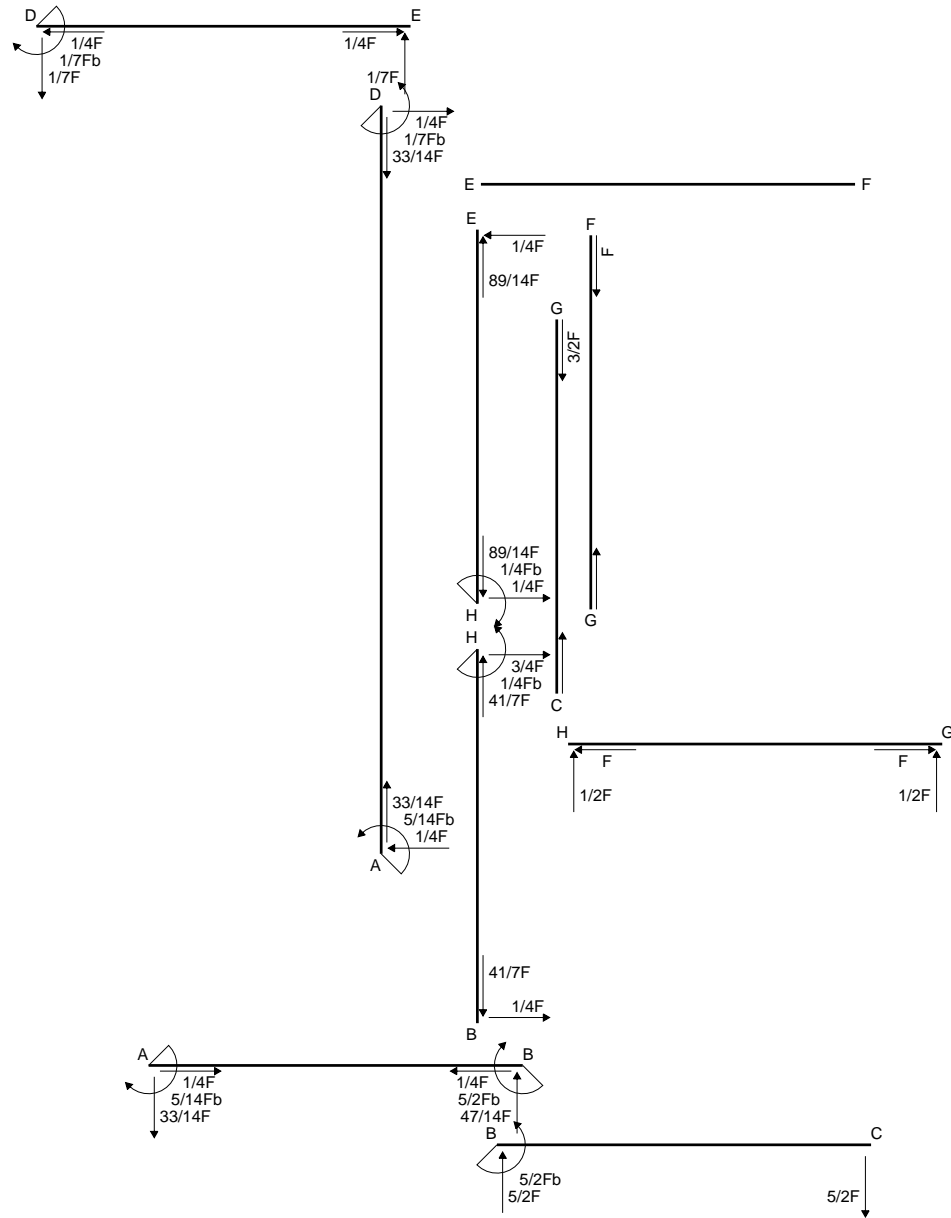
$$= (1/2 b - 1/2 b + 1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$

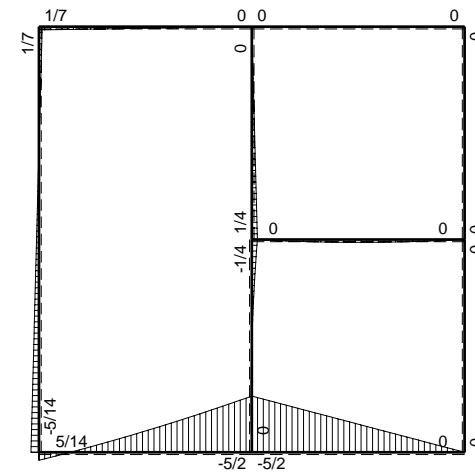


- A = 810. mm<sup>2</sup>
- J<sub>u</sub> = 227958. mm<sup>4</sup>
- J<sub>v</sub> = 77166. mm<sup>4</sup>
- y<sub>g</sub> = 17.34 mm
- T<sub>y</sub> = 1675. N
- M<sub>x</sub> = -1524250. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 53. mm
- u<sub>m</sub> = 9. mm
- v<sub>m</sub> = 35.66 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 238.4 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 43. mm
- v<sub>c</sub> = 25.66 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 171.5 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.689 N/mm<sup>2</sup>
- σ<sub>σ</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 171.7 N/mm<sup>2</sup>
- S = 3829. mm<sup>3</sup>

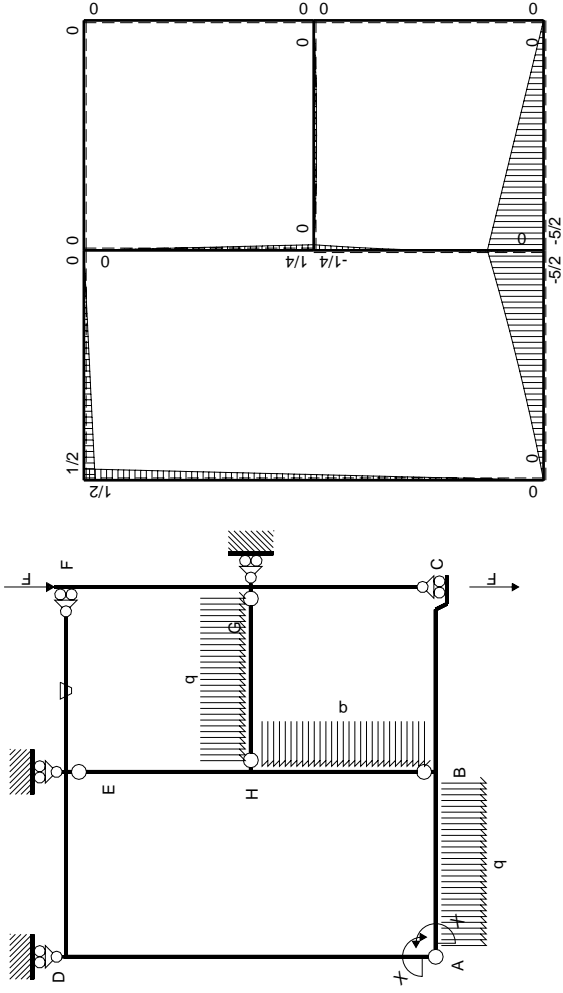


← ⊕ →  $F$

↑ ⊕ ↓  $F_b$

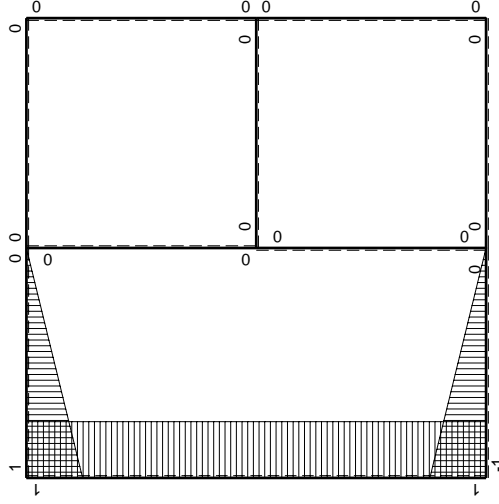


⊕  $F_b$



Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_X$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJdx$
AB b	$-1+x/b$	$-2Fx-1/2qx^2$	0	$2Fx-3/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(3/8+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$5/2Fb-3Fx+1/2qx^2$	0	$5/2Fx-3Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-5/2Fb+5/2Fx$	0	0	0	0	0+0	0
CB b	0	$5/2Fx$	0	0	0	0		
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1		
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$		
EF b	0	0	$-Fb/EJ$	0	0	0	0+0	0
FE b	0	0	$Fb/EJ$	0	0	0		
FG b	0	0	0	0	0	0	0+0	0
GF b	0	0	0	0	0	0		
GC b	0	0	0	0	0	0	0+0	0
CG b	0	0	0	0	0	0		
HG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0
GH b	0	$-1/2Fx+1/2qx^2$	0	0	0	0		
HB b	0	$-1/4Fb+3/4Fx-1/2qx^2$	0	0	0	0	0+0	0
BH b	0	$-1/4Fx+1/2qx^2$	0	0	0	0		
HE b	0	$1/4Fb-1/4Fx$	0	0	0	0	0+0	0
EH b	0	$-1/4Fx$	0	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$25/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$-5/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx + 1 \cdot 1 \cdot \frac{1}{4} \frac{b}{EJ} = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ} + 1 \cdot 1 \cdot \frac{1}{4} \frac{b}{EJ}$$

$$= (b - b + 1/3 b) \frac{1}{EJ} + 1 \cdot 1 \cdot \frac{1}{4} \frac{b}{EJ} = 7/12 \frac{b}{EJ}$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx + 1 \cdot 1 \cdot \frac{1}{4} \frac{b}{EJ} = \left[ 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ} + 1 \cdot 1 \cdot \frac{1}{4} \frac{b}{EJ}$$

$$= (1/3 b) \frac{1}{EJ} + 1 \cdot 1 \cdot \frac{1}{4} \frac{b}{EJ} = 7/12 \frac{b}{EJ}$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \frac{b}{EJ}$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \frac{b}{EJ}$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ}$$

$$= (b - b + 1/3 b) \frac{1}{EJ} = 1/3 \frac{b}{EJ}$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx = \left[ 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ}$$

$$= (1/3 b) \frac{1}{EJ} = 1/3 \frac{b}{EJ}$$

$$L_{AB}^{xo} = \int_0^b (2x/b - 3/2 x^2/b^2 - 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= \left[ x^2/b - 1/2 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= (b - 1/2 b - 1/8 b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ} = 3/8 \frac{Fb^2}{EJ}$$

$$L_{BA}^{xo} = \int_0^b (5/2 x/b - 3x^2/b^2 + 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= \left[ 5/4 x^2/b - x^3/b^2 + 1/8 x^4/b^3 \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= (5/4 b - b + 1/8 b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ} = 3/8 \frac{Fb^2}{EJ}$$

$$L_{AD}^{xo} = \int_0^{2b} (1/4 x/b) Fb \frac{1}{EJ} dx = \left[ 1/8 x^2/b \right]_0^{2b} Fb \frac{1}{EJ}$$

$$= (1/2 b) Fb \frac{1}{EJ} = 1/2 \frac{Fb^2}{EJ}$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 1/4 x/b) Fb \frac{1}{EJ} dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} Fb \frac{1}{EJ}$$

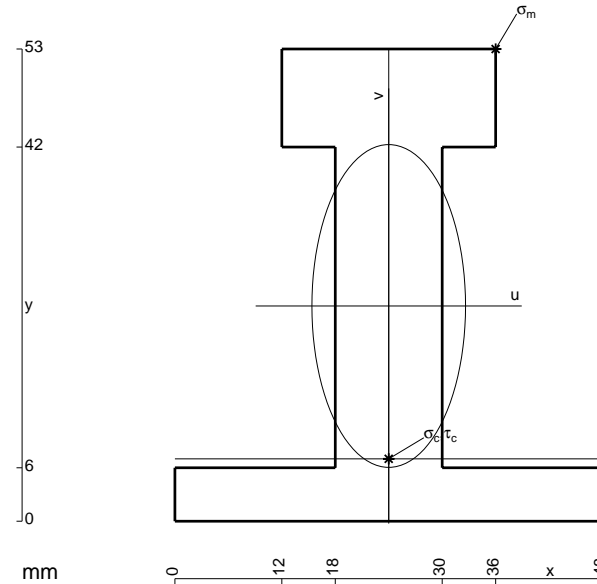
$$= (b - 1/2 b) Fb \frac{1}{EJ} = 1/2 \frac{Fb^2}{EJ}$$

$$L_{DE}^{xo} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) Fb \frac{1}{EJ} dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b Fb \frac{1}{EJ}$$

$$= (1/2 b - 1/2 b + 1/6 b) Fb \frac{1}{EJ} = 1/6 \frac{Fb^2}{EJ}$$

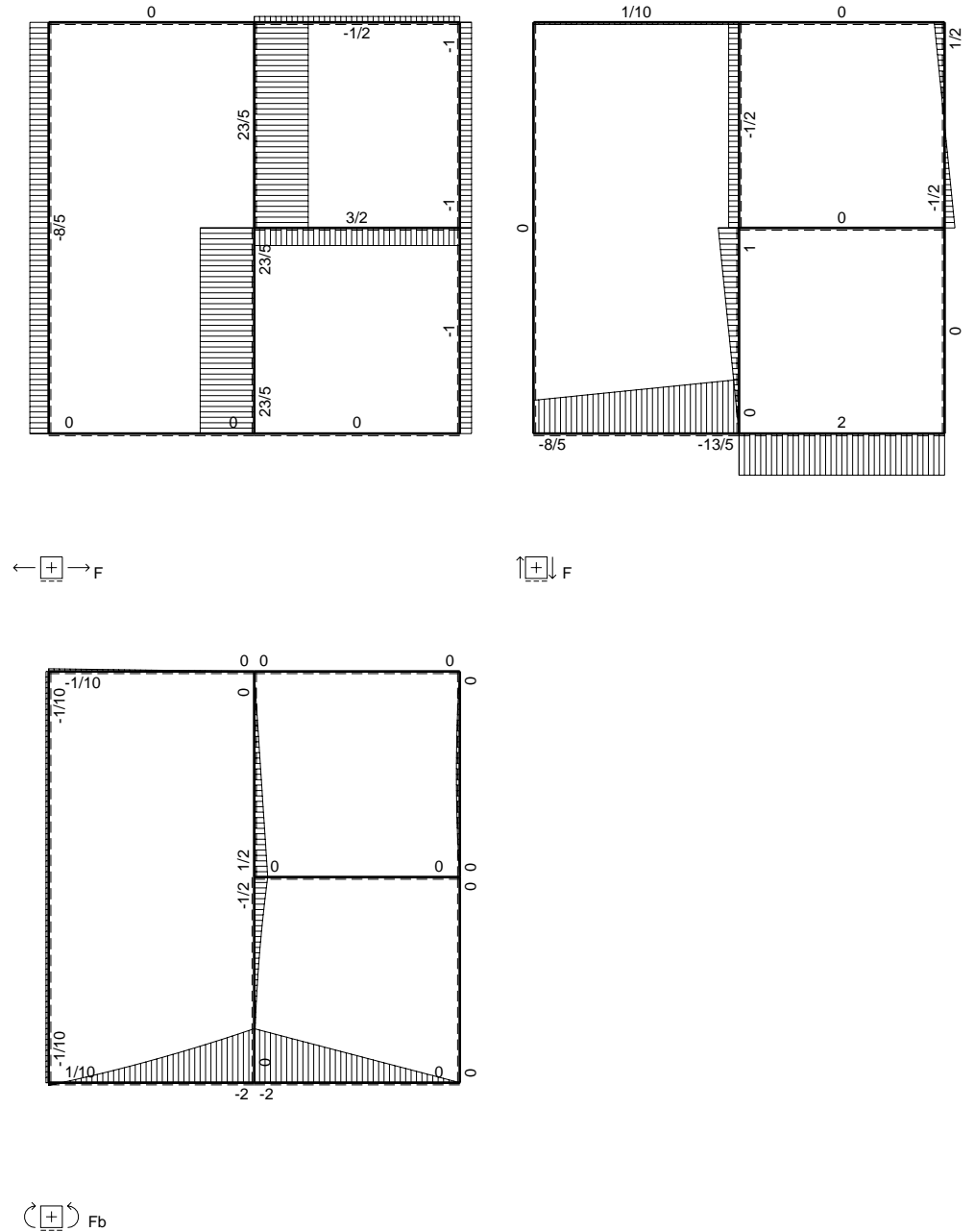
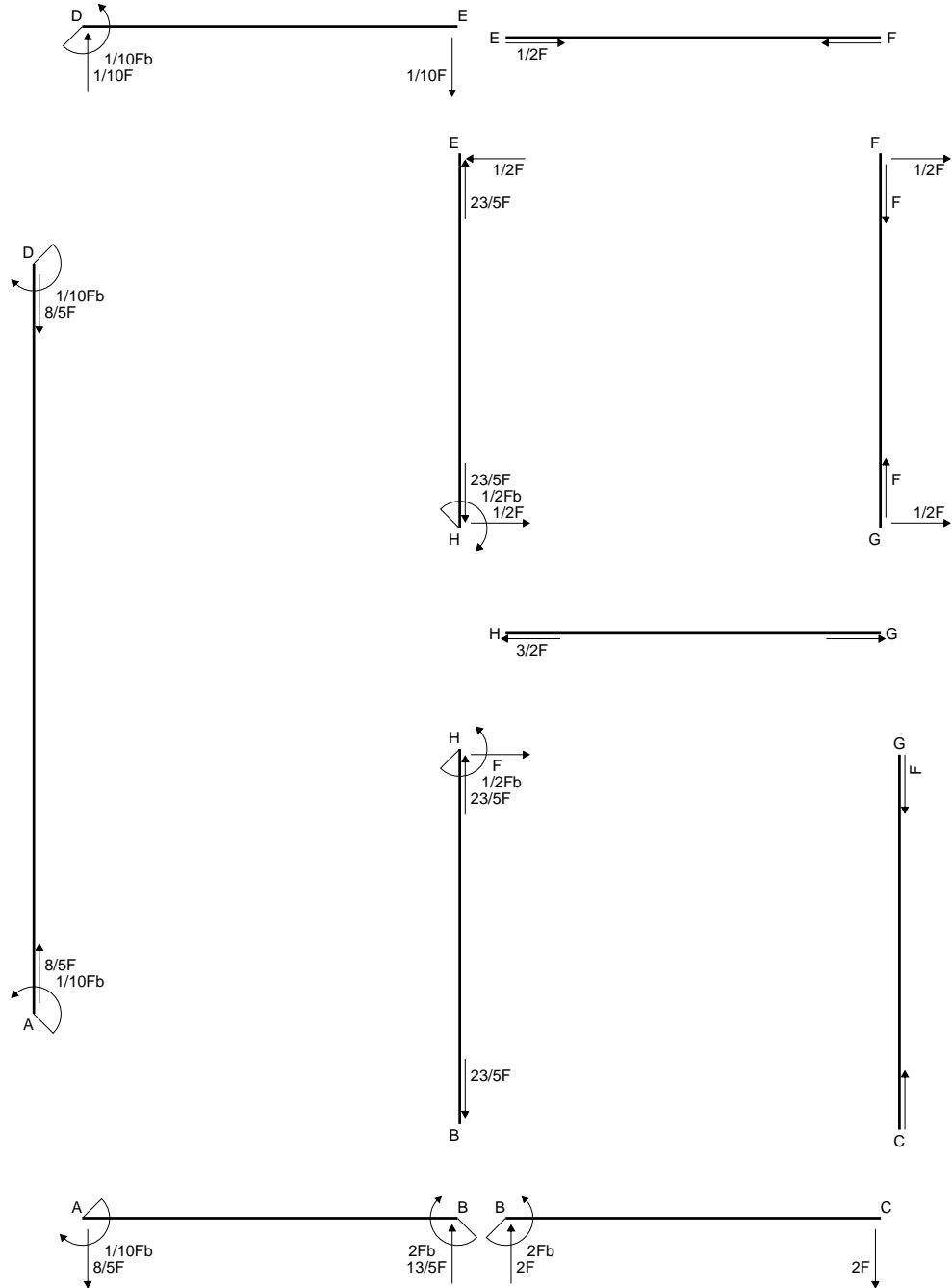
$$L_{ED}^{xo} = \int_0^b (1/2 x^2/b^2) Fb \frac{1}{EJ} dx = \left[ 1/6 x^3/b^2 \right]_0^b Fb \frac{1}{EJ}$$

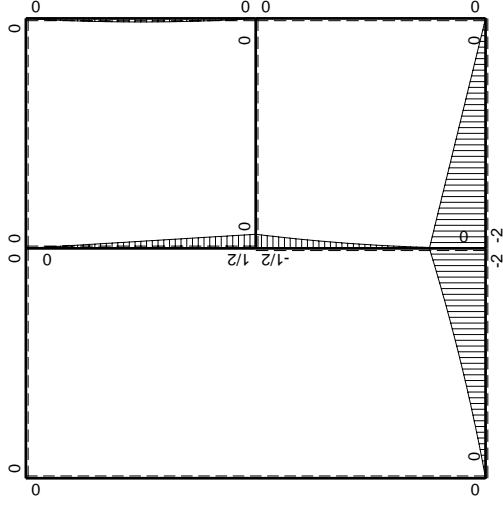
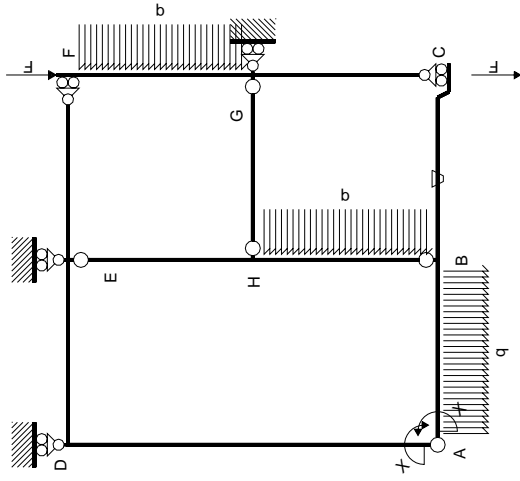
$$= (1/6 b) Fb \frac{1}{EJ} = 1/6 \frac{Fb^2}{EJ}$$



- A = 984. mm<sup>2</sup>
- J<sub>u</sub> = 322959. mm<sup>4</sup>
- J<sub>v</sub> = 73152. mm<sup>4</sup>
- y<sub>g</sub> = 24.16 mm
- T<sub>y</sub> = 4650. N
- M<sub>x</sub> = -2232000. Nmm
- x<sub>m</sub> = 36. mm
- y<sub>m</sub> = 53. mm
- u<sub>m</sub> = 12. mm
- v<sub>m</sub> = 28.84 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 199.3 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 7. mm
- v<sub>c</sub> = -17.16 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -118.6 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.566 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 119.3 N/mm<sup>2</sup>
- S = 6306. mm<sup>3</sup>

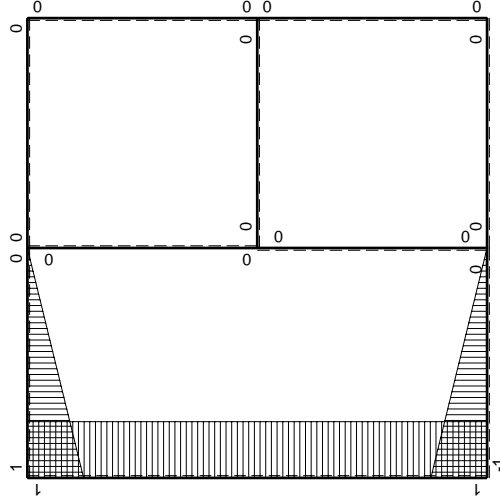






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	$-Fb/EJ$	0	0	0	0+0	0	
CB b	0	$2Fx$	$Fb/EJ$	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
GF b	0	$-1/2Fx+1/2qx^2$	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
BH b	0	$1/2qx^2$	0	0	0	0			
HE b	0	$1/2Fb-1/2Fx$	0	0	0	0	0+0	0	
EH b	0	$-1/2Fx$	0	0	0	0			
AB	molla asta $-W_{1AB} (W_{0AB} + XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

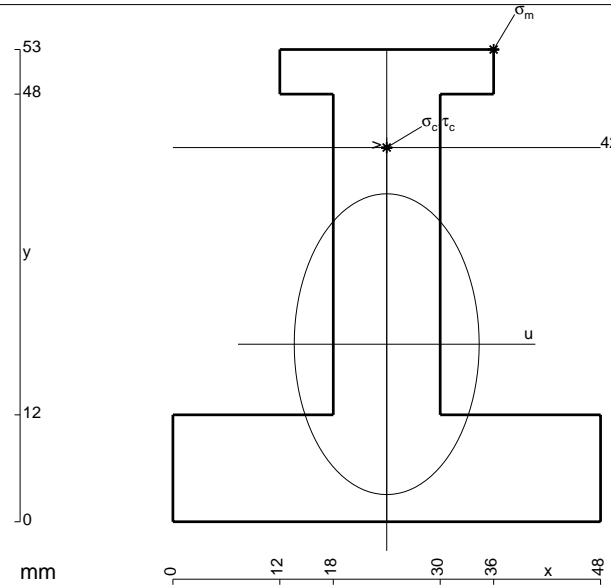
$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

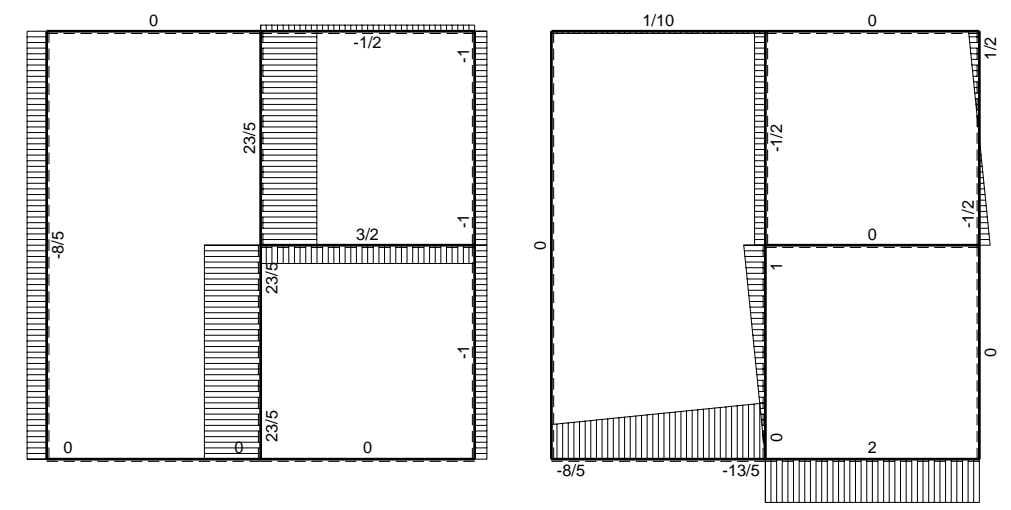
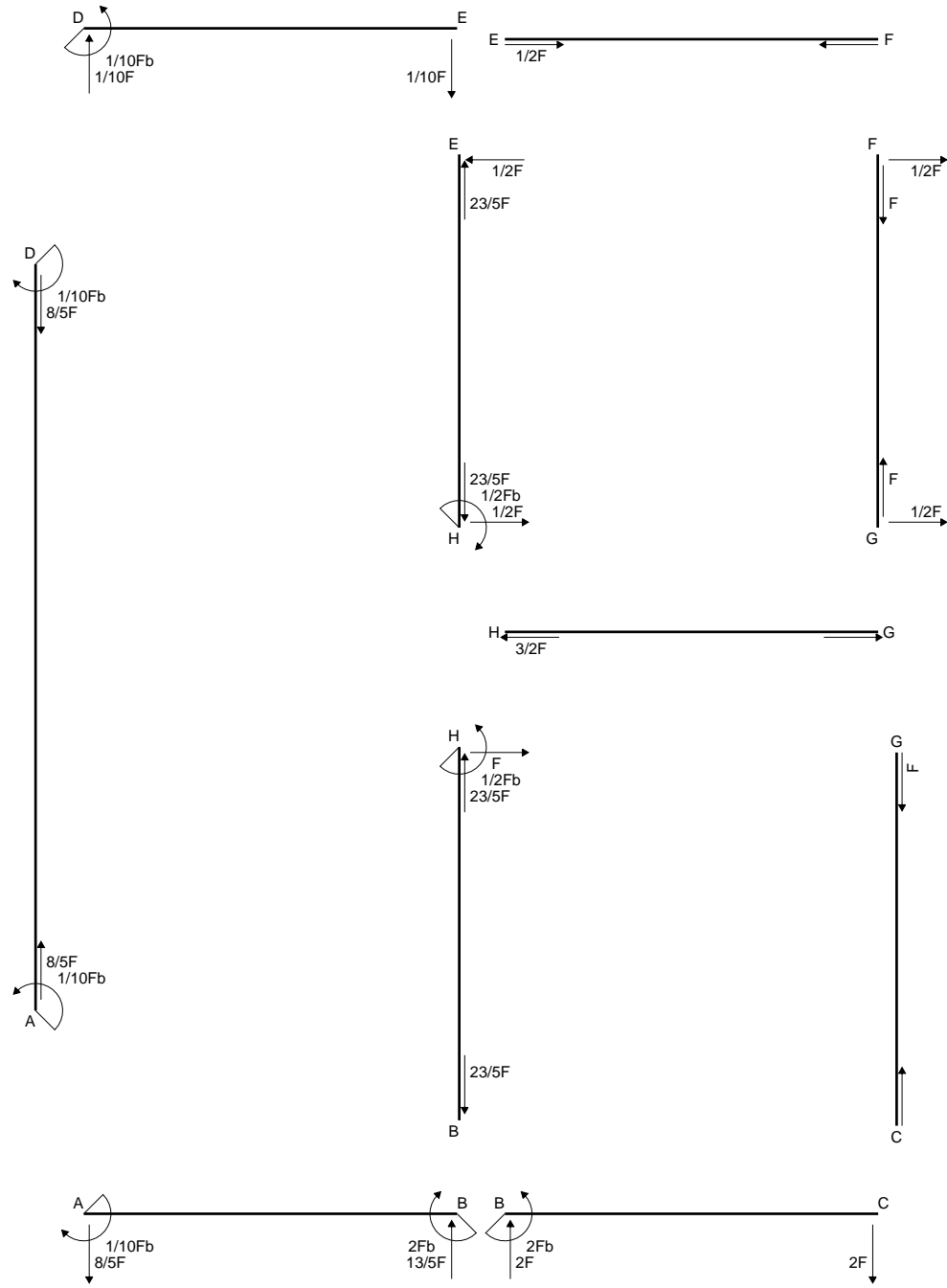
$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

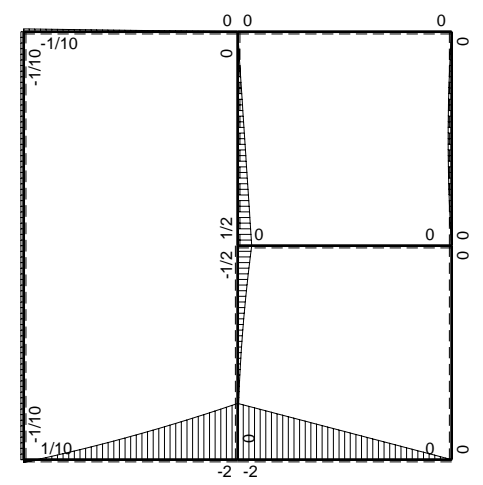


- A = 1128. mm<sup>2</sup>
- J<sub>u</sub> = 321538. mm<sup>4</sup>
- J<sub>v</sub> = 121536. mm<sup>4</sup>
- y<sub>g</sub> = 19.93 mm
- T<sub>y</sub> = 3920. N
- M<sub>x</sub> = -2038400. Nmm
- x<sub>m</sub> = 36. mm
- y<sub>m</sub> = 53. mm
- u<sub>m</sub> = 12. mm
- v<sub>m</sub> = 33.07 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 209.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 42. mm
- v<sub>c</sub> = 22.07 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 139.9 N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.562 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 140.3 N/mm<sup>2</sup>
- S = 5474. mm<sup>3</sup>

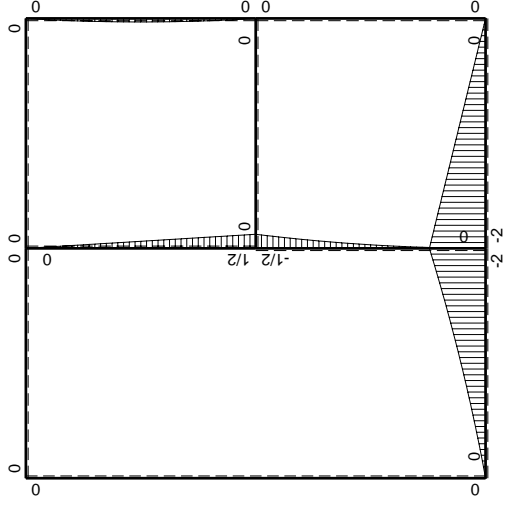
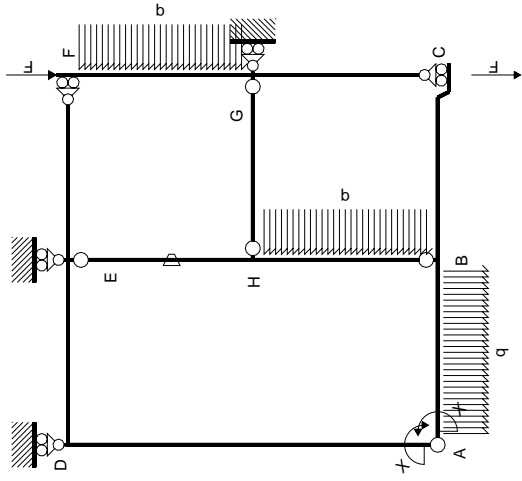


← ⊕ → F

↑ ⊕ ↓ F

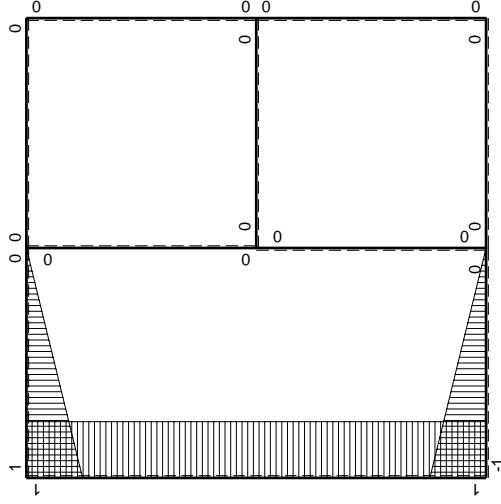


⊕ ⊖ F<sub>b</sub>



Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
GF b	0	$-1/2Fx+1/2qx^2$	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
BH b	0	$1/2qx^2$	0	0	0	0			
HE b	0	$1/2Fb-1/2Fx$	$-Fb/EJ$	0	0	0	0+0	0	
EH b	0	$-1/2Fx$	$Fb/EJ$	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

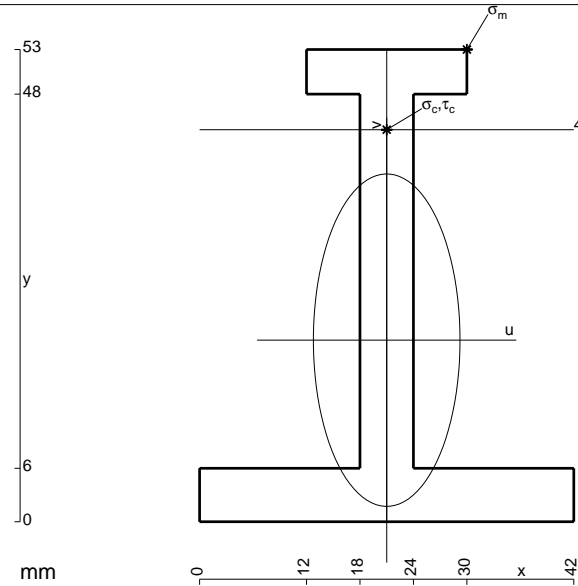
$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

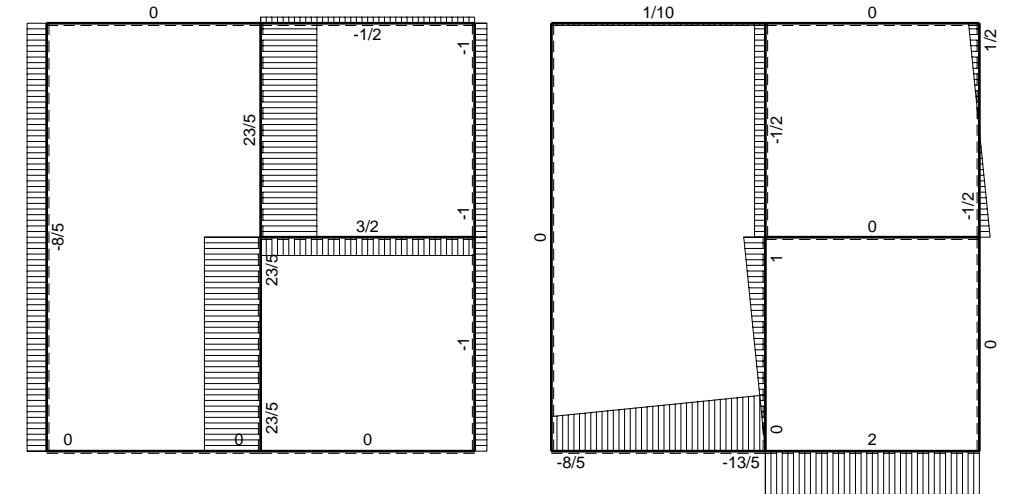
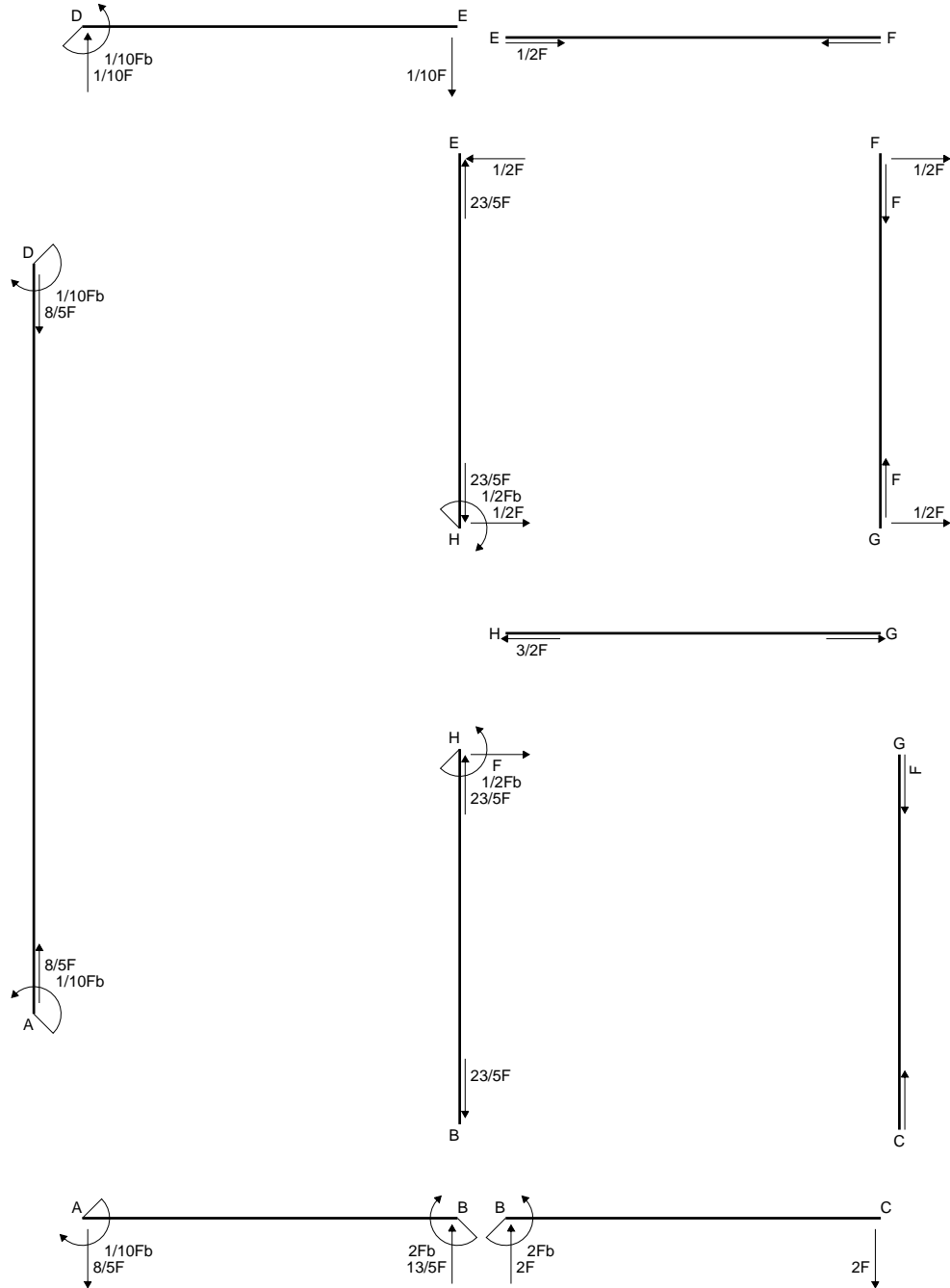
$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$



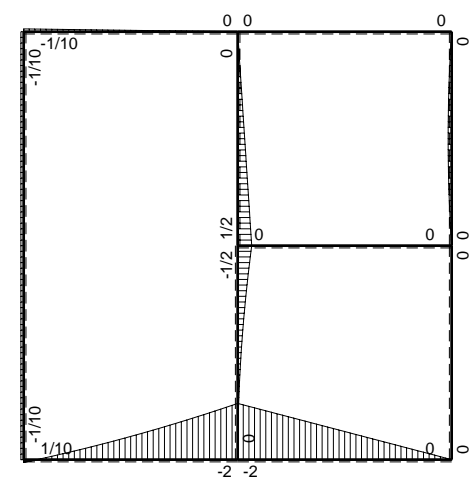
- A = 594. mm<sup>2</sup>
- J<sub>u</sub> = 206801. mm<sup>4</sup>
- J<sub>v</sub> = 40230. mm<sup>4</sup>
- y<sub>g</sub> = 20.38 mm
- T<sub>y</sub> = 2440. N
- M<sub>x</sub> = -1390800. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 53. mm
- u<sub>m</sub> = 9. mm
- v<sub>m</sub> = 32.62 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 219.4 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 44. mm
- v<sub>c</sub> = 23.62 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 158.9 N/mm<sup>2</sup>
- τ<sub>c</sub> = 6.54 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 159.3 N/mm<sup>2</sup>
- S = 3326. mm<sup>3</sup>



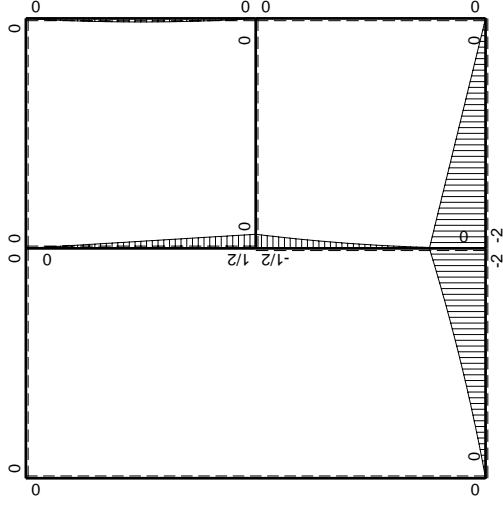
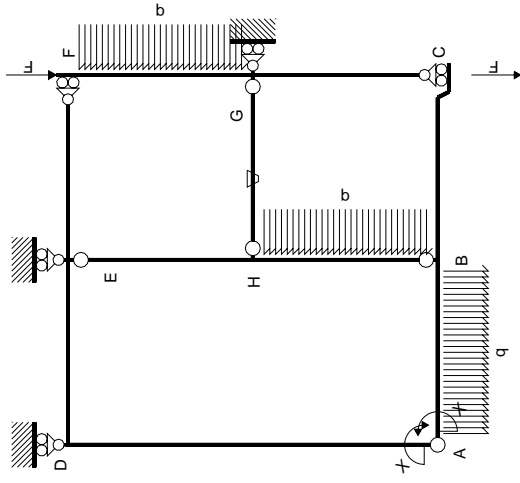


← ⊕ → F

↑ ⊕ ↓ F

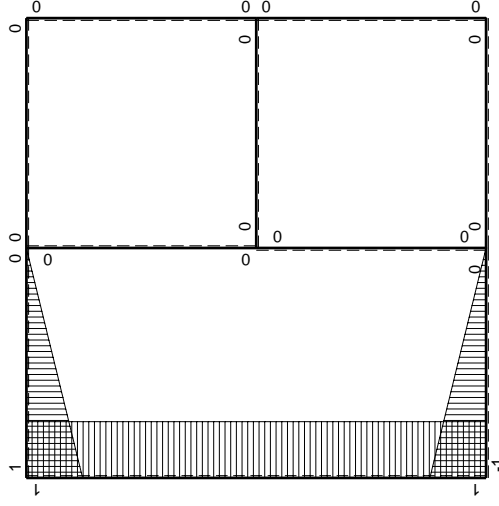


⊕ ⊖ F<sub>b</sub>



Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
GF b	0	$-1/2Fx+1/2qx^2$	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
GH b	0	0	$Fb/EJ$	0	0	0			
HB b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
BH b	0	$1/2qx^2$	0	0	0	0			
HE b	0	$1/2Fb-1/2Fx$	0	0	0	0	0+0	0	
EH b	0	$-1/2Fx$	0	0	0	0			
AB	molla asta $-W_{1AB} (W_{0AB} + XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (-2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (-2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

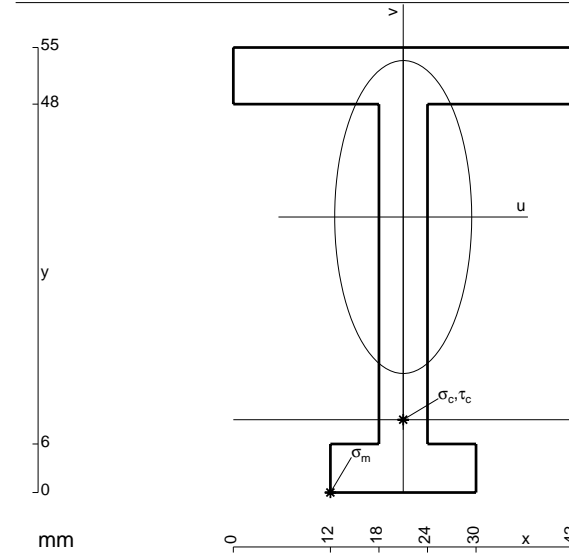
$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

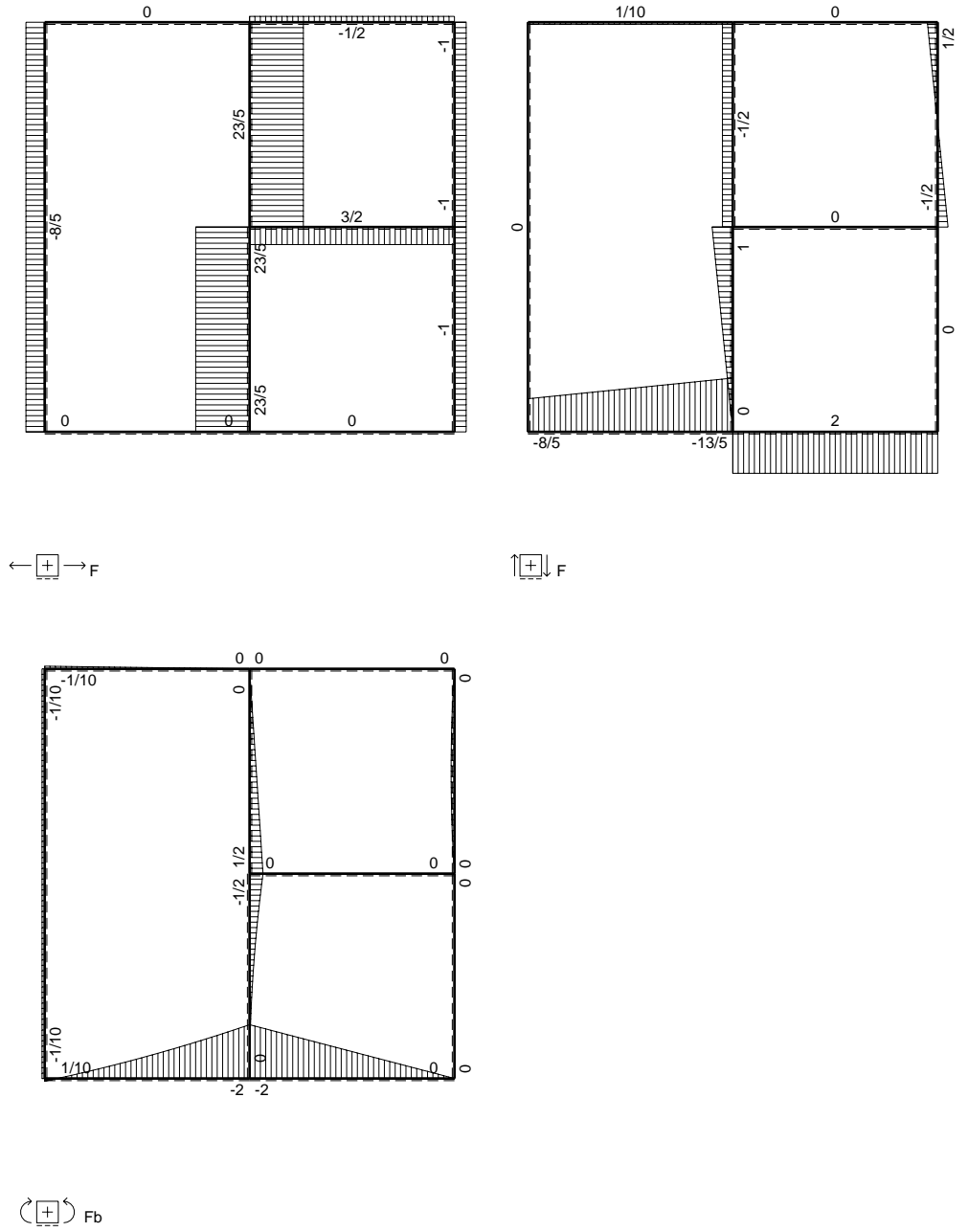
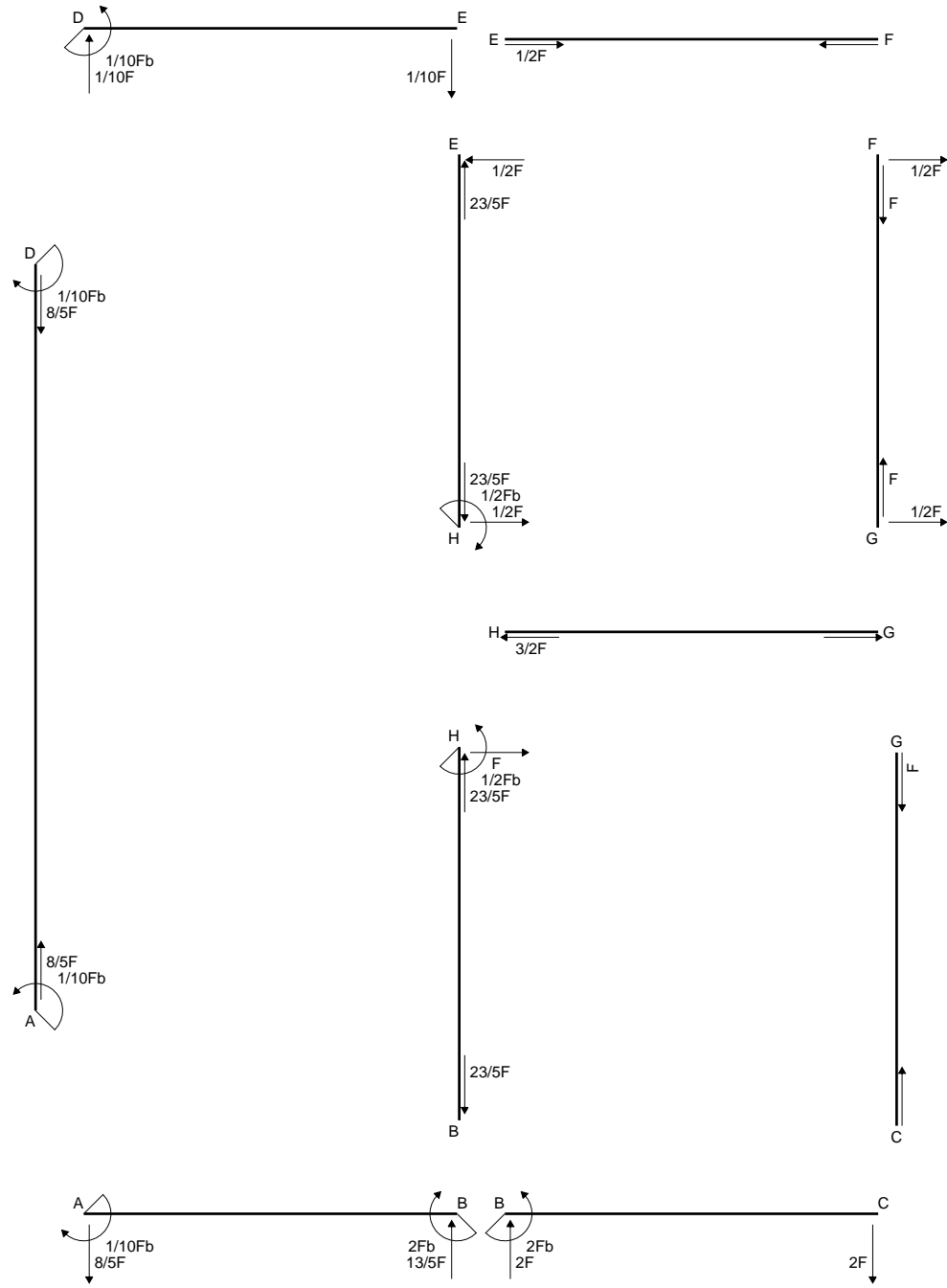
$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

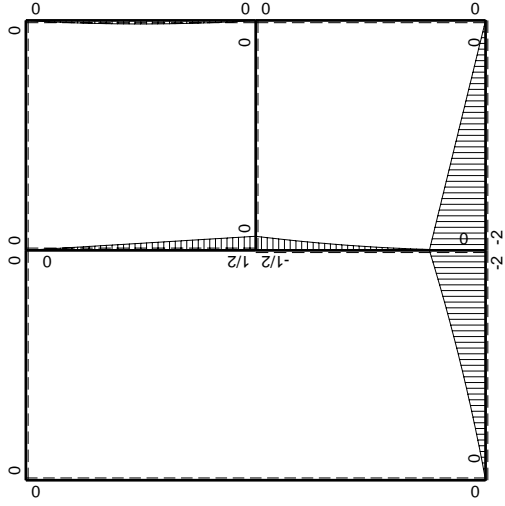
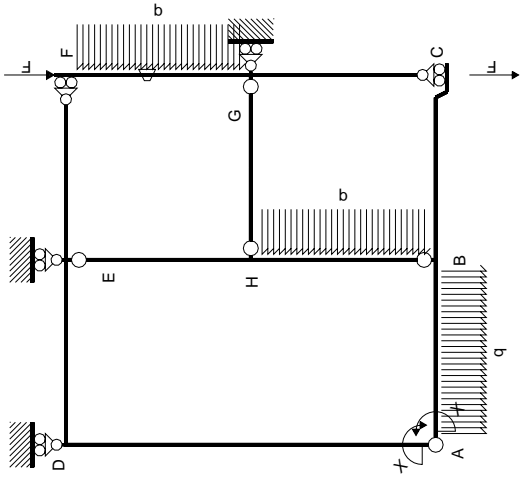
$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$



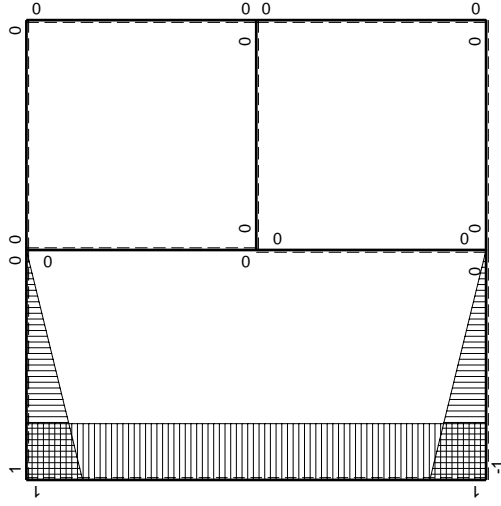
- A = 654. mm<sup>2</sup>
- J<sub>u</sub> = 244740. mm<sup>4</sup>
- J<sub>v</sub> = 46890. mm<sup>4</sup>
- y<sub>g</sub> = 34.05 mm
- T<sub>y</sub> = 2540. N
- M<sub>x</sub> = -1651000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -9. mm
- v<sub>m</sub> = -34.05 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -229.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 9. mm
- v<sub>c</sub> = -25.05 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -169. N/mm<sup>2</sup>
- τ<sub>c</sub> = 6.627 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 169.4 N/mm<sup>2</sup>
- S = 3831. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$1/2Fx-1/2qx^2$	$-Fb/EJ$	0	0	0	0+0	0	
GF b	0	$-1/2Fx+1/2qx^2$	$Fb/EJ$	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
BH b	0	$1/2qx^2$	0	0	0	0			
HE b	0	$1/2Fb-1/2Fx$	0	0	0	0	0+0	0	
EH b	0	$-1/2Fx$	0	0	0	0			
AB	molla asta $-W_{1AB} (W_{0AB} + XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

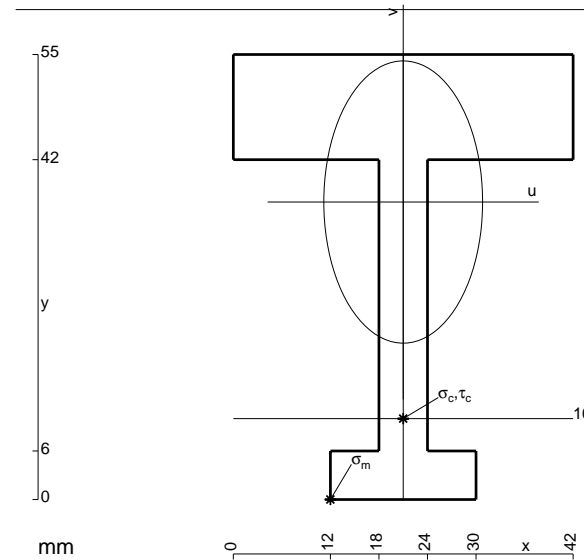
$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

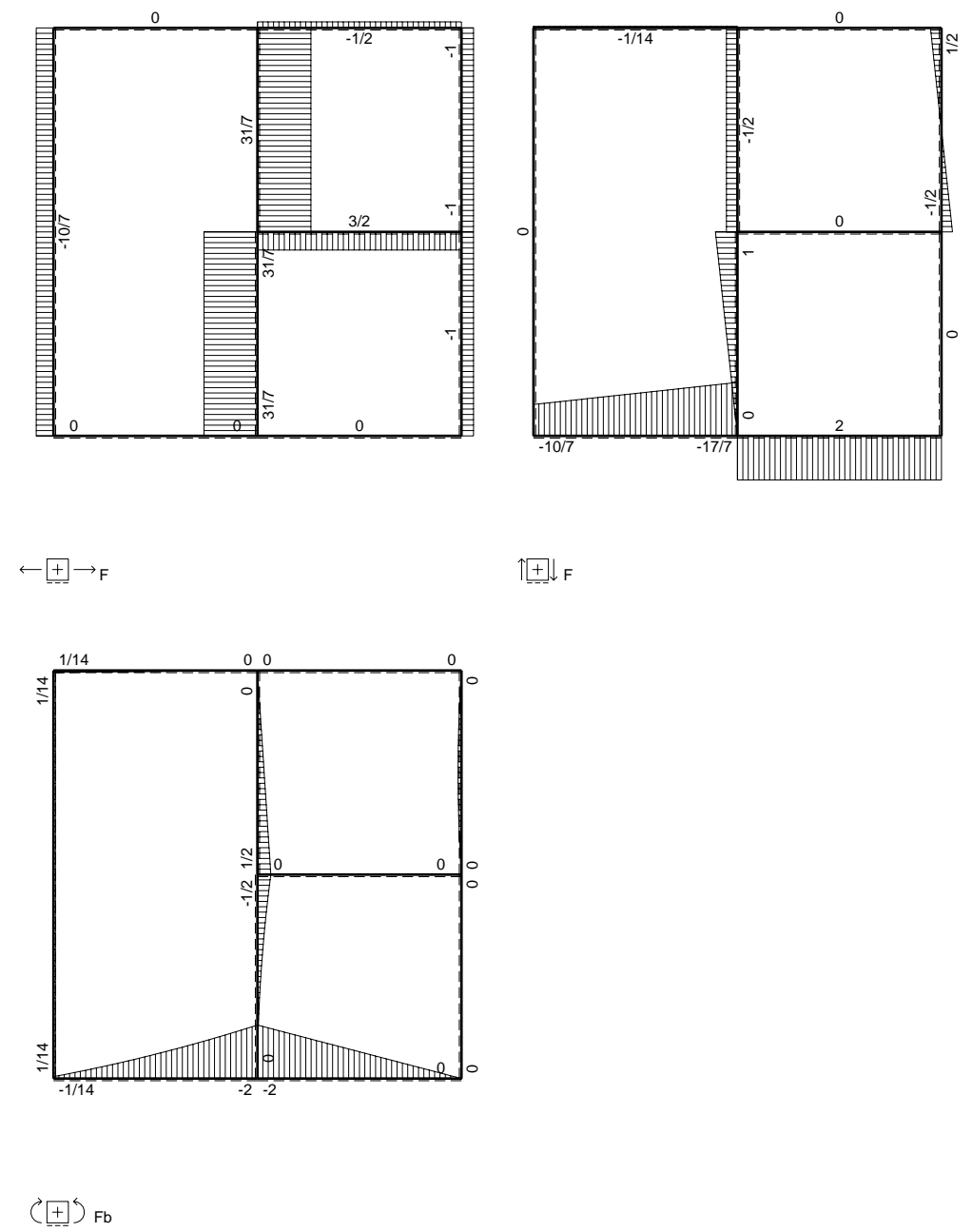
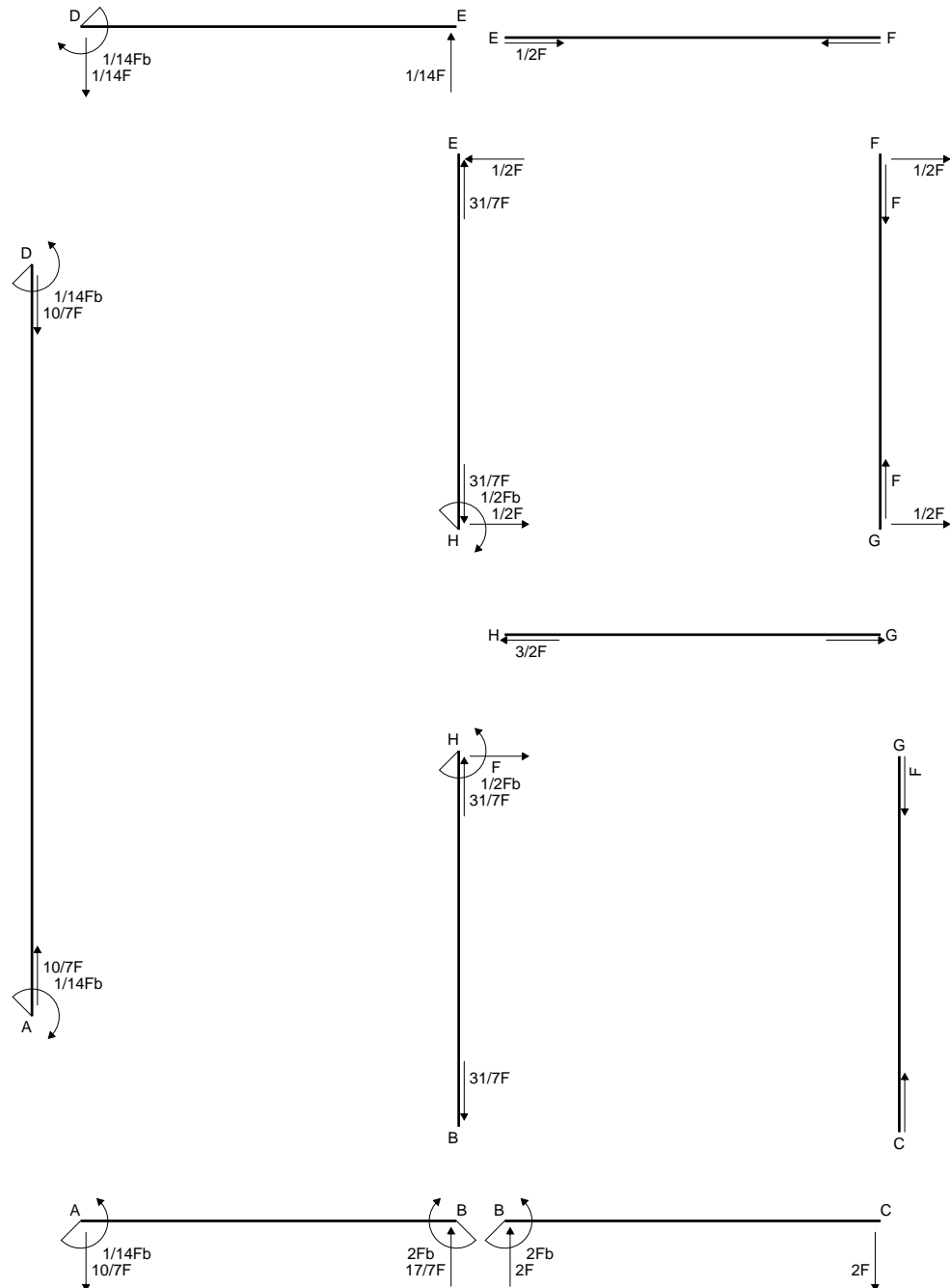
$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

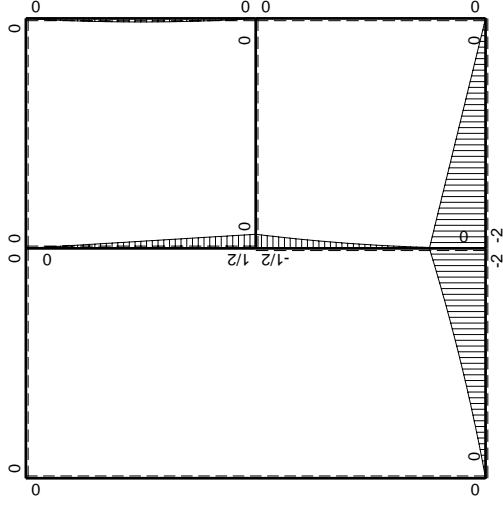
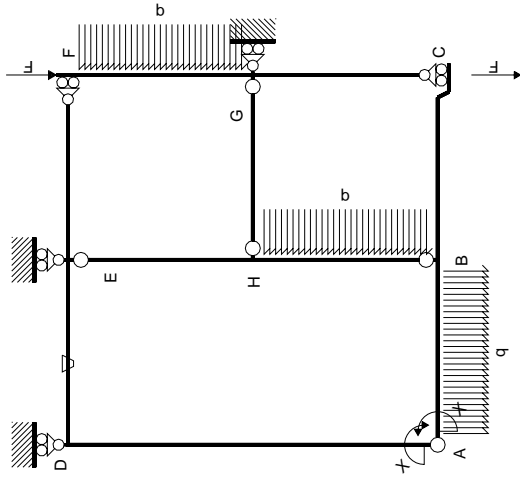
$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$



- A = 870. mm<sup>2</sup>
- J<sub>u</sub> = 264856. mm<sup>4</sup>
- J<sub>v</sub> = 83826. mm<sup>4</sup>
- y<sub>g</sub> = 36.77 mm
- T<sub>y</sub> = 2460. N
- M<sub>x</sub> = -1722000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -9. mm
- v<sub>m</sub> = -36.77 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -239.1 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 10. mm
- v<sub>c</sub> = -26.77 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -174. N/mm<sup>2</sup>
- τ<sub>c</sub> = 6.715 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 174.4 N/mm<sup>2</sup>
- S = 4338. mm<sup>3</sup>

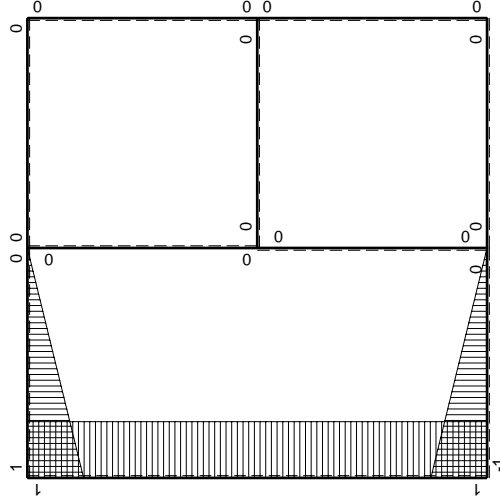






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_1$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x / EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	$-Fb/EJ$	0	$-Fb/EJ+Fx/EJ$	$1-2x/b+x^2/b^2$	$(0-1/2)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	0	$Fb/EJ$	0	$-Fx/EJ$	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
GF b	0	$-1/2Fx+1/2qx^2$	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
BH b	0	$1/2qx^2$	0	0	0	0			
HE b	0	$1/2Fb-1/2Fx$	0	0	0	0	0+0	0	
EH b	0	$-1/2Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$-5/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$1/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ}$$

$$= (b - b + 1/3 b) \frac{1}{EJ} = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx = \left[ 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ}$$

$$= (1/3 b) \frac{1}{EJ} = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

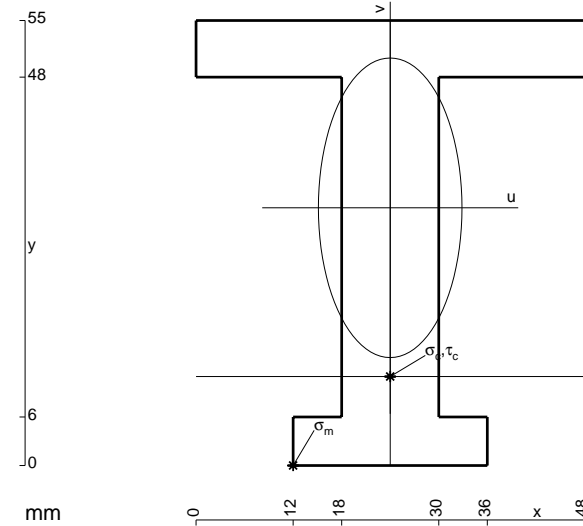
$$= (b - 5/6 b + 1/8 b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (-1 + x/b) \theta dx = \left[ -x + 1/2 x^2/b \right]_0^b \theta$$

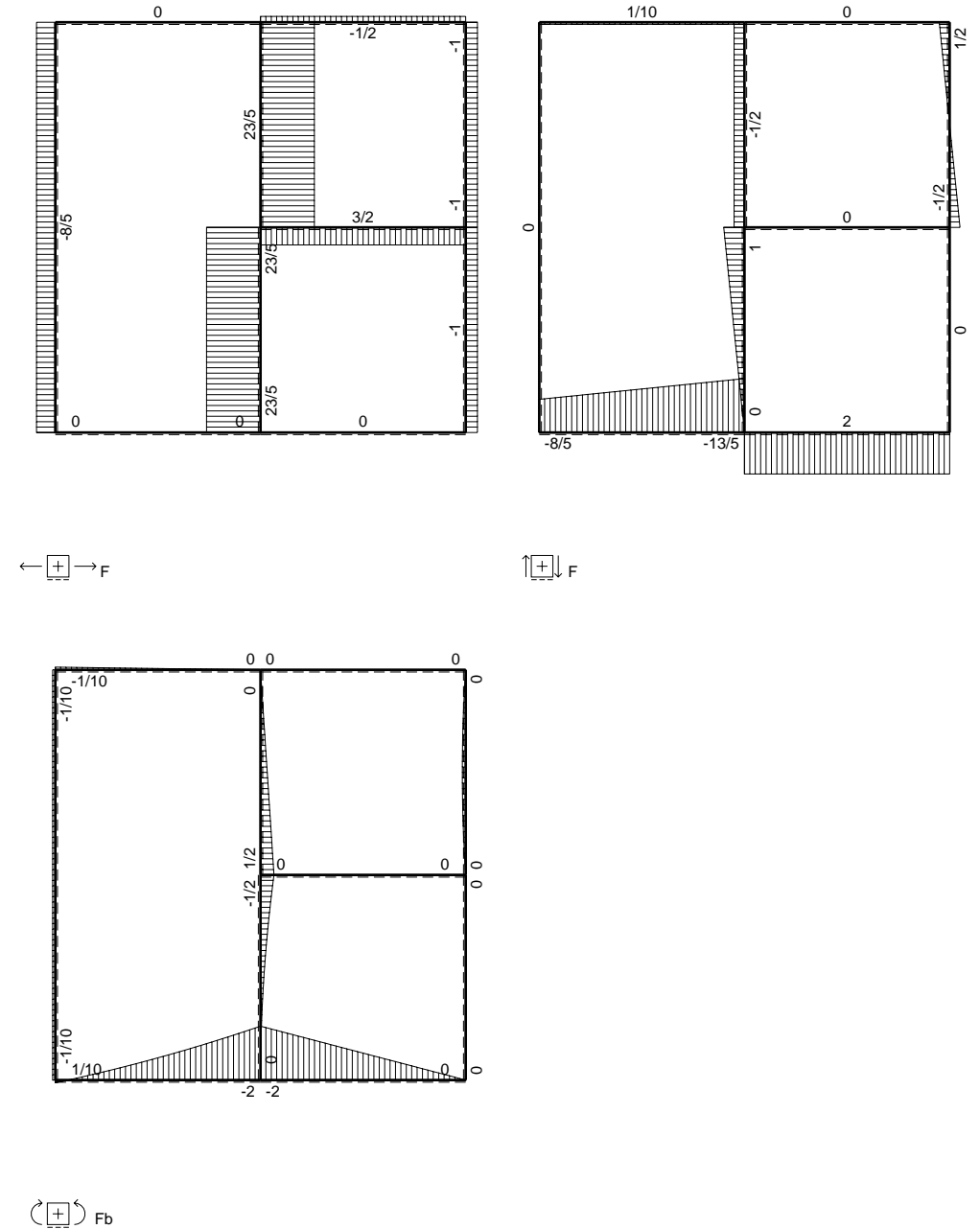
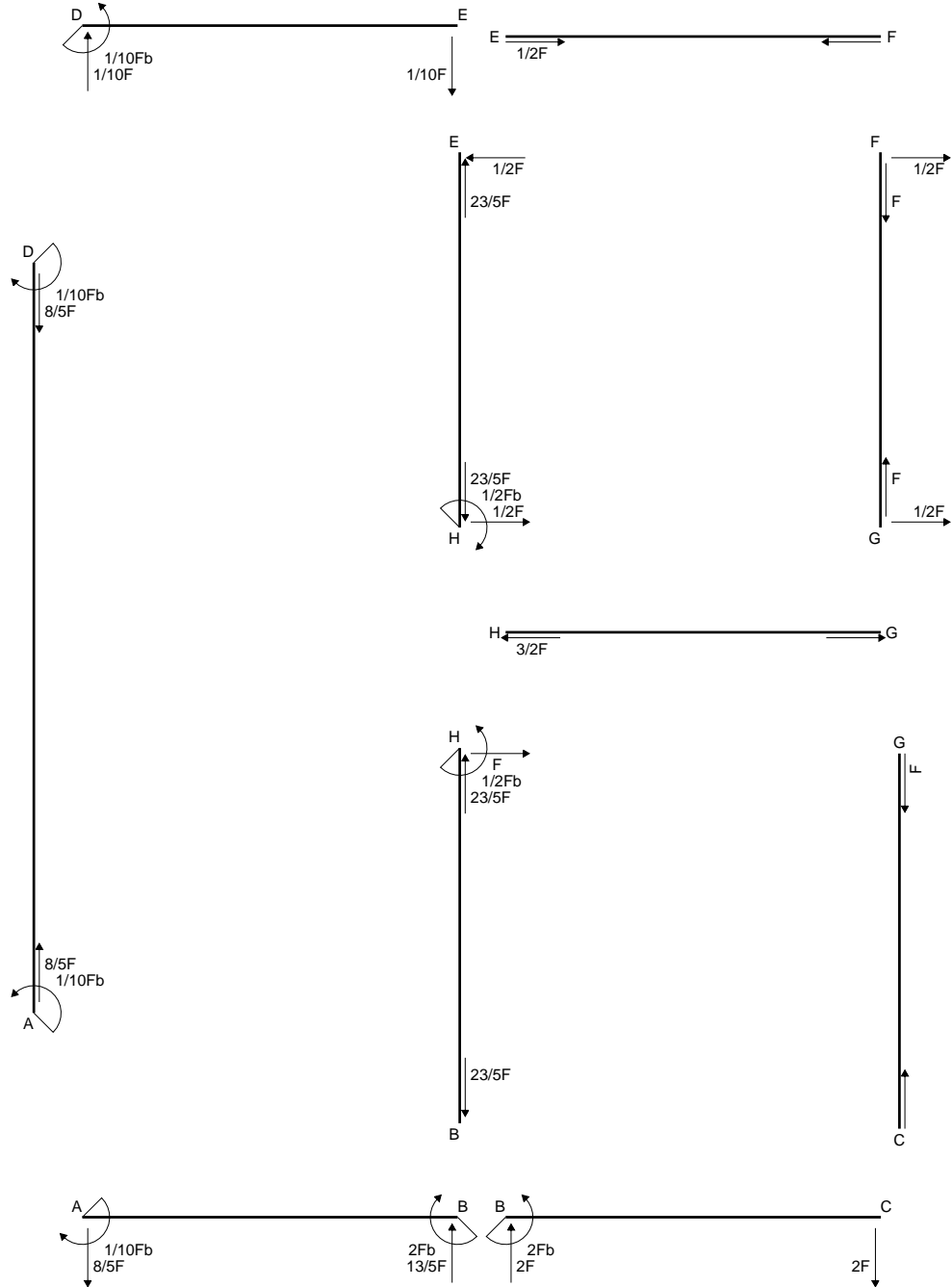
$$= (-b + 1/2 b) \theta = -1/2 \cdot Fb^2/EJ$$

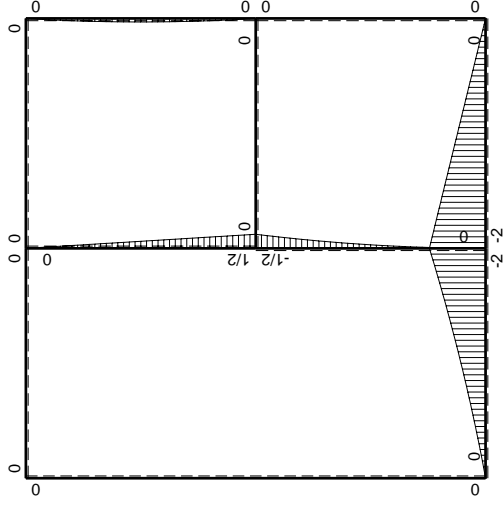
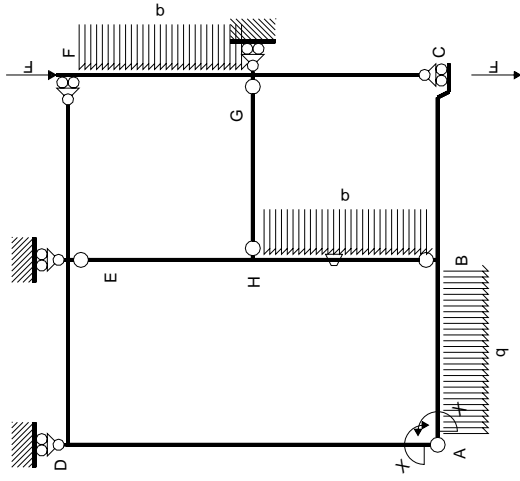
$$L_{ED}^{xo} = \int_0^b (x/b) \theta dx = \left[ 1/2 x^2/b \right]_0^b \theta$$

$$= (1/2 b) \theta = -1/2 \cdot Fb^2/EJ$$



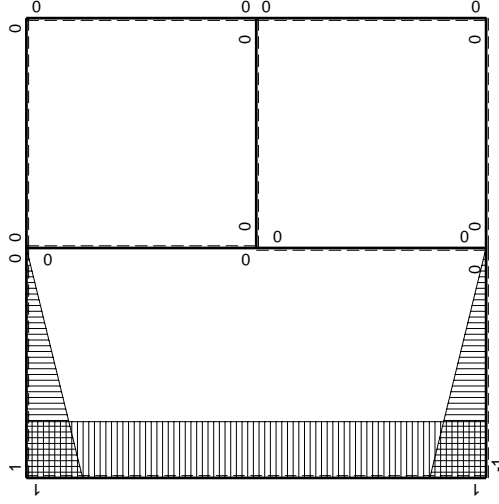
- A = 984. mm<sup>2</sup>
- J<sub>u</sub> = 337339. mm<sup>4</sup>
- J<sub>v</sub> = 77472. mm<sup>4</sup>
- y<sub>g</sub> = 31.85 mm
- T<sub>y</sub> = 2820. N
- M<sub>x</sub> = -2115000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -12. mm
- v<sub>m</sub> = -31.85 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -199.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 11. mm
- v<sub>c</sub> = -20.85 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -130.7 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.871 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 130.9 N/mm<sup>2</sup>
- S = 5556. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
GF b	0	$-1/2Fx+1/2qx^2$	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-1/2Fb+Fx-1/2qx^2$	$-Fb/EJ$	0	0	0	0+0	0	
BH b	0	$1/2qx^2$	$Fb/EJ$	0	0	0			
HE b	0	$1/2Fb-1/2Fx$	0	0	0	0	0+0	0	
EH b	0	$-1/2Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx + 1 \cdot \frac{1}{4} \frac{b}{EJ} = \left[ x - \frac{x^2}{b} + \frac{1}{3} \frac{x^3}{b^2} \right]_0^b \frac{1}{EJ} + 1 \cdot \frac{1}{4} \frac{b}{EJ}$$

$$= (b - b + \frac{1}{3}b) \frac{1}{EJ} + 1 \cdot \frac{1}{4} \frac{b}{EJ} = \frac{7}{12} \frac{b}{EJ}$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx + 1 \cdot \frac{1}{4} \frac{b}{EJ} = \left[ \frac{1}{3} \frac{x^3}{b^2} \right]_0^b \frac{1}{EJ} + 1 \cdot \frac{1}{4} \frac{b}{EJ}$$

$$= (\frac{1}{3}b) \frac{1}{EJ} + 1 \cdot \frac{1}{4} \frac{b}{EJ} = \frac{7}{12} \frac{b}{EJ}$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \frac{b}{EJ}$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \frac{b}{EJ}$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx = \left[ x - \frac{x^2}{b} + \frac{1}{3} \frac{x^3}{b^2} \right]_0^b \frac{1}{EJ}$$

$$= (b - b + \frac{1}{3}b) \frac{1}{EJ} = \frac{1}{3} \frac{b}{EJ}$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx = \left[ \frac{1}{3} \frac{x^3}{b^2} \right]_0^b \frac{1}{EJ}$$

$$= (\frac{1}{3}b) \frac{1}{EJ} = \frac{1}{3} \frac{b}{EJ}$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

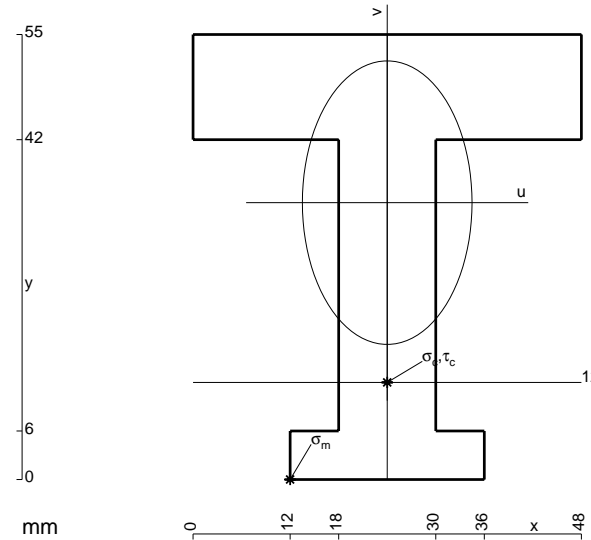
$$= \left[ \frac{3}{4} \frac{x^2}{b} - \frac{1}{3} \frac{x^3}{b^2} - \frac{1}{8} \frac{x^4}{b^3} \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= (\frac{3}{4}b - \frac{1}{3}b - \frac{1}{8}b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ} = \frac{7}{24} \frac{Fb^2}{EJ}$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= \left[ x^2/b - \frac{5}{6} \frac{x^3}{b^2} + \frac{1}{8} \frac{x^4}{b^3} \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= (b - \frac{5}{6}b + \frac{1}{8}b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ} = \frac{7}{24} \frac{Fb^2}{EJ}$$



$$A = 1200. \text{ mm}^2$$

$$J_u = 368598. \text{ mm}^4$$

$$J_v = 131904. \text{ mm}^4$$

$$y_g = 34.22 \text{ mm}$$

$$T_y = 2820. \text{ N}$$

$$M_x = -2256000. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -12. \text{ mm}$$

$$v_m = -34.22 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -209.4 \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 12. \text{ mm}$$

$$v_c = -22.22 \text{ mm}$$

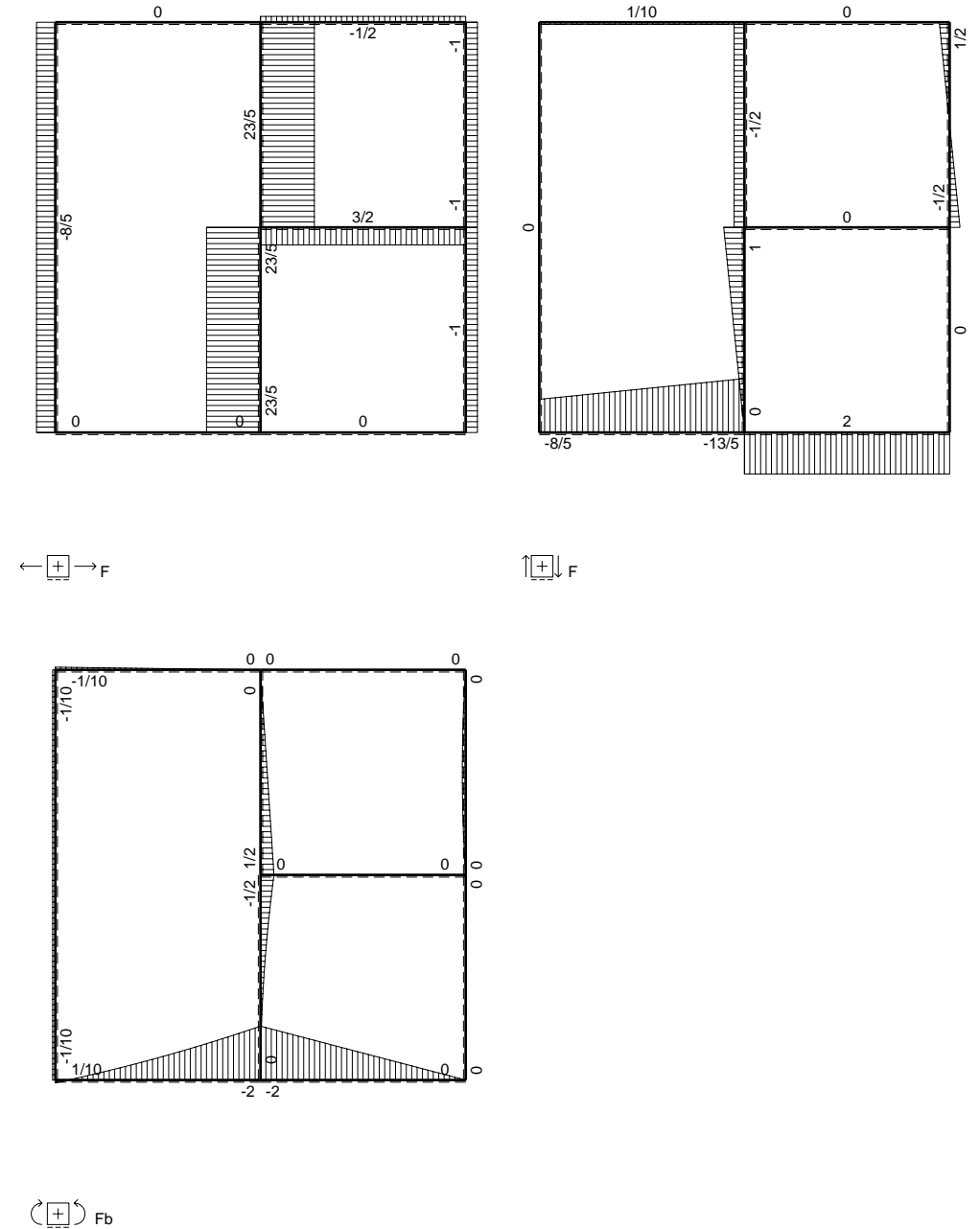
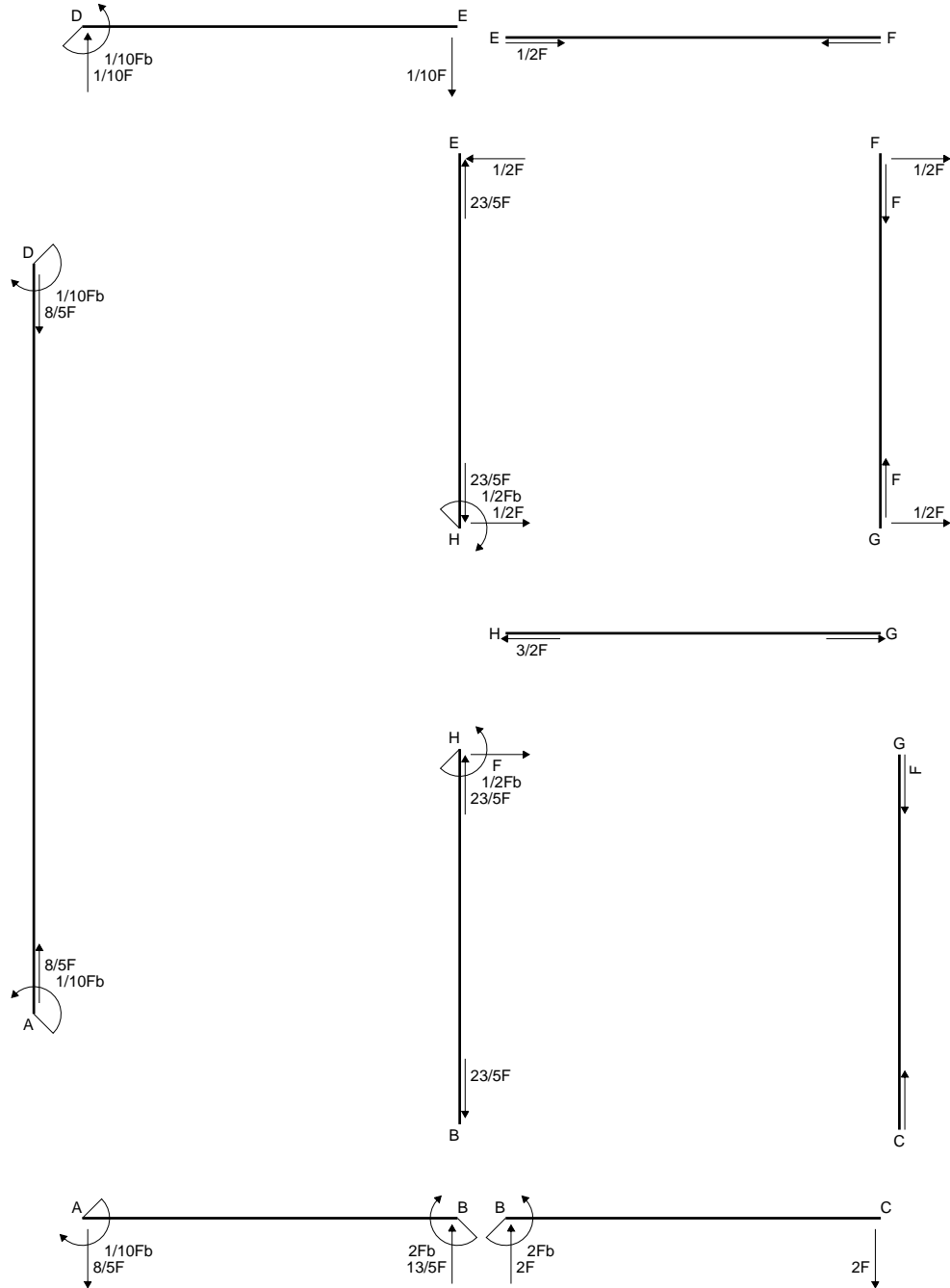
$$\sigma_c = -Mv/J_u = -136. \text{ N/mm}^2$$

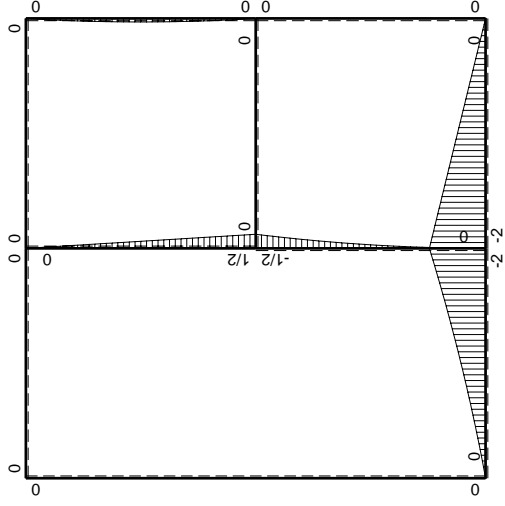
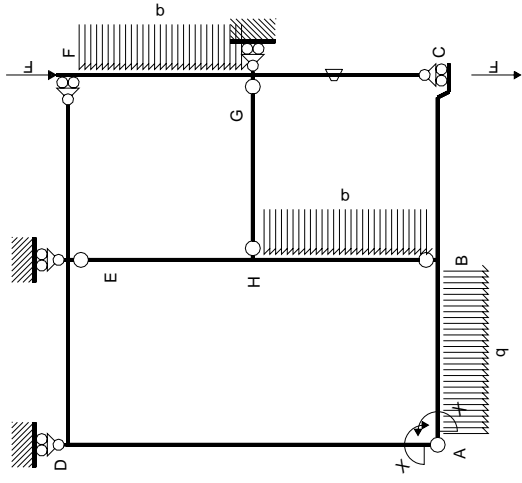
$$\tau_c = 4.024 \text{ N/mm}^2$$

$$\sigma_o = \sqrt{\sigma^2 + 3\tau^2} = 136.2 \text{ N/mm}^2$$

$$S = 6312. \text{ mm}^3$$

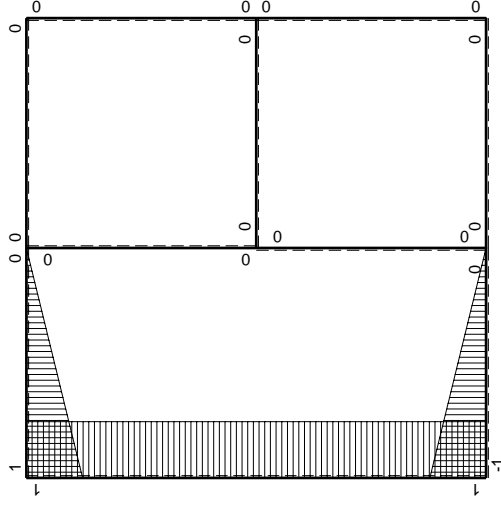






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_X$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
GF b	0	$-1/2Fx+1/2qx^2$	0	0	0	0			
GC b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
CG b	0	0	$Fb/EJ$	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
BH b	0	$1/2qx^2$	0	0	0	0			
HE b	0	$1/2Fb-1/2Fx$	0	0	0	0	0+0	0	
EH b	0	$-1/2Fx$	0	0	0	0			
AB	molla asta $-W_{1AB} (W_{0AB} + XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

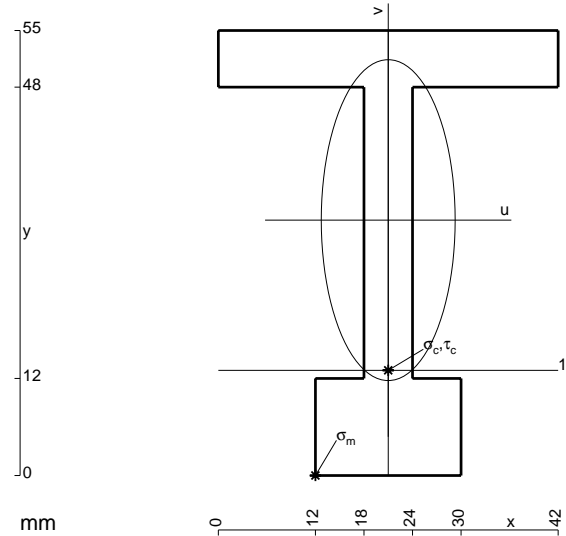
$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

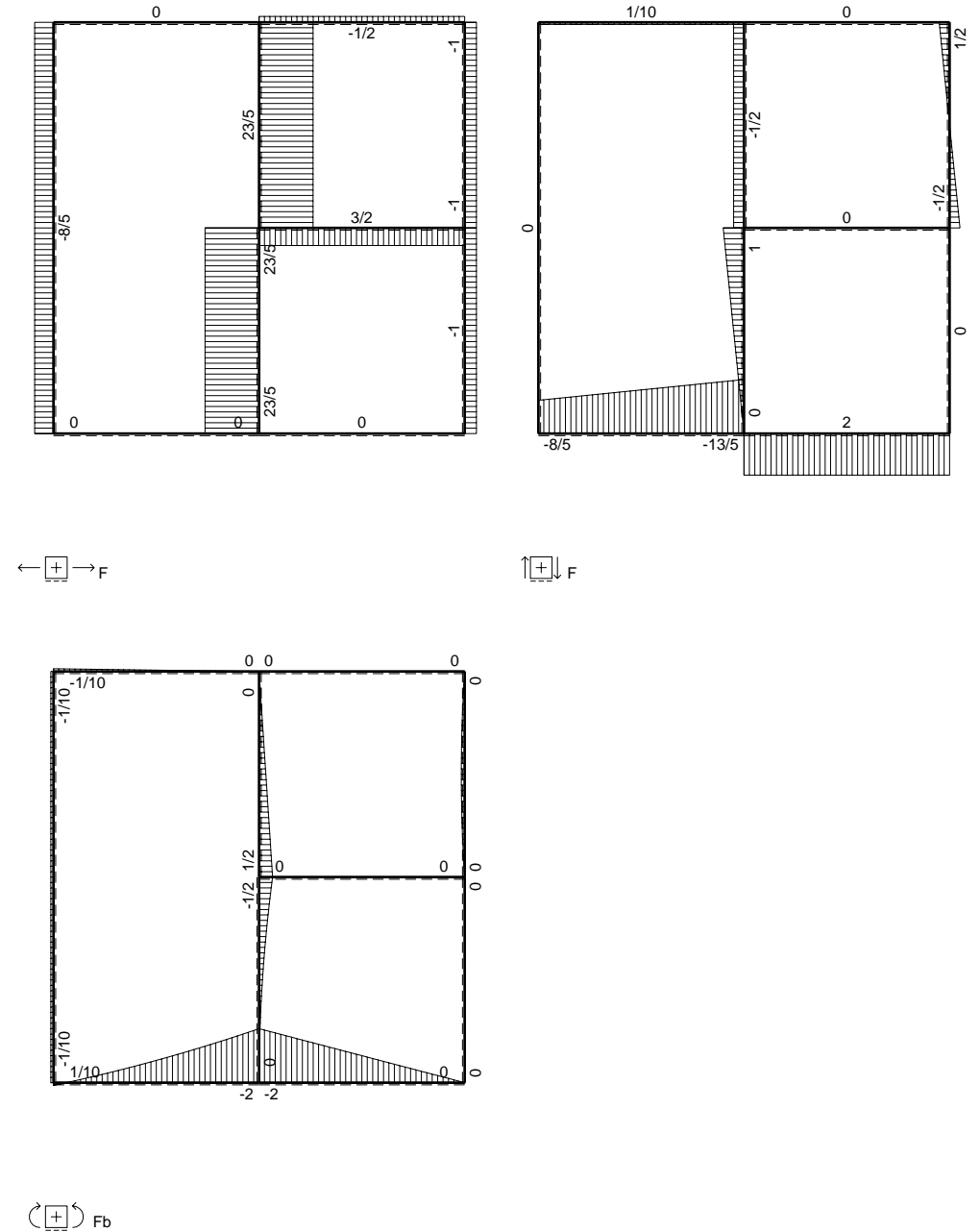
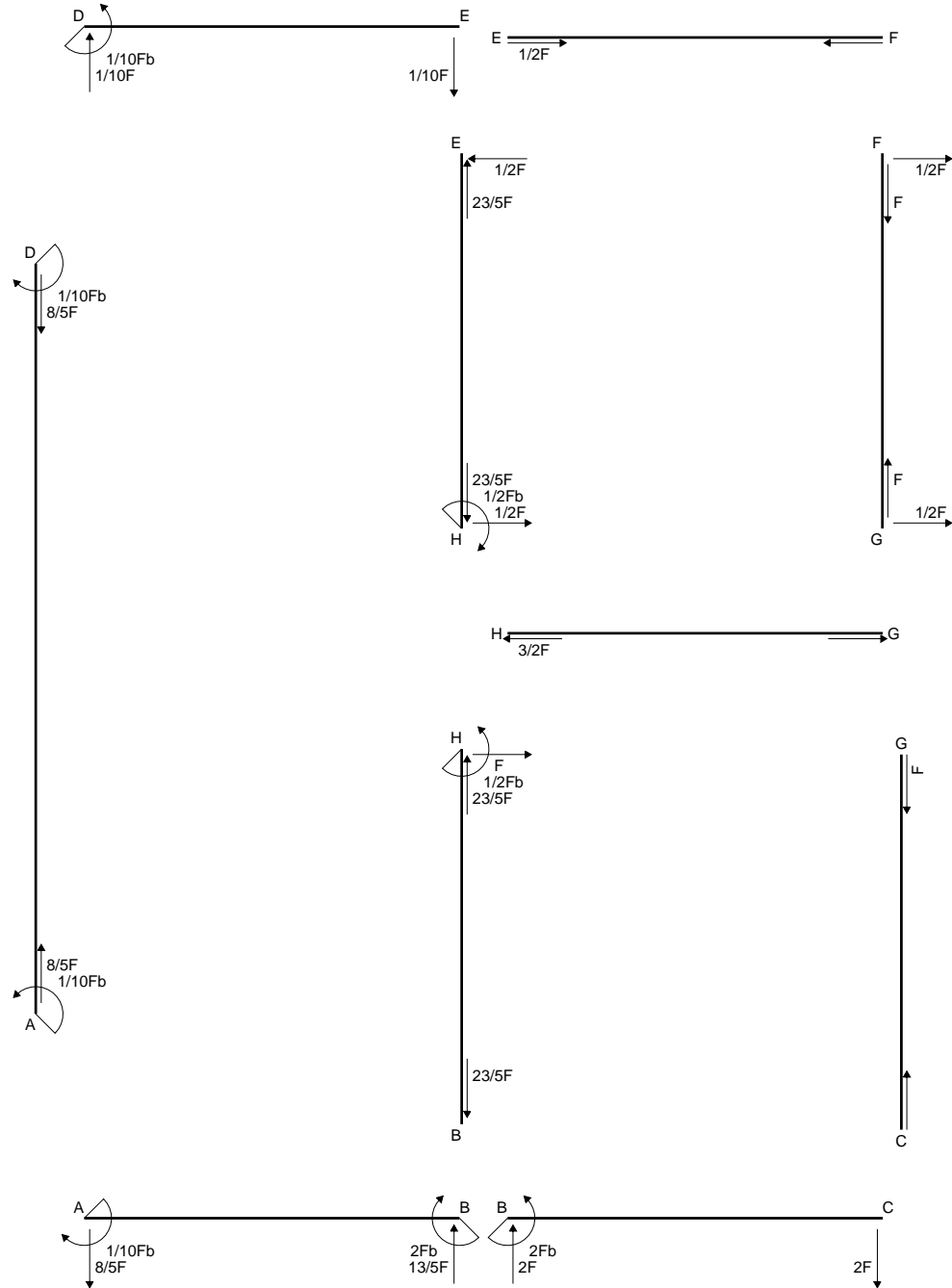
$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

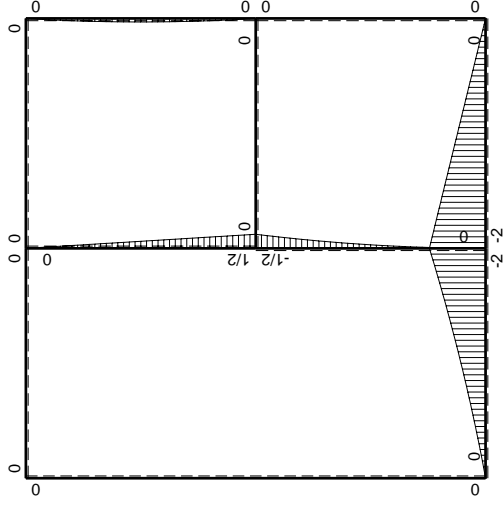
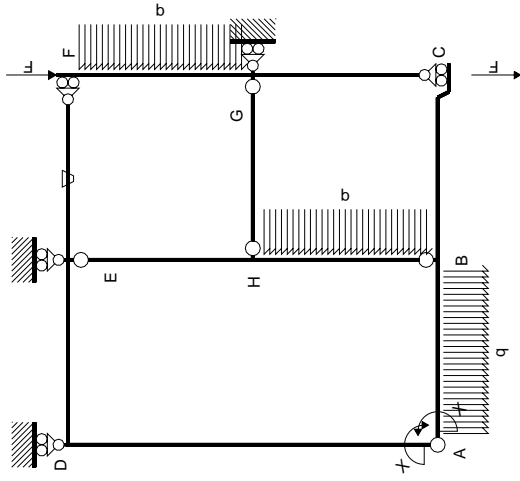
$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$



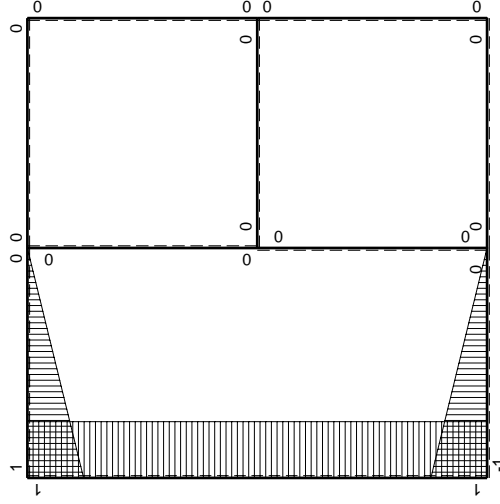
- A = 726. mm<sup>2</sup>
- J<sub>u</sub> = 285657. mm<sup>4</sup>
- J<sub>v</sub> = 49698. mm<sup>4</sup>
- y<sub>g</sub> = 31.57 mm
- T<sub>y</sub> = 2340. N
- M<sub>x</sub> = -1989000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -9. mm
- v<sub>m</sub> = -31.57 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -219.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 13. mm
- v<sub>c</sub> = -18.57 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -129.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.696 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 130. N/mm<sup>2</sup>
- S = 5637. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
FE b	0	0	$Fb/EJ$	0	0	0			
FG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
GF b	0	$-1/2Fx+1/2qx^2$	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
BH b	0	$1/2qx^2$	0	0	0	0			
HE b	0	$1/2Fb-1/2Fx$	0	0	0	0	0+0	0	
EH b	0	$-1/2Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

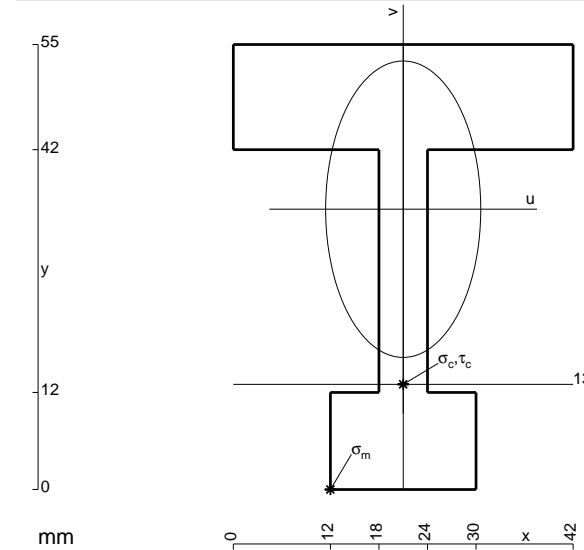
$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

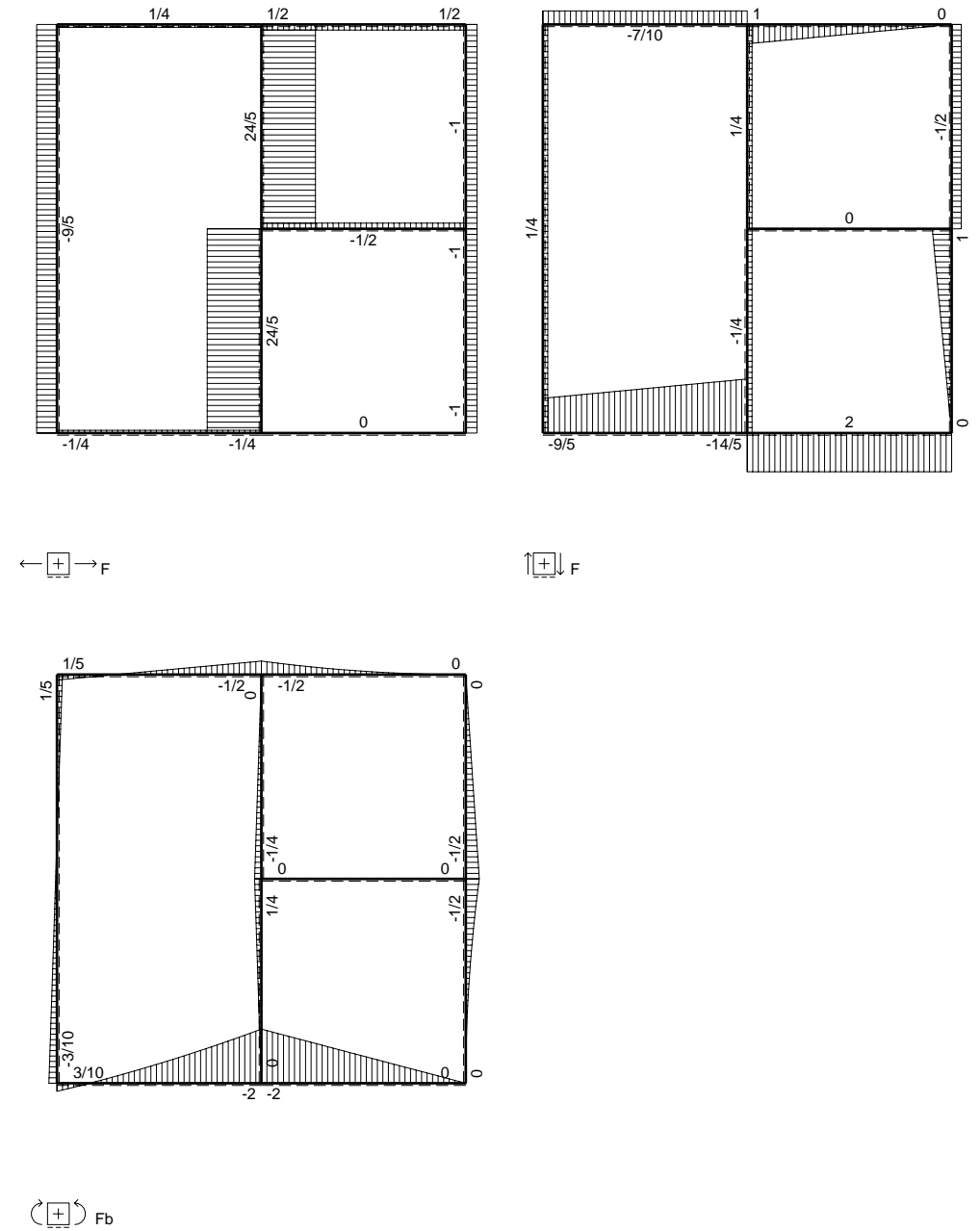
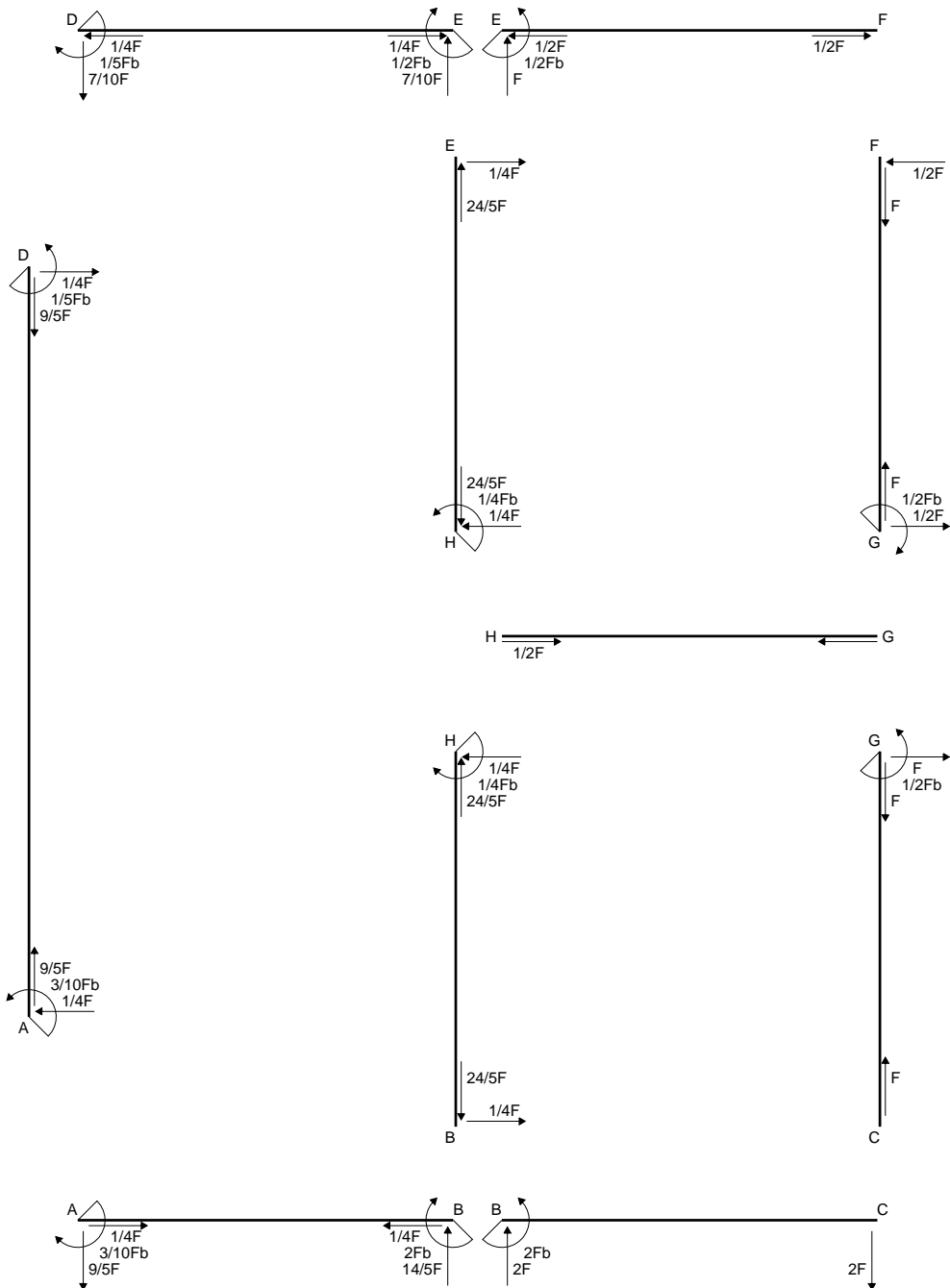
$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

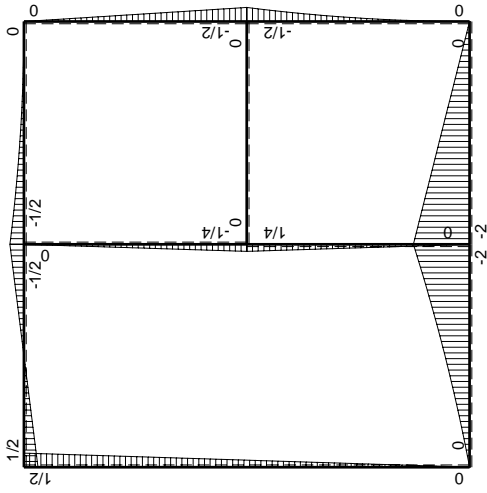
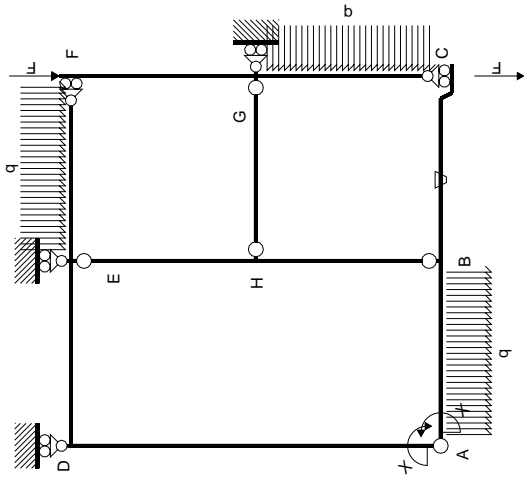
$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$



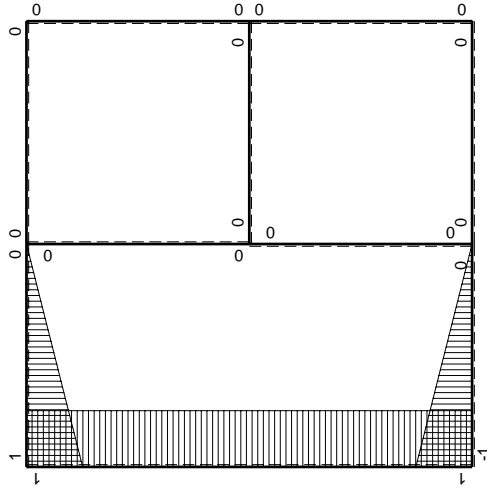
- A = 942. mm<sup>2</sup>
- J<sub>u</sub> = 316348. mm<sup>4</sup>
- J<sub>v</sub> = 86634. mm<sup>4</sup>
- y<sub>g</sub> = 34.65 mm
- T<sub>y</sub> = 2320. N
- M<sub>x</sub> = -2088000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -9. mm
- v<sub>m</sub> = -34.65 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -228.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 13. mm
- v<sub>c</sub> = -21.65 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -142.9 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.725 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 143.5 N/mm<sup>2</sup>
- S = 6321. mm<sup>3</sup>







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	$-Fb/EJ$	0	0	0	0+0	0	
CB b	0	$2Fx$	$Fb/EJ$	0	0	0			
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1			
DE b	$1-x/b$	$1/2Fb-Fx$	0	$1/2Fb-3/2Fx+Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/12+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fb-Fx$	0	$-1/2Fx+Fx^2/b$	0	$x^2/b^2$			
EF b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
FE b	0	$1/2qx^2$	0	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$1/4Fb-1/4Fx$	0	0	0	0	0+0	0	
BH b	0	$-1/4Fx$	0	0	0	0			
HE b	0	$-1/4Fb+1/4Fx$	0	0	0	0	0+0	0	
EH b	0	$1/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/8Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-3/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

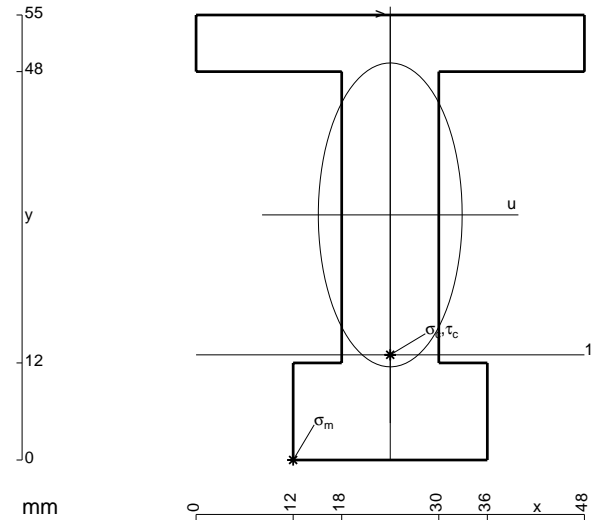
$$= (b - 1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - 3/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 3/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/2 b - 3/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (-1/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$



$$A = 1056. \text{ mm}^2$$

$$J_u = 372596. \text{ mm}^4$$

$$J_v = 83520. \text{ mm}^4$$

$$y_g = 30.3 \text{ mm}$$

$$T_y = 3100. \text{ N}$$

$$M_x = -2945000. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -12. \text{ mm}$$

$$v_m = -30.3 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -239.5 \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 13. \text{ mm}$$

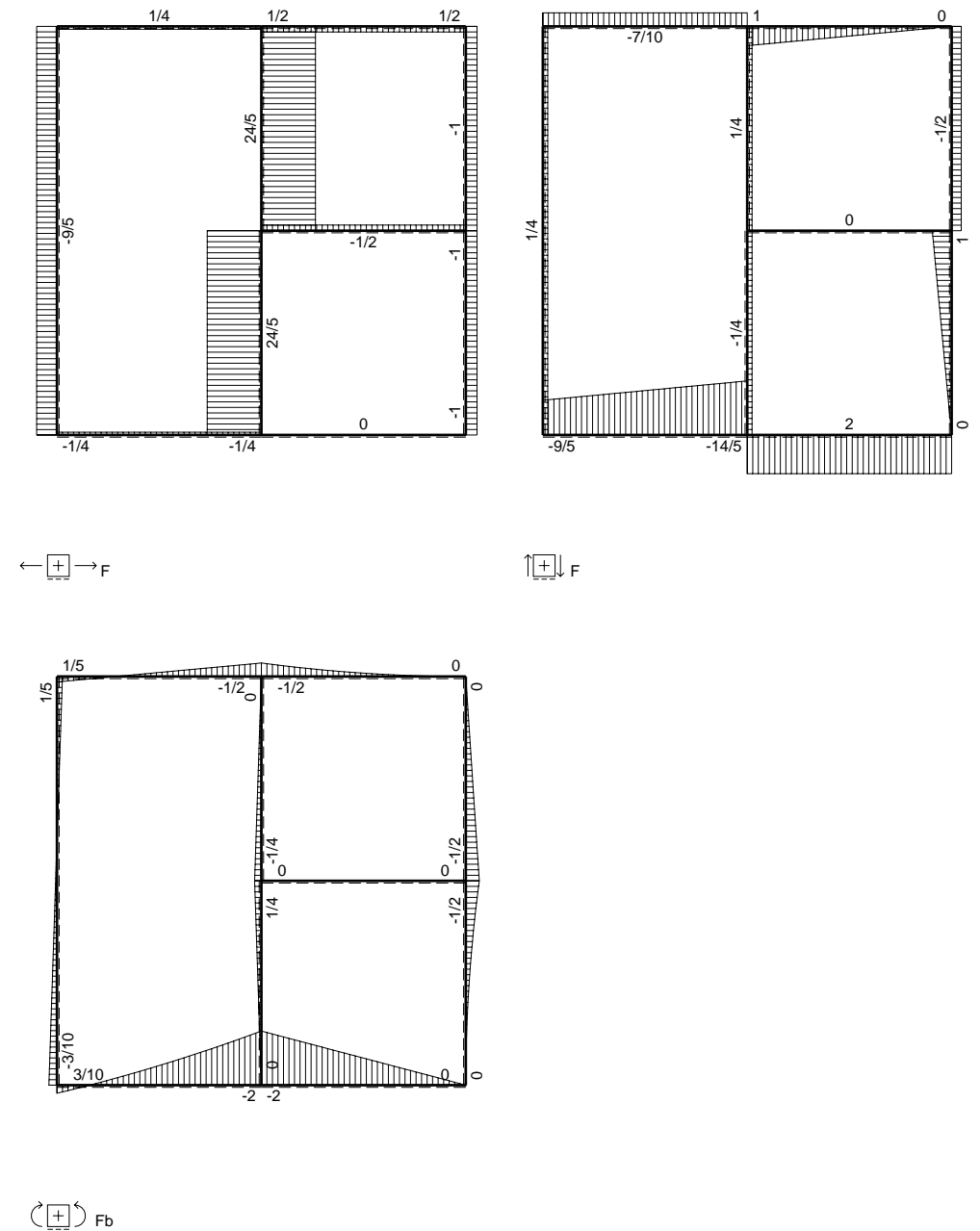
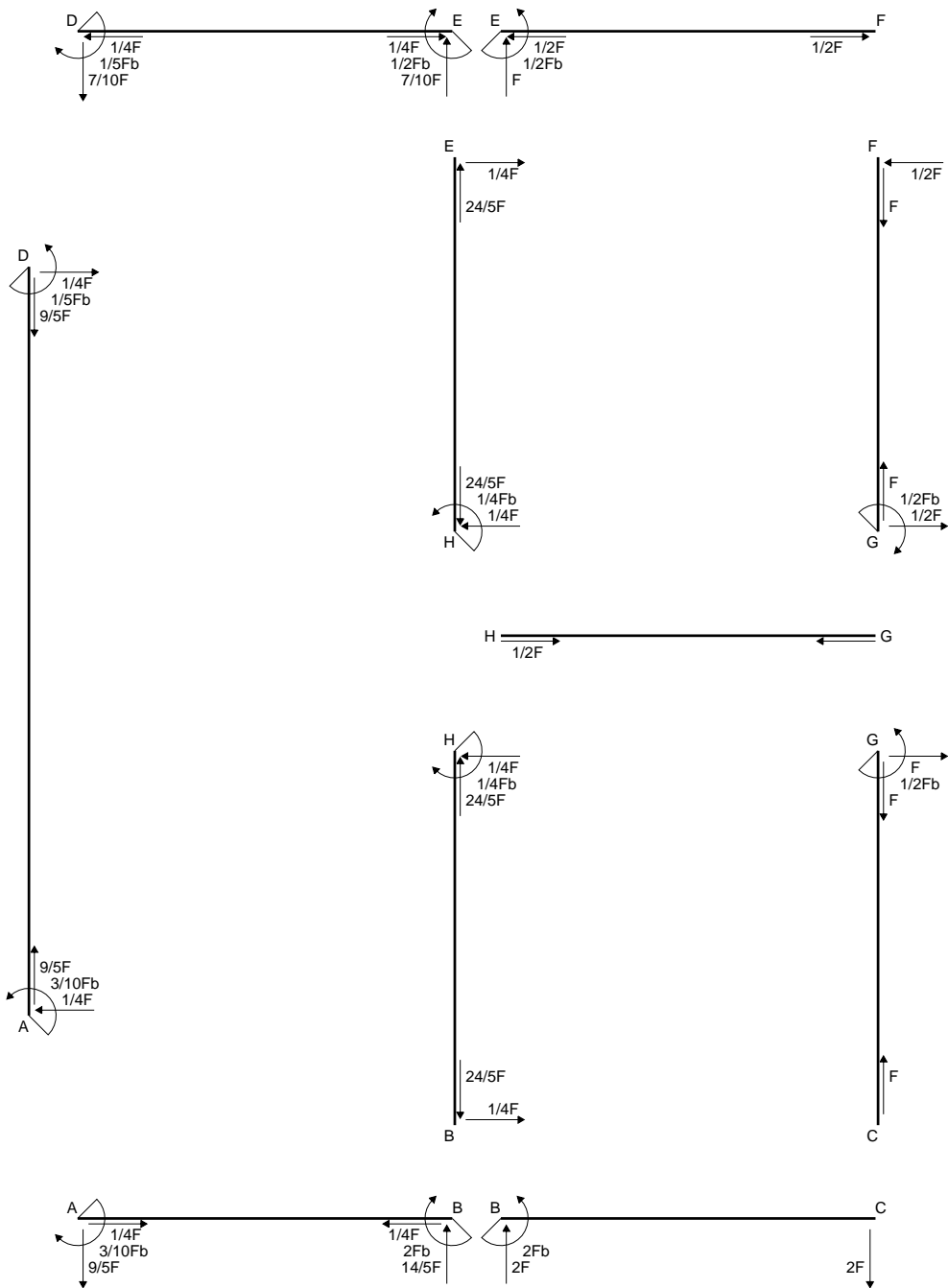
$$v_c = -17.3 \text{ mm}$$

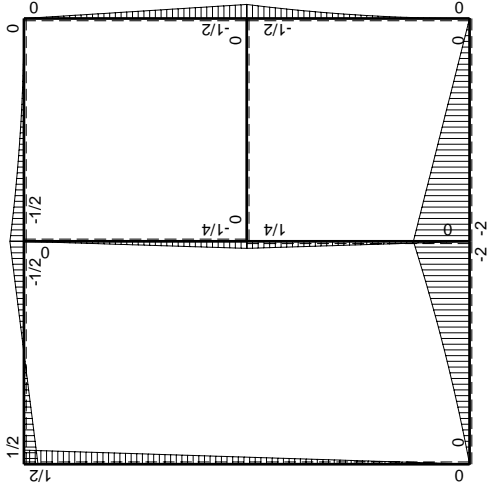
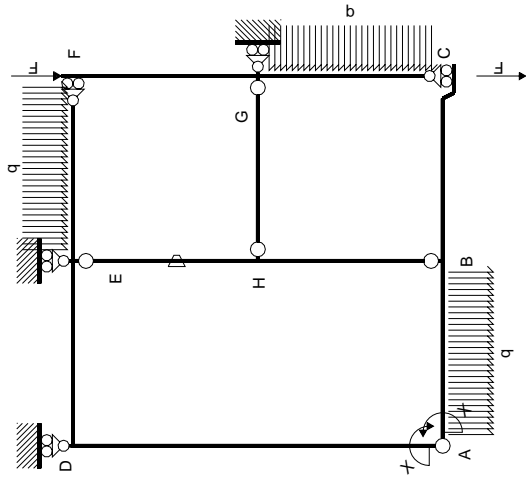
$$\sigma_c = -Mv/J_u = -136.7 \text{ N/mm}^2$$

$$\tau_c = 4.999 \text{ N/mm}^2$$

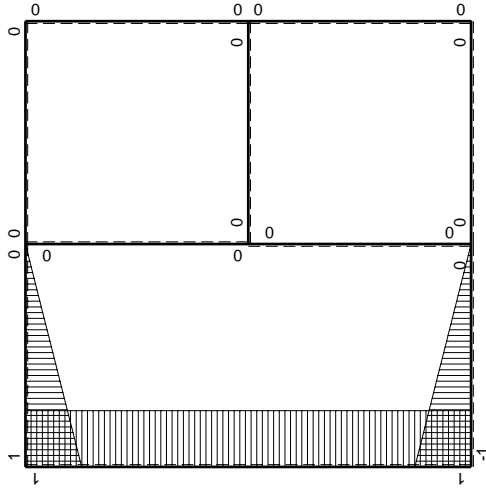
$$\sigma_o = \sqrt{\sigma^2 + 3\tau^2} = 137. \text{ N/mm}^2$$

$$S = 7211. \text{ mm}^3$$





$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1			
DE b	$1-x/b$	$1/2Fb-Fx$	0	$1/2Fb-3/2Fx+Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/12+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fb-Fx$	0	$-1/2Fx+Fx^2/b$	0	$x^2/b^2$			
EF b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
FE b	0	$1/2qx^2$	0	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$1/4Fb-1/4Fx$	0	0	0	0	0+0	0	
BH b	0	$-1/4Fx$	0	0	0	0			
HE b	0	$-1/4Fb+1/4Fx$	$-Fb/EJ$	0	0	0	0+0	0	
EH b	0	$1/4Fx$	$Fb/EJ$	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/8Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-3/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

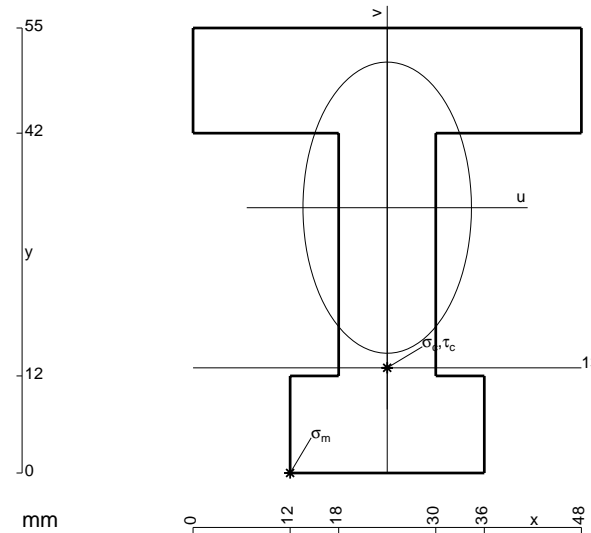
$$= (b - 1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - 3/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 3/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/2 b - 3/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (-1/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$



$$A = 1272. \text{ mm}^2$$

$$J_u = 412017. \text{ mm}^4$$

$$J_v = 137952. \text{ mm}^4$$

$$y_g = 32.79 \text{ mm}$$

$$T_y = 5020. \text{ N}$$

$$M_x = -2510000. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -12. \text{ mm}$$

$$v_m = -32.79 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -199.8 \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 13. \text{ mm}$$

$$v_c = -19.79 \text{ mm}$$

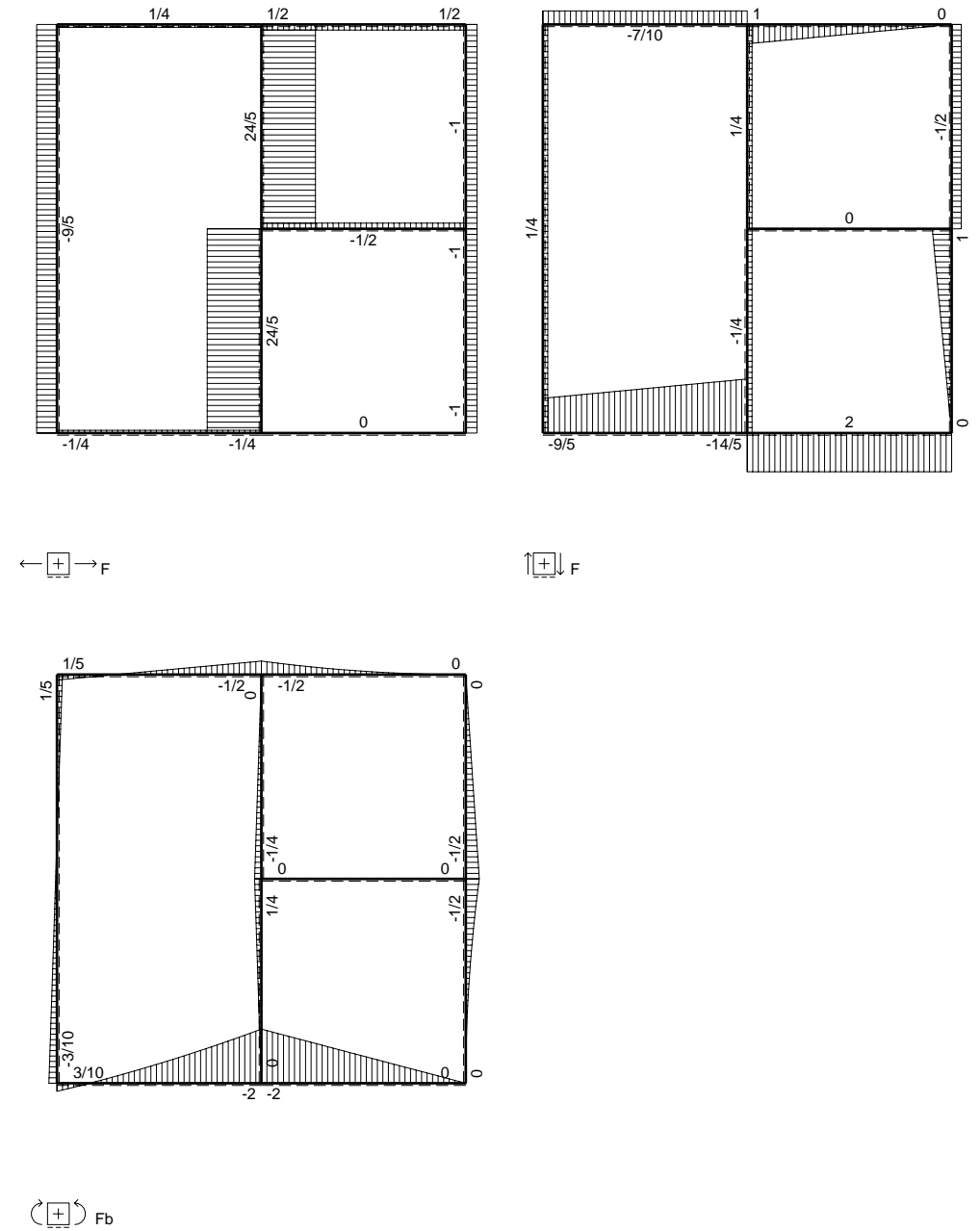
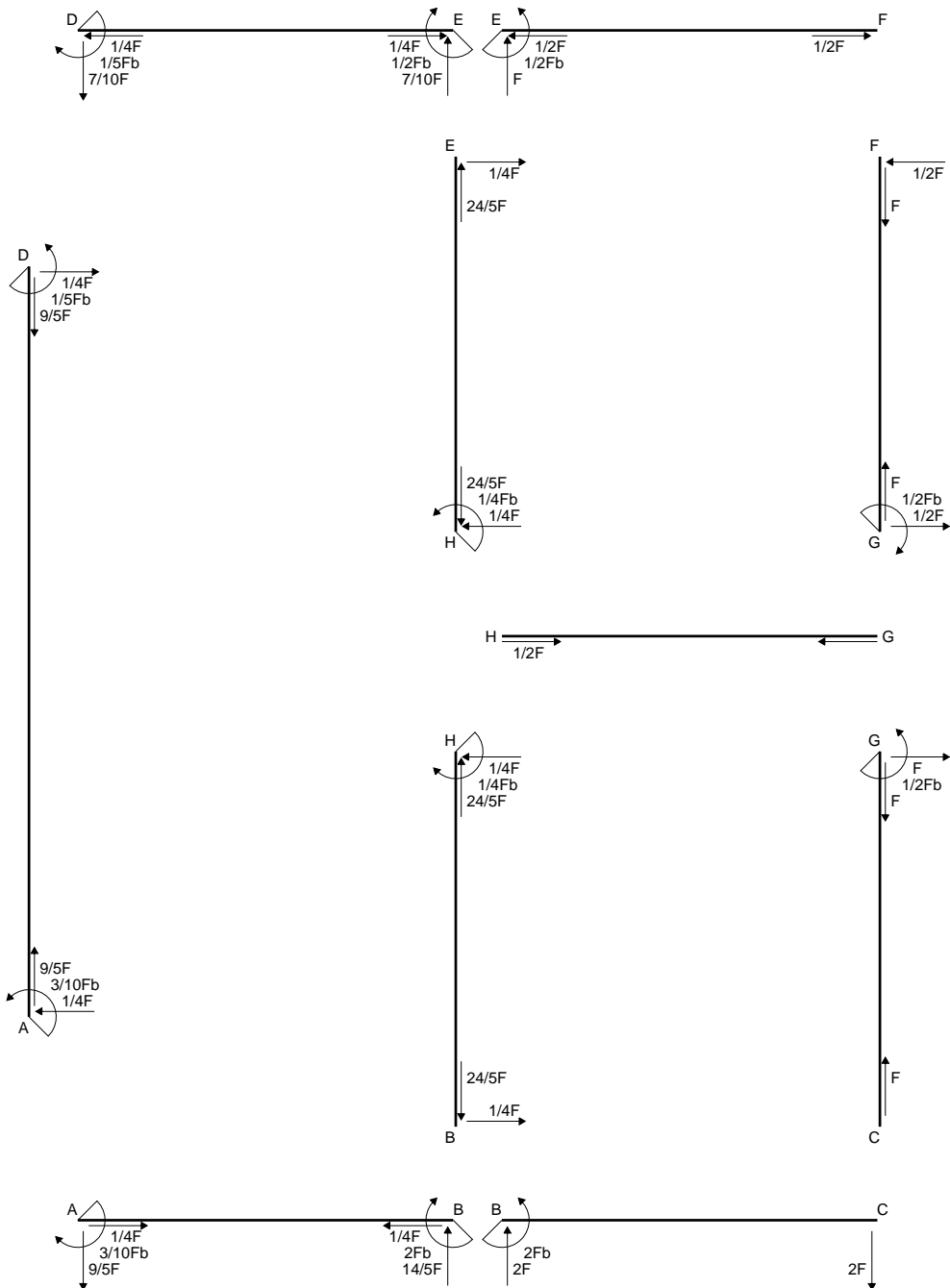
$$\sigma_c = -Mv/J_u = -120.6 \text{ N/mm}^2$$

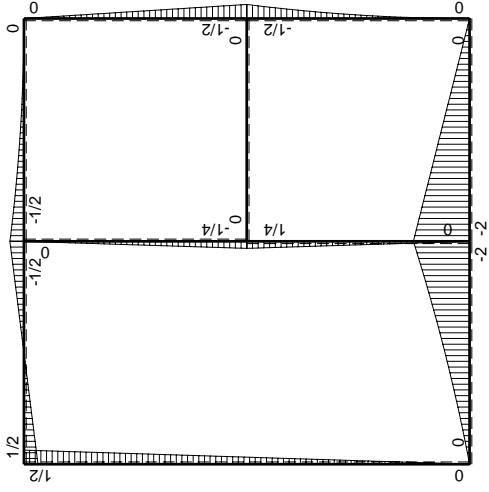
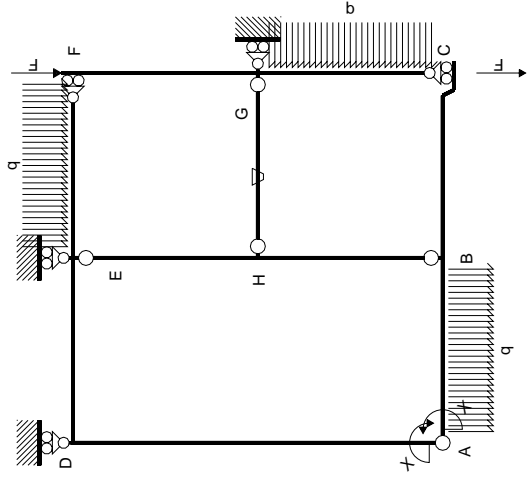
$$\tau_c = 8.082 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 121.4 \text{ N/mm}^2$$

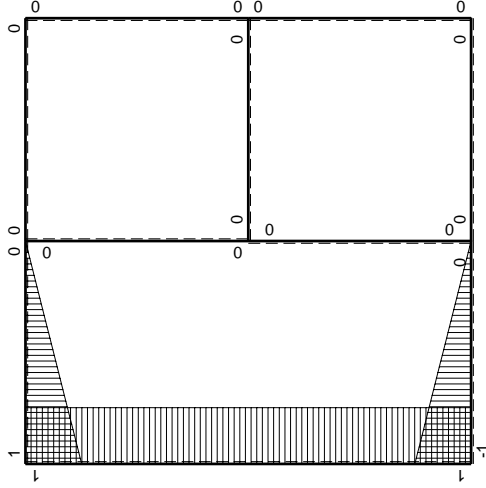
$$S = 7960. \text{ mm}^3$$







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1			
DE b	$1-x/b$	$1/2Fb-Fx$	0	$1/2Fb-3/2Fx+Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/12+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fb-Fx$	0	$-1/2Fx+Fx^2/b$	0	$x^2/b^2$			
EF b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
FE b	0	$1/2qx^2$	0	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
GH b	0	0	$Fb/EJ$	0	0	0			
HB b	0	$1/4Fb-1/4Fx$	0	0	0	0	0+0	0	
BH b	0	$-1/4Fx$	0	0	0	0			
HE b	0	$-1/4Fb+1/4Fx$	0	0	0	0	0+0	0	
EH b	0	$1/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/8Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-3/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

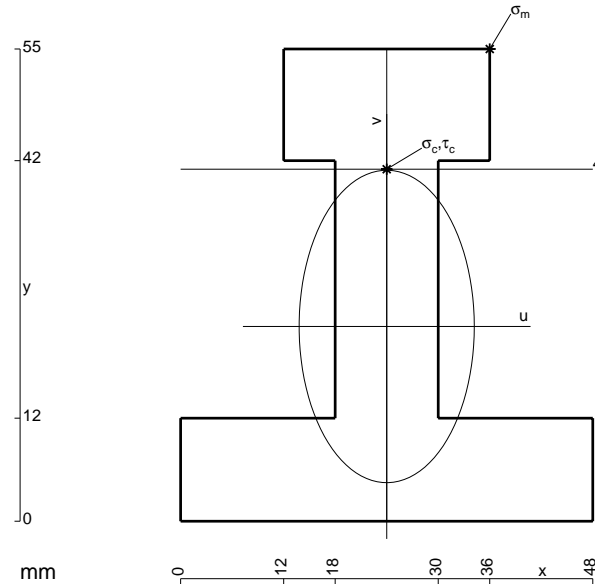
$$= (b - 1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - 3/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 3/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

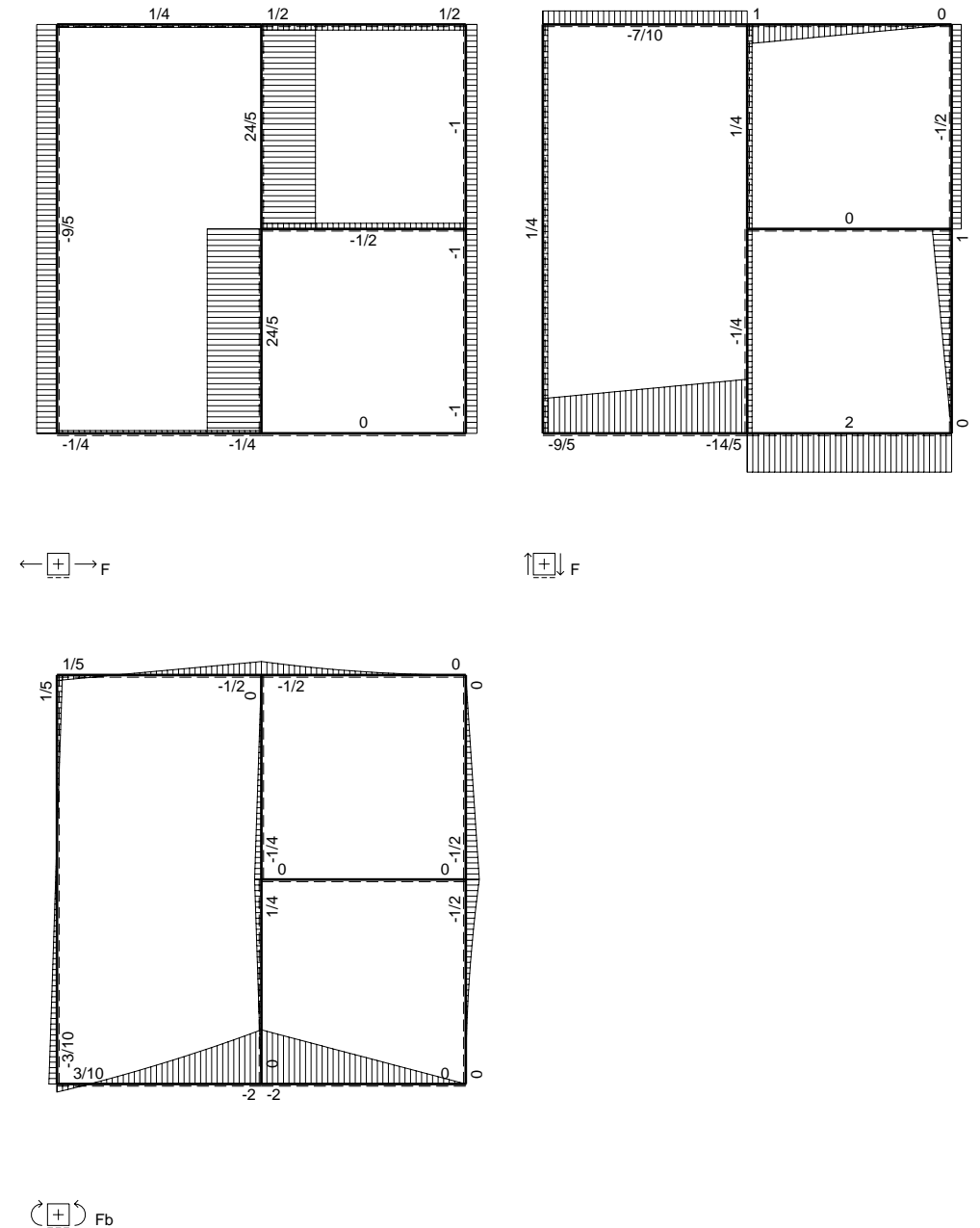
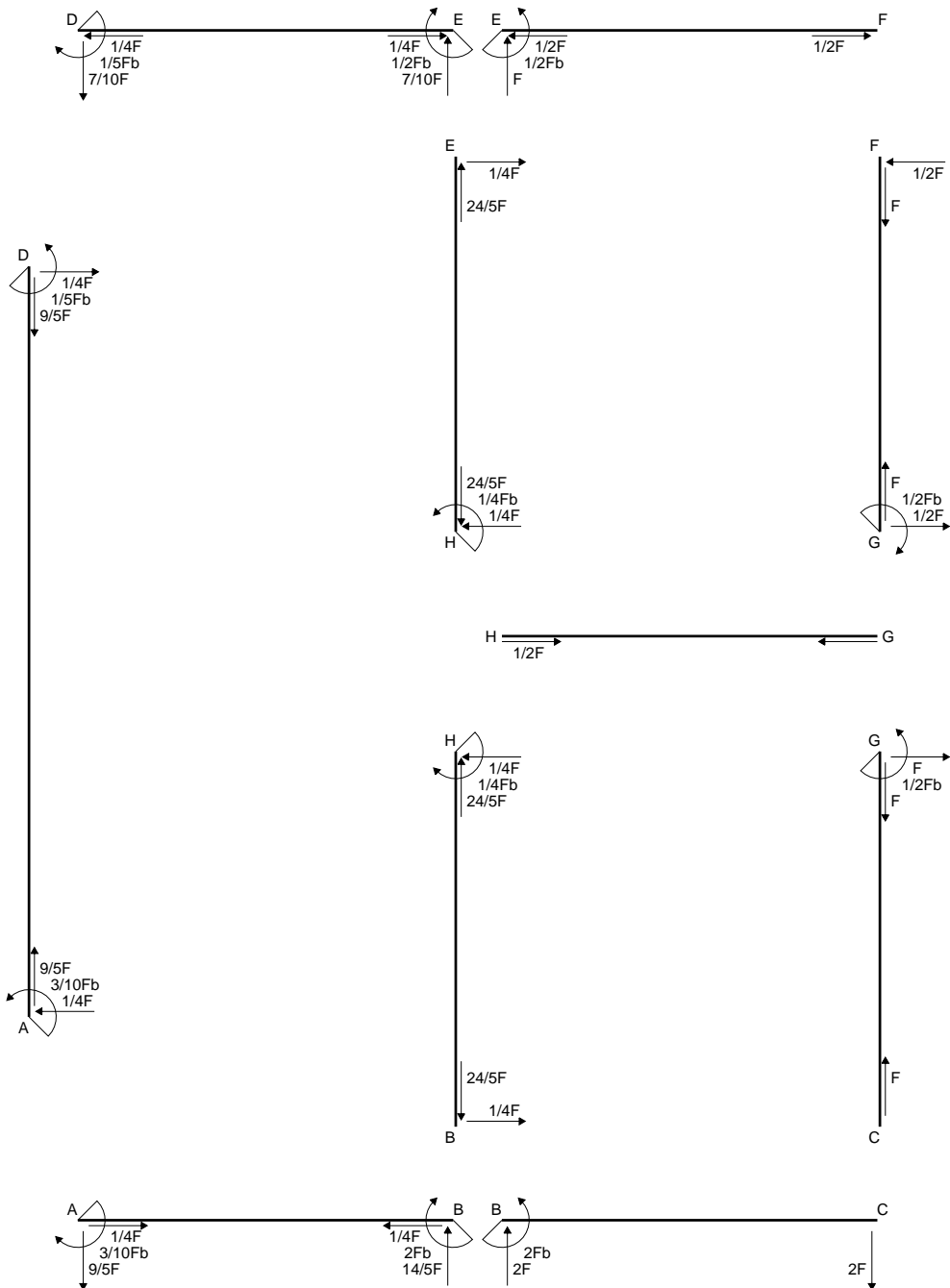
$$= (1/2 b - 3/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$

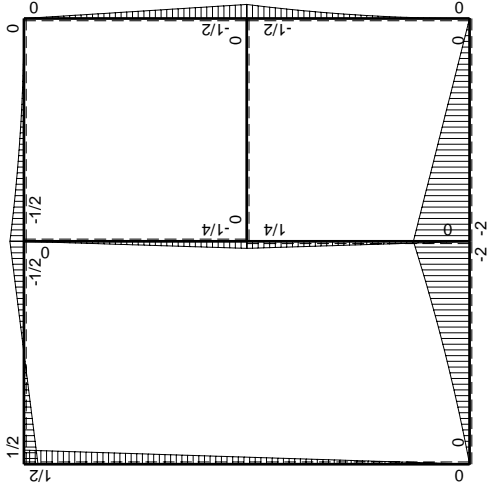
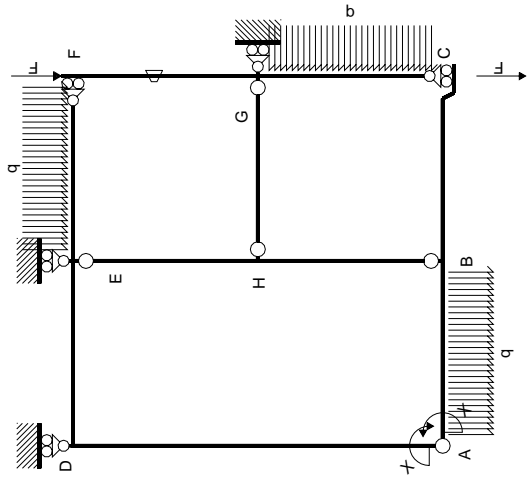
$$L_{ED}^{xo} = \int_0^b (-1/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$

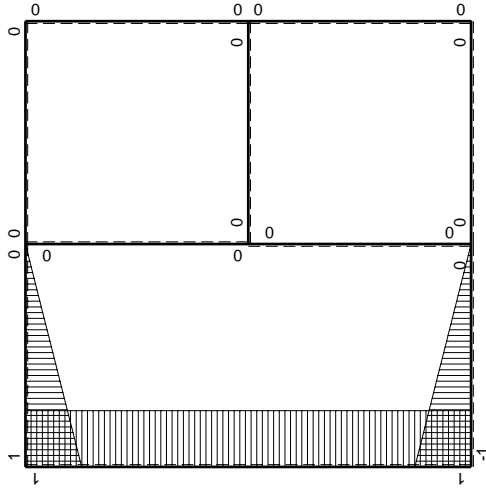


- A = 1248. mm<sup>2</sup>
- J<sub>u</sub> = 413282. mm<sup>4</sup>
- J<sub>v</sub> = 129888. mm<sup>4</sup>
- y<sub>g</sub> = 22.68 mm
- T<sub>y</sub> = 4880. N
- M<sub>x</sub> = -2684000. Nmm
- x<sub>m</sub> = 36. mm
- y<sub>m</sub> = 55. mm
- u<sub>m</sub> = 12. mm
- v<sub>m</sub> = 32.32 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 209.9 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 41. mm
- v<sub>c</sub> = 18.32 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 119. N/mm<sup>2</sup>
- τ<sub>c</sub> = 8.148 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 119.8 N/mm<sup>2</sup>
- S = 8281. mm<sup>3</sup>





$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1			
DE b	$1-x/b$	$1/2Fb-Fx$	0	$1/2Fb-3/2Fx+Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/12+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fb-Fx$	0	$-1/2Fx+Fx^2/b$	0	$x^2/b^2$			
EF b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
FE b	0	$1/2qx^2$	0	0	0	0			
FG b	0	$-1/2Fx$	$-Fb/EJ$	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	$Fb/EJ$	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$1/4Fb-1/4Fx$	0	0	0	0	0+0	0	
BH b	0	$-1/4Fx$	0	0	0	0			
HE b	0	$-1/4Fb+1/4Fx$	0	0	0	0	0+0	0	
EH b	0	$1/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/8Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-3/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

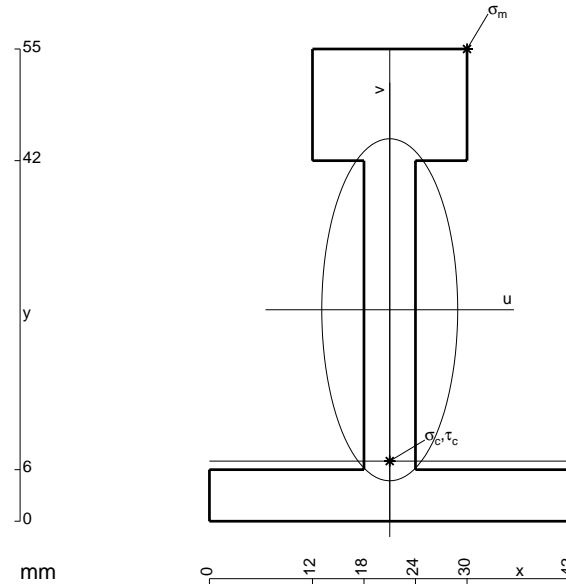
$$= (b - 1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - 3/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 3/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/2 b - 3/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$

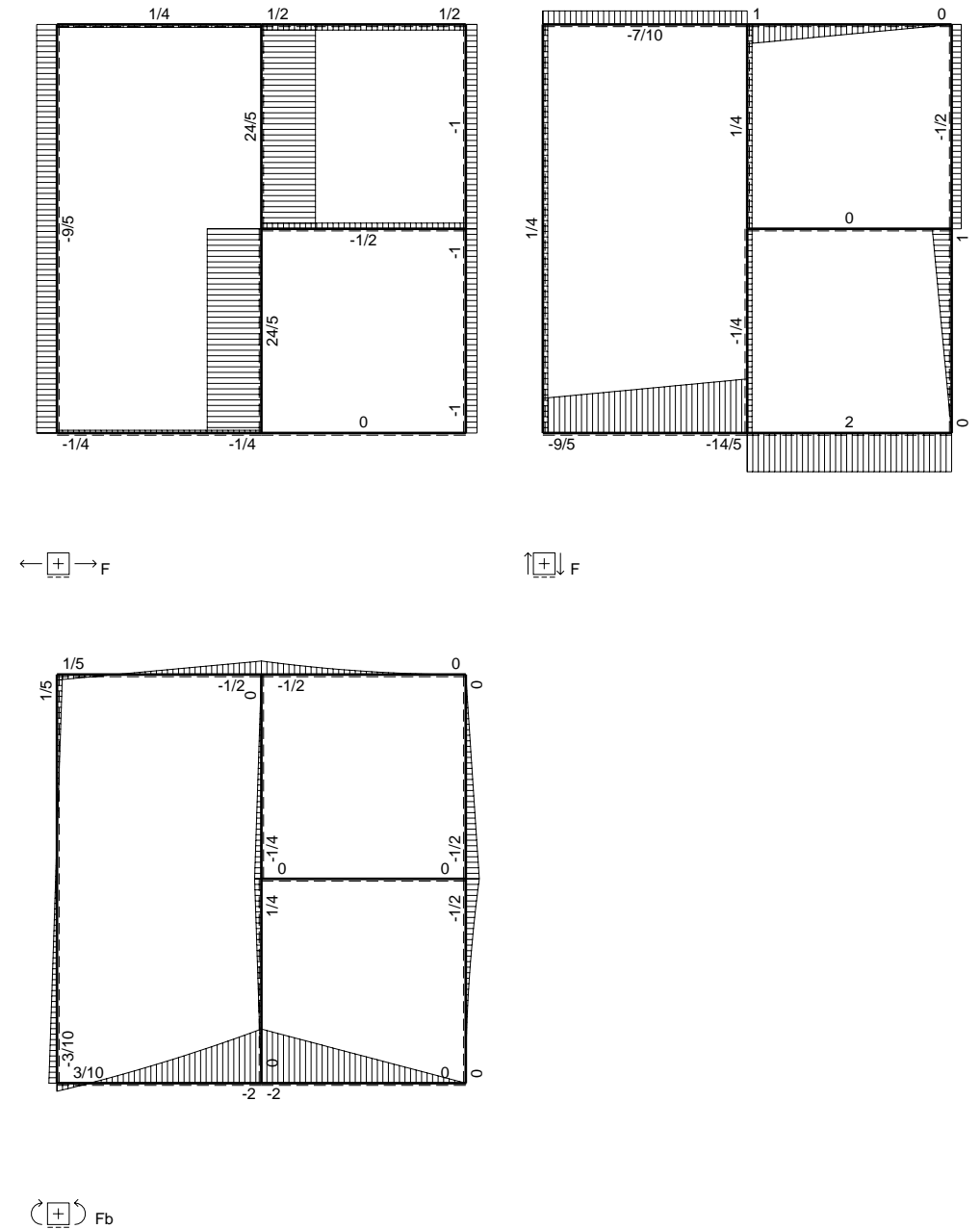
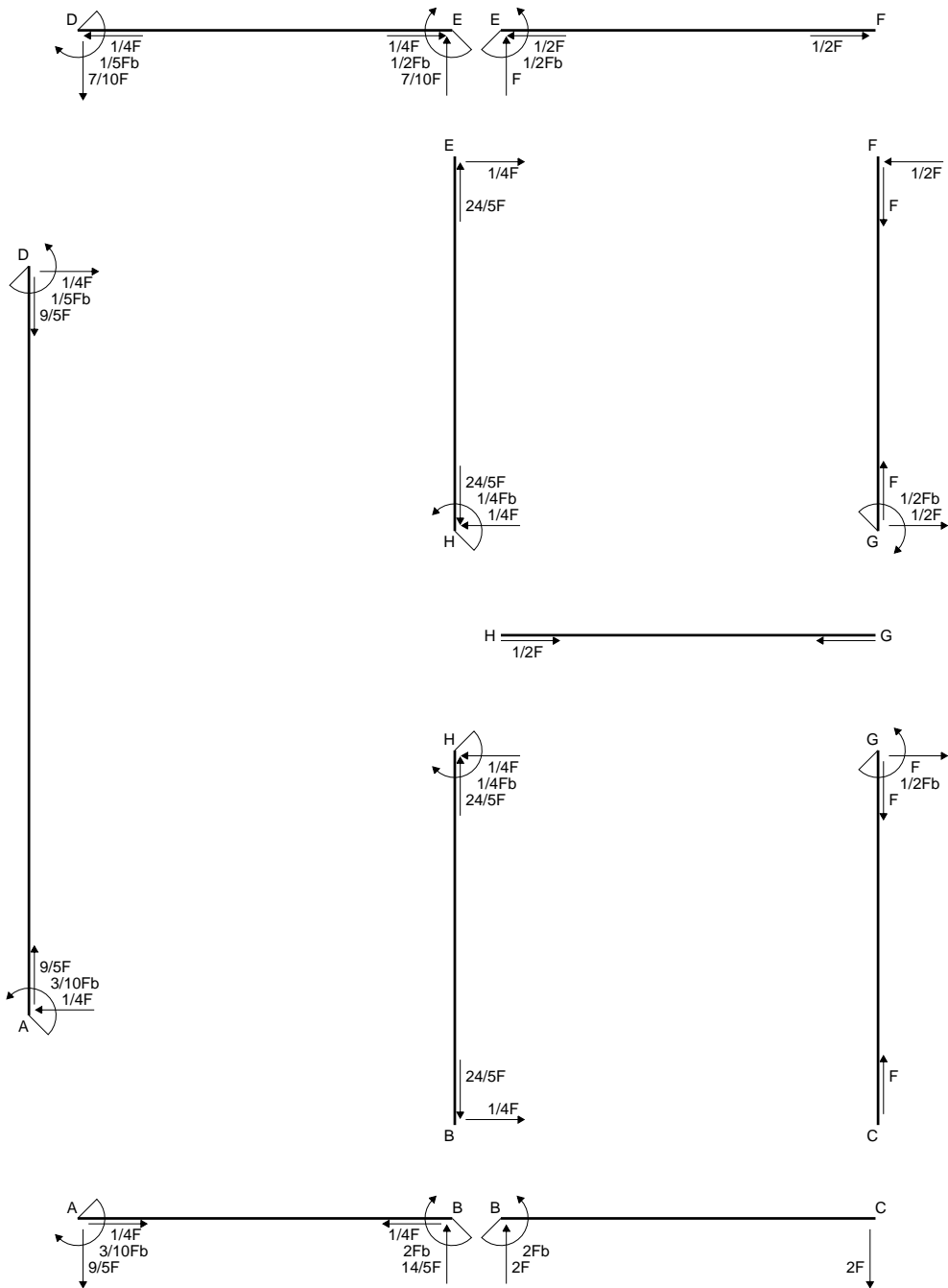
$$L_{ED}^{xo} = \int_0^b (-1/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

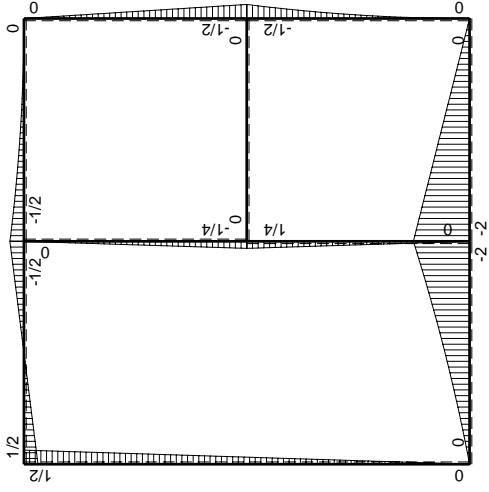
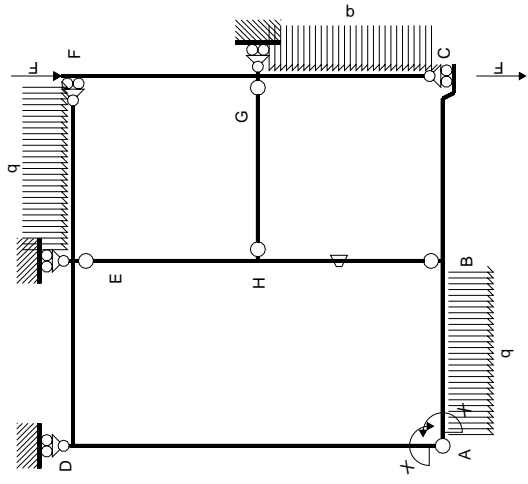
$$= (-1/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$



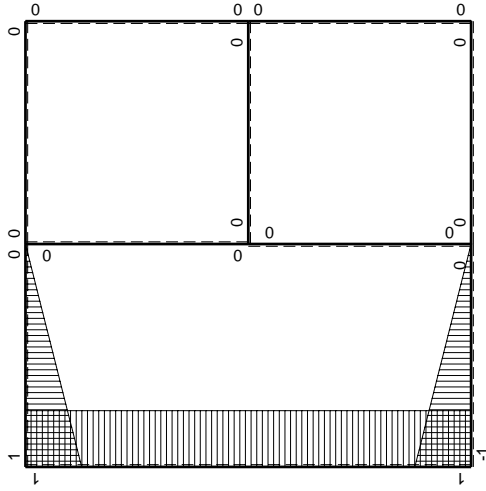
- A = 702. mm<sup>2</sup>
- J<sub>u</sub> = 278693. mm<sup>4</sup>
- J<sub>v</sub> = 44010. mm<sup>4</sup>
- y<sub>g</sub> = 24.63 mm
- T<sub>y</sub> = 3360. N
- M<sub>x</sub> = -2016000. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 55. mm
- u<sub>m</sub> = 9. mm
- v<sub>m</sub> = 30.37 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 219.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 7. mm
- v<sub>c</sub> = -17.63 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -127.5 N/mm<sup>2</sup>
- τ<sub>c</sub> = 11.17 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 129. N/mm<sup>2</sup>
- S = 5559. mm<sup>3</sup>







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1			
DE b	$1-x/b$	$1/2Fb-Fx$	0	$1/2Fb-3/2Fx+Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/12+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fb-Fx$	0	$-1/2Fx+Fx^2/b$	0	$x^2/b^2$			
EF b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
FE b	0	$1/2qx^2$	0	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$1/4Fb-1/4Fx$	$-Fb/EJ$	0	0	0	0+0	0	
BH b	0	$-1/4Fx$	$Fb/EJ$	0	0	0			
HE b	0	$-1/4Fb+1/4Fx$	0	0	0	0	0+0	0	
EH b	0	$1/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/8Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-3/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

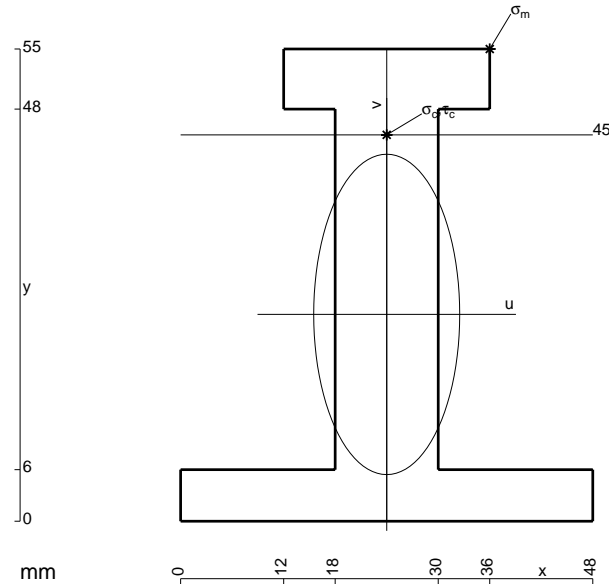
$$= (b - 1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - 3/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 3/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

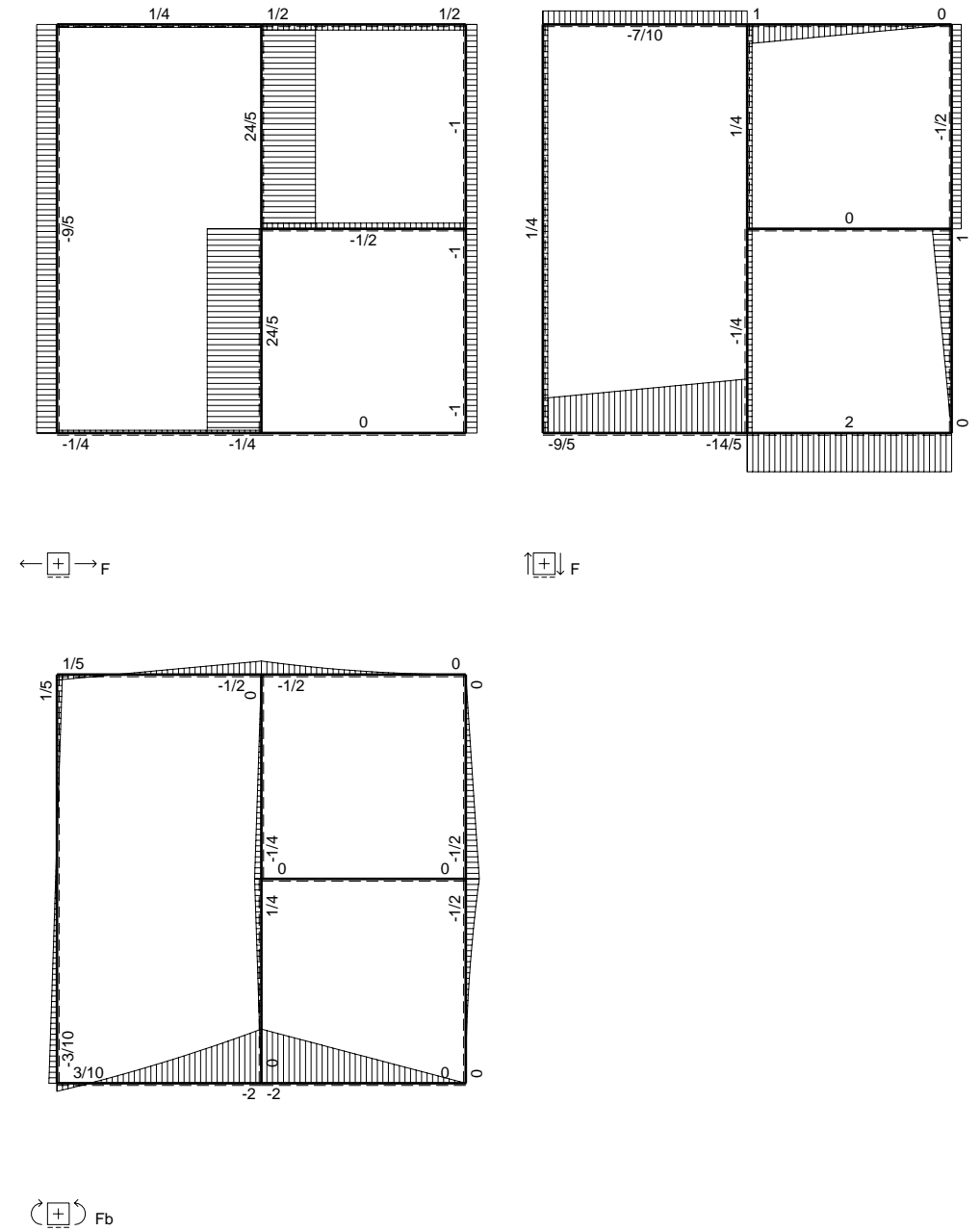
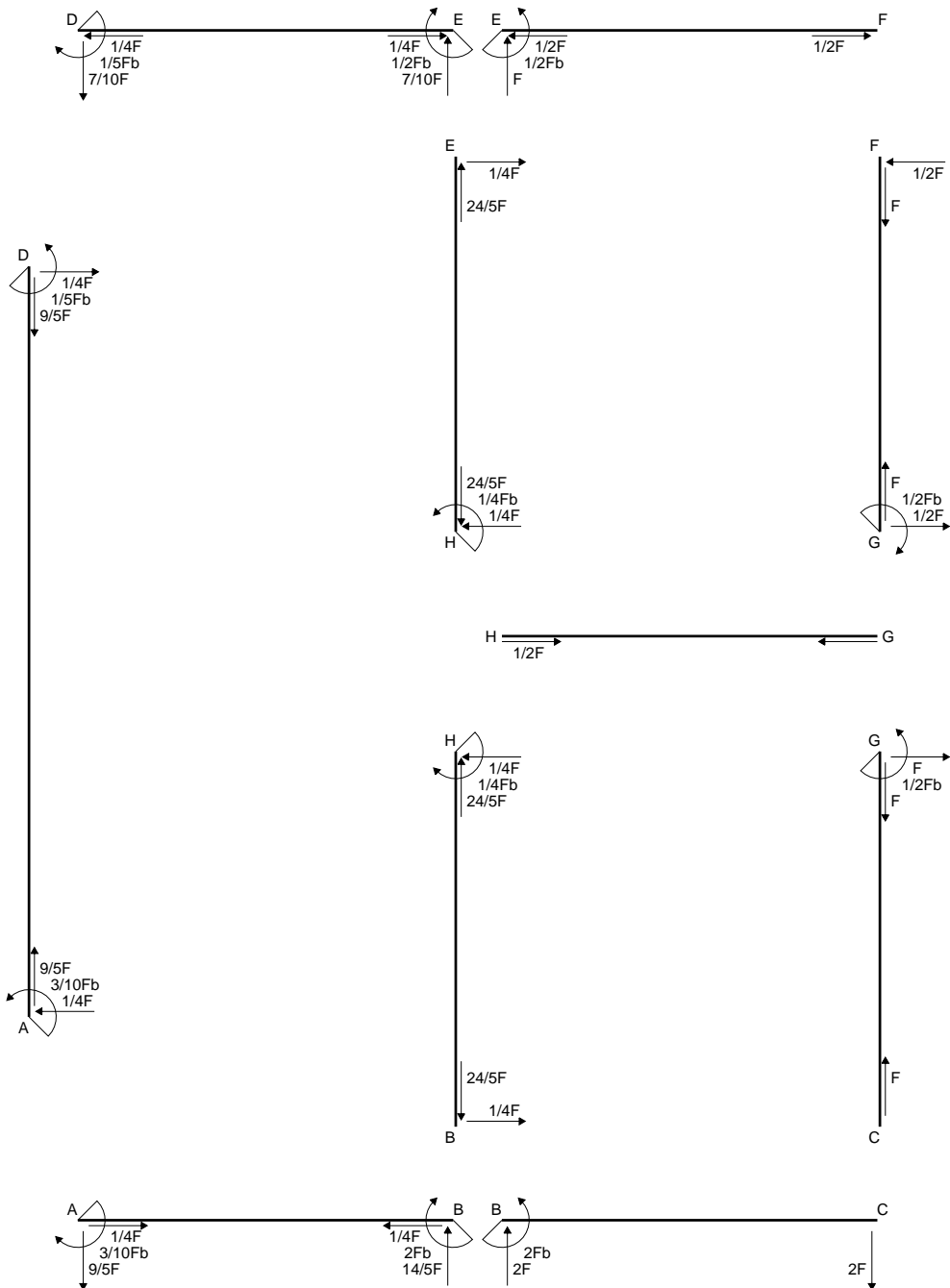
$$= (1/2 b - 3/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$

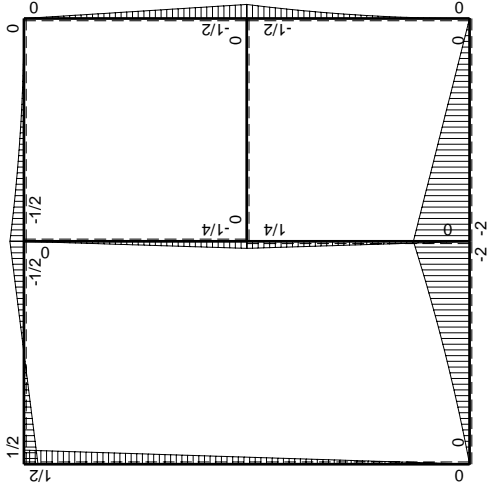
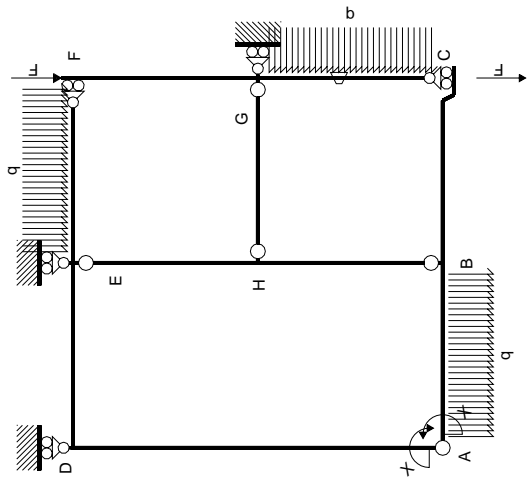
$$L_{ED}^{xo} = \int_0^b (-1/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$

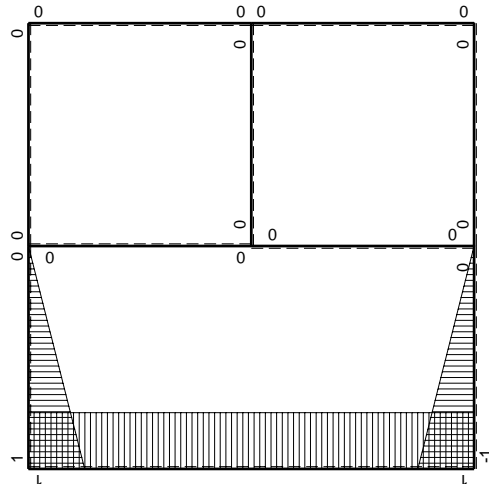


- A = 960. mm<sup>2</sup>
- J<sub>u</sub> = 334225. mm<sup>4</sup>
- J<sub>v</sub> = 69408. mm<sup>4</sup>
- y<sub>g</sub> = 24.09 mm
- T<sub>y</sub> = 3820. N
- M<sub>x</sub> = -2483000. Nmm
- x<sub>m</sub> = 36. mm
- y<sub>m</sub> = 55. mm
- u<sub>m</sub> = 12. mm
- v<sub>m</sub> = 30.91 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 229.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 45. mm
- v<sub>c</sub> = 20.91 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 155.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.155 N/mm<sup>2</sup>
- σ<sub>σ</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 155.6 N/mm<sup>2</sup>
- S = 5412. mm<sup>3</sup>





$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x / EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1			
DE b	$1-x/b$	$1/2Fb-Fx$	0	$1/2Fb-3/2Fx+Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/12+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fb-Fx$	0	$-1/2Fx+Fx^2/b$	0	$x^2/b^2$			
EF b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
FE b	0	$1/2qx^2$	0	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	$-Fb/EJ$	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	$Fb/EJ$	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$1/4Fb-1/4Fx$	0	0	0	0	0+0	0	
BH b	0	$-1/4Fx$	0	0	0	0			
HE b	0	$-1/4Fb+1/4Fx$	0	0	0	0	0+0	0	
EH b	0	$1/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/8Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-3/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

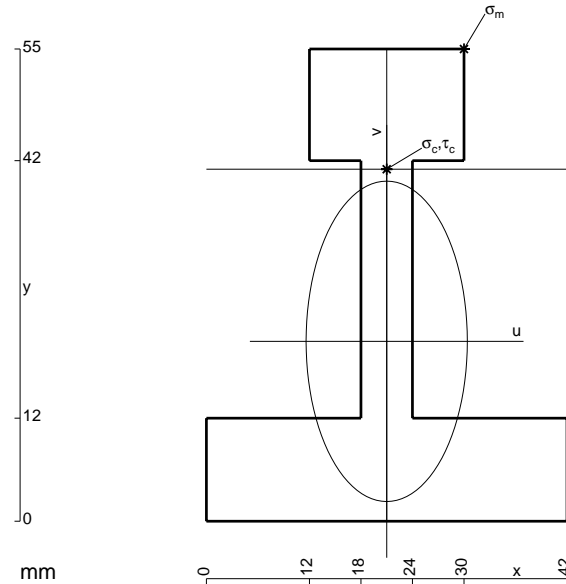
$$= (b - 1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - 3/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 3/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/2 b - 3/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$

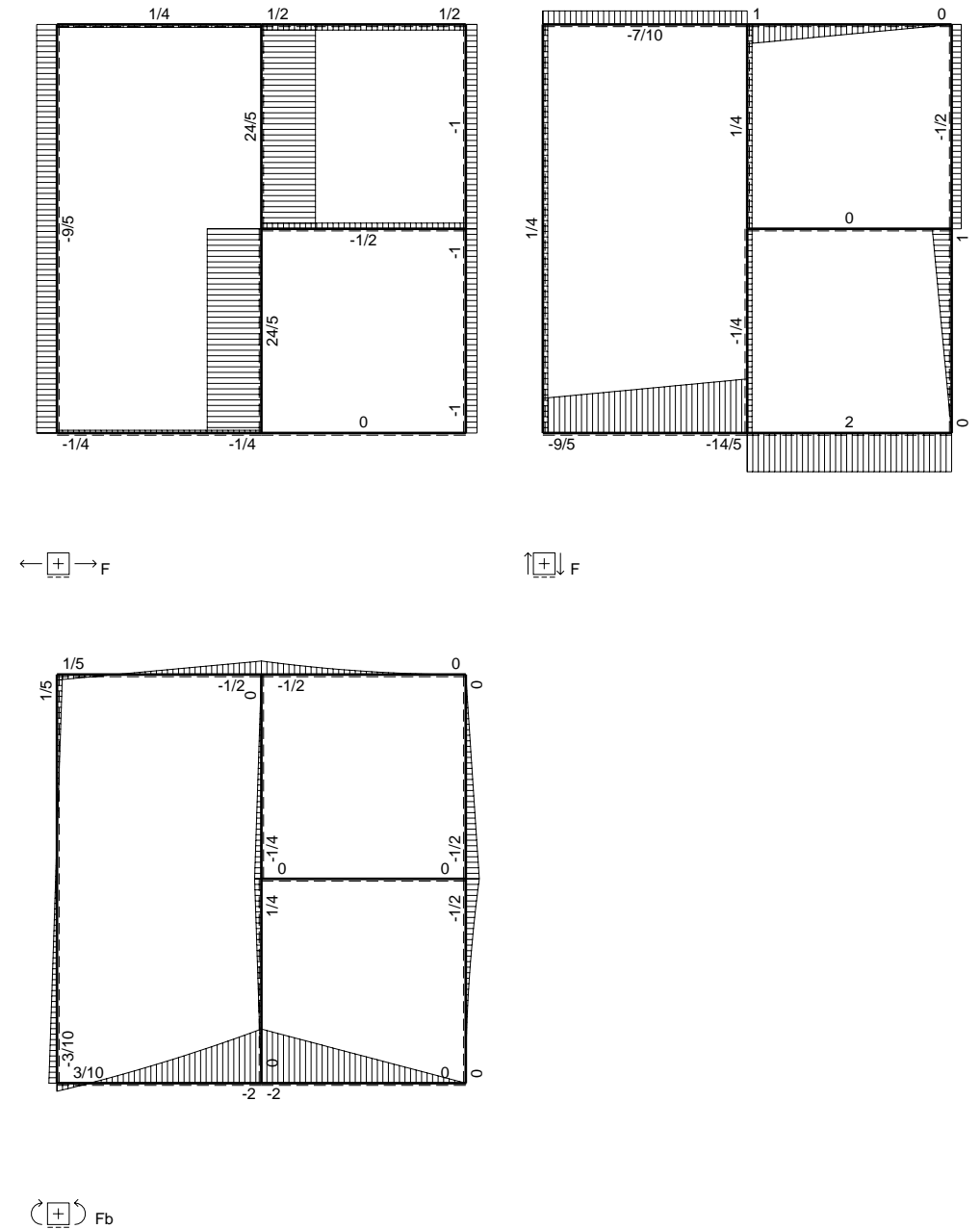
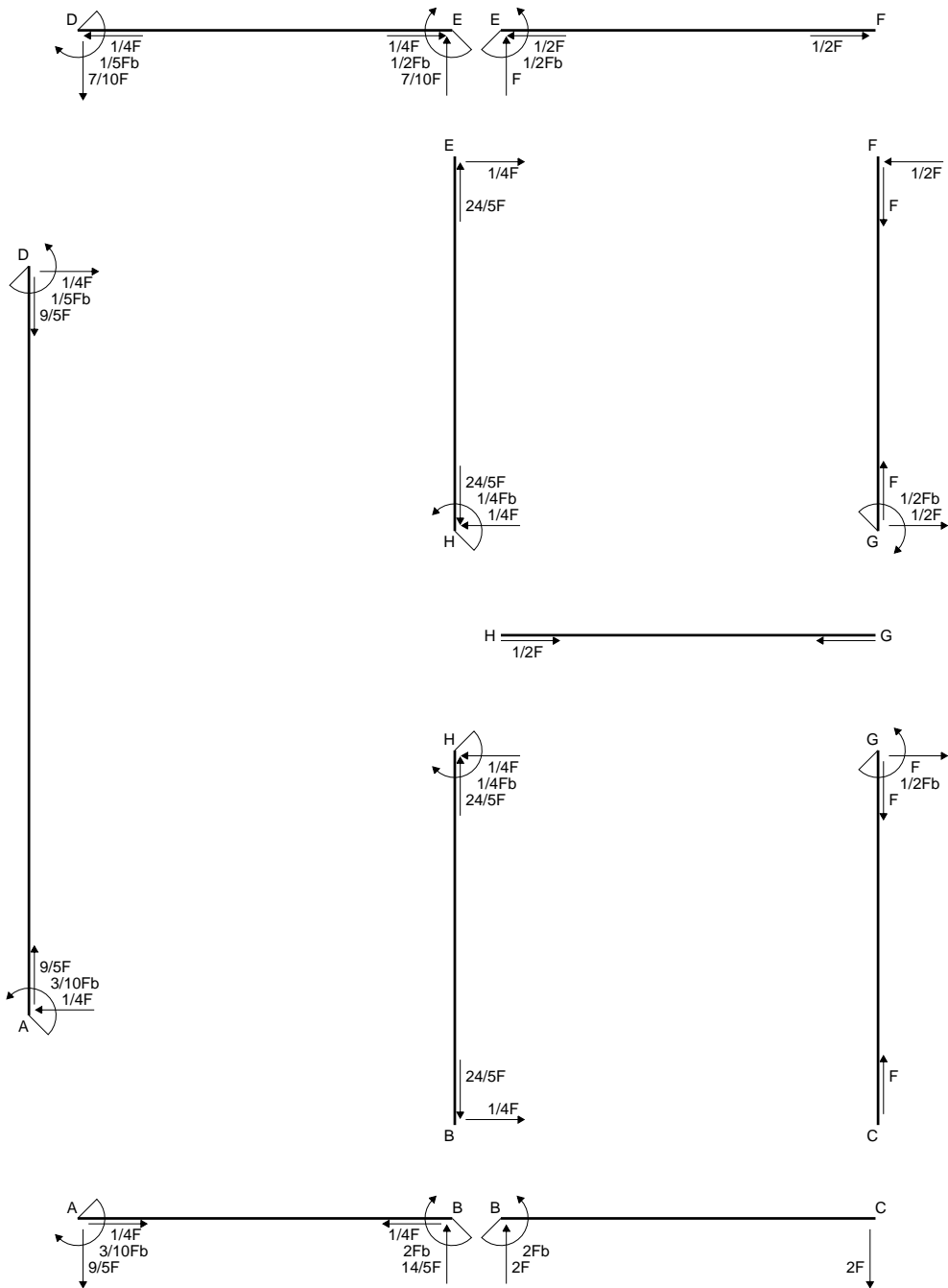
$$L_{ED}^{xo} = \int_0^b (-1/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

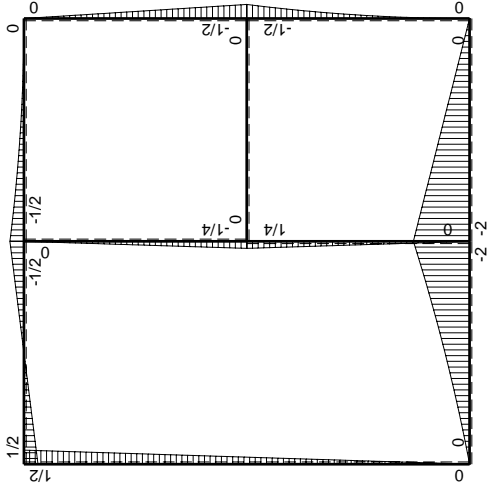
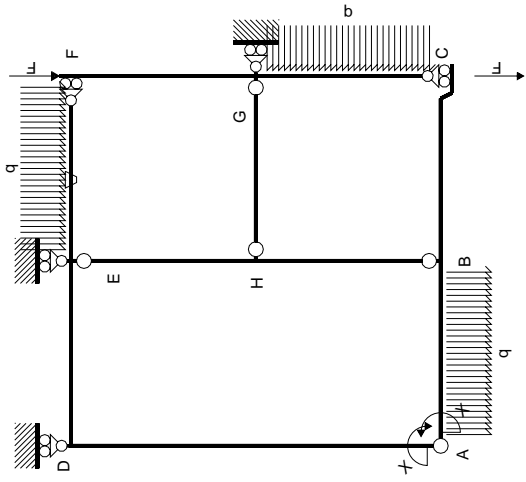
$$= (-1/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$



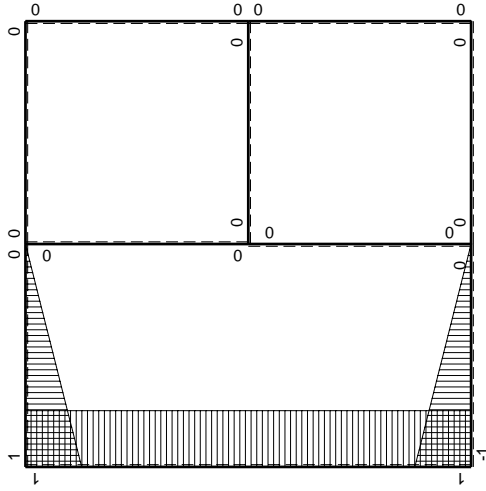
- A = 918. mm<sup>2</sup>
- J<sub>u</sub> = 319684. mm<sup>4</sup>
- J<sub>v</sub> = 80946. mm<sup>4</sup>
- y<sub>g</sub> = 20.95 mm
- T<sub>y</sub> = 3200. N
- M<sub>x</sub> = -2240000. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 55. mm
- u<sub>m</sub> = 9. mm
- v<sub>m</sub> = 34.05 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 238.6 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 41. mm
- v<sub>c</sub> = 20.05 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 140.5 N/mm<sup>2</sup>
- τ<sub>c</sub> = 10.96 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 141.8 N/mm<sup>2</sup>
- S = 6570. mm<sup>3</sup>







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1			
DE b	$1-x/b$	$1/2Fb-Fx$	0	$1/2Fb-3/2Fx+Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/12+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fb-Fx$	0	$-1/2Fx+Fx^2/b$	0	$x^2/b^2$			
EF b	0	$-1/2Fb+Fx-1/2qx^2$	$-Fb/EJ$	0	0	0	0+0	0	
FE b	0	$1/2qx^2$	$Fb/EJ$	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$1/4Fb-1/4Fx$	0	0	0	0	0+0	0	
BH b	0	$-1/4Fx$	0	0	0	0			
HE b	0	$-1/4Fb+1/4Fx$	0	0	0	0	0+0	0	
EH b	0	$1/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/8Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-3/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

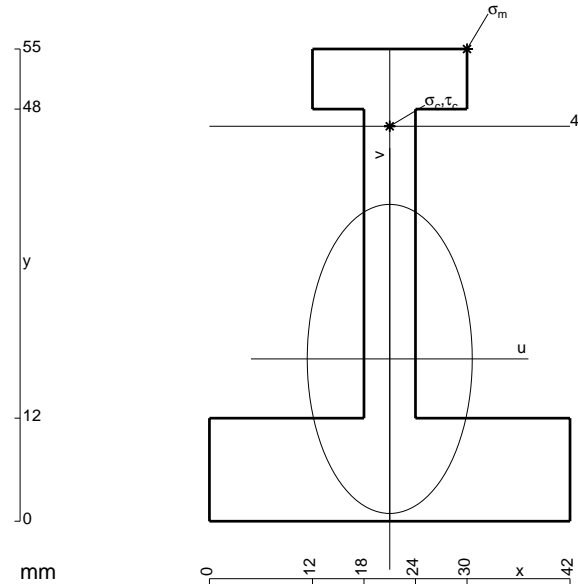
$$= (b - 1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - 3/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 3/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

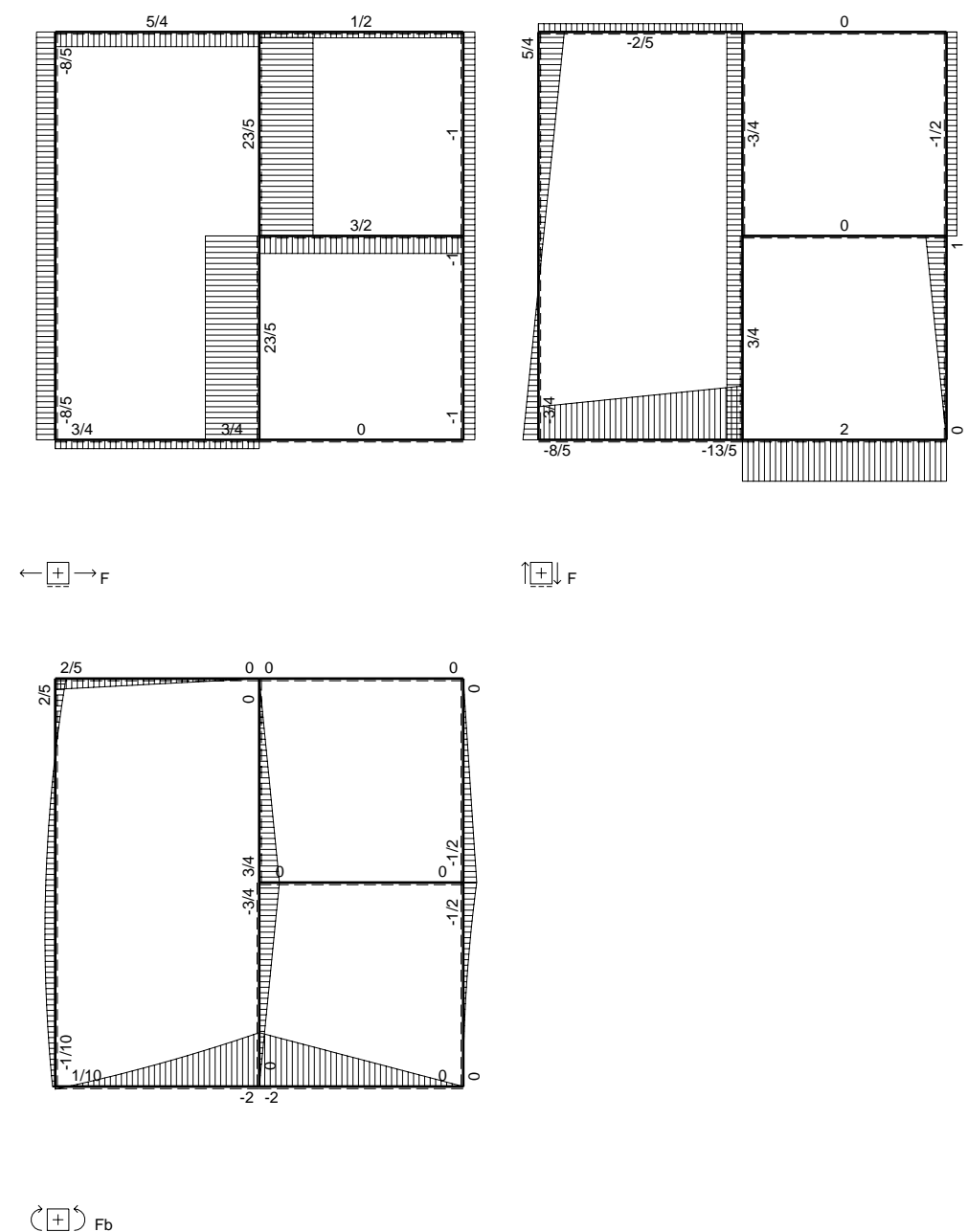
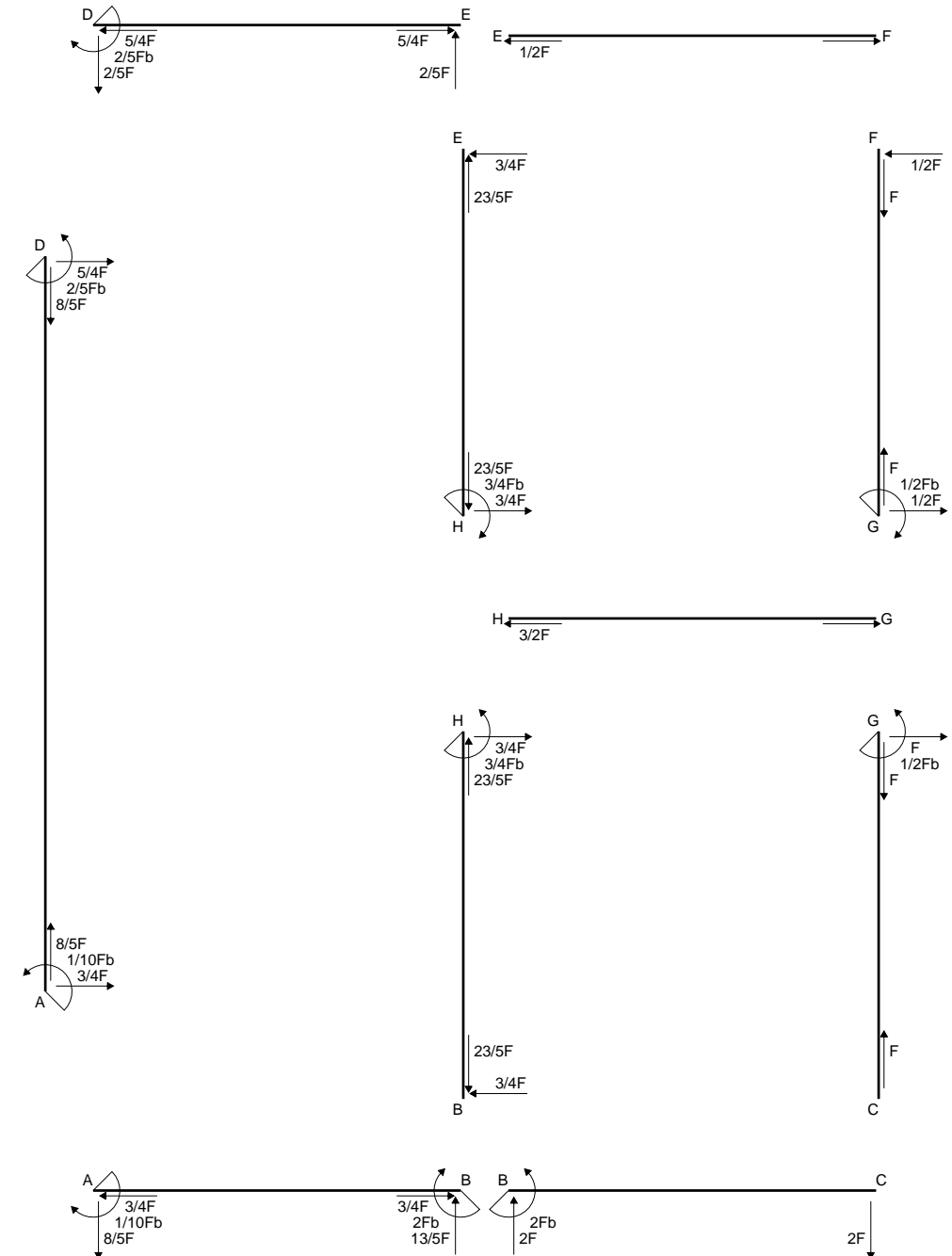
$$= (1/2 b - 3/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$

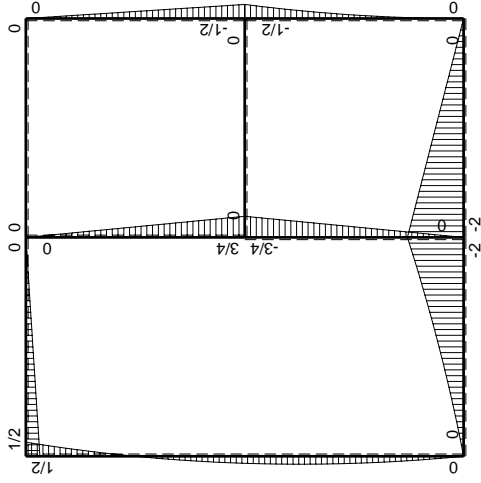
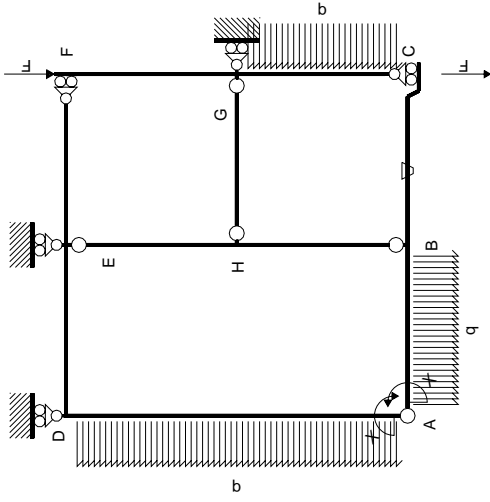
$$L_{ED}^{xo} = \int_0^b (-1/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$



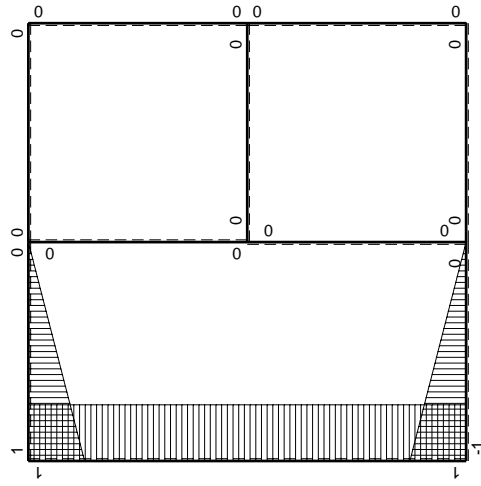
- A = 846. mm<sup>2</sup>
- J<sub>u</sub> = 274282. mm<sup>4</sup>
- J<sub>v</sub> = 78138. mm<sup>4</sup>
- y<sub>g</sub> = 18.9 mm
- T<sub>y</sub> = 2020. N
- M<sub>x</sub> = -1515000. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 55. mm
- u<sub>m</sub> = 9. mm
- v<sub>m</sub> = 36.1 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 199.4 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 46. mm
- v<sub>c</sub> = 27.1 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 149.7 N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.455 N/mm<sup>2</sup>
- σ<sub>o</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 150. N/mm<sup>2</sup>
- S = 4444. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x / EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	$-Fb/EJ$	0	0	0	0+0	0	
CB b	0	$2Fx$	$Fb/EJ$	0	0	0			
AD 2b	1	$-3/4Fx+1/2qx^2$	0	$-3/4Fx+1/2Fx^2/b$	0	1	$(-1/6+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+5/4Fx-1/2qx^2$	0	$1/2Fb-5/4Fx+1/2Fx^2/b$	0	1			
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-3/4Fb+3/4Fx$	0	0	0	0	0+0	0	
BH b	0	$3/4Fx$	0	0	0	0			
HE b	0	$3/4Fb-3/4Fx$	0	0	0	0	0+0	0	
EH b	0	$-3/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-3/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-3/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 5/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

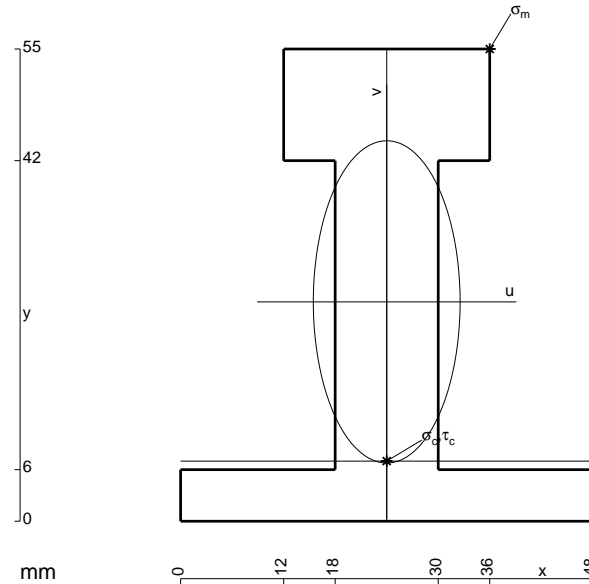
$$= (b - 5/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/2 b - 1/2 b + 1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$

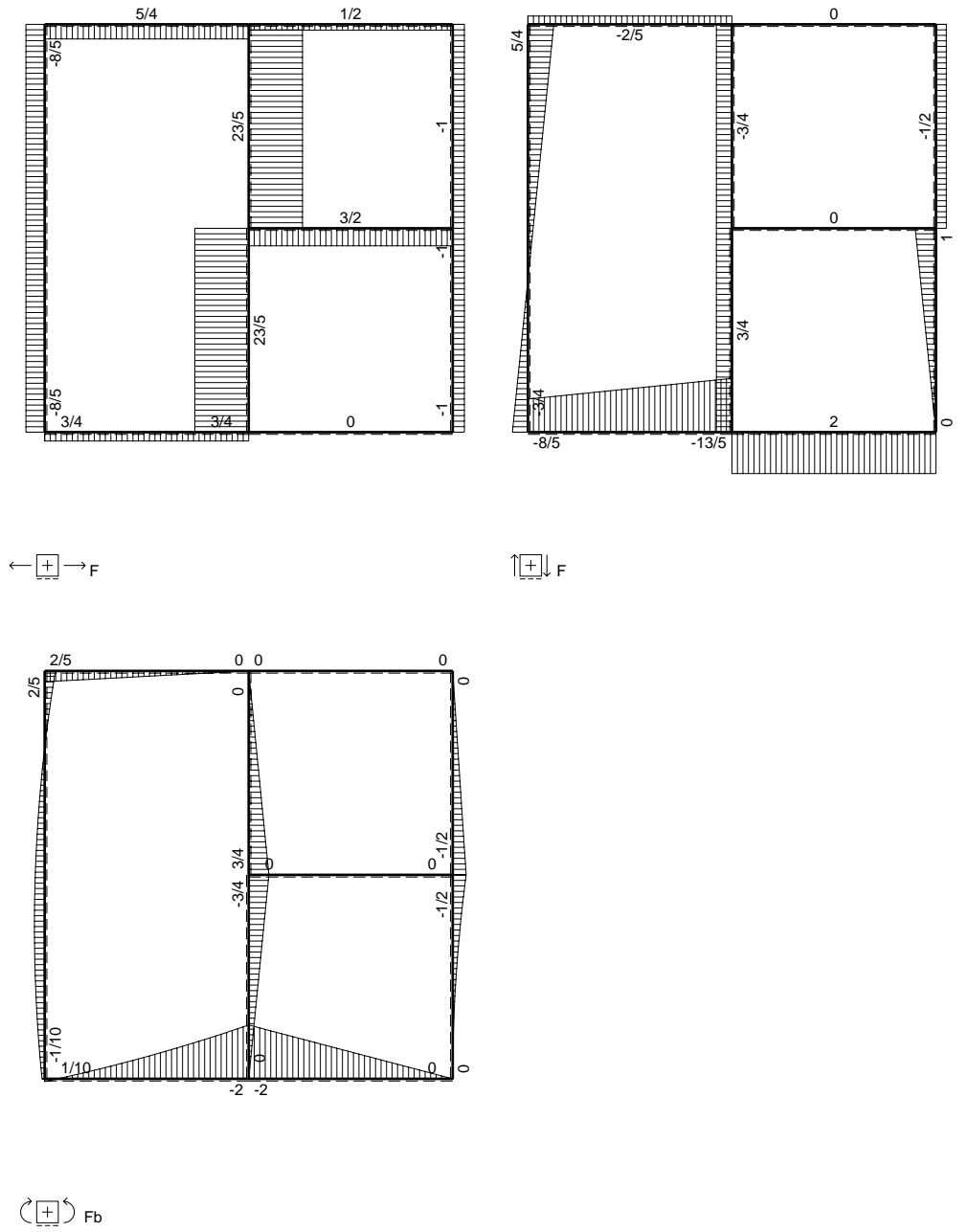
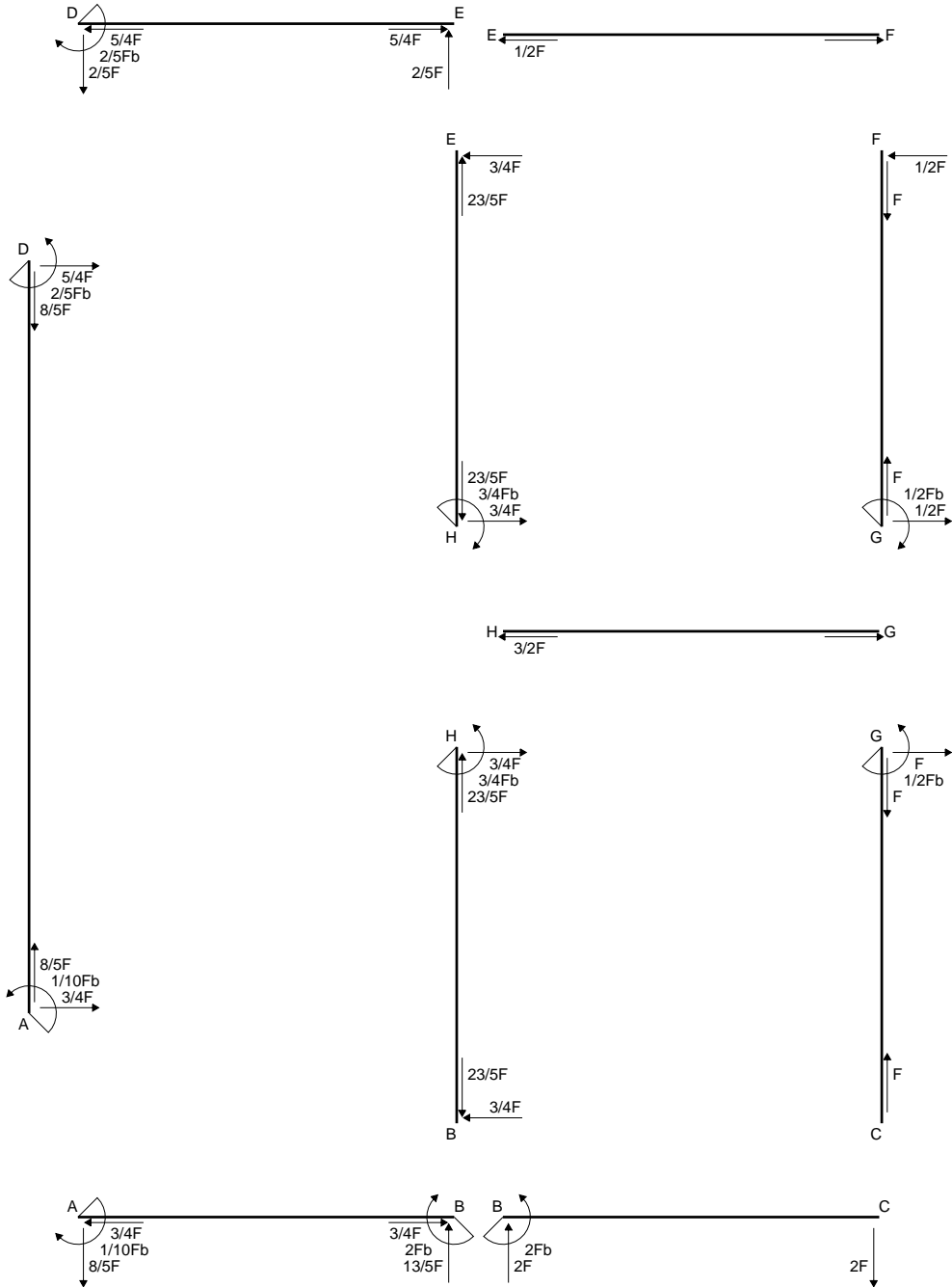
$$L_{ED}^{xo} = \int_0^b (1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

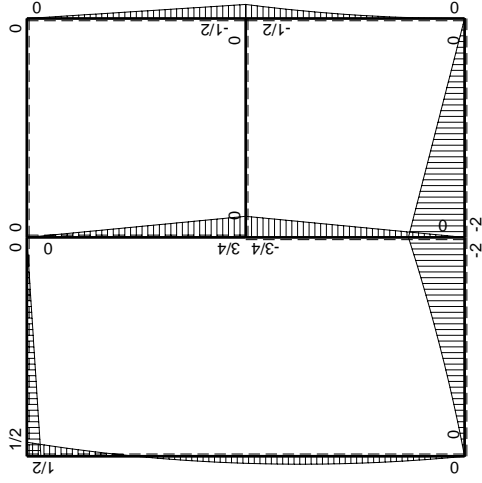
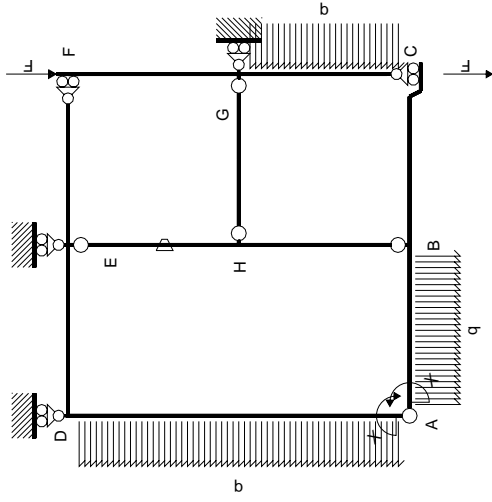
$$= (1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$



$A = 1032. \text{ mm}^2$   
 $J_u = 363732. \text{ mm}^4$   
 $J_v = 75456. \text{ mm}^4$   
 $y_g = 25.55 \text{ mm}$   
 $T_y = 3240. \text{ N}$   
 $M_x = -2592000. \text{ Nmm}$   
 $x_m = 36. \text{ mm}$   
 $y_m = 55. \text{ mm}$   
 $u_m = 12. \text{ mm}$   
 $v_m = 29.45 \text{ mm}$   
 $\sigma_m = -Mv/J_u = 209.9 \text{ N/mm}^2$   
 $x_c = 24. \text{ mm}$   
 $y_c = 7. \text{ mm}$   
 $v_c = -18.55 \text{ mm}$   
 $\sigma_c = -Mv/J_u = -132.2 \text{ N/mm}^2$   
 $\tau_c = 4.99 \text{ N/mm}^2$   
 $\sigma_o = \sqrt{\sigma^2 + 3\tau^2} = 132.4 \text{ N/mm}^2$   
 $S = 6722. \text{ mm}^3$

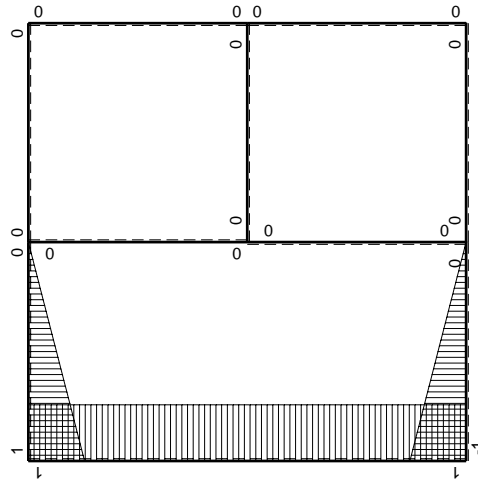






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0
CB b	0	$2Fx$	0	0	0	0		
AD 2b	1	$-3/4Fx+1/2qx^2$	0	$-3/4Fx+1/2Fx^2/b$	0	1	$(-1/6+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$-1/2Fb+5/4Fx-1/2qx^2$	0	$1/2Fb-5/4Fx+1/2Fx^2/b$	0	1		
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$		
EF b	0	0	0	0	0	0	0+0	0
FE b	0	0	0	0	0	0		
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0		
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0
CG b	0	$1/2qx^2$	0	0	0	0		
HG b	0	0	0	0	0	0	0+0	0
GH b	0	0	0	0	0	0		
HB b	0	$-3/4Fb+3/4Fx$	0	0	0	0	0+0	0
BH b	0	$3/4Fx$	0	0	0	0		
HE b	0	$3/4Fb-3/4Fx$	$-Fb/EJ$	0	0	0	0+0	0
EH b	0	$-3/4Fx$	$Fb/EJ$	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-3/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-3/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 5/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

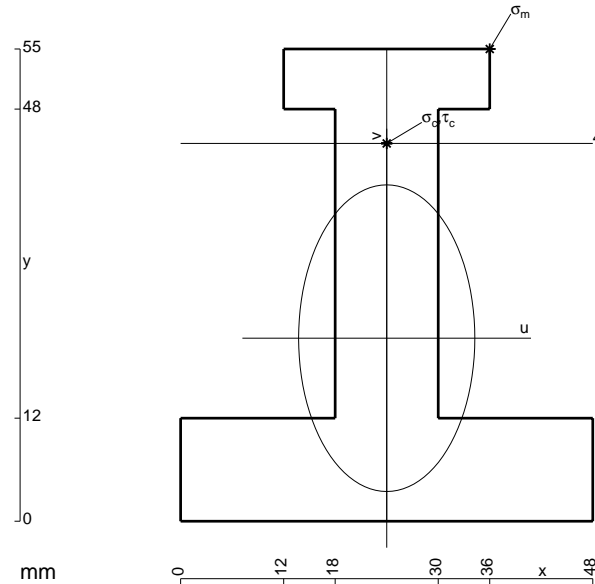
$$= (b - 5/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

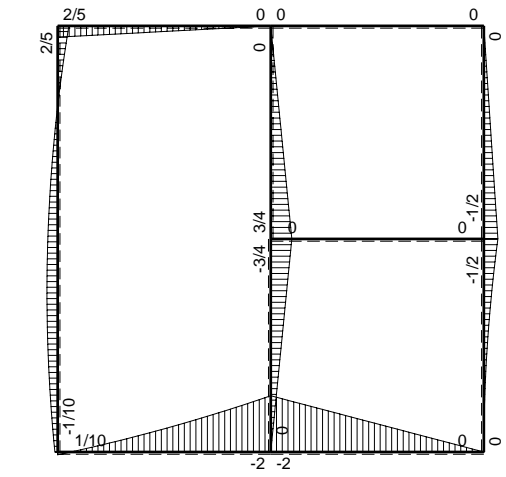
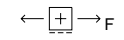
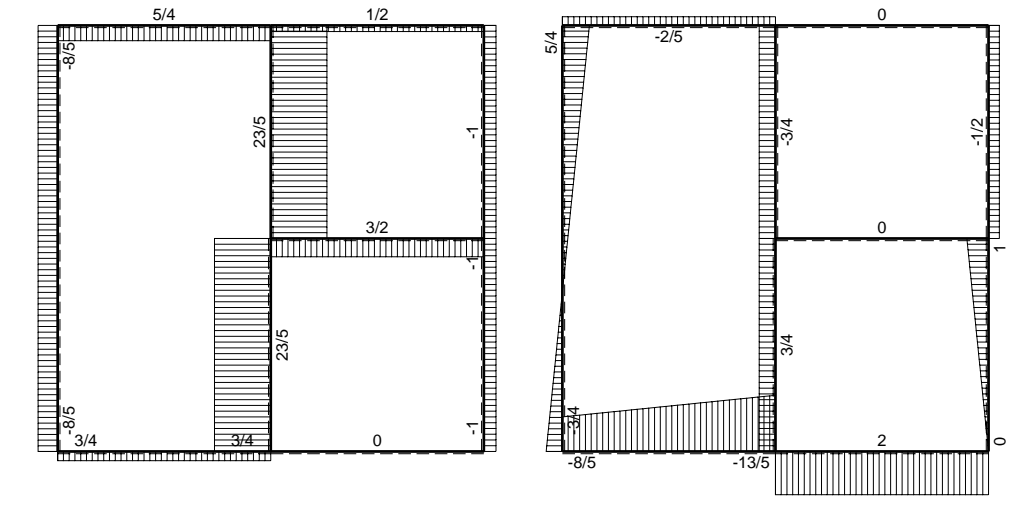
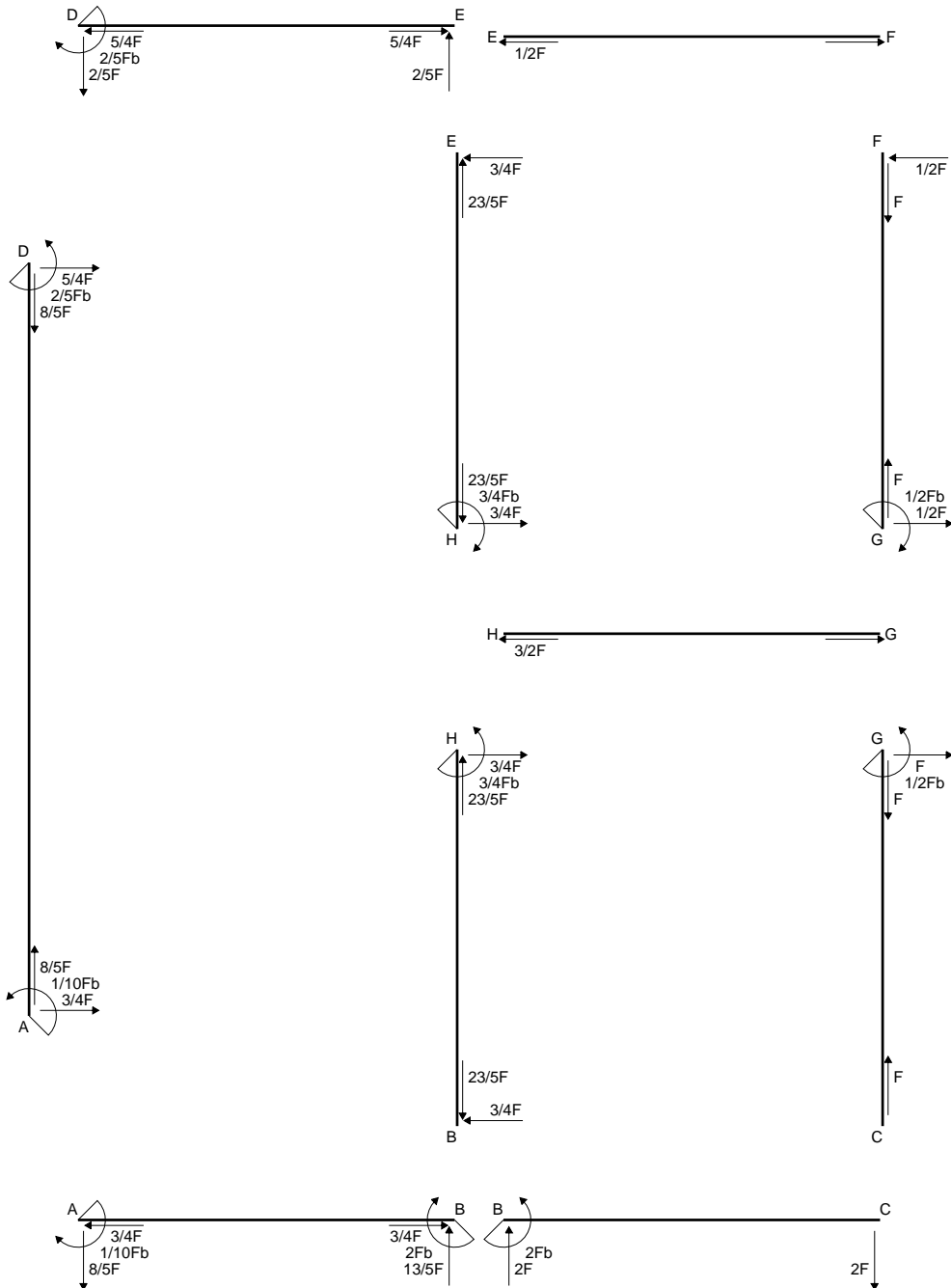
$$= (1/2 b - 1/2 b + 1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$

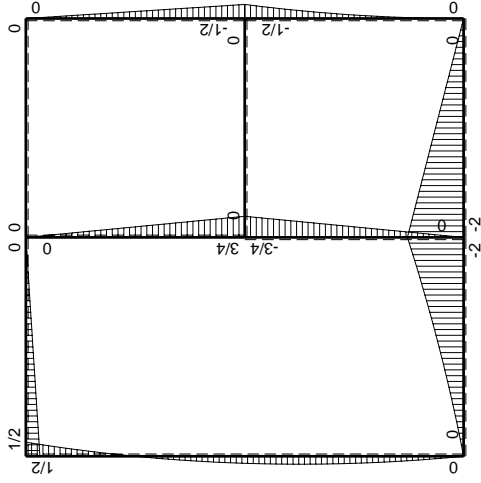
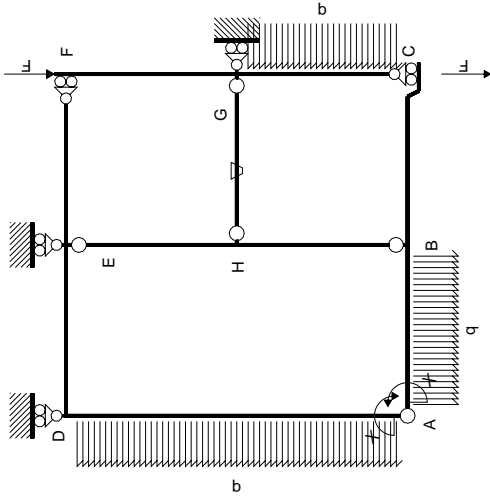
$$L_{ED}^{xo} = \int_0^b (1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$



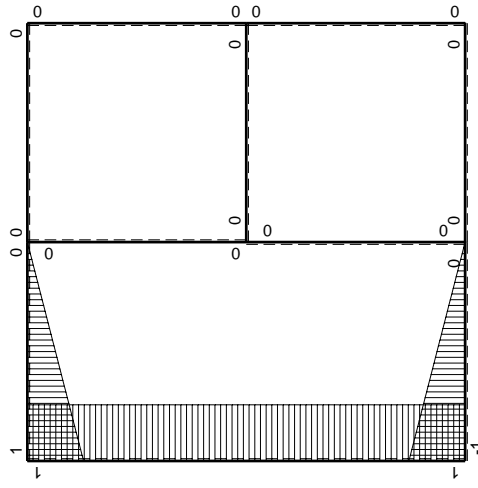
- A = 1176. mm<sup>2</sup>
- J<sub>u</sub> = 375010. mm<sup>4</sup>
- J<sub>v</sub> = 123840. mm<sup>4</sup>
- y<sub>g</sub> = 21.32 mm
- T<sub>y</sub> = 2880. N
- M<sub>x</sub> = -2448000. Nmm
- x<sub>m</sub> = 36. mm
- y<sub>m</sub> = 55. mm
- u<sub>m</sub> = 12. mm
- v<sub>m</sub> = 33.68 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 219.9 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 44. mm
- v<sub>c</sub> = 22.68 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 148.1 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.004 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 148.2 N/mm<sup>2</sup>
- S = 6256. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0
CB b	0	$2Fx$	0	0	0	0		
AD 2b	1	$-3/4Fx+1/2qx^2$	0	$-3/4Fx+1/2Fx^2/b$	0	1	$(-1/6+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$-1/2Fb+5/4Fx-1/2qx^2$	0	$1/2Fb-5/4Fx+1/2Fx^2/b$	0	1		
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$		
EF b	0	0	0	0	0	0	0+0	0
FE b	0	0	0	0	0	0		
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0		
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0
CG b	0	$1/2qx^2$	0	0	0	0		
HG b	0	0	$-Fb/EJ$	0	0	0	0+0	0
GH b	0	0	$Fb/EJ$	0	0	0		
HB b	0	$-3/4Fb+3/4Fx$	0	0	0	0	0+0	0
BH b	0	$3/4Fx$	0	0	0	0		
HE b	0	$3/4Fb-3/4Fx$	0	0	0	0	0+0	0
EH b	0	$-3/4Fx$	0	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (-2x/b + x^2/b^2) 1/EJ dx + 1 \cdot 1/4 b/EJ = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ + 1 \cdot 1/4 b/EJ$$

$$= (b - b + 1/3 b) 1/EJ + 1 \cdot 1/4 b/EJ = 7/12 b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx + 1 \cdot 1/4 b/EJ = [1/3 x^3/b^2]_0^b 1/EJ + 1 \cdot 1/4 b/EJ$$

$$= (1/3 b) 1/EJ + 1 \cdot 1/4 b/EJ = 7/12 b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{DE}^{xx} = \int_0^b (-2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx + 1 \cdot 0 1/4 Fb^2/EJ$$

$$= [3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ + 1 \cdot 0 1/4 Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) Fb 1/EJ + 1 \cdot 0 1/4 Fb^2/EJ = 7/24 Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + 1 \cdot 0 1/4 Fb^2/EJ$$

$$= [x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ + 1 \cdot 0 1/4 Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) Fb 1/EJ + 1 \cdot 0 1/4 Fb^2/EJ = 7/24 Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-3/4 x/b + 1/2 x^2/b^2) Fb 1/EJ dx = [-3/8 x^2/b + 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-3/2 b + 4/3 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 5/4 x/b + 1/2 x^2/b^2) Fb 1/EJ dx = [1/2 x - 5/8 x^2/b + 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

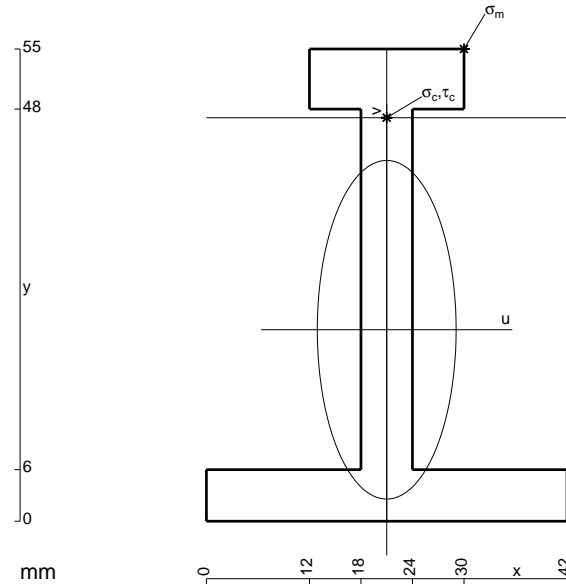
$$= (b - 5/2 b + 4/3 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) Fb 1/EJ dx = [1/2 x - 1/2 x^2/b + 1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (1/2 b - 1/2 b + 1/6 b) Fb 1/EJ = 1/6 Fb^2/EJ$$

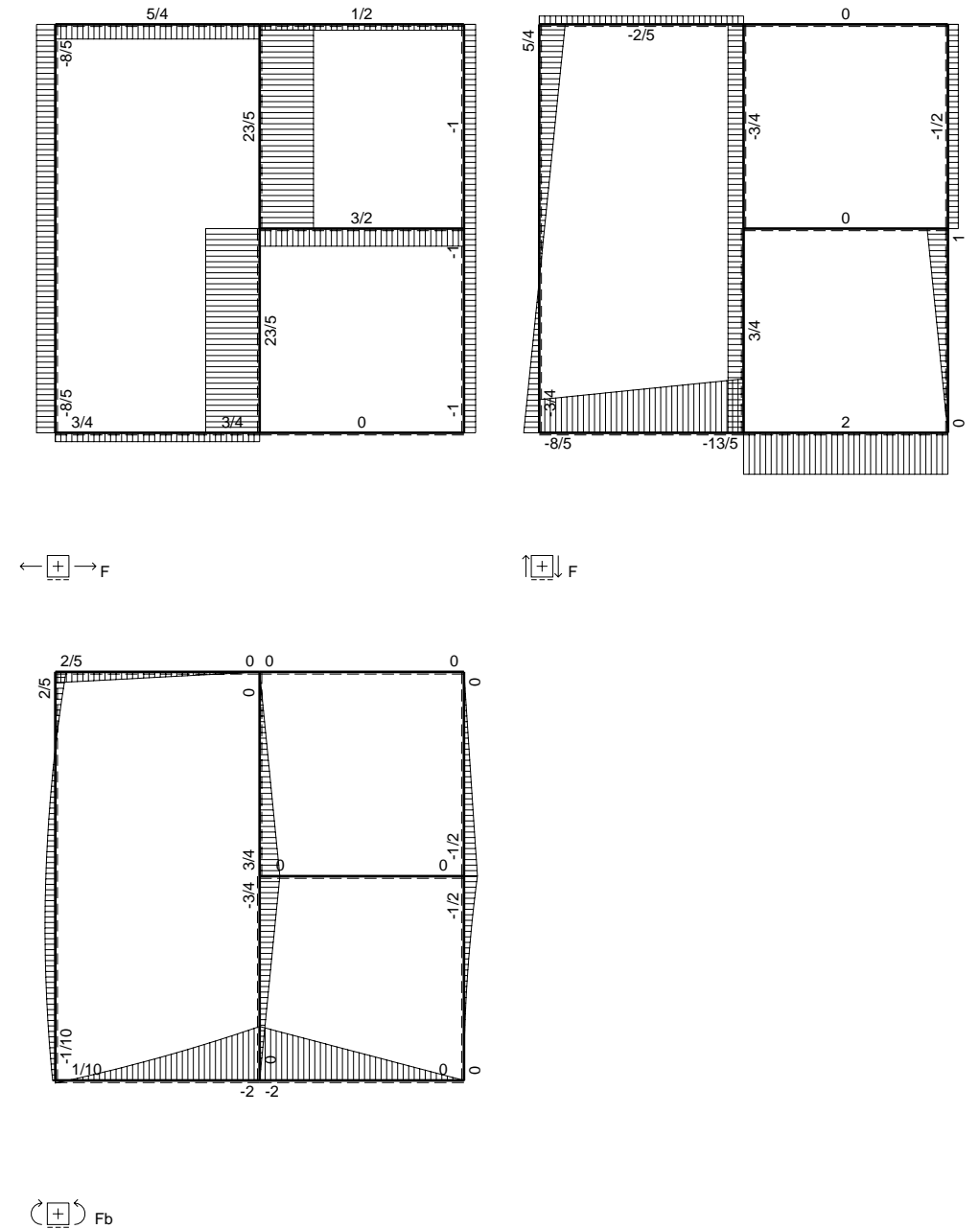
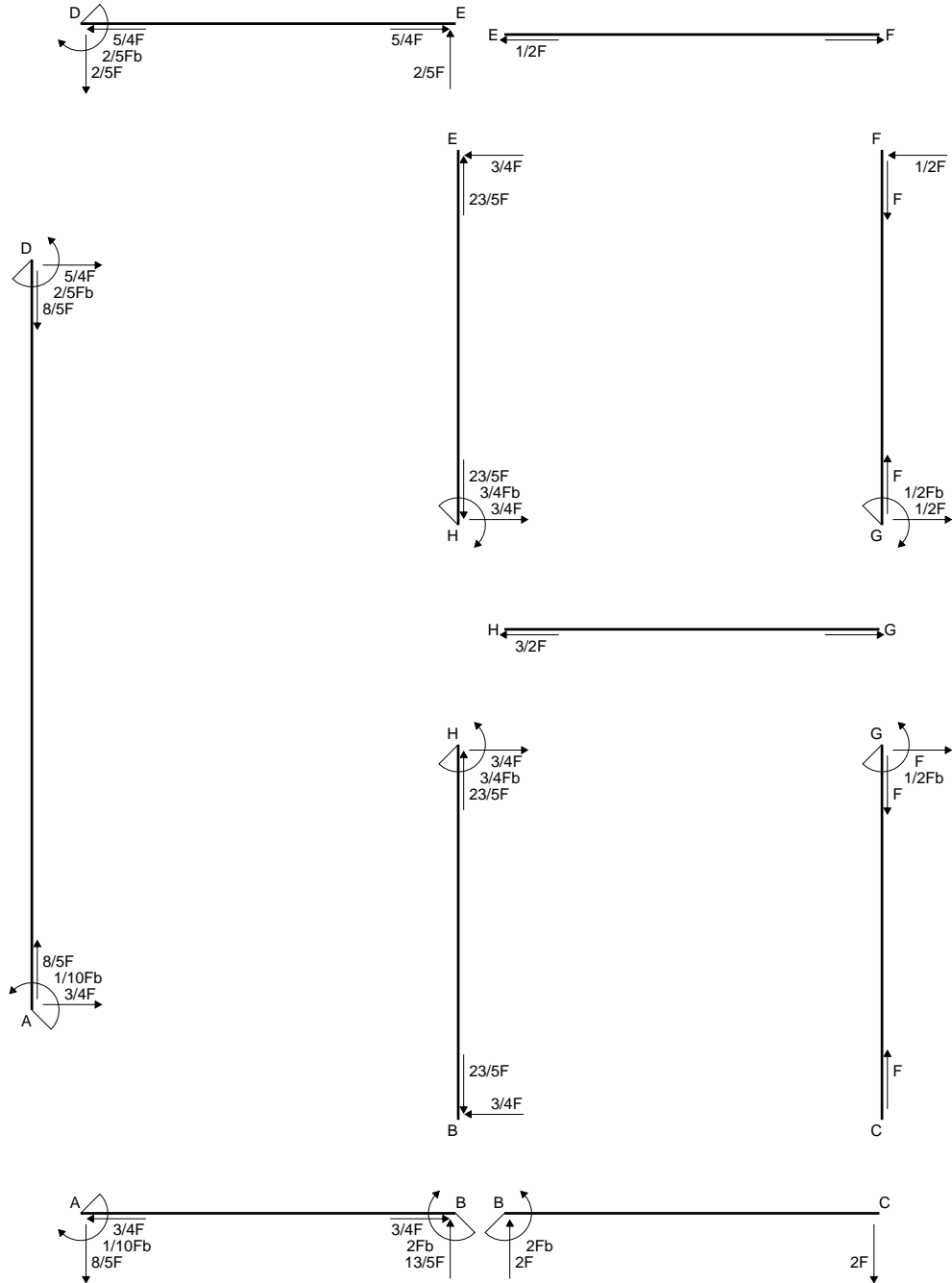
$$L_{ED}^{xo} = \int_0^b (1/2 x^2/b^2) Fb 1/EJ dx = [1/6 x^3/b^2]_0^b Fb 1/EJ$$

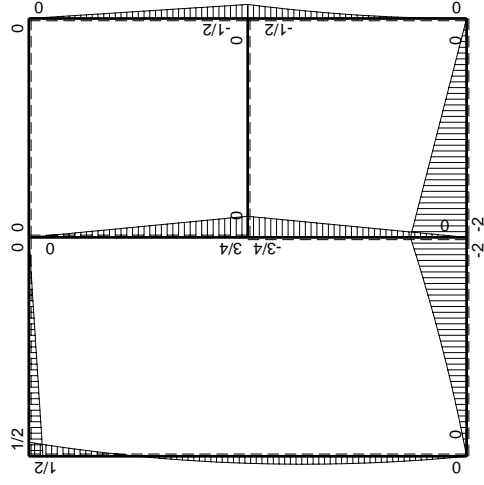
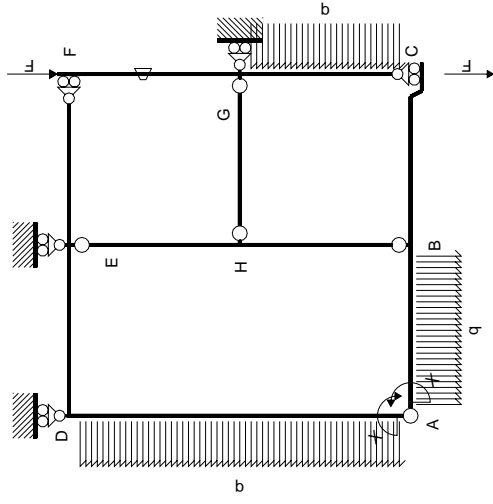
$$= (1/6 b) Fb 1/EJ = 1/6 Fb^2/EJ$$



- A = 630. mm<sup>2</sup>
- J<sub>u</sub> = 245181. mm<sup>4</sup>
- J<sub>v</sub> = 41202. mm<sup>4</sup>
- y<sub>g</sub> = 22.3 mm
- T<sub>y</sub> = 1900. N
- M<sub>x</sub> = -1710000. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 55. mm
- u<sub>m</sub> = 9. mm
- v<sub>m</sub> = 32.7 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 228.1 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 47. mm
- v<sub>c</sub> = 24.7 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 172.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.947 N/mm<sup>2</sup>
- σ<sub>σ</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 172.5 N/mm<sup>2</sup>
- S = 3830. mm<sup>3</sup>

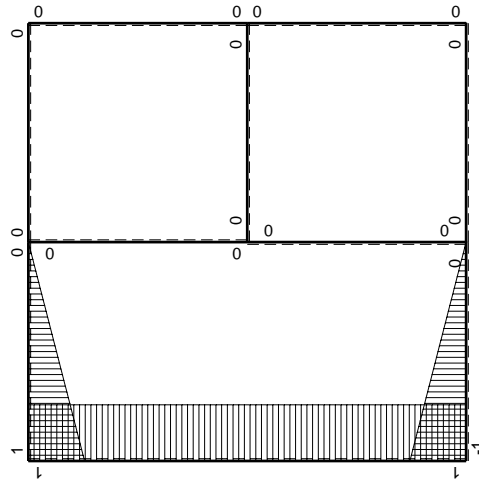






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJdx$
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0
CB b	0	$2Fx$	0	0	0	0		
AD 2b	1	$-3/4Fx+1/2qx^2$	0	$-3/4Fx+1/2Fx^2/b$	0	1	$(-1/6+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$-1/2Fb+5/4Fx-1/2qx^2$	0	$1/2Fb-5/4Fx+1/2Fx^2/b$	0	1		
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$		
EF b	0	0	0	0	0	0	0+0	0
FE b	0	0	0	0	0	0		
FG b	0	$-1/2Fx$	$-Fb/EJ$	0	0	0	0+0	0
GF b	0	$1/2Fb-1/2Fx$	$Fb/EJ$	0	0	0		
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0
CG b	0	$1/2qx^2$	0	0	0	0		
HG b	0	0	0	0	0	0	0+0	0
GH b	0	0	0	0	0	0		
HB b	0	$-3/4Fb+3/4Fx$	0	0	0	0	0+0	0
BH b	0	$3/4Fx$	0	0	0	0		
HE b	0	$3/4Fb-3/4Fx$	0	0	0	0	0+0	0
EH b	0	$-3/4Fx$	0	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{x_0} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{x_0} = \int_0^b (2 x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{x_0} = \int_0^{2b} (-3/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-3/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DA}^{x_0} = \int_0^{2b} (1/2 - 5/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

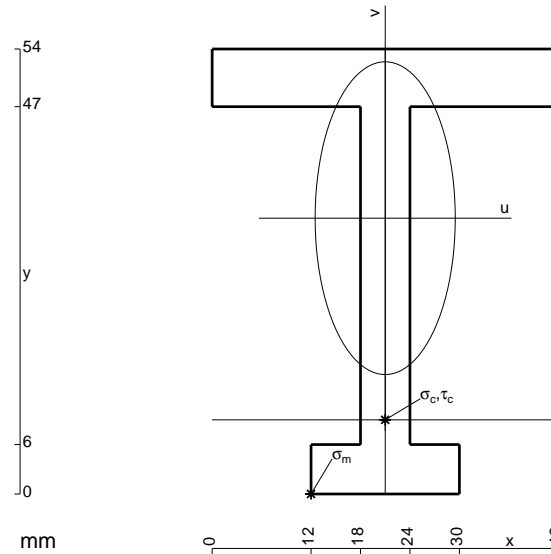
$$= (b - 5/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DE}^{x_0} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

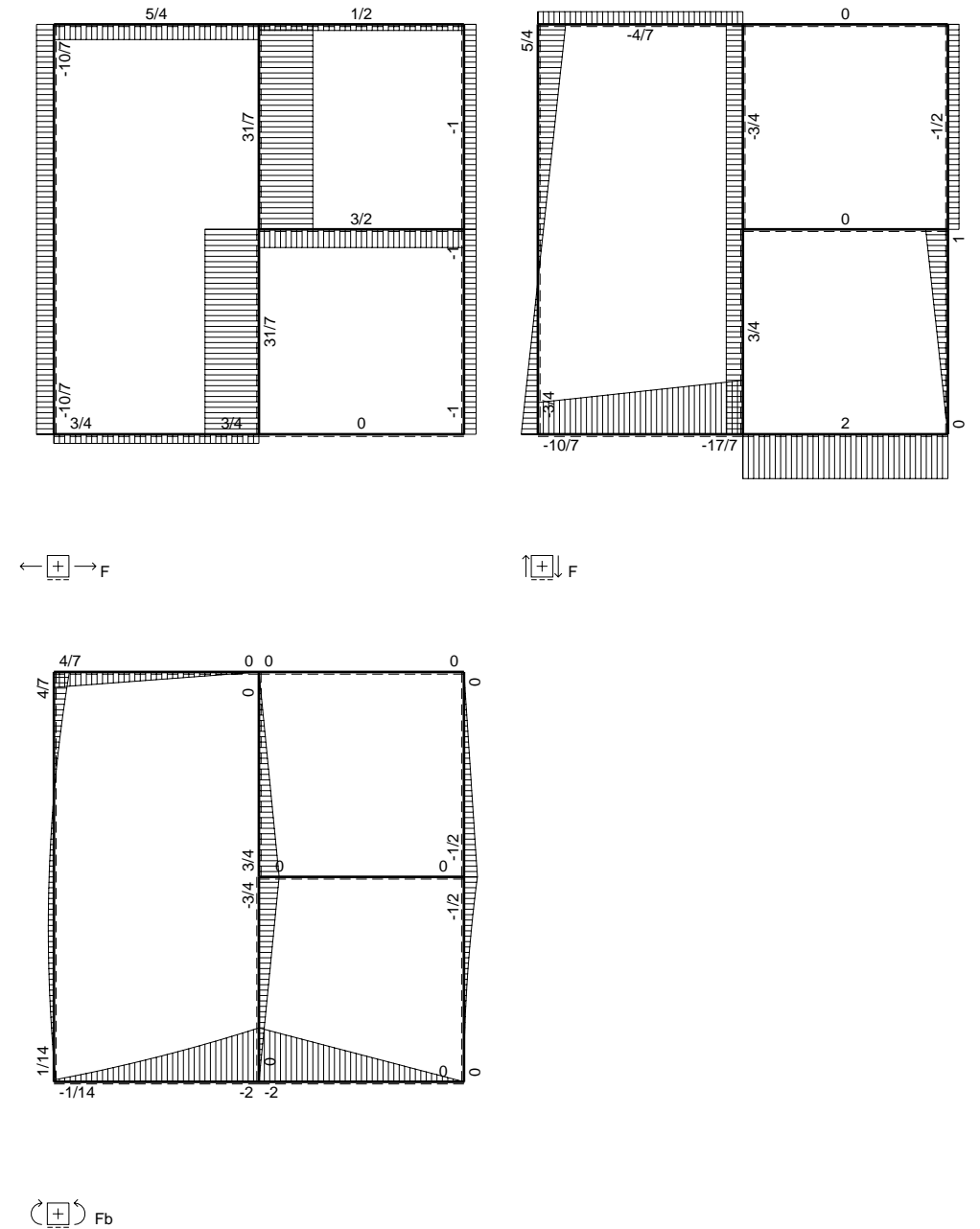
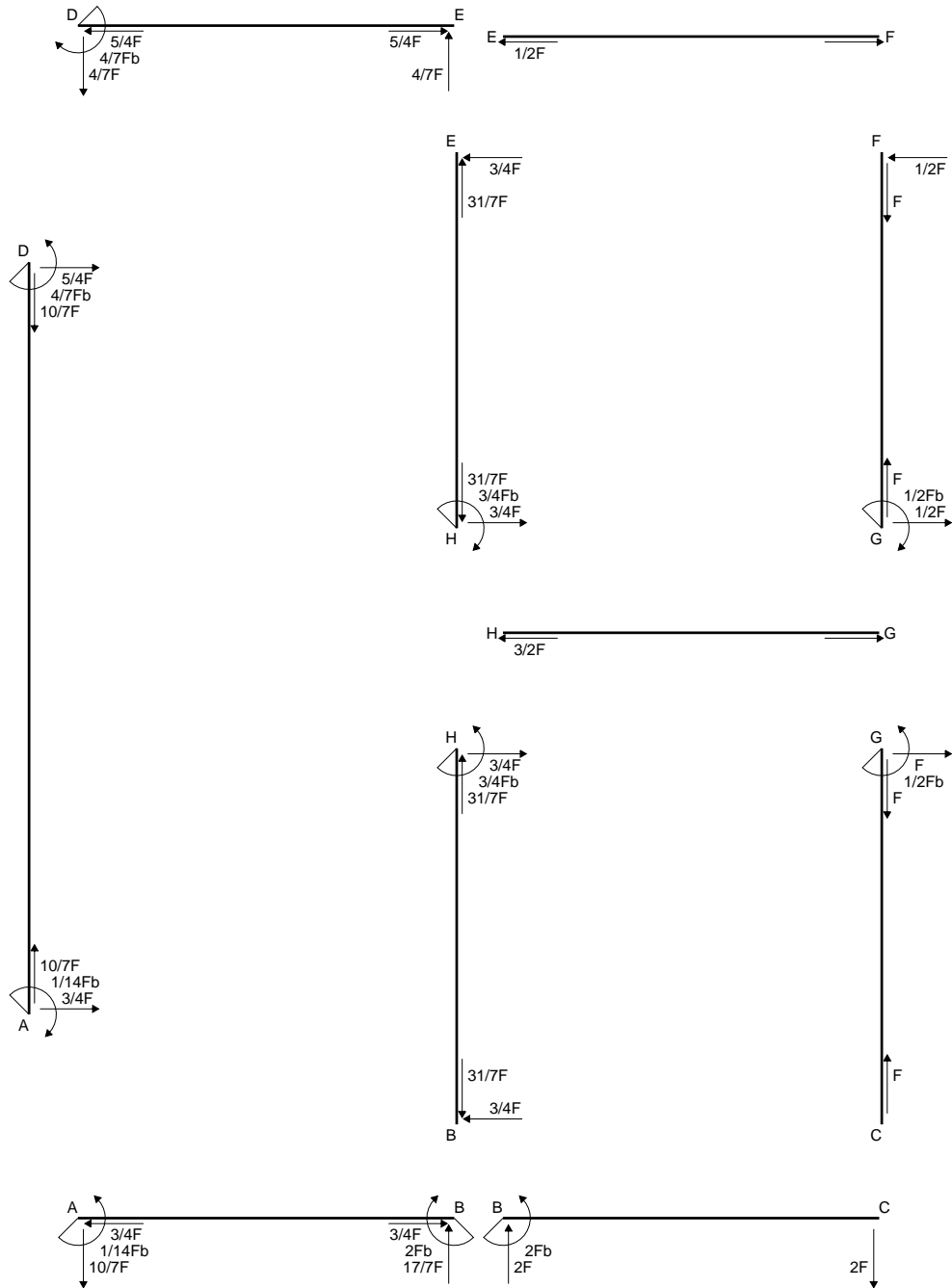
$$= (1/2 b - 1/2 b + 1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$

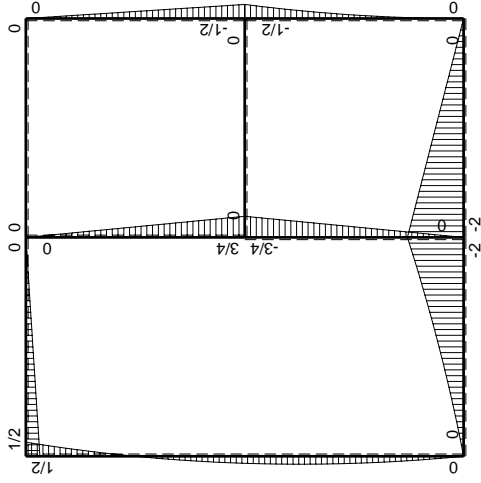
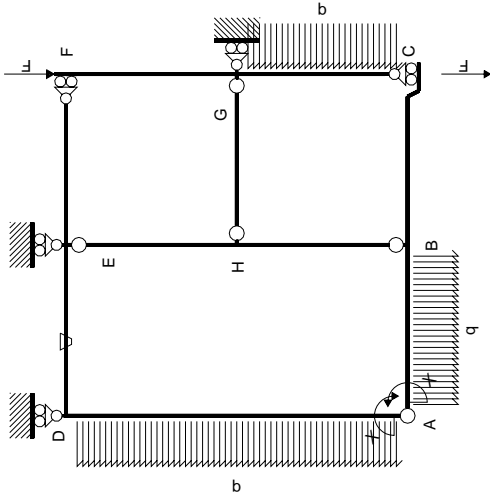
$$L_{ED}^{x_0} = \int_0^b (1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$



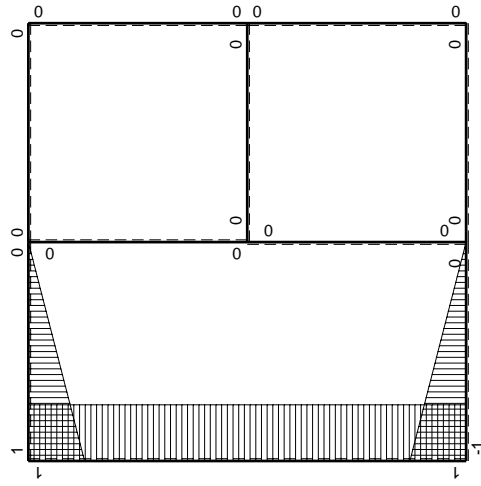
$A = 648. \text{ mm}^2$   
 $J_u = 233472. \text{ mm}^4$   
 $J_v = 46872. \text{ mm}^4$   
 $y_g = 33.47 \text{ mm}$   
 $T_y = 1800. \text{ N}$   
 $M_x = -1674000. \text{ Nmm}$   
 $x_m = 12. \text{ mm}$   
 $u_m = -9. \text{ mm}$   
 $v_m = -33.47 \text{ mm}$   
 $\sigma_m = -Mv/J_u = -240. \text{ N/mm}^2$   
 $x_c = 21. \text{ mm}$   
 $y_c = 9. \text{ mm}$   
 $v_c = -24.47 \text{ mm}$   
 $\sigma_c = -Mv/J_u = -175.5 \text{ N/mm}^2$   
 $\tau_c = 4.83 \text{ N/mm}^2$   
 $\sigma_v = \sqrt{\sigma^2 + 3\tau^2} = 175.7 \text{ N/mm}^2$   
 $S = 3759. \text{ mm}^3$





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJdx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$-3/4Fx+1/2qx^2$	0	$-3/4Fx+1/2Fx^2/b$	0	1	$(-1/6+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+5/4Fx-1/2qx^2$	0	$1/2Fb-5/4Fx+1/2Fx^2/b$	0	1			
DE b	$1-x/b$	$1/2Fb-1/2Fx$	$-Fb/EJ$	$1/2Fb-Fx+1/2Fx^2/b$	$-Fb/EJ+Fx/EJ$	$1-2x/b+x^2/b^2$	$(1/6-1/2)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$-1/2Fx$	$Fb/EJ$	$1/2Fx^2/b$	$-Fx/EJ$	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-3/4Fb+3/4Fx$	0	0	0	0	0+0	0	
BH b	0	$3/4Fx$	0	0	0	0			
HE b	0	$3/4Fb-3/4Fx$	0	0	0	0	0+0	0	
EH b	0	$-3/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$-5/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$1/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{x_0} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{x_0} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{x_0} = \int_0^{2b} (-3/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-3/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DA}^{x_0} = \int_0^{2b} (1/2 - 5/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (b - 5/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

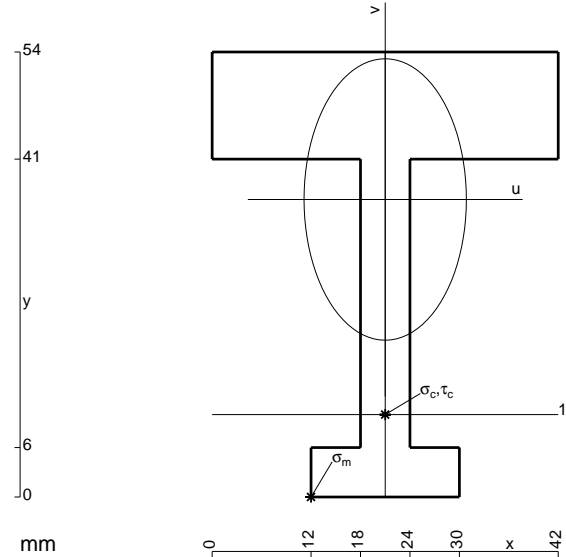
$$L_{DE}^{x_0} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx + \int_0^b (-1 + x/b) \cdot \theta \, dx$$

$$= \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ + \left[ -x + 1/2 x^2/b \right]_0^b \cdot \theta$$

$$= (1/2 b - 1/2 b + 1/6 b) \cdot Fb \cdot 1/EJ + (-b + 1/2 b) \cdot \theta = -1/3 \cdot Fb^2/EJ$$

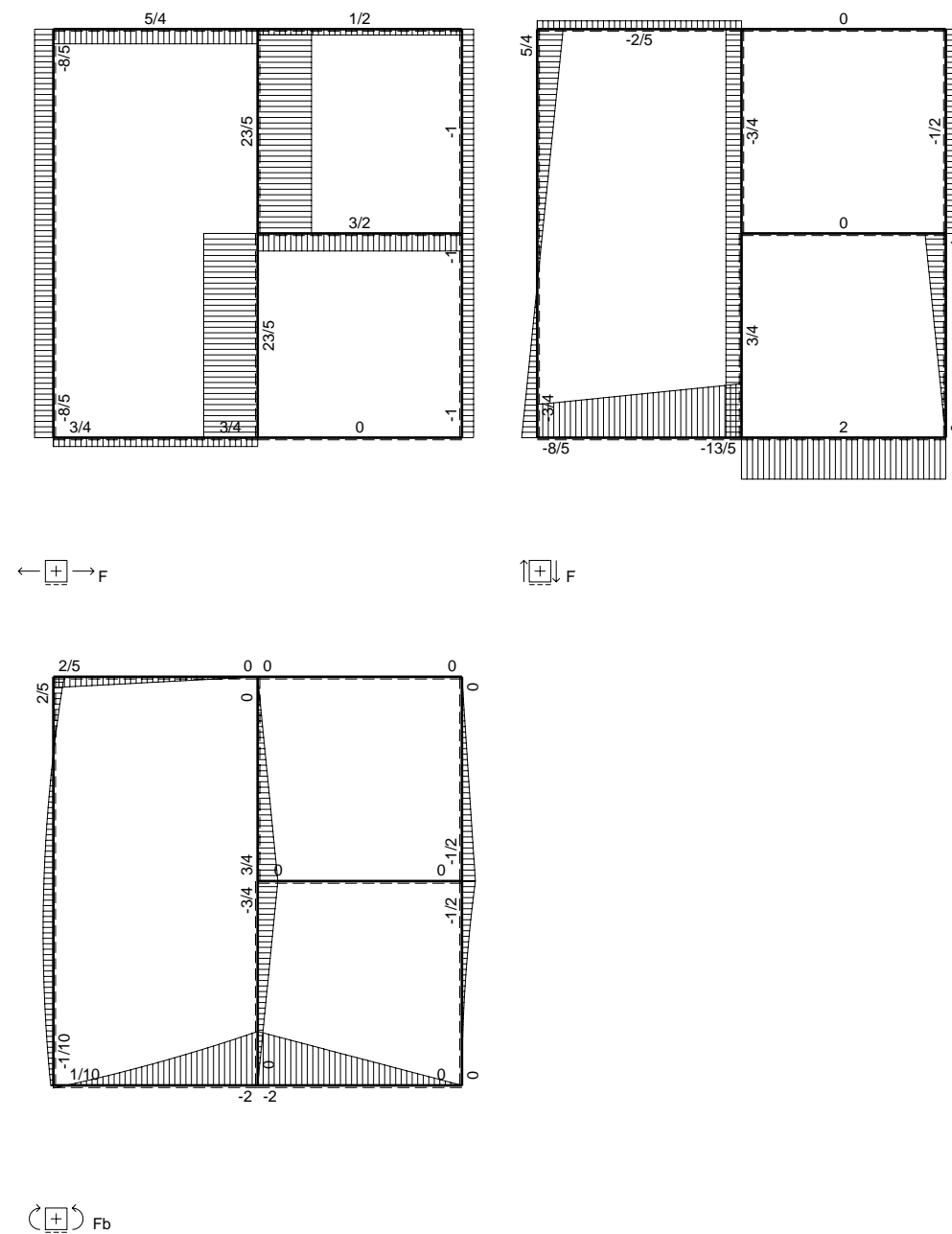
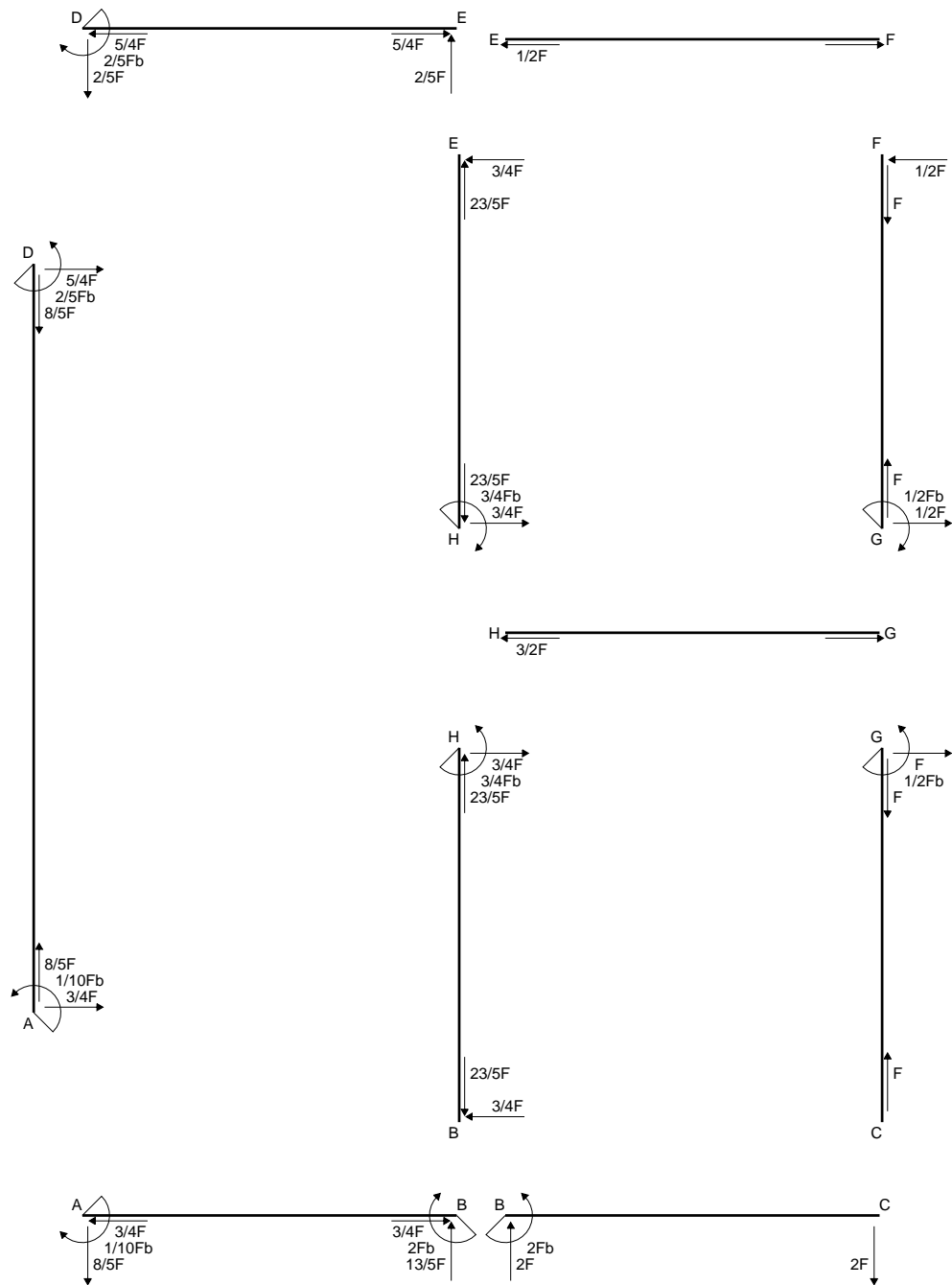
$$L_{ED}^{x_0} = \int_0^b (1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx + \int_0^b (x/b) \cdot \theta \, dx = \left[ 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ + \left[ 1/2 x^2/b \right]_0^b \cdot \theta$$

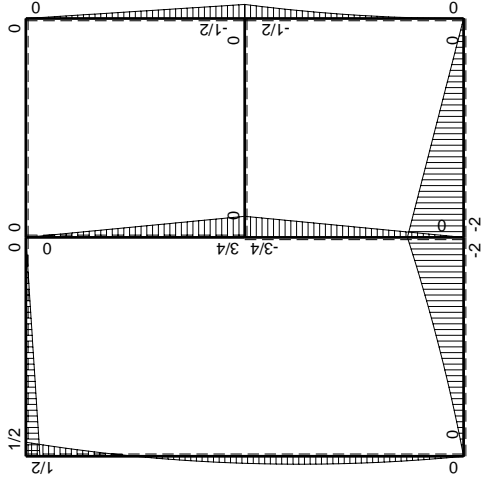
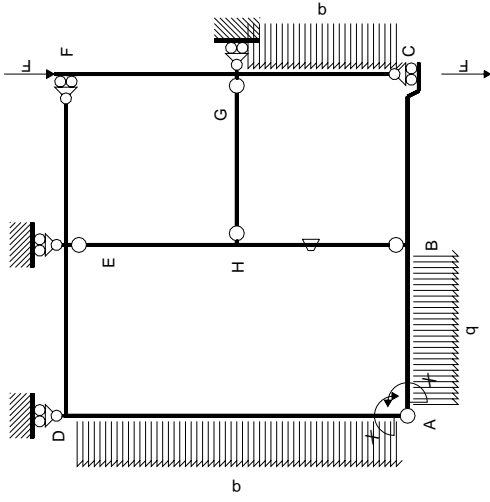
$$= (1/6 b) \cdot Fb \cdot 1/EJ + (1/2 b) \cdot \theta = -1/3 \cdot Fb^2/EJ$$



$A = 864. \text{ mm}^2$   
 $J_u = 252075. \text{ mm}^4$   
 $J_v = 83808. \text{ mm}^4$   
 $y_g = 36.1 \text{ mm}$   
 $T_y = 2840. \text{ N}$   
 $M_x = -1391600. \text{ Nmm}$   
 $x_m = 12. \text{ mm}$   
 $u_m = -9. \text{ mm}$   
 $v_m = -36.1 \text{ mm}$   
 $\sigma_m = -Mv/J_u = -199.3 \text{ N/mm}^2$   
 $x_c = 21. \text{ mm}$   
 $y_c = 10. \text{ mm}$   
 $v_c = -26.1 \text{ mm}$   
 $\sigma_c = -Mv/J_u = -144.1 \text{ N/mm}^2$   
 $\tau_c = 7.98 \text{ N/mm}^2$   
 $\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 144.8 \text{ N/mm}^2$   
 $S = 4250. \text{ mm}^3$

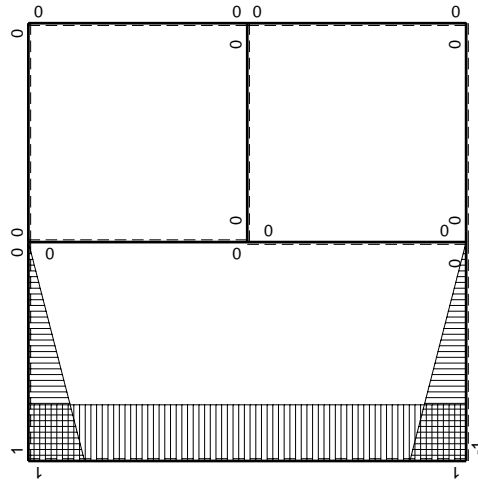






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0
CB b	0	$2Fx$	0	0	0	0		
AD 2b	1	$-3/4Fx+1/2qx^2$	0	$-3/4Fx+1/2Fx^2/b$	0	1	$(-1/6+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$-1/2Fb+5/4Fx-1/2qx^2$	0	$1/2Fb-5/4Fx+1/2Fx^2/b$	0	1		
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$		
EF b	0	0	0	0	0	0	0+0	0
FE b	0	0	0	0	0	0		
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0		
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0
CG b	0	$1/2qx^2$	0	0	0	0		
HG b	0	0	0	0	0	0	0+0	0
GH b	0	0	0	0	0	0		
HB b	0	$-3/4Fb+3/4Fx$	$-Fb/EJ$	0	0	0	0+0	0
BH b	0	$3/4Fx$	$Fb/EJ$	0	0	0		
HE b	0	$3/4Fb-3/4Fx$	0	0	0	0	0+0	0
EH b	0	$-3/4Fx$	0	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-3/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-3/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 5/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

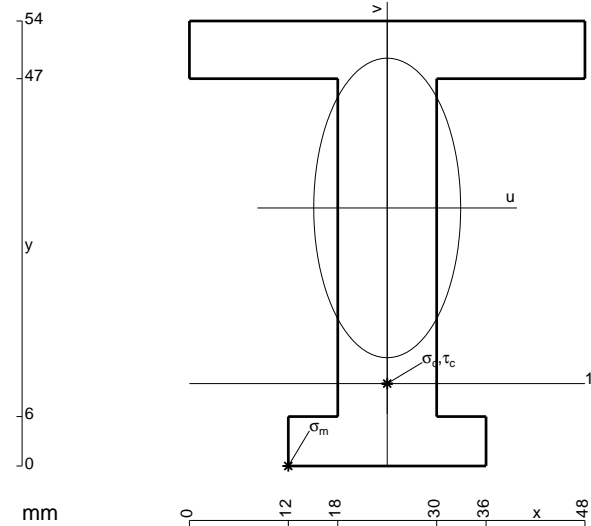
$$= (b - 5/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

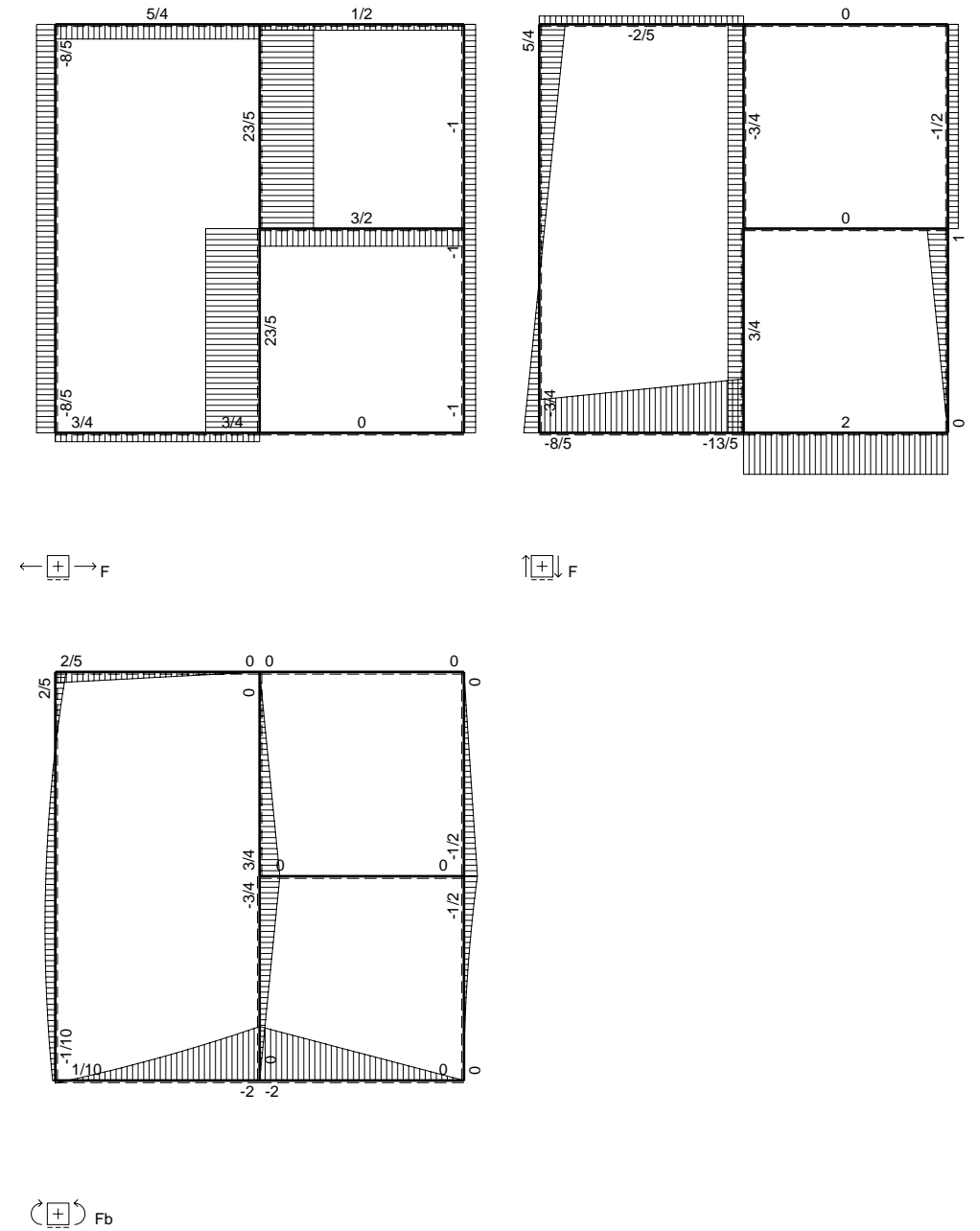
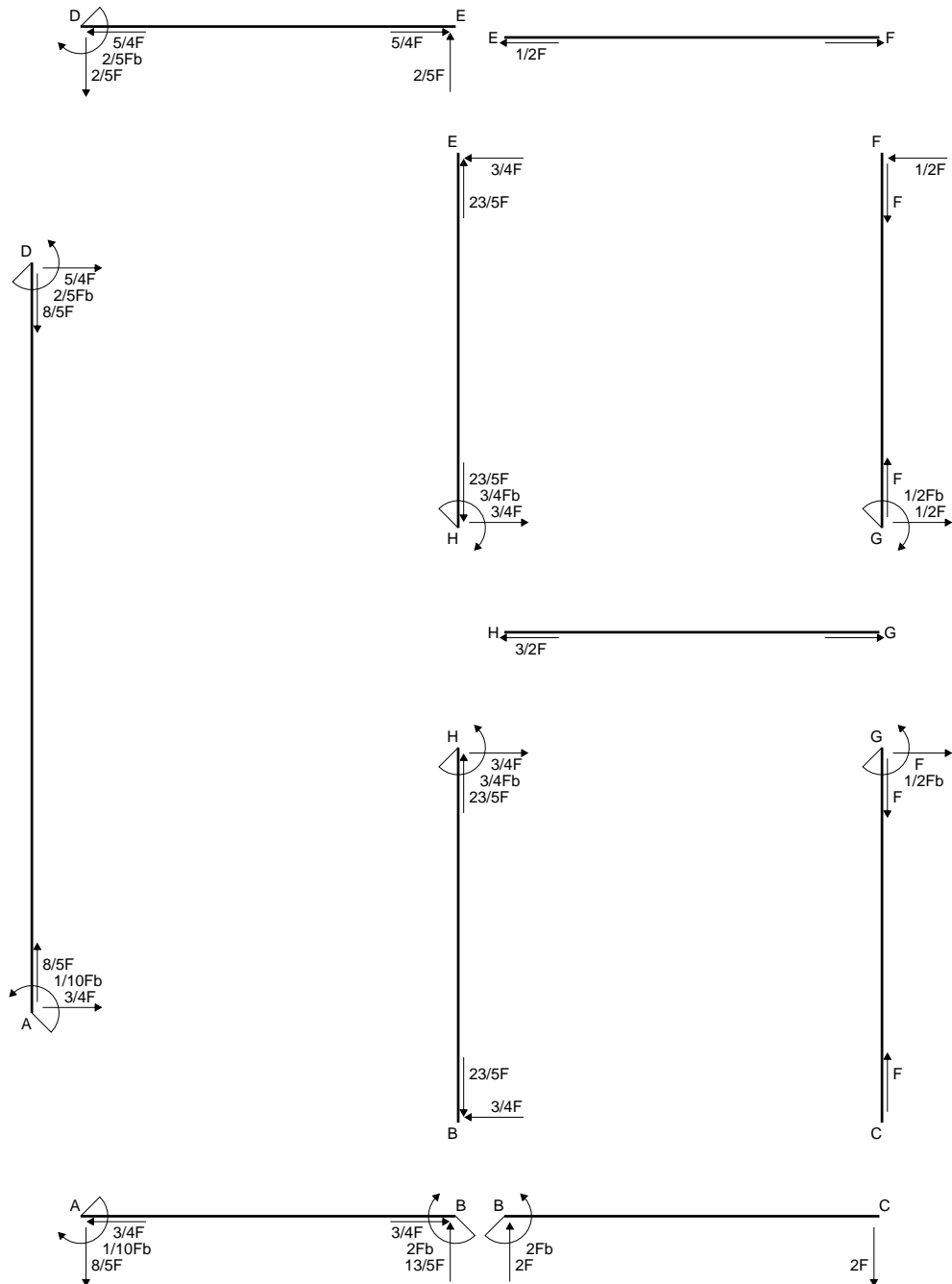
$$= (1/2 b - 1/2 b + 1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$

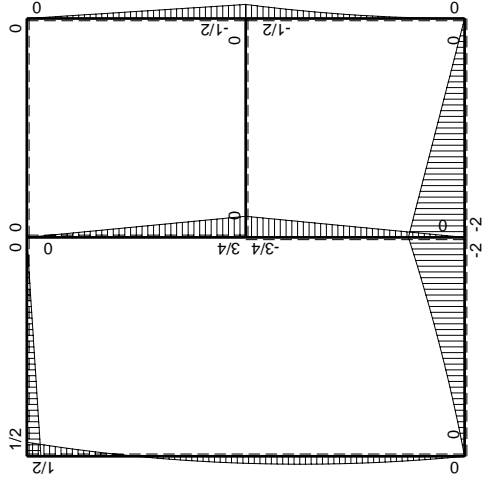
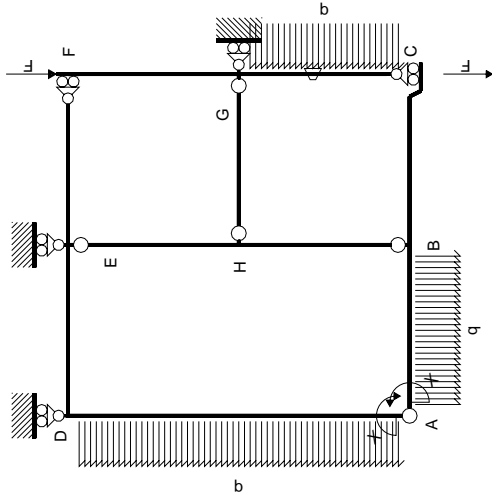
$$L_{ED}^{xo} = \int_0^b (1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$



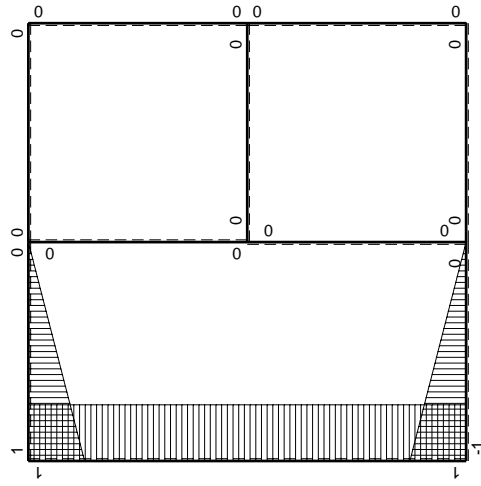
- A = 972. mm<sup>2</sup>
- J<sub>u</sub> = 321252. mm<sup>4</sup>
- J<sub>v</sub> = 77328. mm<sup>4</sup>
- y<sub>g</sub> = 31.31 mm
- T<sub>y</sub> = 4060. N
- M<sub>x</sub> = -2151800. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -12. mm
- v<sub>m</sub> = -31.31 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -209.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 10. mm
- v<sub>c</sub> = -21.31 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -142.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.473 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 143.1 N/mm<sup>2</sup>
- S = 5196. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJdx$
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0
CB b	0	$2Fx$	0	0	0	0		
AD 2b	1	$-3/4Fx+1/2qx^2$	0	$-3/4Fx+1/2Fx^2/b$	0	1	$(-1/6+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$-1/2Fb+5/4Fx-1/2qx^2$	0	$1/2Fb-5/4Fx+1/2Fx^2/b$	0	1		
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$		
EF b	0	0	0	0	0	0	0+0	0
FE b	0	0	0	0	0	0		
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0		
GC b	0	$-1/2Fb+Fx-1/2qx^2$	$-Fb/EJ$	0	0	0	0+0	0
CG b	0	$1/2qx^2$	$Fb/EJ$	0	0	0		
HG b	0	0	0	0	0	0	0+0	0
GH b	0	0	0	0	0	0		
HB b	0	$-3/4Fb+3/4Fx$	0	0	0	0	0+0	0
BH b	0	$3/4Fx$	0	0	0	0		
HE b	0	$3/4Fb-3/4Fx$	0	0	0	0	0+0	0
EH b	0	$-3/4Fx$	0	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{x_0} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{x_0} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{x_0} = \int_0^{2b} (-3/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-3/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DA}^{x_0} = \int_0^{2b} (1/2 - 5/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

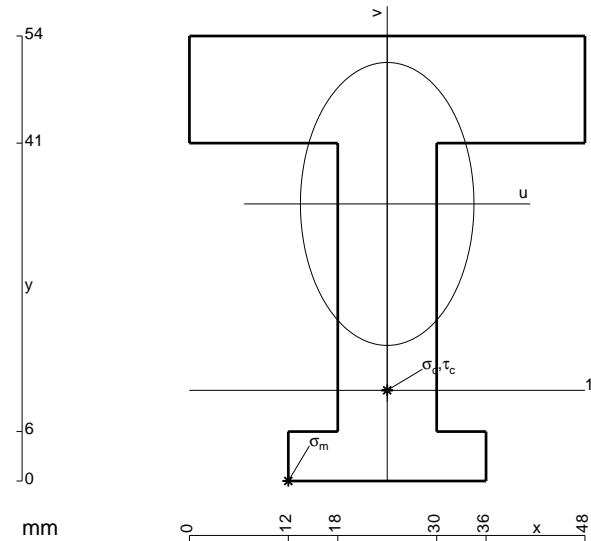
$$= (b - 5/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DE}^{x_0} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/2 b - 1/2 b + 1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$

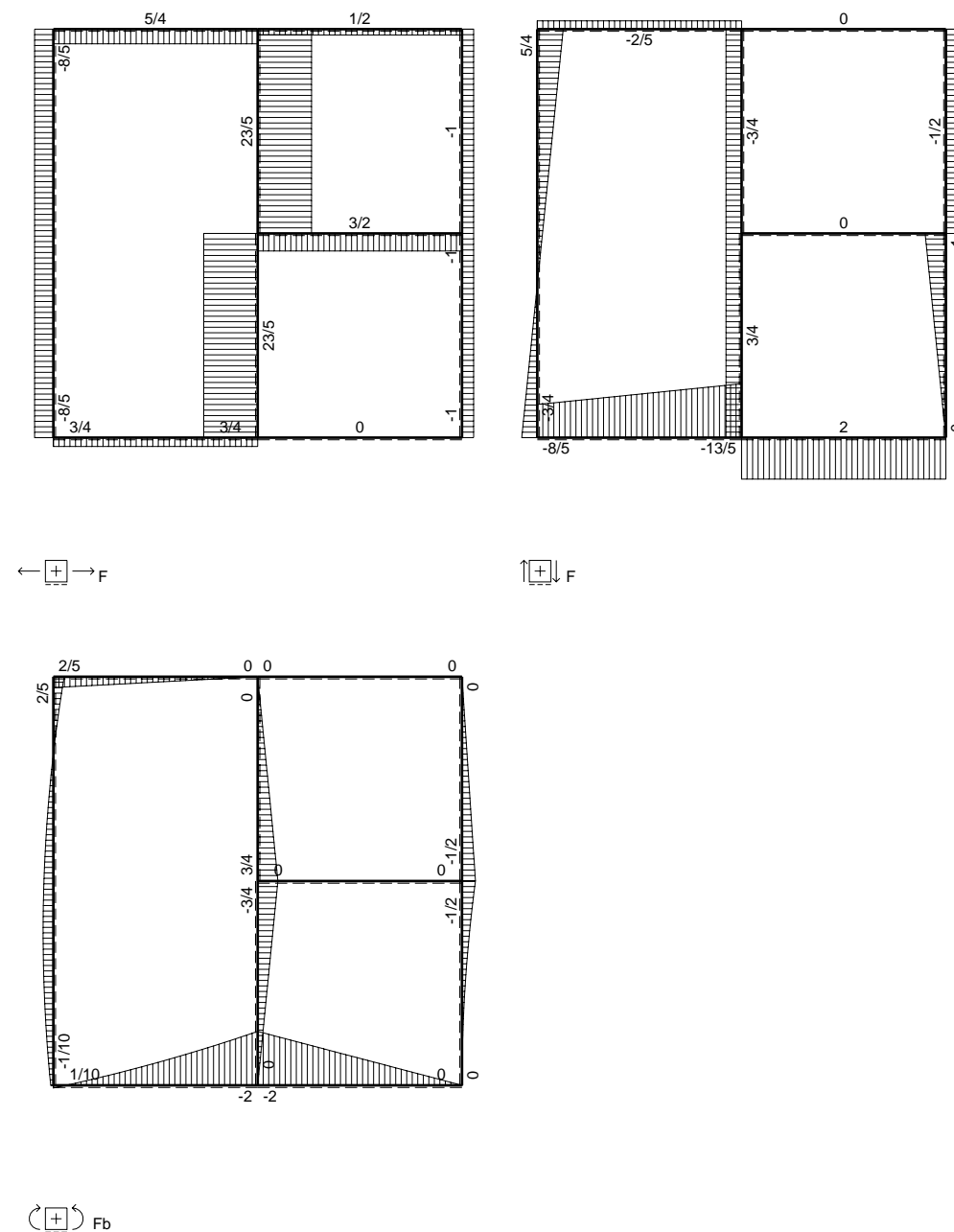
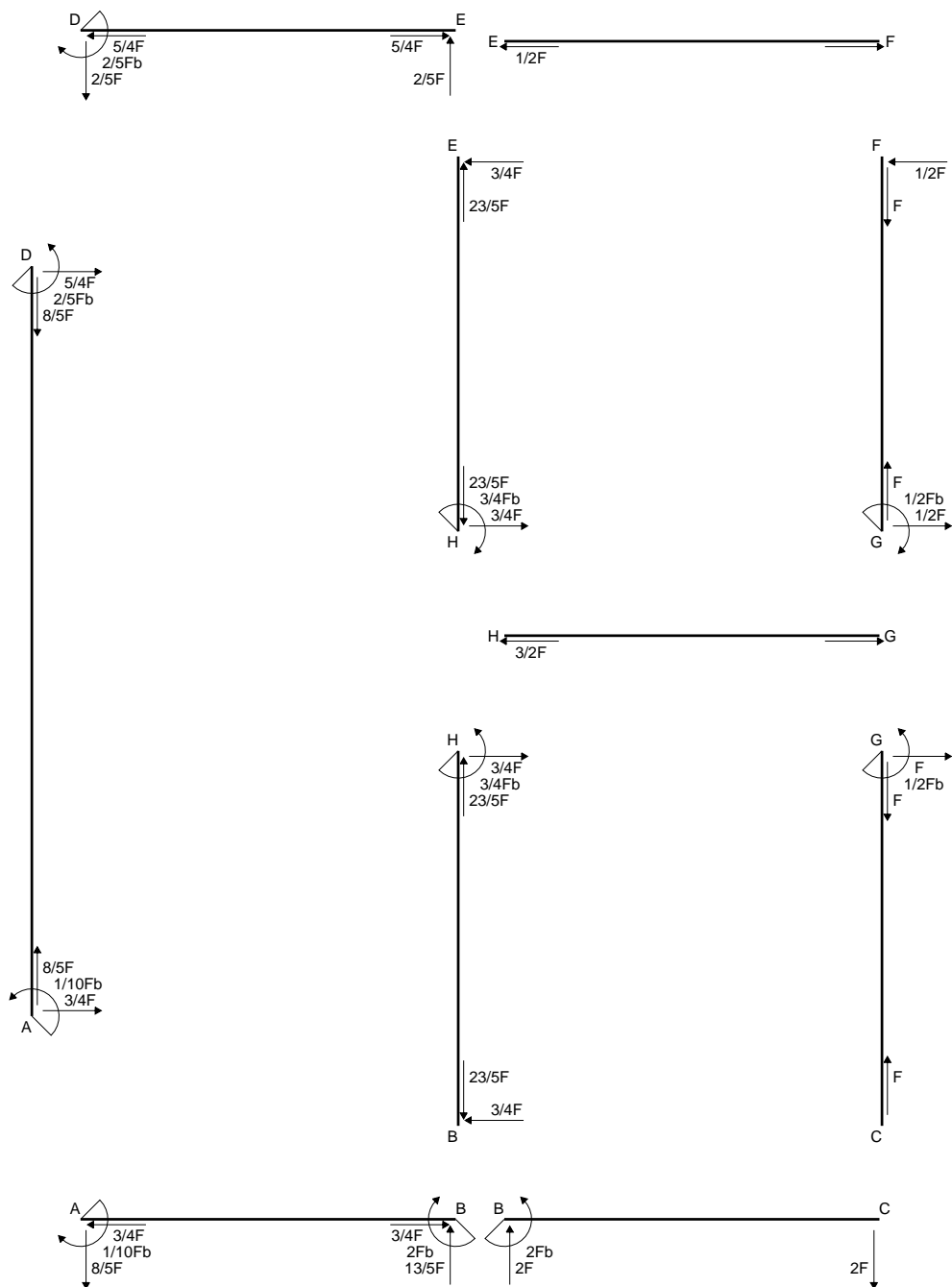
$$L_{ED}^{x_0} = \int_0^b (1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

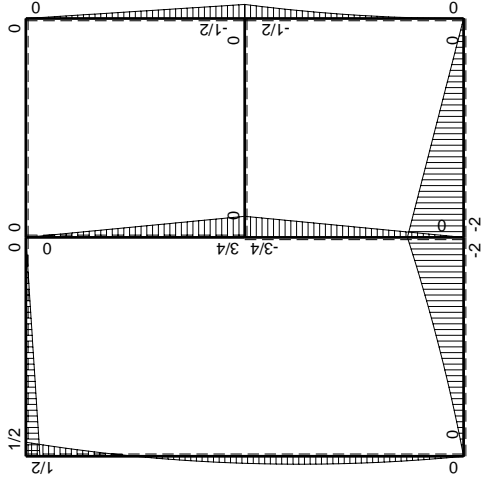
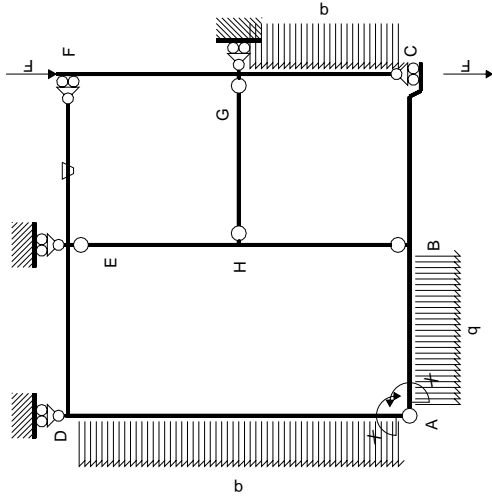
$$= (1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$



- A = 1188. mm<sup>2</sup>
- J<sub>u</sub> = 350338. mm<sup>4</sup>
- J<sub>v</sub> = 131760. mm<sup>4</sup>
- y<sub>g</sub> = 33.62 mm
- T<sub>y</sub> = 3940. N
- M<sub>x</sub> = -2285200. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -12. mm
- v<sub>m</sub> = -33.62 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -219.3 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 11. mm
- v<sub>c</sub> = -22.62 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -147.6 N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.545 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 147.9 N/mm<sup>2</sup>
- S = 5917. mm<sup>3</sup>

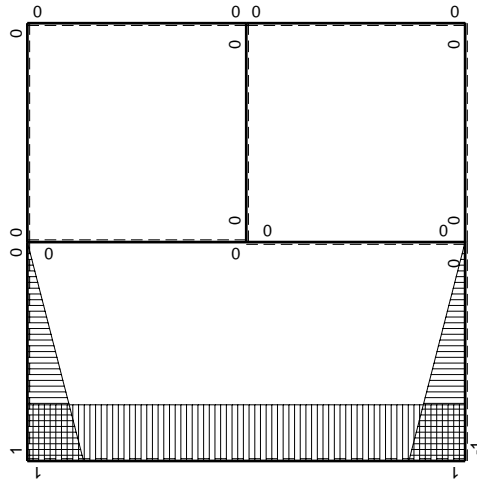






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJdx$
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0
CB b	0	$2Fx$	0	0	0	0		
AD 2b	1	$-3/4Fx+1/2qx^2$	0	$-3/4Fx+1/2Fx^2/b$	0	1	$(-1/6+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$-1/2Fb+5/4Fx-1/2qx^2$	0	$1/2Fb-5/4Fx+1/2Fx^2/b$	0	1		
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$		
EF b	0	0	$-Fb/EJ$	0	0	0	0+0	0
FE b	0	0	$Fb/EJ$	0	0	0		
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0		
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0
CG b	0	$1/2qx^2$	0	0	0	0		
HG b	0	0	0	0	0	0	0+0	0
GH b	0	0	0	0	0	0		
HB b	0	$-3/4Fb+3/4Fx$	0	0	0	0	0+0	0
BH b	0	$3/4Fx$	0	0	0	0		
HE b	0	$3/4Fb-3/4Fx$	0	0	0	0	0+0	0
EH b	0	$-3/4Fx$	0	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) 1/EJ dx = \left[ x \right]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) 1/EJ dx = \left[ x \right]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = \left[ 1/3 x^3/b^2 \right]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{AB}^{x_0} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b Fb 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) Fb 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 Fb^2/EJ$$

$$L_{BA}^{x_0} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b Fb 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) Fb 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 Fb^2/EJ$$

$$L_{AD}^{x_0} = \int_0^{2b} (-3/4 x/b + 1/2 x^2/b^2) Fb 1/EJ dx = \left[ -3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} Fb 1/EJ$$

$$= (-3/2 b + 4/3 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

$$L_{DA}^{x_0} = \int_0^{2b} (1/2 - 5/4 x/b + 1/2 x^2/b^2) Fb 1/EJ dx = \left[ 1/2 x - 5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} Fb 1/EJ$$

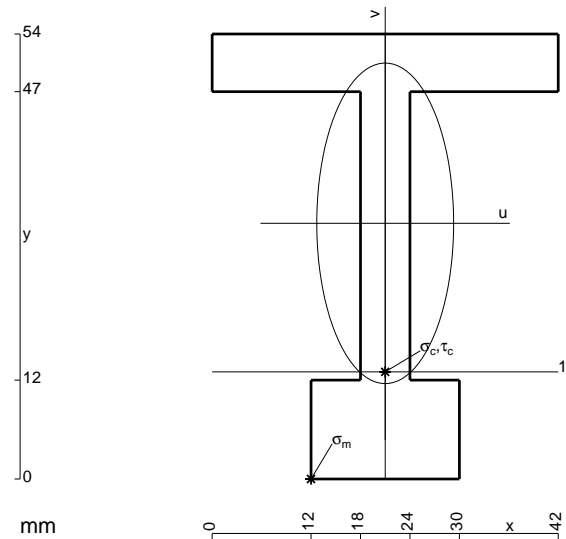
$$= (b - 5/2 b + 4/3 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

$$L_{DE}^{x_0} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) Fb 1/EJ dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b Fb 1/EJ$$

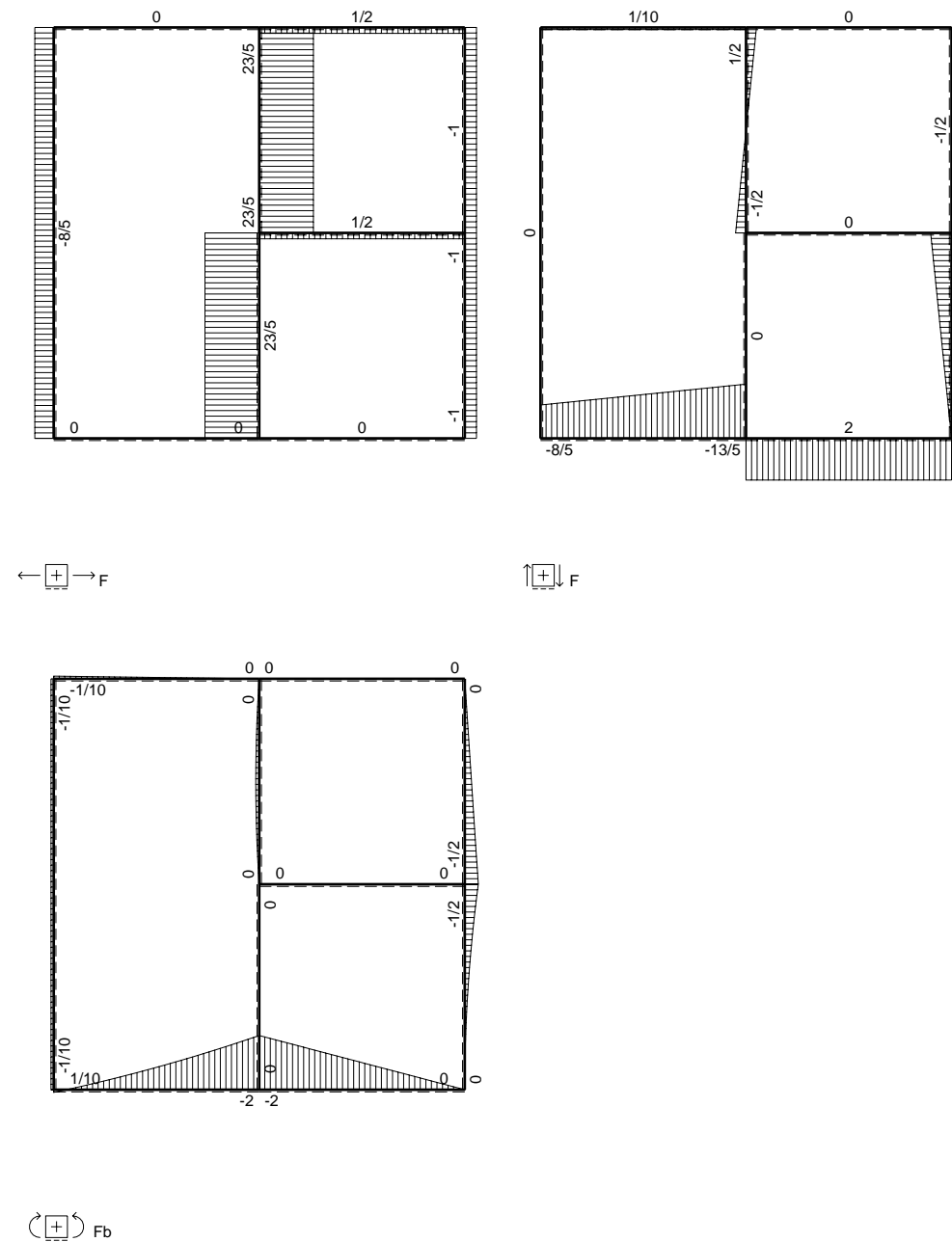
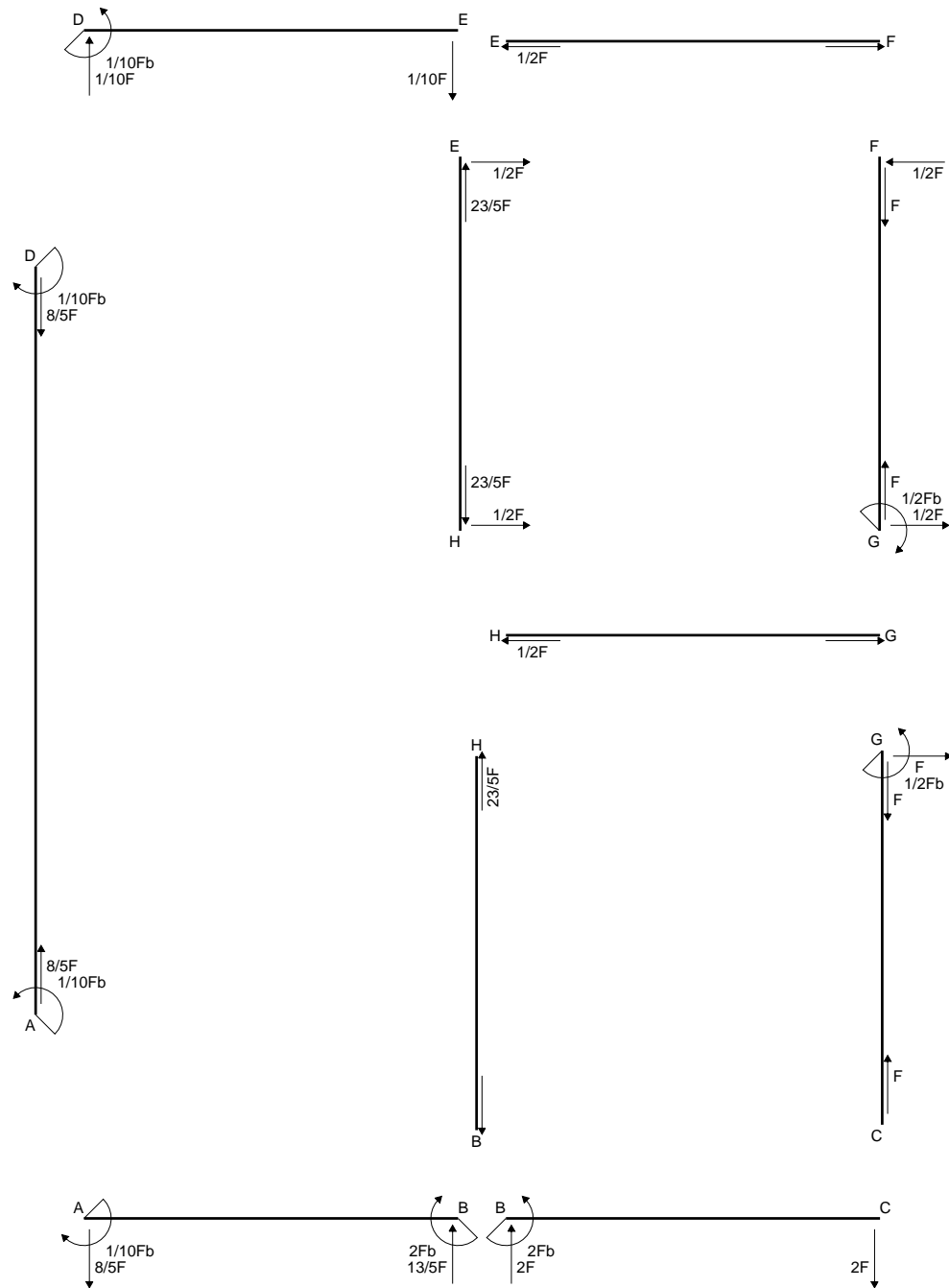
$$= (1/2 b - 1/2 b + 1/6 b) Fb 1/EJ = 1/6 Fb^2/EJ$$

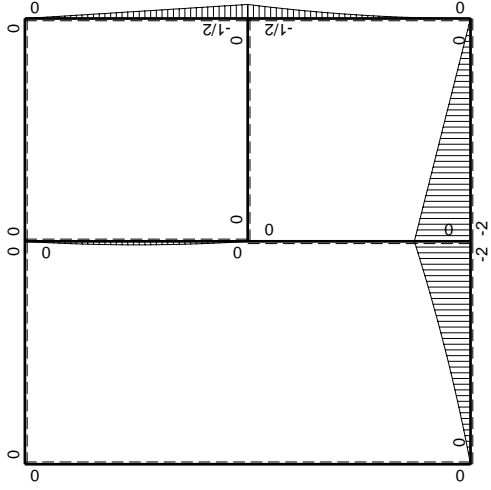
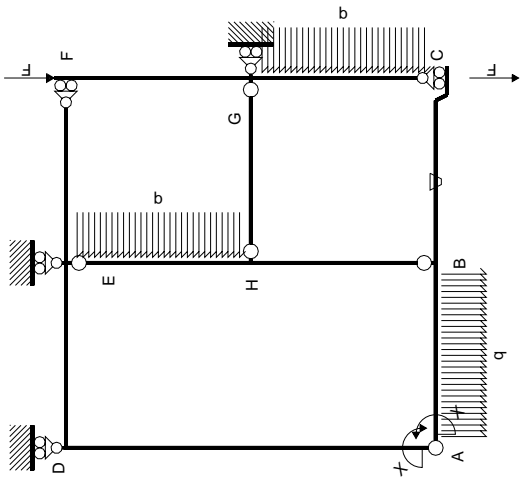
$$L_{ED}^{x_0} = \int_0^b (1/2 x^2/b^2) Fb 1/EJ dx = \left[ 1/6 x^3/b^2 \right]_0^b Fb 1/EJ$$

$$= (1/6 b) Fb 1/EJ = 1/6 Fb^2/EJ$$

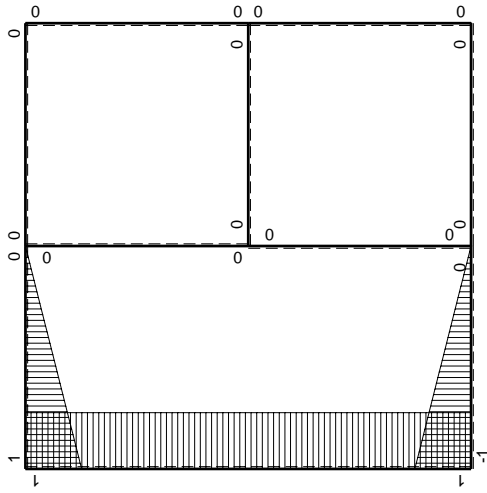


$A = 720. \text{ mm}^2$   
 $J_u = 272496. \text{ mm}^4$   
 $J_v = 49680. \text{ mm}^4$   
 $y_g = 31.02 \text{ mm}$   
 $T_y = 3200. \text{ N}$   
 $M_x = -2016000. \text{ Nmm}$   
 $x_m = 12. \text{ mm}$   
 $u_m = -9. \text{ mm}$   
 $v_m = -31.02 \text{ mm}$   
 $\sigma_m = -Mv/J_u = -229.5 \text{ N/mm}^2$   
 $x_c = 21. \text{ mm}$   
 $y_c = 13. \text{ mm}$   
 $v_c = -18.02 \text{ mm}$   
 $\sigma_c = -Mv/J_u = -133.4 \text{ N/mm}^2$   
 $\tau_c = 10.8 \text{ N/mm}^2$   
 $\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 134.7 \text{ N/mm}^2$   
 $S = 5517. \text{ mm}^3$





$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	$-Fb/EJ$	0	0	0	0+0	0	
CB b	0	$2Fx$	$Fb/EJ$	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	0	0	0	0	0	0+0	0	
BH b	0	0	0	0	0	0			
HE b	0	$-1/2Fx+1/2qx^2$	0	0	0	0	0+0	0	
EH b	0	$1/2Fx-1/2qx^2$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx + 1 \cdot \frac{1}{4} \frac{b}{EJ} = \left[ x - \frac{x^2}{b} + \frac{1}{3} \frac{x^3}{b^2} \right]_0^b \frac{1}{EJ} + 1 \cdot \frac{1}{4} \frac{b}{EJ}$$

$$= (b - b + \frac{1}{3}b) \frac{1}{EJ} + 1 \cdot \frac{1}{4} \frac{b}{EJ} = \frac{7}{12} \frac{b}{EJ}$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx + 1 \cdot \frac{1}{4} \frac{b}{EJ} = \left[ \frac{1}{3} \frac{x^3}{b^2} \right]_0^b \frac{1}{EJ} + 1 \cdot \frac{1}{4} \frac{b}{EJ}$$

$$= (\frac{1}{3}b) \frac{1}{EJ} + 1 \cdot \frac{1}{4} \frac{b}{EJ} = \frac{7}{12} \frac{b}{EJ}$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \frac{b}{EJ}$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \frac{b}{EJ}$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx = \left[ x - \frac{x^2}{b} + \frac{1}{3} \frac{x^3}{b^2} \right]_0^b \frac{1}{EJ}$$

$$= (b - b + \frac{1}{3}b) \frac{1}{EJ} = \frac{1}{3} \frac{b}{EJ}$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx = \left[ \frac{1}{3} \frac{x^3}{b^2} \right]_0^b \frac{1}{EJ}$$

$$= (\frac{1}{3}b) \frac{1}{EJ} = \frac{1}{3} \frac{b}{EJ}$$

$$L_{AB}^{x_0} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

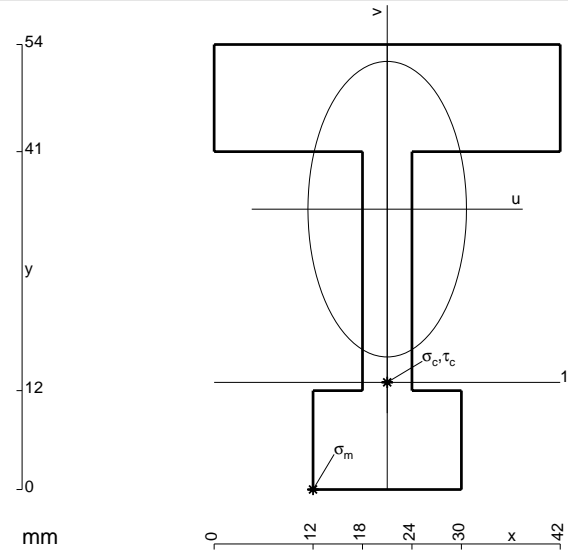
$$= \left[ \frac{3}{4} \frac{x^2}{b} - \frac{1}{3} \frac{x^3}{b^2} - \frac{1}{8} \frac{x^4}{b^3} \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= (\frac{3}{4}b - \frac{1}{3}b - \frac{1}{8}b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ} = \frac{7}{24} \frac{Fb^2}{EJ}$$

$$L_{BA}^{x_0} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= \left[ x^2/b - \frac{5}{6} \frac{x^3}{b^2} + \frac{1}{8} \frac{x^4}{b^3} \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= (b - \frac{5}{6}b + \frac{1}{8}b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ} = \frac{7}{24} \frac{Fb^2}{EJ}$$



$$A = 936. \text{ mm}^2$$

$$J_u = 301116. \text{ mm}^4$$

$$J_v = 86616. \text{ mm}^4$$

$$y_g = 34.02 \text{ mm}$$

$$T_y = 3120. \text{ N}$$

$$M_x = -2121600. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -9. \text{ mm}$$

$$v_m = -34.02 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -239.7 \text{ N/mm}^2$$

$$x_c = 21. \text{ mm}$$

$$y_c = 13. \text{ mm}$$

$$v_c = -21.02 \text{ mm}$$

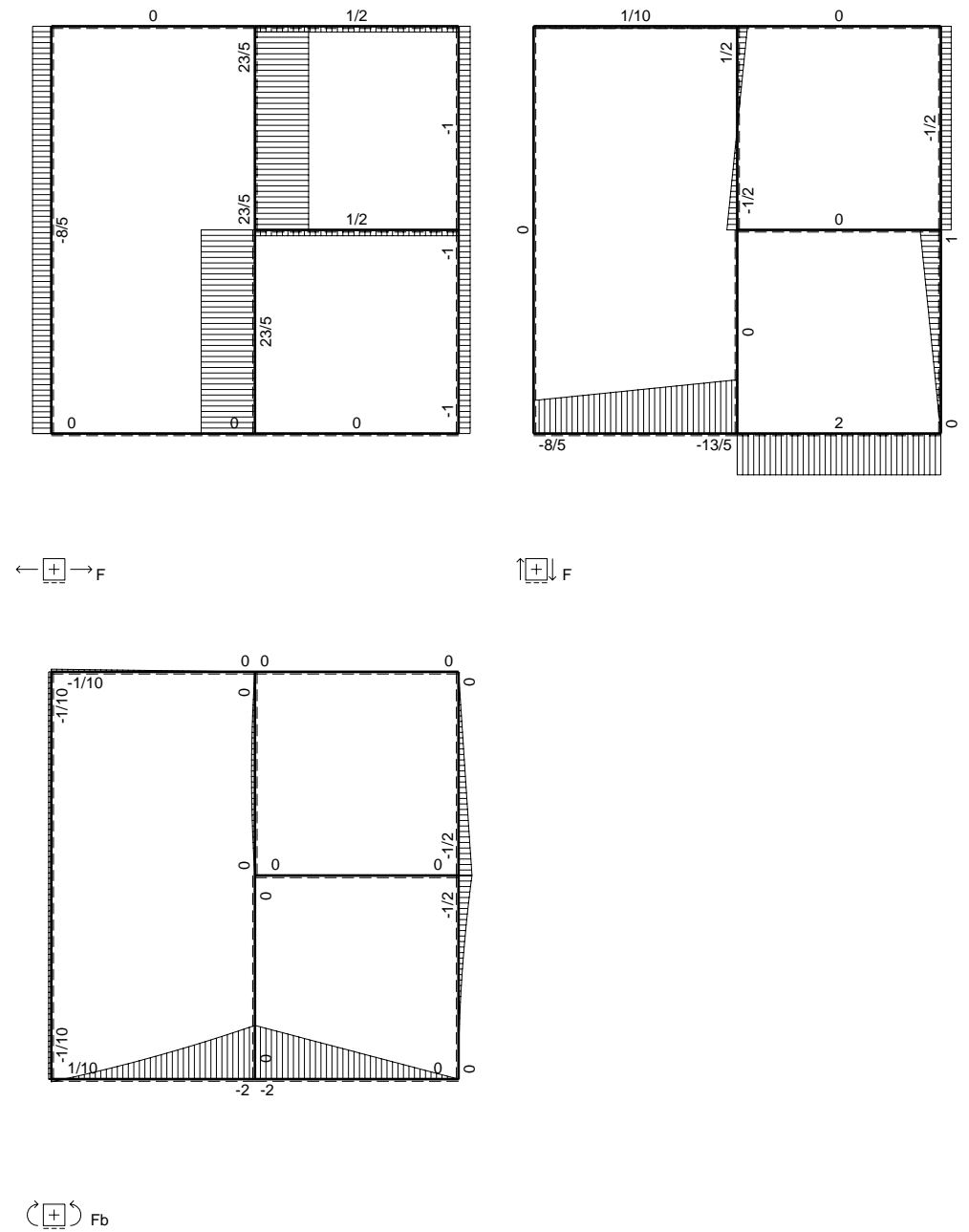
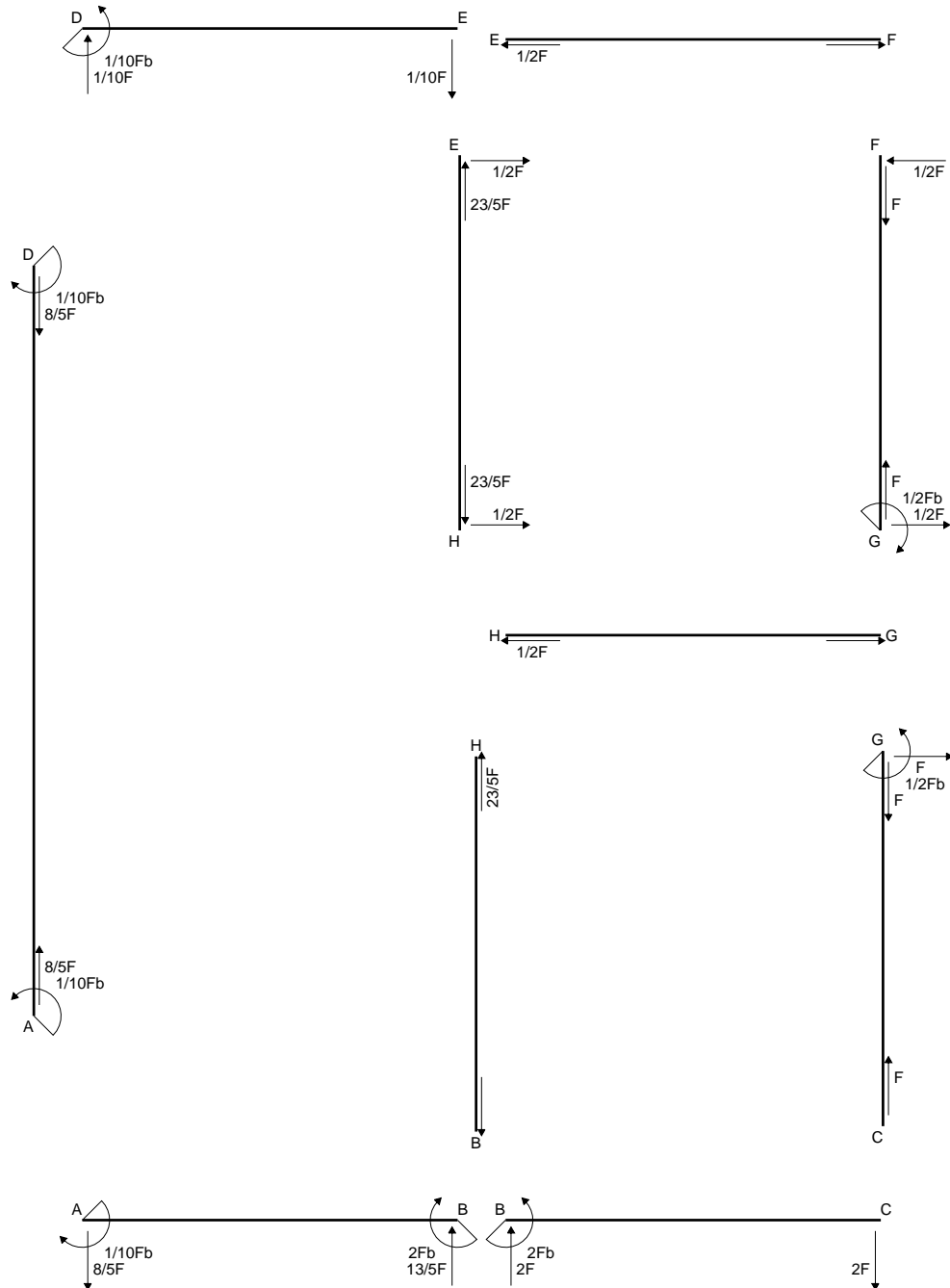
$$\sigma_c = -Mv/J_u = -148.1 \text{ N/mm}^2$$

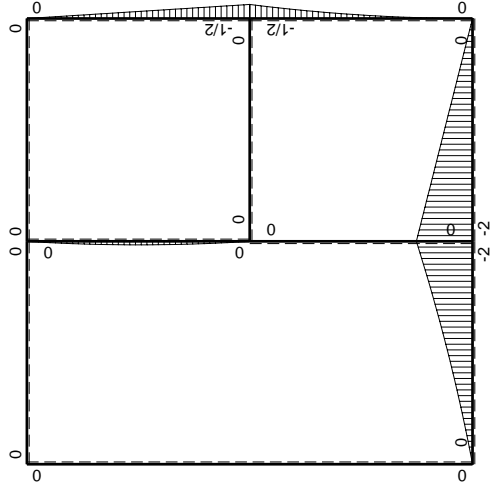
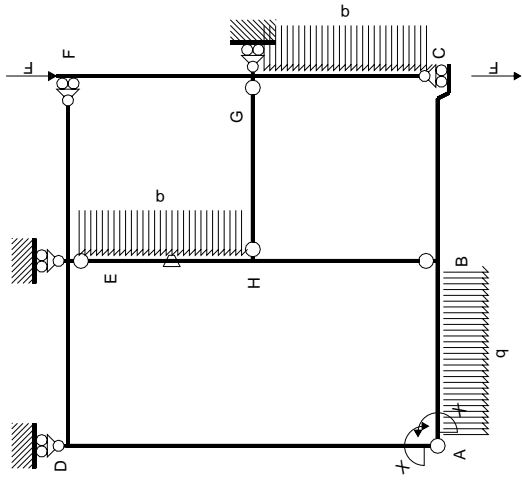
$$\tau_c = 10.67 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 149.2 \text{ N/mm}^2$$

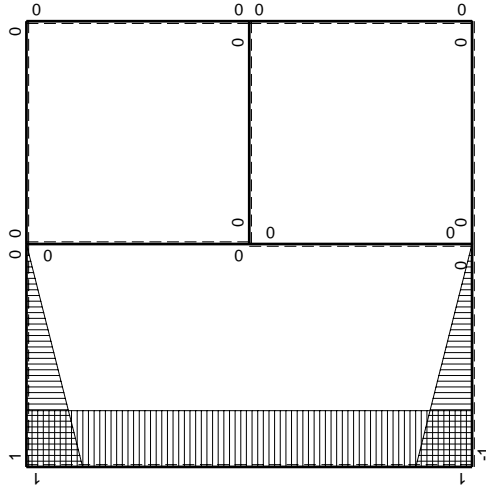
$$S = 6181. \text{ mm}^3$$







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x / EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	0	0	0	0	0	0+0	0	
BH b	0	0	0	0	0	0			
HE b	0	$-1/2Fx+1/2qx^2$	$-Fb/EJ$	0	0	0	0+0	0	
EH b	0	$1/2Fx-1/2qx^2$	$Fb/EJ$	0	0	0			
AB	molla asta $-W_{1AB} (W_{0AB} + XW_{1AB}) / k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

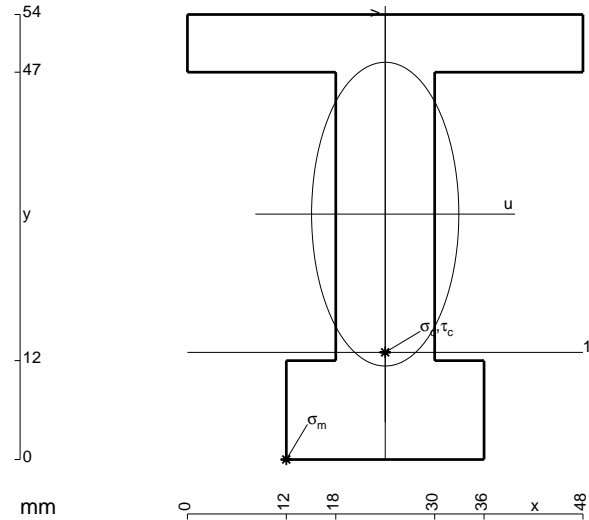
$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

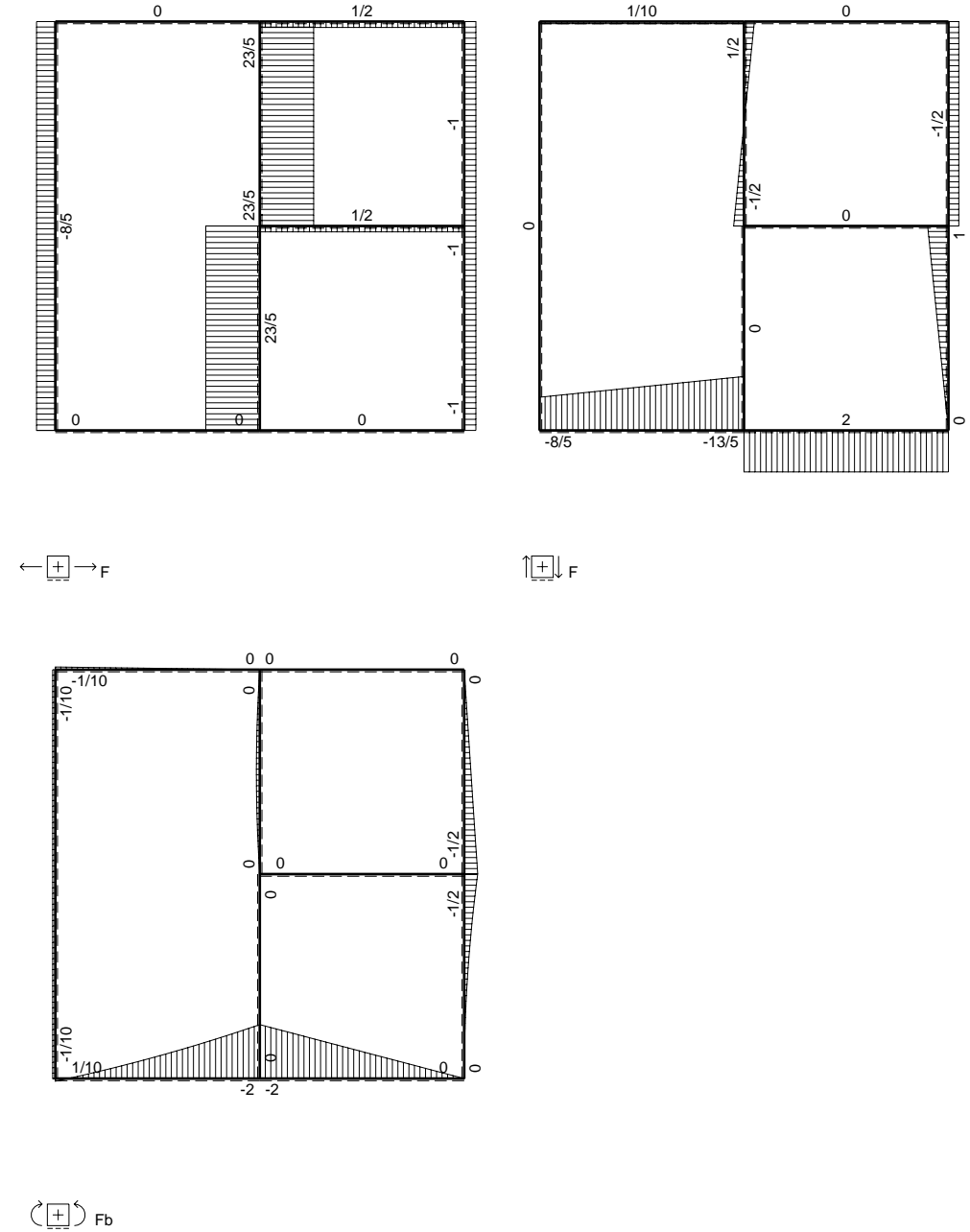
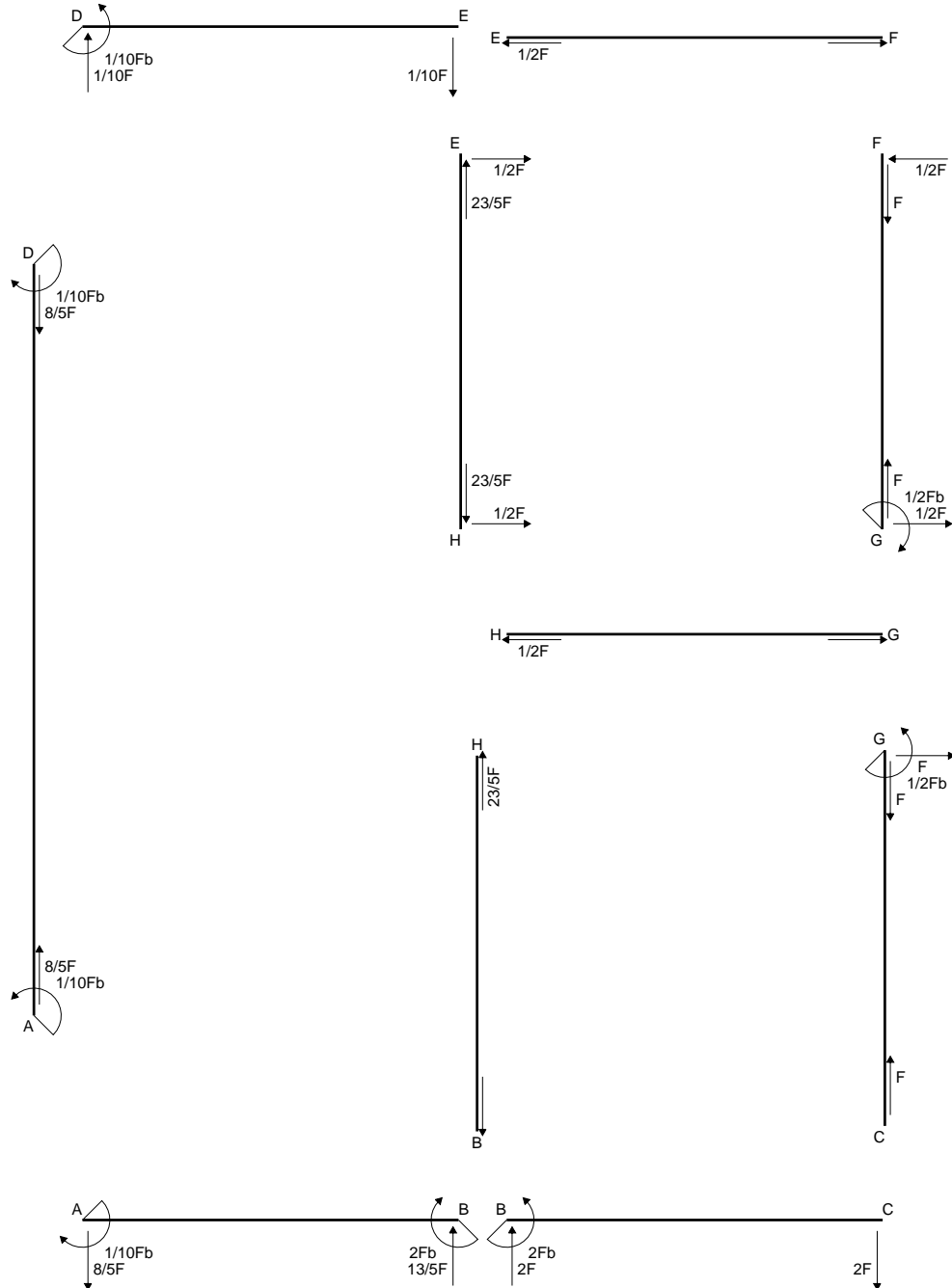
$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

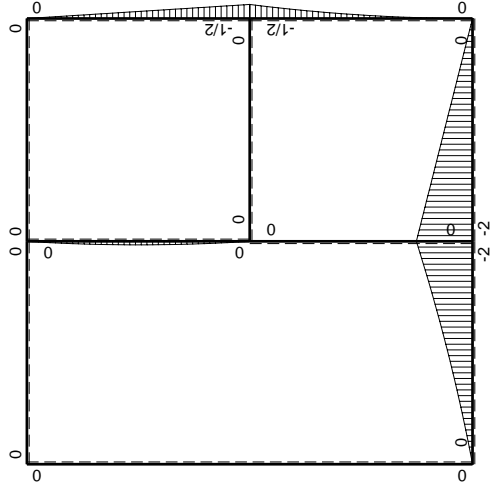
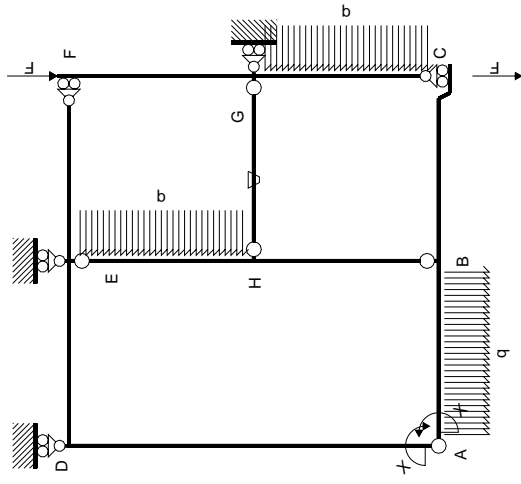
$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

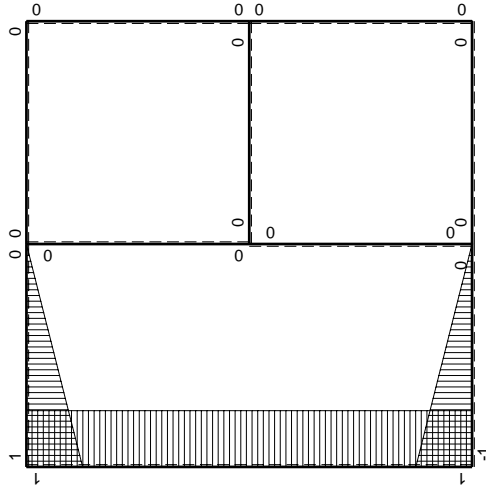


- A = 1044. mm<sup>2</sup>
- J<sub>u</sub> = 354848. mm<sup>4</sup>
- J<sub>v</sub> = 83376. mm<sup>4</sup>
- y<sub>g</sub> = 29.78 mm
- T<sub>y</sub> = 3260. N
- M<sub>x</sub> = -2379800. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -12. mm
- v<sub>m</sub> = -29.78 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -199.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 13. mm
- v<sub>c</sub> = -16.78 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -112.5 N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.401 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 112.9 N/mm<sup>2</sup>
- S = 7055. mm<sup>3</sup>





$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
GH b	0	0	$Fb/EJ$	0	0	0			
HB b	0	0	0	0	0	0	0+0	0	
BH b	0	0	0	0	0	0			
HE b	0	$-1/2Fx+1/2qx^2$	0	0	0	0	0+0	0	
EH b	0	$1/2Fx-1/2qx^2$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx + 1 \cdot \frac{1}{4} \frac{b}{EJ} = \left[ x - \frac{x^2}{b} + \frac{1}{3} \frac{x^3}{b^2} \right]_0^b \frac{1}{EJ} + 1 \cdot \frac{1}{4} \frac{b}{EJ}$$

$$= (b - b + \frac{1}{3}b) \frac{1}{EJ} + 1 \cdot \frac{1}{4} \frac{b}{EJ} = \frac{7}{12} \frac{b}{EJ}$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx + 1 \cdot \frac{1}{4} \frac{b}{EJ} = \left[ \frac{1}{3} \frac{x^3}{b^2} \right]_0^b \frac{1}{EJ} + 1 \cdot \frac{1}{4} \frac{b}{EJ}$$

$$= (\frac{1}{3}b) \frac{1}{EJ} + 1 \cdot \frac{1}{4} \frac{b}{EJ} = \frac{7}{12} \frac{b}{EJ}$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \frac{b}{EJ}$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \frac{b}{EJ}$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx = \left[ x - \frac{x^2}{b} + \frac{1}{3} \frac{x^3}{b^2} \right]_0^b \frac{1}{EJ}$$

$$= (b - b + \frac{1}{3}b) \frac{1}{EJ} = \frac{1}{3} \frac{b}{EJ}$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx = \left[ \frac{1}{3} \frac{x^3}{b^2} \right]_0^b \frac{1}{EJ}$$

$$= (\frac{1}{3}b) \frac{1}{EJ} = \frac{1}{3} \frac{b}{EJ}$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

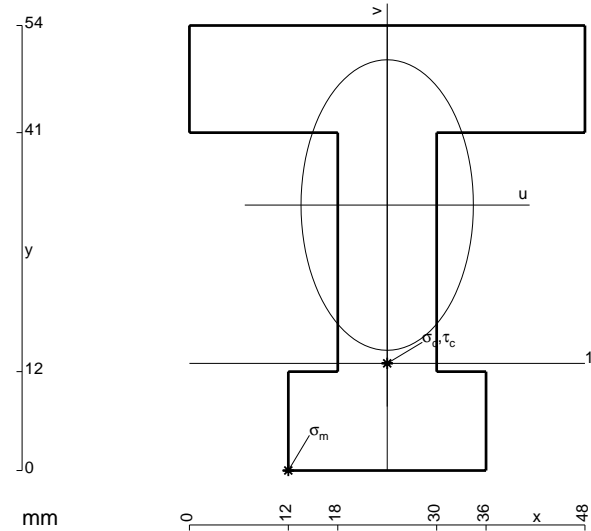
$$= \left[ \frac{3}{4} \frac{x^2}{b} - \frac{1}{3} \frac{x^3}{b^2} - \frac{1}{8} \frac{x^4}{b^3} \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= (3/4 b - 1/3 b - 1/8 b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ} = \frac{7}{24} \frac{Fb^2}{EJ}$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

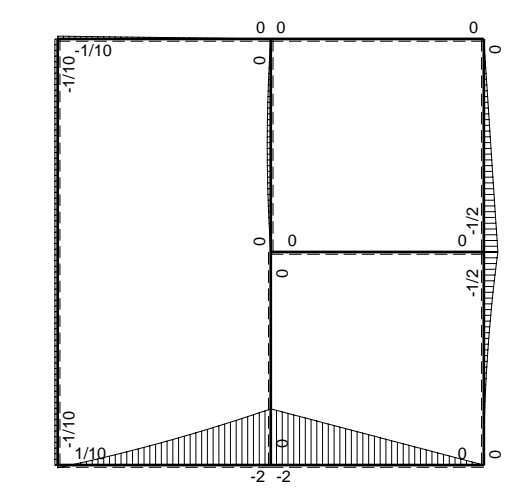
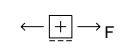
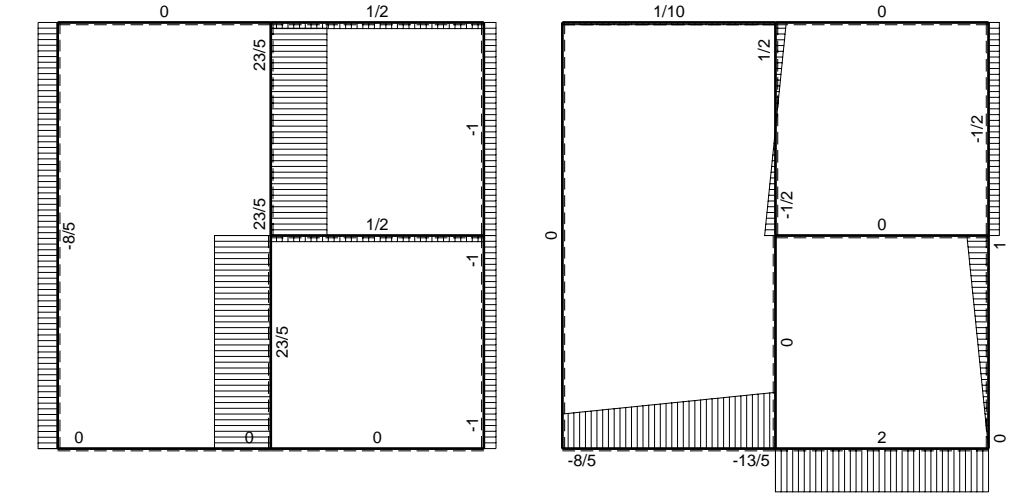
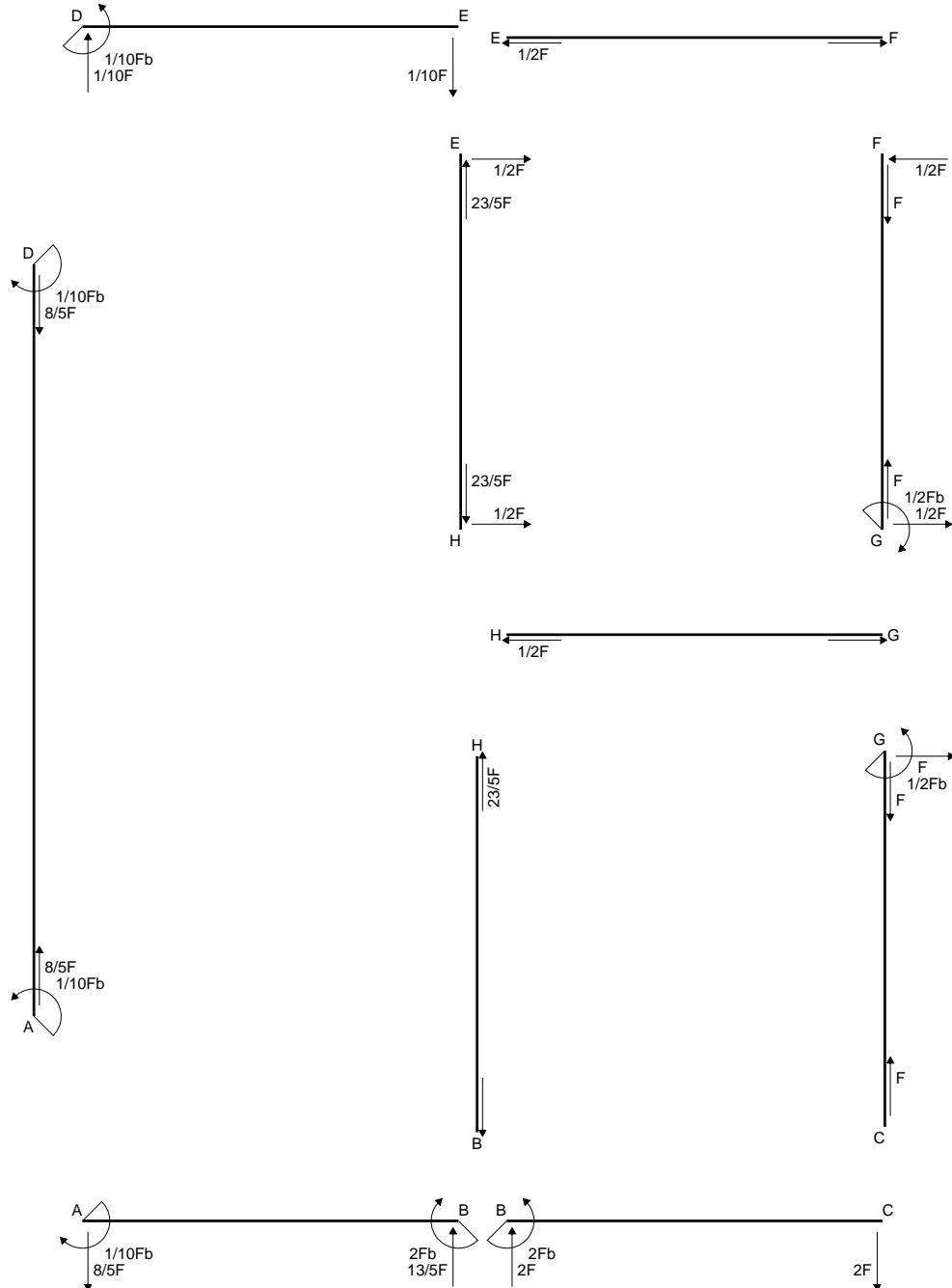
$$= \left[ \frac{x^2}{b} - \frac{5}{6} \frac{x^3}{b^2} + \frac{1}{8} \frac{x^4}{b^3} \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

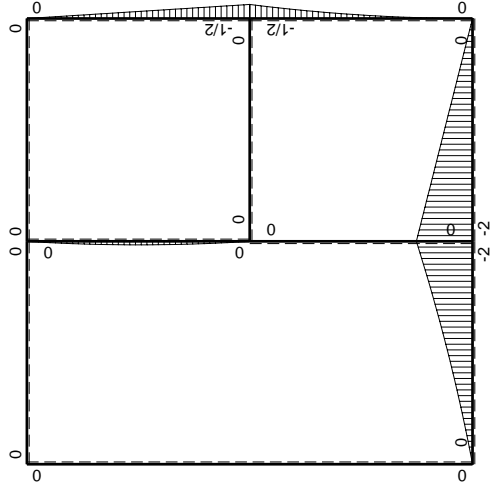
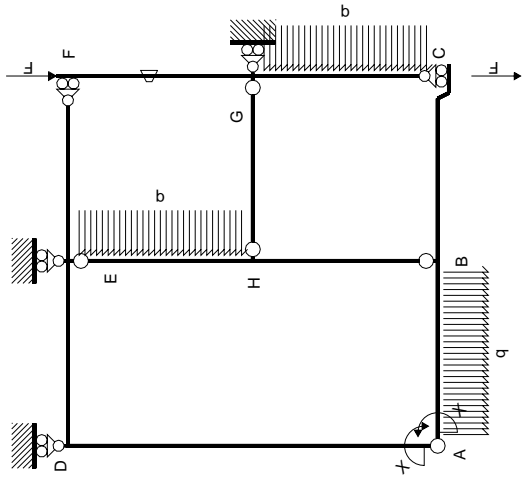
$$= (b - 5/6 b + 1/8 b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ} = \frac{7}{24} \frac{Fb^2}{EJ}$$



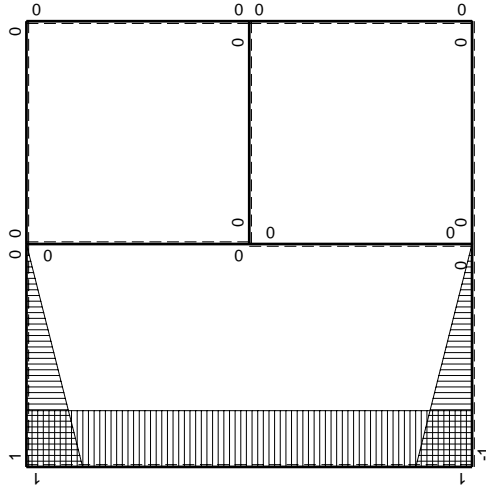
- A = 1260. mm<sup>2</sup>
- J<sub>u</sub> = 391706. mm<sup>4</sup>
- J<sub>v</sub> = 137808. mm<sup>4</sup>
- y<sub>g</sub> = 32.21 mm
- T<sub>y</sub> = 3260. N
- M<sub>x</sub> = -2542800. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -12. mm
- v<sub>m</sub> = -32.21 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -209.1 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 13. mm
- v<sub>c</sub> = -19.21 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -124.7 N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.4 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sub>c</sub><sup>2</sup> + 3τ<sub>c</sub><sup>2</sup> = 125.1 N/mm<sup>2</sup>
- S = 7786. mm<sup>3</sup>







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$-1/2Fx$	$-Fb/EJ$	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	$Fb/EJ$	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	0	0	0	0	0	0+0	0	
BH b	0	0	0	0	0	0			
HE b	0	$-1/2Fx+1/2qx^2$	0	0	0	0	0+0	0	
EH b	0	$1/2Fx-1/2qx^2$	0	0	0	0			
AB	molla asta $-W_{1AB} (W_{0AB} + XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

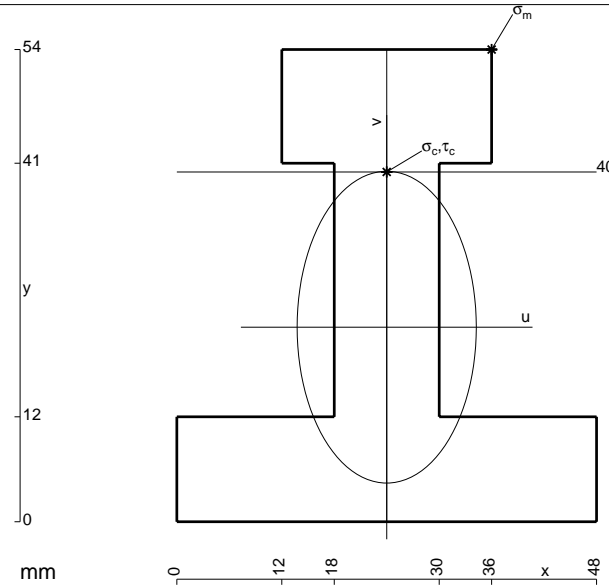
$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

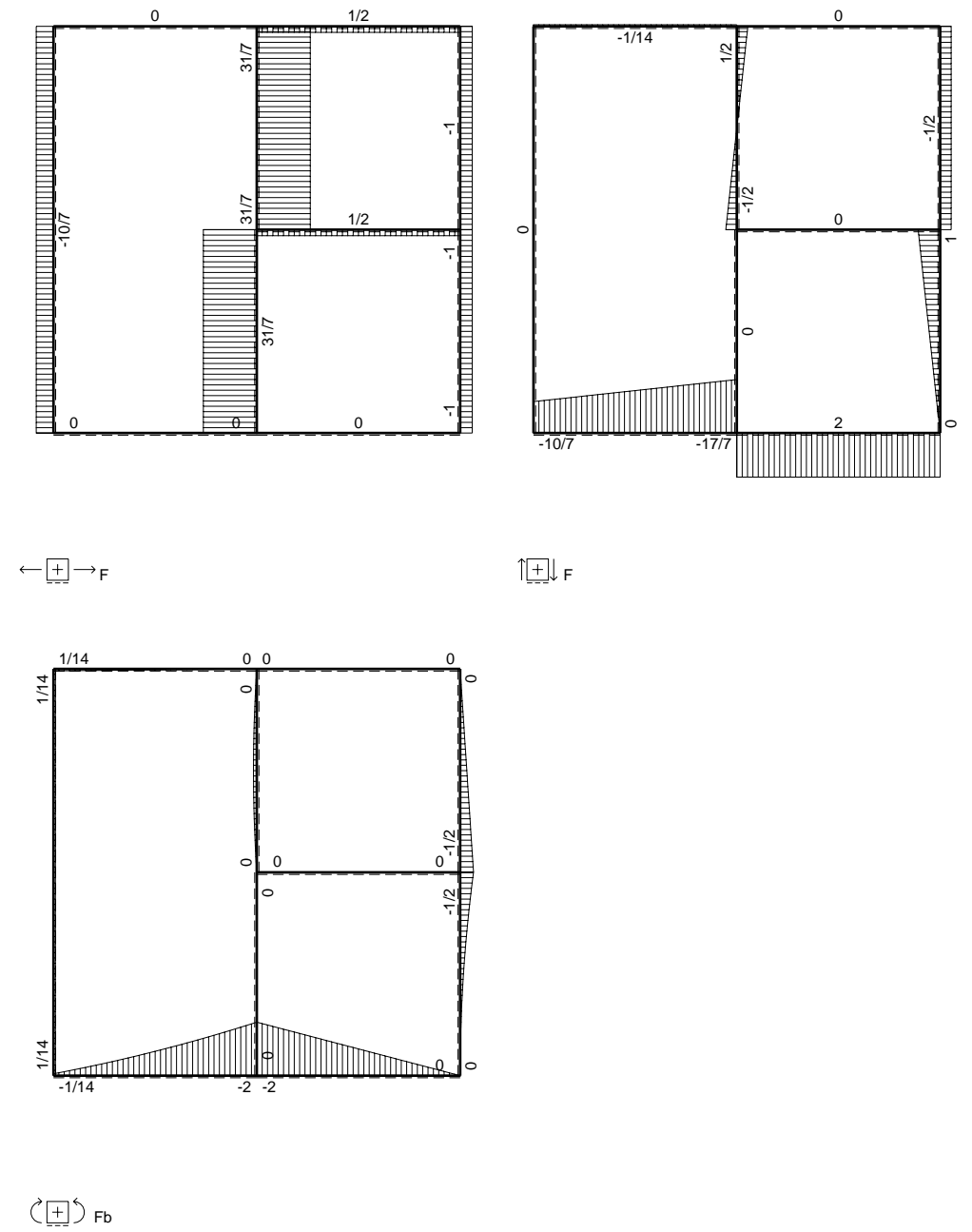
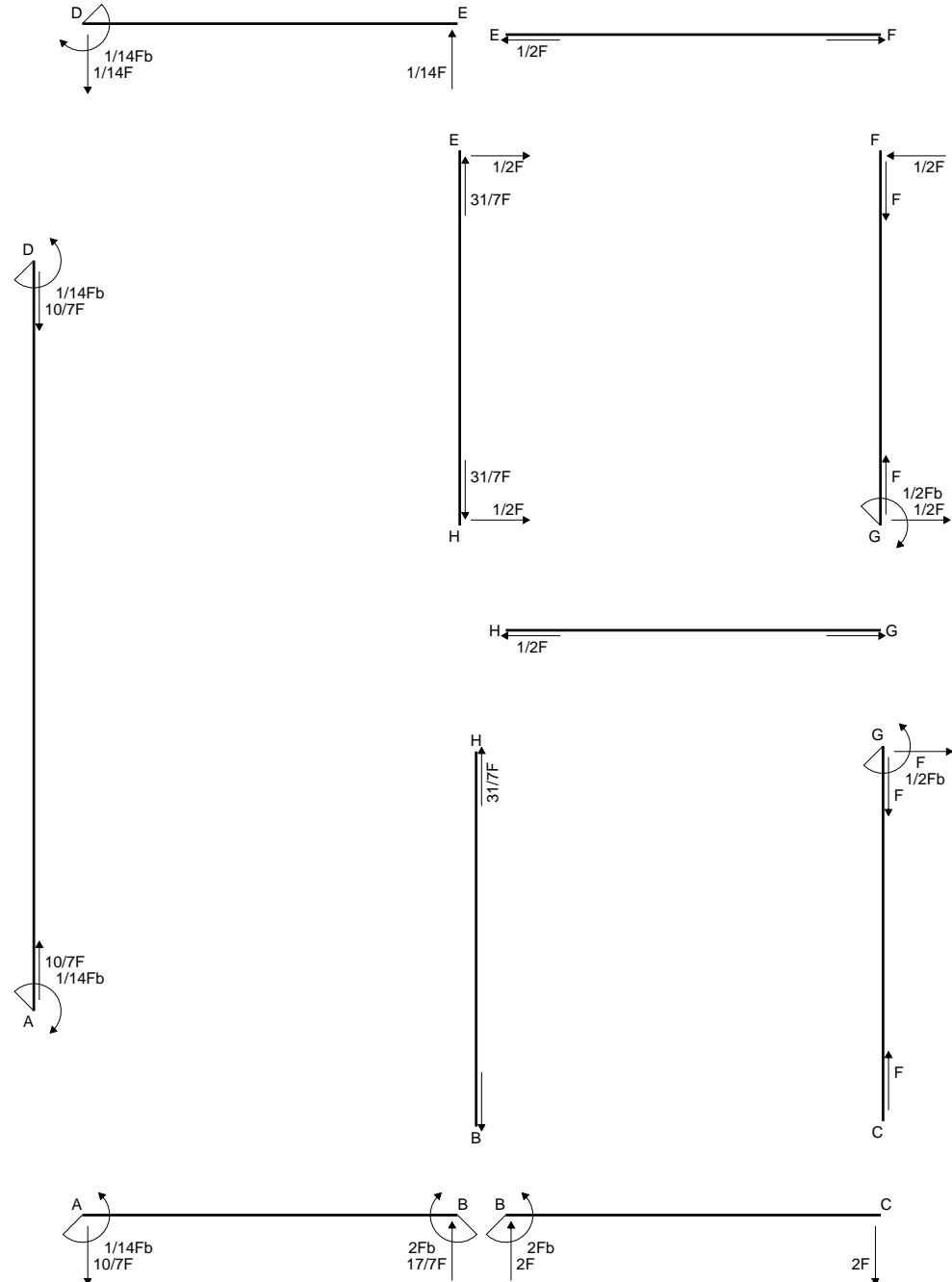
$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

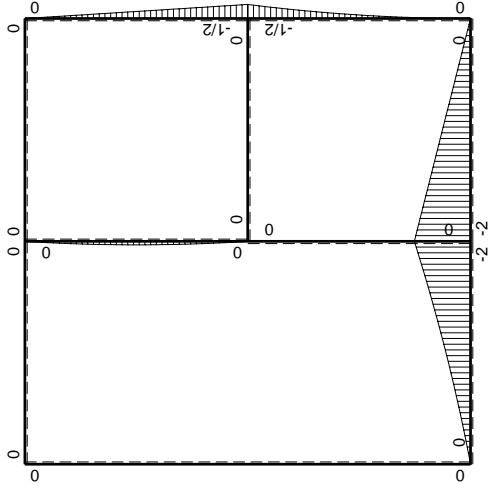
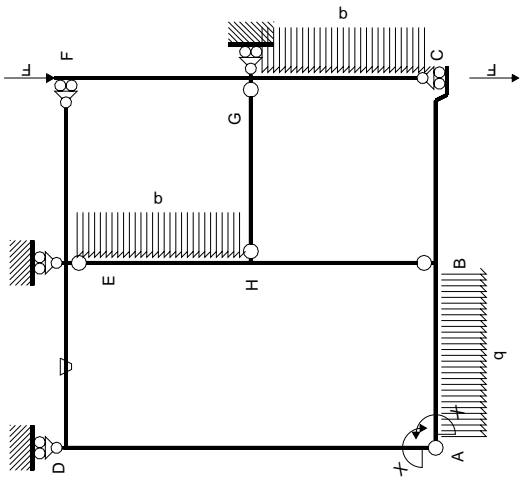
$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

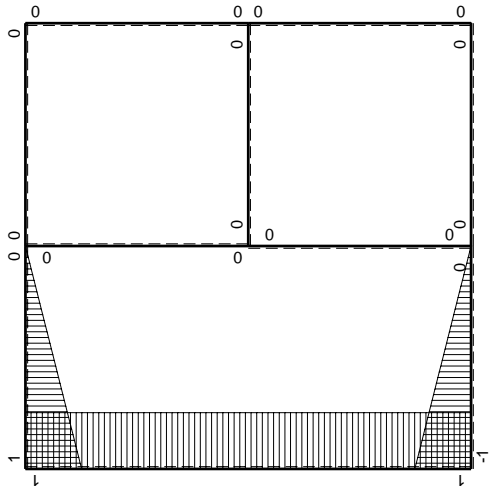


- A = 1236. mm<sup>2</sup>
- J<sub>u</sub> = 393000. mm<sup>4</sup>
- J<sub>v</sub> = 129744. mm<sup>4</sup>
- y<sub>g</sub> = 22.25 mm
- T<sub>y</sub> = 3280. N
- M<sub>x</sub> = -2722400. Nmm
- x<sub>m</sub> = 36. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 12. mm
- v<sub>m</sub> = 31.75 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 220. N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 40. mm
- v<sub>c</sub> = 17.75 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 123. N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.632 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 123.4 N/mm<sup>2</sup>
- S = 8098. mm<sup>3</sup>





$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x / EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	$-Fb/EJ$	0	$-Fb/EJ+Fx/EJ$	$1-2x/b+x^2/b^2$	$(0-1/2)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	0	$Fb/EJ$	0	$-Fx/EJ$	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	0	0	0	0	0	0+0	0	
BH b	0	0	0	0	0	0			
HE b	0	$-1/2Fx+1/2qx^2$	0	0	0	0	0+0	0	
EH b	0	$1/2Fx-1/2qx^2$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$-5/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$1/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

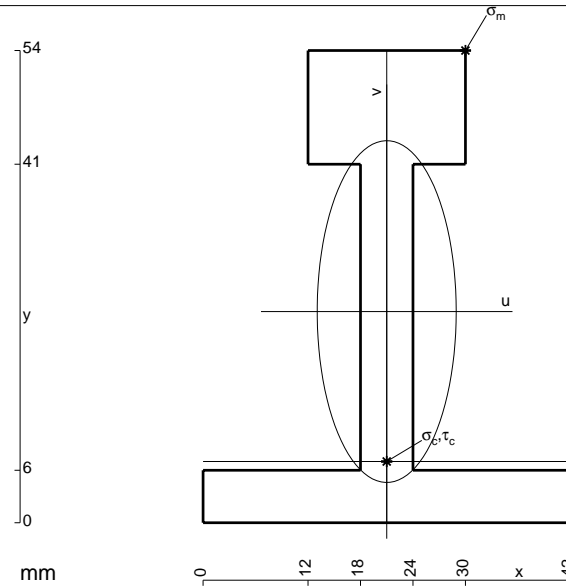
$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (-1 + x/b) \cdot \theta \, dx = \left[ -x + 1/2 x^2/b \right]_0^b \cdot \theta$$

$$= (-b + 1/2 b) \cdot \theta = -1/2 \cdot Fb^2/EJ$$

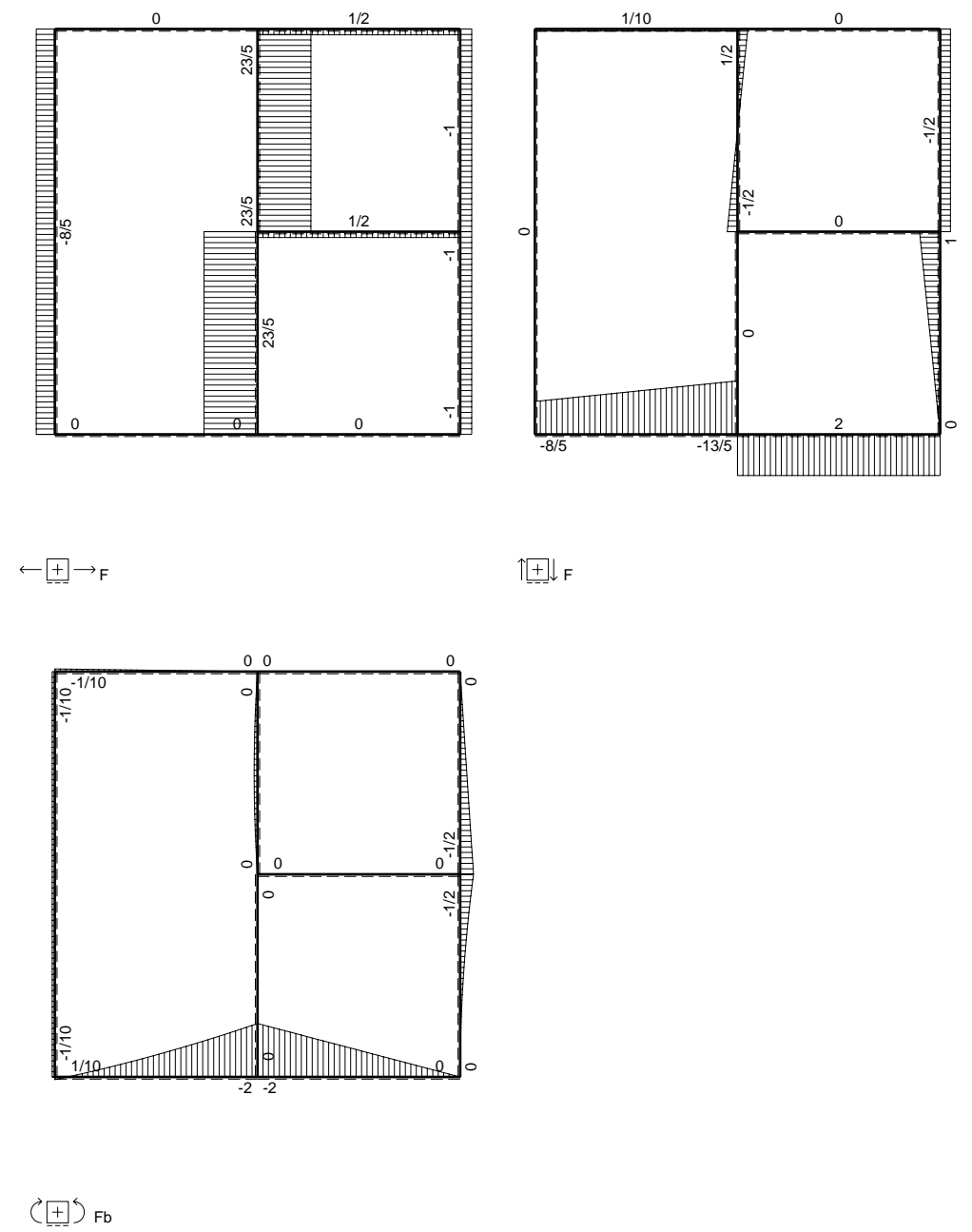
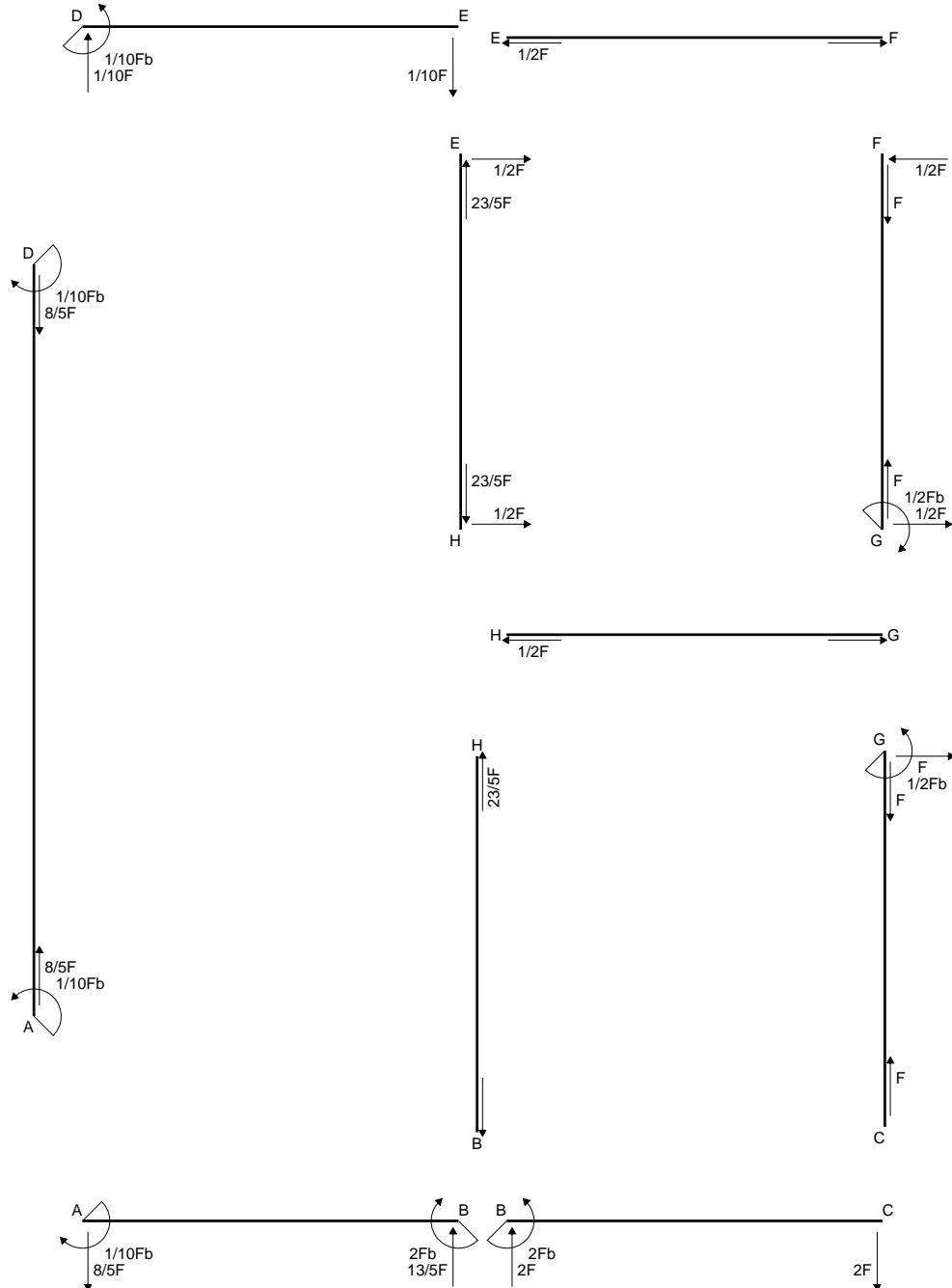
$$L_{ED}^{xo} = \int_0^b (x/b) \cdot \theta \, dx = \left[ 1/2 x^2/b \right]_0^b \cdot \theta$$

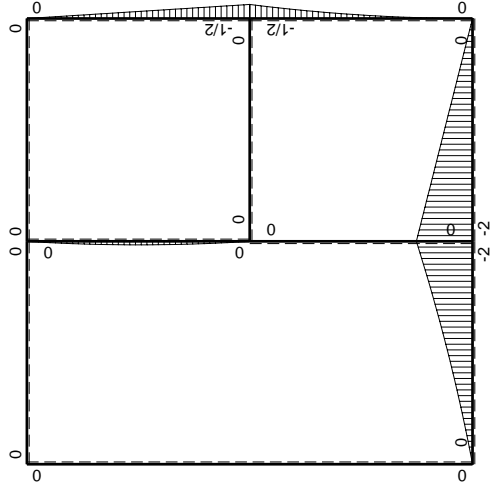
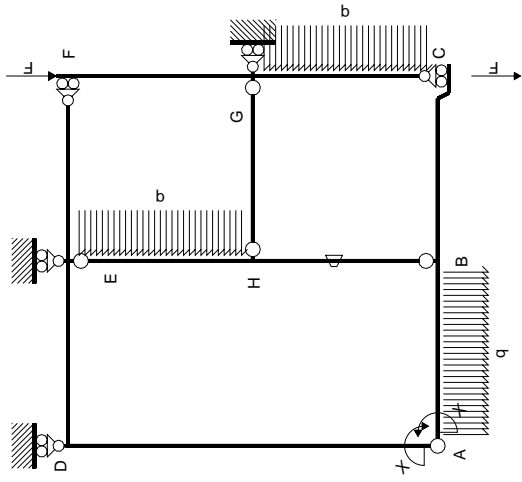
$$= (1/2 b) \cdot \theta = -1/2 \cdot Fb^2/EJ$$



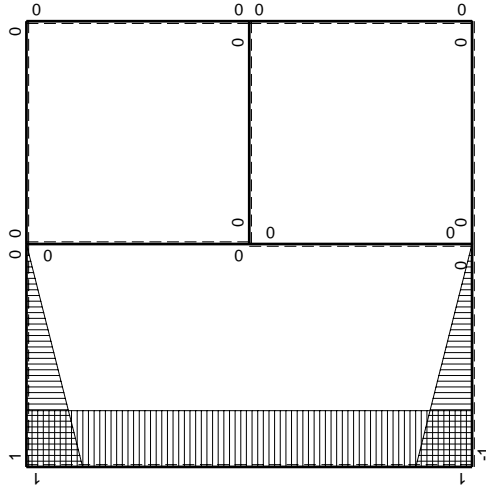
- A = 696. mm<sup>2</sup>
- J<sub>u</sub> = 265885. mm<sup>4</sup>
- J<sub>v</sub> = 43992. mm<sup>4</sup>
- y<sub>g</sub> = 24.15 mm
- T<sub>y</sub> = 2320. N
- M<sub>x</sub> = -2041600. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 9. mm
- v<sub>m</sub> = 29.85 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 229.2 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 7. mm
- v<sub>c</sub> = -17.15 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -131.7 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.904 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 132.4 N/mm<sup>2</sup>
- S = 5435. mm<sup>3</sup>







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
BH b	0	0	$Fb/EJ$	0	0	0			
HE b	0	$-1/2Fx+1/2qx^2$	0	0	0	0	0+0	0	
EH b	0	$1/2Fx-1/2qx^2$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{x_0} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

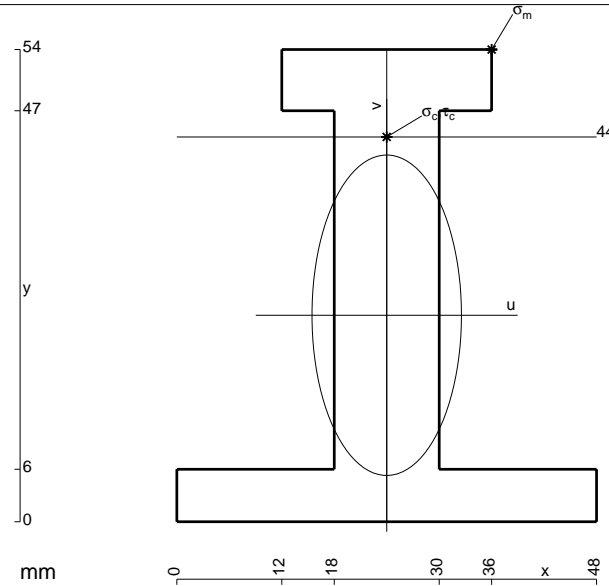
$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

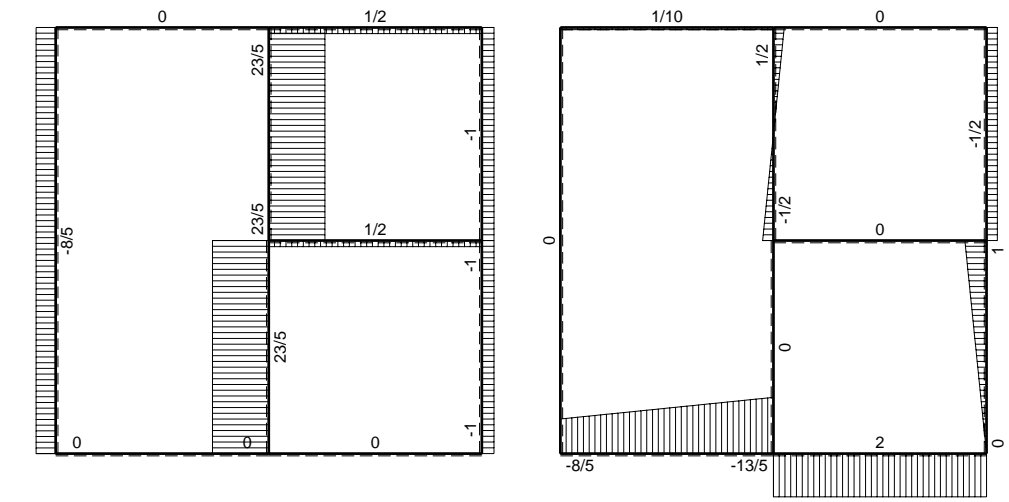
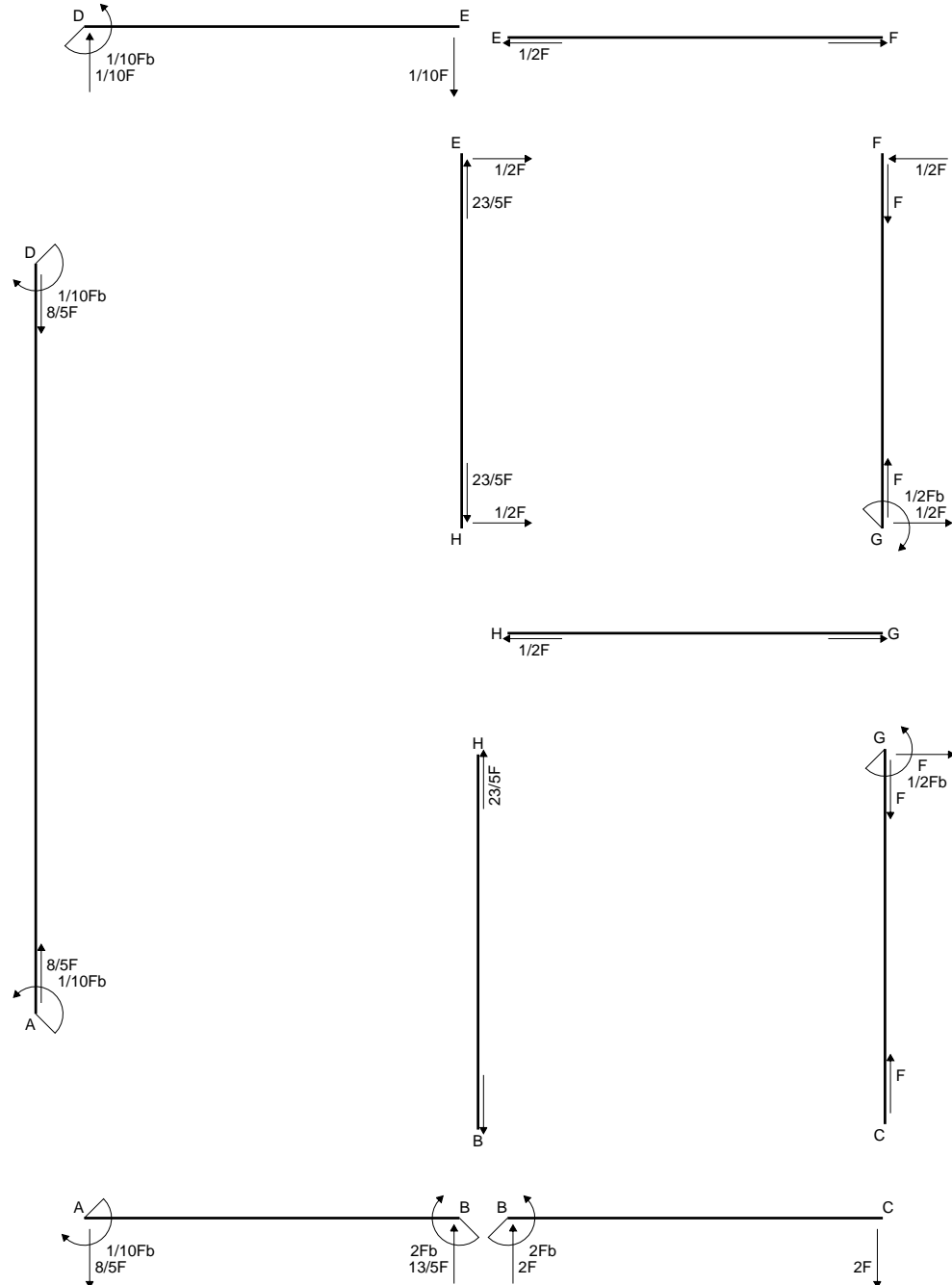
$$L_{BA}^{x_0} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

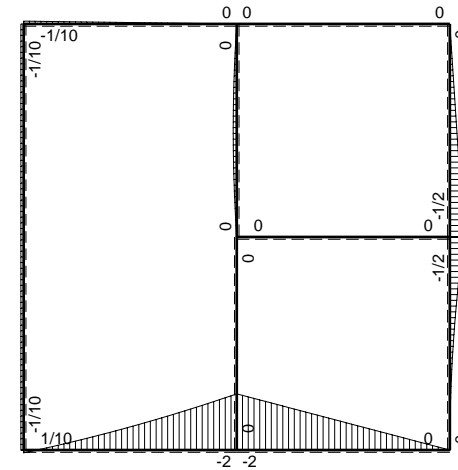


- A = 948. mm<sup>2</sup>
- J<sub>u</sub> = 318391. mm<sup>4</sup>
- J<sub>v</sub> = 69264. mm<sup>4</sup>
- y<sub>g</sub> = 23.61 mm
- T<sub>y</sub> = 2700. N
- M<sub>x</sub> = -2511000. Nmm
- x<sub>m</sub> = 36. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 12. mm
- v<sub>m</sub> = 30.39 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 239.6 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 44. mm
- v<sub>c</sub> = 20.39 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 160.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.749 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 160.9 N/mm<sup>2</sup>
- S = 5305. mm<sup>3</sup>

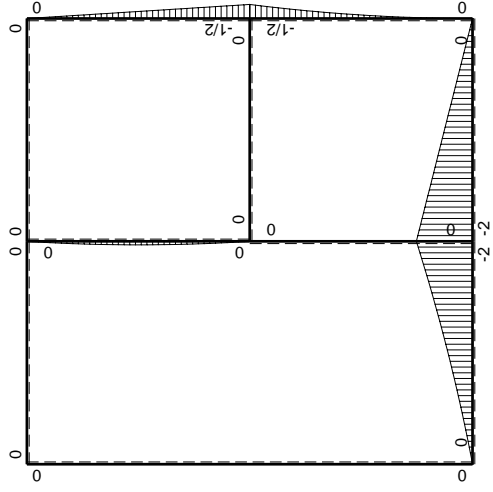
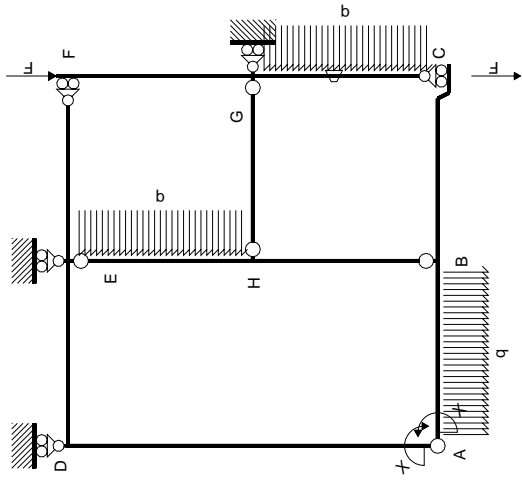


← ⊕ → F

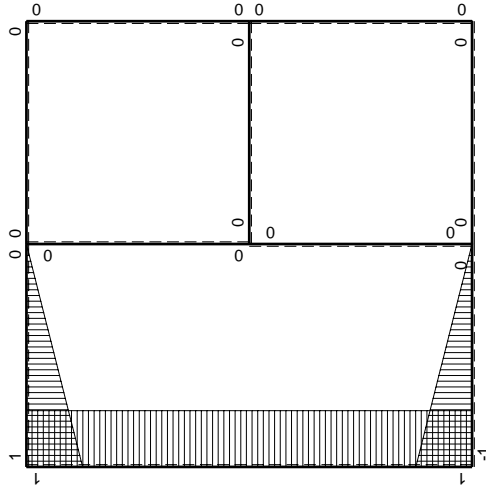
↑ ⊕ ↓ F



⊕ ⊖ Fb



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	$-Fb/EJ$	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	$Fb/EJ$	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	0	0	0	0	0	0+0	0	
BH b	0	0	0	0	0	0			
HE b	0	$-1/2Fx+1/2qx^2$	0	0	0	0	0+0	0	
EH b	0	$1/2Fx-1/2qx^2$	0	0	0	0			
AB	molla asta $-W_{1AB} (W_{0AB} + XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ}$$

$$= (b - b + 1/3 b) \frac{1}{EJ} = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx = \left[ 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ}$$

$$= (1/3 b) \frac{1}{EJ} = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

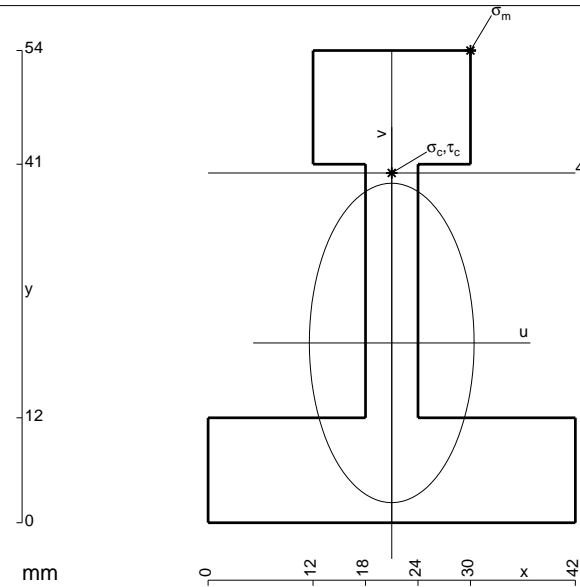
$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

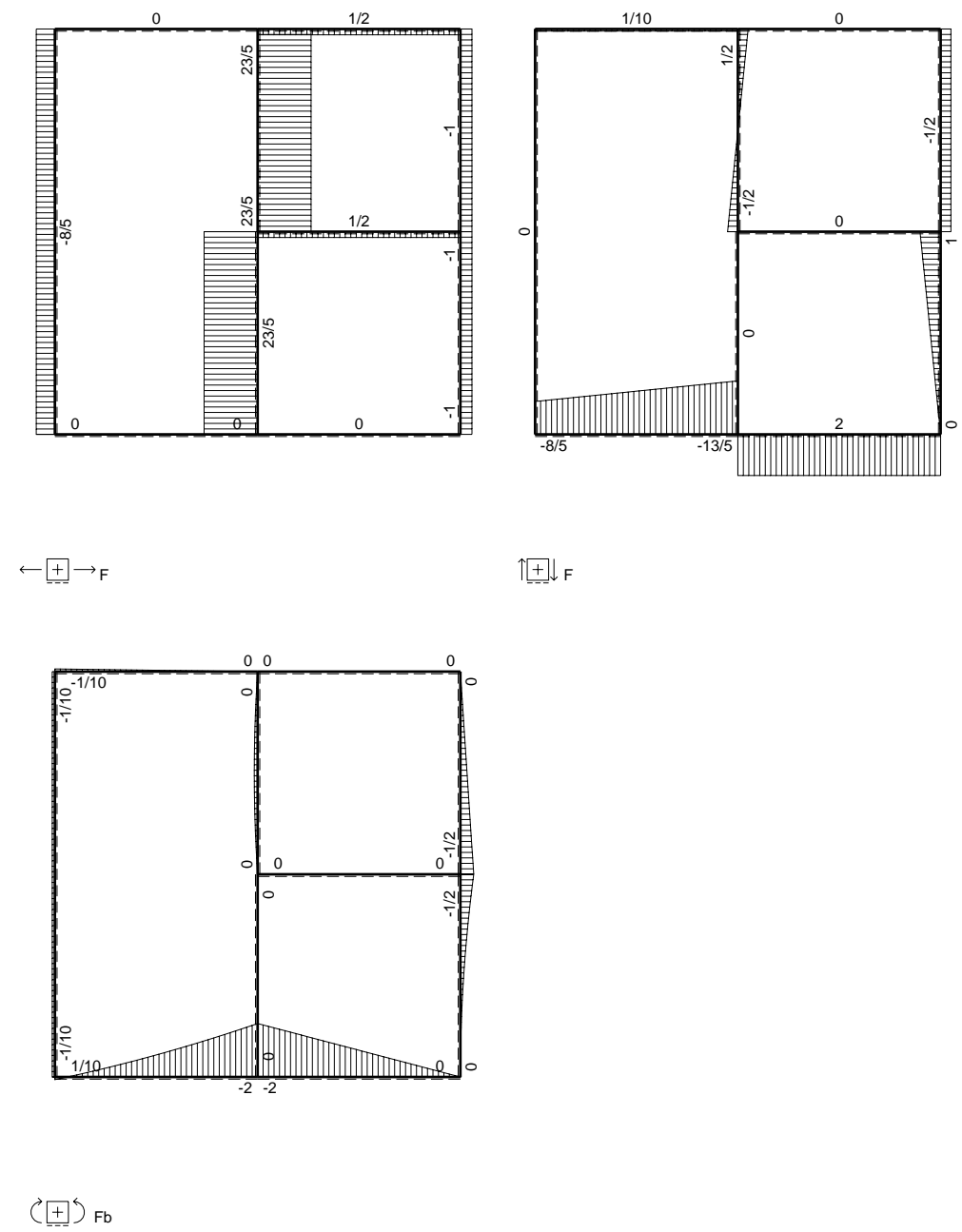
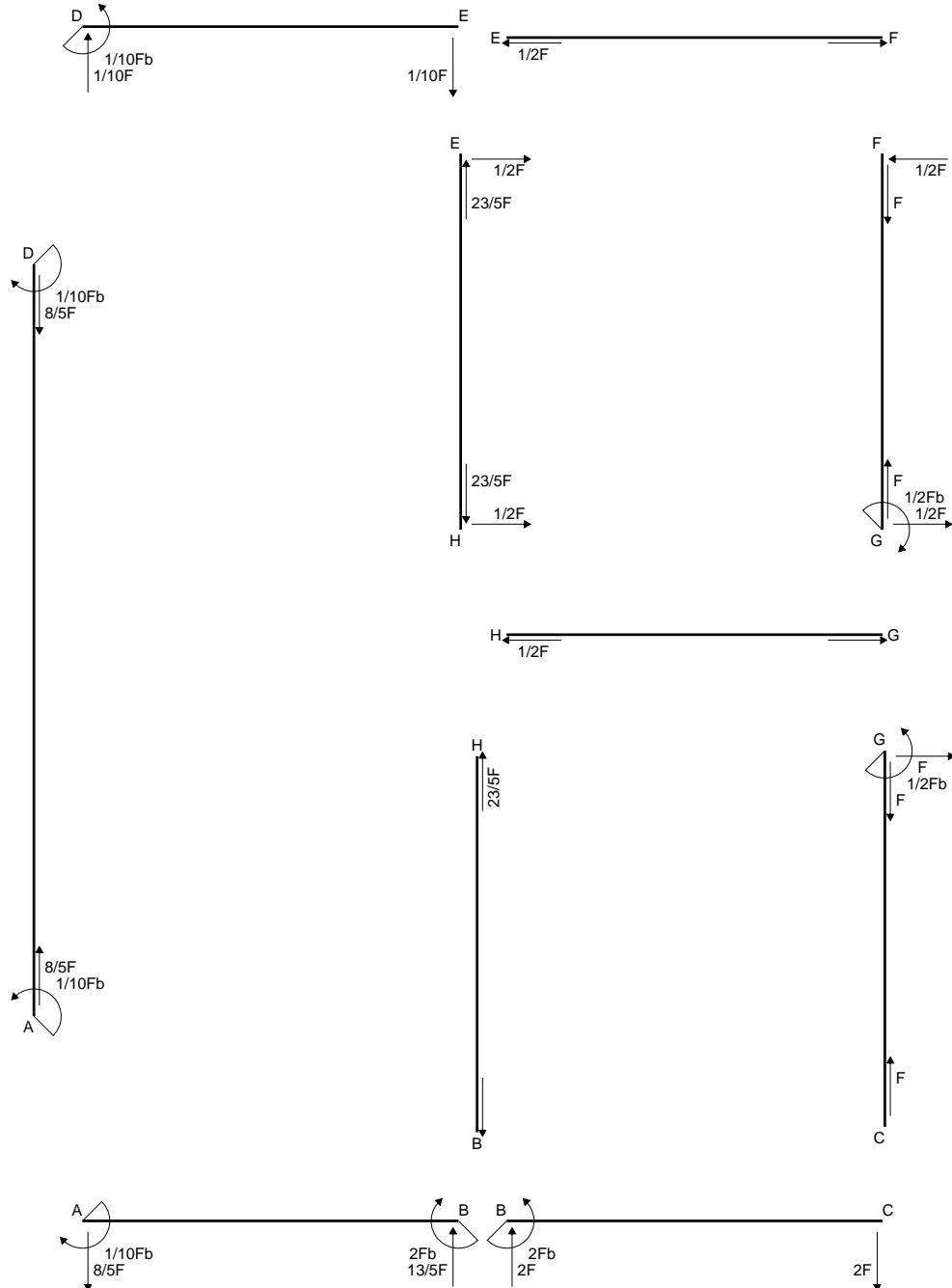
$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

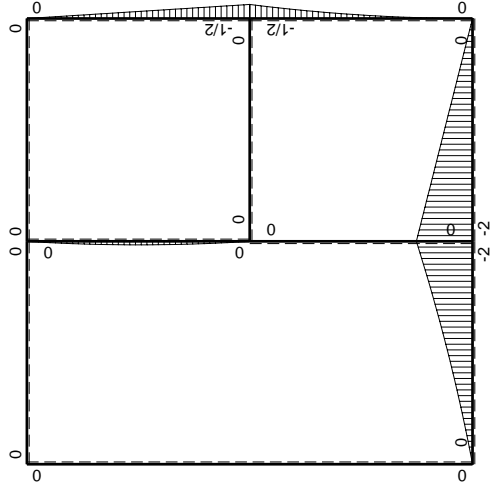
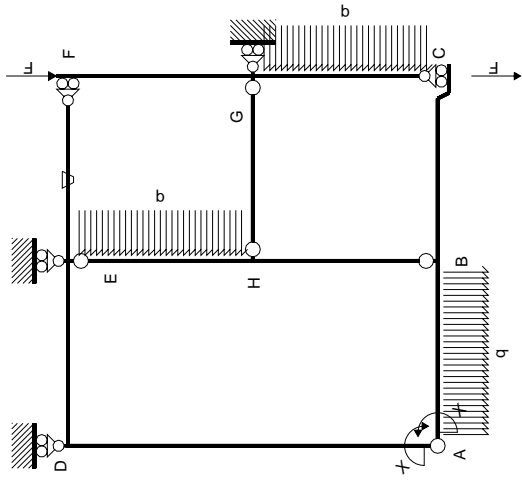
$$= (b - 5/6 b + 1/8 b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$



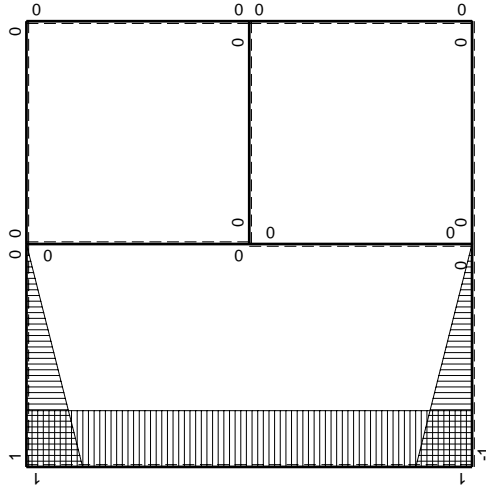
- A = 912. mm<sup>2</sup>
- J<sub>u</sub> = 304351. mm<sup>4</sup>
- J<sub>v</sub> = 80928. mm<sup>4</sup>
- y<sub>g</sub> = 20.56 mm
- T<sub>y</sub> = 3700. N
- M<sub>x</sub> = -1813000. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 9. mm
- v<sub>m</sub> = 33.44 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 199.2 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 40. mm
- v<sub>c</sub> = 19.44 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 115.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 13.02 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 118. N/mm<sup>2</sup>
- S = 6424. mm<sup>3</sup>







$M_0$  flessione da carichi assegnati



$M_X$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
FE b	0	0	$Fb/EJ$	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	0	0	0	0	0	0+0	0	
BH b	0	0	0	0	0	0			
HE b	0	$-1/2Fx+1/2qx^2$	0	0	0	0	0+0	0	
EH b	0	$1/2Fx-1/2qx^2$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

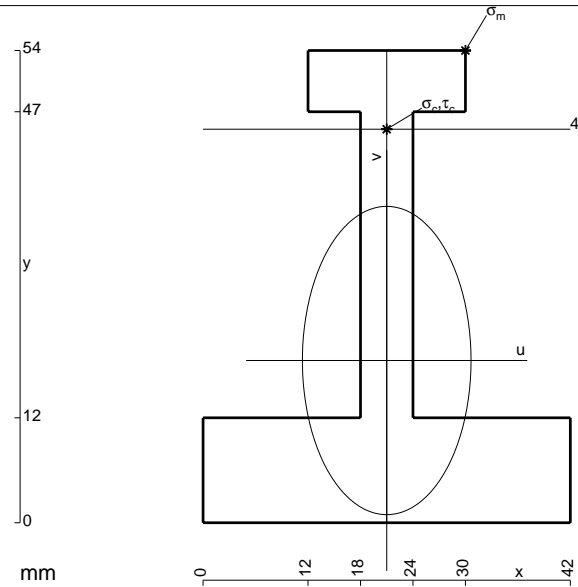
$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

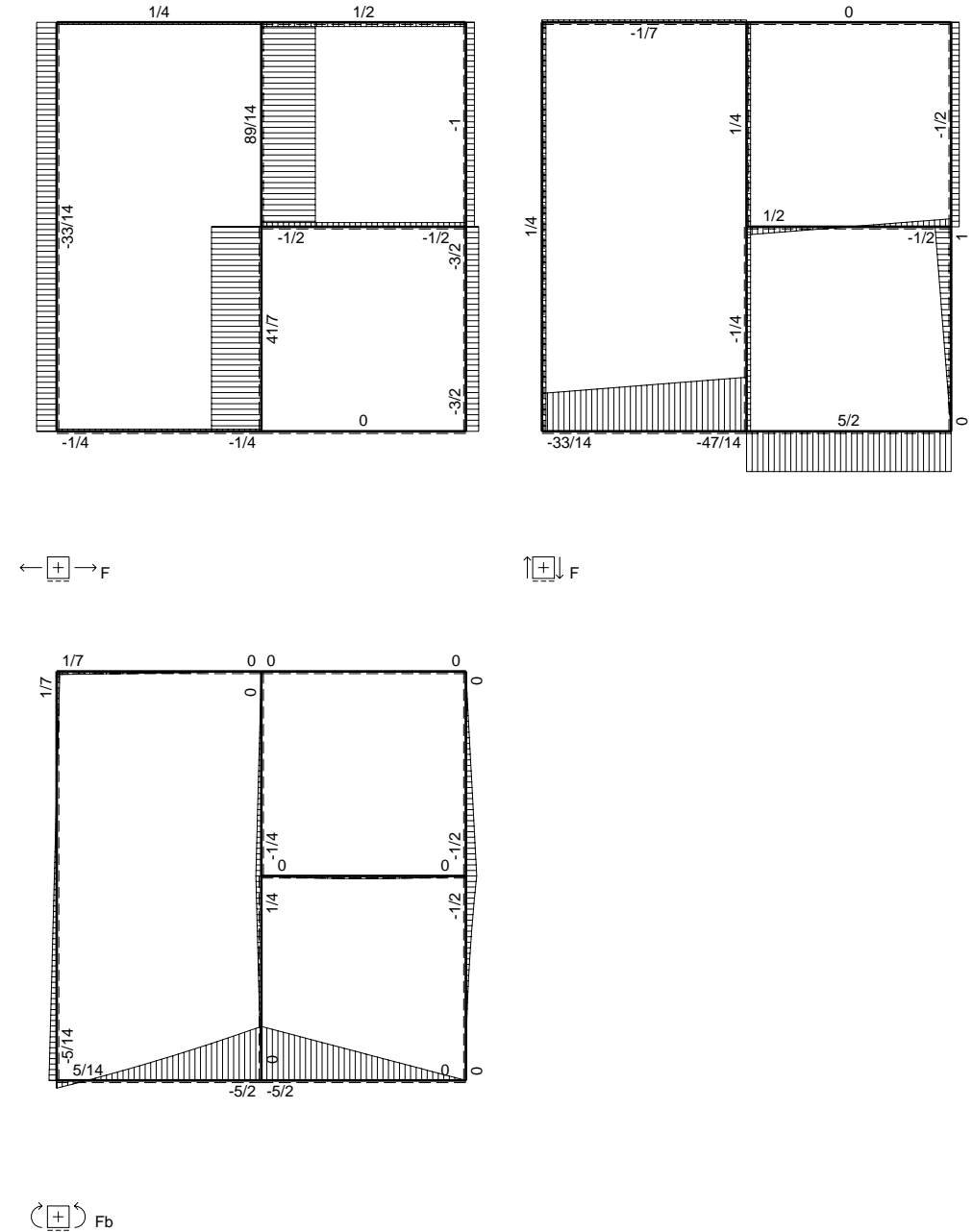
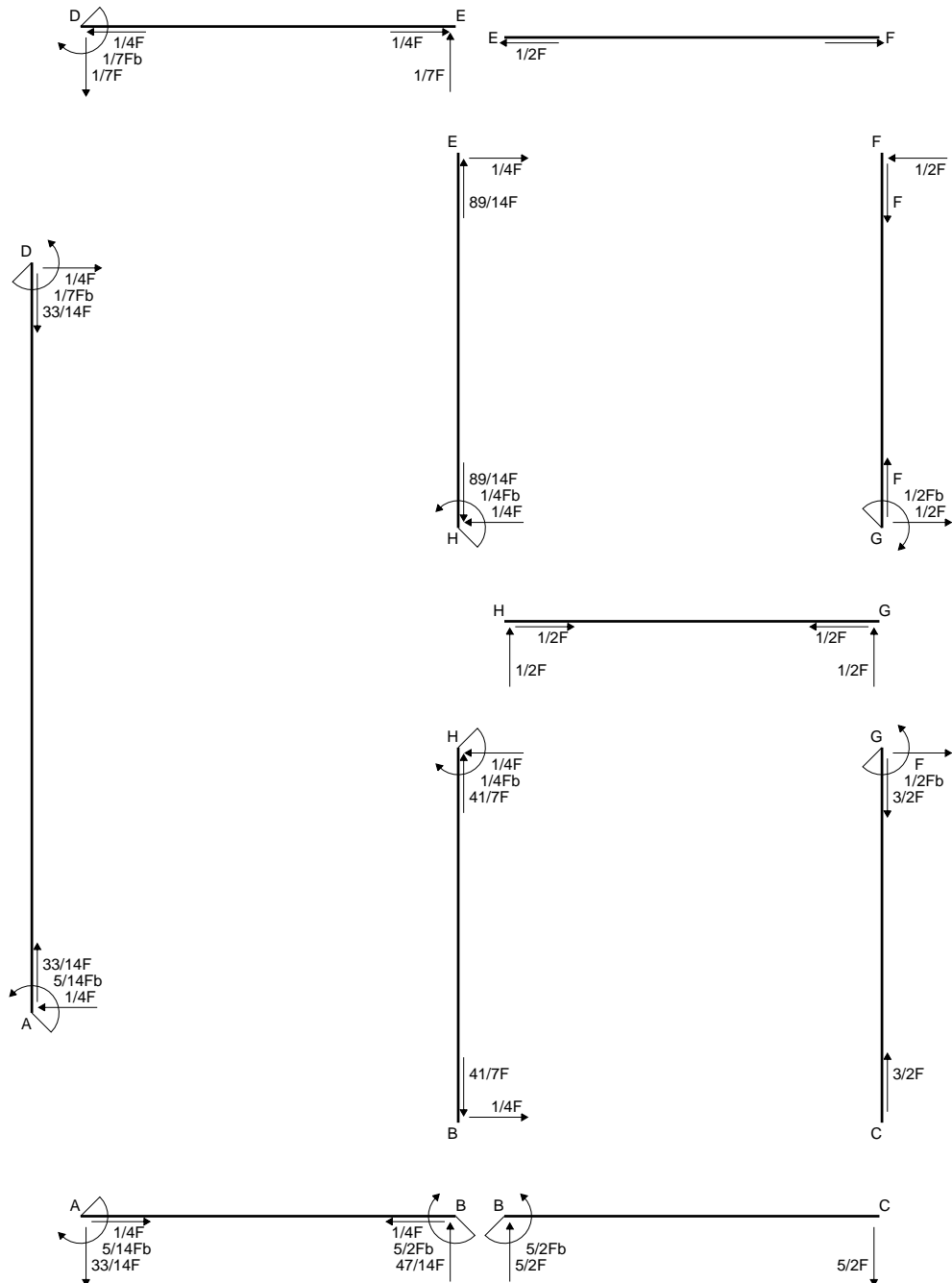
$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

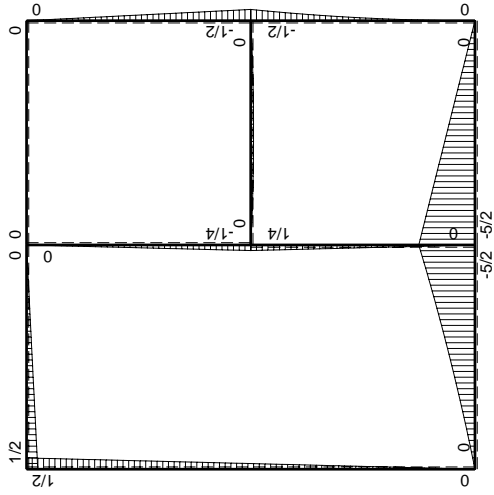
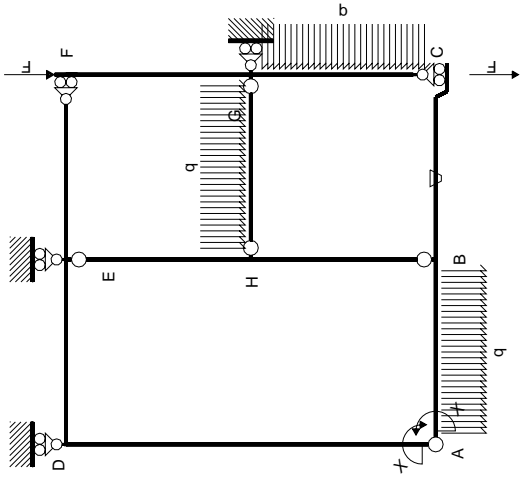
$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$



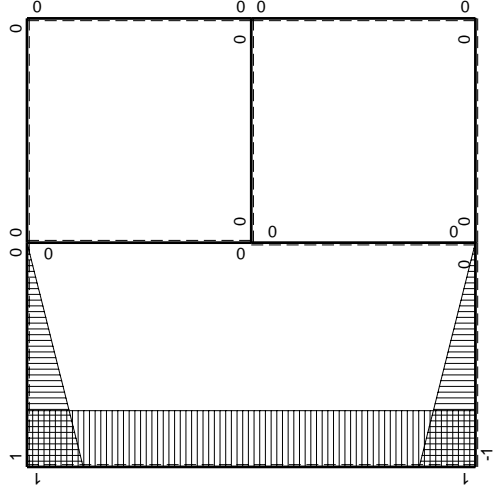
- A = 840. mm<sup>2</sup>
- J<sub>u</sub> = 261182. mm<sup>4</sup>
- J<sub>v</sub> = 78120. mm<sup>4</sup>
- y<sub>g</sub> = 18.55 mm
- T<sub>y</sub> = 2900. N
- M<sub>x</sub> = -1537000. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 9. mm
- v<sub>m</sub> = 35.45 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 208.6 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 45. mm
- v<sub>c</sub> = 26.45 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 155.7 N/mm<sup>2</sup>
- τ<sub>c</sub> = 8.059 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 156.3 N/mm<sup>2</sup>
- S = 4355. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x / EJ dx$	
AB b	$-1+x/b$	$-2Fx-1/2qx^2$	0	$2Fx-3/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(3/8+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$5/2Fb-3Fx+1/2qx^2$	0	$5/2Fx-3Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-5/2Fb+5/2Fx$	$-Fb/EJ$	0	0	0	0+0	0	
CB b	0	$5/2Fx$	$Fb/EJ$	0	0	0			
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1			
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
GH b	0	$-1/2Fx+1/2qx^2$	0	0	0	0			
HB b	0	$1/4Fb-1/4Fx$	0	0	0	0	0+0	0	
BH b	0	$-1/4Fx$	0	0	0	0			
HE b	0	$-1/4Fb+1/4Fx$	0	0	0	0	0+0	0	
EH b	0	$1/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB} (W_{0AB} + XW_{1AB}) / k_{AB}$								$1/4Xb/EJ$
	totali							$25/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-5/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (2x/b - 3/2 x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 1/2 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 1/2 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (5/2 x/b - 3 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 5/4 x^2/b - x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (5/4 b - b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

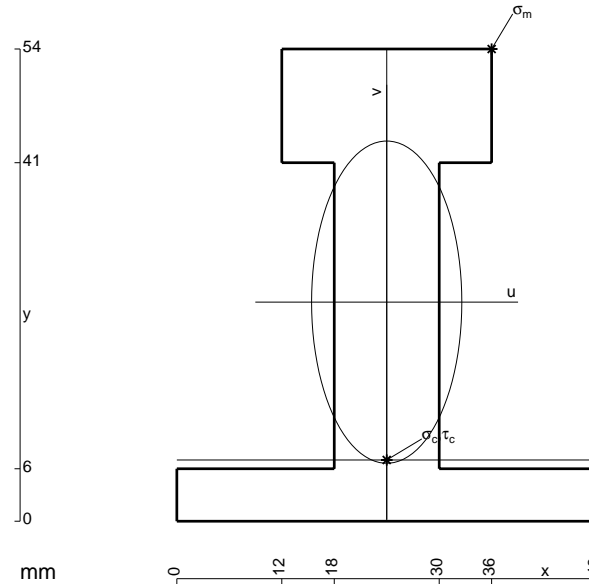
$$= (b - 1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/2 b - 1/2 b + 1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$

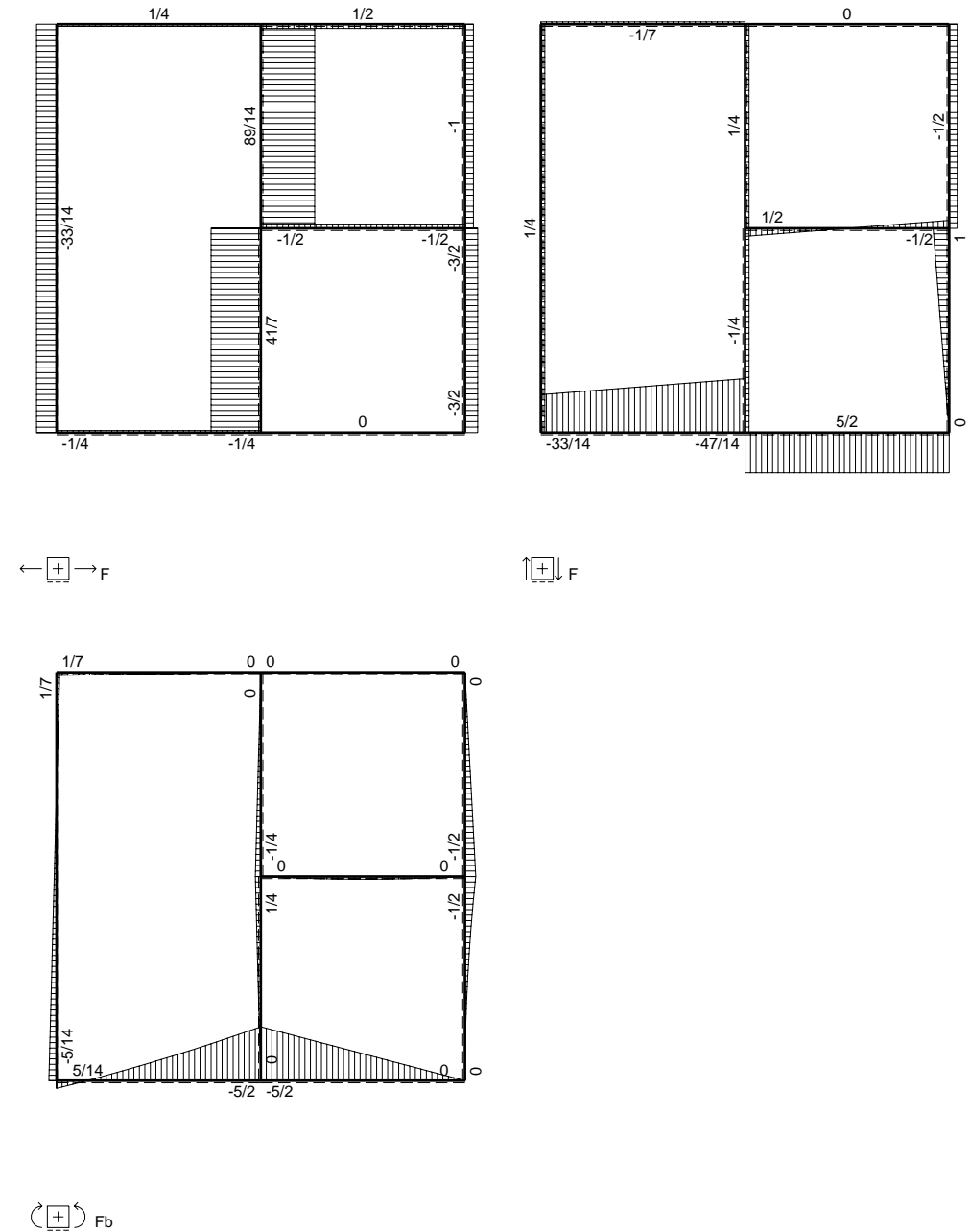
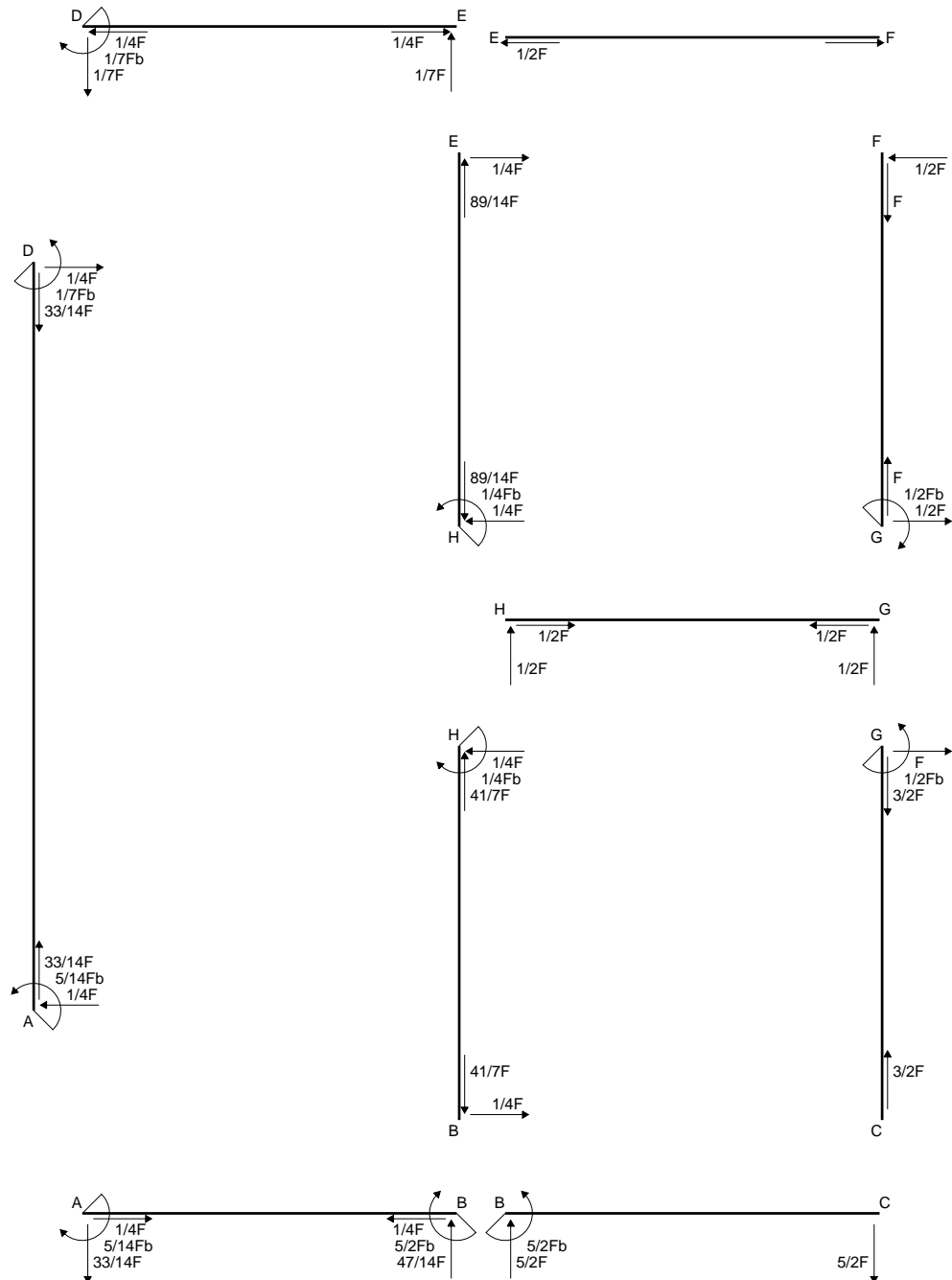
$$L_{ED}^{xo} = \int_0^b (1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

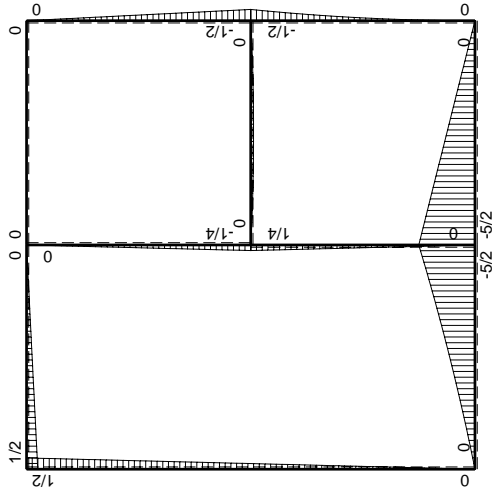
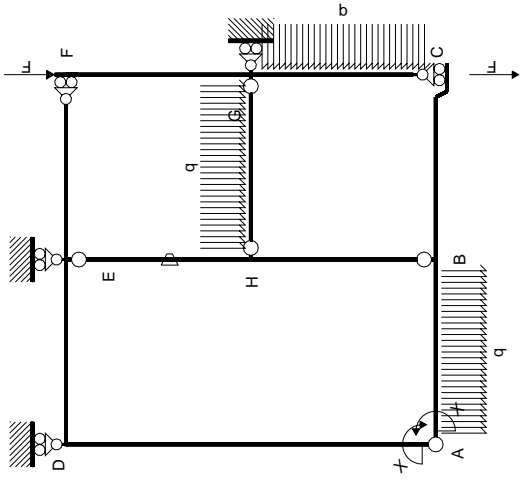
$$= (1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$



- A = 1020. mm<sup>2</sup>
- J<sub>u</sub> = 346417. mm<sup>4</sup>
- J<sub>v</sub> = 75312. mm<sup>4</sup>
- y<sub>g</sub> = 25.05 mm
- T<sub>y</sub> = 4525. N
- M<sub>x</sub> = -2624500. Nmm
- x<sub>m</sub> = 36. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 12. mm
- v<sub>m</sub> = 28.95 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 219.3 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 7. mm
- v<sub>c</sub> = -18.05 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -136.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.156 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 137.3 N/mm<sup>2</sup>
- S = 6574. mm<sup>3</sup>

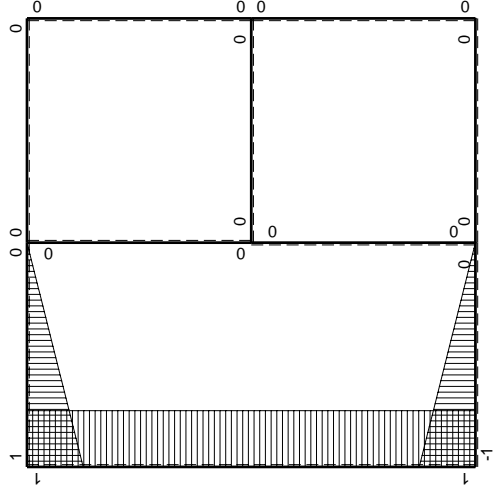






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_1$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-2Fx-1/2qx^2$	0	$2Fx-3/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(3/8+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$5/2Fb-3Fx+1/2qx^2$	0	$5/2Fx-3Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-5/2Fb+5/2Fx$	0	0	0	0	0+0	0	
CB b	0	$5/2Fx$	0	0	0	0			
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1			
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
GH b	0	$-1/2Fx+1/2qx^2$	0	0	0	0			
HB b	0	$1/4Fb-1/4Fx$	0	0	0	0	0+0	0	
BH b	0	$-1/4Fx$	0	0	0	0			
HE b	0	$-1/4Fb+1/4Fx$	$-Fb/EJ$	0	0	0	0+0	0	
EH b	0	$1/4Fx$	$Fb/EJ$	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$25/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-5/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx + 1 \cdot \frac{1}{4} \frac{b}{EJ} = \left[ x - \frac{x^2}{b} + \frac{1}{3} \frac{x^3}{b^2} \right]_0^b \frac{1}{EJ} + 1 \cdot \frac{1}{4} \frac{b}{EJ}$$

$$= (b - b + \frac{1}{3}b) \frac{1}{EJ} + 1 \cdot \frac{1}{4} \frac{b}{EJ} = \frac{7}{12} \frac{b}{EJ}$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx + 1 \cdot \frac{1}{4} \frac{b}{EJ} = \left[ \frac{1}{3} \frac{x^3}{b^2} \right]_0^b \frac{1}{EJ} + 1 \cdot \frac{1}{4} \frac{b}{EJ}$$

$$= (\frac{1}{3}b) \frac{1}{EJ} + 1 \cdot \frac{1}{4} \frac{b}{EJ} = \frac{7}{12} \frac{b}{EJ}$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \frac{b}{EJ}$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \frac{b}{EJ}$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx = \left[ x - \frac{x^2}{b} + \frac{1}{3} \frac{x^3}{b^2} \right]_0^b \frac{1}{EJ}$$

$$= (b - b + \frac{1}{3}b) \frac{1}{EJ} = \frac{1}{3} \frac{b}{EJ}$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx = \left[ \frac{1}{3} \frac{x^3}{b^2} \right]_0^b \frac{1}{EJ}$$

$$= (\frac{1}{3}b) \frac{1}{EJ} = \frac{1}{3} \frac{b}{EJ}$$

$$L_{AB}^{xo} = \int_0^b (2x/b - \frac{3}{2} \frac{x^2}{b^2} - \frac{1}{2} \frac{x^3}{b^3}) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= \left[ \frac{x^2}{b} - \frac{1}{2} \frac{x^3}{b^2} - \frac{1}{8} \frac{x^4}{b^3} \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= (b - \frac{1}{2}b - \frac{1}{8}b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ} = \frac{3}{8} \frac{Fb^2}{EJ}$$

$$L_{BA}^{xo} = \int_0^b (\frac{5}{2} \frac{x}{b} - 3 \frac{x^2}{b^2} + \frac{1}{2} \frac{x^3}{b^3}) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= \left[ \frac{5}{4} \frac{x^2}{b} - \frac{x^3}{b^2} + \frac{1}{8} \frac{x^4}{b^3} \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= (\frac{5}{4}b - b + \frac{1}{8}b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ} = \frac{3}{8} \frac{Fb^2}{EJ}$$

$$L_{AD}^{xo} = \int_0^{2b} (\frac{1}{4} \frac{x}{b}) Fb \frac{1}{EJ} dx = \left[ \frac{1}{8} \frac{x^2}{b} \right]_0^{2b} Fb \frac{1}{EJ}$$

$$= (\frac{1}{2}b) Fb \frac{1}{EJ} = \frac{1}{2} \frac{Fb^2}{EJ}$$

$$L_{DA}^{xo} = \int_0^{2b} (\frac{1}{2} - \frac{1}{4} \frac{x}{b}) Fb \frac{1}{EJ} dx = \left[ \frac{1}{2}x - \frac{1}{8} \frac{x^2}{b} \right]_0^{2b} Fb \frac{1}{EJ}$$

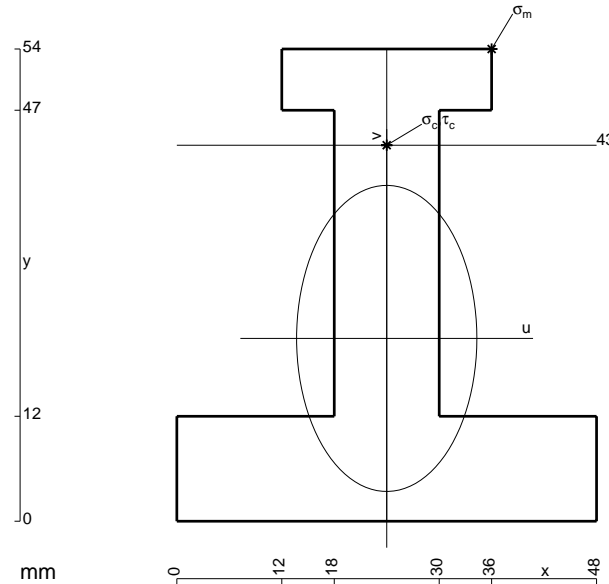
$$= (b - \frac{1}{2}b) Fb \frac{1}{EJ} = \frac{1}{2} \frac{Fb^2}{EJ}$$

$$L_{DE}^{xo} = \int_0^b (\frac{1}{2} - \frac{x}{b} + \frac{1}{2} \frac{x^2}{b^2}) Fb \frac{1}{EJ} dx = \left[ \frac{1}{2}x - \frac{1}{2} \frac{x^2}{b} + \frac{1}{6} \frac{x^3}{b^2} \right]_0^b Fb \frac{1}{EJ}$$

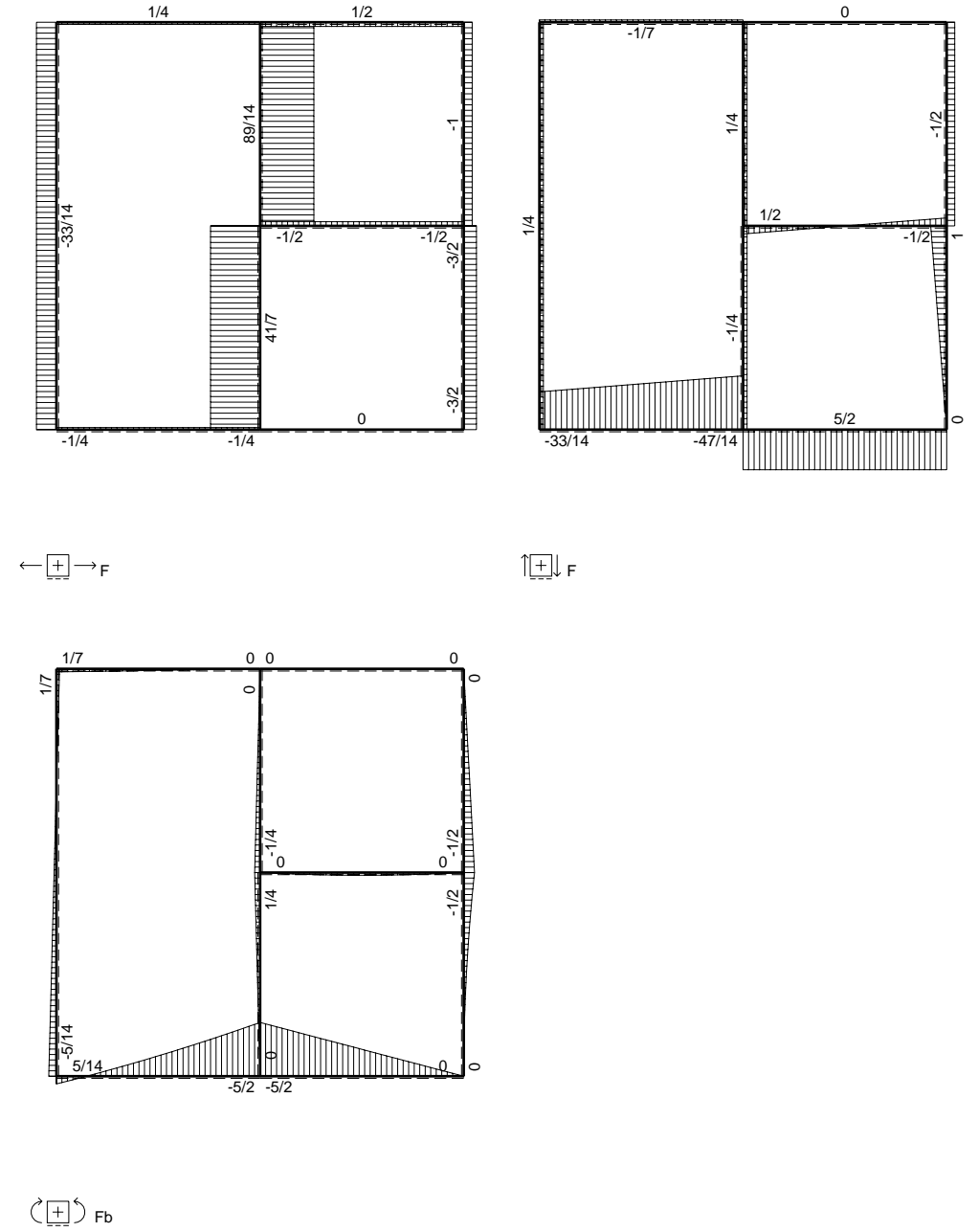
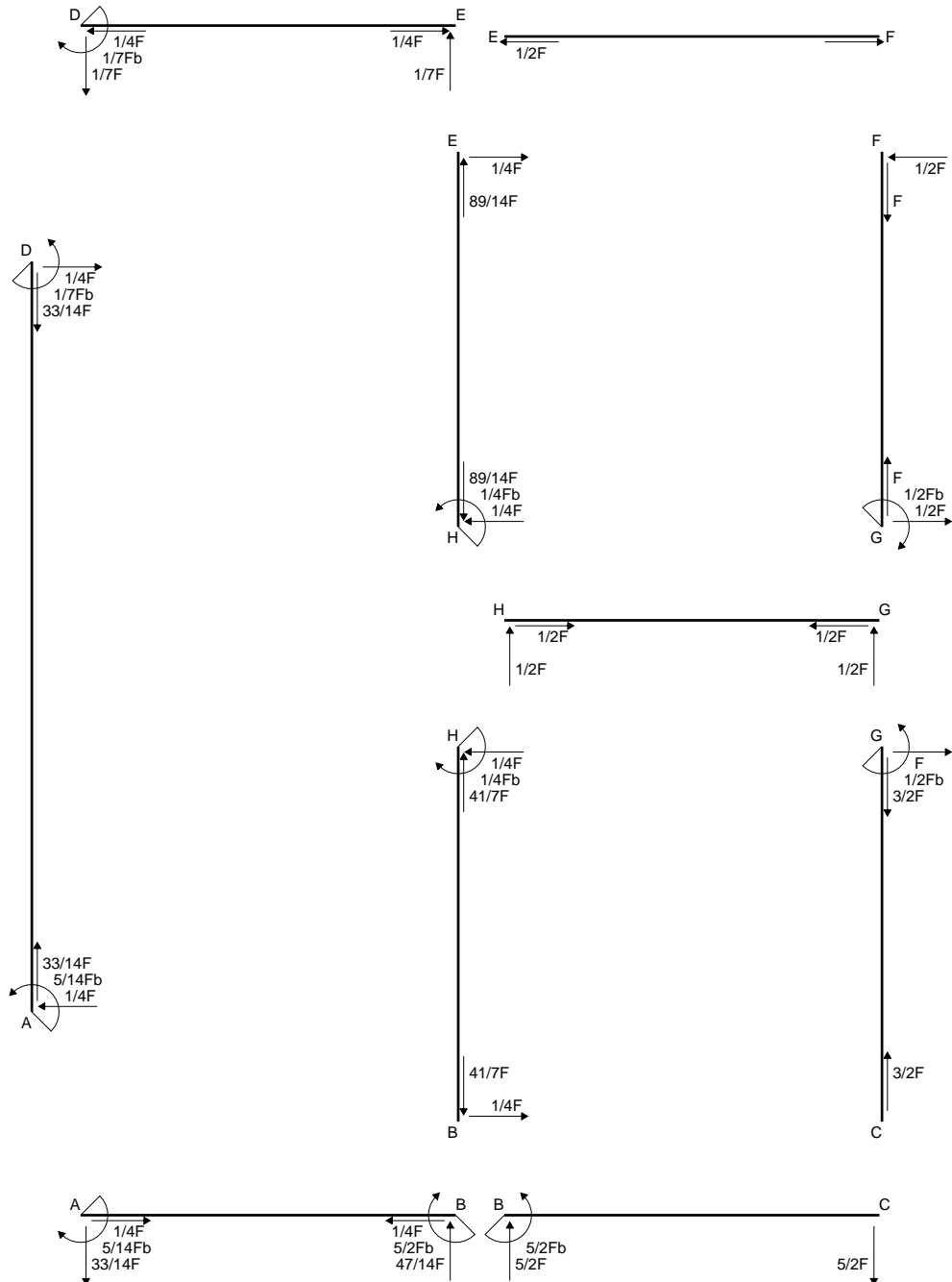
$$= (\frac{1}{2}b - \frac{1}{2}b + \frac{1}{6}b) Fb \frac{1}{EJ} = \frac{1}{6} \frac{Fb^2}{EJ}$$

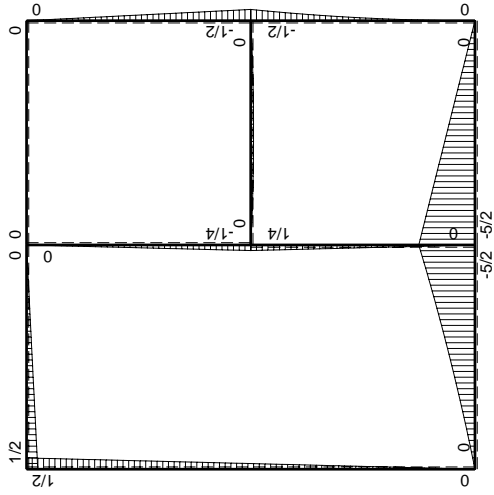
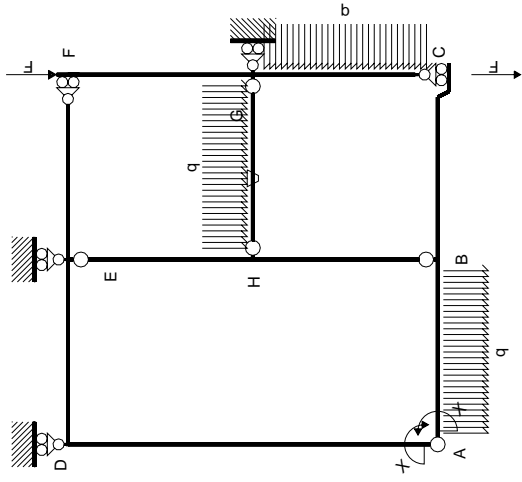
$$L_{ED}^{xo} = \int_0^b (\frac{1}{2} \frac{x^2}{b^2}) Fb \frac{1}{EJ} dx = \left[ \frac{1}{6} \frac{x^3}{b^2} \right]_0^b Fb \frac{1}{EJ}$$

$$= (\frac{1}{6}b) Fb \frac{1}{EJ} = \frac{1}{6} \frac{Fb^2}{EJ}$$



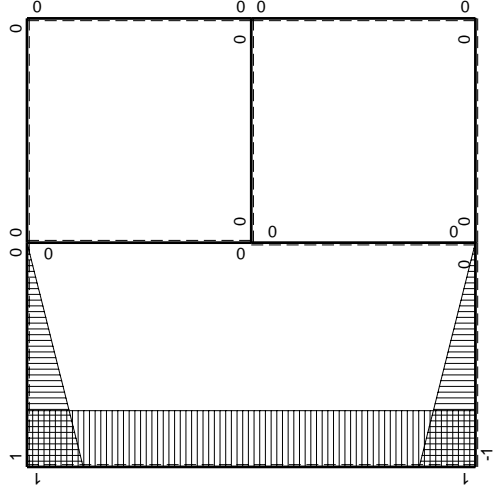
- A = 1164. mm<sup>2</sup>
- J<sub>u</sub> = 356609. mm<sup>4</sup>
- J<sub>v</sub> = 123696. mm<sup>4</sup>
- y<sub>g</sub> = 20.9 mm
- T<sub>y</sub> = 3925. N
- M<sub>x</sub> = -2472750. Nmm
- x<sub>m</sub> = 36. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 12. mm
- v<sub>m</sub> = 33.1 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 229.5 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 43. mm
- v<sub>c</sub> = 22.1 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 153.2 N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.622 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 153.5 N/mm<sup>2</sup>
- S = 6129. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_1$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-2Fx-1/2qx^2$	0	$2Fx-3/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(3/8+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$5/2Fb-3Fx+1/2qx^2$	0	$5/2Fx-3Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-5/2Fb+5/2Fx$	0	0	0	0	0+0	0	
CB b	0	$5/2Fx$	0	0	0	0			
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1			
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	$1/2Fx-1/2qx^2$	$-Fb/EJ$	0	0	0	0+0	0	
GH b	0	$-1/2Fx+1/2qx^2$	$Fb/EJ$	0	0	0			
HB b	0	$1/4Fb-1/4Fx$	0	0	0	0	0+0	0	
BH b	0	$-1/4Fx$	0	0	0	0			
HE b	0	$-1/4Fb+1/4Fx$	0	0	0	0	0+0	0	
EH b	0	$1/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB} (W_{0AB} + XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$25/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-5/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (2xb - 3/2 x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 1/2 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 1/2 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (5/2 xb - 3x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 5/4 x^2/b - x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (5/4 b - b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

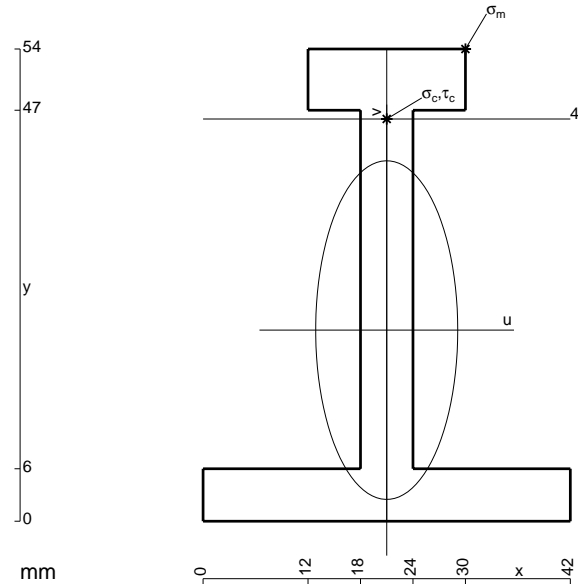
$$= (b - 1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/2 b - 1/2 b + 1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$

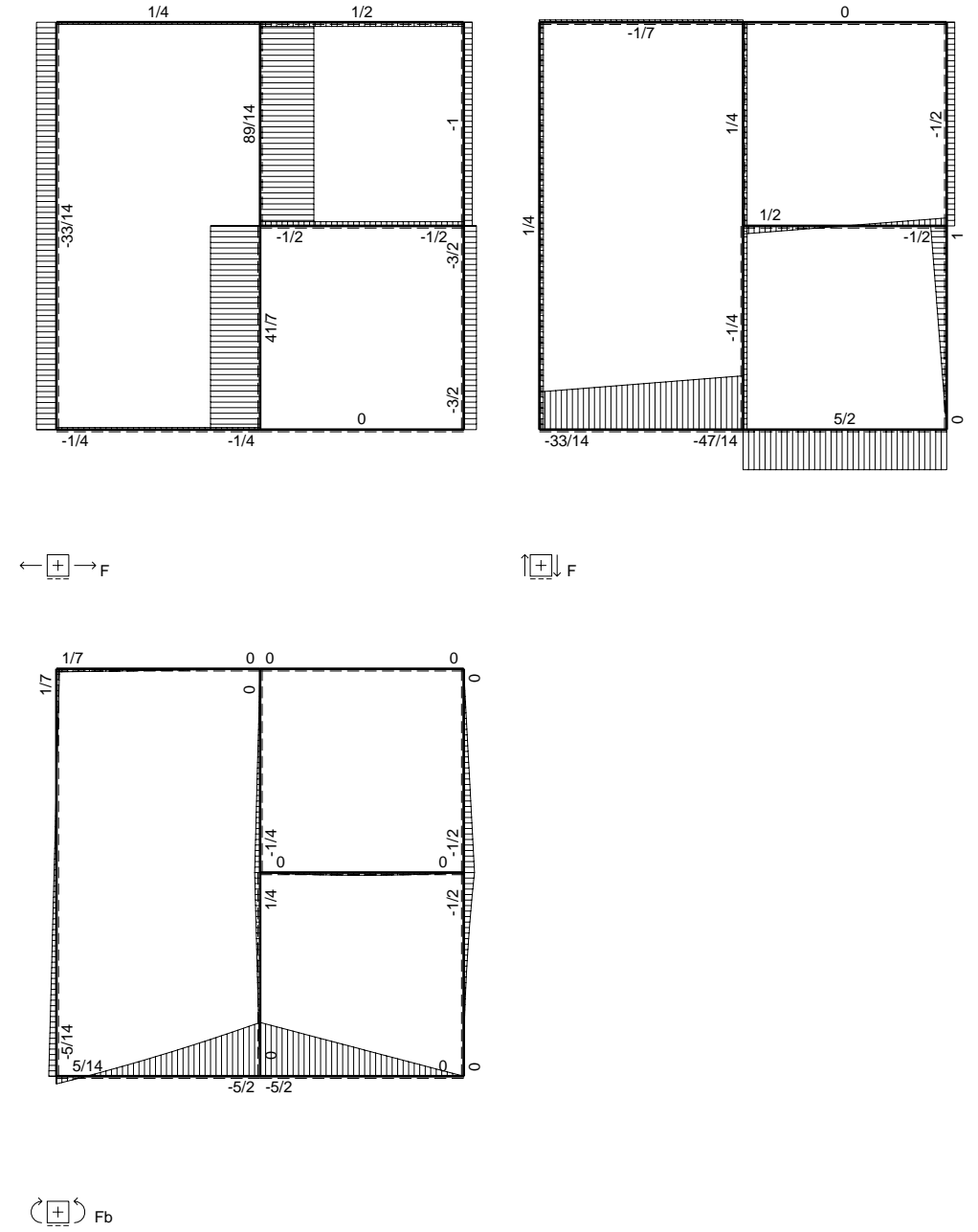
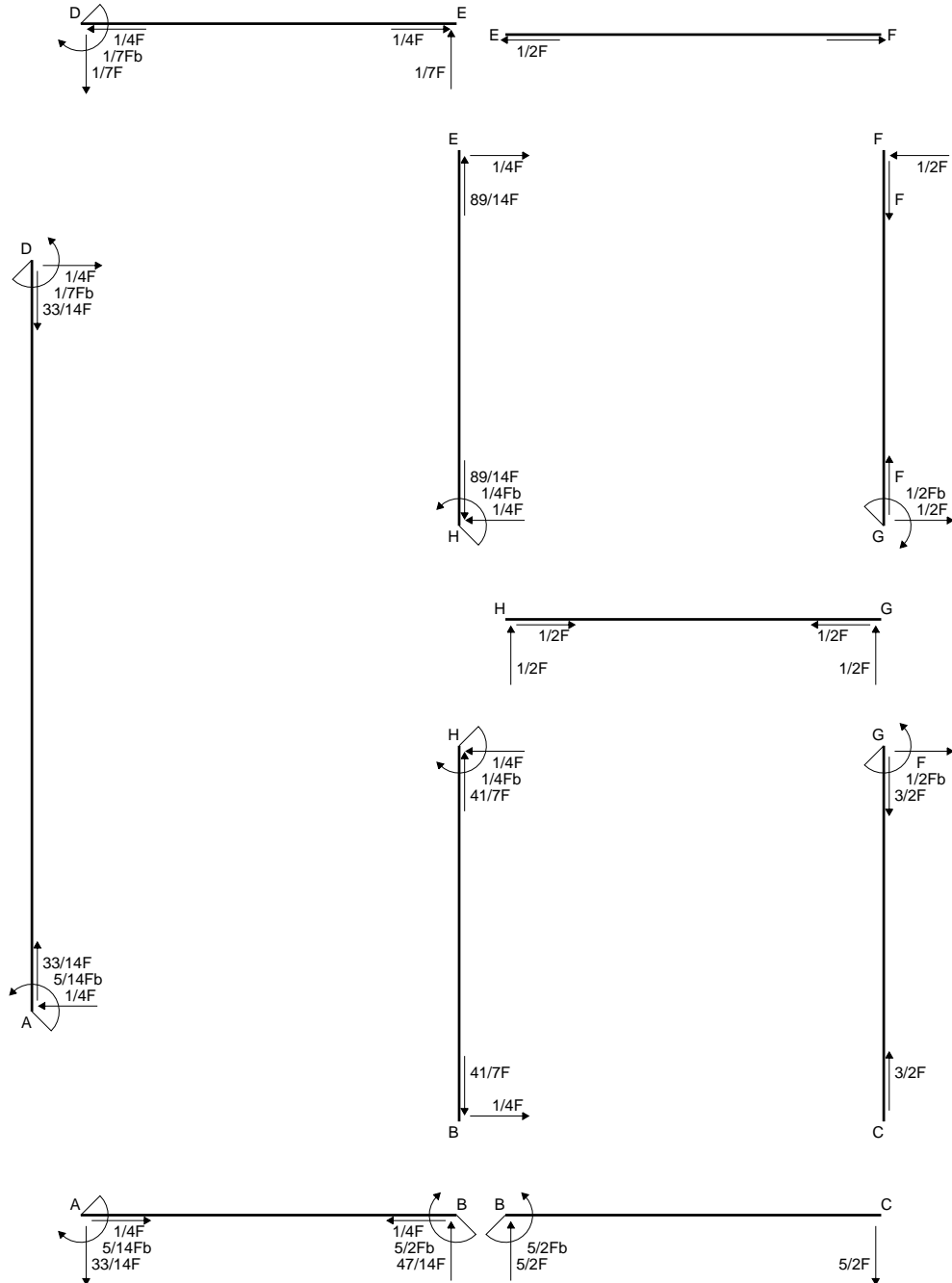
$$L_{ED}^{xo} = \int_0^b (1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

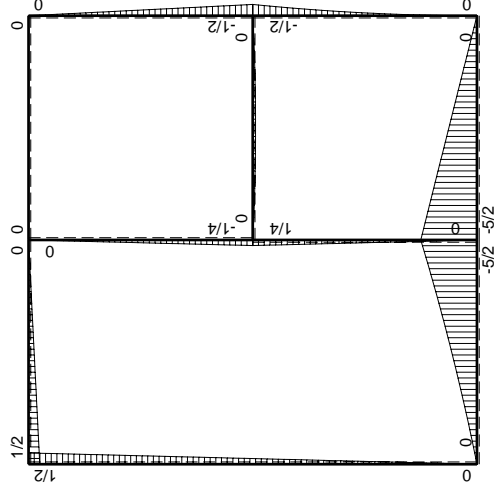
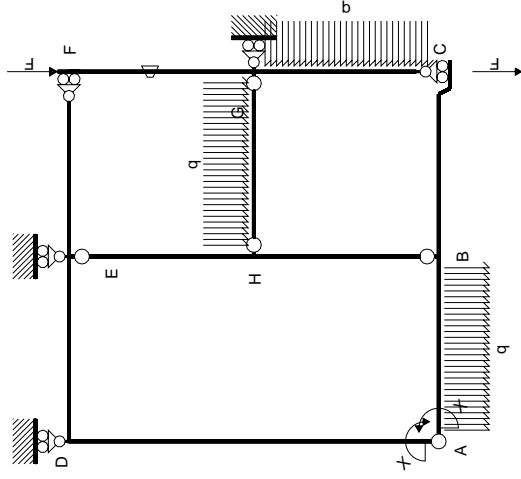
$$= (1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$



- A = 624. mm<sup>2</sup>
- J<sub>u</sub> = 234015. mm<sup>4</sup>
- J<sub>v</sub> = 41184. mm<sup>4</sup>
- y<sub>g</sub> = 21.86 mm
- T<sub>y</sub> = 2550. N
- M<sub>x</sub> = -1734000. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 9. mm
- v<sub>m</sub> = 32.14 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 238.2 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 46. mm
- v<sub>c</sub> = 24.14 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 178.9 N/mm<sup>2</sup>
- τ<sub>c</sub> = 6.823 N/mm<sup>2</sup>
- σ<sub>o</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 179.3 N/mm<sup>2</sup>
- S = 3757. mm<sup>3</sup>

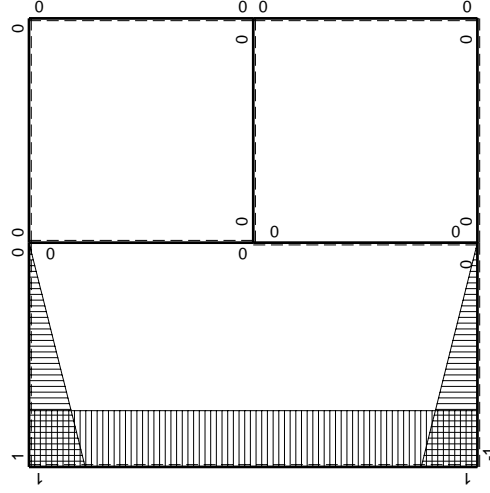






Schema di calcolo iperstatico

$M_0$ , flessione da carichi assegnati



$M_x$ , flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-2Fx-1/2qx^2$	0	$2Fx-3/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(3/8+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$5/2Fb-3Fx+1/2qx^2$	0	$5/2Fx-3Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-5/2Fb+5/2Fx$	0	0	0	0	0+0	0	
CB b	0	$5/2Fx$	0	0	0	0			
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1			
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$-1/2Fx$	$-Fb/EJ$	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	$Fb/EJ$	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
GH b	0	$-1/2Fx+1/2qx^2$	0	0	0	0			
HB b	0	$1/4Fb-1/4Fx$	0	0	0	0	0+0	0	
BH b	0	$-1/4Fx$	0	0	0	0			
HE b	0	$-1/4Fb+1/4Fx$	0	0	0	0	0+0	0	
EH b	0	$1/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$25/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-5/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (2x/b - 3/2 x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 1/2 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 1/2 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (5/2 x/b - 3 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 5/4 x^2/b - x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (5/4 b - b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

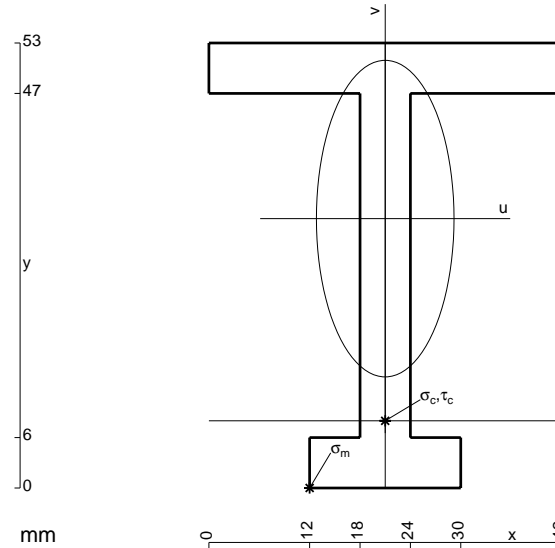
$$= (b - 1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

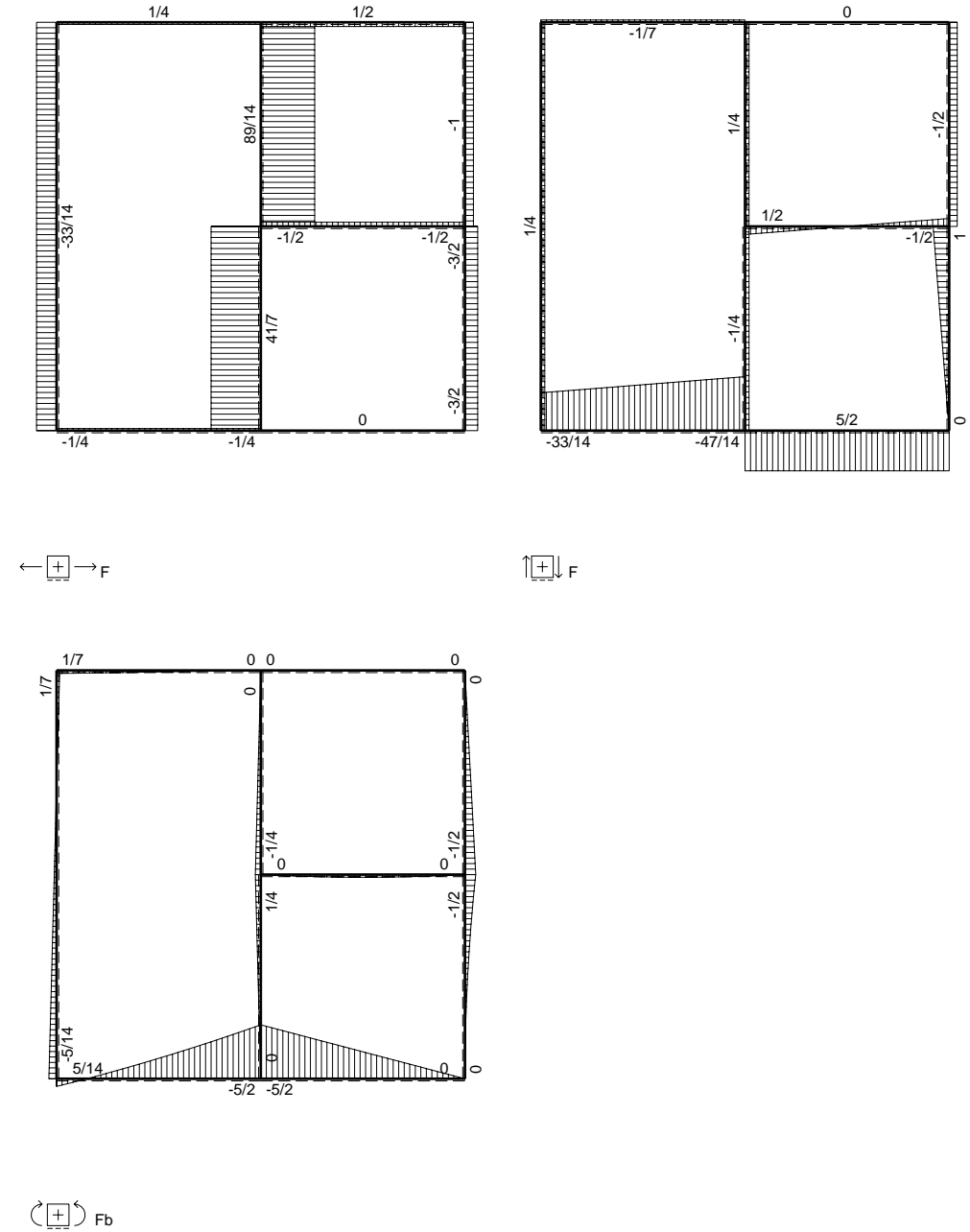
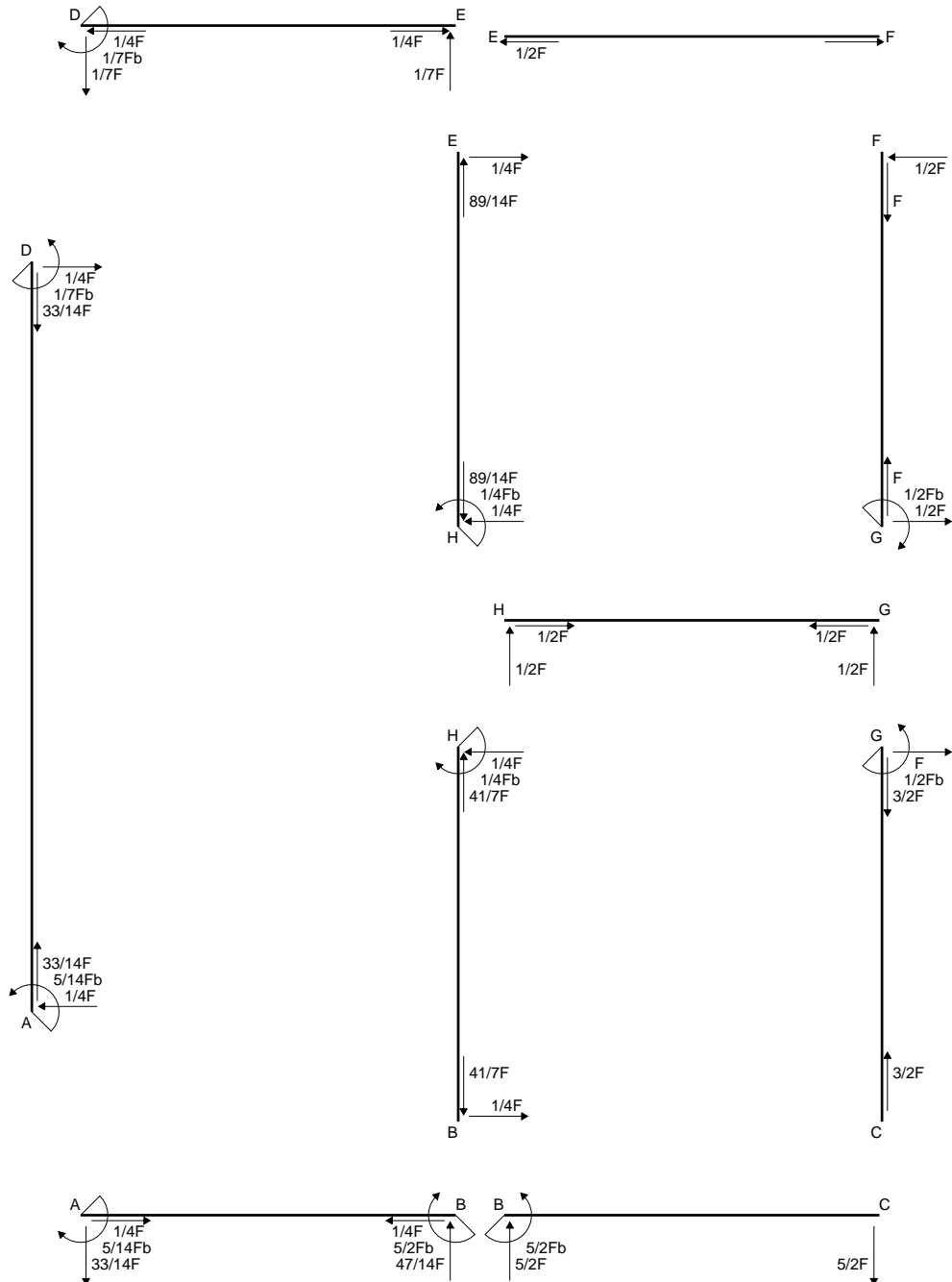
$$= (1/2 b - 1/2 b + 1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$

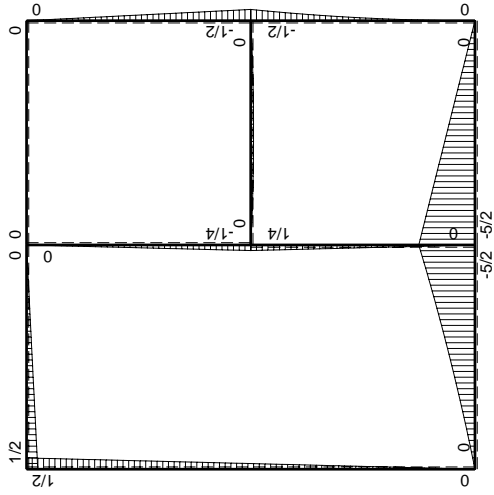
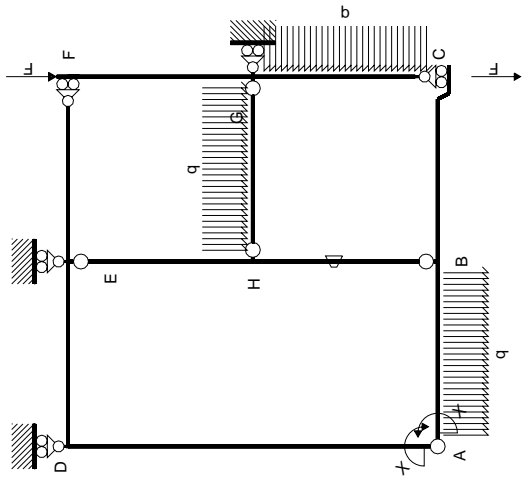
$$L_{ED}^{xo} = \int_0^b (1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$



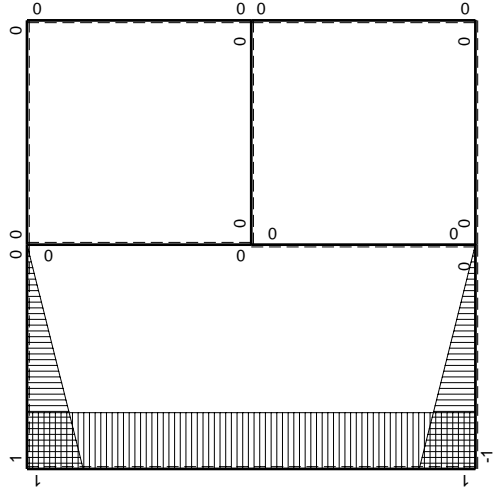
- A = 606. mm<sup>2</sup>
- J<sub>u</sub> = 215454. mm<sup>4</sup>
- J<sub>v</sub> = 40698. mm<sup>4</sup>
- y<sub>g</sub> = 32.08 mm
- T<sub>y</sub> = 1850. N
- M<sub>x</sub> = -1332000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -9. mm
- v<sub>m</sub> = -32.08 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -198.4 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 8. mm
- v<sub>c</sub> = -24.08 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -148.9 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.926 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 149.1 N/mm<sup>2</sup>
- S = 3442. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_1$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-2Fx-1/2qx^2$	0	$2Fx-3/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(3/8+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$5/2Fb-3Fx+1/2qx^2$	0	$5/2Fx-3Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-5/2Fb+5/2Fx$	0	0	0	0	0+0	0	
CB b	0	$5/2Fx$	0	0	0	0			
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1			
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
GH b	0	$-1/2Fx+1/2qx^2$	0	0	0	0			
HB b	0	$1/4Fb-1/4Fx$	$-Fb/EJ$	0	0	0	0+0	0	
BH b	0	$-1/4Fx$	$Fb/EJ$	0	0	0			
HE b	0	$-1/4Fb+1/4Fx$	0	0	0	0	0+0	0	
EH b	0	$1/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$25/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-5/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (2x/b - 3/2 x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 1/2 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 1/2 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (5/2 x/b - 3 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 5/4 x^2/b - x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (5/4 b - b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

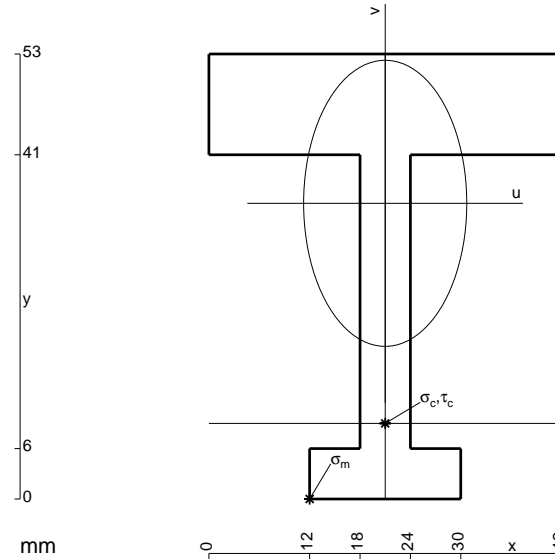
$$= (b - 1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/2 b - 1/2 b + 1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$

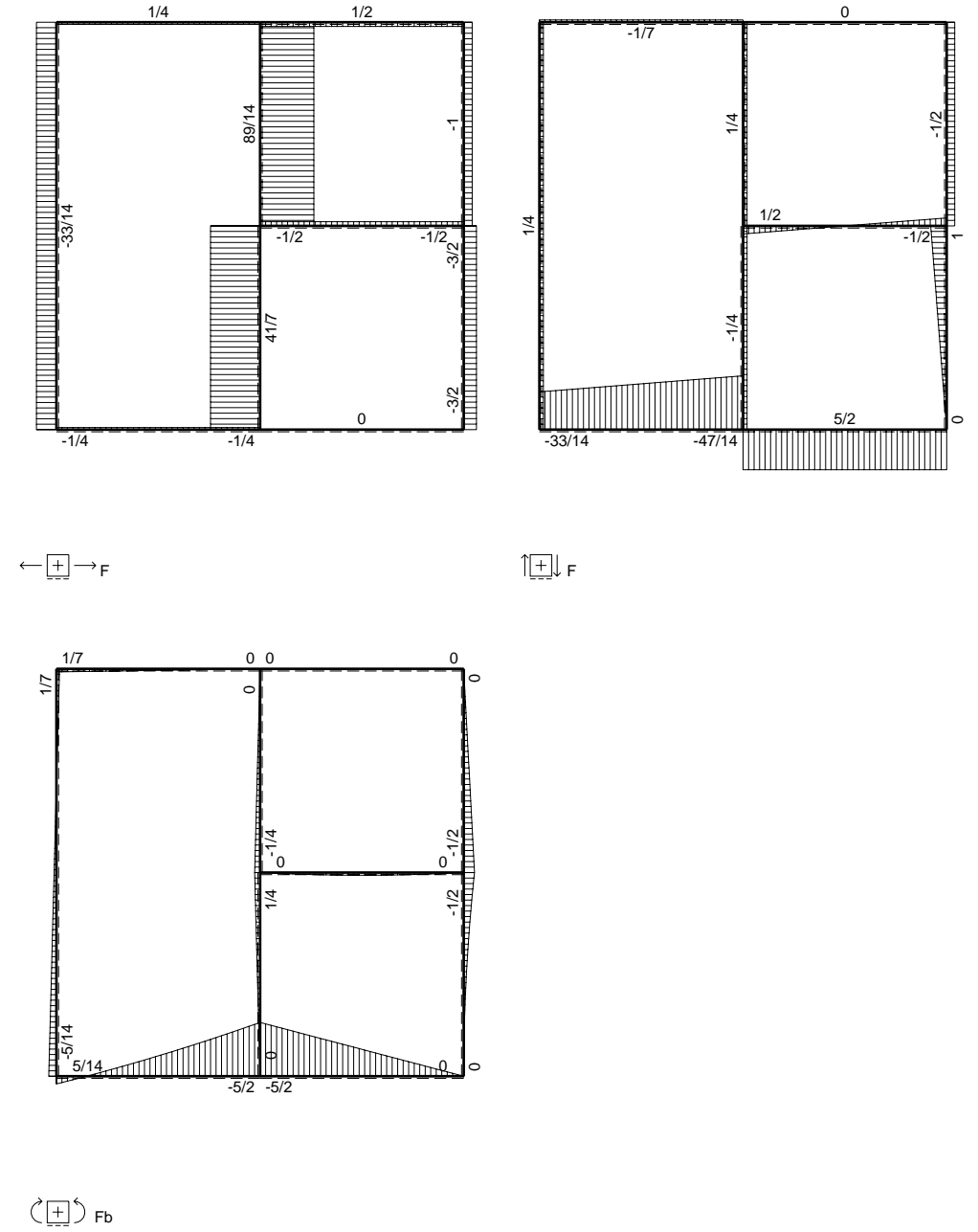
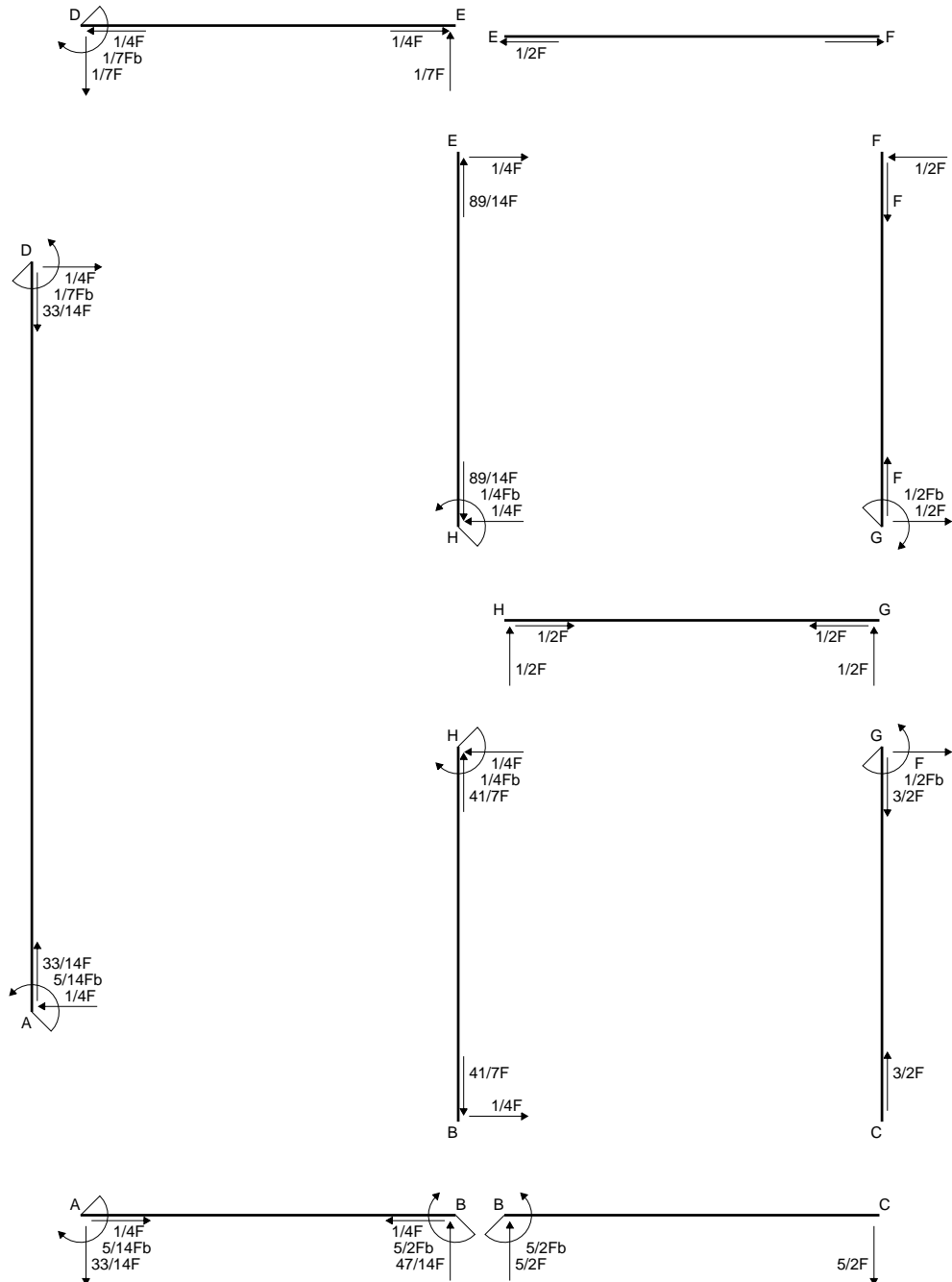
$$L_{ED}^{xo} = \int_0^b (1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

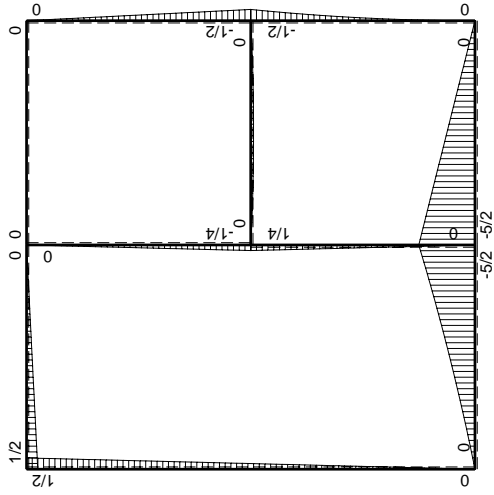
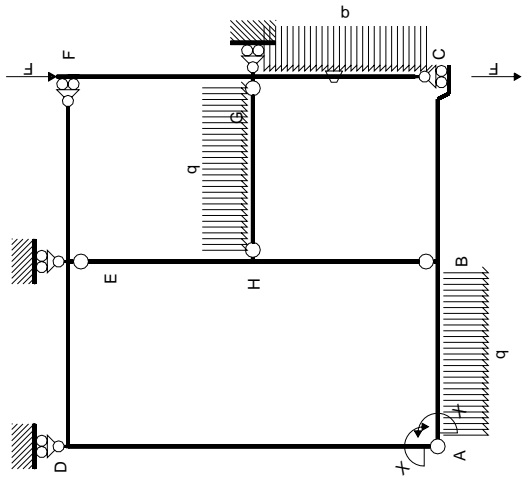
$$= (1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$



- A = 822. mm<sup>2</sup>
- J<sub>u</sub> = 238712. mm<sup>4</sup>
- J<sub>v</sub> = 77634. mm<sup>4</sup>
- y<sub>g</sub> = 35.22 mm
- T<sub>y</sub> = 1850. N
- M<sub>x</sub> = -1406000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -9. mm
- v<sub>m</sub> = -35.22 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -207.4 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 9. mm
- v<sub>c</sub> = -26.22 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -154.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.138 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 154.7 N/mm<sup>2</sup>
- S = 3978. mm<sup>3</sup>

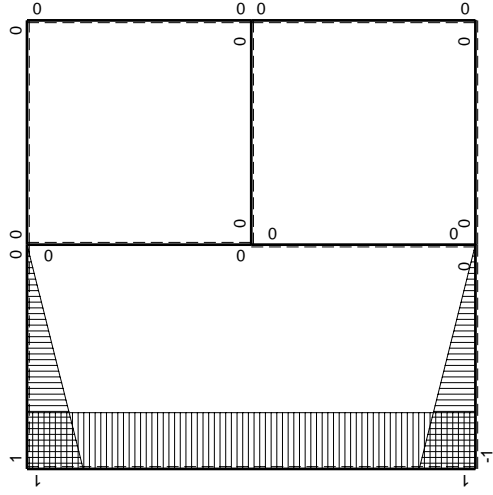






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-2Fx-1/2qx^2$	0	$2Fx-3/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(3/8+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$5/2Fb-3Fx+1/2qx^2$	0	$5/2Fx-3Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-5/2Fb+5/2Fx$	0	0	0	0	0+0	0	
CB b	0	$5/2Fx$	0	0	0	0			
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1			
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	$-Fb/EJ$	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	$Fb/EJ$	0	0	0			
HG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
GH b	0	$-1/2Fx+1/2qx^2$	0	0	0	0			
HB b	0	$1/4Fb-1/4Fx$	0	0	0	0	0+0	0	
BH b	0	$-1/4Fx$	0	0	0	0			
HE b	0	$-1/4Fb+1/4Fx$	0	0	0	0	0+0	0	
EH b	0	$1/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$25/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-5/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx + 1 \cdot 1 \cdot \frac{1}{4} \frac{b}{EJ} = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ} + 1 \cdot 1 \cdot \frac{1}{4} \frac{b}{EJ}$$

$$= (b - b + 1/3 b) \frac{1}{EJ} + 1 \cdot 1 \cdot \frac{1}{4} \frac{b}{EJ} = 7/12 \frac{b}{EJ}$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx + 1 \cdot 1 \cdot \frac{1}{4} \frac{b}{EJ} = \left[ 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ} + 1 \cdot 1 \cdot \frac{1}{4} \frac{b}{EJ}$$

$$= (1/3 b) \frac{1}{EJ} + 1 \cdot 1 \cdot \frac{1}{4} \frac{b}{EJ} = 7/12 \frac{b}{EJ}$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \frac{b}{EJ}$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \frac{b}{EJ}$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ}$$

$$= (b - b + 1/3 b) \frac{1}{EJ} = 1/3 \frac{b}{EJ}$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx = \left[ 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ}$$

$$= (1/3 b) \frac{1}{EJ} = 1/3 \frac{b}{EJ}$$

$$L_{AB}^{xo} = \int_0^b (2xb - 3/2 x^2/b^2 - 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= \left[ x^2/b - 1/2 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= (b - 1/2 b - 1/8 b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ} = 3/8 \frac{Fb^2}{EJ}$$

$$L_{BA}^{xo} = \int_0^b (5/2 xb - 3x^2/b^2 + 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= \left[ 5/4 x^2/b - x^3/b^2 + 1/8 x^4/b^3 \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= (5/4 b - b + 1/8 b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ} = 3/8 \frac{Fb^2}{EJ}$$

$$L_{AD}^{xo} = \int_0^{2b} (1/4 x/b) Fb \frac{1}{EJ} dx = \left[ 1/8 x^2/b \right]_0^{2b} Fb \frac{1}{EJ}$$

$$= (1/2 b) Fb \frac{1}{EJ} = 1/2 \frac{Fb^2}{EJ}$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 1/4 x/b) Fb \frac{1}{EJ} dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} Fb \frac{1}{EJ}$$

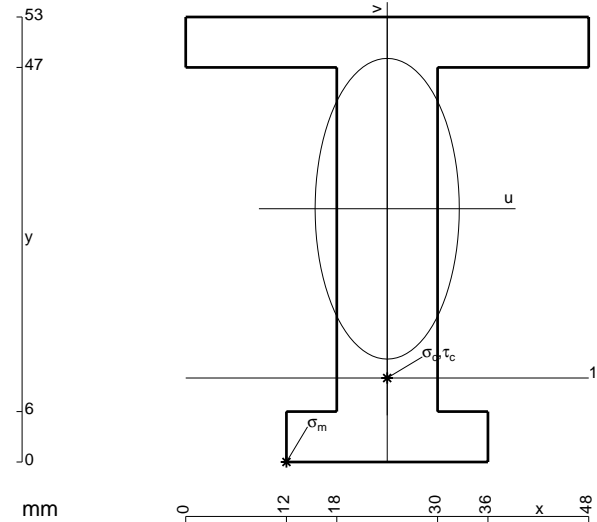
$$= (b - 1/2 b) Fb \frac{1}{EJ} = 1/2 \frac{Fb^2}{EJ}$$

$$L_{DE}^{xo} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) Fb \frac{1}{EJ} dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b Fb \frac{1}{EJ}$$

$$= (1/2 b - 1/2 b + 1/6 b) Fb \frac{1}{EJ} = 1/6 \frac{Fb^2}{EJ}$$

$$L_{ED}^{xo} = \int_0^b (1/2 x^2/b^2) Fb \frac{1}{EJ} dx = \left[ 1/6 x^3/b^2 \right]_0^b Fb \frac{1}{EJ}$$

$$= (1/6 b) Fb \frac{1}{EJ} = 1/6 \frac{Fb^2}{EJ}$$



$$A = 924. \text{ mm}^2$$

$$J_u = 296396. \text{ mm}^4$$

$$J_v = 68112. \text{ mm}^4$$

$$y_g = 30.16 \text{ mm}$$

$$T_y = 2650. \text{ N}$$

$$M_x = -2146500. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -12. \text{ mm}$$

$$v_m = -30.16 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -218.4 \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 10. \text{ mm}$$

$$v_c = -20.16 \text{ mm}$$

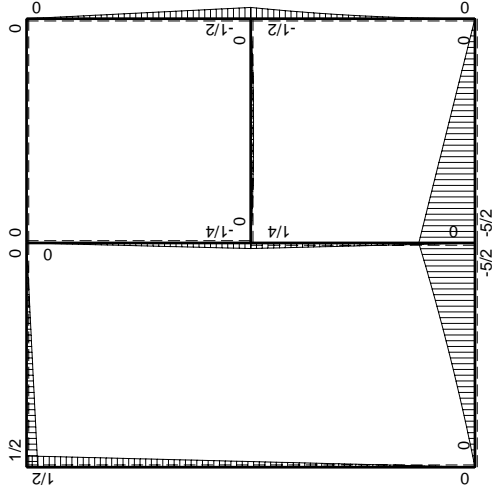
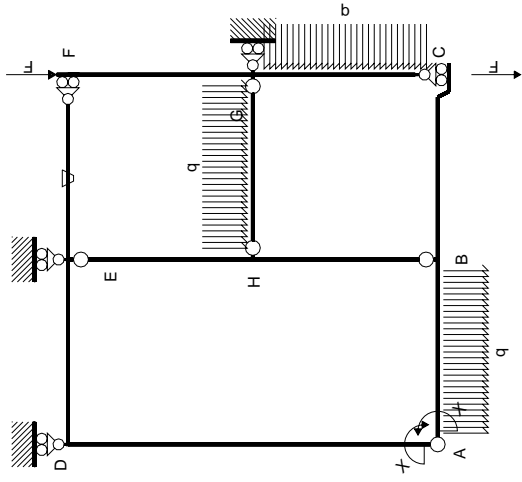
$$\sigma_c = -Mv/J_u = -146. \text{ N/mm}^2$$

$$\tau_c = 3.707 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 146.2 \text{ N/mm}^2$$

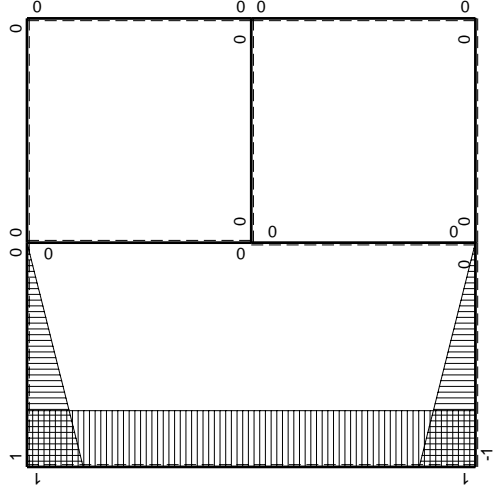
$$S = 4975. \text{ mm}^3$$





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_X$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-2Fx-1/2qx^2$	0	$2Fx-3/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(3/8+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$5/2Fb-3Fx+1/2qx^2$	0	$5/2Fx-3Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-5/2Fb+5/2Fx$	0	0	0	0	0+0	0	
CB b	0	$5/2Fx$	0	0	0	0			
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1			
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
FE b	0	0	$Fb/EJ$	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
GH b	0	$-1/2Fx+1/2qx^2$	0	0	0	0			
HB b	0	$1/4Fb-1/4Fx$	0	0	0	0	0+0	0	
BH b	0	$-1/4Fx$	0	0	0	0			
HE b	0	$-1/4Fb+1/4Fx$	0	0	0	0	0+0	0	
EH b	0	$1/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$25/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-5/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (2x/b - 3/2 x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 1/2 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 1/2 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (5/2 x/b - 3 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 5/4 x^2/b - x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (5/4 b - b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

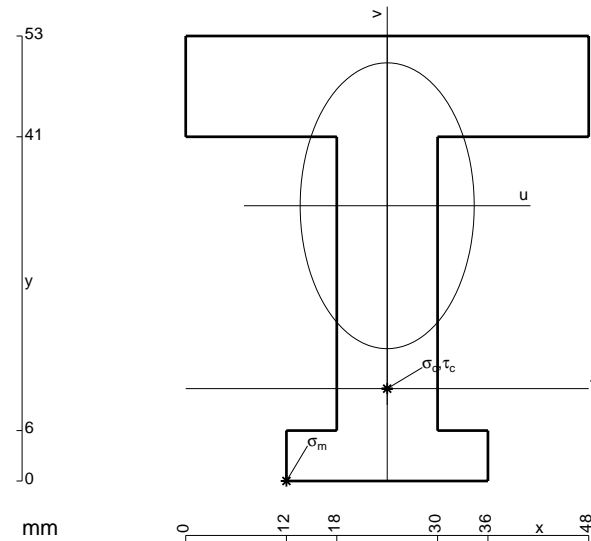
$$= (b - 1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/2 b - 1/2 b + 1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$

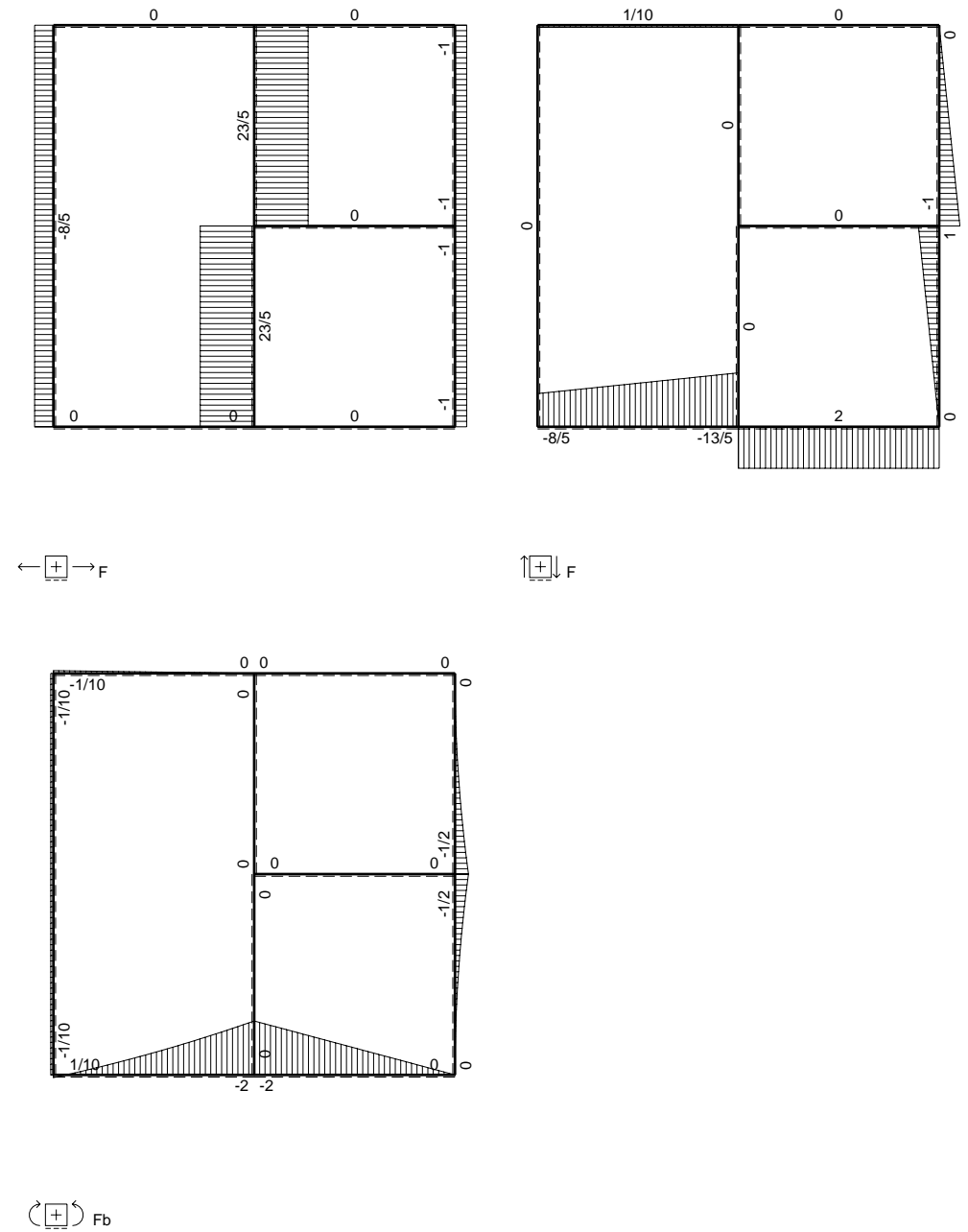
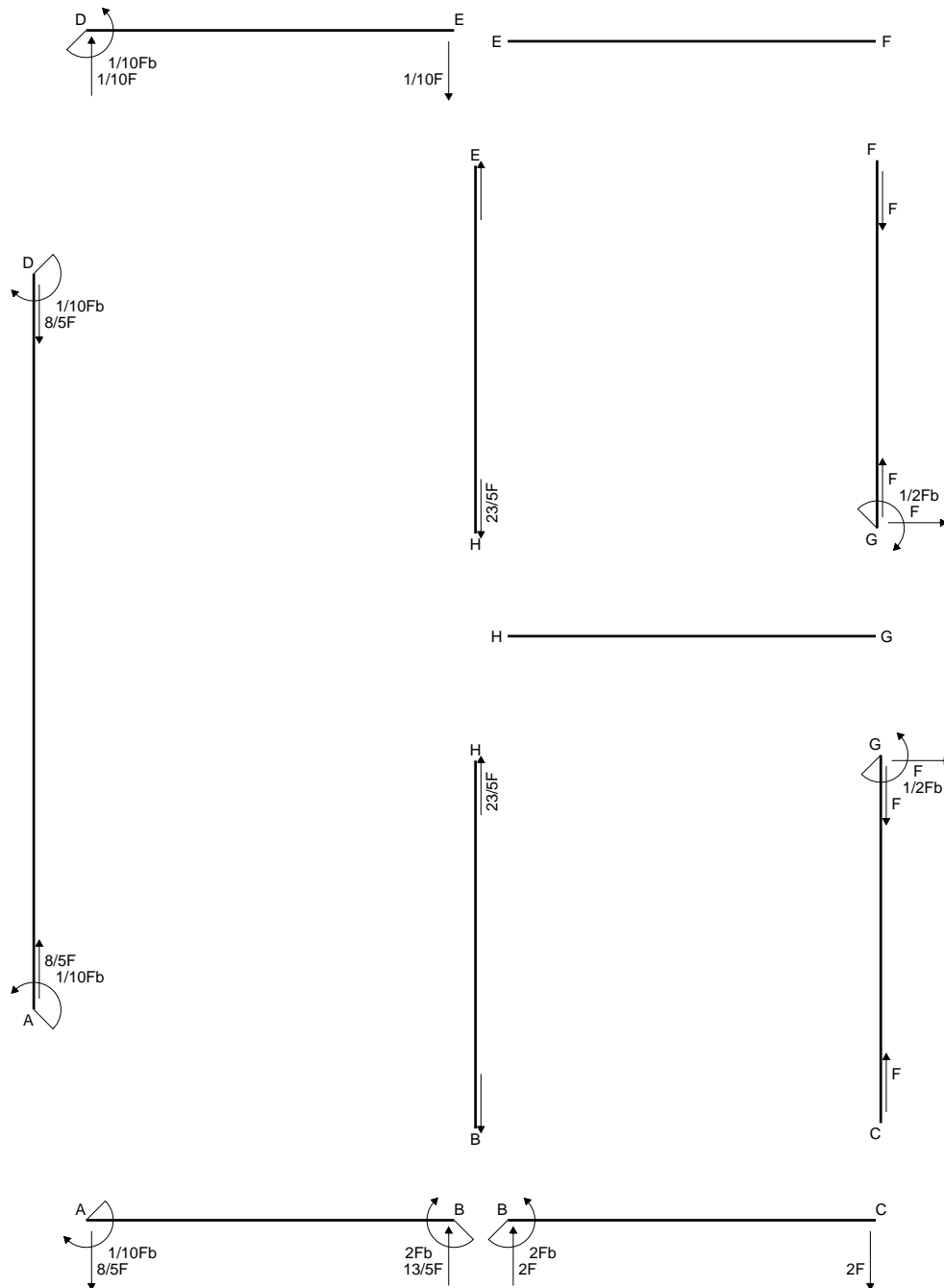
$$L_{ED}^{xo} = \int_0^b (1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

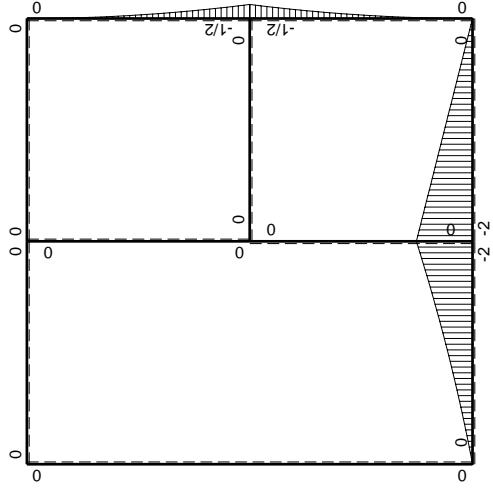
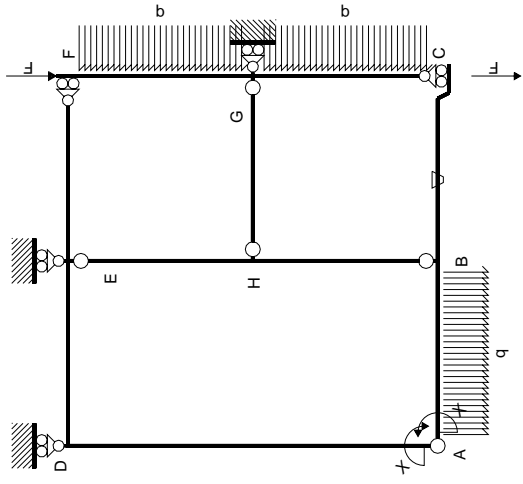
$$= (1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$



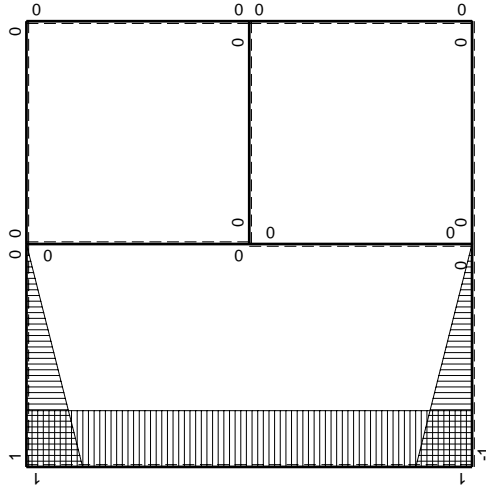
- A = 1140. mm<sup>2</sup>
- J<sub>u</sub> = 330567. mm<sup>4</sup>
- J<sub>v</sub> = 122544. mm<sup>4</sup>
- y<sub>g</sub> = 32.78 mm
- T<sub>y</sub> = 2675. N
- M<sub>x</sub> = -2300500. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -12. mm
- v<sub>m</sub> = -32.78 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -228.2 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 11. mm
- v<sub>c</sub> = -21.78 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -151.6 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.875 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 151.8 N/mm<sup>2</sup>
- S = 5746. mm<sup>3</sup>







$M_0$  flessione da carichi assegnati



$M_X$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x / EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	$-Fb/EJ$	0	0	0	0+0	0	
CB b	0	$2Fx$	$Fb/EJ$	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	2Xb/EJ	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	1/3Xb/EJ	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$-1/2qx^2$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	0	0	0	0	0	0+0	0	
BH b	0	0	0	0	0	0			
HE b	0	0	0	0	0	0	0+0	0	
EH b	0	0	0	0	0	0			
AB	molla asta $-W_{1AB} (W_{0AB} + XW_{1AB}) / k_{AB}$								1/4Xb/EJ
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

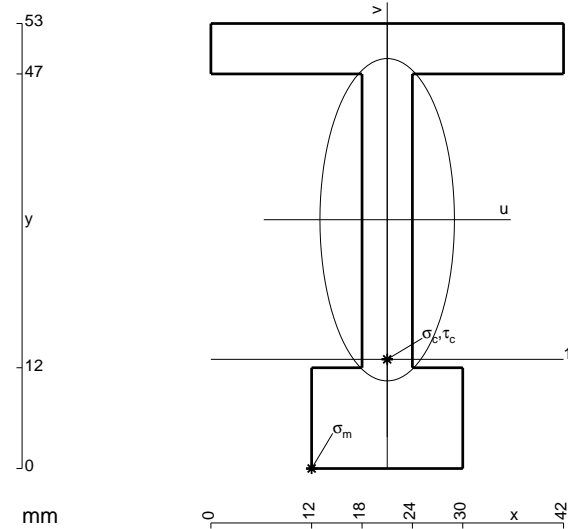
$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

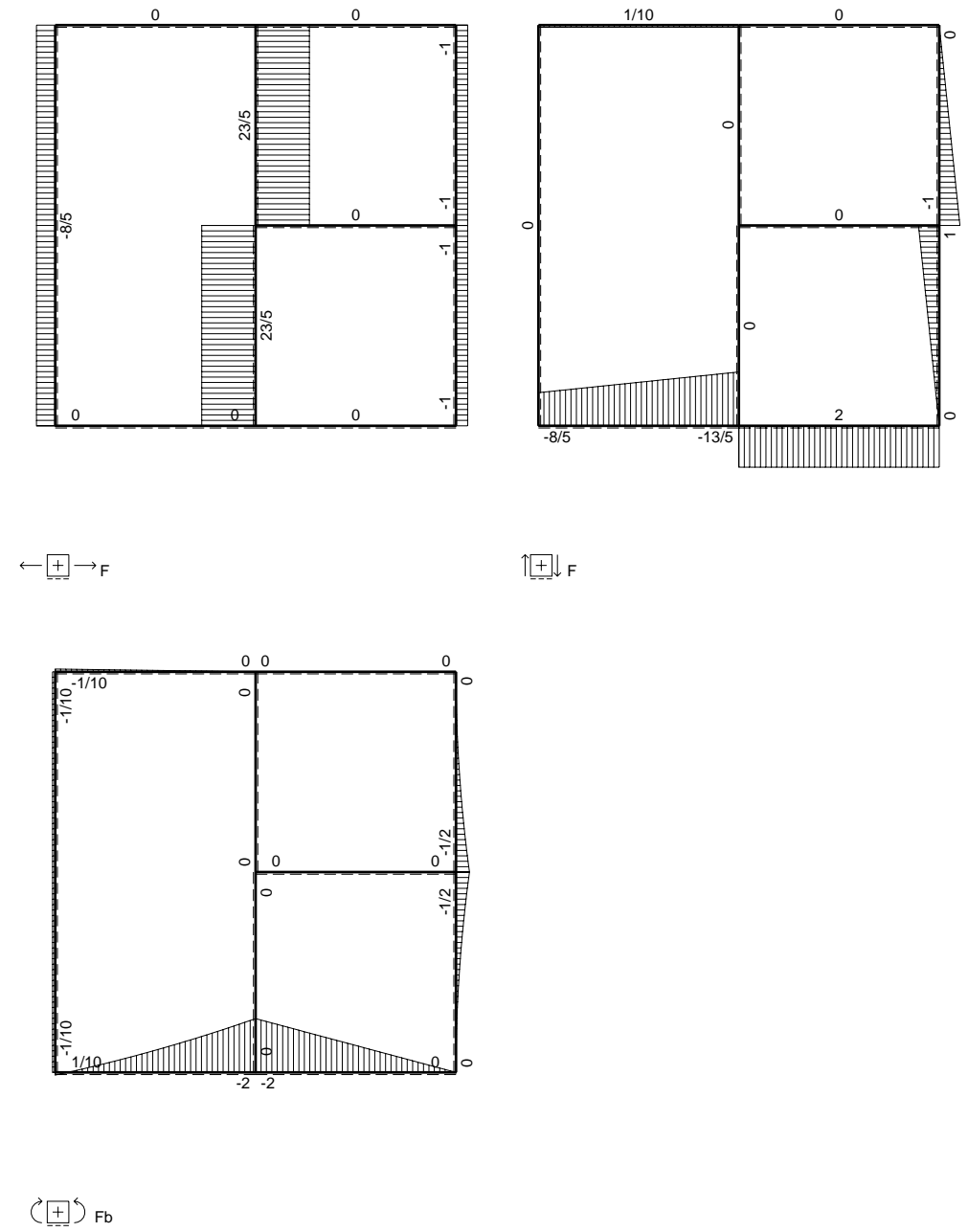
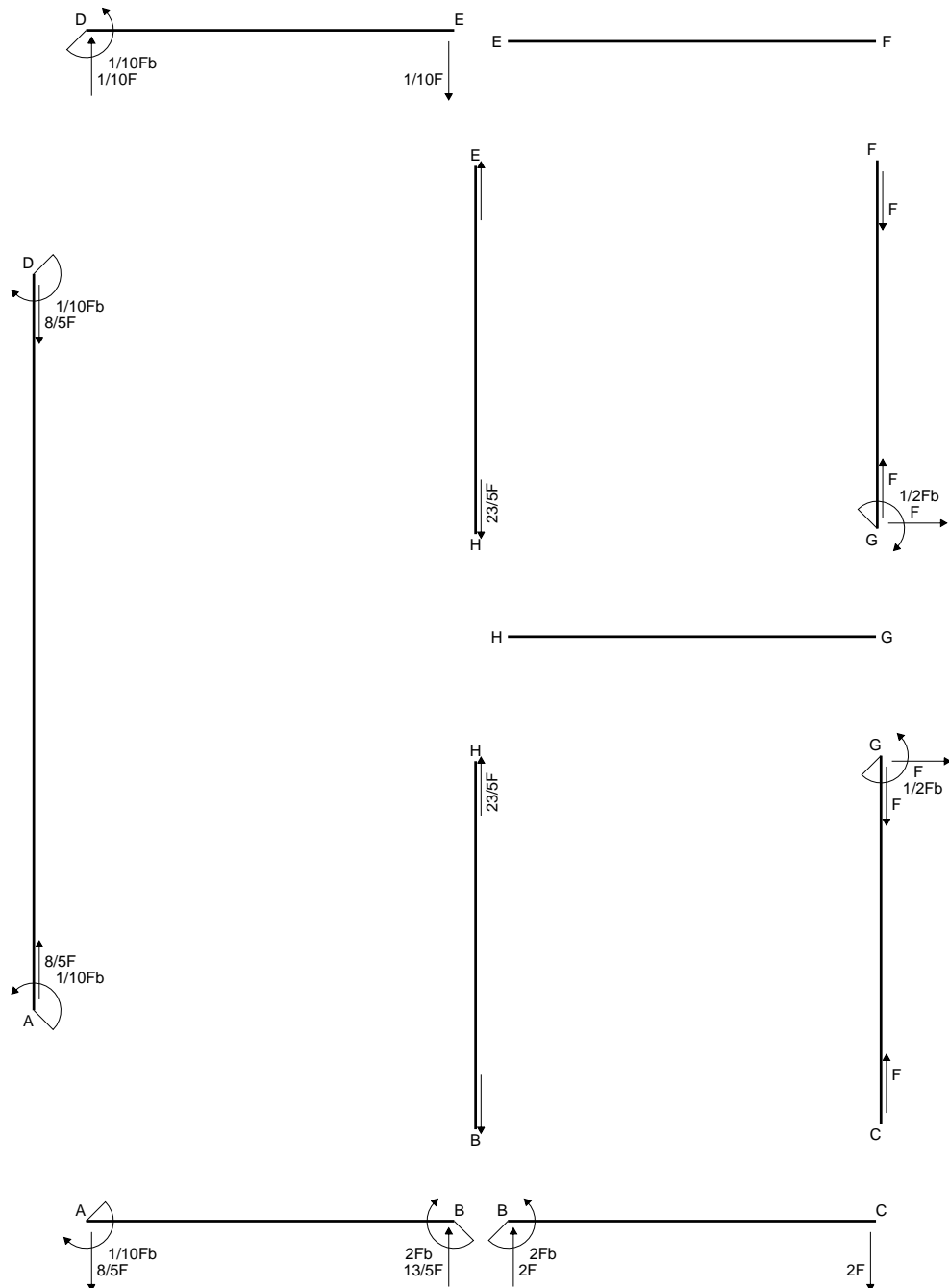
$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

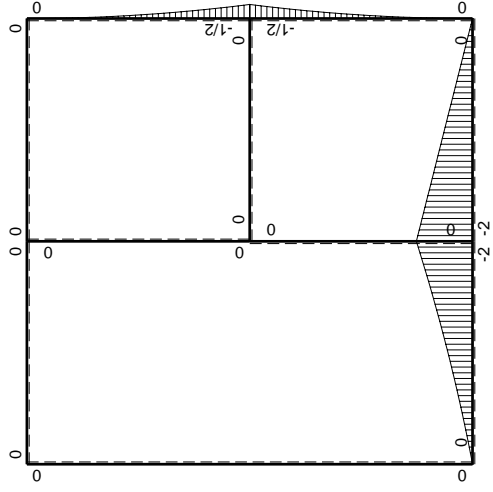
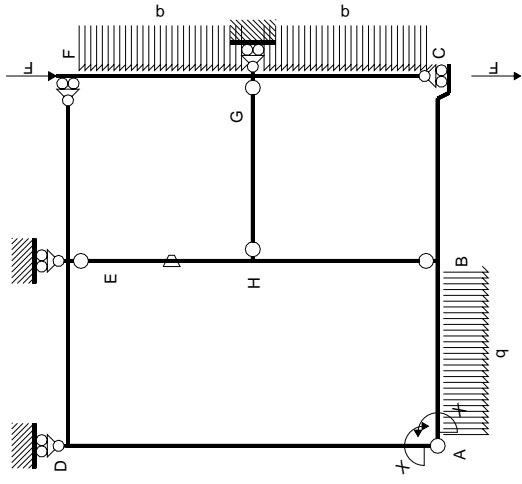
$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

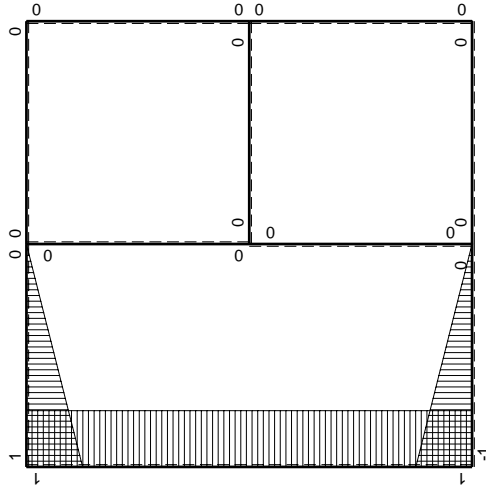


- A = 678. mm<sup>2</sup>
- J<sub>u</sub> = 249963. mm<sup>4</sup>
- J<sub>v</sub> = 43506. mm<sup>4</sup>
- y<sub>g</sub> = 29.63 mm
- T<sub>y</sub> = 2220. N
- M<sub>x</sub> = -2020200. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -9. mm
- v<sub>m</sub> = -29.63 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -239.5 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 13. mm
- v<sub>c</sub> = -16.63 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -134.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.708 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 135.1 N/mm<sup>2</sup>
- S = 5207. mm<sup>3</sup>





$M_0$  flessione da carichi assegnati



$M_X$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$-1/2qx^2$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	0	0	0	0	0	0+0	0	
BH b	0	0	0	0	0	0			
HE b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
EH b	0	0	$Fb/EJ$	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ}$$

$$= (b - b + 1/3 b) \frac{1}{EJ} = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx = \left[ 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ}$$

$$= (1/3 b) \frac{1}{EJ} = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

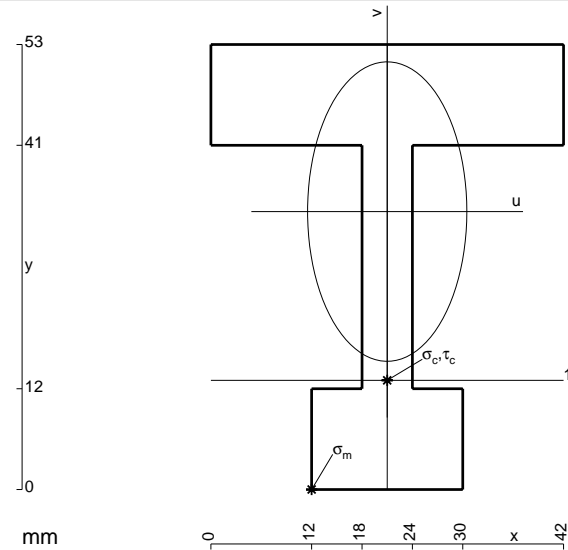
$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

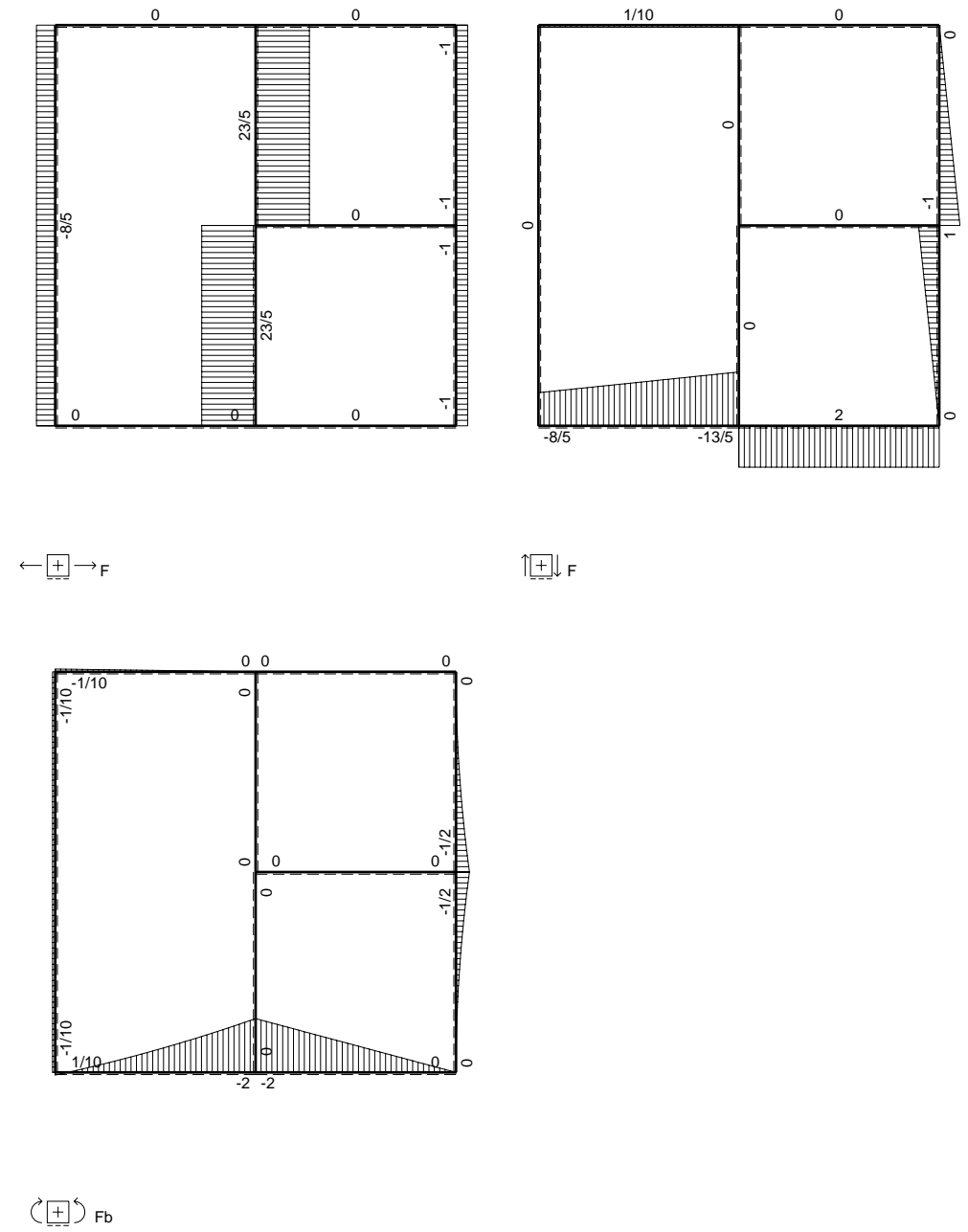
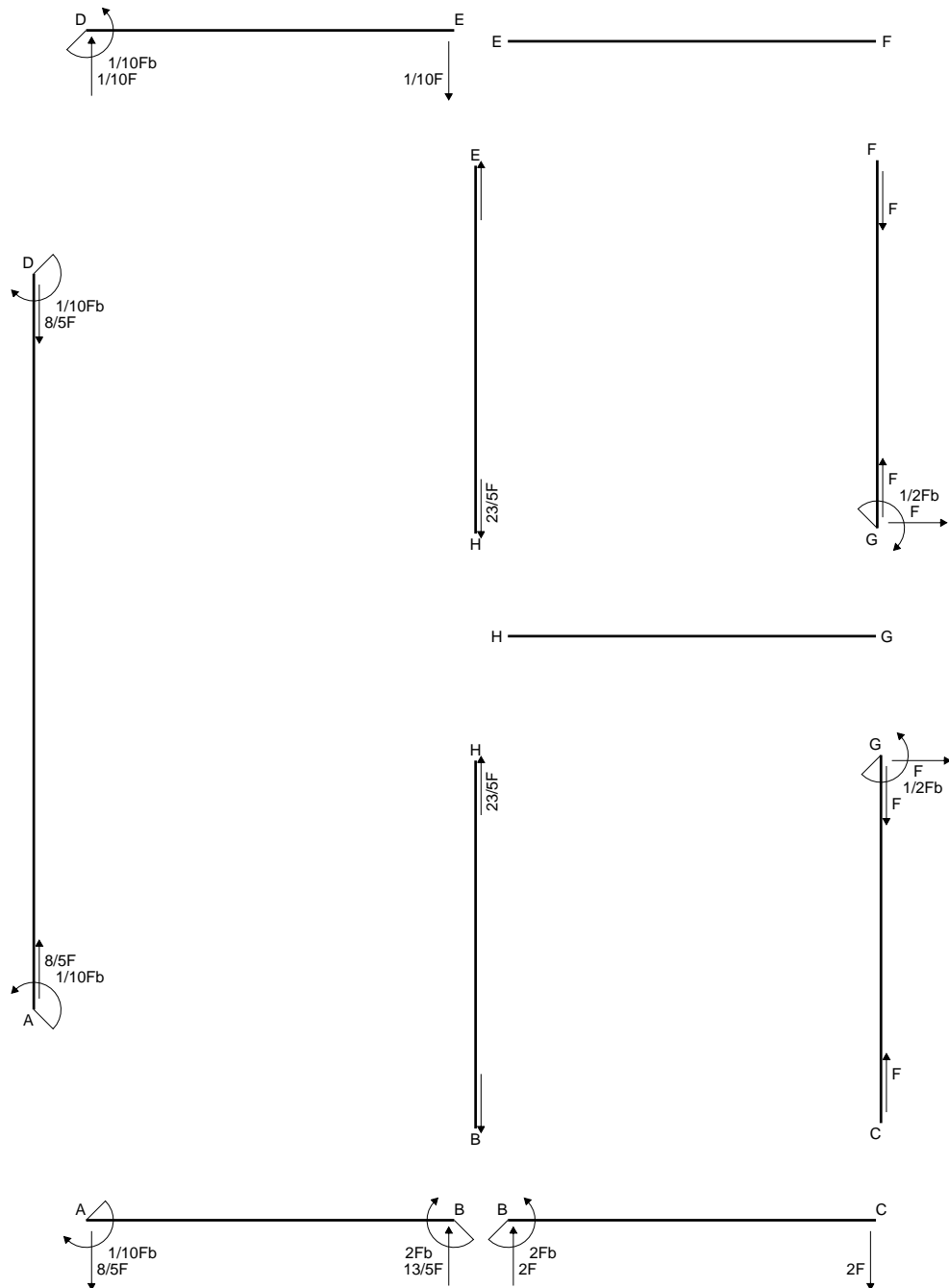
$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

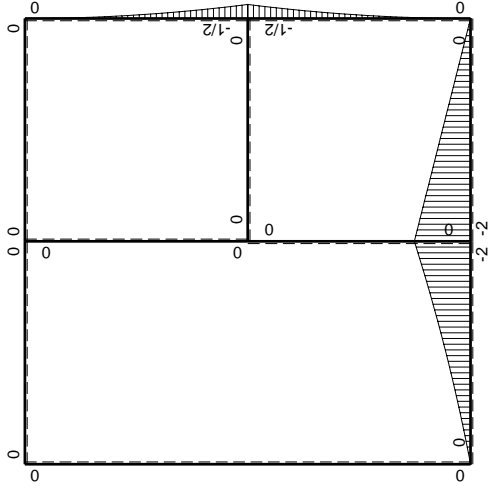
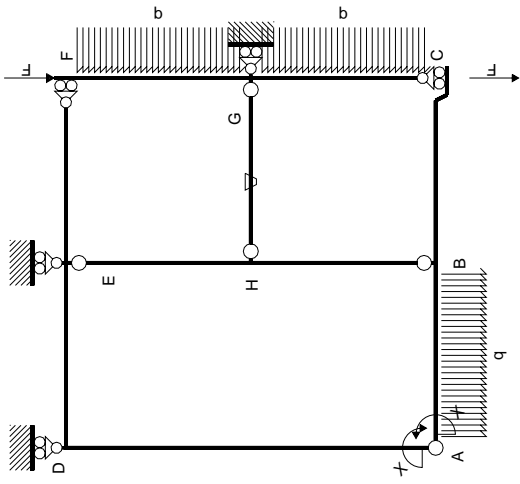
$$= (b - 5/6 b + 1/8 b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$



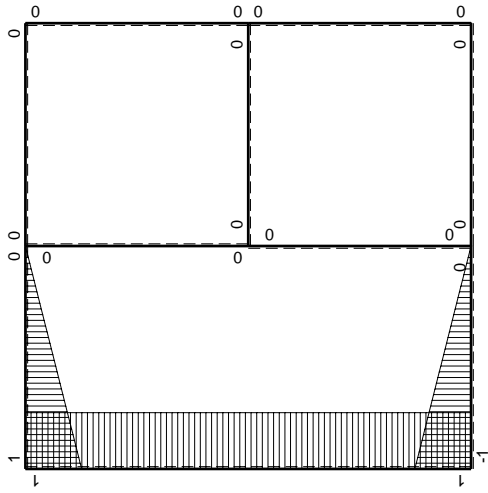
- A = 894. mm<sup>2</sup>
- J<sub>u</sub> = 284424. mm<sup>4</sup>
- J<sub>v</sub> = 80442. mm<sup>4</sup>
- y<sub>g</sub> = 33.1 mm
- T<sub>y</sub> = 3560. N
- M<sub>x</sub> = -1708800. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -9. mm
- v<sub>m</sub> = -33.1 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -198.9 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 13. mm
- v<sub>c</sub> = -20.1 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -120.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 12.47 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 122.7 N/mm<sup>2</sup>
- S = 5978. mm<sup>3</sup>







$M_0$  flessione da carichi assegnati



$M_X$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$-1/2qx^2$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
GH b	0	0	$Fb/EJ$	0	0	0			
HB b	0	0	0	0	0	0	0+0	0	
BH b	0	0	0	0	0	0			
HE b	0	0	0	0	0	0	0+0	0	
EH b	0	0	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{x_0} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

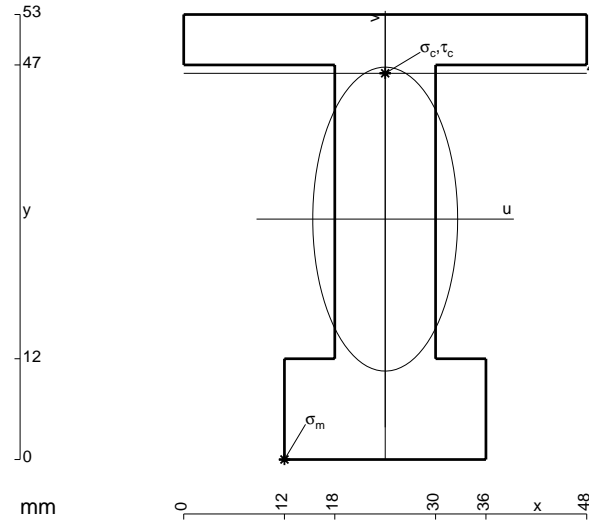
$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

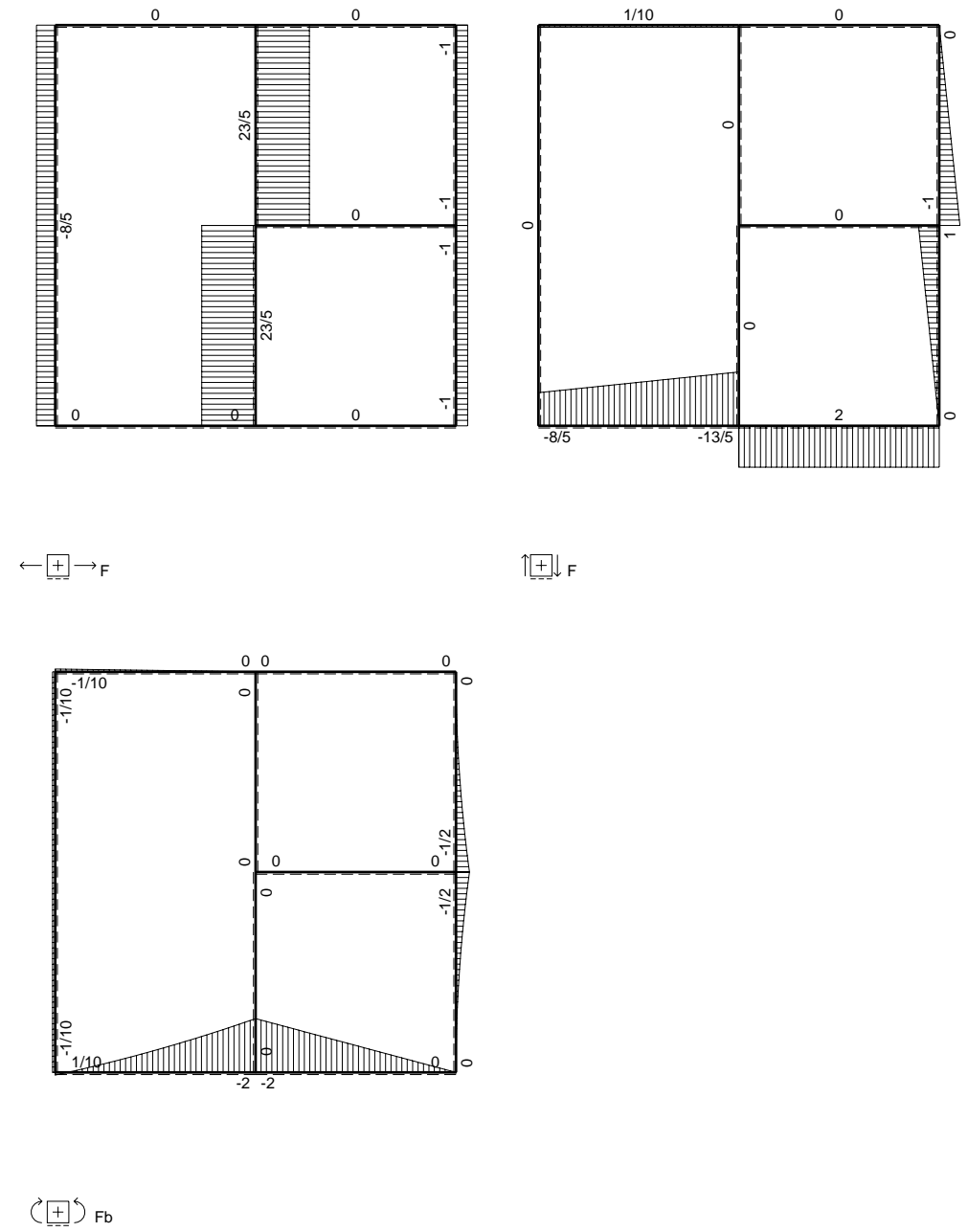
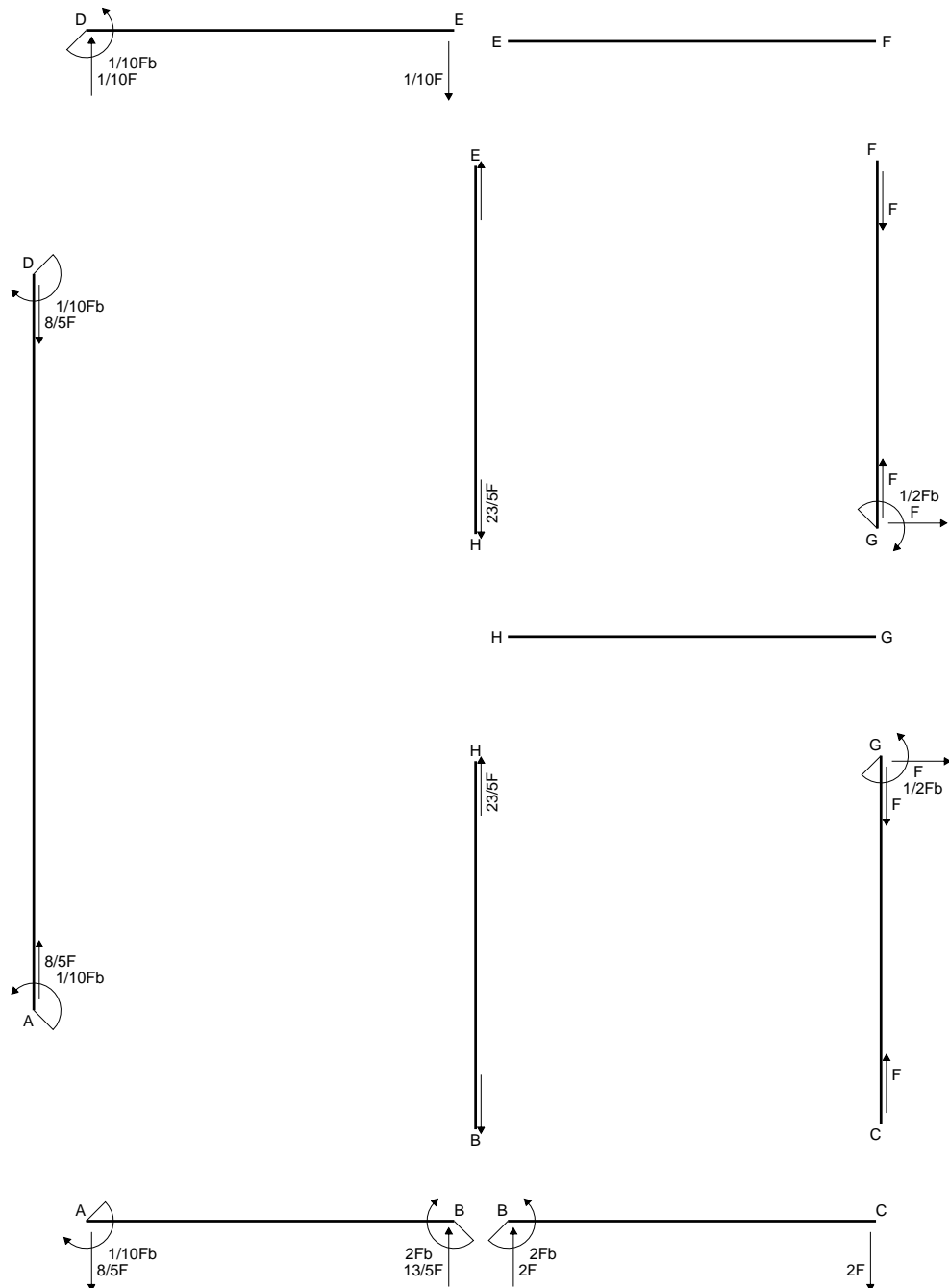
$$L_{BA}^{x_0} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

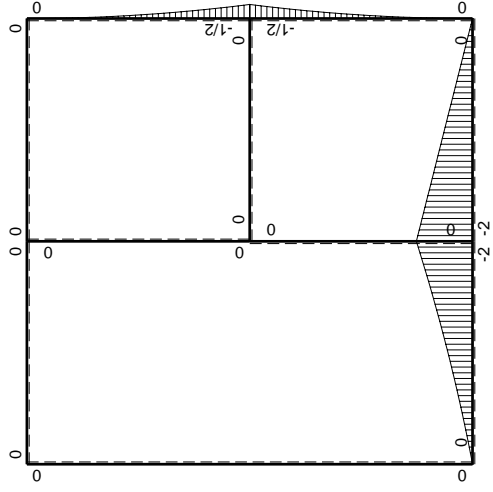
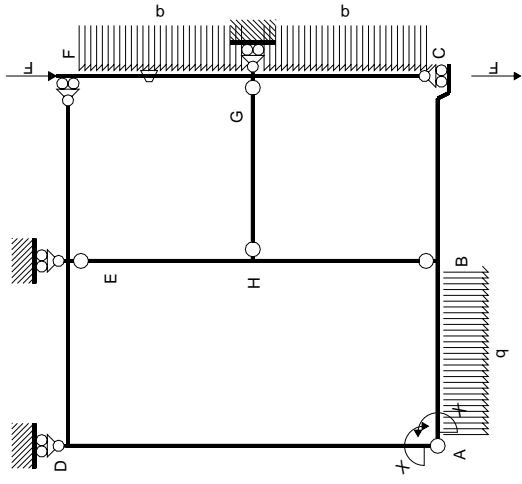
$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

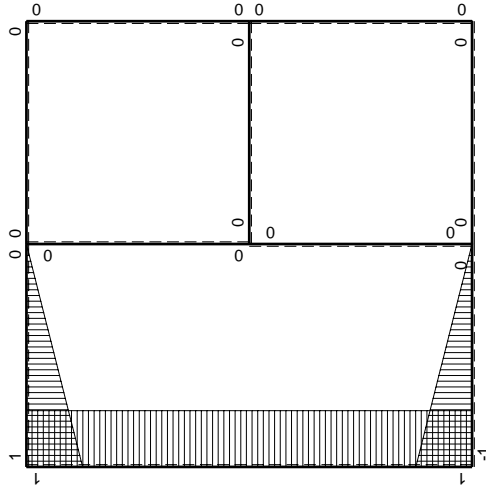


- A = 996. mm<sup>2</sup>
- J<sub>u</sub> = 326526. mm<sup>4</sup>
- J<sub>v</sub> = 74160. mm<sup>4</sup>
- y<sub>g</sub> = 28.63 mm
- T<sub>y</sub> = 4600. N
- M<sub>x</sub> = -2392000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -12. mm
- v<sub>m</sub> = -28.63 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -209.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 46. mm
- v<sub>c</sub> = 17.37 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 127.2 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.476 N/mm<sup>2</sup>
- σ<sub>ρ</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 127.9 N/mm<sup>2</sup>
- S = 6368. mm<sup>3</sup>





$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$-1/2qx^2$	$-Fb/EJ$	0	0	0	0+0	0	
GF b	0	$1/2Fb-Fx+1/2qx^2$	$Fb/EJ$	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	0	0	0	0	0	0+0	0	
BH b	0	0	0	0	0	0			
HE b	0	0	0	0	0	0	0+0	0	
EH b	0	0	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx + 1 \cdot \frac{1}{4} \frac{b}{EJ} = \left[ x - \frac{x^2}{b} + \frac{1}{3} \frac{x^3}{b^2} \right]_0^b \frac{1}{EJ} + 1 \cdot \frac{1}{4} \frac{b}{EJ}$$

$$= (b - b + \frac{1}{3}b) \frac{1}{EJ} + 1 \cdot \frac{1}{4} \frac{b}{EJ} = \frac{7}{12} \frac{b}{EJ}$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx + 1 \cdot \frac{1}{4} \frac{b}{EJ} = \left[ \frac{1}{3} \frac{x^3}{b^2} \right]_0^b \frac{1}{EJ} + 1 \cdot \frac{1}{4} \frac{b}{EJ}$$

$$= (\frac{1}{3}b) \frac{1}{EJ} + 1 \cdot \frac{1}{4} \frac{b}{EJ} = \frac{7}{12} \frac{b}{EJ}$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \frac{b}{EJ}$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \frac{b}{EJ}$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx = \left[ x - \frac{x^2}{b} + \frac{1}{3} \frac{x^3}{b^2} \right]_0^b \frac{1}{EJ}$$

$$= (b - b + \frac{1}{3}b) \frac{1}{EJ} = \frac{1}{3} \frac{b}{EJ}$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx = \left[ \frac{1}{3} \frac{x^3}{b^2} \right]_0^b \frac{1}{EJ}$$

$$= (\frac{1}{3}b) \frac{1}{EJ} = \frac{1}{3} \frac{b}{EJ}$$

$$L_{AB}^{x_0} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

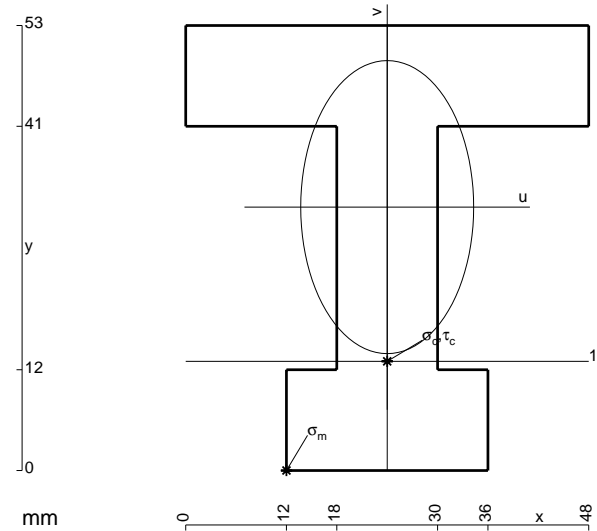
$$= \left[ \frac{3}{4} \frac{x^2}{b} - \frac{1}{3} \frac{x^3}{b^2} - \frac{1}{8} \frac{x^4}{b^3} \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= (\frac{3}{4}b - \frac{1}{3}b - \frac{1}{8}b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ} = \frac{7}{24} \frac{Fb^2}{EJ}$$

$$L_{BA}^{x_0} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= \left[ \frac{x^2}{b} - \frac{5}{6} \frac{x^3}{b^2} + \frac{1}{8} \frac{x^4}{b^3} \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= (b - \frac{5}{6}b + \frac{1}{8}b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ} = \frac{7}{24} \frac{Fb^2}{EJ}$$



$$A = 1212. \text{ mm}^2$$

$$J_u = 369093. \text{ mm}^4$$

$$J_v = 128592. \text{ mm}^4$$

$$y_g = 31.37 \text{ mm}$$

$$T_y = 4540. \text{ N}$$

$$M_x = -2587800. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -12. \text{ mm}$$

$$v_m = -31.37 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -220. \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 13. \text{ mm}$$

$$v_c = -18.37 \text{ mm}$$

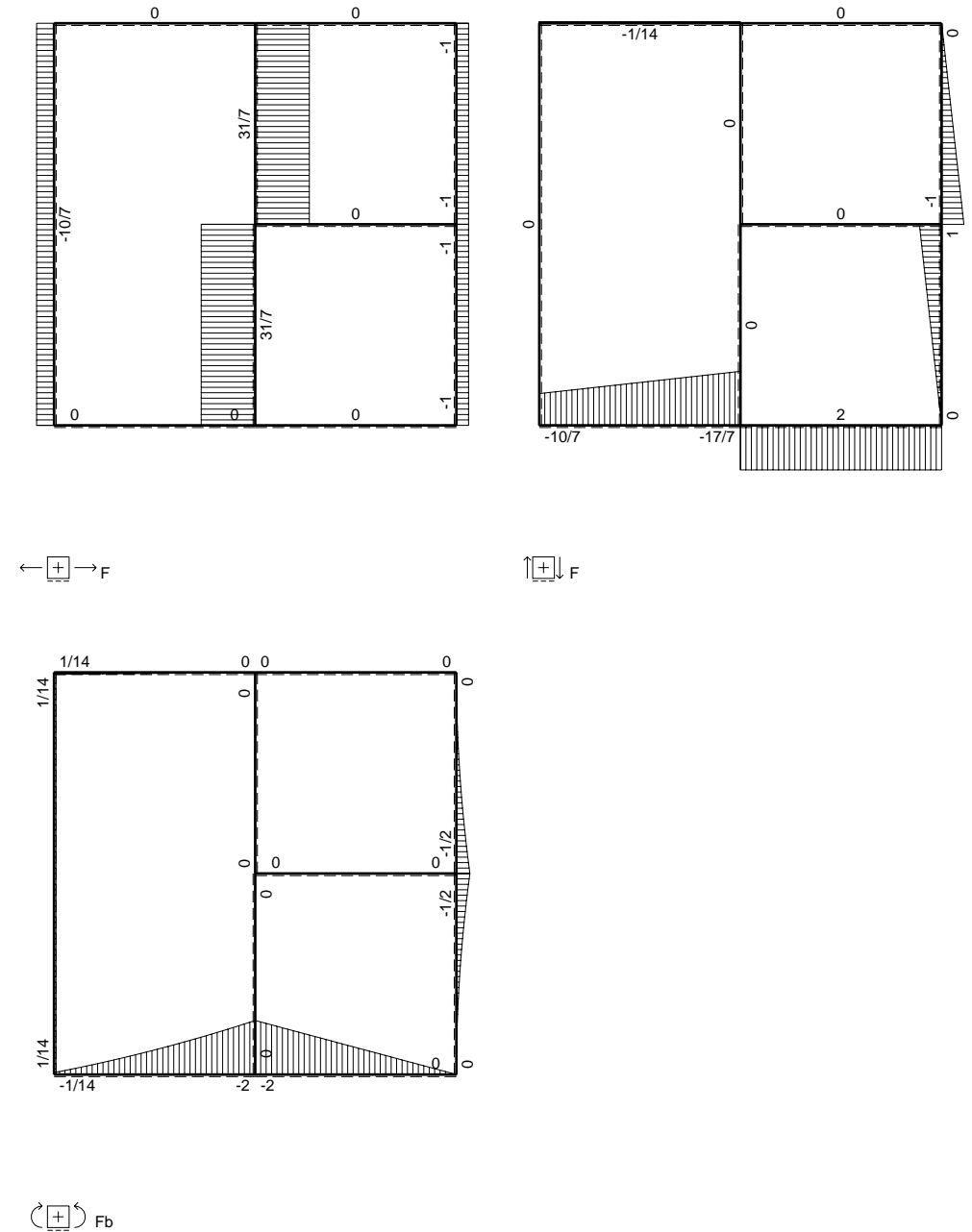
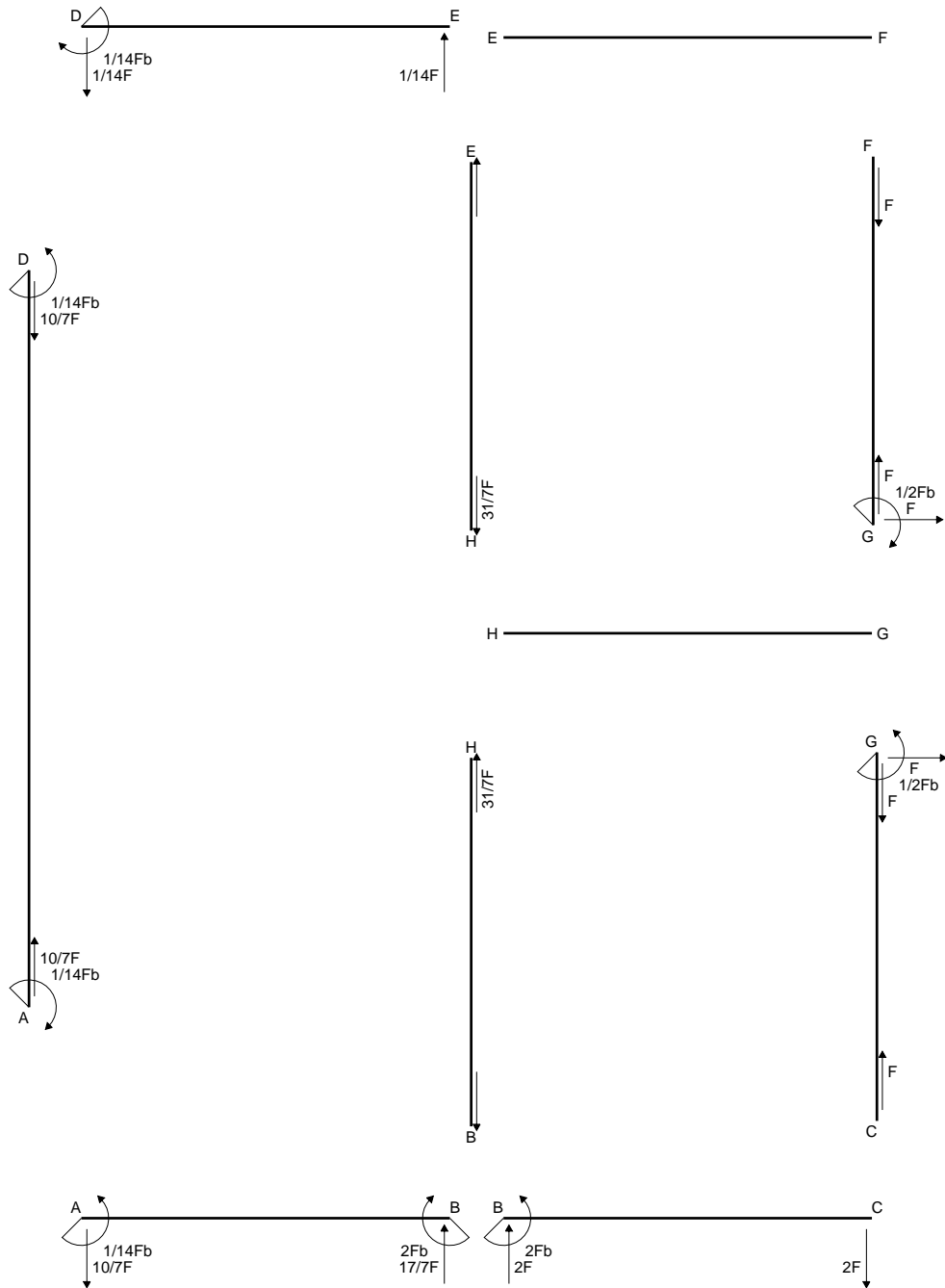
$$\sigma_c = -Mv/J_u = -128.8 \text{ N/mm}^2$$

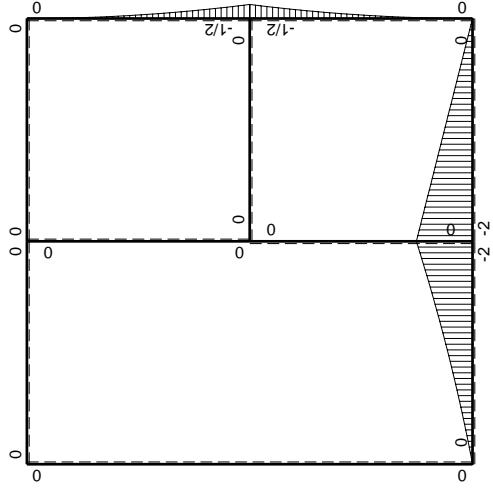
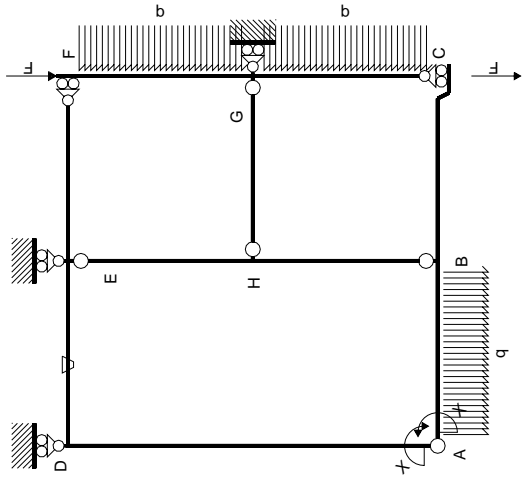
$$\tau_c = 7.722 \text{ N/mm}^2$$

$$\sigma_0 = \sqrt{\sigma^2 + 3\tau^2} = 129.5 \text{ N/mm}^2$$

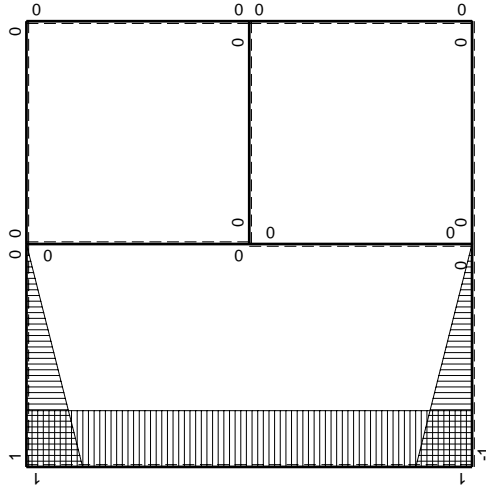
$$S = 7533. \text{ mm}^3$$







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x / EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	2Xb/EJ	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	$-Fb/EJ$	0	$-Fb/EJ+Fx/EJ$	$1-2x/b+x^2/b^2$	$(0-1/2)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	0	$Fb/EJ$	0	$-Fx/EJ$	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$-1/2qx^2$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	0	0	0	0	0	0+0	0	
BH b	0	0	0	0	0	0			
HE b	0	0	0	0	0	0	0+0	0	
EH b	0	0	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$-5/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$1/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

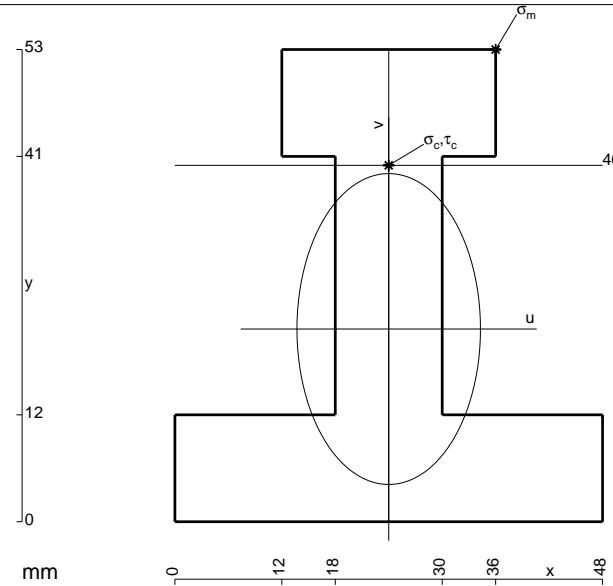
$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (-1 + x/b) \cdot \theta \, dx = \left[ -x + 1/2 x^2/b \right]_0^b \cdot \theta$$

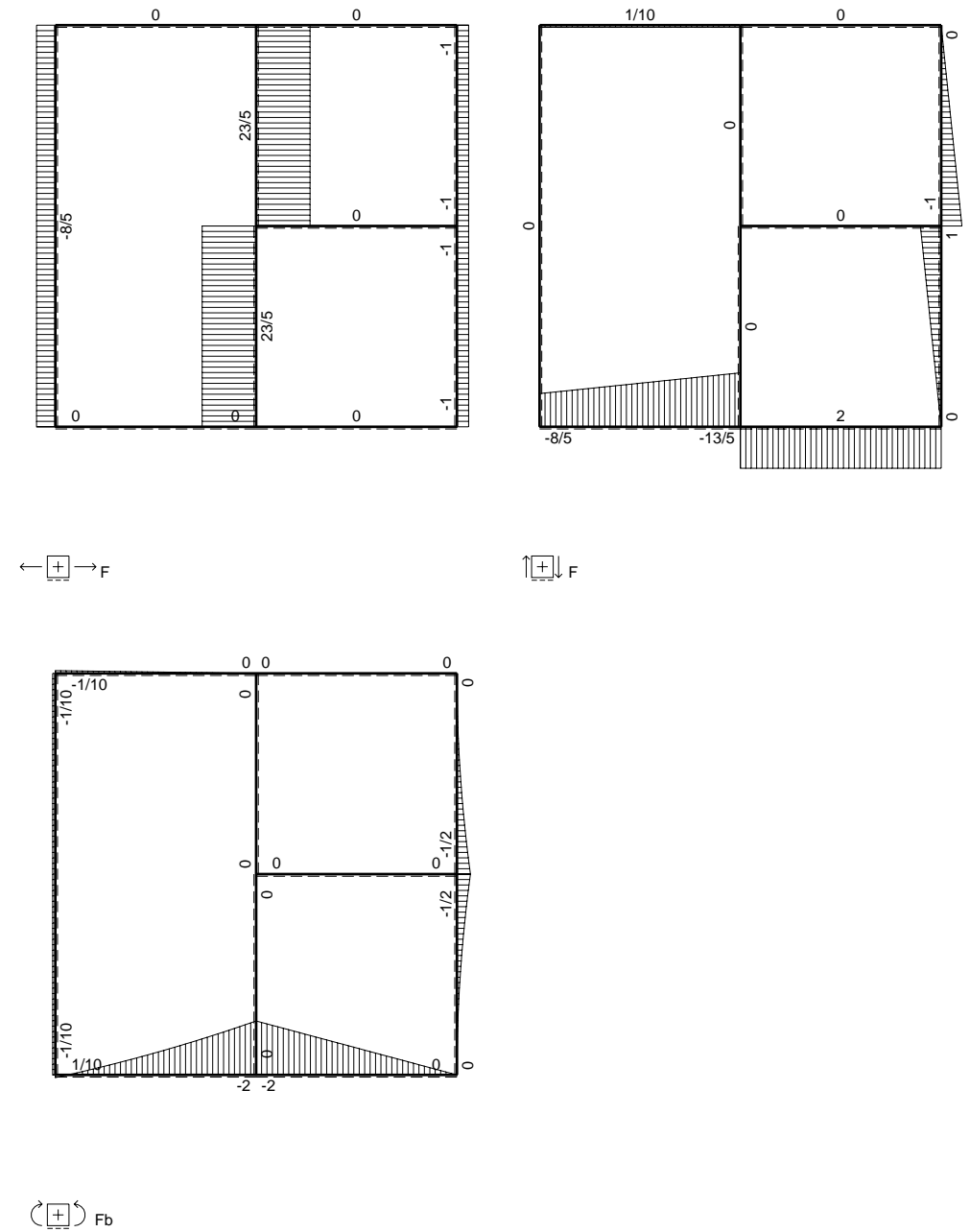
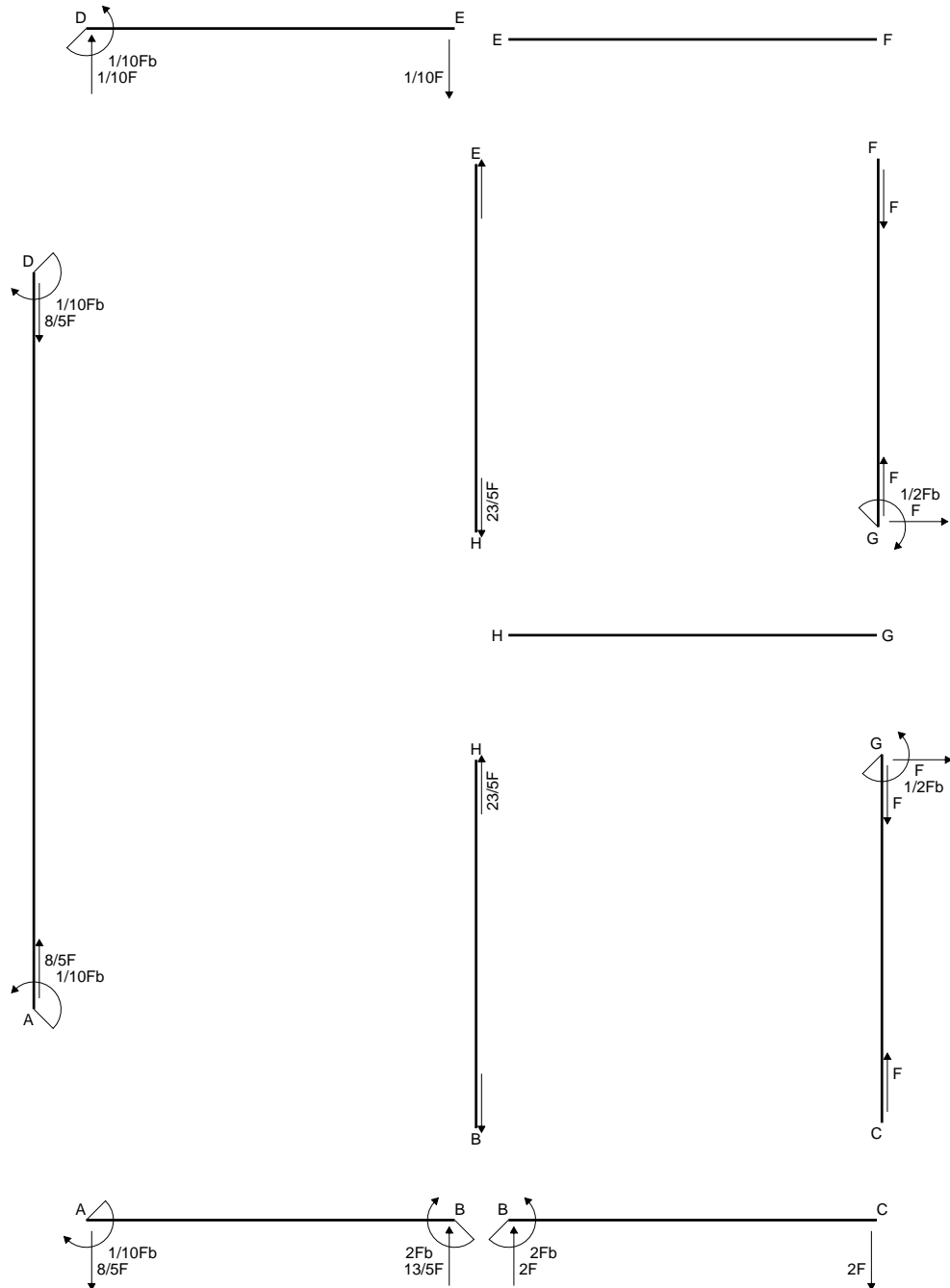
$$= (-b + 1/2 b) \cdot \theta = -1/2 \cdot Fb^2/EJ$$

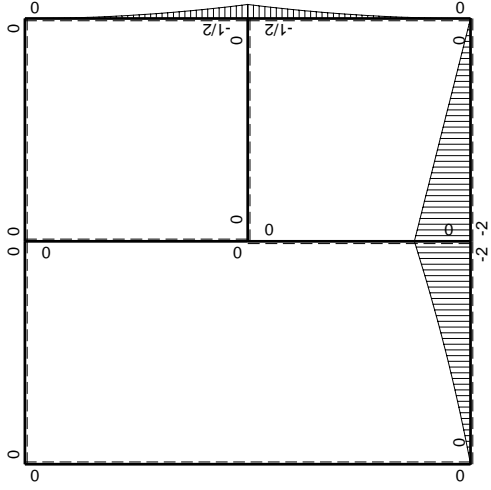
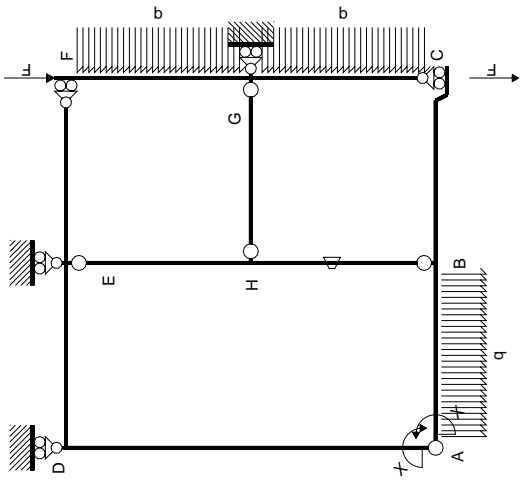
$$L_{ED}^{xo} = \int_0^b (x/b) \cdot \theta \, dx = \left[ 1/2 x^2/b \right]_0^b \cdot \theta$$

$$= (1/2 b) \cdot \theta = -1/2 \cdot Fb^2/EJ$$

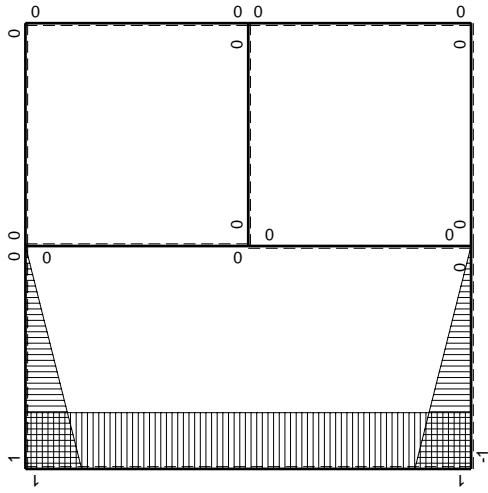


- A = 1212. mm<sup>2</sup>
- J<sub>u</sub> = 369093. mm<sup>4</sup>
- J<sub>v</sub> = 128592. mm<sup>4</sup>
- y<sub>g</sub> = 21.63 mm
- T<sub>y</sub> = 4360. N
- M<sub>x</sub> = -2703200. Nmm
- x<sub>m</sub> = 36. mm
- y<sub>m</sub> = 53. mm
- u<sub>m</sub> = 12. mm
- v<sub>m</sub> = 31.37 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 229.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 40. mm
- v<sub>c</sub> = 18.37 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 134.5 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.416 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 135.2 N/mm<sup>2</sup>
- S = 7533. mm<sup>3</sup>





$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	2Xb/EJ	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	1/3Xb/EJ	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$-1/2qx^2$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
BH b	0	0	$Fb/EJ$	0	0	0			
HE b	0	0	0	0	0	0	0+0	0	
EH b	0	0	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								1/4Xb/EJ
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

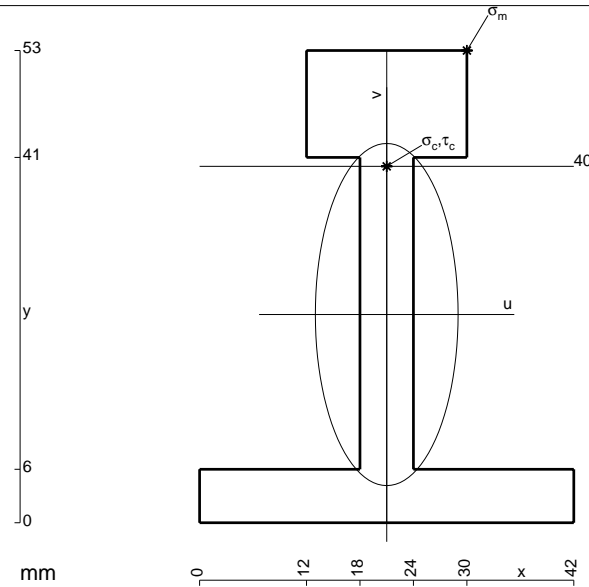
$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

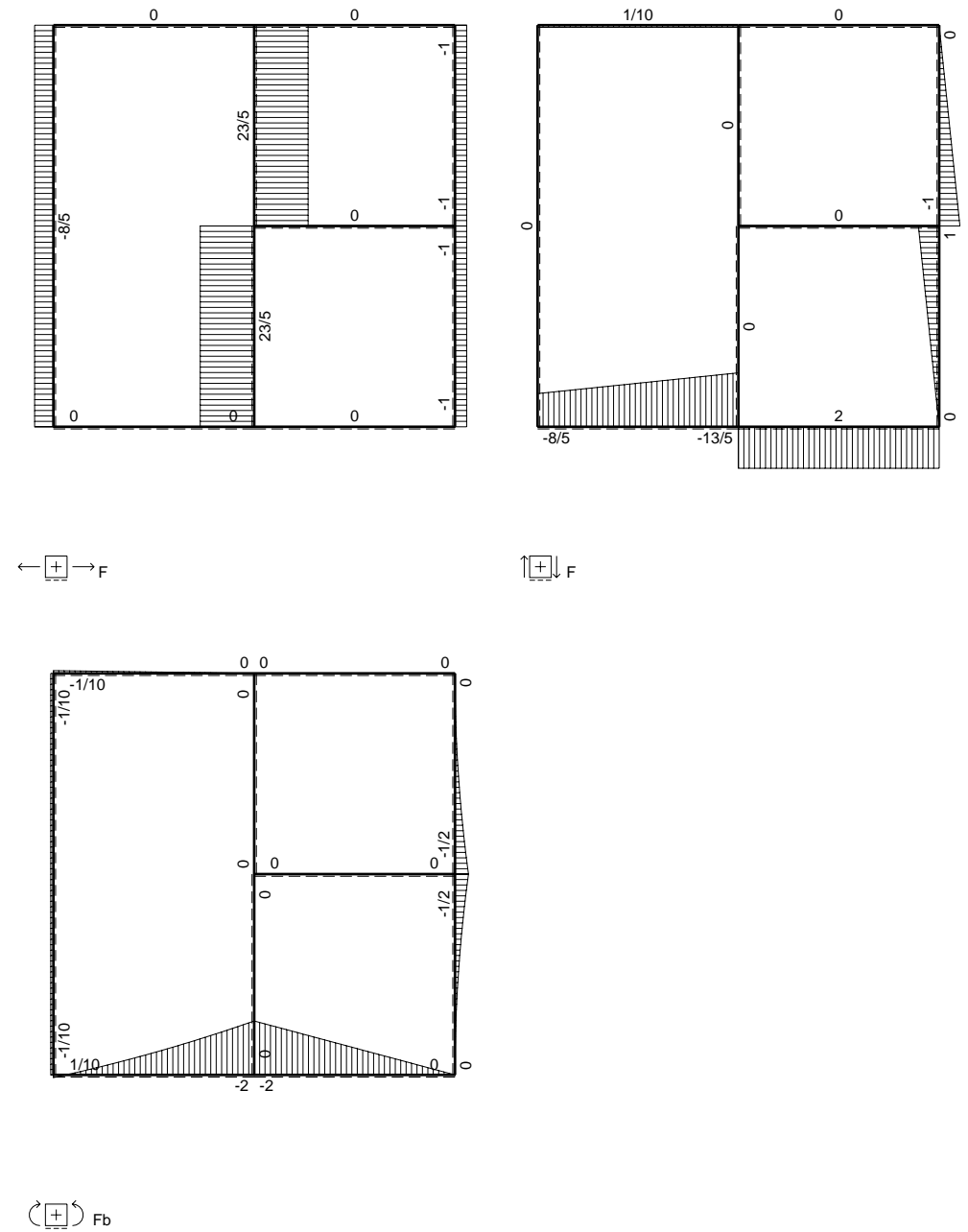
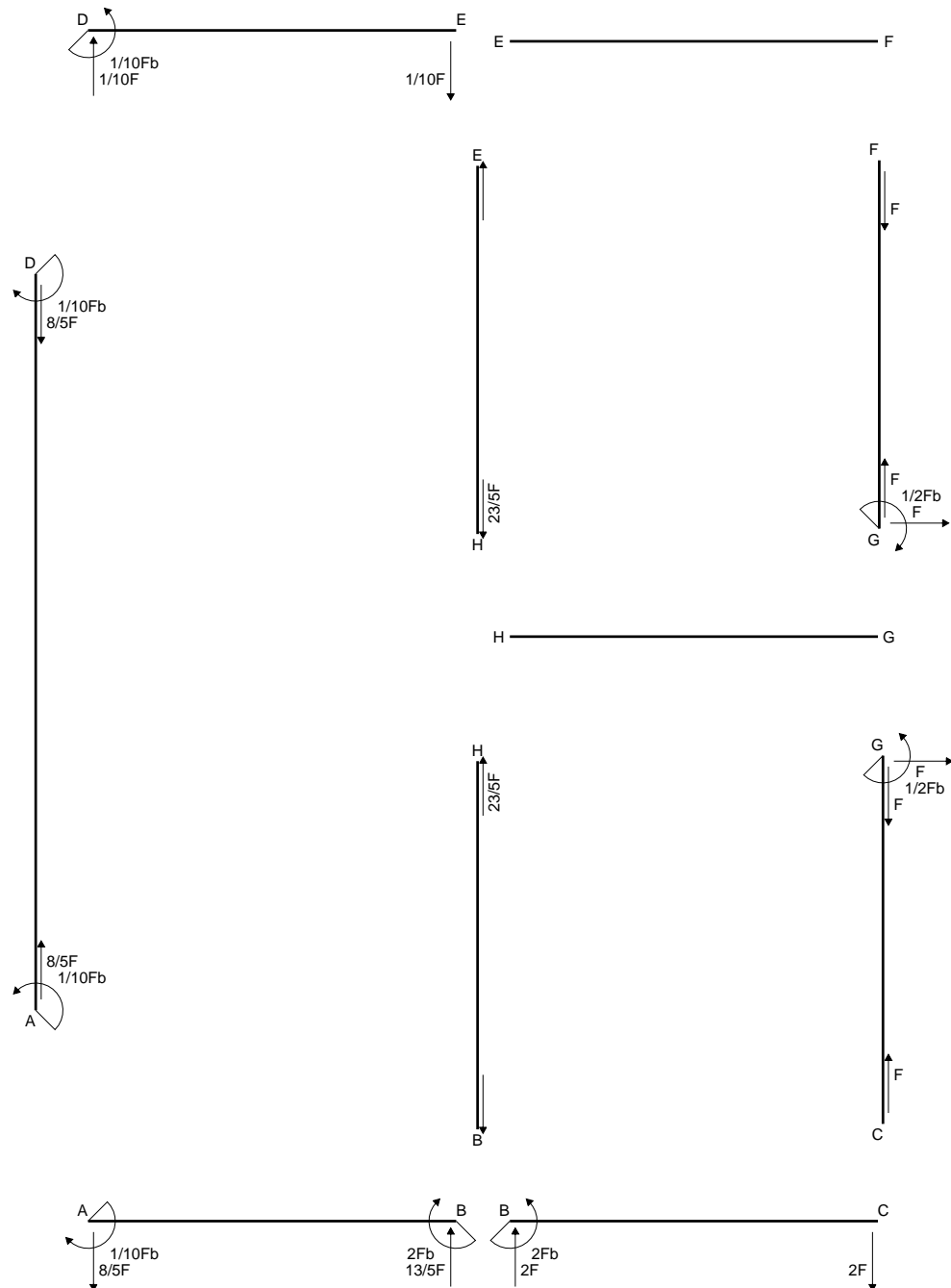
$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

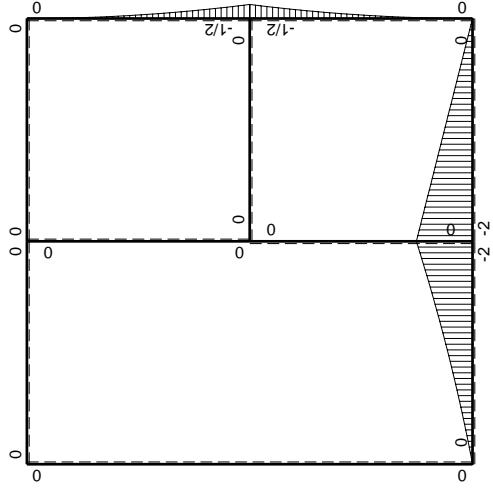
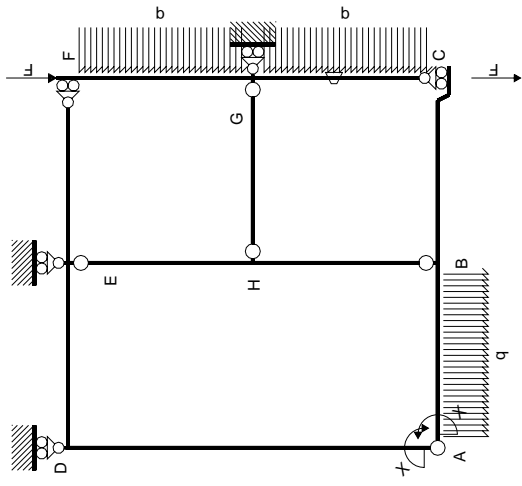
$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$



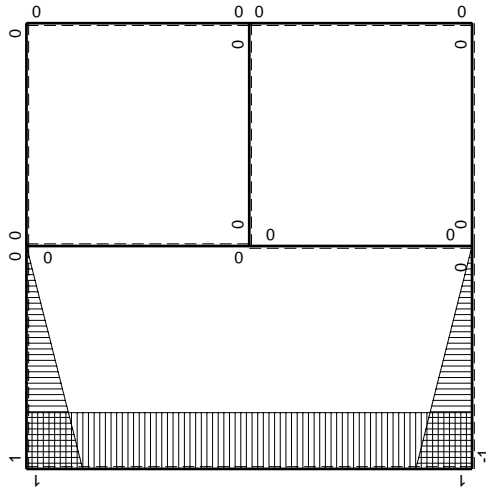
- A = 678. mm<sup>2</sup>
- J<sub>u</sub> = 249963. mm<sup>4</sup>
- J<sub>v</sub> = 43506. mm<sup>4</sup>
- y<sub>g</sub> = 23.37 mm
- T<sub>y</sub> = 3020. N
- M<sub>x</sub> = -2023400. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 53. mm
- u<sub>m</sub> = 9. mm
- v<sub>m</sub> = 29.63 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 239.9 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 40. mm
- v<sub>c</sub> = 16.63 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 134.6 N/mm<sup>2</sup>
- τ<sub>c</sub> = 10.49 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 135.9 N/mm<sup>2</sup>
- S = 5207. mm<sup>3</sup>







$M_0$  flessione da carichi assegnati



$M_X$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$-1/2qx^2$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	$-Fb/EJ$	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	$Fb/EJ$	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	0	0	0	0	0	0+0	0	
BH b	0	0	0	0	0	0			
HE b	0	0	0	0	0	0	0+0	0	
EH b	0	0	0	0	0	0			
AB	molla asta $-W_{1AB} (W_{0AB} + XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (-2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (-2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{x_0} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

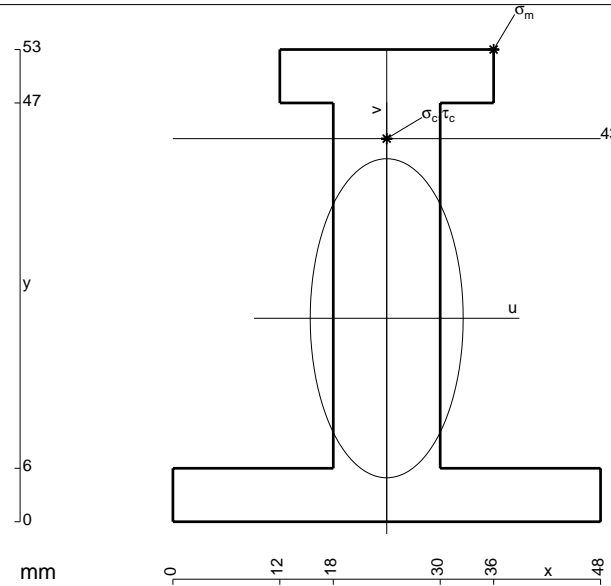
$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

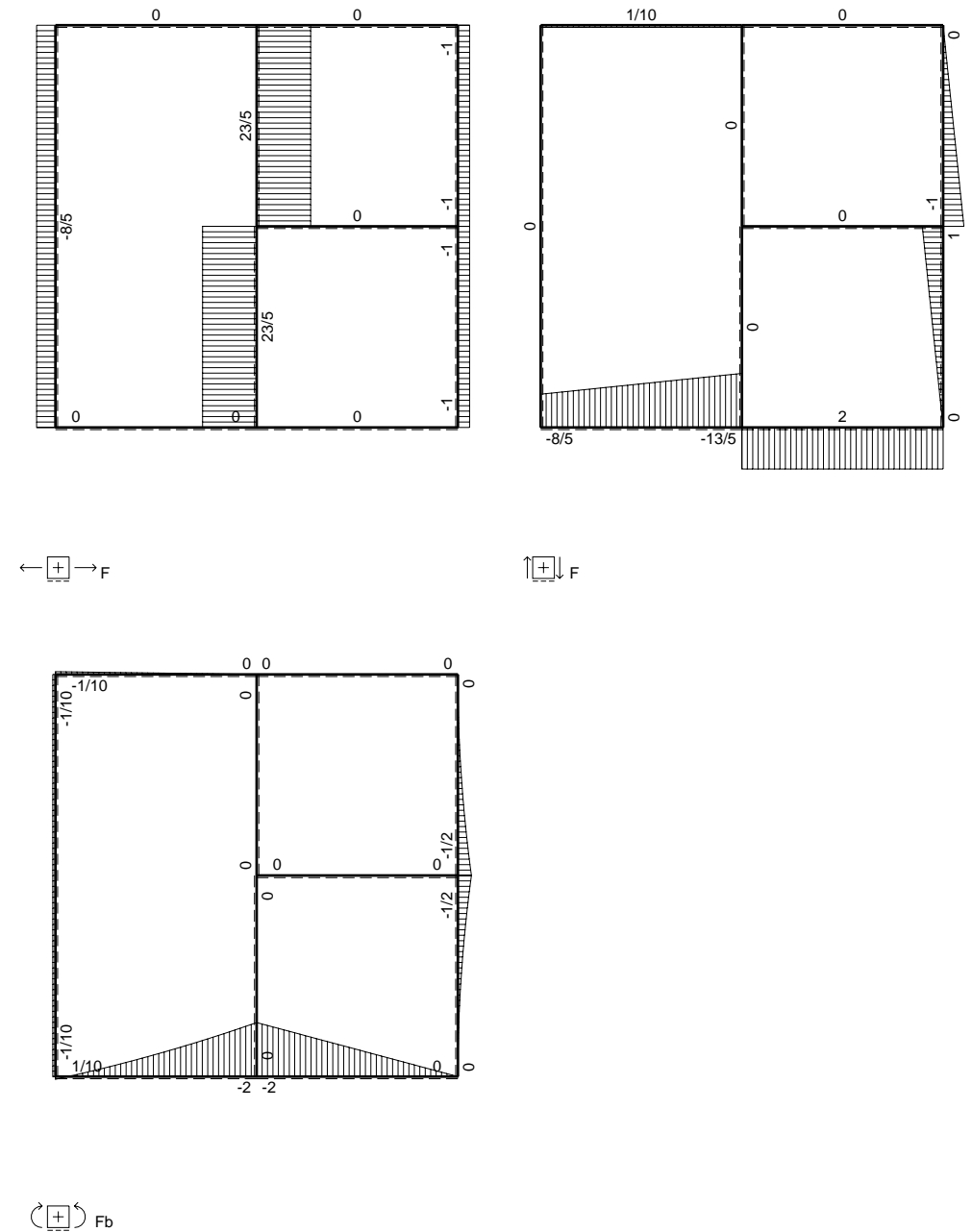
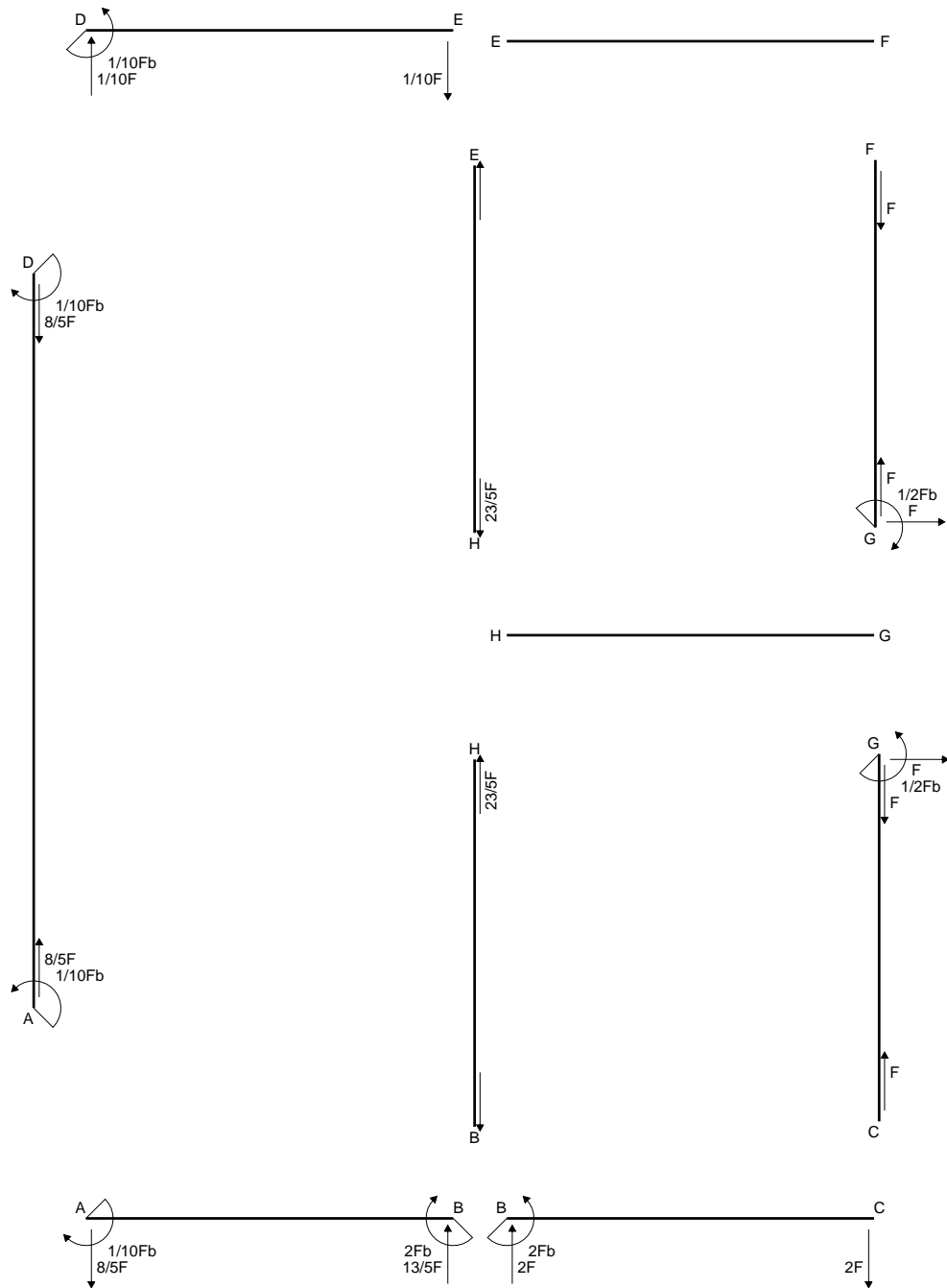
$$L_{BA}^{x_0} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

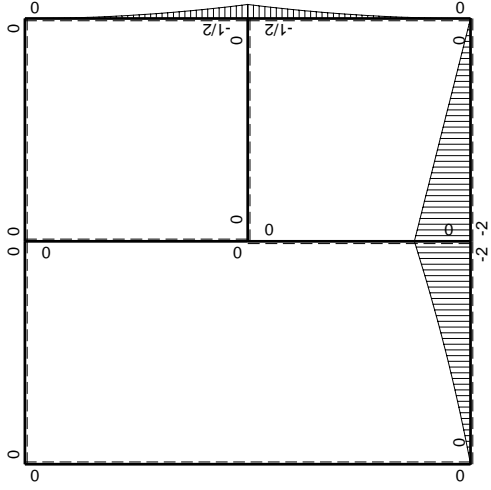
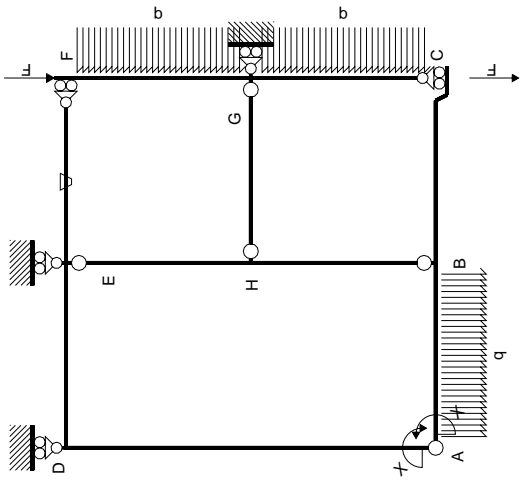
$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

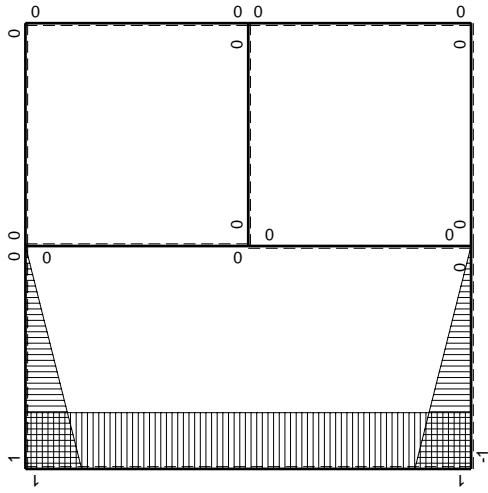


- A = 924. mm<sup>2</sup>
- J<sub>u</sub> = 296396. mm<sup>4</sup>
- J<sub>v</sub> = 68112. mm<sup>4</sup>
- y<sub>g</sub> = 22.84 mm
- T<sub>y</sub> = 2720. N
- M<sub>x</sub> = -1958400. Nmm
- x<sub>m</sub> = 36. mm
- y<sub>m</sub> = 53. mm
- u<sub>m</sub> = 12. mm
- v<sub>m</sub> = 30.16 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 199.3 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 43. mm
- v<sub>c</sub> = 20.16 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 133.2 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.805 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 133.4 N/mm<sup>2</sup>
- S = 4975. mm<sup>3</sup>





$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	2Xb/EJ	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	1/3Xb/EJ	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
FE b	0	0	$Fb/EJ$	0	0	0			
FG b	0	$-1/2qx^2$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	0	0	0	0	0	0+0	0	
BH b	0	0	0	0	0	0			
HE b	0	0	0	0	0	0	0+0	0	
EH b	0	0	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								1/4Xb/EJ
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

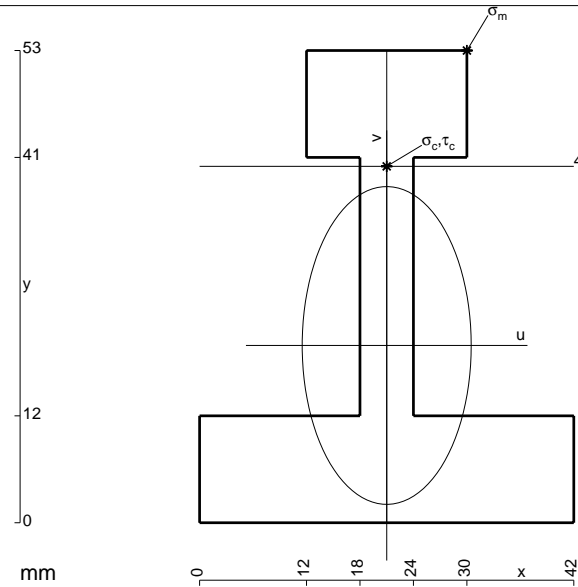
$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

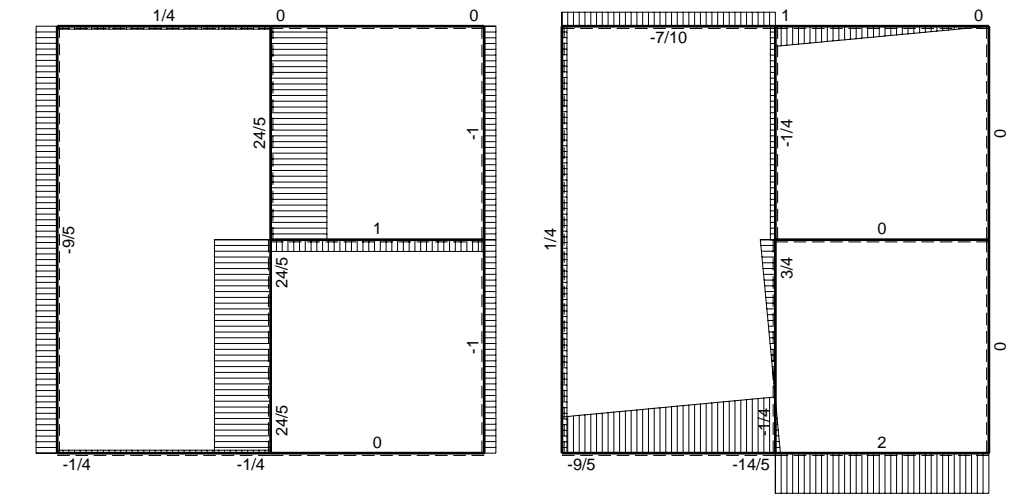
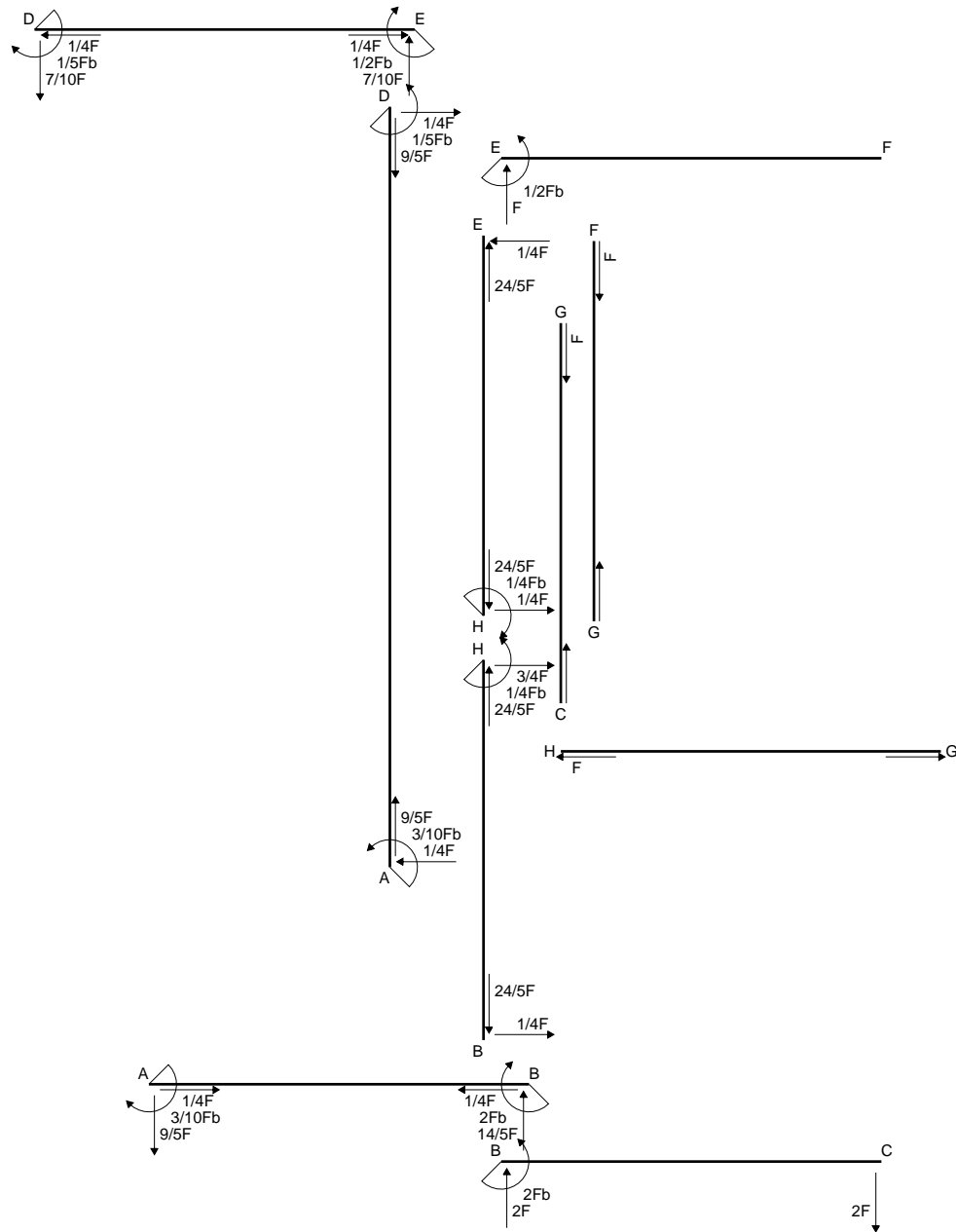
$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$



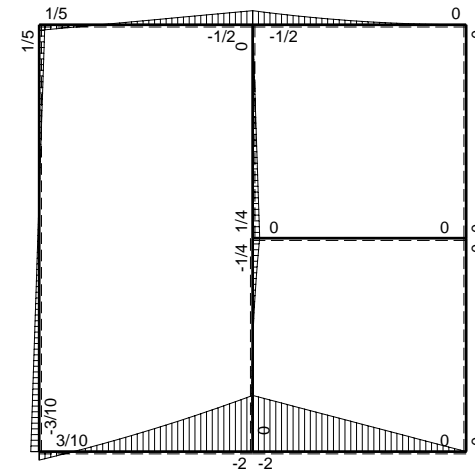
- A = 894. mm<sup>2</sup>
- J<sub>u</sub> = 284424. mm<sup>4</sup>
- J<sub>v</sub> = 80442. mm<sup>4</sup>
- y<sub>g</sub> = 19.9 mm
- T<sub>y</sub> = 2360. N
- M<sub>x</sub> = -1793600. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 53. mm
- u<sub>m</sub> = 9. mm
- v<sub>m</sub> = 33.1 mm
- σ<sub>m</sub> = -M<sub>v</sub>/J<sub>u</sub> = 208.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 40. mm
- v<sub>c</sub> = 20.1 mm
- σ<sub>c</sub> = -M<sub>v</sub>/J<sub>u</sub> = 126.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 8.267 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 127.6 N/mm<sup>2</sup>
- S = 5978. mm<sup>3</sup>



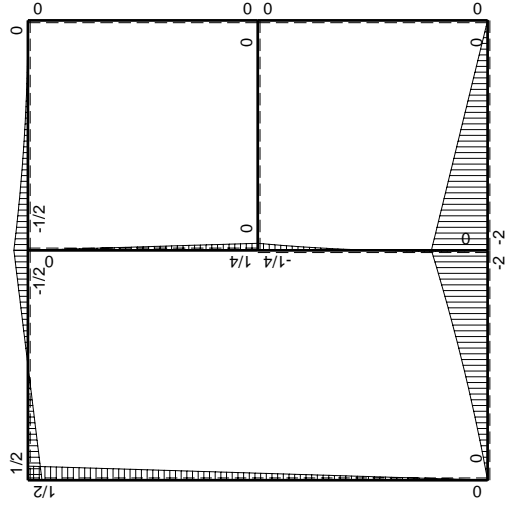
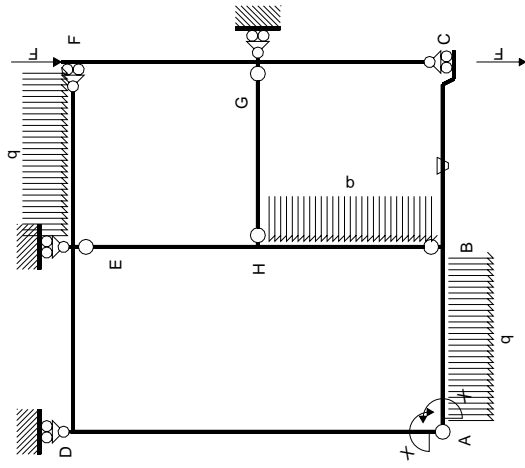


← ⊕ → F

↑ ⊕ ↓ F

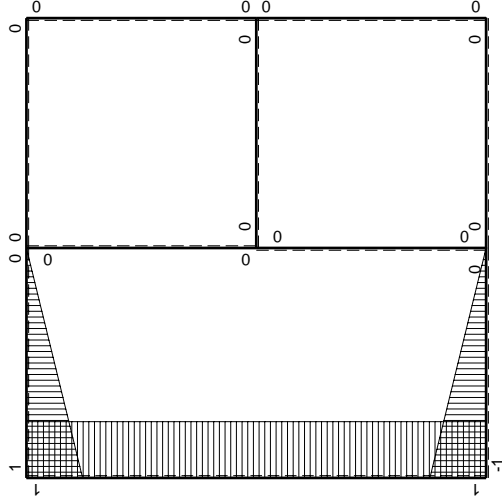


⊕ ⊖ F<sub>b</sub>



Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	$-Fb/EJ$	0	0	0	0+0	0	
CB b	0	$2Fx$	$Fb/EJ$	0	0	0			
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1			
DE b	$1-x/b$	$1/2Fb-Fx$	0	$1/2Fb-3/2Fx+Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/12+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fb-Fx$	0	$-1/2Fx+Fx^2/b$	0	$x^2/b^2$			
EF b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
FE b	0	$1/2qx^2$	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-1/4Fb+3/4Fx-1/2qx^2$	0	0	0	0	0+0	0	
BH b	0	$-1/4Fx+1/2qx^2$	0	0	0	0			
HE b	0	$1/4Fb-1/4Fx$	0	0	0	0	0+0	0	
EH b	0	$-1/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/8Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-3/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

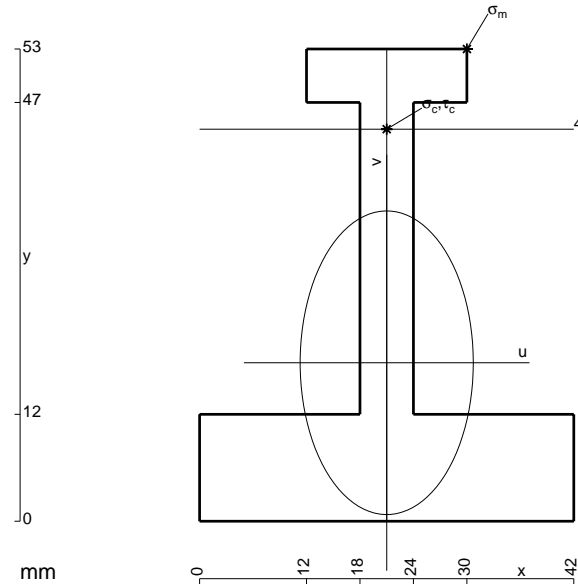
$$= (b - 1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - 3/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 3/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

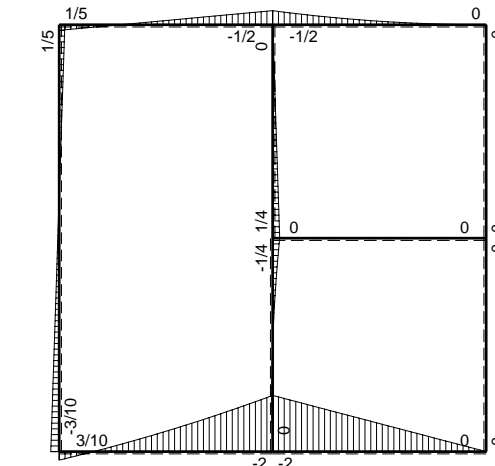
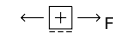
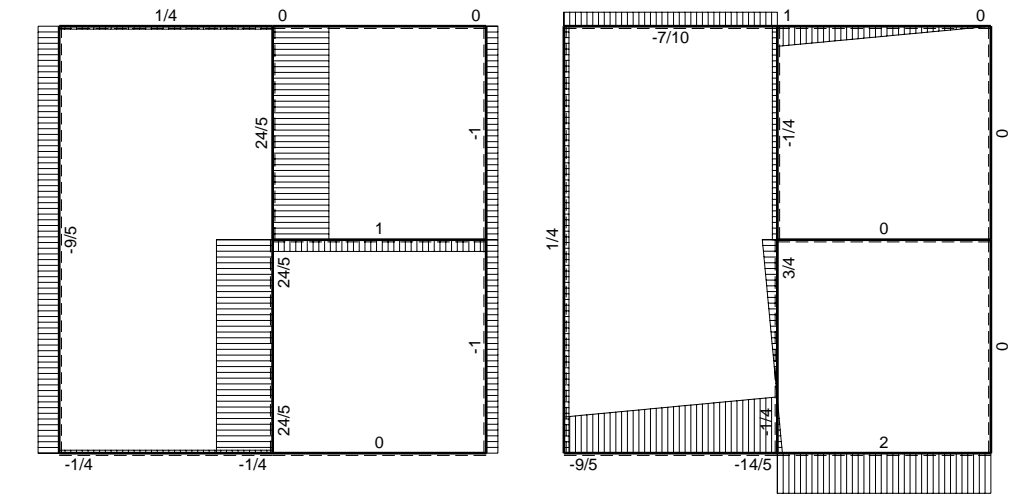
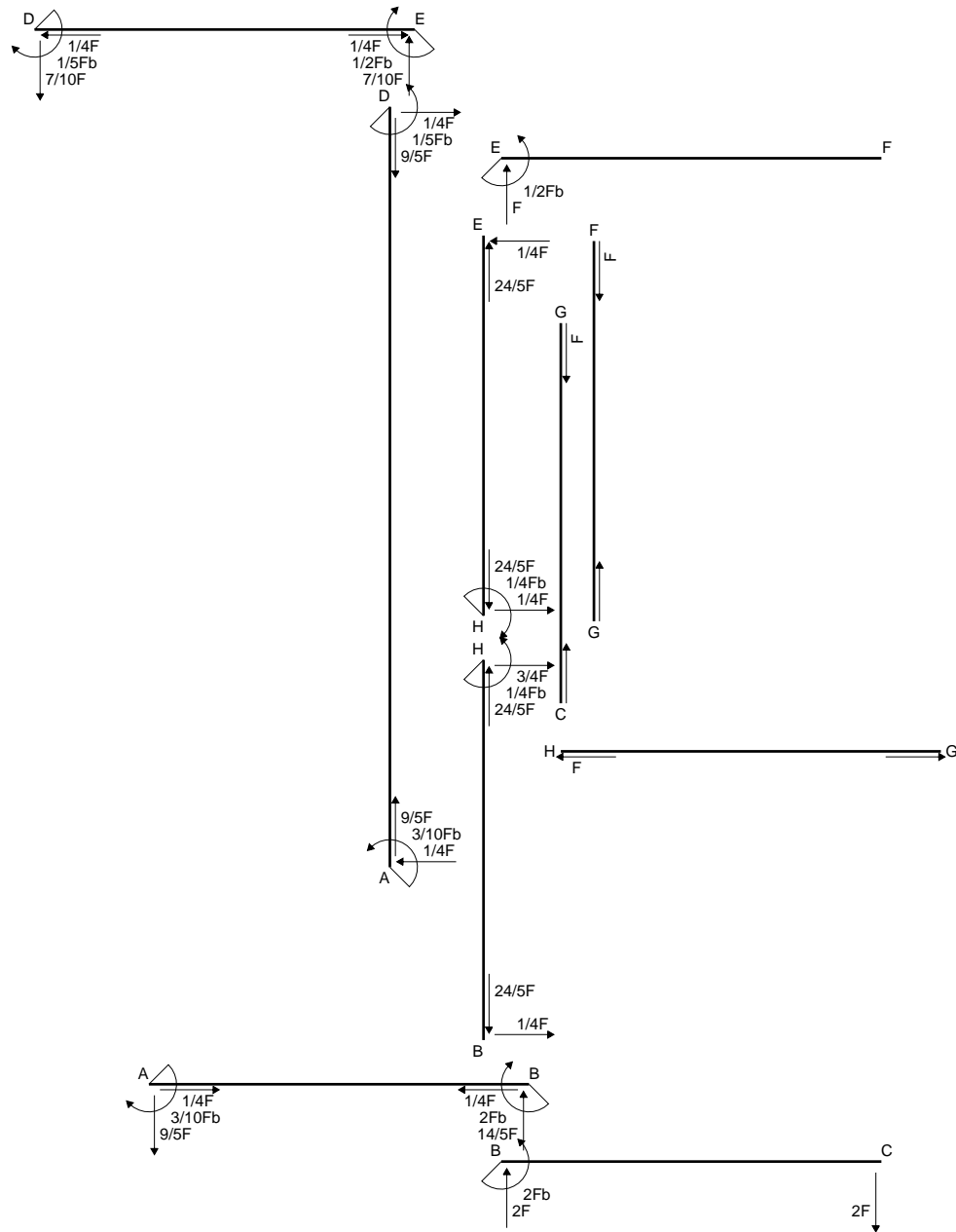
$$= (1/2 b - 3/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$

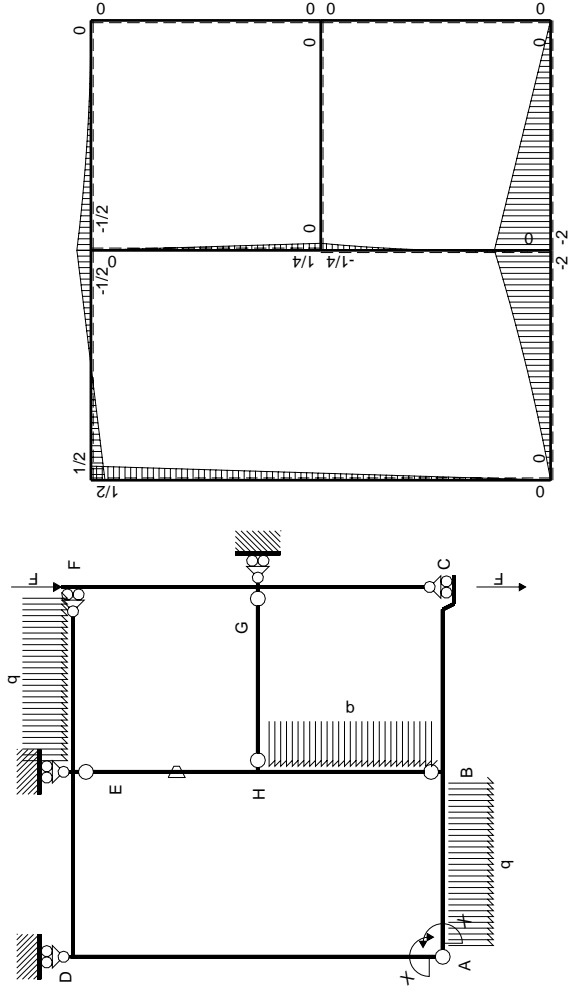
$$L_{ED}^{xo} = \int_0^b (-1/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$



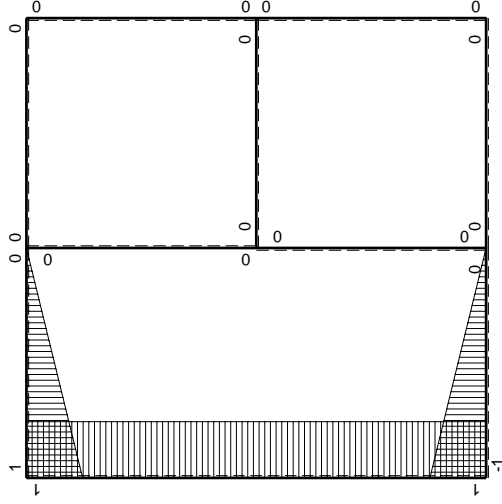
- A = 822. mm<sup>2</sup>
- J<sub>u</sub> = 238712. mm<sup>4</sup>
- J<sub>v</sub> = 77634. mm<sup>4</sup>
- y<sub>g</sub> = 17.78 mm
- T<sub>y</sub> = 1840. N
- M<sub>x</sub> = -1490400. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 53. mm
- u<sub>m</sub> = 9. mm
- v<sub>m</sub> = 35.22 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 219.9 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 44. mm
- v<sub>c</sub> = 26.22 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 163.7 N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.111 N/mm<sup>2</sup>
- σ<sub>σ</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 163.9 N/mm<sup>2</sup>
- S = 3978. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJdx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1			
DE b	$1-x/b$	$1/2Fb-Fx$	0	$1/2Fb-3/2Fx+Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/12+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fb-Fx$	0	$-1/2Fx+Fx^2/b$	0	$x^2/b^2$			
EF b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
FE b	0	$1/2qx^2$	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-1/4Fb+3/4Fx-1/2qx^2$	0	0	0	0	0+0	0	
BH b	0	$-1/4Fx+1/2qx^2$	0	0	0	0			
HE b	0	$1/4Fb-1/4Fx$	$-Fb/EJ$	0	0	0	0+0	0	
EH b	0	$-1/4Fx$	$Fb/EJ$	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/8Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-3/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

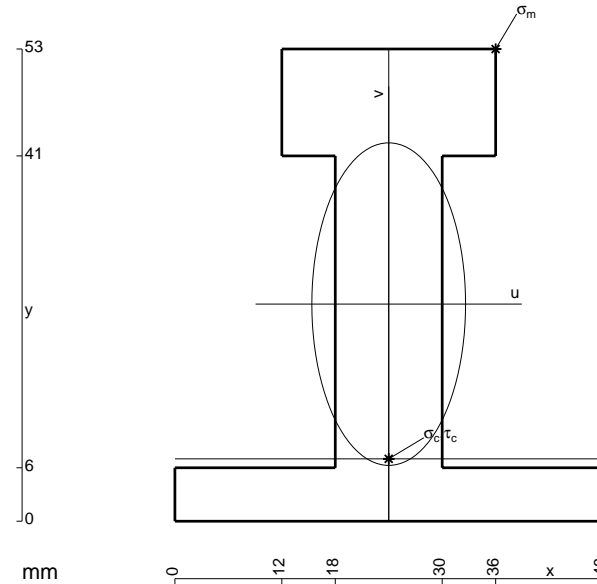
$$= (b - 1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - 3/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 3/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/2 b - 3/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$

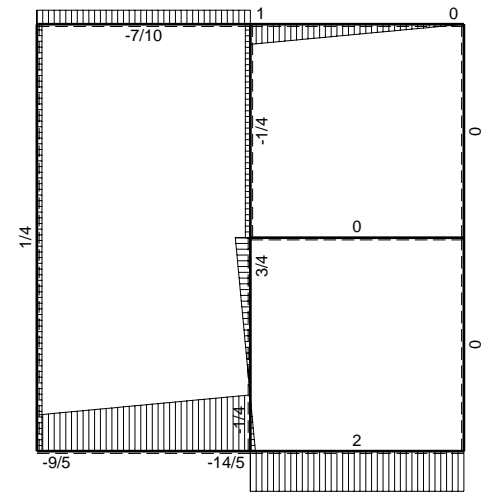
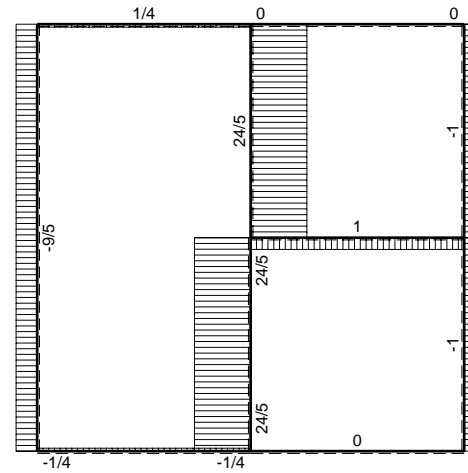
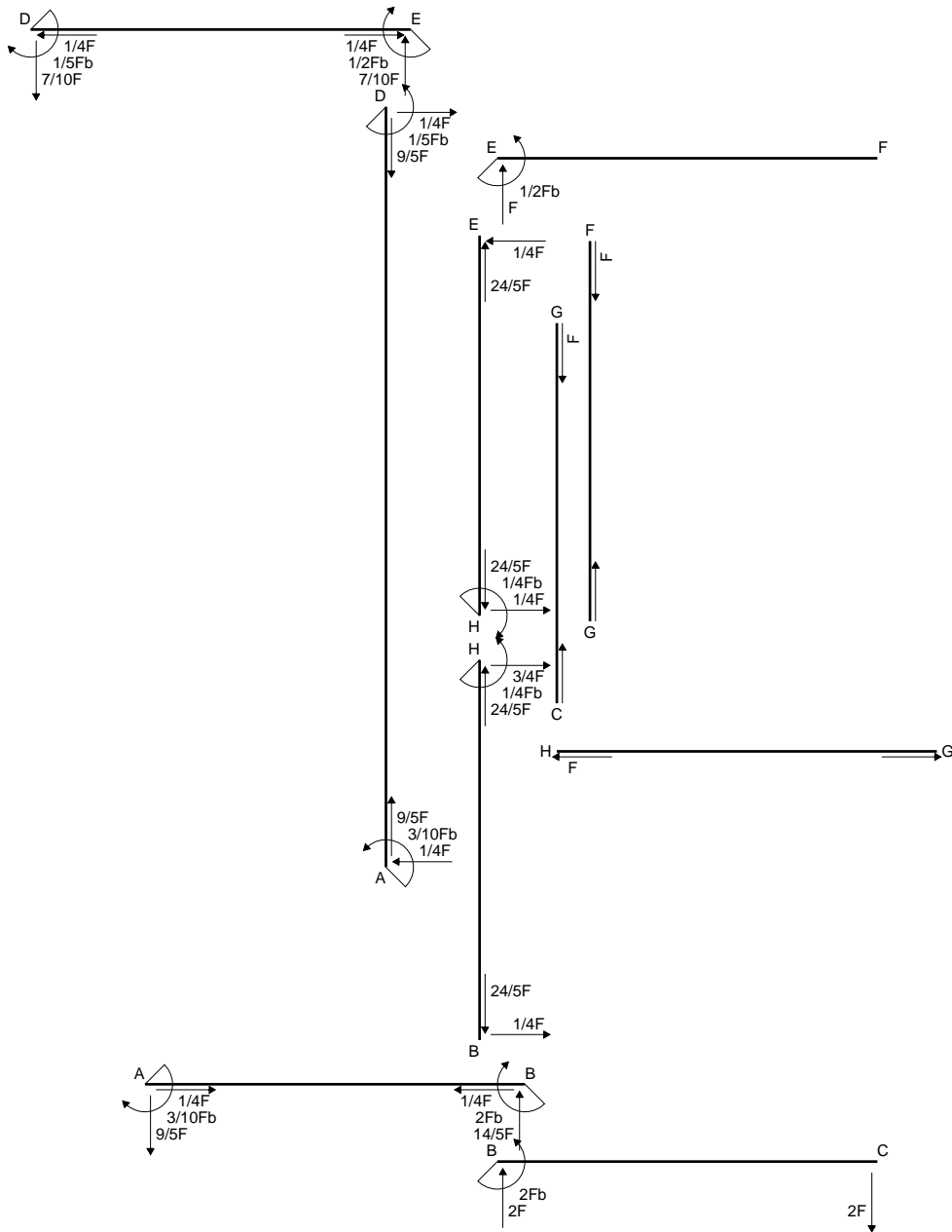
$$L_{ED}^{xo} = \int_0^b (-1/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$



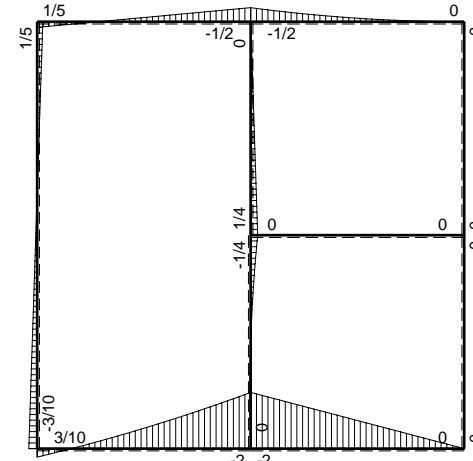
$A = 996. \text{ mm}^2$   
 $J_u = 326526. \text{ mm}^4$   
 $J_v = 74160. \text{ mm}^4$   
 $y_g = 24.37 \text{ mm}$   
 $T_y = 3040. \text{ N}$   
 $M_x = -2614400. \text{ Nmm}$   
 $x_m = 36. \text{ mm}$   
 $y_m = 53. \text{ mm}$   
 $u_m = 12. \text{ mm}$   
 $v_m = 28.63 \text{ mm}$   
 $\sigma_m = -Mv/J_u = 229.3 \text{ N/mm}^2$   
 $x_c = 24. \text{ mm}$   
 $y_c = 7. \text{ mm}$   
 $v_c = -17.37 \text{ mm}$   
 $\sigma_c = -Mv/J_u = -139.1 \text{ N/mm}^2$   
 $\tau_c = 4.941 \text{ N/mm}^2$   
 $\sigma_o = \sqrt{\sigma^2 + 3\tau^2} = 139.3 \text{ N/mm}^2$   
 $S = 6368. \text{ mm}^3$



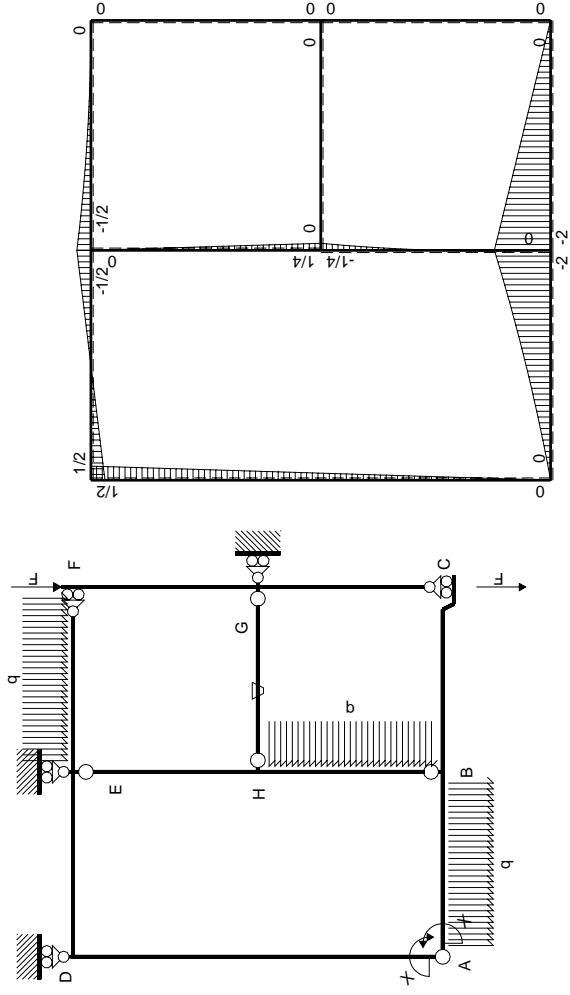


← ⊕ → F

↑ ⊕ ↓ F

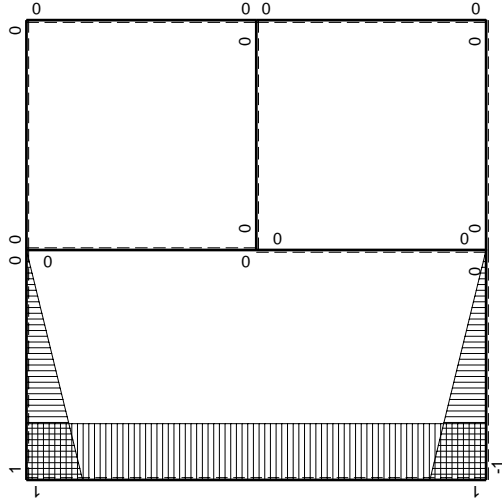


⊕ ⊖ F<sub>b</sub>



Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJdx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1			
DE b	$1-x/b$	$1/2Fb-Fx$	0	$1/2Fb-3/2Fx+Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/12+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fb-Fx$	0	$-1/2Fx+Fx^2/b$	0	$x^2/b^2$			
EF b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
FE b	0	$1/2qx^2$	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
GH b	0	0	$Fb/EJ$	0	0	0			
HB b	0	$-1/4Fb+3/4Fx-1/2qx^2$	0	0	0	0	0+0	0	
BH b	0	$-1/4Fx+1/2qx^2$	0	0	0	0			
HE b	0	$1/4Fb-1/4Fx$	0	0	0	0	0+0	0	
EH b	0	$-1/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/8Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-3/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx + 1 \cdot 1 \cdot \frac{1}{4} \frac{b}{EJ} = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ} + 1 \cdot 1 \cdot \frac{1}{4} \frac{b}{EJ}$$

$$= (b - b + 1/3 b) \frac{1}{EJ} + 1 \cdot 1 \cdot \frac{1}{4} \frac{b}{EJ} = 7/12 \frac{b}{EJ}$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx + 1 \cdot 1 \cdot \frac{1}{4} \frac{b}{EJ} = \left[ 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ} + 1 \cdot 1 \cdot \frac{1}{4} \frac{b}{EJ}$$

$$= (1/3 b) \frac{1}{EJ} + 1 \cdot 1 \cdot \frac{1}{4} \frac{b}{EJ} = 7/12 \frac{b}{EJ}$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \frac{b}{EJ}$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \frac{b}{EJ}$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ}$$

$$= (b - b + 1/3 b) \frac{1}{EJ} = 1/3 \frac{b}{EJ}$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx = \left[ 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ}$$

$$= (1/3 b) \frac{1}{EJ} = 1/3 \frac{b}{EJ}$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= (3/4 b - 1/3 b - 1/8 b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ} = 7/24 \frac{Fb^2}{EJ}$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= (b - 5/6 b + 1/8 b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ} = 7/24 \frac{Fb^2}{EJ}$$

$$L_{AD}^{xo} = \int_0^{2b} (1/4 x/b) Fb \frac{1}{EJ} dx = \left[ 1/8 x^2/b \right]_0^{2b} Fb \frac{1}{EJ}$$

$$= (1/2 b) Fb \frac{1}{EJ} = 1/2 \frac{Fb^2}{EJ}$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 1/4 x/b) Fb \frac{1}{EJ} dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} Fb \frac{1}{EJ}$$

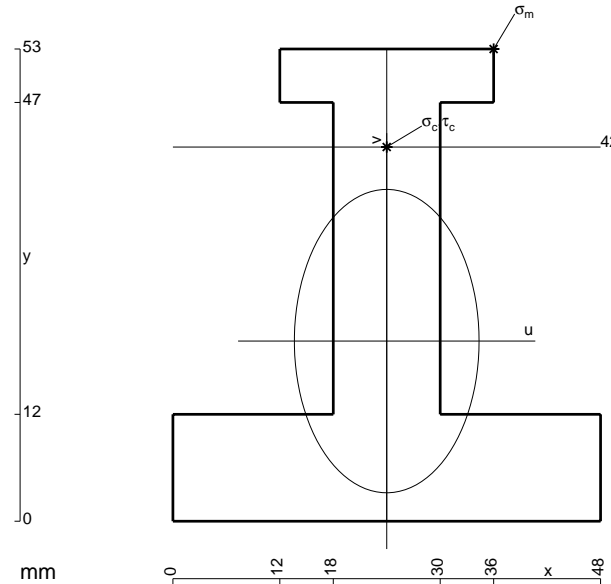
$$= (b - 1/2 b) Fb \frac{1}{EJ} = 1/2 \frac{Fb^2}{EJ}$$

$$L_{DE}^{xo} = \int_0^b (1/2 - 3/2 x/b + x^2/b^2) Fb \frac{1}{EJ} dx = \left[ 1/2 x - 3/4 x^2/b + 1/3 x^3/b^2 \right]_0^b Fb \frac{1}{EJ}$$

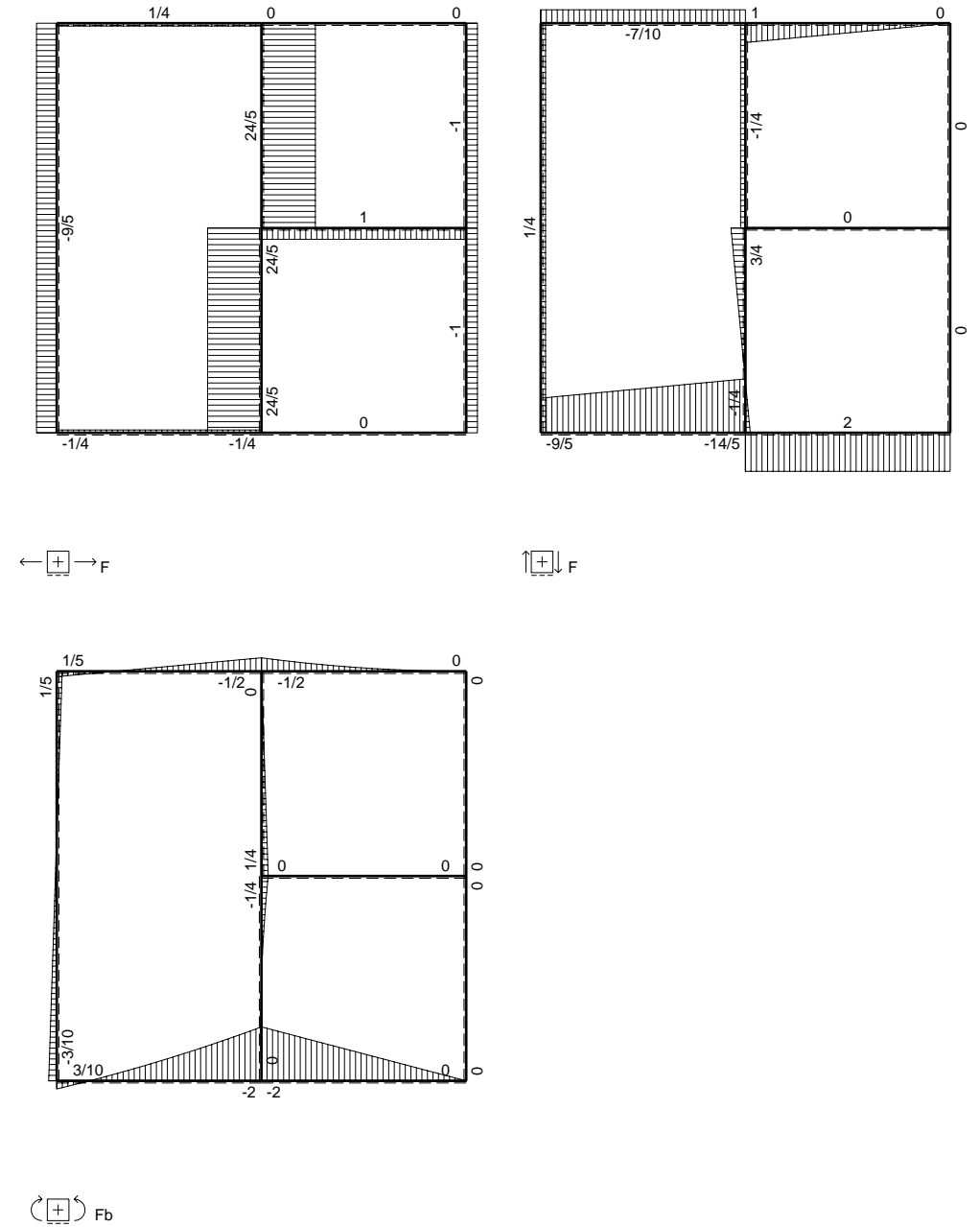
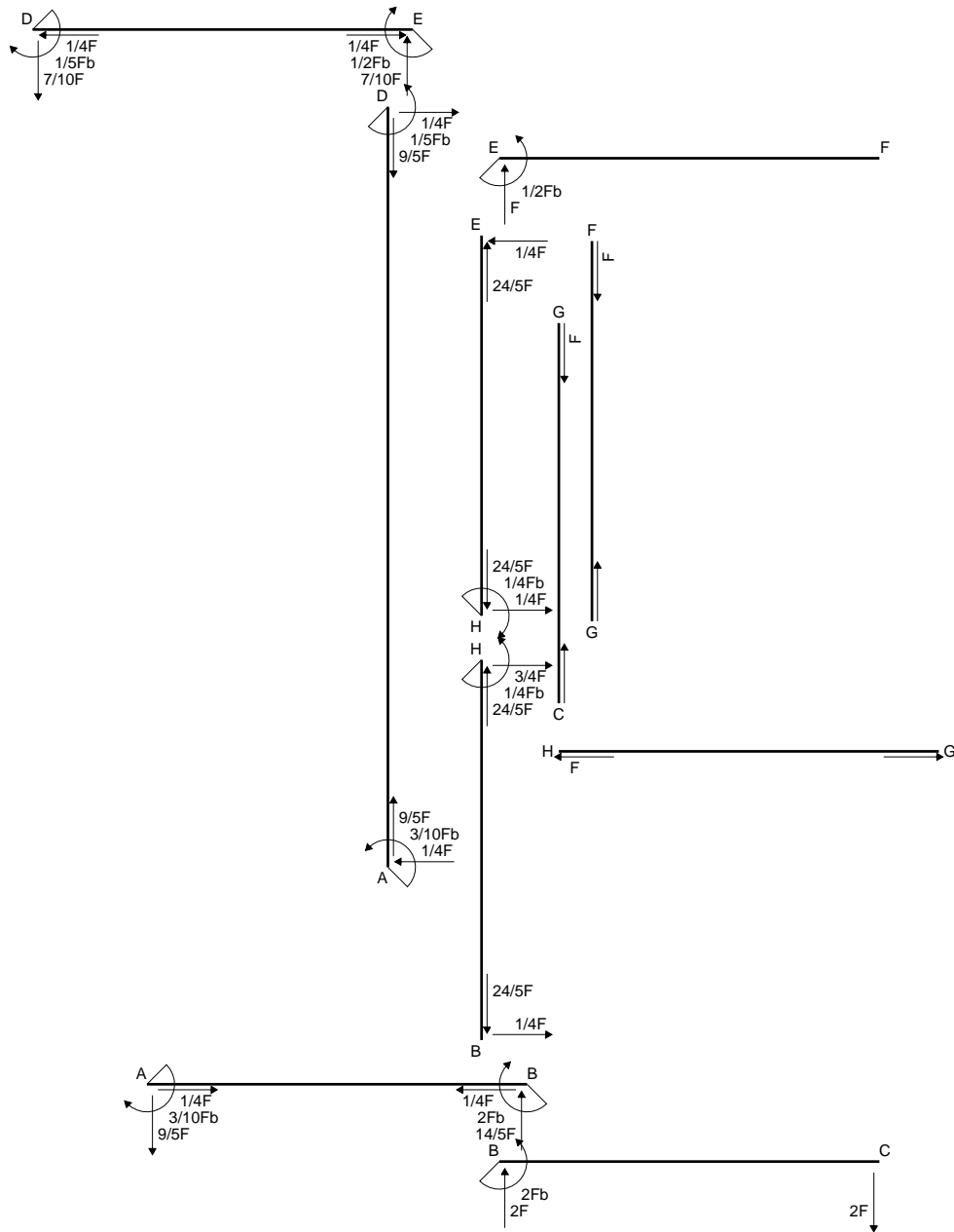
$$= (1/2 b - 3/4 b + 1/3 b) Fb \frac{1}{EJ} = 1/12 \frac{Fb^2}{EJ}$$

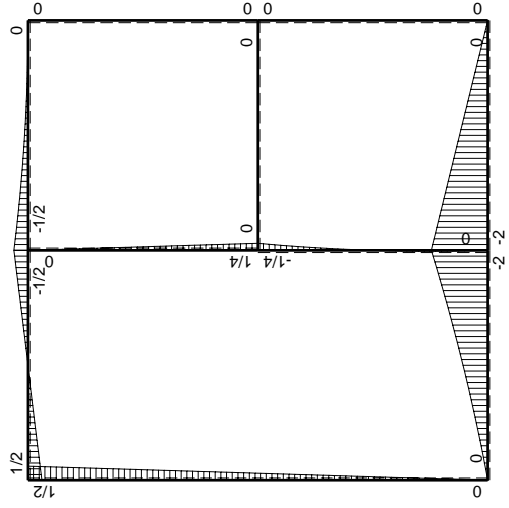
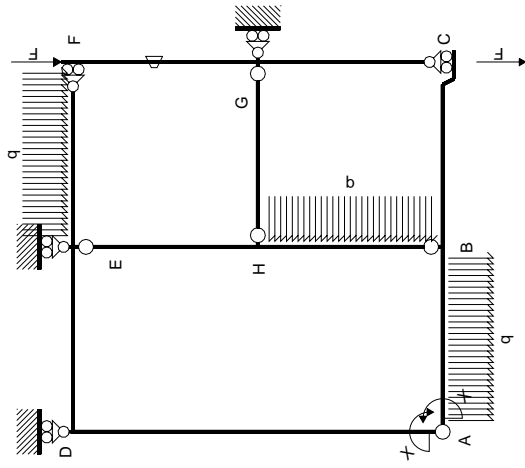
$$L_{ED}^{xo} = \int_0^b (-1/2 x/b + x^2/b^2) Fb \frac{1}{EJ} dx = \left[ -1/4 x^2/b + 1/3 x^3/b^2 \right]_0^b Fb \frac{1}{EJ}$$

$$= (-1/4 b + 1/3 b) Fb \frac{1}{EJ} = 1/12 \frac{Fb^2}{EJ}$$



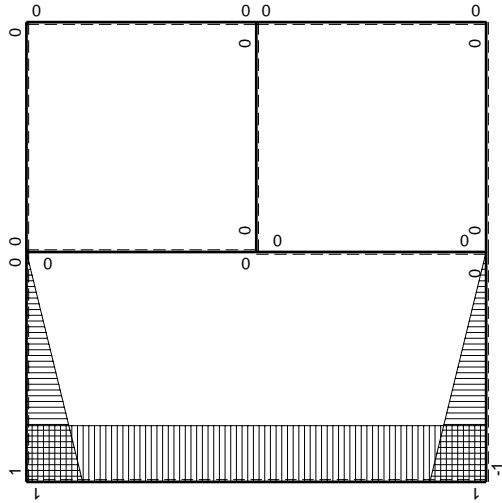
$A = 1140. \text{ mm}^2$   
 $J_u = 330567. \text{ mm}^4$   
 $J_v = 122544. \text{ mm}^4$   
 $y_g = 20.22 \text{ mm}$   
 $T_y = 2640. \text{ N}$   
 $M_x = -2402400. \text{ Nmm}$   
 $x_m = 36. \text{ mm}$   
 $y_m = 53. \text{ mm}$   
 $u_m = 12. \text{ mm}$   
 $v_m = 32.78 \text{ mm}$   
 $\sigma_m = -Mv/J_u = 238.3 \text{ N/mm}^2$   
 $x_c = 24. \text{ mm}$   
 $y_c = 42. \text{ mm}$   
 $v_c = 21.78 \text{ mm}$   
 $\sigma_c = -Mv/J_u = 158.3 \text{ N/mm}^2$   
 $\tau_c = 3.824 \text{ N/mm}^2$   
 $\sigma_o = \sqrt{\sigma^2 + 3\tau^2} = 158.5 \text{ N/mm}^2$   
 $S = 5746. \text{ mm}^3$





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJdx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1			
DE b	$1-x/b$	$1/2Fb-Fx$	0	$1/2Fb-3/2Fx+Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/12+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fb-Fx$	0	$-1/2Fx+Fx^2/b$	0	$x^2/b^2$			
EF b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
FE b	0	$1/2qx^2$	0	0	0	0			
FG b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
GF b	0	0	$Fb/EJ$	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-1/4Fb+3/4Fx-1/2qx^2$	0	0	0	0	0+0	0	
BH b	0	$-1/4Fx+1/2qx^2$	0	0	0	0			
HE b	0	$1/4Fb-1/4Fx$	0	0	0	0	0+0	0	
EH b	0	$-1/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/8Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-3/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

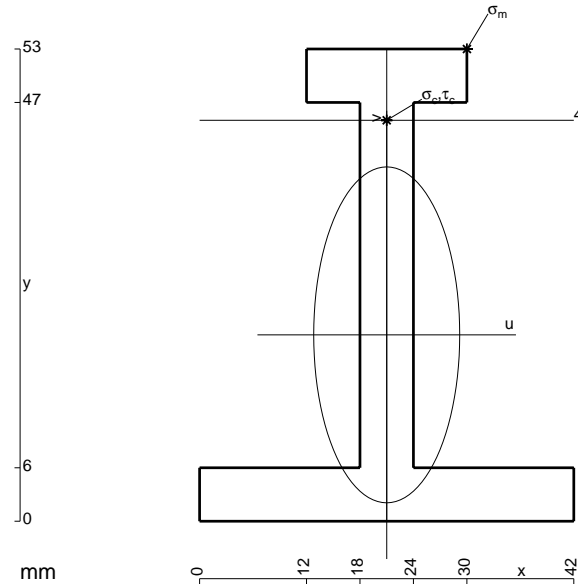
$$= (b - 1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - 3/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 3/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/2 b - 3/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$

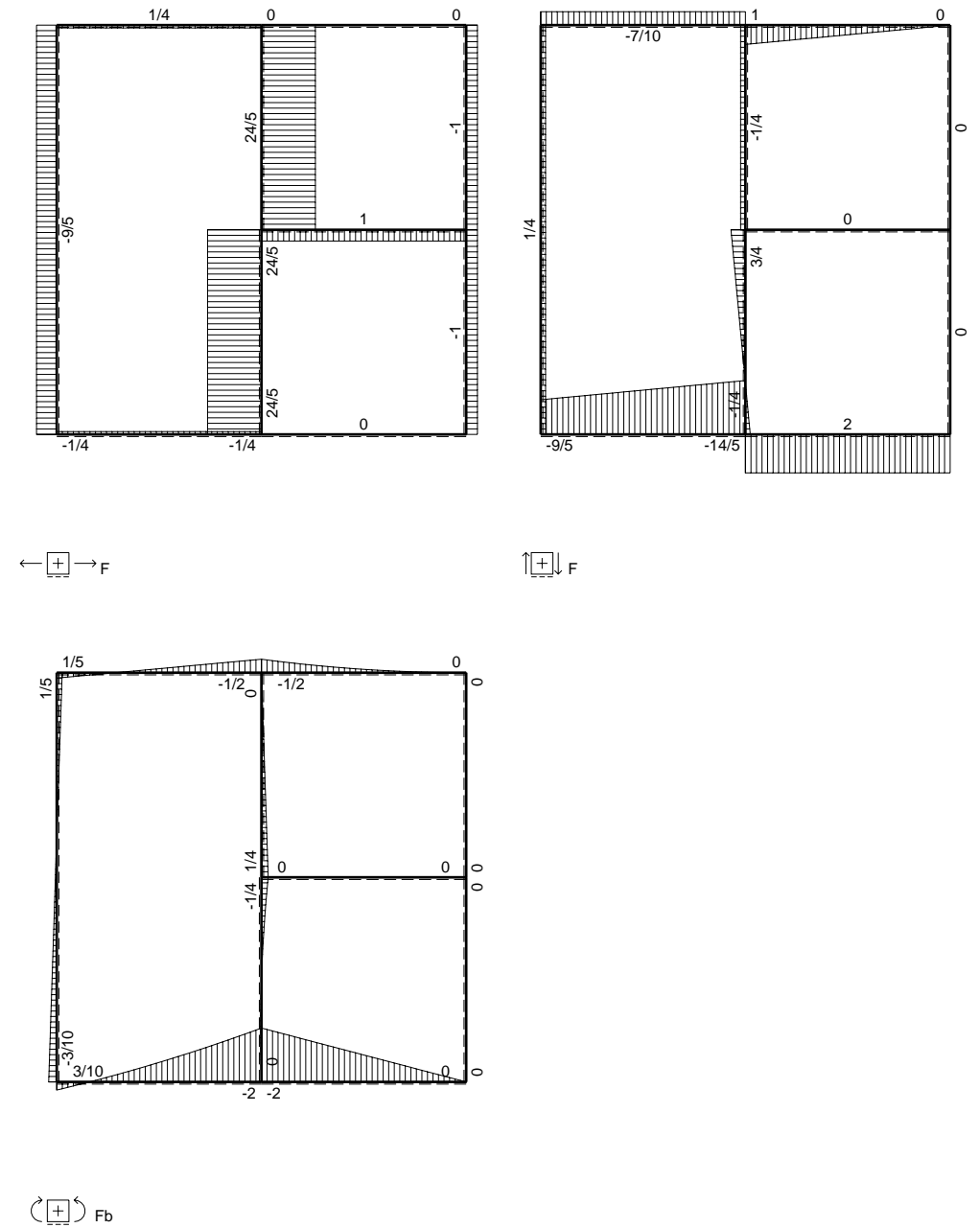
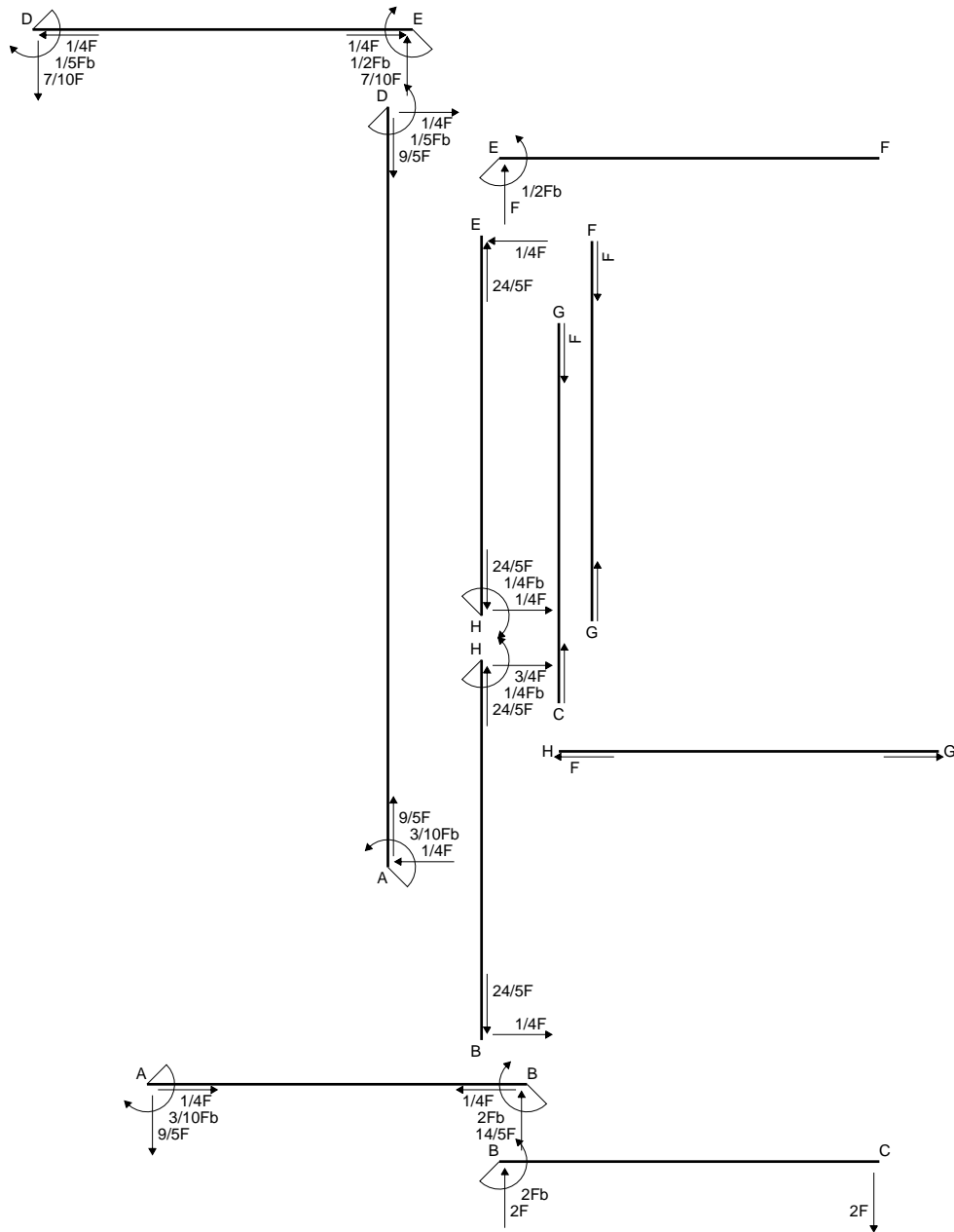
$$L_{ED}^{xo} = \int_0^b (-1/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

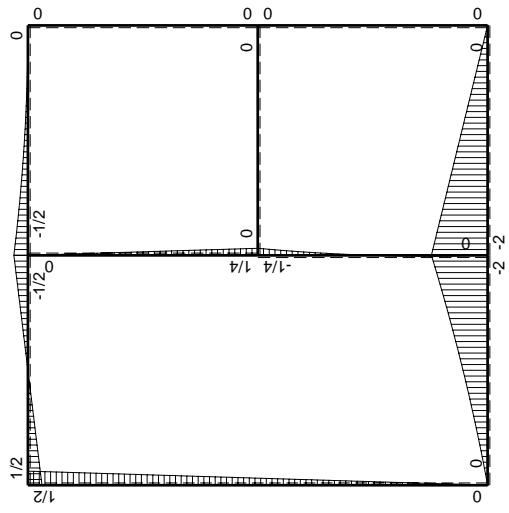
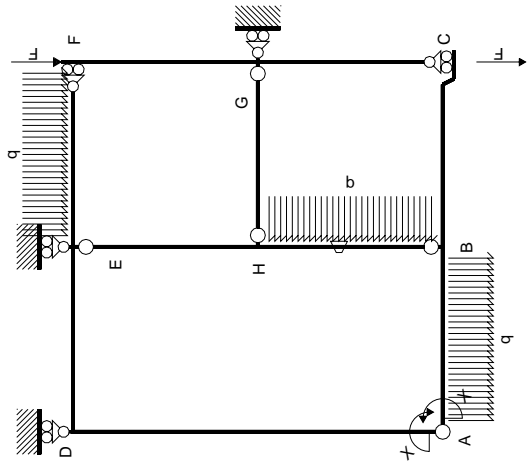
$$= (-1/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$



- A = 606. mm<sup>2</sup>
- J<sub>u</sub> = 215454. mm<sup>4</sup>
- J<sub>v</sub> = 40698. mm<sup>4</sup>
- y<sub>g</sub> = 20.92 mm
- T<sub>y</sub> = 2780. N
- M<sub>x</sub> = -1334400. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 53. mm
- u<sub>m</sub> = 9. mm
- v<sub>m</sub> = 32.08 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 198.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 45. mm
- v<sub>c</sub> = 24.08 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 149.2 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.402 N/mm<sup>2</sup>
- σ<sub>σ</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 149.7 N/mm<sup>2</sup>
- S = 3442. mm<sup>3</sup>

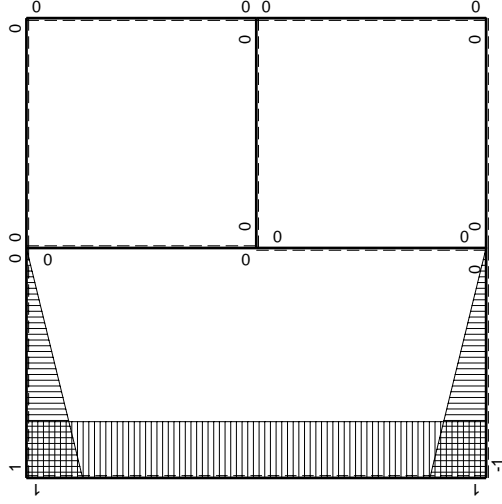






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int X M_x M_x/EJdx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1			
DE b	$1-x/b$	$1/2Fb-Fx$	0	$1/2Fb-3/2Fx+Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/12+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fb-Fx$	0	$-1/2Fx+Fx^2/b$	0	$x^2/b^2$			
EF b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
FE b	0	$1/2qx^2$	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-1/4Fb+3/4Fx-1/2qx^2$	$-Fb/EJ$	0	0	0	$0+0$	$0$	
BH b	0	$-1/4Fx+1/2qx^2$	$Fb/EJ$	0	0	0			
HE b	0	$1/4Fb-1/4Fx$	0	0	0	0	0+0	0	
EH b	0	$-1/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/8Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-3/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

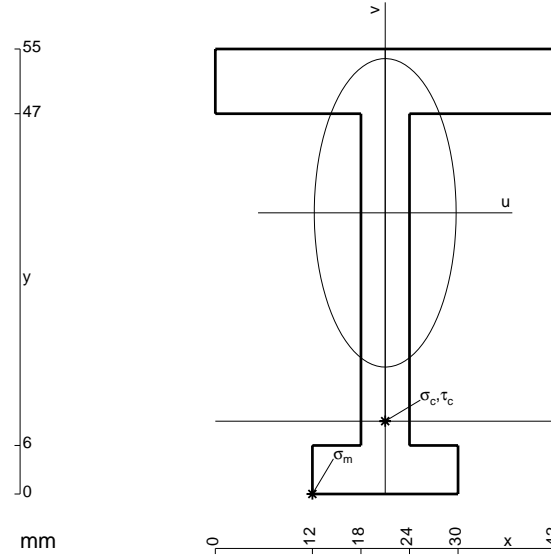
$$= (b - 1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - 3/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 3/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

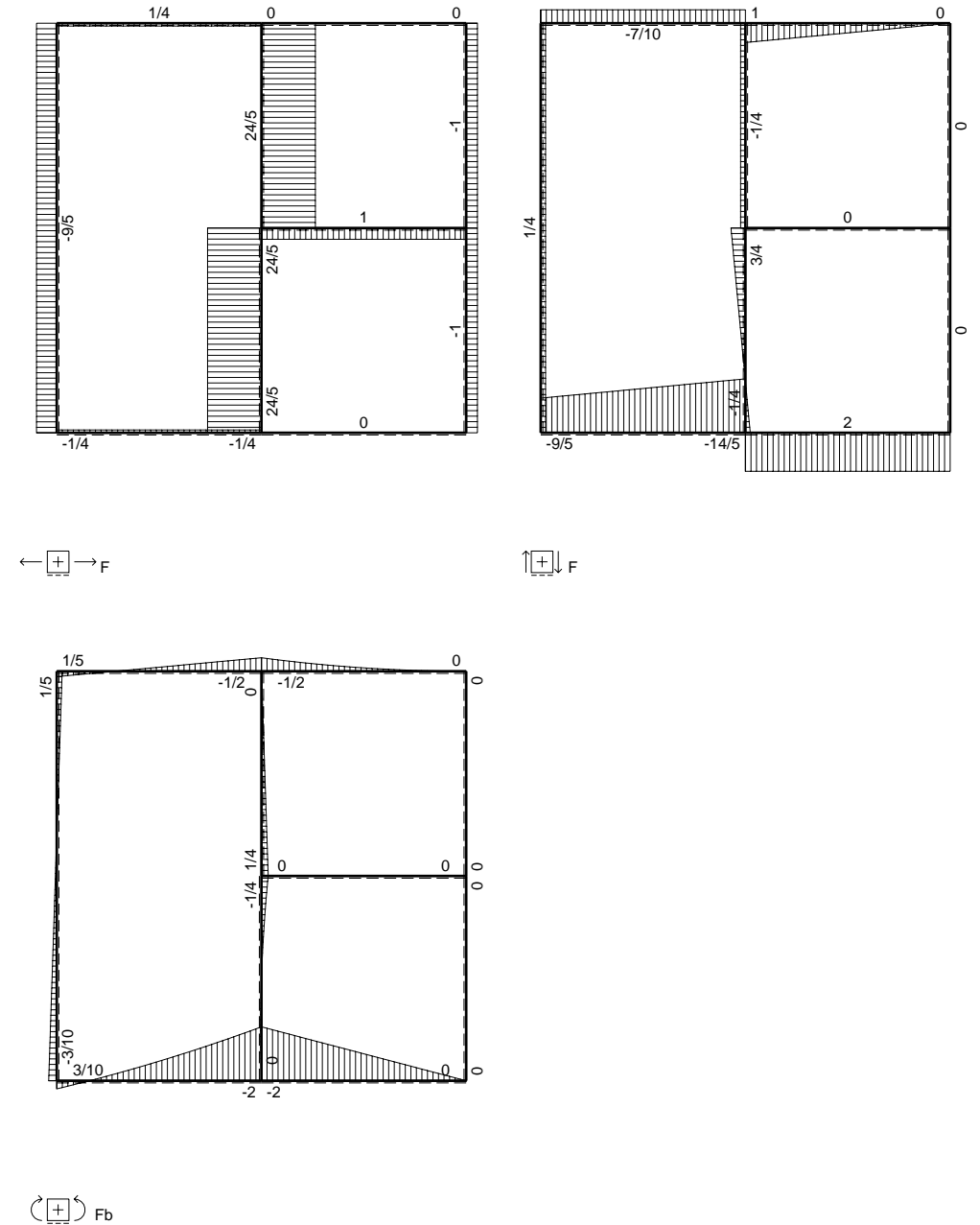
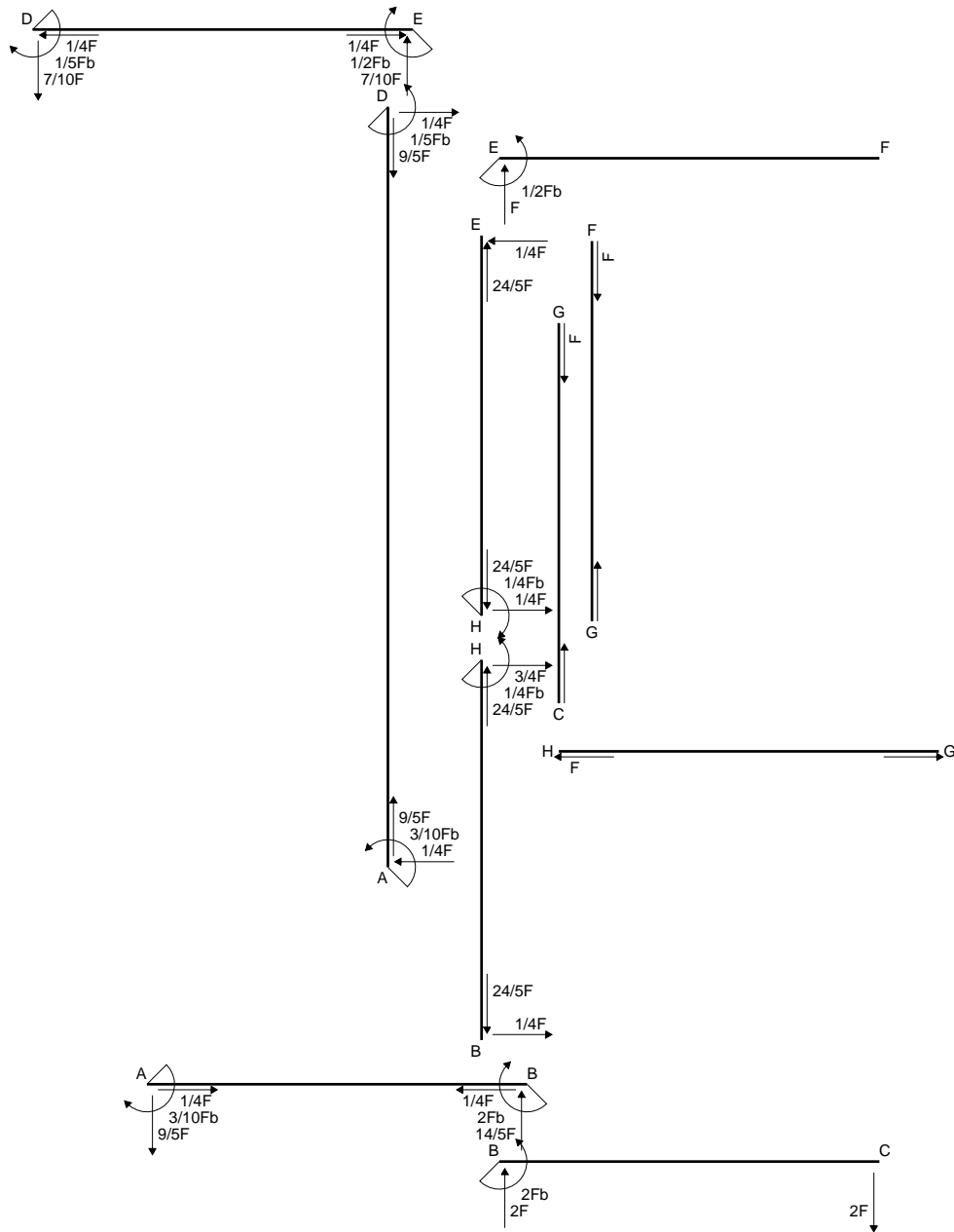
$$= (1/2 b - 3/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$

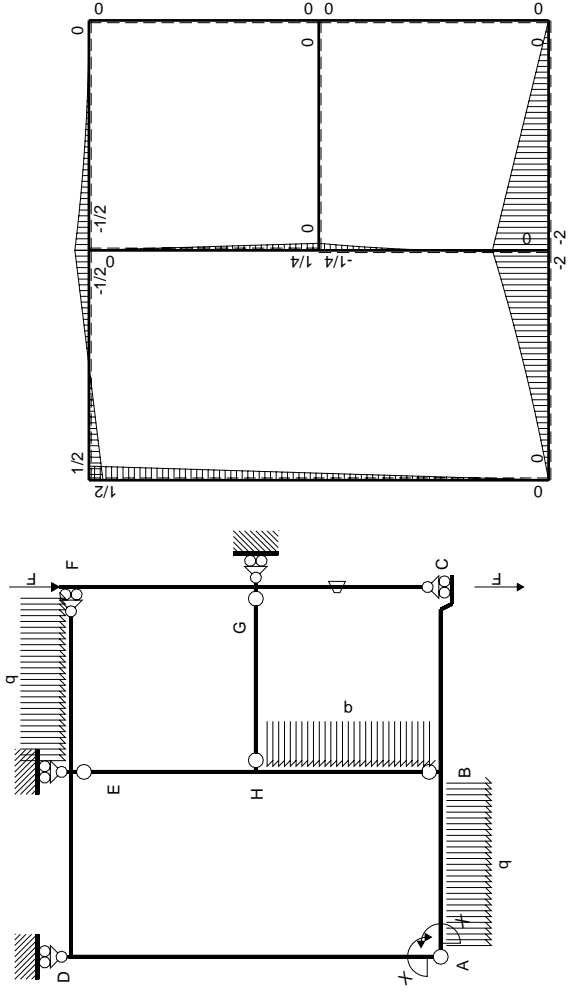
$$L_{ED}^{xo} = \int_0^b (-1/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$



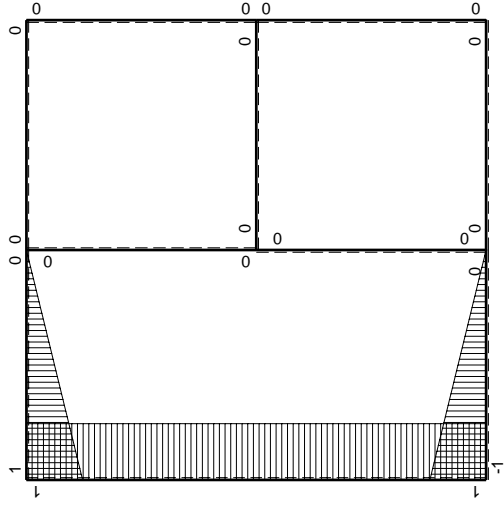
- A = 690. mm<sup>2</sup>
- J<sub>u</sub> = 250916. mm<sup>4</sup>
- J<sub>v</sub> = 53046. mm<sup>4</sup>
- y<sub>g</sub> = 34.75 mm
- T<sub>y</sub> = 2740. N
- M<sub>x</sub> = -1507000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -9. mm
- v<sub>m</sub> = -34.75 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -208.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 9. mm
- v<sub>c</sub> = -25.75 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -154.7 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.134 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 155.2 N/mm<sup>2</sup>
- S = 3920. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJdx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1			
DE b	$1-x/b$	$1/2Fb-Fx$	0	$1/2Fb-3/2Fx+Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/12+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fb-Fx$	0	$-1/2Fx+Fx^2/b$	0	$x^2/b^2$			
EF b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
FE b	0	$1/2qx^2$	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
CG b	0	0	$Fb/EJ$	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-1/4Fb+3/4Fx-1/2qx^2$	0	0	0	0	0+0	0	
BH b	0	$-1/4Fx+1/2qx^2$	0	0	0	0			
HE b	0	$1/4Fb-1/4Fx$	0	0	0	0	0+0	0	
EH b	0	$-1/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/8Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-3/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

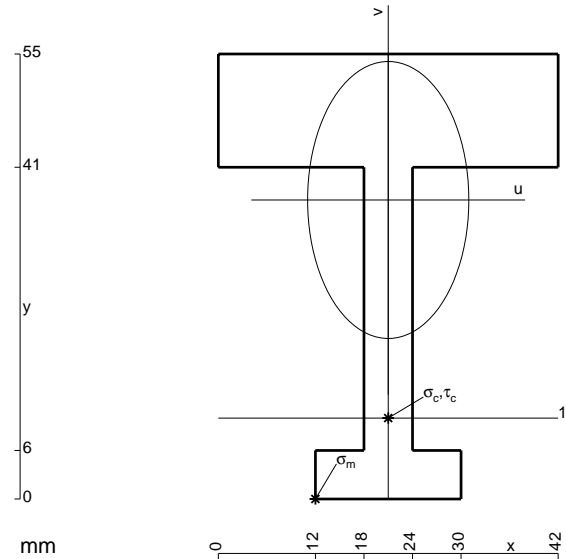
$$= (b - 1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - 3/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 3/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/2 b - 3/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$

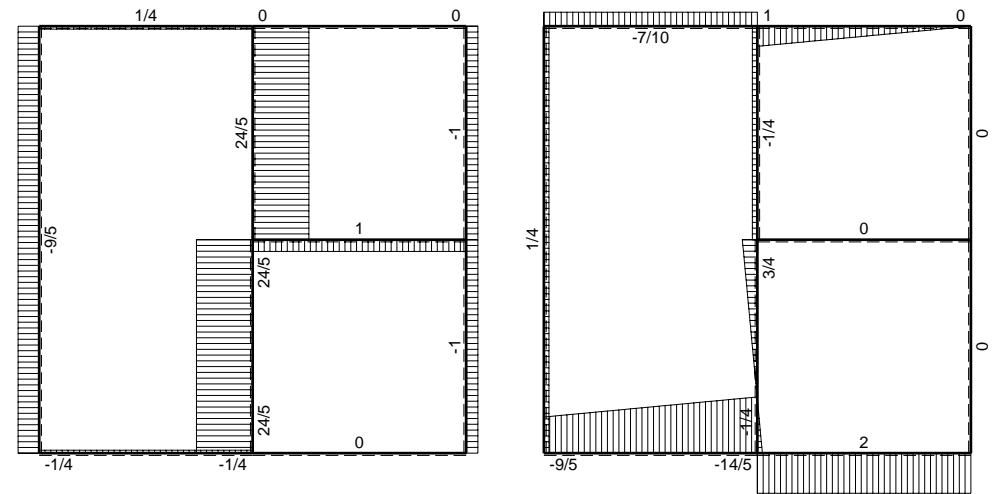
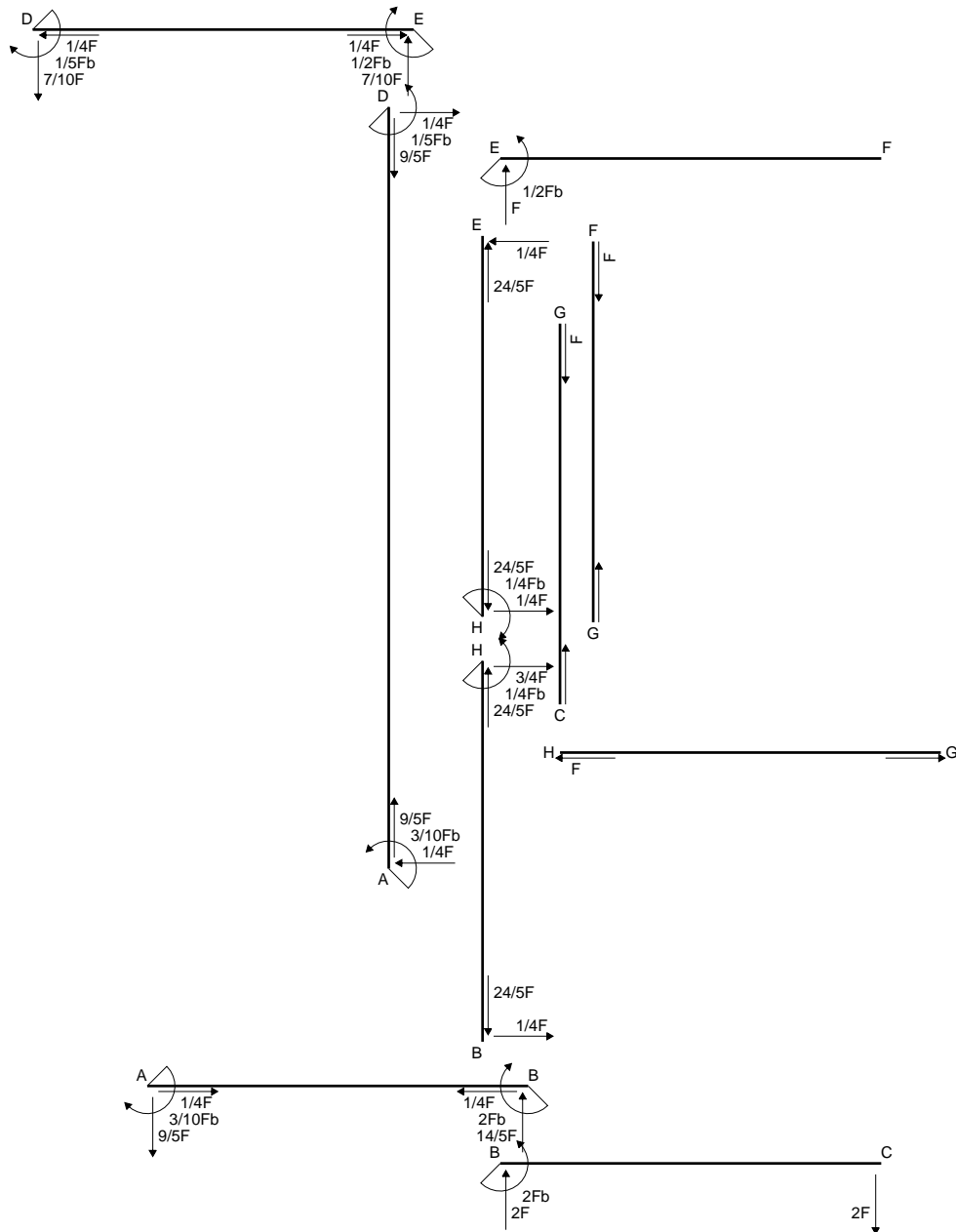
$$L_{ED}^{xo} = \int_0^b (-1/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$



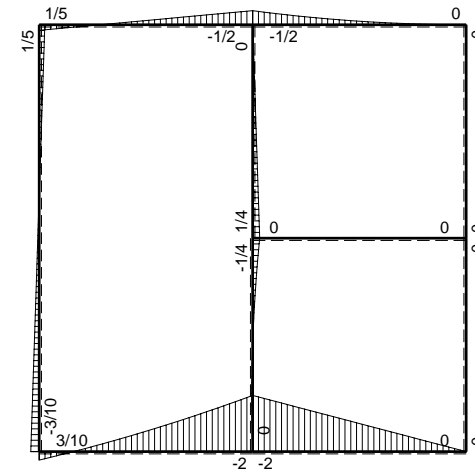
- A = 906. mm<sup>2</sup>
- J<sub>u</sub> = 265632. mm<sup>4</sup>
- J<sub>v</sub> = 89982. mm<sup>4</sup>
- y<sub>g</sub> = 36.96 mm
- T<sub>y</sub> = 2620. N
- M<sub>x</sub> = -1572000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -9. mm
- v<sub>m</sub> = -36.96 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -218.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 10. mm
- v<sub>c</sub> = -26.96 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -159.5 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.171 N/mm<sup>2</sup>
- σ<sub>o</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 160. N/mm<sup>2</sup>
- S = 4362. mm<sup>3</sup>



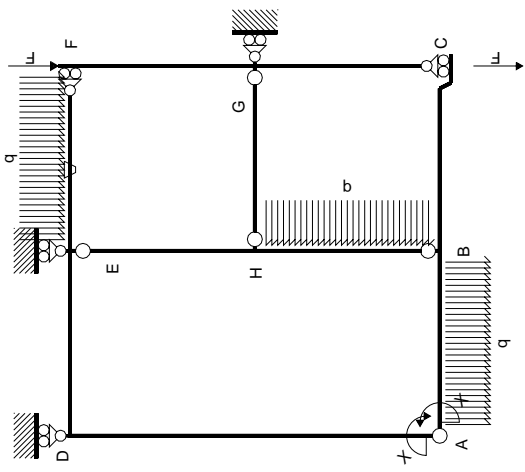


← ⊕ → F

↑ ⊕ ↓ Fb

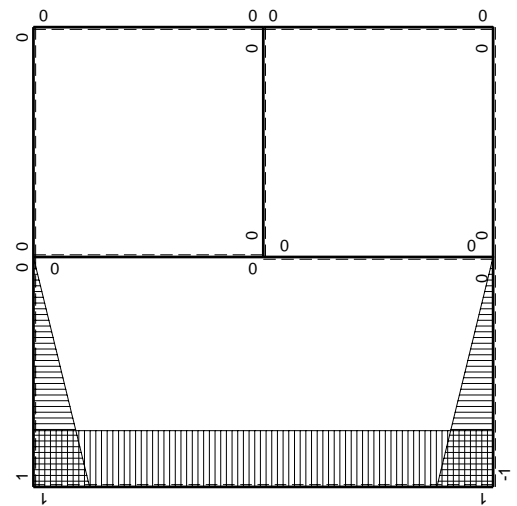
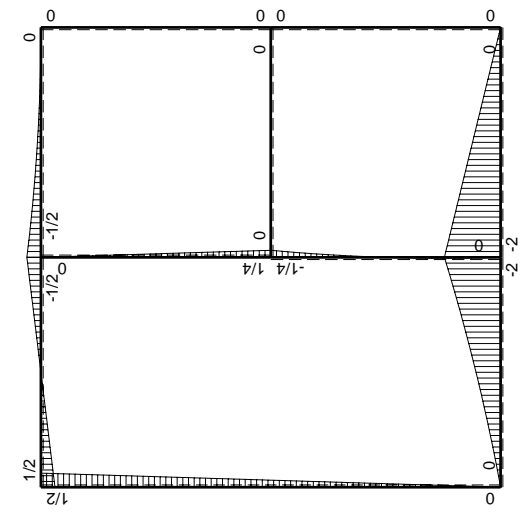


⊕ ⊖ Fb



Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJdx$
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0
CB b	0	$2Fx$	0	0	0	0		
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1		
DE b	$1-x/b$	$1/2Fb-Fx$	0	$1/2Fb-3/2Fx+Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/12+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$1/2Fb-Fx$	0	$-1/2Fx+Fx^2/b$	0	$x^2/b^2$		
EF b	0	$-1/2Fb+Fx-1/2qx^2$	$-Fb/EJ$	0	0	0	0+0	0
FE b	0	$1/2qx^2$	$Fb/EJ$	0	0	0		
FG b	0	0	0	0	0	0	0+0	0
GF b	0	0	0	0	0	0		
GC b	0	0	0	0	0	0	0+0	0
CG b	0	0	0	0	0	0		
HG b	0	0	0	0	0	0	0+0	0
GH b	0	0	0	0	0	0		
HB b	0	$-1/4Fb+3/4Fx-1/2qx^2$	0	0	0	0	0+0	0
BH b	0	$-1/4Fx+1/2qx^2$	0	0	0	0		
HE b	0	$1/4Fb-1/4Fx$	0	0	0	0	0+0	0
EH b	0	$-1/4Fx$	0	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$7/8Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$-3/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

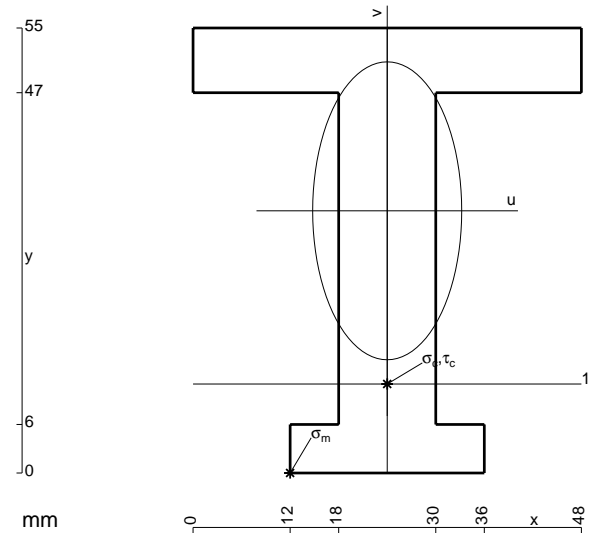
$$= (b - 1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - 3/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 3/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

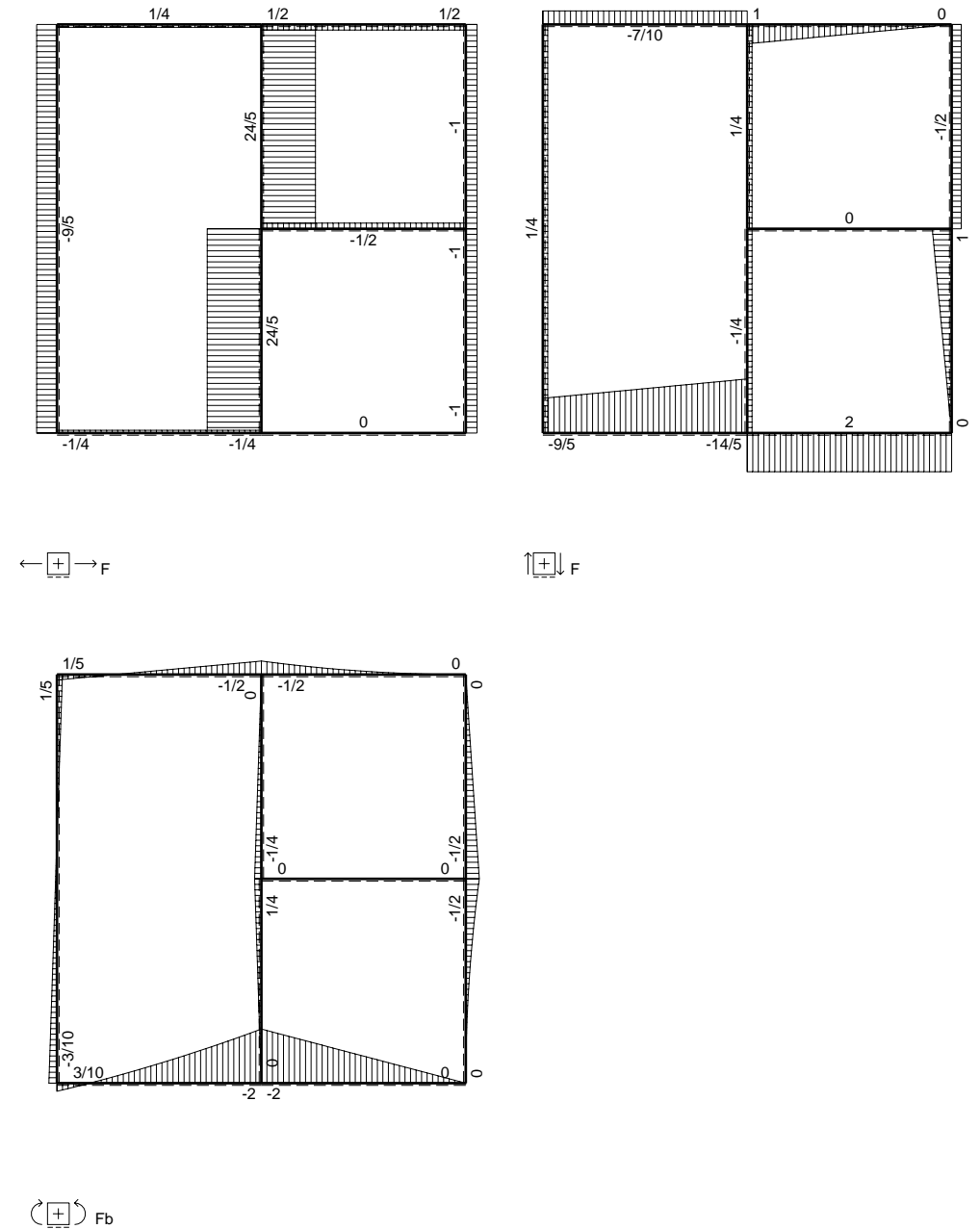
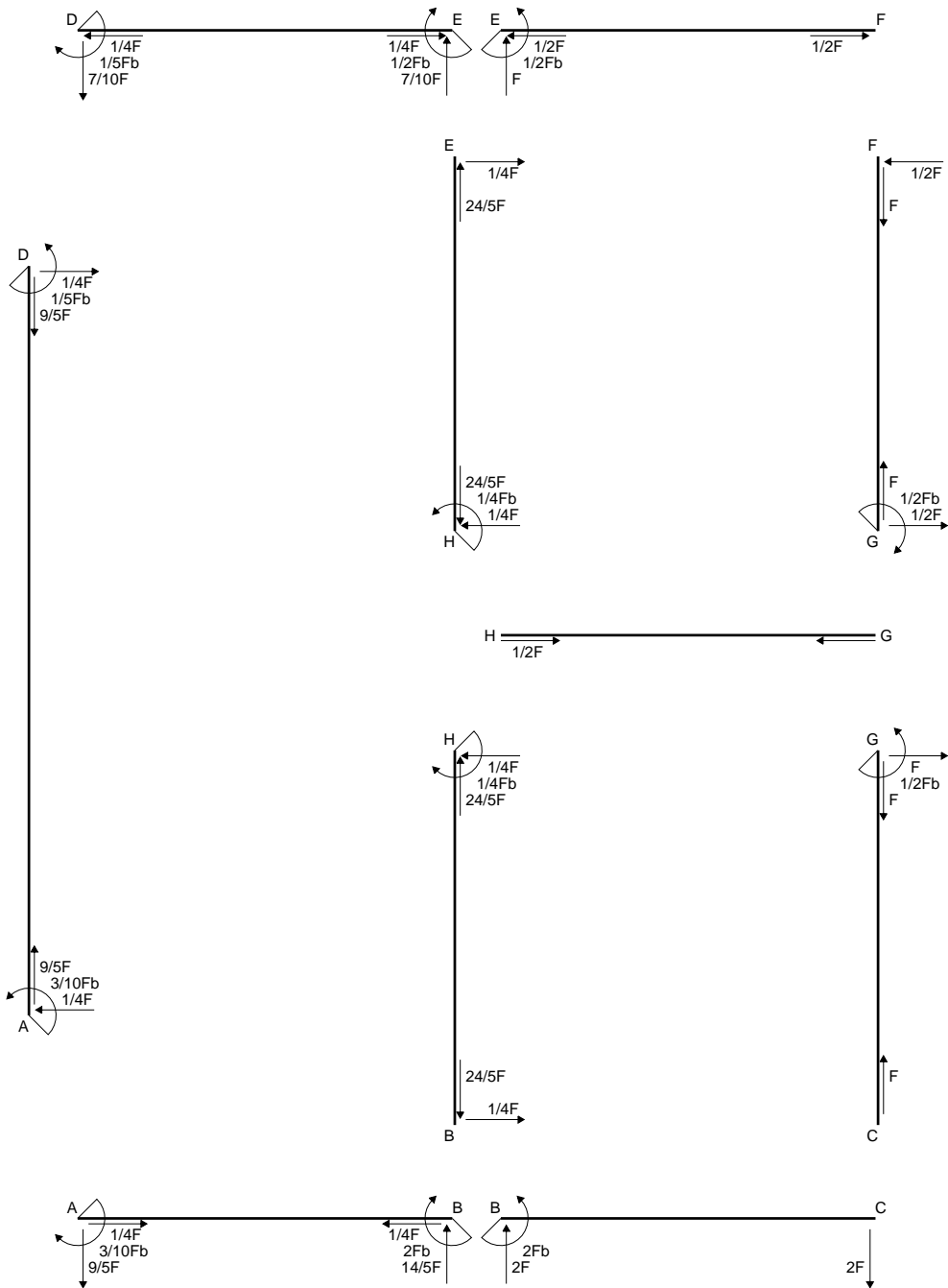
$$= (1/2 b - 3/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$

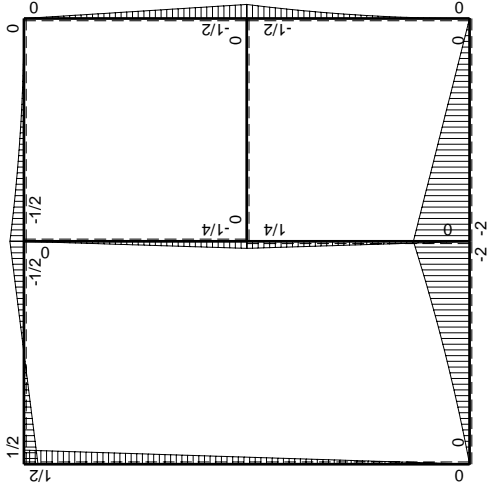
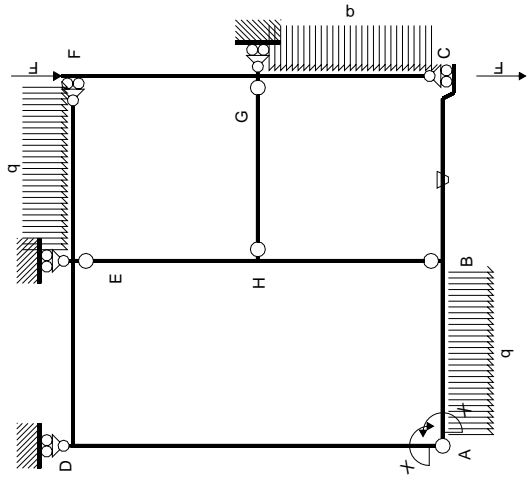
$$L_{ED}^{xo} = \int_0^b (-1/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$

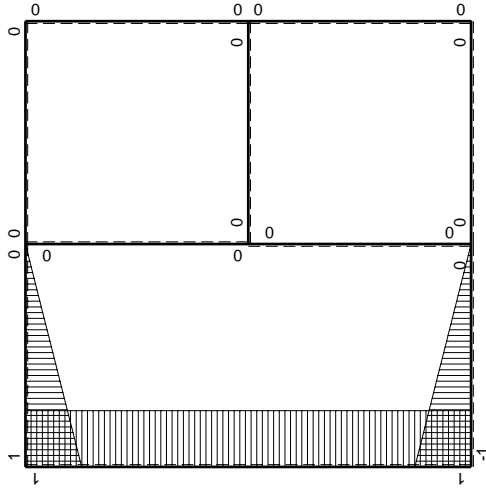


- A = 1020. mm<sup>2</sup>
- J<sub>u</sub> = 345844. mm<sup>4</sup>
- J<sub>v</sub> = 86544. mm<sup>4</sup>
- y<sub>g</sub> = 32.41 mm
- T<sub>y</sub> = 3760. N
- M<sub>x</sub> = -2444000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -12. mm
- v<sub>m</sub> = -32.41 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -229. N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 11. mm
- v<sub>c</sub> = -21.41 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -151.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.136 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 151.5 N/mm<sup>2</sup>
- S = 5669. mm<sup>3</sup>





$M_0$  flessione da carichi assegnati



$M_1$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	$-Fb/EJ$	0	0	0	0+0	0	
CB b	0	$2Fx$	$Fb/EJ$	0	0	0			
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1			
DE b	$1-x/b$	$1/2Fb-Fx$	0	$1/2Fb-3/2Fx+Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/12+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fb-Fx$	0	$-1/2Fx+Fx^2/b$	0	$x^2/b^2$			
EF b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
FE b	0	$1/2qx^2$	0	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$1/4Fb-1/4Fx$	0	0	0	0	0+0	0	
BH b	0	$-1/4Fx$	0	0	0	0			
HE b	0	$-1/4Fb+1/4Fx$	0	0	0	0	0+0	0	
EH b	0	$1/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/8Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-3/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{x_0} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{x_0} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{x_0} = \int_0^{2b} (1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{x_0} = \int_0^{2b} (1/2 - 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

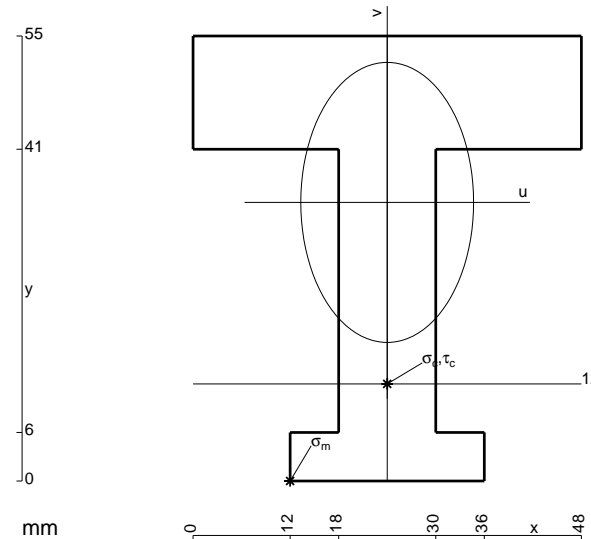
$$= (b - 1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{x_0} = \int_0^b (1/2 - 3/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 3/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/2 b - 3/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$

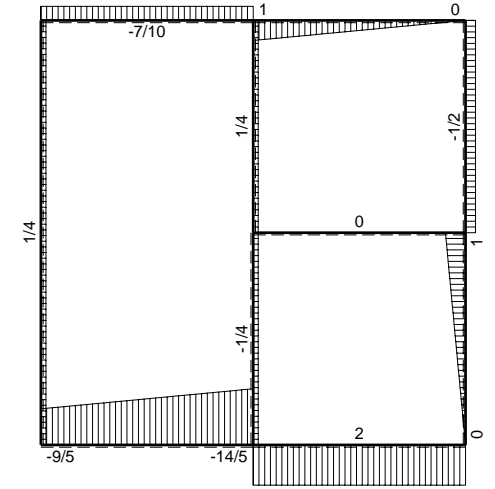
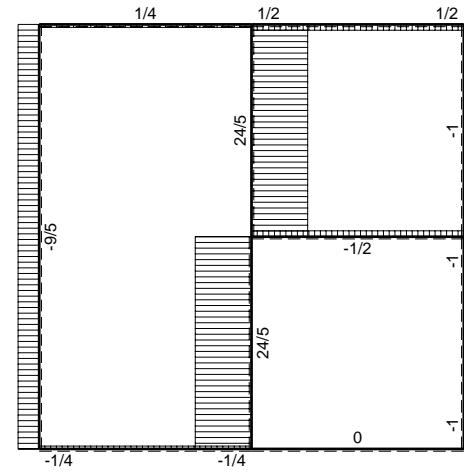
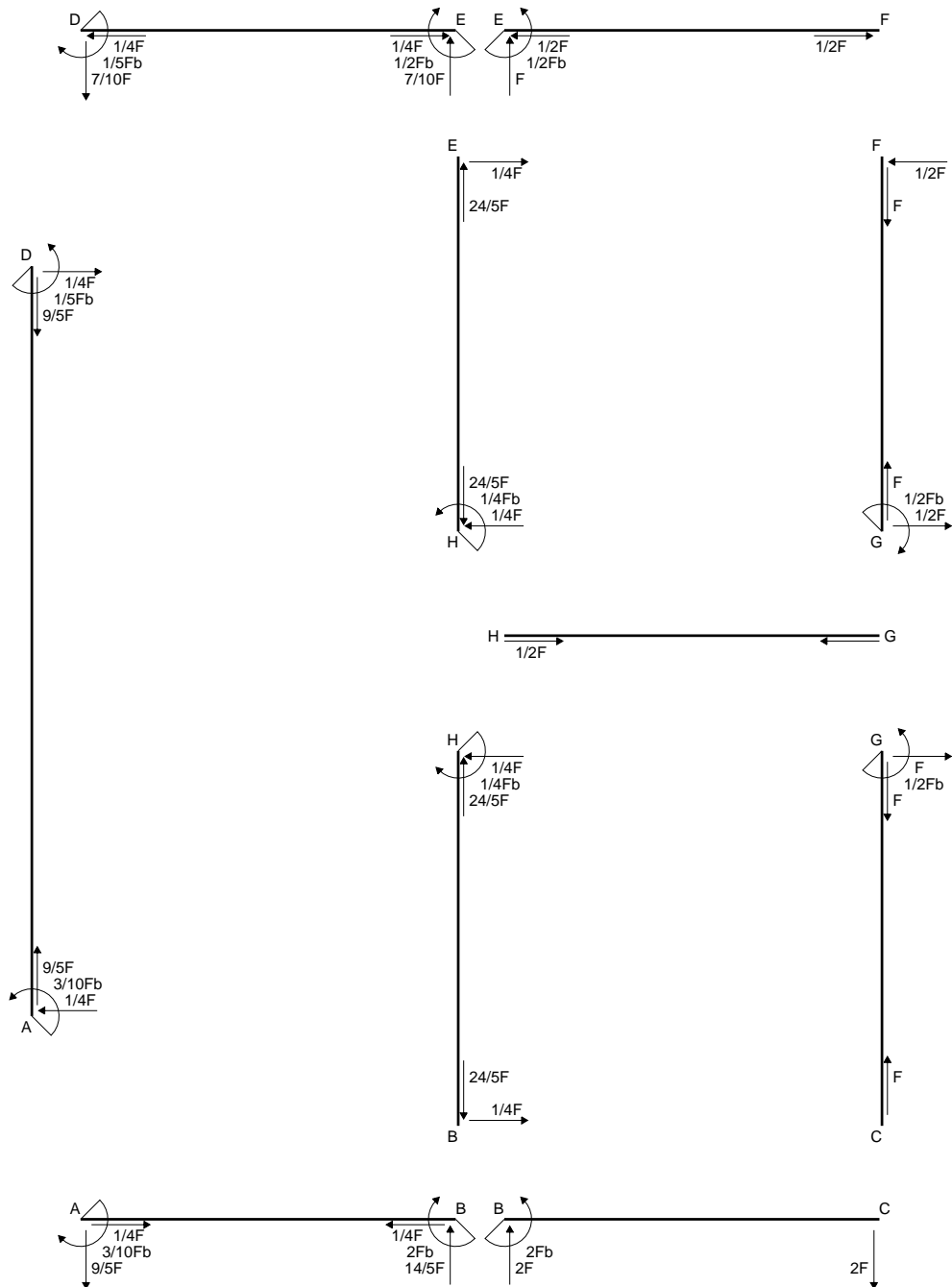
$$L_{ED}^{x_0} = \int_0^b (-1/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$



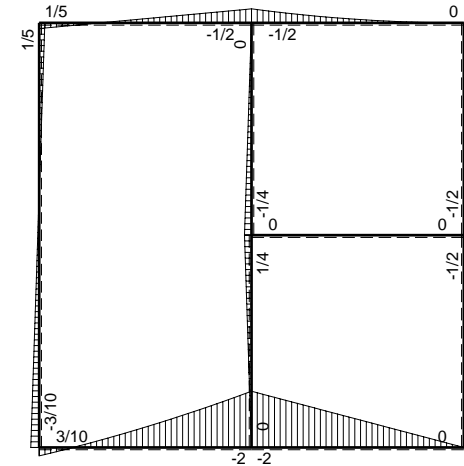
- A = 1236. mm<sup>2</sup>
- J<sub>u</sub> = 370453. mm<sup>4</sup>
- J<sub>v</sub> = 140976. mm<sup>4</sup>
- y<sub>g</sub> = 34.43 mm
- T<sub>y</sub> = 3680. N
- M<sub>x</sub> = -2576000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -12. mm
- v<sub>m</sub> = -34.43 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -239.4 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 12. mm
- v<sub>c</sub> = -22.43 mm
- σ<sub>c</sub> = -Mv/J<sub>v</sub> = -156. N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.263 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 156.3 N/mm<sup>2</sup>
- S = 6357. mm<sup>3</sup>



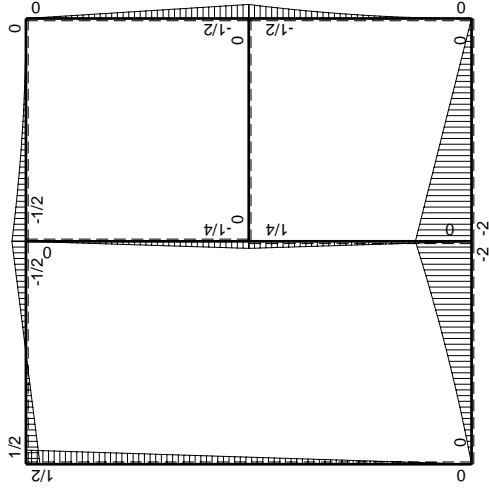
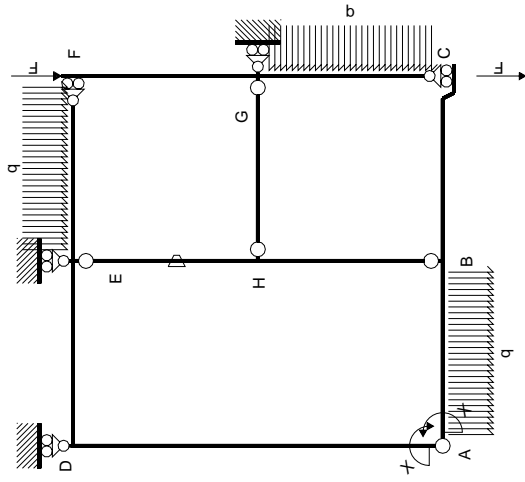


← ⊕ → F

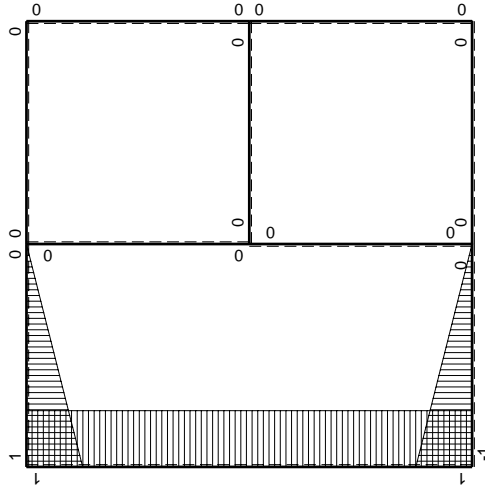
↑ ⊕ ↓ F



⊕ ⊕ Fb



$M_0$  flessione da carichi assegnati



$M_1$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1			
DE b	$1-x/b$	$1/2Fb-Fx$	0	$1/2Fb-3/2Fx+Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/12+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fb-Fx$	0	$-1/2Fx+Fx^2/b$	0	$x^2/b^2$			
EF b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
FE b	0	$1/2qx^2$	0	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$1/4Fb-1/4Fx$	0	0	0	0	0+0	0	
BH b	0	$-1/4Fx$	0	0	0	0			
HE b	0	$-1/4Fb+1/4Fx$	$-Fb/EJ$	0	0	0	0+0	0	
EH b	0	$1/4Fx$	$Fb/EJ$	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/8Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-3/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

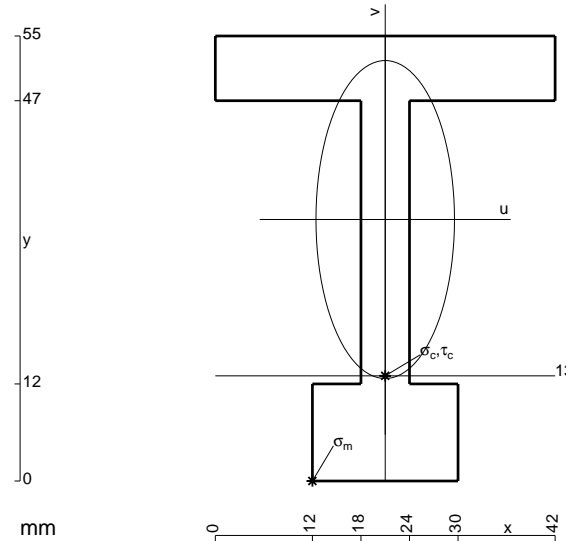
$$= (b - 1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - 3/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 3/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

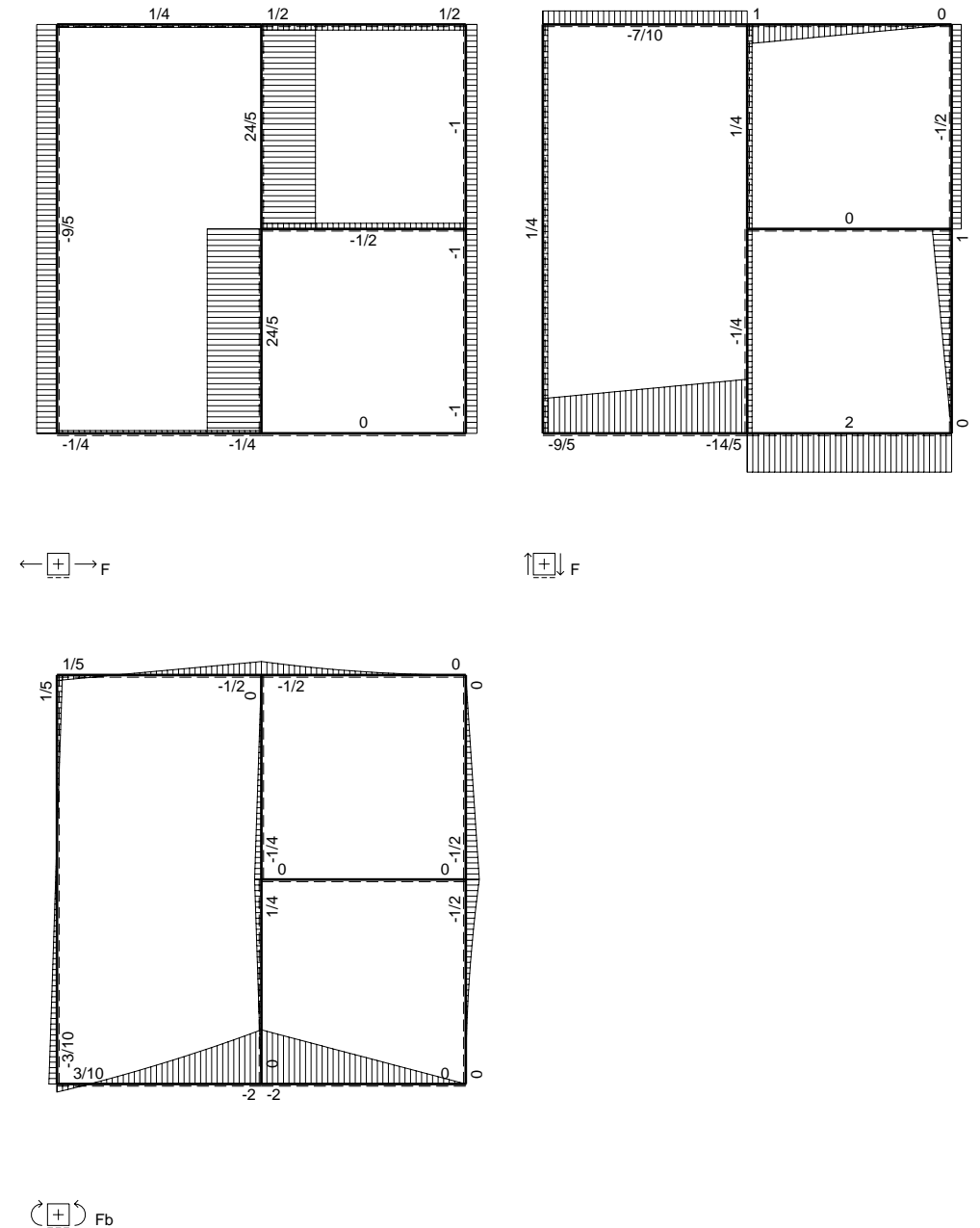
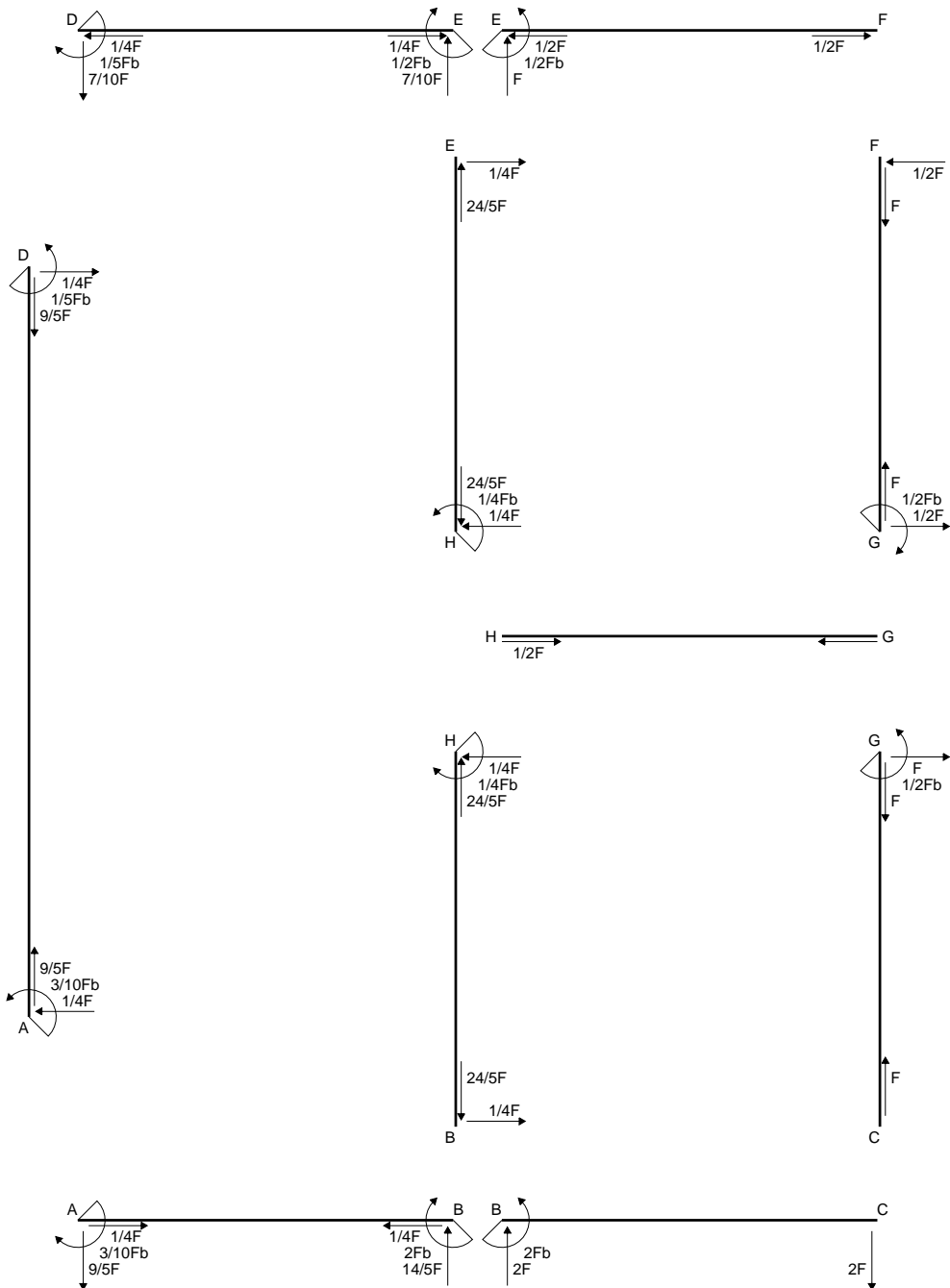
$$= (1/2 b - 3/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$

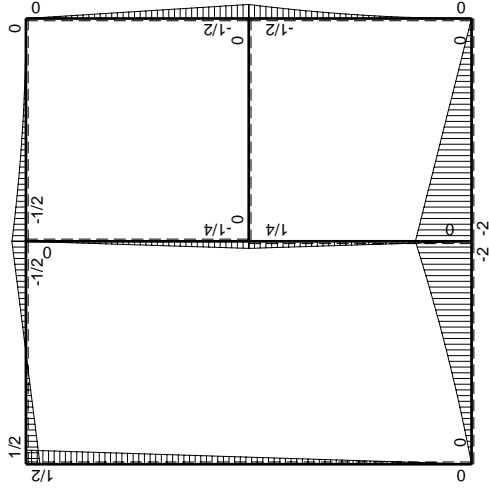
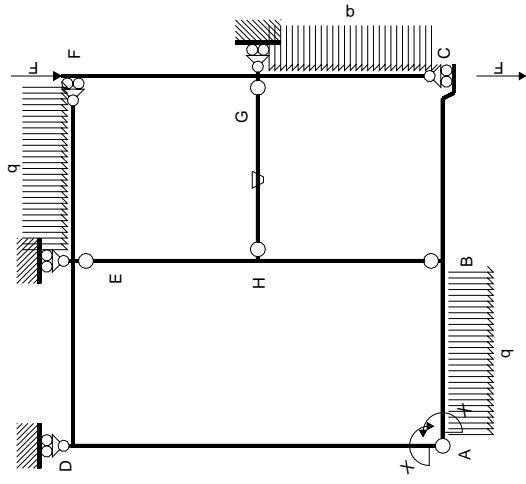
$$L_{ED}^{xo} = \int_0^b (-1/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$

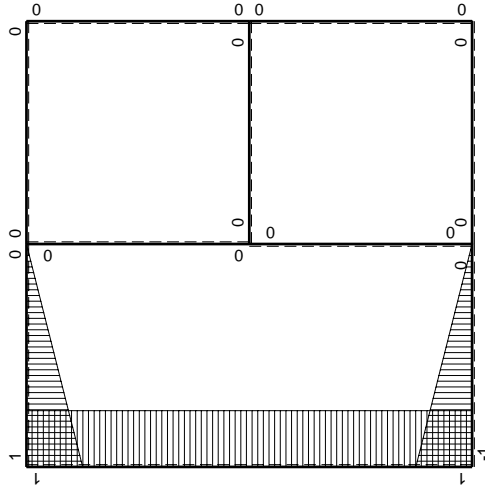


$A = 762. \text{ mm}^2$   
 $J_u = 294369. \text{ mm}^4$   
 $J_v = 55854. \text{ mm}^4$   
 $y_g = 32.32 \text{ mm}$   
 $T_y = 2420. \text{ N}$   
 $M_x = -1815000. \text{ Nmm}$   
 $x_m = 12. \text{ mm}$   
 $u_m = -9. \text{ mm}$   
 $v_m = -32.32 \text{ mm}$   
 $\sigma_m = -Mv/J_u = -199.3 \text{ N/mm}^2$   
 $x_c = 21. \text{ mm}$   
 $y_c = 13. \text{ mm}$   
 $v_c = -19.32 \text{ mm}$   
 $\sigma_c = -Mv/J_u = -119.1 \text{ N/mm}^2$   
 $\tau_c = 7.952 \text{ N/mm}^2$   
 $\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 119.9 \text{ N/mm}^2$   
 $S = 5804. \text{ mm}^3$





$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1			
DE b	$1-x/b$	$1/2Fb-Fx$	0	$1/2Fb-3/2Fx+Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/12+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fb-Fx$	0	$-1/2Fx+Fx^2/b$	0	$x^2/b^2$			
EF b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
FE b	0	$1/2qx^2$	0	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
GH b	0	0	$Fb/EJ$	0	0	0			
HB b	0	$1/4Fb-1/4Fx$	0	0	0	0	0+0	0	
BH b	0	$-1/4Fx$	0	0	0	0			
HE b	0	$-1/4Fb+1/4Fx$	0	0	0	0	0+0	0	
EH b	0	$1/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/8Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-3/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ}$$

$$= (b - b + 1/3 b) \frac{1}{EJ} = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx = \left[ 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ}$$

$$= (1/3 b) \frac{1}{EJ} = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (1/4 x/b) Fb \frac{1}{EJ} dx = \left[ 1/8 x^2/b \right]_0^{2b} Fb \frac{1}{EJ}$$

$$= (1/2 b) Fb \frac{1}{EJ} = 1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 1/4 x/b) Fb \frac{1}{EJ} dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} Fb \frac{1}{EJ}$$

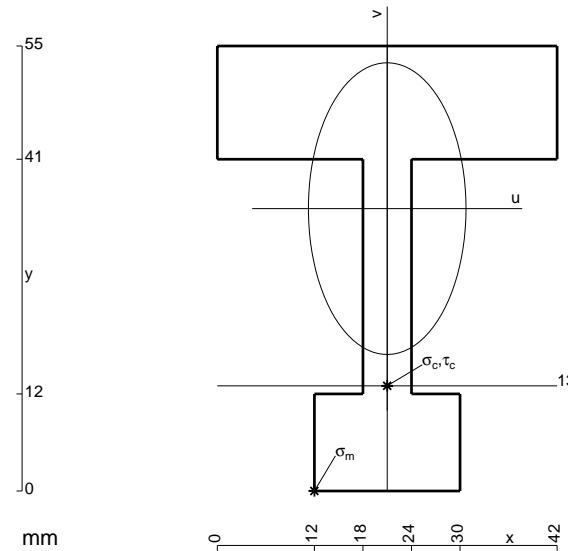
$$= (b - 1/2 b) Fb \frac{1}{EJ} = 1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - 3/2 x/b + x^2/b^2) Fb \frac{1}{EJ} dx = \left[ 1/2 x - 3/4 x^2/b + 1/3 x^3/b^2 \right]_0^b Fb \frac{1}{EJ}$$

$$= (1/2 b - 3/4 b + 1/3 b) Fb \frac{1}{EJ} = 1/12 \cdot Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (-1/2 x/b + x^2/b^2) Fb \frac{1}{EJ} dx = \left[ -1/4 x^2/b + 1/3 x^3/b^2 \right]_0^b Fb \frac{1}{EJ}$$

$$= (-1/4 b + 1/3 b) Fb \frac{1}{EJ} = 1/12 \cdot Fb^2/EJ$$



$$A = 978. \text{ mm}^2$$

$$J_u = 317980. \text{ mm}^4$$

$$J_v = 92790. \text{ mm}^4$$

$$y_g = 34.9 \text{ mm}$$

$$T_y = 2380. \text{ N}$$

$$M_x = -1904000. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -9. \text{ mm}$$

$$v_m = -34.9 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -209. \text{ N/mm}^2$$

$$x_c = 21. \text{ mm}$$

$$y_c = 13. \text{ mm}$$

$$v_c = -21.9 \text{ mm}$$

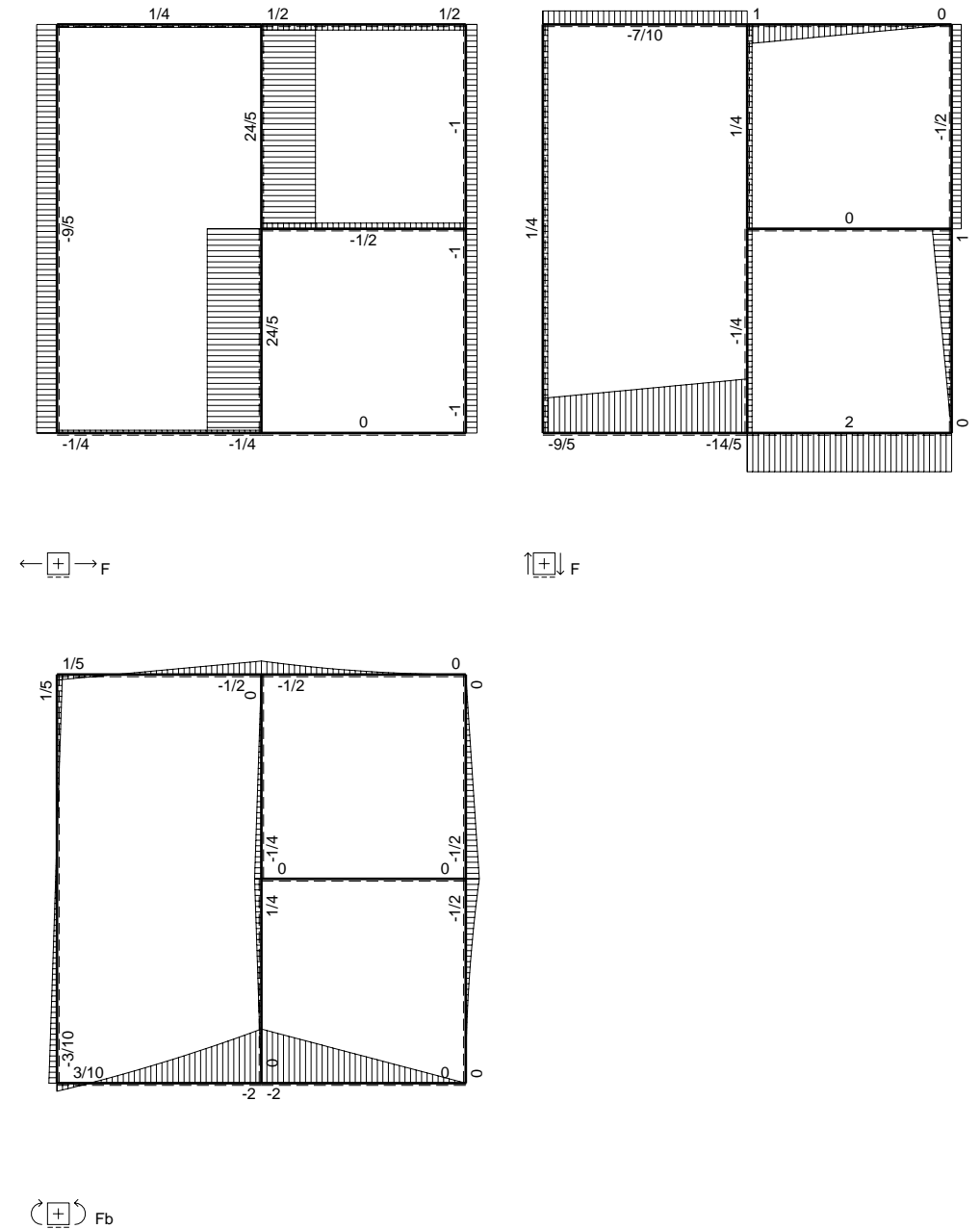
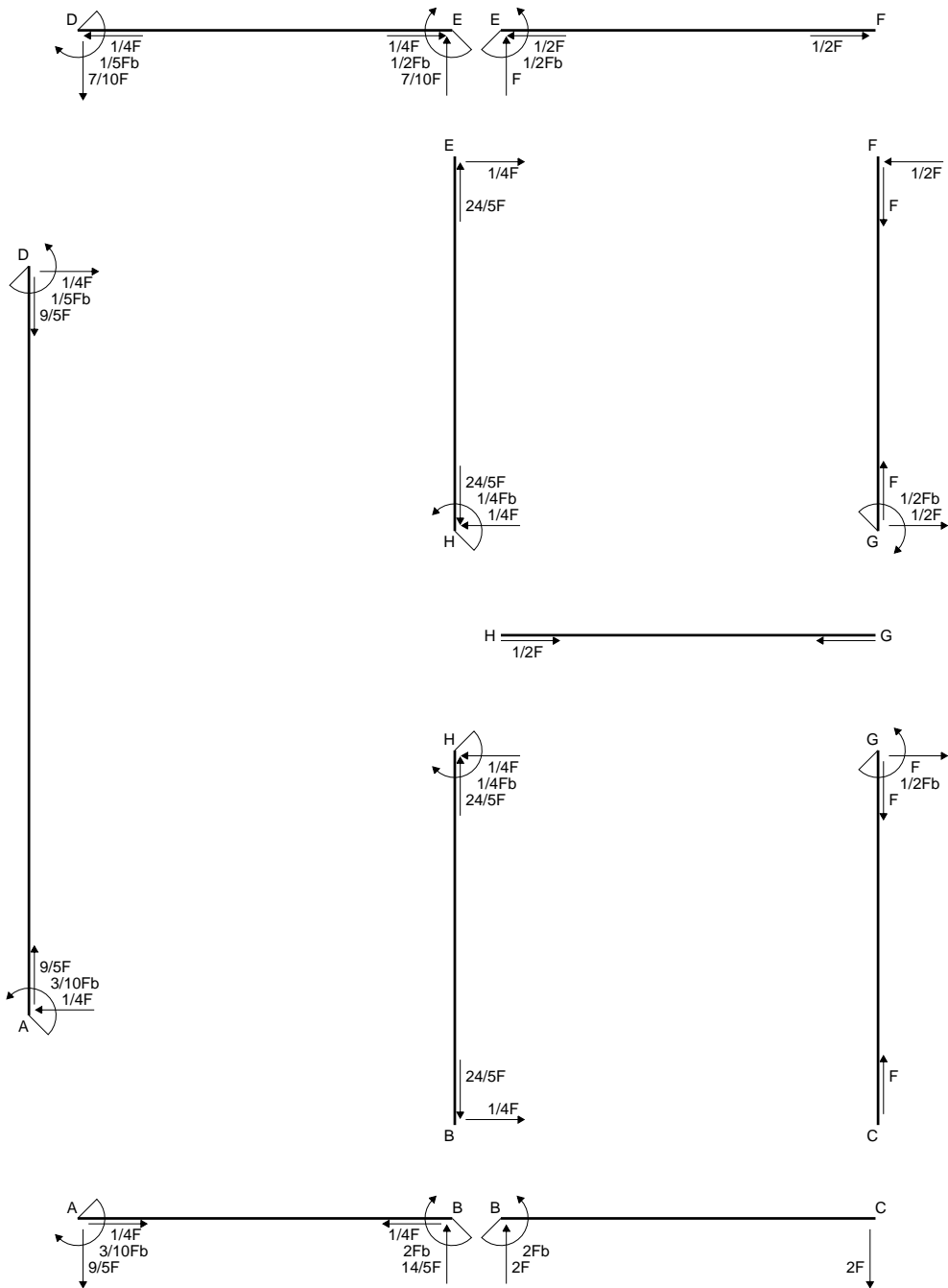
$$\sigma_c = -Mv/J_u = -131.1 \text{ N/mm}^2$$

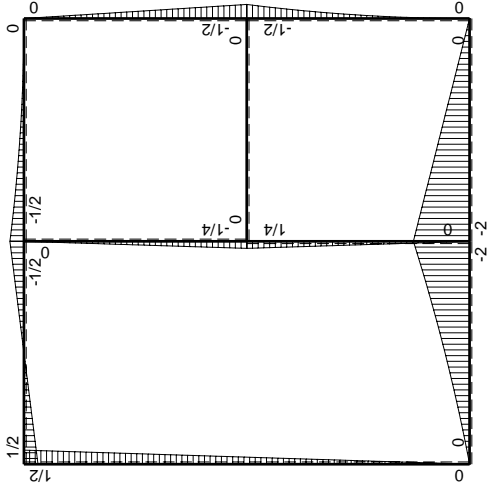
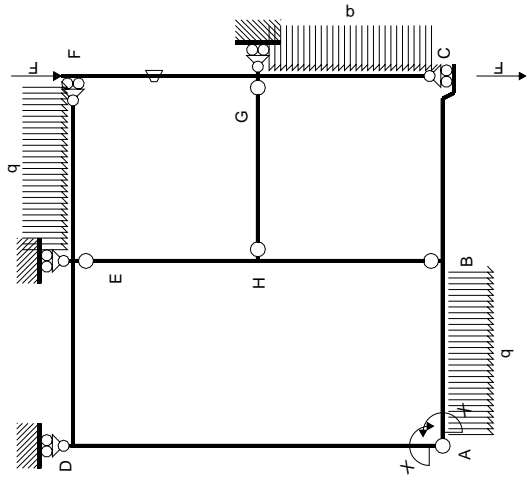
$$\tau_c = 7.954 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 131.8 \text{ N/mm}^2$$

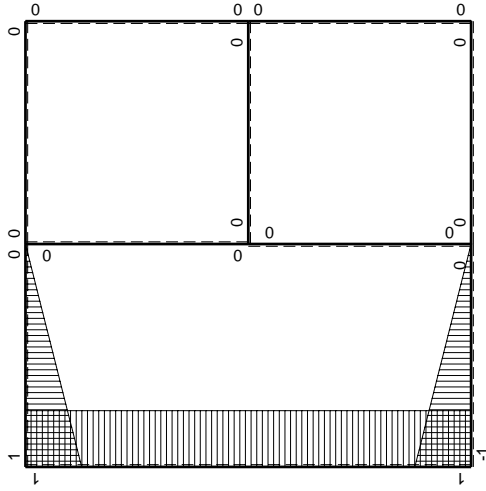
$$S = 6377. \text{ mm}^3$$







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1			
DE b	$1-x/b$	$1/2Fb-Fx$	0	$1/2Fb-3/2Fx+Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/12+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fb-Fx$	0	$-1/2Fx+Fx^2/b$	0	$x^2/b^2$			
EF b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
FE b	0	$1/2qx^2$	0	0	0	0			
FG b	0	$-1/2Fx$	$-Fb/EJ$	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	$Fb/EJ$	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$1/4Fb-1/4Fx$	0	0	0	0	0+0	0	
BH b	0	$-1/4Fx$	0	0	0	0			
HE b	0	$-1/4Fb+1/4Fx$	0	0	0	0	0+0	0	
EH b	0	$1/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/8Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-3/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

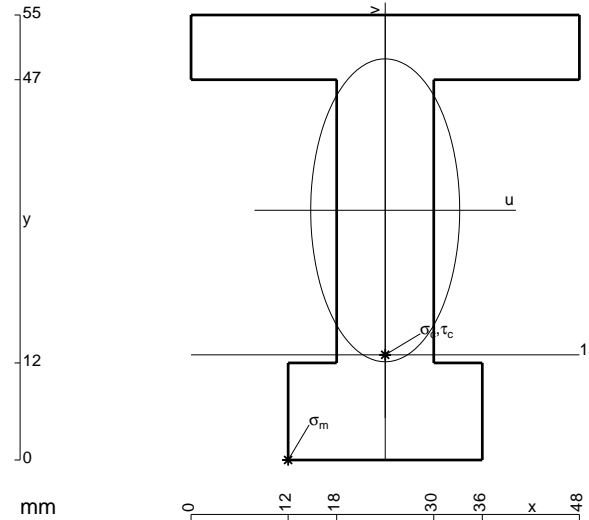
$$= (b - 1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - 3/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 3/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/2 b - 3/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (-1/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$



$$A = 1092. \text{ mm}^2$$

$$J_u = 382903. \text{ mm}^4$$

$$J_v = 92592. \text{ mm}^4$$

$$y_g = 30.86 \text{ mm}$$

$$T_y = 3200. \text{ N}$$

$$M_x = -2720000. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -12. \text{ mm}$$

$$v_m = -30.86 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -219.2 \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 13. \text{ mm}$$

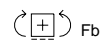
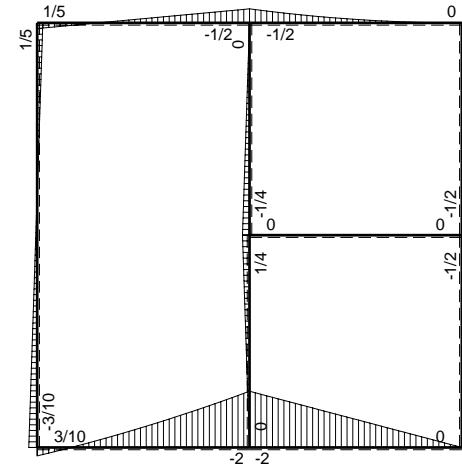
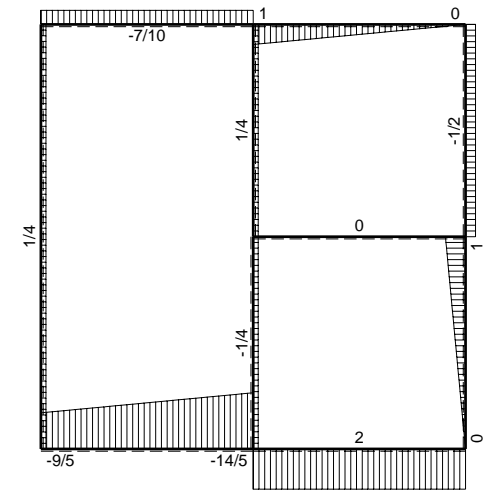
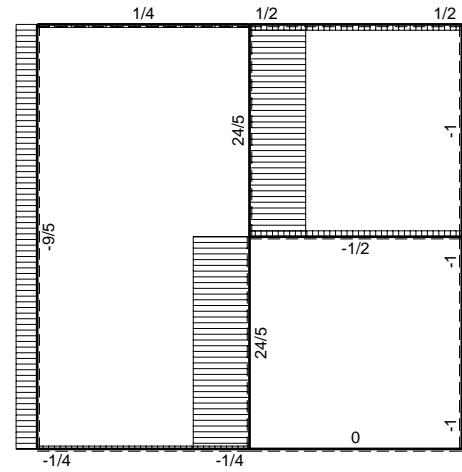
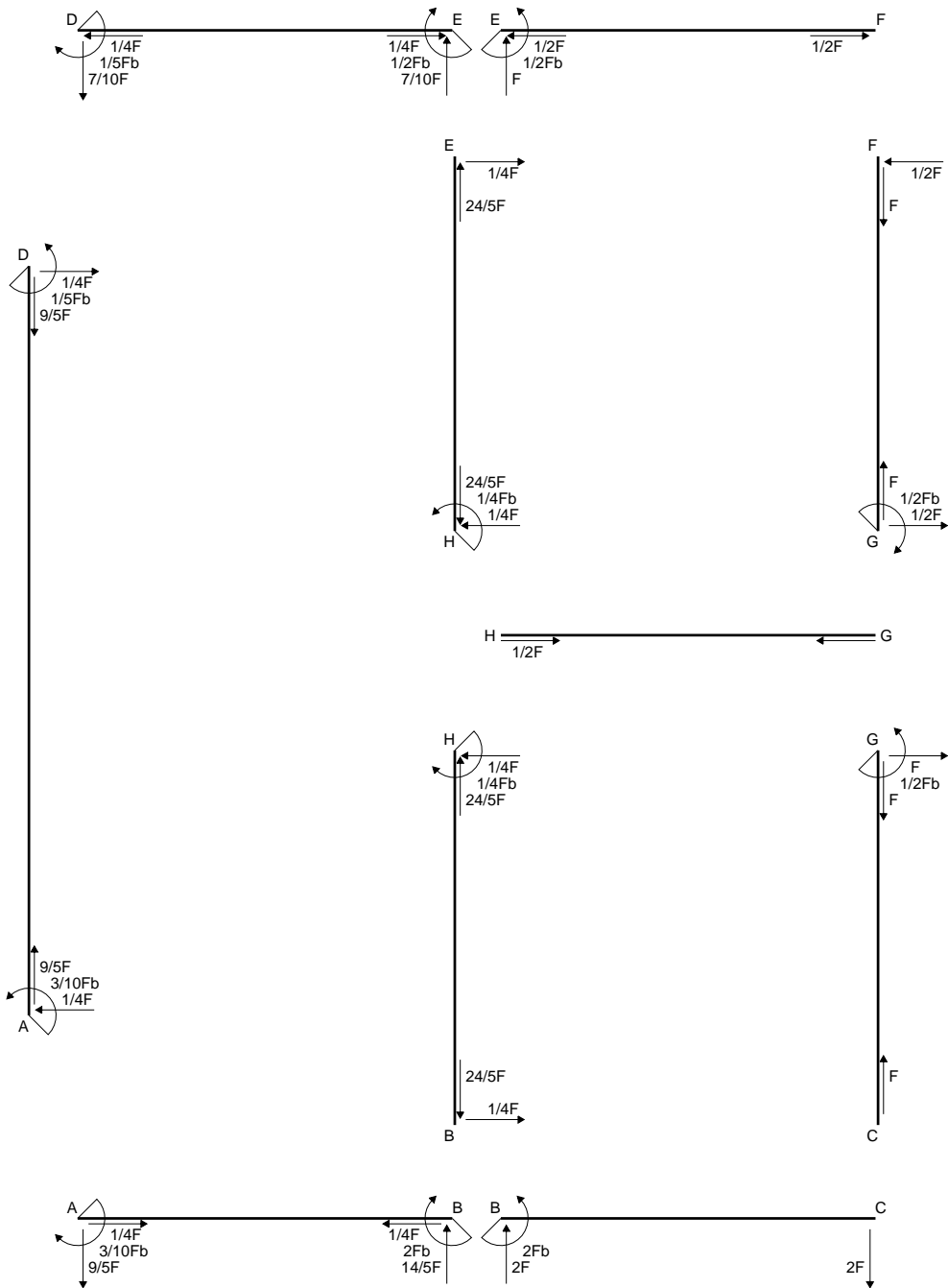
$$v_c = -17.86 \text{ mm}$$

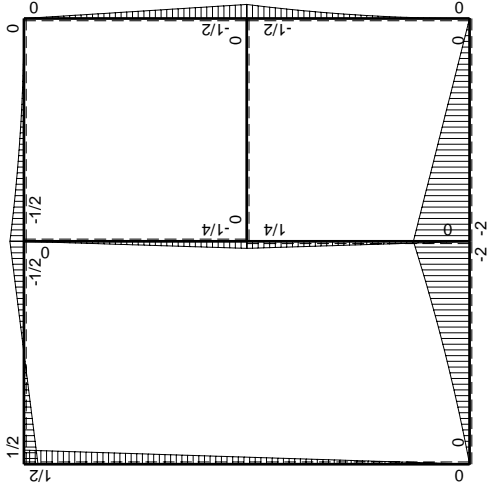
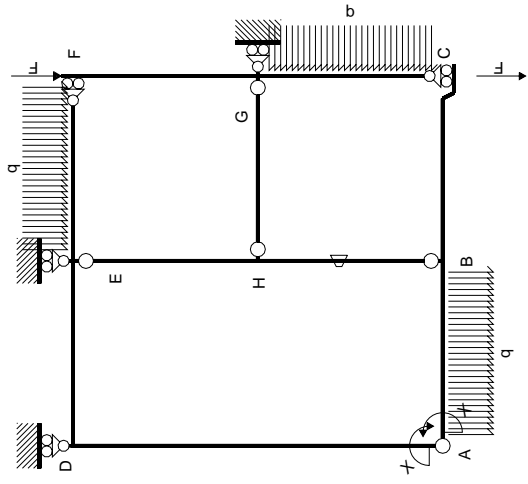
$$\sigma_c = -Mv/J_u = -126.9 \text{ N/mm}^2$$

$$\tau_c = 5.14 \text{ N/mm}^2$$

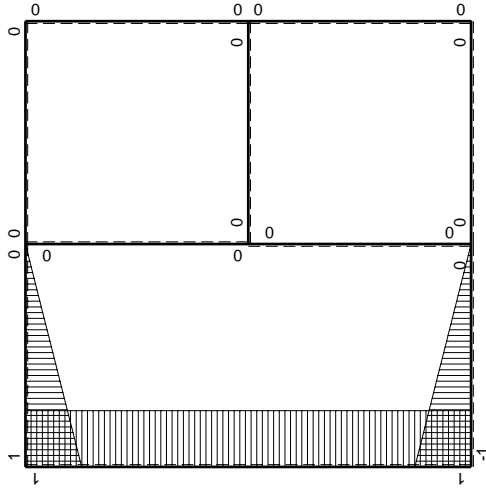
$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 127.2 \text{ N/mm}^2$$

$$S = 7381. \text{ mm}^3$$





$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x / EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1			
DE b	$1-x/b$	$1/2Fb-Fx$	0	$1/2Fb-3/2Fx+Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/12+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fb-Fx$	0	$-1/2Fx+Fx^2/b$	0	$x^2/b^2$			
EF b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
FE b	0	$1/2qx^2$	0	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$1/4Fb-1/4Fx$	$-Fb/EJ$	0	0	0	0+0	0	
BH b	0	$-1/4Fx$	$Fb/EJ$	0	0	0			
HE b	0	$-1/4Fb+1/4Fx$	0	0	0	0	0+0	0	
EH b	0	$1/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/8Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-3/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

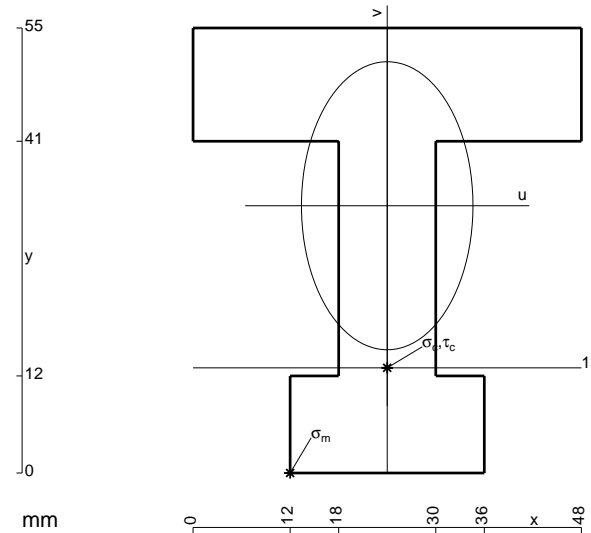
$$= (b - 1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - 3/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 3/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/2 b - 3/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (-1/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$



$$A = 1308. \text{ mm}^2$$

$$J_u = 414675. \text{ mm}^4$$

$$J_v = 147024. \text{ mm}^4$$

$$y_g = 33.03 \text{ mm}$$

$$T_y = 3200. \text{ N}$$

$$M_x = -2880000. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -12. \text{ mm}$$

$$v_m = -33.03 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -229.4 \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 13. \text{ mm}$$

$$v_c = -20.03 \text{ mm}$$

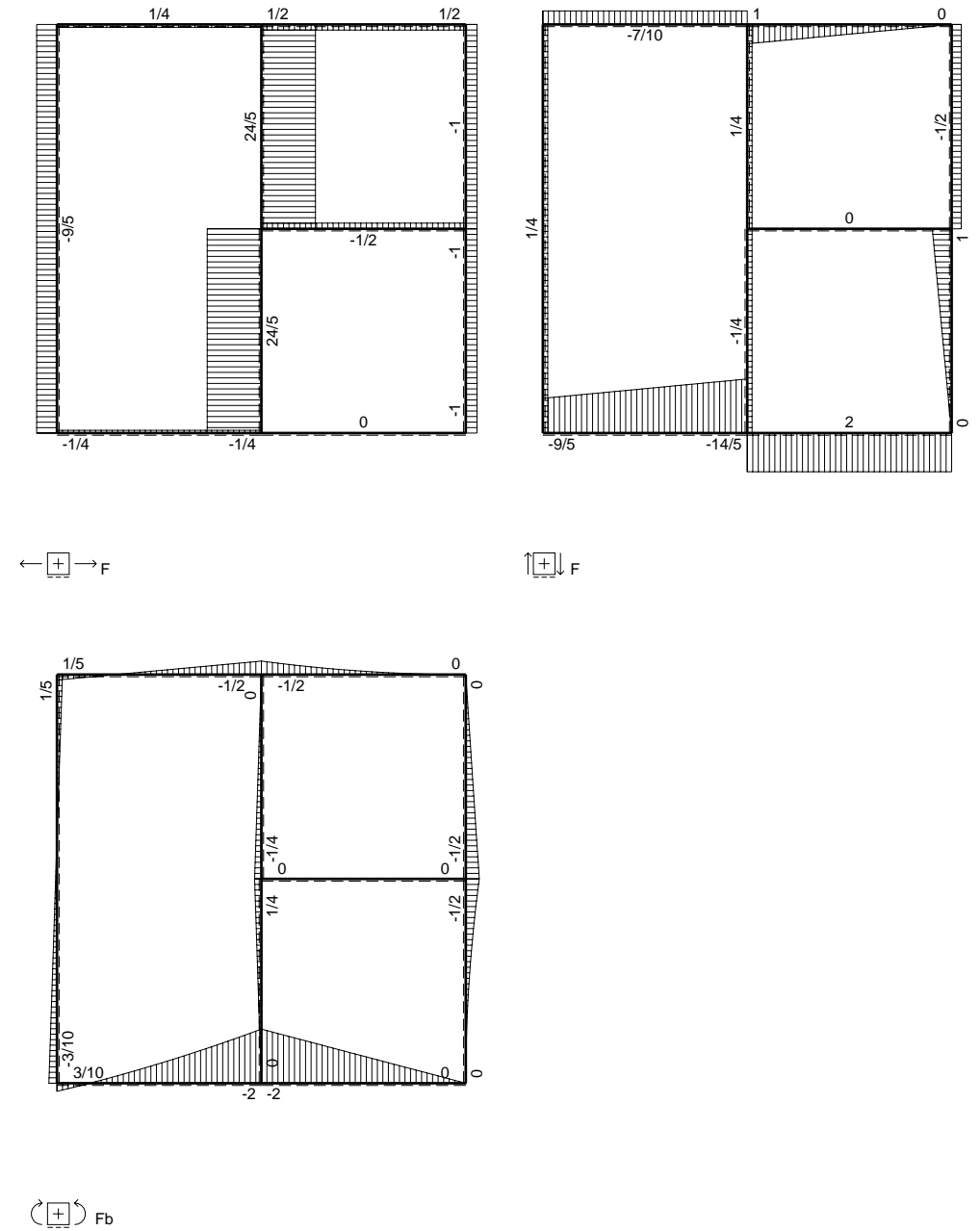
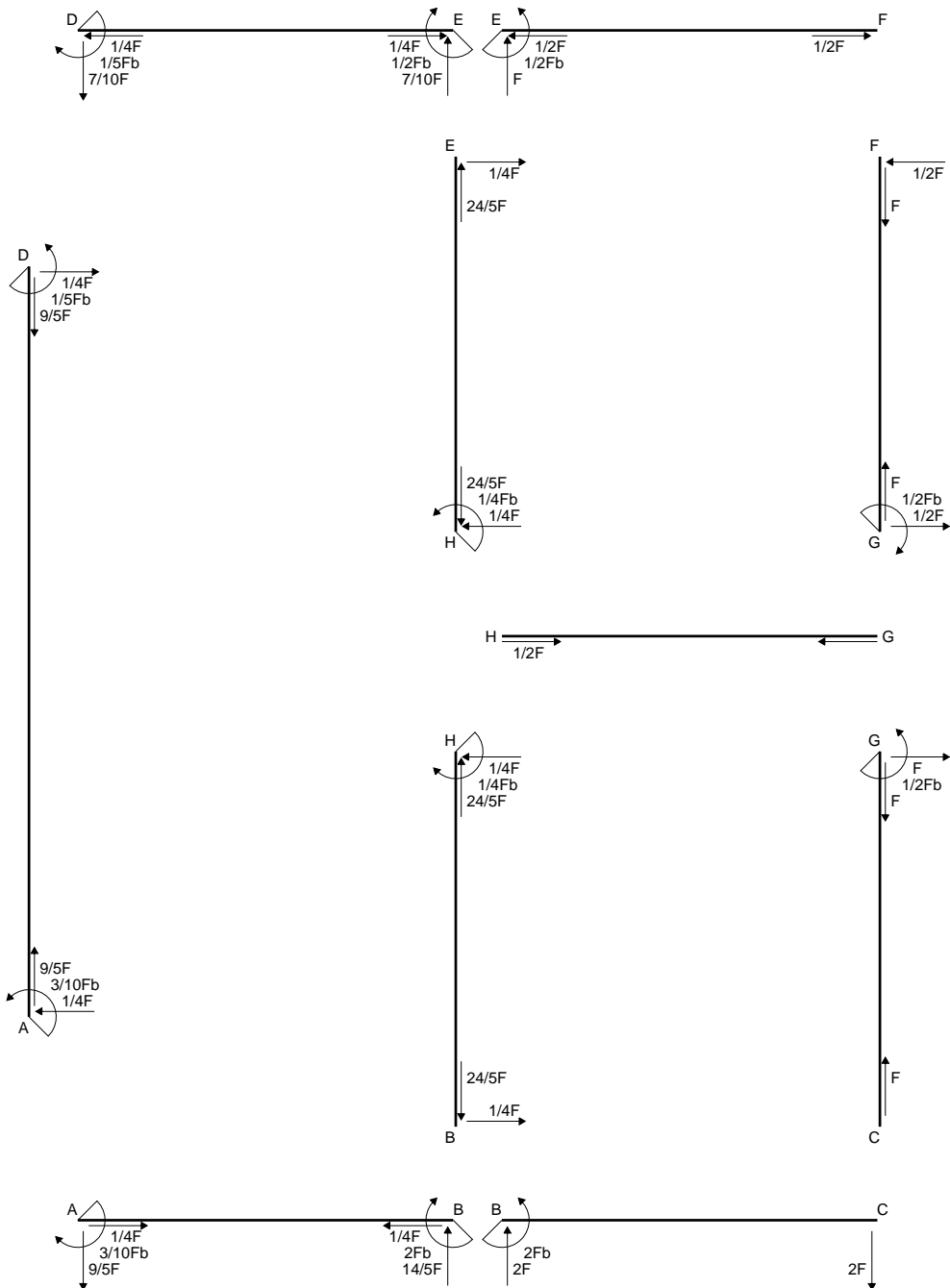
$$\sigma_c = -Mv/J_u = -139.1 \text{ N/mm}^2$$

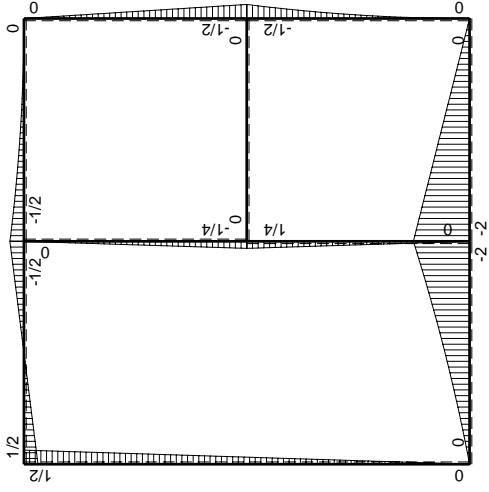
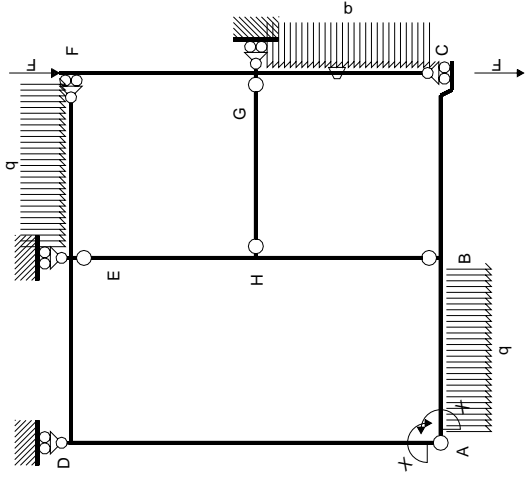
$$\tau_c = 5.165 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 139.4 \text{ N/mm}^2$$

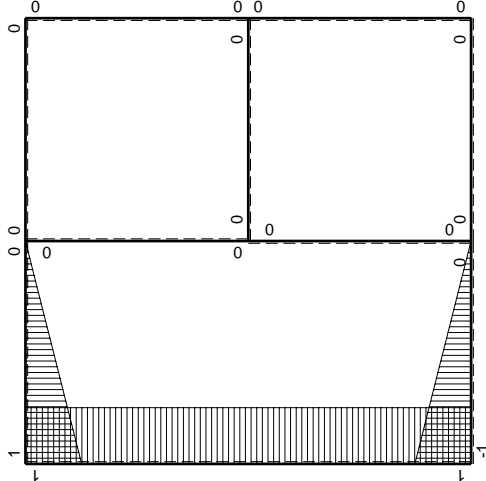
$$S = 8032. \text{ mm}^3$$







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1			
DE b	$1-x/b$	$1/2Fb-Fx$	0	$1/2Fb-3/2Fx+Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/12+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fb-Fx$	0	$-1/2Fx+Fx^2/b$	0	$x^2/b^2$			
EF b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
FE b	0	$1/2qx^2$	0	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	$-Fb/EJ$	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	$Fb/EJ$	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$1/4Fb-1/4Fx$	0	0	0	0	0+0	0	
BH b	0	$-1/4Fx$	0	0	0	0			
HE b	0	$-1/4Fb+1/4Fx$	0	0	0	0	0+0	0	
EH b	0	$1/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/8Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-3/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

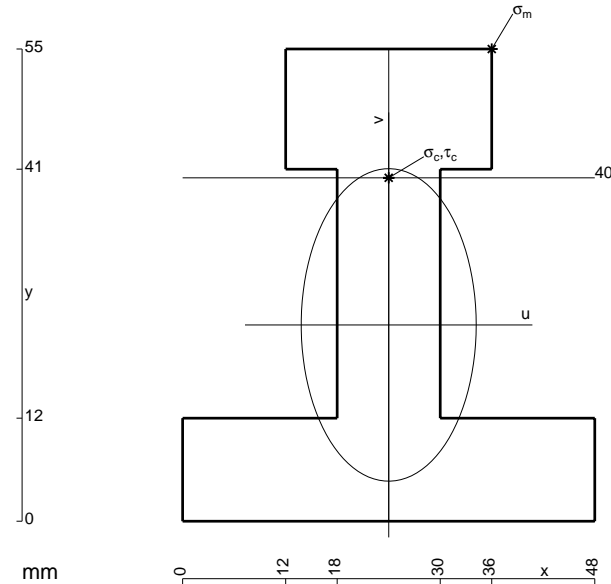
$$= (b - 1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - 3/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 3/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

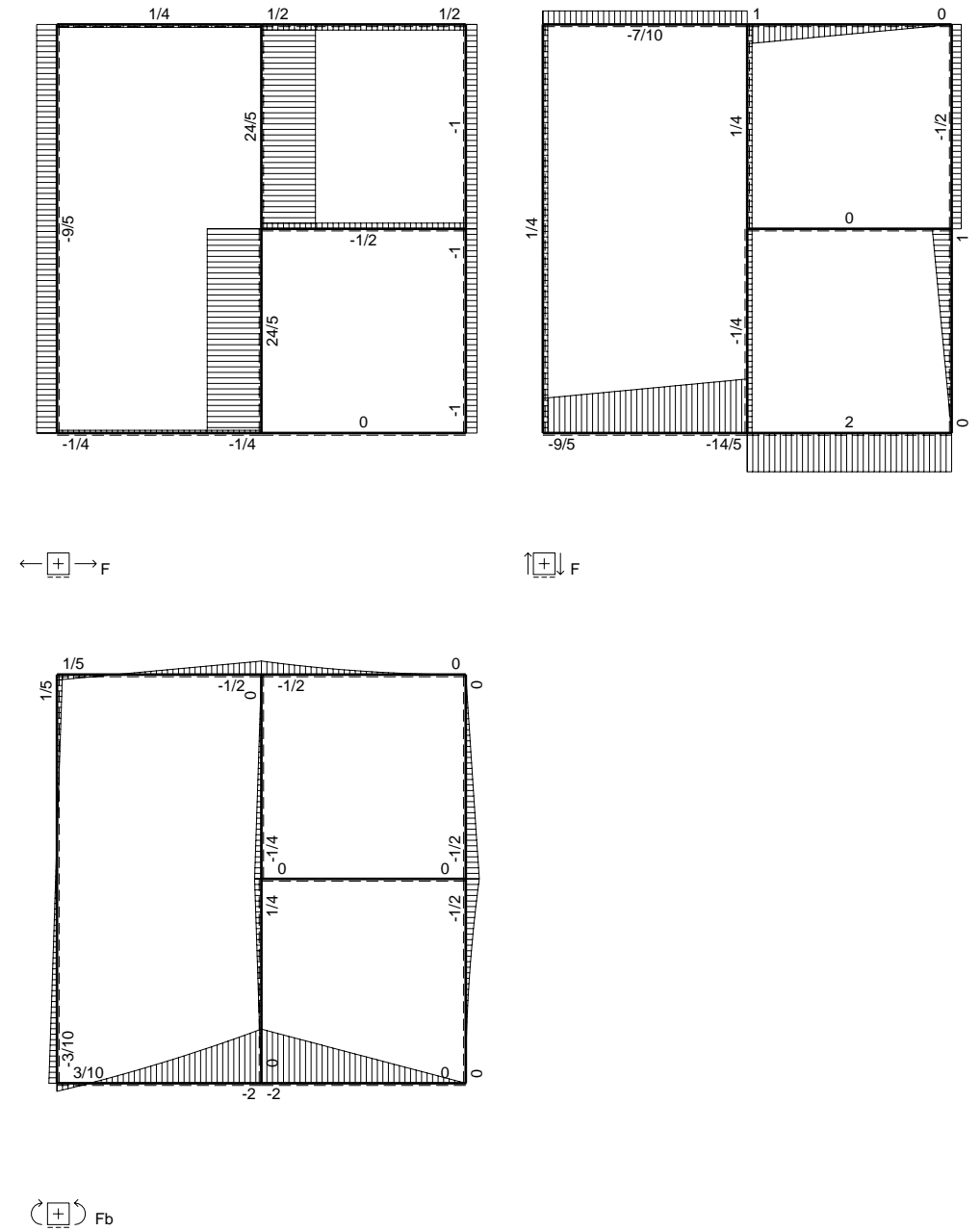
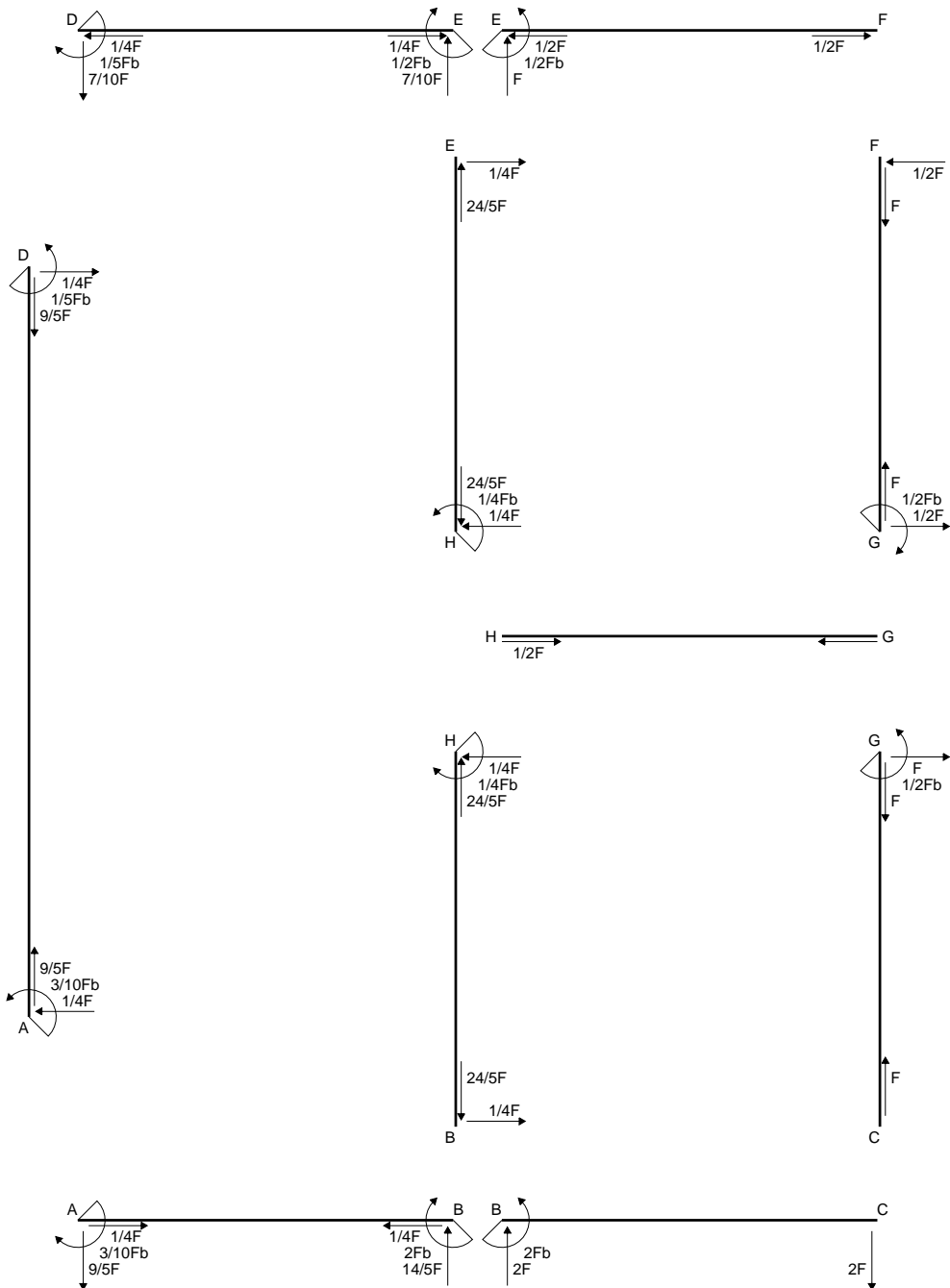
$$= (1/2 b - 3/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$

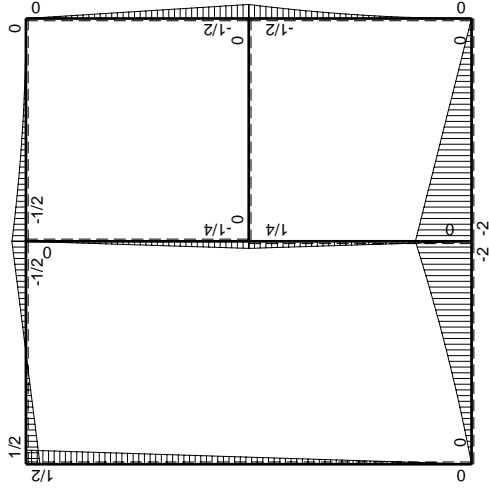
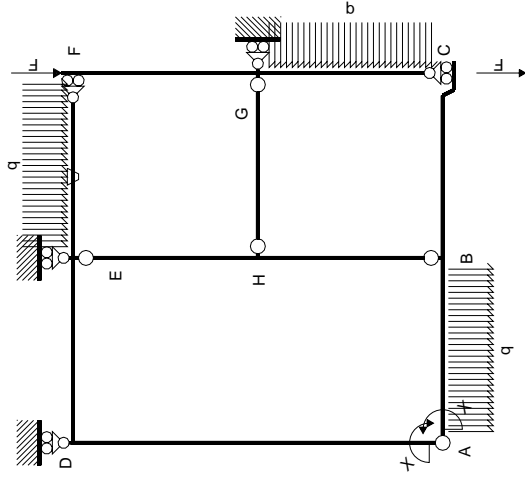
$$L_{ED}^{xo} = \int_0^b (-1/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$

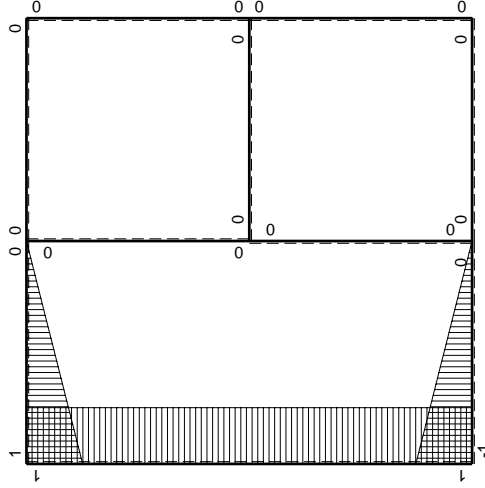


- A = 1260. mm<sup>2</sup>
- J<sub>u</sub> = 417492. mm<sup>4</sup>
- J<sub>v</sub> = 130896. mm<sup>4</sup>
- y<sub>g</sub> = 22.86 mm
- T<sub>y</sub> = 3280. N
- M<sub>x</sub> = -3116000. Nmm
- x<sub>m</sub> = 36. mm
- y<sub>m</sub> = 55. mm
- u<sub>m</sub> = 12. mm
- v<sub>m</sub> = 32.14 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 239.9 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 40. mm
- v<sub>c</sub> = 17.14 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 127.9 N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.668 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 128.3 N/mm<sup>2</sup>
- S = 8658. mm<sup>3</sup>





$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$1/4Fx$	0	$1/4Fx$	0	1	$(1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+1/4Fx$	0	$1/2Fb-1/4Fx$	0	1			
DE b	$1-x/b$	$1/2Fb-Fx$	0	$1/2Fb-3/2Fx+Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/12+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fb-Fx$	0	$-1/2Fx+Fx^2/b$	0	$x^2/b^2$			
EF b	0	$-1/2Fb+Fx-1/2qx^2$	$-Fb/EJ$	0	0	0	0+0	0	
FE b	0	$1/2qx^2$	$Fb/EJ$	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$1/4Fb-1/4Fx$	0	0	0	0	0+0	0	
BH b	0	$-1/4Fx$	0	0	0	0			
HE b	0	$-1/4Fb+1/4Fx$	0	0	0	0	0+0	0	
EH b	0	$1/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/8Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-3/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

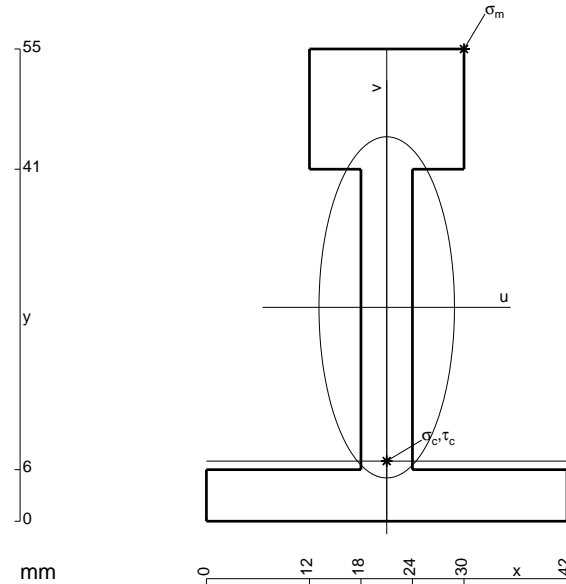
$$= (b - 1/2 b) \cdot Fb \cdot 1/EJ = 1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - 3/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 3/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/2 b - 3/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$

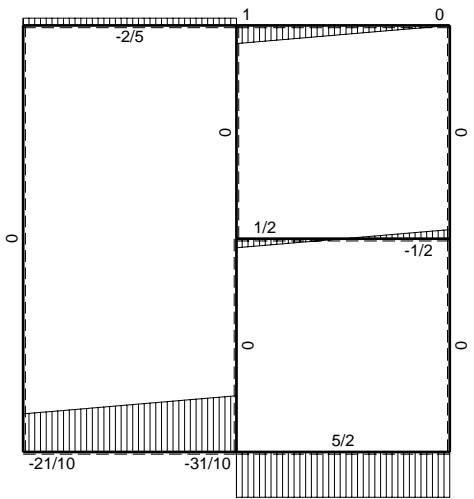
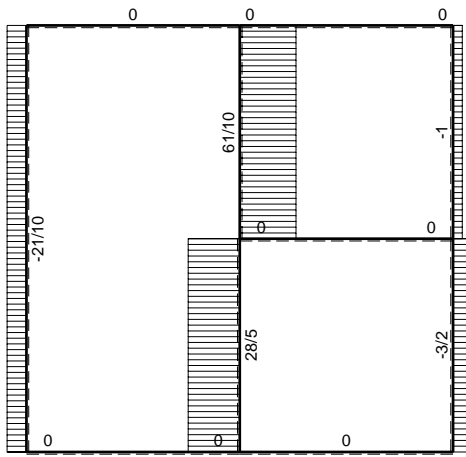
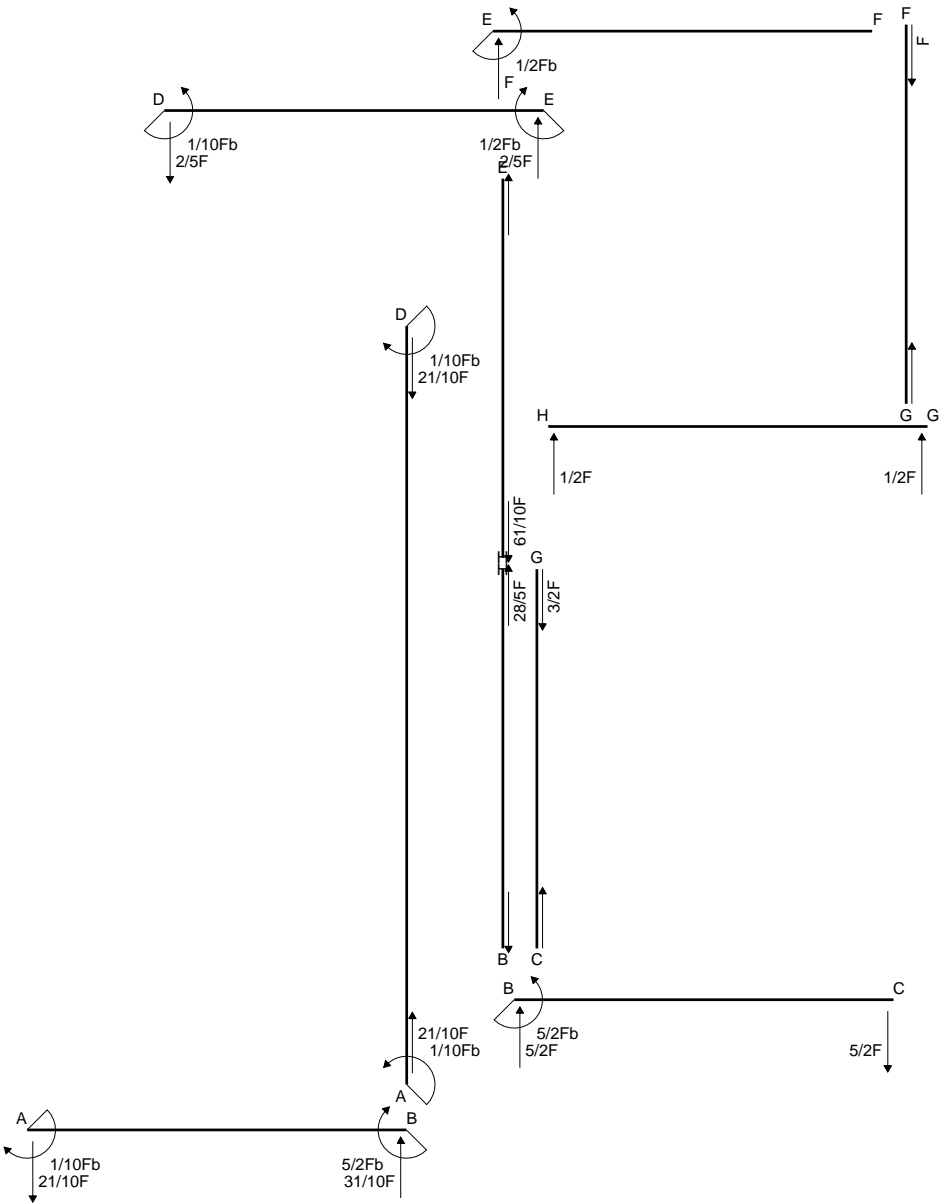
$$L_{ED}^{xo} = \int_0^b (-1/2 x/b + x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/4 x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/4 b + 1/3 b) \cdot Fb \cdot 1/EJ = 1/12 \cdot Fb^2/EJ$$



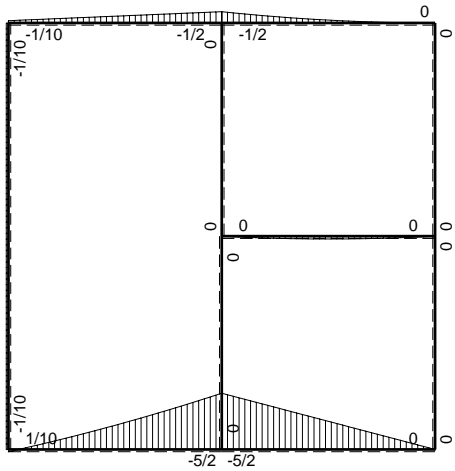
$A = 714. \text{ mm}^2$   
 $J_u = 282052. \text{ mm}^4$   
 $J_v = 44478. \text{ mm}^4$   
 $y_g = 24.91 \text{ mm}$   
 $T_y = 3740. \text{ N}$   
 $M_x = -1870000. \text{ Nmm}$   
 $x_m = 30. \text{ mm}$   
 $y_m = 55. \text{ mm}$   
 $u_m = 9. \text{ mm}$   
 $v_m = 30.09 \text{ mm}$   
 $\sigma_m = -Mv/J_u = 199.5 \text{ N/mm}^2$   
 $x_c = 21. \text{ mm}$   
 $y_c = 7. \text{ mm}$   
 $v_c = -17.91 \text{ mm}$   
 $\sigma_c = -Mv/J_u = -118.8 \text{ N/mm}^2$   
 $\tau_c = 12.45 \text{ N/mm}^2$   
 $\sigma_o = \sqrt{\sigma^2 + 3\tau^2} = 120.7 \text{ N/mm}^2$   
 $S = 5632. \text{ mm}^3$



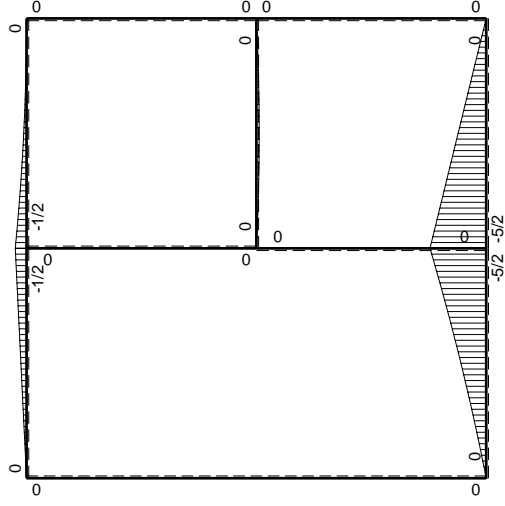
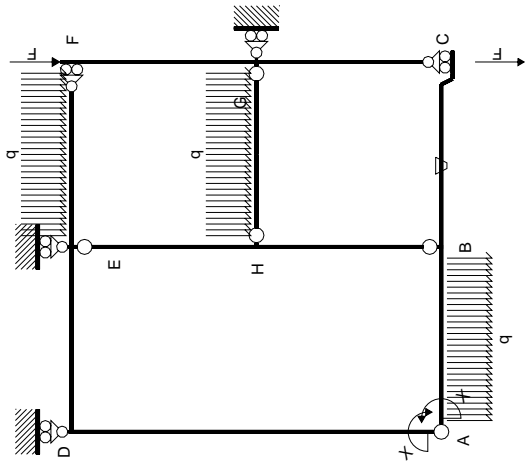


← (+) → F

↑ (+) ↓ F

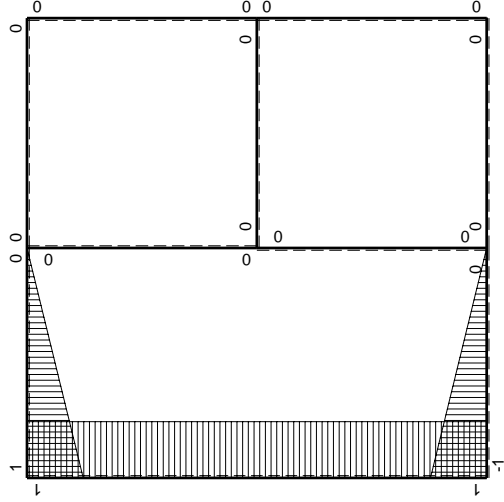


⊕ (+) ⊖ (-) F<sub>b</sub>



Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x / EJ dx$	
AB b	$-1+x/b$	$-2Fx-1/2qx^2$	0	$2Fx-3/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(3/8+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$5/2Fb-3Fx+1/2qx^2$	0	$5/2Fx-3Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-5/2Fb+5/2Fx$	$-Fb/EJ$	0	0	0	0+0	0	
CB b	0	$5/2Fx$	$Fb/EJ$	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	$-1/2Fx$	0	$-1/2Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-1/12+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fb-1/2Fx$	0	$-1/2Fx+1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
FE b	0	$1/2qx^2$	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
GH b	0	$-1/2Fx+1/2qx^2$	0	0	0	0			
HB b	0	0	0	0	0	0	0+0	0	
BH b	0	0	0	0	0	0			
HE b	0	0	0	0	0	0	0+0	0	
EH b	0	0	0	0	0	0			
AB	molla asta $-W_{1AB} (W_{0AB} + XW_{1AB}) / k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (2x/b - 3/2 x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 1/2 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 1/2 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (5/2 x/b - 3 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 5/4 x^2/b - x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

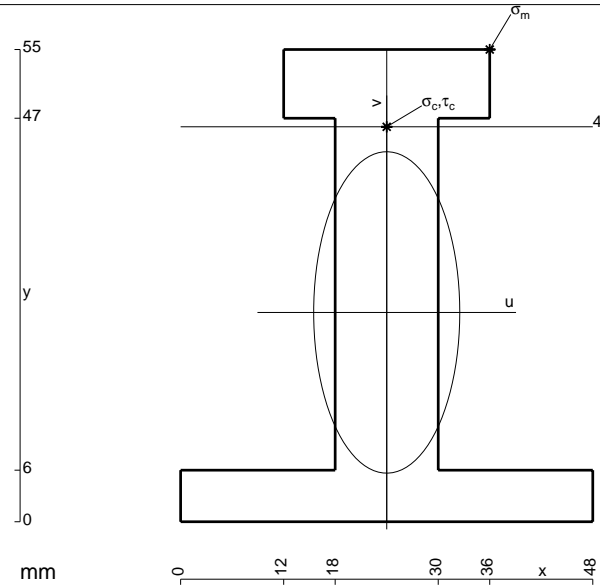
$$= (5/4 b - b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (-1/2 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/4 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

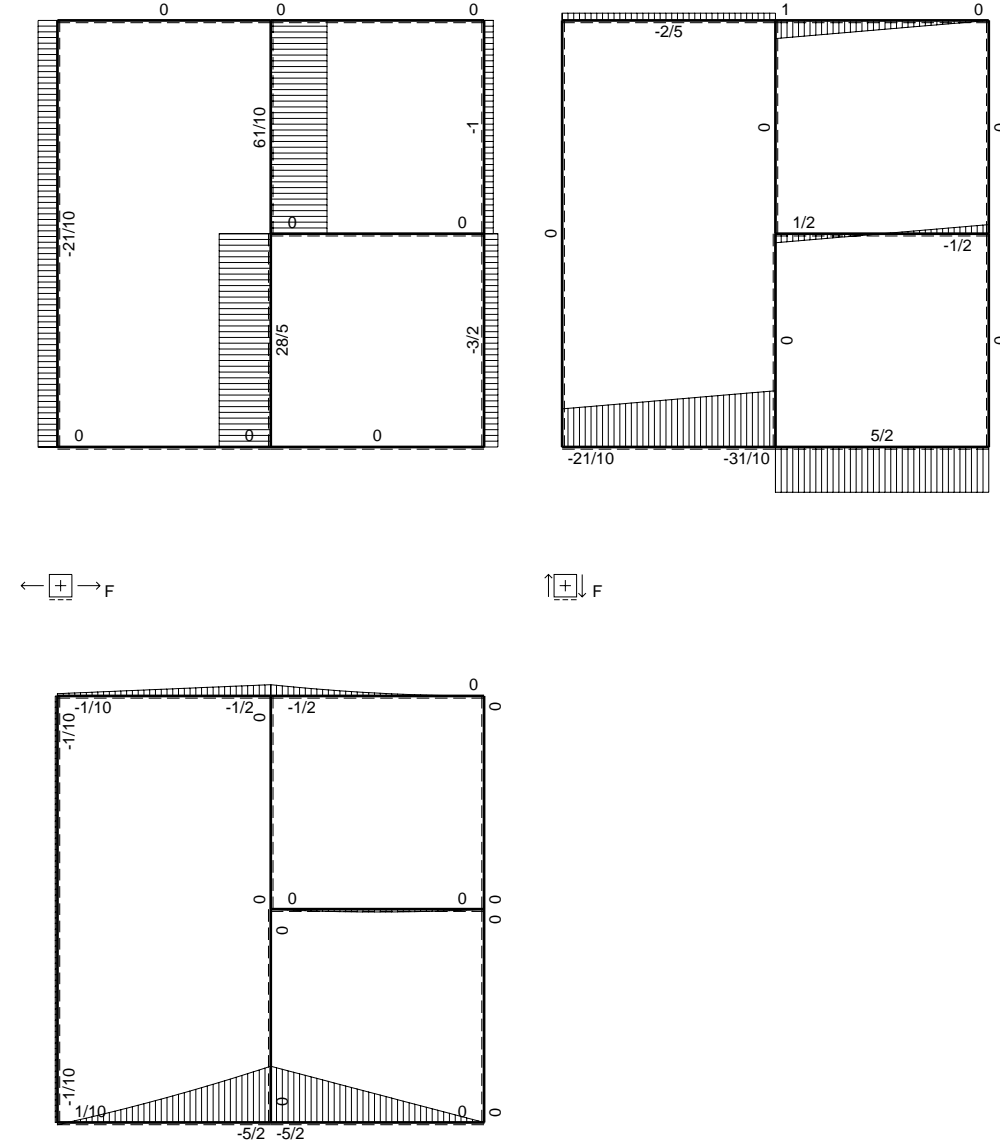
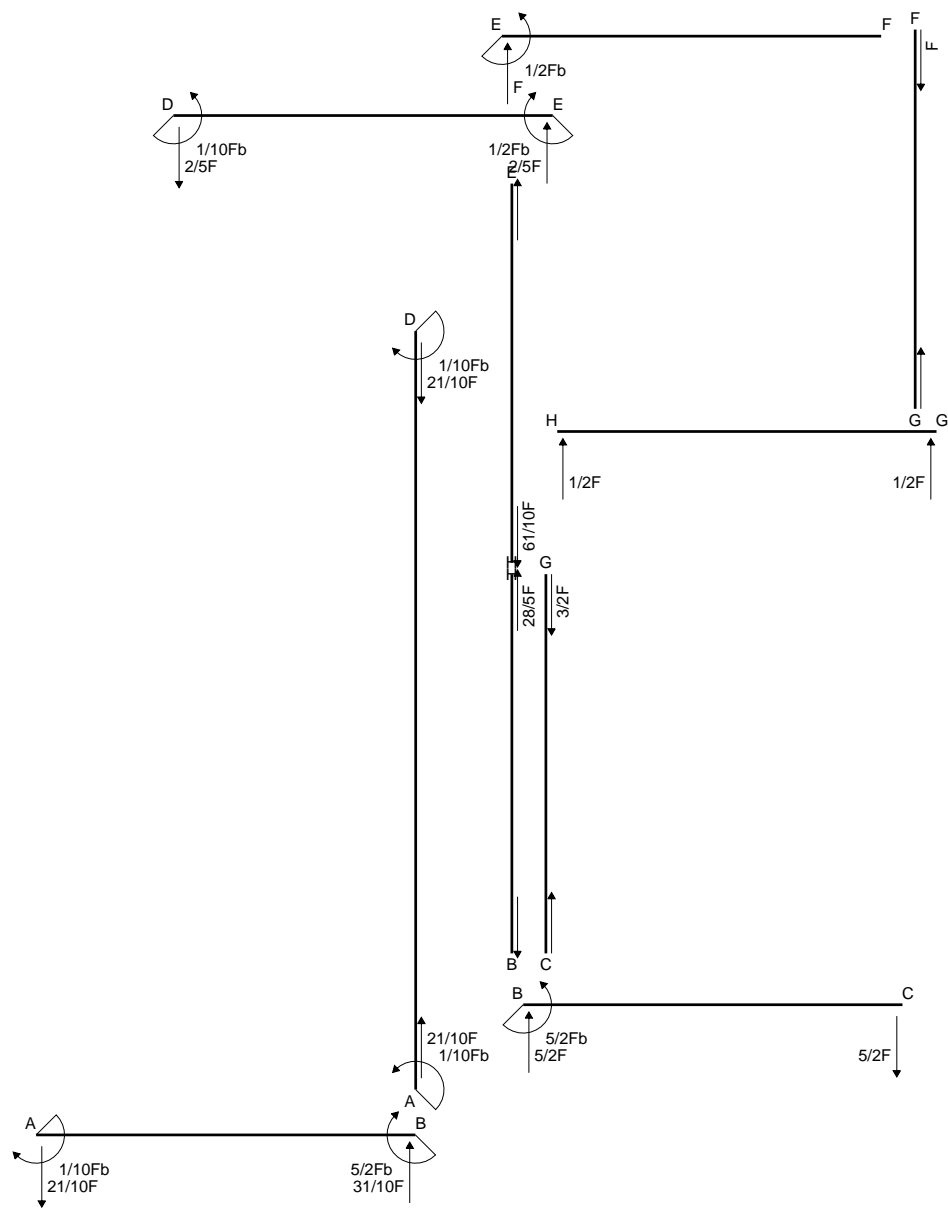
$$= (-1/4 b + 1/6 b) \cdot Fb \cdot 1/EJ = -1/12 \cdot Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (-1/2 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/4 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

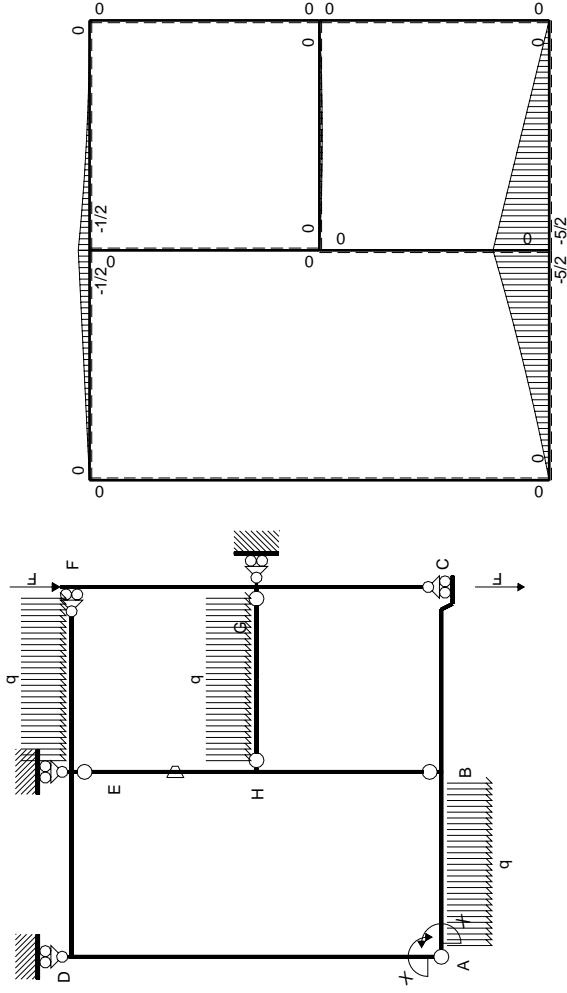
$$= (-1/4 b + 1/6 b) \cdot Fb \cdot 1/EJ = -1/12 \cdot Fb^2/EJ$$



- A = 972. mm<sup>2</sup>
- J<sub>u</sub> = 340722. mm<sup>4</sup>
- J<sub>v</sub> = 70416. mm<sup>4</sup>
- y<sub>g</sub> = 24.38 mm
- T<sub>y</sub> = 4225. N
- M<sub>x</sub> = -2323750. Nmm
- x<sub>m</sub> = 36. mm
- y<sub>m</sub> = 55. mm
- u<sub>m</sub> = 12. mm
- v<sub>m</sub> = 30.62 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 208.9 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 46. mm
- v<sub>c</sub> = 21.62 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 147.5 N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.556 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 147.8 N/mm<sup>2</sup>
- S = 5377. mm<sup>3</sup>

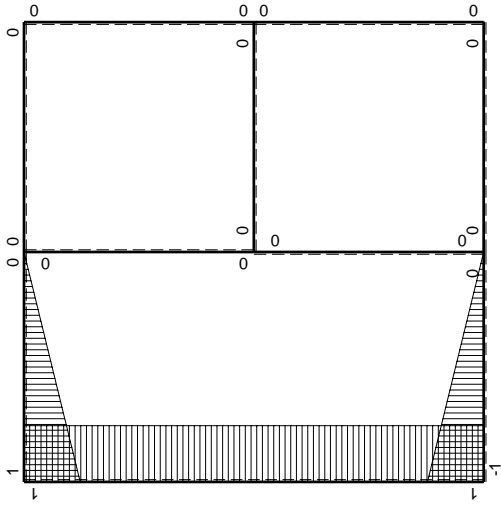


$\left[ \begin{smallmatrix} + \\ + \end{smallmatrix} \right] F_b$



Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-2Fx-1/2qx^2$	0	$2Fx-3/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(3/8+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$5/2Fb-3Fx+1/2qx^2$	0	$5/2Fx-3Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-5/2Fb+5/2Fx$	0	0	0	0	0+0	0	
CB b	0	$5/2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	$-1/2Fx$	0	$-1/2Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-1/12+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fb-1/2Fx$	0	$-1/2Fx+1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
FE b	0	$1/2qx^2$	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
GH b	0	$-1/2Fx+1/2qx^2$	0	0	0	0			
HB b	0	0	0	0	0	0	0+0	0	
BH b	0	0	0	0	0	0			
HE b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
EH b	0	0	$Fb/EJ$	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (2x/b - 3/2 x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 1/2 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 1/2 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (5/2 x/b - 3x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 5/4 x^2/b - x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

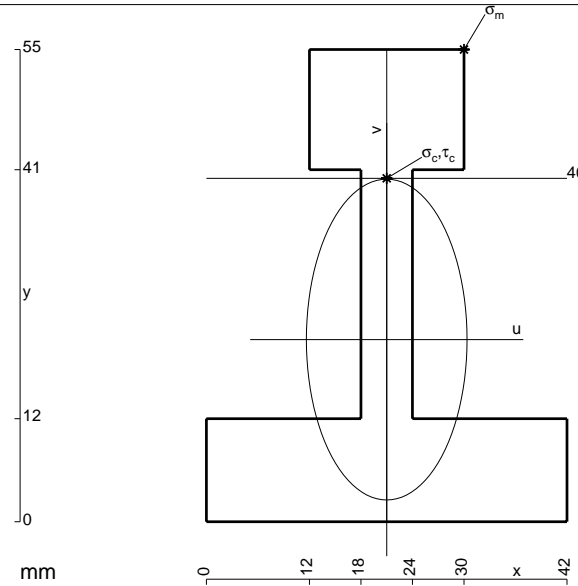
$$= (5/4 b - b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (-1/2 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/4 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/4 b + 1/6 b) \cdot Fb \cdot 1/EJ = -1/12 \cdot Fb^2/EJ$$

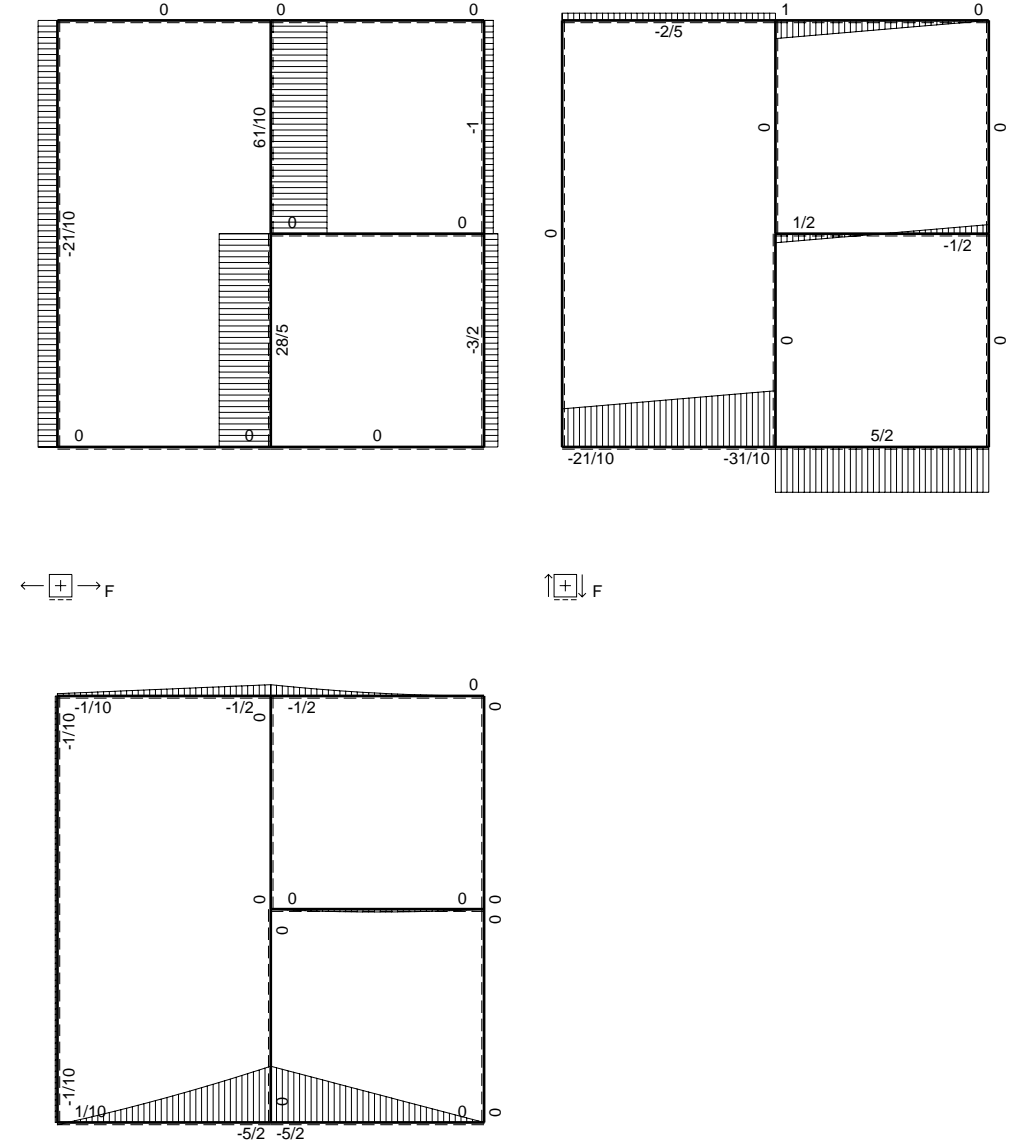
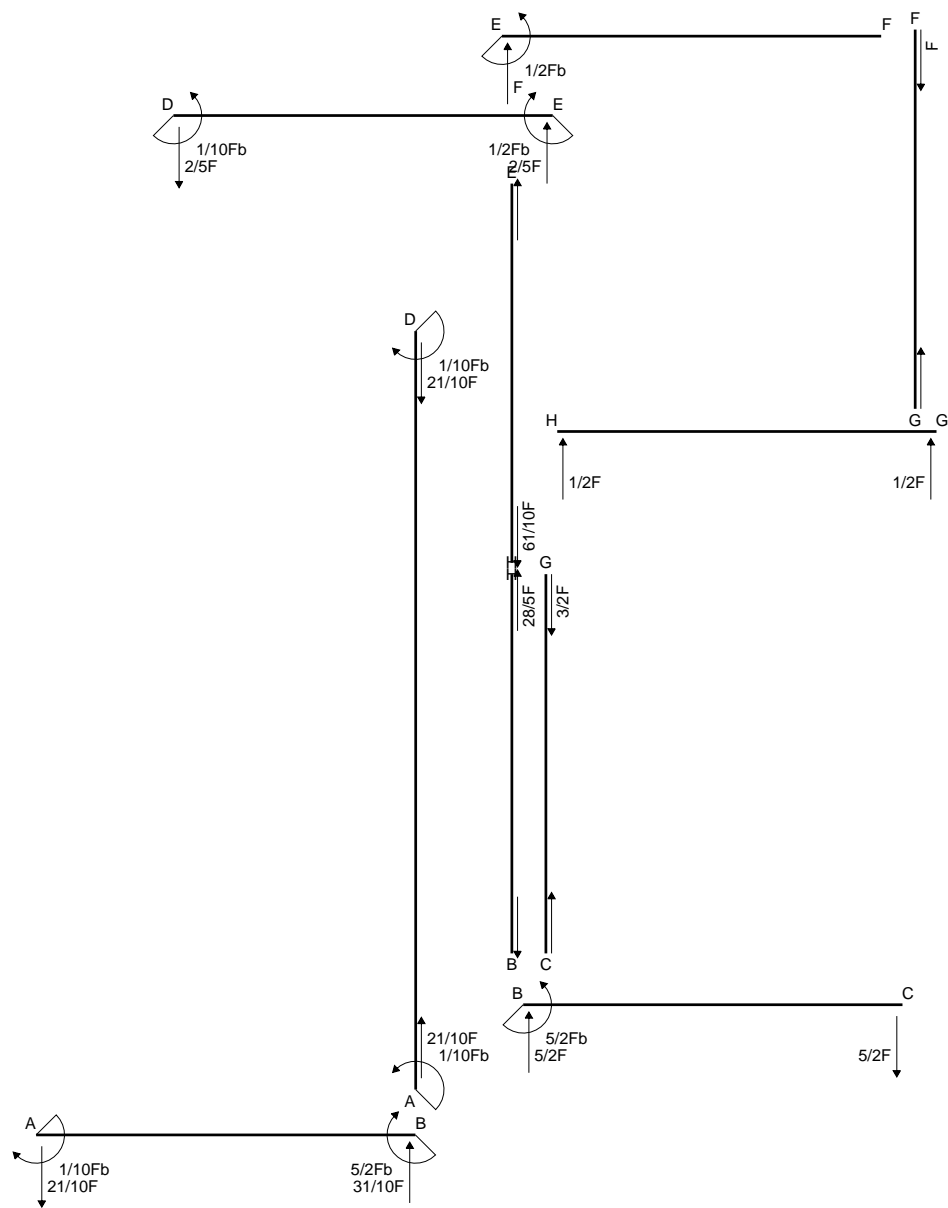
$$L_{ED}^{xo} = \int_0^b (-1/2 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/4 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

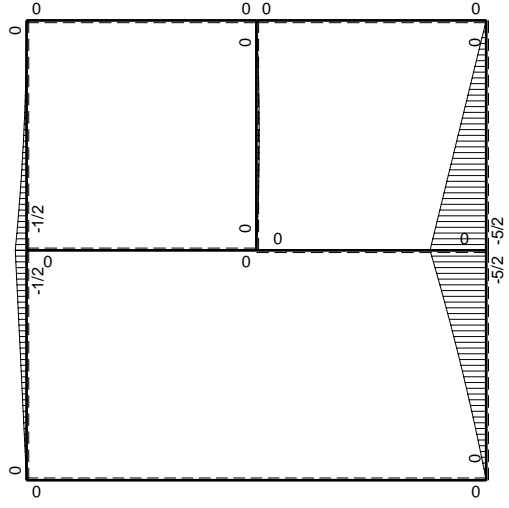
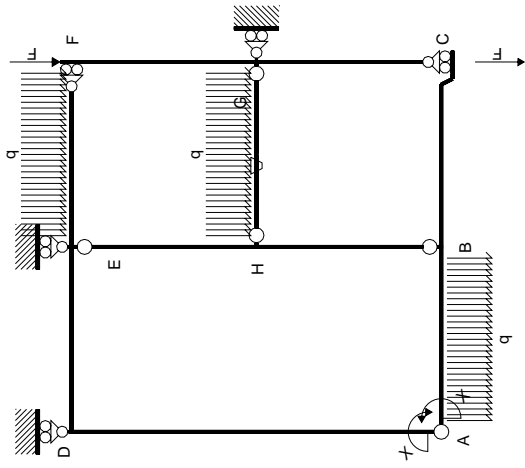
$$= (-1/4 b + 1/6 b) \cdot Fb \cdot 1/EJ = -1/12 \cdot Fb^2/EJ$$



- A = 930. mm<sup>2</sup>
- J<sub>u</sub> = 324687. mm<sup>4</sup>
- J<sub>v</sub> = 81414. mm<sup>4</sup>
- y<sub>g</sub> = 21.22 mm
- T<sub>y</sub> = 3500. N
- M<sub>x</sub> = -2100000. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 55. mm
- u<sub>m</sub> = 9. mm
- v<sub>m</sub> = 33.78 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 218.5 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 40. mm
- v<sub>c</sub> = 18.78 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 121.5 N/mm<sup>2</sup>
- τ<sub>c</sub> = 12.33 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 123.4 N/mm<sup>2</sup>
- S = 6865. mm<sup>3</sup>

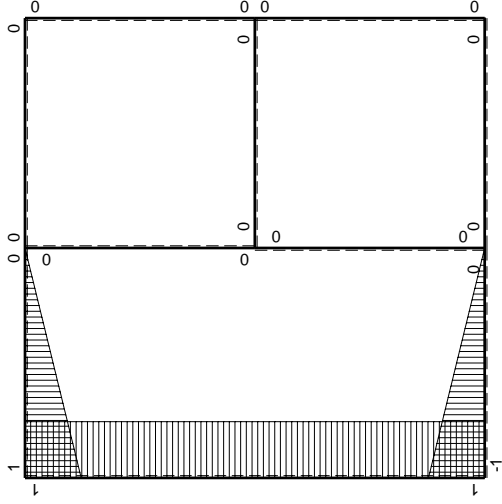






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-2Fx-1/2qx^2$	0	$2Fx-3/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(3/8+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$5/2Fb-3Fx+1/2qx^2$	0	$5/2Fx-3Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-5/2Fb+5/2Fx$	0	0	0	0	0+0	0	
CB b	0	$5/2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	$-1/2Fx$	0	$-1/2Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-1/12+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fb-1/2Fx$	0	$-1/2Fx+1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
FE b	0	$1/2qx^2$	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	$1/2Fx-1/2qx^2$	$-Fb/EJ$	0	0	0	0+0	0	
GH b	0	$-1/2Fx+1/2qx^2$	$Fb/EJ$	0	0	0			
HB b	0	0	0	0	0	0	0+0	0	
BH b	0	0	0	0	0	0			
HE b	0	0	0	0	0	0	0+0	0	
EH b	0	0	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx + 1 \cdot 1/4 b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b 1/EJ + 1 \cdot 1/4 b/EJ$$

$$= (b - b + 1/3 b) 1/EJ + 1 \cdot 1/4 b/EJ = 7/12 b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx + 1 \cdot 1/4 b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b 1/EJ + 1 \cdot 1/4 b/EJ$$

$$= (1/3 b) 1/EJ + 1 \cdot 1/4 b/EJ = 7/12 b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) 1/EJ dx = \left[ x \right]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) 1/EJ dx = \left[ x \right]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = \left[ 1/3 x^3/b^2 \right]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{AB}^{xo} = \int_0^b (2x/b - 3/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx + 1 \cdot 0 1/4 Fb^2/EJ$$

$$= \left[ x^2/b - 1/2 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b Fb 1/EJ + 1 \cdot 0 1/4 Fb^2/EJ$$

$$= (b - 1/2 b - 1/8 b) Fb 1/EJ + 1 \cdot 0 1/4 Fb^2/EJ = 3/8 Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (5/2 x/b - 3 x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + 1 \cdot 0 1/4 Fb^2/EJ$$

$$= \left[ 5/4 x^2/b - x^3/b^2 + 1/8 x^4/b^3 \right]_0^b Fb 1/EJ + 1 \cdot 0 1/4 Fb^2/EJ$$

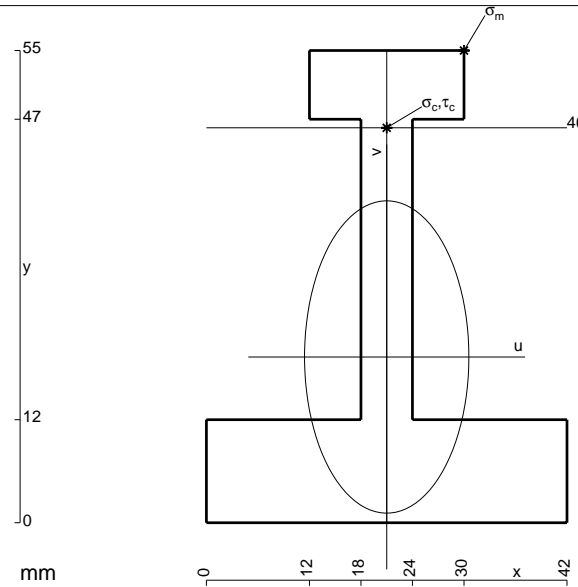
$$= (5/4 b - b + 1/8 b) Fb 1/EJ + 1 \cdot 0 1/4 Fb^2/EJ = 3/8 Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (-1/2 x/b + 1/2 x^2/b^2) Fb 1/EJ dx = \left[ -1/4 x^2/b + 1/6 x^3/b^2 \right]_0^b Fb 1/EJ$$

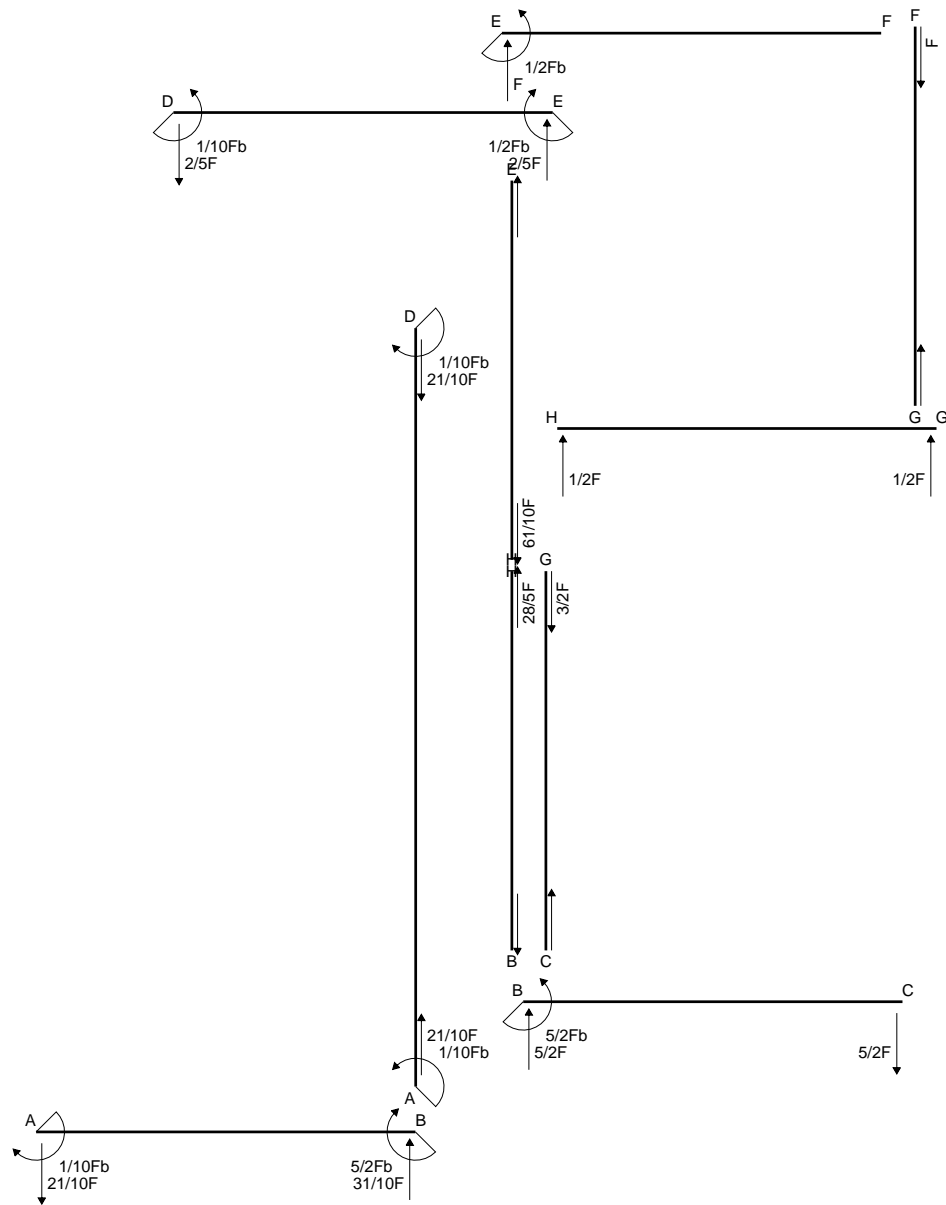
$$= (-1/4 b + 1/6 b) Fb 1/EJ = -1/12 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (-1/2 x/b + 1/2 x^2/b^2) Fb 1/EJ dx = \left[ -1/4 x^2/b + 1/6 x^3/b^2 \right]_0^b Fb 1/EJ$$

$$= (-1/4 b + 1/6 b) Fb 1/EJ = -1/12 Fb^2/EJ$$

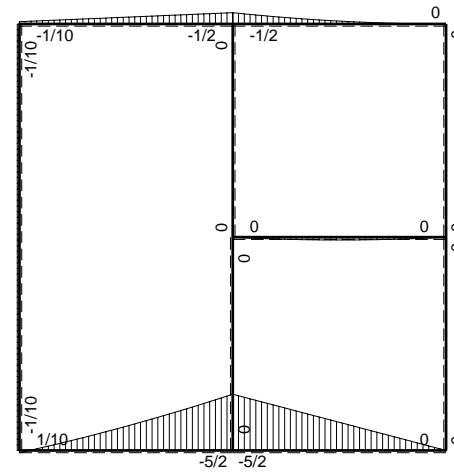


- A = 858. mm<sup>2</sup>
- J<sub>u</sub> = 283959. mm<sup>4</sup>
- J<sub>v</sub> = 78606. mm<sup>4</sup>
- y<sub>g</sub> = 19.3 mm
- T<sub>y</sub> = 2800. N
- M<sub>x</sub> = -1820000. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 55. mm
- u<sub>m</sub> = 9. mm
- v<sub>m</sub> = 35.7 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 228.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 46. mm
- v<sub>c</sub> = 26.7 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 171.1 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.769 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 171.6 N/mm<sup>2</sup>
- S = 4727. mm<sup>3</sup>

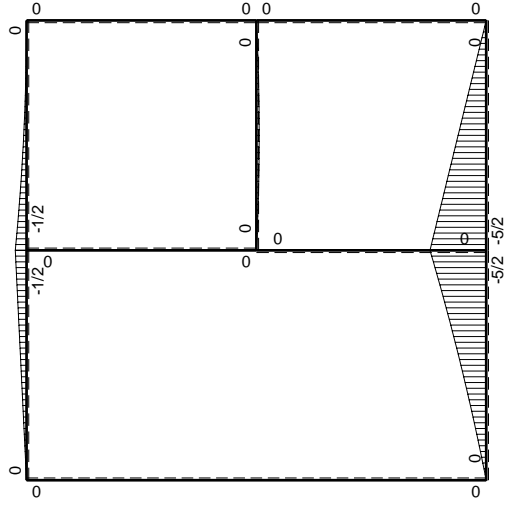
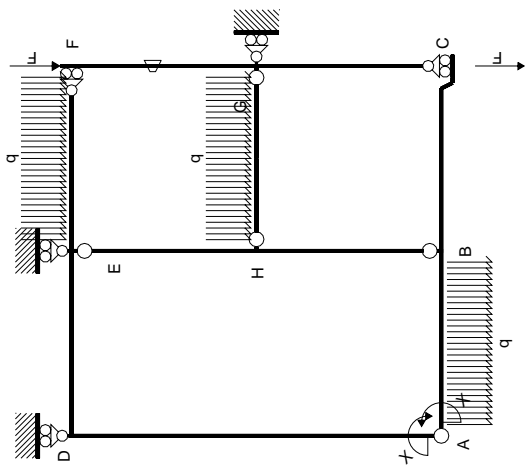


← ⊕ → F

↑ ⊕ ↓ F

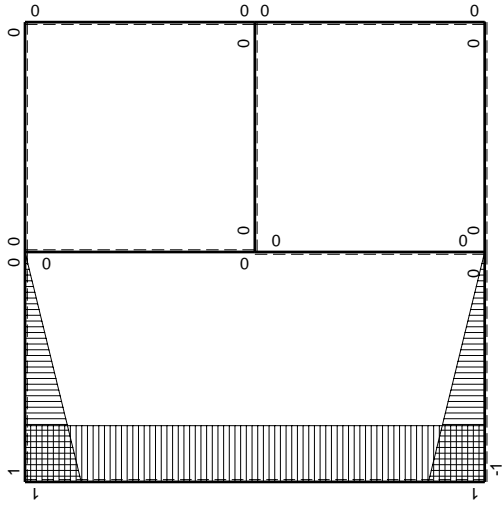


⊕ ⊖ F<sub>b</sub>



Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_1$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-2Fx-1/2qx^2$	0	$2Fx-3/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(3/8+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$5/2Fb-3Fx+1/2qx^2$	0	$5/2Fx-3Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-5/2Fb+5/2Fx$	0	0	0	0	0+0	0	
CB b	0	$5/2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	$-1/2Fx$	0	$-1/2Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-1/12+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fb-1/2Fx$	0	$-1/2Fx+1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
FE b	0	$1/2qx^2$	0	0	0	0			
FG b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
GF b	0	0	$Fb/EJ$	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
GH b	0	$-1/2Fx+1/2qx^2$	0	0	0	0			
HB b	0	0	0	0	0	0	0+0	0	
BH b	0	0	0	0	0	0			
HE b	0	0	0	0	0	0	0+0	0	
EH b	0	0	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (2x/b - 3/2 x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 1/2 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 1/2 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (5/2 x/b - 3x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 5/4 x^2/b - x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

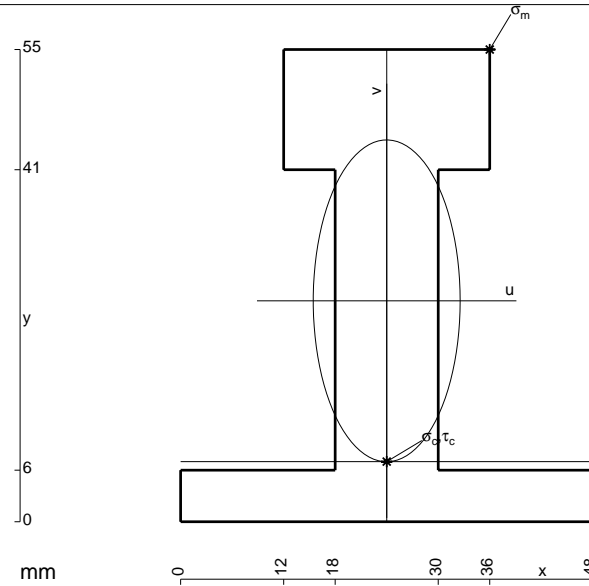
$$= (5/4 b - b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (-1/2 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/4 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/4 b + 1/6 b) \cdot Fb \cdot 1/EJ = -1/12 \cdot Fb^2/EJ$$

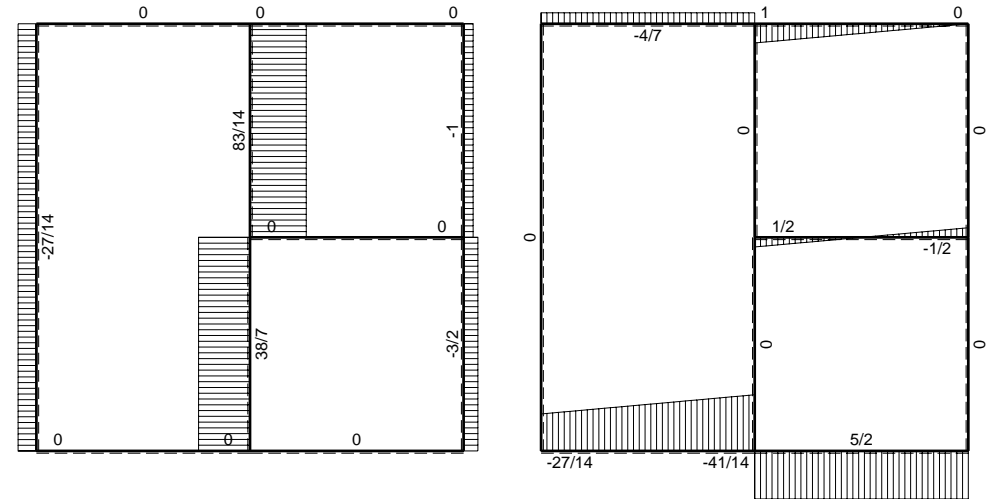
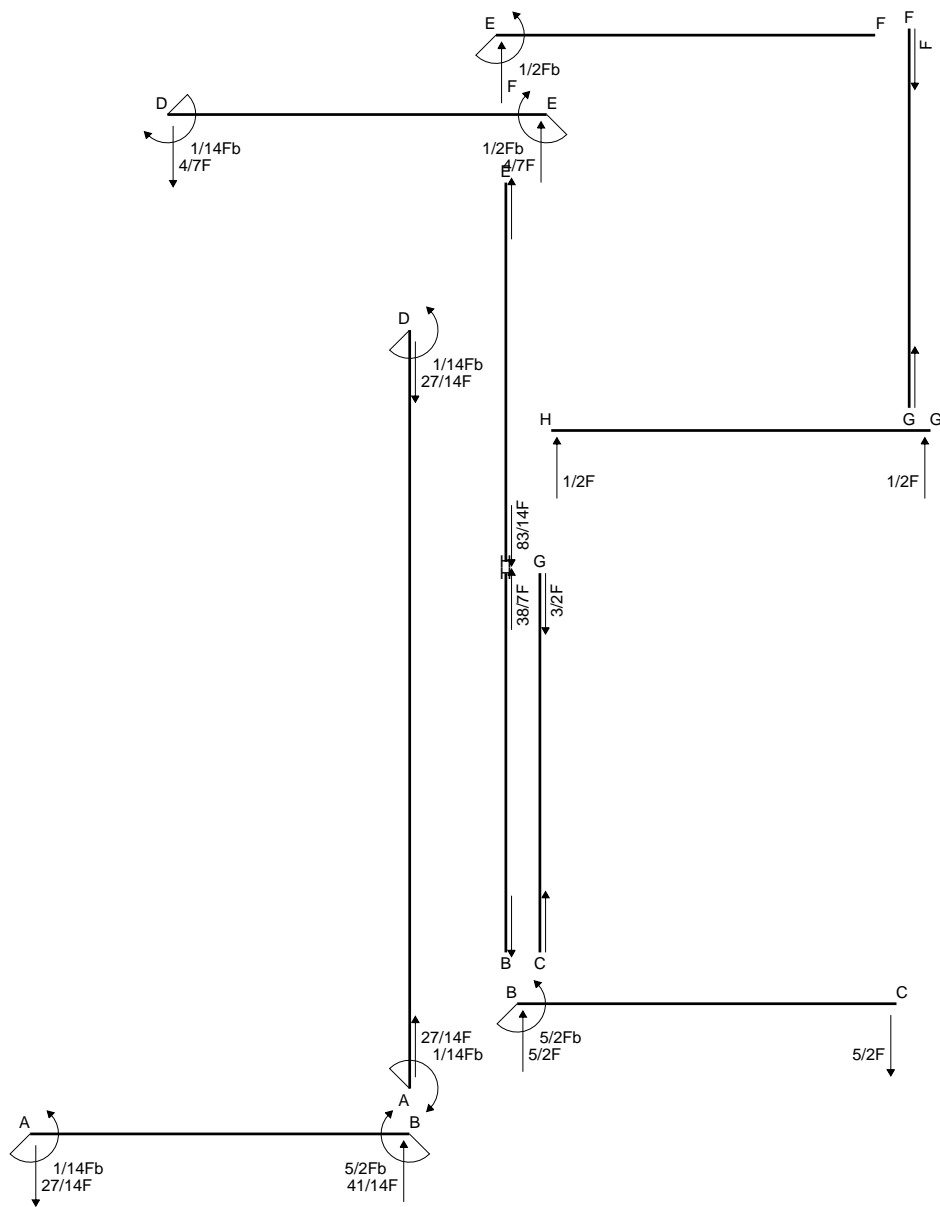
$$L_{ED}^{xo} = \int_0^b (-1/2 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/4 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/4 b + 1/6 b) \cdot Fb \cdot 1/EJ = -1/12 \cdot Fb^2/EJ$$



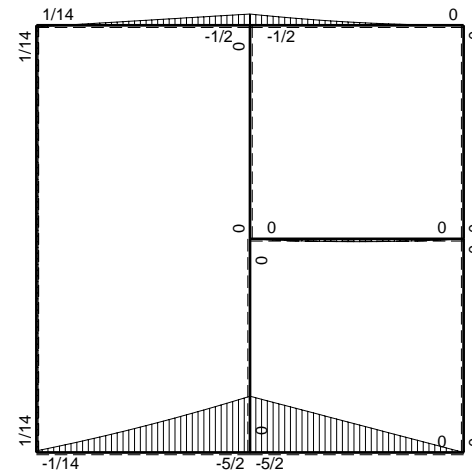
- A = 1044. mm<sup>2</sup>
- J<sub>u</sub> = 366752. mm<sup>4</sup>
- J<sub>v</sub> = 76464. mm<sup>4</sup>
- y<sub>g</sub> = 25.73 mm
- T<sub>y</sub> = 4275. N
- M<sub>x</sub> = -2992500. Nmm
- x<sub>m</sub> = 36. mm
- y<sub>m</sub> = 55. mm
- u<sub>m</sub> = 12. mm
- v<sub>m</sub> = 29.27 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 238.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 7. mm
- v<sub>c</sub> = -18.73 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -152.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 6.583 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 153.3 N/mm<sup>2</sup>
- S = 6777. mm<sup>3</sup>



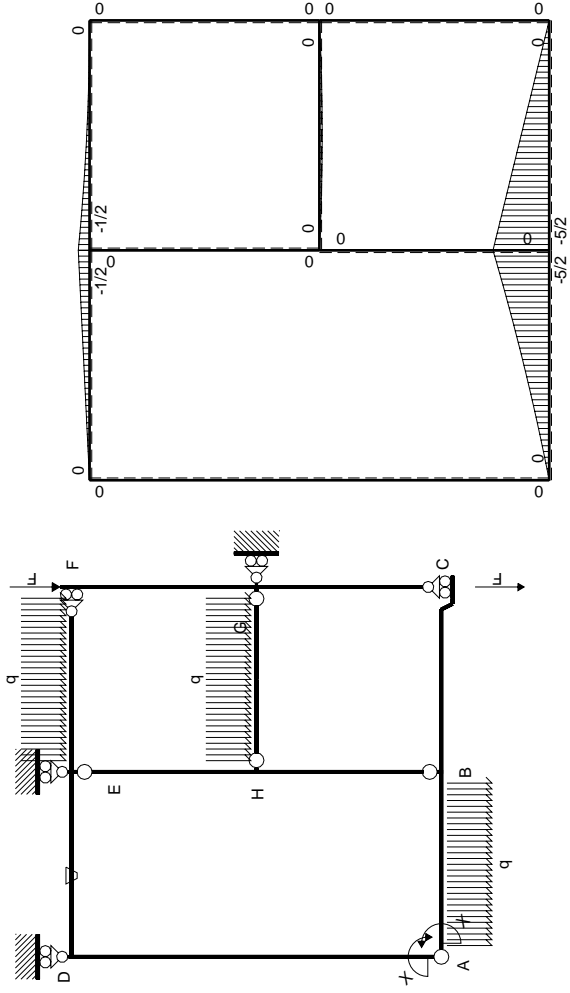


← ⊕ → F

↑ ⊕ ↓ F

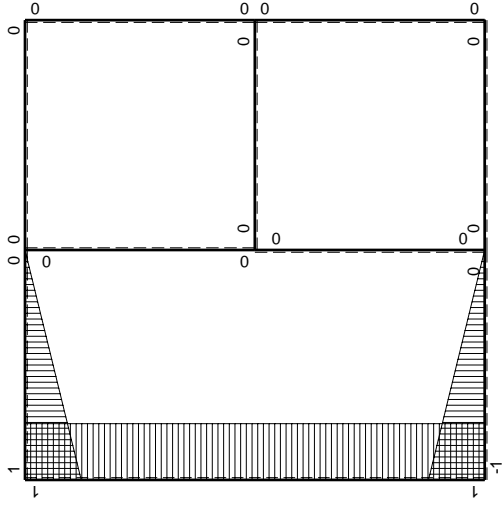


⊕ ⊖ F<sub>b</sub>



Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x / EJ dx$	
AB b	$-1+x/b$	$-2Fx-1/2qx^2$	0	$2Fx-3/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(3/8+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$5/2Fb-3Fx+1/2qx^2$	0	$5/2Fx-3Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-5/2Fb+5/2Fx$	0	0	0	0	0+0	0	
CB b	0	$5/2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	2Xb/EJ	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	$-1/2Fx$	$-Fb/EJ$	$-1/2Fx+1/2Fx^2/b$	$-Fb/EJ+Fx/EJ$	$1-2x/b+x^2/b^2$	$(-1/12-1/2)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fb-1/2Fx$	$Fb/EJ$	$-1/2Fx+1/2Fx^2/b$	$-Fx/EJ$	$x^2/b^2$			
EF b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
FE b	0	$1/2qx^2$	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
GH b	0	$-1/2Fx+1/2qx^2$	0	0	0	0			
HB b	0	0	0	0	0	0	0+0	0	
BH b	0	0	0	0	0	0			
HE b	0	0	0	0	0	0	0+0	0	
EH b	0	0	0	0	0	0			
AB	molla asta $-W_{1AB} (W_{0AB} + XW_{1AB}) / k_{AB}$								$1/4Xb/EJ$
	totali							$-5/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$1/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx + 1 \cdot \frac{1}{4} \frac{b}{EJ} = \left[ x - \frac{x^2}{b} + \frac{1}{3} \frac{x^3}{b^2} \right]_0^b \frac{1}{EJ} + \frac{1}{4} \frac{b}{EJ}$$

$$= (b - b + \frac{1}{3}b) \frac{1}{EJ} + \frac{1}{4} \frac{b}{EJ} = \frac{7}{12} \frac{b}{EJ}$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx + 1 \cdot \frac{1}{4} \frac{b}{EJ} = \left[ \frac{1}{3} \frac{x^3}{b^2} \right]_0^b \frac{1}{EJ} + \frac{1}{4} \frac{b}{EJ}$$

$$= (\frac{1}{3}b) \frac{1}{EJ} + \frac{1}{4} \frac{b}{EJ} = \frac{7}{12} \frac{b}{EJ}$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \frac{b}{EJ}$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \frac{b}{EJ}$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx = \left[ x - \frac{x^2}{b} + \frac{1}{3} \frac{x^3}{b^2} \right]_0^b \frac{1}{EJ}$$

$$= (b - b + \frac{1}{3}b) \frac{1}{EJ} = \frac{1}{3} \frac{b}{EJ}$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx = \left[ \frac{1}{3} \frac{x^3}{b^2} \right]_0^b \frac{1}{EJ}$$

$$= (\frac{1}{3}b) \frac{1}{EJ} = \frac{1}{3} \frac{b}{EJ}$$

$$L_{AB}^{xo} = \int_0^b (2x/b - \frac{3}{2} \frac{x^2}{b^2} - \frac{1}{2} \frac{x^3}{b^3}) Fb \frac{1}{EJ} dx + 1 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= \left[ \frac{x^2}{b} - \frac{1}{2} \frac{x^3}{b^2} - \frac{1}{8} \frac{x^4}{b^3} \right]_0^b Fb \frac{1}{EJ} + \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= (b - \frac{1}{2}b - \frac{1}{8}b) Fb \frac{1}{EJ} + \frac{1}{4} \frac{Fb^2}{EJ} = \frac{3}{8} \frac{Fb^2}{EJ}$$

$$L_{BA}^{xo} = \int_0^b (\frac{5}{2} \frac{x}{b} - 3 \frac{x^2}{b^2} + \frac{1}{2} \frac{x^3}{b^3}) Fb \frac{1}{EJ} dx + 1 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= \left[ \frac{5}{4} \frac{x^2}{b} - \frac{x^3}{b^2} + \frac{1}{8} \frac{x^4}{b^3} \right]_0^b Fb \frac{1}{EJ} + \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= (\frac{5}{4}b - b + \frac{1}{8}b) Fb \frac{1}{EJ} + \frac{1}{4} \frac{Fb^2}{EJ} = \frac{3}{8} \frac{Fb^2}{EJ}$$

$$L_{DE}^{xo} = \int_0^b (-\frac{1}{2} \frac{x}{b} + \frac{1}{2} \frac{x^2}{b^2}) Fb \frac{1}{EJ} dx + \int_0^b (-1 + x/b) \theta dx$$

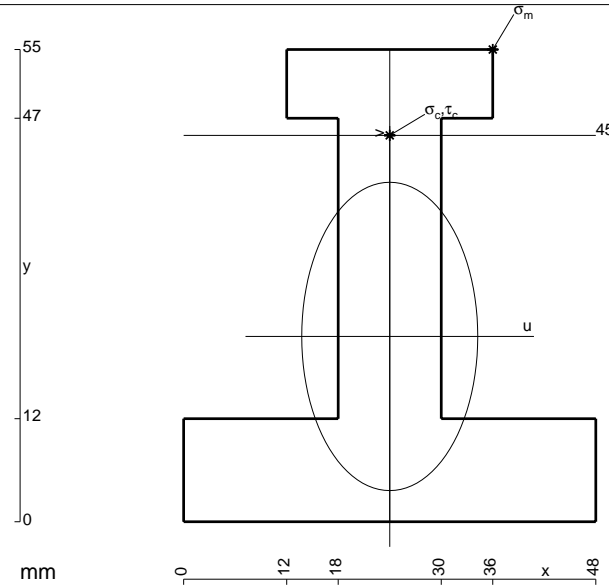
$$= \left[ -\frac{1}{4} \frac{x^2}{b} + \frac{1}{6} \frac{x^3}{b^2} \right]_0^b Fb \frac{1}{EJ} + \left[ -x + \frac{1}{2} \frac{x^2}{b} \right]_0^b \theta$$

$$= (-\frac{1}{4}b + \frac{1}{6}b) Fb \frac{1}{EJ} + (-b + \frac{1}{2}b) \theta = -\frac{7}{12} \frac{Fb^2}{EJ}$$

$$L_{ED}^{xo} = \int_0^b (-\frac{1}{2} \frac{x}{b} + \frac{1}{2} \frac{x^2}{b^2}) Fb \frac{1}{EJ} dx + \int_0^b (x/b) \theta dx$$

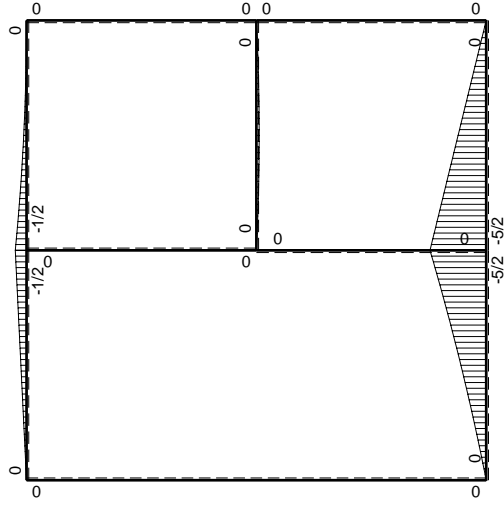
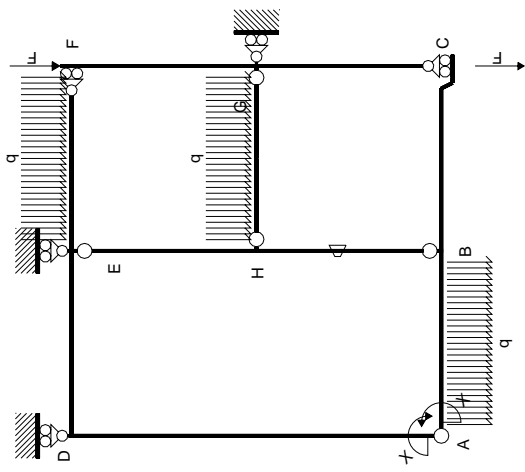
$$= \left[ -\frac{1}{4} \frac{x^2}{b} + \frac{1}{6} \frac{x^3}{b^2} \right]_0^b Fb \frac{1}{EJ} + \left[ \frac{1}{2} \frac{x^2}{b} \right]_0^b \theta$$

$$= (-\frac{1}{4}b + \frac{1}{6}b) Fb \frac{1}{EJ} + (\frac{1}{2}b) \theta = -\frac{7}{12} \frac{Fb^2}{EJ}$$

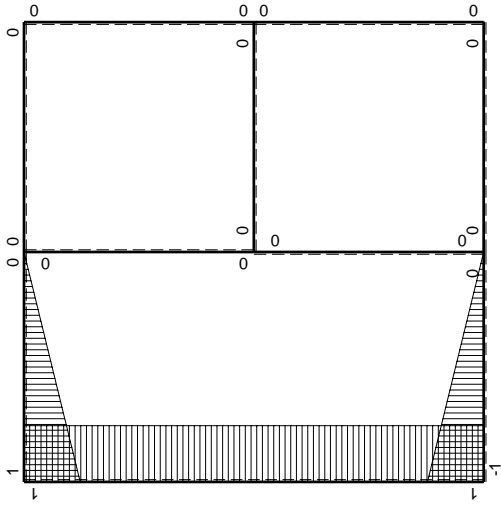


- A = 1188. mm<sup>2</sup>
- J<sub>u</sub> = 383155. mm<sup>4</sup>
- J<sub>v</sub> = 124848. mm<sup>4</sup>
- y<sub>g</sub> = 21.58 mm
- T<sub>y</sub> = 3050. N
- M<sub>x</sub> = -2287500. Nmm
- x<sub>m</sub> = 36. mm
- y<sub>m</sub> = 55. mm
- u<sub>m</sub> = 12. mm
- v<sub>m</sub> = 33.42 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 199.5 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 45. mm
- v<sub>c</sub> = 23.42 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 139.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.136 N/mm<sup>2</sup>
- σ<sub>ρ</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 140. N/mm<sup>2</sup>
- S = 6235. mm<sup>3</sup>





Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati

$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-2Fx-1/2qx^2$	0	$2Fx-3/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(3/8+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$5/2Fb-3Fx+1/2qx^2$	0	$5/2Fx-3Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-5/2Fb+5/2Fx$	0	0	0	0	0+0	0	
CB b	0	$5/2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	$-1/2Fx$	0	$-1/2Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-1/12+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fb-1/2Fx$	0	$-1/2Fx+1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
FE b	0	$1/2qx^2$	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
GH b	0	$-1/2Fx+1/2qx^2$	0	0	0	0			
HB b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
BH b	0	0	$Fb/EJ$	0	0	0			
HE b	0	0	0	0	0	0	0+0	0	
EH b	0	0	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (2x/b - 3/2 x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 1/2 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 1/2 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (5/2 x/b - 3 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 5/4 x^2/b - x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

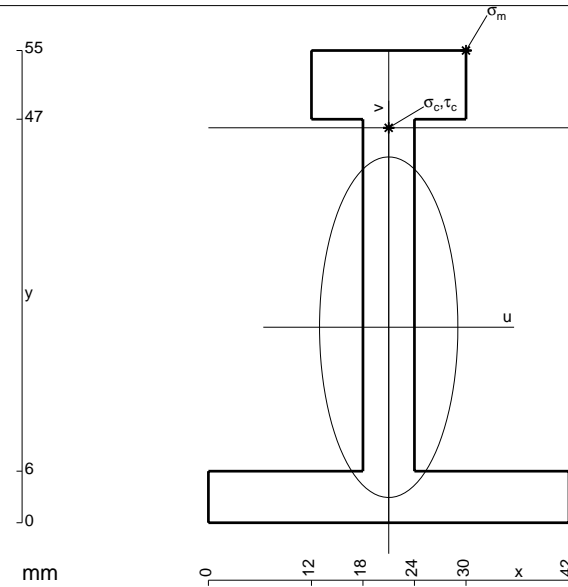
$$= (5/4 b - b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (-1/2 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/4 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/4 b + 1/6 b) \cdot Fb \cdot 1/EJ = -1/12 \cdot Fb^2/EJ$$

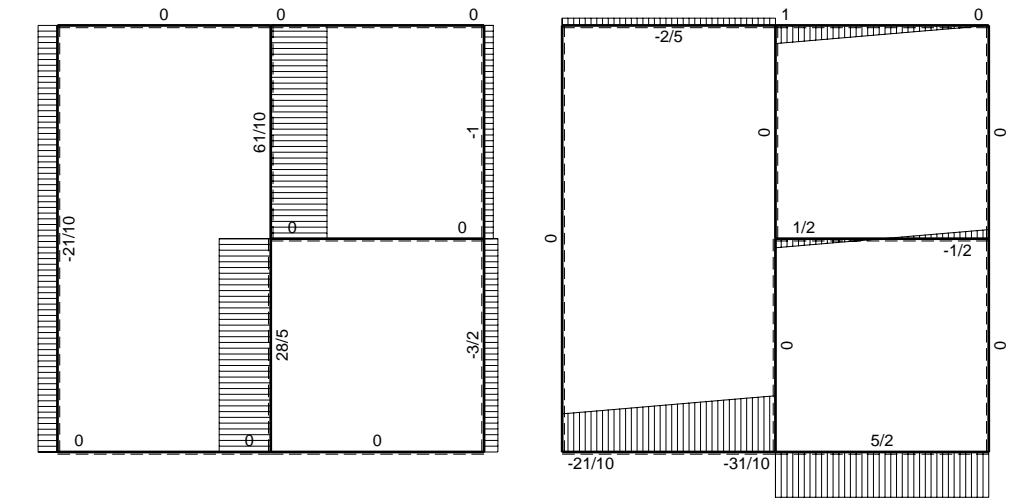
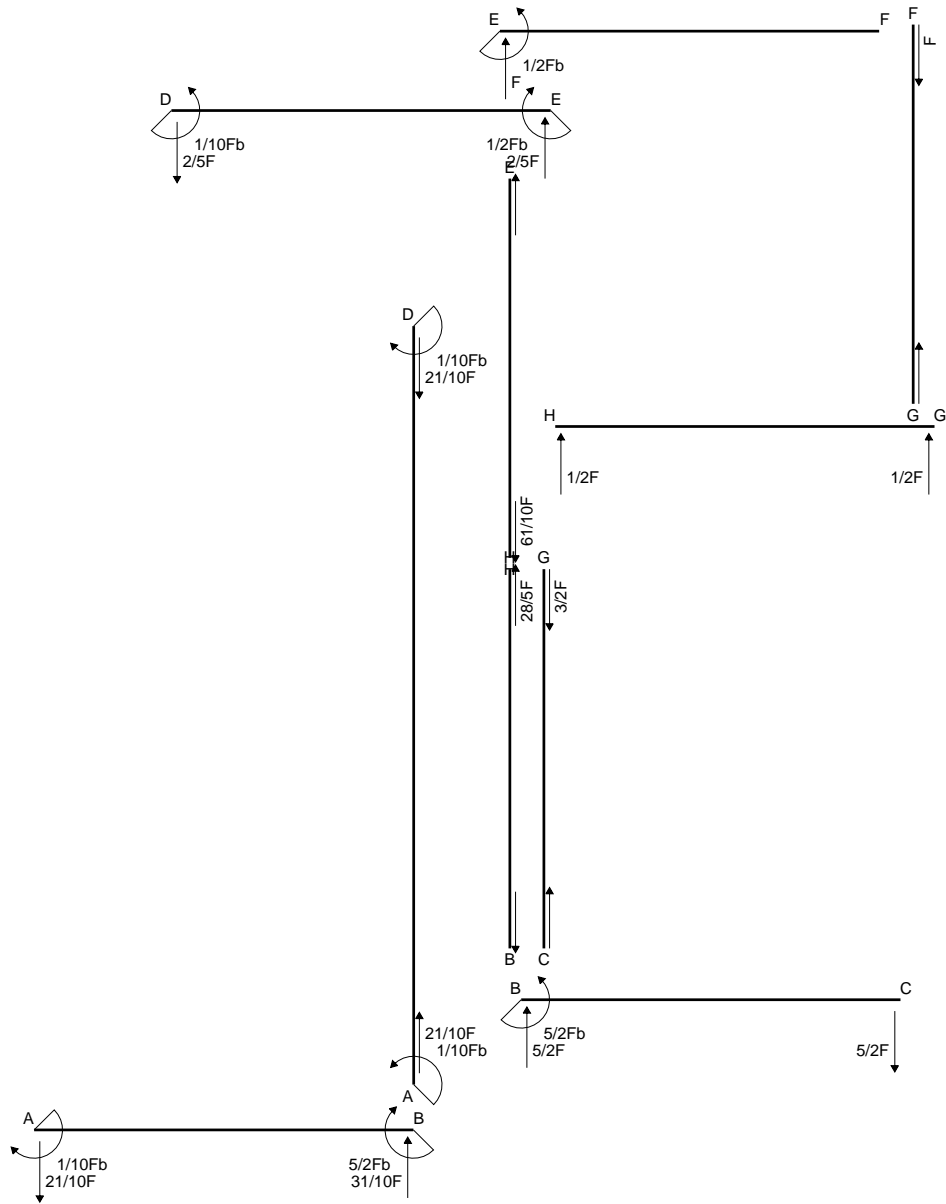
$$L_{ED}^{xo} = \int_0^b (-1/2 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/4 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/4 b + 1/6 b) \cdot Fb \cdot 1/EJ = -1/12 \cdot Fb^2/EJ$$



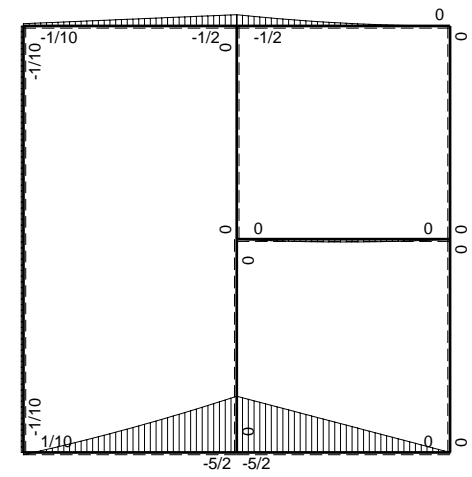
- A = 642. mm<sup>2</sup>
- J<sub>u</sub> = 252660. mm<sup>4</sup>
- J<sub>v</sub> = 41670. mm<sup>4</sup>
- y<sub>g</sub> = 22.77 mm
- T<sub>y</sub> = 2050. N
- M<sub>x</sub> = -1640000. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 55. mm
- u<sub>m</sub> = 9. mm
- v<sub>m</sub> = 32.23 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 209.2 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 46. mm
- v<sub>c</sub> = 23.23 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 150.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.689 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 151.1 N/mm<sup>2</sup>
- S = 4207. mm<sup>3</sup>



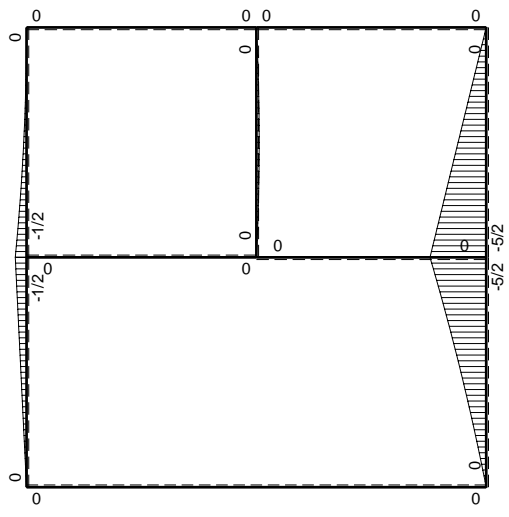
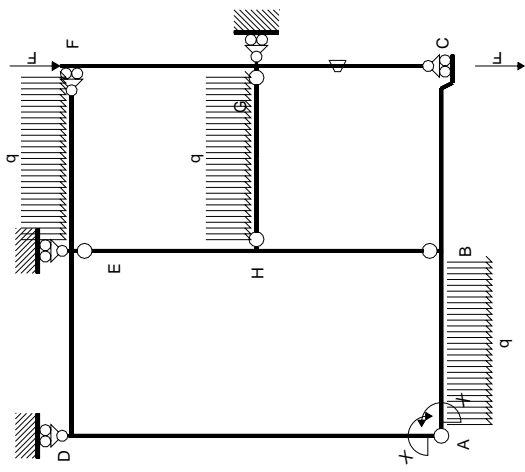


← ⊕ → F

↑ ⊕ ↓ F

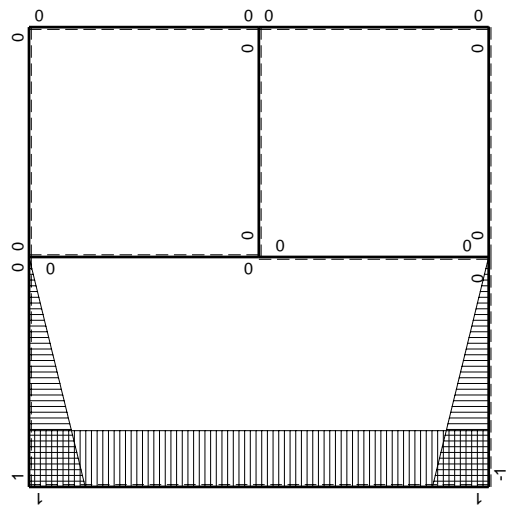


⊕ ⊖ Fb



Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_1$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-2Fx-1/2qx^2$	0	$2Fx-3/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(3/8+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$5/2Fb-3Fx+1/2qx^2$	0	$5/2Fx-3Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-5/2Fb+5/2Fx$	0	0	0	0	0+0	0	
CB b	0	$5/2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	$-1/2Fx$	0	$-1/2Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-1/12+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fb-1/2Fx$	0	$-1/2Fx+1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
FE b	0	$1/2qx^2$	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
CG b	0	0	$Fb/EJ$	0	0	0			
HG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
GH b	0	$-1/2Fx+1/2qx^2$	0	0	0	0			
HB b	0	0	0	0	0	0	0+0	0	
BH b	0	0	0	0	0	0			
HE b	0	0	0	0	0	0	0+0	0	
EH b	0	0	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (-2x/b + x^2/b^2) 1/EJ dx + 1 \cdot 1/4 b/EJ = \left[ -x^2/b + 1/3 x^3/b^2 \right]_0^b 1/EJ + 1 \cdot 1/4 b/EJ$$

$$= (b - b + 1/3 b) 1/EJ + 1 \cdot 1/4 b/EJ = 7/12 b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx + 1 \cdot 1/4 b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b 1/EJ + 1 \cdot 1/4 b/EJ$$

$$= (1/3 b) 1/EJ + 1 \cdot 1/4 b/EJ = 7/12 b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) 1/EJ dx = \left[ x \right]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) 1/EJ dx = \left[ x \right]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{DE}^{xx} = \int_0^b (-2x/b + x^2/b^2) 1/EJ dx = \left[ -x^2/b + 1/3 x^3/b^2 \right]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = \left[ 1/3 x^3/b^2 \right]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{AB}^{xo} = \int_0^b (2x/b - 3/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx + 1 \cdot 0 1/4 Fb^2/EJ$$

$$= \left[ x^2/b - 1/2 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b Fb 1/EJ + 1 \cdot 0 1/4 Fb^2/EJ$$

$$= (b - 1/2 b - 1/8 b) Fb 1/EJ + 1 \cdot 0 1/4 Fb^2/EJ = 3/8 Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (5/2 x/b - 3 x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + 1 \cdot 0 1/4 Fb^2/EJ$$

$$= \left[ 5/4 x^2/b - x^3/b^2 + 1/8 x^4/b^3 \right]_0^b Fb 1/EJ + 1 \cdot 0 1/4 Fb^2/EJ$$

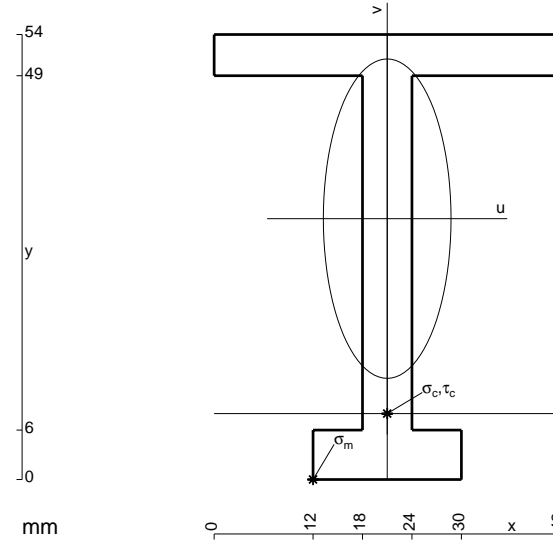
$$= (5/4 b - b + 1/8 b) Fb 1/EJ + 1 \cdot 0 1/4 Fb^2/EJ = 3/8 Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (-1/2 x/b + 1/2 x^2/b^2) Fb 1/EJ dx = \left[ -1/4 x^2/b + 1/6 x^3/b^2 \right]_0^b Fb 1/EJ$$

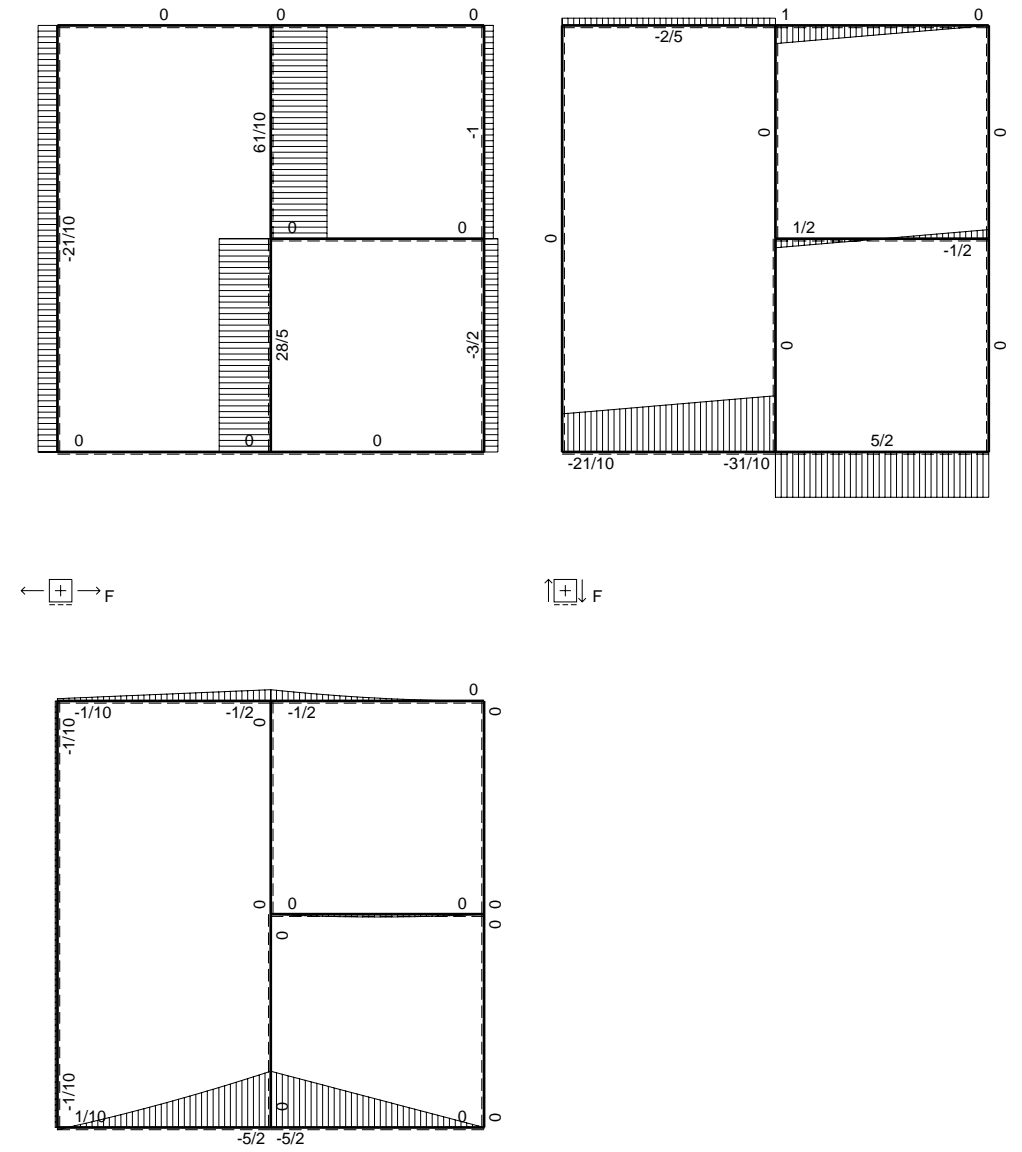
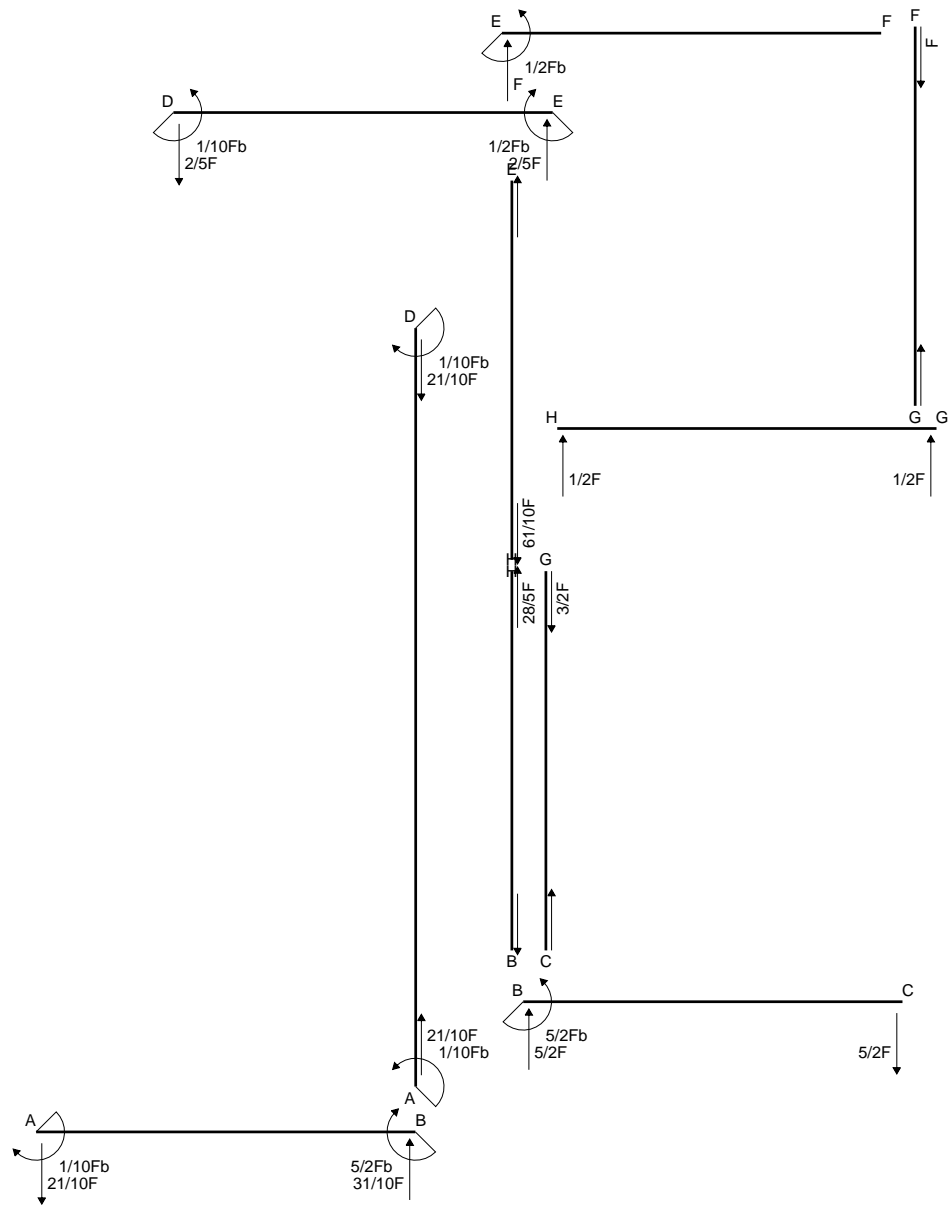
$$= (-1/4 b + 1/6 b) Fb 1/EJ = -1/12 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (-1/2 x/b + 1/2 x^2/b^2) Fb 1/EJ dx = \left[ -1/4 x^2/b + 1/6 x^3/b^2 \right]_0^b Fb 1/EJ$$

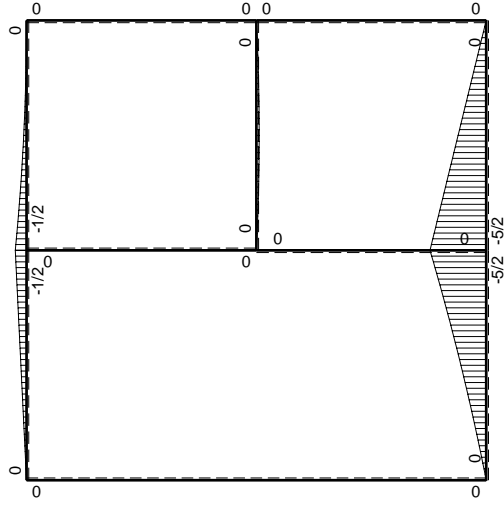
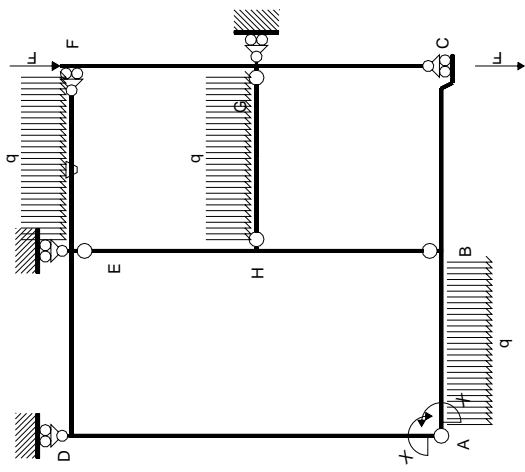
$$= (-1/4 b + 1/6 b) Fb 1/EJ = -1/12 Fb^2/EJ$$



- A = 576. mm<sup>2</sup>
- J<sub>u</sub> = 216352. mm<sup>4</sup>
- J<sub>v</sub> = 34560. mm<sup>4</sup>
- y<sub>g</sub> = 31.66 mm
- T<sub>y</sub> = 1800. N
- M<sub>x</sub> = -1494000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -9. mm
- v<sub>m</sub> = -31.66 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -218.6 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 8. mm
- v<sub>c</sub> = -23.66 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -163.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.702 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 163.6 N/mm<sup>2</sup>
- S = 3391. mm<sup>3</sup>

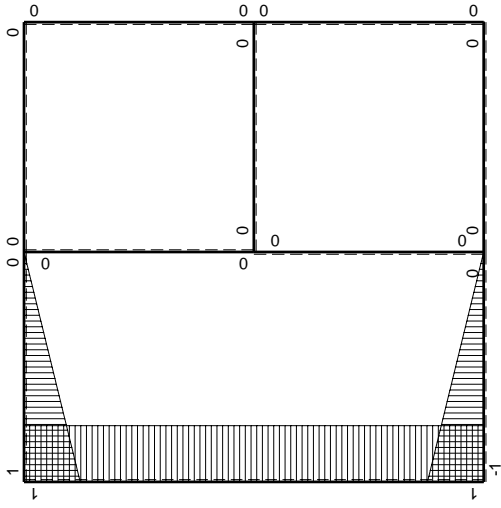


$\left[ \begin{matrix} + \\ - \end{matrix} \right] F_b$



Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_X$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x / EJ dx$	
AB b	$-1+x/b$	$-2Fx-1/2qx^2$	0	$2Fx-3/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(3/8+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$5/2Fb-3Fx+1/2qx^2$	0	$5/2Fx-3Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-5/2Fb+5/2Fx$	0	0	0	0	0+0	0	
CB b	0	$5/2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	$-1/2Fx$	0	$-1/2Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-1/12+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fb-1/2Fx$	0	$-1/2Fx+1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	$-1/2Fb+Fx-1/2qx^2$	$-Fb/EJ$	0	0	0	0+0	0	
FE b	0	$1/2qx^2$	$Fb/EJ$	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
GH b	0	$-1/2Fx+1/2qx^2$	0	0	0	0			
HB b	0	0	0	0	0	0	0+0	0	
BH b	0	0	0	0	0	0			
HE b	0	0	0	0	0	0	0+0	0	
EH b	0	0	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (-2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ -x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (-2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ -x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (2x/b - 3/2 x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 1/2 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 1/2 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (5/2 x/b - 3 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 5/4 x^2/b - x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

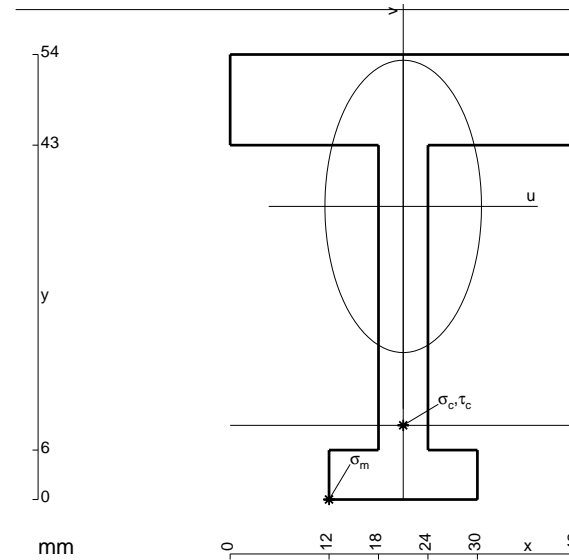
$$= (5/4 b - b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (-1/2 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/4 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/4 b + 1/6 b) \cdot Fb \cdot 1/EJ = -1/12 \cdot Fb^2/EJ$$

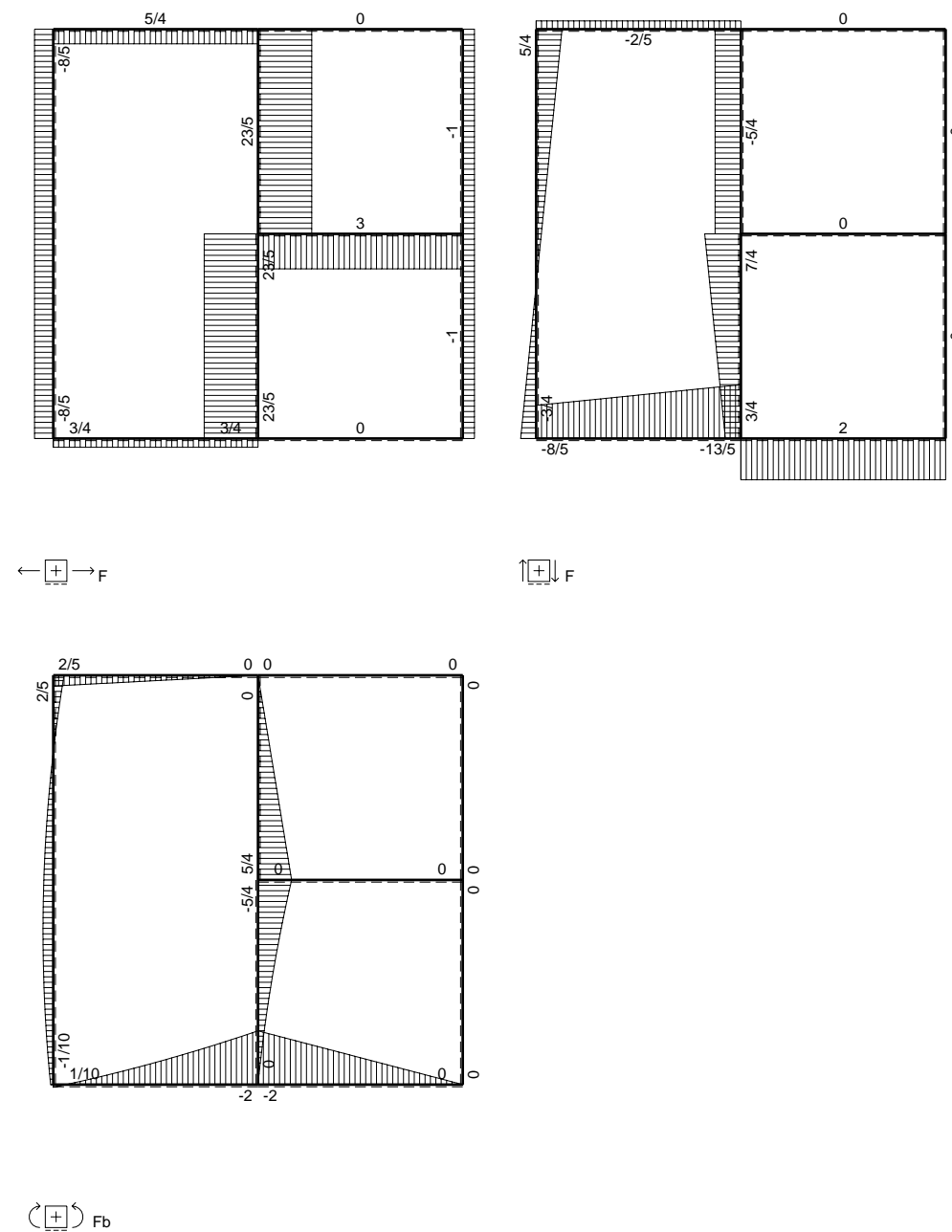
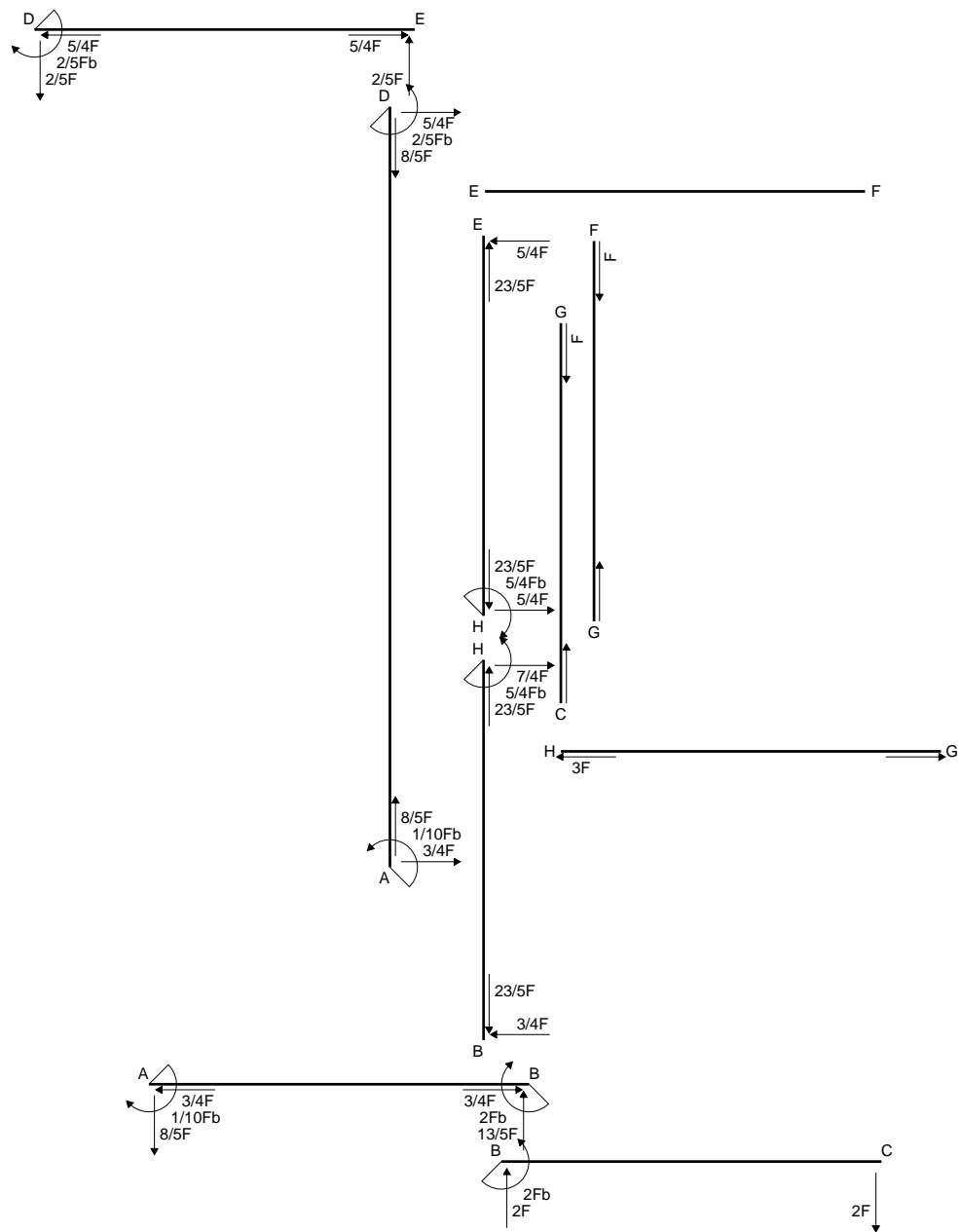
$$L_{ED}^{xo} = \int_0^b (-1/2 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/4 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

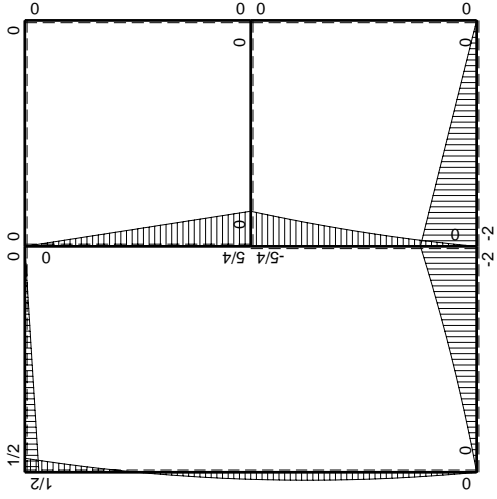
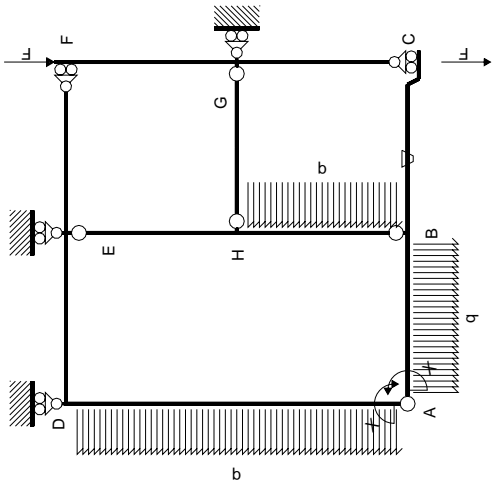
$$= (-1/4 b + 1/6 b) \cdot Fb \cdot 1/EJ = -1/12 \cdot Fb^2/EJ$$



- A = 792. mm<sup>2</sup>
- J<sub>u</sub> = 249320. mm<sup>4</sup>
- J<sub>v</sub> = 71496. mm<sup>4</sup>
- y<sub>g</sub> = 35.57 mm
- T<sub>y</sub> = 1825. N
- M<sub>x</sub> = -1606000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -9. mm
- v<sub>m</sub> = -35.57 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -229.1 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 9. mm
- v<sub>c</sub> = -26.57 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -171.1 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.907 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 171.4 N/mm<sup>2</sup>
- S = 4023. mm<sup>3</sup>

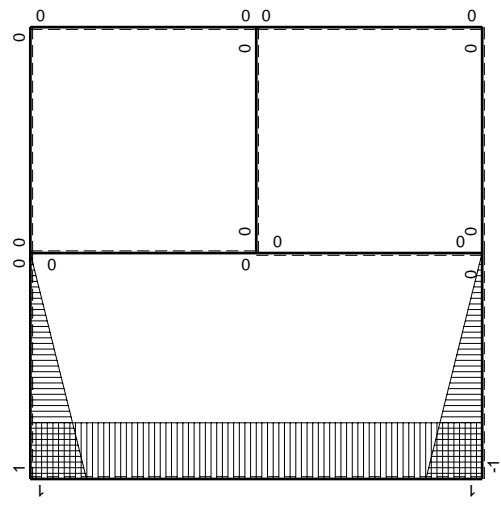






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJdx$
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-2Fb+2Fx$	$-Fb/EJ$	0	0	0	0+0	0
CB b	0	$2Fx$	$Fb/EJ$	0	0	0		
AD 2b	1	$-3/4Fx+1/2qx^2$	0	$-3/4Fx+1/2Fx^2/b$	0	1	$(-1/6+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$-1/2Fb+5/4Fx-1/2qx^2$	0	$1/2Fb-5/4Fx+1/2Fx^2/b$	0	1		
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$		
EF b	0	0	0	0	0	0	0+0	0
FE b	0	0	0	0	0	0		
FG b	0	0	0	0	0	0	0+0	0
GF b	0	0	0	0	0	0		
GC b	0	0	0	0	0	0	0+0	0
CG b	0	0	0	0	0	0		
HG b	0	0	0	0	0	0	0+0	0
GH b	0	0	0	0	0	0		
HB b	0	$-5/4Fb+7/4Fx-1/2qx^2$	0	0	0	0	0+0	0
BH b	0	$3/4Fx+1/2qx^2$	0	0	0	0		
HE b	0	$5/4Fb-5/4Fx$	0	0	0	0	0+0	0
EH b	0	$-5/4Fx$	0	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{x_0} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{x_0} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{x_0} = \int_0^{2b} (-3/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-3/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DA}^{x_0} = \int_0^{2b} (1/2 - 5/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

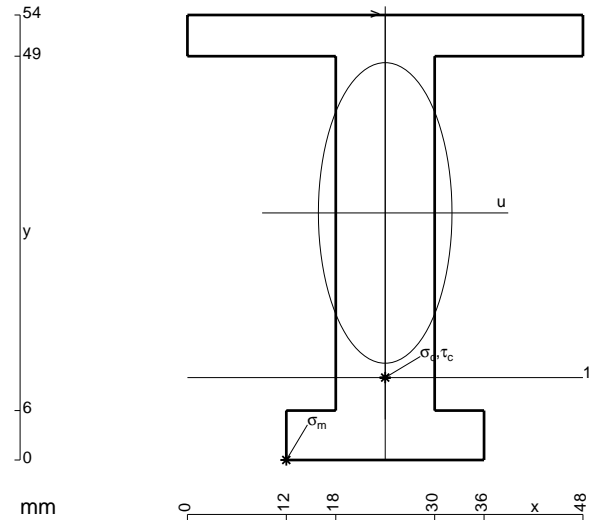
$$= (b - 5/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DE}^{x_0} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

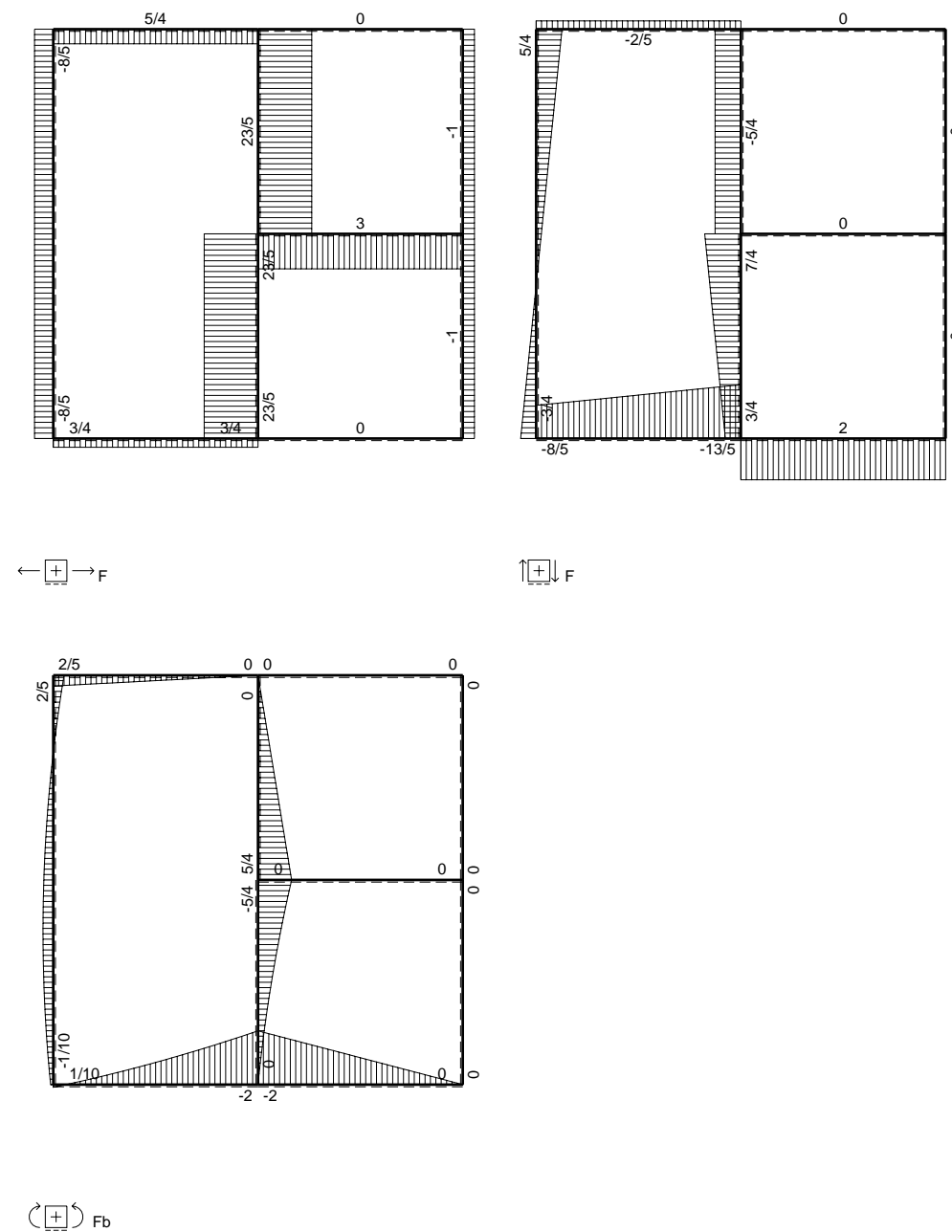
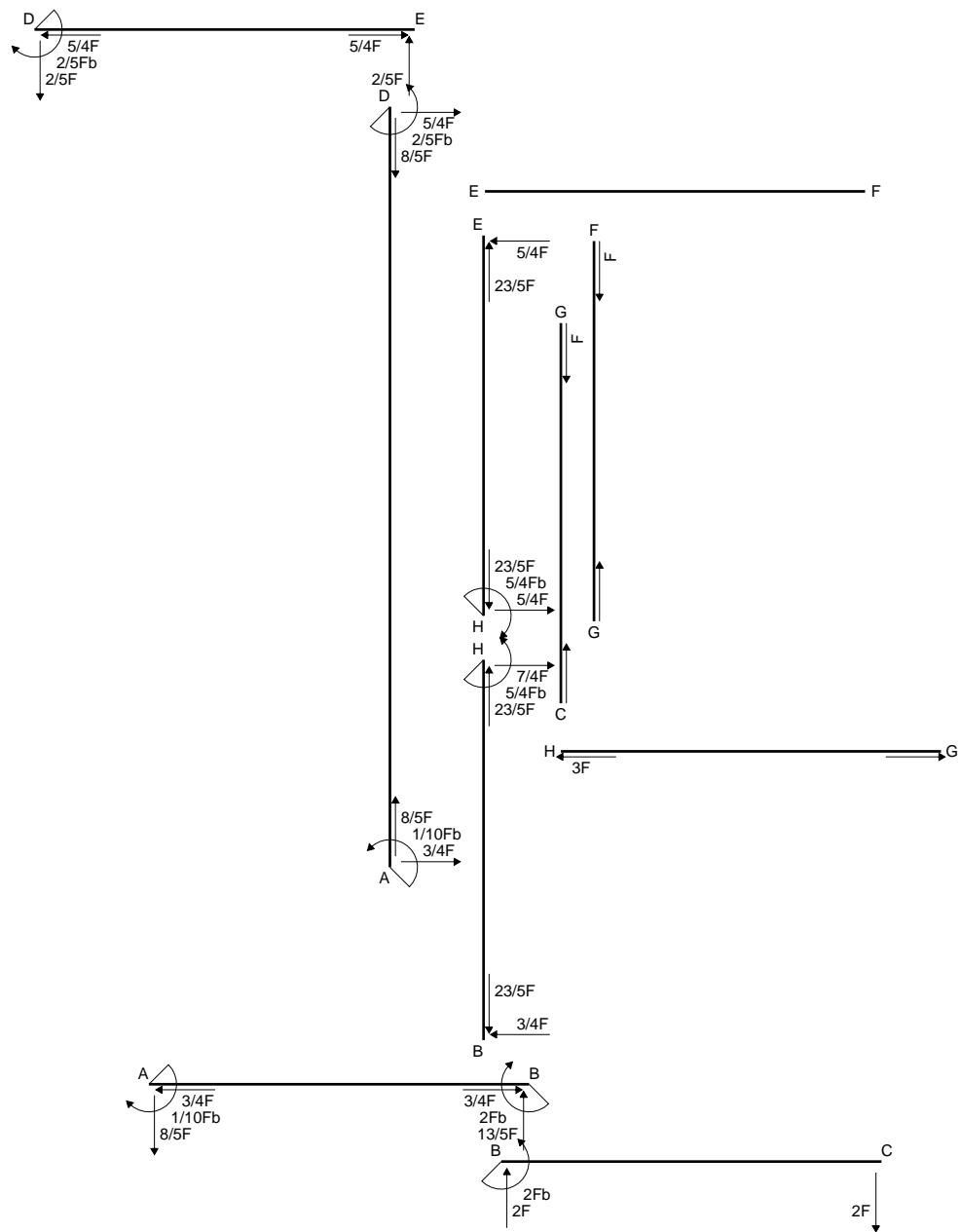
$$= (1/2 b - 1/2 b + 1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$

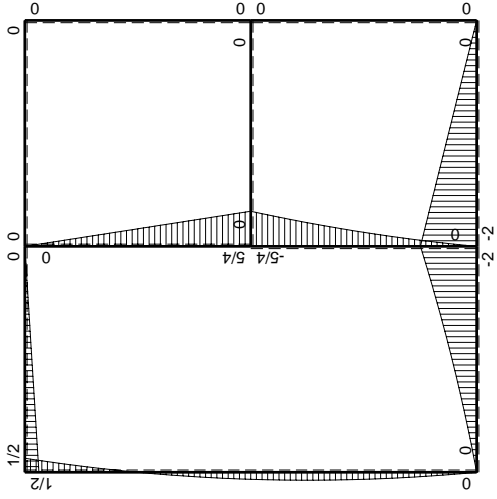
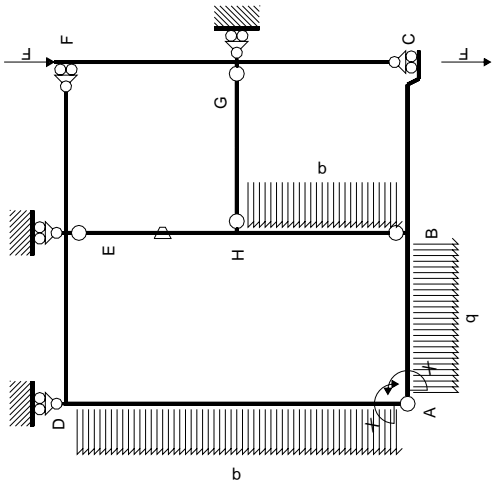
$$L_{ED}^{x_0} = \int_0^b (1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$



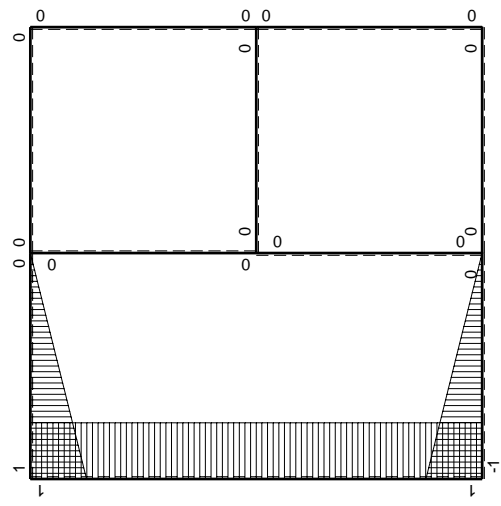
- A = 900. mm<sup>2</sup>
- J<sub>u</sub> = 299580. mm<sup>4</sup>
- J<sub>v</sub> = 59184. mm<sup>4</sup>
- y<sub>g</sub> = 29.98 mm
- T<sub>y</sub> = 2560. N
- M<sub>x</sub> = -2380800. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -12. mm
- v<sub>m</sub> = -29.98 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -238.3 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 10. mm
- v<sub>c</sub> = -19.98 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -158.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.518 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 158.9 N/mm<sup>2</sup>
- S = 4940. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0
CB b	0	$2Fx$	0	0	0	0		
AD 2b	1	$-3/4Fx+1/2qx^2$	0	$-3/4Fx+1/2Fx^2/b$	0	1	$(-1/6+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$-1/2Fb+5/4Fx-1/2qx^2$	0	$1/2Fb-5/4Fx+1/2Fx^2/b$	0	1		
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$		
EF b	0	0	0	0	0	0	0+0	0
FE b	0	0	0	0	0	0		
FG b	0	0	0	0	0	0	0+0	0
GF b	0	0	0	0	0	0		
GC b	0	0	0	0	0	0	0+0	0
CG b	0	0	0	0	0	0		
HG b	0	0	0	0	0	0	0+0	0
GH b	0	0	0	0	0	0		
HB b	0	$-5/4Fb+7/4Fx-1/2qx^2$	0	0	0	0	0+0	0
BH b	0	$3/4Fx+1/2qx^2$	0	0	0	0		
HE b	0	$5/4Fb-5/4Fx$	$-Fb/EJ$	0	0	0	0+0	0
EH b	0	$-5/4Fx$	$Fb/EJ$	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{x_0} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{x_0} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{x_0} = \int_0^{2b} (-3/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-3/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DA}^{x_0} = \int_0^{2b} (1/2 - 5/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

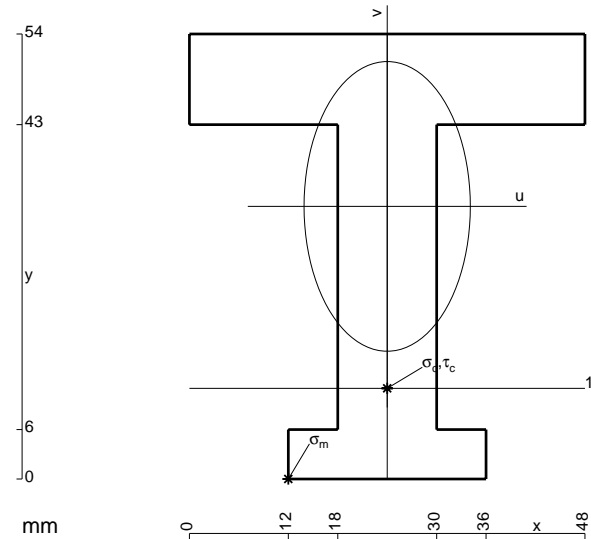
$$= (b - 5/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DE}^{x_0} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/2 b - 1/2 b + 1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$

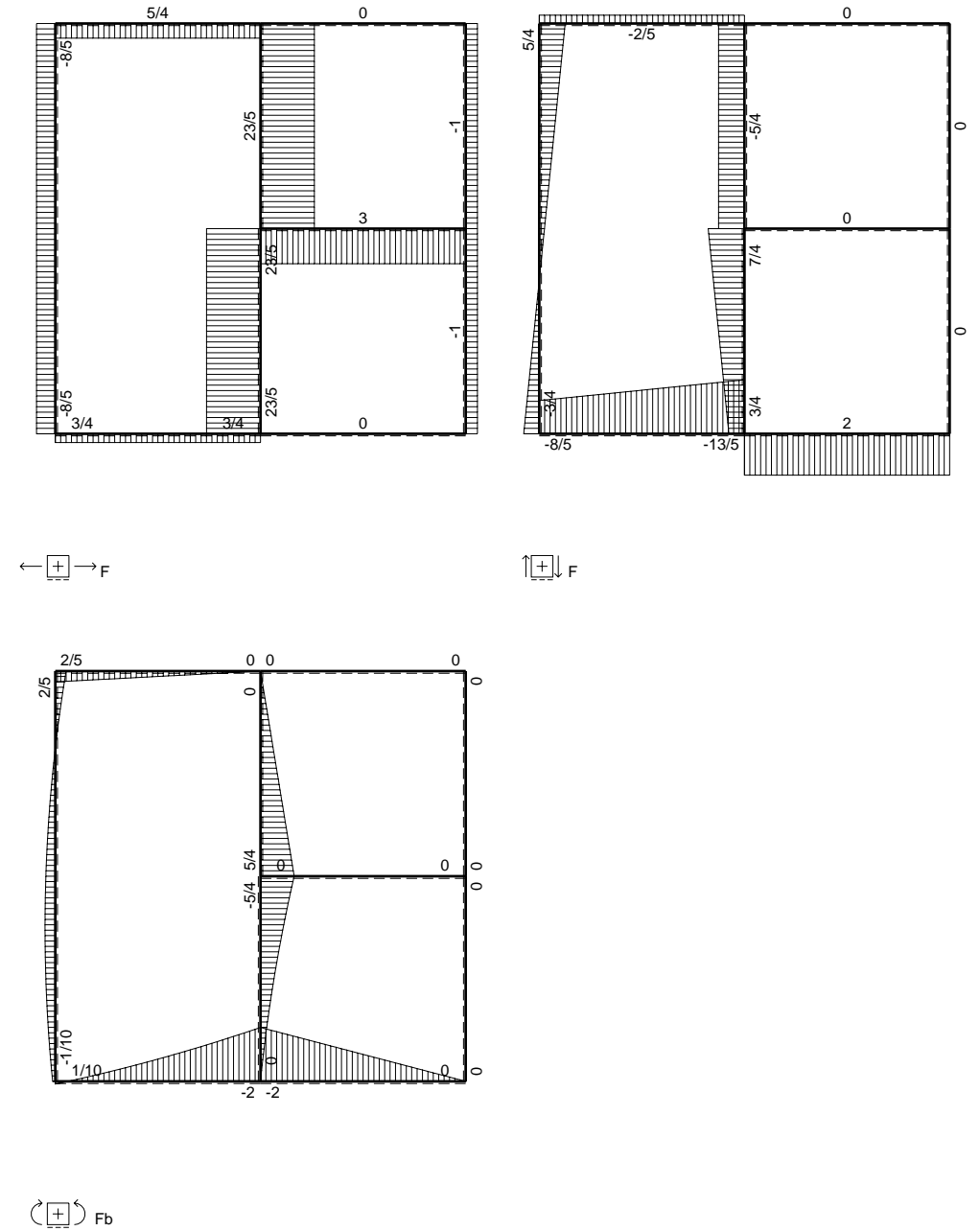
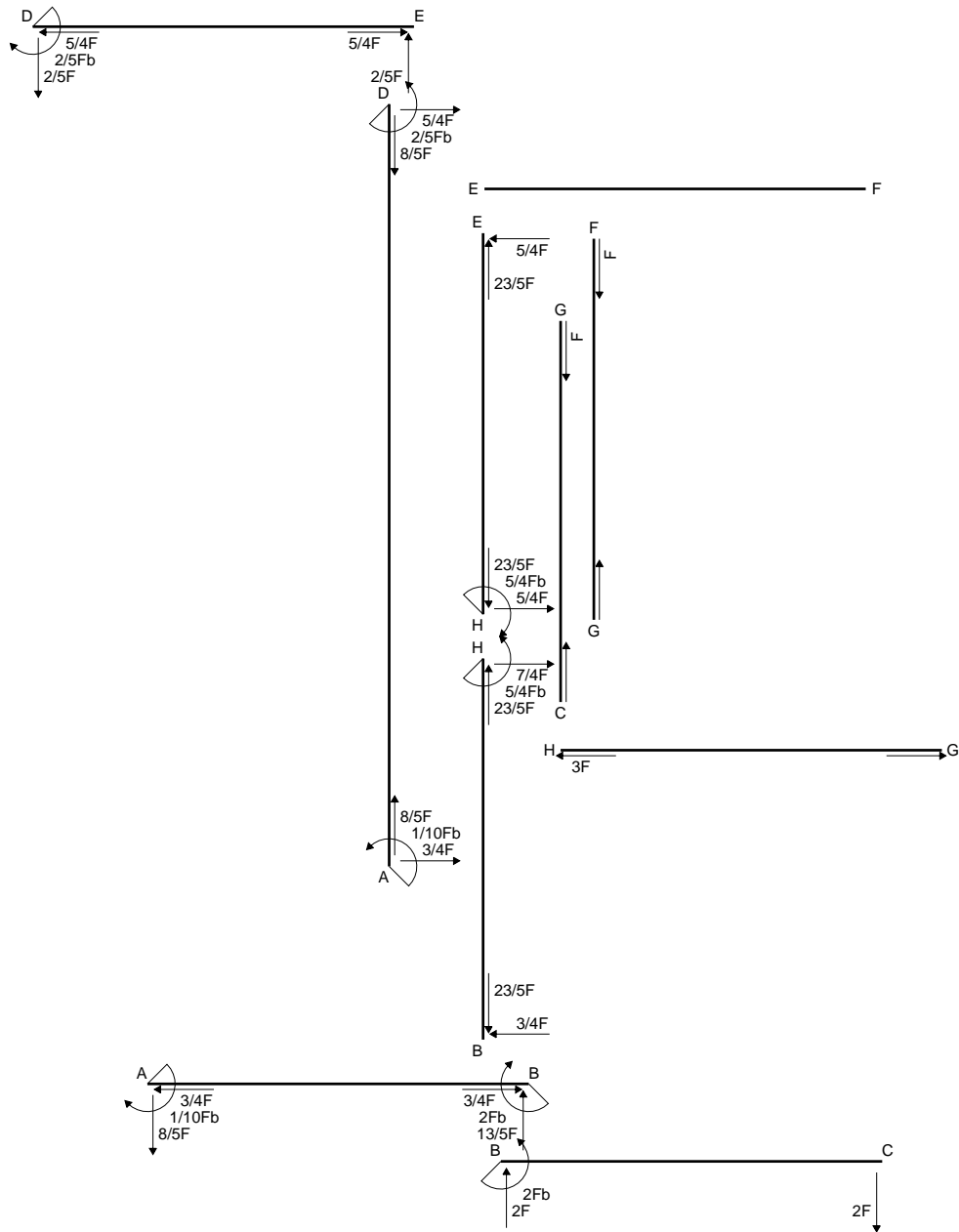
$$L_{ED}^{x_0} = \int_0^b (1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

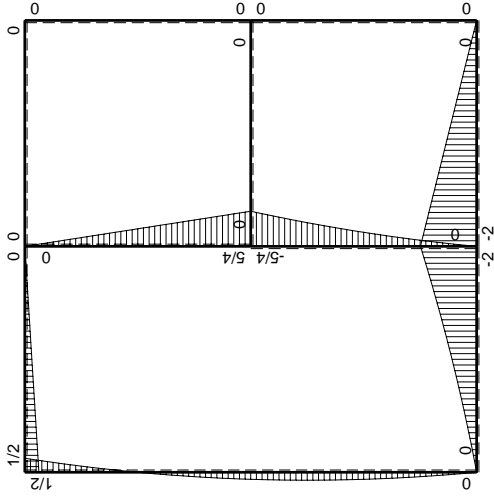
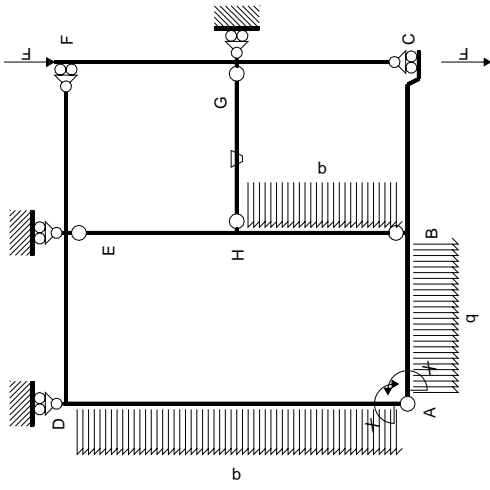
$$= (1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$



$A = 1116. \text{ mm}^2$   
 $J_u = 344933. \text{ mm}^4$   
 $J_v = 113616. \text{ mm}^4$   
 $y_g = 33.08 \text{ mm}$   
 $T_y = 4240. \text{ N}$   
 $M_x = -2077600. \text{ Nmm}$   
 $x_m = 12. \text{ mm}$   
 $u_m = -12. \text{ mm}$   
 $v_m = -33.08 \text{ mm}$   
 $\sigma_m = -Mv/J_u = -199.3 \text{ N/mm}^2$   
 $x_c = 24. \text{ mm}$   
 $y_c = 11. \text{ mm}$   
 $v_c = -22.08 \text{ mm}$   
 $\sigma_c = -Mv/J_u = -133. \text{ N/mm}^2$   
 $\tau_c = 5.948 \text{ N/mm}^2$   
 $\sigma_v = \sqrt{\sigma^2 + 3\tau^2} = 133.4 \text{ N/mm}^2$   
 $S = 5806. \text{ mm}^3$

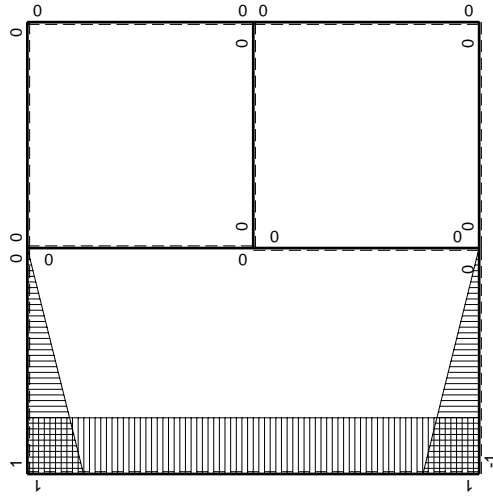






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJdx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$-3/4Fx+1/2qx^2$	0	$-3/4Fx+1/2Fx^2/b$	0	1	$(-1/6+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+5/4Fx-1/2qx^2$	0	$1/2Fb-5/4Fx+1/2Fx^2/b$	0	1			
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
GH b	0	0	$Fb/EJ$	0	0	0			
HB b	0	$-5/4Fb+7/4Fx-1/2qx^2$	0	0	0	0	0+0	0	
BH b	0	$3/4Fx+1/2qx^2$	0	0	0	0			
HE b	0	$5/4Fb-5/4Fx$	0	0	0	0	0+0	0	
EH b	0	$-5/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{x_0} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{x_0} = \int_0^b (2 x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{x_0} = \int_0^{2b} (-3/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-3/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DA}^{x_0} = \int_0^{2b} (1/2 - 5/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

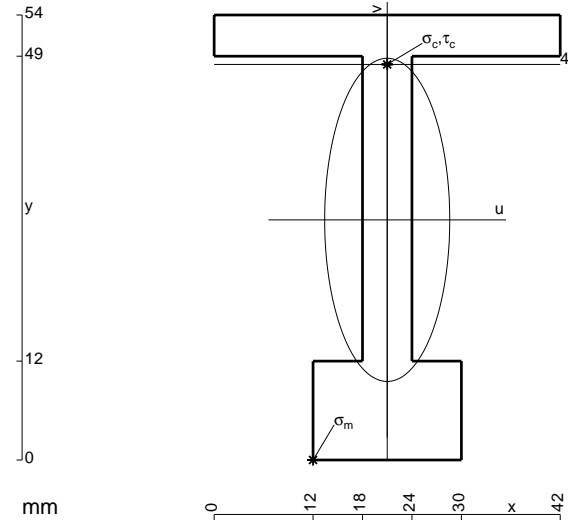
$$= (b - 5/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DE}^{x_0} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/2 b - 1/2 b + 1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$

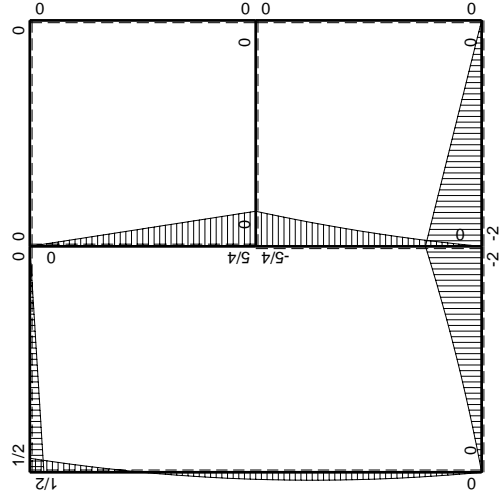
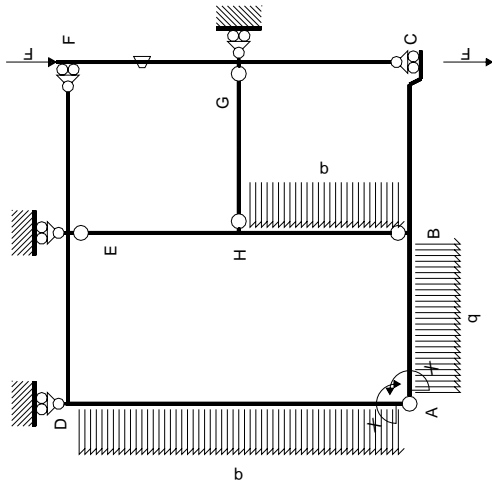
$$L_{ED}^{x_0} = \int_0^b (1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$



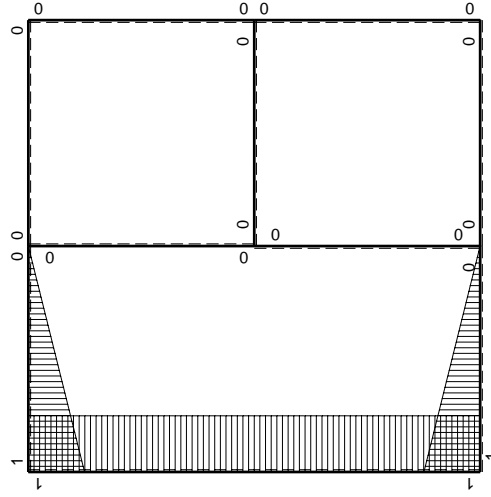
- A = 648. mm<sup>2</sup>
- J<sub>u</sub> = 249419. mm<sup>4</sup>
- J<sub>v</sub> = 37368. mm<sup>4</sup>
- y<sub>g</sub> = 29.14 mm
- T<sub>y</sub> = 3380. N
- M<sub>x</sub> = -1791400. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -9. mm
- v<sub>m</sub> = -29.14 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -209.3 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 48. mm
- v<sub>c</sub> = 18.86 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 135.5 N/mm<sup>2</sup>
- τ<sub>c</sub> = 10.87 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 136.8 N/mm<sup>2</sup>
- S = 4812. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJdx$
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0
CB b	0	$2Fx$	0	0	0	0		
AD 2b	1	$-3/4Fx+1/2qx^2$	0	$-3/4Fx+1/2Fx^2/b$	0	1	$(-1/6+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$-1/2Fb+5/4Fx-1/2qx^2$	0	$1/2Fb-5/4Fx+1/2Fx^2/b$	0	1		
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$		
EF b	0	0	0	0	0	0	0+0	0
FE b	0	0	0	0	0	0		
FG b	0	0	$-Fb/EJ$	0	0	0	0+0	0
GF b	0	0	$Fb/EJ$	0	0	0		
GC b	0	0	0	0	0	0	0+0	0
CG b	0	0	0	0	0	0		
HG b	0	0	0	0	0	0	0+0	0
GH b	0	0	0	0	0	0		
HB b	0	$-5/4Fb+7/4Fx-1/2qx^2$	0	0	0	0	0+0	0
BH b	0	$3/4Fx+1/2qx^2$	0	0	0	0		
HE b	0	$5/4Fb-5/4Fx$	0	0	0	0	0+0	0
EH b	0	$-5/4Fx$	0	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{x_0} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{x_0} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{x_0} = \int_0^{2b} (-3/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-3/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DA}^{x_0} = \int_0^{2b} (1/2 - 5/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

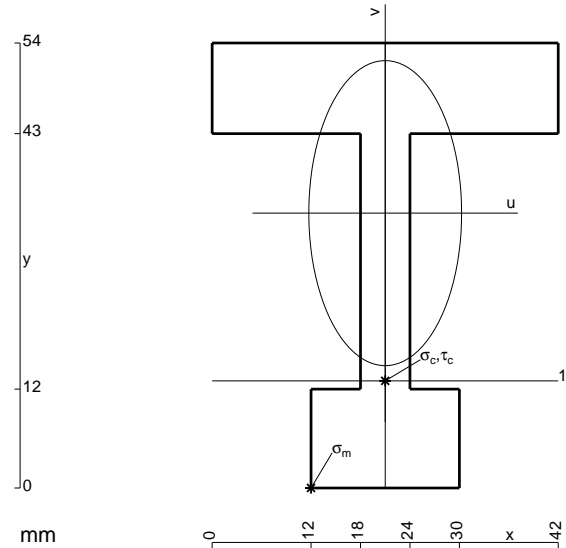
$$= (b - 5/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DE}^{x_0} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/2 b - 1/2 b + 1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$

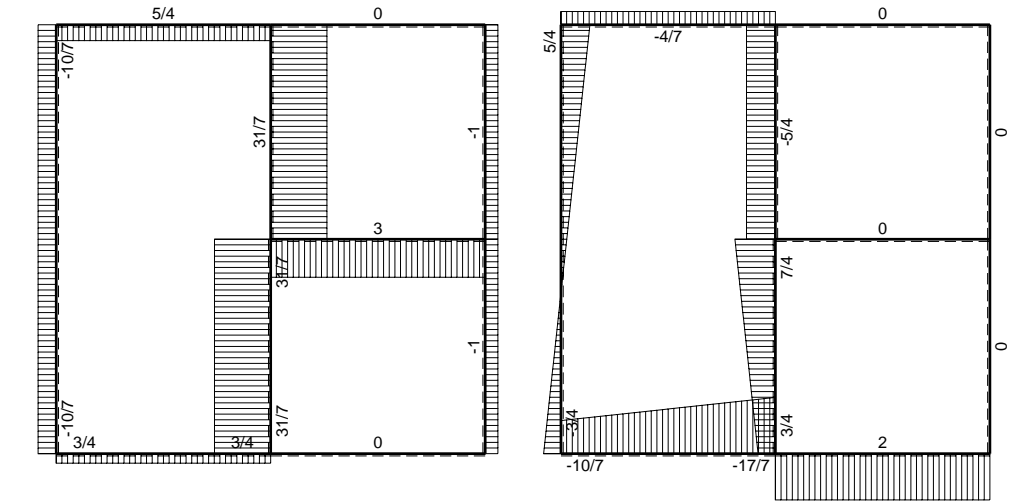
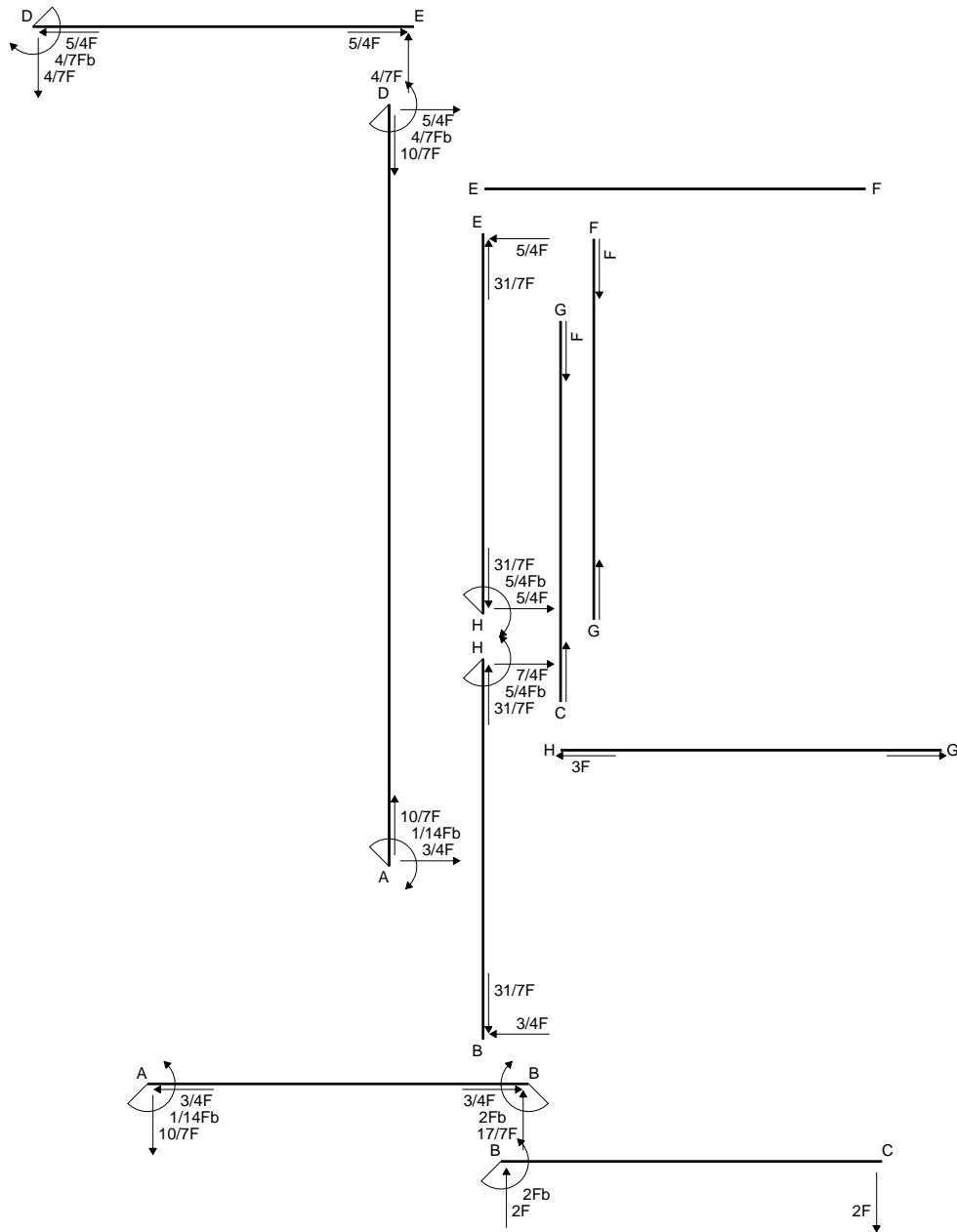
$$L_{ED}^{x_0} = \int_0^b (1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$



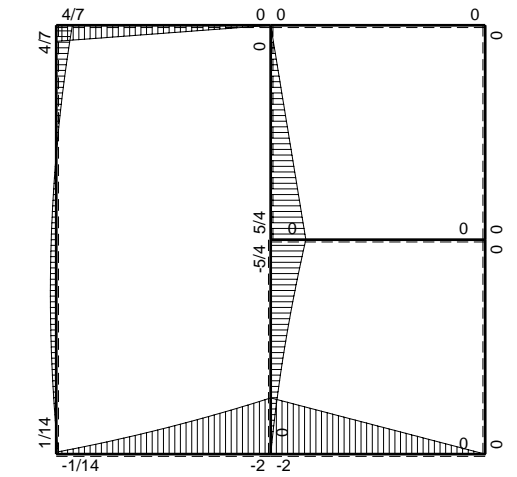
$A = 864. \text{ mm}^2$   
 $J_u = 296124. \text{ mm}^4$   
 $J_v = 74304. \text{ mm}^4$   
 $y_g = 33.35 \text{ mm}$   
 $T_y = 3360. \text{ N}$   
 $M_x = -1948800. \text{ Nmm}$   
 $x_m = 12. \text{ mm}$   
 $u_m = -9. \text{ mm}$   
 $v_m = -33.35 \text{ mm}$   
 $\sigma_m = -Mv/J_u = -219.5 \text{ N/mm}^2$   
 $x_c = 21. \text{ mm}$   
 $y_c = 13. \text{ mm}$   
 $v_c = -20.35 \text{ mm}$   
 $\sigma_c = -Mv/J_u = -134. \text{ N/mm}^2$   
 $\tau_c = 11.41 \text{ N/mm}^2$   
 $\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 135.4 \text{ N/mm}^2$   
 $S = 6034. \text{ mm}^3$



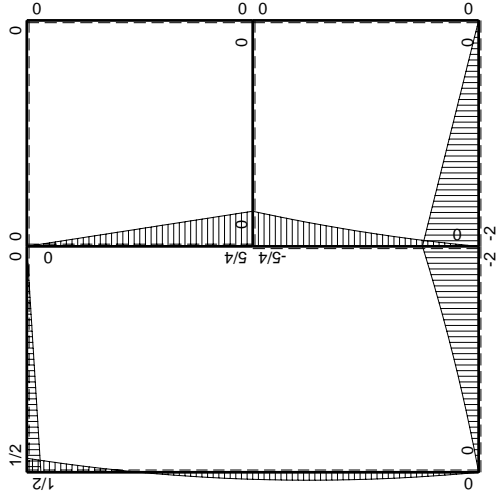
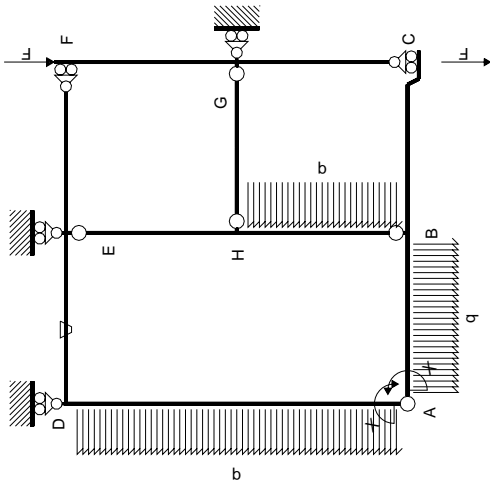


← ⊕ → F

↑ ⊕ ↓ F

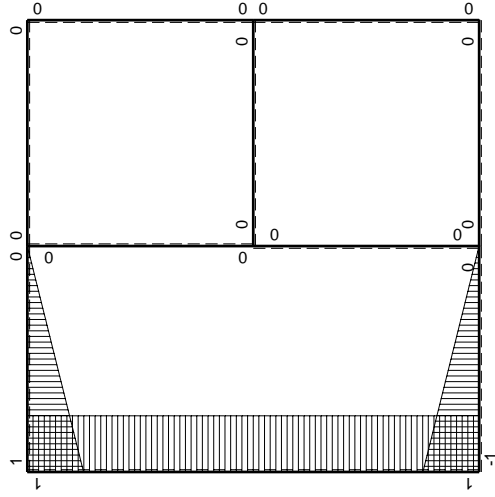


⊕ ⊖ F<sub>b</sub>



Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x / EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$-3/4Fx+1/2qx^2$	0	$-3/4Fx+1/2Fx^2/b$	0	1	$(-1/6+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+5/4Fx-1/2qx^2$	0	$1/2Fb-5/4Fx+1/2Fx^2/b$	0	1			
DE b	$1-x/b$	$1/2Fb-1/2Fx$	$-Fb/EJ$	$1/2Fb-Fx+1/2Fx^2/b$	$-Fb/EJ+Fx/EJ$	$1-2x/b+x^2/b^2$	$(1/6-1/2)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$-1/2Fx$	$Fb/EJ$	$1/2Fx^2/b$	$-Fx/EJ$	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-5/4Fb+7/4Fx-1/2qx^2$	0	0	0	0	0+0	0	
BH b	0	$3/4Fx+1/2qx^2$	0	0	0	0			
HE b	0	$5/4Fb-5/4Fx$	0	0	0	0	0+0	0	
EH b	0	$-5/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$-5/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$1/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{x_0} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{x_0} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{x_0} = \int_0^{2b} (-3/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-3/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DA}^{x_0} = \int_0^{2b} (1/2 - 5/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (b - 5/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

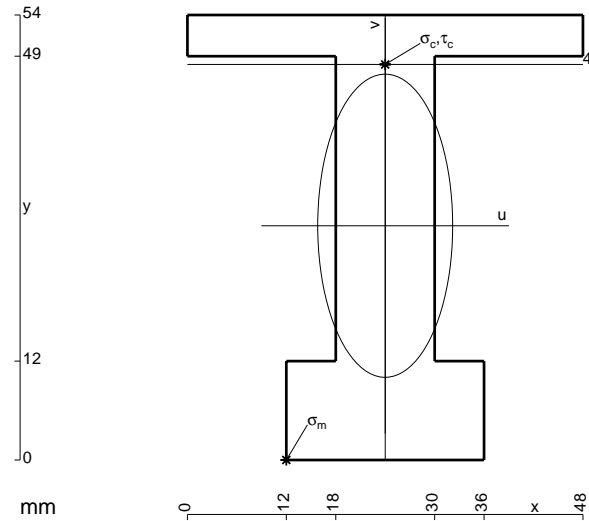
$$L_{DE}^{x_0} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx + \int_0^b (-1 + x/b) \cdot \theta \, dx$$

$$= \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ + \left[ -x + 1/2 x^2/b \right]_0^b \cdot \theta$$

$$= (1/2 b - 1/2 b + 1/6 b) \cdot Fb \cdot 1/EJ + (-b + 1/2 b) \cdot \theta = -1/3 \cdot Fb^2/EJ$$

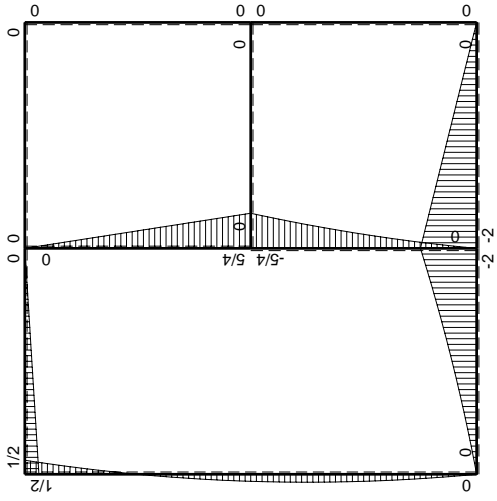
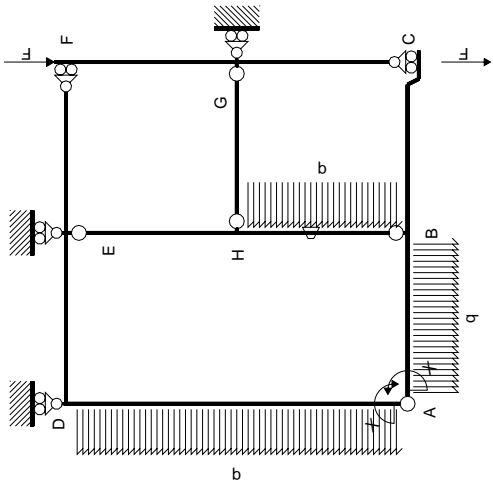
$$L_{ED}^{x_0} = \int_0^b (1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx + \int_0^b (x/b) \cdot \theta \, dx = \left[ 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ + \left[ 1/2 x^2/b \right]_0^b \cdot \theta$$

$$= (1/6 b) \cdot Fb \cdot 1/EJ + (1/2 b) \cdot \theta = -1/3 \cdot Fb^2/EJ$$



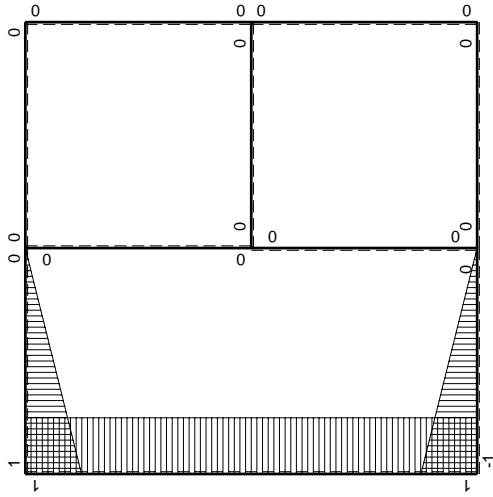
- A = 972. mm<sup>2</sup>
- J<sub>u</sub> = 329140. mm<sup>4</sup>
- J<sub>v</sub> = 65232. mm<sup>4</sup>
- y<sub>g</sub> = 28.43 mm
- T<sub>y</sub> = 4220. N
- M<sub>x</sub> = -2658600. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -12. mm
- v<sub>m</sub> = -28.43 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -229.6 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 48. mm
- v<sub>c</sub> = 19.57 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 158.1 N/mm<sup>2</sup>
- τ<sub>c</sub> = 6.174 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 158.5 N/mm<sup>2</sup>
- S = 5779. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int X M_x M_x/EJdx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$-3/4Fx+1/2qx^2$	0	$-3/4Fx+1/2Fx^2/b$	0	1	$(-1/6+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+5/4Fx-1/2qx^2$	0	$1/2Fb-5/4Fx+1/2Fx^2/b$	0	1			
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-5/4Fb+7/4Fx-1/2qx^2$	$-Fb/EJ$	0	0	0	0+0	0	
BH b	0	$3/4Fx+1/2qx^2$	$Fb/EJ$	0	0	0			
HE b	0	$5/4Fb-5/4Fx$	0	0	0	0	0+0	0	
EH b	0	$-5/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-3/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-3/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 5/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

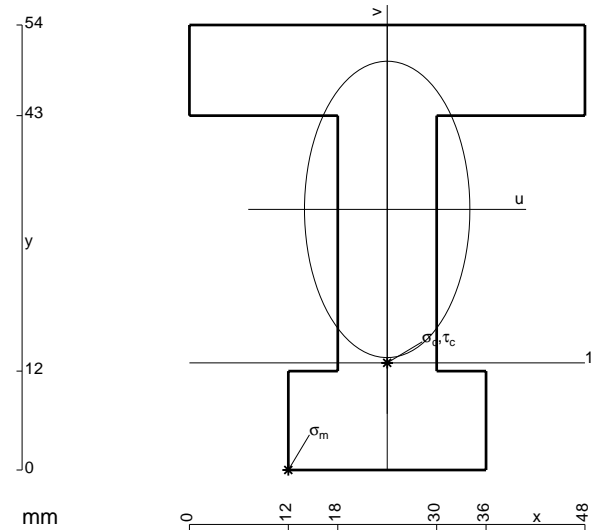
$$= (b - 5/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/2 b - 1/2 b + 1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$



$$A = 1188. \text{ mm}^2$$

$$J_u = 384370. \text{ mm}^4$$

$$J_v = 119664. \text{ mm}^4$$

$$y_g = 31.62 \text{ mm}$$

$$T_y = 4280. \text{ N}$$

$$M_x = -2910400. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -12. \text{ mm}$$

$$v_m = -31.62 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -239.4 \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 13. \text{ mm}$$

$$v_c = -18.62 \text{ mm}$$

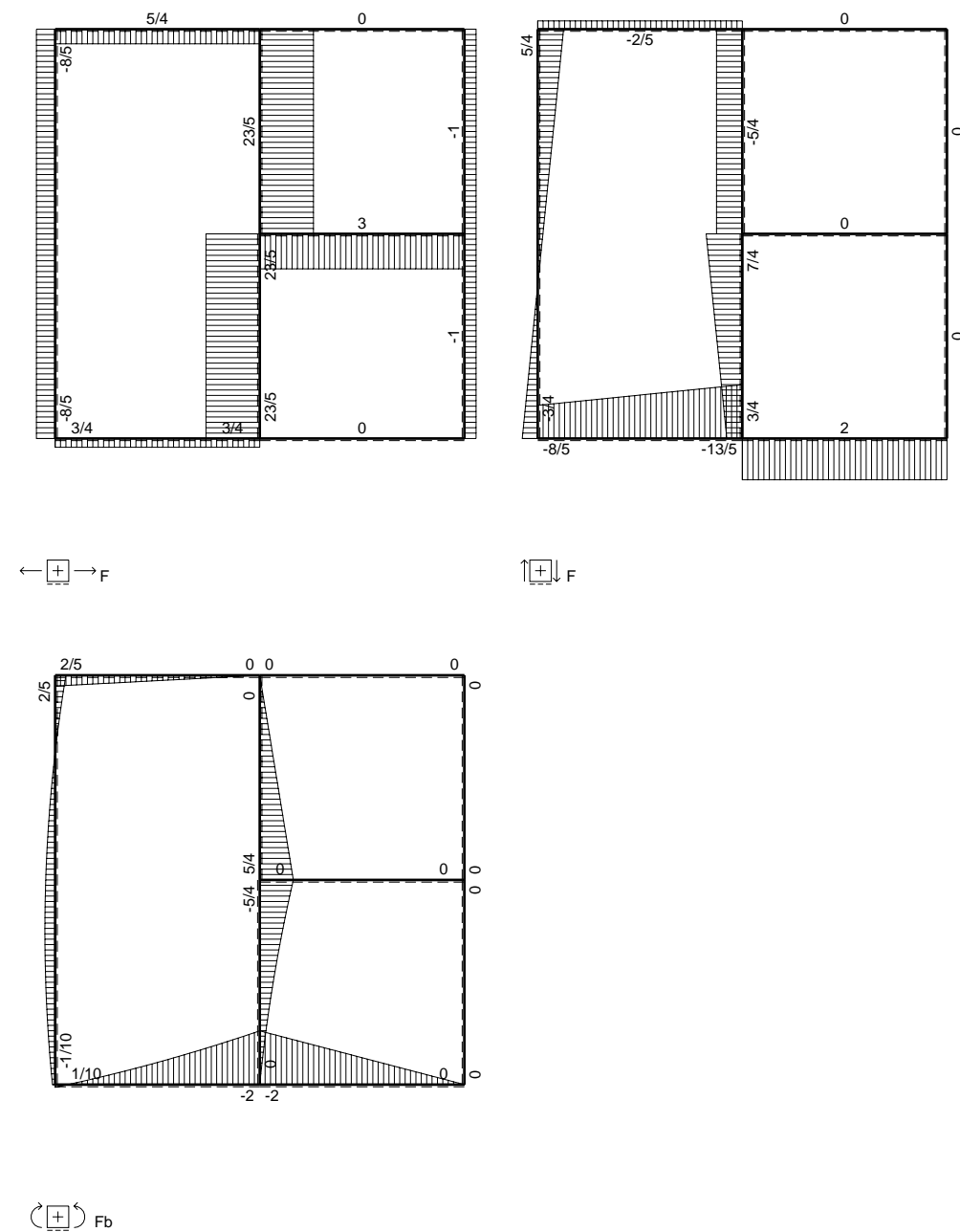
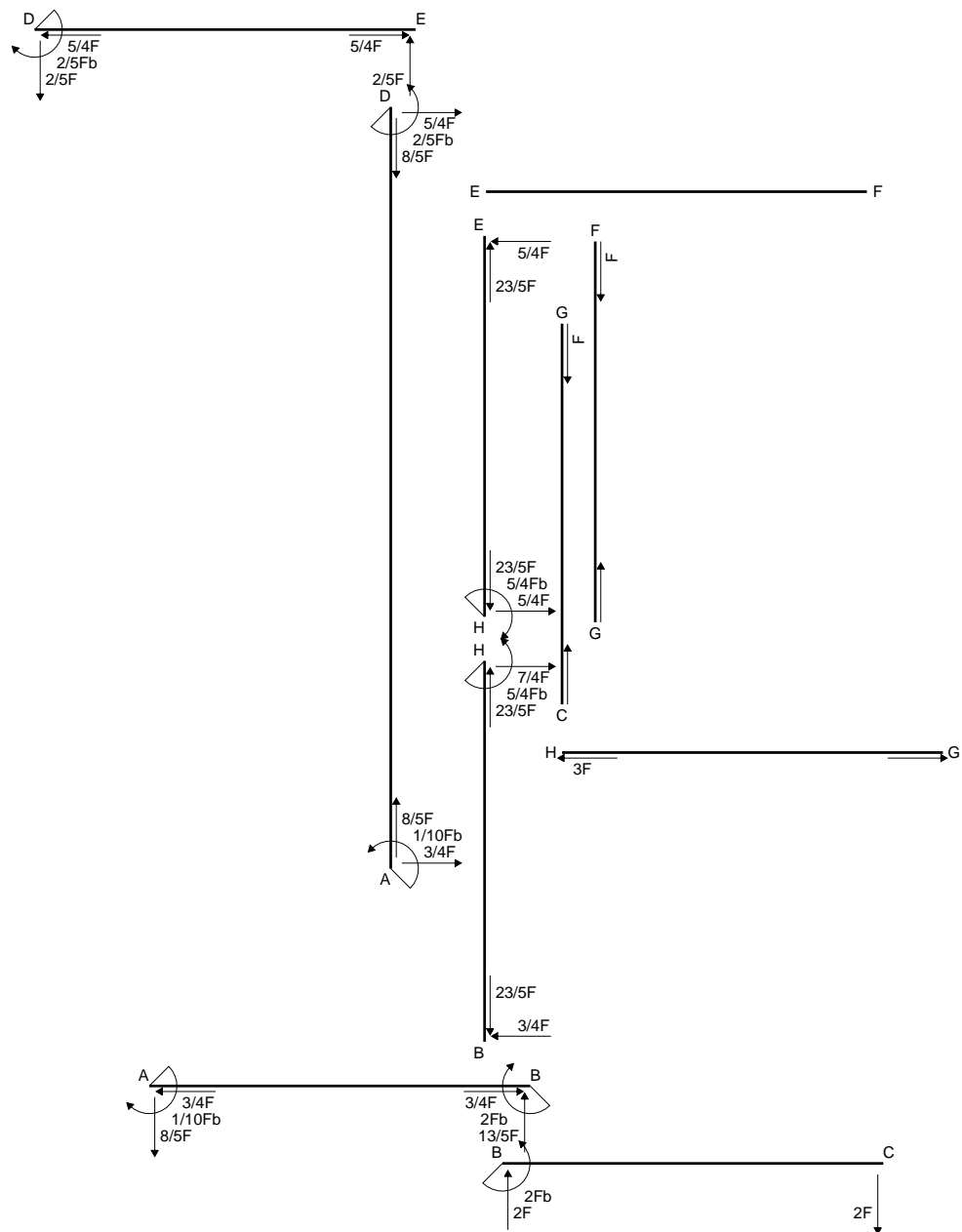
$$\sigma_c = -Mv/J_u = -141. \text{ N/mm}^2$$

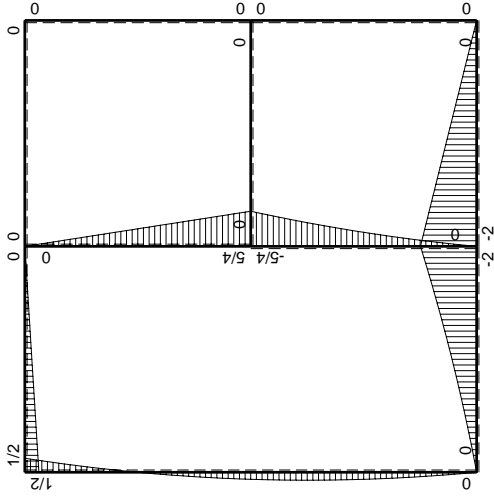
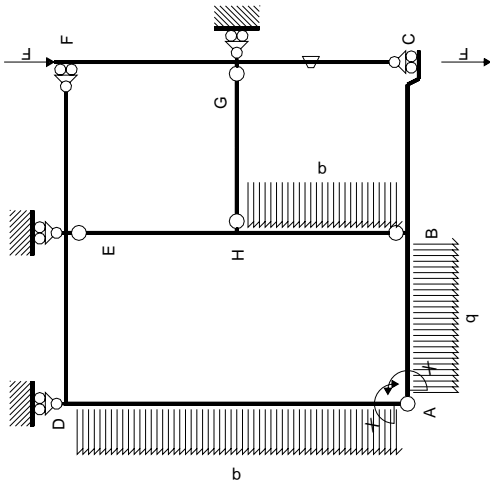
$$\tau_c = 7.06 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 141.5 \text{ N/mm}^2$$

$$S = 7608. \text{ mm}^3$$

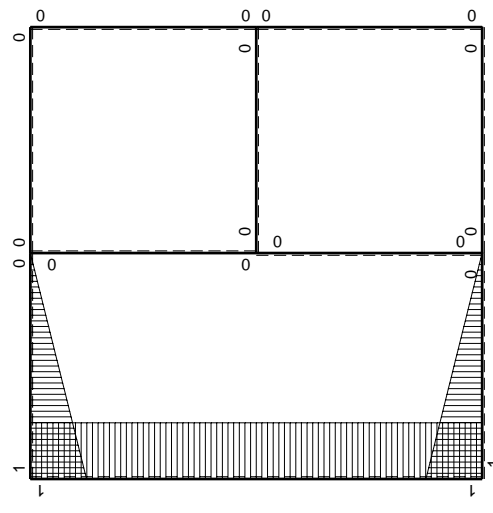






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJdx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$-3/4Fx+1/2qx^2$	0	$-3/4Fx+1/2Fx^2/b$	0	1	$(-1/6+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+5/4Fx-1/2qx^2$	0	$1/2Fb-5/4Fx+1/2Fx^2/b$	0	1			
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
CG b	0	0	$Fb/EJ$	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-5/4Fb+7/4Fx-1/2qx^2$	0	0	0	0	0+0	0	
BH b	0	$3/4Fx+1/2qx^2$	0	0	0	0			
HE b	0	$5/4Fb-5/4Fx$	0	0	0	0	0+0	0	
EH b	0	$-5/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-3/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-3/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 5/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

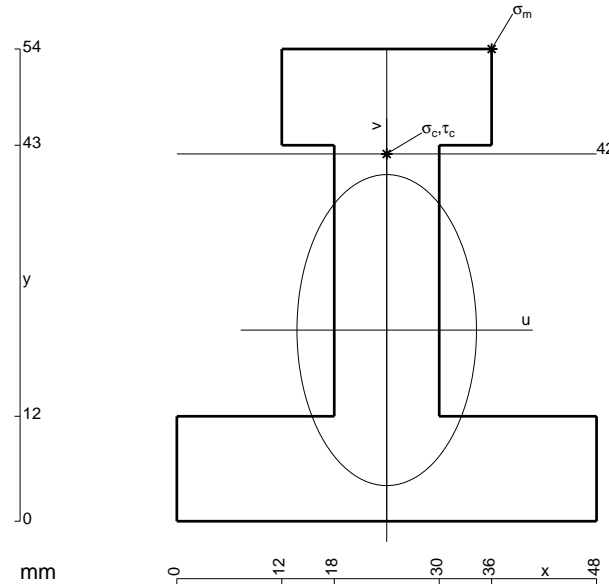
$$= (b - 5/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

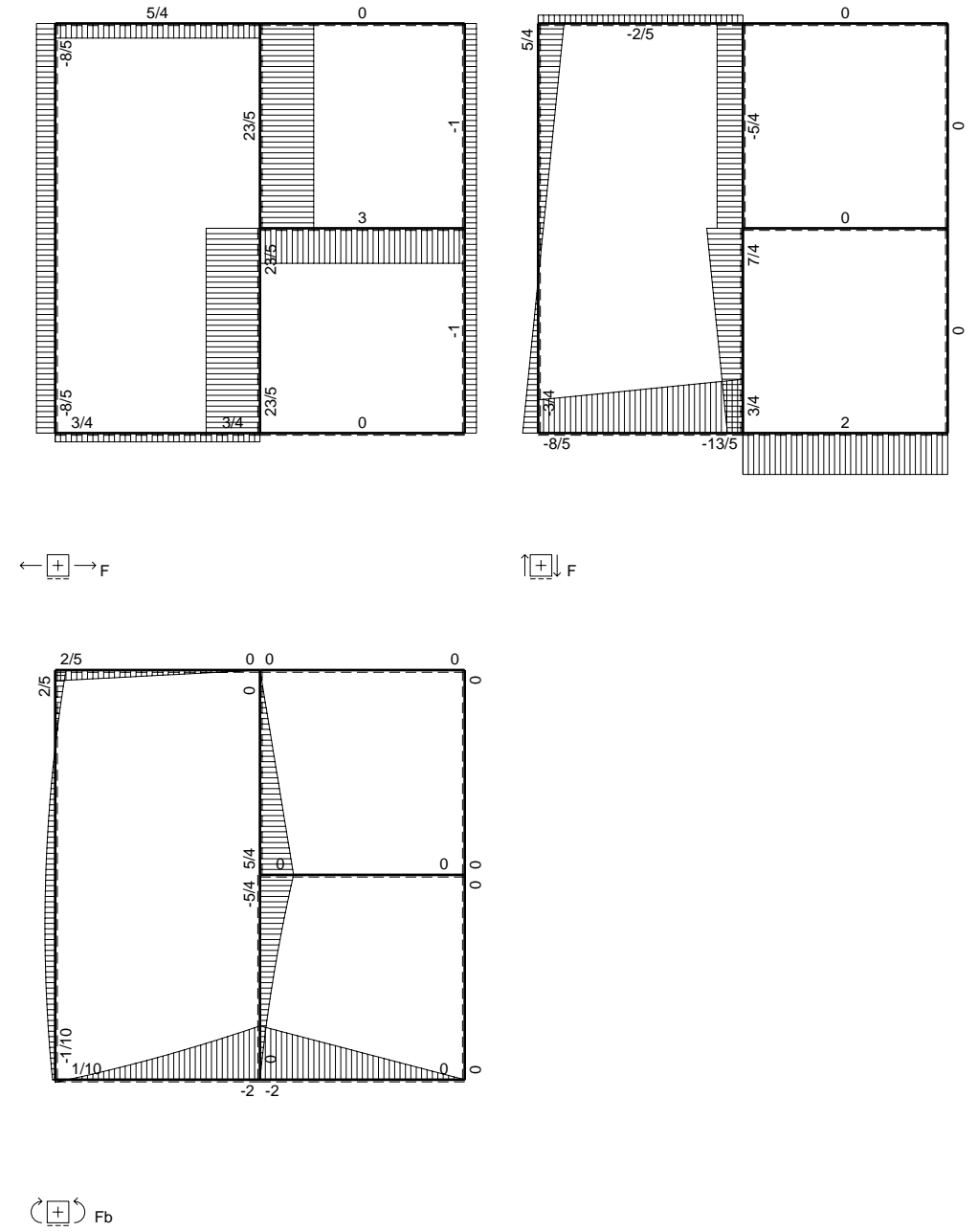
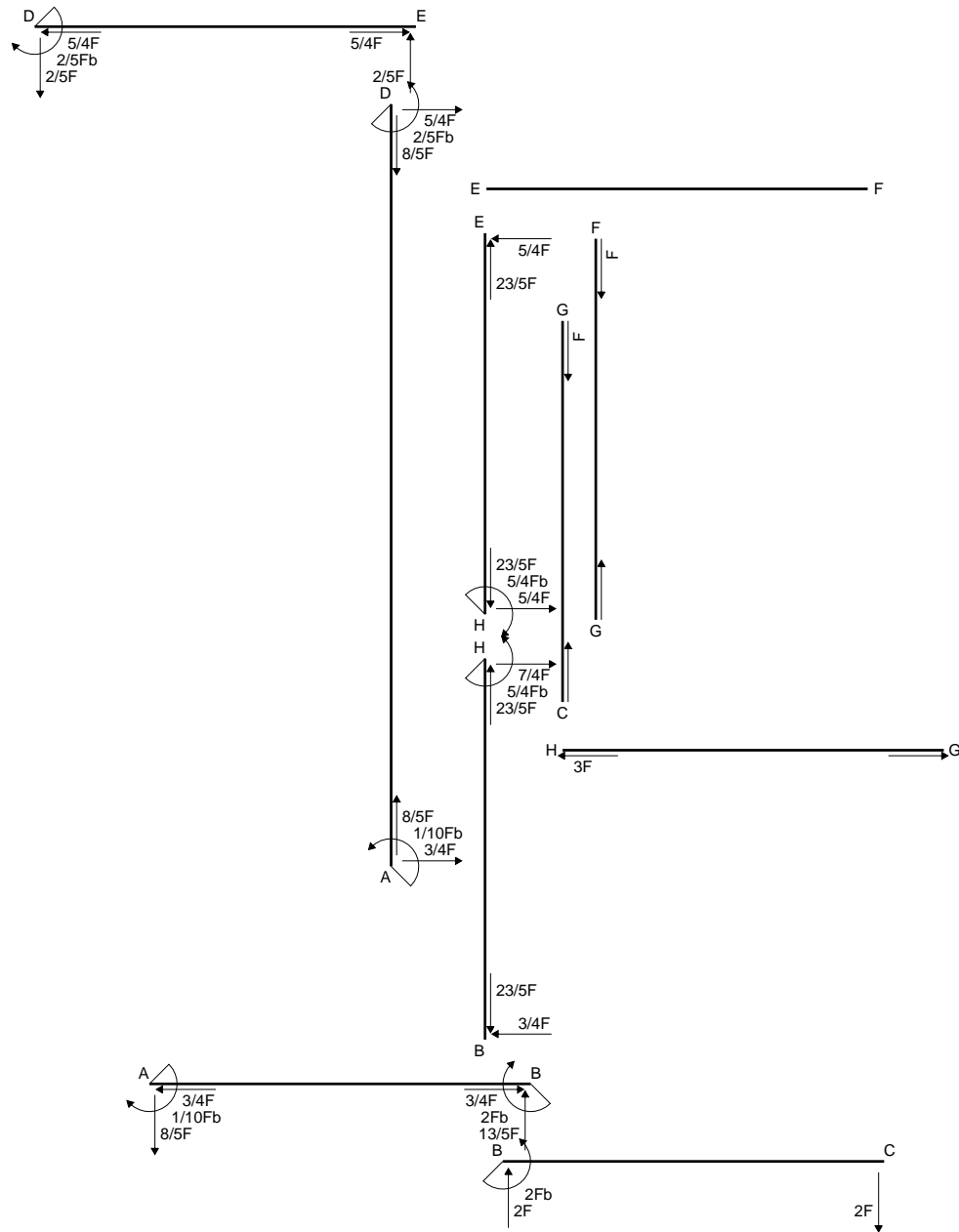
$$= (1/2 b - 1/2 b + 1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$

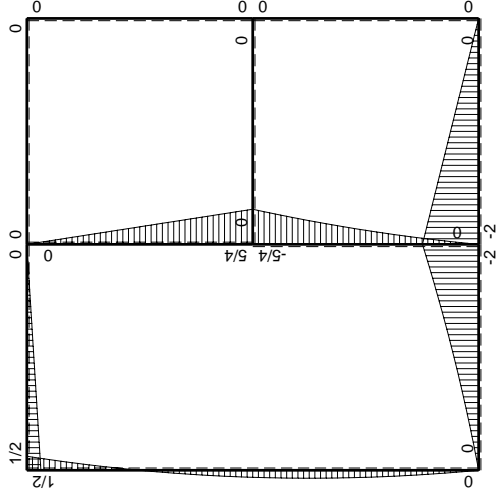
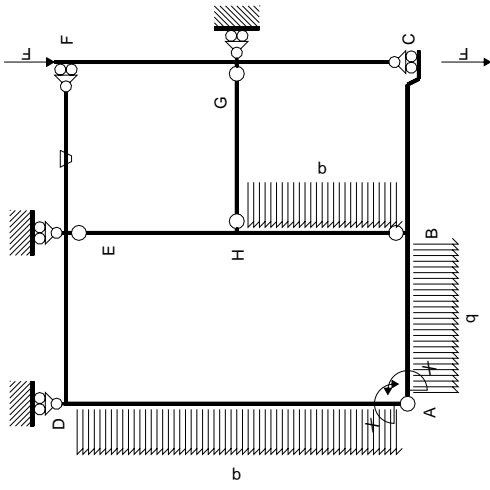
$$L_{ED}^{xo} = \int_0^b (1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$



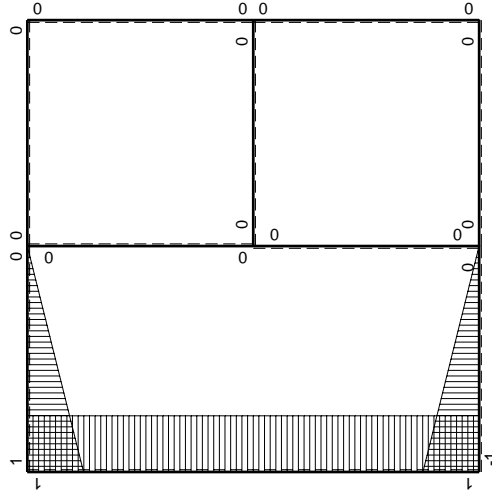
$A = 1212. \text{ mm}^2$   
 $J_u = 383443. \text{ mm}^4$   
 $J_v = 127728. \text{ mm}^4$   
 $y_g = 21.86 \text{ mm}$   
 $T_y = 3260. \text{ N}$   
 $M_x = -2379800. \text{ Nmm}$   
 $x_m = 36. \text{ mm}$   
 $y_m = 54. \text{ mm}$   
 $u_m = 12. \text{ mm}$   
 $v_m = 32.14 \text{ mm}$   
 $\sigma_m = -Mv/J_u = 199.5 \text{ N/mm}^2$   
 $x_c = 24. \text{ mm}$   
 $y_c = 42. \text{ mm}$   
 $v_c = 20.14 \text{ mm}$   
 $\sigma_c = -Mv/J_u = 125. \text{ N/mm}^2$   
 $\tau_c = 5.159 \text{ N/mm}^2$   
 $\sigma_o = \sqrt{\sigma^2 + 3\tau^2} = 125.3 \text{ N/mm}^2$   
 $S = 7282. \text{ mm}^3$





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$-3/4Fx+1/2qx^2$	0	$-3/4Fx+1/2Fx^2/b$	0	1	$(-1/6+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+5/4Fx-1/2qx^2$	0	$1/2Fb-5/4Fx+1/2Fx^2/b$	0	1			
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
FE b	0	0	$Fb/EJ$	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-5/4Fb+7/4Fx-1/2qx^2$	0	0	0	0	0+0	0	
BH b	0	$3/4Fx+1/2qx^2$	0	0	0	0			
HE b	0	$5/4Fb-5/4Fx$	0	0	0	0	0+0	0	
EH b	0	$-5/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-3/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-3/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 5/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

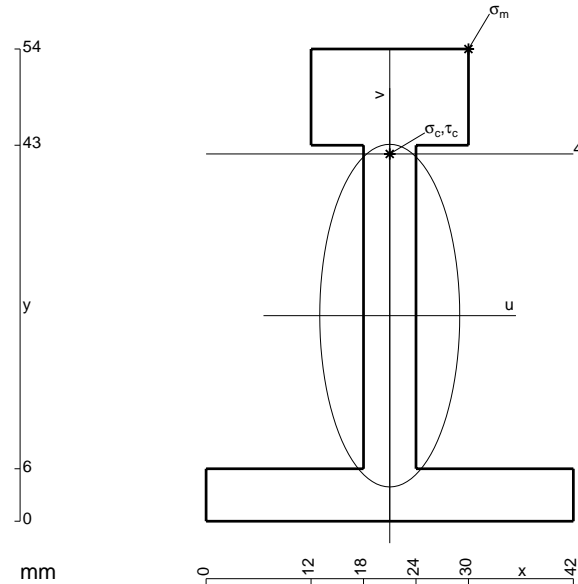
$$= (b - 5/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/2 b - 1/2 b + 1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$

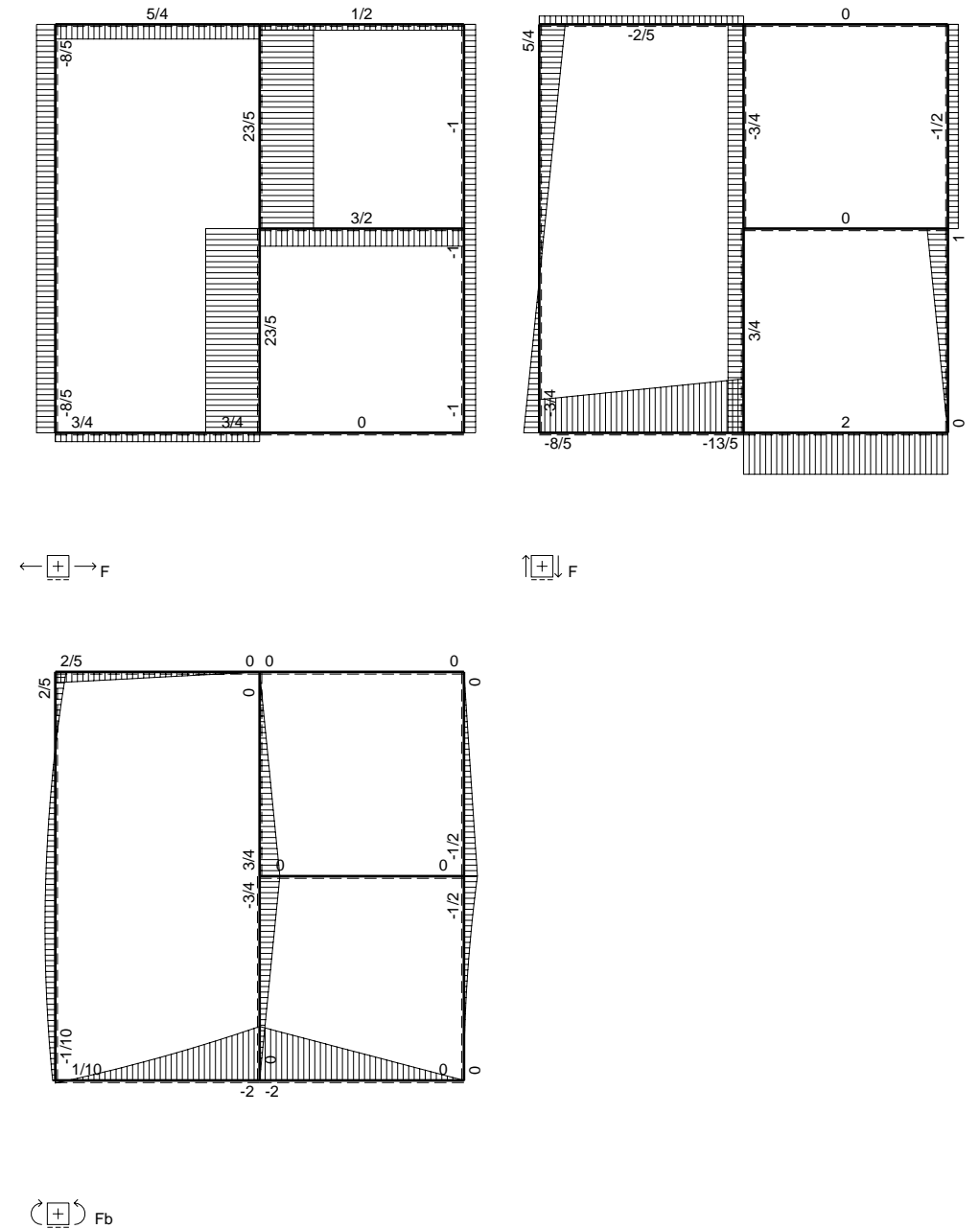
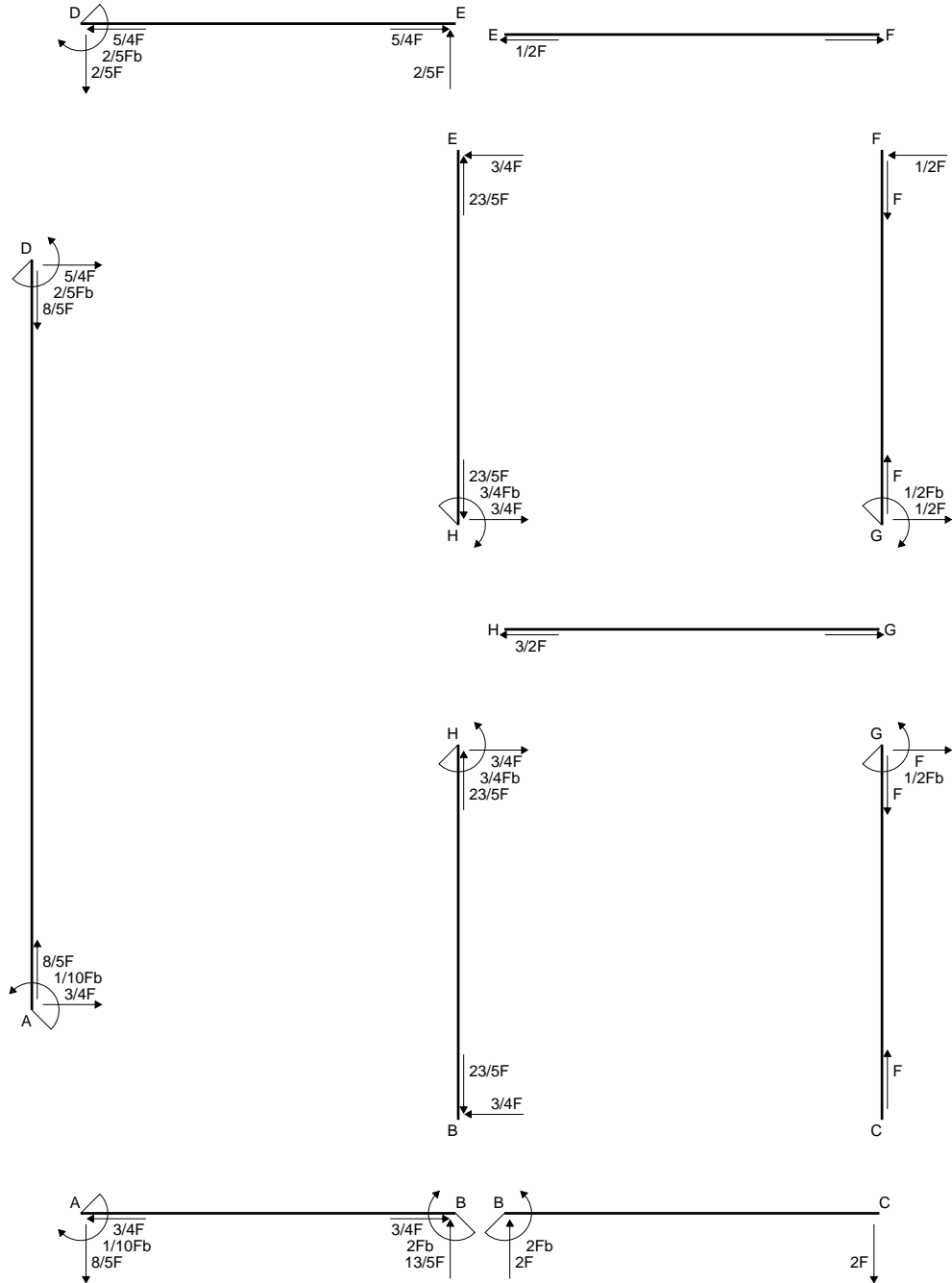
$$L_{ED}^{xo} = \int_0^b (1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

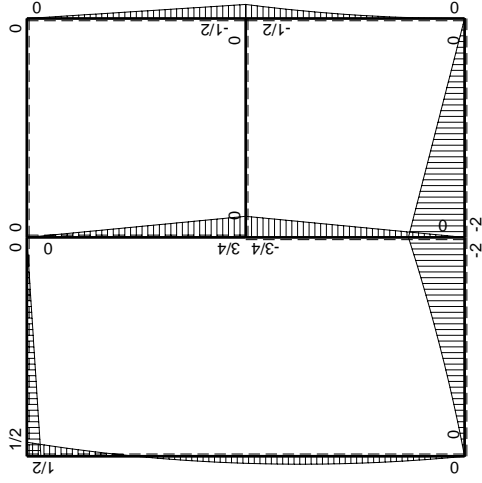
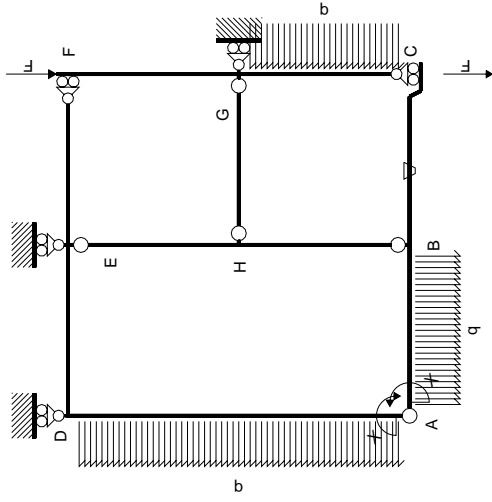
$$= (1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$



- A = 672. mm<sup>2</sup>
- J<sub>u</sub> = 257954. mm<sup>4</sup>
- J<sub>v</sub> = 43056. mm<sup>4</sup>
- y<sub>g</sub> = 23.51 mm
- T<sub>y</sub> = 2260. N
- M<sub>x</sub> = -1762800. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 9. mm
- v<sub>m</sub> = 30.49 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 208.4 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 42. mm
- v<sub>c</sub> = 18.49 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 126.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.392 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 127. N/mm<sup>2</sup>
- S = 5062. mm<sup>3</sup>

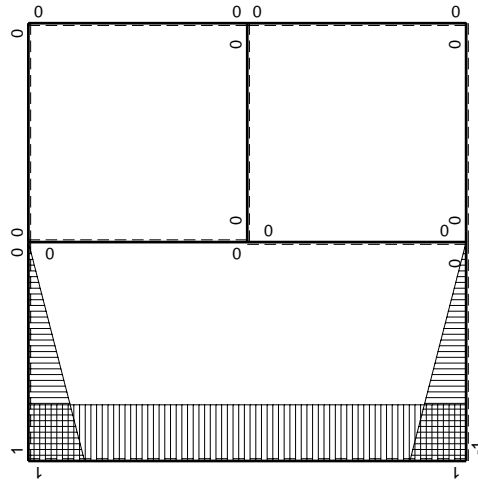






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJdx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	$-Fb/EJ$	0	0	0	0+0	0	
CB b	0	$2Fx$	$Fb/EJ$	0	0	0			
AD 2b	1	$-3/4Fx+1/2qx^2$	0	$-3/4Fx+1/2Fx^2/b$	0	1	$(-1/6+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+5/4Fx-1/2qx^2$	0	$1/2Fb-5/4Fx+1/2Fx^2/b$	0	1			
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-3/4Fb+3/4Fx$	0	0	0	0	0+0	0	
BH b	0	$3/4Fx$	0	0	0	0			
HE b	0	$3/4Fb-3/4Fx$	0	0	0	0	0+0	0	
EH b	0	$-3/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-3/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-3/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 5/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

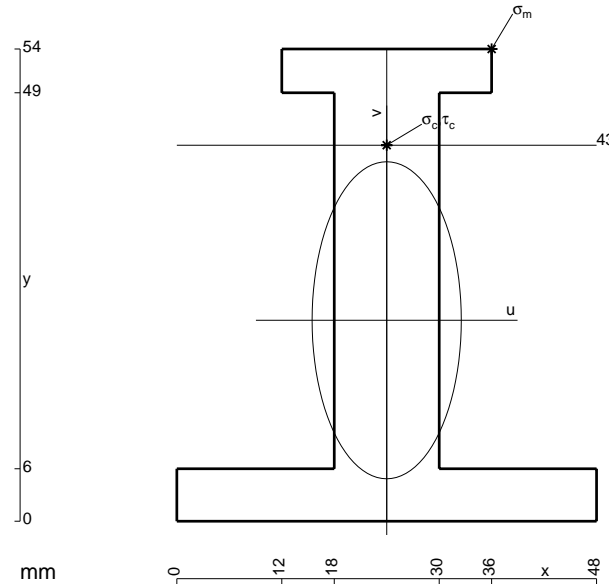
$$= (b - 5/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

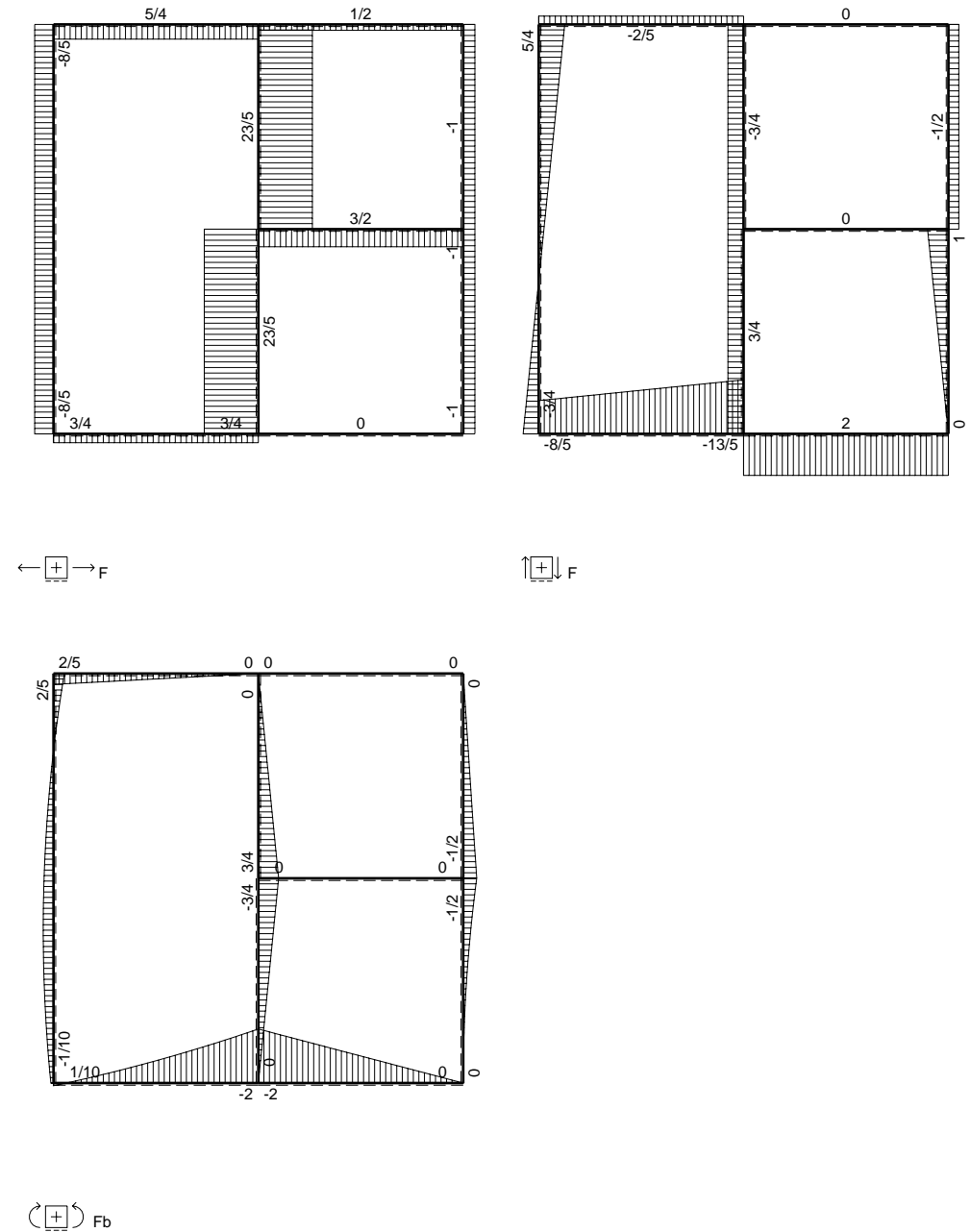
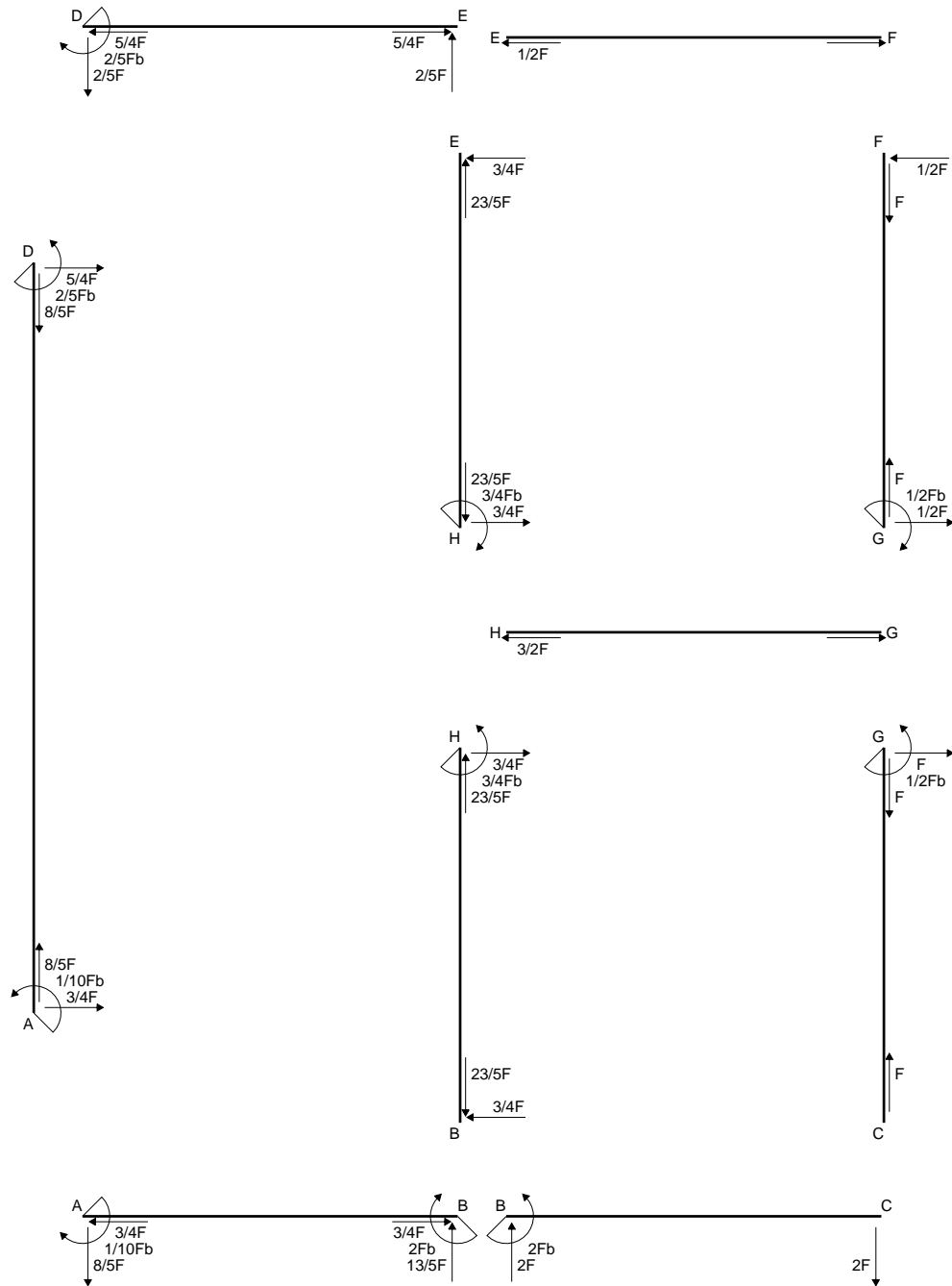
$$= (1/2 b - 1/2 b + 1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$

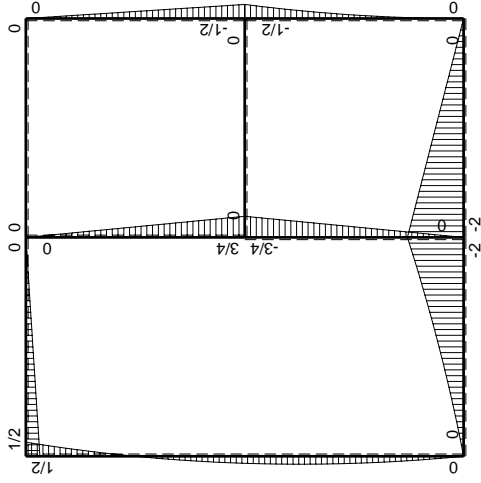
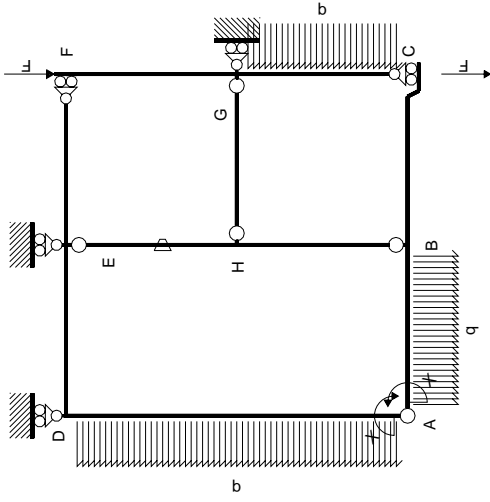
$$L_{ED}^{xo} = \int_0^b (1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$



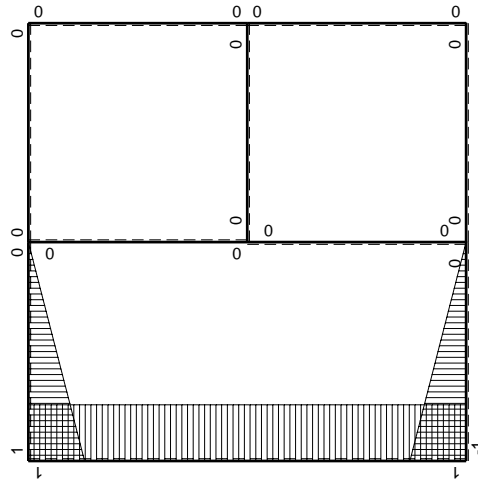
- A = 924. mm<sup>2</sup>
- J<sub>u</sub> = 303740. mm<sup>4</sup>
- J<sub>v</sub> = 67248. mm<sup>4</sup>
- y<sub>g</sub> = 22.98 mm
- T<sub>y</sub> = 2580. N
- M<sub>x</sub> = -2141400. Nmm
- x<sub>m</sub> = 36. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 12. mm
- v<sub>m</sub> = 31.02 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 218.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 43. mm
- v<sub>c</sub> = 20.02 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 141.1 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.596 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 141.3 N/mm<sup>2</sup>
- S = 5080. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJdx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$-3/4Fx+1/2qx^2$	0	$-3/4Fx+1/2Fx^2/b$	0	1	$(-1/6+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+5/4Fx-1/2qx^2$	0	$1/2Fb-5/4Fx+1/2Fx^2/b$	0	1			
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-3/4Fb+3/4Fx$	0	0	0	0	0+0	0	
BH b	0	$3/4Fx$	0	0	0	0			
HE b	0	$3/4Fb-3/4Fx$	$-Fb/EJ$	0	0	0	0+0	0	
EH b	0	$-3/4Fx$	$Fb/EJ$	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ}$$

$$= (b - b + 1/3 b) \frac{1}{EJ} = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx = \left[ 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ}$$

$$= (1/3 b) \frac{1}{EJ} = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-3/4 x/b + 1/2 x^2/b^2) Fb \frac{1}{EJ} dx = \left[ -3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} Fb \frac{1}{EJ}$$

$$= (-3/2 b + 4/3 b) Fb \frac{1}{EJ} = -1/6 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 5/4 x/b + 1/2 x^2/b^2) Fb \frac{1}{EJ} dx = \left[ 1/2 x - 5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} Fb \frac{1}{EJ}$$

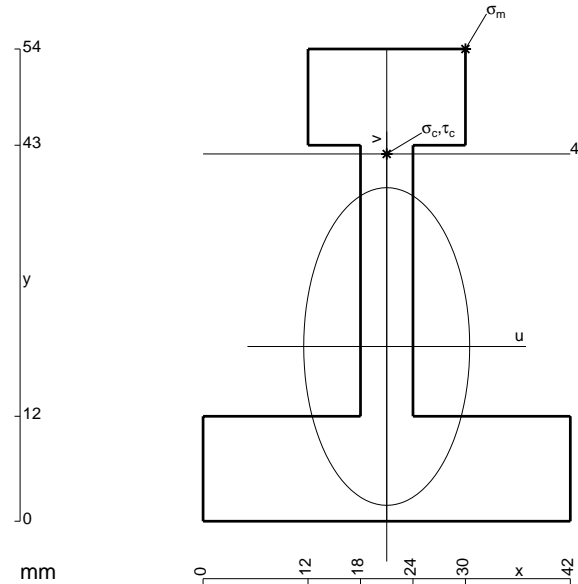
$$= (b - 5/2 b + 4/3 b) Fb \frac{1}{EJ} = -1/6 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) Fb \frac{1}{EJ} dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b Fb \frac{1}{EJ}$$

$$= (1/2 b - 1/2 b + 1/6 b) Fb \frac{1}{EJ} = 1/6 \cdot Fb^2/EJ$$

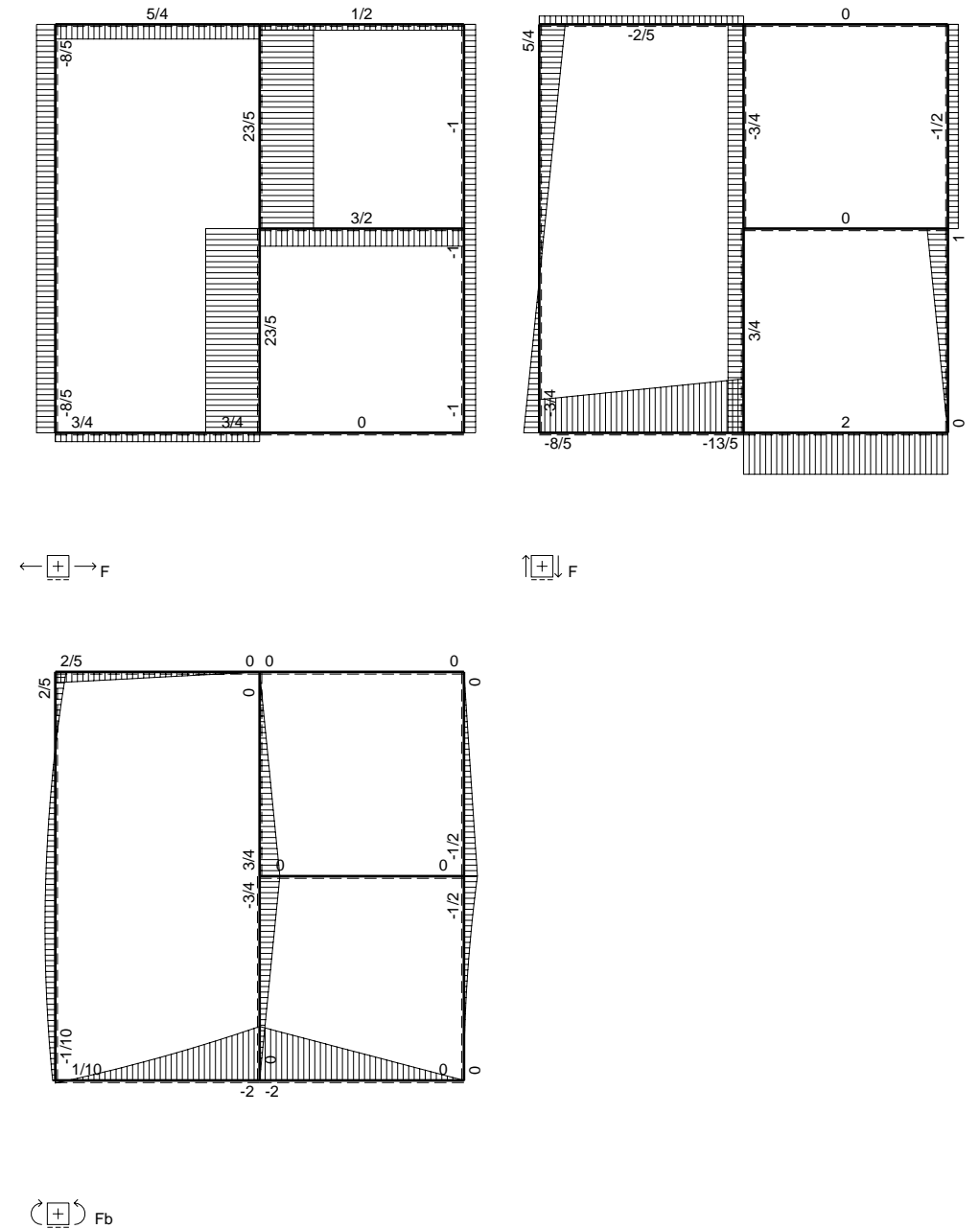
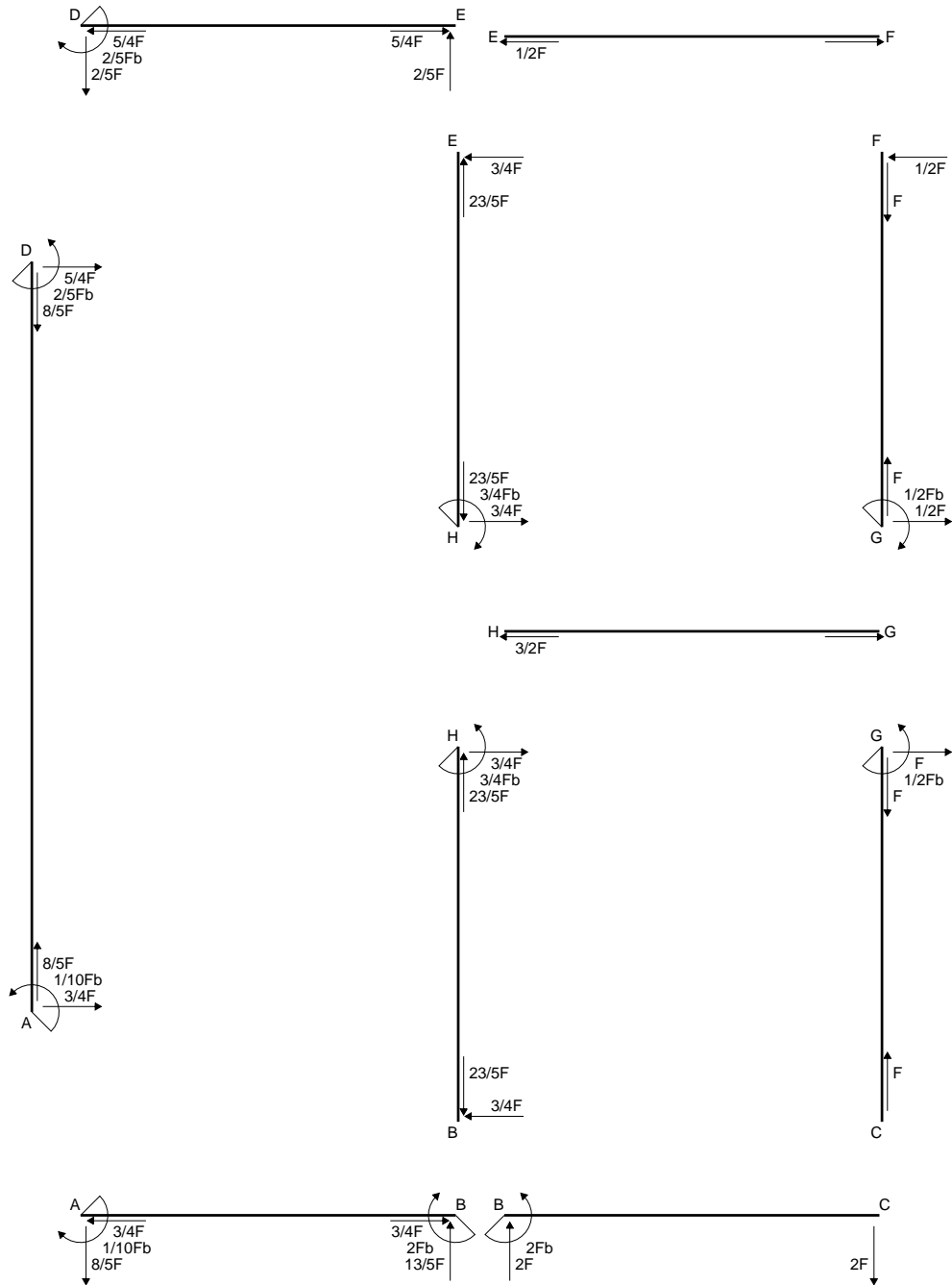
$$L_{ED}^{xo} = \int_0^b (1/2 x^2/b^2) Fb \frac{1}{EJ} dx = \left[ 1/6 x^3/b^2 \right]_0^b Fb \frac{1}{EJ}$$

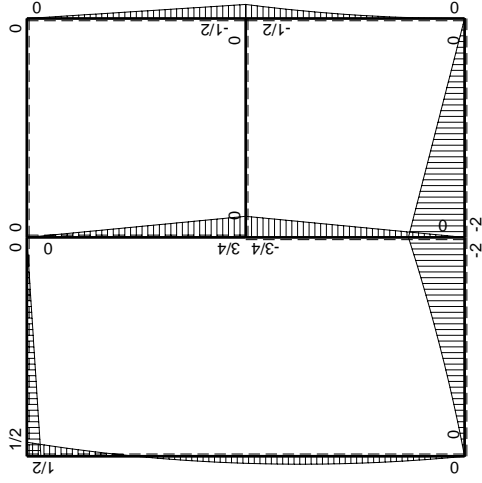
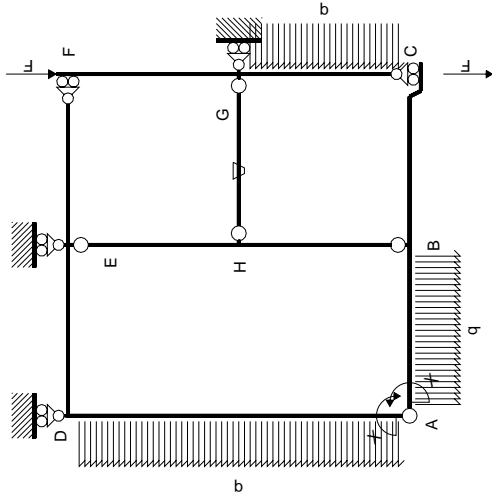
$$= (1/6 b) Fb \frac{1}{EJ} = 1/6 \cdot Fb^2/EJ$$



- A = 888. mm<sup>2</sup>
- J<sub>u</sub> = 293012. mm<sup>4</sup>
- J<sub>v</sub> = 79992. mm<sup>4</sup>
- y<sub>g</sub> = 19.98 mm
- T<sub>y</sub> = 2240. N
- M<sub>x</sub> = -1971200. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 9. mm
- v<sub>m</sub> = 34.02 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 228.9 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 42. mm
- v<sub>c</sub> = 22.02 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 148.1 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.367 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sub>c</sub><sup>2</sup> + 3τ<sub>c</sub><sup>2</sup> = 148.7 N/mm<sup>2</sup>
- S = 5782. mm<sup>3</sup>

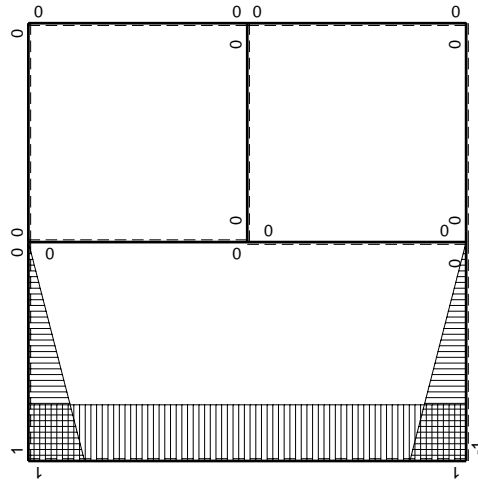






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$-3/4Fx+1/2qx^2$	0	$-3/4Fx+1/2Fx^2/b$	0	1	$(-1/6+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+5/4Fx-1/2qx^2$	0	$1/2Fb-5/4Fx+1/2Fx^2/b$	0	1			
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
GH b	0	0	$Fb/EJ$	0	0	0			
HB b	0	$-3/4Fb+3/4Fx$	0	0	0	0	0+0	0	
BH b	0	$3/4Fx$	0	0	0	0			
HE b	0	$3/4Fb-3/4Fx$	0	0	0	0	0+0	0	
EH b	0	$-3/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-3/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-3/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 5/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

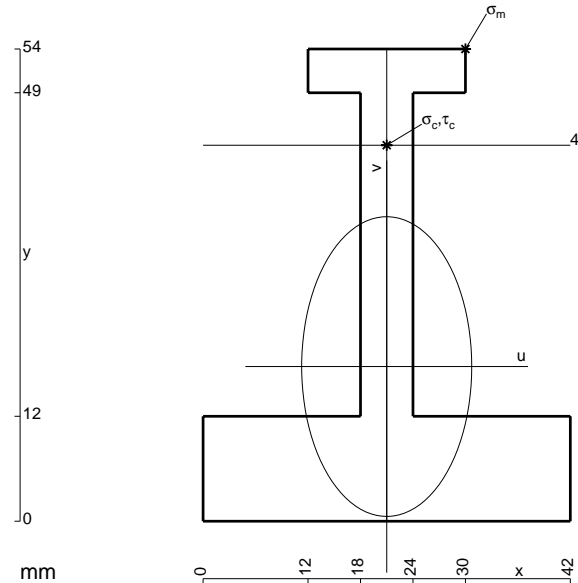
$$= (b - 5/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

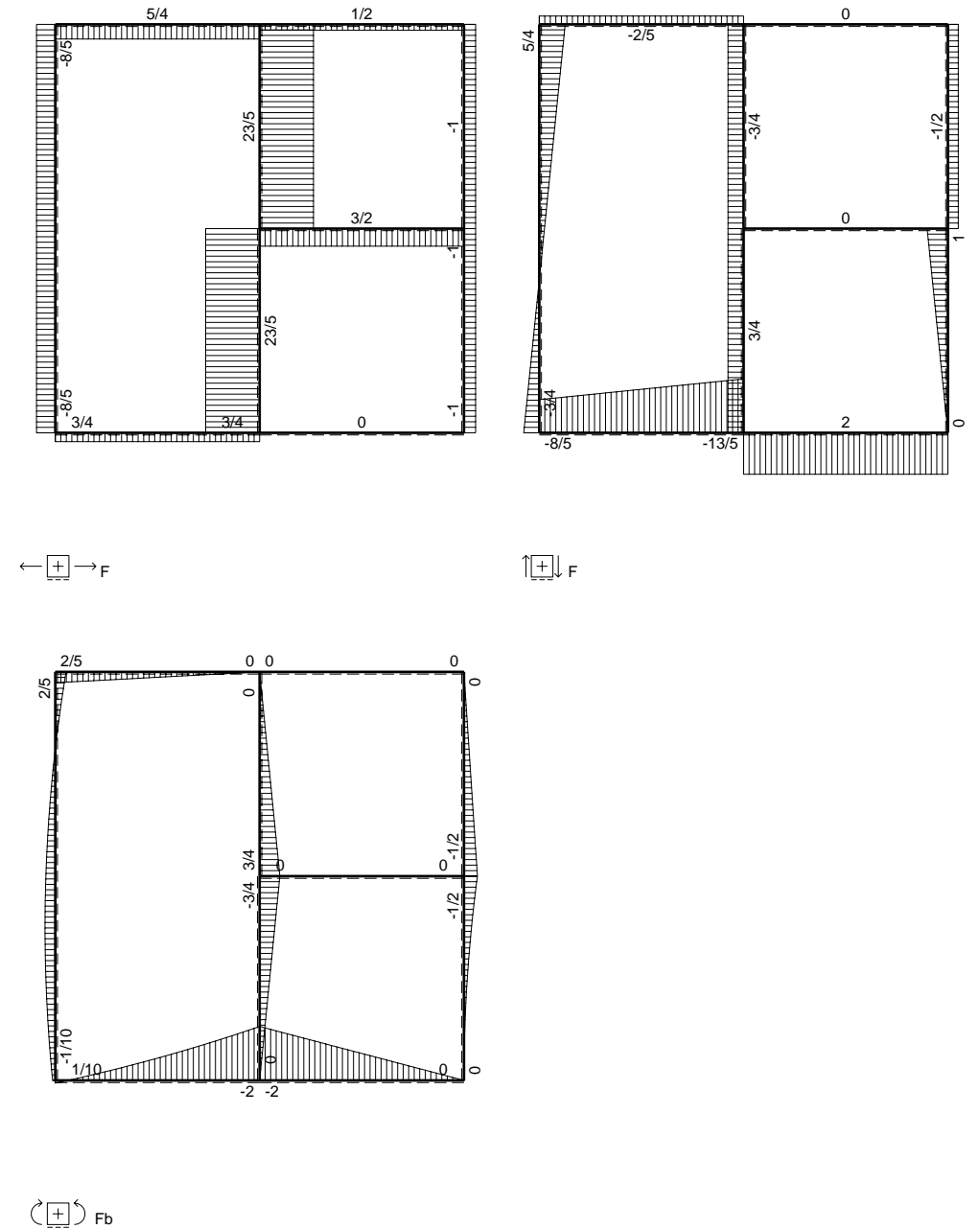
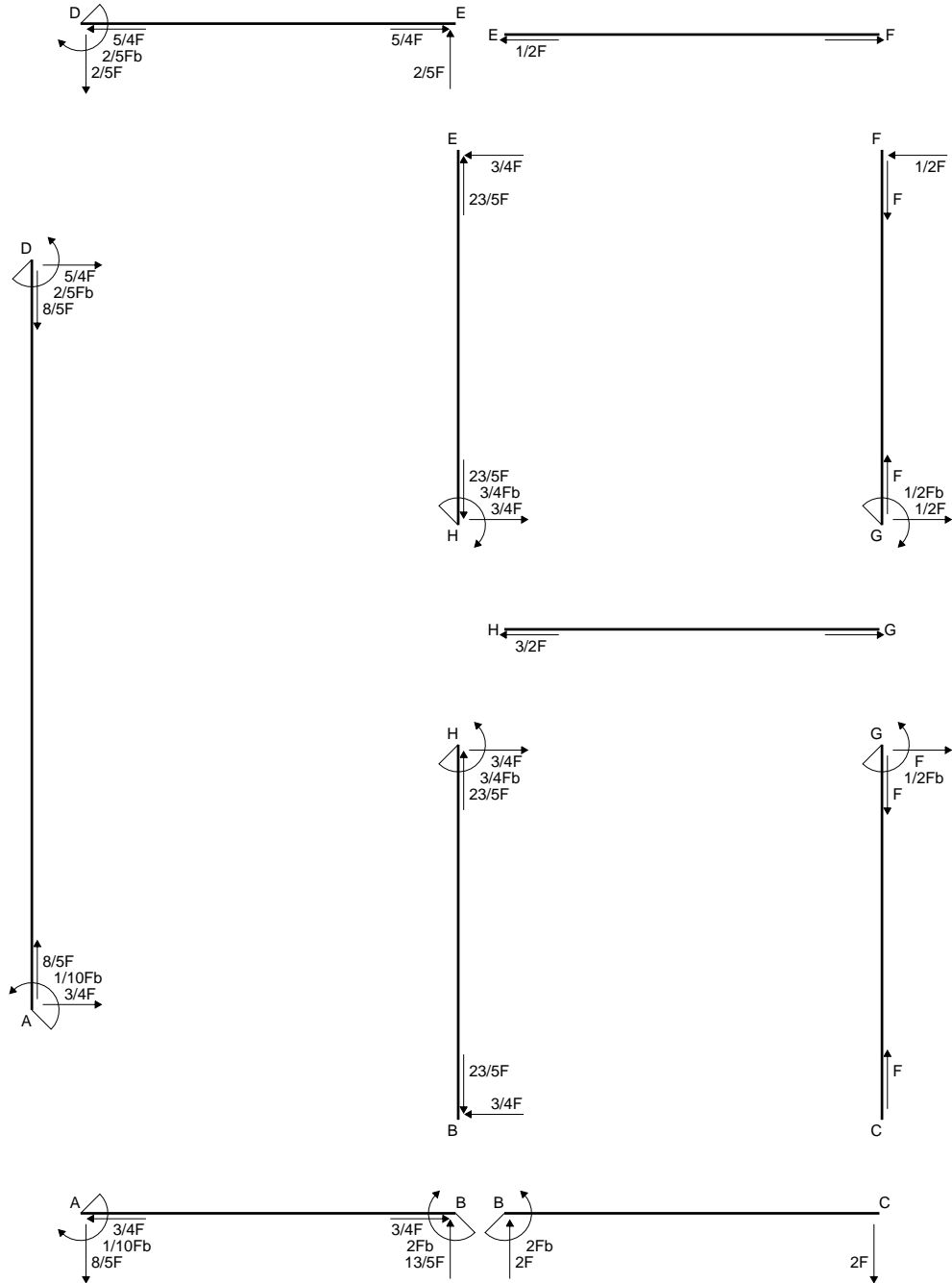
$$= (1/2 b - 1/2 b + 1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$

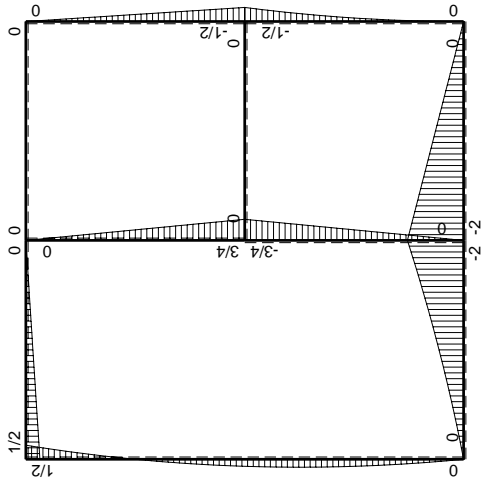
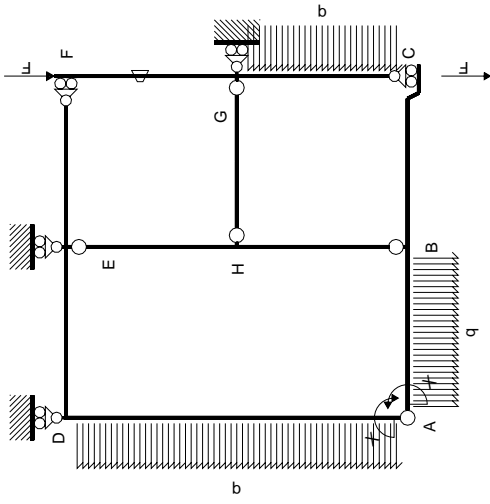
$$L_{ED}^{xo} = \int_0^b (1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$



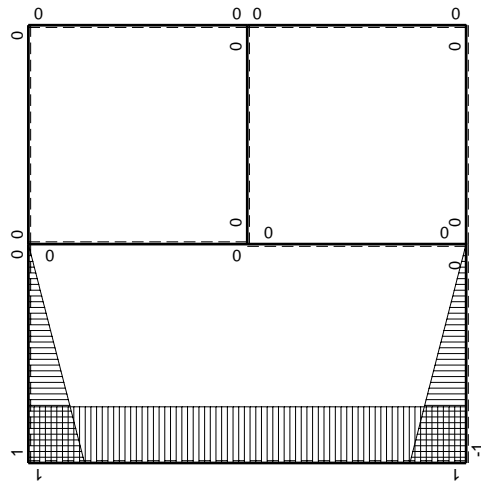
- A = 816. mm<sup>2</sup>
- J<sub>u</sub> = 239746. mm<sup>4</sup>
- J<sub>v</sub> = 77184. mm<sup>4</sup>
- y<sub>g</sub> = 17.68 mm
- T<sub>y</sub> = 1700. N
- M<sub>x</sub> = -1581000. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 9. mm
- v<sub>m</sub> = 36.32 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 239.5 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 43. mm
- v<sub>c</sub> = 25.32 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 166.9 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.801 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 167.2 N/mm<sup>2</sup>
- S = 4063. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJdx$
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0
CB b	0	$2Fx$	0	0	0	0		
AD 2b	1	$-3/4Fx+1/2qx^2$	0	$-3/4Fx+1/2Fx^2/b$	0	1	$(-1/6+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$-1/2Fb+5/4Fx-1/2qx^2$	0	$1/2Fb-5/4Fx+1/2Fx^2/b$	0	1		
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$		
EF b	0	0	0	0	0	0	0+0	0
FE b	0	0	0	0	0	0		
FG b	0	$-1/2Fx$	$-Fb/EJ$	0	0	0	0+0	0
GF b	0	$1/2Fb-1/2Fx$	$Fb/EJ$	0	0	0		
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0
CG b	0	$1/2qx^2$	0	0	0	0		
HG b	0	0	0	0	0	0	0+0	0
GH b	0	0	0	0	0	0		
HB b	0	$-3/4Fb+3/4Fx$	0	0	0	0	0+0	0
BH b	0	$3/4Fx$	0	0	0	0		
HE b	0	$3/4Fb-3/4Fx$	0	0	0	0	0+0	0
EH b	0	$-3/4Fx$	0	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{x_0} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{x_0} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{x_0} = \int_0^{2b} (-3/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-3/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DA}^{x_0} = \int_0^{2b} (1/2 - 5/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

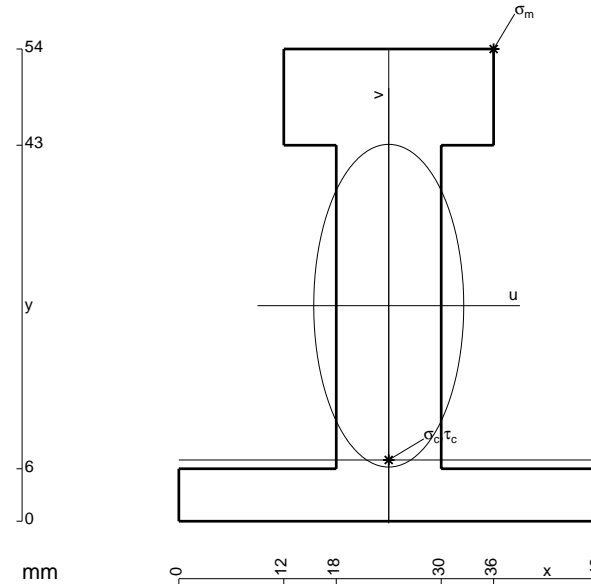
$$= (b - 5/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DE}^{x_0} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/2 b - 1/2 b + 1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$

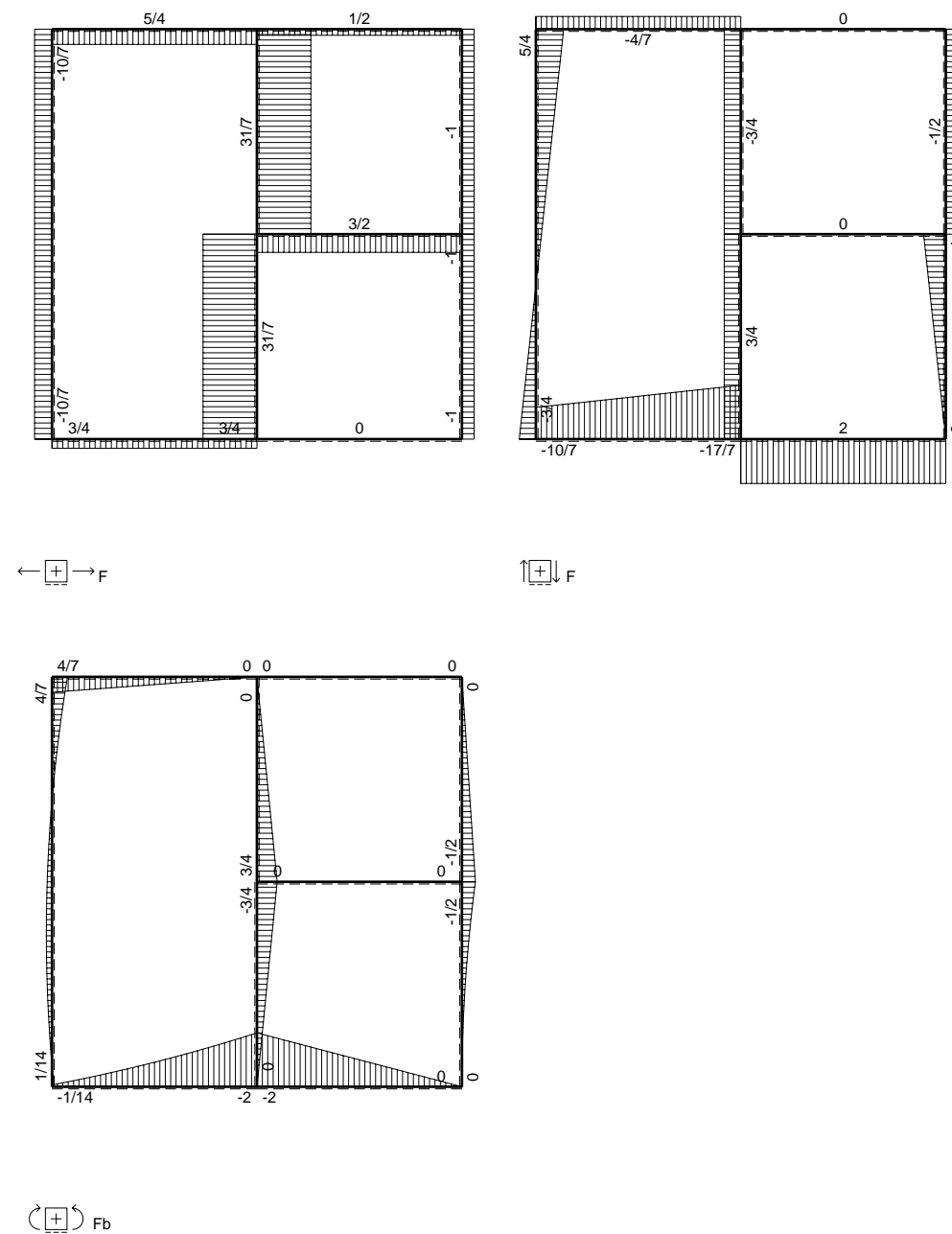
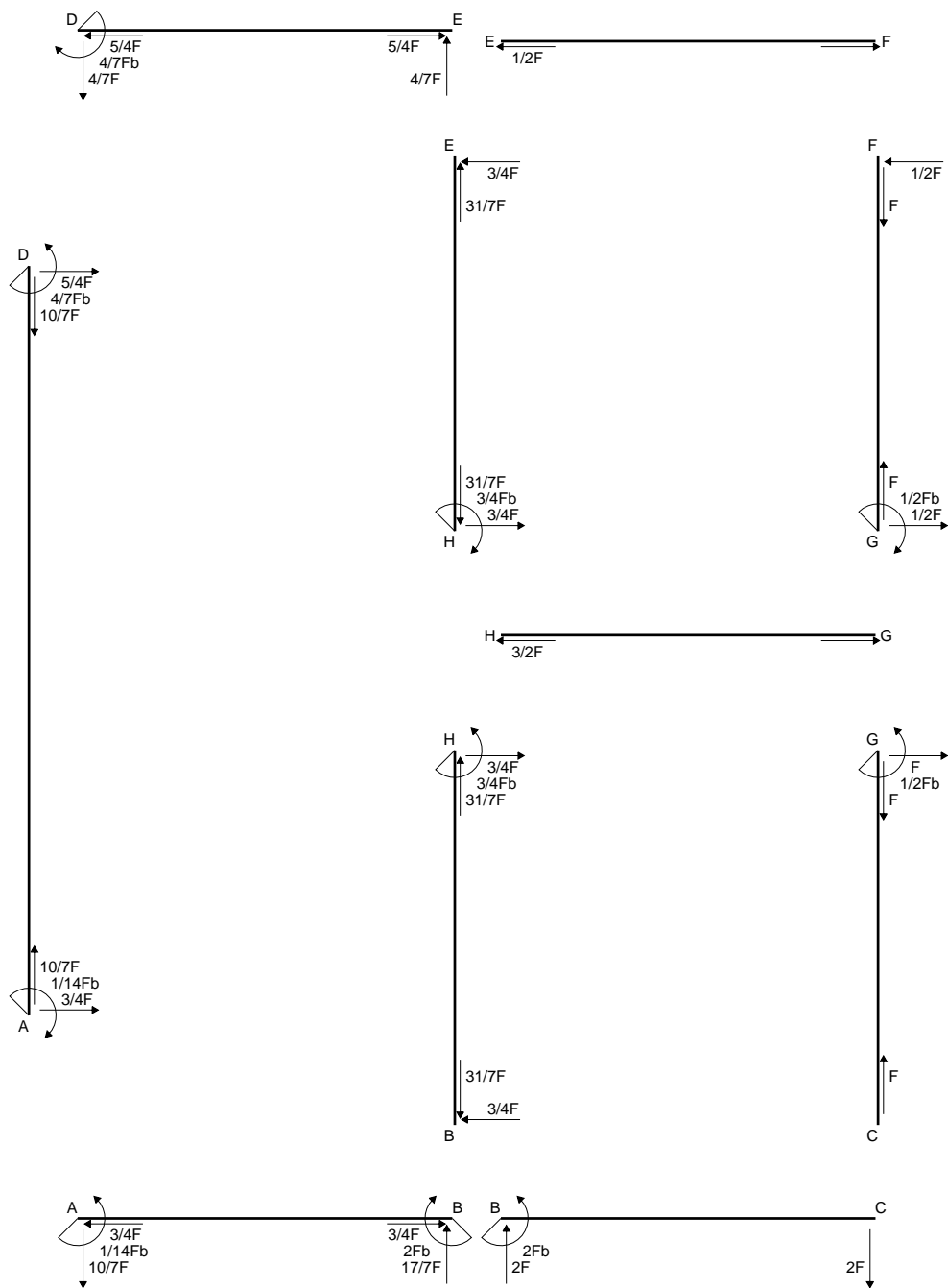
$$L_{ED}^{x_0} = \int_0^b (1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

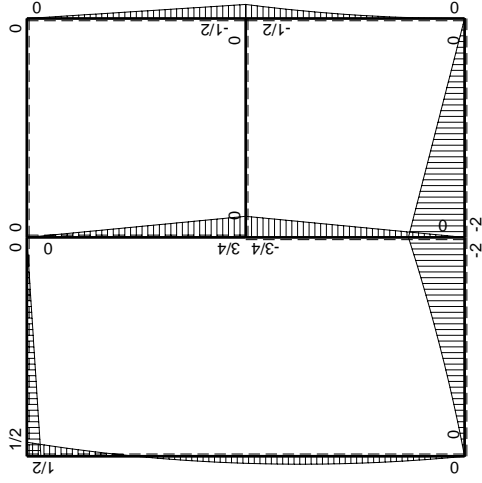
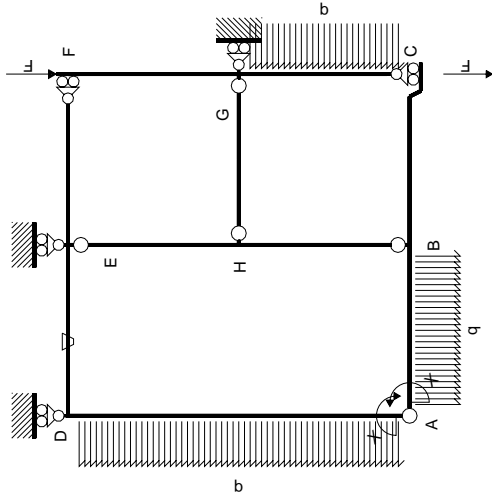
$$= (1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$



- A = 996. mm<sup>2</sup>
- J<sub>u</sub> = 339350. mm<sup>4</sup>
- J<sub>v</sub> = 73296. mm<sup>4</sup>
- y<sub>g</sub> = 24.64 mm
- T<sub>y</sub> = 4700. N
- M<sub>x</sub> = -2303000. Nmm
- x<sub>m</sub> = 36. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 12. mm
- v<sub>m</sub> = 29.36 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 199.2 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 7. mm
- v<sub>c</sub> = -17.64 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -119.7 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.446 N/mm<sup>2</sup>
- σ<sub>σ</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 120.4 N/mm<sup>2</sup>
- S = 6451. mm<sup>3</sup>

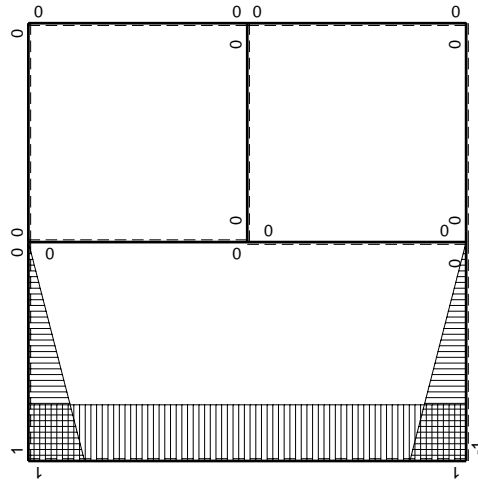






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



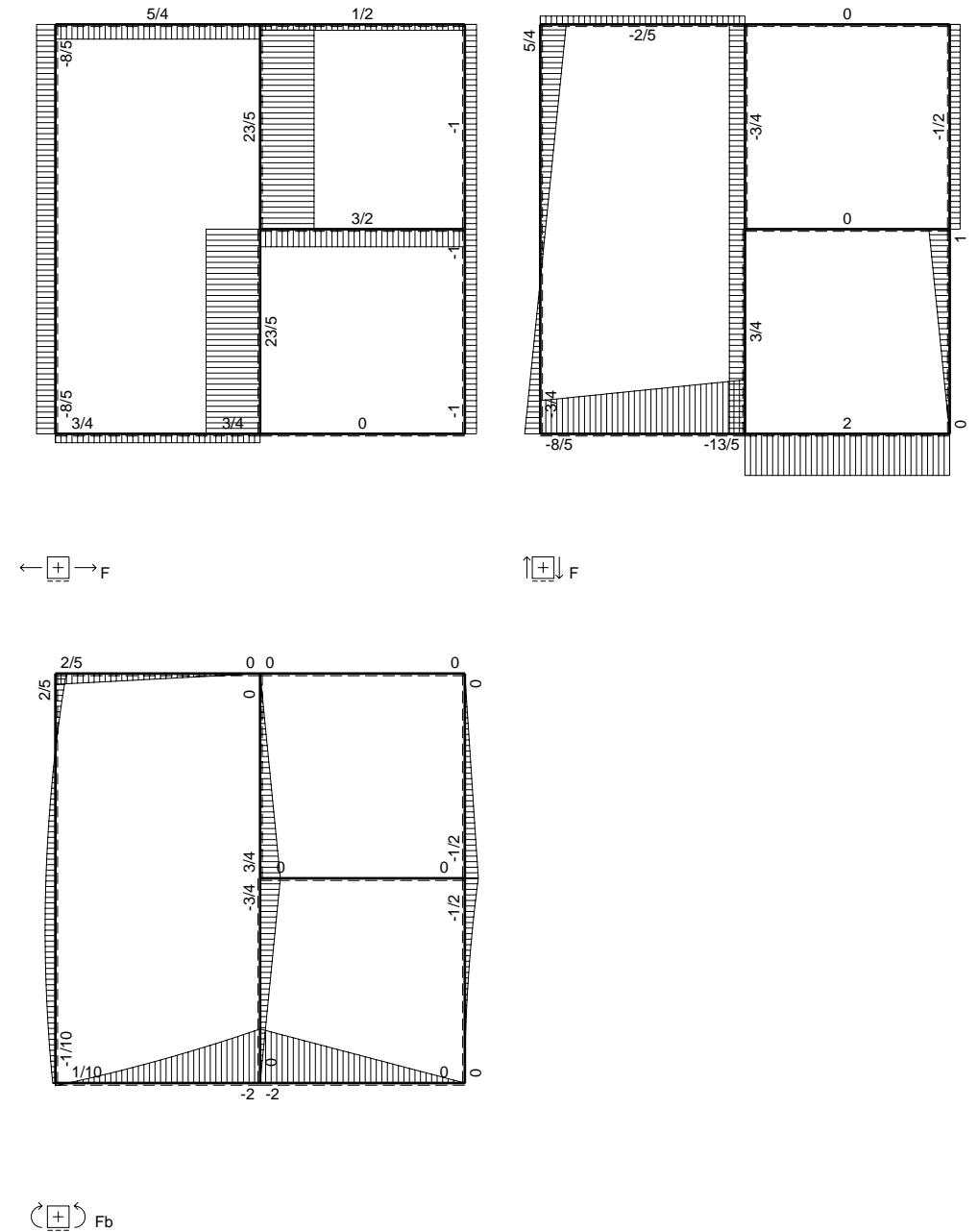
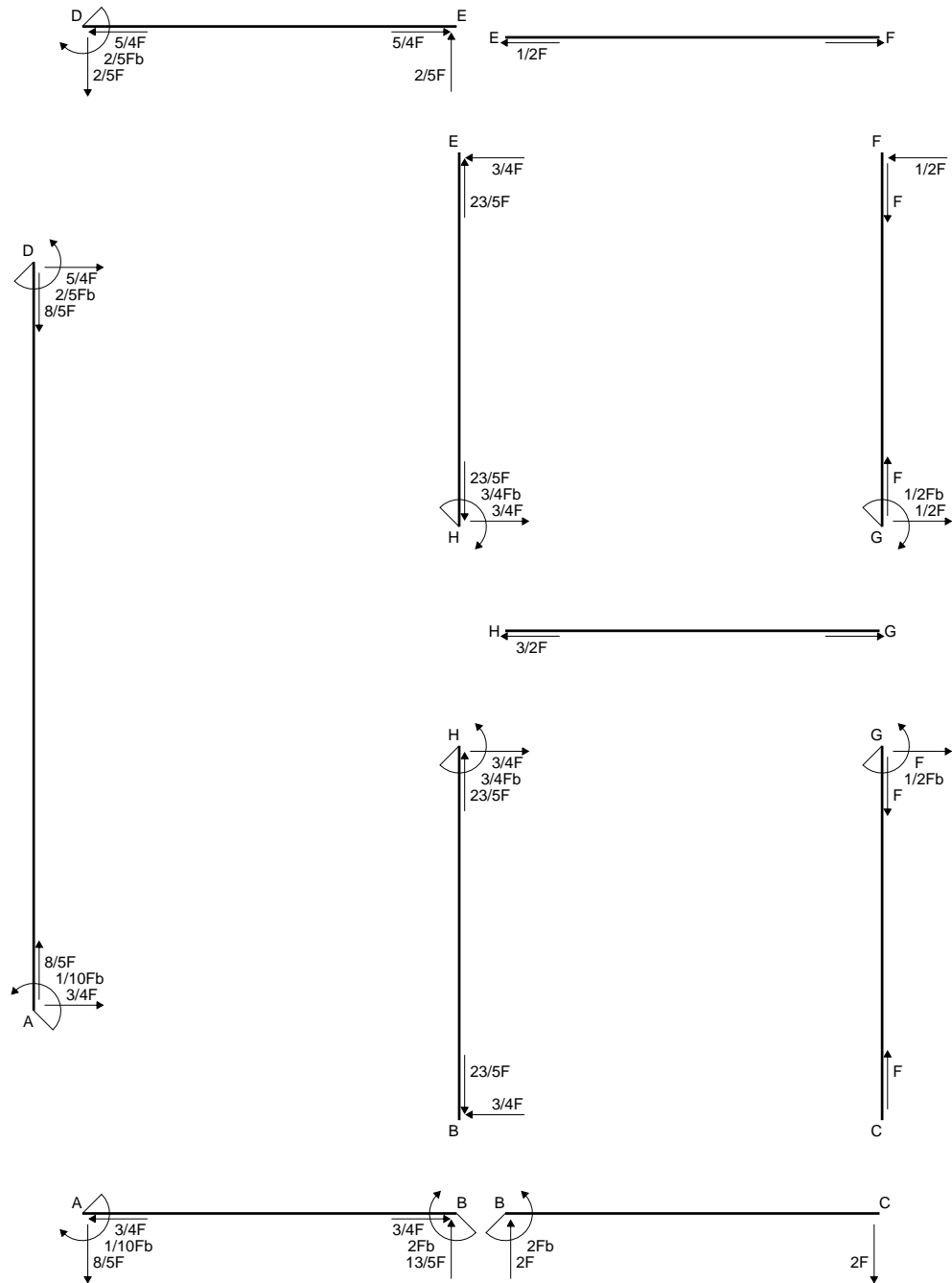
$M_x$  flessione da iperstatica  $X=1$

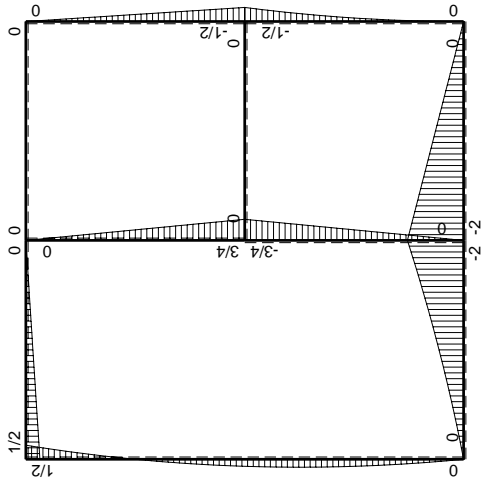
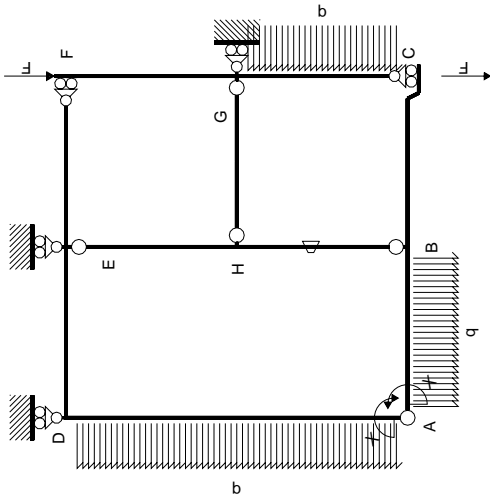
Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJdx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$-3/4Fx+1/2qx^2$	0	$-3/4Fx+1/2Fx^2/b$	0	1	$(-1/6+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+5/4Fx-1/2qx^2$	0	$1/2Fb-5/4Fx+1/2Fx^2/b$	0	1			
DE b	$1-x/b$	$1/2Fb-1/2Fx$	$-Fb/EJ$	$1/2Fb-Fx+1/2Fx^2/b$	$-Fb/EJ+Fx/EJ$	$1-2x/b+x^2/b^2$	$(1/6-1/2)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$-1/2Fx$	$Fb/EJ$	$1/2Fx^2/b$	$-Fx/EJ$	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-3/4Fb+3/4Fx$	0	0	0	0	0+0	0	
BH b	0	$3/4Fx$	0	0	0	0			
HE b	0	$3/4Fb-3/4Fx$	0	0	0	0	0+0	0	
EH b	0	$-3/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$-5/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$1/14Fb$	

Sviluppi di calcolo iperstatica

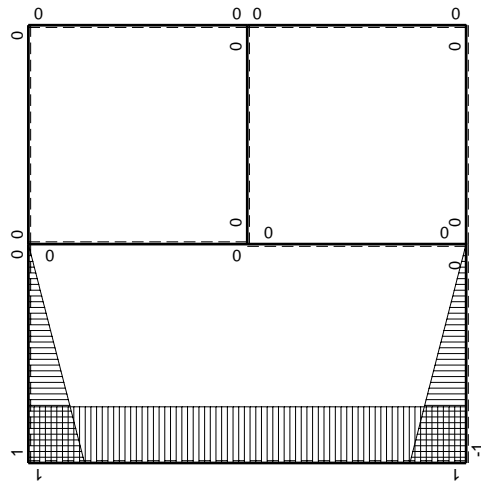






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0
CB b	0	$2Fx$	0	0	0	0		
AD 2b	1	$-3/4Fx+1/2qx^2$	0	$-3/4Fx+1/2Fx^2/b$	0	1	$(-1/6+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$-1/2Fb+5/4Fx-1/2qx^2$	0	$1/2Fb-5/4Fx+1/2Fx^2/b$	0	1		
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$		
EF b	0	0	0	0	0	0	0+0	0
FE b	0	0	0	0	0	0		
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0		
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0
CG b	0	$1/2qx^2$	0	0	0	0		
HG b	0	0	0	0	0	0	0+0	0
GH b	0	0	0	0	0	0		
HB b	0	$-3/4Fb+3/4Fx$	$-Fb/EJ$	0	0	0	0+0	0
BH b	0	$3/4Fx$	$Fb/EJ$	0	0	0		
HE b	0	$3/4Fb-3/4Fx$	0	0	0	0	0+0	0
EH b	0	$-3/4Fx$	0	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ}$$

$$= (b - b + 1/3 b) \frac{1}{EJ} = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx = \left[ 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ}$$

$$= (1/3 b) \frac{1}{EJ} = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-3/4 x/b + 1/2 x^2/b^2) Fb \frac{1}{EJ} dx = \left[ -3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} Fb \frac{1}{EJ}$$

$$= (-3/2 b + 4/3 b) Fb \frac{1}{EJ} = -1/6 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (1/2 - 5/4 x/b + 1/2 x^2/b^2) Fb \frac{1}{EJ} dx = \left[ 1/2 x - 5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} Fb \frac{1}{EJ}$$

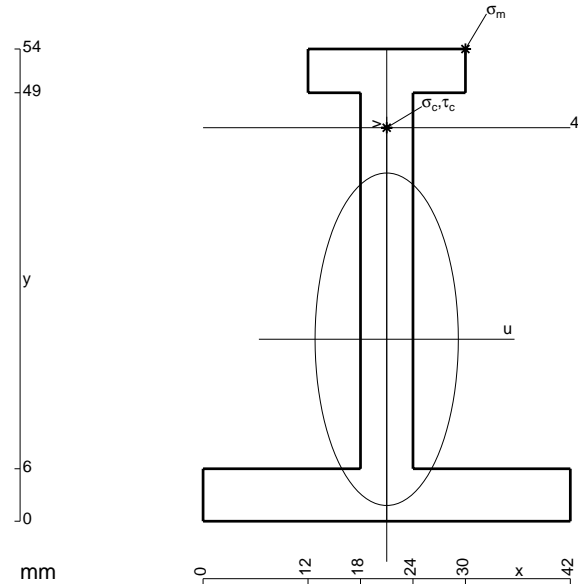
$$= (b - 5/2 b + 4/3 b) Fb \frac{1}{EJ} = -1/6 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) Fb \frac{1}{EJ} dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b Fb \frac{1}{EJ}$$

$$= (1/2 b - 1/2 b + 1/6 b) Fb \frac{1}{EJ} = 1/6 \cdot Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x^2/b^2) Fb \frac{1}{EJ} dx = \left[ 1/6 x^3/b^2 \right]_0^b Fb \frac{1}{EJ}$$

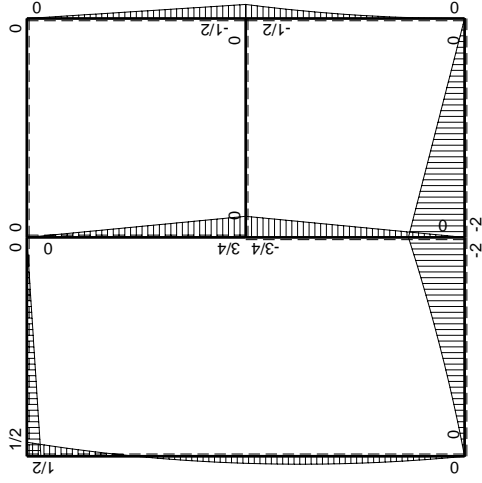
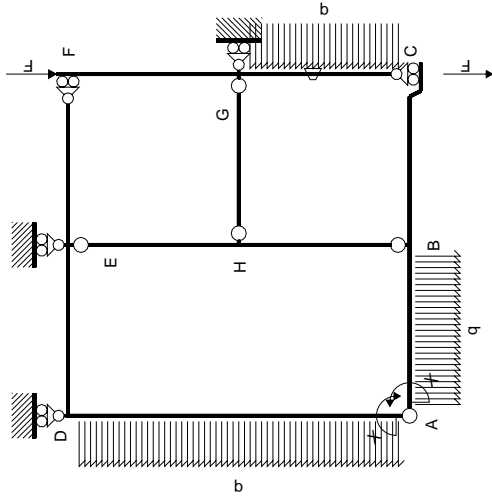
$$= (1/6 b) Fb \frac{1}{EJ} = 1/6 \cdot Fb^2/EJ$$



- A = 600. mm<sup>2</sup>
- J<sub>u</sub> = 216946. mm<sup>4</sup>
- J<sub>v</sub> = 40248. mm<sup>4</sup>
- y<sub>g</sub> = 20.81 mm
- T<sub>y</sub> = 2460. N
- M<sub>x</sub> = -1426800. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 9. mm
- v<sub>m</sub> = 33.19 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 218.3 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 45. mm
- v<sub>c</sub> = 24.19 mm
- σ<sub>c</sub> = -Mv/J<sub>v</sub> = 159.1 N/mm<sup>2</sup>
- τ<sub>c</sub> = 6.408 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 159.5 N/mm<sup>2</sup>
- S = 3391. mm<sup>3</sup>

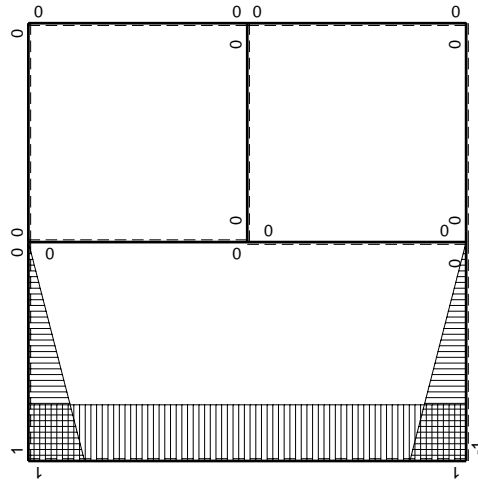






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJdx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$-3/4Fx+1/2qx^2$	0	$-3/4Fx+1/2Fx^2/b$	0	1	$(-1/6+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+5/4Fx-1/2qx^2$	0	$1/2Fb-5/4Fx+1/2Fx^2/b$	0	1			
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	$-Fb/EJ$	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	$Fb/EJ$	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-3/4Fb+3/4Fx$	0	0	0	0	0+0	0	
BH b	0	$3/4Fx$	0	0	0	0			
HE b	0	$3/4Fb-3/4Fx$	0	0	0	0	0+0	0	
EH b	0	$-3/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{x_0} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{x_0} = \int_0^b (2 x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{x_0} = \int_0^{2b} (-3/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-3/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DA}^{x_0} = \int_0^{2b} (1/2 - 5/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

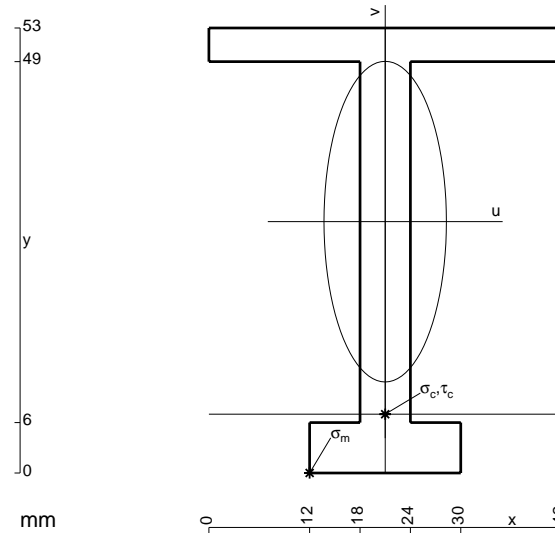
$$= (b - 5/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DE}^{x_0} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

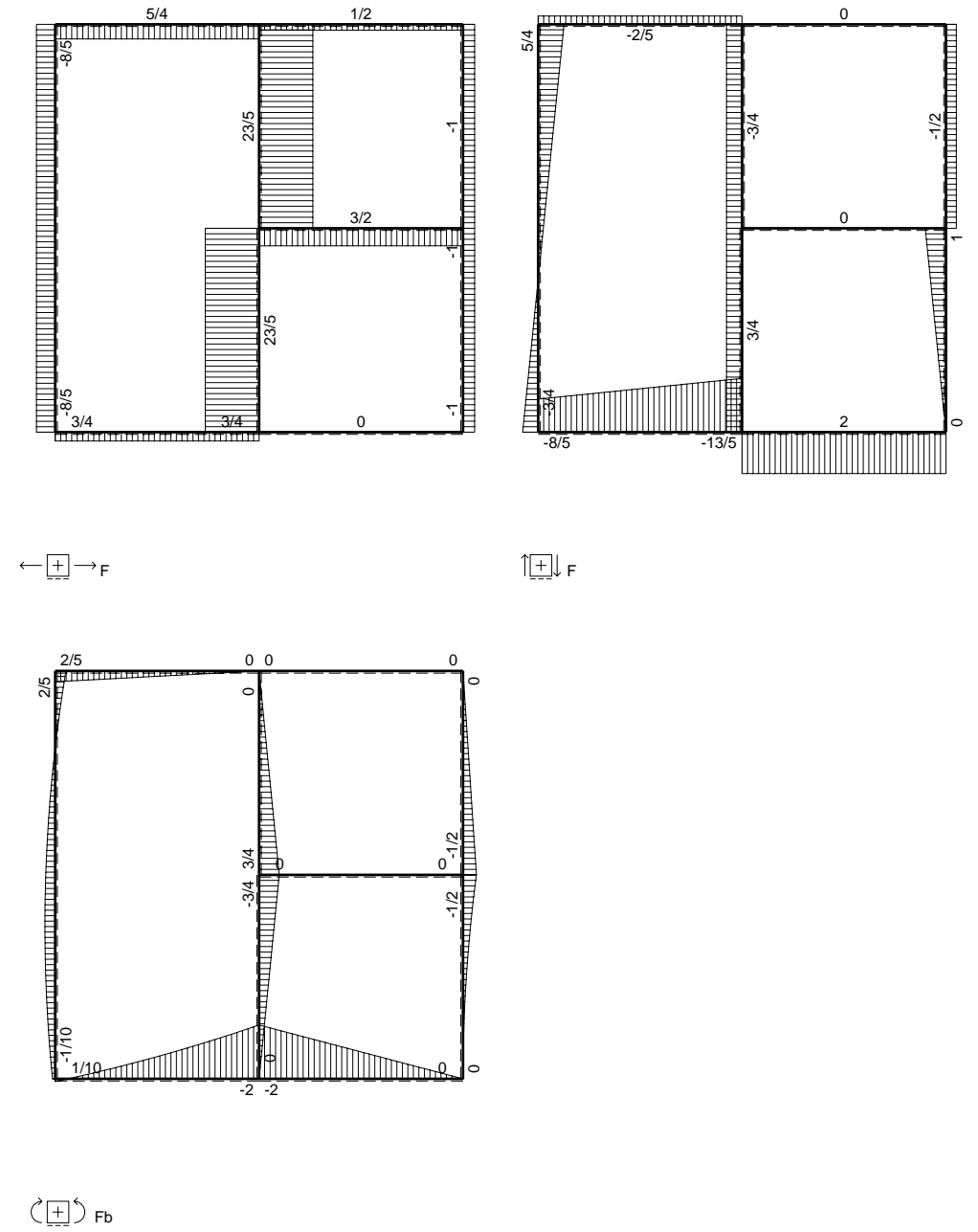
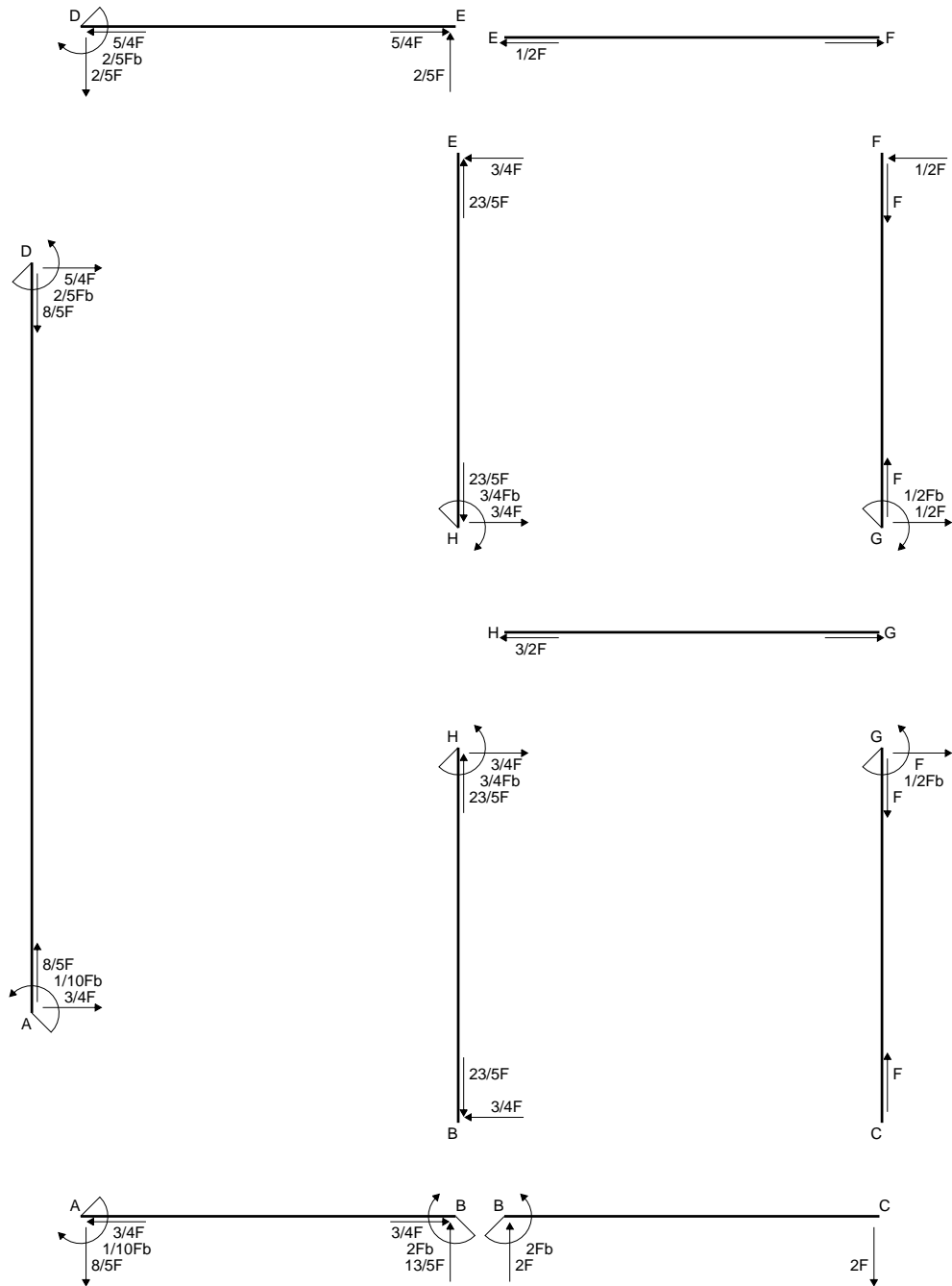
$$= (1/2 b - 1/2 b + 1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$

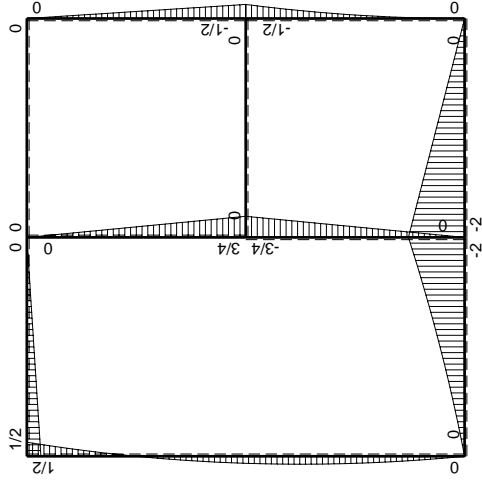
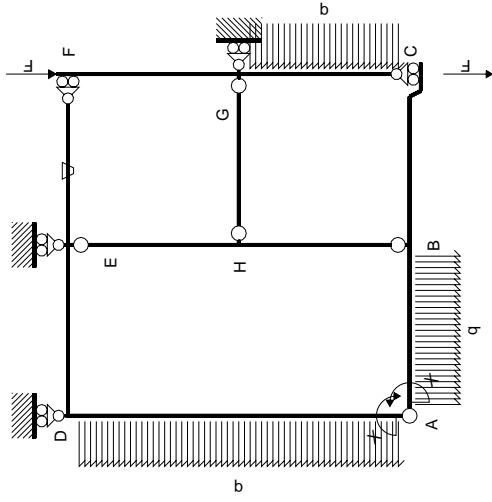
$$L_{ED}^{x_0} = \int_0^b (1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$



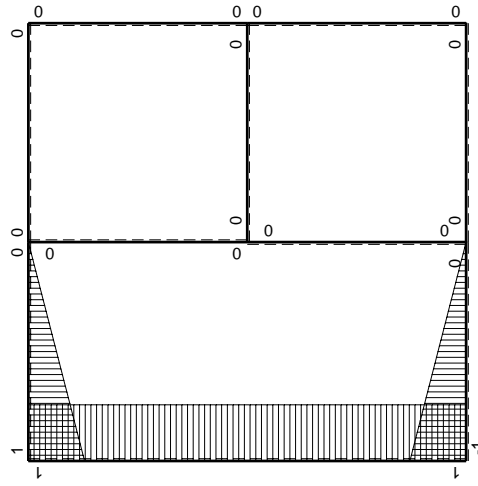
- A = 534. mm<sup>2</sup>
- J<sub>u</sub> = 194732. mm<sup>4</sup>
- J<sub>v</sub> = 28386. mm<sup>4</sup>
- y<sub>g</sub> = 29.94 mm
- T<sub>y</sub> = 2400. N
- M<sub>x</sub> = -1488000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -9. mm
- v<sub>m</sub> = -29.94 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -228.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 7. mm
- v<sub>c</sub> = -22.94 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -175.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 6.265 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 175.6 N/mm<sup>2</sup>
- S = 3050. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJdx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$-3/4Fx+1/2qx^2$	0	$-3/4Fx+1/2Fx^2/b$	0	1	$(-1/6+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$-1/2Fb+5/4Fx-1/2qx^2$	0	$1/2Fb-5/4Fx+1/2Fx^2/b$	0	1			
DE b	$1-x/b$	$1/2Fb-1/2Fx$	0	$1/2Fb-Fx+1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(1/6+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$-1/2Fx$	0	$1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
FE b	0	0	$Fb/EJ$	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-3/4Fb+3/4Fx$	0	0	0	0	0+0	0	
BH b	0	$3/4Fx$	0	0	0	0			
HE b	0	$3/4Fb-3/4Fx$	0	0	0	0	0+0	0	
EH b	0	$-3/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{x_0} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{x_0} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{x_0} = \int_0^{2b} (-3/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-3/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DA}^{x_0} = \int_0^{2b} (1/2 - 5/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

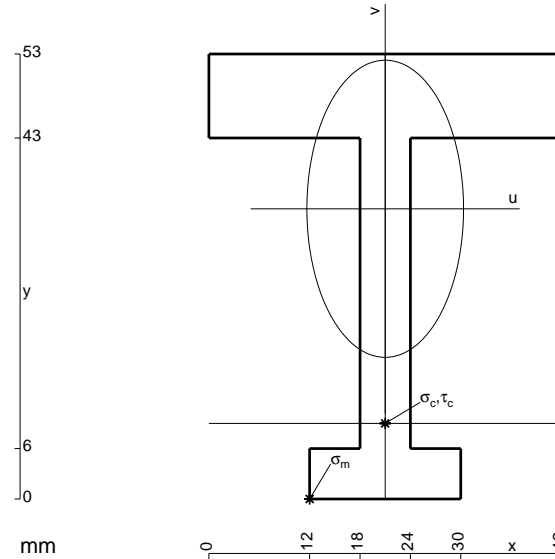
$$= (b - 5/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{DE}^{x_0} = \int_0^b (1/2 - x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/2 x - 1/2 x^2/b + 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (1/2 b - 1/2 b + 1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$

$$L_{ED}^{x_0} = \int_0^b (1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

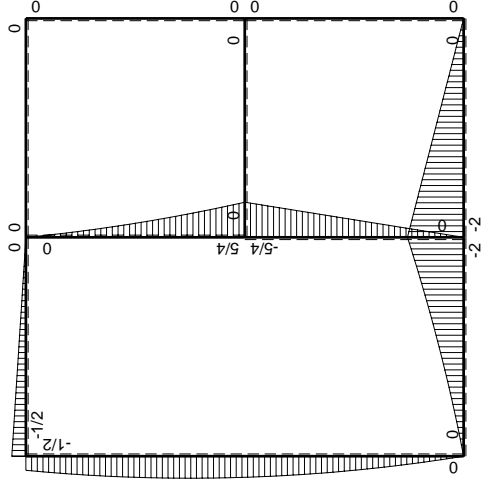
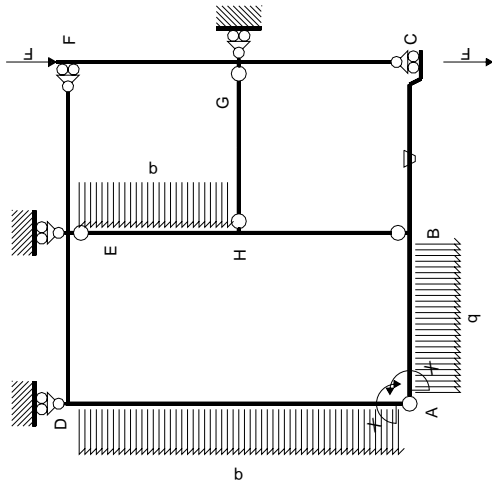
$$= (1/6 b) \cdot Fb \cdot 1/EJ = 1/6 \cdot Fb^2/EJ$$



- A = 750. mm<sup>2</sup>
- J<sub>u</sub> = 235055. mm<sup>4</sup>
- J<sub>v</sub> = 65322. mm<sup>4</sup>
- y<sub>g</sub> = 34.56 mm
- T<sub>y</sub> = 2420. N
- M<sub>x</sub> = -1621400. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -9. mm
- v<sub>m</sub> = -34.56 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -238.4 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 9. mm
- v<sub>c</sub> = -25.56 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -176.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 6.685 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 176.7 N/mm<sup>2</sup>
- S = 3896. mm<sup>3</sup>

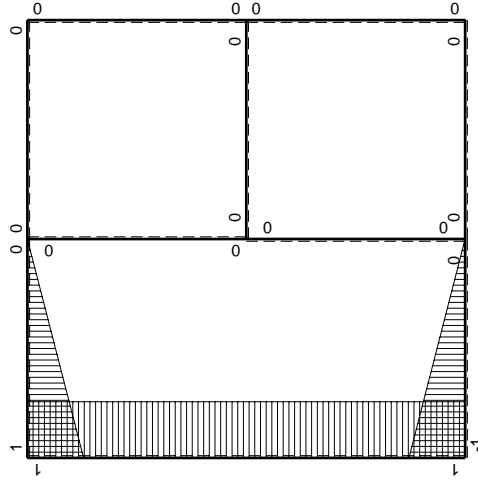






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_1$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-2Fb+2Fx$	$-Fb/EJ$	0	0	0	0+0	0
CB b	0	$2Fx$	$Fb/EJ$	0	0	0		
AD 2b	1	$-5/4Fx+1/2qx^2$	0	$-5/4Fx+1/2Fx^2/b$	0	1	$(-7/6+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$1/2Fb+3/4Fx-1/2qx^2$	0	$-1/2Fb-3/4Fx+1/2Fx^2/b$	0	1		
DE b	$1-x/b$	$-1/2Fb+1/2Fx$	0	$-1/2Fb+Fx-1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$1/2Fx$	0	$-1/2Fx^2/b$	0	$x^2/b^2$		
EF b	0	0	0	0	0	0	0+0	0
FE b	0	0	0	0	0	0		
FG b	0	0	0	0	0	0	0+0	0
GF b	0	0	0	0	0	0		
GC b	0	0	0	0	0	0	0+0	0
CG b	0	0	0	0	0	0		
HG b	0	0	0	0	0	0	0+0	0
GH b	0	0	0	0	0	0		
HB b	0	$-5/4Fb+5/4Fx$	0	0	0	0	0+0	0
BH b	0	$5/4Fx$	0	0	0	0		
HE b	0	$5/4Fb-7/4Fx+1/2qx^2$	0	0	0	0	0+0	0
EH b	0	$-3/4Fx-1/2qx^2$	0	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$-25/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$5/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx + 1 \cdot 1/4 \cdot b/EJ = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx + 1 \cdot 1/4 \cdot b/EJ = [1/3 x^3/b^2]_0^b 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= [3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) Fb 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= [x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) Fb 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-5/4 x/b + 1/2 x^2/b^2) Fb 1/EJ dx = [-5/8 x^2/b + 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-5/2 b + 4/3 b) Fb 1/EJ = -7/6 Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (-1/2 - 3/4 x/b + 1/2 x^2/b^2) Fb 1/EJ dx = [-1/2 x - 3/8 x^2/b + 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

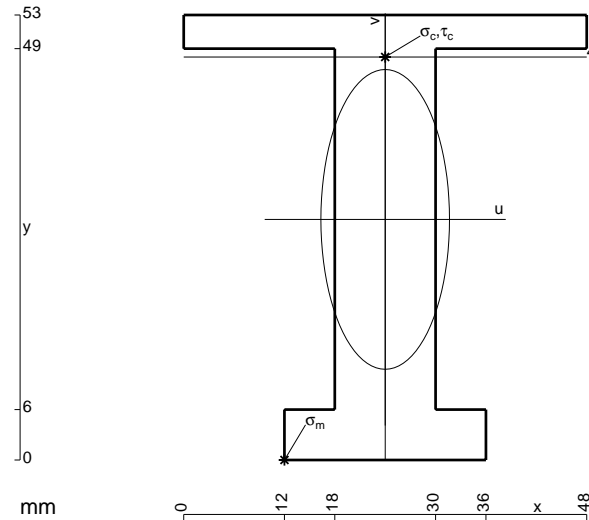
$$= (-b - 3/2 b + 4/3 b) Fb 1/EJ = -7/6 Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

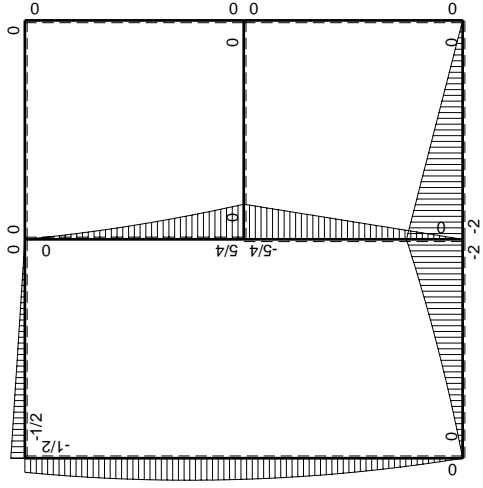
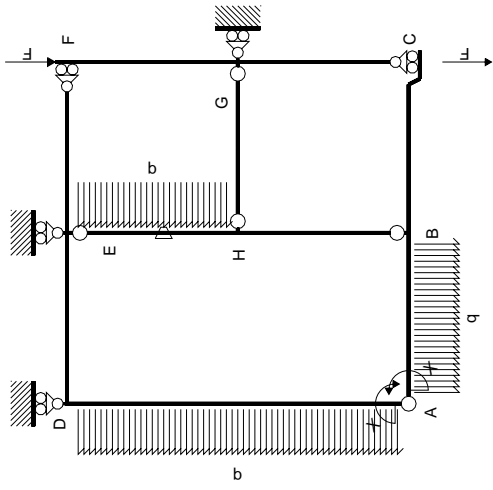
$$L_{ED}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$



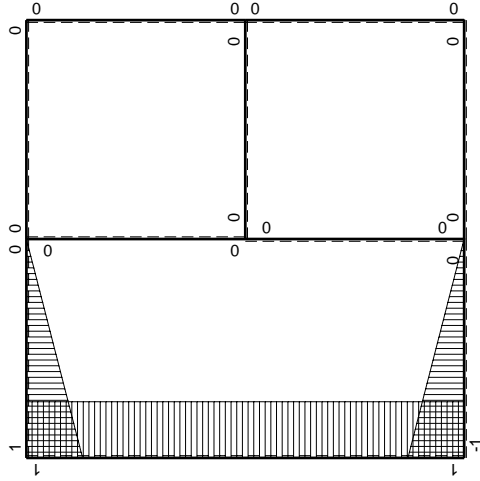
- A = 852. mm<sup>2</sup>
- J<sub>u</sub> = 271527. mm<sup>4</sup>
- J<sub>v</sub> = 49968. mm<sup>4</sup>
- y<sub>g</sub> = 28.65 mm
- T<sub>y</sub> = 2620. N
- M<sub>x</sub> = -1886400. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -12. mm
- v<sub>m</sub> = -28.65 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -199.1 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 48. mm
- v<sub>c</sub> = 19.35 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 134.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.641 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 134.5 N/mm<sup>2</sup>
- S = 4528. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_1$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0
CB b	0	$2Fx$	0	0	0	0		
AD 2b	1	$-5/4Fx+1/2qx^2$	0	$-5/4Fx+1/2Fx^2/b$	0	1	$(-7/6+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$1/2Fb+3/4Fx-1/2qx^2$	0	$-1/2Fb-3/4Fx+1/2Fx^2/b$	0	1		
DE b	$1-x/b$	$-1/2Fb+1/2Fx$	0	$-1/2Fb+Fx-1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$1/2Fx$	0	$-1/2Fx^2/b$	0	$x^2/b^2$		
EF b	0	0	0	0	0	0	0+0	0
FE b	0	0	0	0	0	0		
FG b	0	0	0	0	0	0	0+0	0
GF b	0	0	0	0	0	0		
GC b	0	0	0	0	0	0	0+0	0
CG b	0	0	0	0	0	0		
HG b	0	0	0	0	0	0	0+0	0
GH b	0	0	0	0	0	0		
HB b	0	$-5/4Fb+5/4Fx$	0	0	0	0	0+0	0
BH b	0	$5/4Fx$	0	0	0	0		
HE b	0	$5/4Fb-7/4Fx+1/2qx^2$	$-Fb/EJ$	0	0	0	0+0	0
EH b	0	$-3/4Fx-1/2qx^2$	$Fb/EJ$	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$-25/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$5/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-5/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-5/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -7/6 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (-1/2 - 3/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x - 3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

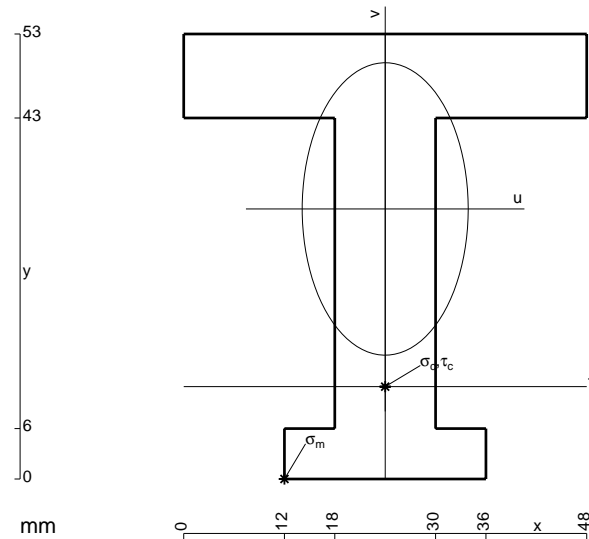
$$= (-b - 3/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -7/6 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x + 1/2 x^2/b - 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

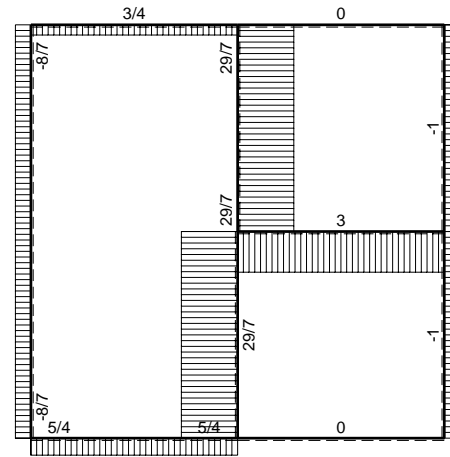
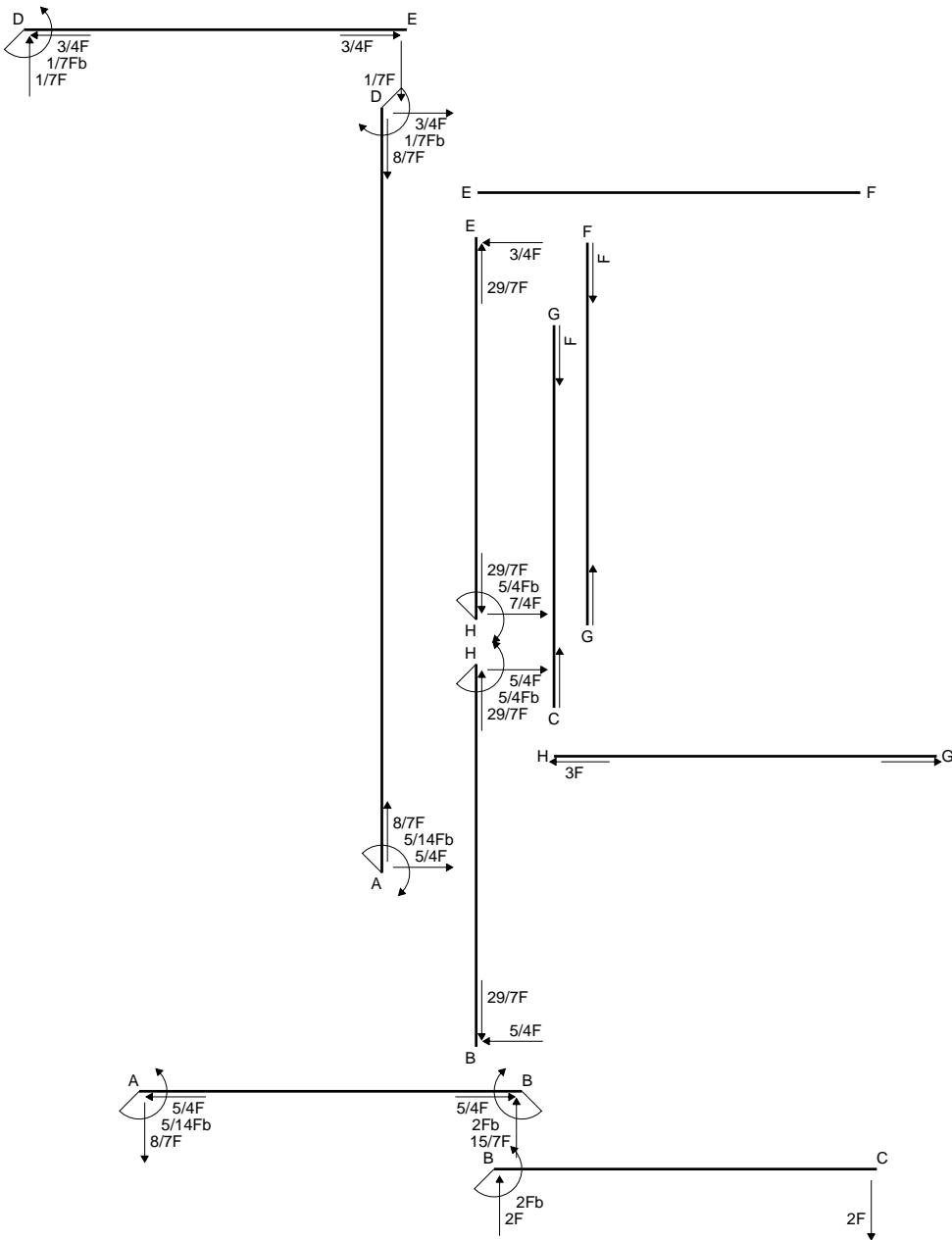
$$L_{ED}^{xo} = \int_0^b (-1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/6 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

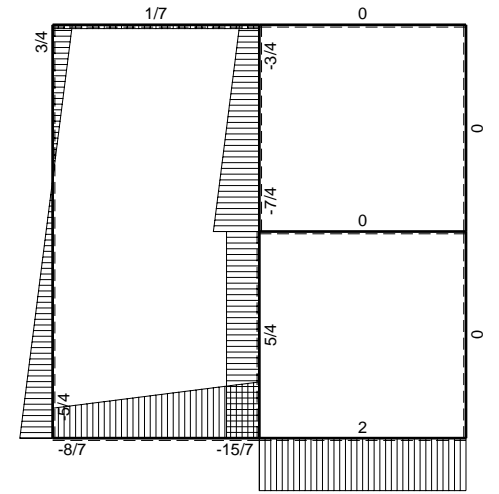


- A = 1068. mm<sup>2</sup>
- J<sub>u</sub> = 324016. mm<sup>4</sup>
- J<sub>v</sub> = 104400. mm<sup>4</sup>
- y<sub>g</sub> = 32.16 mm
- T<sub>y</sub> = 2780. N
- M<sub>x</sub> = -2112800. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -12. mm
- v<sub>m</sub> = -32.16 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -209.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 11. mm
- v<sub>c</sub> = -21.16 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -138. N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.018 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 138.2 N/mm<sup>2</sup>
- S = 5619. mm<sup>3</sup>

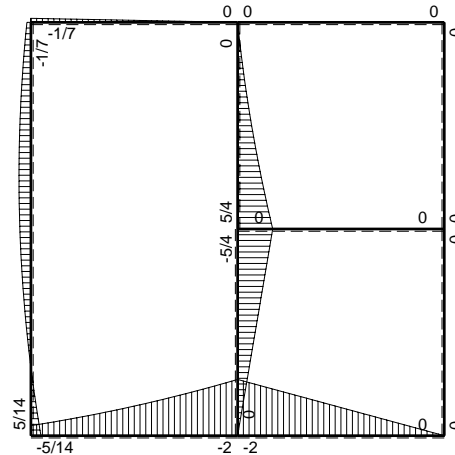




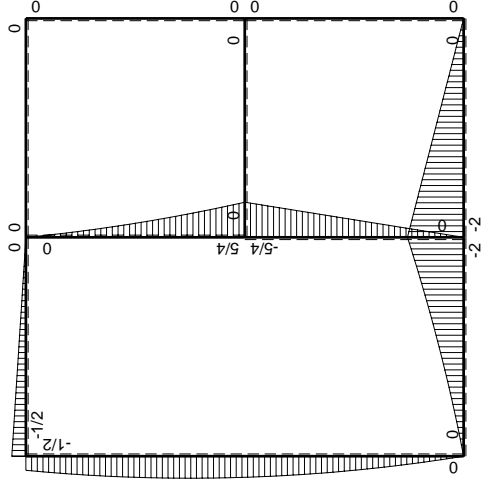
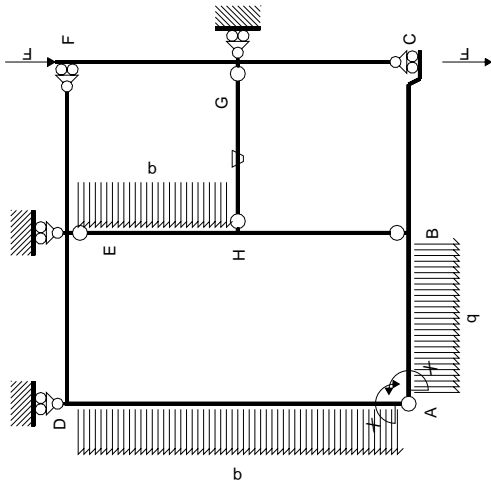
← ⊕ → F



↑ ⊕ ↓ F

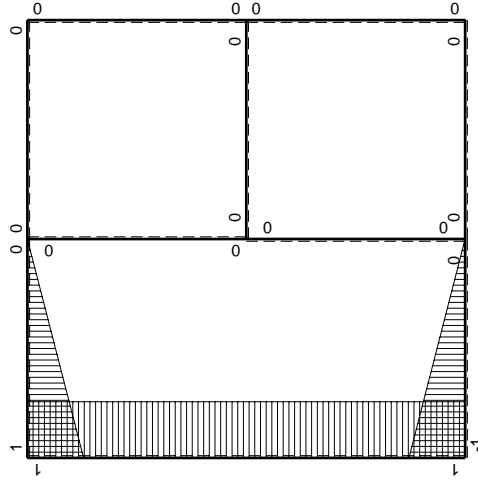


⊕ ⊖ Fb



Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_1$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0
CB b	0	$2Fx$	0	0	0	0		
AD 2b	1	$-5/4Fx+1/2qx^2$	0	$-5/4Fx+1/2Fx^2/b$	0	1	$(-7/6+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$1/2Fb+3/4Fx-1/2qx^2$	0	$-1/2Fb-3/4Fx+1/2Fx^2/b$	0	1		
DE b	$1-x/b$	$-1/2Fb+1/2Fx$	0	$-1/2Fb+Fx-1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$1/2Fx$	0	$-1/2Fx^2/b$	0	$x^2/b^2$		
EF b	0	0	0	0	0	0	0+0	0
FE b	0	0	0	0	0	0		
FG b	0	0	0	0	0	0	0+0	0
GF b	0	0	0	0	0	0		
GC b	0	0	0	0	0	0	0+0	0
CG b	0	0	0	0	0	0		
HG b	0	0	$-Fb/EJ$	0	0	0	0+0	0
GH b	0	0	$Fb/EJ$	0	0	0		
HB b	0	$-5/4Fb+5/4Fx$	0	0	0	0	0+0	0
BH b	0	$5/4Fx$	0	0	0	0		
HE b	0	$5/4Fb-7/4Fx+1/2qx^2$	0	0	0	0	0+0	0
EH b	0	$-3/4Fx-1/2qx^2$	0	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$-25/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$5/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{x_0} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{x_0} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{x_0} = \int_0^{2b} (-5/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-5/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -7/6 \cdot Fb^2/EJ$$

$$L_{DA}^{x_0} = \int_0^{2b} (-1/2 - 3/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x - 3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

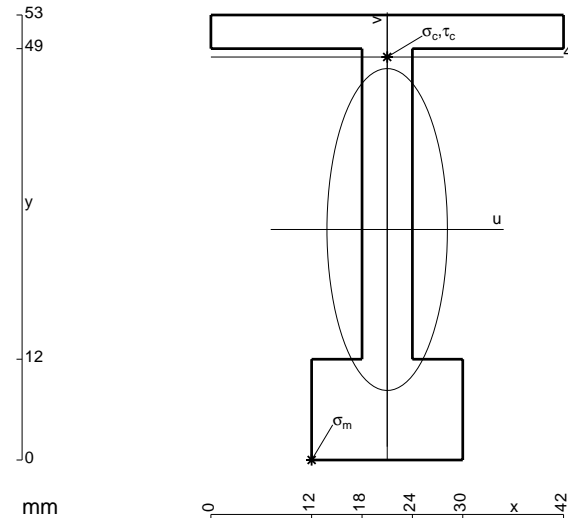
$$= (-b - 3/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -7/6 \cdot Fb^2/EJ$$

$$L_{DE}^{x_0} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x + 1/2 x^2/b - 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

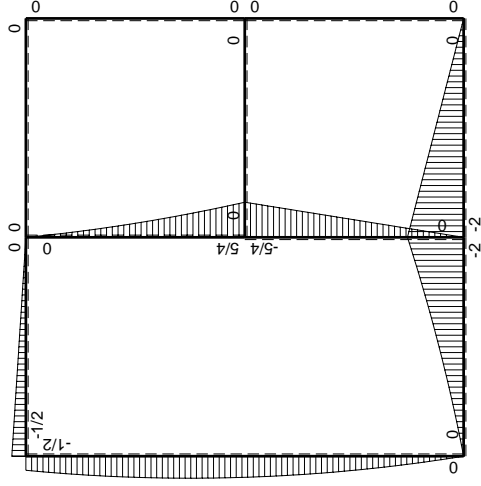
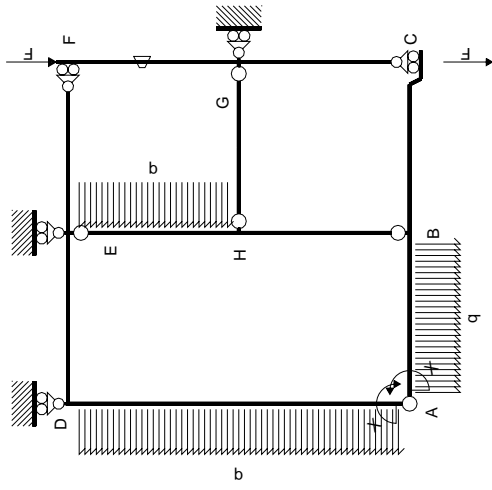
$$L_{ED}^{x_0} = \int_0^b (-1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/6 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$



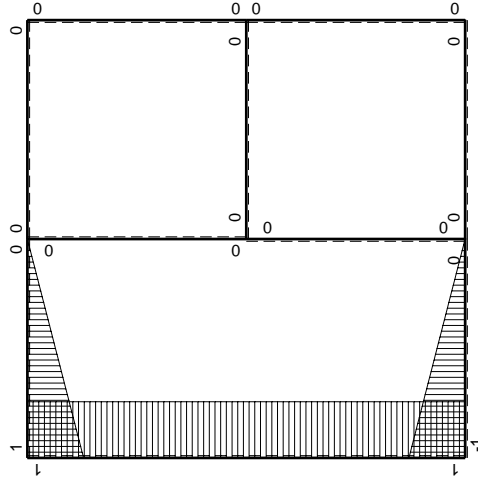
- A = 606. mm<sup>2</sup>
- J<sub>u</sub> = 222763. mm<sup>4</sup>
- J<sub>v</sub> = 31194. mm<sup>4</sup>
- y<sub>g</sub> = 27.45 mm
- T<sub>y</sub> = 2200. N
- M<sub>x</sub> = -1782000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -9. mm
- v<sub>m</sub> = -27.45 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -219.6 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 48. mm
- v<sub>c</sub> = 20.55 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 164.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 6.72 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 164.8 N/mm<sup>2</sup>
- S = 4083. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_1$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$-5/4Fx+1/2qx^2$	0	$-5/4Fx+1/2Fx^2/b$	0	1	$(-7/6+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$1/2Fb+3/4Fx-1/2qx^2$	0	$-1/2Fb-3/4Fx+1/2Fx^2/b$	0	1			
DE b	$1-x/b$	$-1/2Fb+1/2Fx$	0	$-1/2Fb+Fx-1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-1/6+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fx$	0	$-1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
GF b	0	0	$Fb/EJ$	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-5/4Fb+5/4Fx$	0	0	0	0	0+0	0	
BH b	0	$5/4Fx$	0	0	0	0			
HE b	0	$5/4Fb-7/4Fx+1/2qx^2$	0	0	0	0	0+0	0	
EH b	0	$-3/4Fx-1/2qx^2$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$-25/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$5/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) 1/EJ dx = \left[ x \right]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) 1/EJ dx = \left[ x \right]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = \left[ 1/3 x^3/b^2 \right]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{AB}^{x_0} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b Fb 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) Fb 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 Fb^2/EJ$$

$$L_{BA}^{x_0} = \int_0^b (2 x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b Fb 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) Fb 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 Fb^2/EJ$$

$$L_{AD}^{x_0} = \int_0^{2b} (-5/4 x/b + 1/2 x^2/b^2) Fb 1/EJ dx = \left[ -5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} Fb 1/EJ$$

$$= (-5/2 b + 4/3 b) Fb 1/EJ = -7/6 Fb^2/EJ$$

$$L_{DA}^{x_0} = \int_0^{2b} (-1/2 - 3/4 x/b + 1/2 x^2/b^2) Fb 1/EJ dx = \left[ -1/2 x - 3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} Fb 1/EJ$$

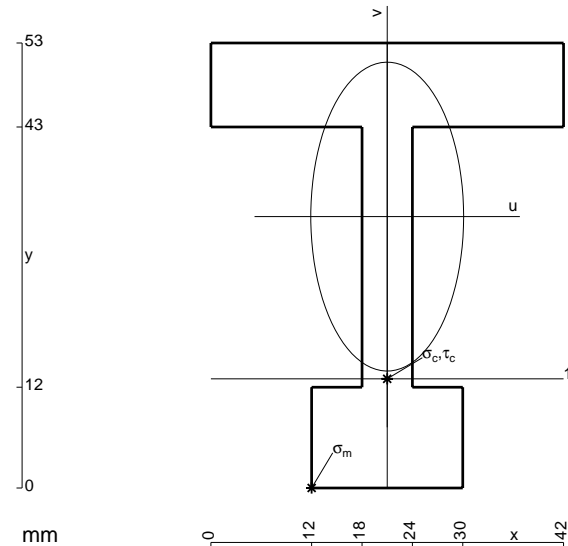
$$= (-b - 3/2 b + 4/3 b) Fb 1/EJ = -7/6 Fb^2/EJ$$

$$L_{DE}^{x_0} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx = \left[ -1/2 x + 1/2 x^2/b - 1/6 x^3/b^2 \right]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

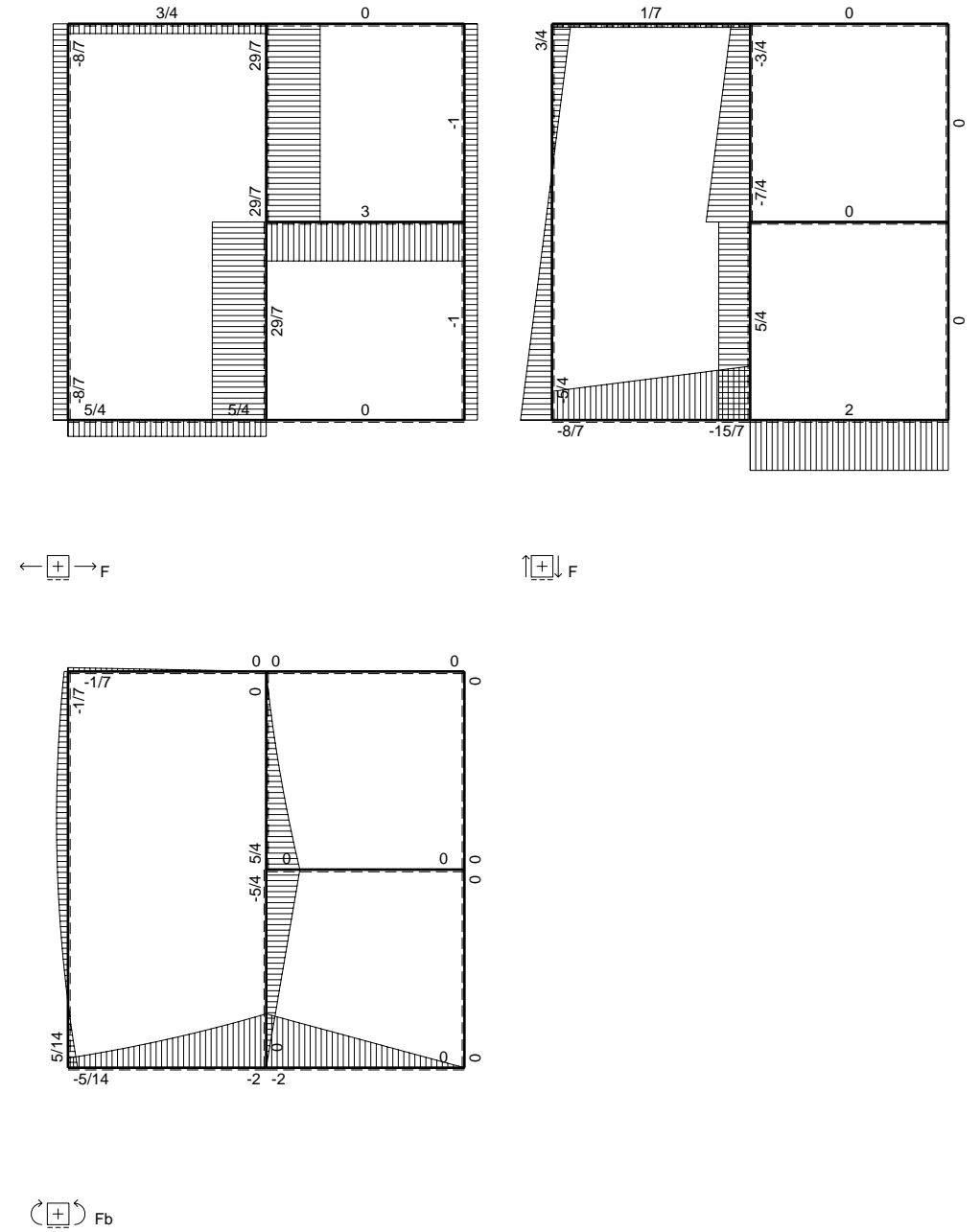
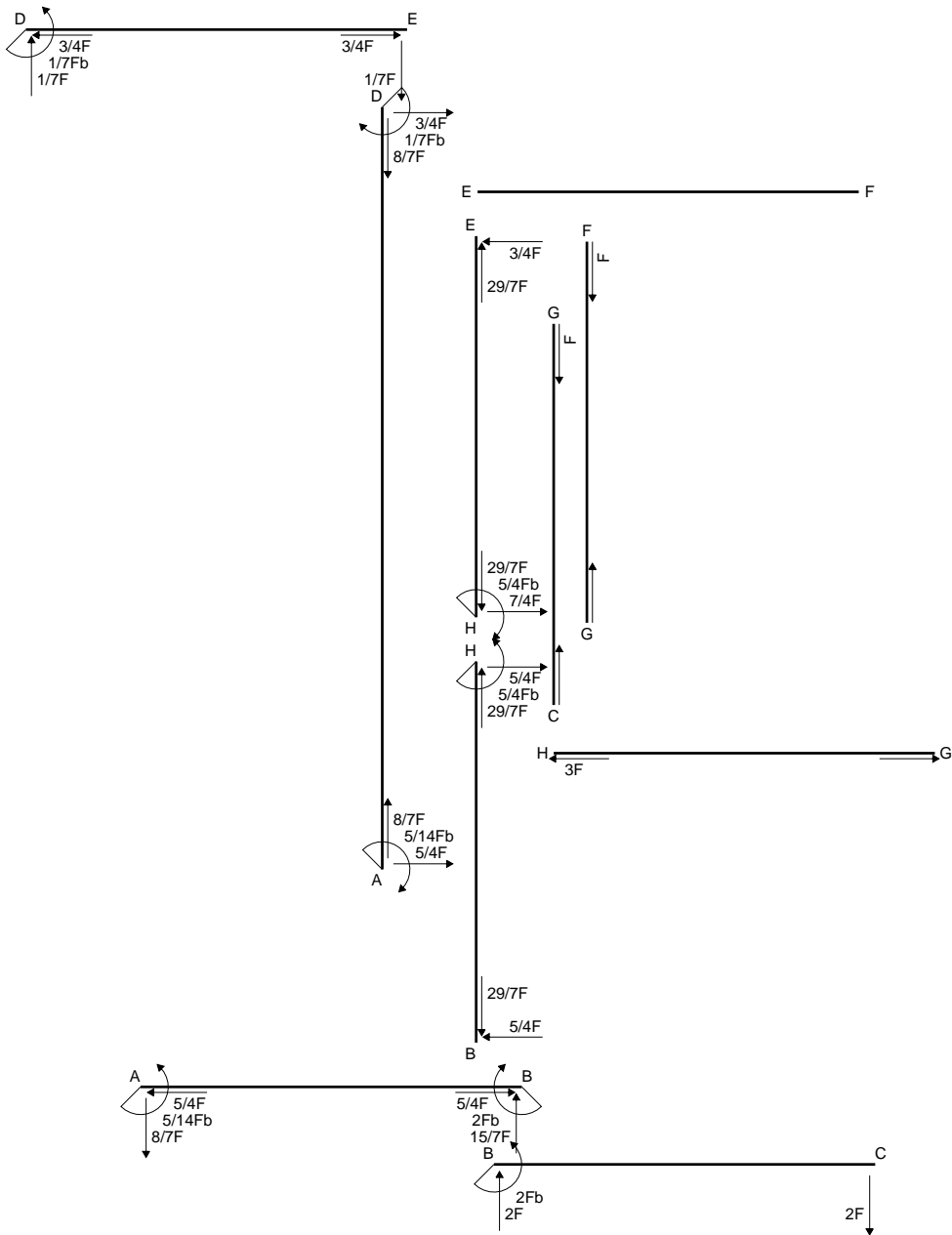
$$L_{ED}^{x_0} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx = \left[ -1/6 x^3/b^2 \right]_0^b Fb 1/EJ$$

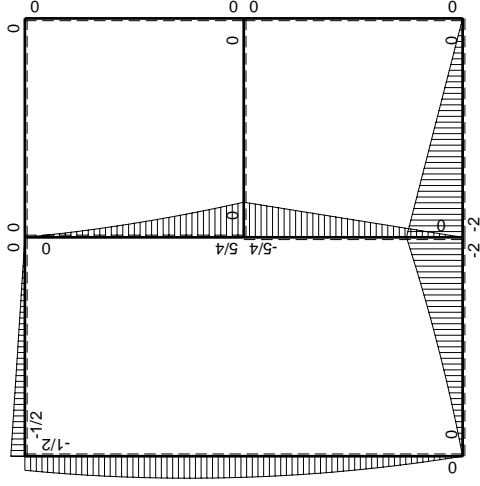
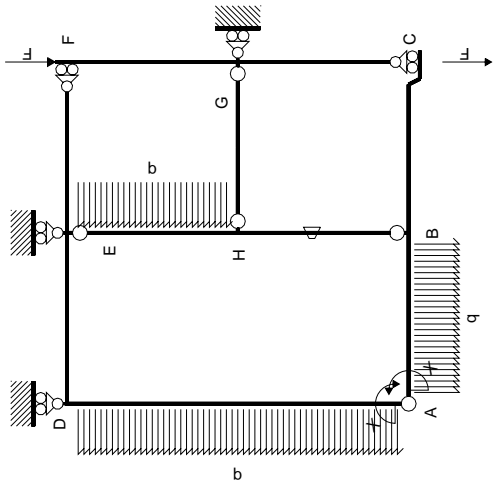
$$= (-1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$



- A = 822. mm<sup>2</sup>
- J<sub>u</sub> = 278203. mm<sup>4</sup>
- J<sub>v</sub> = 68130. mm<sup>4</sup>
- y<sub>g</sub> = 32.32 mm
- T<sub>y</sub> = 2300. N
- M<sub>x</sub> = -1978000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -9. mm
- v<sub>m</sub> = -32.32 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -229.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 13. mm
- v<sub>c</sub> = -19.32 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -137.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.999 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 138.1 N/mm<sup>2</sup>
- S = 5805. mm<sup>3</sup>

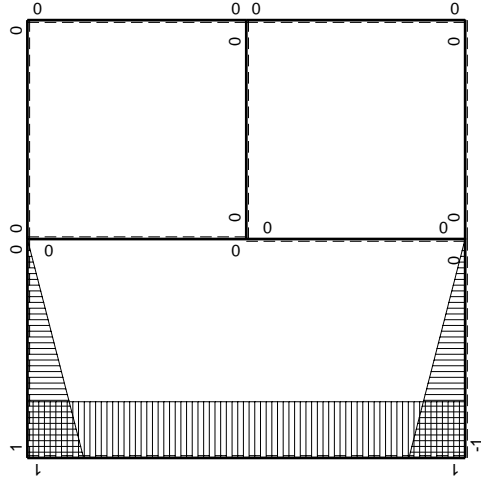






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_1$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0
CB b	0	$2Fx$	0	0	0	0		
AD 2b	1	$-5/4Fx+1/2qx^2$	0	$-5/4Fx+1/2Fx^2/b$	0	1	$(-7/6+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$1/2Fb+3/4Fx-1/2qx^2$	0	$-1/2Fb-3/4Fx+1/2Fx^2/b$	0	1		
DE b	$1-x/b$	$-1/2Fb+1/2Fx$	0	$-1/2Fb+Fx-1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$1/2Fx$	0	$-1/2Fx^2/b$	0	$x^2/b^2$		
EF b	0	0	0	0	0	0	0+0	0
FE b	0	0	0	0	0	0		
FG b	0	0	0	0	0	0	0+0	0
GF b	0	0	0	0	0	0		
GC b	0	0	0	0	0	0	0+0	0
CG b	0	0	0	0	0	0		
HG b	0	0	0	0	0	0	0+0	0
GH b	0	0	0	0	0	0		
HB b	0	$-5/4Fb+5/4Fx$	$-Fb/EJ$	0	0	0	0+0	0
BH b	0	$5/4Fx$	$Fb/EJ$	0	0	0		
HE b	0	$5/4Fb-7/4Fx+1/2qx^2$	0	0	0	0	0+0	0
EH b	0	$-3/4Fx-1/2qx^2$	0	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$-25/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$5/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{x_0} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{x_0} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{x_0} = \int_0^{2b} (-5/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-5/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -7/6 \cdot Fb^2/EJ$$

$$L_{DA}^{x_0} = \int_0^{2b} (-1/2 - 3/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x - 3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

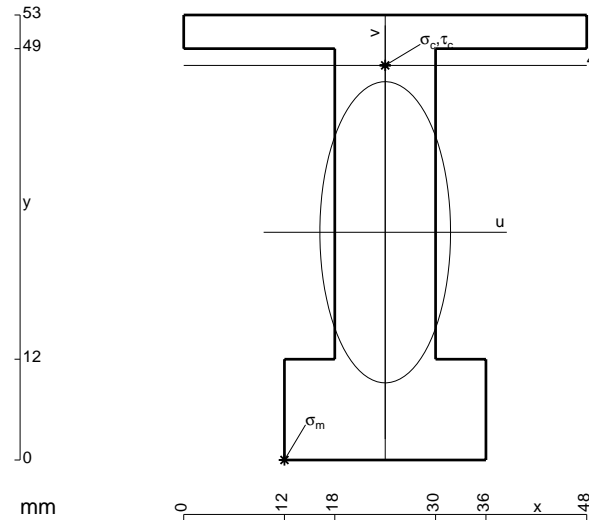
$$= (-b - 3/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -7/6 \cdot Fb^2/EJ$$

$$L_{DE}^{x_0} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x + 1/2 x^2/b - 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

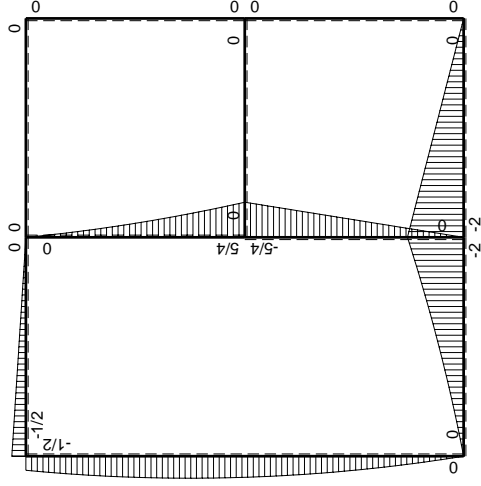
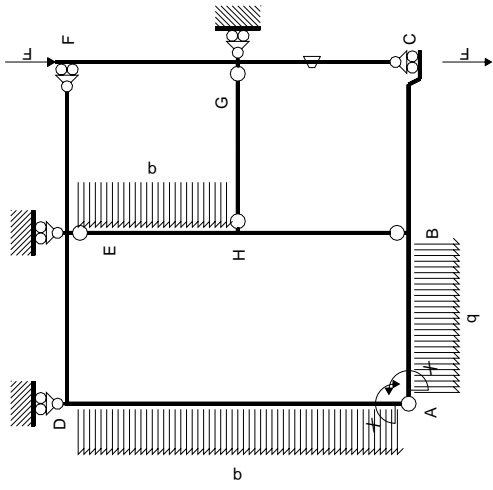
$$L_{ED}^{x_0} = \int_0^b (-1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/6 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$



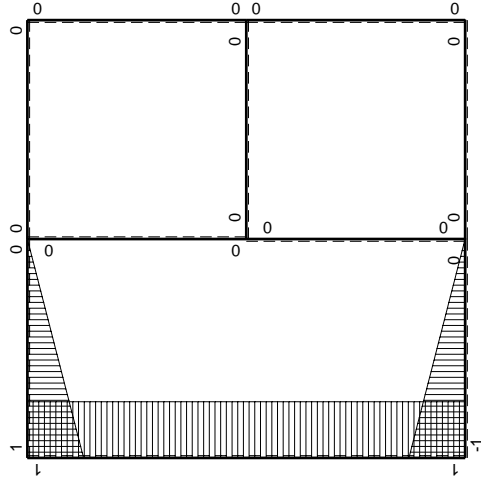
- A = 924. mm<sup>2</sup>
- J<sub>u</sub> = 297390. mm<sup>4</sup>
- J<sub>v</sub> = 56016. mm<sup>4</sup>
- y<sub>g</sub> = 27.12 mm
- T<sub>y</sub> = 2880. N
- M<sub>x</sub> = -2620800. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -12. mm
- v<sub>m</sub> = -27.12 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -239. N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 47. mm
- v<sub>c</sub> = 19.88 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 175.2 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.104 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 175.3 N/mm<sup>2</sup>
- S = 5085. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0
CB b	0	$2Fx$	0	0	0	0		
AD 2b	1	$-5/4Fx+1/2qx^2$	0	$-5/4Fx+1/2Fx^2/b$	0	1	$(-7/6+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$1/2Fb+3/4Fx-1/2qx^2$	0	$-1/2Fb-3/4Fx+1/2Fx^2/b$	0	1		
DE b	$1-x/b$	$-1/2Fb+1/2Fx$	0	$-1/2Fb+Fx-1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$1/2Fx$	0	$-1/2Fx^2/b$	0	$x^2/b^2$		
EF b	0	0	0	0	0	0	0+0	0
FE b	0	0	0	0	0	0		
FG b	0	0	0	0	0	0	0+0	0
GF b	0	0	0	0	0	0		
GC b	0	0	$-Fb/EJ$	0	0	0	0+0	0
CG b	0	0	$Fb/EJ$	0	0	0		
HG b	0	0	0	0	0	0	0+0	0
GH b	0	0	0	0	0	0		
HB b	0	$-5/4Fb+5/4Fx$	0	0	0	0	0+0	0
BH b	0	$5/4Fx$	0	0	0	0		
HE b	0	$5/4Fb-7/4Fx+1/2qx^2$	0	0	0	0	0+0	0
EH b	0	$-3/4Fx-1/2qx^2$	0	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$-25/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$5/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-5/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-5/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -7/6 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (-1/2 - 3/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x - 3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

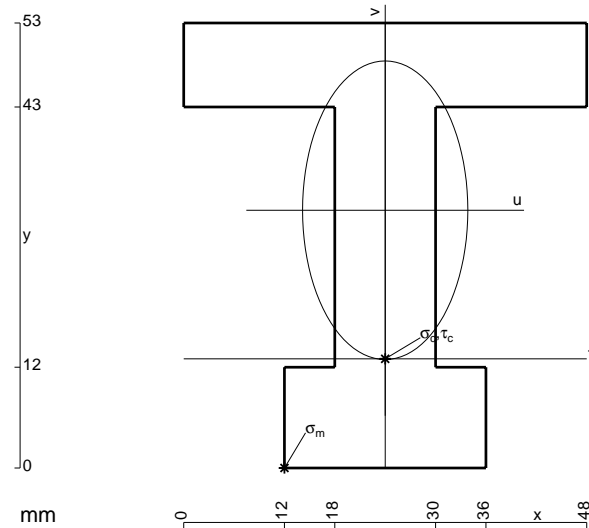
$$= (-b - 3/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -7/6 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x + 1/2 x^2/b - 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (-1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/6 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$



$$A = 1140. \text{ mm}^2$$

$$J_u = 360421. \text{ mm}^4$$

$$J_v = 110448. \text{ mm}^4$$

$$y_g = 30.7 \text{ mm}$$

$$T_y = 4880. \text{ N}$$

$$M_x = -2342400. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -12. \text{ mm}$$

$$v_m = -30.7 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -199.5 \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 13. \text{ mm}$$

$$v_c = -17.7 \text{ mm}$$

$$\sigma_c = -Mv/J_u = -115. \text{ N/mm}^2$$

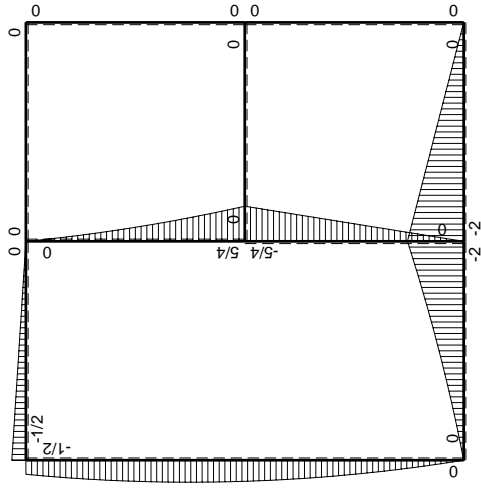
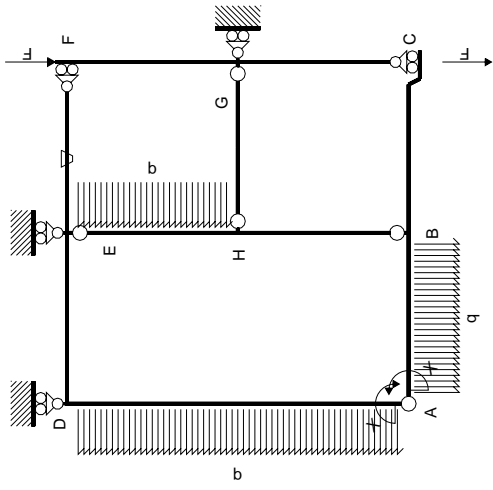
$$\tau_c = 8.273 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 115.9 \text{ N/mm}^2$$

$$S = 7332. \text{ mm}^3$$

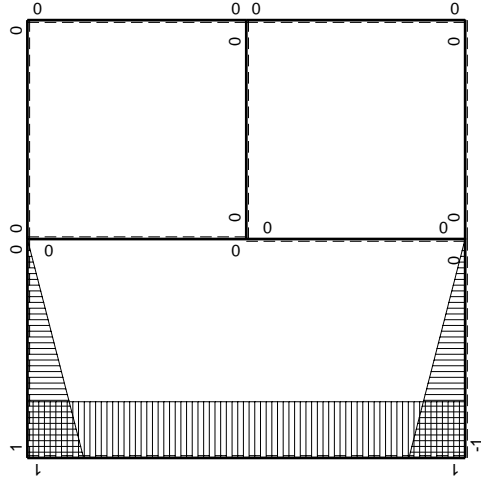






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_1$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0
CB b	0	$2Fx$	0	0	0	0		
AD 2b	1	$-5/4Fx+1/2qx^2$	0	$-5/4Fx+1/2Fx^2/b$	0	1	$(-7/6+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$1/2Fb+3/4Fx-1/2qx^2$	0	$-1/2Fb-3/4Fx+1/2Fx^2/b$	0	1		
DE b	$1-x/b$	$-1/2Fb+1/2Fx$	0	$-1/2Fb+Fx-1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$1/2Fx$	0	$-1/2Fx^2/b$	0	$x^2/b^2$		
EF b	0	0	$-Fb/EJ$	0	0	0	0+0	0
FE b	0	0	$Fb/EJ$	0	0	0		
FG b	0	0	0	0	0	0	0+0	0
GF b	0	0	0	0	0	0		
GC b	0	0	0	0	0	0	0+0	0
CG b	0	0	0	0	0	0		
HG b	0	0	0	0	0	0	0+0	0
GH b	0	0	0	0	0	0		
HB b	0	$-5/4Fb+5/4Fx$	0	0	0	0	0+0	0
BH b	0	$5/4Fx$	0	0	0	0		
HE b	0	$5/4Fb-7/4Fx+1/2qx^2$	0	0	0	0	0+0	0
EH b	0	$-3/4Fx-1/2qx^2$	0	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$-25/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$5/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-5/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-5/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -7/6 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (-1/2 - 3/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x - 3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

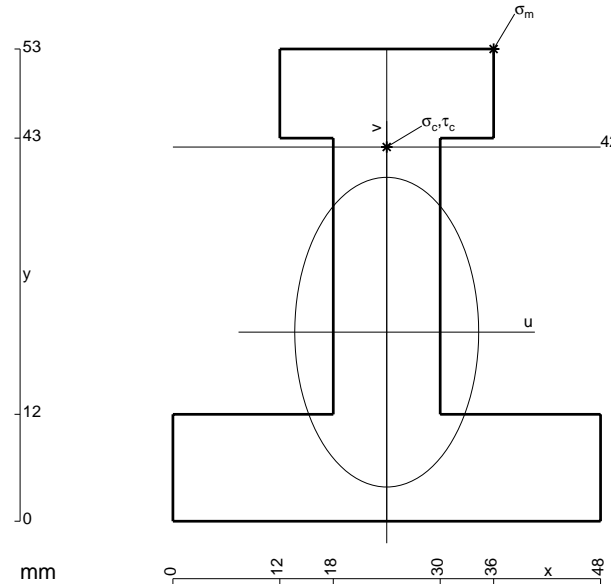
$$= (-b - 3/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -7/6 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x + 1/2 x^2/b - 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

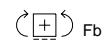
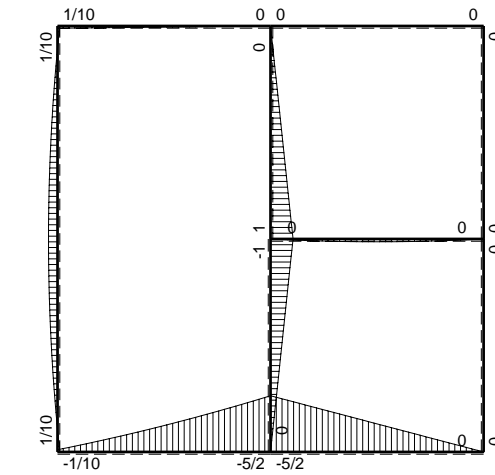
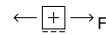
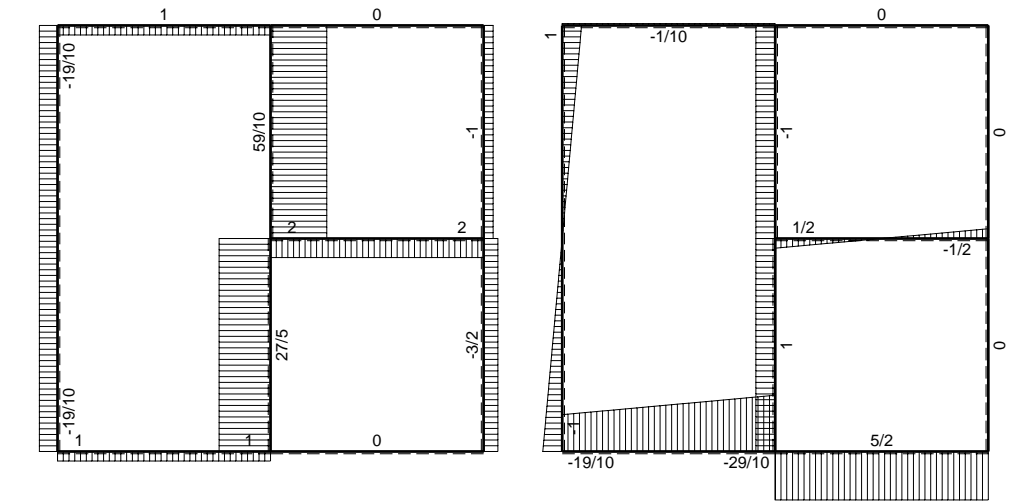
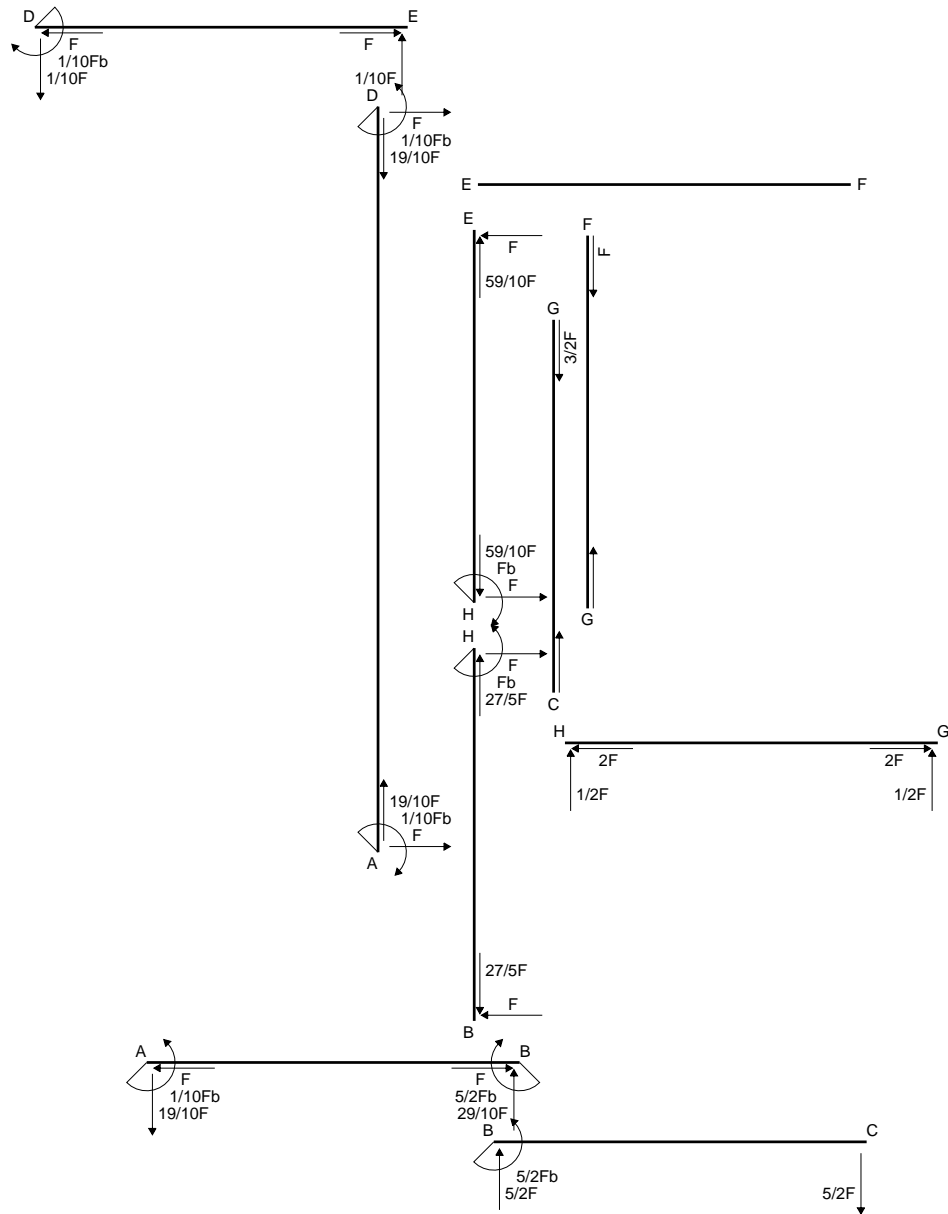
$$= (-1/2 b + 1/2 b - 1/6 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

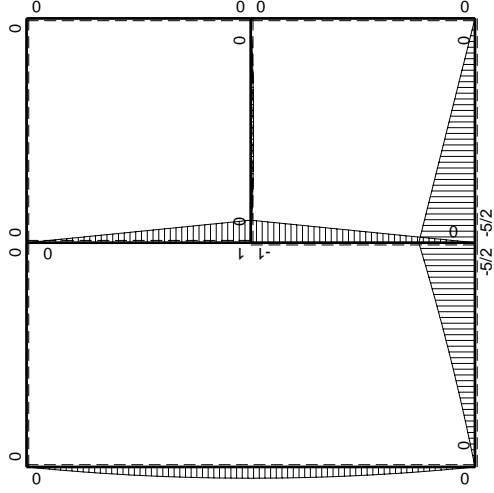
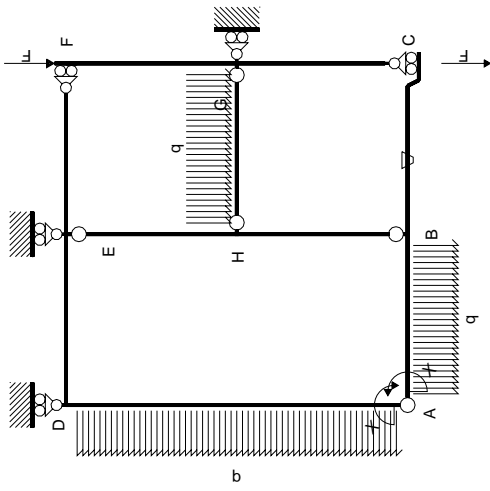
$$L_{ED}^{xo} = \int_0^b (-1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/6 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$



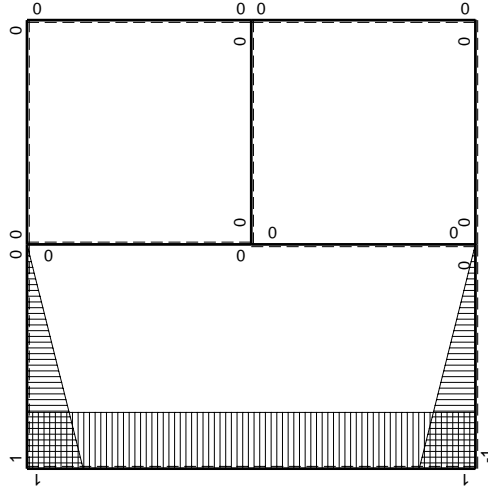
- A = 1188. mm<sup>2</sup>
- J<sub>u</sub> = 358924. mm<sup>4</sup>
- J<sub>v</sub> = 126576. mm<sup>4</sup>
- y<sub>g</sub> = 21.22 mm
- T<sub>y</sub> = 4560. N
- M<sub>x</sub> = -2371200. Nmm
- x<sub>m</sub> = 36. mm
- y<sub>m</sub> = 53. mm
- u<sub>m</sub> = 12. mm
- v<sub>m</sub> = 31.78 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 210. N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 42. mm
- v<sub>c</sub> = 20.78 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 137.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.076 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 137.8 N/mm<sup>2</sup>
- S = 6683. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-2Fx-1/2qx^2$	0	$2Fx-3/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(3/8+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$5/2Fb-3Fx+1/2qx^2$	0	$5/2Fx-3Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-5/2Fb+5/2Fx$	$-Fb/EJ$	0	0	0	0+0	0	
CB b	0	$5/2Fx$	$Fb/EJ$	0	0	0			
AD 2b	1	$-Fx+1/2qx^2$	0	$-Fx+1/2Fx^2/b$	0	1	$(-2/3+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$Fx-1/2qx^2$	0	$-Fx+1/2Fx^2/b$	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
GH b	0	$-1/2Fx+1/2qx^2$	0	0	0	0			
HB b	0	$-Fb+Fx$	0	0	0	0	0+0	0	
BH b	0	$Fx$	0	0	0	0			
HE b	0	$Fb-Fx$	0	0	0	0	0+0	0	
EH b	0	$-Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$-7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{x_0} = \int_0^b (2x/b - 3/2 x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 1/2 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 1/2 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{BA}^{x_0} = \int_0^b (5/2 x/b - 3x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 5/4 x^2/b - x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

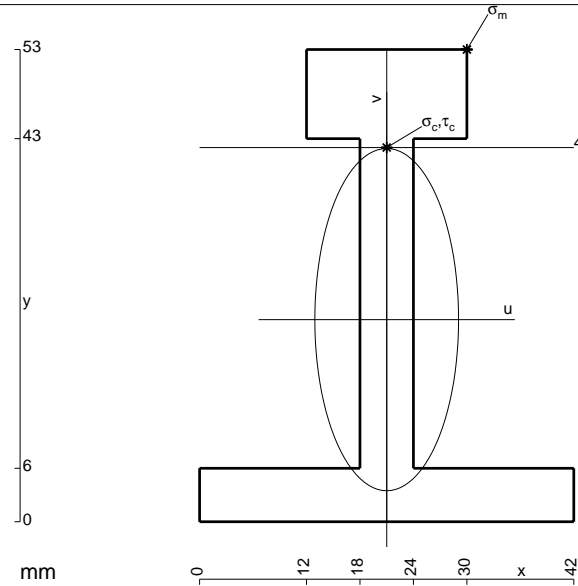
$$= (5/4 b - b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{AD}^{x_0} = \int_0^{2b} (-x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-2b + 4/3 b) \cdot Fb \cdot 1/EJ = -2/3 \cdot Fb^2/EJ$$

$$L_{DA}^{x_0} = \int_0^{2b} (-x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

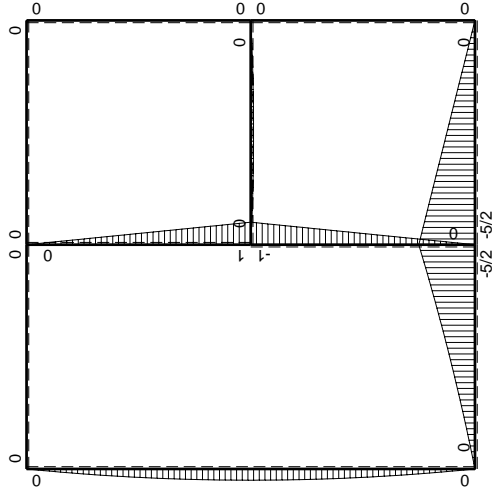
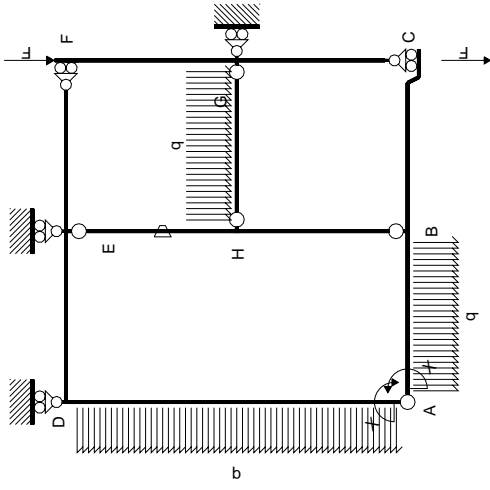
$$= (-2b + 4/3 b) \cdot Fb \cdot 1/EJ = -2/3 \cdot Fb^2/EJ$$



- A = 654. mm<sup>2</sup>
- J<sub>u</sub> = 241316. mm<sup>4</sup>
- J<sub>v</sub> = 42570. mm<sup>4</sup>
- y<sub>g</sub> = 22.68 mm
- T<sub>y</sub> = 3050. N
- M<sub>x</sub> = -1738500. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 53. mm
- u<sub>m</sub> = 9. mm
- v<sub>m</sub> = 30.32 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 218.4 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 42. mm
- v<sub>c</sub> = 19.32 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 139.2 N/mm<sup>2</sup>
- τ<sub>c</sub> = 9.85 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 140.2 N/mm<sup>2</sup>
- S = 4676. mm<sup>3</sup>

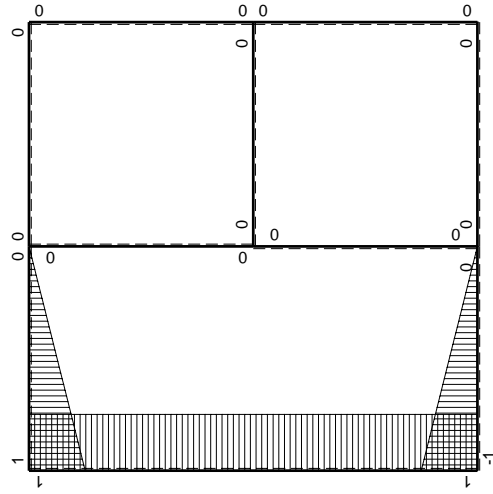






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_1$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-2Fx-1/2qx^2$	0	$2Fx-3/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(3/8+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$5/2Fb-3Fx+1/2qx^2$	0	$5/2Fx-3Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-5/2Fb+5/2Fx$	0	0	0	0	0+0	0	
CB b	0	$5/2Fx$	0	0	0	0			
AD 2b	1	$-Fx+1/2qx^2$	0	$-Fx+1/2Fx^2/b$	0	1	$(-2/3+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$Fx-1/2qx^2$	0	$-Fx+1/2Fx^2/b$	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
GH b	0	$-1/2Fx+1/2qx^2$	0	0	0	0			
HB b	0	$-Fb+Fx$	0	0	0	0	0+0	0	
BH b	0	$Fx$	0	0	0	0			
HE b	0	$Fb-Fx$	$-Fb/EJ$	0	0	0	0+0	0	
EH b	0	$-Fx$	$Fb/EJ$	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$-7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx + 1 \cdot \frac{1}{4} \frac{b}{EJ} = \left[ x - \frac{x^2}{b} + \frac{1}{3} \frac{x^3}{b^2} \right]_0^b \frac{1}{EJ} + \frac{1}{4} \frac{b}{EJ}$$

$$= (b - b + \frac{1}{3}b) \frac{1}{EJ} + \frac{1}{4} \frac{b}{EJ} = \frac{7}{12} \frac{b}{EJ}$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx + 1 \cdot \frac{1}{4} \frac{b}{EJ} = \left[ \frac{1}{3} \frac{x^3}{b^2} \right]_0^b \frac{1}{EJ} + \frac{1}{4} \frac{b}{EJ}$$

$$= (\frac{1}{3}b) \frac{1}{EJ} + \frac{1}{4} \frac{b}{EJ} = \frac{7}{12} \frac{b}{EJ}$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \frac{b}{EJ}$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \frac{b}{EJ}$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx = \left[ x - \frac{x^2}{b} + \frac{1}{3} \frac{x^3}{b^2} \right]_0^b \frac{1}{EJ}$$

$$= (b - b + \frac{1}{3}b) \frac{1}{EJ} = \frac{1}{3} \frac{b}{EJ}$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx = \left[ \frac{1}{3} \frac{x^3}{b^2} \right]_0^b \frac{1}{EJ}$$

$$= (\frac{1}{3}b) \frac{1}{EJ} = \frac{1}{3} \frac{b}{EJ}$$

$$L_{AB}^{xo} = \int_0^b (2x/b - \frac{3}{2} \frac{x^2}{b^2} - \frac{1}{2} \frac{x^3}{b^3}) Fb \frac{1}{EJ} dx + 1 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= \left[ \frac{x^2}{b} - \frac{1}{2} \frac{x^3}{b^2} - \frac{1}{8} \frac{x^4}{b^3} \right]_0^b Fb \frac{1}{EJ} + \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= (b - \frac{1}{2}b - \frac{1}{8}b) Fb \frac{1}{EJ} + \frac{1}{4} \frac{Fb^2}{EJ} = \frac{3}{8} \frac{Fb^2}{EJ}$$

$$L_{BA}^{xo} = \int_0^b (\frac{5}{2} \frac{x}{b} - 3 \frac{x^2}{b^2} + \frac{1}{2} \frac{x^3}{b^3}) Fb \frac{1}{EJ} dx + 1 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= \left[ \frac{5}{4} \frac{x^2}{b} - \frac{x^3}{b^2} + \frac{1}{8} \frac{x^4}{b^3} \right]_0^b Fb \frac{1}{EJ} + \frac{1}{4} \frac{Fb^2}{EJ}$$

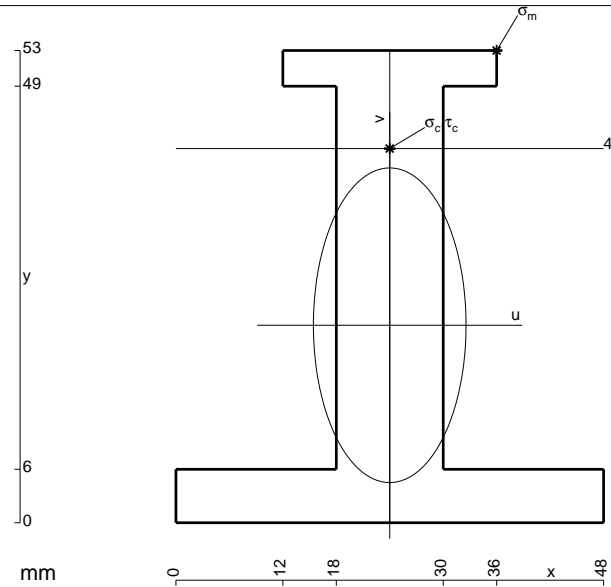
$$= (\frac{5}{4}b - b + \frac{1}{8}b) Fb \frac{1}{EJ} + \frac{1}{4} \frac{Fb^2}{EJ} = \frac{3}{8} \frac{Fb^2}{EJ}$$

$$L_{AD}^{xo} = \int_0^{2b} (-x/b + \frac{1}{2} \frac{x^2}{b^2}) Fb \frac{1}{EJ} dx = \left[ -\frac{1}{2} \frac{x^2}{b} + \frac{1}{6} \frac{x^3}{b^2} \right]_0^{2b} Fb \frac{1}{EJ}$$

$$= (-2b + \frac{4}{3}b) Fb \frac{1}{EJ} = -\frac{2}{3} \frac{Fb^2}{EJ}$$

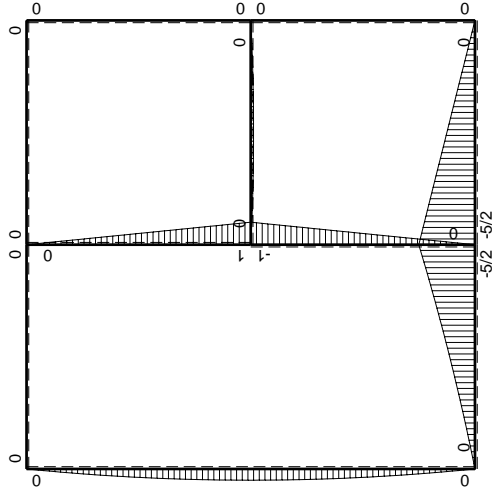
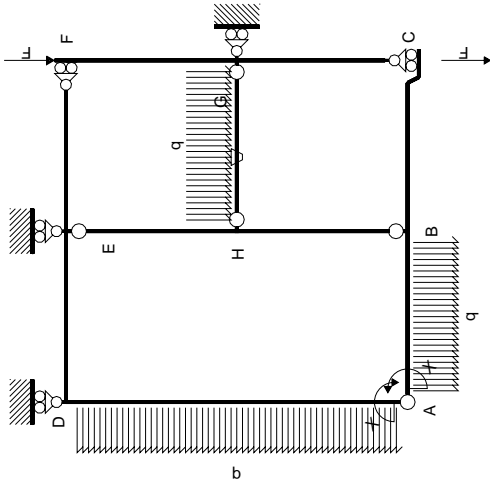
$$L_{DA}^{xo} = \int_0^{2b} (-x/b + \frac{1}{2} \frac{x^2}{b^2}) Fb \frac{1}{EJ} dx = \left[ -\frac{1}{2} \frac{x^2}{b} + \frac{1}{6} \frac{x^3}{b^2} \right]_0^{2b} Fb \frac{1}{EJ}$$

$$= (-2b + \frac{4}{3}b) Fb \frac{1}{EJ} = -\frac{2}{3} \frac{Fb^2}{EJ}$$



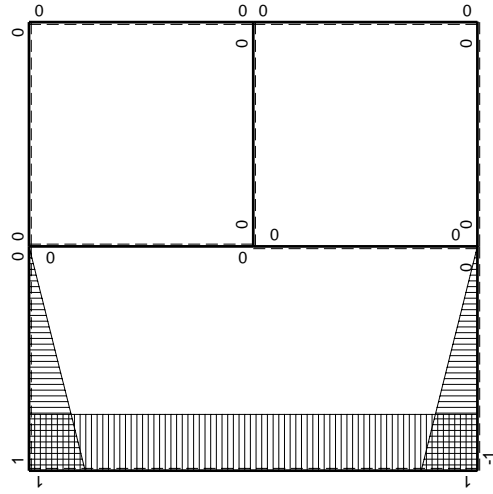
- A = 900. mm<sup>2</sup>
- J<sub>u</sub> = 280787. mm<sup>4</sup>
- J<sub>v</sub> = 66096. mm<sup>4</sup>
- y<sub>g</sub> = 22.17 mm
- T<sub>y</sub> = 3375. N
- M<sub>x</sub> = -2092500. Nmm
- x<sub>m</sub> = 36. mm
- y<sub>m</sub> = 53. mm
- u<sub>m</sub> = 12. mm
- v<sub>m</sub> = 30.83 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 229.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 42. mm
- v<sub>c</sub> = 19.83 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 147.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.736 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 148. N/mm<sup>2</sup>
- S = 4728. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-2Fx-1/2qx^2$	0	$2Fx-3/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(3/8+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$5/2Fb-3Fx+1/2qx^2$	0	$5/2Fx-3Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-5/2Fb+5/2Fx$	0	0	0	0	0+0	0	
CB b	0	$5/2Fx$	0	0	0	0			
AD 2b	1	$-Fx+1/2qx^2$	0	$-Fx+1/2Fx^2/b$	0	1	$(-2/3+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$Fx-1/2qx^2$	0	$-Fx+1/2Fx^2/b$	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	$1/2Fx-1/2qx^2$	$-Fb/EJ$	0	0	0	0+0	0	
GH b	0	$-1/2Fx+1/2qx^2$	$Fb/EJ$	0	0	0			
HB b	0	$-Fb+Fx$	0	0	0	0	0+0	0	
BH b	0	$Fx$	0	0	0	0			
HE b	0	$Fb-Fx$	0	0	0	0	0+0	0	
EH b	0	$-Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$-7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx + 1 \cdot \frac{1}{4} \frac{b}{EJ} = \left[ x - \frac{x^2}{b} + \frac{1}{3} \frac{x^3}{b^2} \right]_0^b \frac{1}{EJ} + 1 \cdot \frac{1}{4} \frac{b}{EJ}$$

$$= (b - b + \frac{1}{3} b) \frac{1}{EJ} + 1 \cdot \frac{1}{4} \frac{b}{EJ} = \frac{7}{12} \frac{b}{EJ}$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx + 1 \cdot \frac{1}{4} \frac{b}{EJ} = \left[ \frac{1}{3} \frac{x^3}{b^2} \right]_0^b \frac{1}{EJ} + 1 \cdot \frac{1}{4} \frac{b}{EJ}$$

$$= (\frac{1}{3} b) \frac{1}{EJ} + 1 \cdot \frac{1}{4} \frac{b}{EJ} = \frac{7}{12} \frac{b}{EJ}$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \frac{b}{EJ}$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \frac{b}{EJ}$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx = \left[ x - \frac{x^2}{b} + \frac{1}{3} \frac{x^3}{b^2} \right]_0^b \frac{1}{EJ}$$

$$= (b - b + \frac{1}{3} b) \frac{1}{EJ} = \frac{1}{3} \frac{b}{EJ}$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx = \left[ \frac{1}{3} \frac{x^3}{b^2} \right]_0^b \frac{1}{EJ}$$

$$= (\frac{1}{3} b) \frac{1}{EJ} = \frac{1}{3} \frac{b}{EJ}$$

$$L_{AB}^{xo} = \int_0^b (2x/b - \frac{3}{2} \frac{x^2}{b^2} - \frac{1}{2} \frac{x^3}{b^3}) Fb \frac{1}{EJ} dx + 1 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= \left[ \frac{x^2}{b} - \frac{1}{2} \frac{x^3}{b^2} - \frac{1}{8} \frac{x^4}{b^3} \right]_0^b Fb \frac{1}{EJ} + 1 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= (b - \frac{1}{2} b - \frac{1}{8} b) Fb \frac{1}{EJ} + 1 \cdot \frac{1}{4} \frac{Fb^2}{EJ} = \frac{3}{8} \frac{Fb^2}{EJ}$$

$$L_{BA}^{xo} = \int_0^b (\frac{5}{2} \frac{x}{b} - 3 \frac{x^2}{b^2} + \frac{1}{2} \frac{x^3}{b^3}) Fb \frac{1}{EJ} dx + 1 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= \left[ \frac{5}{4} \frac{x^2}{b} - \frac{x^3}{b^2} + \frac{1}{8} \frac{x^4}{b^3} \right]_0^b Fb \frac{1}{EJ} + 1 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

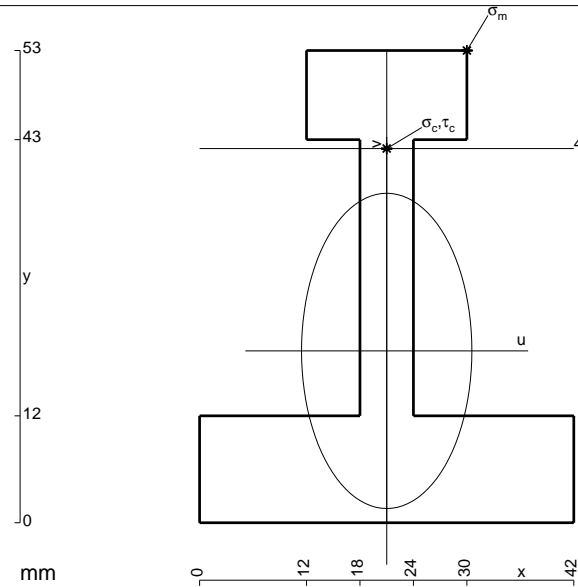
$$= (\frac{5}{4} b - b + \frac{1}{8} b) Fb \frac{1}{EJ} + 1 \cdot \frac{1}{4} \frac{Fb^2}{EJ} = \frac{3}{8} \frac{Fb^2}{EJ}$$

$$L_{AD}^{xo} = \int_0^{2b} (-x/b + \frac{1}{2} \frac{x^2}{b^2}) Fb \frac{1}{EJ} dx = \left[ -\frac{1}{2} \frac{x^2}{b} + \frac{1}{6} \frac{x^3}{b^2} \right]_0^{2b} Fb \frac{1}{EJ}$$

$$= (-2b + \frac{4}{3} b) Fb \frac{1}{EJ} = -\frac{2}{3} \frac{Fb^2}{EJ}$$

$$L_{DA}^{xo} = \int_0^{2b} (-x/b + \frac{1}{2} \frac{x^2}{b^2}) Fb \frac{1}{EJ} dx = \left[ -\frac{1}{2} \frac{x^2}{b} + \frac{1}{6} \frac{x^3}{b^2} \right]_0^{2b} Fb \frac{1}{EJ}$$

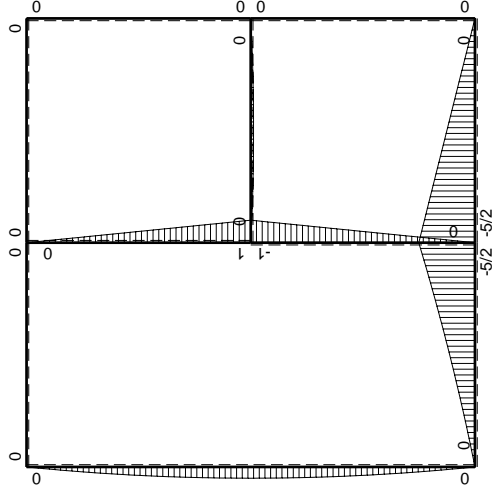
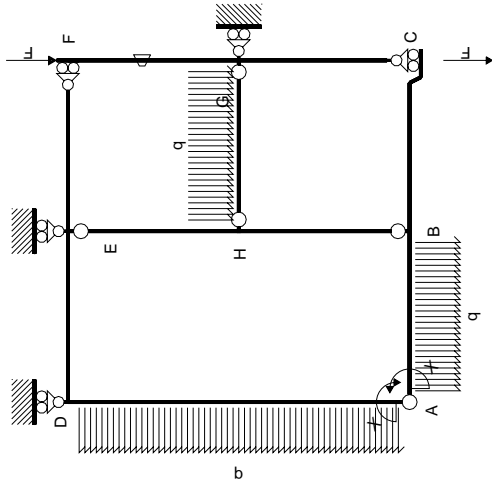
$$= (-2b + \frac{4}{3} b) Fb \frac{1}{EJ} = -\frac{2}{3} \frac{Fb^2}{EJ}$$



- A = 870. mm<sup>2</sup>
- J<sub>u</sub> = 272367. mm<sup>4</sup>
- J<sub>v</sub> = 79506. mm<sup>4</sup>
- y<sub>g</sub> = 19.29 mm
- T<sub>y</sub> = 2875. N
- M<sub>x</sub> = -1926250. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 53. mm
- u<sub>m</sub> = 9. mm
- v<sub>m</sub> = 33.71 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 238.4 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 42. mm
- v<sub>c</sub> = 22.71 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 160.6 N/mm<sup>2</sup>
- τ<sub>c</sub> = 9.338 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 161.4 N/mm<sup>2</sup>
- S = 5308. mm<sup>3</sup>

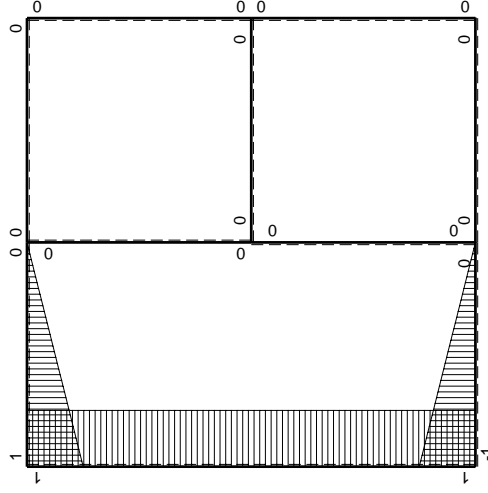






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-2Fx-1/2qx^2$	0	$2Fx-3/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(3/8+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$5/2Fb-3Fx+1/2qx^2$	0	$5/2Fx-3Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-5/2Fb+5/2Fx$	0	0	0	0	0+0	0	
CB b	0	$5/2Fx$	0	0	0	0			
AD 2b	1	$-Fx+1/2qx^2$	0	$-Fx+1/2Fx^2/b$	0	1	$(-2/3+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$Fx-1/2qx^2$	0	$-Fx+1/2Fx^2/b$	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
GF b	0	0	$Fb/EJ$	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
GH b	0	$-1/2Fx+1/2qx^2$	0	0	0	0			
HB b	0	$-Fb+Fx$	0	0	0	0	0+0	0	
BH b	0	$Fx$	0	0	0	0			
HE b	0	$Fb-Fx$	0	0	0	0	0+0	0	
EH b	0	$-Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$-7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx + 1 \cdot 1/4 \frac{b}{EJ} = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ} + 1 \cdot 1/4 \frac{b}{EJ}$$

$$= (b - b + 1/3 b) \frac{1}{EJ} + 1 \cdot 1/4 \frac{b}{EJ} = 7/12 \frac{b}{EJ}$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx + 1 \cdot 1/4 \frac{b}{EJ} = \left[ 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ} + 1 \cdot 1/4 \frac{b}{EJ}$$

$$= (1/3 b) \frac{1}{EJ} + 1 \cdot 1/4 \frac{b}{EJ} = 7/12 \frac{b}{EJ}$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \frac{b}{EJ}$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \frac{b}{EJ}$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ}$$

$$= (b - b + 1/3 b) \frac{1}{EJ} = 1/3 \frac{b}{EJ}$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx = \left[ 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ}$$

$$= (1/3 b) \frac{1}{EJ} = 1/3 \frac{b}{EJ}$$

$$L_{AB}^{xo} = \int_0^b (2x/b - 3/2 x^2/b^2 - 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot 1/4 \frac{Fb^2}{EJ}$$

$$= \left[ x^2/b - 1/2 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \frac{Fb^2}{EJ}$$

$$= (b - 1/2 b - 1/8 b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \frac{Fb^2}{EJ} = 3/8 \frac{Fb^2}{EJ}$$

$$L_{BA}^{xo} = \int_0^b (5/2 x/b - 3x^2/b^2 + 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot 1/4 \frac{Fb^2}{EJ}$$

$$= \left[ 5/4 x^2/b - x^3/b^2 + 1/8 x^4/b^3 \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \frac{Fb^2}{EJ}$$

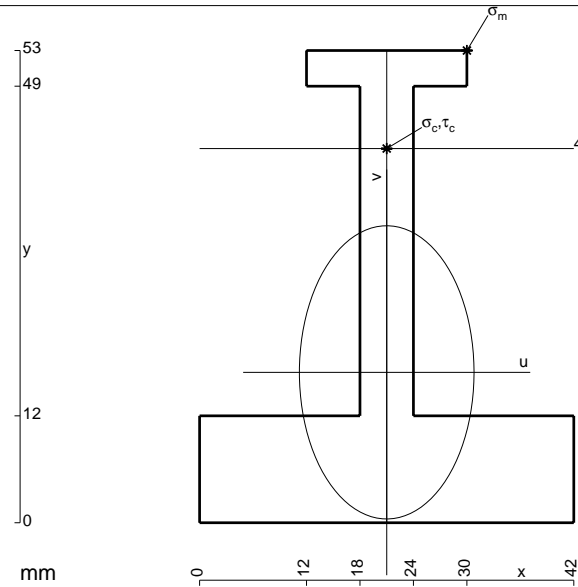
$$= (5/4 b - b + 1/8 b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \frac{Fb^2}{EJ} = 3/8 \frac{Fb^2}{EJ}$$

$$L_{AD}^{xo} = \int_0^{2b} (-x/b + 1/2 x^2/b^2) Fb \frac{1}{EJ} dx = \left[ -1/2 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} Fb \frac{1}{EJ}$$

$$= (-2b + 4/3 b) Fb \frac{1}{EJ} = -2/3 \frac{Fb^2}{EJ}$$

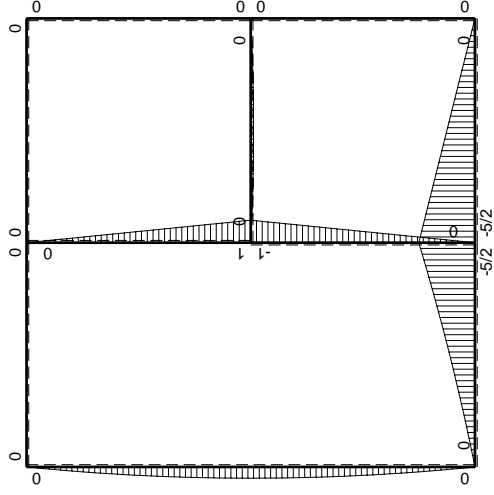
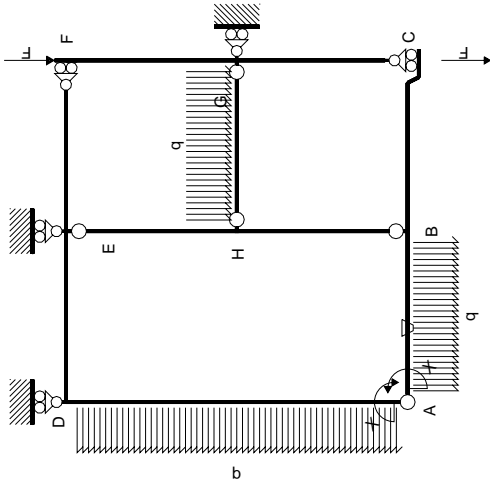
$$L_{DA}^{xo} = \int_0^{2b} (-x/b + 1/2 x^2/b^2) Fb \frac{1}{EJ} dx = \left[ -1/2 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} Fb \frac{1}{EJ}$$

$$= (-2b + 4/3 b) Fb \frac{1}{EJ} = -2/3 \frac{Fb^2}{EJ}$$



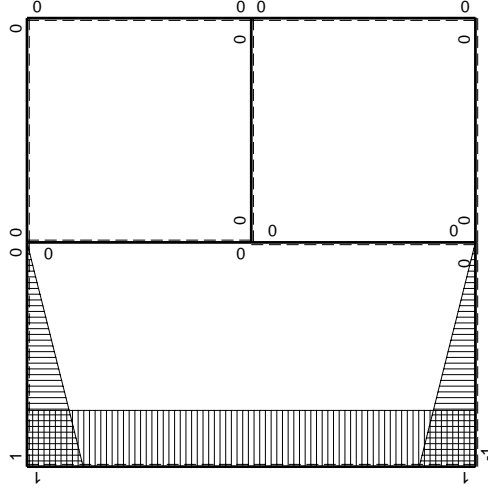
- A = 798. mm<sup>2</sup>
- J<sub>u</sub> = 216134. mm<sup>4</sup>
- J<sub>v</sub> = 76698. mm<sup>4</sup>
- y<sub>g</sub> = 16.88 mm
- T<sub>y</sub> = 1650. N
- M<sub>x</sub> = -1188000. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 53. mm
- u<sub>m</sub> = 9. mm
- v<sub>m</sub> = 36.12 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 198.6 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 42. mm
- v<sub>c</sub> = 25.12 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 138.1 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.656 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 138.3 N/mm<sup>2</sup>
- S = 3659. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-2Fx-1/2qx^2$	$-Fb/EJ$	$2Fx-3/2Fx^2/b-1/2qx^3/b$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$(3/8+1/2)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$5/2Fb-3Fx+1/2qx^2$	$Fb/EJ$	$5/2Fx-3Fx^2/b+1/2qx^3/b$	$Fx/EJ$	$x^2/b^2$			
BC b	0	$-5/2Fb+5/2Fx$	0	0	0	0	0+0	0	
CB b	0	$5/2Fx$	0	0	0	0			
AD 2b	1	$-Fx+1/2qx^2$	0	$-Fx+1/2Fx^2/b$	0	1	$(-2/3+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$Fx-1/2qx^2$	0	$-Fx+1/2Fx^2/b$	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
GH b	0	$-1/2Fx+1/2qx^2$	0	0	0	0			
HB b	0	$-Fb+Fx$	0	0	0	0	0+0	0	
BH b	0	$Fx$	0	0	0	0			
HE b	0	$Fb-Fx$	0	0	0	0	0+0	0	
EH b	0	$-Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$5/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{x\theta} = \int_0^b (2x/b - 3/2 x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + \int_0^b (1 - x/b) \cdot \theta \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 1/2 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + \left[ x - 1/2 x^2/b \right]_0^b \cdot \theta + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 1/2 b - 1/8 b) \cdot Fb \cdot 1/EJ + (b - 1/2 b) \cdot \theta + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/8 \cdot Fb^2/EJ$$

$$L_{BA}^{x\theta} = \int_0^b (5/2 x/b - 3 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + \int_0^b (-x/b) \cdot \theta \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 5/4 x^2/b - x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + \left[ -1/2 x^2/b \right]_0^b \cdot \theta + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

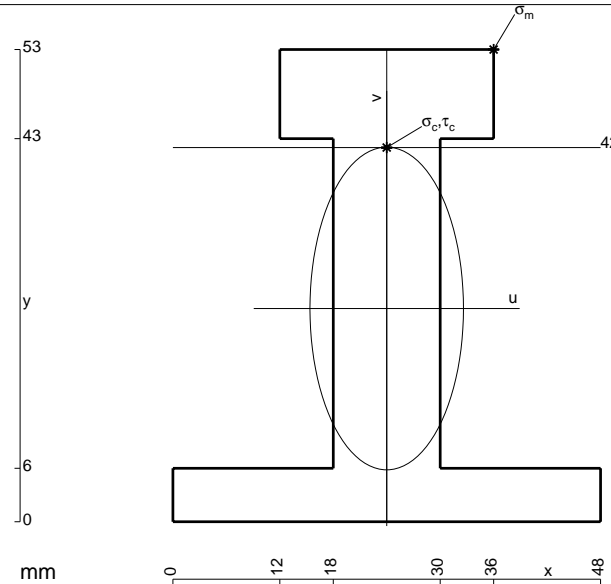
$$= (5/4 b - b + 1/8 b) \cdot Fb \cdot 1/EJ + (-1/2 b) \cdot \theta + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/8 \cdot Fb^2/EJ$$

$$L_{AD}^{x\theta} = \int_0^{2b} (-x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-2b + 4/3 b) \cdot Fb \cdot 1/EJ = -2/3 \cdot Fb^2/EJ$$

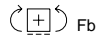
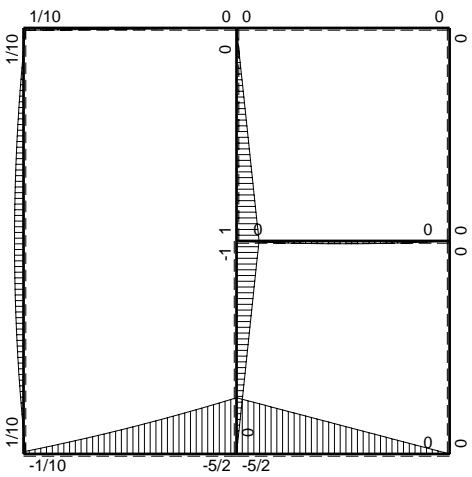
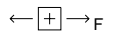
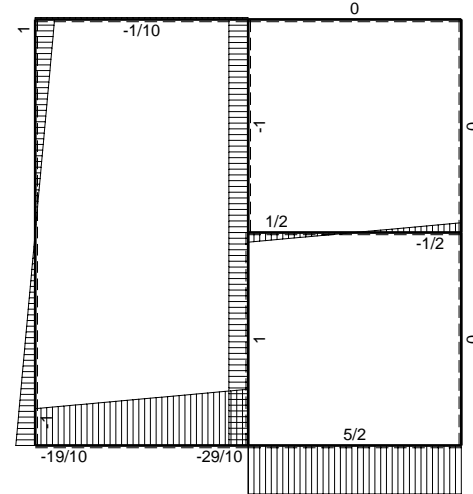
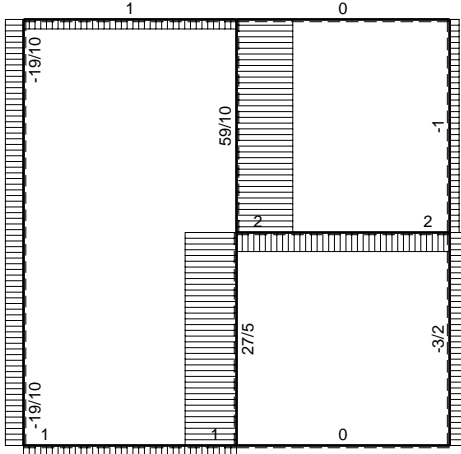
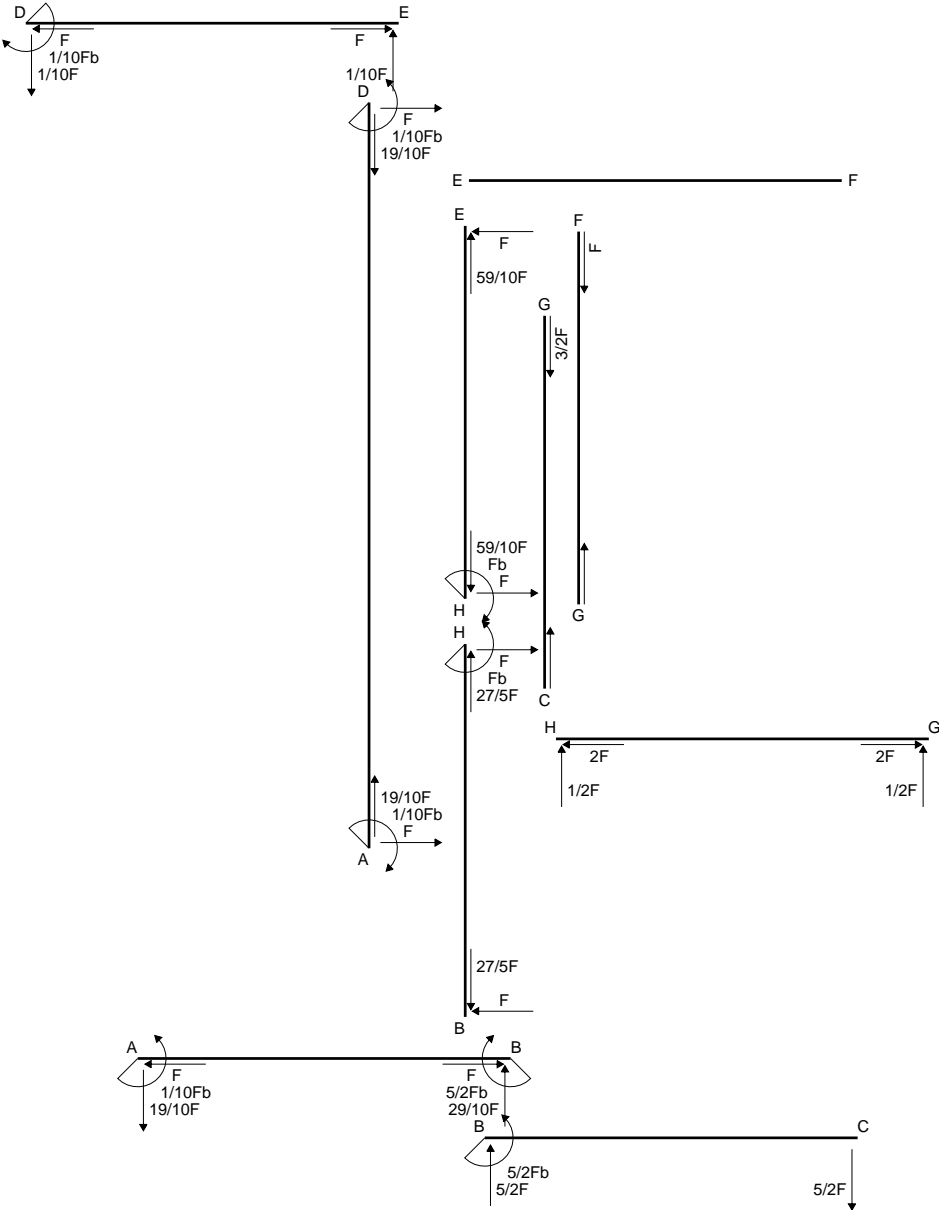
$$L_{DA}^{x\theta} = \int_0^{2b} (-x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

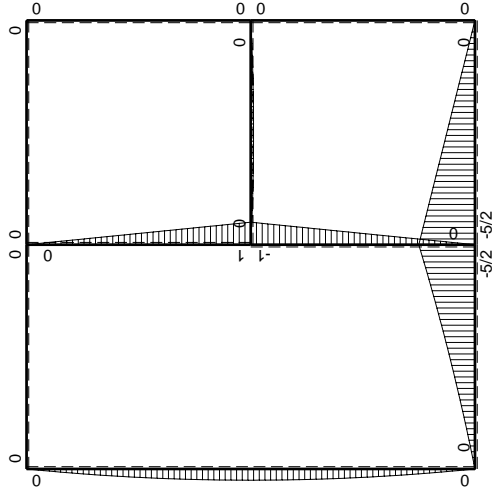
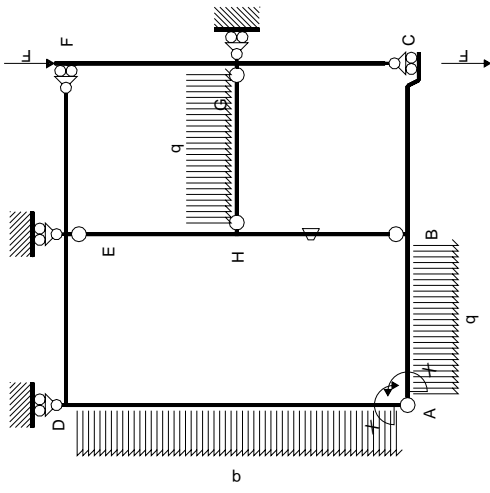
$$= (-2b + 4/3 b) \cdot Fb \cdot 1/EJ = -2/3 \cdot Fb^2/EJ$$



- A = 972. mm<sup>2</sup>
- J<sub>u</sub> = 318872. mm<sup>4</sup>
- J<sub>v</sub> = 72144. mm<sup>4</sup>
- y<sub>g</sub> = 23.93 mm
- T<sub>y</sub> = 3025. N
- M<sub>x</sub> = -2299000. Nmm
- x<sub>m</sub> = 36. mm
- y<sub>m</sub> = 53. mm
- u<sub>m</sub> = 12. mm
- v<sub>m</sub> = 29.07 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 209.6 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 42. mm
- v<sub>c</sub> = 18.07 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 130.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.743 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 130.5 N/mm<sup>2</sup>
- S = 5999. mm<sup>3</sup>

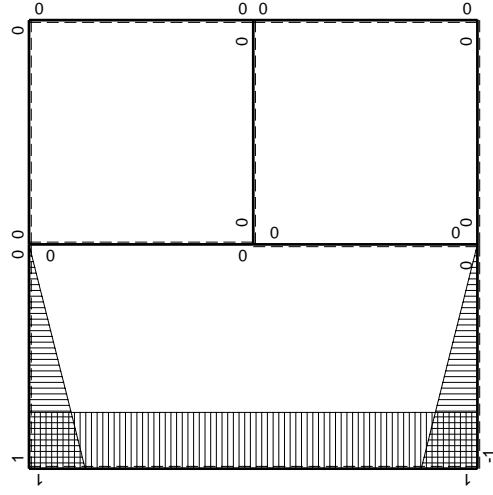






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-2Fx-1/2qx^2$	0	$2Fx-3/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(3/8+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$5/2Fb-3Fx+1/2qx^2$	0	$5/2Fx-3Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-5/2Fb+5/2Fx$	0	0	0	0	0+0	0	
CB b	0	$5/2Fx$	0	0	0	0			
AD 2b	1	$-Fx+1/2qx^2$	0	$-Fx+1/2Fx^2/b$	0	1	$(-2/3+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$Fx-1/2qx^2$	0	$-Fx+1/2Fx^2/b$	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
GH b	0	$-1/2Fx+1/2qx^2$	0	0	0	0			
HB b	0	$-Fb+Fx$	$-Fb/EJ$	0	0	0	0+0	0	
BH b	0	$Fx$	$Fb/EJ$	0	0	0			
HE b	0	$Fb-Fx$	0	0	0	0	0+0	0	
EH b	0	$-Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$-7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (2x/b - 3/2 x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 1/2 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 1/2 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (5/2 x/b - 3x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 5/4 x^2/b - x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

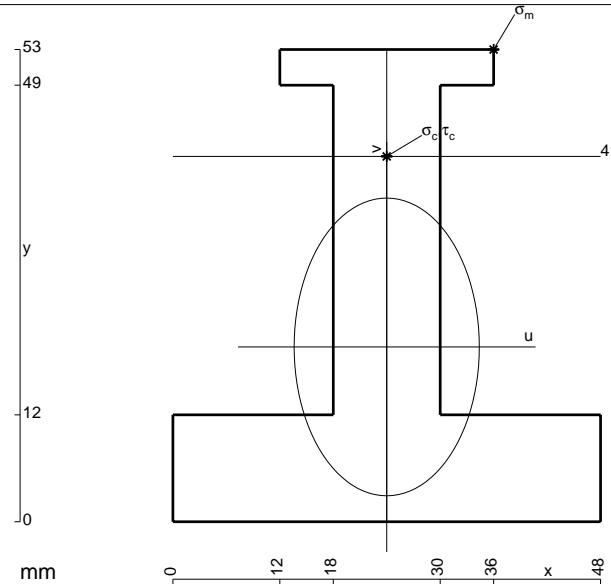
$$= (5/4 b - b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

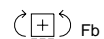
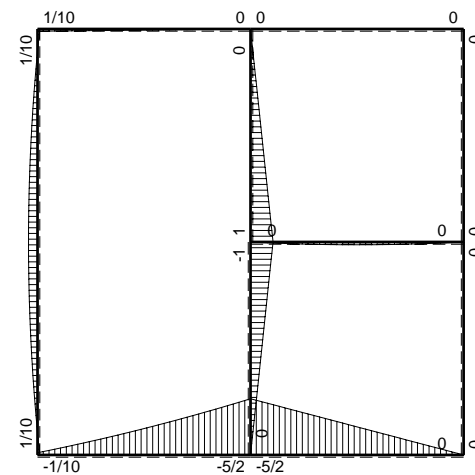
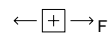
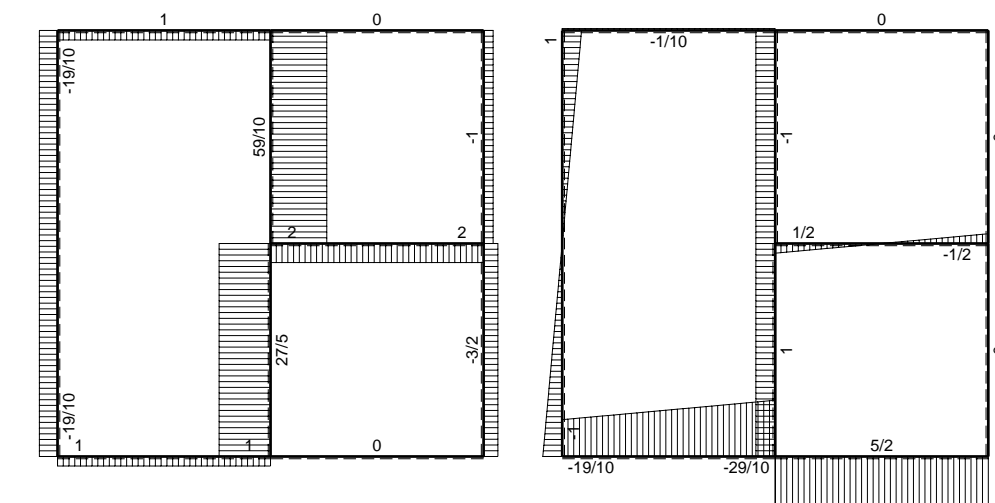
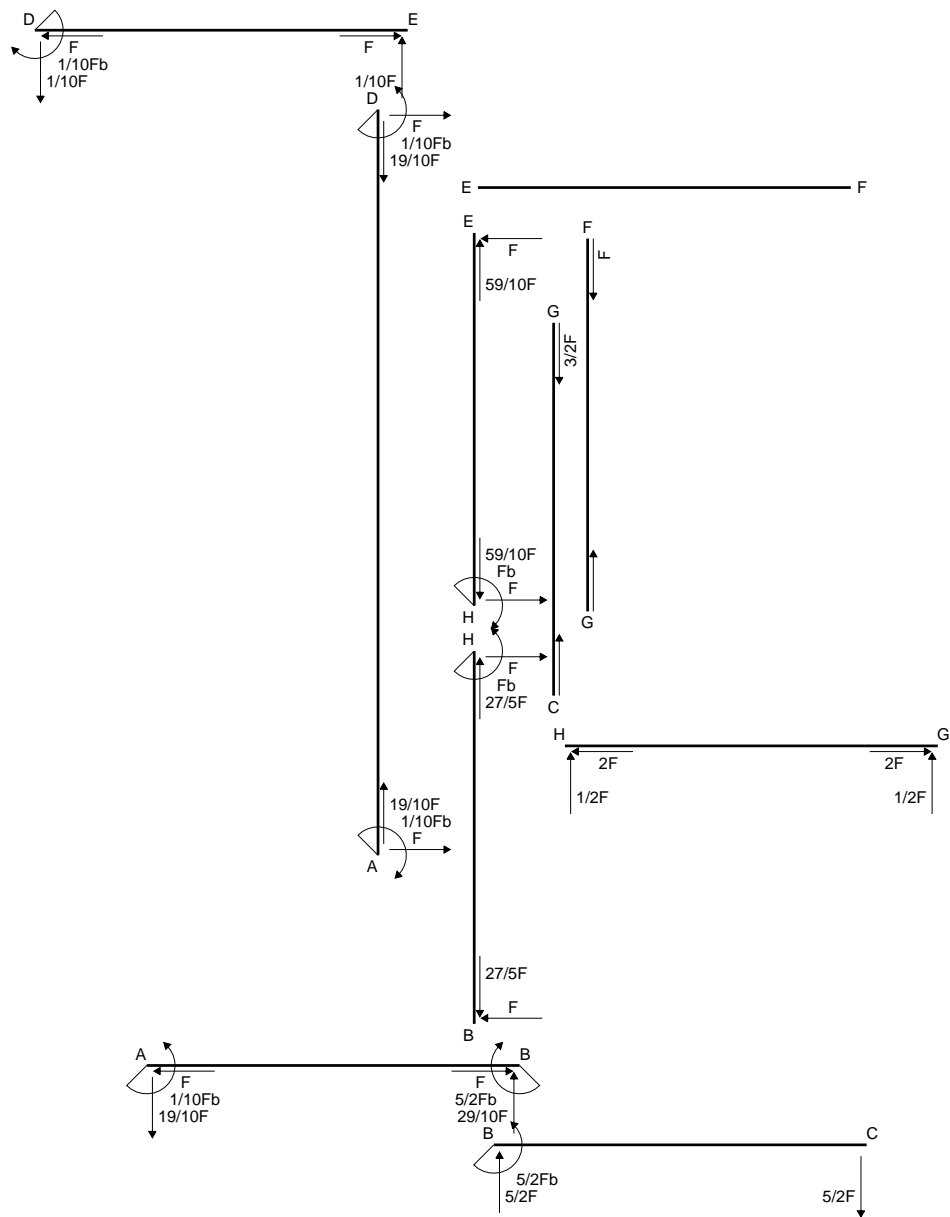
$$= (-2b + 4/3 b) \cdot Fb \cdot 1/EJ = -2/3 \cdot Fb^2/EJ$$

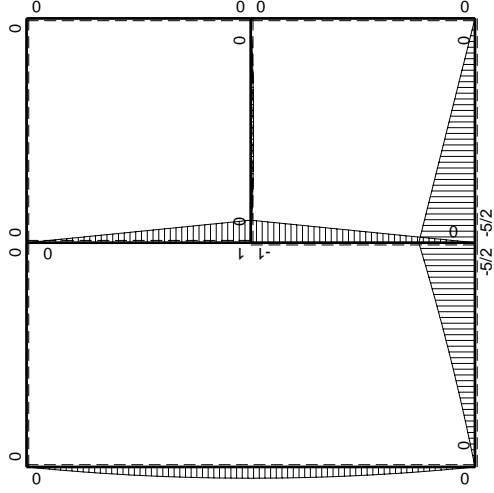
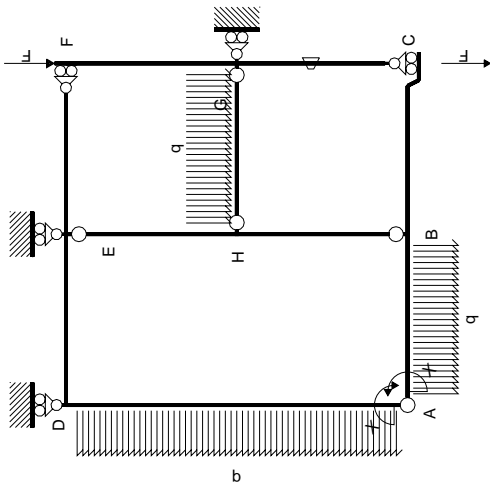
$$L_{DA}^{xo} = \int_0^{2b} (-x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-2b + 4/3 b) \cdot Fb \cdot 1/EJ = -2/3 \cdot Fb^2/EJ$$



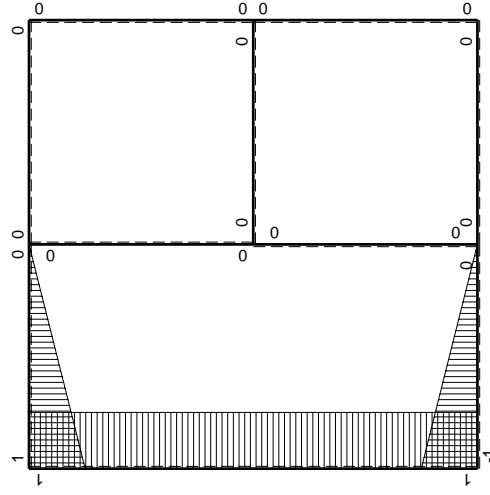
- A = 1116. mm<sup>2</sup>
- J<sub>u</sub> = 311633. mm<sup>4</sup>
- J<sub>v</sub> = 120528. mm<sup>4</sup>
- y<sub>g</sub> = 19.62 mm
- T<sub>y</sub> = 2525. N
- M<sub>x</sub> = -2045250. Nmm
- x<sub>m</sub> = 36. mm
- y<sub>m</sub> = 53. mm
- u<sub>m</sub> = 12. mm
- v<sub>m</sub> = 33.38 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 219.1 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 41. mm
- v<sub>c</sub> = 21.38 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 140.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.679 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 140.5 N/mm<sup>2</sup>
- S = 5449. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-2Fx-1/2qx^2$	0	$2Fx-3/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(3/8+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$5/2Fb-3Fx+1/2qx^2$	0	$5/2Fx-3Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-5/2Fb+5/2Fx$	0	0	0	0	0+0	0	
CB b	0	$5/2Fx$	0	0	0	0			
AD 2b	1	$-Fx+1/2qx^2$	0	$-Fx+1/2Fx^2/b$	0	1	$(-2/3+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$Fx-1/2qx^2$	0	$-Fx+1/2Fx^2/b$	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
CG b	0	0	$Fb/EJ$	0	0	0			
HG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
GH b	0	$-1/2Fx+1/2qx^2$	0	0	0	0			
HB b	0	$-Fb+Fx$	0	0	0	0	0+0	0	
BH b	0	$Fx$	0	0	0	0			
HE b	0	$Fb-Fx$	0	0	0	0	0+0	0	
EH b	0	$-Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$-7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (2x/b - 3/2 x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 1/2 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 1/2 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (5/2 x/b - 3x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 5/4 x^2/b - x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

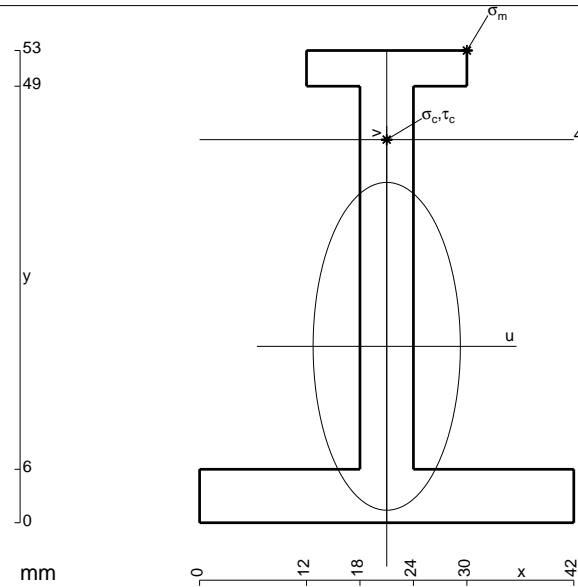
$$= (5/4 b - b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-2b + 4/3 b) \cdot Fb \cdot 1/EJ = -2/3 \cdot Fb^2/EJ$$

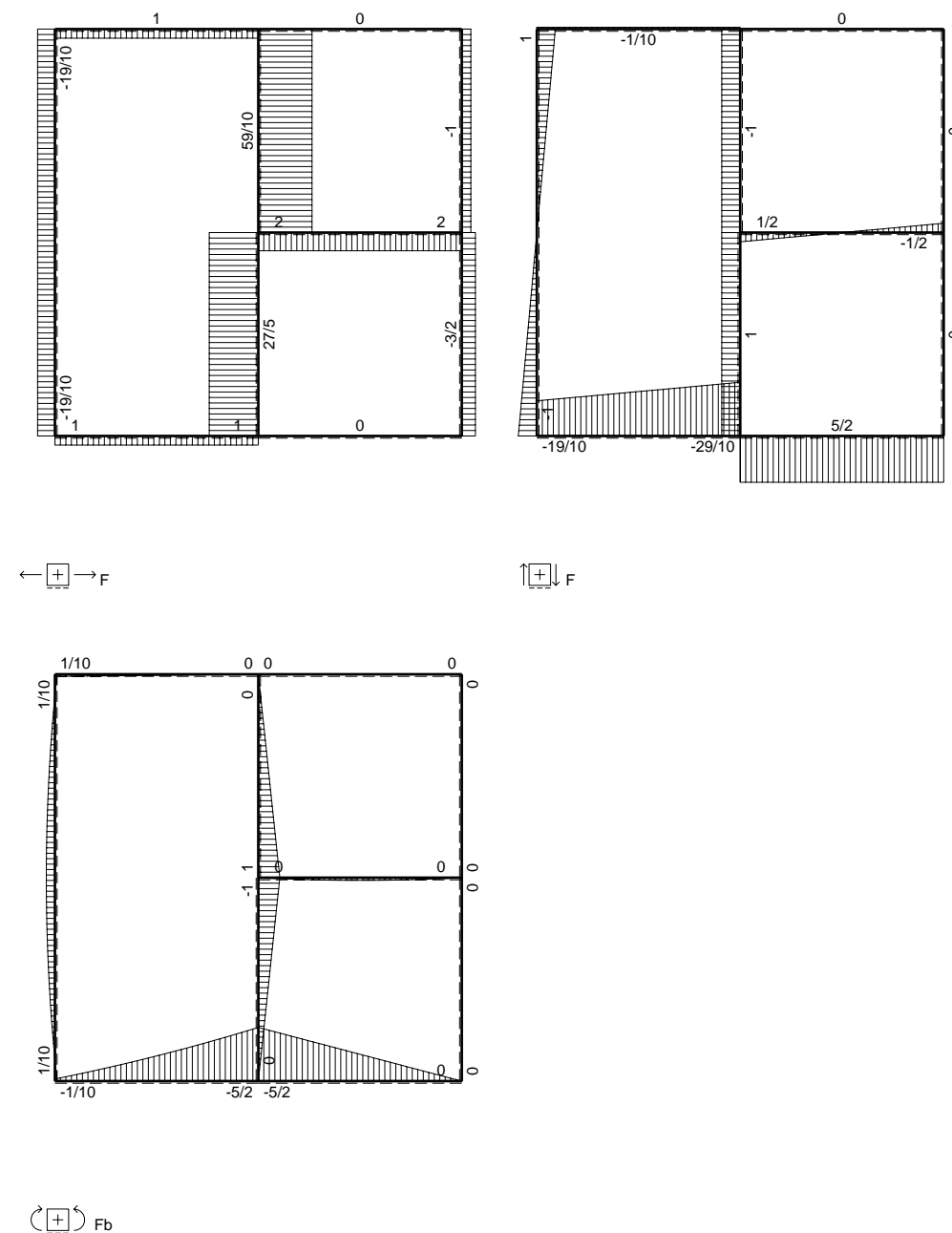
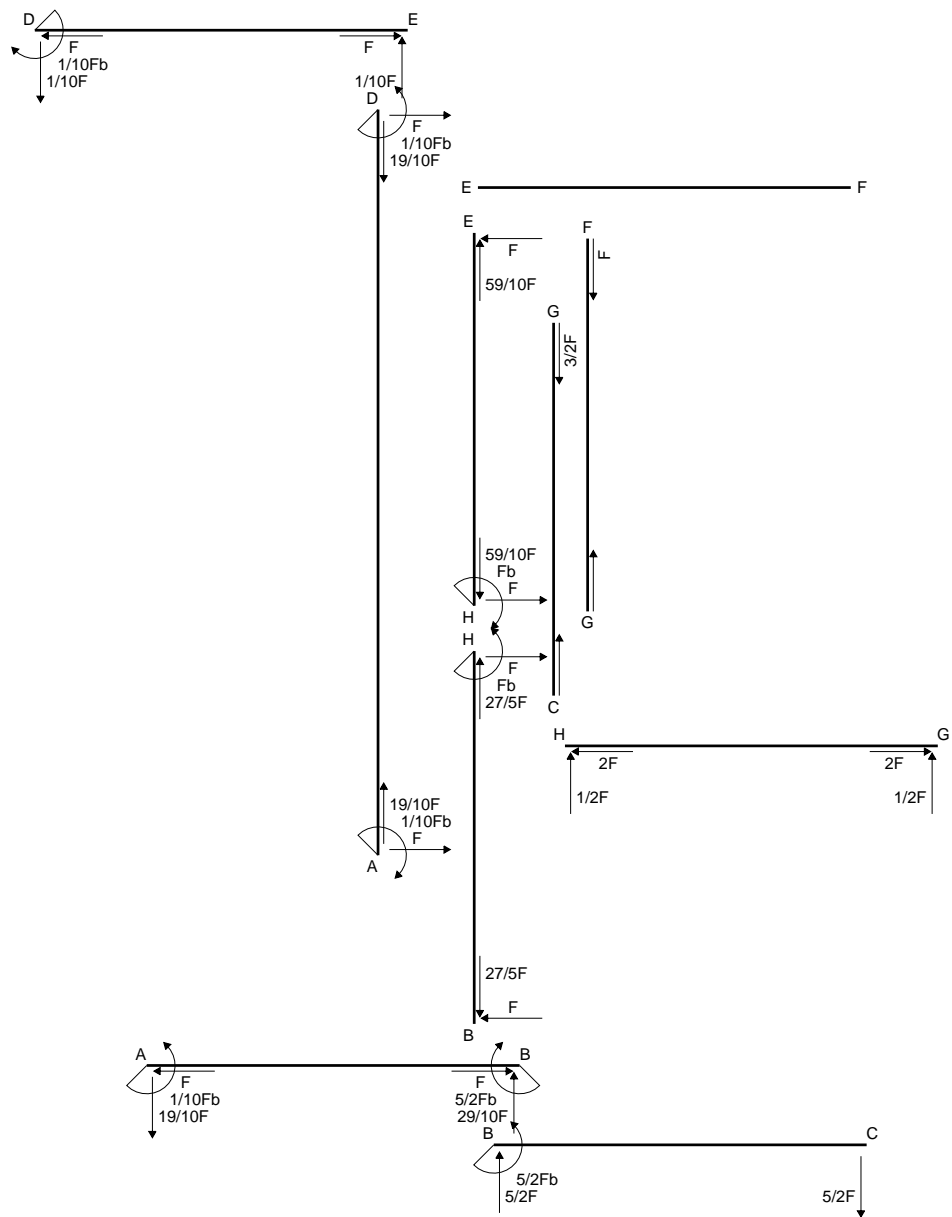
$$L_{DA}^{xo} = \int_0^{2b} (-x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

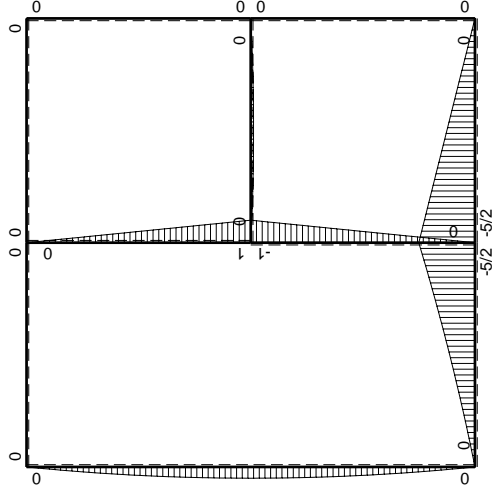
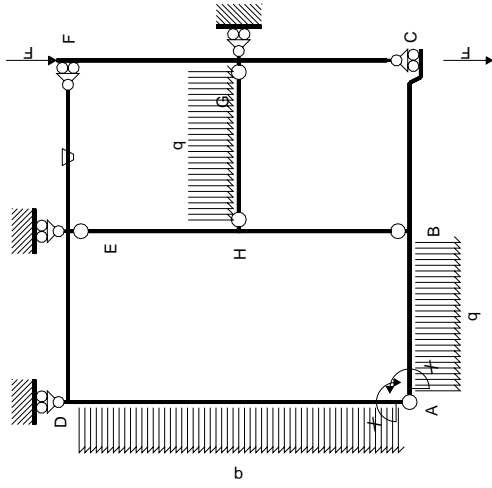
$$= (-2b + 4/3 b) \cdot Fb \cdot 1/EJ = -2/3 \cdot Fb^2/EJ$$



- A = 582. mm<sup>2</sup>
- J<sub>u</sub> = 197114. mm<sup>4</sup>
- J<sub>v</sub> = 39762. mm<sup>4</sup>
- y<sub>g</sub> = 19.8 mm
- T<sub>y</sub> = 1575. N
- M<sub>x</sub> = -1354500. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 53. mm
- u<sub>m</sub> = 9. mm
- v<sub>m</sub> = 33.2 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 228.1 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 43. mm
- v<sub>c</sub> = 23.2 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 159.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.248 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 159.6 N/mm<sup>2</sup>
- S = 3190. mm<sup>3</sup>

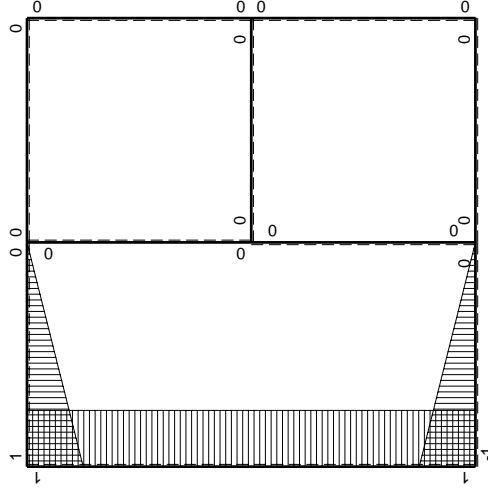






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-2Fx-1/2qx^2$	0	$2Fx-3/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(3/8+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$5/2Fb-3Fx+1/2qx^2$	0	$5/2Fx-3Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-5/2Fb+5/2Fx$	0	0	0	0	0+0	0	
CB b	0	$5/2Fx$	0	0	0	0			
AD 2b	1	$-Fx+1/2qx^2$	0	$-Fx+1/2Fx^2/b$	0	1	$(-2/3+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$Fx-1/2qx^2$	0	$-Fx+1/2Fx^2/b$	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
FE b	0	0	$Fb/EJ$	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
GH b	0	$-1/2Fx+1/2qx^2$	0	0	0	0			
HB b	0	$-Fb+Fx$	0	0	0	0	0+0	0	
BH b	0	$Fx$	0	0	0	0			
HE b	0	$Fb-Fx$	0	0	0	0	0+0	0	
EH b	0	$-Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$-7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{x_0} = \int_0^b (2x/b - 3/2 x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 1/2 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 1/2 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{BA}^{x_0} = \int_0^b (5/2 x/b - 3 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 5/4 x^2/b - x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

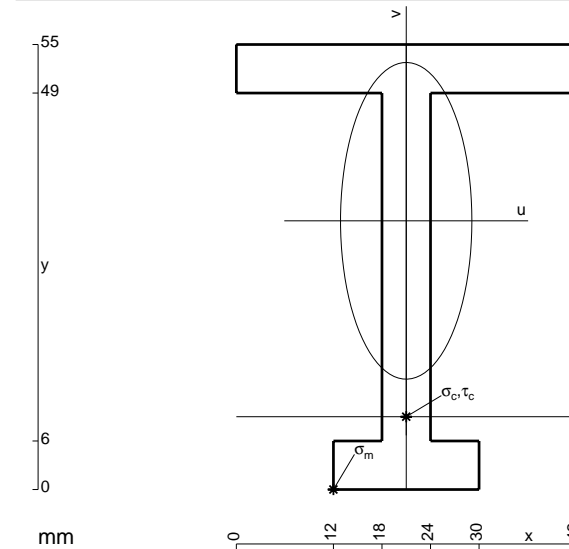
$$= (5/4 b - b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{AD}^{x_0} = \int_0^{2b} (-x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

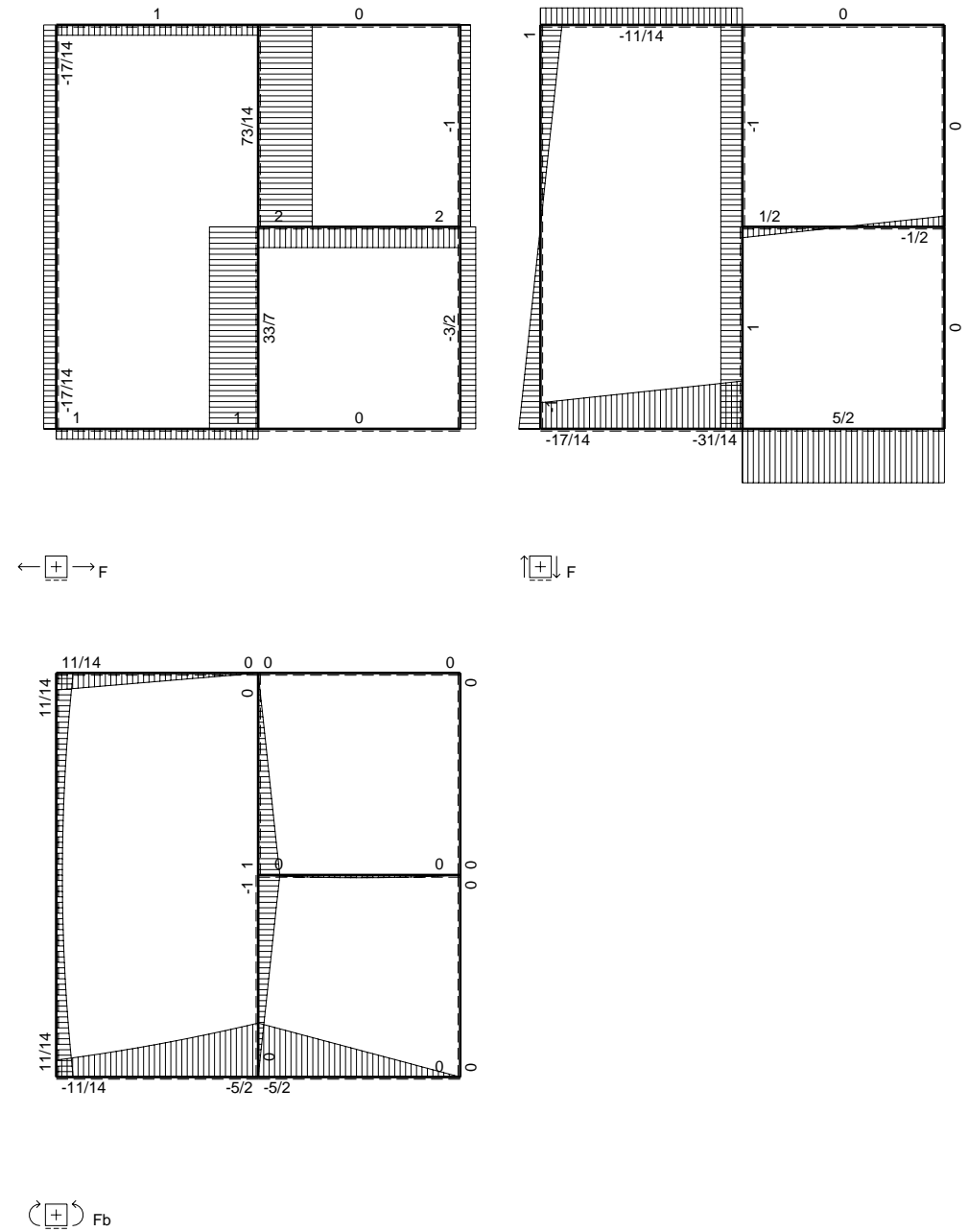
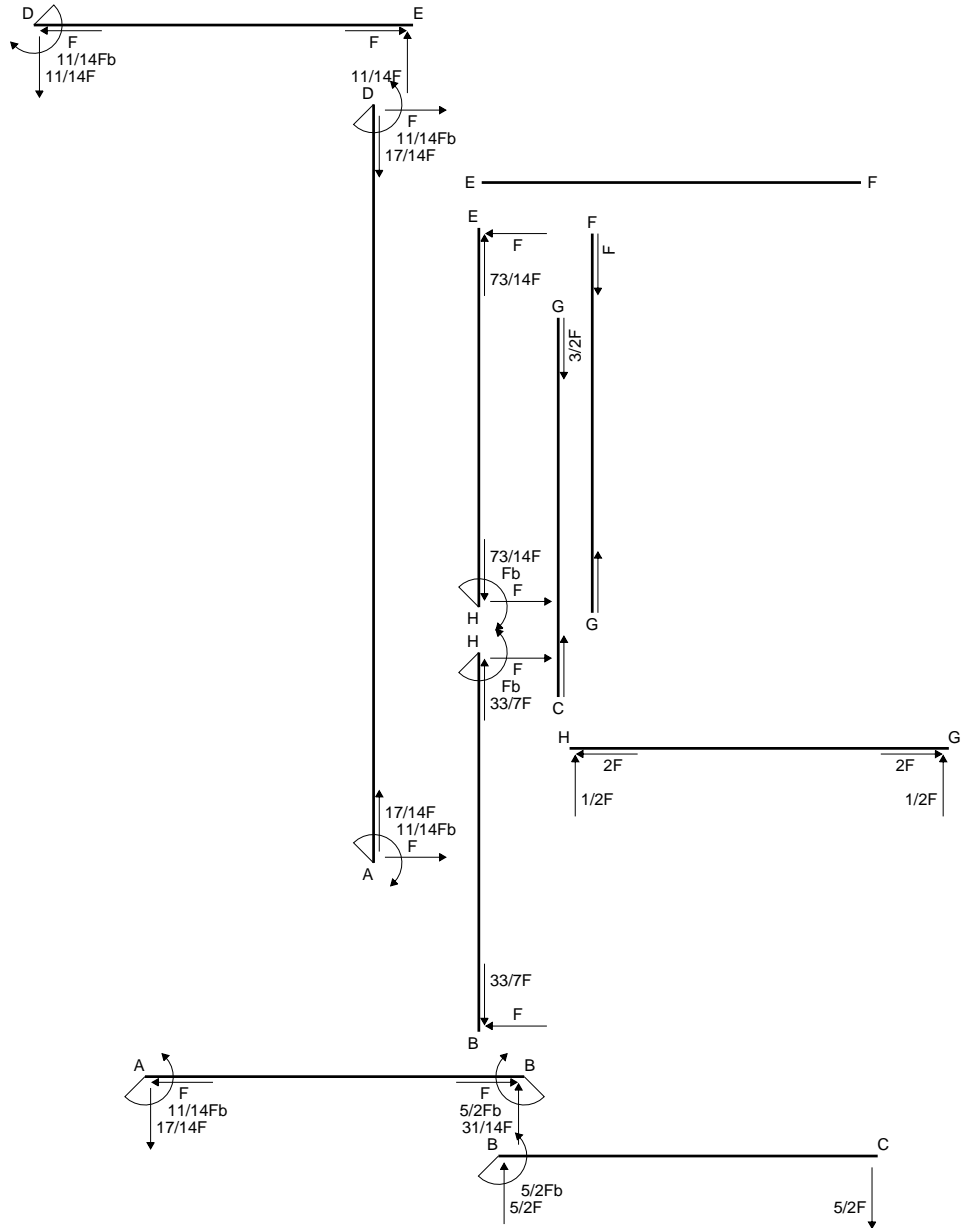
$$= (-2b + 4/3 b) \cdot Fb \cdot 1/EJ = -2/3 \cdot Fb^2/EJ$$

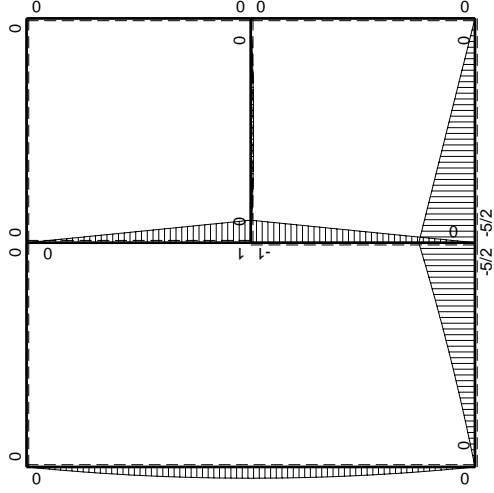
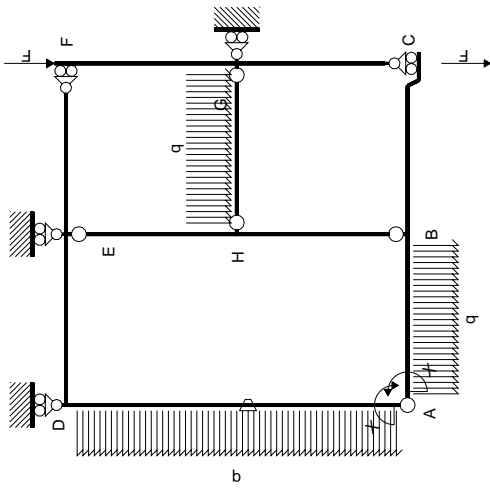
$$L_{DA}^{x_0} = \int_0^{2b} (-x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-2b + 4/3 b) \cdot Fb \cdot 1/EJ = -2/3 \cdot Fb^2/EJ$$



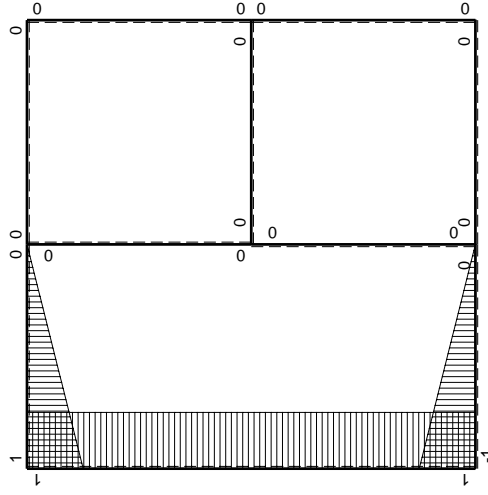
- A = 618. mm<sup>2</sup>
- J<sub>u</sub> = 236783. mm<sup>4</sup>
- J<sub>v</sub> = 40734. mm<sup>4</sup>
- y<sub>g</sub> = 33.21 mm
- T<sub>y</sub> = 1800. N
- M<sub>x</sub> = -1710000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -9. mm
- v<sub>m</sub> = -33.21 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -239.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 9. mm
- v<sub>c</sub> = -24.21 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -174.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.72 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 175. N/mm<sup>2</sup>
- S = 3725. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-2Fx-1/2qx^2$	0	$2Fx-3/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(3/8+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$5/2Fb-3Fx+1/2qx^2$	0	$5/2Fx-3Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-5/2Fb+5/2Fx$	0	0	0	0	0+0	0	
CB b	0	$5/2Fx$	0	0	0	0			
AD 2b	1	$-Fx+1/2qx^2$	$-Fb/EJ$	$-Fx+1/2Fx^2/b$	$-Fb/EJ$	1	$(-2/3-2)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$Fx-1/2qx^2$	$Fb/EJ$	$-Fx+1/2Fx^2/b$	$-Fb/EJ$	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
GH b	0	$-1/2Fx+1/2qx^2$	0	0	0	0			
HB b	0	$-Fb+Fx$	0	0	0	0	0+0	0	
BH b	0	$Fx$	0	0	0	0			
HE b	0	$Fb-Fx$	0	0	0	0	0+0	0	
EH b	0	$-Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$-55/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$11/14Fb$		

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ}$$

$$= (b - b + 1/3 b) \frac{1}{EJ} = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx = \left[ 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ}$$

$$= (1/3 b) \frac{1}{EJ} = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (2x/b - 3/2 x^2/b^2 - 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 1/2 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 1/2 b - 1/8 b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (5/2 x/b - 3 x^2/b^2 + 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 5/4 x^2/b - x^3/b^2 + 1/8 x^4/b^3 \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (5/4 b - b + 1/8 b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-x/b + 1/2 x^2/b^2) Fb \frac{1}{EJ} dx + \int_0^{2b} (-1) \theta dx$$

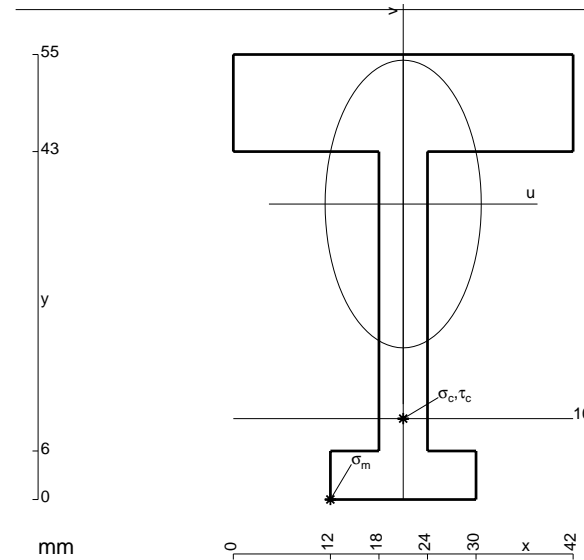
$$= \left[ -1/2 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} Fb \frac{1}{EJ} + \left[ -x \right]_0^{2b} \theta$$

$$= (-2b + 4/3 b) Fb \frac{1}{EJ} + (-2b) \theta = -8/3 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (-x/b + 1/2 x^2/b^2) Fb \frac{1}{EJ} dx + \int_0^{2b} (1) \theta dx$$

$$= \left[ -1/2 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} Fb \frac{1}{EJ} + \left[ x \right]_0^{2b} \theta$$

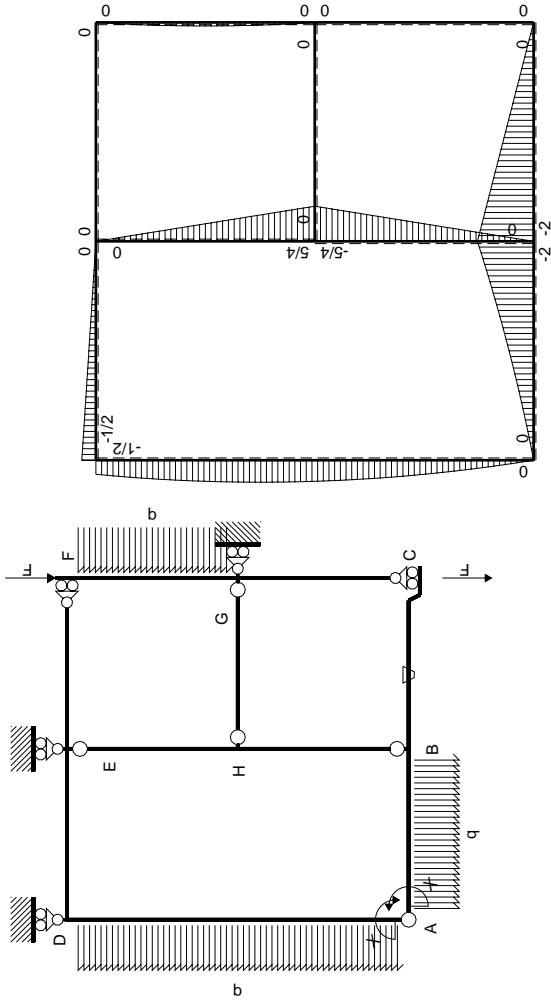
$$= (-2b + 4/3 b) Fb \frac{1}{EJ} + (2b) \theta = -8/3 \cdot Fb^2/EJ$$



- A = 834. mm<sup>2</sup>
- J<sub>u</sub> = 263619. mm<sup>4</sup>
- J<sub>v</sub> = 77670. mm<sup>4</sup>
- y<sub>g</sub> = 36.52 mm
- T<sub>y</sub> = 2875. N
- M<sub>x</sub> = -1437500. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -9. mm
- v<sub>m</sub> = -36.52 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -199.1 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 10. mm
- v<sub>c</sub> = -26.52 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -144.6 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.825 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 145.3 N/mm<sup>2</sup>
- S = 4305. mm<sup>3</sup>

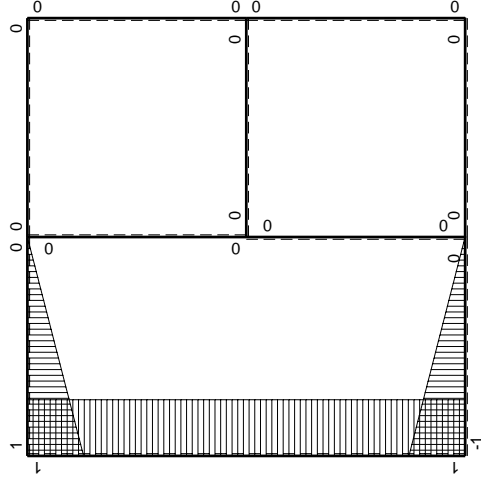






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-2Fb+2Fx$	$-Fb/EJ$	0	0	0	0+0	0
CB b	0	$2Fx$	$Fb/EJ$	0	0	0		
AD 2b	1	$-5/4Fx+1/2qx^2$	0	$-5/4Fx+1/2Fx^2/b$	0	1	$(-7/6+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$1/2Fb+3/4Fx-1/2qx^2$	0	$-1/2Fb-3/4Fx+1/2Fx^2/b$	0	1		
DE b	$1-x/b$	$-1/2Fb+1/2Fx$	0	$-1/2Fb+Fx-1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$1/2Fx$	0	$-1/2Fx^2/b$	0	$x^2/b^2$		
EF b	0	0	0	0	0	0	0+0	0
FE b	0	0	0	0	0	0		
FG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0
GF b	0	$-1/2Fx+1/2qx^2$	0	0	0	0		
GC b	0	0	0	0	0	0	0+0	0
CG b	0	0	0	0	0	0		
HG b	0	0	0	0	0	0	0+0	0
GH b	0	0	0	0	0	0		
HB b	0	$-5/4Fb+5/4Fx$	0	0	0	0	0+0	0
BH b	0	$5/4Fx$	0	0	0	0		
HE b	0	$5/4Fb-5/4Fx$	0	0	0	0	0+0	0
EH b	0	$-5/4Fx$	0	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$-25/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$5/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-5/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-5/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -7/6 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (-1/2 - 3/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x - 3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

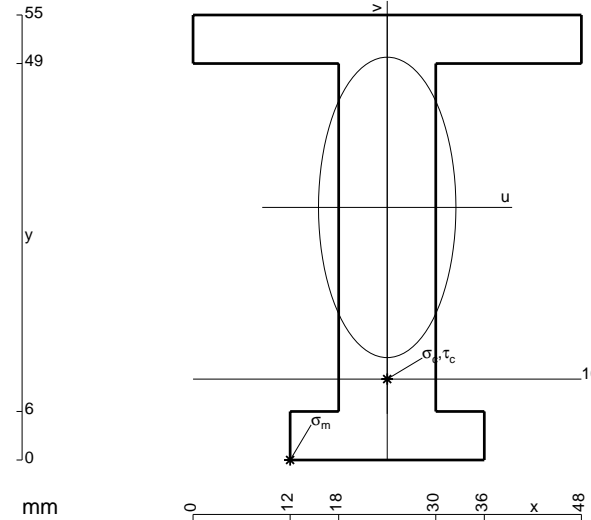
$$= (-b - 3/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -7/6 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x + 1/2 x^2/b - 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

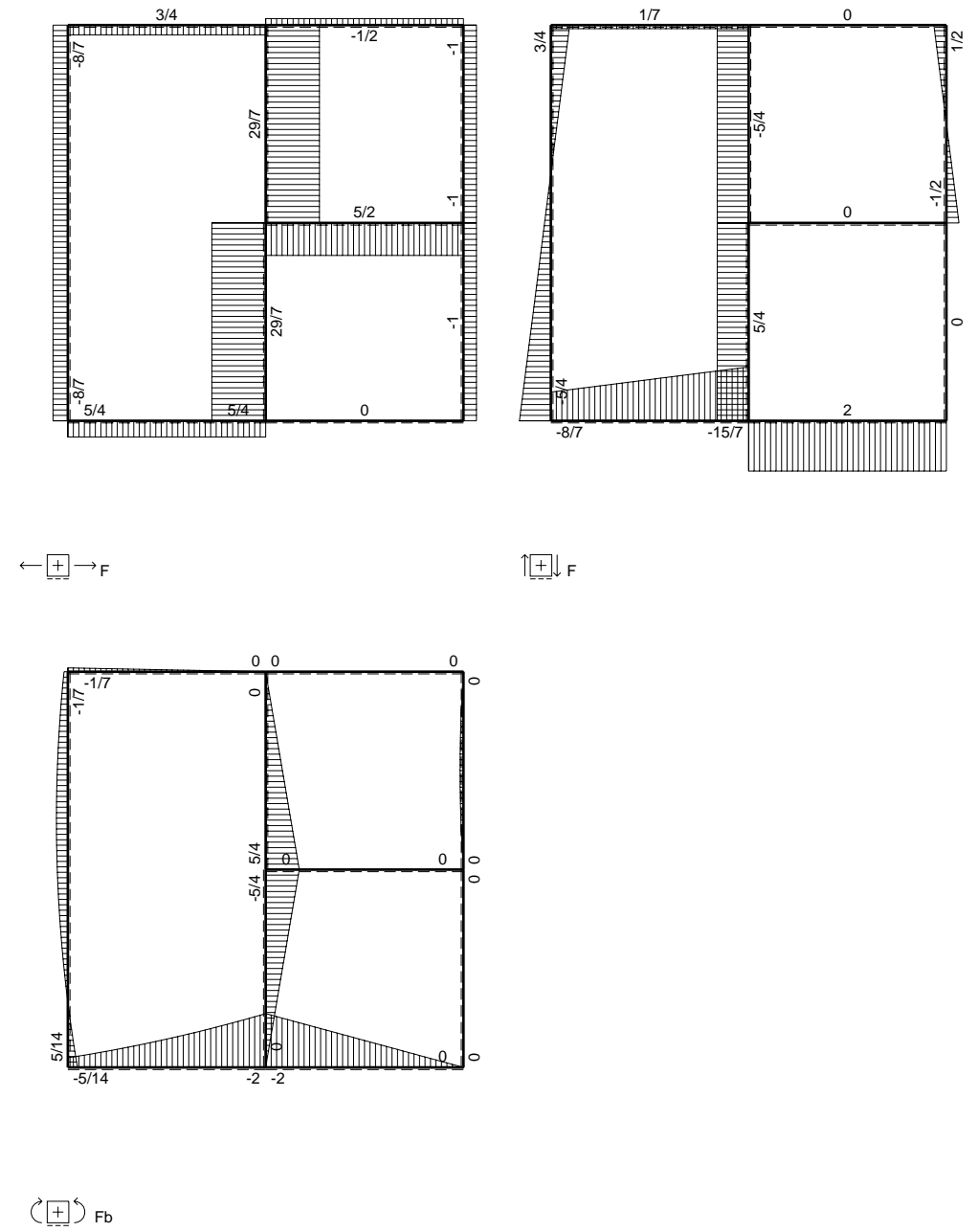
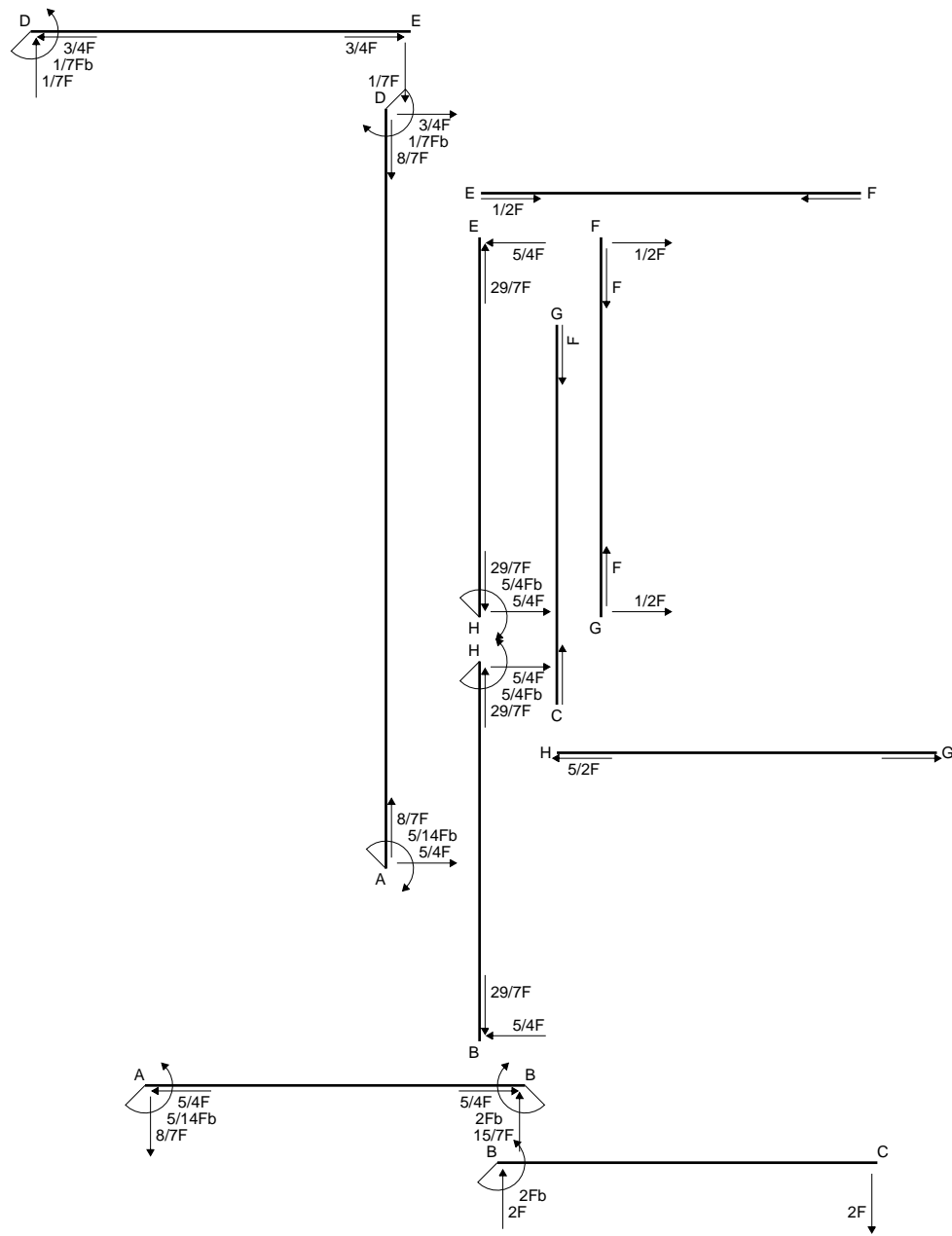
$$= (-1/2 b + 1/2 b - 1/6 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

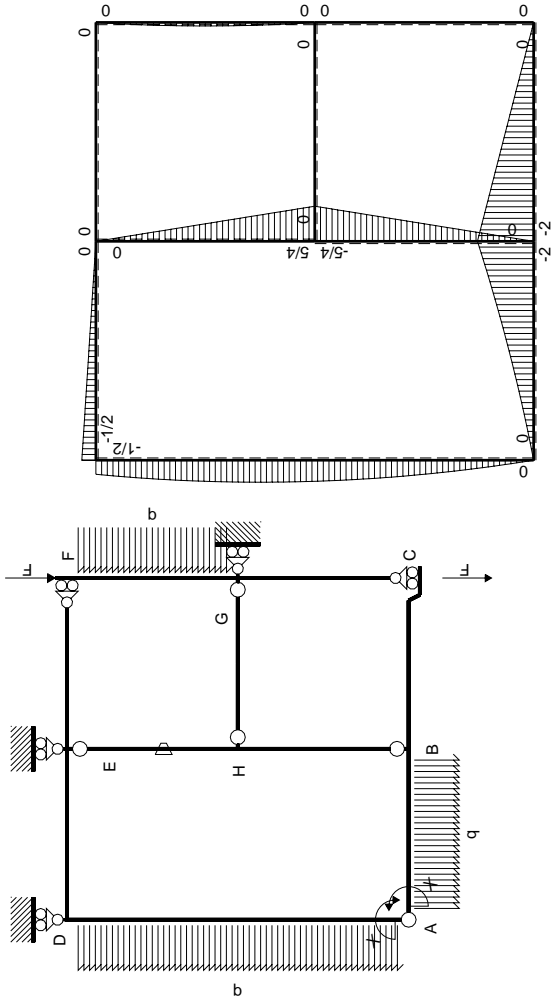
$$L_{ED}^{xo} = \int_0^b (-1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/6 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$



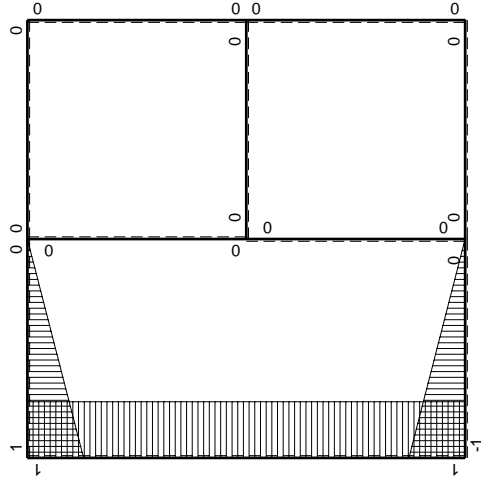
- A = 948. mm<sup>2</sup>
- J<sub>u</sub> = 326981. mm<sup>4</sup>
- J<sub>v</sub> = 68400. mm<sup>4</sup>
- y<sub>g</sub> = 31.22 mm
- T<sub>y</sub> = 3980. N
- M<sub>x</sub> = -2189000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -12. mm
- v<sub>m</sub> = -31.22 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -209. N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 10. mm
- v<sub>c</sub> = -21.22 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -142.1 N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.253 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 142.4 N/mm<sup>2</sup>
- S = 5179. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0
CB b	0	$2Fx$	0	0	0	0		
AD 2b	1	$-5/4Fx+1/2qx^2$	0	$-5/4Fx+1/2Fx^2/b$	0	1	$(-7/6+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$1/2Fb+3/4Fx-1/2qx^2$	0	$-1/2Fb-3/4Fx+1/2Fx^2/b$	0	1		
DE b	$1-x/b$	$-1/2Fb+1/2Fx$	0	$-1/2Fb+Fx-1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$1/2Fx$	0	$-1/2Fx^2/b$	0	$x^2/b^2$		
EF b	0	0	0	0	0	0	0+0	0
FE b	0	0	0	0	0	0		
FG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0
GF b	0	$-1/2Fx+1/2qx^2$	0	0	0	0		
GC b	0	0	0	0	0	0	0+0	0
CG b	0	0	0	0	0	0		
HG b	0	0	0	0	0	0	0+0	0
GH b	0	0	0	0	0	0		
HB b	0	$-5/4Fb+5/4Fx$	0	0	0	0	0+0	0
BH b	0	$5/4Fx$	0	0	0	0		
HE b	0	$5/4Fb-5/4Fx$	$-Fb/EJ$	0	0	0	0+0	0
EH b	0	$-5/4Fx$	$Fb/EJ$	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$-25/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$5/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-5/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-5/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -7/6 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (-1/2 - 3/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x - 3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

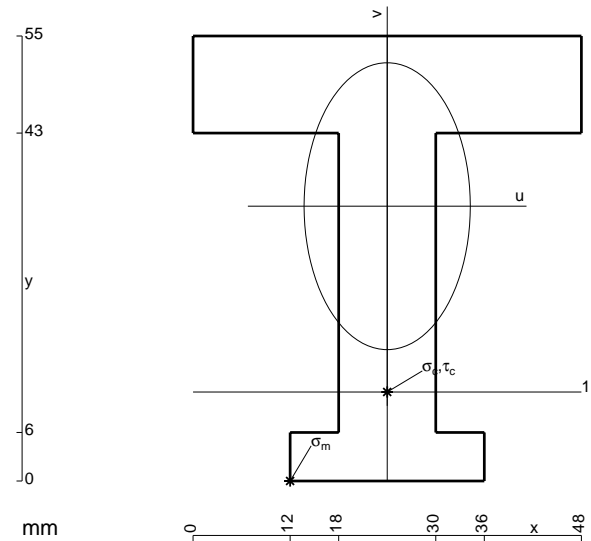
$$= (-b - 3/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -7/6 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x + 1/2 x^2/b - 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (-1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/6 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$



$$A = 1164. \text{ mm}^2$$

$$J_u = 366051. \text{ mm}^4$$

$$J_v = 122832. \text{ mm}^4$$

$$y_g = 33.96 \text{ mm}$$

$$T_y = 3940. \text{ N}$$

$$M_x = -2364000. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -12. \text{ mm}$$

$$v_m = -33.96 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -219.3 \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 11. \text{ mm}$$

$$v_c = -22.96 \text{ mm}$$

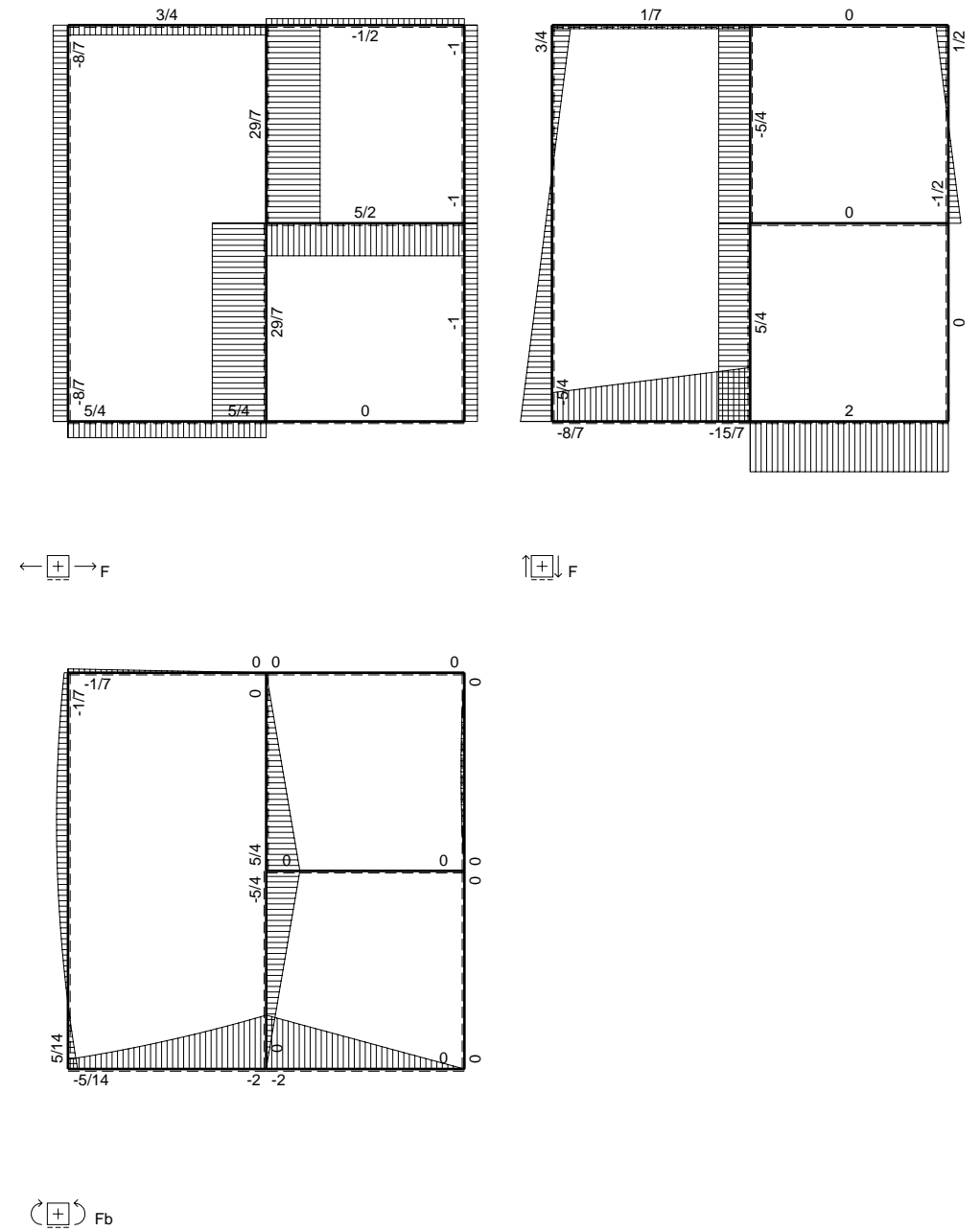
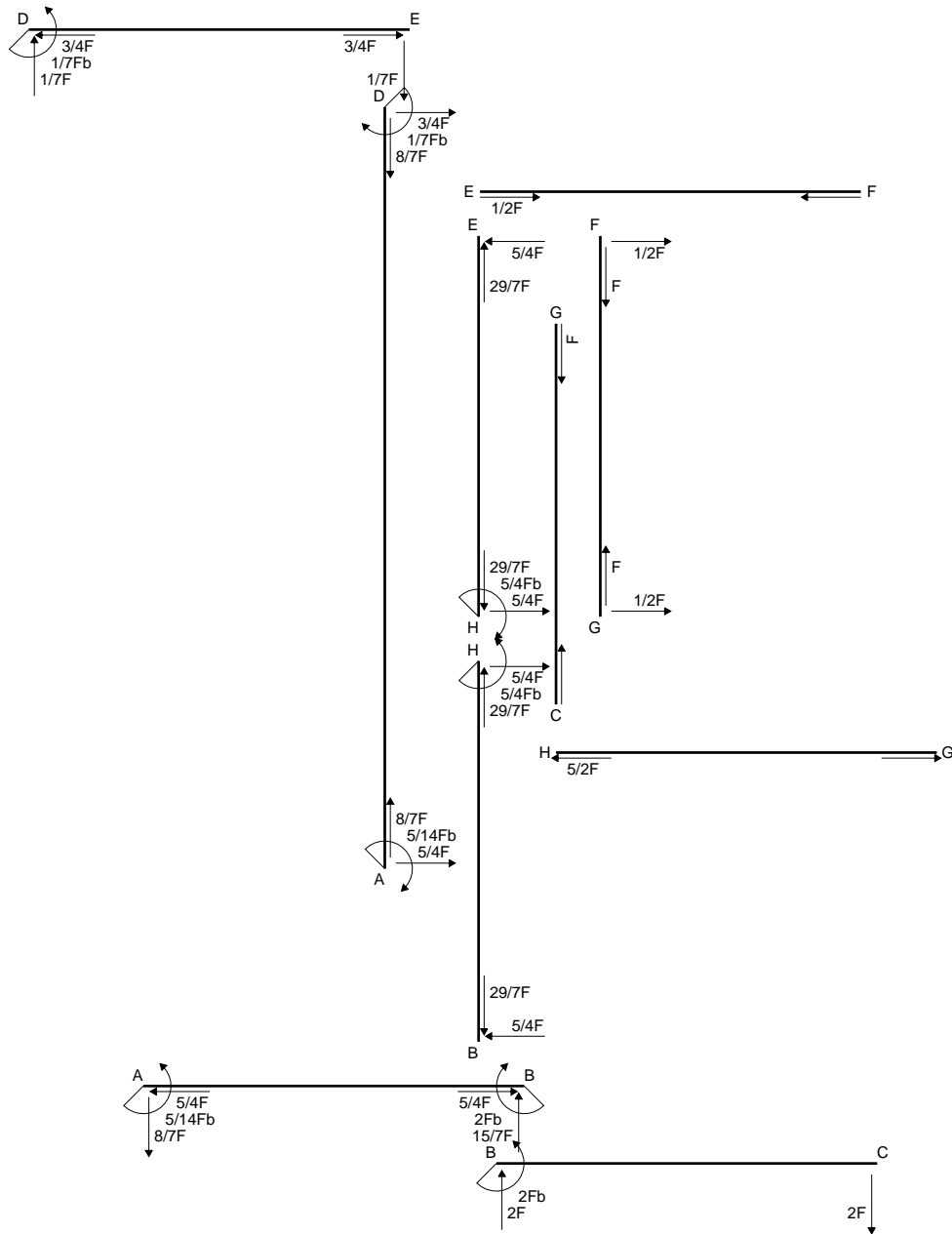
$$\sigma_c = -Mv/J_u = -148.3 \text{ N/mm}^2$$

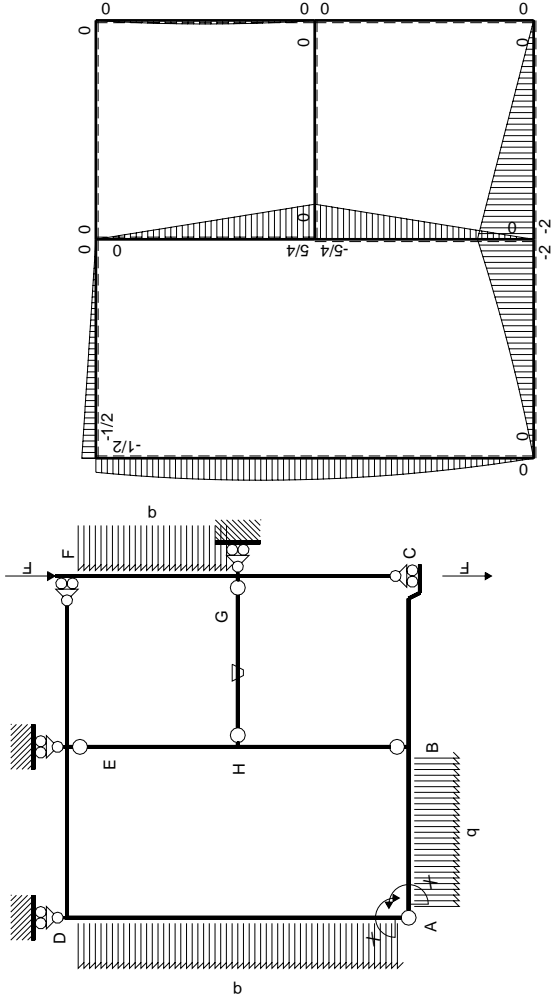
$$\tau_c = 5.37 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 148.6 \text{ N/mm}^2$$

$$S = 5987. \text{ mm}^3$$

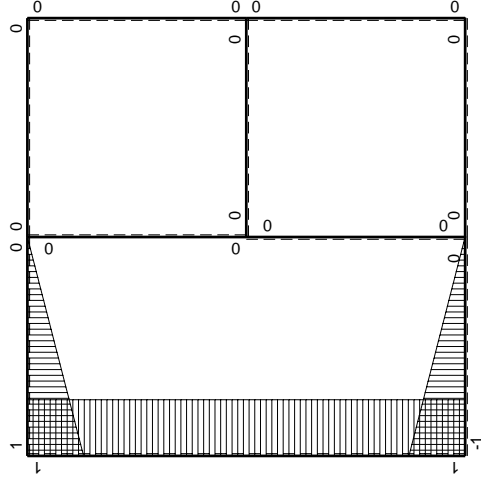






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0
CB b	0	$2Fx$	0	0	0	0		
AD 2b	1	$-5/4Fx+1/2qx^2$	0	$-5/4Fx+1/2Fx^2/b$	0	1	$(-7/6+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$1/2Fb+3/4Fx-1/2qx^2$	0	$-1/2Fb-3/4Fx+1/2Fx^2/b$	0	1		
DE b	$1-x/b$	$-1/2Fb+1/2Fx$	0	$-1/2Fb+Fx-1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$1/2Fx$	0	$-1/2Fx^2/b$	0	$x^2/b^2$		
EF b	0	0	0	0	0	0	0+0	0
FE b	0	0	0	0	0	0		
FG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0
GF b	0	$-1/2Fx+1/2qx^2$	0	0	0	0		
GC b	0	0	0	0	0	0	0+0	0
CG b	0	0	0	0	0	0		
HG b	0	0	$-Fb/EJ$	0	0	0	0+0	0
GH b	0	0	$Fb/EJ$	0	0	0		
HB b	0	$-5/4Fb+5/4Fx$	0	0	0	0	0+0	0
BH b	0	$5/4Fx$	0	0	0	0		
HE b	0	$5/4Fb-5/4Fx$	0	0	0	0	0+0	0
EH b	0	$-5/4Fx$	0	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$-25/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$5/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) 1/EJ dx = \left[ x \right]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) 1/EJ dx = \left[ x \right]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = \left[ 1/3 x^3/b^2 \right]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b Fb 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) Fb 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b Fb 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) Fb 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-5/4 x/b + 1/2 x^2/b^2) Fb 1/EJ dx = \left[ -5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} Fb 1/EJ$$

$$= (-5/2 b + 4/3 b) Fb 1/EJ = -7/6 Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (-1/2 - 3/4 x/b + 1/2 x^2/b^2) Fb 1/EJ dx = \left[ -1/2 x - 3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} Fb 1/EJ$$

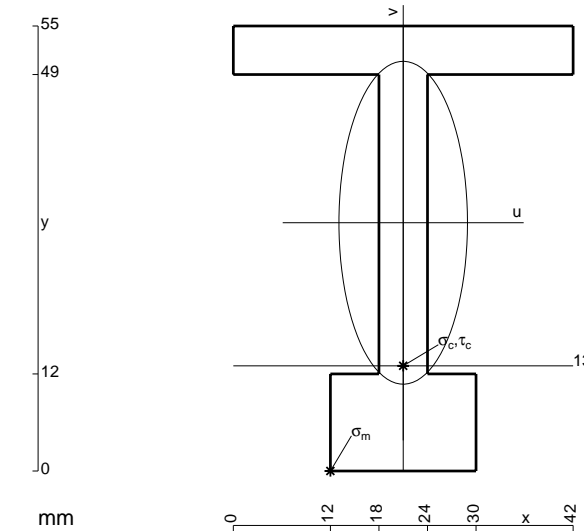
$$= (-b - 3/2 b + 4/3 b) Fb 1/EJ = -7/6 Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx = \left[ -1/2 x + 1/2 x^2/b - 1/6 x^3/b^2 \right]_0^b Fb 1/EJ$$

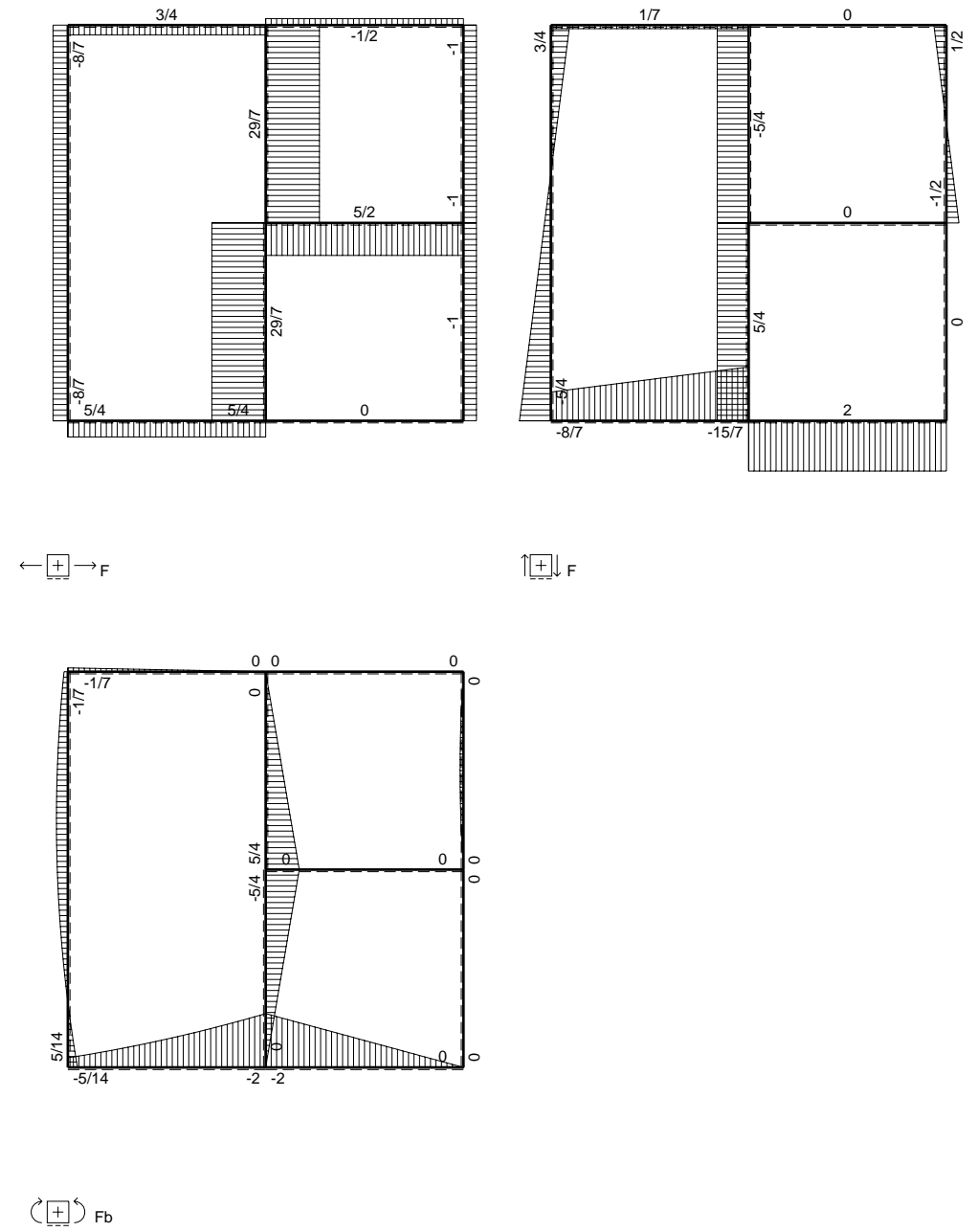
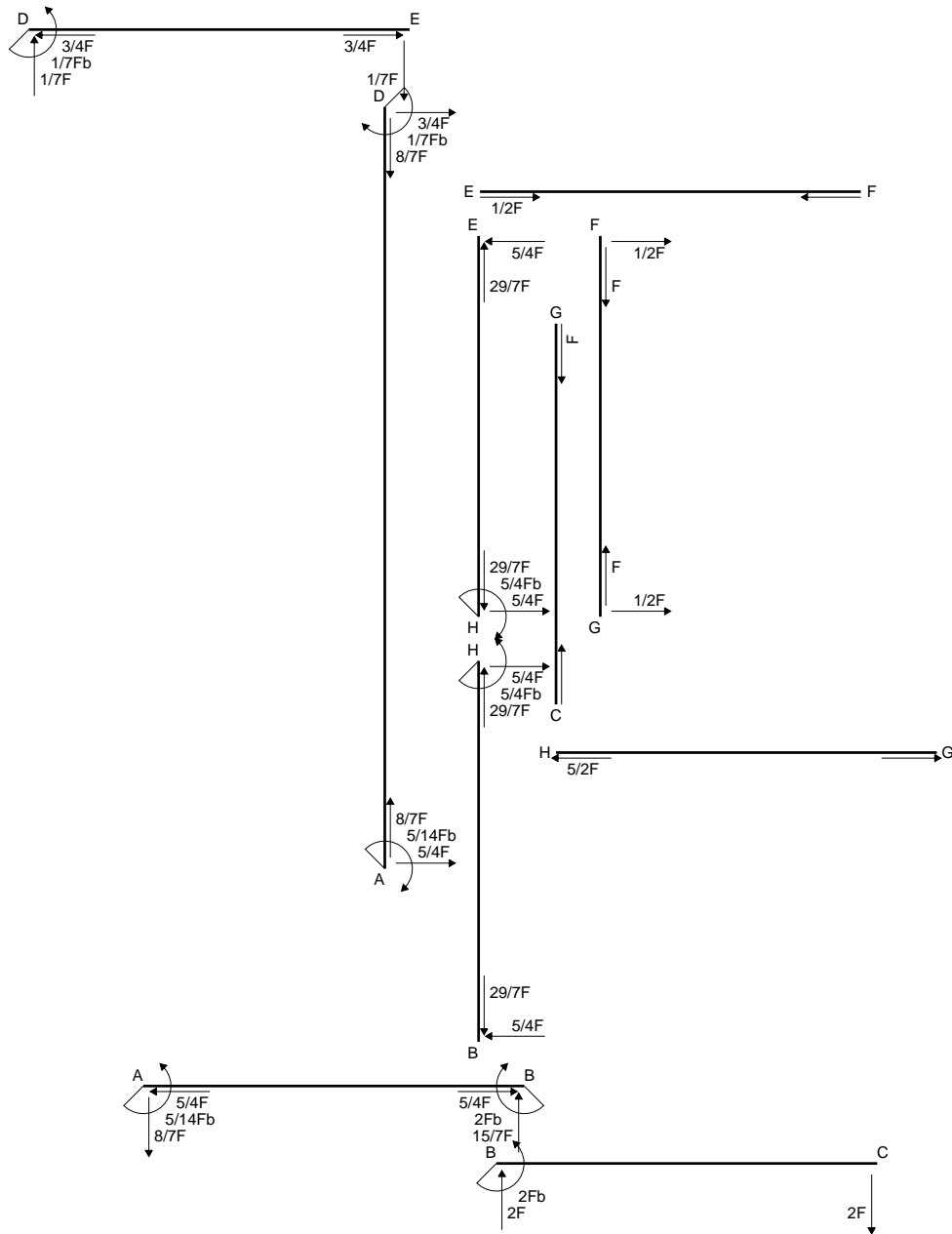
$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

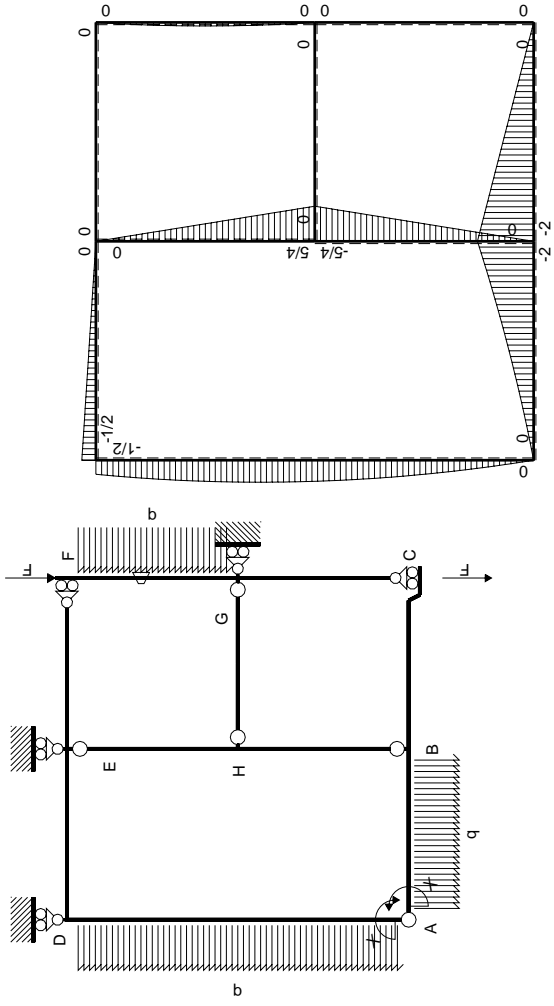
$$L_{ED}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx = \left[ -1/6 x^3/b^2 \right]_0^b Fb 1/EJ$$

$$= (-1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$



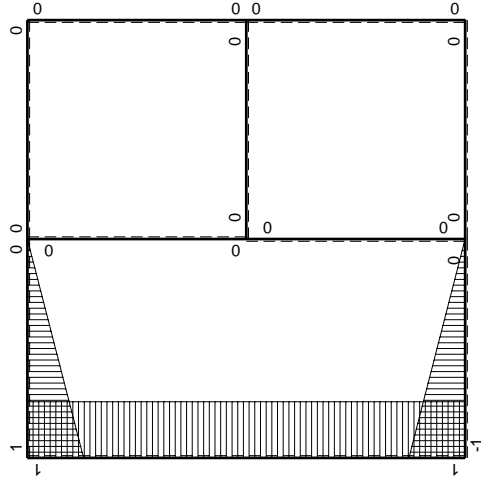
- A = 690. mm<sup>2</sup>
- J<sub>u</sub> = 274792. mm<sup>4</sup>
- J<sub>v</sub> = 43542. mm<sup>4</sup>
- y<sub>g</sub> = 30.68 mm
- T<sub>y</sub> = 3160. N
- M<sub>x</sub> = -2054000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -9. mm
- v<sub>m</sub> = -30.68 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -229.3 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 13. mm
- v<sub>c</sub> = -17.68 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -132.2 N/mm<sup>2</sup>
- τ<sub>c</sub> = 10.43 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 133.4 N/mm<sup>2</sup>
- S = 5441. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_1$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$-5/4Fx+1/2qx^2$	0	$-5/4Fx+1/2Fx^2/b$	0	1	$(-7/6+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$1/2Fb+3/4Fx-1/2qx^2$	0	$-1/2Fb-3/4Fx+1/2Fx^2/b$	0	1			
DE b	$1-x/b$	$-1/2Fb+1/2Fx$	0	$-1/2Fb+Fx-1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-1/6+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fx$	0	$-1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$1/2Fx-1/2qx^2$	$-Fb/EJ$	0	0	0	0+0	0	
GF b	0	$-1/2Fx+1/2qx^2$	$Fb/EJ$	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-5/4Fb+5/4Fx$	0	0	0	0	0+0	0	
BH b	0	$5/4Fx$	0	0	0	0			
HE b	0	$5/4Fb-5/4Fx$	0	0	0	0	0+0	0	
EH b	0	$-5/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$-25/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$5/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx + 1 \cdot 1/4 \cdot b/EJ = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx + 1 \cdot 1/4 \cdot b/EJ = [1/3 x^3/b^2]_0^b 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= [3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) Fb 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= [x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) Fb 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-5/4 x/b + 1/2 x^2/b^2) Fb 1/EJ dx = [-5/8 x^2/b + 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-5/2 b + 4/3 b) Fb 1/EJ = -7/6 Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (-1/2 - 3/4 x/b + 1/2 x^2/b^2) Fb 1/EJ dx = [-1/2 x - 3/8 x^2/b + 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

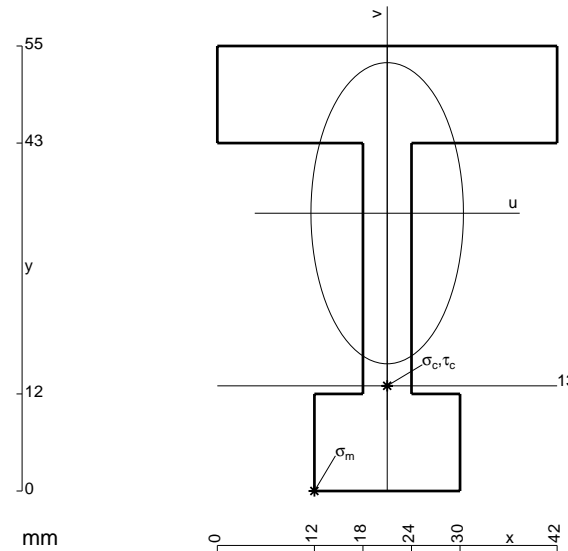
$$= (-b - 3/2 b + 4/3 b) Fb 1/EJ = -7/6 Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

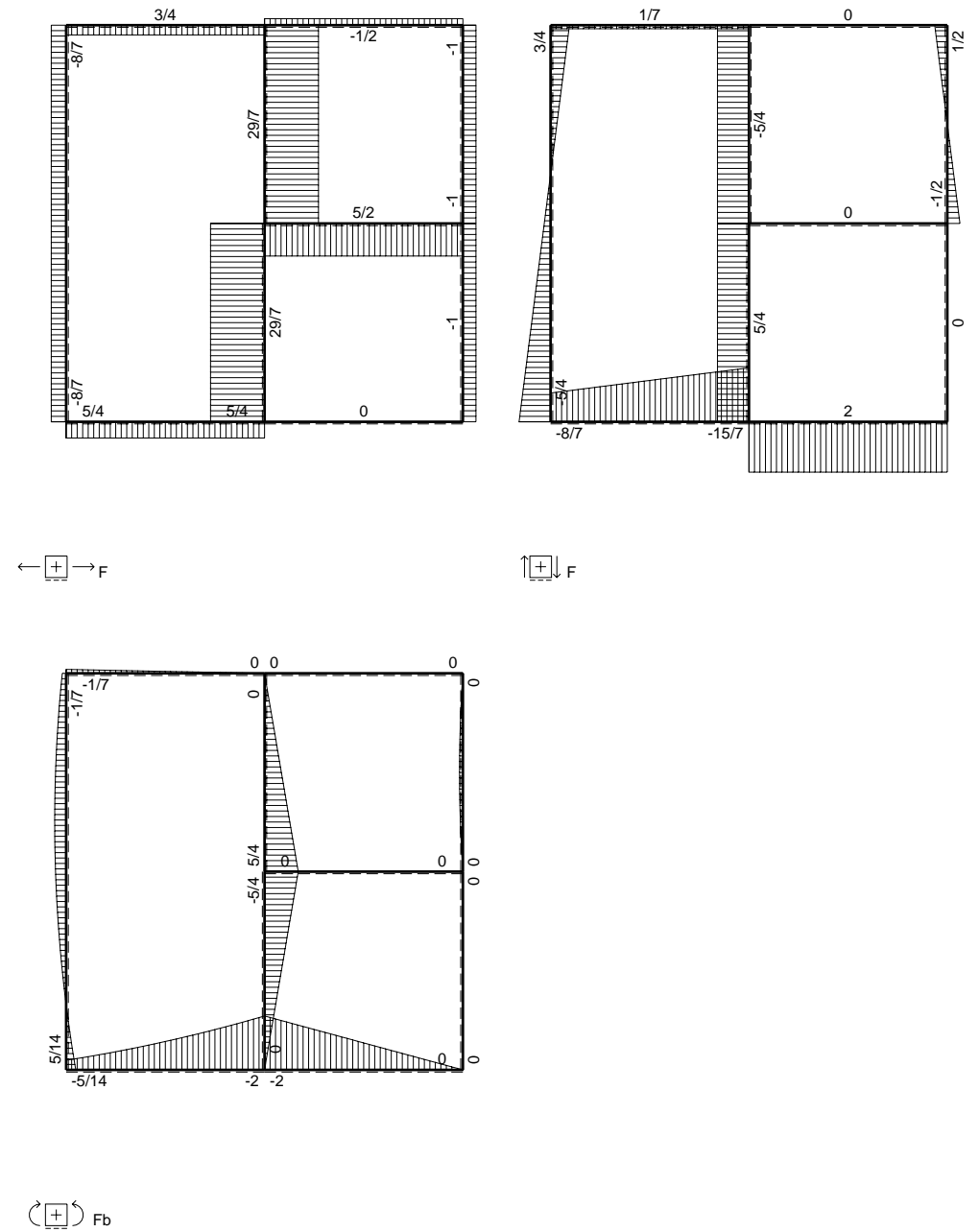
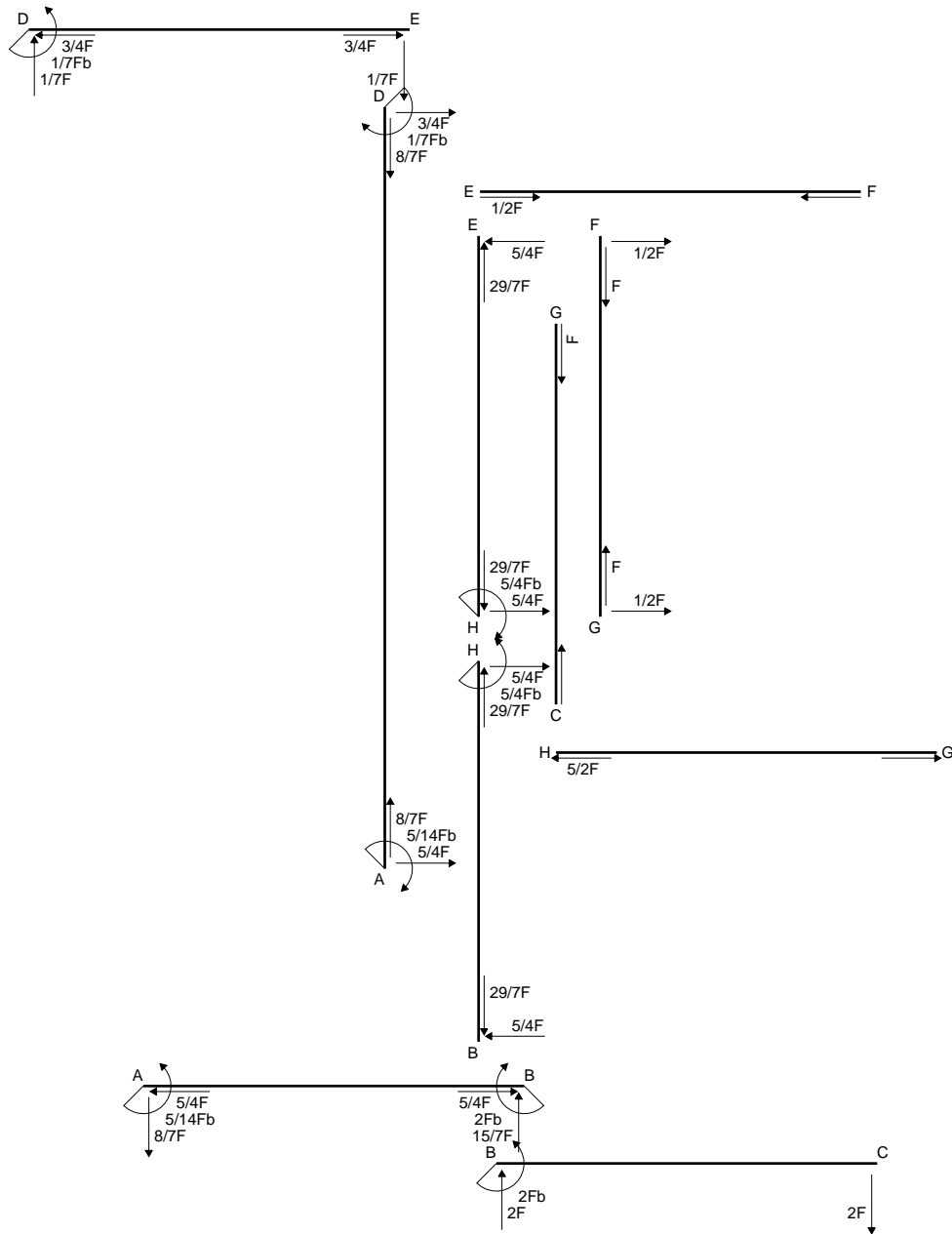
$$L_{ED}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ$$

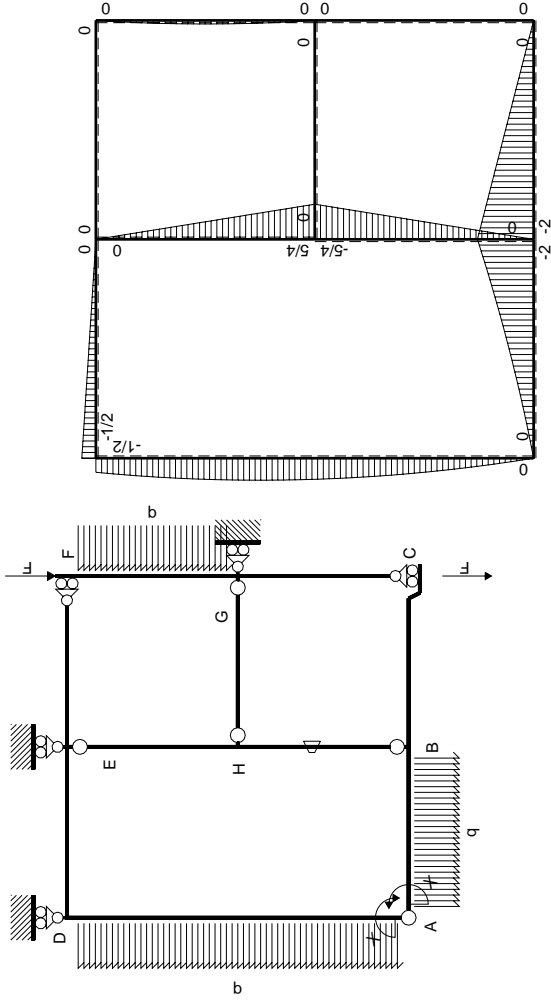
$$= (-1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$



- A = 906. mm<sup>2</sup>
- J<sub>u</sub> = 314037. mm<sup>4</sup>
- J<sub>v</sub> = 80478. mm<sup>4</sup>
- y<sub>g</sub> = 34.33 mm
- T<sub>y</sub> = 3120. N
- M<sub>x</sub> = -2184000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -9. mm
- v<sub>m</sub> = -34.33 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -238.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 13. mm
- v<sub>c</sub> = -21.33 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -148.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 10.35 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 149.5 N/mm<sup>2</sup>
- S = 6251. mm<sup>3</sup>

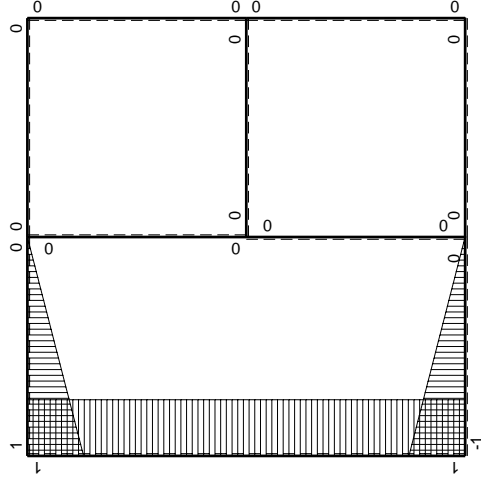






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJdx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$-5/4Fx+1/2qx^2$	0	$-5/4Fx+1/2Fx^2/b$	0	1	$(-7/6+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$1/2Fb+3/4Fx-1/2qx^2$	0	$-1/2Fb-3/4Fx+1/2Fx^2/b$	0	1			
DE b	$1-x/b$	$-1/2Fb+1/2Fx$	0	$-1/2Fb+Fx-1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-1/6+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fx$	0	$-1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
GF b	0	$-1/2Fx+1/2qx^2$	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-5/4Fb+5/4Fx$	$-Fb/EJ$	0	0	0	0+0	0	
BH b	0	$5/4Fx$	$Fb/EJ$	0	0	0			
HE b	0	$5/4Fb-5/4Fx$	0	0	0	0	0+0	0	
EH b	0	$-5/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$-25/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$5/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-5/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-5/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -7/6 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (-1/2 - 3/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x - 3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

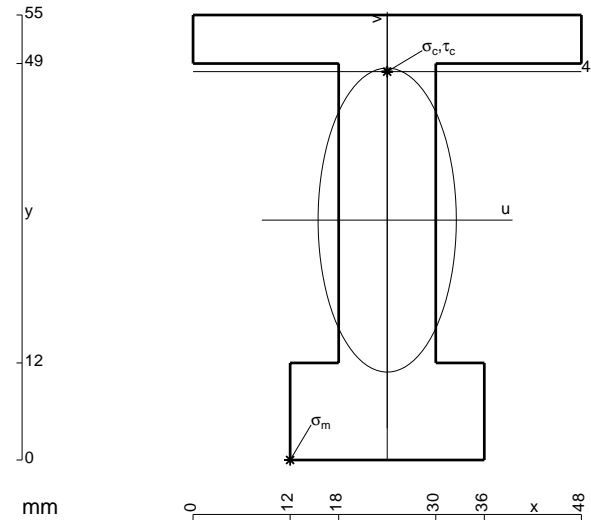
$$= (-b - 3/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -7/6 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x + 1/2 x^2/b - 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (-1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/6 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$



$$A = 1020. \text{ mm}^2$$

$$J_u = 360241. \text{ mm}^4$$

$$J_v = 74448. \text{ mm}^4$$

$$y_g = 29.65 \text{ mm}$$

$$T_y = 3220. \text{ N}$$

$$M_x = -2415000. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -12. \text{ mm}$$

$$v_m = -29.65 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -198.8 \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 48. \text{ mm}$$

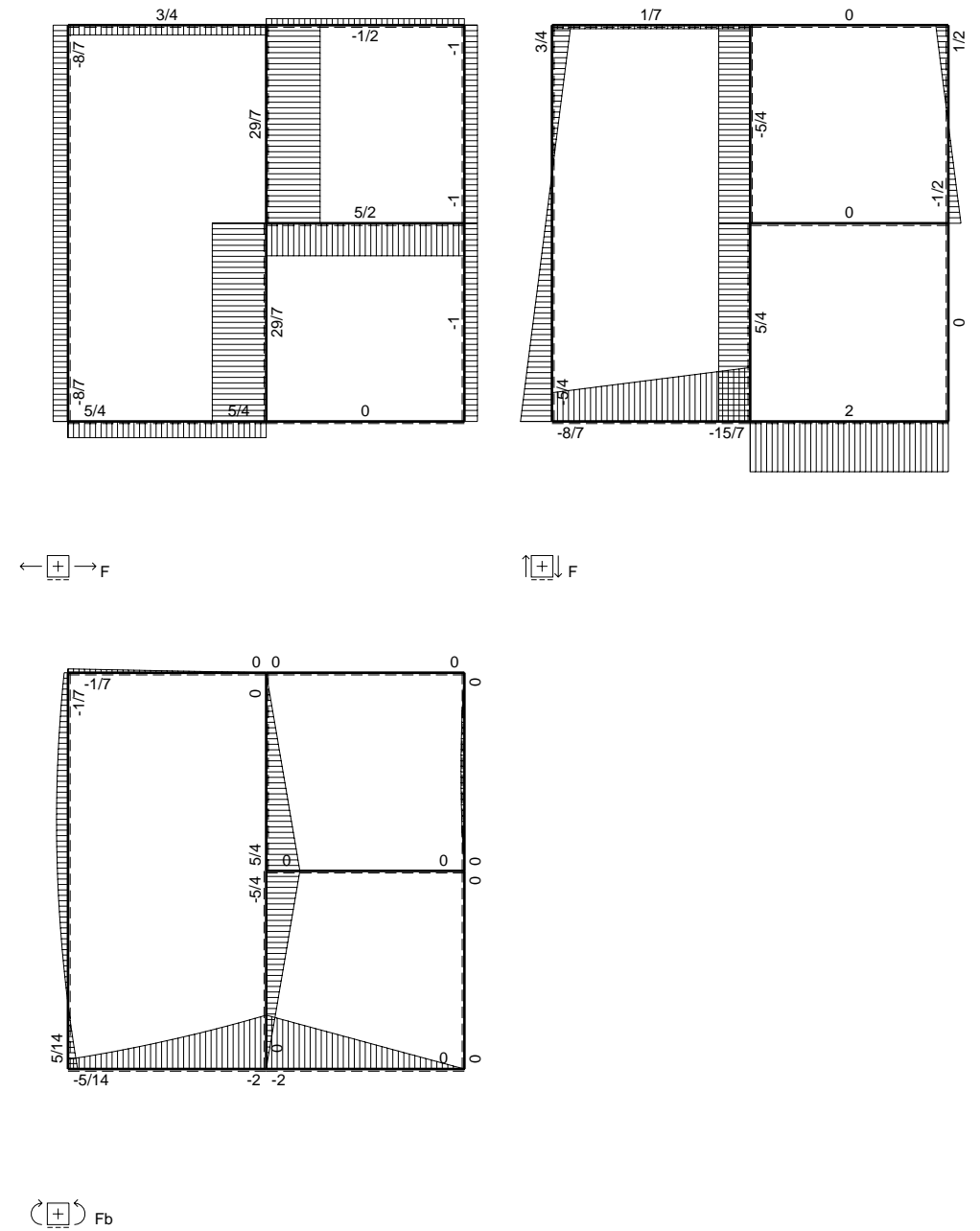
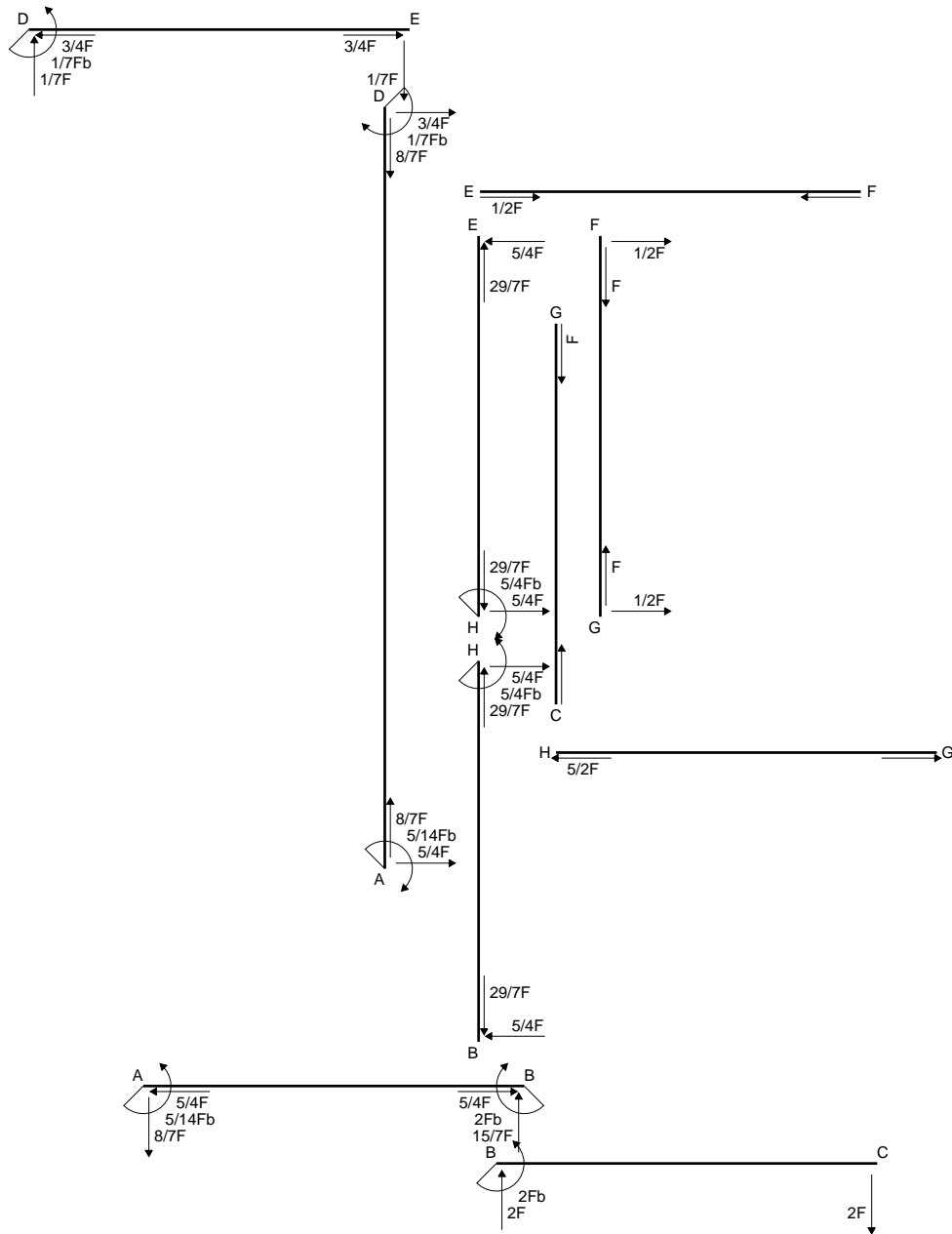
$$v_c = 18.35 \text{ mm}$$

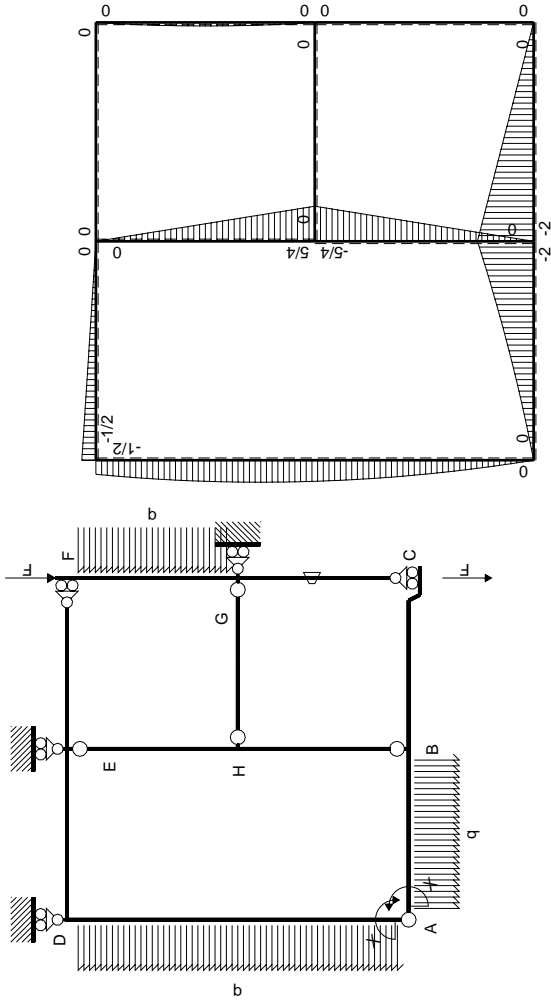
$$\sigma_c = -Mv/J_u = 123. \text{ N/mm}^2$$

$$\tau_c = 4.962 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 123.3 \text{ N/mm}^2$$

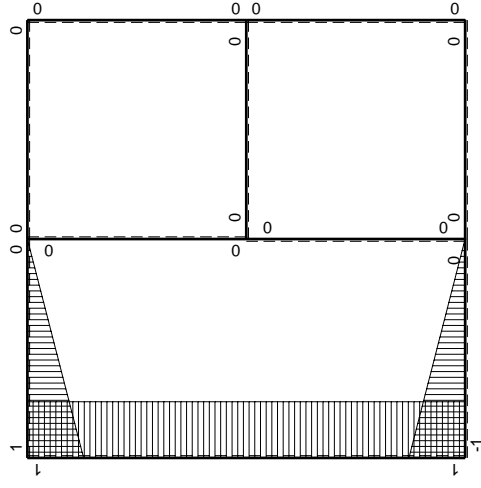
$$S = 6662. \text{ mm}^3$$





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$-5/4Fx+1/2qx^2$	0	$-5/4Fx+1/2Fx^2/b$	0	1	$(-7/6+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$1/2Fb+3/4Fx-1/2qx^2$	0	$-1/2Fb-3/4Fx+1/2Fx^2/b$	0	1			
DE b	$1-x/b$	$-1/2Fb+1/2Fx$	0	$-1/2Fb+Fx-1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-1/6+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fx$	0	$-1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
GF b	0	$-1/2Fx+1/2qx^2$	0	0	0	0			
GC b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
CG b	0	0	$Fb/EJ$	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-5/4Fb+5/4Fx$	0	0	0	0	0+0	0	
BH b	0	$5/4Fx$	0	0	0	0			
HE b	0	$5/4Fb-5/4Fx$	0	0	0	0	0+0	0	
EH b	0	$-5/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$-25/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$5/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-5/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-5/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -7/6 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (-1/2 - 3/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x - 3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

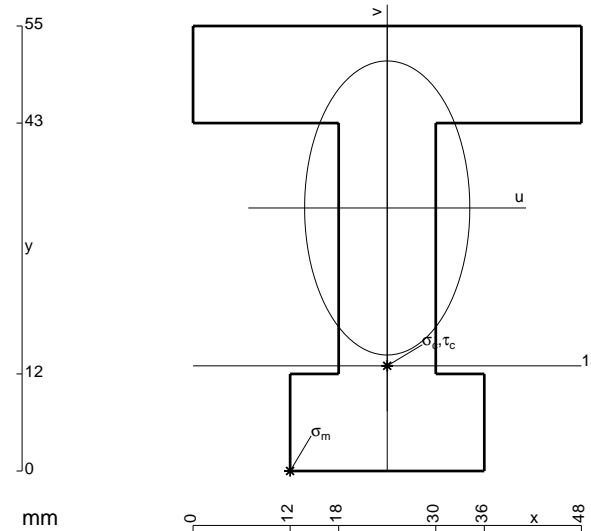
$$= (-b - 3/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -7/6 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x + 1/2 x^2/b - 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

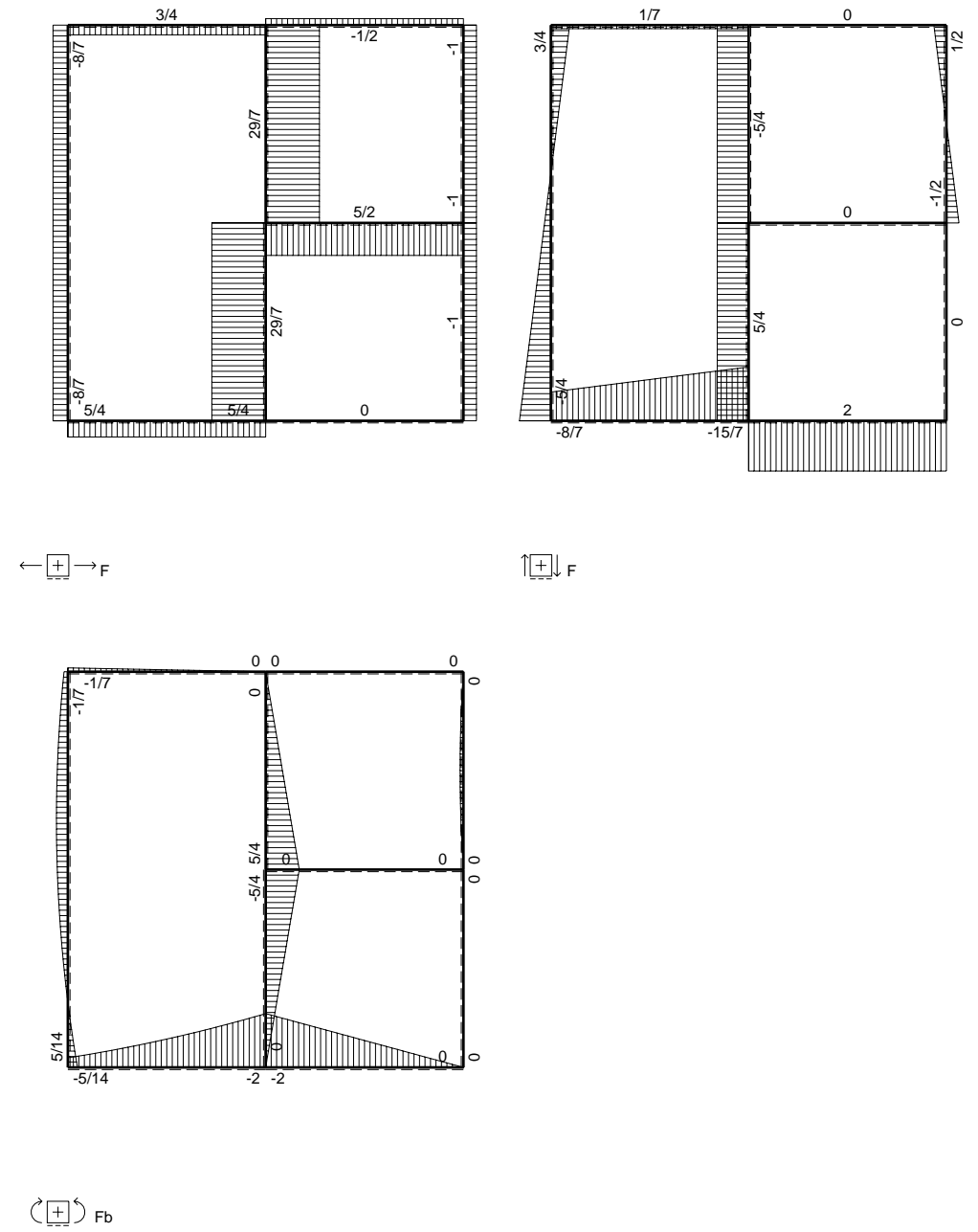
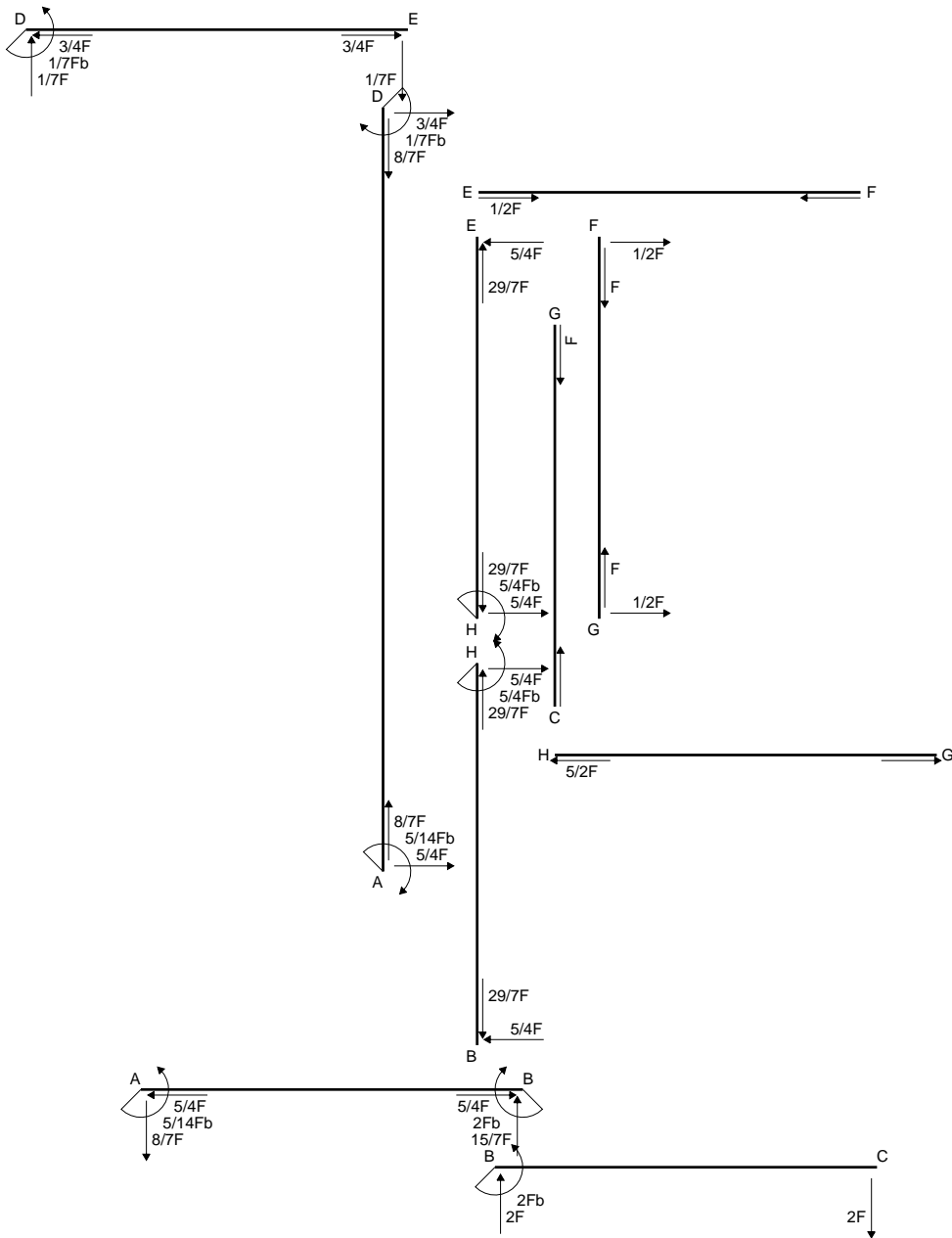
$$L_{ED}^{xo} = \int_0^b (-1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

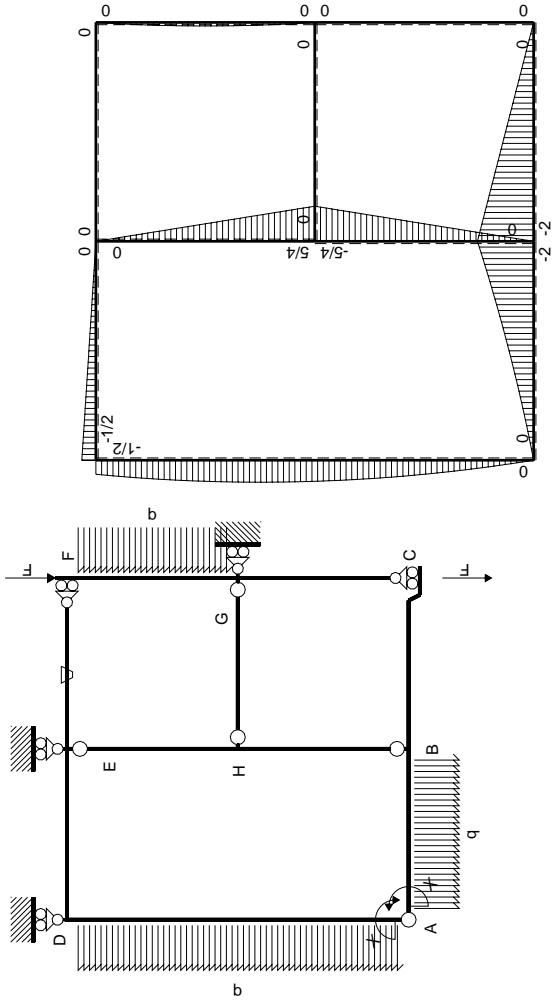
$$= (-1/6 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$



- A = 1236. mm<sup>2</sup>
- J<sub>u</sub> = 408523. mm<sup>4</sup>
- J<sub>v</sub> = 128880. mm<sup>4</sup>
- y<sub>g</sub> = 32.51 mm
- T<sub>y</sub> = 3280. N
- M<sub>x</sub> = -2624000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -12. mm
- v<sub>m</sub> = -32.51 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -208.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 13. mm
- v<sub>c</sub> = -19.51 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -125.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.269 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 125.6 N/mm<sup>2</sup>
- S = 7875. mm<sup>3</sup>

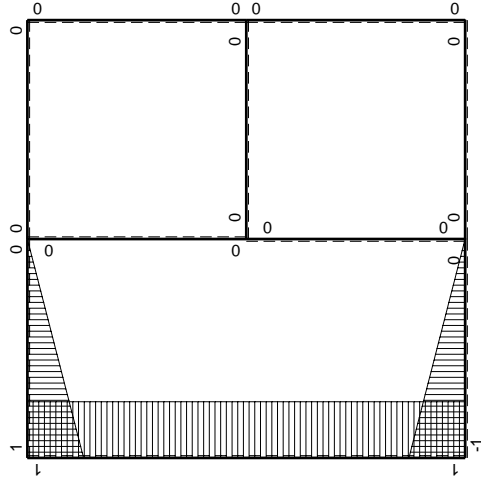






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$-5/4Fx+1/2qx^2$	0	$-5/4Fx+1/2Fx^2/b$	0	1	$(-7/6+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$1/2Fb+3/4Fx-1/2qx^2$	0	$-1/2Fb-3/4Fx+1/2Fx^2/b$	0	1			
DE b	$1-x/b$	$-1/2Fb+1/2Fx$	0	$-1/2Fb+Fx-1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-1/6+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fx$	0	$-1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
FE b	0	0	$Fb/EJ$	0	0	0			
FG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
GF b	0	$-1/2Fx+1/2qx^2$	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-5/4Fb+5/4Fx$	0	0	0	0	0+0	0	
BH b	0	$5/4Fx$	0	0	0	0			
HE b	0	$5/4Fb-5/4Fx$	0	0	0	0	0+0	0	
EH b	0	$-5/4Fx$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$-25/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$5/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{x_0} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{x_0} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{x_0} = \int_0^{2b} (-5/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-5/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -7/6 \cdot Fb^2/EJ$$

$$L_{DA}^{x_0} = \int_0^{2b} (-1/2 - 3/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x - 3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

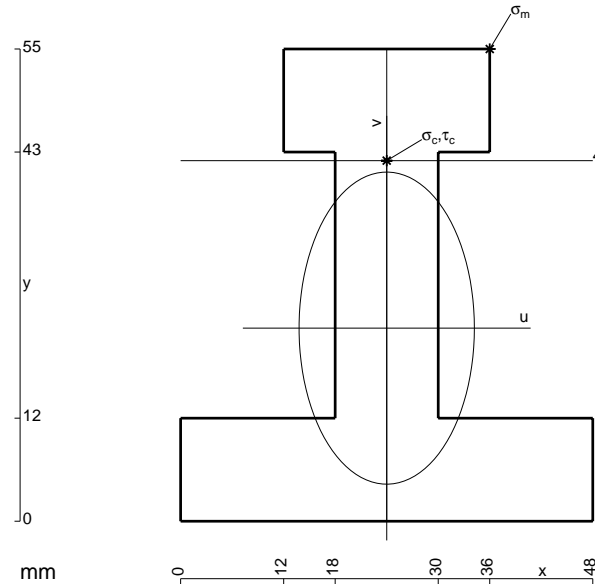
$$= (-b - 3/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -7/6 \cdot Fb^2/EJ$$

$$L_{DE}^{x_0} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x + 1/2 x^2/b - 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

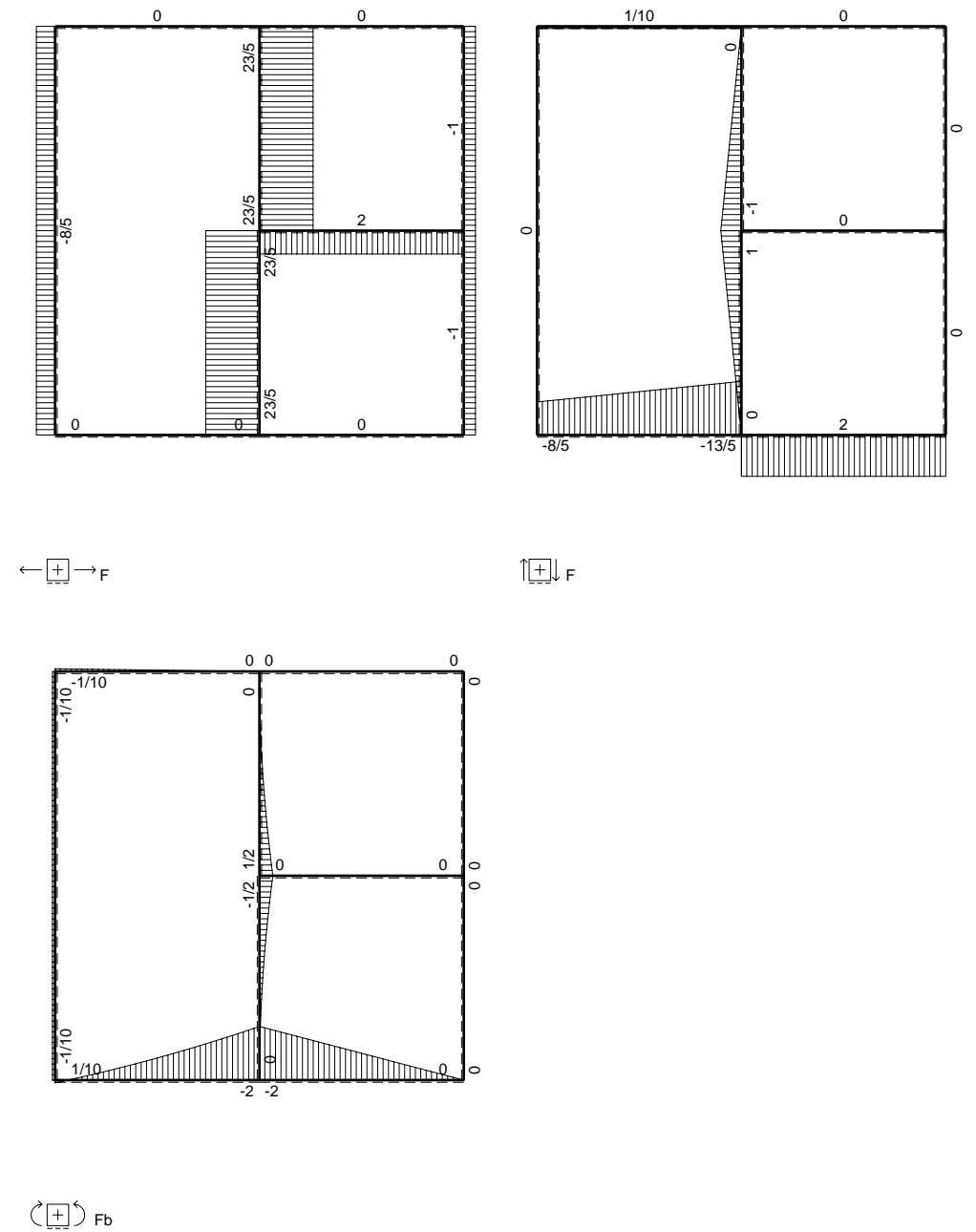
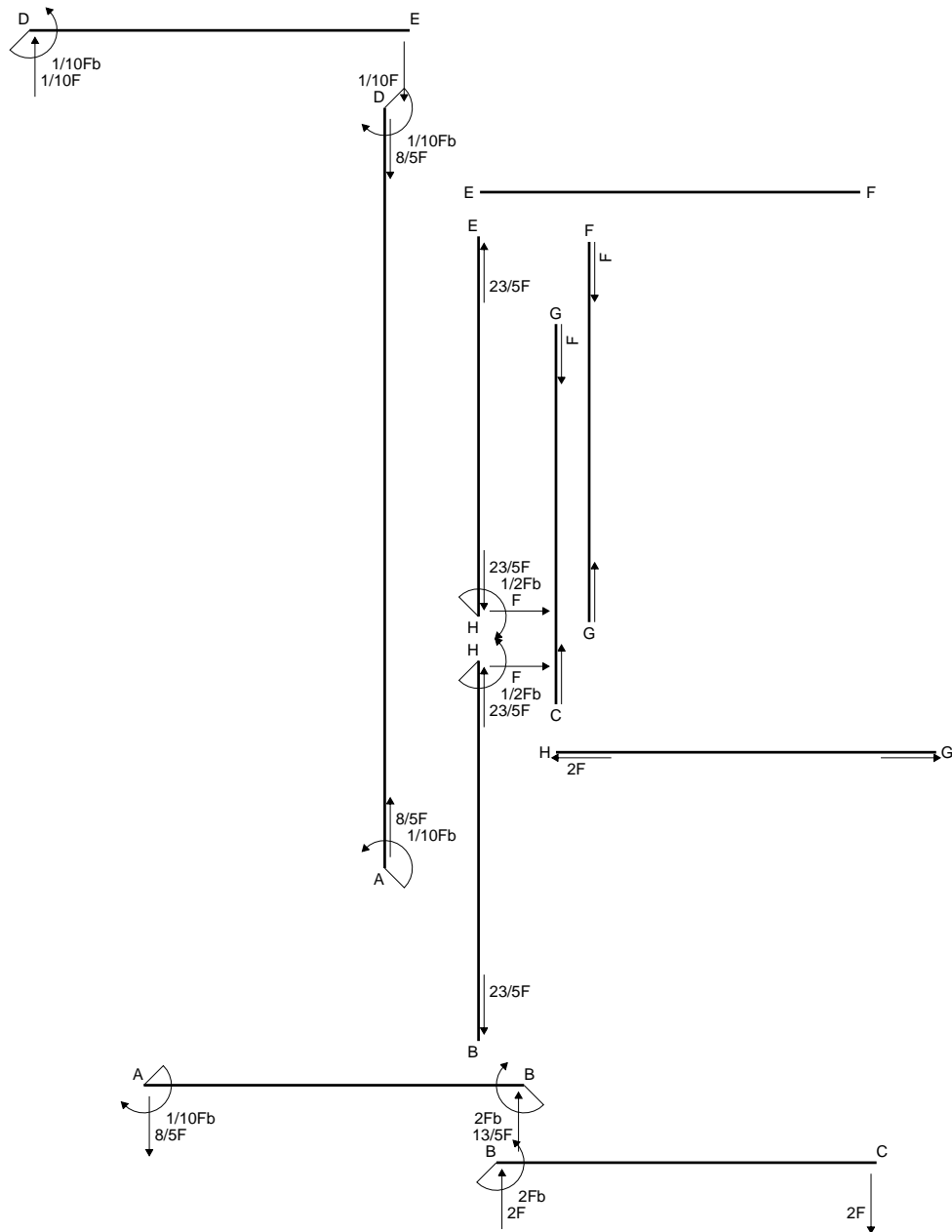
$$= (-1/2 b + 1/2 b - 1/6 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

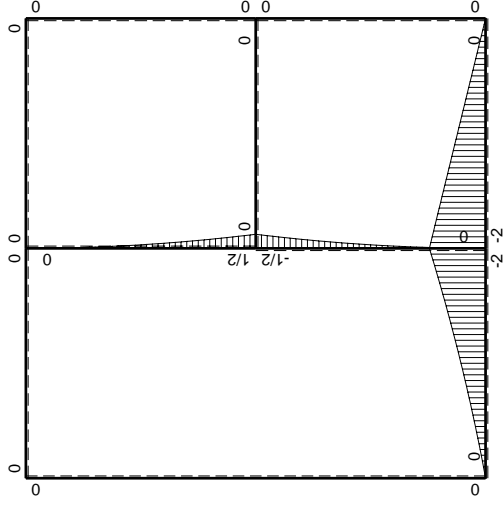
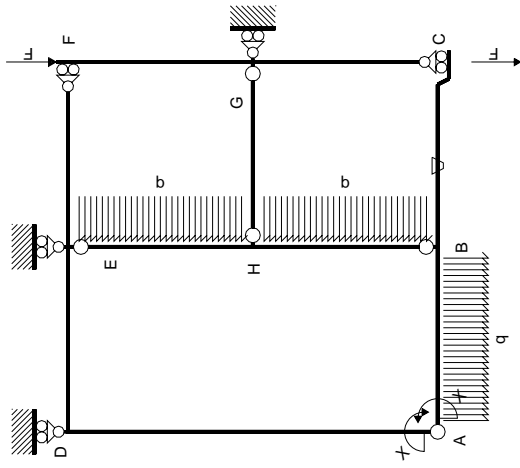
$$L_{ED}^{x_0} = \int_0^b (-1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/6 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$



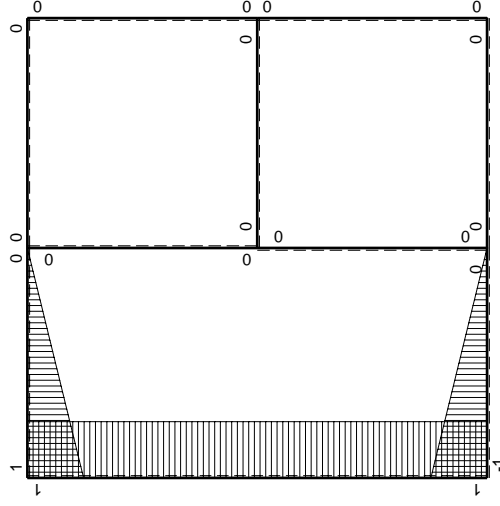
- A = 1236. mm<sup>2</sup>
- J<sub>u</sub> = 408523. mm<sup>4</sup>
- J<sub>v</sub> = 128880. mm<sup>4</sup>
- y<sub>g</sub> = 22.49 mm
- T<sub>y</sub> = 3240. N
- M<sub>x</sub> = -2754000. Nmm
- x<sub>m</sub> = 36. mm
- y<sub>m</sub> = 55. mm
- u<sub>m</sub> = 12. mm
- v<sub>m</sub> = 32.51 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 219.2 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 42. mm
- v<sub>c</sub> = 19.51 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 131.5 N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.205 N/mm<sup>2</sup>
- σ<sub>σ</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 131.8 N/mm<sup>2</sup>
- S = 7875. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	$-Fb/EJ$	0	0	0	0+0	0	
CB b	0	$2Fx$	$Fb/EJ$	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
BH b	0	$1/2qx^2$	0	0	0	0			
HE b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0+0	0	
EH b	0	$-1/2qx^2$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

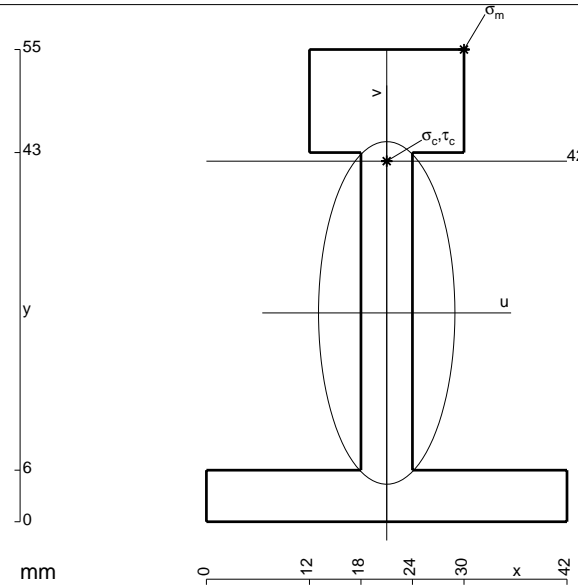
$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

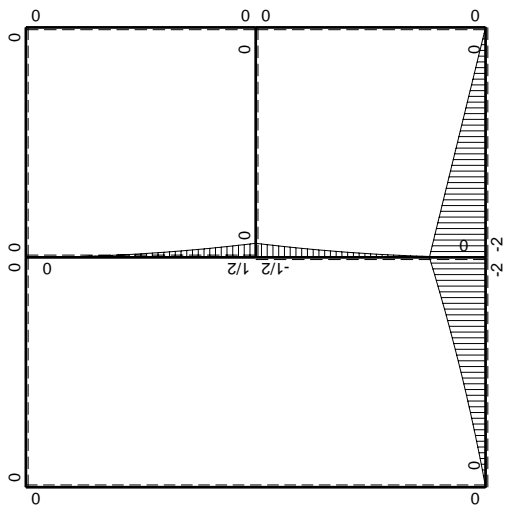
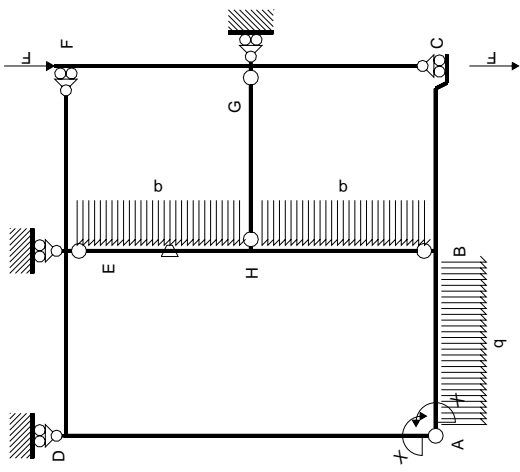
$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$



- A = 690. mm<sup>2</sup>
- J<sub>u</sub> = 274793. mm<sup>4</sup>
- J<sub>v</sub> = 43542. mm<sup>4</sup>
- y<sub>g</sub> = 24.32 mm
- T<sub>y</sub> = 2280. N
- M<sub>x</sub> = -2052000. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 55. mm
- u<sub>m</sub> = 9. mm
- v<sub>m</sub> = 30.68 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 229.1 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 42. mm
- v<sub>c</sub> = 17.68 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 132. N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.524 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 132.7 N/mm<sup>2</sup>
- S = 5441. mm<sup>3</sup>

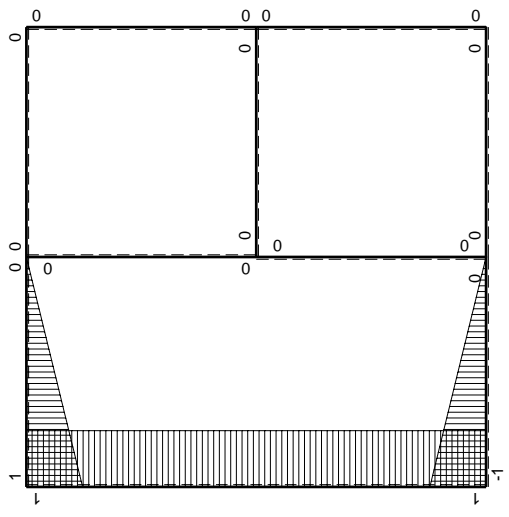






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_1$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
BH b	0	$1/2qx^2$	0	0	0	0			
HE b	0	$1/2Fb-Fx+1/2qx^2$	$-Fb/EJ$	0	0	0	0+0	0	
EH b	0	$-1/2qx^2$	$Fb/EJ$	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (-2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ -x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (-2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ -x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

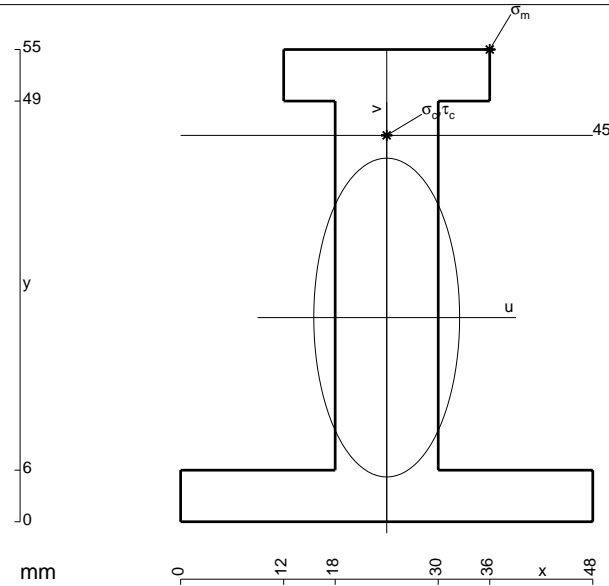
$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

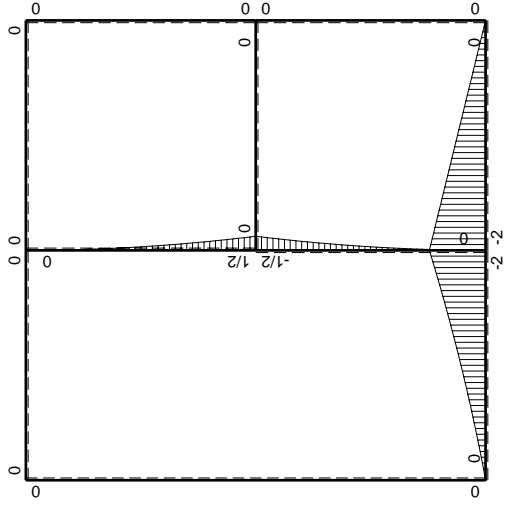
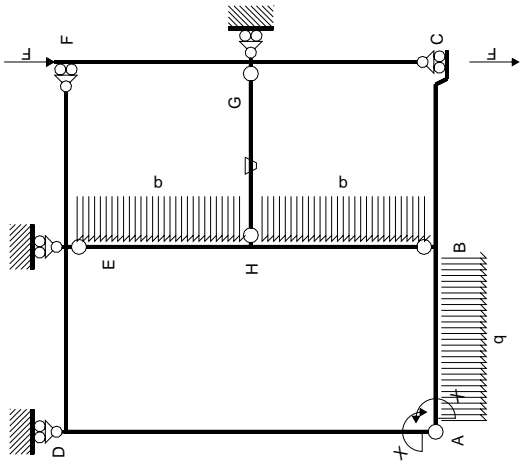
$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$



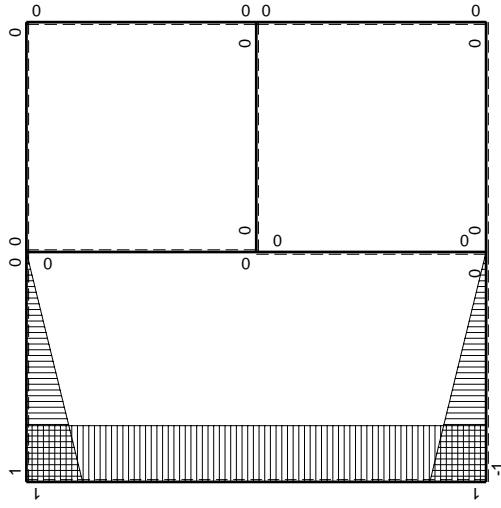
- A = 948. mm<sup>2</sup>
- J<sub>u</sub> = 326982. mm<sup>4</sup>
- J<sub>v</sub> = 68400. mm<sup>4</sup>
- y<sub>g</sub> = 23.78 mm
- T<sub>y</sub> = 2640. N
- M<sub>x</sub> = -2508000. Nmm
- x<sub>m</sub> = 36. mm
- y<sub>m</sub> = 55. mm
- u<sub>m</sub> = 12. mm
- v<sub>m</sub> = 31.22 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 239.5 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 45. mm
- v<sub>c</sub> = 21.22 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 162.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.484 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 162.9 N/mm<sup>2</sup>
- S = 5179. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
GH b	0	0	$Fb/EJ$	0	0	0			
HB b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
BH b	0	$1/2qx^2$	0	0	0	0			
HE b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0+0	0	
EH b	0	$-1/2qx^2$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

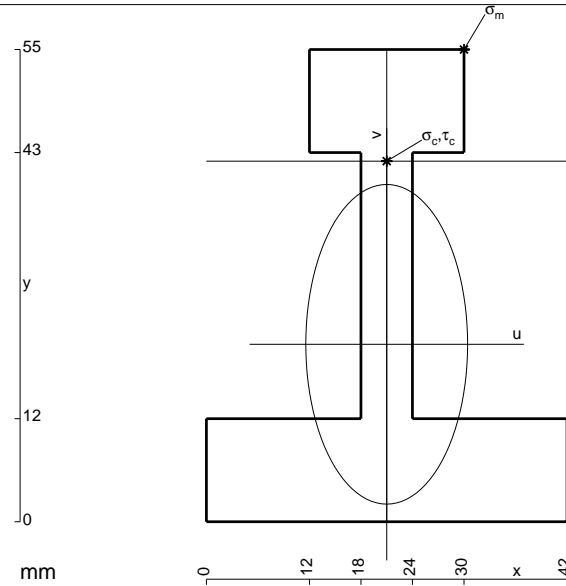
$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

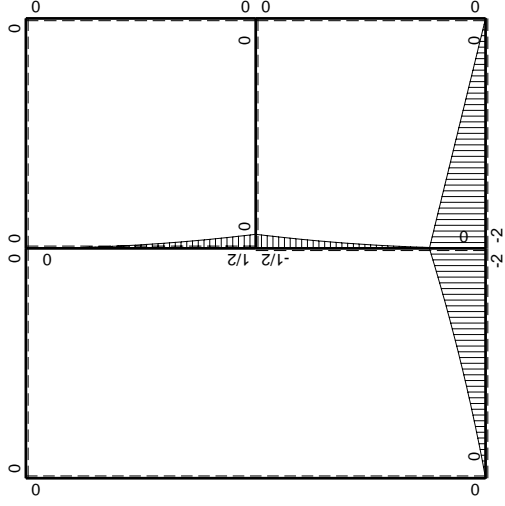
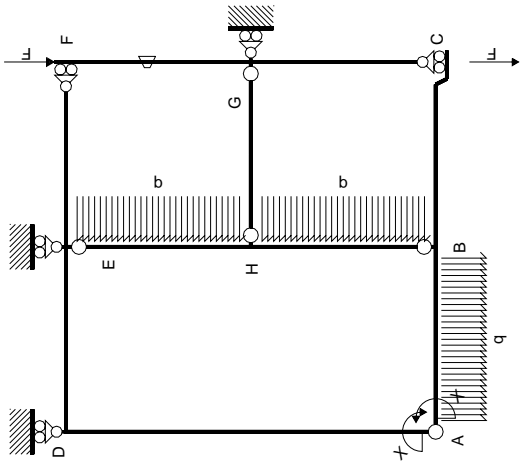
$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$



- A = 906. mm<sup>2</sup>
- J<sub>u</sub> = 314037. mm<sup>4</sup>
- J<sub>v</sub> = 80478. mm<sup>4</sup>
- y<sub>g</sub> = 20.67 mm
- T<sub>y</sub> = 3640. N
- M<sub>x</sub> = -1820000. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 55. mm
- u<sub>m</sub> = 9. mm
- v<sub>m</sub> = 34.33 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 199. N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 42. mm
- v<sub>c</sub> = 21.33 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 123.6 N/mm<sup>2</sup>
- τ<sub>c</sub> = 12.08 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 125.4 N/mm<sup>2</sup>
- S = 6251. mm<sup>3</sup>

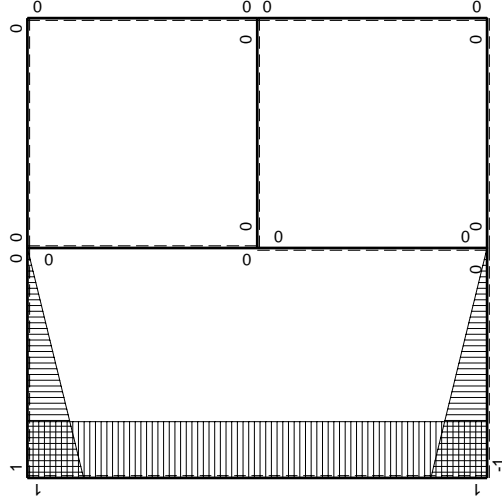






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
GF b	0	0	$Fb/EJ$	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
BH b	0	$1/2qx^2$	0	0	0	0			
HE b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0+0	0	
EH b	0	$-1/2qx^2$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

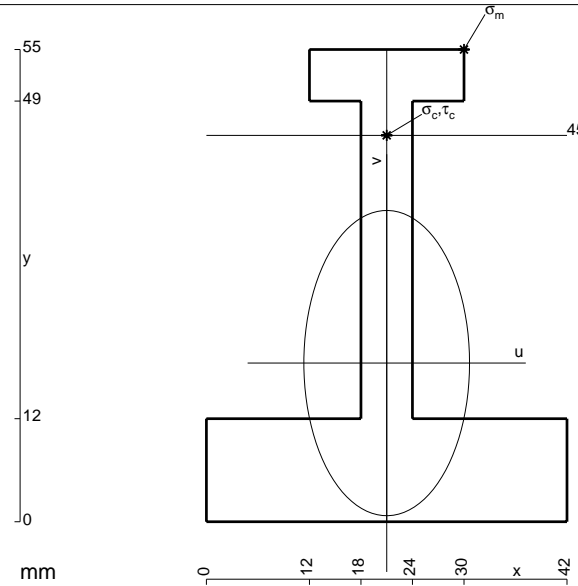
$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

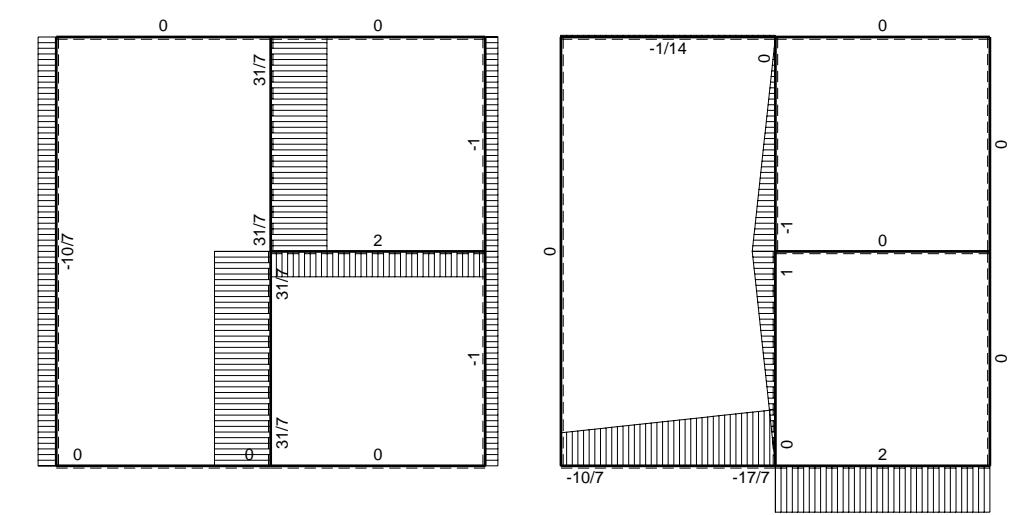
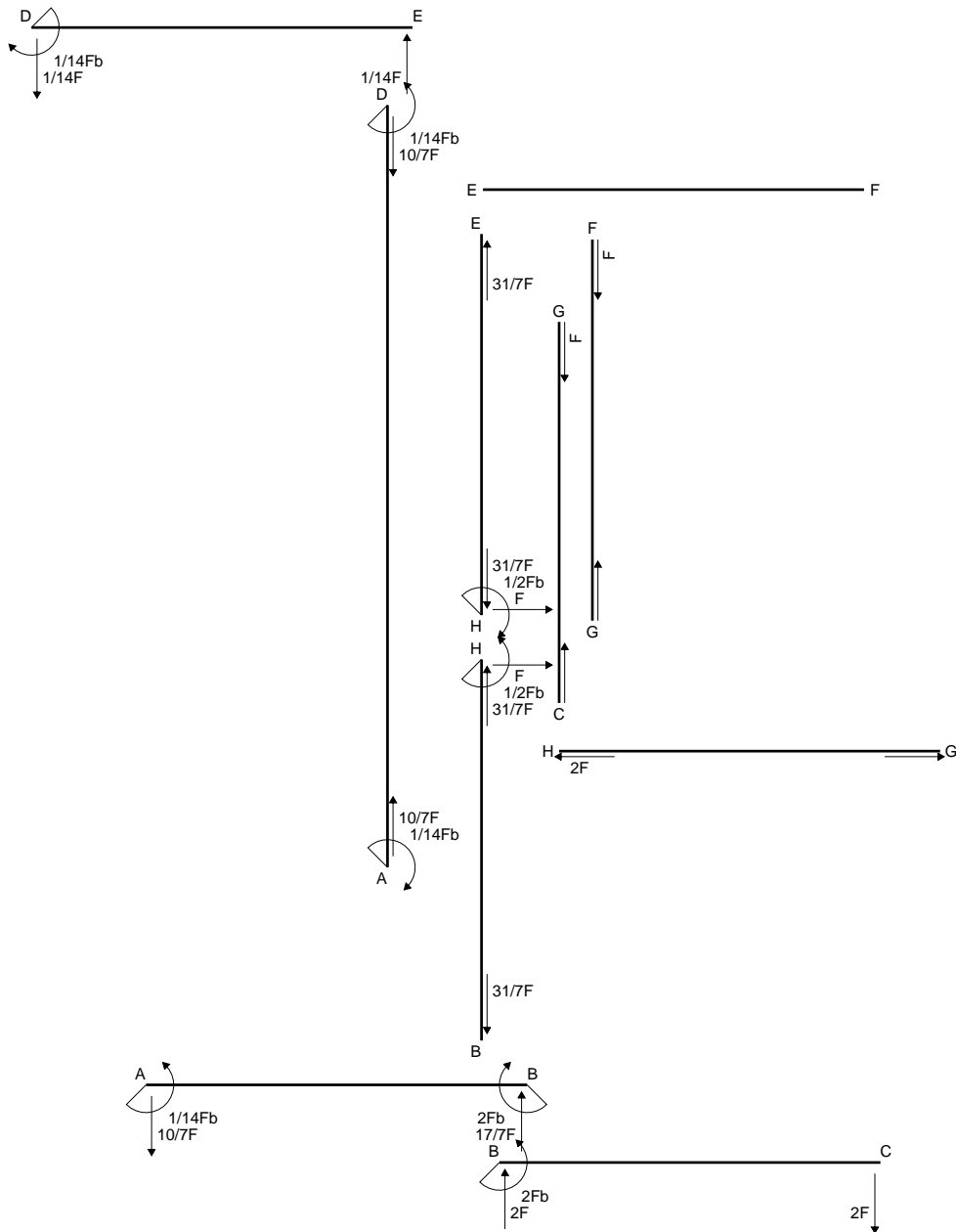
$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

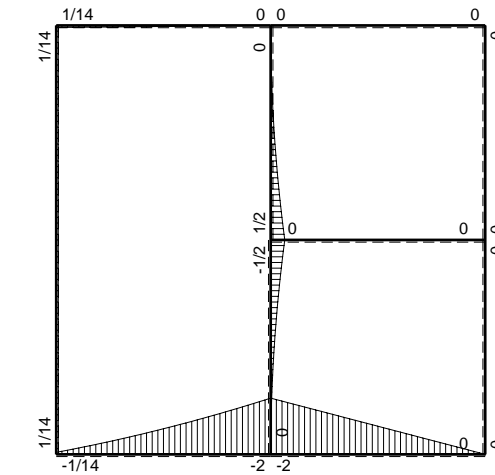


- A = 834. mm<sup>2</sup>
- J<sub>u</sub> = 263619. mm<sup>4</sup>
- J<sub>v</sub> = 77670. mm<sup>4</sup>
- y<sub>g</sub> = 18.48 mm
- T<sub>y</sub> = 2740. N
- M<sub>x</sub> = -1507000. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 55. mm
- u<sub>m</sub> = 9. mm
- v<sub>m</sub> = 36.52 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 208.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 45. mm
- v<sub>c</sub> = 26.52 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 151.6 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.457 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 152.2 N/mm<sup>2</sup>
- S = 4305. mm<sup>3</sup>

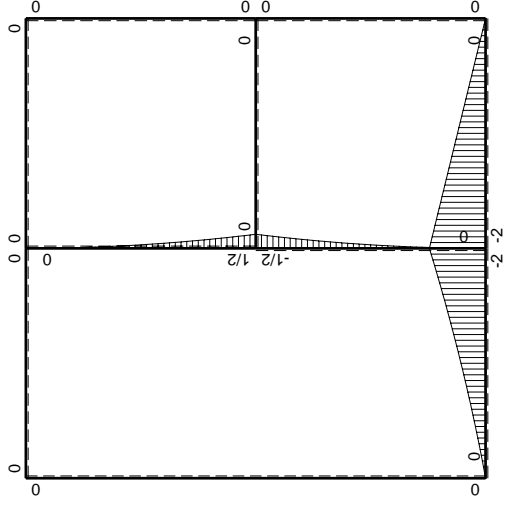
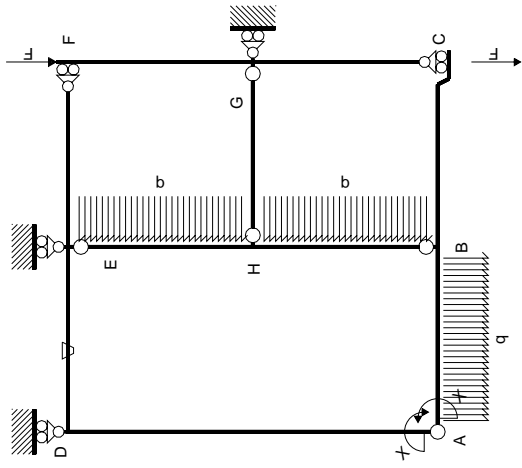


← ⊕ → F

↑ ⊕ ↓ F

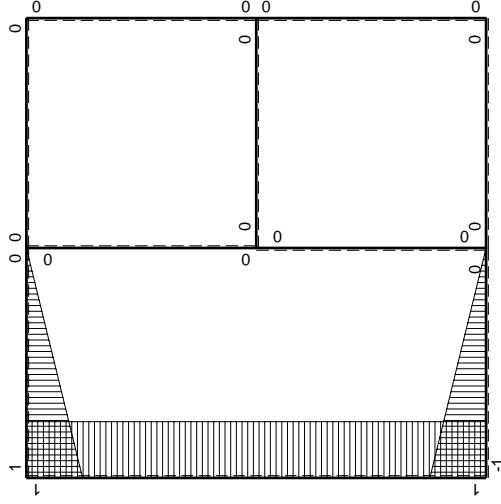


⊕ ⊖ F<sub>b</sub>



Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x / EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	$-Fb/EJ$	0	$-Fb/EJ+Fx/EJ$	$1-2x/b+x^2/b^2$	$(0-1/2)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	0	$Fb/EJ$	0	$-Fx/EJ$	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
BH b	0	$1/2qx^2$	0	0	0	0			
HE b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0+0	0	
EH b	0	$-1/2qx^2$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$-5/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$1/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

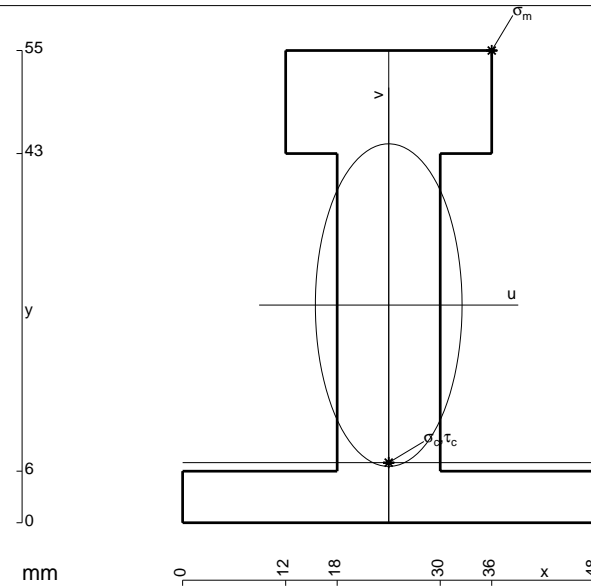
$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (-1 + x/b) \cdot \theta \, dx = \left[ -x + 1/2 x^2/b \right]_0^b \cdot \theta$$

$$= (-b + 1/2 b) \cdot \theta = -1/2 \cdot Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (x/b) \cdot \theta \, dx = \left[ 1/2 x^2/b \right]_0^b \cdot \theta$$

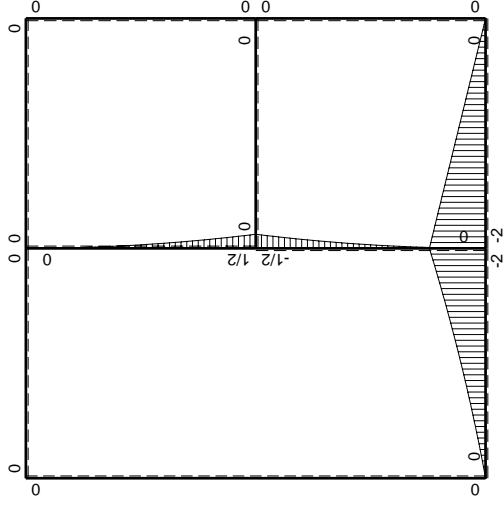
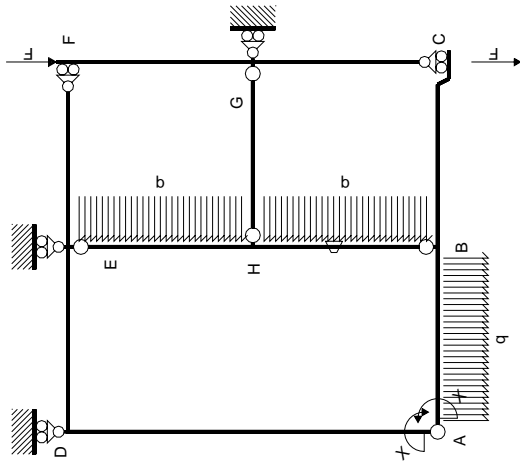
$$= (1/2 b) \cdot \theta = -1/2 \cdot Fb^2/EJ$$



- A = 1020. mm<sup>2</sup>
- J<sub>u</sub> = 360241. mm<sup>4</sup>
- J<sub>v</sub> = 74448. mm<sup>4</sup>
- y<sub>g</sub> = 25.35 mm
- T<sub>y</sub> = 4440. N
- M<sub>x</sub> = -2664000. Nmm
- x<sub>m</sub> = 36. mm
- y<sub>m</sub> = 55. mm
- u<sub>m</sub> = 12. mm
- v<sub>m</sub> = 29.65 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 219.3 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 7. mm
- v<sub>c</sub> = -18.35 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -135.7 N/mm<sup>2</sup>
- τ<sub>c</sub> = 6.843 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 136.2 N/mm<sup>2</sup>
- S = 6662. mm<sup>3</sup>

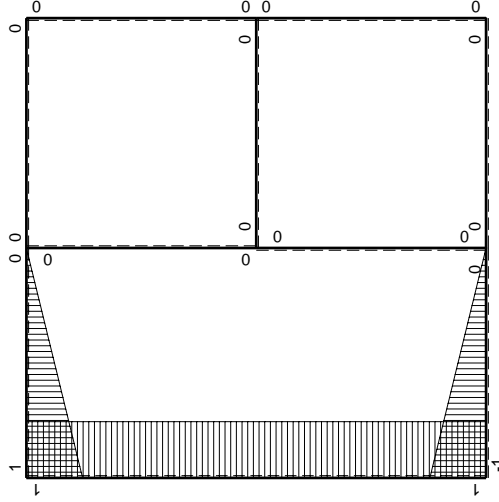






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-1/2Fb+Fx-1/2qx^2$	$-Fb/EJ$	0	0	0	0+0	0	
BH b	0	$1/2qx^2$	$Fb/EJ$	0	0	0			
HE b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0+0	0	
EH b	0	$-1/2qx^2$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{x_0} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

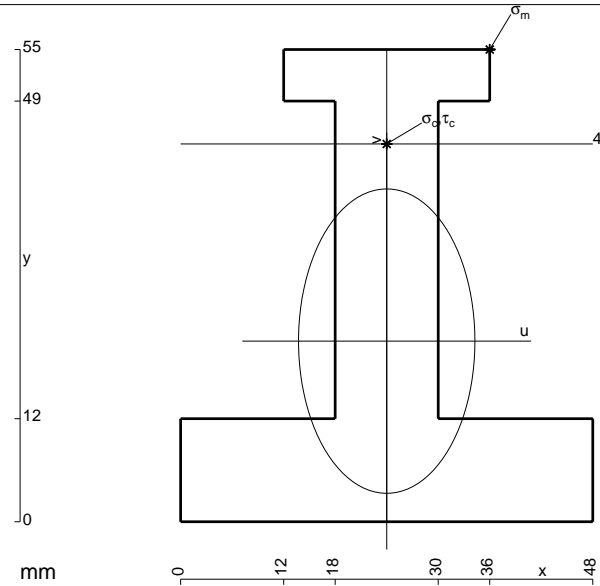
$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

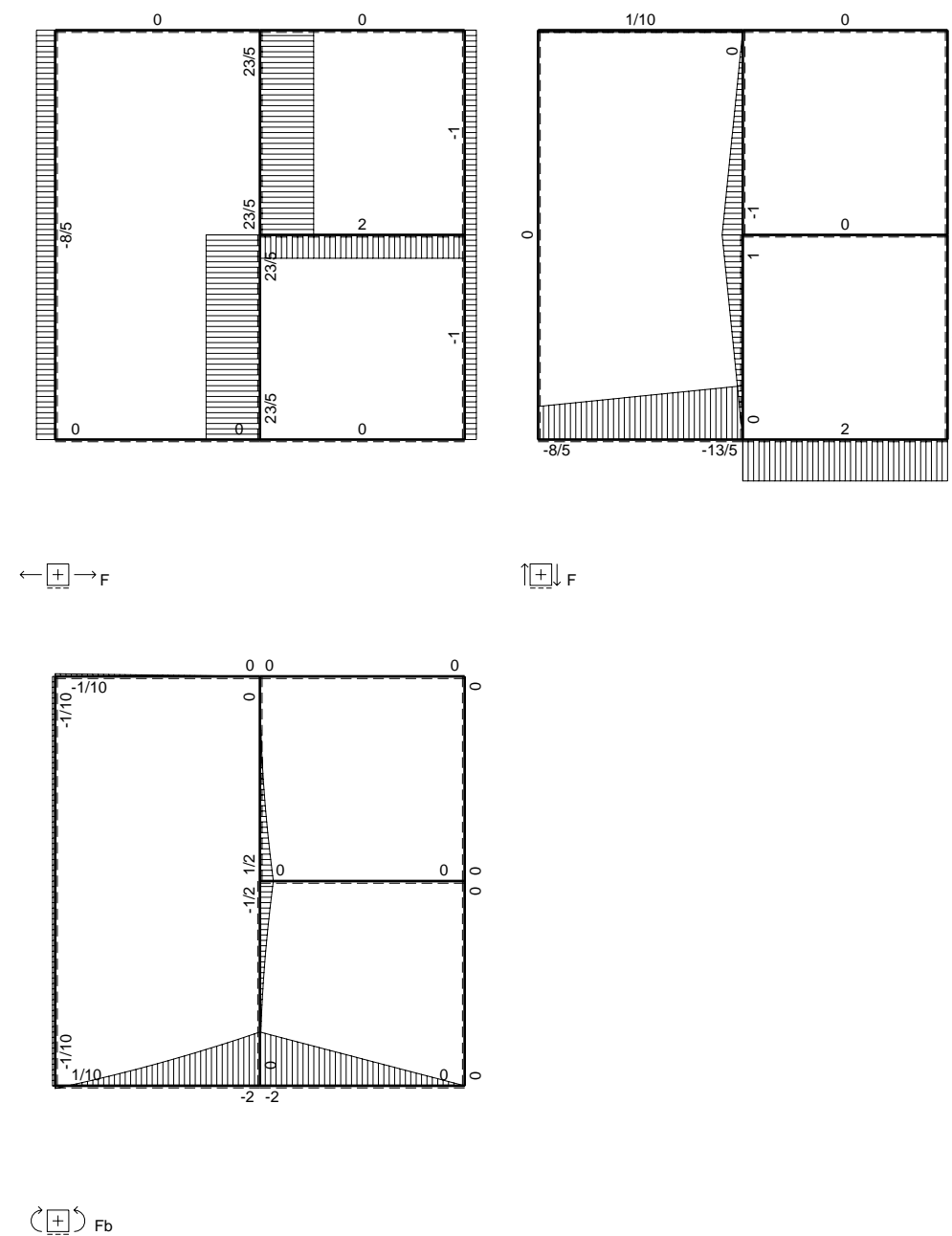
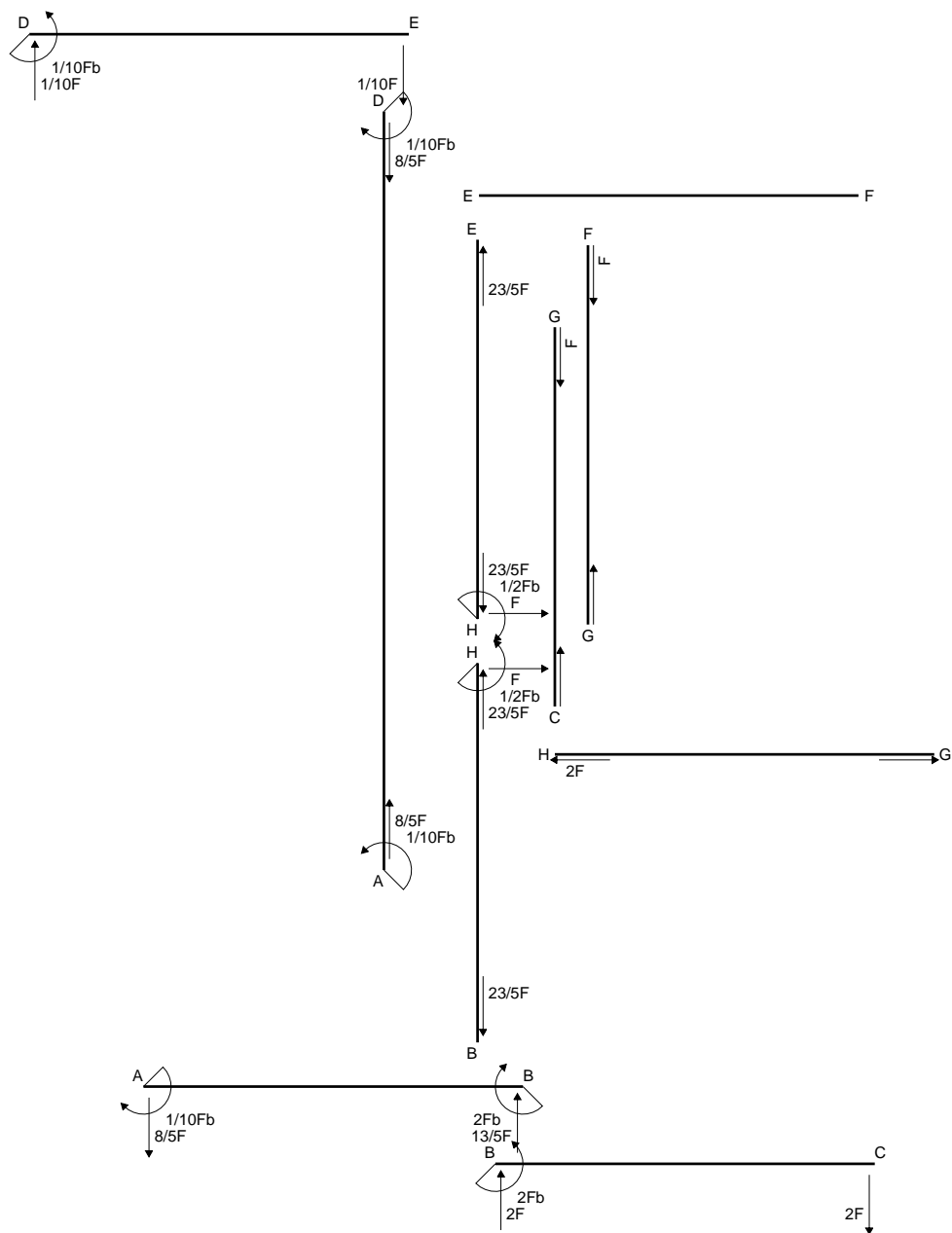
$$L_{BA}^{x_0} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

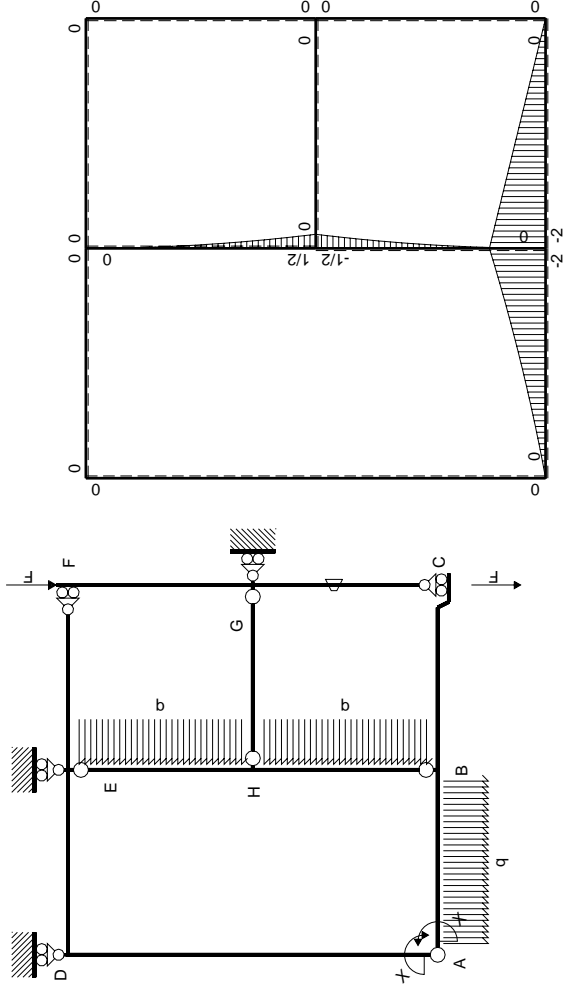
$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$



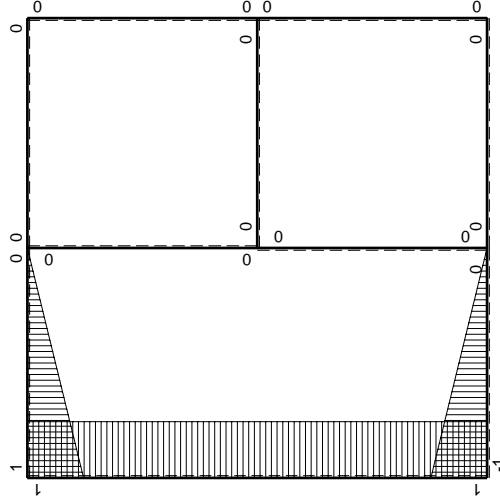
- A = 1164. mm<sup>2</sup>
- J<sub>u</sub> = 366050. mm<sup>4</sup>
- J<sub>v</sub> = 122832. mm<sup>4</sup>
- y<sub>g</sub> = 21.04 mm
- T<sub>y</sub> = 3800. N
- M<sub>x</sub> = -2470000. Nmm
- x<sub>m</sub> = 36. mm
- y<sub>m</sub> = 55. mm
- u<sub>m</sub> = 12. mm
- v<sub>m</sub> = 33.96 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 229.2 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 44. mm
- v<sub>c</sub> = 22.96 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 155. N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.179 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 155.2 N/mm<sup>2</sup>
- S = 5987. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
CG b	0	0	$Fb/EJ$	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
BH b	0	$1/2qx^2$	0	0	0	0			
HE b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0+0	0	
EH b	0	$-1/2qx^2$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

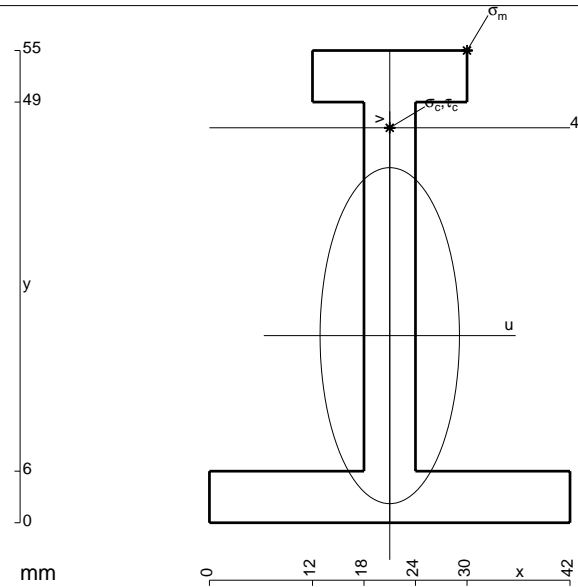
$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

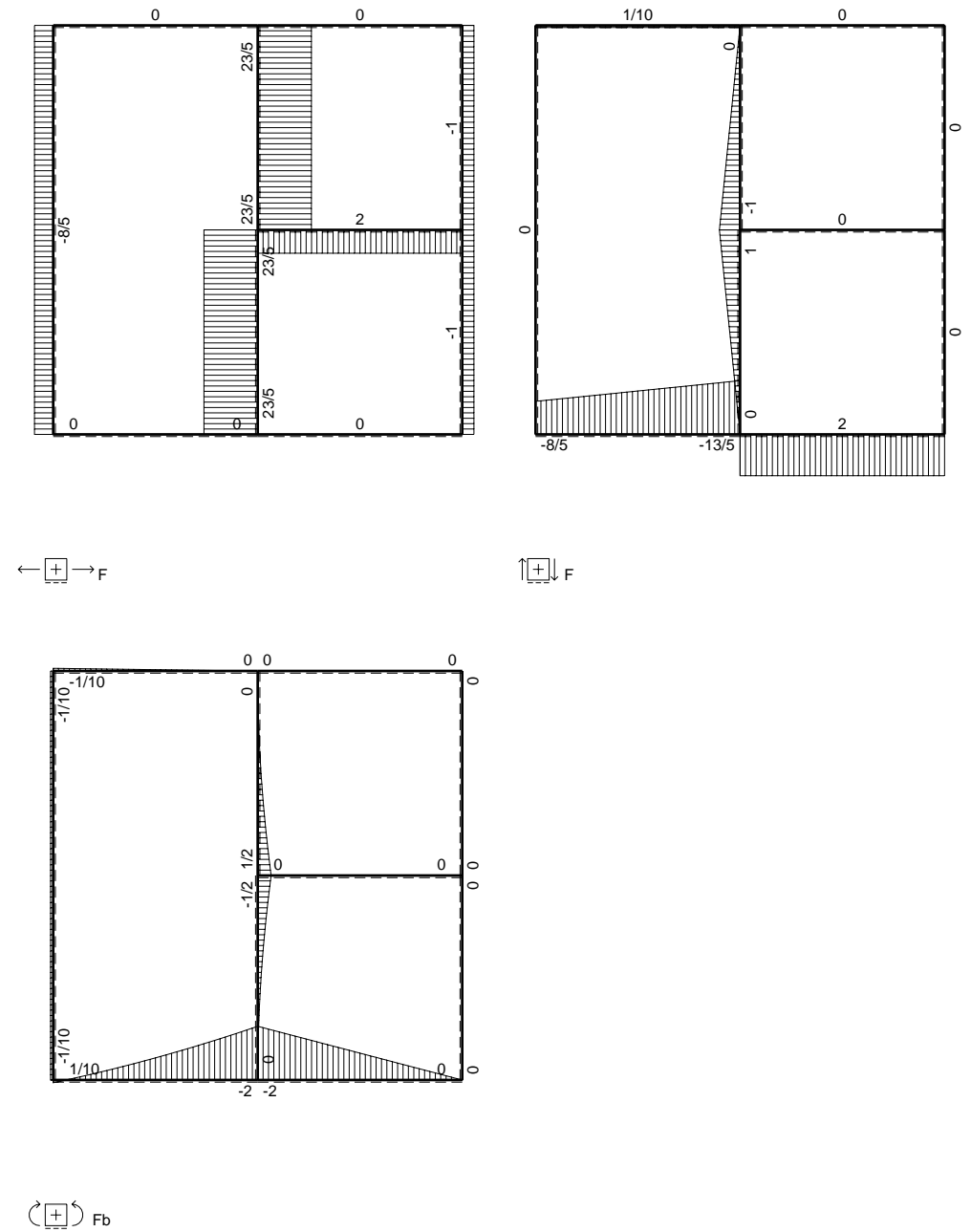
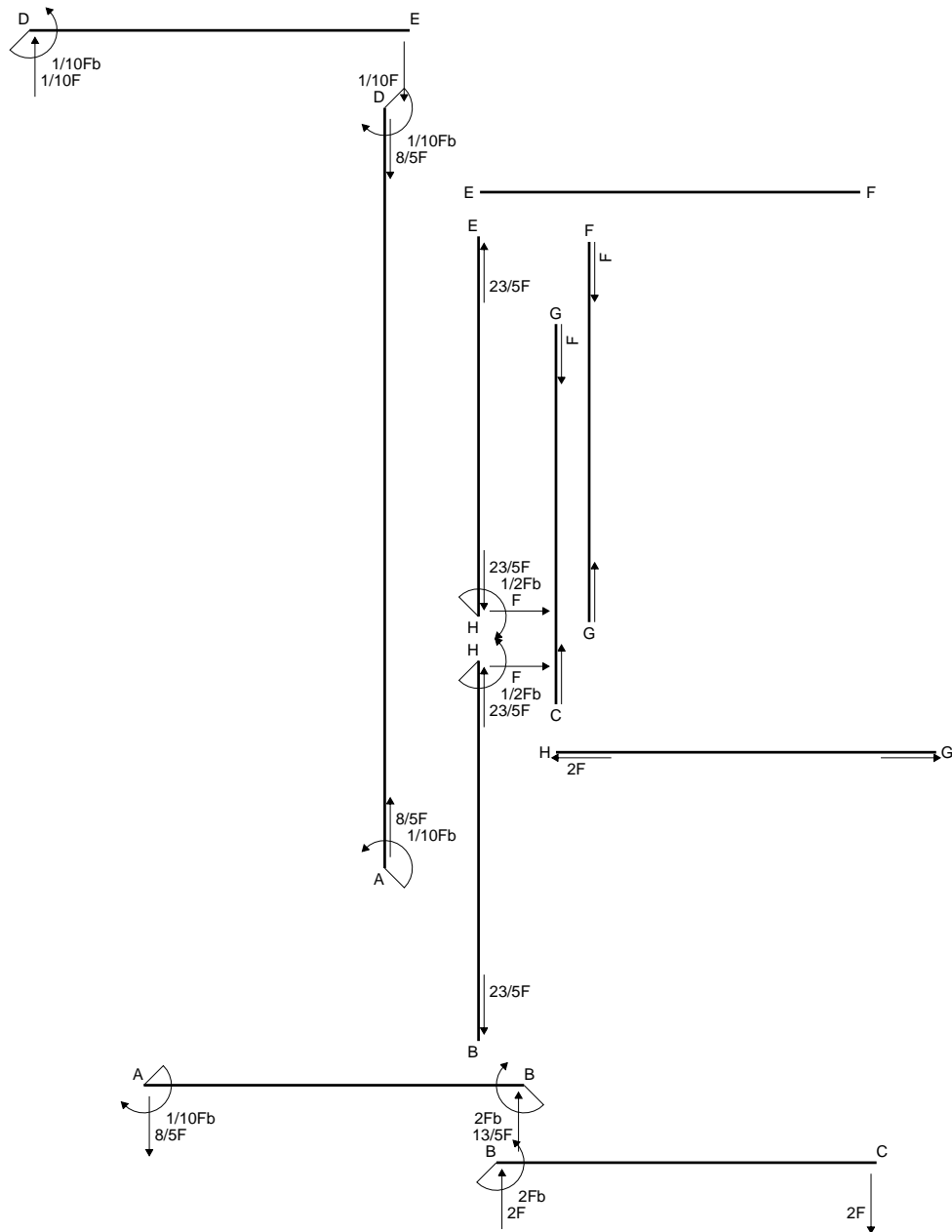
$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

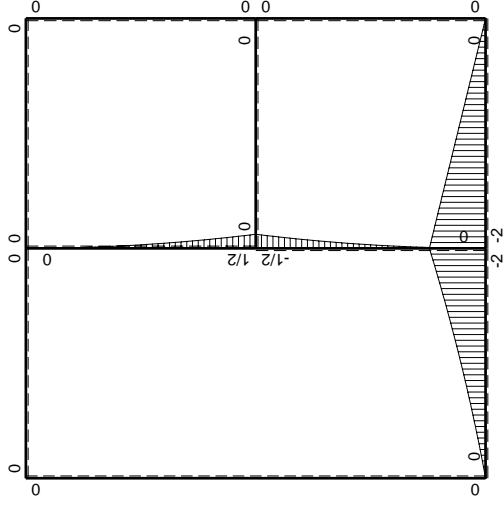
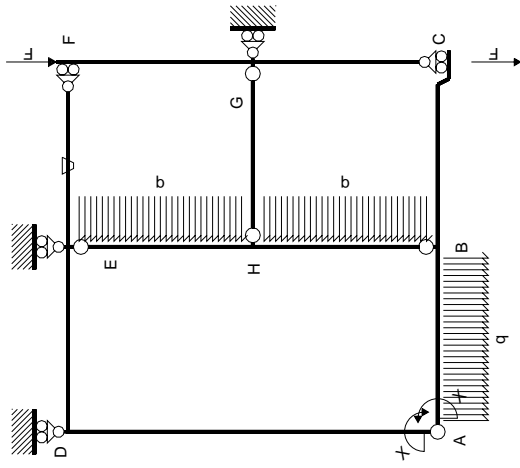
$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$



- A = 618. mm<sup>2</sup>
- J<sub>u</sub> = 236783. mm<sup>4</sup>
- J<sub>v</sub> = 40734. mm<sup>4</sup>
- y<sub>g</sub> = 21.79 mm
- T<sub>y</sub> = 2440. N
- M<sub>x</sub> = -1708000. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 55. mm
- u<sub>m</sub> = 9. mm
- v<sub>m</sub> = 33.21 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 239.5 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 46. mm
- v<sub>c</sub> = 24.21 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 174.6 N/mm<sup>2</sup>
- τ<sub>c</sub> = 6.398 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 175. N/mm<sup>2</sup>
- S = 3725. mm<sup>3</sup>

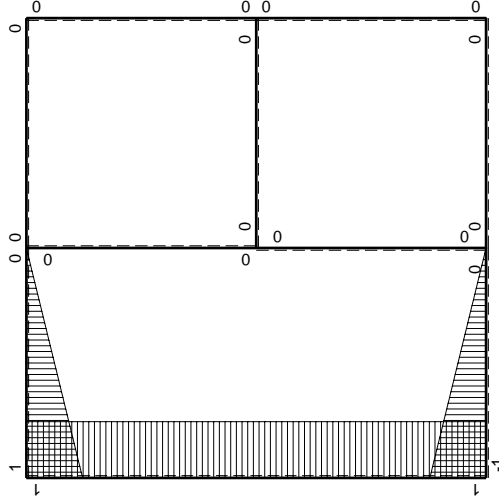






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
FE b	0	0	$Fb/EJ$	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
BH b	0	$1/2qx^2$	0	0	0	0			
HE b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0+0	0	
EH b	0	$-1/2qx^2$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (-2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (-2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

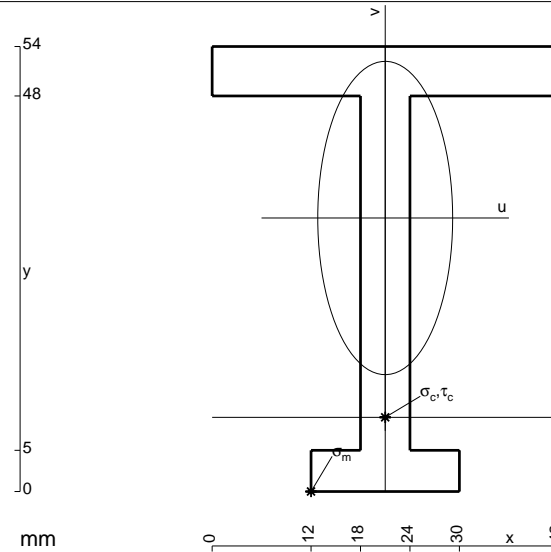
$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

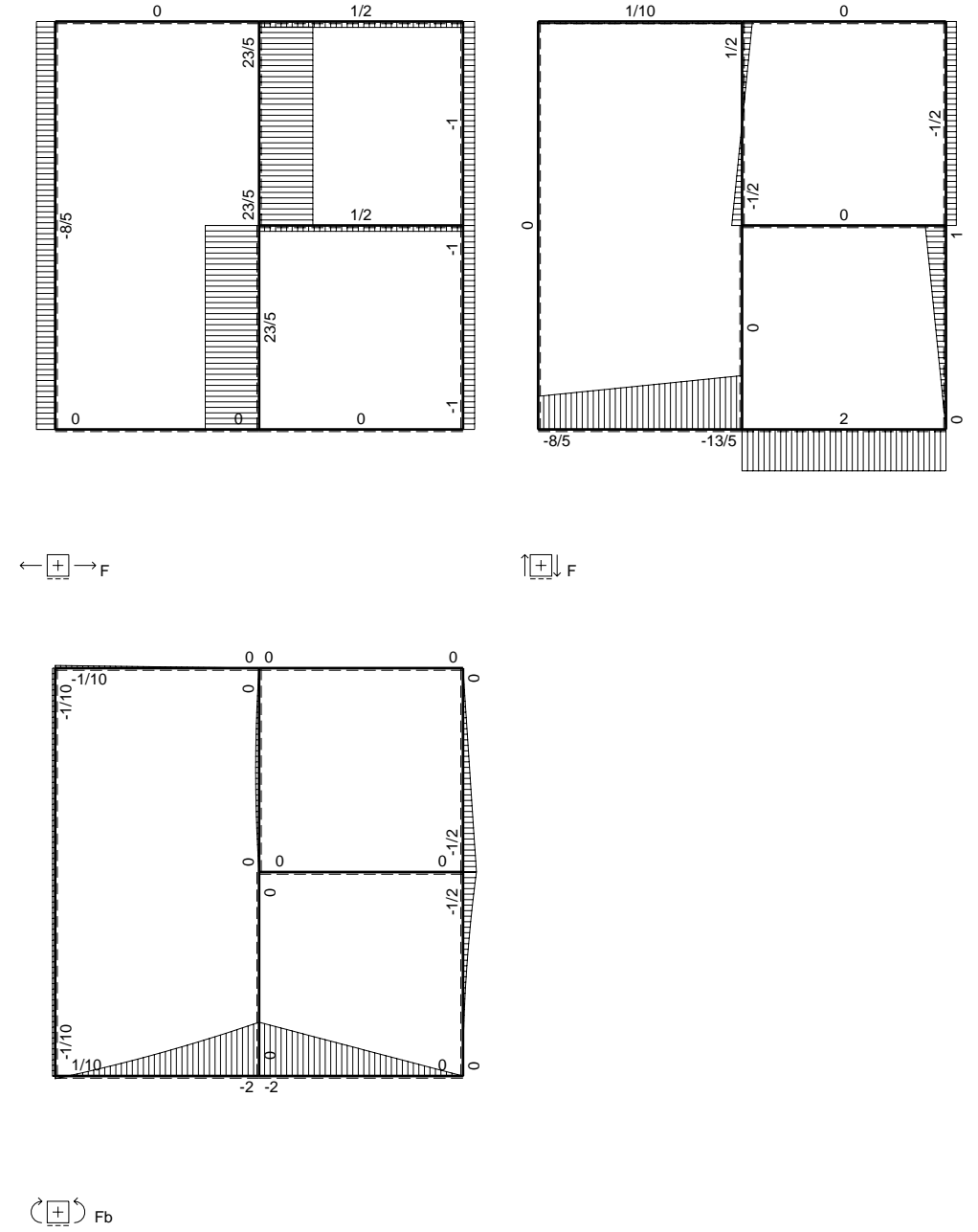
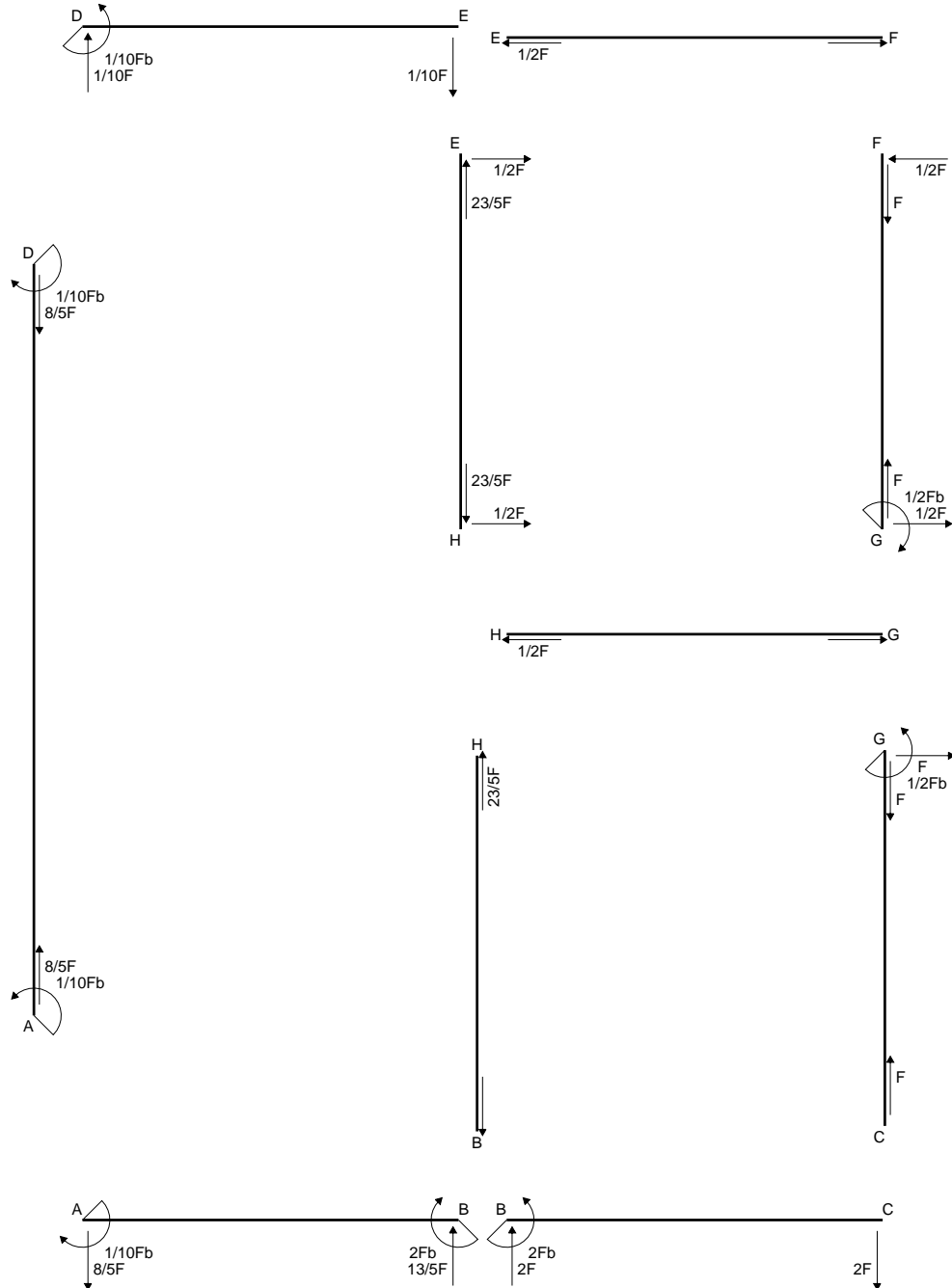
$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

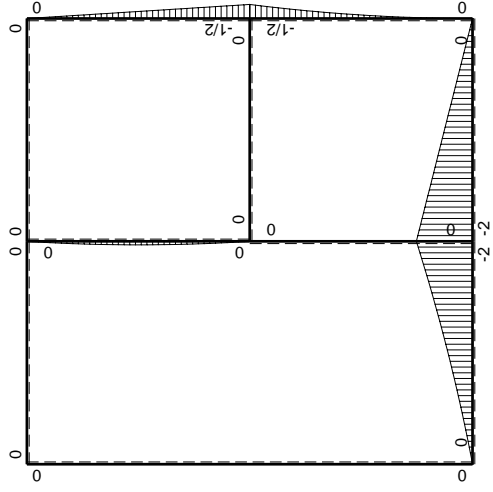
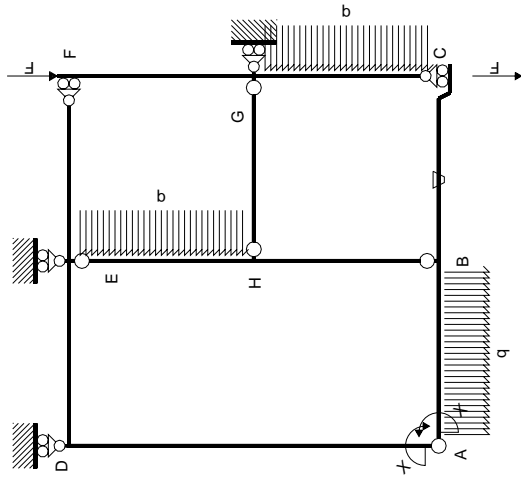
$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

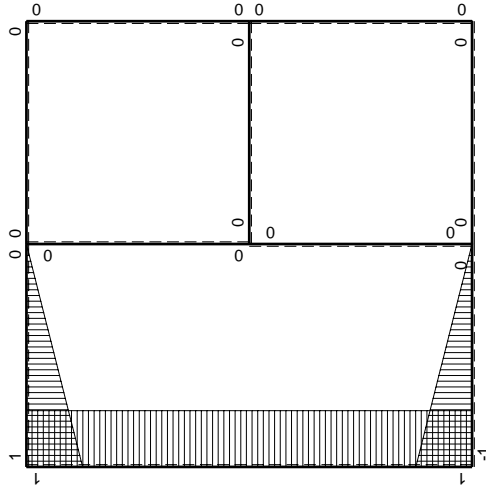


- A = 600. mm<sup>2</sup>
- J<sub>u</sub> = 216946. mm<sup>4</sup>
- J<sub>v</sub> = 40248. mm<sup>4</sup>
- y<sub>g</sub> = 33.19 mm
- T<sub>y</sub> = 1780. N
- M<sub>x</sub> = -1299400. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -9. mm
- v<sub>m</sub> = -33.19 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -198.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 9. mm
- v<sub>c</sub> = -24.19 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -144.9 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.637 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 145.1 N/mm<sup>2</sup>
- S = 3391. mm<sup>3</sup>





$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	$-Fb/EJ$	0	0	0	0+0	0	
CB b	0	$2Fx$	$Fb/EJ$	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	2Xb/EJ	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	1/3Xb/EJ	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	0	0	0	0	0	0+0	0	
BH b	0	0	0	0	0	0			
HE b	0	$-1/2Fx+1/2qx^2$	0	0	0	0	0+0	0	
EH b	0	$1/2Fx-1/2qx^2$	0	0	0	0			
AB	molla asta $-W_{1AB} (W_{0AB} + XW_{1AB})/k_{AB}$								1/4Xb/EJ
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx + 1 \cdot \frac{1}{4} \frac{b}{EJ} = \left[ x - \frac{x^2}{b} + \frac{1}{3} \frac{x^3}{b^2} \right]_0^b \frac{1}{EJ} + \frac{1}{4} \frac{b}{EJ}$$

$$= (b - b + \frac{1}{3}b) \frac{1}{EJ} + \frac{1}{4} \frac{b}{EJ} = \frac{7}{12} \frac{b}{EJ}$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx + 1 \cdot \frac{1}{4} \frac{b}{EJ} = \left[ \frac{1}{3} \frac{x^3}{b^2} \right]_0^b \frac{1}{EJ} + \frac{1}{4} \frac{b}{EJ}$$

$$= (\frac{1}{3}b) \frac{1}{EJ} + \frac{1}{4} \frac{b}{EJ} = \frac{7}{12} \frac{b}{EJ}$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \frac{b}{EJ}$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \frac{b}{EJ}$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx = \left[ x - \frac{x^2}{b} + \frac{1}{3} \frac{x^3}{b^2} \right]_0^b \frac{1}{EJ}$$

$$= (b - b + \frac{1}{3}b) \frac{1}{EJ} = \frac{1}{3} \frac{b}{EJ}$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx = \left[ \frac{1}{3} \frac{x^3}{b^2} \right]_0^b \frac{1}{EJ}$$

$$= (\frac{1}{3}b) \frac{1}{EJ} = \frac{1}{3} \frac{b}{EJ}$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

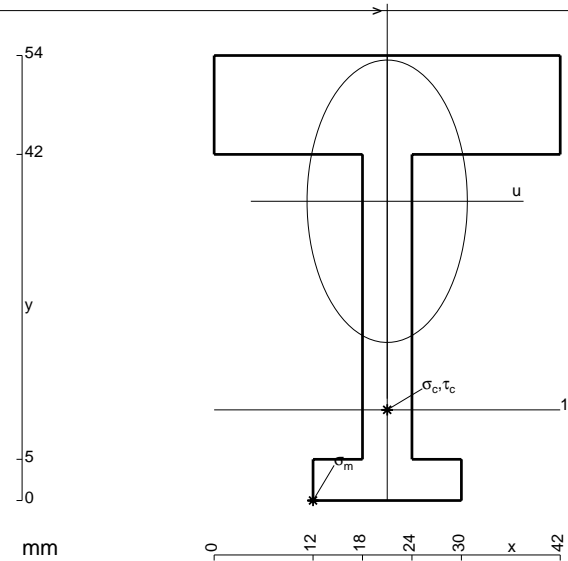
$$= \left[ \frac{3}{4} \frac{x^2}{b} - \frac{1}{3} \frac{x^3}{b^2} - \frac{1}{8} \frac{x^4}{b^3} \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= (\frac{3}{4}b - \frac{1}{3}b - \frac{1}{8}b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ} = \frac{7}{24} \frac{Fb^2}{EJ}$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

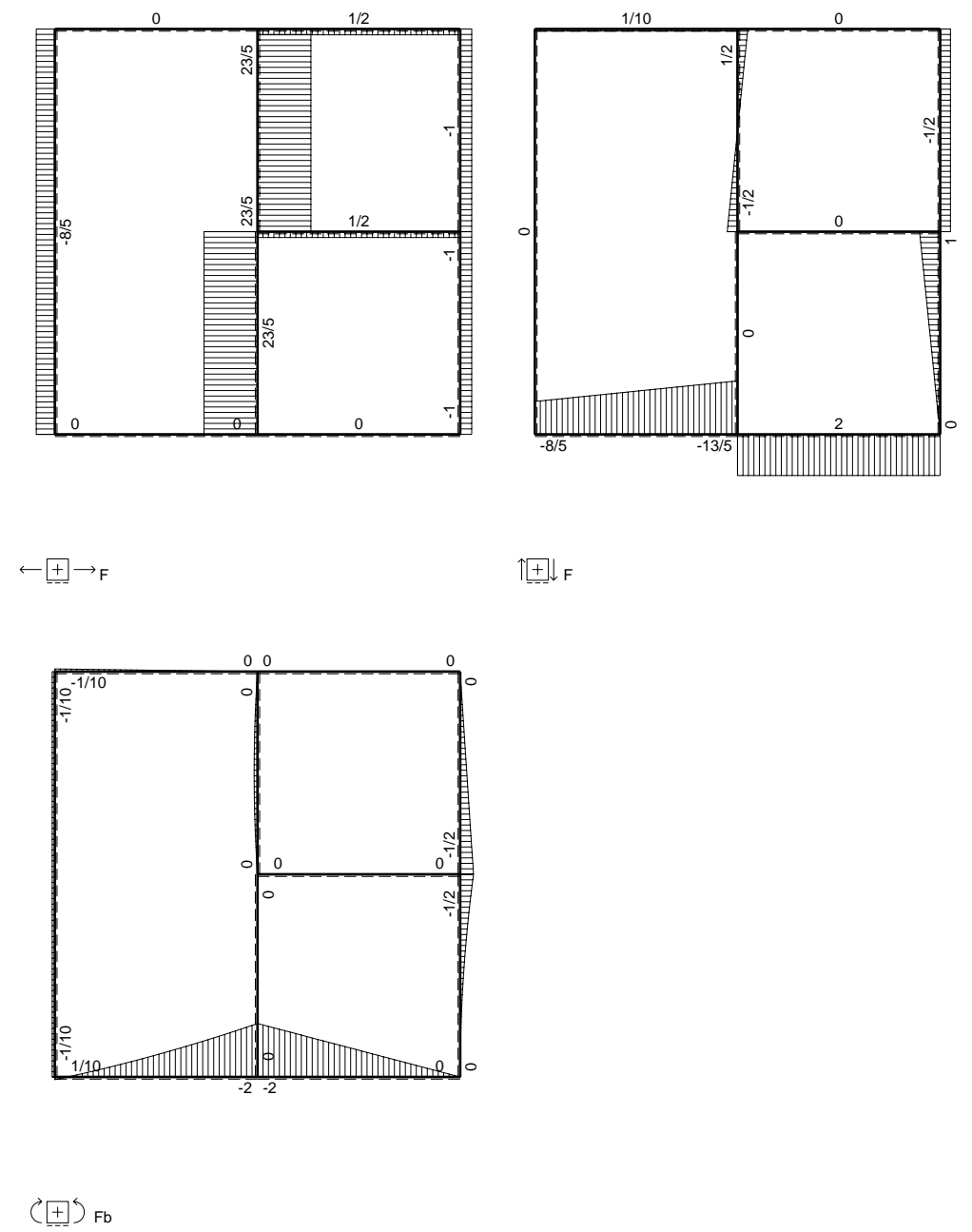
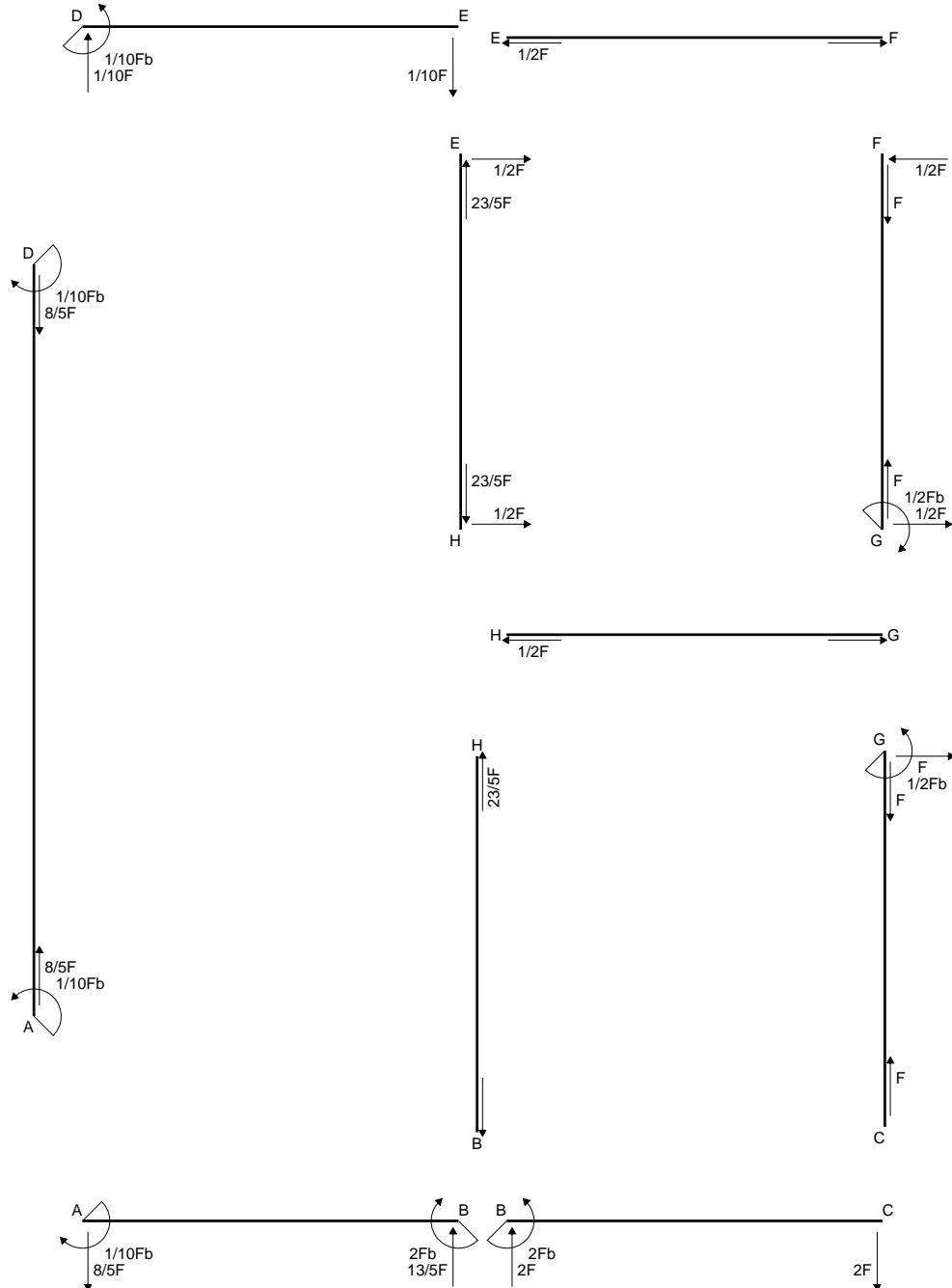
$$= \left[ \frac{x^2}{b} - \frac{5}{6} \frac{x^3}{b^2} + \frac{1}{8} \frac{x^4}{b^3} \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= (b - \frac{5}{6}b + \frac{1}{8}b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ} = \frac{7}{24} \frac{Fb^2}{EJ}$$



- A = 816. mm<sup>2</sup>
- J<sub>u</sub> = 239746. mm<sup>4</sup>
- J<sub>v</sub> = 77184. mm<sup>4</sup>
- y<sub>g</sub> = 36.32 mm
- T<sub>y</sub> = 1760. N
- M<sub>x</sub> = -1372800. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -9. mm
- v<sub>m</sub> = -36.32 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -207.9 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 11. mm
- v<sub>c</sub> = -25.32 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -145. N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.971 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 145.2 N/mm<sup>2</sup>
- S = 4063. mm<sup>3</sup>







Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	0	0	0	0	0	0+0	0	
BH b	0	0	0	0	0	0			
HE b	0	$-1/2Fx+1/2qx^2$	$-Fb/EJ$	0	0	0	0+0	0	
EH b	0	$1/2Fx-1/2qx^2$	$Fb/EJ$	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (-2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (-2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

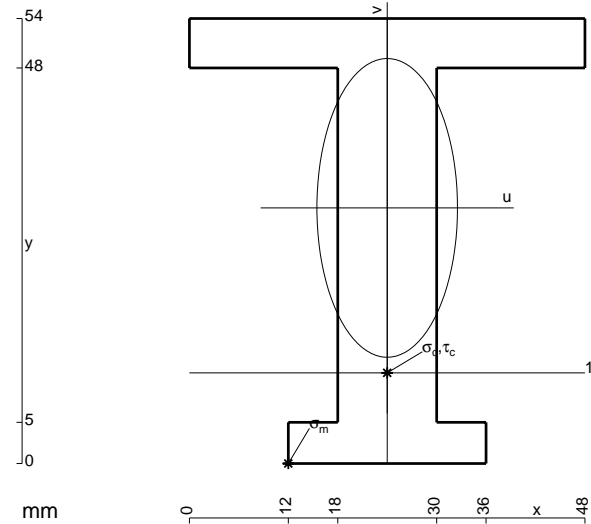
$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

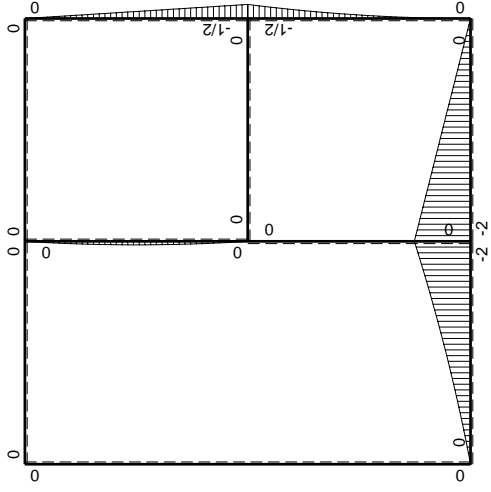
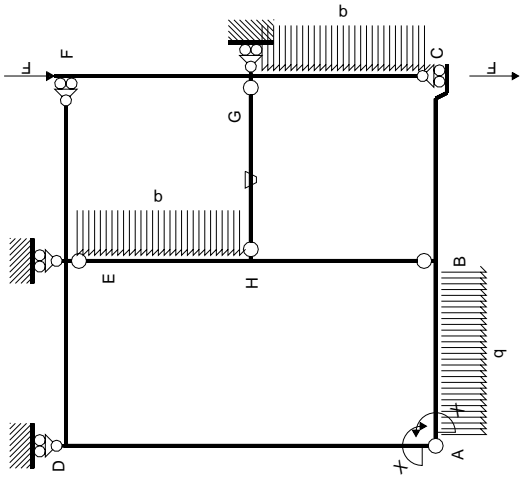
$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

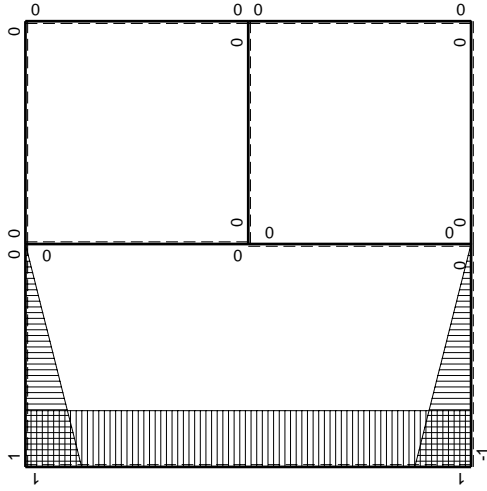


- A = 924. mm<sup>2</sup>
- J<sub>u</sub> = 303740. mm<sup>4</sup>
- J<sub>v</sub> = 67248. mm<sup>4</sup>
- y<sub>g</sub> = 31.02 mm
- T<sub>y</sub> = 2580. N
- M<sub>x</sub> = -2141400. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -12. mm
- v<sub>m</sub> = -31.02 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -218.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 11. mm
- v<sub>c</sub> = -20.02 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -141.1 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.596 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 141.3 N/mm<sup>2</sup>
- S = 5080. mm<sup>3</sup>





$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
GH b	0	0	$Fb/EJ$	0	0	0			
HB b	0	0	0	0	0	0	0+0	0	
BH b	0	0	0	0	0	0			
HE b	0	$-1/2Fx+1/2qx^2$	0	0	0	0	0+0	0	
EH b	0	$1/2Fx-1/2qx^2$	0	0	0	0			
AB	molla asta $-W_{1AB} (W_{0AB} + XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (-2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (-2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

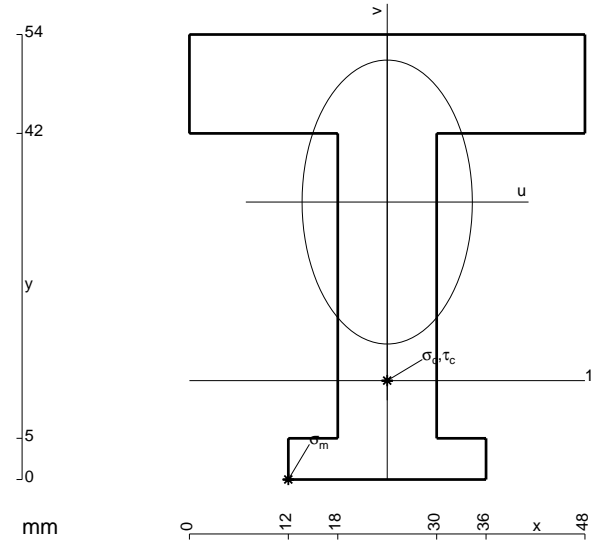
$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

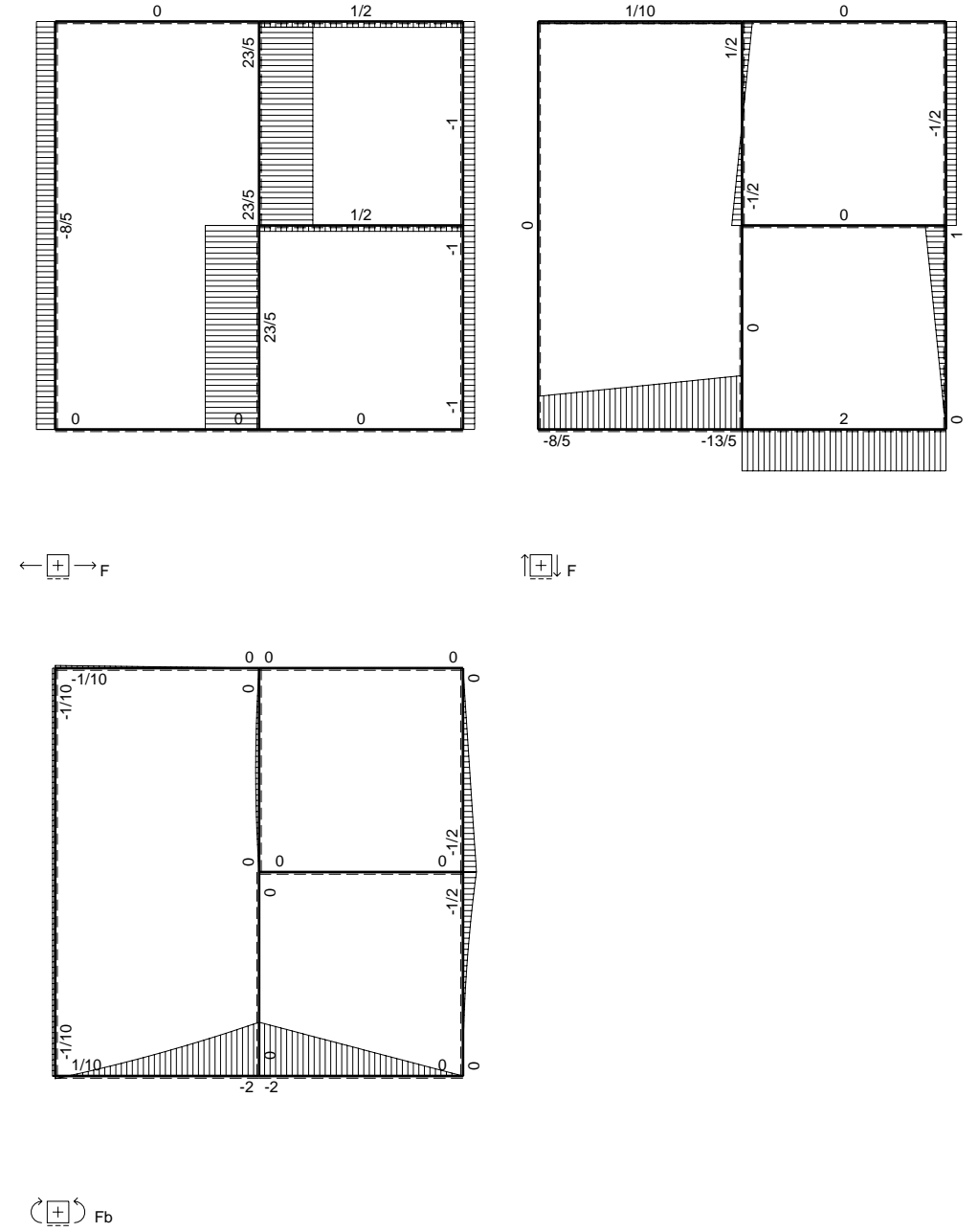
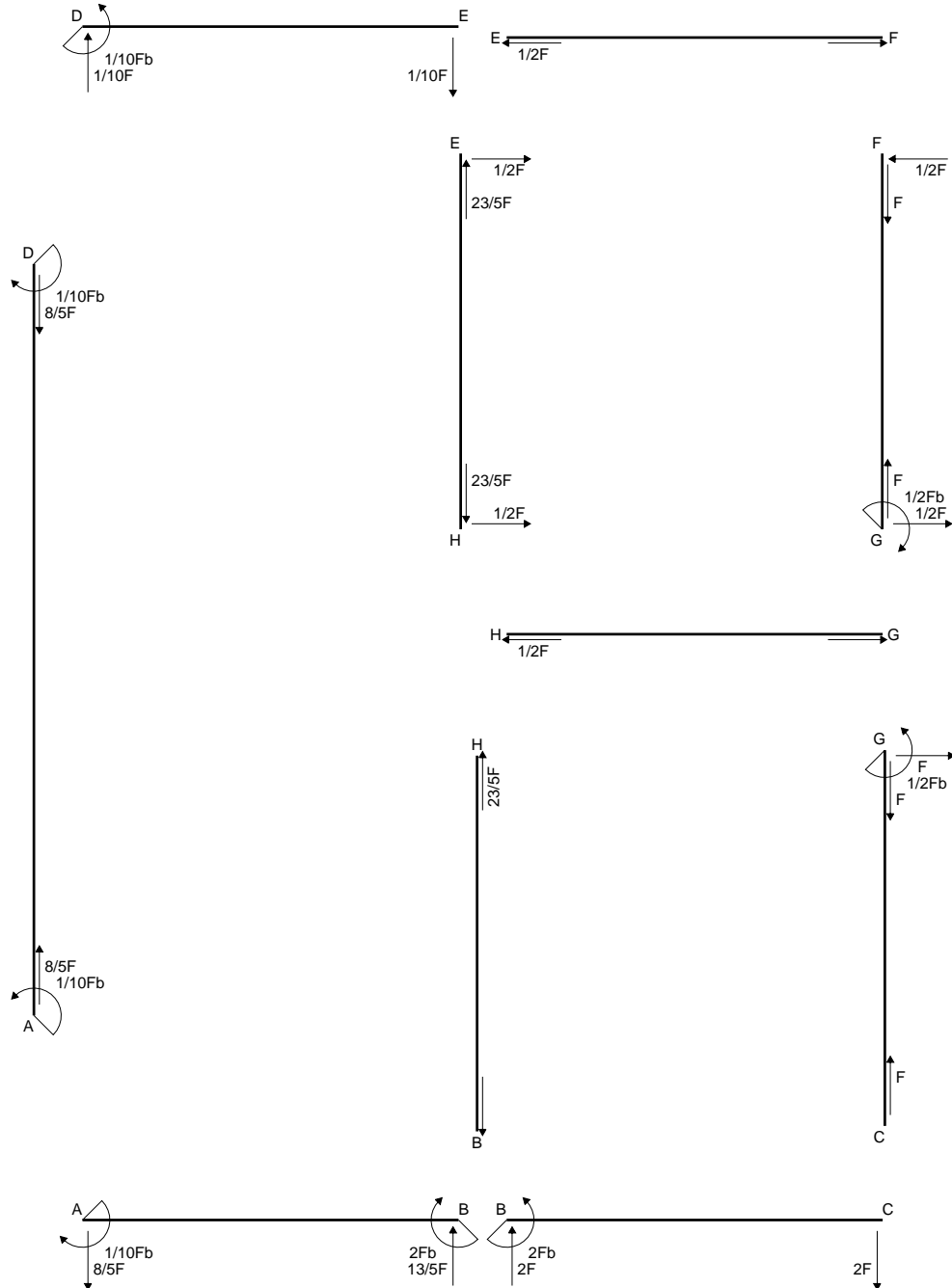
$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

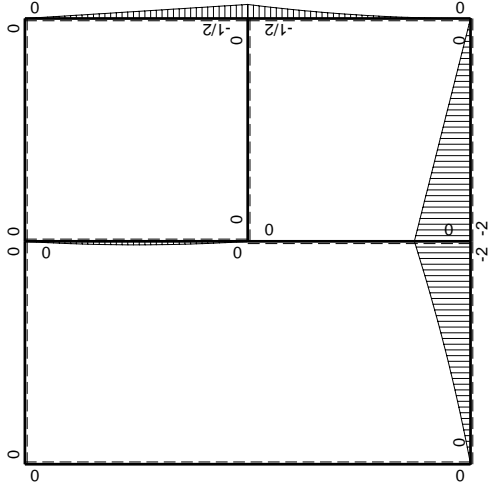
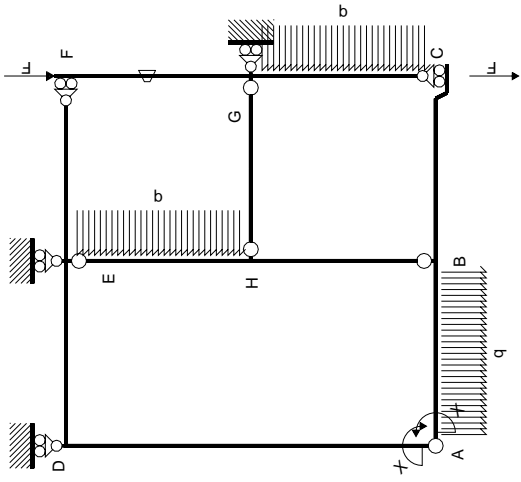
$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$



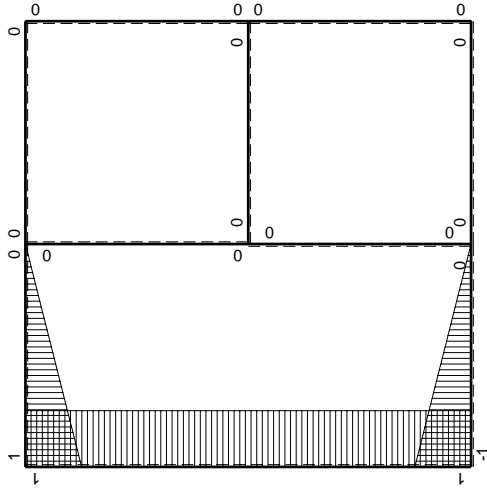
- A = 1140. mm<sup>2</sup>
- J<sub>u</sub> = 338607. mm<sup>4</sup>
- J<sub>v</sub> = 121680. mm<sup>4</sup>
- y<sub>g</sub> = 33.67 mm
- T<sub>y</sub> = 2620. N
- M<sub>x</sub> = -2305600. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -12. mm
- v<sub>m</sub> = -33.67 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -229.3 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 12. mm
- v<sub>c</sub> = -21.67 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -147.5 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.775 N/mm<sup>2</sup>
- σ<sub>ρ</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 147.7 N/mm<sup>2</sup>
- S = 5854. mm<sup>3</sup>







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$-1/2Fx$	$-Fb/EJ$	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	$Fb/EJ$	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	0	0	0	0	0	0+0	0	
BH b	0	0	0	0	0	0			
HE b	0	$-1/2Fx+1/2qx^2$	0	0	0	0	0+0	0	
EH b	0	$1/2Fx-1/2qx^2$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (-2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (-2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

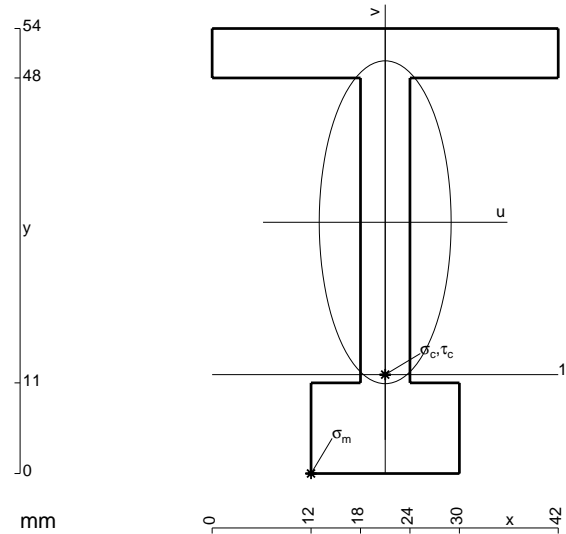
$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

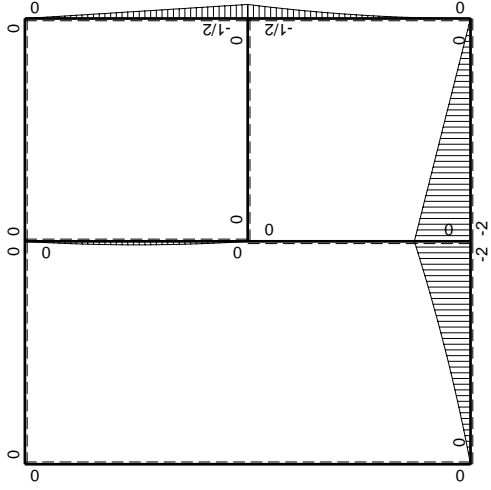
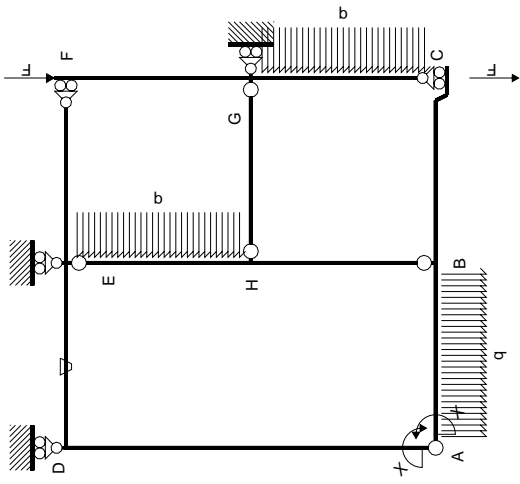
$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

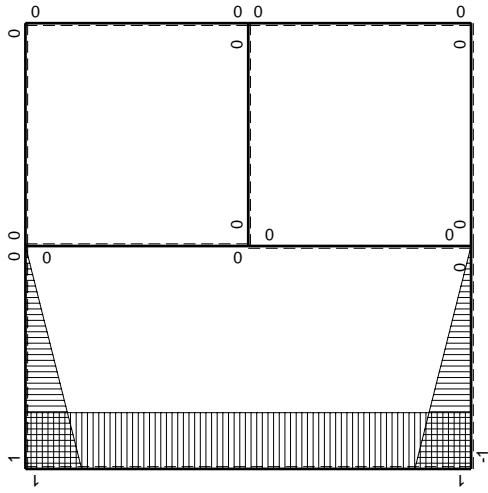


- A = 672. mm<sup>2</sup>
- J<sub>u</sub> = 257954. mm<sup>4</sup>
- J<sub>v</sub> = 43056. mm<sup>4</sup>
- y<sub>g</sub> = 30.49 mm
- T<sub>y</sub> = 2180. N
- M<sub>x</sub> = -2027400. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -9. mm
- v<sub>m</sub> = -30.49 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -239.6 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 12. mm
- v<sub>c</sub> = -18.49 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -145.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.13 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 145.9 N/mm<sup>2</sup>
- S = 5062. mm<sup>3</sup>





$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x / EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	$-Fb/EJ$	0	$-Fb/EJ+Fx/EJ$	$1-2x/b+x^2/b^2$	$(0-1/2)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	0	$Fb/EJ$	0	$-Fx/EJ$	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	0	0	0	0	0	0+0	0	
BH b	0	0	0	0	0	0			
HE b	0	$-1/2Fx+1/2qx^2$	0	0	0	0	0+0	0	
EH b	0	$1/2Fx-1/2qx^2$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$-5/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$1/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ}$$

$$= (b - b + 1/3 b) \frac{1}{EJ} = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx = \left[ 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ}$$

$$= (1/3 b) \frac{1}{EJ} = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

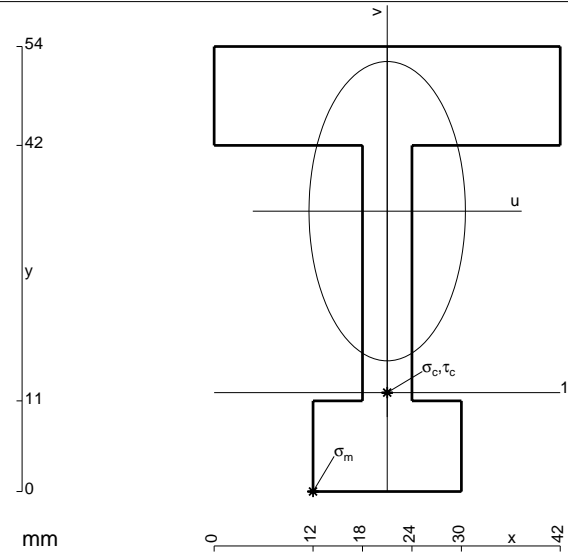
$$= (b - 5/6 b + 1/8 b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (-1 + x/b) \theta dx = \left[ -x + 1/2 x^2/b \right]_0^b \theta$$

$$= (-b + 1/2 b) \theta = -1/2 \cdot Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (x/b) \theta dx = \left[ 1/2 x^2/b \right]_0^b \theta$$

$$= (1/2 b) \theta = -1/2 \cdot Fb^2/EJ$$



$$A = 888. \text{ mm}^2$$

$$J_u = 293012. \text{ mm}^4$$

$$J_v = 79992. \text{ mm}^4$$

$$y_g = 34.02 \text{ mm}$$

$$T_y = 3500. \text{ N}$$

$$M_x = -1715000. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -9. \text{ mm}$$

$$v_m = -34.02 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -199.1 \text{ N/mm}^2$$

$$x_c = 21. \text{ mm}$$

$$y_c = 12. \text{ mm}$$

$$v_c = -22.02 \text{ mm}$$

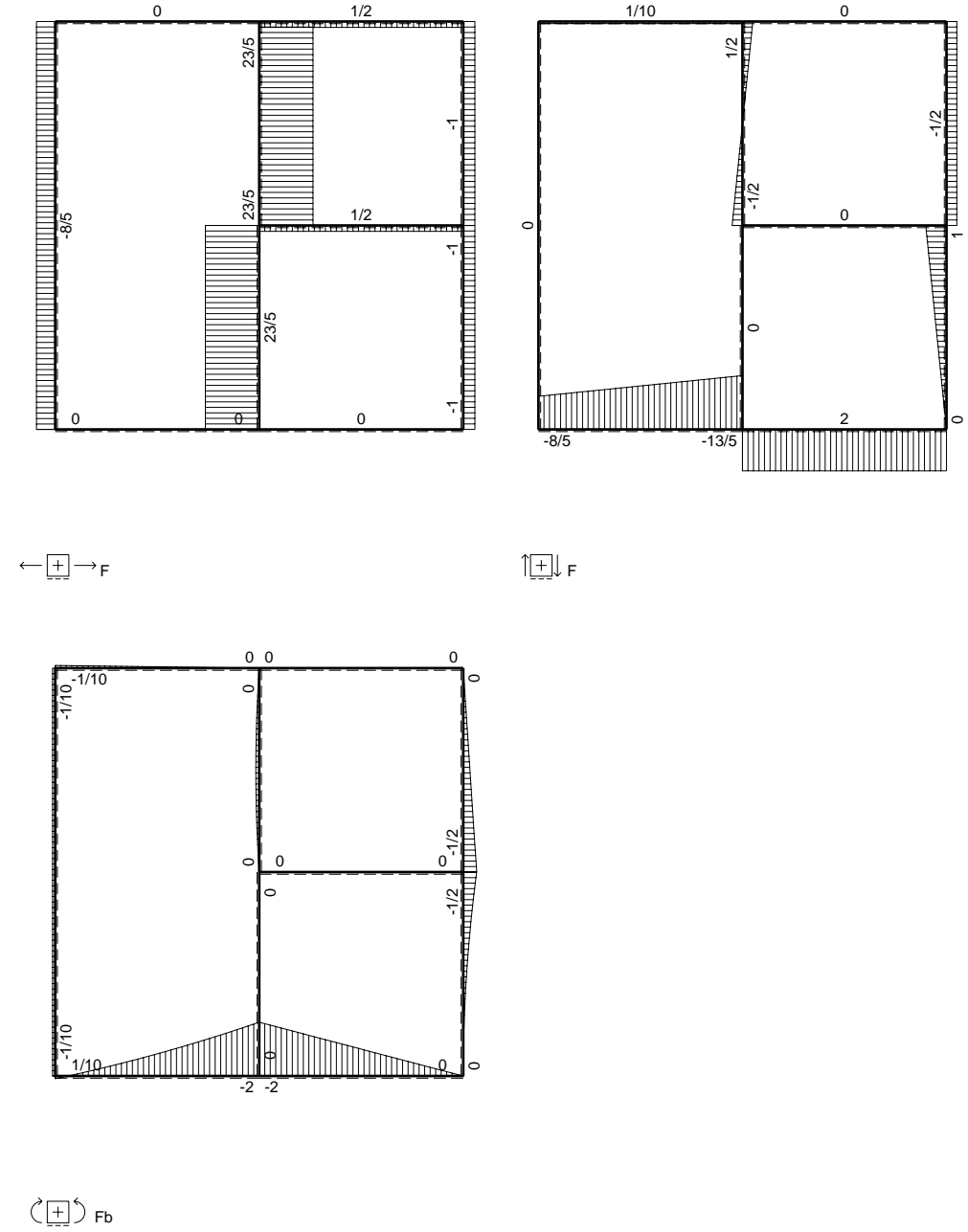
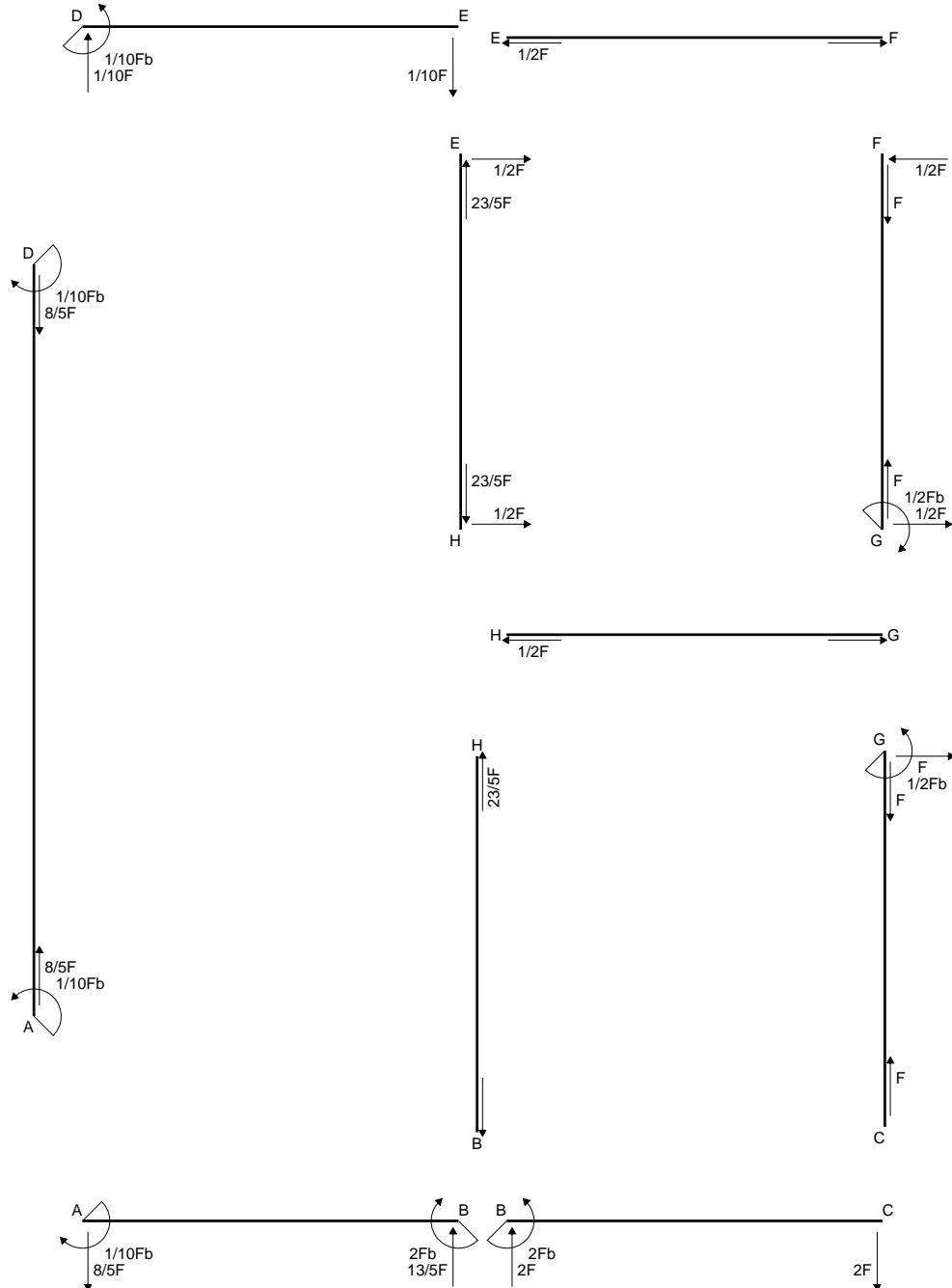
$$\sigma_c = -Mv/J_u = -128.9 \text{ N/mm}^2$$

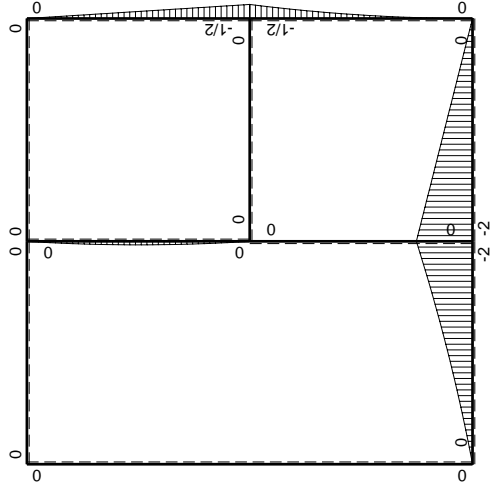
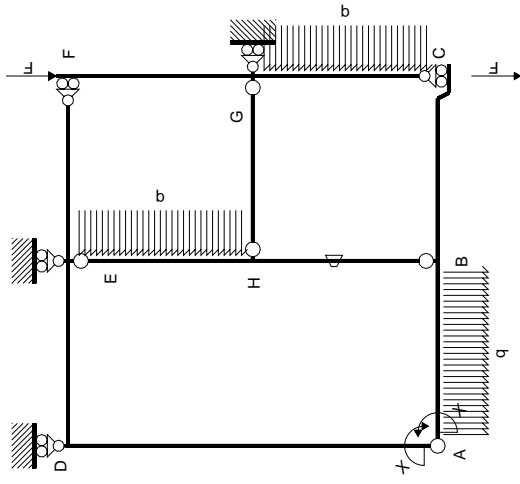
$$\tau_c = 11.51 \text{ N/mm}^2$$

$$\sigma_o = \sqrt{\sigma^2 + 3\tau^2} = 130.4 \text{ N/mm}^2$$

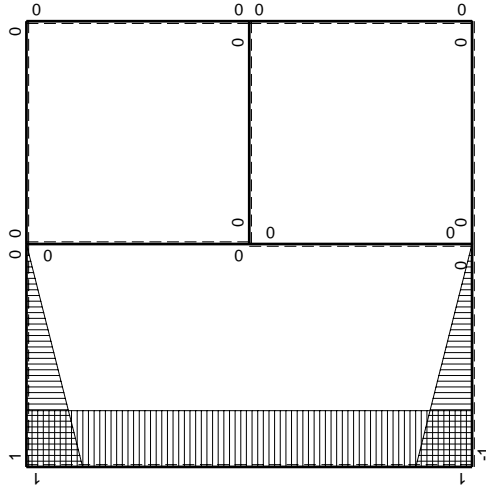
$$S = 5782. \text{ mm}^3$$







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
BH b	0	0	$Fb/EJ$	0	0	0			
HE b	0	$-1/2Fx+1/2qx^2$	0	0	0	0	0+0	0	
EH b	0	$1/2Fx-1/2qx^2$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

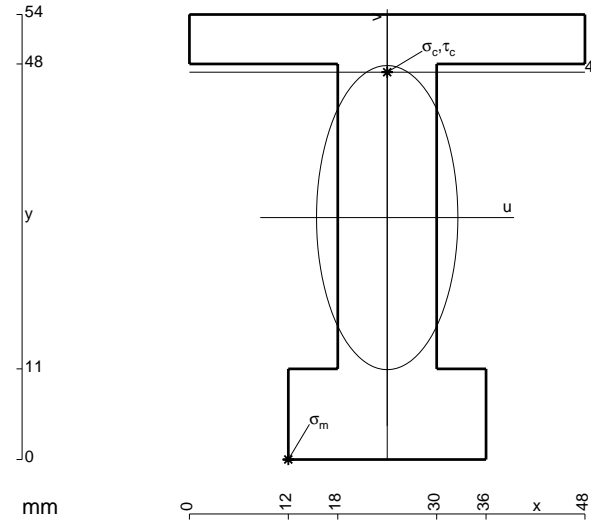
$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

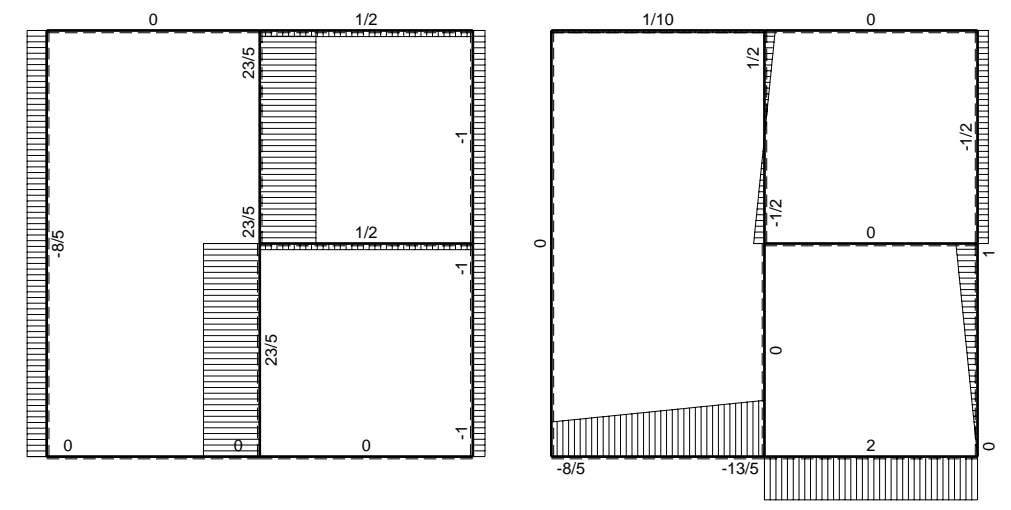
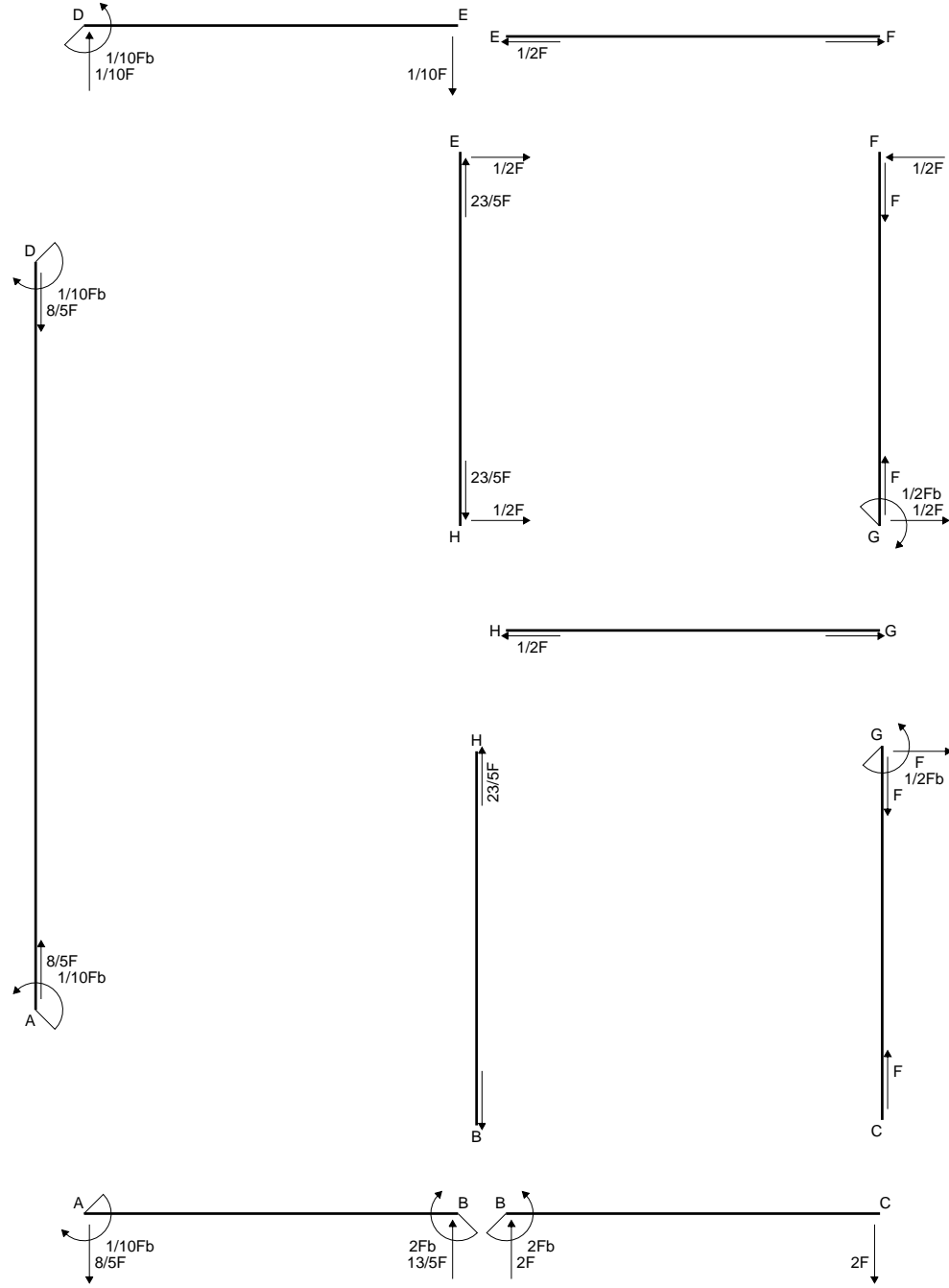
$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

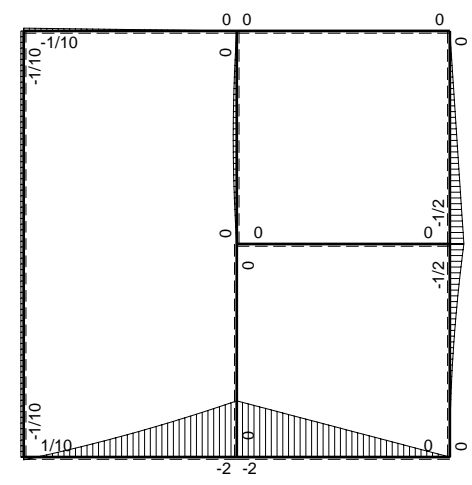


- A = 996. mm<sup>2</sup>
- J<sub>u</sub> = 339350. mm<sup>4</sup>
- J<sub>v</sub> = 73296. mm<sup>4</sup>
- y<sub>g</sub> = 29.36 mm
- T<sub>y</sub> = 4580. N
- M<sub>x</sub> = -2427400. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -12. mm
- v<sub>m</sub> = -29.36 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -210. N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 47. mm
- v<sub>c</sub> = 17.64 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 126.2 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.256 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 126.8 N/mm<sup>2</sup>
- S = 6451. mm<sup>3</sup>

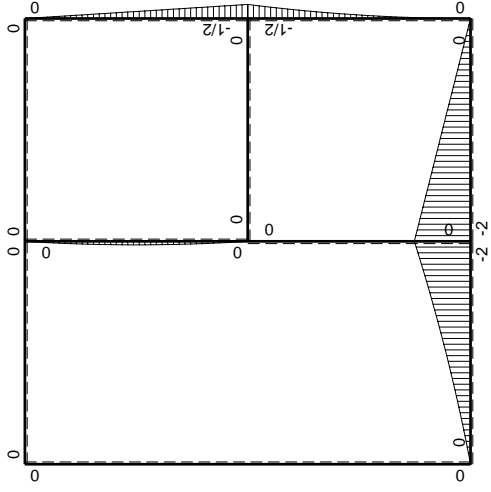
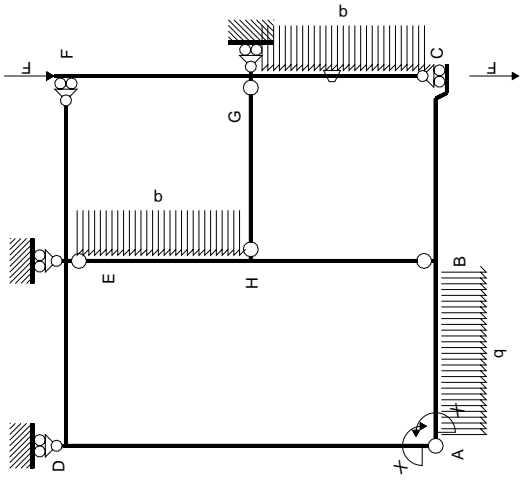


← ⊕ → F

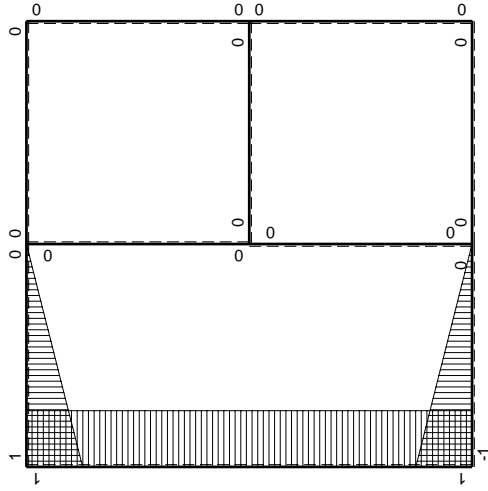
↑ ⊕ ↓ F



⊕ ⊖ F<sub>b</sub>



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	$-Fb/EJ$	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	$Fb/EJ$	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	0	0	0	0	0	0+0	0	
BH b	0	0	0	0	0	0			
HE b	0	$-1/2Fx+1/2qx^2$	0	0	0	0	0+0	0	
EH b	0	$1/2Fx-1/2qx^2$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (-2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (-2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

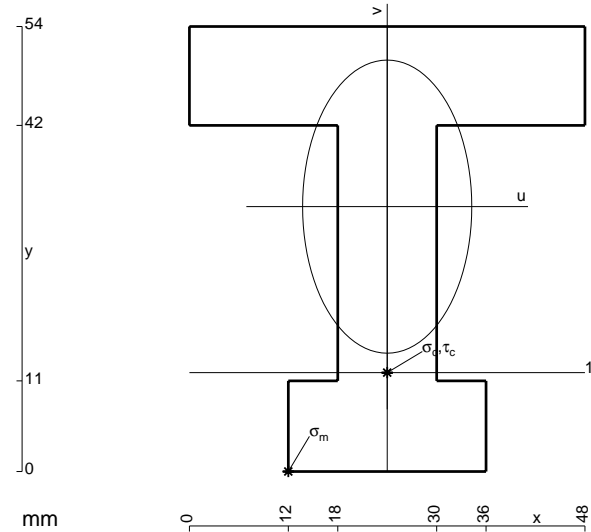
$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

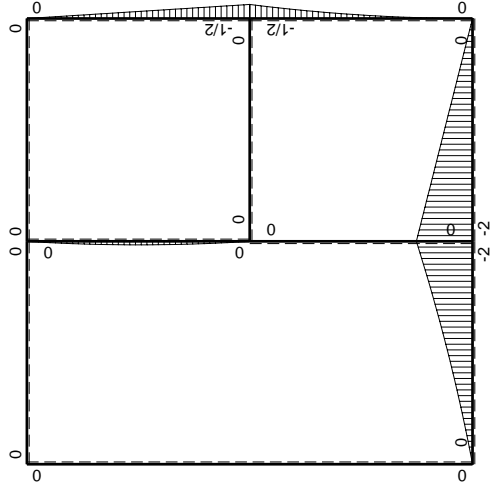
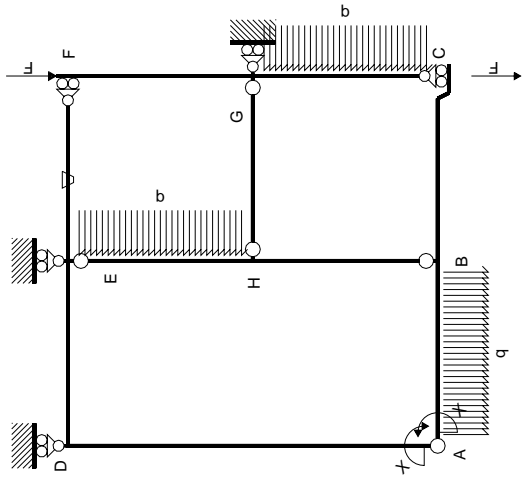
$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$



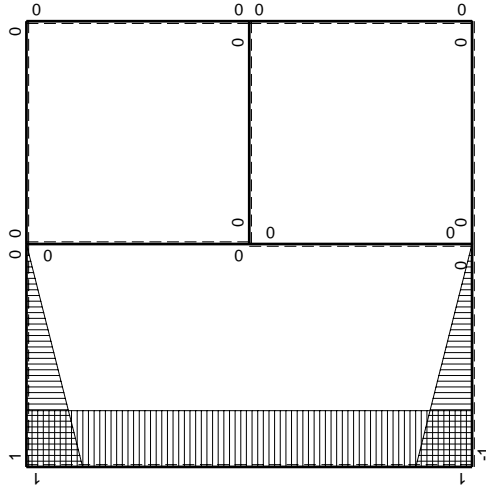
- A = 1212. mm<sup>2</sup>
- J<sub>u</sub> = 383443. mm<sup>4</sup>
- J<sub>v</sub> = 127728. mm<sup>4</sup>
- y<sub>g</sub> = 32.14 mm
- T<sub>y</sub> = 4520. N
- M<sub>x</sub> = -2621600. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -12. mm
- v<sub>m</sub> = -32.14 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -219.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 12. mm
- v<sub>c</sub> = -20.14 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -137.7 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.153 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 138.3 N/mm<sup>2</sup>
- S = 7282. mm<sup>3</sup>







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
DA 2b	-1	0	0	0	0	1			
DE b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$-x/b$	0	0	0	0	$x^2/b^2$			
EF b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
FE b	0	0	$Fb/EJ$	0	0	0			
FG b	0	$-1/2Fx$	0	0	0	0	0+0	0	
GF b	0	$1/2Fb-1/2Fx$	0	0	0	0			
GC b	0	$-1/2Fb+Fx-1/2qx^2$	0	0	0	0	0+0	0	
CG b	0	$1/2qx^2$	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	0	0	0	0	0	0+0	0	
BH b	0	0	0	0	0	0			
HE b	0	$-1/2Fx+1/2qx^2$	0	0	0	0	0+0	0	
EH b	0	$1/2Fx-1/2qx^2$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (-2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (-2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

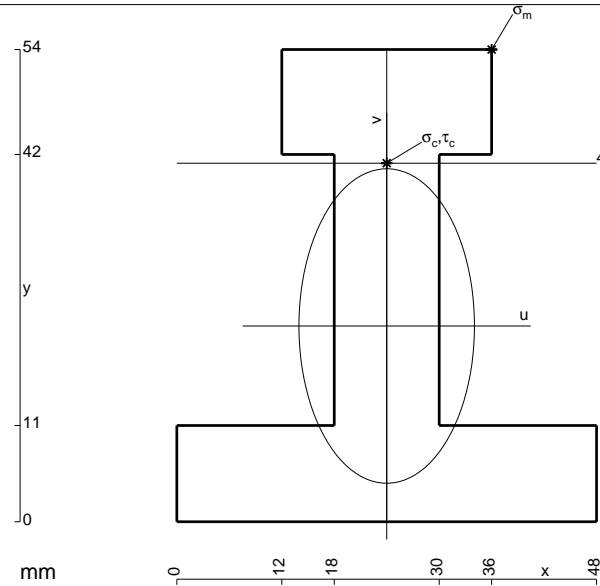
$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

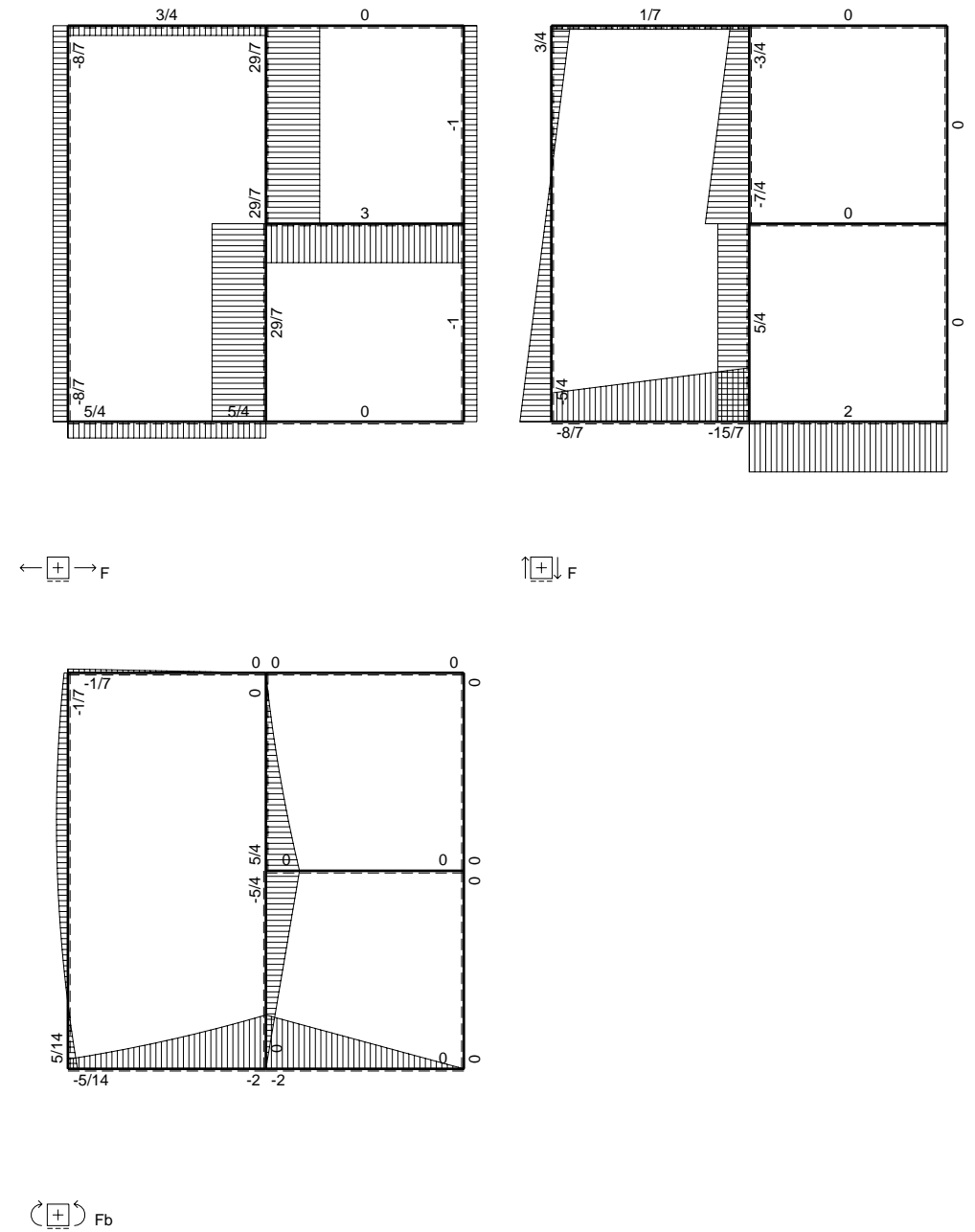
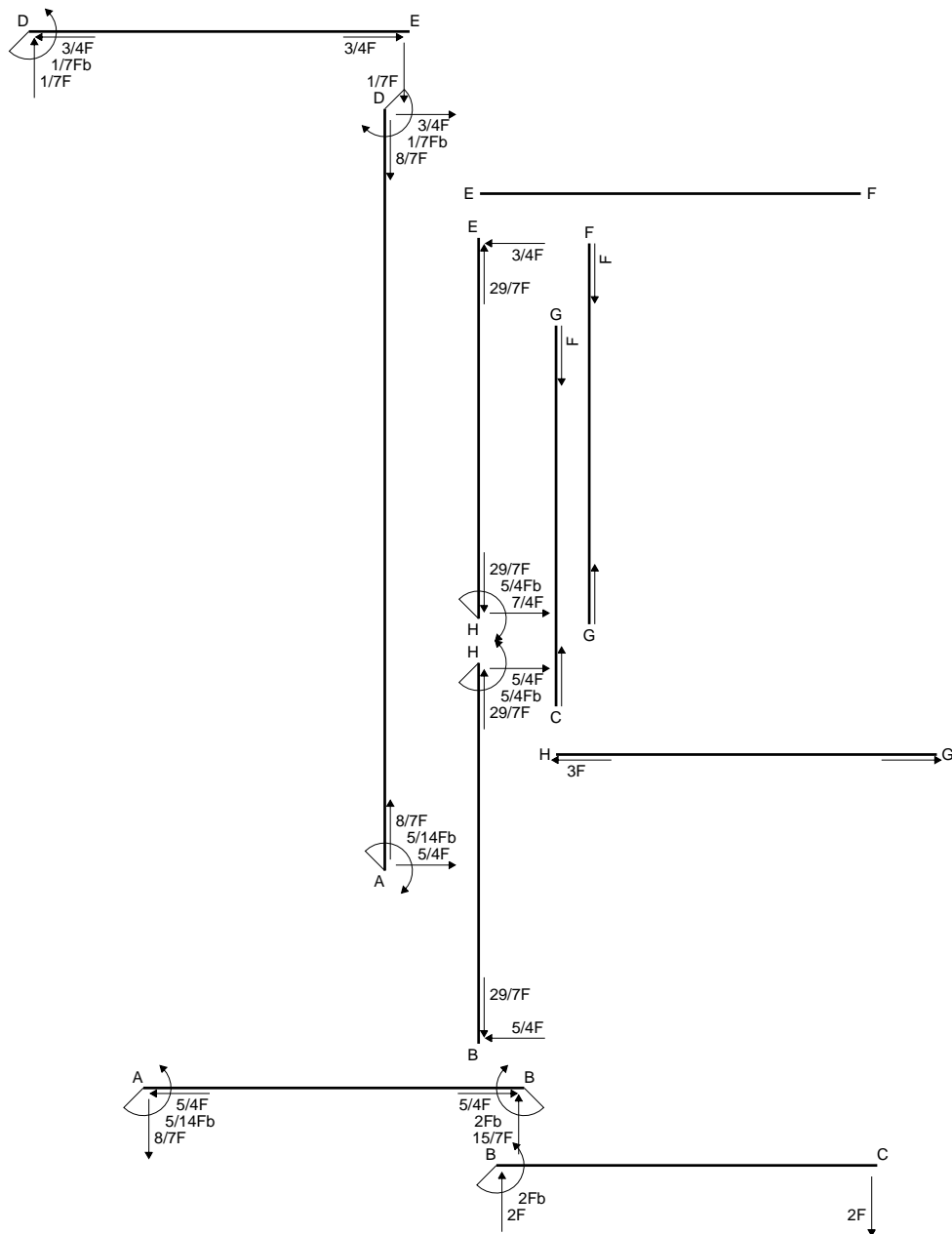
$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

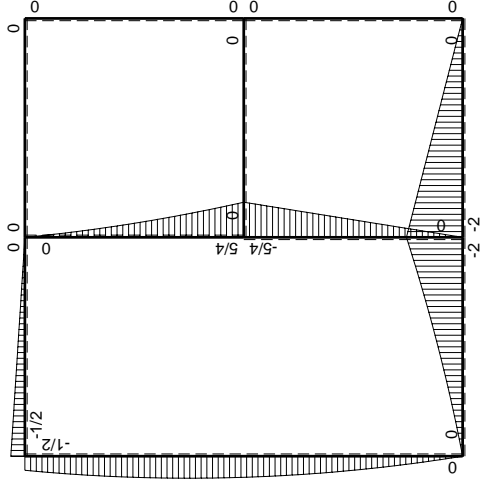
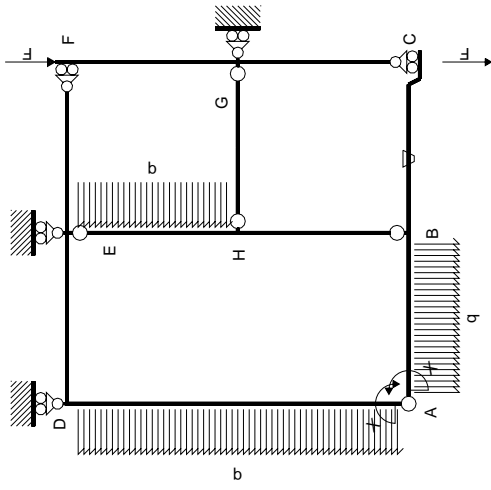
$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$



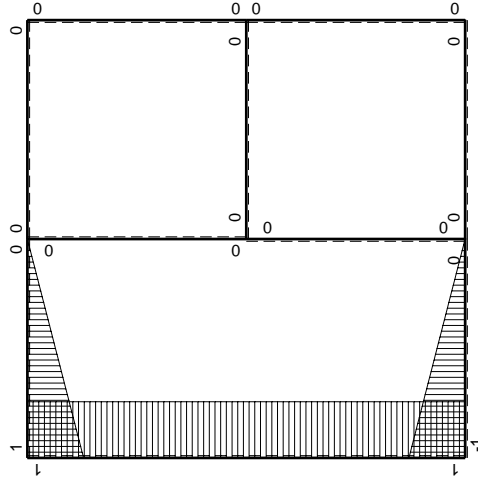
- A = 1188. mm<sup>2</sup>
- J<sub>u</sub> = 384370. mm<sup>4</sup>
- J<sub>v</sub> = 119664. mm<sup>4</sup>
- y<sub>g</sub> = 22.38 mm
- T<sub>y</sub> = 4420. N
- M<sub>x</sub> = -2784600. Nmm
- x<sub>m</sub> = 36. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 12. mm
- v<sub>m</sub> = 31.62 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 229.1 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 41. mm
- v<sub>c</sub> = 18.62 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 134.9 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.291 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 135.5 N/mm<sup>2</sup>
- S = 7608. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_1$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJdx$
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-2Fb+2Fx$	$-Fb/EJ$	0	0	0	0+0	0
CB b	0	$2Fx$	$Fb/EJ$	0	0	0		
AD 2b	1	$-5/4Fx+1/2qx^2$	0	$-5/4Fx+1/2Fx^2/b$	0	1	$(-7/6+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$1/2Fb+3/4Fx-1/2qx^2$	0	$-1/2Fb-3/4Fx+1/2Fx^2/b$	0	1		
DE b	$1-x/b$	$-1/2Fb+1/2Fx$	0	$-1/2Fb+Fx-1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$1/2Fx$	0	$-1/2Fx^2/b$	0	$x^2/b^2$		
EF b	0	0	0	0	0	0	0+0	0
FE b	0	0	0	0	0	0		
FG b	0	0	0	0	0	0	0+0	0
GF b	0	0	0	0	0	0		
GC b	0	0	0	0	0	0	0+0	0
CG b	0	0	0	0	0	0		
HG b	0	0	0	0	0	0	0+0	0
GH b	0	0	0	0	0	0		
HB b	0	$-5/4Fb+5/4Fx$	0	0	0	0	0+0	0
BH b	0	$5/4Fx$	0	0	0	0		
HE b	0	$5/4Fb-7/4Fx+1/2qx^2$	0	0	0	0	0+0	0
EH b	0	$-3/4Fx-1/2qx^2$	0	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$-25/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$5/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-5/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-5/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -7/6 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (-1/2 - 3/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x - 3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

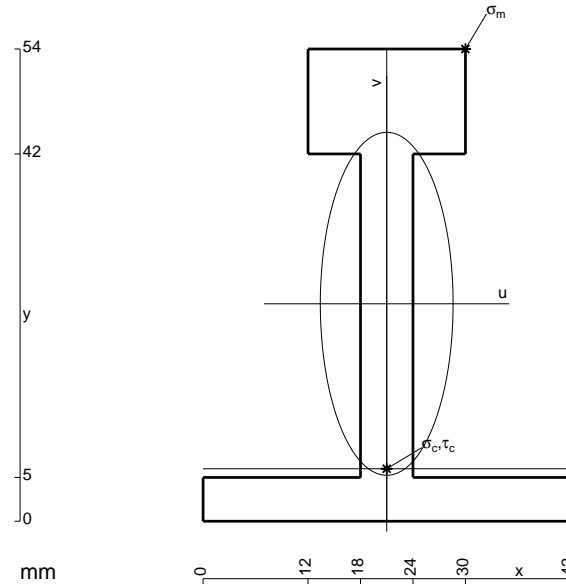
$$= (-b - 3/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -7/6 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x + 1/2 x^2/b - 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (-1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

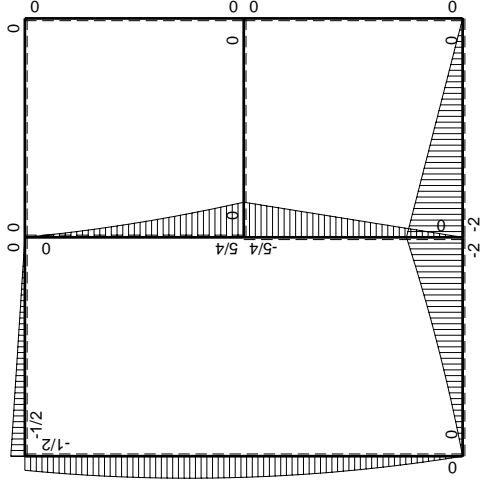
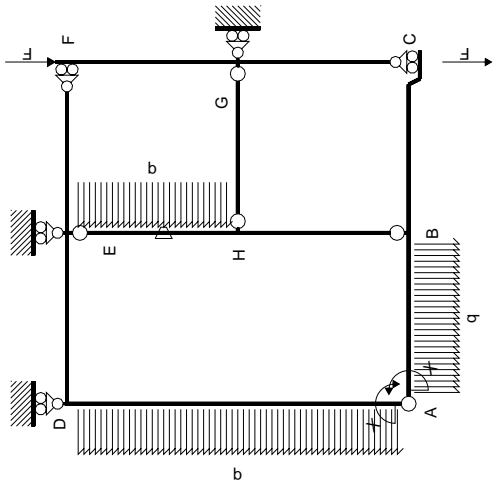
$$= (-1/6 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$



- A = 648. mm<sup>2</sup>
- J<sub>u</sub> = 249420. mm<sup>4</sup>
- J<sub>v</sub> = 37368. mm<sup>4</sup>
- y<sub>g</sub> = 24.86 mm
- T<sub>y</sub> = 3020. N
- M<sub>x</sub> = -2053600. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 9. mm
- v<sub>m</sub> = 29.14 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 239.9 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 6. mm
- v<sub>c</sub> = -18.86 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -155.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 9.711 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 156.2 N/mm<sup>2</sup>
- S = 4812. mm<sup>3</sup>

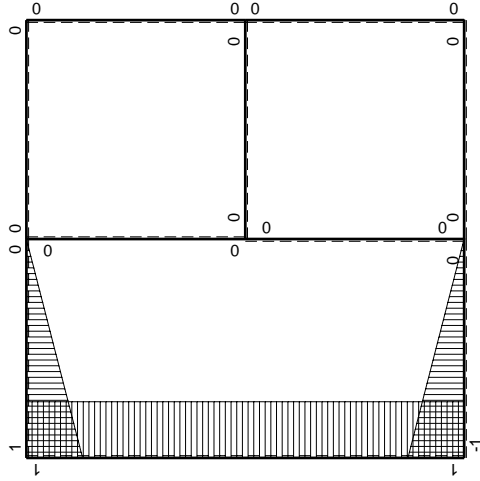






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_1$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$-5/4Fx+1/2qx^2$	0	$-5/4Fx+1/2Fx^2/b$	0	1	$(-7/6+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$1/2Fb+3/4Fx-1/2qx^2$	0	$-1/2Fb-3/4Fx+1/2Fx^2/b$	0	1			
DE b	$1-x/b$	$-1/2Fb+1/2Fx$	0	$-1/2Fb+Fx-1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-1/6+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fx$	0	$-1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-5/4Fb+5/4Fx$	0	0	0	0	0+0	0	
BH b	0	$5/4Fx$	0	0	0	0			
HE b	0	$5/4Fb-7/4Fx+1/2qx^2$	$-Fb/EJ$	0	0	0	0+0	0	
EH b	0	$-3/4Fx-1/2qx^2$	$Fb/EJ$	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$-25/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$5/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx + 1 \cdot 1/4 \cdot b/EJ = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx + 1 \cdot 1/4 \cdot b/EJ = [1/3 x^3/b^2]_0^b 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= [3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) Fb 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= [x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) Fb 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-5/4 x/b + 1/2 x^2/b^2) Fb 1/EJ dx = [-5/8 x^2/b + 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-5/2 b + 4/3 b) Fb 1/EJ = -7/6 Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (-1/2 - 3/4 x/b + 1/2 x^2/b^2) Fb 1/EJ dx = [-1/2 x - 3/8 x^2/b + 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

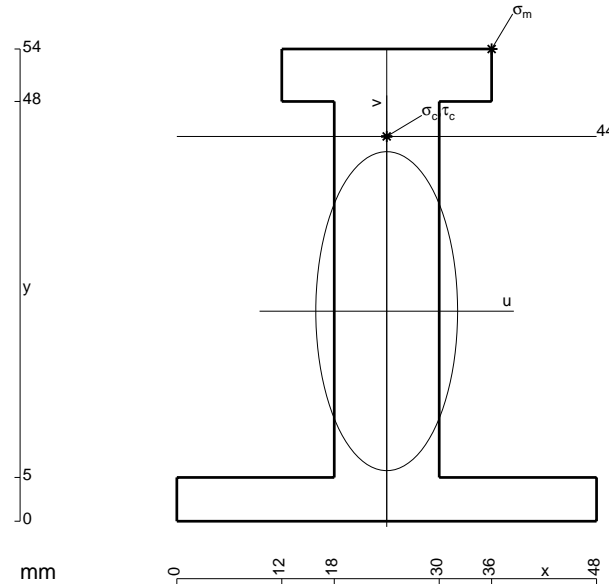
$$= (-b - 3/2 b + 4/3 b) Fb 1/EJ = -7/6 Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

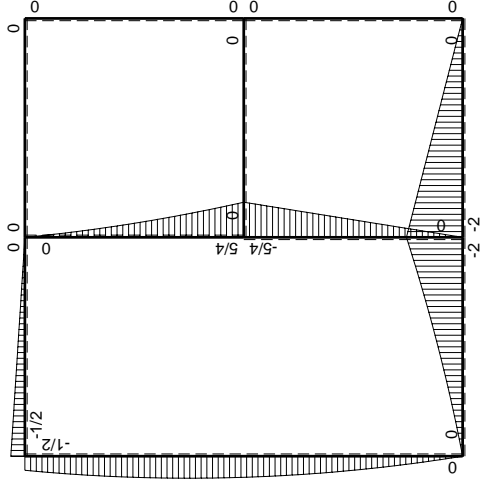
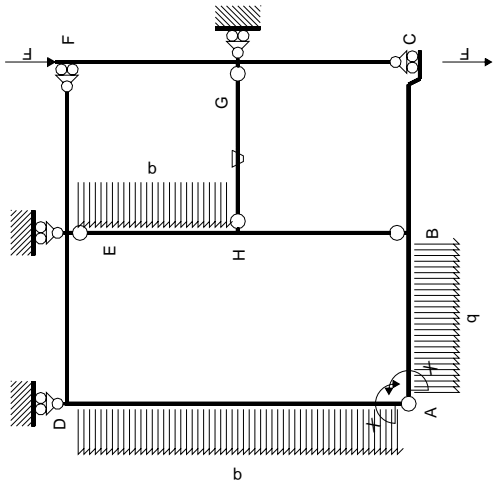
$$L_{ED}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$



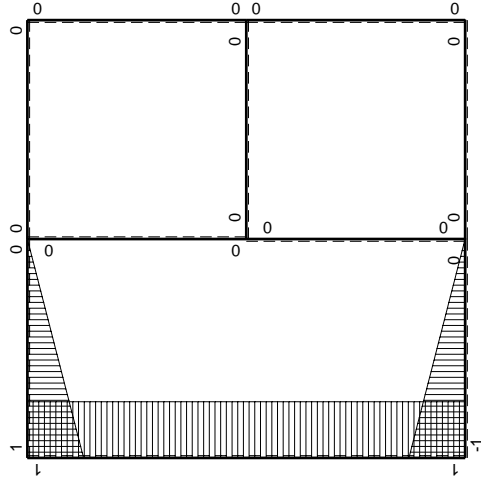
- A = 900. mm<sup>2</sup>
- J<sub>u</sub> = 299580. mm<sup>4</sup>
- J<sub>v</sub> = 59184. mm<sup>4</sup>
- y<sub>g</sub> = 24.02 mm
- T<sub>y</sub> = 2720. N
- M<sub>x</sub> = -1985600. Nmm
- x<sub>m</sub> = 36. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 12. mm
- v<sub>m</sub> = 29.98 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 198.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 44. mm
- v<sub>c</sub> = 19.98 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 132.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.738 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 132.6 N/mm<sup>2</sup>
- S = 4940. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_1$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0
CB b	0	$2Fx$	0	0	0	0		
AD 2b	1	$-5/4Fx+1/2qx^2$	0	$-5/4Fx+1/2Fx^2/b$	0	1	$(-7/6+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$1/2Fb+3/4Fx-1/2qx^2$	0	$-1/2Fb-3/4Fx+1/2Fx^2/b$	0	1		
DE b	$1-x/b$	$-1/2Fb+1/2Fx$	0	$-1/2Fb+Fx-1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$1/2Fx$	0	$-1/2Fx^2/b$	0	$x^2/b^2$		
EF b	0	0	0	0	0	0	0+0	0
FE b	0	0	0	0	0	0		
FG b	0	0	0	0	0	0	0+0	0
GF b	0	0	0	0	0	0		
GC b	0	0	0	0	0	0	0+0	0
CG b	0	0	0	0	0	0		
HG b	0	0	$-Fb/EJ$	0	0	0	0+0	0
GH b	0	0	$Fb/EJ$	0	0	0		
HB b	0	$-5/4Fb+5/4Fx$	0	0	0	0	0+0	0
BH b	0	$5/4Fx$	0	0	0	0		
HE b	0	$5/4Fb-7/4Fx+1/2qx^2$	0	0	0	0	0+0	0
EH b	0	$-3/4Fx-1/2qx^2$	0	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$-25/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$5/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \frac{1}{EJ} + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ}$$

$$= (b - b + 1/3 b) \frac{1}{EJ} = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx = \left[ 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ}$$

$$= (1/3 b) \frac{1}{EJ} = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-5/4 x/b + 1/2 x^2/b^2) Fb \frac{1}{EJ} dx = \left[ -5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} Fb \frac{1}{EJ}$$

$$= (-5/2 b + 4/3 b) Fb \frac{1}{EJ} = -7/6 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (-1/2 - 3/4 x/b + 1/2 x^2/b^2) Fb \frac{1}{EJ} dx = \left[ -1/2 x - 3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} Fb \frac{1}{EJ}$$

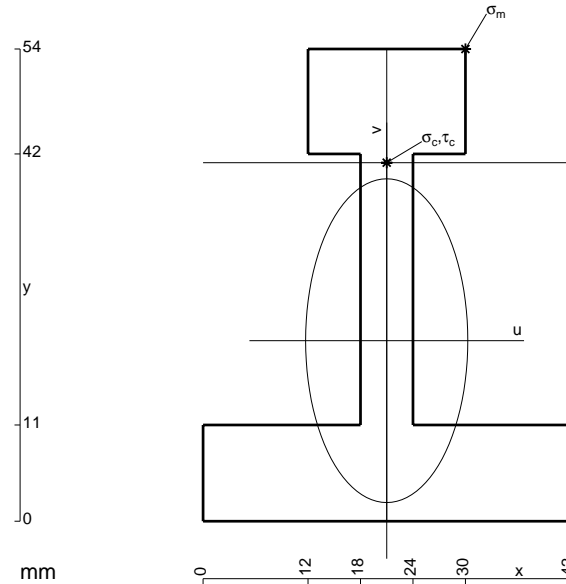
$$= (-b - 3/2 b + 4/3 b) Fb \frac{1}{EJ} = -7/6 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb \frac{1}{EJ} dx = \left[ -1/2 x + 1/2 x^2/b - 1/6 x^3/b^2 \right]_0^b Fb \frac{1}{EJ}$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb \frac{1}{EJ} = -1/6 \cdot Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb \frac{1}{EJ} dx = \left[ -1/6 x^3/b^2 \right]_0^b Fb \frac{1}{EJ}$$

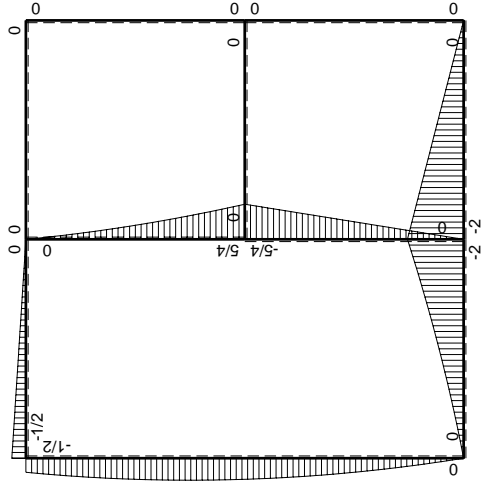
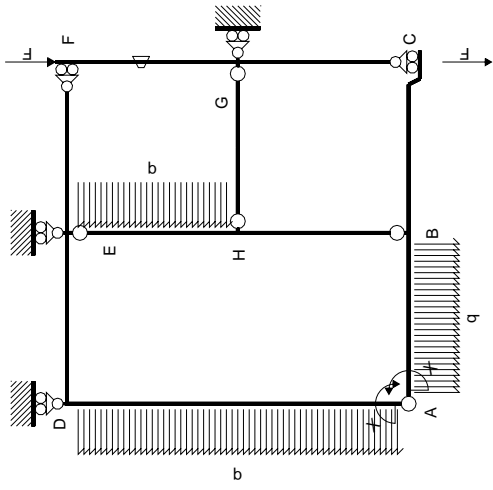
$$= (-1/6 b) Fb \frac{1}{EJ} = -1/6 \cdot Fb^2/EJ$$



- A = 864. mm<sup>2</sup>
- J<sub>u</sub> = 296124. mm<sup>4</sup>
- J<sub>v</sub> = 74304. mm<sup>4</sup>
- y<sub>g</sub> = 20.65 mm
- T<sub>y</sub> = 2380. N
- M<sub>x</sub> = -1856400. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 9. mm
- v<sub>m</sub> = 33.35 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 209.1 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 41. mm
- v<sub>c</sub> = 20.35 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 127.6 N/mm<sup>2</sup>
- τ<sub>c</sub> = 8.082 N/mm<sup>2</sup>
- σ<sub>σ</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 128.4 N/mm<sup>2</sup>
- S = 6034. mm<sup>3</sup>

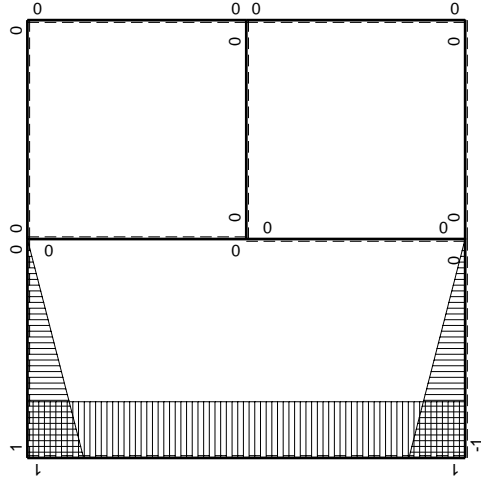






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_1$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0
CB b	0	$2Fx$	0	0	0	0		
AD 2b	1	$-5/4Fx+1/2qx^2$	0	$-5/4Fx+1/2Fx^2/b$	0	1	$(-7/6+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$1/2Fb+3/4Fx-1/2qx^2$	0	$-1/2Fb-3/4Fx+1/2Fx^2/b$	0	1		
DE b	$1-x/b$	$-1/2Fb+1/2Fx$	0	$-1/2Fb+Fx-1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$1/2Fx$	0	$-1/2Fx^2/b$	0	$x^2/b^2$		
EF b	0	0	0	0	0	0	0+0	0
FE b	0	0	0	0	0	0		
FG b	0	0	$-Fb/EJ$	0	0	0	0+0	0
GF b	0	0	$Fb/EJ$	0	0	0		
GC b	0	0	0	0	0	0	0+0	0
CG b	0	0	0	0	0	0		
HG b	0	0	0	0	0	0	0+0	0
GH b	0	0	0	0	0	0		
HB b	0	$-5/4Fb+5/4Fx$	0	0	0	0	0+0	0
BH b	0	$5/4Fx$	0	0	0	0		
HE b	0	$5/4Fb-7/4Fx+1/2qx^2$	0	0	0	0	0+0	0
EH b	0	$-3/4Fx-1/2qx^2$	0	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$-25/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$5/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx + 1 \cdot 1/4 \cdot b/EJ = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx + 1 \cdot 1/4 \cdot b/EJ = [1/3 x^3/b^2]_0^b 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= [3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) Fb 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2 x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= [x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) Fb 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-5/4 x/b + 1/2 x^2/b^2) Fb 1/EJ dx = [-5/8 x^2/b + 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-5/2 b + 4/3 b) Fb 1/EJ = -7/6 Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (-1/2 - 3/4 x/b + 1/2 x^2/b^2) Fb 1/EJ dx = [-1/2 x - 3/8 x^2/b + 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

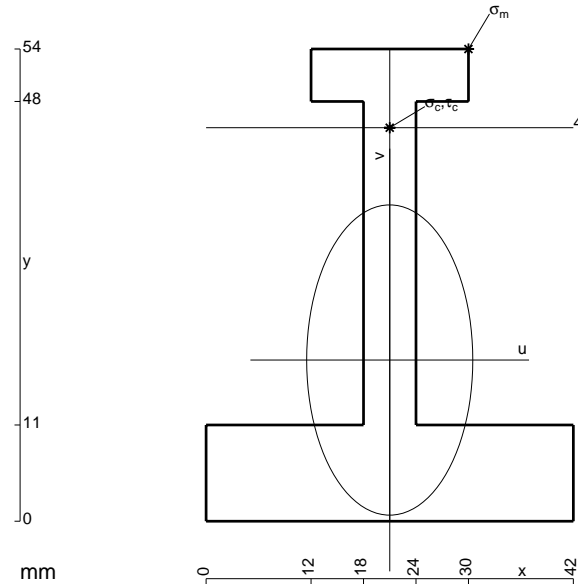
$$= (-b - 3/2 b + 4/3 b) Fb 1/EJ = -7/6 Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ$$

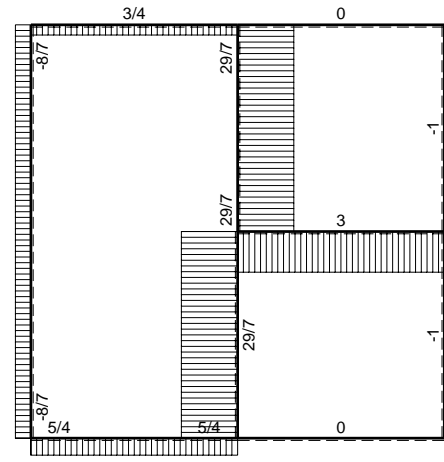
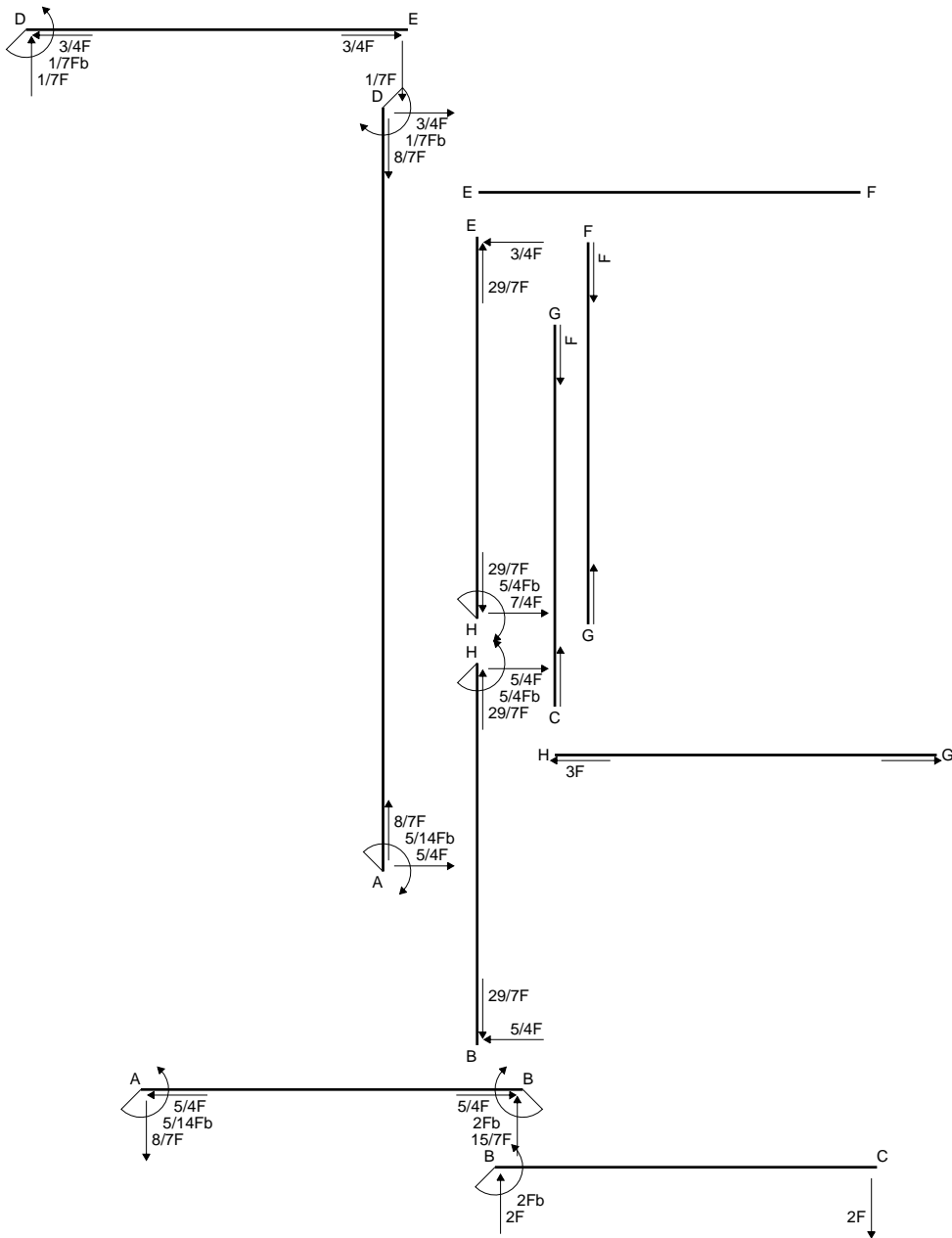
$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ$$

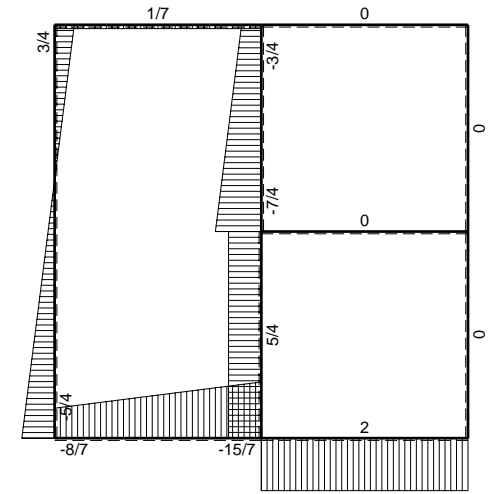
$$= (-1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$



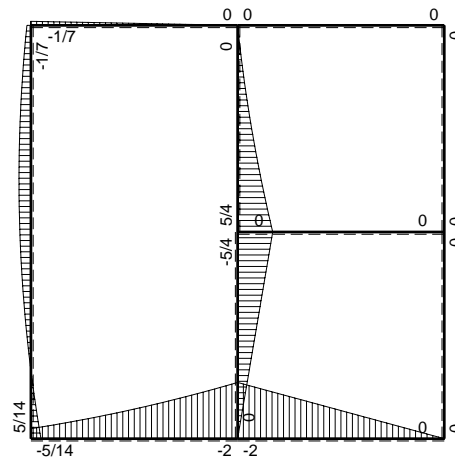
- A = 792. mm<sup>2</sup>
- J<sub>u</sub> = 249320. mm<sup>4</sup>
- J<sub>v</sub> = 71496. mm<sup>4</sup>
- y<sub>g</sub> = 18.43 mm
- T<sub>y</sub> = 1840. N
- M<sub>x</sub> = -1527200. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 9. mm
- v<sub>m</sub> = 35.57 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 217.9 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 45. mm
- v<sub>c</sub> = 26.57 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 162.7 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.948 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 163. N/mm<sup>2</sup>
- S = 4023. mm<sup>3</sup>



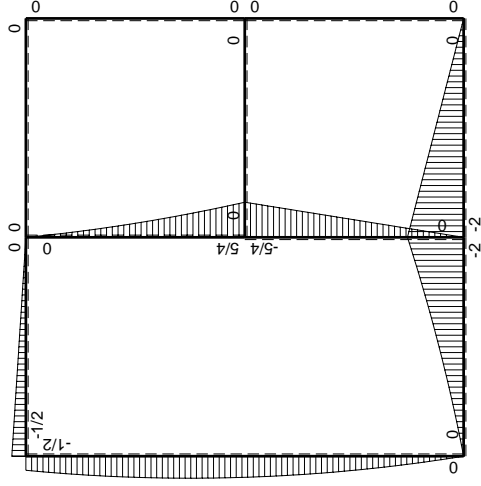
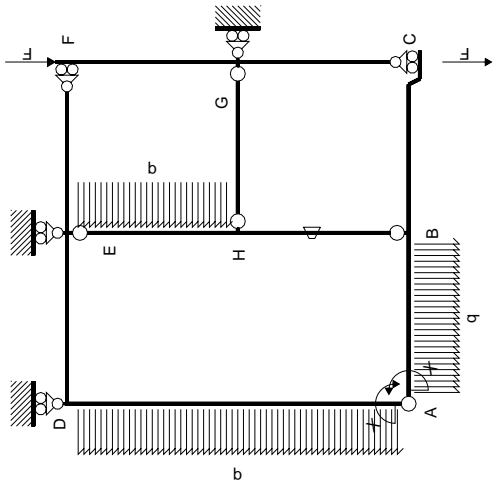
← ⊕ → F



↑ ⊕ ↓ F

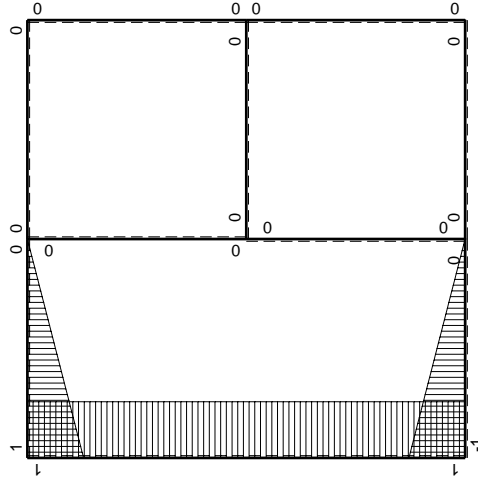


⊕ ⊖ Fb



Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_1$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0
CB b	0	$2Fx$	0	0	0	0		
AD 2b	1	$-5/4Fx+1/2qx^2$	0	$-5/4Fx+1/2Fx^2/b$	0	1	$(-7/6+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$1/2Fb+3/4Fx-1/2qx^2$	0	$-1/2Fb-3/4Fx+1/2Fx^2/b$	0	1		
DE b	$1-x/b$	$-1/2Fb+1/2Fx$	0	$-1/2Fb+Fx-1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$1/2Fx$	0	$-1/2Fx^2/b$	0	$x^2/b^2$		
EF b	0	0	0	0	0	0	0+0	0
FE b	0	0	0	0	0	0		
FG b	0	0	0	0	0	0	0+0	0
GF b	0	0	0	0	0	0		
GC b	0	0	0	0	0	0	0+0	0
CG b	0	0	0	0	0	0		
HG b	0	0	0	0	0	0	0+0	0
GH b	0	0	0	0	0	0		
HB b	0	$-5/4Fb+5/4Fx$	$-Fb/EJ$	0	0	0	0+0	0
BH b	0	$5/4Fx$	$Fb/EJ$	0	0	0		
HE b	0	$5/4Fb-7/4Fx+1/2qx^2$	0	0	0	0	0+0	0
EH b	0	$-3/4Fx-1/2qx^2$	0	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$-25/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$5/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx + 1 \cdot 1 \cdot \frac{1}{4} \frac{b}{EJ} = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ} + 1 \cdot 1 \cdot \frac{1}{4} \frac{b}{EJ}$$

$$= (b - b + 1/3 b) \frac{1}{EJ} + 1 \cdot 1 \cdot \frac{1}{4} \frac{b}{EJ} = 7/12 \frac{b}{EJ}$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx + 1 \cdot 1 \cdot \frac{1}{4} \frac{b}{EJ} = \left[ 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ} + 1 \cdot 1 \cdot \frac{1}{4} \frac{b}{EJ}$$

$$= (1/3 b) \frac{1}{EJ} + 1 \cdot 1 \cdot \frac{1}{4} \frac{b}{EJ} = 7/12 \frac{b}{EJ}$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \frac{b}{EJ}$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \frac{b}{EJ}$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ}$$

$$= (b - b + 1/3 b) \frac{1}{EJ} = 1/3 \frac{b}{EJ}$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx = \left[ 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ}$$

$$= (1/3 b) \frac{1}{EJ} = 1/3 \frac{b}{EJ}$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= (3/4 b - 1/3 b - 1/8 b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ} = 7/24 \frac{Fb^2}{EJ}$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= (b - 5/6 b + 1/8 b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ} = 7/24 \frac{Fb^2}{EJ}$$

$$L_{AD}^{xo} = \int_0^{2b} (-5/4 x/b + 1/2 x^2/b^2) Fb \frac{1}{EJ} dx = \left[ -5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} Fb \frac{1}{EJ}$$

$$= (-5/2 b + 4/3 b) Fb \frac{1}{EJ} = -7/6 \frac{Fb^2}{EJ}$$

$$L_{DA}^{xo} = \int_0^{2b} (-1/2 - 3/4 x/b + 1/2 x^2/b^2) Fb \frac{1}{EJ} dx = \left[ -1/2 x - 3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} Fb \frac{1}{EJ}$$

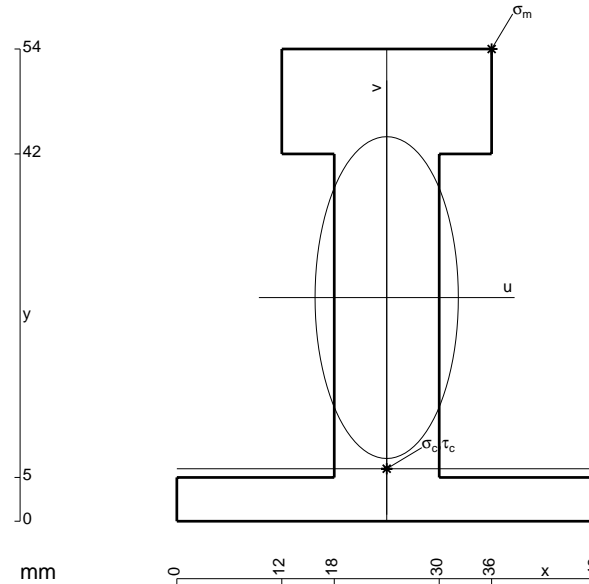
$$= (-b - 3/2 b + 4/3 b) Fb \frac{1}{EJ} = -7/6 \frac{Fb^2}{EJ}$$

$$L_{DE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb \frac{1}{EJ} dx = \left[ -1/2 x + 1/2 x^2/b - 1/6 x^3/b^2 \right]_0^b Fb \frac{1}{EJ}$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb \frac{1}{EJ} = -1/6 \frac{Fb^2}{EJ}$$

$$L_{ED}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb \frac{1}{EJ} dx = \left[ -1/6 x^3/b^2 \right]_0^b Fb \frac{1}{EJ}$$

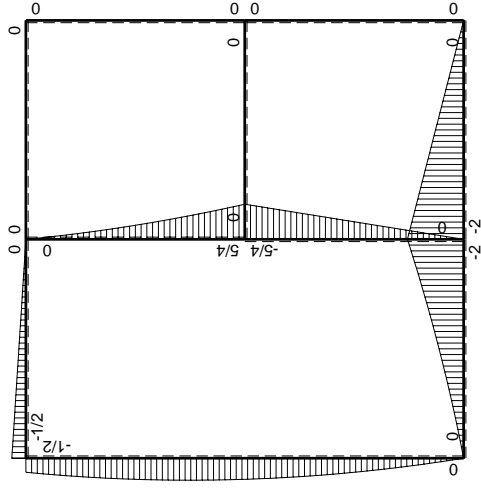
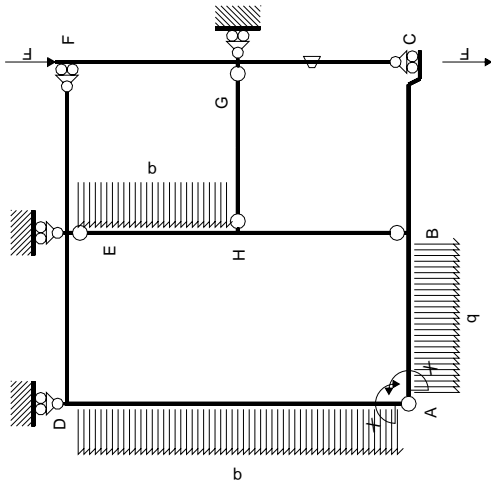
$$= (-1/6 b) Fb \frac{1}{EJ} = -1/6 \frac{Fb^2}{EJ}$$



- A = 972. mm<sup>2</sup>
- J<sub>u</sub> = 329140. mm<sup>4</sup>
- J<sub>v</sub> = 65232. mm<sup>4</sup>
- y<sub>g</sub> = 25.57 mm
- T<sub>y</sub> = 3020. N
- M<sub>x</sub> = -2657600. Nmm
- x<sub>m</sub> = 36. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 12. mm
- v<sub>m</sub> = 28.43 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 229.5 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 6. mm
- v<sub>c</sub> = -19.57 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -158. N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.418 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 158.2 N/mm<sup>2</sup>
- S = 5779. mm<sup>3</sup>

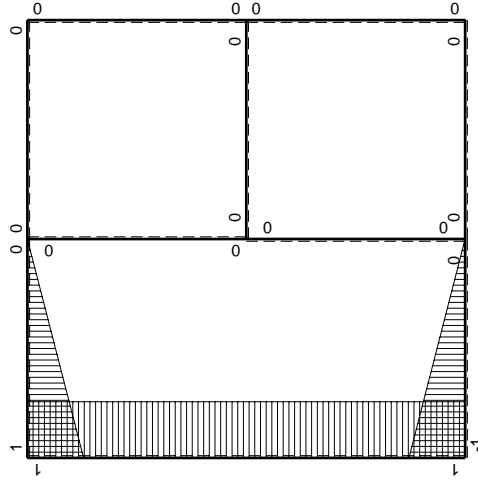






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_1$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0	
CB b	0	$2Fx$	0	0	0	0			
AD 2b	1	$-5/4Fx+1/2qx^2$	0	$-5/4Fx+1/2Fx^2/b$	0	1	$(-7/6+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$1/2Fb+3/4Fx-1/2qx^2$	0	$-1/2Fb-3/4Fx+1/2Fx^2/b$	0	1			
DE b	$1-x/b$	$-1/2Fb+1/2Fx$	0	$-1/2Fb+Fx-1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-1/6+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fx$	0	$-1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
CG b	0	0	$Fb/EJ$	0	0	0			
HG b	0	0	0	0	0	0	0+0	0	
GH b	0	0	0	0	0	0			
HB b	0	$-5/4Fb+5/4Fx$	0	0	0	0	0+0	0	
BH b	0	$5/4Fx$	0	0	0	0			
HE b	0	$5/4Fb-7/4Fx+1/2qx^2$	0	0	0	0	0+0	0	
EH b	0	$-3/4Fx-1/2qx^2$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$-25/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$5/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 7/24 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-5/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -5/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-5/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -7/6 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (-1/2 - 3/4 x/b + 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x - 3/8 x^2/b + 1/6 x^3/b^2 \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

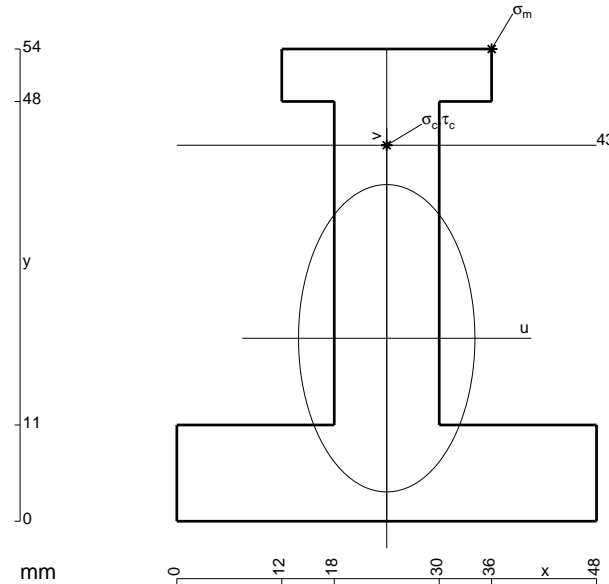
$$= (-b - 3/2 b + 4/3 b) \cdot Fb \cdot 1/EJ = -7/6 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x + 1/2 x^2/b - 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

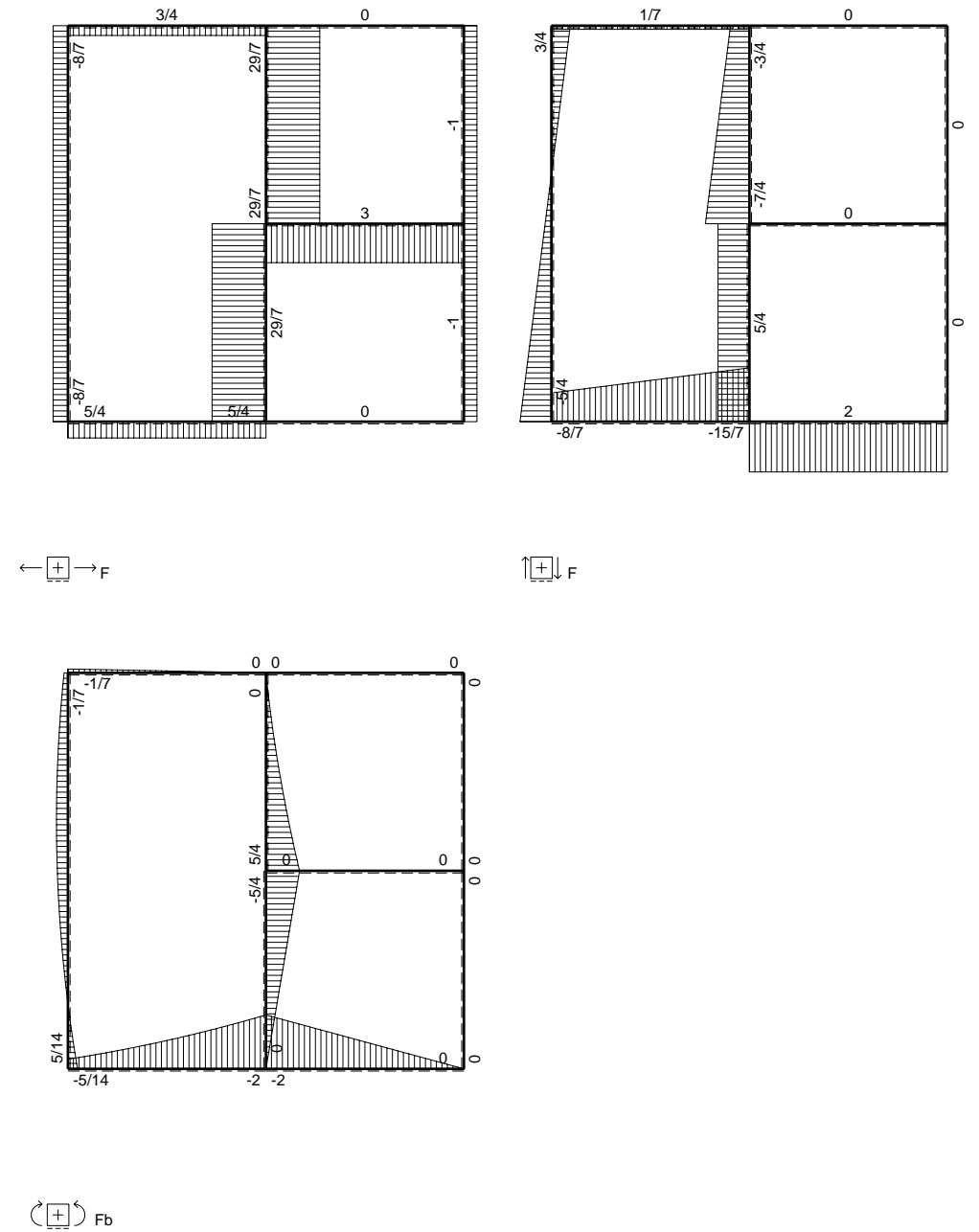
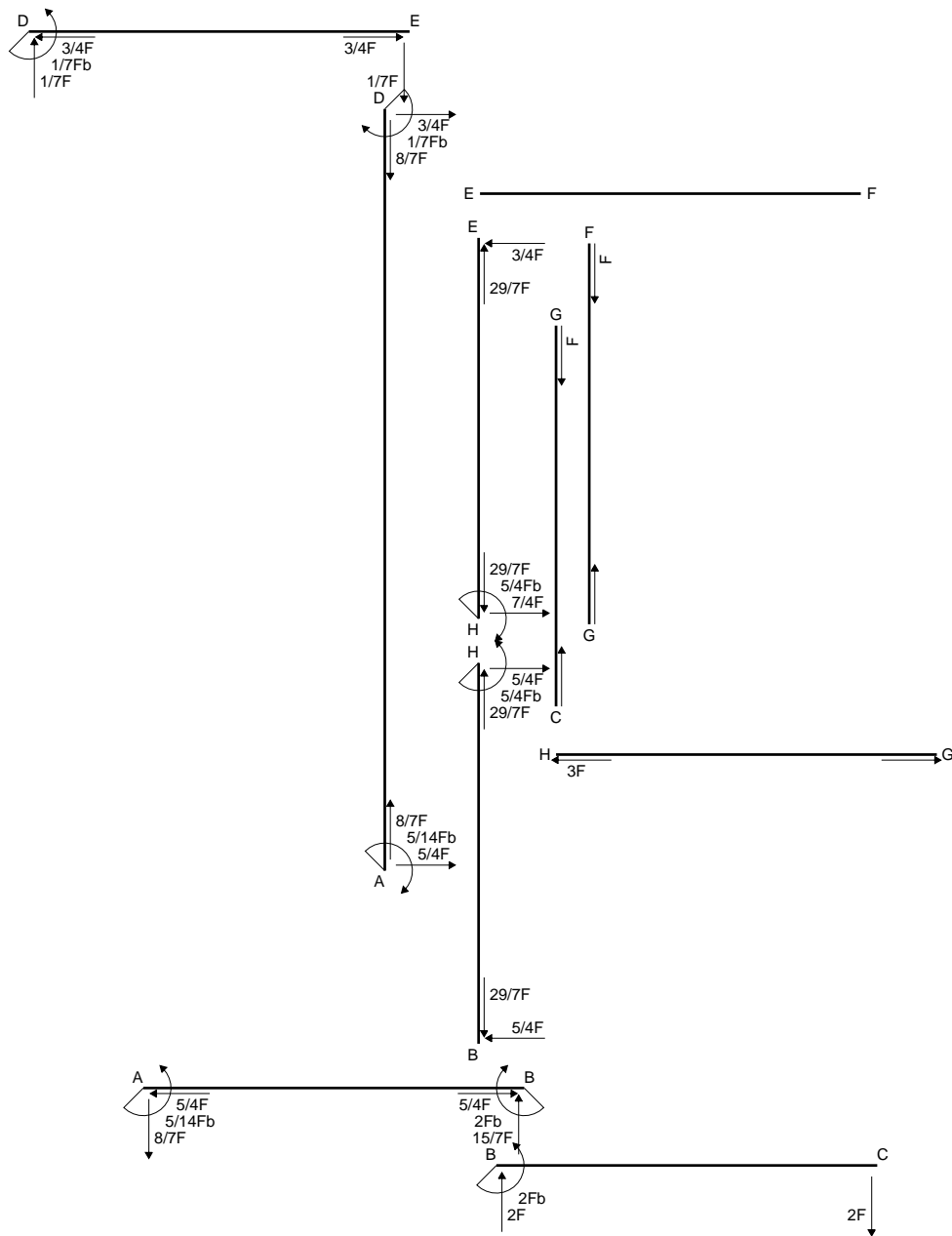
$$= (-1/2 b + 1/2 b - 1/6 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

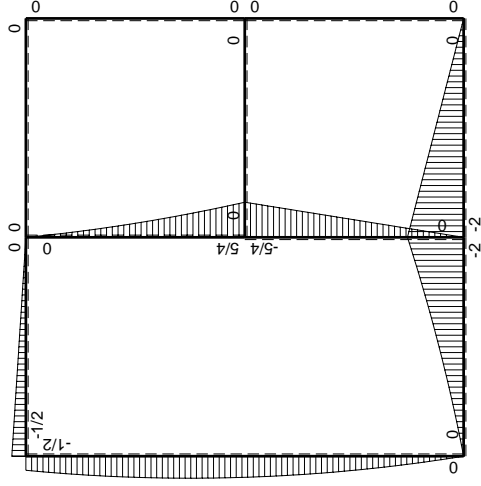
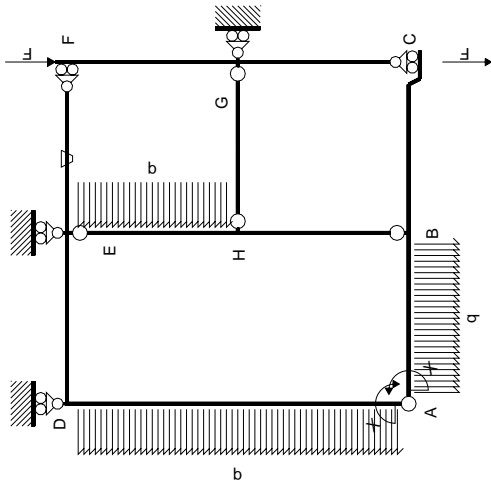
$$L_{ED}^{xo} = \int_0^b (-1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/6 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$



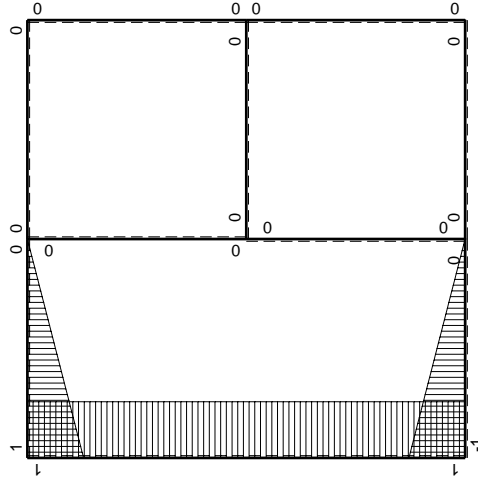
- A = 1116. mm<sup>2</sup>
- J<sub>u</sub> = 344933. mm<sup>4</sup>
- J<sub>v</sub> = 113616. mm<sup>4</sup>
- y<sub>g</sub> = 20.92 mm
- T<sub>y</sub> = 2680. N
- M<sub>x</sub> = -2492400. Nmm
- x<sub>m</sub> = 36. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 12. mm
- v<sub>m</sub> = 33.08 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 239. N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 43. mm
- v<sub>c</sub> = 22.08 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 159.5 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.76 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 159.7 N/mm<sup>2</sup>
- S = 5806. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_1$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$
AB b	$-1+x/b$	$-3/2Fx-1/2qx^2$	0	$3/2Fx-Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(7/24+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$2Fb-5/2Fx+1/2qx^2$	0	$2Fx-5/2Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-2Fb+2Fx$	0	0	0	0	0+0	0
CB b	0	$2Fx$	0	0	0	0		
AD 2b	1	$-5/4Fx+1/2qx^2$	0	$-5/4Fx+1/2Fx^2/b$	0	1	$(-7/6+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$1/2Fb+3/4Fx-1/2qx^2$	0	$-1/2Fb-3/4Fx+1/2Fx^2/b$	0	1		
DE b	$1-x/b$	$-1/2Fb+1/2Fx$	0	$-1/2Fb+Fx-1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$1/2Fx$	0	$-1/2Fx^2/b$	0	$x^2/b^2$		
EF b	0	0	$-Fb/EJ$	0	0	0	0+0	0
FE b	0	0	$Fb/EJ$	0	0	0		
FG b	0	0	0	0	0	0	0+0	0
GF b	0	0	0	0	0	0		
GC b	0	0	0	0	0	0	0+0	0
CG b	0	0	0	0	0	0		
HG b	0	0	0	0	0	0	0+0	0
GH b	0	0	0	0	0	0		
HB b	0	$-5/4Fb+5/4Fx$	0	0	0	0	0+0	0
BH b	0	$5/4Fx$	0	0	0	0		
HE b	0	$5/4Fb-7/4Fx+1/2qx^2$	0	0	0	0	0+0	0
EH b	0	$-3/4Fx-1/2qx^2$	0	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$-25/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$5/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (-2x/b + x^2/b^2) 1/EJ dx + 1 \cdot 1/4 b/EJ = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ + 1 \cdot 1/4 b/EJ$$

$$= (b - b + 1/3 b) 1/EJ + 1 \cdot 1/4 b/EJ = 7/12 b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx + 1 \cdot 1/4 b/EJ = [1/3 x^3/b^2]_0^b 1/EJ + 1 \cdot 1/4 b/EJ$$

$$= (1/3 b) 1/EJ + 1 \cdot 1/4 b/EJ = 7/12 b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{DE}^{xx} = \int_0^b (-2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{AB}^{xo} = \int_0^b (3/2 x/b - x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx + 1 \cdot 0 1/4 Fb^2/EJ$$

$$= [3/4 x^2/b - 1/3 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ + 1 \cdot 0 1/4 Fb^2/EJ$$

$$= (3/4 b - 1/3 b - 1/8 b) Fb 1/EJ + 1 \cdot 0 1/4 Fb^2/EJ = 7/24 Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (2x/b - 5/2 x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + 1 \cdot 0 1/4 Fb^2/EJ$$

$$= [x^2/b - 5/6 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ + 1 \cdot 0 1/4 Fb^2/EJ$$

$$= (b - 5/6 b + 1/8 b) Fb 1/EJ + 1 \cdot 0 1/4 Fb^2/EJ = 7/24 Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-5/4 x/b + 1/2 x^2/b^2) Fb 1/EJ dx = [-5/8 x^2/b + 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-5/2 b + 4/3 b) Fb 1/EJ = -7/6 Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (-1/2 - 3/4 x/b + 1/2 x^2/b^2) Fb 1/EJ dx = [-1/2 x - 3/8 x^2/b + 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

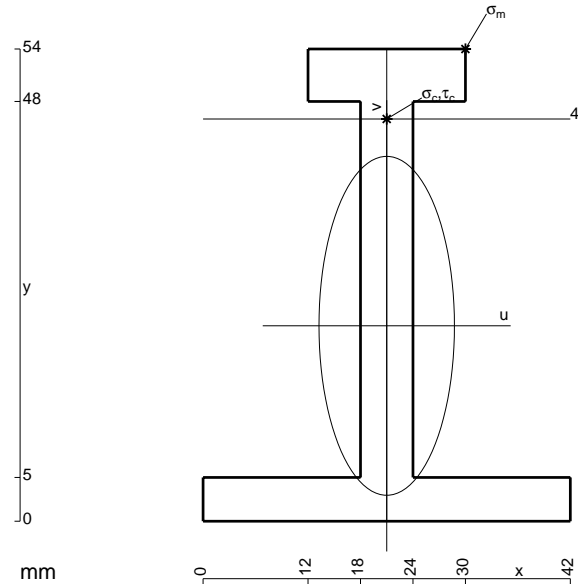
$$= (-b - 3/2 b + 4/3 b) Fb 1/EJ = -7/6 Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ$$

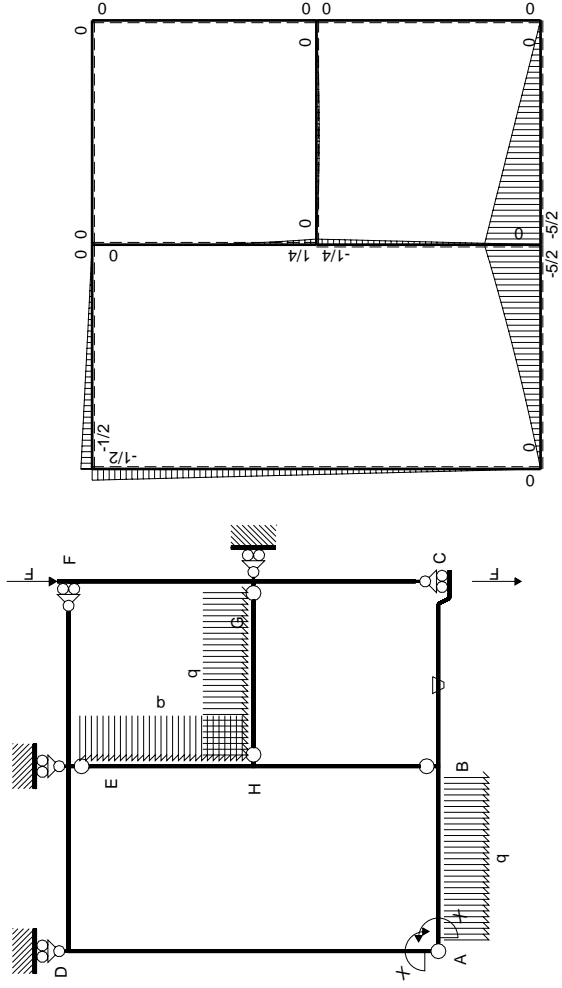
$$= (-1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$



- A = 576. mm<sup>2</sup>
- J<sub>u</sub> = 216352. mm<sup>4</sup>
- J<sub>v</sub> = 34560. mm<sup>4</sup>
- y<sub>g</sub> = 22.34 mm
- T<sub>y</sub> = 2780. N
- M<sub>x</sub> = -1362200. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 9. mm
- v<sub>m</sub> = 31.66 mm
- σ<sub>m</sub> = -M<sub>v</sub>/J<sub>u</sub> = 199.3 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 46. mm
- v<sub>c</sub> = 23.66 mm
- σ<sub>c</sub> = -M<sub>v</sub>/J<sub>u</sub> = 148.9 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.262 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 149.5 N/mm<sup>2</sup>
- S = 3391. mm<sup>3</sup>

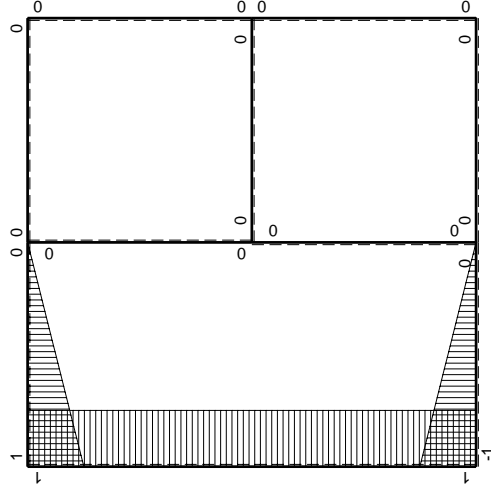






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$
AB b	$-1+x/b$	$-2Fx-1/2qx^2$	0	$2Fx-3/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(3/8+0)Fb^2/EJ$	$1/3Xb/EJ$
BA b	$x/b$	$5/2Fb-3Fx+1/2qx^2$	0	$5/2Fx-3Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$		
BC b	0	$-5/2Fb+5/2Fx$	$-Fb/EJ$	0	0	0	0+0	0
CB b	0	$5/2Fx$	$Fb/EJ$	0	0	0		
AD 2b	1	$-1/4Fx$	0	$-1/4Fx$	0	1	$(-1/2+0)Fb^2/EJ$	$2Xb/EJ$
DA 2b	-1	$1/2Fb-1/4Fx$	0	$-1/2Fb+1/4Fx$	0	1		
DE b	$1-x/b$	$-1/2Fb+1/2Fx$	0	$-1/2Fb+Fx-1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$-x/b$	$1/2Fx$	0	$-1/2Fx^2/b$	0	$x^2/b^2$		
EF b	0	0	0	0	0	0	0+0	0
FE b	0	0	0	0	0	0		
FG b	0	0	0	0	0	0	0+0	0
GF b	0	0	0	0	0	0		
GC b	0	0	0	0	0	0	0+0	0
CG b	0	0	0	0	0	0		
HG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0
GH b	0	$-1/2Fx+1/2qx^2$	0	0	0	0		
HB b	0	$-1/4Fb+1/4Fx$	0	0	0	0	0+0	0
BH b	0	$1/4Fx$	0	0	0	0		
HE b	0	$1/4Fb-3/4Fx+1/2qx^2$	0	0	0	0	0+0	0
EH b	0	$1/4Fx-1/2qx^2$	0	0	0	0		
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$							$1/4Xb/EJ$
	totali						$-7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$						$1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (2x/b - 3/2 x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 1/2 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 1/2 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (5/2 x/b - 3 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 5/4 x^2/b - x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (5/4 b - b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-1/2 b) \cdot Fb \cdot 1/EJ = -1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (-1/2 + 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x + 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

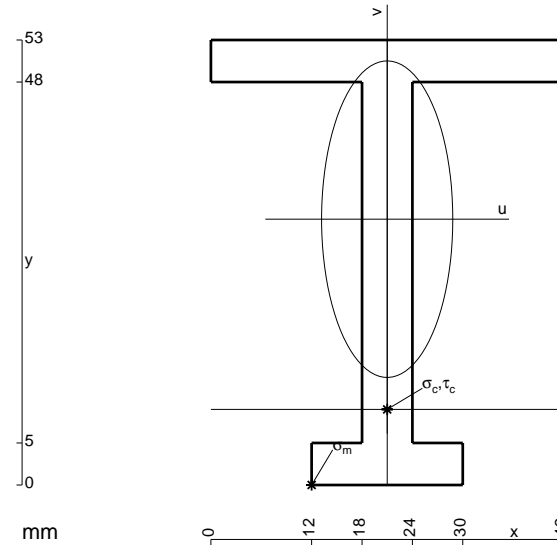
$$= (-b + 1/2 b) \cdot Fb \cdot 1/EJ = -1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x + 1/2 x^2/b - 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

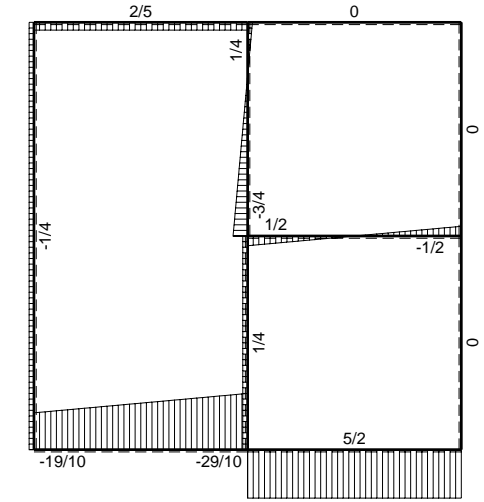
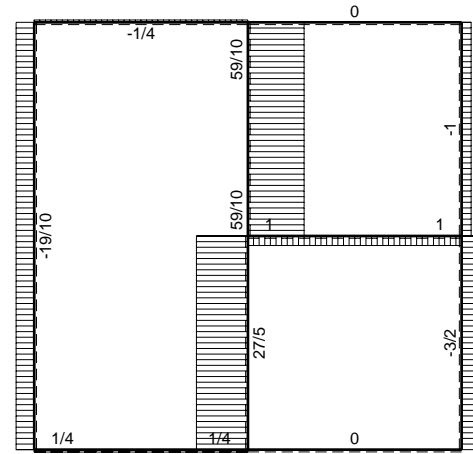
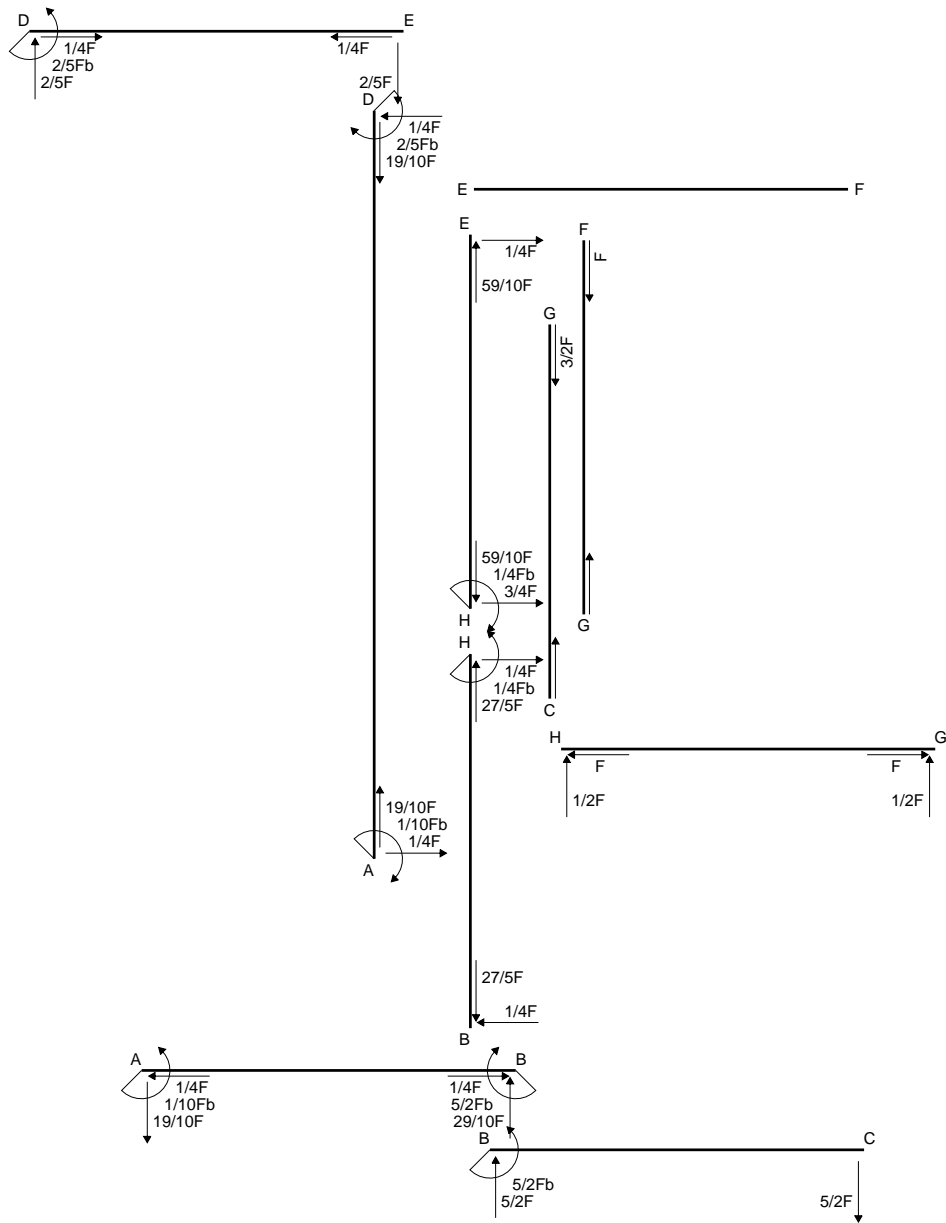
$$= (-1/2 b + 1/2 b - 1/6 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (-1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/6 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

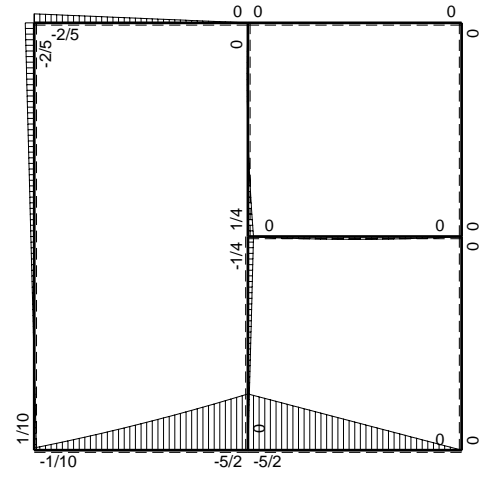


- A = 558. mm<sup>2</sup>
- J<sub>u</sub> = 198314. mm<sup>4</sup>
- J<sub>v</sub> = 34074. mm<sup>4</sup>
- y<sub>g</sub> = 31.66 mm
- T<sub>y</sub> = 2525. N
- M<sub>x</sub> = -1313000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -9. mm
- v<sub>m</sub> = -31.66 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -209.6 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 9. mm
- v<sub>c</sub> = -22.66 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -150. N/mm<sup>2</sup>
- τ<sub>c</sub> = 6.825 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 150.5 N/mm<sup>2</sup>
- S = 3216. mm<sup>3</sup>

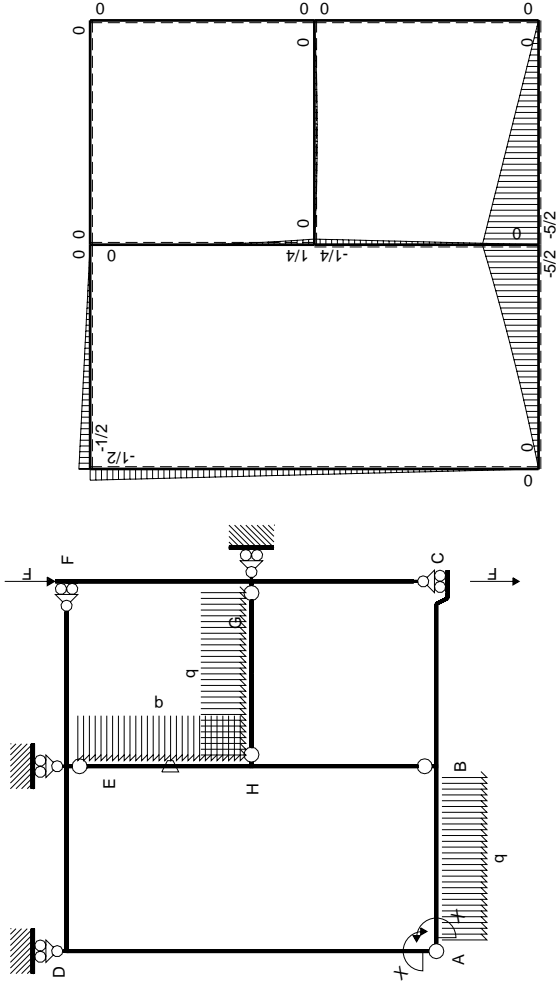


← ⊕ → F

↑ ⊕ ↓ F

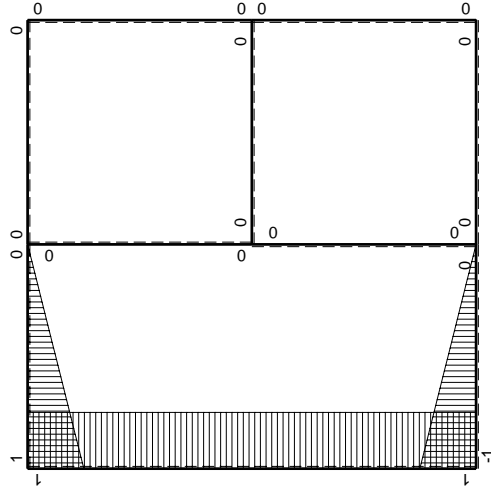


⊕ F<sub>b</sub>



Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-2Fx-1/2qx^2$	0	$2Fx-3/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(3/8+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$5/2Fb-3Fx+1/2qx^2$	0	$5/2Fx-3Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-5/2Fb+5/2Fx$	0	0	0	0	0+0	0	
CB b	0	$5/2Fx$	0	0	0	0			
AD 2b	1	$-1/4Fx$	0	$-1/4Fx$	0	1	$(-1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$1/2Fb-1/4Fx$	0	$-1/2Fb+1/4Fx$	0	1			
DE b	$1-x/b$	$-1/2Fb+1/2Fx$	0	$-1/2Fb+Fx-1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-1/6+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fx$	0	$-1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
GH b	0	$-1/2Fx+1/2qx^2$	0	0	0	0			
HB b	0	$-1/4Fb+1/4Fx$	0	0	0	0	0+0	0	
BH b	0	$1/4Fx$	0	0	0	0			
HE b	0	$1/4Fb-3/4Fx+1/2qx^2$	$-Fb/EJ$	0	0	0	0+0	0	
EH b	0	$1/4Fx-1/2qx^2$	$Fb/EJ$	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$-7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx + 1 \cdot 1 \cdot \frac{1}{4} \frac{b}{EJ} = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ} + 1 \cdot 1 \cdot \frac{1}{4} \frac{b}{EJ}$$

$$= (b - b + 1/3 b) \frac{1}{EJ} + 1 \cdot 1 \cdot \frac{1}{4} \frac{b}{EJ} = 7/12 \frac{b}{EJ}$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx + 1 \cdot 1 \cdot \frac{1}{4} \frac{b}{EJ} = \left[ 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ} + 1 \cdot 1 \cdot \frac{1}{4} \frac{b}{EJ}$$

$$= (1/3 b) \frac{1}{EJ} + 1 \cdot 1 \cdot \frac{1}{4} \frac{b}{EJ} = 7/12 \frac{b}{EJ}$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \frac{b}{EJ}$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \frac{1}{EJ} dx = \left[ x \right]_0^{2b} \frac{1}{EJ}$$

$$= (2b) \frac{1}{EJ} = 2 \frac{b}{EJ}$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \frac{1}{EJ} dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ}$$

$$= (b - b + 1/3 b) \frac{1}{EJ} = 1/3 \frac{b}{EJ}$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \frac{1}{EJ} dx = \left[ 1/3 x^3/b^2 \right]_0^b \frac{1}{EJ}$$

$$= (1/3 b) \frac{1}{EJ} = 1/3 \frac{b}{EJ}$$

$$L_{AB}^{xo} = \int_0^b (2x/b - 3/2 x^2/b^2 - 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= \left[ x^2/b - 1/2 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= (b - 1/2 b - 1/8 b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ} = 3/8 \frac{Fb^2}{EJ}$$

$$L_{BA}^{xo} = \int_0^b (5/2 x/b - 3 x^2/b^2 + 1/2 x^3/b^3) Fb \frac{1}{EJ} dx + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= \left[ 5/4 x^2/b - x^3/b^2 + 1/8 x^4/b^3 \right]_0^b Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ}$$

$$= (5/4 b - b + 1/8 b) Fb \frac{1}{EJ} + 1 \cdot 0 \cdot \frac{1}{4} \frac{Fb^2}{EJ} = 3/8 \frac{Fb^2}{EJ}$$

$$L_{AD}^{xo} = \int_0^{2b} (-1/4 x/b) Fb \frac{1}{EJ} dx = \left[ -1/8 x^2/b \right]_0^{2b} Fb \frac{1}{EJ}$$

$$= (-1/2 b) Fb \frac{1}{EJ} = -1/2 \frac{Fb^2}{EJ}$$

$$L_{DA}^{xo} = \int_0^{2b} (-1/2 + 1/4 x/b) Fb \frac{1}{EJ} dx = \left[ -1/2 x + 1/8 x^2/b \right]_0^{2b} Fb \frac{1}{EJ}$$

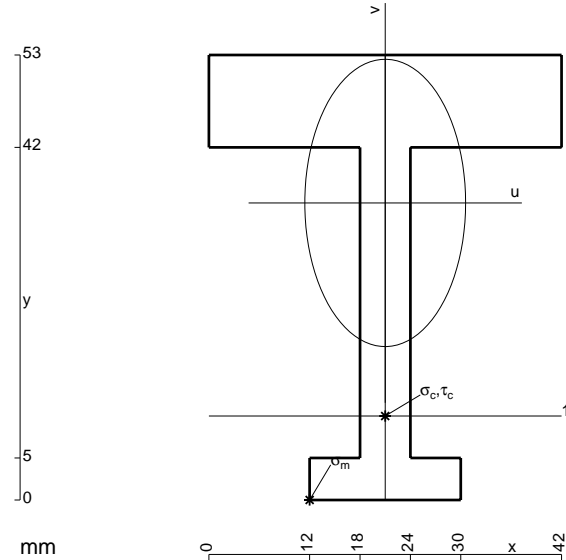
$$= (-b + 1/2 b) Fb \frac{1}{EJ} = -1/2 \frac{Fb^2}{EJ}$$

$$L_{DE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb \frac{1}{EJ} dx = \left[ -1/2 x + 1/2 x^2/b - 1/6 x^3/b^2 \right]_0^b Fb \frac{1}{EJ}$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb \frac{1}{EJ} = -1/6 \frac{Fb^2}{EJ}$$

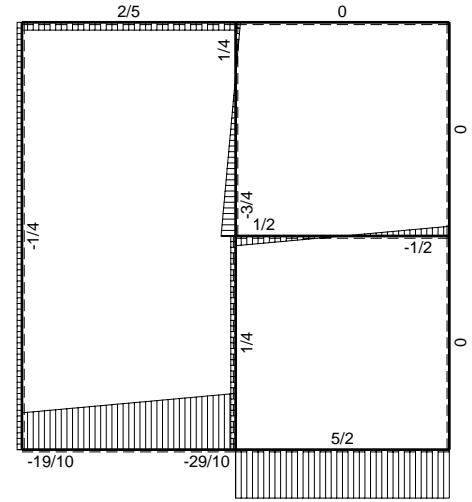
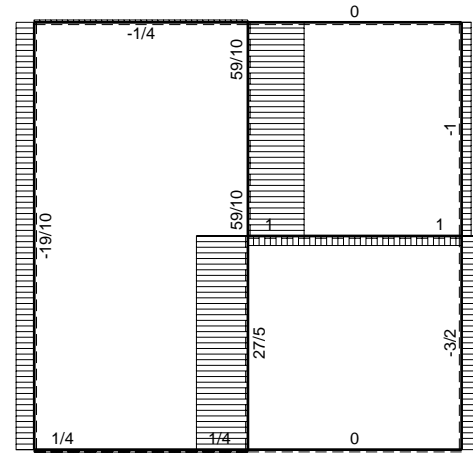
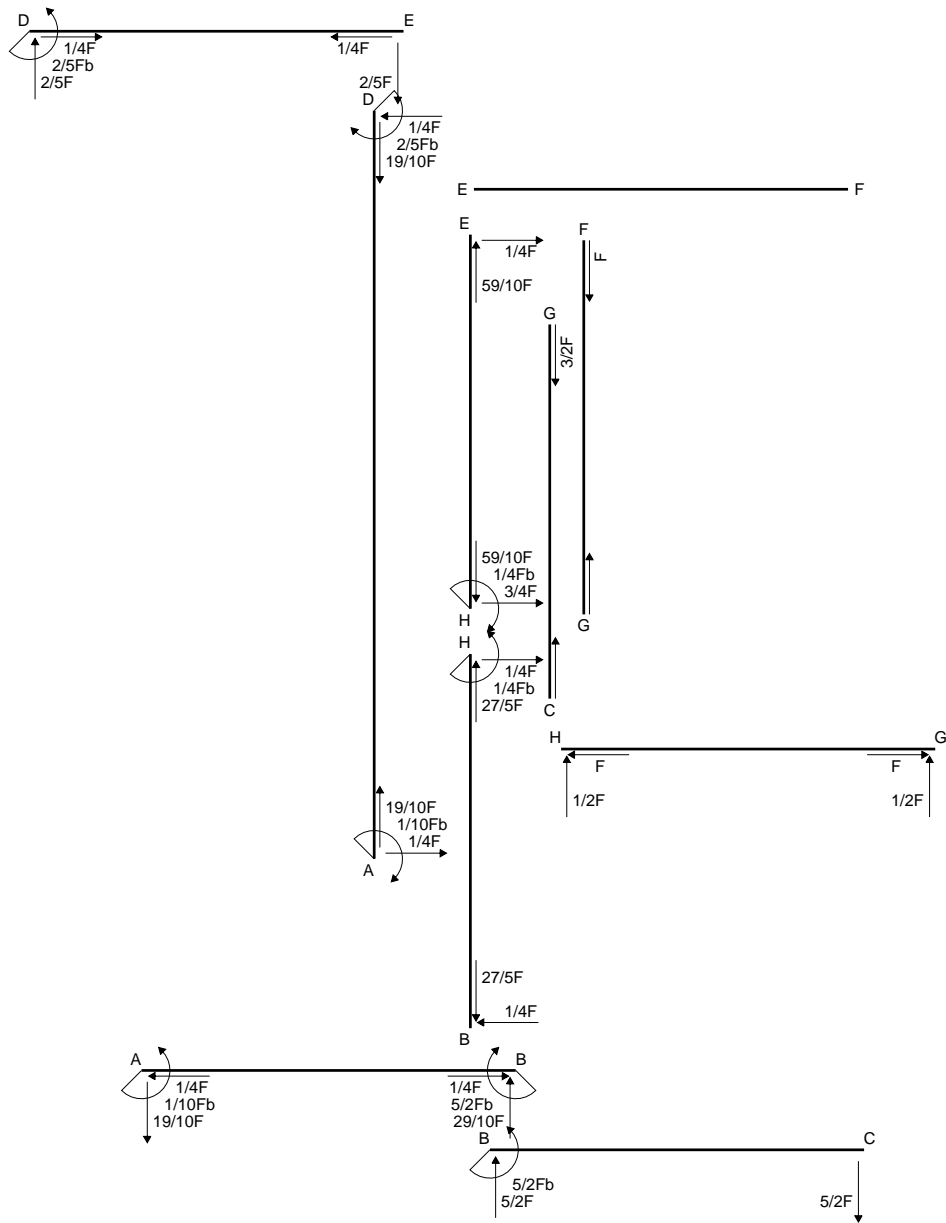
$$L_{ED}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb \frac{1}{EJ} dx = \left[ -1/6 x^3/b^2 \right]_0^b Fb \frac{1}{EJ}$$

$$= (-1/6 b) Fb \frac{1}{EJ} = -1/6 \frac{Fb^2}{EJ}$$



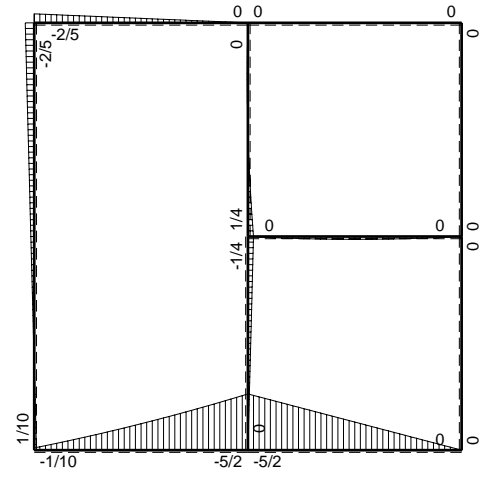
$A = 774. \text{ mm}^2$   
 $J_u = 226668. \text{ mm}^4$   
 $J_v = 71010. \text{ mm}^4$   
 $y_g = 35.38 \text{ mm}$   
 $T_y = 2450. \text{ N}$   
 $M_x = -1396500. \text{ Nmm}$   
 $x_m = 12. \text{ mm}$   
 $u_m = -9. \text{ mm}$   
 $v_m = -35.38 \text{ mm}$   
 $\sigma_m = -Mv/J_u = -218. \text{ N/mm}^2$   
 $x_c = 21. \text{ mm}$   
 $y_c = 10. \text{ mm}$   
 $v_c = -25.38 \text{ mm}$   
 $\sigma_c = -Mv/J_u = -156.4 \text{ N/mm}^2$   
 $\tau_c = 6.838 \text{ N/mm}^2$   
 $\sigma_q = \sqrt{\sigma_c^2 + 3\tau_c^2} = 156.8 \text{ N/mm}^2$   
 $S = 3796. \text{ mm}^3$



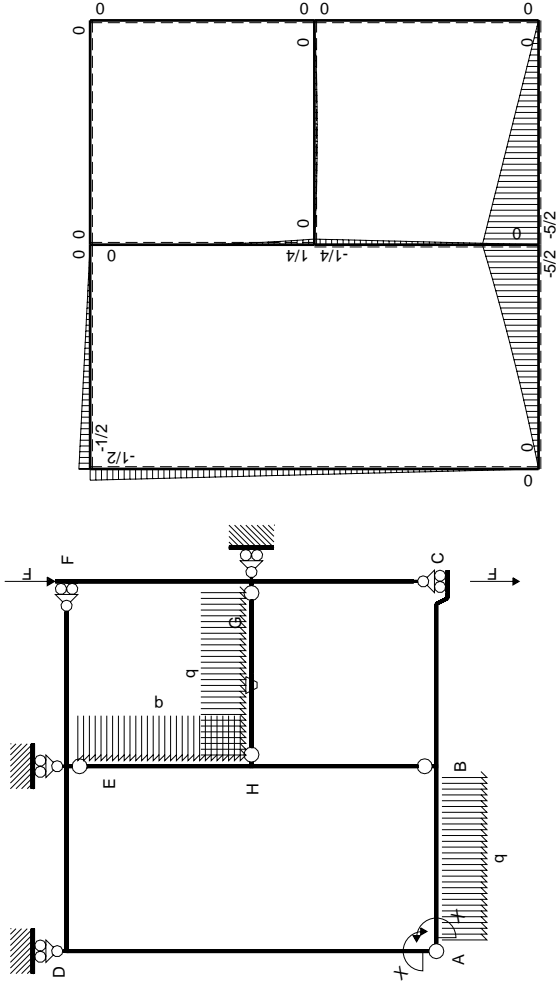


← ⊕ → F

↑ ⊕ ↓ F

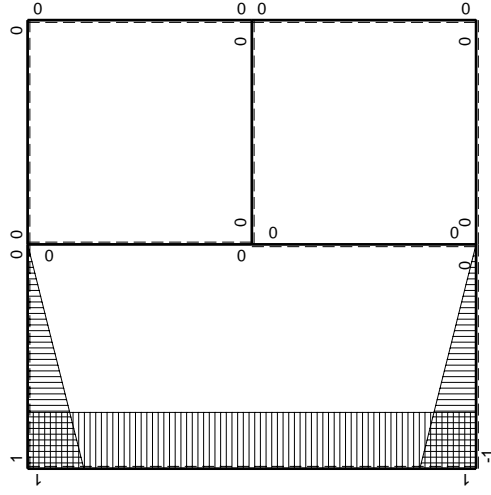


⊕ ⊖ F<sub>b</sub>



Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-2Fx-1/2qx^2$	0	$2Fx-3/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(3/8+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$5/2Fb-3Fx+1/2qx^2$	0	$5/2Fx-3Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-5/2Fb+5/2Fx$	0	0	0	0	0+0	0	
CB b	0	$5/2Fx$	0	0	0	0			
AD 2b	1	$-1/4Fx$	0	$-1/4Fx$	0	1	$(-1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$1/2Fb-1/4Fx$	0	$-1/2Fb+1/4Fx$	0	1			
DE b	$1-x/b$	$-1/2Fb+1/2Fx$	0	$-1/2Fb+Fx-1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-1/6+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fx$	0	$-1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	$1/2Fx-1/2qx^2$	$-Fb/EJ$	0	0	0	0+0	0	
GH b	0	$-1/2Fx+1/2qx^2$	$Fb/EJ$	0	0	0			
HB b	0	$-1/4Fb+1/4Fx$	0	0	0	0	0+0	0	
BH b	0	$1/4Fx$	0	0	0	0			
HE b	0	$1/4Fb-3/4Fx+1/2qx^2$	0	0	0	0	0+0	0	
EH b	0	$1/4Fx-1/2qx^2$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$-7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (2xb - 3/2 x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 1/2 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 1/2 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (5/2 xb - 3x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 5/4 x^2/b - x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (5/4 b - b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-1/2 b) \cdot Fb \cdot 1/EJ = -1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (-1/2 + 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x + 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

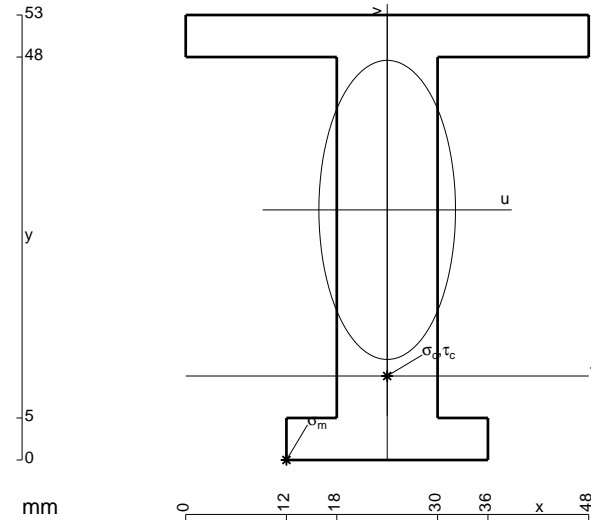
$$= (-b + 1/2 b) \cdot Fb \cdot 1/EJ = -1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x + 1/2 x^2/b - 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

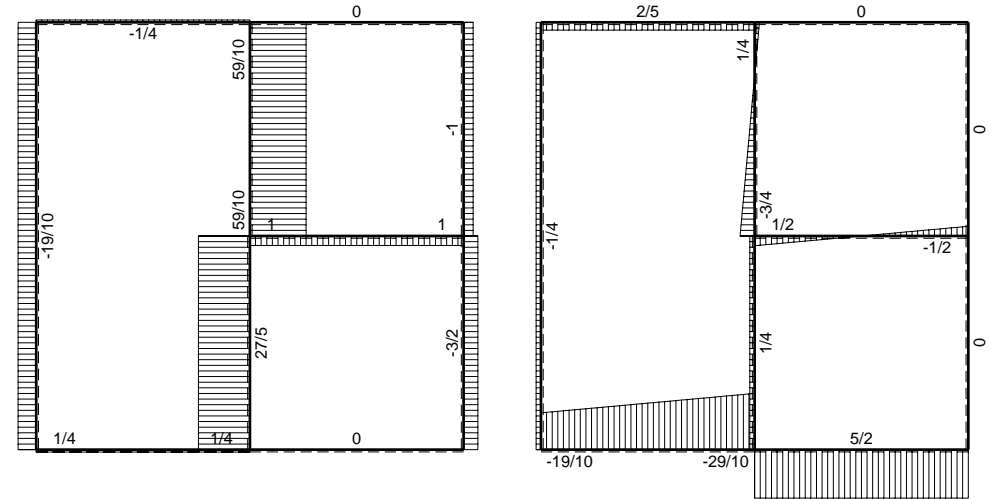
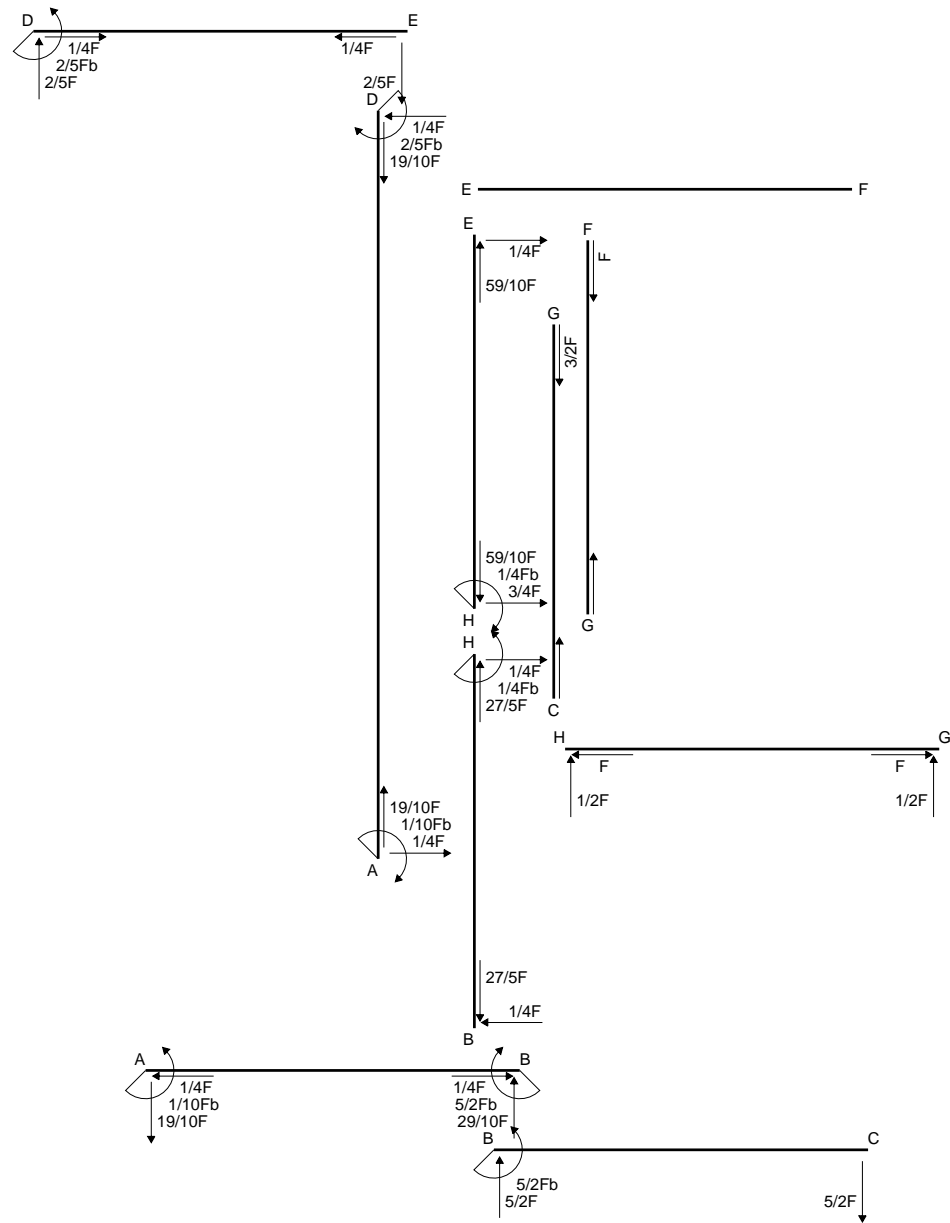
$$= (-1/2 b + 1/2 b - 1/6 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (-1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/6 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

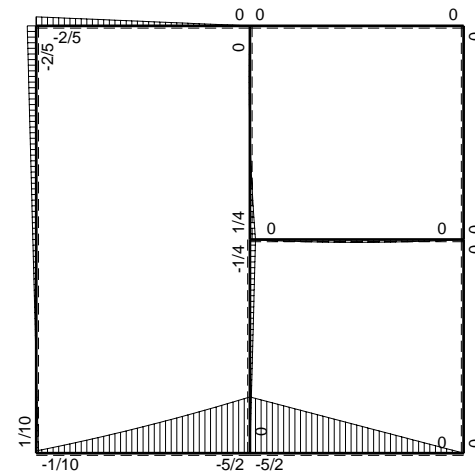


- A = 876. mm<sup>2</sup>
- J<sub>u</sub> = 278148. mm<sup>4</sup>
- J<sub>v</sub> = 58032. mm<sup>4</sup>
- y<sub>g</sub> = 29.79 mm
- T<sub>y</sub> = 3450. N
- M<sub>x</sub> = -2139000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -12. mm
- v<sub>m</sub> = -29.79 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -229.1 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 10. mm
- v<sub>c</sub> = -19.79 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -152.2 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.767 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 152.4 N/mm<sup>2</sup>
- S = 4612. mm<sup>3</sup>

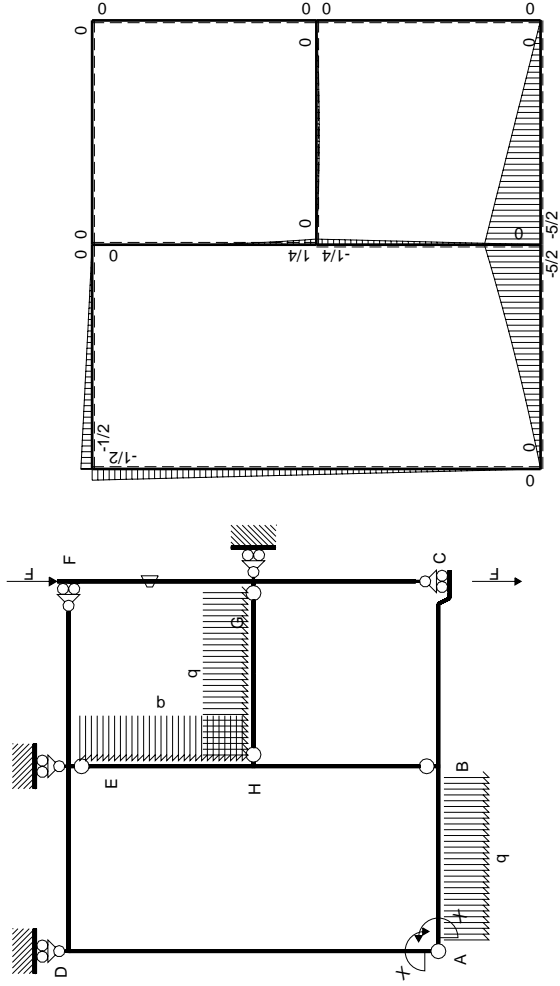


← (+) →  $F$

↑ (+) ↓  $F_b$

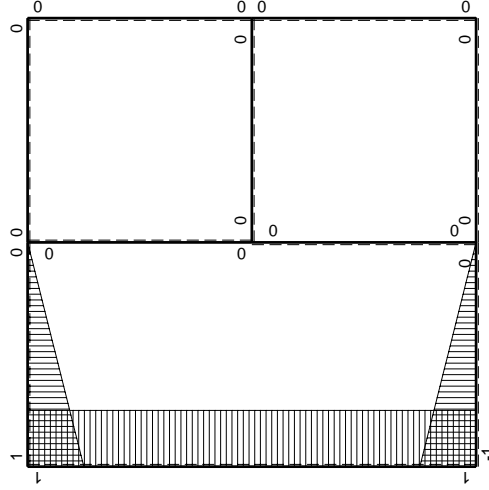


↺ (+) ↻  $F_b$



Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_X$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-2Fx-1/2qx^2$	0	$2Fx-3/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(3/8+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$5/2Fb-3Fx+1/2qx^2$	0	$5/2Fx-3Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-5/2Fb+5/2Fx$	0	0	0	0	0+0	0	
CB b	0	$5/2Fx$	0	0	0	0			
AD 2b	1	$-1/4Fx$	0	$-1/4Fx$	0	1	$(-1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$1/2Fb-1/4Fx$	0	$-1/2Fb+1/4Fx$	0	1			
DE b	$1-x/b$	$-1/2Fb+1/2Fx$	0	$-1/2Fb+Fx-1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-1/6+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fx$	0	$-1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
GF b	0	0	$Fb/EJ$	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
GH b	0	$-1/2Fx+1/2qx^2$	0	0	0	0			
HB b	0	$-1/4Fb+1/4Fx$	0	0	0	0	0+0	0	
BH b	0	$1/4Fx$	0	0	0	0			
HE b	0	$1/4Fb-3/4Fx+1/2qx^2$	0	0	0	0	0+0	0	
EH b	0	$1/4Fx-1/2qx^2$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$-7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (2x/b - 3/2 x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 1/2 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 1/2 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (5/2 x/b - 3 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 5/4 x^2/b - x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (5/4 b - b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-1/2 b) \cdot Fb \cdot 1/EJ = -1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (-1/2 + 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x + 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

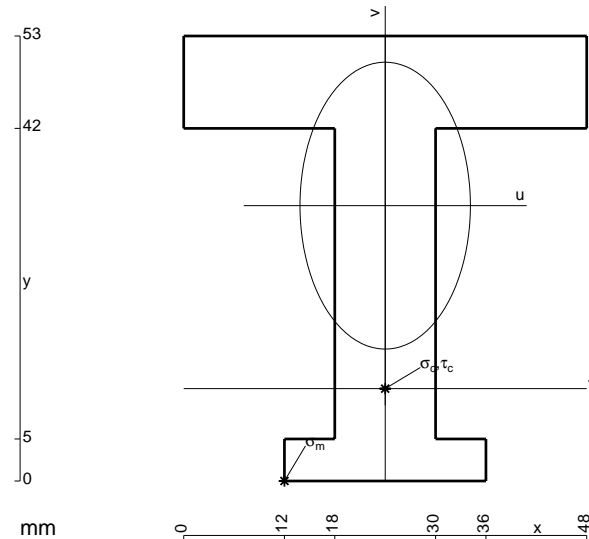
$$= (-b + 1/2 b) \cdot Fb \cdot 1/EJ = -1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x + 1/2 x^2/b - 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

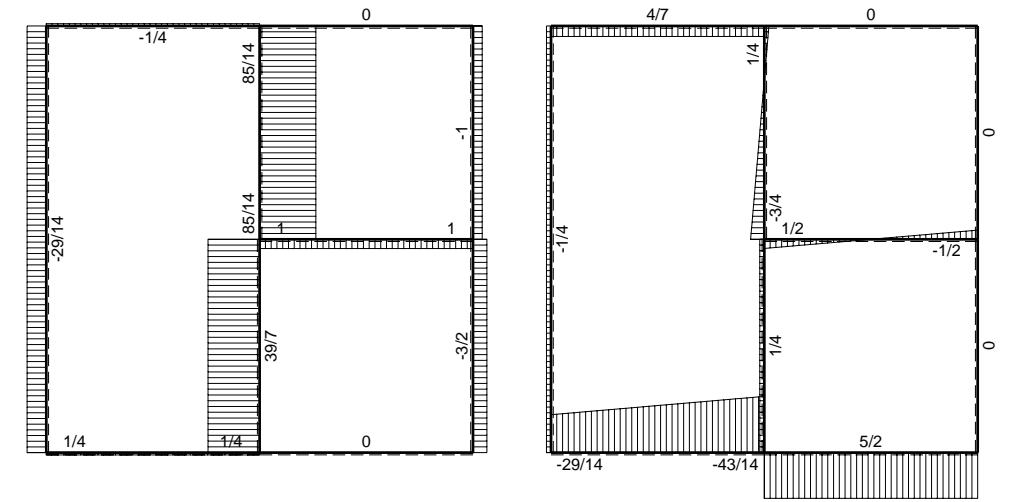
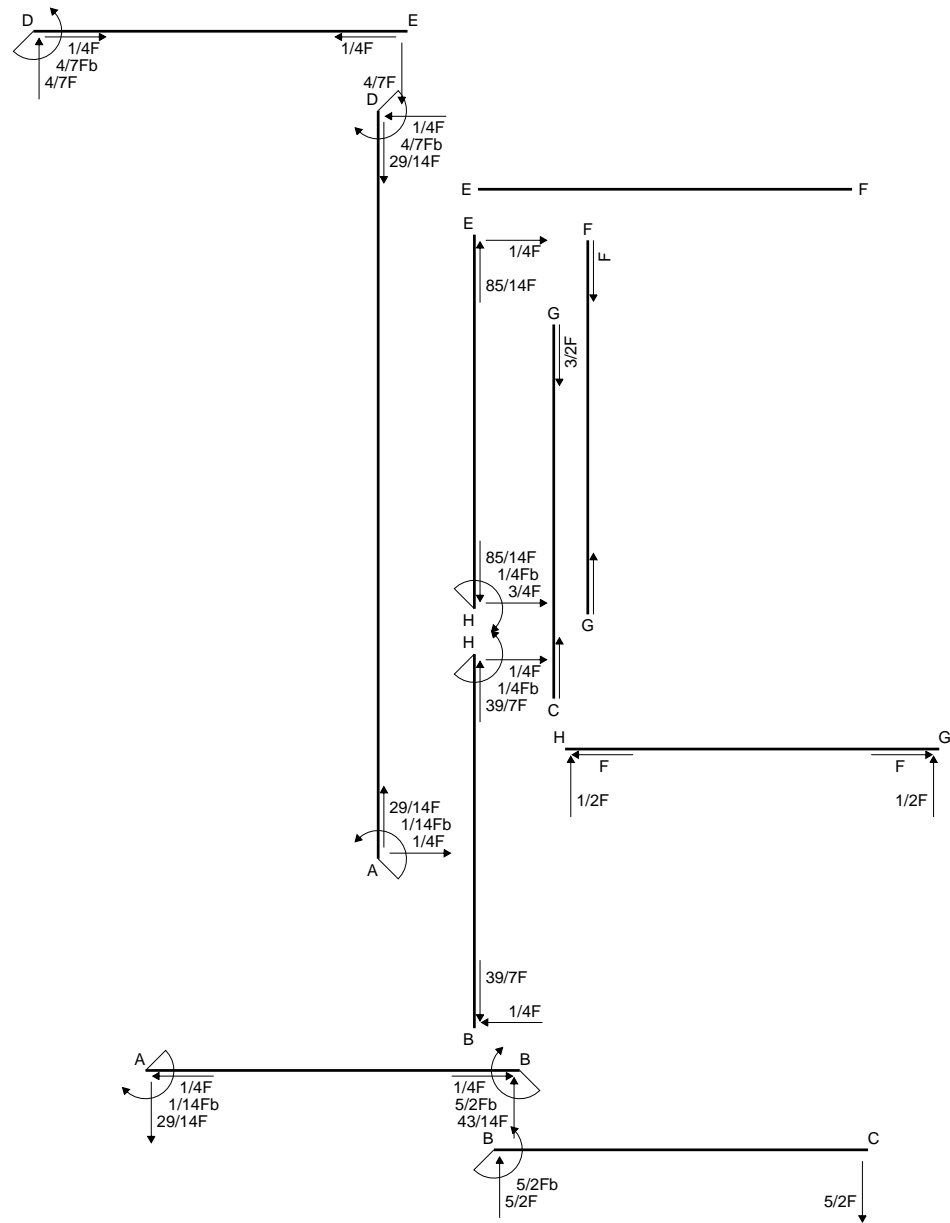
$$L_{ED}^{xo} = \int_0^b (-1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/6 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$



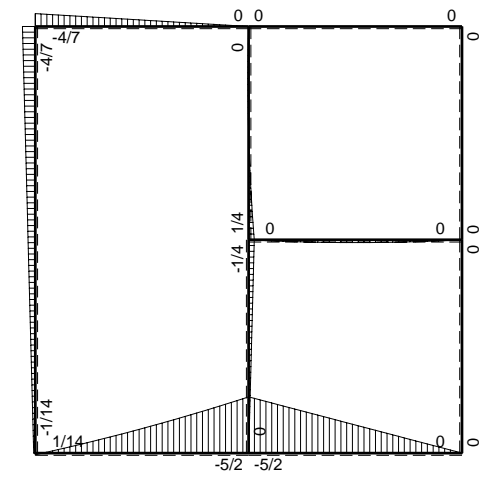
- A = 1092. mm<sup>2</sup>
- J<sub>u</sub> = 318895. mm<sup>4</sup>
- J<sub>v</sub> = 112464. mm<sup>4</sup>
- y<sub>g</sub> = 32.8 mm
- T<sub>y</sub> = 3475. N
- M<sub>x</sub> = -2328250. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -12. mm
- v<sub>m</sub> = -32.8 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -239.4 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 11. mm
- v<sub>c</sub> = -21.8 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -159.1 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.923 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 159.4 N/mm<sup>2</sup>
- S = 5421. mm<sup>3</sup>



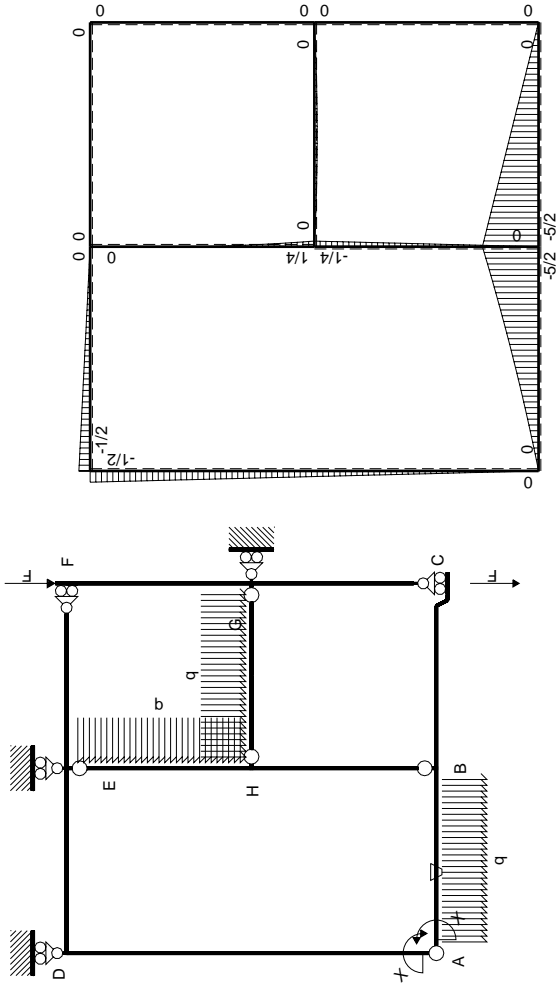


← ⊕ → F

↑ ⊕ ↓ F

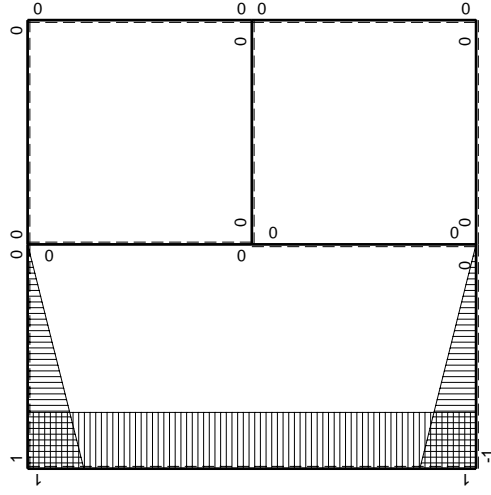


⊕ ⊖ F<sub>b</sub>



Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-2Fx-1/2qx^2$	$-Fb/EJ$	$2Fx-3/2Fx^2/b-1/2qx^3/b$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$(3/8+1/2)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$5/2Fb-3Fx+1/2qx^2$	$Fb/EJ$	$5/2Fx-3Fx^2/b+1/2qx^3/b$	$Fx/EJ$	$x^2/b^2$			
BC b	0	$-5/2Fb+5/2Fx$	0	0	0	0	0+0	0	
CB b	0	$5/2Fx$	0	0	0	0			
AD 2b	1	$-1/4Fx$	0	$-1/4Fx$	0	1	$(-1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$1/2Fb-1/4Fx$	0	$-1/2Fb+1/4Fx$	0	1			
DE b	$1-x/b$	$-1/2Fb+1/2Fx$	0	$-1/2Fb+Fx-1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-1/6+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fx$	0	$-1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
GH b	0	$-1/2Fx+1/2qx^2$	0	0	0	0			
HB b	0	$-1/4Fb+1/4Fx$	0	0	0	0	0+0	0	
BH b	0	$1/4Fx$	0	0	0	0			
HE b	0	$1/4Fb-3/4Fx+1/2qx^2$	0	0	0	0	0+0	0	
EH b	0	$1/4Fx-1/2qx^2$	0	0	0	0			
AB	molla asta $-W_{1AB} \setminus (W_{oAB} + XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$5/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$-1/14Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) 1/EJ dx = \left[ x \right]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) 1/EJ dx = \left[ x \right]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = \left[ 1/3 x^3/b^2 \right]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{AB}^{x_0} = \int_0^b (2x/b - 3/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (1 - x/b) \theta dx + 1 \cdot 0 \cdot 1/4 Fb^2/EJ$$

$$= \left[ x^2/b - 1/2 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b Fb 1/EJ + \left[ x - 1/2 x^2/b \right]_0^b \theta + 1 \cdot 0 \cdot 1/4 Fb^2/EJ$$

$$= (b - 1/2 b - 1/8 b) Fb 1/EJ + (b - 1/2 b) \theta + 1 \cdot 0 \cdot 1/4 Fb^2/EJ = 7/8 Fb^2/EJ$$

$$L_{BA}^{x_0} = \int_0^b (5/2 x/b - 3 x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (-x/b) \theta dx + 1 \cdot 0 \cdot 1/4 Fb^2/EJ$$

$$= \left[ 5/4 x^2/b - x^3/b^2 + 1/8 x^4/b^3 \right]_0^b Fb 1/EJ + \left[ -1/2 x^2/b \right]_0^b \theta + 1 \cdot 0 \cdot 1/4 Fb^2/EJ$$

$$= (5/4 b - b + 1/8 b) Fb 1/EJ + (-1/2 b) \theta + 1 \cdot 0 \cdot 1/4 Fb^2/EJ = 7/8 Fb^2/EJ$$

$$L_{AD}^{x_0} = \int_0^{2b} (-1/4 x/b) Fb 1/EJ dx = \left[ -1/8 x^2/b \right]_0^{2b} Fb 1/EJ$$

$$= (-1/2 b) Fb 1/EJ = -1/2 Fb^2/EJ$$

$$L_{DA}^{x_0} = \int_0^{2b} (-1/2 + 1/4 x/b) Fb 1/EJ dx = \left[ -1/2 x + 1/8 x^2/b \right]_0^{2b} Fb 1/EJ$$

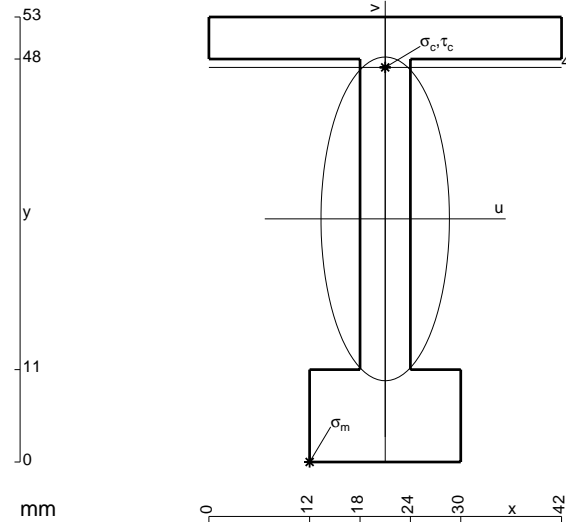
$$= (-b + 1/2 b) Fb 1/EJ = -1/2 Fb^2/EJ$$

$$L_{DE}^{x_0} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx = \left[ -1/2 x + 1/2 x^2/b - 1/6 x^3/b^2 \right]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

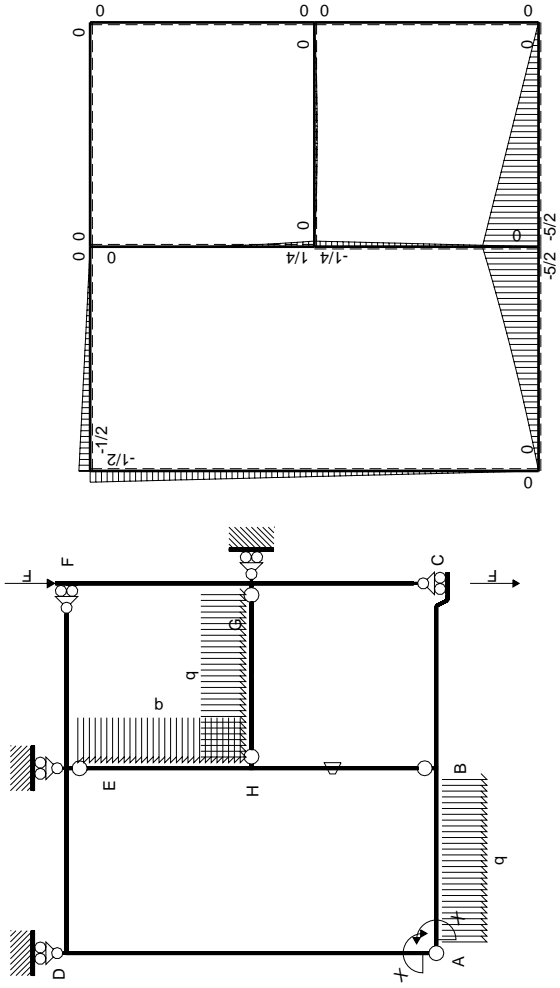
$$L_{ED}^{x_0} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx = \left[ -1/6 x^3/b^2 \right]_0^b Fb 1/EJ$$

$$= (-1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$



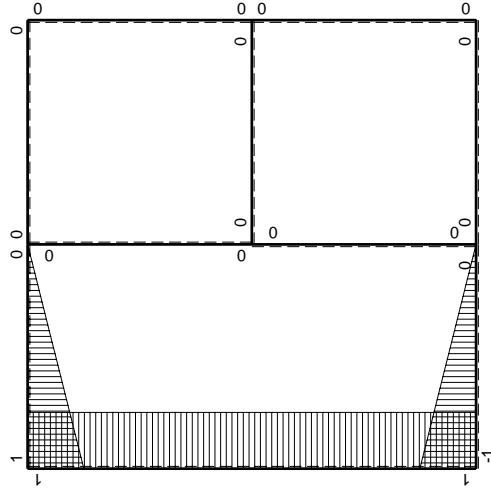
- A = 630. mm<sup>2</sup>
- J<sub>u</sub> = 234233. mm<sup>4</sup>
- J<sub>v</sub> = 36882. mm<sup>4</sup>
- y<sub>g</sub> = 28.96 mm
- T<sub>y</sub> = 2225. N
- M<sub>x</sub> = -1602000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -9. mm
- v<sub>m</sub> = -28.96 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -198. N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 47. mm
- v<sub>c</sub> = 18.04 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 123.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.338 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 124.1 N/mm<sup>2</sup>
- S = 4635. mm<sup>3</sup>





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-2Fx-1/2qx^2$	0	$2Fx-3/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(3/8+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$5/2Fb-3Fx+1/2qx^2$	0	$5/2Fx-3Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-5/2Fb+5/2Fx$	0	0	0	0	0+0	0	
CB b	0	$5/2Fx$	0	0	0	0			
AD 2b	1	$-1/4Fx$	0	$-1/4Fx$	0	1	$(-1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$1/2Fb-1/4Fx$	0	$-1/2Fb+1/4Fx$	0	1			
DE b	$1-x/b$	$-1/2Fb+1/2Fx$	0	$-1/2Fb+Fx-1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-1/6+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fx$	0	$-1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
GH b	0	$-1/2Fx+1/2qx^2$	0	0	0	0			
HB b	0	$-1/4Fb+1/4Fx$	$-Fb/EJ$	0	0	0	0+0	0	
BH b	0	$1/4Fx$	$Fb/EJ$	0	0	0			
HE b	0	$1/4Fb-3/4Fx+1/2qx^2$	0	0	0	0	0+0	0	
EH b	0	$1/4Fx-1/2qx^2$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$-7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (2x/b - 3/2 x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 1/2 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 1/2 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (5/2 x/b - 3 x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 5/4 x^2/b - x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (5/4 b - b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-1/2 b) \cdot Fb \cdot 1/EJ = -1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (-1/2 + 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x + 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

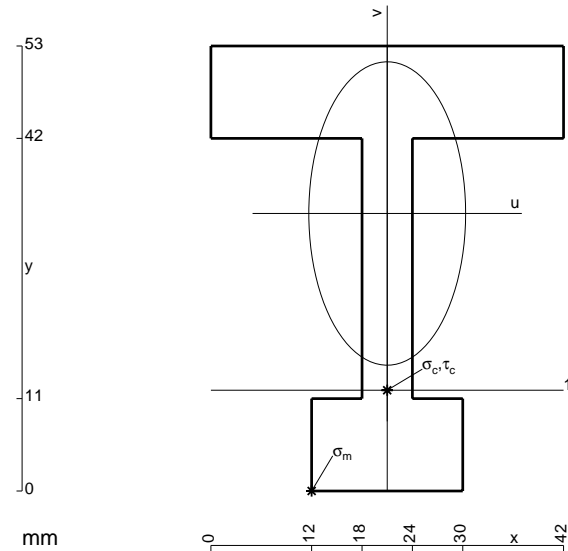
$$= (-b + 1/2 b) \cdot Fb \cdot 1/EJ = -1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x + 1/2 x^2/b - 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (-1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/6 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$



- A = 846. mm<sup>2</sup>
- J<sub>u</sub> = 276280. mm<sup>4</sup>
- J<sub>v</sub> = 73818. mm<sup>4</sup>
- y<sub>g</sub> = 33.05 mm
- T<sub>y</sub> = 2300. N
- M<sub>x</sub> = -1748000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -9. mm
- v<sub>m</sub> = -33.05 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -209.1 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 12. mm
- v<sub>c</sub> = -21.05 mm
- σ<sub>c</sub> = -Mv/J<sub>v</sub> = -133.2 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.749 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 133.9 N/mm<sup>2</sup>
- S = 5585. mm<sup>3</sup>







Quadro contributi PLV per iperstatica  $X=W_{AB}$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-2Fx-1/2qx^2$	0	$2Fx-3/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(3/8+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$5/2Fb-3Fx+1/2qx^2$	0	$5/2Fx-3Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-5/2Fb+5/2Fx$	0	0	0	0	0+0	0	
CB b	0	$5/2Fx$	0	0	0	0			
AD 2b	1	$-1/4Fx$	0	$-1/4Fx$	0	1	$(-1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$1/2Fb-1/4Fx$	0	$-1/2Fb+1/4Fx$	0	1			
DE b	$1-x/b$	$-1/2Fb+1/2Fx$	0	$-1/2Fb+Fx-1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-1/6+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fx$	0	$-1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	0	0	0	0	0	0+0	0	
FE b	0	0	0	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
CG b	0	0	$Fb/EJ$	0	0	0			
HG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
GH b	0	$-1/2Fx+1/2qx^2$	0	0	0	0			
HB b	0	$-1/4Fb+1/4Fx$	0	0	0	0	0+0	0	
BH b	0	$1/4Fx$	0	0	0	0			
HE b	0	$1/4Fb-3/4Fx+1/2qx^2$	0	0	0	0	0+0	0	
EH b	0	$1/4Fx-1/2qx^2$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$-7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (2xb - 3/2 x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 1/2 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 1/2 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (5/2 xb - 3x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 5/4 x^2/b - x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (5/4 b - b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-1/2 b) \cdot Fb \cdot 1/EJ = -1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (-1/2 + 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x + 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

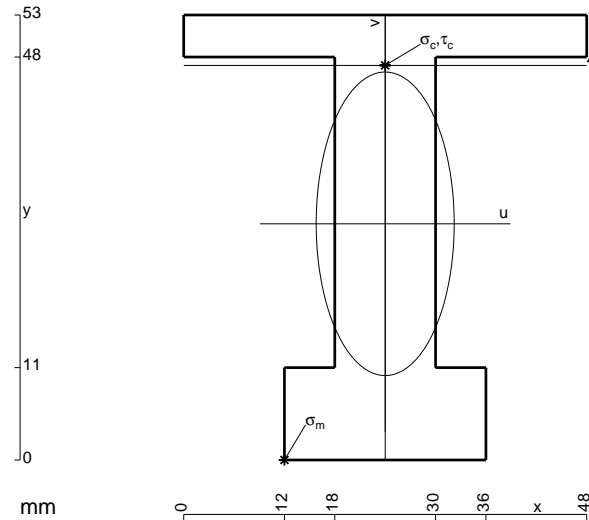
$$= (-b + 1/2 b) \cdot Fb \cdot 1/EJ = -1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x + 1/2 x^2/b - 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

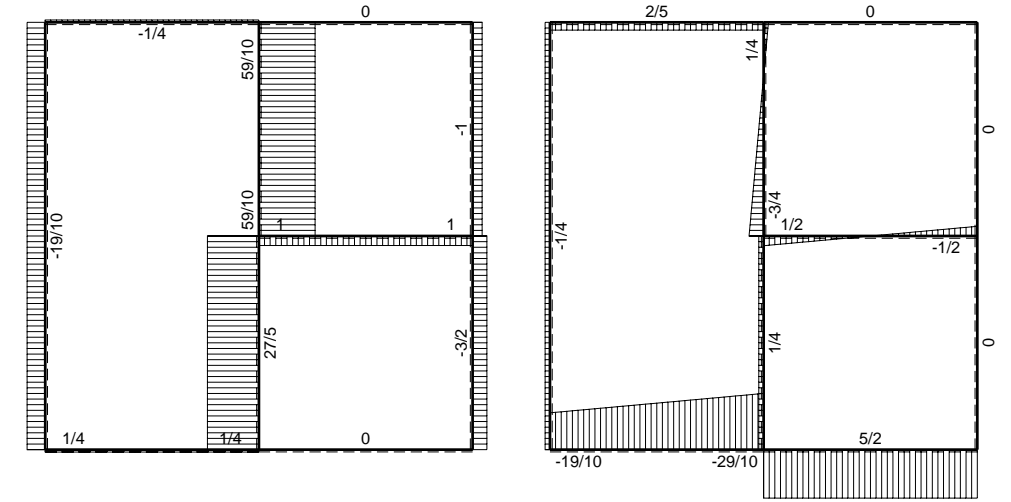
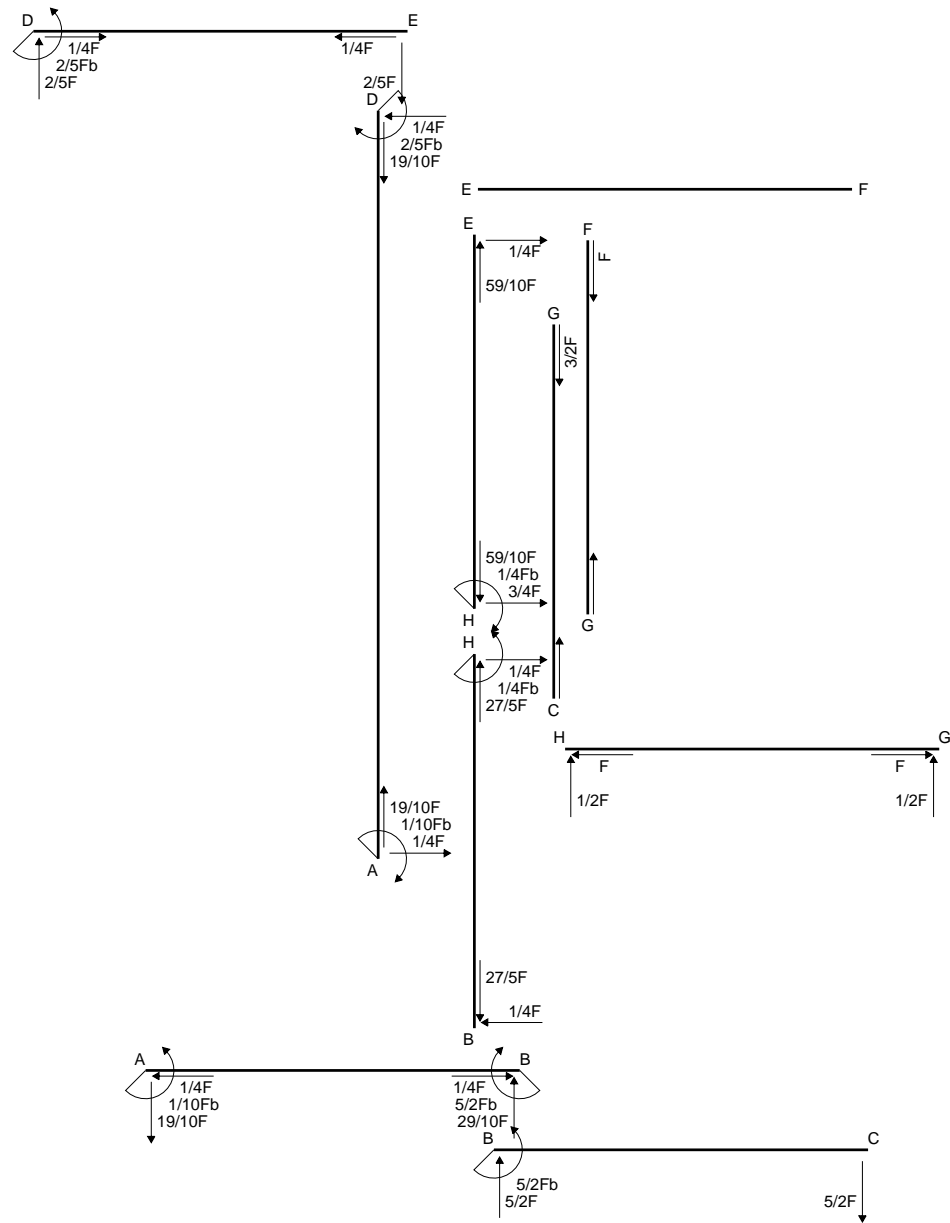
$$= (-1/2 b + 1/2 b - 1/6 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (-1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/6 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

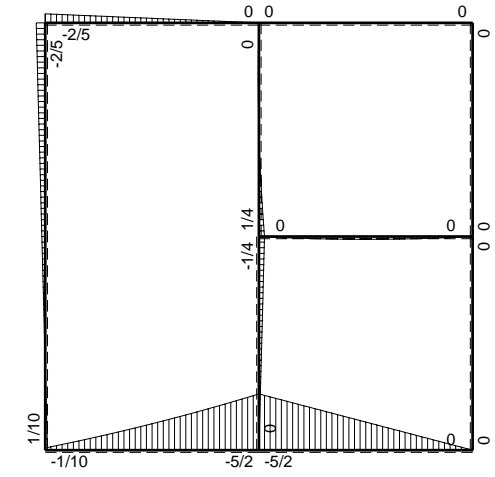


- A = 948. mm<sup>2</sup>
- J<sub>u</sub> = 309947. mm<sup>4</sup>
- J<sub>v</sub> = 64080. mm<sup>4</sup>
- y<sub>g</sub> = 28.13 mm
- T<sub>y</sub> = 2975. N
- M<sub>x</sub> = -2409750. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -12. mm
- v<sub>m</sub> = -28.13 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -218.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 47. mm
- v<sub>c</sub> = 18.87 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 146.7 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.48 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 146.9 N/mm<sup>2</sup>
- S = 5601. mm<sup>3</sup>

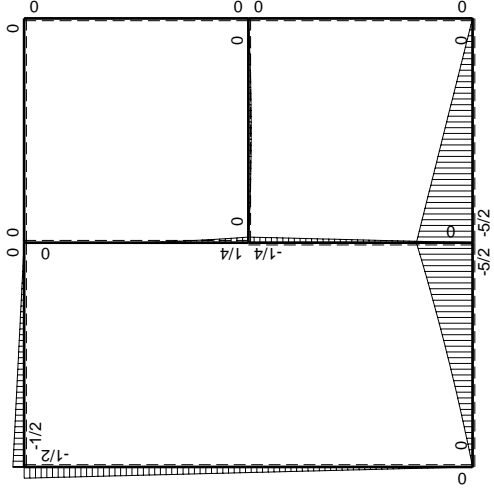
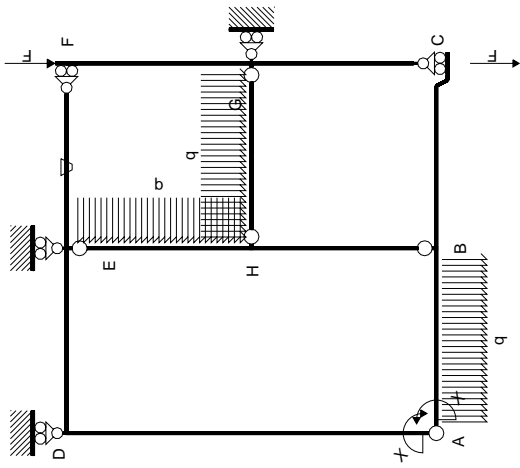


← (+) →  $F$

↑ (+) ↓  $F_b$

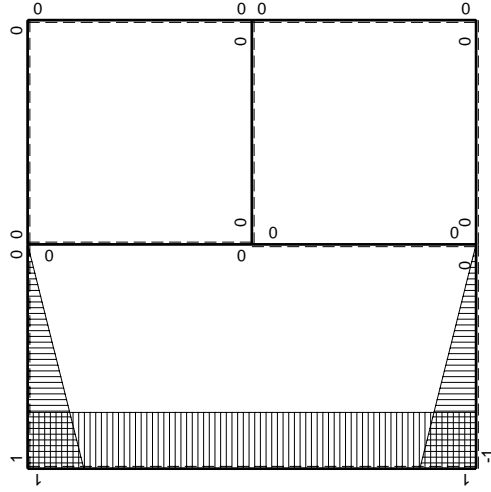


↺ (+) ↻  $F_b$



Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{AB}$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	$-1+x/b$	$-2Fx-1/2qx^2$	0	$2Fx-3/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(3/8+0)Fb^2/EJ$	$1/3Xb/EJ$	
BA b	$x/b$	$5/2Fb-3Fx+1/2qx^2$	0	$5/2Fx-3Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$			
BC b	0	$-5/2Fb+5/2Fx$	0	0	0	0	0+0	0	
CB b	0	$5/2Fx$	0	0	0	0			
AD 2b	1	$-1/4Fx$	0	$-1/4Fx$	0	1	$(-1/2+0)Fb^2/EJ$	$2Xb/EJ$	
DA 2b	-1	$1/2Fb-1/4Fx$	0	$-1/2Fb+1/4Fx$	0	1			
DE b	$1-x/b$	$-1/2Fb+1/2Fx$	0	$-1/2Fb+Fx-1/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-1/6+0)Fb^2/EJ$	$1/3Xb/EJ$	
ED b	$-x/b$	$1/2Fx$	0	$-1/2Fx^2/b$	0	$x^2/b^2$			
EF b	0	0	$-Fb/EJ$	0	0	0	0+0	0	
FE b	0	0	$Fb/EJ$	0	0	0			
FG b	0	0	0	0	0	0	0+0	0	
GF b	0	0	0	0	0	0			
GC b	0	0	0	0	0	0	0+0	0	
CG b	0	0	0	0	0	0			
HG b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
GH b	0	$-1/2Fx+1/2qx^2$	0	0	0	0			
HB b	0	$-1/4Fb+1/4Fx$	0	0	0	0	0+0	0	
BH b	0	$1/4Fx$	0	0	0	0			
HE b	0	$1/4Fb-3/4Fx+1/2qx^2$	0	0	0	0	0+0	0	
EH b	0	$1/4Fx-1/2qx^2$	0	0	0	0			
AB	molla asta $-W_{1AB}(W_{0AB}+XW_{1AB})/k_{AB}$								$1/4Xb/EJ$
	totali							$-7/24Fb^2/EJ$	$35/12Xb/EJ$
	iperstatica $X=W_{AB}$							$1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{AB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{BA}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx + 1 \cdot 1/4 \cdot b/EJ = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ$$

$$= (1/3 b) \cdot 1/EJ + 1 \cdot 1/4 \cdot b/EJ = 7/12 \cdot b/EJ$$

$$L_{AD}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DA}^{xx} = \int_0^{2b} (1) \cdot 1/EJ \, dx = \left[ x \right]_0^{2b} \cdot 1/EJ$$

$$= (2b) \cdot 1/EJ = 2 \cdot b/EJ$$

$$L_{DE}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) \cdot 1/EJ \, dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (b - b + 1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{ED}^{xx} = \int_0^b (x^2/b^2) \cdot 1/EJ \, dx = \left[ 1/3 x^3/b^2 \right]_0^b \cdot 1/EJ$$

$$= (1/3 b) \cdot 1/EJ = 1/3 \cdot b/EJ$$

$$L_{AB}^{xo} = \int_0^b (2xb - 3/2 x^2/b^2 - 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ x^2/b - 1/2 x^3/b^2 - 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (b - 1/2 b - 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{BA}^{xo} = \int_0^b (5/2 xb - 3x^2/b^2 + 1/2 x^3/b^3) \cdot Fb \cdot 1/EJ \, dx + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= \left[ 5/4 x^2/b - x^3/b^2 + 1/8 x^4/b^3 \right]_0^b \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ$$

$$= (5/4 b - b + 1/8 b) \cdot Fb \cdot 1/EJ + 1 \cdot 0 \cdot 1/4 \cdot Fb^2/EJ = 3/8 \cdot Fb^2/EJ$$

$$L_{AD}^{xo} = \int_0^{2b} (-1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

$$= (-1/2 b) \cdot Fb \cdot 1/EJ = -1/2 \cdot Fb^2/EJ$$

$$L_{DA}^{xo} = \int_0^{2b} (-1/2 + 1/4 x/b) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x + 1/8 x^2/b \right]_0^{2b} \cdot Fb \cdot 1/EJ$$

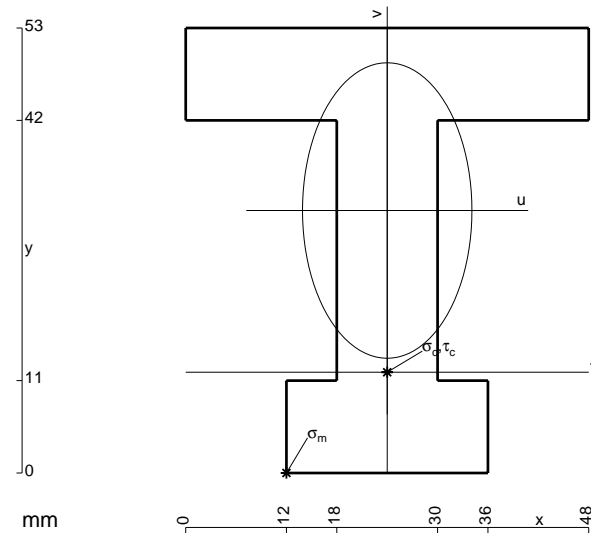
$$= (-b + 1/2 b) \cdot Fb \cdot 1/EJ = -1/2 \cdot Fb^2/EJ$$

$$L_{DE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/2 x + 1/2 x^2/b - 1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (-1/2 x^2/b^2) \cdot Fb \cdot 1/EJ \, dx = \left[ -1/6 x^3/b^2 \right]_0^b \cdot Fb \cdot 1/EJ$$

$$= (-1/6 b) \cdot Fb \cdot 1/EJ = -1/6 \cdot Fb^2/EJ$$



- A = 1164. mm<sup>2</sup>
- J<sub>u</sub> = 360644. mm<sup>4</sup>
- J<sub>v</sub> = 118512. mm<sup>4</sup>
- y<sub>g</sub> = 31.26 mm
- T<sub>y</sub> = 3075. N
- M<sub>x</sub> = -2644500. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -12. mm
- v<sub>m</sub> = -31.26 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -229.2 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 12. mm
- v<sub>c</sub> = -19.26 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -141.2 N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.001 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 141.5 N/mm<sup>2</sup>
- S = 7039. mm<sup>3</sup>