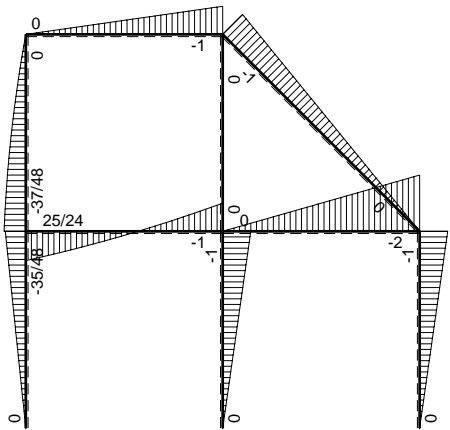
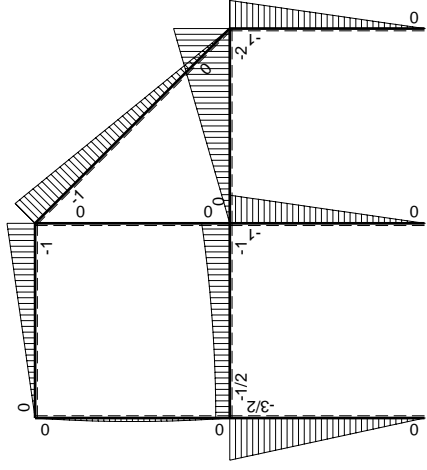
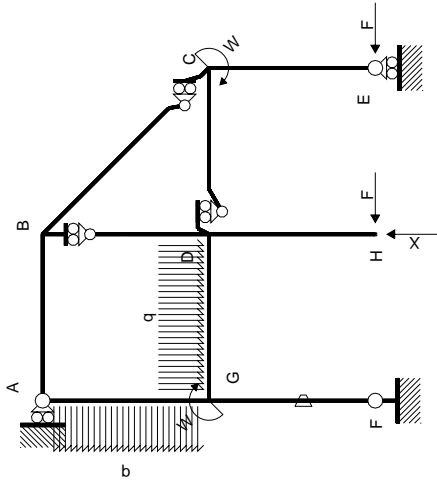


← (+) → F

↑ (+) ↓ F

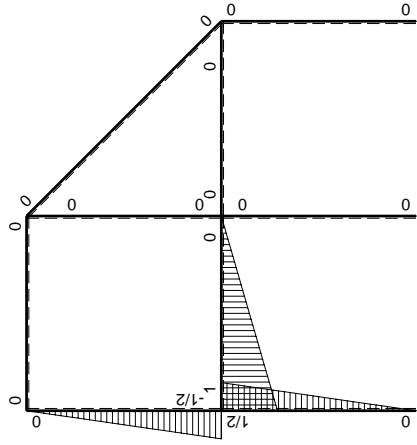


↺ (+) ↻ F\_b



Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica  $X=V_H$

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	0	-Fx	0	0	0	0	0+0	0	
BA b	0	Fb-Fx	0	0	0	0			
BC $\sqrt{2}b$	0	-Fb+ $\sqrt{2}/2Fx$	0	0	0	0	0	0	
BD b	0	0	0	0	0	0	0+0	0	
DB b	0	0	0	0	0	0			
DC b	0	-2Fx	0	0	0	0	0+0	0	
CD b	0	2Fb-2Fx	0	0	0	0			
CE b	0	-Fb+Fx	0	0	0	0	0+0	0	
EC b	0	Fx	0	0	0	0			
FG b	1/2x	-3/2Fx	-Fb/EJ	-3/4Fx <sup>2</sup>	-1/2Fxb/EJ	1/4x <sup>2</sup>	(-1/4-1/4)Fb <sup>3</sup> /EJ	1/12Xb <sup>3</sup> /EJ	
GF b	-1/2b+1/2x	3/2Fb-3/2Fx	Fb/EJ	-3/4Fb <sup>2</sup> +3/2Fbx-3/4Fx <sup>2</sup>	-1/2Fb <sup>2</sup> /EJ+1/2Fxb/EJ	1/4b <sup>2</sup> -1/2bx+1/4x <sup>2</sup>			
GD b	b-x	-1/2Fb-1/2qx <sup>2</sup>	0	-1/2Fb <sup>2</sup> +1/2Fbx-1/2Fx <sup>2</sup> +1/2qx <sup>3</sup>	0	b <sup>2</sup> -2bx+x <sup>2</sup>	(-7/24+0)Fb <sup>3</sup> /EJ	1/3Xb <sup>3</sup> /EJ	
DG b	-x	Fb-Fx+1/2qx <sup>2</sup>	0	-Fbx+Fx <sup>2</sup> -1/2qx <sup>3</sup>	0	x <sup>2</sup>			
DH b	0	-Fb+Fx	0	0	0	0	0+0	0	
HD b	0	Fx	0	0	0	0			
GA b	-1/2b+1/2x	-1/2Fx+1/2qx <sup>2</sup>	0	1/4Fbx-1/2Fx <sup>2</sup> +1/4qx <sup>3</sup>	0	1/4b <sup>2</sup> -1/2bx+1/4x <sup>2</sup>	(1/48+0)Fb <sup>3</sup> /EJ	1/12Xb <sup>3</sup> /EJ	
AG b	1/2x	1/2Fx-1/2qx <sup>2</sup>	0	1/4Fx <sup>2</sup> -1/4qx <sup>3</sup>	0	1/4x <sup>2</sup>			
	totali							-37/48Fb <sup>3</sup> /EJ	1/2Xb <sup>3</sup> /EJ
	iperstatica $X=V_H$							37/24F	

Sviluppi di calcolo iperstatica

$$L_{FG}^{xx} = \int_0^b (1/4 x^2/b^2) b^2 1/EJ dx = [1/12 x^3/b^2]_0^b b^2 1/EJ$$

$$= (1/12 b) b^2 1/EJ = 1/12 b^3/EJ$$

$$L_{GF}^{xx} = \int_0^b (1/4 - 1/2 x/b + 1/4 x^2/b^2) b^2 1/EJ dx = [1/4 x - 1/4 x^2/b + 1/12 x^3/b^2]_0^b b^2 1/EJ$$

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

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

$$= (b - b + 1/3 b) b^2 1/EJ = 1/3 b^3/EJ$$

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

$$= (1/3 b) b^2 1/EJ = 1/3 b^3/EJ$$

$$L_{GA}^{xx} = \int_0^b (1/4 - 1/2 x/b + 1/4 x^2/b^2) b^2 1/EJ dx = [1/4 x - 1/4 x^2/b + 1/12 x^3/b^2]_0^b b^2 1/EJ$$

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

$$L_{AG}^{xx} = \int_0^b (1/4 x^2/b^2) b^2 1/EJ dx = [1/12 x^3/b^2]_0^b b^2 1/EJ$$

$$= (1/12 b) b^2 1/EJ = 1/12 b^3/EJ$$

$$L_{FG}^{xo} = \int_0^b (-3/4 x^2/b^2) Fb^2 1/EJ dx + \int_0^b (-1/2 x/b) \theta dx = [-1/4 x^3/b^2]_0^b Fb^2 1/EJ + [-1/4 x^2/b]_0^b \theta$$

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

$$L_{GF}^{xo} = \int_0^b (-3/4 + 3/2 x/b - 3/4 x^2/b^2) Fb^2 1/EJ dx + \int_0^b (1/2 - 1/2 x/b) \theta dx$$

$$= [-3/4 x + 3/4 x^2/b - 1/4 x^3/b^2]_0^b Fb^2 1/EJ + [1/2 x - 1/4 x^2/b]_0^b \theta$$

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

$$L_{GD}^{xo} = \int_0^b (-1/2 + 1/2 x/b - 1/2 x^2/b^2 + 1/2 x^3/b^3) Fb^2 1/EJ dx$$

$$= [-1/2 x + 1/4 x^2/b - 1/6 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb^2 1/EJ$$

$$= (-1/2 b + 1/4 b - 1/6 b + 1/8 b) Fb^2 1/EJ = -7/24 Fb^3/EJ$$

$$L_{DG}^{xo} = \int_0^b (-x/b + x^2/b^2 - 1/2 x^3/b^3) Fb^2 1/EJ dx = [-1/2 x^2/b + 1/3 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb^2 1/EJ$$

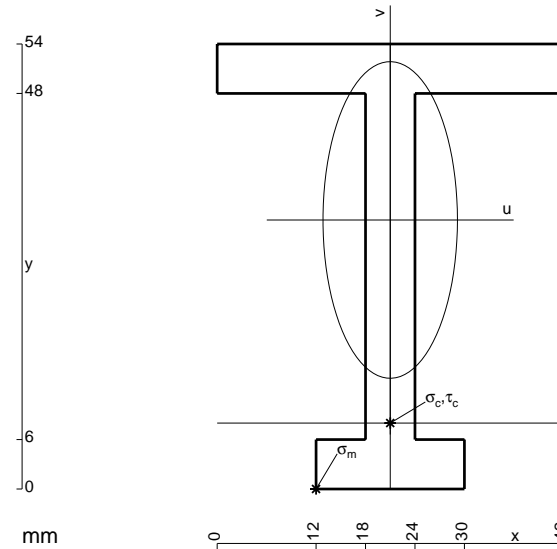
$$= (-1/2 b + 1/3 b - 1/8 b) Fb^2 1/EJ = -7/24 Fb^3/EJ$$

$$L_{GA}^{xo} = \int_0^b (1/4 x/b - 1/2 x^2/b^2 + 1/4 x^3/b^3) Fb^2 1/EJ dx = [1/8 x^2/b - 1/6 x^3/b^2 + 1/16 x^4/b^3]_0^b Fb^2 1/EJ$$

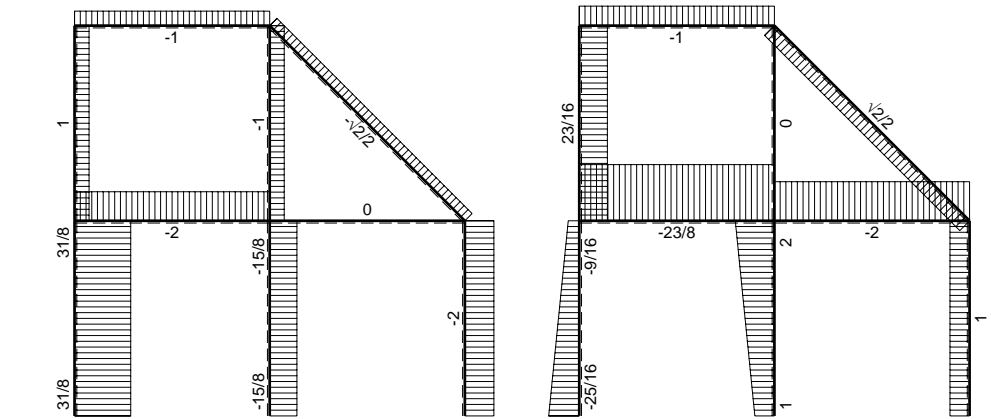
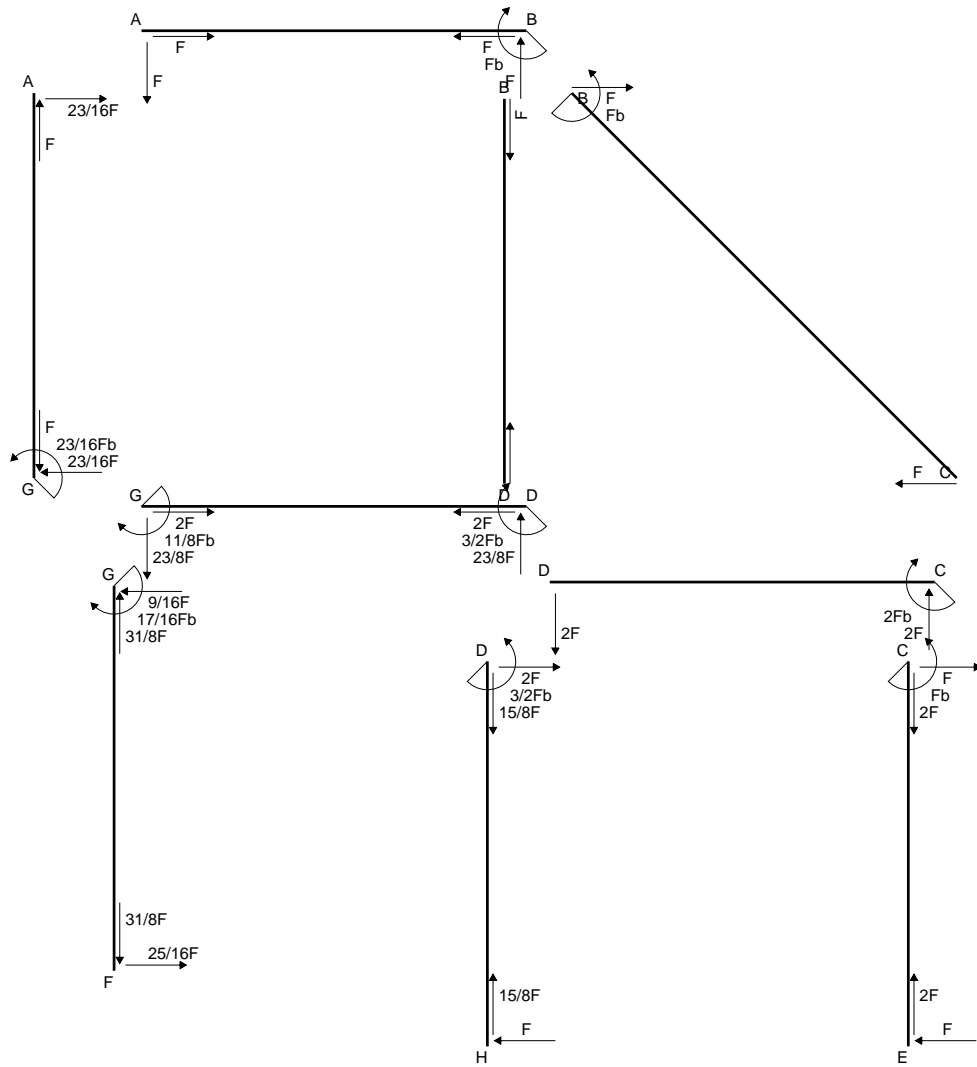
$$= (1/8 b - 1/6 b + 1/16 b) Fb^2 1/EJ = 1/48 Fb^3/EJ$$

$$L_{AG}^{xo} = \int_0^b (1/4 x^2/b^2 - 1/4 x^3/b^3) Fb^2 1/EJ dx = [1/12 x^3/b^2 - 1/16 x^4/b^3]_0^b Fb^2 1/EJ$$

$$= (1/12 b - 1/16 b) Fb^2 1/EJ = 1/48 Fb^3/EJ$$

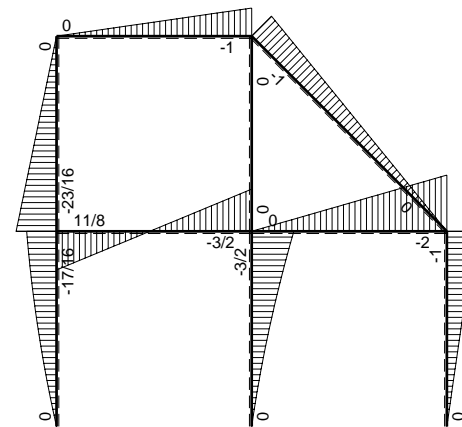


- A = 612. mm<sup>2</sup>
- J<sub>u</sub> = 225968. mm<sup>4</sup>
- J<sub>v</sub> = 40716. mm<sup>4</sup>
- y<sub>g</sub> = 32.65 mm
- T<sub>y</sub> = -2580. N
- M<sub>x</sub> = -1444800. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -9. mm
- v<sub>m</sub> = -32.65 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -208.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 8. mm
- v<sub>c</sub> = -24.65 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -157.6 N/mm<sup>2</sup>
- τ<sub>c</sub> = 6.679 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 158. N/mm<sup>2</sup>
- S = 3510. mm<sup>3</sup>

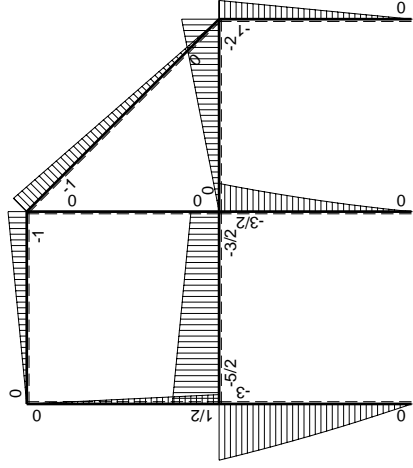
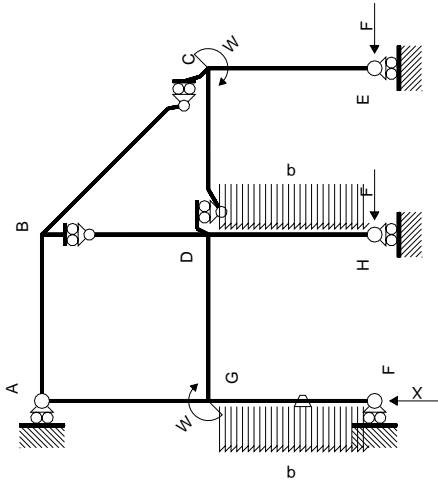


← ⊕ → F

↑ ⊕ ↓ F

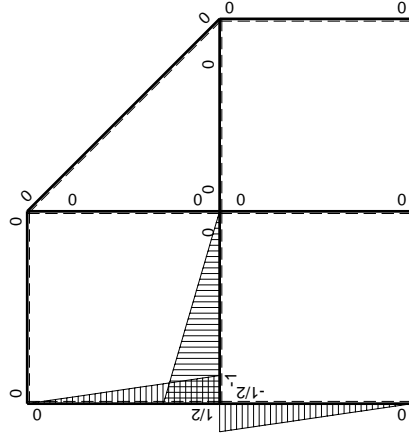


⊕ ⊖ F<sub>b</sub>



Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=V_F$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$
AB b	0	-Fx	0	0	0	0	0+0	0
BA b	0	Fb-Fx	0	0	0	0		
BC $\sqrt{2}b$	0	-Fb+ $\sqrt{2}/2Fx$	0	0	0	0	0	0
BD b	0	0	0	0	0	0	0+0	0
DB b	0	0	0	0	0	0		
DC b	0	-2Fx	0	0	0	0	0+0	0
CD b	0	2Fb-2Fx	0	0	0	0		
CE b	0	-Fb+Fx	0	0	0	0	0+0	0
EC b	0	Fx	0	0	0	0		
FG b	-1/2x	-7/2Fx+1/2qx <sup>2</sup>	-Fb/EJ	7/4Fx <sup>2</sup> -1/4qx <sup>3</sup>	1/2Fxb/EJ	1/4x <sup>2</sup>	(25/48+1/4)Fb <sup>3</sup> /EJ	1/12Xb <sup>3</sup> /EJ
GF b	1/2b-1/2x	3Fb-5/2Fx-1/2qx <sup>2</sup>	Fb/EJ	3/2Fb <sup>2</sup> -11/4Fbx+Fx <sup>2</sup> +1/4qx <sup>3</sup>	1/2Fb <sup>2</sup> /EJ-1/2Fxb/EJ	1/4b <sup>2</sup> -1/2bx+1/4x <sup>2</sup>		
GD b	-b+x	-5/2Fb+Fx	0	5/2Fb <sup>2</sup> -7/2Fbx+Fx <sup>2</sup>	0	b <sup>2</sup> -2bx+x <sup>2</sup>	(13/12+0)Fb <sup>3</sup> /EJ	1/3Xb <sup>3</sup> /EJ
DG b	x	3/2Fb+Fx	0	3/2Fbx+Fx <sup>2</sup>	0	x <sup>2</sup>		
DH b	0	-3/2Fb+2Fx-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
HD b	0	Fx+1/2qx <sup>2</sup>	0	0	0	0		
GA b	1/2b-1/2x	1/2Fb-1/2Fx	0	1/4Fb <sup>2</sup> -1/2Fbx+1/4Fx <sup>2</sup>	0	1/4b <sup>2</sup> -1/2bx+1/4x <sup>2</sup>	(1/12+0)Fb <sup>3</sup> /EJ	1/12Xb <sup>3</sup> /EJ
AG b	-1/2x	-1/2Fx	0	1/4Fx <sup>2</sup>	0	1/4x <sup>2</sup>		
	totali						31/16Fb <sup>3</sup> /EJ	1/2Xb <sup>3</sup> /EJ
	iperstatica $X=V_F$						-31/8F	

Sviluppi di calcolo iperstatica

$$L_{FG}^{xx} = \int_0^b (1/4 x^2/b^2) b^2 1/EJ dx = [1/12 x^3/b^2]_0^b b^2 1/EJ$$

$$= (1/12 b) b^2 1/EJ = 1/12 b^3/EJ$$

$$L_{GF}^{xx} = \int_0^b (1/4 - 1/2 x/b + 1/4 x^2/b^2) b^2 1/EJ dx = [1/4 x - 1/4 x^2/b + 1/12 x^3/b^2]_0^b b^2 1/EJ$$

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

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

$$= (b - b + 1/3 b) b^2 1/EJ = 1/3 b^3/EJ$$

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

$$= (1/3 b) b^2 1/EJ = 1/3 b^3/EJ$$

$$L_{GA}^{xx} = \int_0^b (1/4 - 1/2 x/b + 1/4 x^2/b^2) b^2 1/EJ dx = [1/4 x - 1/4 x^2/b + 1/12 x^3/b^2]_0^b b^2 1/EJ$$

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

$$L_{AG}^{xx} = \int_0^b (1/4 x^2/b^2) b^2 1/EJ dx = [1/12 x^3/b^2]_0^b b^2 1/EJ$$

$$= (1/12 b) b^2 1/EJ = 1/12 b^3/EJ$$

$$L_{FG}^{xo} = \int_0^b (7/4 x^2/b^2 - 1/4 x^3/b^3) Fb^2 1/EJ dx + \int_0^b (1/2 x/b) \theta dx$$

$$= [7/12 x^3/b^2 - 1/16 x^4/b^3]_0^b Fb^2 1/EJ + [1/4 x^2/b]_0^b \theta$$

$$= (7/12 b - 1/16 b) Fb^2 1/EJ + (1/4 b) \theta = 37/48 Fb^3/EJ$$

$$L_{GF}^{xo} = \int_0^b (3/2 - 11/4 x/b + x^2/b^2 + 1/4 x^3/b^3) Fb^2 1/EJ dx + \int_0^b (-1/2 + 1/2 x/b) \theta dx$$

$$= [3/2 x - 11/8 x^2/b + 1/3 x^3/b^2 + 1/16 x^4/b^3]_0^b Fb^2 1/EJ + [-1/2 x + 1/4 x^2/b]_0^b \theta$$

$$= (3/2 b - 11/8 b + 1/3 b + 1/16 b) Fb^2 1/EJ + (-1/2 b + 1/4 b) \theta = 37/48 Fb^3/EJ$$

$$L_{GD}^{xo} = \int_0^b (5/2 - 7/2 x/b + x^2/b^2) Fb^2 1/EJ dx = [5/2 x - 7/4 x^2/b + 1/3 x^3/b^2]_0^b Fb^2 1/EJ$$

$$= (5/2 b - 7/4 b + 1/3 b) Fb^2 1/EJ = 13/12 Fb^3/EJ$$

$$L_{DG}^{xo} = \int_0^b (3/2 x/b + x^2/b^2) Fb^2 1/EJ dx = [3/4 x^2/b + 1/3 x^3/b^2]_0^b Fb^2 1/EJ$$

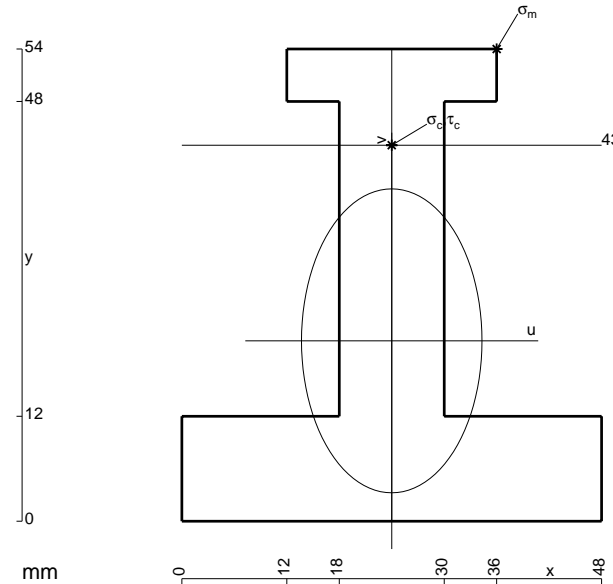
$$= (3/4 b + 1/3 b) Fb^2 1/EJ = 13/12 Fb^3/EJ$$

$$L_{GA}^{xo} = \int_0^b (1/4 - 1/2 x/b + 1/4 x^2/b^2) Fb^2 1/EJ dx = [1/4 x - 1/4 x^2/b + 1/12 x^3/b^2]_0^b Fb^2 1/EJ$$

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

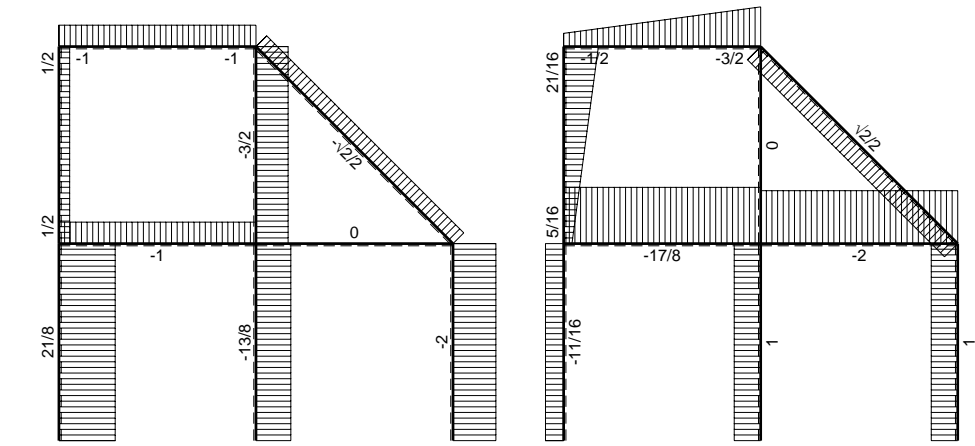
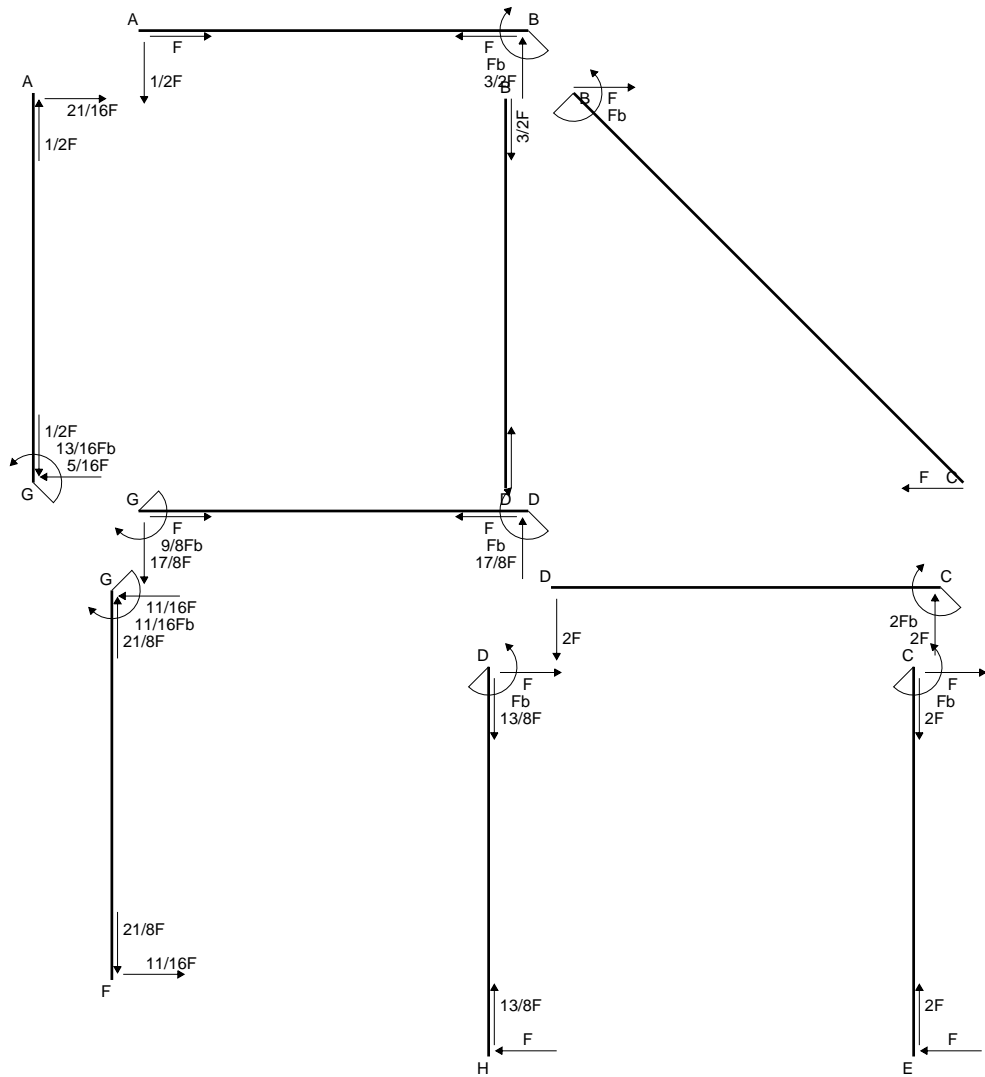
$$L_{AG}^{xo} = \int_0^b (1/4 x^2/b^2) Fb^2 1/EJ dx = [1/12 x^3/b^2]_0^b Fb^2 1/EJ$$

$$= (1/12 b) Fb^2 1/EJ = 1/12 Fb^3/EJ$$



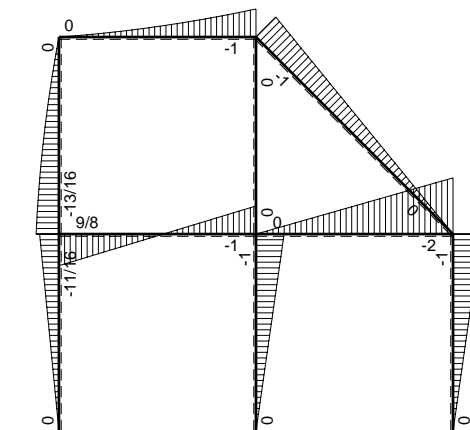
- A = 1152. mm<sup>2</sup>
- J<sub>u</sub> = 348030. mm<sup>4</sup>
- J<sub>v</sub> = 122688. mm<sup>4</sup>
- y<sub>g</sub> = 20.63 mm
- T<sub>y</sub> = -2740. N
- M<sub>x</sub> = -2082400. Nmm
- x<sub>m</sub> = 36. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 12. mm
- v<sub>m</sub> = 33.38 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 199.7 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> = 133.9 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.849 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 134. N/mm<sup>2</sup>
- S = 5867. mm<sup>3</sup>



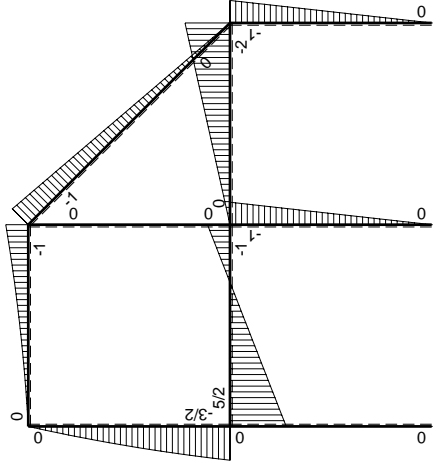
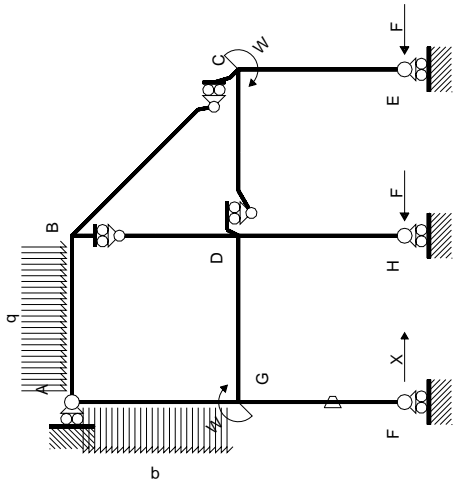


← ⊕ → F

↑ ⊕ ↓ Fb

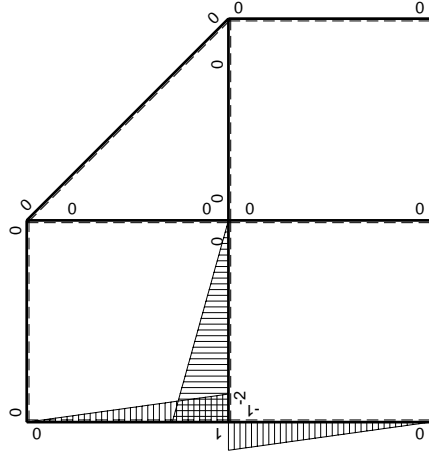


⊕ ⊖ Fb



Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=H_f$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$
AB b	0	$-1/2Fx-1/2qx^2$	0	0	0	0	0+0	0
BA b	0	$Fb-3/2Fx+1/2qx^2$	0	0	0	0	0	0
BC $\sqrt{2}b$	0	$-Fb+\sqrt{2}/2Fx$	0	0	0	0	0	0
BD b	0	0	0	0	0	0	0+0	0
DB b	0	0	0	0	0	0	0	0
DC b	0	$-2Fx$	0	0	0	0	0+0	0
CD b	0	$2Fb-2Fx$	0	0	0	0	0	0
CE b	0	$-Fb+Fx$	0	0	0	0	0+0	0
EC b	0	$Fx$	0	0	0	0	0	0
FG b	$-x$	0	$-Fb/EJ$	0	$Fxb/EJ$	$x^2$	$(0+1/2)Fb^3/EJ$	$1/3Xb^3/EJ$
GF b	$b-x$	0	$Fb/EJ$	0	$Fb^2/EJ-Fxb/EJ$	$b^2-2bx+x^2$		
GD b	$-2b+2x$	$5/2Fb-7/2Fx$	0	$-5Fb^2+12Fbx-7Fx^2$	0	$4b^2-8bx+4x^2$	$(-4/3+0)Fb^3/EJ$	$4/3Xb^3/EJ$
DG b	$2x$	$Fb-7/2Fx$	0	$2Fbx-7Fx^2$	0	$4x^2$		
DH b	0	$-Fb+Fx$	0	0	0	0	0+0	0
HD b	0	$Fx$	0	0	0	0	0	0
GA b	$b-x$	$-3/2Fb+Fx+1/2qx^2$	0	$-3/2Fb^2+5/2Fbx-1/2Fx^2-1/2qx^3$	0	$b^2-2bx+x^2$	$(-13/24+0)Fb^3/EJ$	$1/3Xb^3/EJ$
AG b	$-x$	$2Fx-1/2qx^2$	0	$-2Fx^2+1/2qx^3$	0	$x^2$		
	totali						$-11/8Fb^3/EJ$	$2Xb^3/EJ$
	iperstatica $X=H_f$						$11/16F$	

Sviluppi di calcolo iperstatica

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

$$= (1/3 b) b^2 1/EJ = 1/3 b^3/EJ$$

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

$$= (b - b + 1/3 b) b^2 1/EJ = 1/3 b^3/EJ$$

$$L_{GD}^{xx} = \int_0^b (4 - 8x/b + 4x^2/b^2) b^2 1/EJ dx = [4x - 4x^2/b + 4/3 x^3/b^2]_0^b b^2 1/EJ$$

$$= (4b - 4b + 4/3 b) b^2 1/EJ = 4/3 b^3/EJ$$

$$L_{DG}^{xx} = \int_0^b (4x^2/b^2) b^2 1/EJ dx = [4/3 x^3/b^2]_0^b b^2 1/EJ$$

$$= (4/3 b) b^2 1/EJ = 4/3 b^3/EJ$$

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

$$= (b - b + 1/3 b) b^2 1/EJ = 1/3 b^3/EJ$$

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

$$= (1/3 b) b^2 1/EJ = 1/3 b^3/EJ$$

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

$$= (1/2 b) \theta = 1/2 Fb^3/EJ$$

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

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

$$L_{GD}^{xo} = \int_0^b (-5 + 12x/b - 7x^2/b^2) Fb^2 1/EJ dx = [-5x + 6x^2/b - 7/3 x^3/b^2]_0^b Fb^2 1/EJ$$

$$= (-5b + 6b - 7/3 b) Fb^2 1/EJ = -4/3 Fb^3/EJ$$

$$L_{DG}^{xo} = \int_0^b (2x/b - 7x^2/b^2) Fb^2 1/EJ dx = [x^2/b - 7/3 x^3/b^2]_0^b Fb^2 1/EJ$$

$$= (b - 7/3 b) Fb^2 1/EJ = -4/3 Fb^3/EJ$$

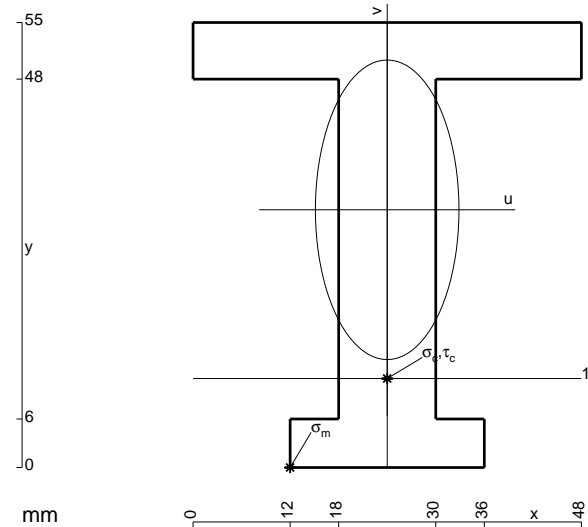
$$L_{GA}^{xo} = \int_0^b (-3/2 + 5/2 x/b - 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb^2 1/EJ dx$$

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

$$= (-3/2 b + 5/4 b - 1/6 b - 1/8 b) Fb^2 1/EJ = -13/24 Fb^3/EJ$$

$$L_{AG}^{xo} = \int_0^b (-2x^2/b^2 + 1/2 x^3/b^3) Fb^2 1/EJ dx = [-2/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb^2 1/EJ$$

$$= (-2/3 b + 1/8 b) Fb^2 1/EJ = -13/24 Fb^3/EJ$$



$$A = 984. \text{ mm}^2$$

$$J_u = 337339. \text{ mm}^4$$

$$J_v = 77472. \text{ mm}^4$$

$$y_g = 31.85 \text{ mm}$$

$$T_y = -2700. \text{ N}$$

$$M_x = -2106000. \text{ Nmm}$$

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

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

$$v_m = -31.85 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -198.9 \text{ N/mm}^2$$

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

$$y_c = 11. \text{ mm}$$

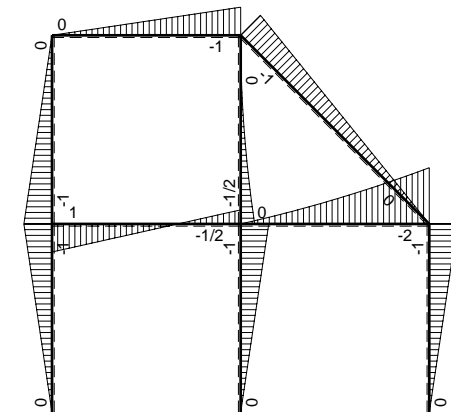
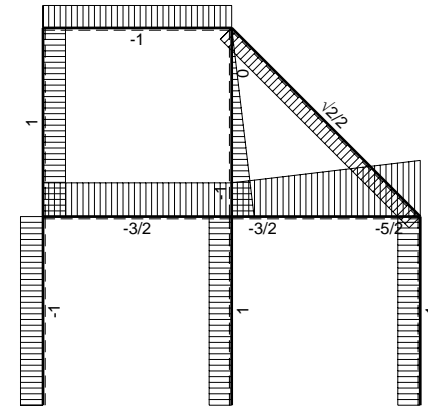
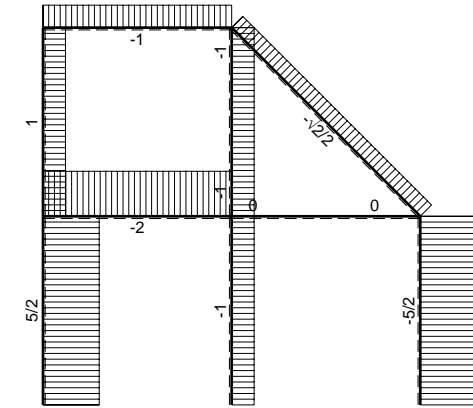
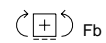
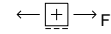
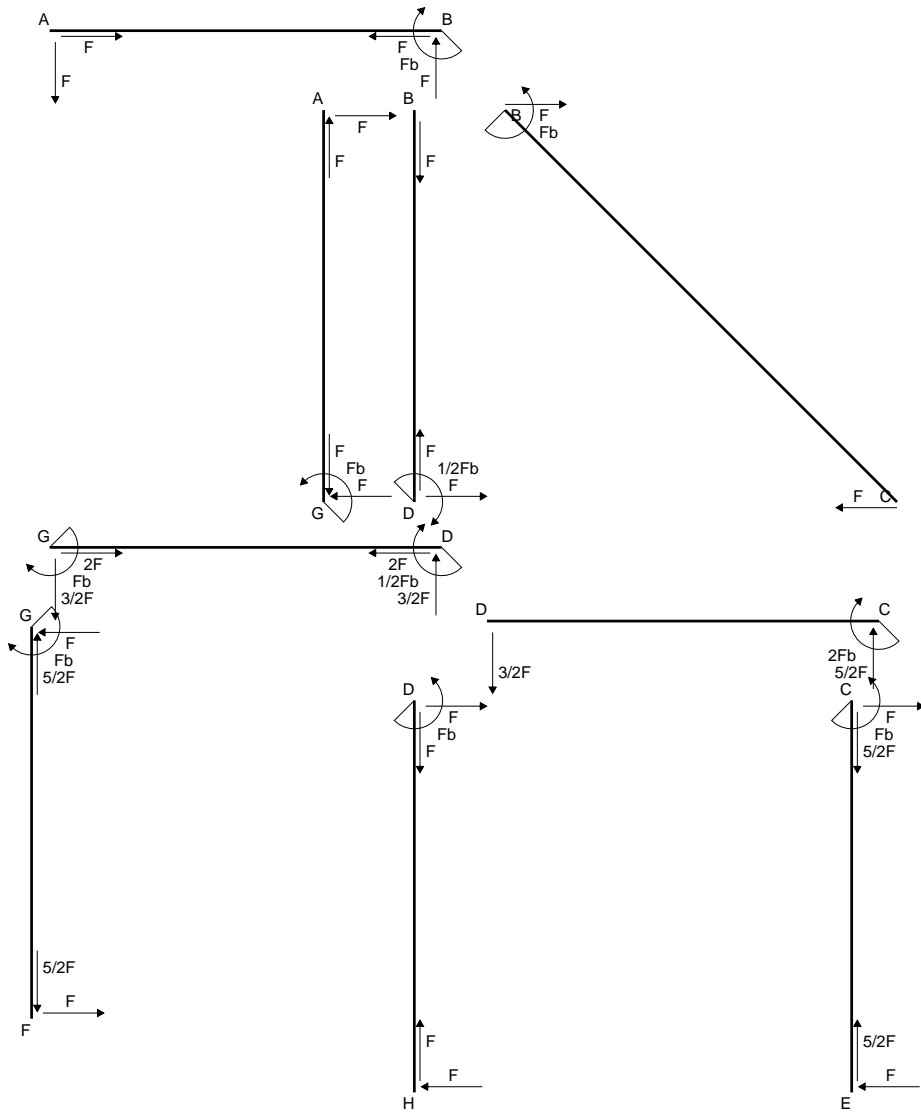
$$v_c = -20.85 \text{ mm}$$

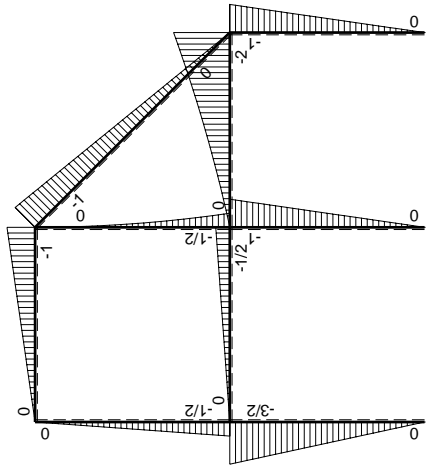
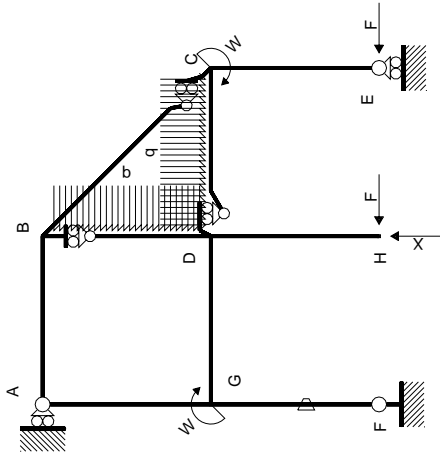
$$\sigma_c = -Mv/J_u = -130.2 \text{ N/mm}^2$$

$$\tau_c = 3.706 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 130.3 \text{ N/mm}^2$$

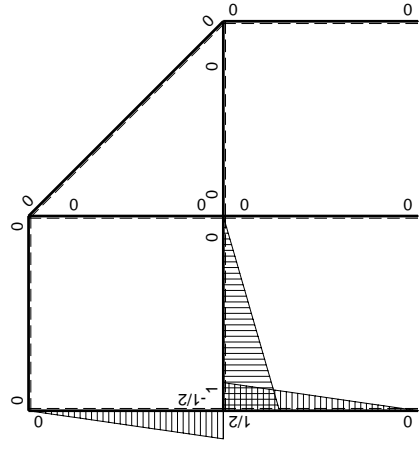
$$S = 5556. \text{ mm}^3$$





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=V_H$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x / EJ dx$
AB b	0	-Fx	0	0	0	0	0+0	0
BA b	0	Fb-Fx	0	0	0	0	0	0
BC $\sqrt{2}b$	0	-Fb+ $\sqrt{2}/2Fx$	0	0	0	0	0	0
BD b	0	-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
DB b	0	1/2Fb-Fx+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
DC b	0	-3/2Fx-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
CD b	0	2Fb-5/2Fx+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
CE b	0	-Fb+Fx	0	0	0	0	0+0	0
EC b	0	Fx	0	0	0	0	0+0	0
FG b	1/2x	-3/2Fx	-Fb/EJ	-3/4Fx <sup>2</sup>	-1/2Fxb/EJ	1/4x <sup>2</sup>	(-1/4-1/4)Fb <sup>3</sup> /EJ	1/12Xb <sup>3</sup> /EJ
GF b	-1/2b+1/2x	3/2Fb-3/2Fx	Fb/EJ	-3/4Fb <sup>2</sup> +3/2Fbx-3/4Fx <sup>2</sup>	-1/2Fb <sup>2</sup> /EJ+1/2Fxb/EJ	1/4b <sup>2</sup> -1/2bx+1/4x <sup>2</sup>		
GD b	b-x	-1/2Fx	0	-1/2Fbx+1/2Fx <sup>2</sup>	0	b <sup>2</sup> -2bx+x <sup>2</sup>	(-1/12+0)Fb <sup>3</sup> /EJ	1/3Xb <sup>3</sup> /EJ
DG b	-x	1/2Fb-1/2Fx	0	-1/2Fbx+1/2Fx <sup>2</sup>	0	x <sup>2</sup>		
DH b	0	-Fb+Fx	0	0	0	0	0+0	0
HD b	0	Fx	0	0	0	0	0+0	0
GA b	-1/2b+1/2x	-1/2Fb+1/2Fx	0	1/4Fb <sup>2</sup> -1/2Fbx+1/4Fx <sup>2</sup>	0	1/4b <sup>2</sup> -1/2bx+1/4x <sup>2</sup>	(1/12+0)Fb <sup>3</sup> /EJ	1/12Xb <sup>3</sup> /EJ
AG b	1/2x	1/2Fx	0	1/4Fx <sup>2</sup>	0	1/4x <sup>2</sup>		
	totali						-1/2Fb <sup>3</sup> /EJ	1/2Xb <sup>3</sup> /EJ
	iperstatica $X=V_H$						F	

Sviluppi di calcolo iperstatica

$$L_{FG}^{xx} = \int_0^b (1/4 x^2/b^2) b^2 1/EJ dx = [1/12 x^3/b^2]_0^b b^2 1/EJ$$

$$= (1/12 b) b^2 1/EJ = 1/12 b^3/EJ$$

$$L_{GF}^{xx} = \int_0^b (1/4 - 1/2 x/b + 1/4 x^2/b^2) b^2 1/EJ dx = [1/4 x - 1/4 x^2/b + 1/12 x^3/b^2]_0^b b^2 1/EJ$$

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

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

$$= (b - b + 1/3 b) b^2 1/EJ = 1/3 b^3/EJ$$

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

$$= (1/3 b) b^2 1/EJ = 1/3 b^3/EJ$$

$$L_{GA}^{xx} = \int_0^b (1/4 - 1/2 x/b + 1/4 x^2/b^2) b^2 1/EJ dx = [1/4 x - 1/4 x^2/b + 1/12 x^3/b^2]_0^b b^2 1/EJ$$

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

$$L_{AG}^{xx} = \int_0^b (1/4 x^2/b^2) b^2 1/EJ dx = [1/12 x^3/b^2]_0^b b^2 1/EJ$$

$$= (1/12 b) b^2 1/EJ = 1/12 b^3/EJ$$

$$L_{FG}^{xo} = \int_0^b (-3/4 x^2/b^2) Fb^2 1/EJ dx + \int_0^b (-1/2 x/b) \theta dx = [-1/4 x^3/b^2]_0^b Fb^2 1/EJ + [-1/4 x^2/b]_0^b \theta$$

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

$$L_{GF}^{xo} = \int_0^b (-3/4 + 3/2 x/b - 3/4 x^2/b^2) Fb^2 1/EJ dx + \int_0^b (1/2 - 1/2 x/b) \theta dx$$

$$= [-3/4 x + 3/4 x^2/b - 1/4 x^3/b^2]_0^b Fb^2 1/EJ + [1/2 x - 1/4 x^2/b]_0^b \theta$$

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

$$L_{GD}^{xo} = \int_0^b (-1/2 x/b + 1/2 x^2/b^2) Fb^2 1/EJ dx = [-1/4 x^2/b + 1/6 x^3/b^2]_0^b Fb^2 1/EJ$$

$$= (-1/4 b + 1/6 b) Fb^2 1/EJ = -1/12 Fb^3/EJ$$

$$L_{DG}^{xo} = \int_0^b (-1/2 x/b + 1/2 x^2/b^2) Fb^2 1/EJ dx = [-1/4 x^2/b + 1/6 x^3/b^2]_0^b Fb^2 1/EJ$$

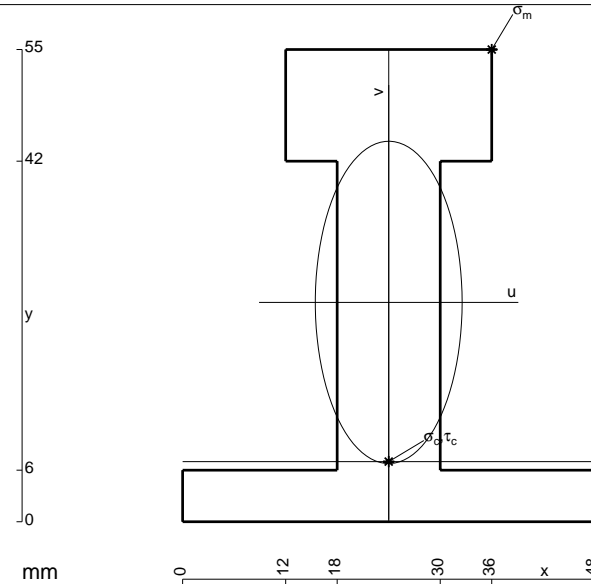
$$= (-1/4 b + 1/6 b) Fb^2 1/EJ = -1/12 Fb^3/EJ$$

$$L_{GA}^{xo} = \int_0^b (1/4 - 1/2 x/b + 1/4 x^2/b^2) Fb^2 1/EJ dx = [1/4 x - 1/4 x^2/b + 1/12 x^3/b^2]_0^b Fb^2 1/EJ$$

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

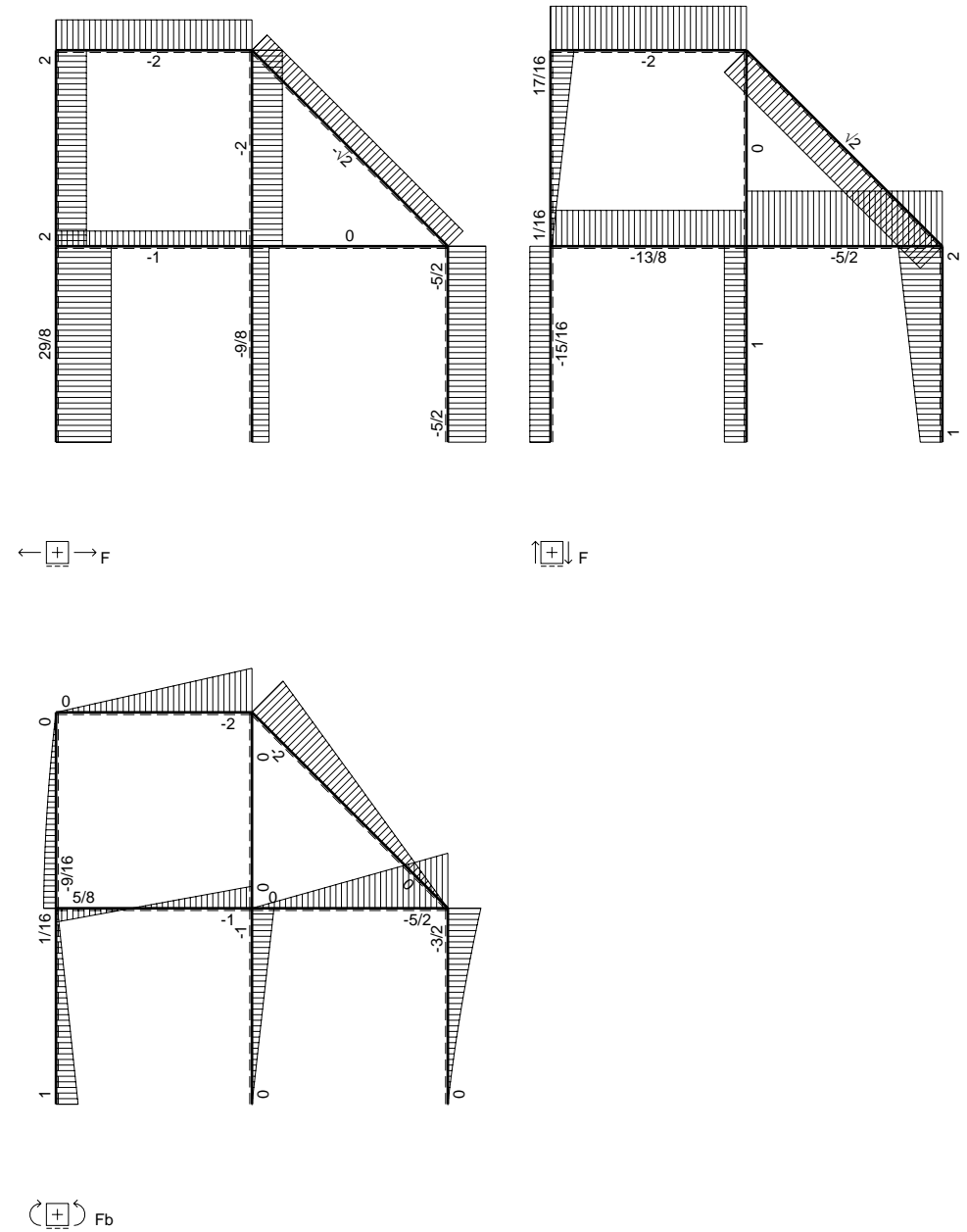
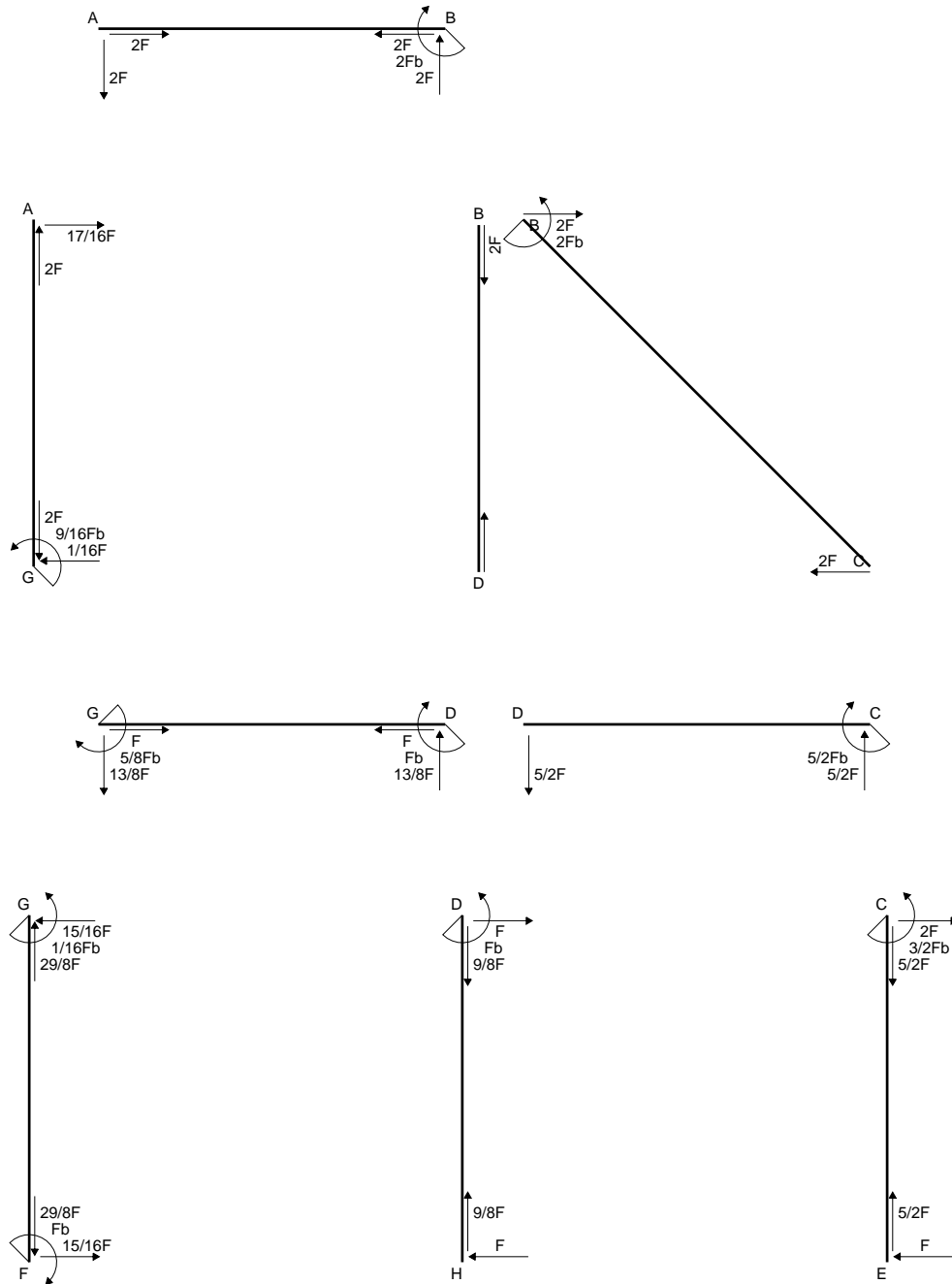
$$L_{AG}^{xo} = \int_0^b (1/4 x^2/b^2) Fb^2 1/EJ dx = [1/12 x^3/b^2]_0^b Fb^2 1/EJ$$

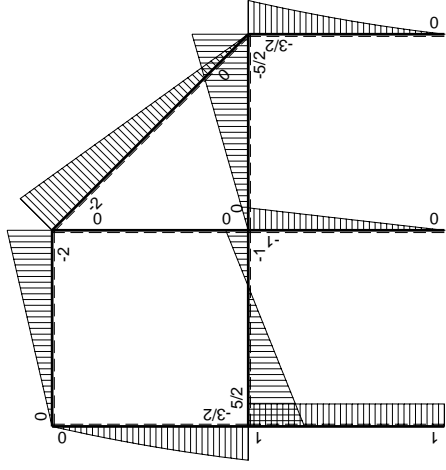
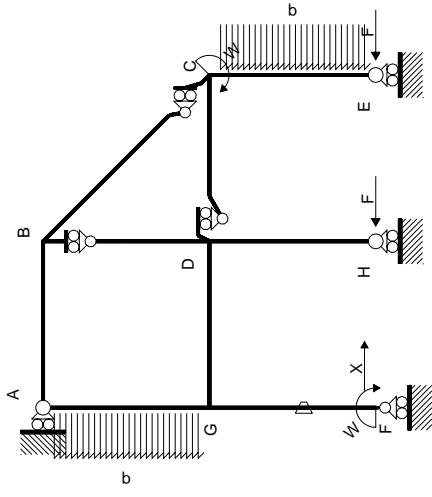
$$= (1/12 b) Fb^2 1/EJ = 1/12 Fb^3/EJ$$



- A = 1032. mm<sup>2</sup>
- J<sub>u</sub> = 363732. mm<sup>4</sup>
- J<sub>v</sub> = 75456. mm<sup>4</sup>
- y<sub>g</sub> = 25.55 mm
- T<sub>y</sub> = -3900. N
- M<sub>x</sub> = -2589600. Nmm
- x<sub>m</sub> = 36. mm
- y<sub>m</sub> = 55. mm
- u<sub>m</sub> = 12. mm
- v<sub>m</sub> = 29.45 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> = 7. mm
- v<sub>c</sub> = -18.55 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -132. N/mm<sup>2</sup>
- τ<sub>c</sub> = 6.006 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 132.5 N/mm<sup>2</sup>
- S = 6722. mm<sup>3</sup>

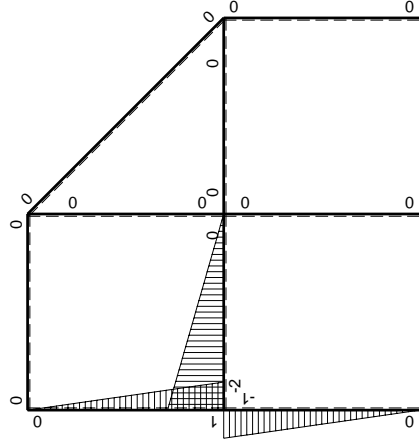






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=H_f$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$	
AB b	0	-2Fx	0	0	0	0	0+0	0	
BA b	0	2Fb-2Fx	0	0	0	0	0	0	
BC $\sqrt{2}b$	0	-2Fb+ $\sqrt{2}Fx$	0	0	0	0	0	0	
BD b	0	0	0	0	0	0	0+0	0	
DB b	0	0	0	0	0	0	0	0	
DC b	0	-5/2Fx	0	0	0	0	0+0	0	
CD b	0	5/2Fb-5/2Fx	0	0	0	0	0	0	
CE b	0	-3/2Fb+2Fx-1/2qx <sup>2</sup>	0	0	0	0	0+0	0	
EC b	0	Fx+1/2qx <sup>2</sup>	0	0	0	0	0	0	
FG b	-x	Fb	-Fb/EJ	-Fbx	Fxb/EJ	x <sup>2</sup>	(-1/2+1/2)Fb <sup>3</sup> /EJ	1/3Xb <sup>3</sup> /EJ	
GF b	b-x	-Fb	Fb/EJ	-Fb <sup>2</sup> +Fbx	Fb <sup>2</sup> /EJ-Fxb/EJ	b <sup>2</sup> -2bx+x <sup>2</sup>			
GD b	-2b+2x	5/2Fb-7/2Fx	0	-5Fb <sup>2</sup> +12Fbx-7Fx <sup>2</sup>	0	4b <sup>2</sup> -8bx+4x <sup>2</sup>	(-4/3+0)Fb <sup>3</sup> /EJ	4/3Xb <sup>3</sup> /EJ	
DG b	2x	Fb-7/2Fx	0	2Fbx-7Fx <sup>2</sup>	0	4x <sup>2</sup>			
DH b	0	-Fb+Fx	0	0	0	0	0+0	0	
HD b	0	Fx	0	0	0	0	0	0	
GA b	b-x	-3/2Fb+Fx+1/2qx <sup>2</sup>	0	-3/2Fb <sup>2</sup> +5/2Fbx-1/2Fx <sup>2</sup> -1/2qx <sup>3</sup>	0	b <sup>2</sup> -2bx+x <sup>2</sup>	(-13/24+0)Fb <sup>3</sup> /EJ	1/3Xb <sup>3</sup> /EJ	
AG b	-x	2Fx-1/2qx <sup>2</sup>	0	-2Fx <sup>2</sup> +1/2qx <sup>3</sup>	0	x <sup>2</sup>			
	totali							-15/8Fb <sup>3</sup> /EJ	2Xb <sup>3</sup> /EJ
	iperstatica $X=H_f$							15/16F	

Sviluppi di calcolo iperstatica

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

$$= (1/3 b) b^2 1/EJ = 1/3 b^3/EJ$$

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

$$= (b - b + 1/3 b) b^2 1/EJ = 1/3 b^3/EJ$$

$$L_{GD}^{xx} = \int_0^b (4 - 8x/b + 4x^2/b^2) b^2 1/EJ dx = [4x - 4x^2/b + 4/3 x^3/b^2]_0^b b^2 1/EJ$$

$$= (4b - 4b + 4/3 b) b^2 1/EJ = 4/3 b^3/EJ$$

$$L_{DG}^{xx} = \int_0^b (4x^2/b^2) b^2 1/EJ dx = [4/3 x^3/b^2]_0^b b^2 1/EJ$$

$$= (4/3 b) b^2 1/EJ = 4/3 b^3/EJ$$

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

$$= (b - b + 1/3 b) b^2 1/EJ = 1/3 b^3/EJ$$

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

$$= (1/3 b) b^2 1/EJ = 1/3 b^3/EJ$$

$$L_{FG}^{xo} = \int_0^b (-x/b) Fb^2 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb^2 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb^2 1/EJ + (1/2 b) \theta = 0$$

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

$$= [-x + 1/2 x^2/b]_0^b Fb^2 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (-b + 1/2 b) Fb^2 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{GD}^{xo} = \int_0^b (-5 + 12x/b - 7x^2/b^2) Fb^2 1/EJ dx = [-5x + 6x^2/b - 7/3 x^3/b^2]_0^b Fb^2 1/EJ$$

$$= (-5b + 6b - 7/3 b) Fb^2 1/EJ = -4/3 Fb^3/EJ$$

$$L_{DG}^{xo} = \int_0^b (2x/b - 7x^2/b^2) Fb^2 1/EJ dx = [x^2/b - 7/3 x^3/b^2]_0^b Fb^2 1/EJ$$

$$= (b - 7/3 b) Fb^2 1/EJ = -4/3 Fb^3/EJ$$

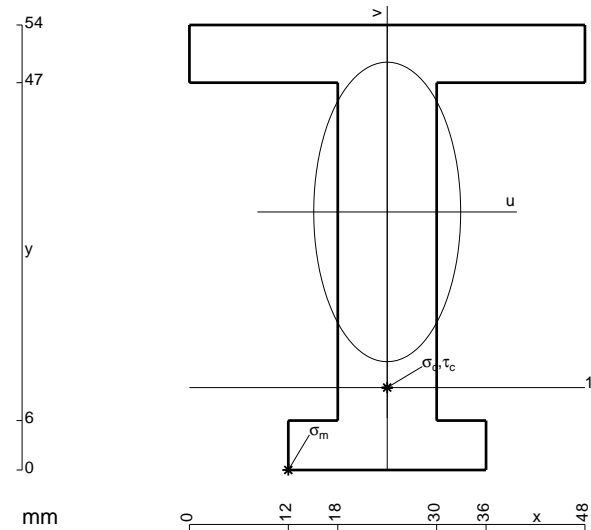
$$L_{GA}^{xo} = \int_0^b (-3/2 + 5/2 x/b - 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb^2 1/EJ dx$$

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

$$= (-3/2 b + 5/4 b - 1/6 b - 1/8 b) Fb^2 1/EJ = -13/24 Fb^3/EJ$$

$$L_{AG}^{xo} = \int_0^b (-2x^2/b^2 + 1/2 x^3/b^3) Fb^2 1/EJ dx = [-2/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb^2 1/EJ$$

$$= (-2/3 b + 1/8 b) Fb^2 1/EJ = -13/24 Fb^3/EJ$$



$$A = 972. \text{ mm}^2$$

$$J_u = 321252. \text{ mm}^4$$

$$J_v = 77328. \text{ mm}^4$$

$$y_g = 31.31 \text{ mm}$$

$$T_y = -3825. \text{ N}$$

$$M_x = -2142000. \text{ Nmm}$$

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

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

$$v_m = -31.31 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -208.8 \text{ N/mm}^2$$

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

$$y_c = 10. \text{ mm}$$

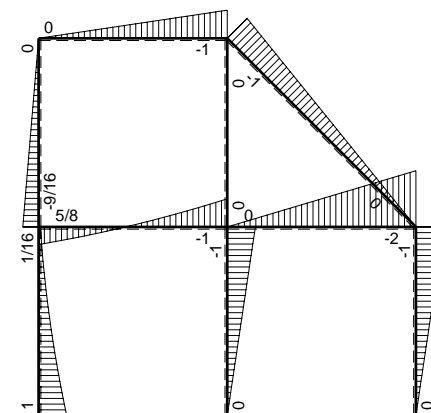
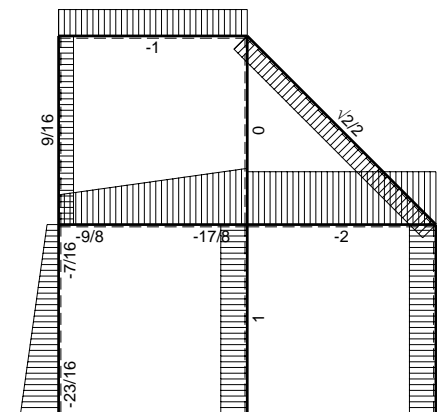
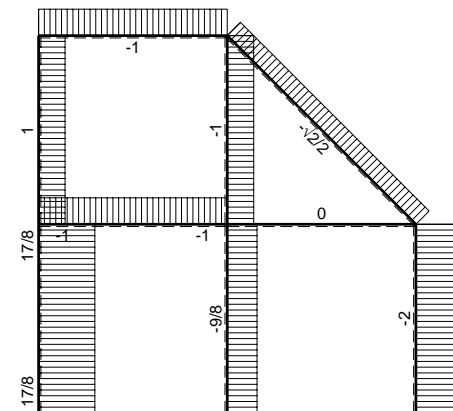
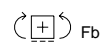
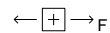
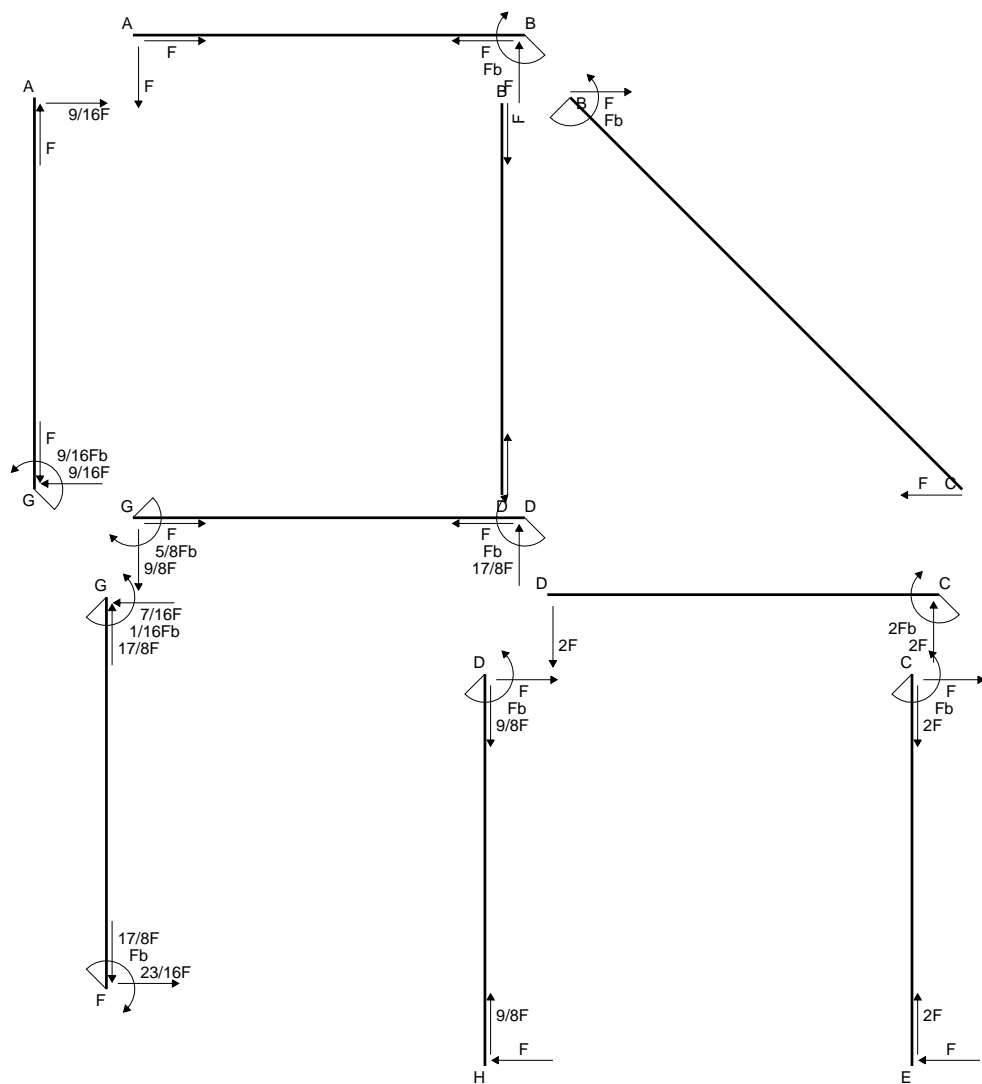
$$v_c = -21.31 \text{ mm}$$

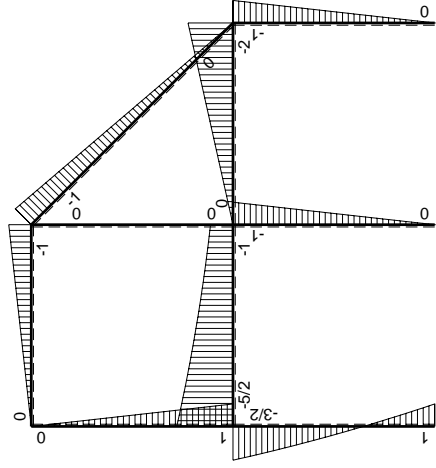
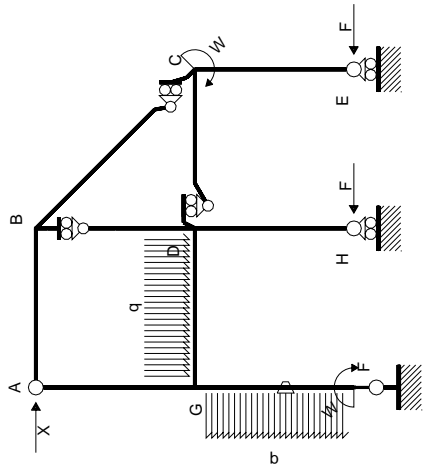
$$\sigma_c = -Mv/J_u = -142.1 \text{ N/mm}^2$$

$$\tau_c = 5.156 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 142.4 \text{ N/mm}^2$$

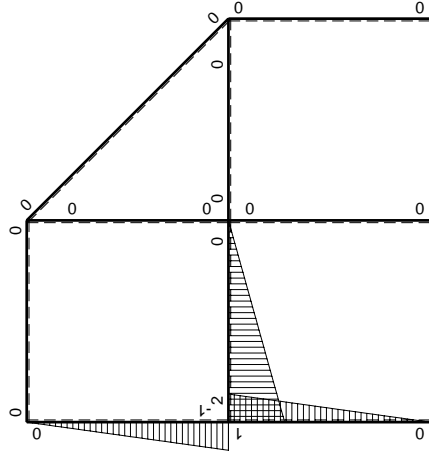
$$S = 5196. \text{ mm}^3$$





Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_1$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica X=H<sub>A</sub>

→	M <sub>x</sub> (x)	M <sub>o</sub> (x)	θ	M <sub>x</sub> M <sub>o</sub>	M <sub>x</sub> θ	M <sub>x</sub> M <sub>x</sub>	∫M <sub>x</sub> (M <sub>o</sub> /EJ+θ)dx	∫XM <sub>x</sub> M <sub>x</sub> /EJdx
AB b	0	-Fx	0	0	0	0	0+0	0
BA b	0	Fb-Fx	0	0	0	0		
BC √2b	0	-Fb+√2/2Fx	0	0	0	0	0	0
BD b	0	0	0	0	0	0	0+0	0
DB b	0	0	0	0	0	0		
DC b	0	-2Fx	0	0	0	0	0+0	0
CD b	0	2Fb-2Fx	0	0	0	0		
CE b	0	-Fb+Fx	0	0	0	0	0+0	0
EC b	0	Fx	0	0	0	0		
FG b	x	Fb-3Fx+1/2qx <sup>2</sup>	-Fb/EJ	Fbx-3Fx <sup>2</sup> +1/2qx <sup>3</sup>	-Fxb/EJ	x <sup>2</sup>	(-3/8-1/2)Fb <sup>3</sup> /EJ	1/3Xb <sup>3</sup> /EJ
GF b	-b+x	3/2Fb-2Fx-1/2qx <sup>2</sup>	Fb/EJ	-3/2Fb <sup>2</sup> +7/2Fbx-3/2Fx <sup>2</sup> -1/2qx <sup>3</sup>	-Fb <sup>2</sup> /EJ+Fxb/EJ	b <sup>2</sup> -2bx+x <sup>2</sup>		
GD b	2b-2x	-5/2Fb+2Fx-1/2qx <sup>2</sup>	0	-5Fb <sup>2</sup> +9Fbx-5Fx <sup>2</sup> +qx <sup>3</sup>	0	4b <sup>2</sup> -8bx+4x <sup>2</sup>	(-23/12+0)Fb <sup>3</sup> /EJ	4/3Xb <sup>3</sup> /EJ
DG b	-2x	Fb+Fx+1/2qx <sup>2</sup>	0	-2Fbx-2Fx <sup>2</sup> -qx <sup>3</sup>	0	4x <sup>2</sup>		
DH b	0	-Fb+Fx	0	0	0	0	0+0	0
HD b	0	Fx	0	0	0	0		
GA b	-b+x	Fb-Fx	0	-Fb <sup>2</sup> +2Fbx-Fx <sup>2</sup>	0	b <sup>2</sup> -2bx+x <sup>2</sup>	(-1/3+0)Fb <sup>3</sup> /EJ	1/3Xb <sup>3</sup> /EJ
AG b	x	-Fx	0	-Fx <sup>2</sup>	0	x <sup>2</sup>		
	totali						-25/8Fb <sup>3</sup> /EJ	2Xb <sup>3</sup> /EJ
	iperstatica X=H <sub>A</sub>						25/16F	

Sviluppi di calcolo iperstatica

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

$$= (1/3 b) b^2 1/EJ = 1/3 b^3/EJ$$

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

$$= (b - b + 1/3 b) b^2 1/EJ = 1/3 b^3/EJ$$

$$L_{GD}^{xx} = \int_0^b (4 - 8x/b + 4x^2/b^2) b^2 1/EJ dx = [4x - 4x^2/b + 4/3 x^3/b^2]_0^b b^2 1/EJ$$

$$= (4b - 4b + 4/3 b) b^2 1/EJ = 4/3 b^3/EJ$$

$$L_{DG}^{xx} = \int_0^b (4x^2/b^2) b^2 1/EJ dx = [4/3 x^3/b^2]_0^b b^2 1/EJ$$

$$= (4/3 b) b^2 1/EJ = 4/3 b^3/EJ$$

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

$$= (b - b + 1/3 b) b^2 1/EJ = 1/3 b^3/EJ$$

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

$$= (1/3 b) b^2 1/EJ = 1/3 b^3/EJ$$

$$L_{FG}^{xo} = \int_0^b (x/b - 3x^2/b^2 + 1/2 x^3/b^3) Fb^2 1/EJ dx + \int_0^b (-x/b) \theta dx$$

$$= [1/2 x^2/b - x^3/b^2 + 1/8 x^4/b^3]_0^b Fb^2 1/EJ + [-1/2 x^2/b]_0^b \theta$$

$$= (1/2 b - b + 1/8 b) Fb^2 1/EJ + (-1/2 b) \theta = -7/8 Fb^3/EJ$$

$$L_{GF}^{xo} = \int_0^b (-3/2 + 7/2 x/b - 3/2 x^2/b^2 - 1/2 x^3/b^3) Fb^2 1/EJ dx + \int_0^b (1 - x/b) \theta dx$$

$$= [-3/2 x + 7/4 x^2/b - 1/2 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb^2 1/EJ + [x - 1/2 x^2/b]_0^b \theta$$

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

$$L_{GD}^{xo} = \int_0^b (-5 + 9x/b - 5x^2/b^2 + x^3/b^3) Fb^2 1/EJ dx = [-5x + 9/2 x^2/b - 5/3 x^3/b^2 + 1/4 x^4/b^3]_0^b Fb^2 1/EJ$$

$$= (-5b + 9/2 b - 5/3 b + 1/4 b) Fb^2 1/EJ = -23/12 Fb^3/EJ$$

$$L_{DG}^{xo} = \int_0^b (-2x/b - 2x^2/b^2 - x^3/b^3) Fb^2 1/EJ dx = [-x^2/b - 2/3 x^3/b^2 - 1/4 x^4/b^3]_0^b Fb^2 1/EJ$$

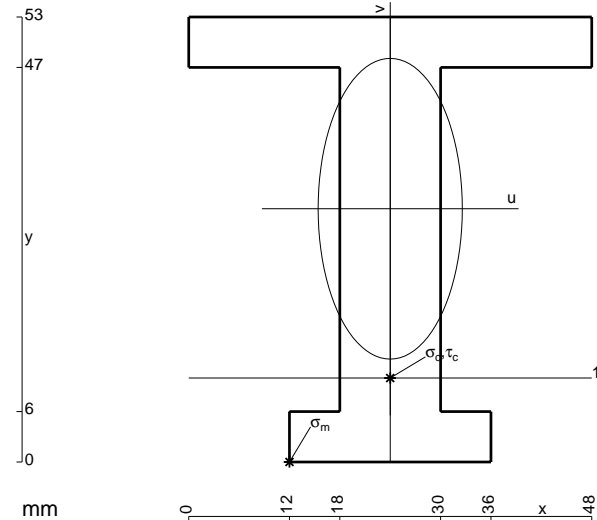
$$= (-b - 2/3 b - 1/4 b) Fb^2 1/EJ = -23/12 Fb^3/EJ$$

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

$$= (-b + b - 1/3 b) Fb^2 1/EJ = -1/3 Fb^3/EJ$$

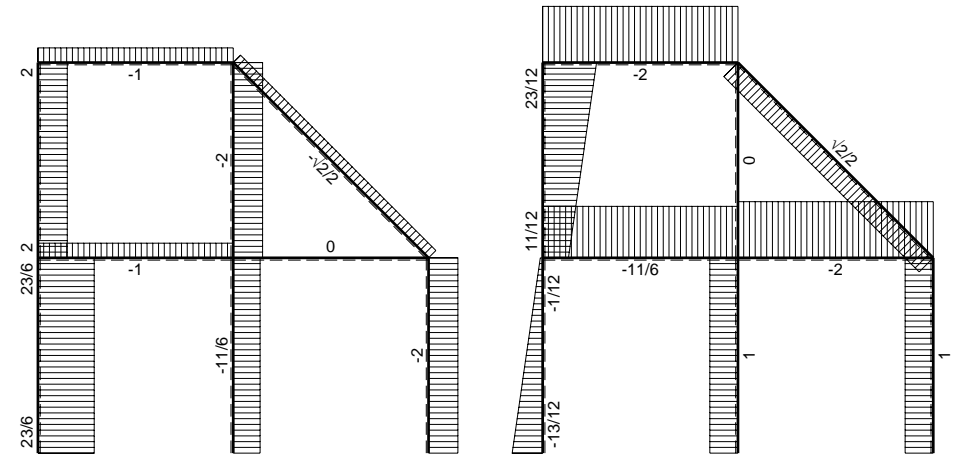
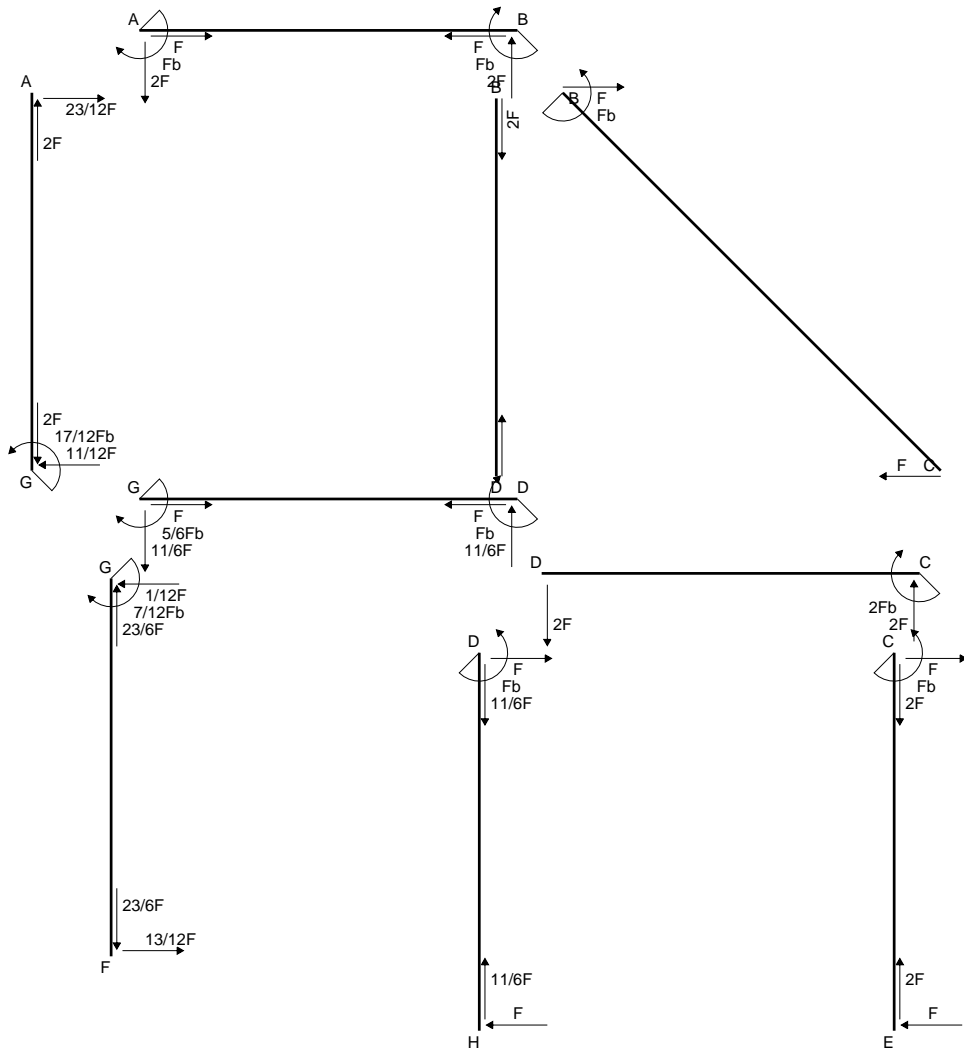
$$L_{AG}^{xo} = \int_0^b (-x^2/b^2) Fb^2 1/EJ dx = [-1/3 x^3/b^2]_0^b Fb^2 1/EJ$$

$$= (-1/3 b) Fb^2 1/EJ = -1/3 Fb^3/EJ$$



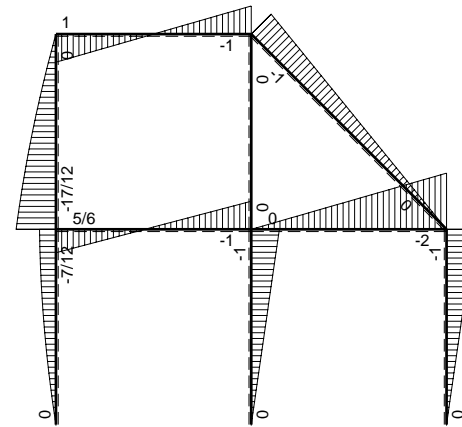
- A = 924. mm<sup>2</sup>
- J<sub>u</sub> = 296396. mm<sup>4</sup>
- J<sub>v</sub> = 68112. mm<sup>4</sup>
- y<sub>g</sub> = 30.16 mm
- T<sub>y</sub> = -2540. N
- M<sub>x</sub> = -2159000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -12. mm
- v<sub>m</sub> = -30.16 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -219.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 10. mm
- v<sub>c</sub> = -20.16 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -146.9 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.553 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 147. N/mm<sup>2</sup>
- S = 4975. mm<sup>3</sup>



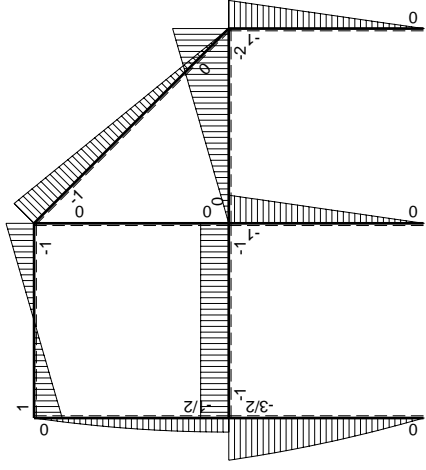
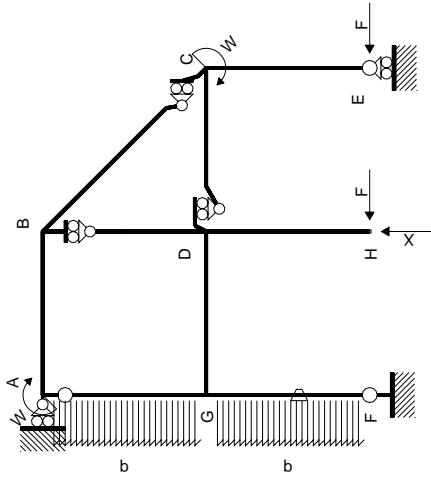


← ⊕ → F

↑ ⊕ ↓ F

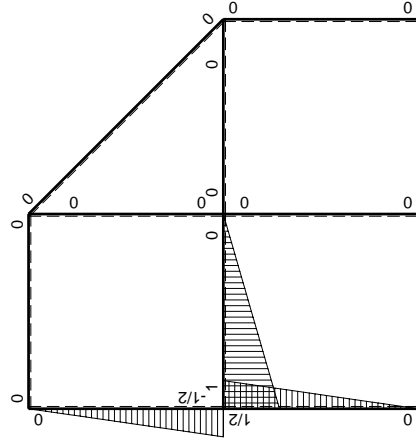


⊕ F<sub>b</sub>



Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_X$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=V_H$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$
AB b	0	$Fb-2Fx$	0	0	0	0	0+0	0
BA b	0	$Fb-2Fx$	0	0	0	0		
BC $\sqrt{2}b$	0	$-Fb+\sqrt{2}/2Fx$	0	0	0	0	0	0
BD b	0	0	0	0	0	0	0+0	0
DB b	0	0	0	0	0	0		
DC b	0	$-2Fx$	0	0	0	0	0+0	0
CD b	0	$2Fb-2Fx$	0	0	0	0		
CE b	0	$-Fb+Fx$	0	0	0	0	0+0	0
EC b	0	$Fx$	0	0	0	0		
FG b	$1/2x$	$-2Fx+1/2qx^2$	$-Fb/EJ$	$-Fx^2+1/4qx^3$	$-1/2Fxb/EJ$	$1/4x^2$	$(-13/48-1/4)Fb^3/EJ$	$1/12Xb^3/EJ$
GF b	$-1/2b+1/2x$	$3/2Fb-Fx-1/2qx^2$	$Fb/EJ$	$-3/4Fb^2+5/4Fbx-1/4Fx^2-1/4qx^3$	$-1/2Fb^2/EJ+1/2Fxb/EJ$	$1/4b^2-1/2bx+1/4x^2$		
GD b	$b-x$	$-Fb$	0	$-Fb^2+Fbx$	0	$b^2-2bx+x^2$	$(-1/2+0)Fb^3/EJ$	$1/3Xb^3/EJ$
DG b	$-x$	$Fb$	0	$-Fbx$	0	$x^2$		
DH b	0	$-Fb+Fx$	0	0	0	0	0+0	0
HD b	0	$Fx$	0	0	0	0		
GA b	$-1/2b+1/2x$	$-1/2Fb+1/2qx^2$	0	$1/4Fb^2-1/4Fbx-1/4Fx^2+1/4qx^3$	0	$1/4b^2-1/2bx+1/4x^2$	$(5/48+0)Fb^3/EJ$	$1/12Xb^3/EJ$
AG b	$1/2x$	$Fx-1/2qx^2$	0	$1/2Fx^2-1/4qx^3$	0	$1/4x^2$		
	totali						$-11/12Fb^3/EJ$	$1/2Xb^3/EJ$
	iperstatica $X=V_H$						$11/6F$	

Sviluppi di calcolo iperstatica

$$L_{FG}^{xx} = \int_0^b (1/4 x^2/b^2) b^2 1/EJ dx = [1/12 x^3/b^2]_0^b b^2 1/EJ$$

$$= (1/12 b) b^2 1/EJ = 1/12 b^3/EJ$$

$$L_{GF}^{xx} = \int_0^b (1/4 - 1/2 x/b + 1/4 x^2/b^2) b^2 1/EJ dx = [1/4 x - 1/4 x^2/b + 1/12 x^3/b^2]_0^b b^2 1/EJ$$

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

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

$$= (b - b + 1/3 b) b^2 1/EJ = 1/3 b^3/EJ$$

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

$$= (1/3 b) b^2 1/EJ = 1/3 b^3/EJ$$

$$L_{GA}^{xx} = \int_0^b (1/4 - 1/2 x/b + 1/4 x^2/b^2) b^2 1/EJ dx = [1/4 x - 1/4 x^2/b + 1/12 x^3/b^2]_0^b b^2 1/EJ$$

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

$$L_{AG}^{xx} = \int_0^b (1/4 x^2/b^2) b^2 1/EJ dx = [1/12 x^3/b^2]_0^b b^2 1/EJ$$

$$= (1/12 b) b^2 1/EJ = 1/12 b^3/EJ$$

$$L_{FG}^{xo} = \int_0^b (-x^2/b^2 + 1/4 x^3/b^3) Fb^2 1/EJ dx + \int_0^b (-1/2 x/b) \theta dx$$

$$= [-1/3 x^3/b^2 + 1/16 x^4/b^3]_0^b Fb^2 1/EJ + [-1/4 x^2/b]_0^b \theta$$

$$= (-1/3 b + 1/16 b) Fb^2 1/EJ + (-1/4 b) \theta = -25/48 Fb^3/EJ$$

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

$$= [-3/4 x + 5/8 x^2/b - 1/12 x^3/b^2 - 1/16 x^4/b^3]_0^b Fb^2 1/EJ + [1/2 x - 1/4 x^2/b]_0^b \theta$$

$$= (-3/4 b + 5/8 b - 1/12 b - 1/16 b) Fb^2 1/EJ + (1/2 b - 1/4 b) \theta = -25/48 Fb^3/EJ$$

$$L_{GD}^{xo} = \int_0^b (-1 + x/b) Fb^2 1/EJ dx = [-x + 1/2 x^2/b]_0^b Fb^2 1/EJ$$

$$= (-b + 1/2 b) Fb^2 1/EJ = -1/2 Fb^3/EJ$$

$$L_{DG}^{xo} = \int_0^b (-x/b) Fb^2 1/EJ dx = [-1/2 x^2/b]_0^b Fb^2 1/EJ$$

$$= (-1/2 b) Fb^2 1/EJ = -1/2 Fb^3/EJ$$

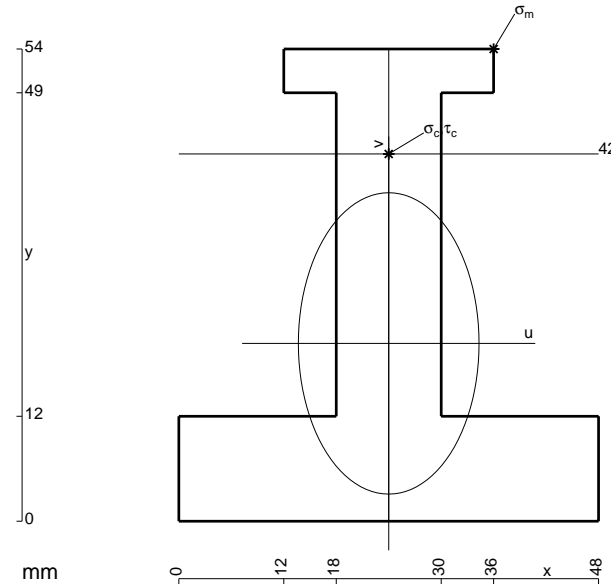
$$L_{GA}^{xo} = \int_0^b (1/4 - 1/4 x/b - 1/4 x^2/b^2 + 1/4 x^3/b^3) Fb^2 1/EJ dx$$

$$= [1/4 x - 1/8 x^2/b - 1/12 x^3/b^2 + 1/16 x^4/b^3]_0^b Fb^2 1/EJ$$

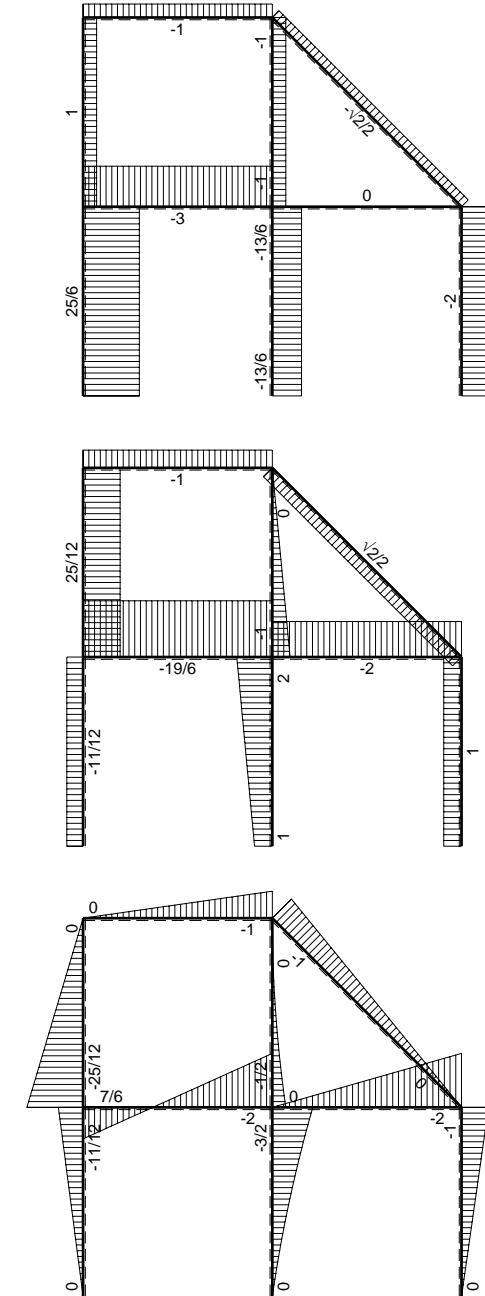
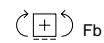
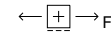
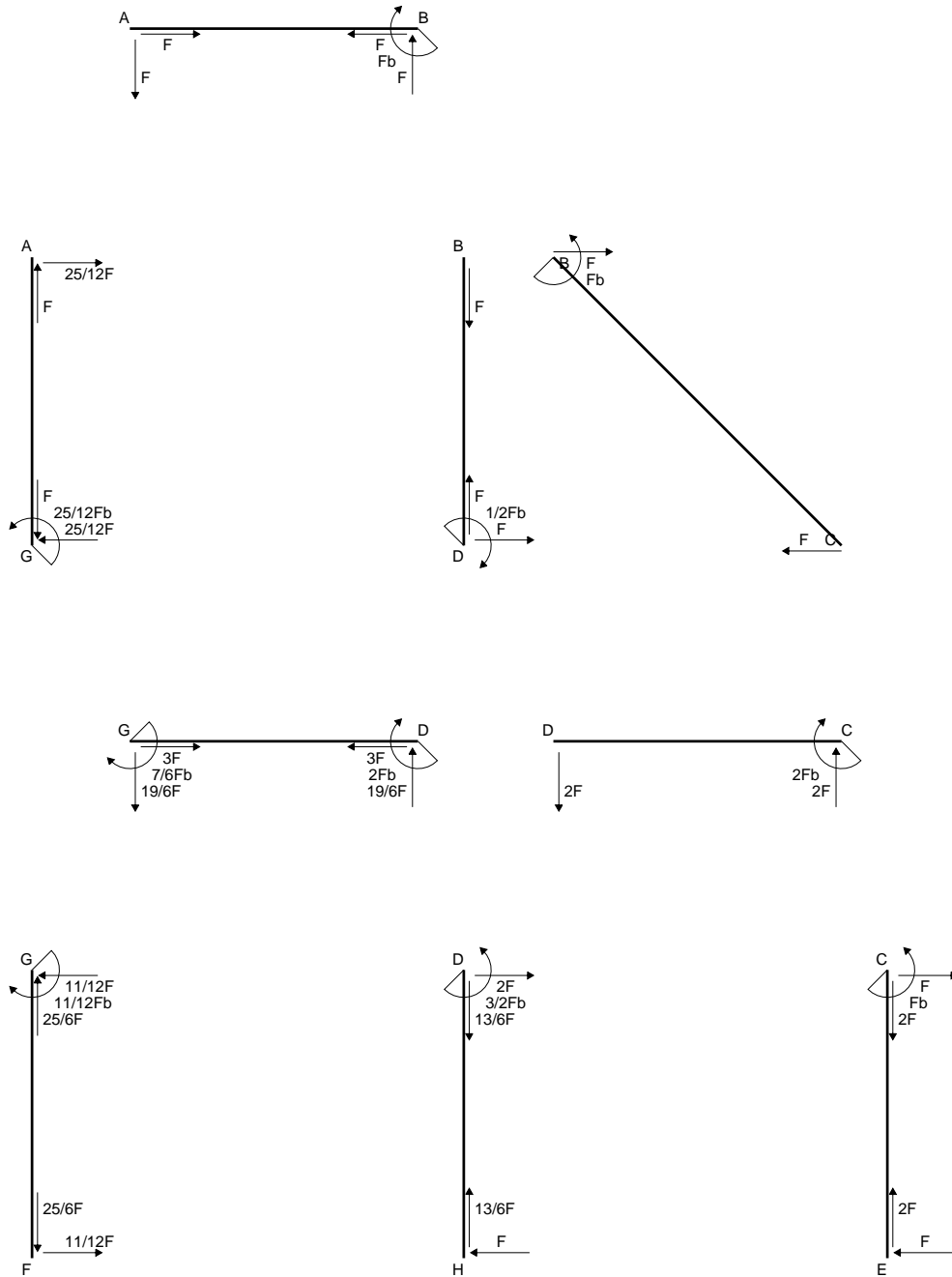
$$= (1/4 b - 1/8 b - 1/12 b + 1/16 b) Fb^2 1/EJ = 5/48 Fb^3/EJ$$

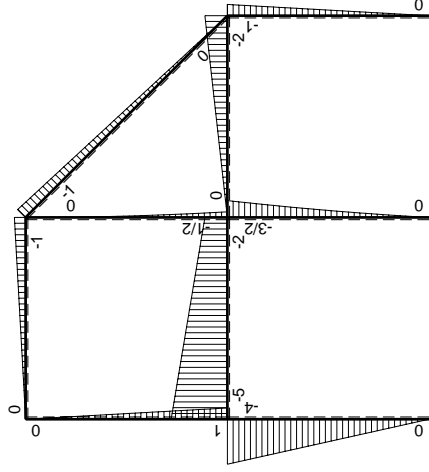
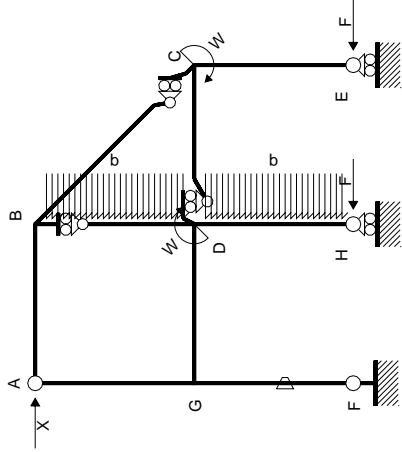
$$L_{AG}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/4 x^3/b^3) Fb^2 1/EJ dx = [1/6 x^3/b^2 - 1/16 x^4/b^3]_0^b Fb^2 1/EJ$$

$$= (1/6 b - 1/16 b) Fb^2 1/EJ = 5/48 Fb^3/EJ$$



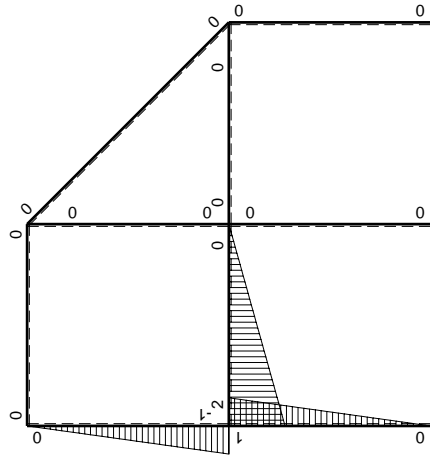
- A = 1140. mm<sup>2</sup>
- J<sub>u</sub> = 338607. mm<sup>4</sup>
- J<sub>v</sub> = 121680. mm<sup>4</sup>
- y<sub>g</sub> = 20.33 mm
- T<sub>y</sub> = -3760. N
- M<sub>x</sub> = -2105600. Nmm
- x<sub>m</sub> = 36. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 12. mm
- v<sub>m</sub> = 33.67 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 209.4 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 42. mm
- v<sub>c</sub> = 21.67 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 134.7 N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.417 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 = 5854. 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  $X=H_A$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$
AB b	0	-Fx	0	0	0	0	0+0	0
BA b	0	Fb-Fx	0	0	0	0		
BC $\sqrt{2}b$	0	-Fb+ $\sqrt{2}/2Fx$	0	0	0	0	0	0
BD b	0	-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
DB b	0	1/2Fb-Fx+1/2qx <sup>2</sup>	0	0	0	0		
DC b	0	-2Fx	0	0	0	0	0+0	0
CD b	0	2Fb-2Fx	0	0	0	0		
CE b	0	-Fb+Fx	0	0	0	0	0+0	0
EC b	0	Fx	0	0	0	0		
FG b	x	-4Fx	-Fb/EJ	-4Fx <sup>2</sup>	-Fxb/EJ	x <sup>2</sup>	(-4/3-1/2)Fb <sup>3</sup> /EJ	1/3Xb <sup>3</sup> /EJ
GF b	-b+x	4Fb-4Fx	Fb/EJ	-4Fb <sup>2</sup> +8Fbx-4Fx <sup>2</sup>	-Fb <sup>2</sup> /EJ+Fxb/EJ	b <sup>2</sup> -2bx+x <sup>2</sup>		
GD b	2b-2x	-5Fb+3Fx	0	-10Fb <sup>2</sup> +16Fbx-6Fx <sup>2</sup>	0	4b <sup>2</sup> -8bx+4x <sup>2</sup>	(-4+0)Fb <sup>3</sup> /EJ	4/3Xb <sup>3</sup> /EJ
DG b	-2x	2Fb+3Fx	0	-4Fbx-6Fx <sup>2</sup>	0	4x <sup>2</sup>		
DH b	0	-3/2Fb+2Fx-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
HD b	0	Fx+1/2qx <sup>2</sup>	0	0	0	0		
GA b	-b+x	Fb-Fx	0	-Fb <sup>2</sup> +2Fbx-Fx <sup>2</sup>	0	b <sup>2</sup> -2bx+x <sup>2</sup>	(-1/3+0)Fb <sup>3</sup> /EJ	1/3Xb <sup>3</sup> /EJ
AG b	x	-Fx	0	-Fx <sup>2</sup>	0	x <sup>2</sup>		
	totali						-37/6Fb <sup>3</sup> /EJ	2Xb <sup>3</sup> /EJ
	iperstatica $X=H_A$						37/12F	

Sviluppi di calcolo iperstatica

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

$$= (1/3 b) b^2 1/EJ = 1/3 b^3/EJ$$

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

$$= (b - b + 1/3 b) b^2 1/EJ = 1/3 b^3/EJ$$

$$L_{GD}^{xx} = \int_0^b (4 - 8x/b + 4x^2/b^2) b^2 1/EJ dx = [4x - 4x^2/b + 4/3 x^3/b^2]_0^b b^2 1/EJ$$

$$= (4b - 4b + 4/3 b) b^2 1/EJ = 4/3 b^3/EJ$$

$$L_{DG}^{xx} = \int_0^b (4x^2/b^2) b^2 1/EJ dx = [4/3 x^3/b^2]_0^b b^2 1/EJ$$

$$= (4/3 b) b^2 1/EJ = 4/3 b^3/EJ$$

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

$$= (b - b + 1/3 b) b^2 1/EJ = 1/3 b^3/EJ$$

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

$$= (1/3 b) b^2 1/EJ = 1/3 b^3/EJ$$

$$L_{FG}^{xo} = \int_0^b (-4x^2/b^2) Fb^2 1/EJ dx + \int_0^b (-x/b) \theta dx = [-4/3 x^3/b^2]_0^b Fb^2 1/EJ + [-1/2 x^2/b]_0^b \theta$$

$$= (-4/3 b) Fb^2 1/EJ + (-1/2 b) \theta = -11/6 Fb^3/EJ$$

$$L_{GF}^{xo} = \int_0^b (-4 + 8x/b - 4x^2/b^2) Fb^2 1/EJ dx + \int_0^b (1 - x/b) \theta dx$$

$$= [-4x + 4x^2/b - 4/3 x^3/b^2]_0^b Fb^2 1/EJ + [x - 1/2 x^2/b]_0^b \theta$$

$$= (-4b + 4b - 4/3 b) Fb^2 1/EJ + (b - 1/2 b) \theta = -11/6 Fb^3/EJ$$

$$L_{GD}^{xo} = \int_0^b (-10 + 16x/b - 6x^2/b^2) Fb^2 1/EJ dx = [-10x + 8x^2/b - 2x^3/b^2]_0^b Fb^2 1/EJ$$

$$= (-10b + 8b - 2b) Fb^2 1/EJ = -4 Fb^3/EJ$$

$$L_{DG}^{xo} = \int_0^b (-4x/b - 6x^2/b^2) Fb^2 1/EJ dx = [-2x^2/b - 2x^3/b^2]_0^b Fb^2 1/EJ$$

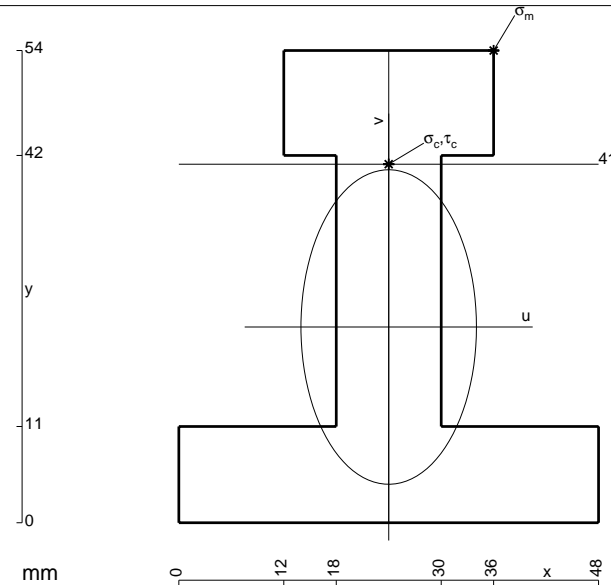
$$= (-2b - 2b) Fb^2 1/EJ = -4 Fb^3/EJ$$

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

$$= (-b + b - 1/3 b) Fb^2 1/EJ = -1/3 Fb^3/EJ$$

$$L_{AG}^{xo} = \int_0^b (-x^2/b^2) Fb^2 1/EJ dx = [-1/3 x^3/b^2]_0^b Fb^2 1/EJ$$

$$= (-1/3 b) Fb^2 1/EJ = -1/3 Fb^3/EJ$$



$$A = 1188. \text{ mm}^2$$

$$J_u = 384370. \text{ mm}^4$$

$$J_v = 119664. \text{ mm}^4$$

$$y_g = 22.38 \text{ mm}$$

$$T_y = -4220. \text{ N}$$

$$M_x = -2785200. \text{ Nmm}$$

$$x_m = 36. \text{ mm}$$

$$y_m = 54. \text{ mm}$$

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

$$v_m = 31.62 \text{ mm}$$

$$\sigma_m = -Mv/J_u = 229.1 \text{ N/mm}^2$$

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

$$y_c = 41. \text{ mm}$$

$$v_c = 18.62 \text{ mm}$$

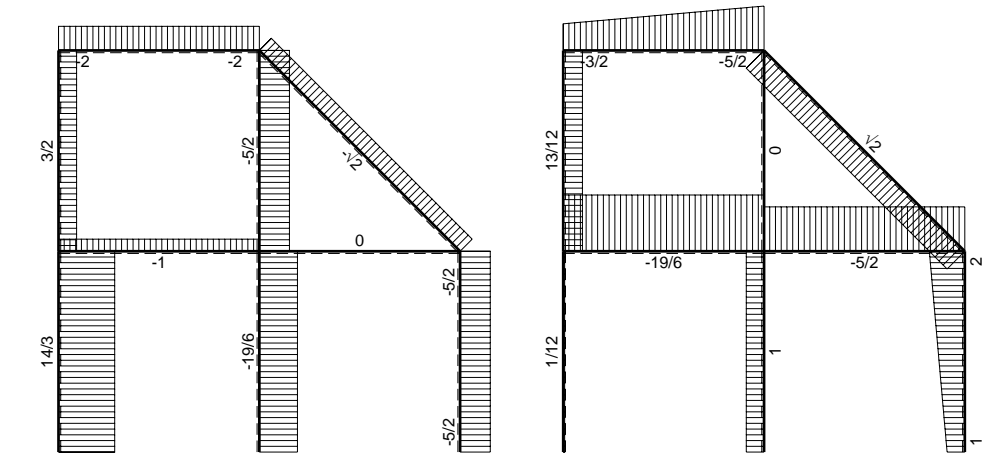
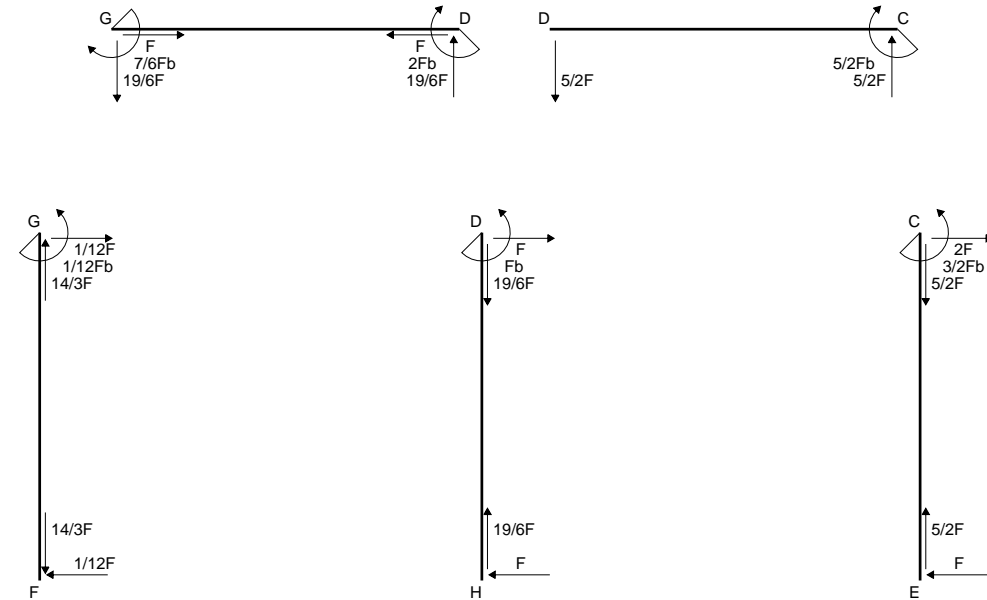
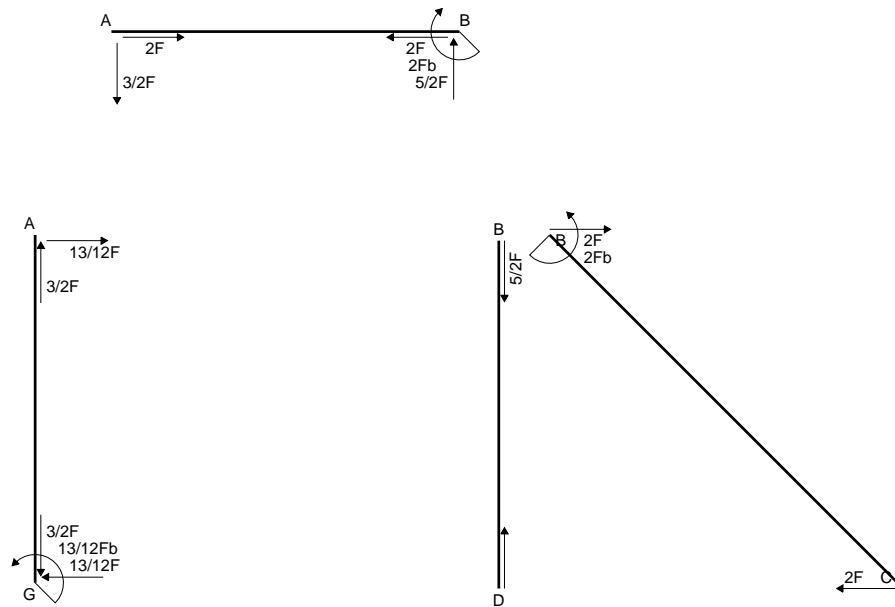
$$\sigma_c = -Mv/J_u = 134.9 \text{ N/mm}^2$$

$$\tau_c = 6.961 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 135.5 \text{ N/mm}^2$$

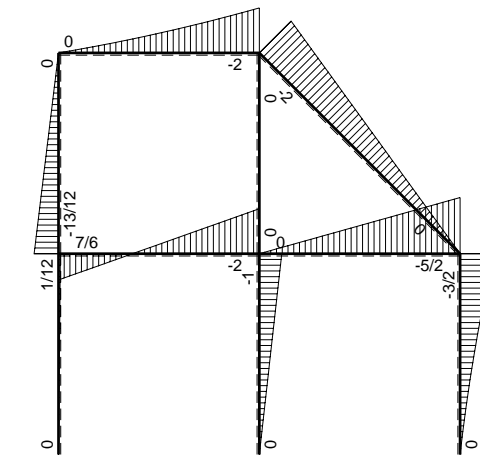
$$S = 7608. \text{ mm}^3$$



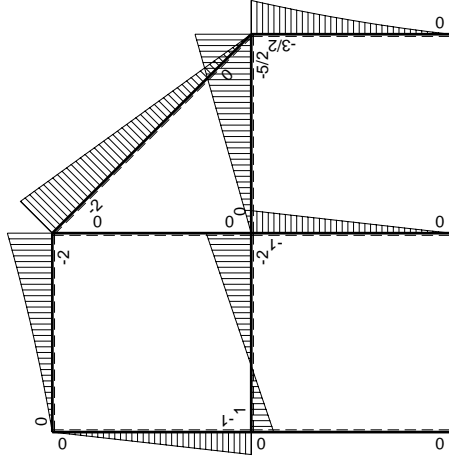
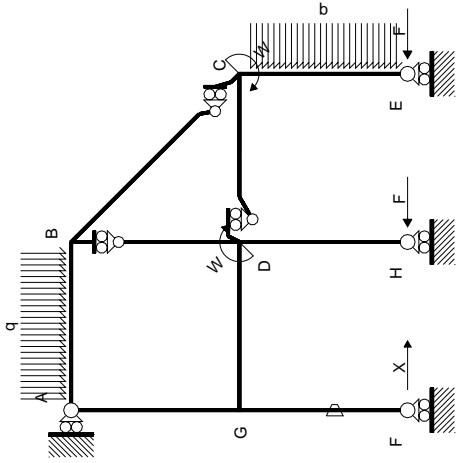


← ⊕ → F

↑ ⊕ ↓ F

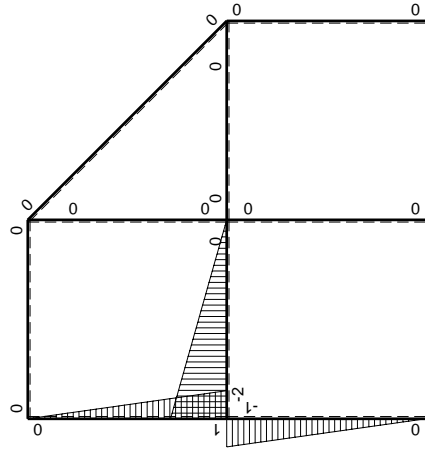


⊕ ⊖ F<sub>b</sub>



Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_X$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=H_f$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$
AB b	0	$-3/2Fx-1/2qx^2$	0	0	0	0	0+0	0
BA b	0	$2Fb-5/2Fx+1/2qx^2$	0	0	0	0	0	0
BC $\sqrt{2}b$	0	$-2Fb+\sqrt{2}Fx$	0	0	0	0	0	0
BD b	0	0	0	0	0	0	0+0	0
DB b	0	0	0	0	0	0	0	0
DC b	0	$-5/2Fx$	0	0	0	0	0+0	0
CD b	0	$5/2Fb-5/2Fx$	0	0	0	0	0	0
CE b	0	$-3/2Fb+2Fx-1/2qx^2$	0	0	0	0	0+0	0
EC b	0	$Fx+1/2qx^2$	0	0	0	0	0	0
FG b	-x	0	$-Fb/EJ$	0	$Fxb/EJ$	$x^2$	$(0+1/2)Fb^3/EJ$	$1/3Xb^3/EJ$
GF b	b-x	0	$Fb/EJ$	0	$Fb^2/EJ-Fxb/EJ$	$b^2-2bx+x^2$		
GD b	$-2b+2x$	$Fb-3Fx$	0	$-2Fb^2+8Fbx-6Fx^2$	0	$4b^2-8bx+4x^2$	0+0	$4/3Xb^3/EJ$
DG b	2x	$2Fb-3Fx$	0	$4Fbx-6Fx^2$	0	$4x^2$		
DH b	0	$-Fb+Fx$	0	0	0	0	0+0	0
HD b	0	$Fx$	0	0	0	0		
GA b	b-x	$-Fb+Fx$	0	$-Fb^2+2Fbx-Fx^2$	0	$b^2-2bx+x^2$	$(-1/3+0)Fb^3/EJ$	$1/3Xb^3/EJ$
AG b	-x	$Fx$	0	$-Fx^2$	0	$x^2$		
	totali						$1/6Fb^3/EJ$	$2Xb^3/EJ$
	iperstatica $X=H_f$						$-1/12F$	

Sviluppi di calcolo iperstatica

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

$$= (1/3 b) b^2 1/EJ = 1/3 b^3/EJ$$

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

$$= (b - b + 1/3 b) b^2 1/EJ = 1/3 b^3/EJ$$

$$L_{GD}^{xx} = \int_0^b (4 - 8x/b + 4x^2/b^2) b^2 1/EJ dx = [4x - 4x^2/b + 4/3 x^3/b^2]_0^b b^2 1/EJ$$

$$= (4b - 4b + 4/3 b) b^2 1/EJ = 4/3 b^3/EJ$$

$$L_{DG}^{xx} = \int_0^b (4x^2/b^2) b^2 1/EJ dx = [4/3 x^3/b^2]_0^b b^2 1/EJ$$

$$= (4/3 b) b^2 1/EJ = 4/3 b^3/EJ$$

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

$$= (b - b + 1/3 b) b^2 1/EJ = 1/3 b^3/EJ$$

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

$$= (1/3 b) b^2 1/EJ = 1/3 b^3/EJ$$

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

$$= (1/2 b) \theta = 1/2 Fb^3/EJ$$

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

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

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

$$= (-2b + 4b - 2b) Fb^2 1/EJ = 0$$

$$L_{DG}^{xo} = \int_0^b (4x/b - 6x^2/b^2) Fb^2 1/EJ dx = [2x^2/b - 2x^3/b^2]_0^b Fb^2 1/EJ$$

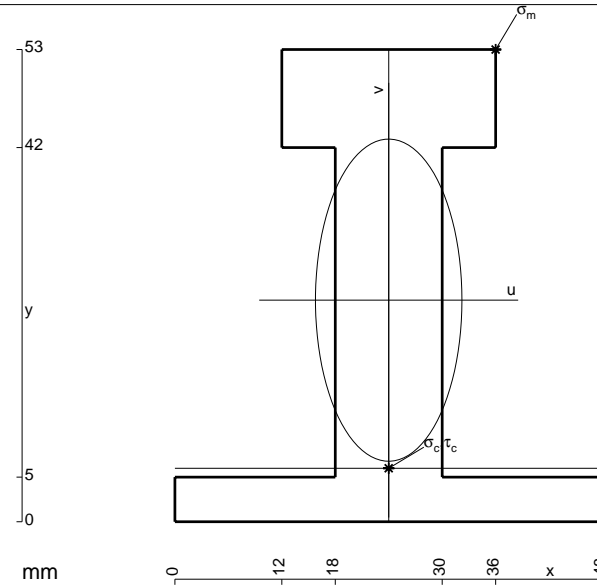
$$= (2b - 2b) Fb^2 1/EJ = 0$$

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

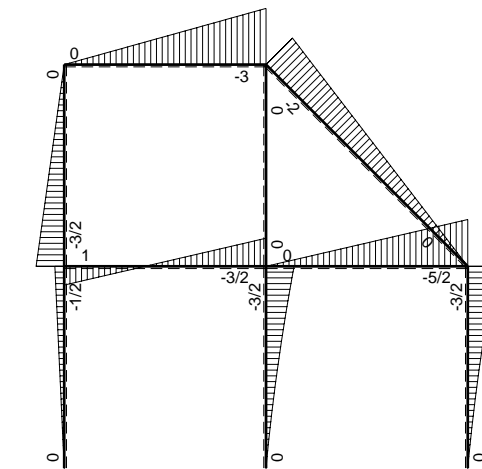
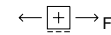
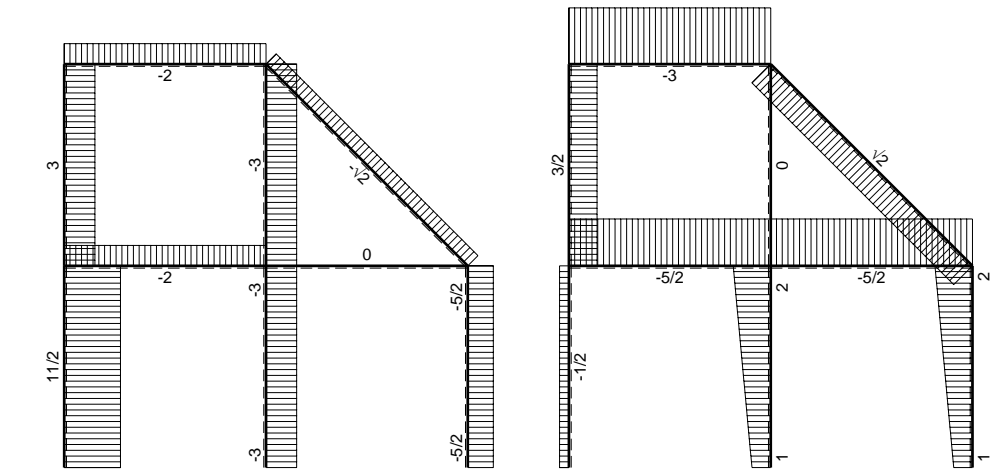
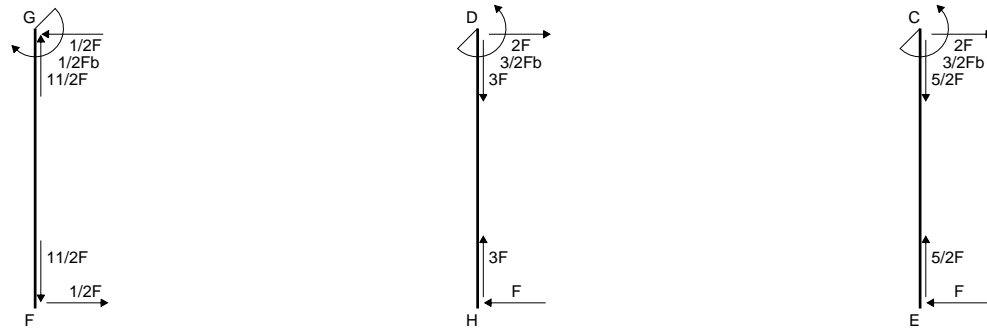
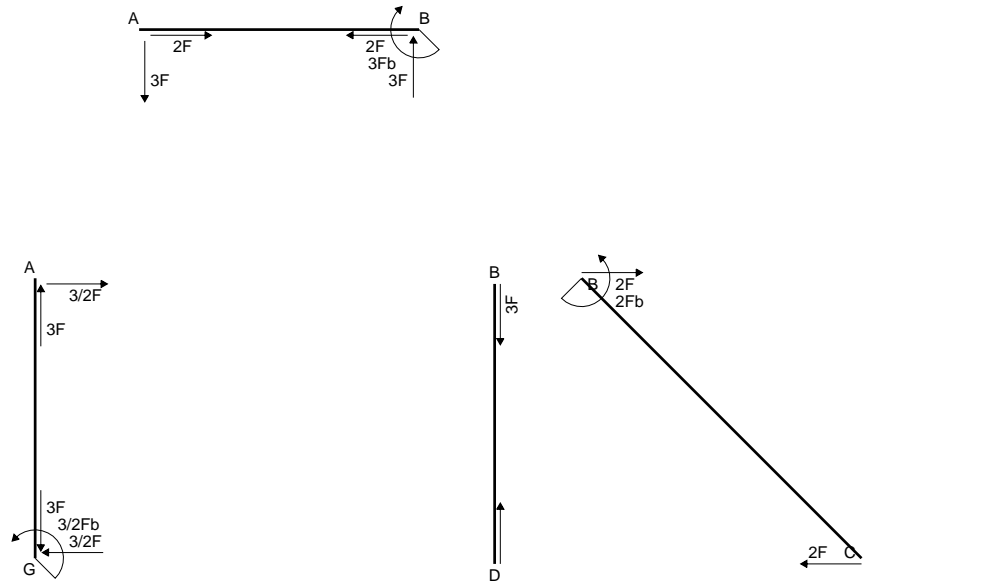
$$= (-b + b - 1/3 b) Fb^2 1/EJ = -1/3 Fb^3/EJ$$

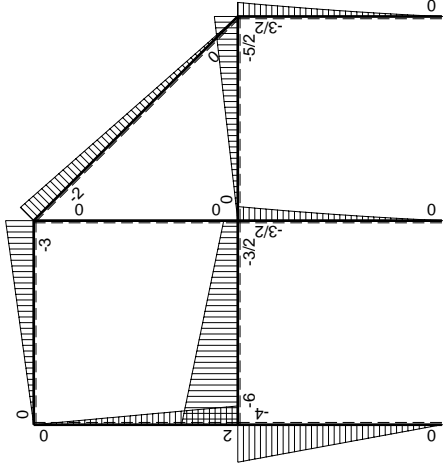
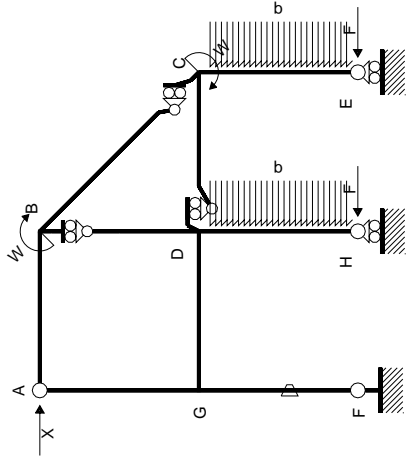
$$L_{AG}^{xo} = \int_0^b (-x^2/b^2) Fb^2 1/EJ dx = [-1/3 x^3/b^2]_0^b Fb^2 1/EJ$$

$$= (-1/3 b) Fb^2 1/EJ = -1/3 Fb^3/EJ$$



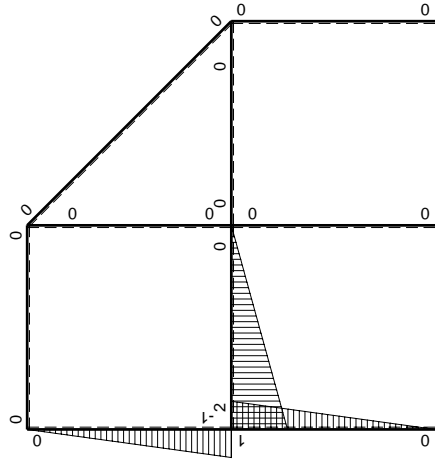
- A = 948. mm<sup>2</sup>
- J<sub>u</sub> = 309947. mm<sup>4</sup>
- J<sub>v</sub> = 64080. mm<sup>4</sup>
- y<sub>g</sub> = 24.87 mm
- T<sub>y</sub> = -3775. N
- M<sub>x</sub> = -2642500. Nmm
- x<sub>m</sub> = 36. mm
- y<sub>m</sub> = 53. mm
- u<sub>m</sub> = 12. mm
- v<sub>m</sub> = 28.13 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 239.9 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 6. mm
- v<sub>c</sub> = -18.87 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -160.9 N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.684 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 161.2 N/mm<sup>2</sup>
- S = 5601. 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  $X=H_A$ 

→	$M_x(x)$	$M_o(x)$	$\theta$	$M_x M_o$	$M_x \theta$	$M_x M_x$	$\int M_x(M_o/EJ+\theta)dx$	$\int x M_x M_x/EJ dx$
AB b	0	-3Fx	0	0	0	0	0+0	0
BA b	0	3Fb-3Fx	0	0	0	0		
BC $\sqrt{2}b$	0	-2Fb+ $\sqrt{2}Fx$	0	0	0	0	0	0
BD b	0	0	0	0	0	0	0+0	0
DB b	0	0	0	0	0	0		
DC b	0	-5/2Fx	0	0	0	0	0+0	0
CD b	0	5/2Fb-5/2Fx	0	0	0	0		
CE b	0	-3/2Fb+2Fx-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
EC b	0	Fx+1/2qx <sup>2</sup>	0	0	0	0		
FG b	x	-4Fx	-Fb/EJ	-4Fx <sup>2</sup>	-Fxb/EJ	x <sup>2</sup>	(-4/3-1/2)Fb <sup>3</sup> /EJ	1/3Xb <sup>3</sup> /EJ
GF b	-b+x	4Fb-4Fx	Fb/EJ	-4Fb <sup>2</sup> +8Fbx-4Fx <sup>2</sup>	-Fb <sup>2</sup> /EJ+Fxb/EJ	b <sup>2</sup> -2bx+x <sup>2</sup>		
GD b	2b-2x	-6Fb+9/2Fx	0	-12Fb <sup>2</sup> +21Fbx-9Fx <sup>2</sup>	0	4b <sup>2</sup> -8bx+4x <sup>2</sup>	(-9/2+0)Fb <sup>3</sup> /EJ	4/3Xb <sup>3</sup> /EJ
DG b	-2x	3/2Fb+9/2Fx	0	-3Fbx-9Fx <sup>2</sup>	0	4x <sup>2</sup>		
DH b	0	-3/2Fb+2Fx-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
HD b	0	Fx+1/2qx <sup>2</sup>	0	0	0	0		
GA b	-b+x	2Fb-2Fx	0	-2Fb <sup>2</sup> +4Fbx-2Fx <sup>2</sup>	0	b <sup>2</sup> -2bx+x <sup>2</sup>	(-2/3+0)Fb <sup>3</sup> /EJ	1/3Xb <sup>3</sup> /EJ
AG b	x	-2Fx	0	-2Fx <sup>2</sup>	0	x <sup>2</sup>		
	totali						-7Fb <sup>3</sup> /EJ	2Xb <sup>3</sup> /EJ
	iperstatica $X=H_A$						7/2F	

Sviluppi di calcolo iperstatica

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

$$= (1/3 b) b^2 1/EJ = 1/3 b^3/EJ$$

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

$$= (b - b + 1/3 b) b^2 1/EJ = 1/3 b^3/EJ$$

$$L_{GD}^{xx} = \int_0^b (4 - 8x/b + 4x^2/b^2) b^2 1/EJ dx = [4x - 4x^2/b + 4/3 x^3/b^2]_0^b b^2 1/EJ$$

$$= (4b - 4b + 4/3 b) b^2 1/EJ = 4/3 b^3/EJ$$

$$L_{DG}^{xx} = \int_0^b (4x^2/b^2) b^2 1/EJ dx = [4/3 x^3/b^2]_0^b b^2 1/EJ$$

$$= (4/3 b) b^2 1/EJ = 4/3 b^3/EJ$$

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

$$= (b - b + 1/3 b) b^2 1/EJ = 1/3 b^3/EJ$$

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

$$= (1/3 b) b^2 1/EJ = 1/3 b^3/EJ$$

$$L_{FG}^{xo} = \int_0^b (-4x^2/b^2) Fb^2 1/EJ dx + \int_0^b (-x/b) \theta dx = [-4/3 x^3/b^2]_0^b Fb^2 1/EJ + [-1/2 x^2/b]_0^b \theta$$

$$= (-4/3 b) Fb^2 1/EJ + (-1/2 b) \theta = -11/6 Fb^3/EJ$$

$$L_{GF}^{xo} = \int_0^b (-4 + 8x/b - 4x^2/b^2) Fb^2 1/EJ dx + \int_0^b (1 - x/b) \theta dx$$

$$= [-4x + 4x^2/b - 4/3 x^3/b^2]_0^b Fb^2 1/EJ + [x - 1/2 x^2/b]_0^b \theta$$

$$= (-4b + 4b - 4/3 b) Fb^2 1/EJ + (b - 1/2 b) \theta = -11/6 Fb^3/EJ$$

$$L_{GD}^{xo} = \int_0^b (-12 + 21x/b - 9x^2/b^2) Fb^2 1/EJ dx = [-12x + 21/2 x^2/b - 3x^3/b^2]_0^b Fb^2 1/EJ$$

$$= (-12b + 21/2 b - 3b) Fb^2 1/EJ = -9/2 Fb^3/EJ$$

$$L_{DG}^{xo} = \int_0^b (-3x/b - 9x^2/b^2) Fb^2 1/EJ dx = [-3/2 x^2/b - 3x^3/b^2]_0^b Fb^2 1/EJ$$

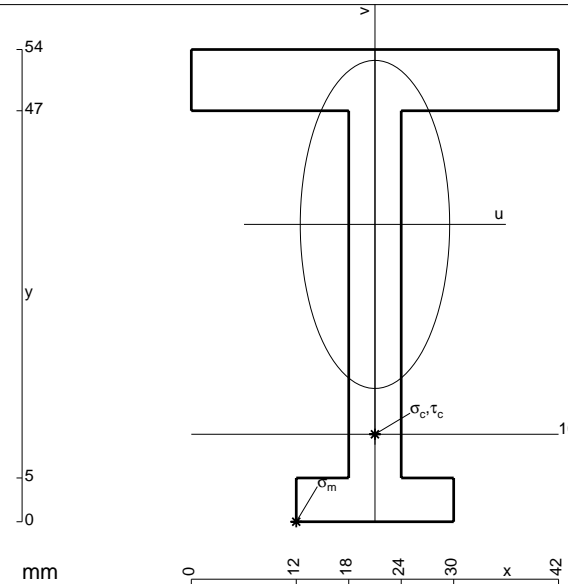
$$= (-3/2 b - 3b) Fb^2 1/EJ = -9/2 Fb^3/EJ$$

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

$$= (-2b + 2b - 2/3 b) Fb^2 1/EJ = -2/3 Fb^3/EJ$$

$$L_{AG}^{xo} = \int_0^b (-2x^2/b^2) Fb^2 1/EJ dx = [-2/3 x^3/b^2]_0^b Fb^2 1/EJ$$

$$= (-2/3 b) Fb^2 1/EJ = -2/3 Fb^3/EJ$$



$$A = 636. \text{ mm}^2$$

$$J_u = 223904. \text{ mm}^4$$

$$J_v = 46404. \text{ mm}^4$$

$$y_g = 34. \text{ mm}$$

$$N = -1500. \text{ N}$$

$$T_y = -2250. \text{ N}$$

$$M_x = -1485000. \text{ Nmm}$$

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

$$u_m = -9. \text{ mm}$$

$$v_m = -34. \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -227.9 \text{ N/mm}^2$$

$$x_c = 21. \text{ mm}$$

$$y_c = 10. \text{ mm}$$

$$v_c = -24. \text{ mm}$$

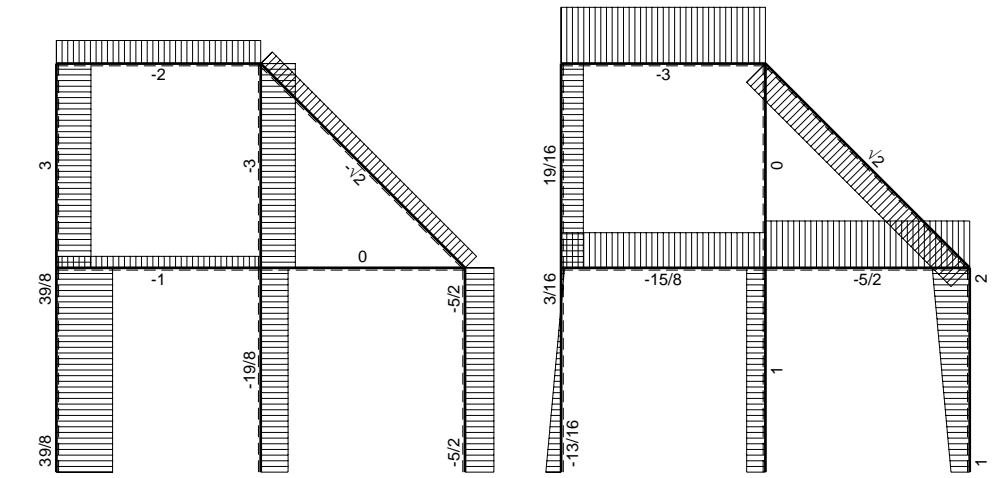
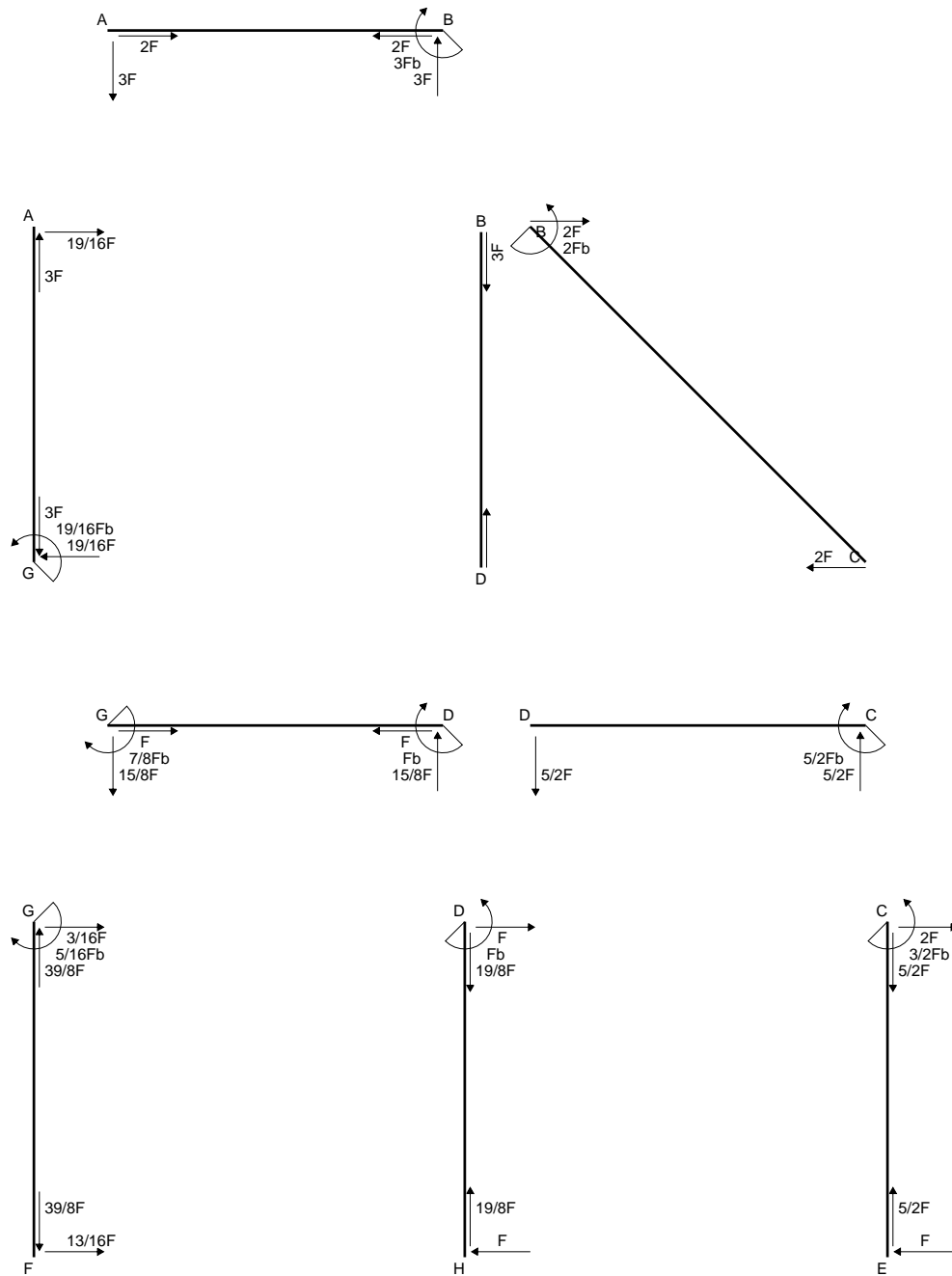
$$\sigma_c = N/A - Mv/J_u = -161.5 \text{ N/mm}^2$$

$$\tau_c = 6.08 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 161.9 \text{ N/mm}^2$$

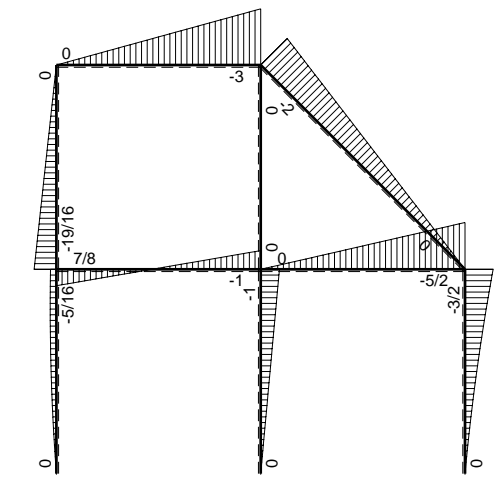
$$S = 3630. \text{ mm}^3$$



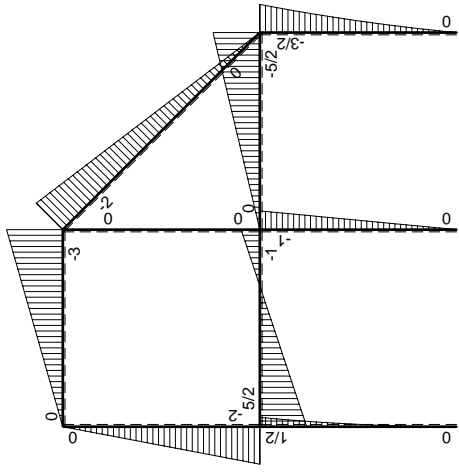
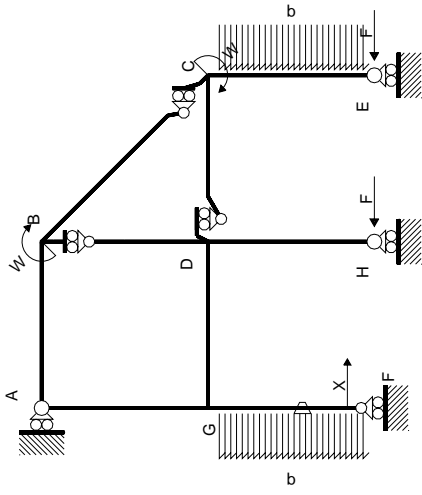


← ⊕ → F

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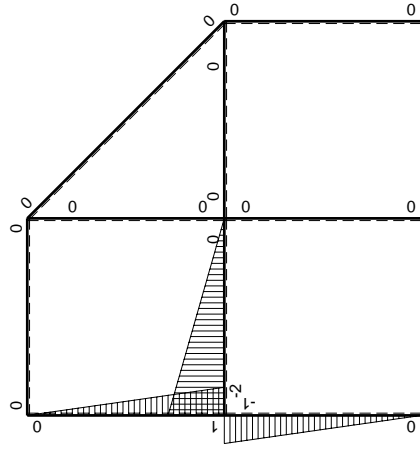


⊕ ⊖ Mb



Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica X=H<sub>FG</sub>

→	M <sub>x</sub> (x)	M <sub>o</sub> (x)	θ	M <sub>x</sub> M <sub>o</sub>	M <sub>x</sub> θ	M <sub>x</sub> M <sub>x</sub>	∫M <sub>x</sub> (M <sub>o</sub> /EJ+θ)dx	∫XM <sub>x</sub> M <sub>x</sub> /EJdx	
AB b	0	-3Fx	0	0	0	0	0+0	0	
BA b	0	3Fb-3Fx	0	0	0	0	0	0	
BC √2b	0	-2Fb+√2Fx	0	0	0	0	0	0	
BD b	0	0	0	0	0	0	0+0	0	
DB b	0	0	0	0	0	0	0	0	
DC b	0	-5/2Fx	0	0	0	0	0+0	0	
CD b	0	5/2Fb-5/2Fx	0	0	0	0	0	0	
CE b	0	-3/2Fb+2Fx-1/2qx <sup>2</sup>	0	0	0	0	0+0	0	
EC b	0	Fx+1/2qx <sup>2</sup>	0	0	0	0	0	0	
FG b	-x	1/2qx <sup>2</sup>	-Fb/EJ	-1/2qx <sup>3</sup>	Fxb/EJ	x <sup>2</sup>	(-1/8+1/2)Fb <sup>3</sup> /EJ	1/3Xb <sup>3</sup> /EJ	
GF b	b-x	-1/2Fb+Fx-1/2qx <sup>2</sup>	Fb/EJ	-1/2Fb <sup>2</sup> +3/2Fbx-3/2Fx <sup>2</sup> +1/2qx <sup>3</sup>	Fb <sup>2</sup> /EJ-Fxb/EJ	b <sup>2</sup> -2bx+x <sup>2</sup>			
GD b	-2b+2x	5/2Fb-7/2Fx	0	-5Fb <sup>2</sup> +12Fbx-7Fx <sup>2</sup>	0	4b <sup>2</sup> -8bx+4x <sup>2</sup>	(-4/3+0)Fb <sup>3</sup> /EJ	4/3Xb <sup>3</sup> /EJ	
DG b	2x	Fb-7/2Fx	0	2Fbx-7Fx <sup>2</sup>	0	4x <sup>2</sup>			
DH b	0	-Fb+Fx	0	0	0	0	0+0	0	
HD b	0	Fx	0	0	0	0	0	0	
GA b	b-x	-2Fb+2Fx	0	-2Fb <sup>2</sup> +4Fbx-2Fx <sup>2</sup>	0	b <sup>2</sup> -2bx+x <sup>2</sup>	(-2/3+0)Fb <sup>3</sup> /EJ	1/3Xb <sup>3</sup> /EJ	
AG b	-x	2Fx	0	-2Fx <sup>2</sup>	0	x <sup>2</sup>			
	totali							-13/8Fb <sup>3</sup> /EJ	2Xb <sup>3</sup> /EJ
	iperstatica X=H <sub>FG</sub>							13/16F	

Sviluppi di calcolo iperstatica

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

$$= (1/3 b) b^2 1/EJ = 1/3 b^3/EJ$$

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

$$= (b - b + 1/3 b) b^2 1/EJ = 1/3 b^3/EJ$$

$$L_{GD}^{xx} = \int_0^b (4 - 8x/b + 4x^2/b^2) b^2 1/EJ dx = [4x - 4x^2/b + 4/3 x^3/b^2]_0^b b^2 1/EJ$$

$$= (4b - 4b + 4/3 b) b^2 1/EJ = 4/3 b^3/EJ$$

$$L_{DG}^{xx} = \int_0^b (4x^2/b^2) b^2 1/EJ dx = [4/3 x^3/b^2]_0^b b^2 1/EJ$$

$$= (4/3 b) b^2 1/EJ = 4/3 b^3/EJ$$

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

$$= (b - b + 1/3 b) b^2 1/EJ = 1/3 b^3/EJ$$

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

$$= (1/3 b) b^2 1/EJ = 1/3 b^3/EJ$$

$$L_{FG}^{x\theta} = \int_0^b (-1/2 x^3/b^3) Fb^2 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/8 x^4/b^3]_0^b Fb^2 1/EJ + [1/2 x^2/b]_0^b \theta$$

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

$$L_{GF}^{x\theta} = \int_0^b (-1/2 + 3/2 x/b - 3/2 x^2/b^2 + 1/2 x^3/b^3) Fb^2 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-1/2 x + 3/4 x^2/b - 1/2 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb^2 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

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

$$L_{GD}^{x\theta} = \int_0^b (-5 + 12x/b - 7x^2/b^2) Fb^2 1/EJ dx = [-5x + 6x^2/b - 7/3 x^3/b^2]_0^b Fb^2 1/EJ$$

$$= (-5b + 6b - 7/3 b) Fb^2 1/EJ = -4/3 Fb^3/EJ$$

$$L_{DG}^{x\theta} = \int_0^b (2x/b - 7x^2/b^2) Fb^2 1/EJ dx = [x^2/b - 7/3 x^3/b^2]_0^b Fb^2 1/EJ$$

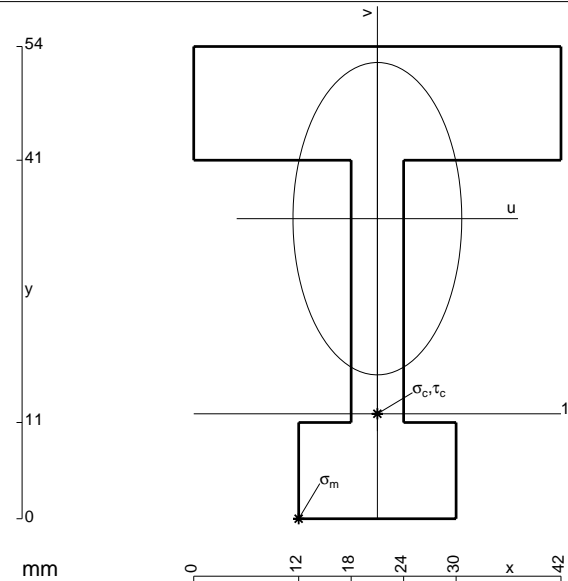
$$= (b - 7/3 b) Fb^2 1/EJ = -4/3 Fb^3/EJ$$

$$L_{GA}^{x\theta} = \int_0^b (-2 + 4x/b - 2x^2/b^2) Fb^2 1/EJ dx = [-2x + 2x^2/b - 2/3 x^3/b^2]_0^b Fb^2 1/EJ$$

$$= (-2b + 2b - 2/3 b) Fb^2 1/EJ = -2/3 Fb^3/EJ$$

$$L_{AG}^{x\theta} = \int_0^b (-2x^2/b^2) Fb^2 1/EJ dx = [-2/3 x^3/b^2]_0^b Fb^2 1/EJ$$

$$= (-2/3 b) Fb^2 1/EJ = -2/3 Fb^3/EJ$$



- A = 924. mm<sup>2</sup>
- J<sub>u</sub> = 294950. mm<sup>4</sup>
- J<sub>v</sub> = 86148. mm<sup>4</sup>
- y<sub>g</sub> = 34.31 mm
- N = -1420. N
- T<sub>y</sub> = -2130. N
- M<sub>x</sub> = -1938300. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -9. mm
- v<sub>m</sub> = -34.31 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = -227. N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 12. mm
- v<sub>c</sub> = -22.31 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = -148.2 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.031 N/mm<sup>2</sup>
- σ<sub>g</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 148.7 N/mm<sup>2</sup>
- S<sup>i</sup> = 5842. mm<sup>3</sup>