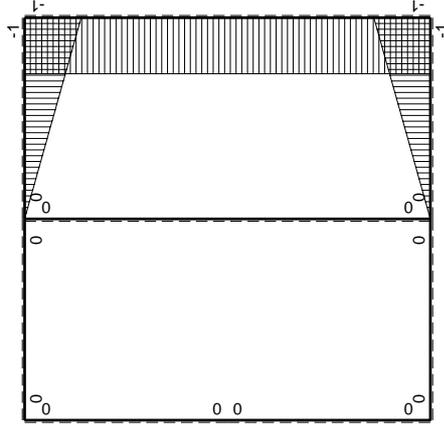


$M_0$ , flessione da carichi assegnati



$M_x$ , flessione da iperstatica  $X=1$

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

$\rightarrow$	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x (M^0/EJ + \theta) dx$	$\int M^x M_x / E J dx$
AB b	0	0	0	0	0	0	0	0
BA b	0	0	0	0	0	0	0	0
CD b	0	$-1/2Fx + 1/2Fx$	0	0	0	0	0	0
DC b	0	$1/2Fx$	0	0	0	0	0	0
DE b	0	0	0	0	0	0	0	0
EA b	0	0	0	0	0	0	0	0
AE b	0	0	0	0	0	0	0	0
BF b	$-x/b$	$1/2Fb + Fx - 1/2qx^2$	$-Fb/EJ$	$-1/2Fx - Fx^2/b + 1/2qx^3/b$	$Fx/EJ$	$x^2/b^2$	$(-1/1/24 + 1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$-Fb + 1/2qx^2$	$Fb/EJ$	$-Fb + Fx + 1/2Fx^2/b - 1/2qx^3/b$	$Fb/EJ - Fx/EJ$	$1-2x/b + x^2/b^2$	$(-1/1/24 + 1/2)Fb^2/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b + x^2/b^2$	0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0	$1/3xb/EJ$
FG 2b	-1	$2Fb - 2Fx + 1/2qx^2$	0	$-2Fb + 2Fx - 1/2Fx^2/b$	0	1	$(-4/3 + 0)Fb^2/EJ$	$2xb/EJ$
GF 2b	1	$-1/2qx^2$	0	$-1/2Fx^2/b$	0	1	$(-4/3 + 0)Fb^2/EJ$	$2xb/EJ$
CB 2b	0	$1/2Fb$	0	0	0	0	0	0
BC 2b	0	$-1/2Fb$	0	0	0	0	0	0
totali							$-31/24Fb^2/EJ$	$8/3xb/EJ$
								$31/64Fb$

Sviluppi di calcolo iperstatica

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

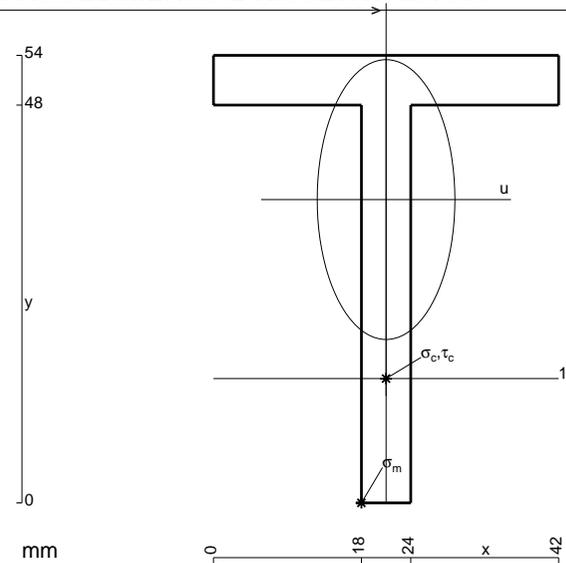
$$= (-b + 1/2 b + 1/6 b - 1/8 b) Fb 1/EJ + (-b + 1/2 b) \theta = 1/24 Fb^2/EJ$$

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

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

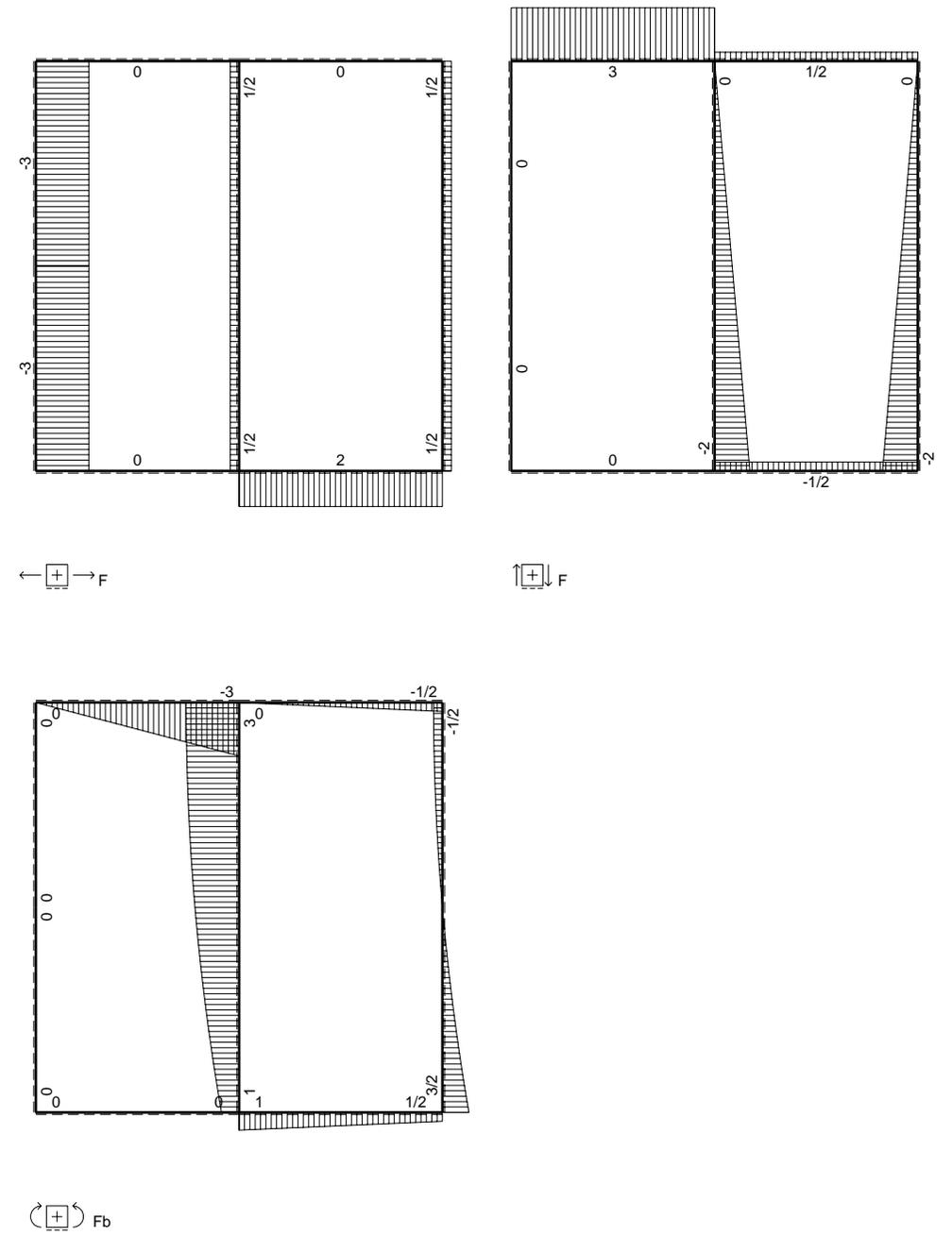
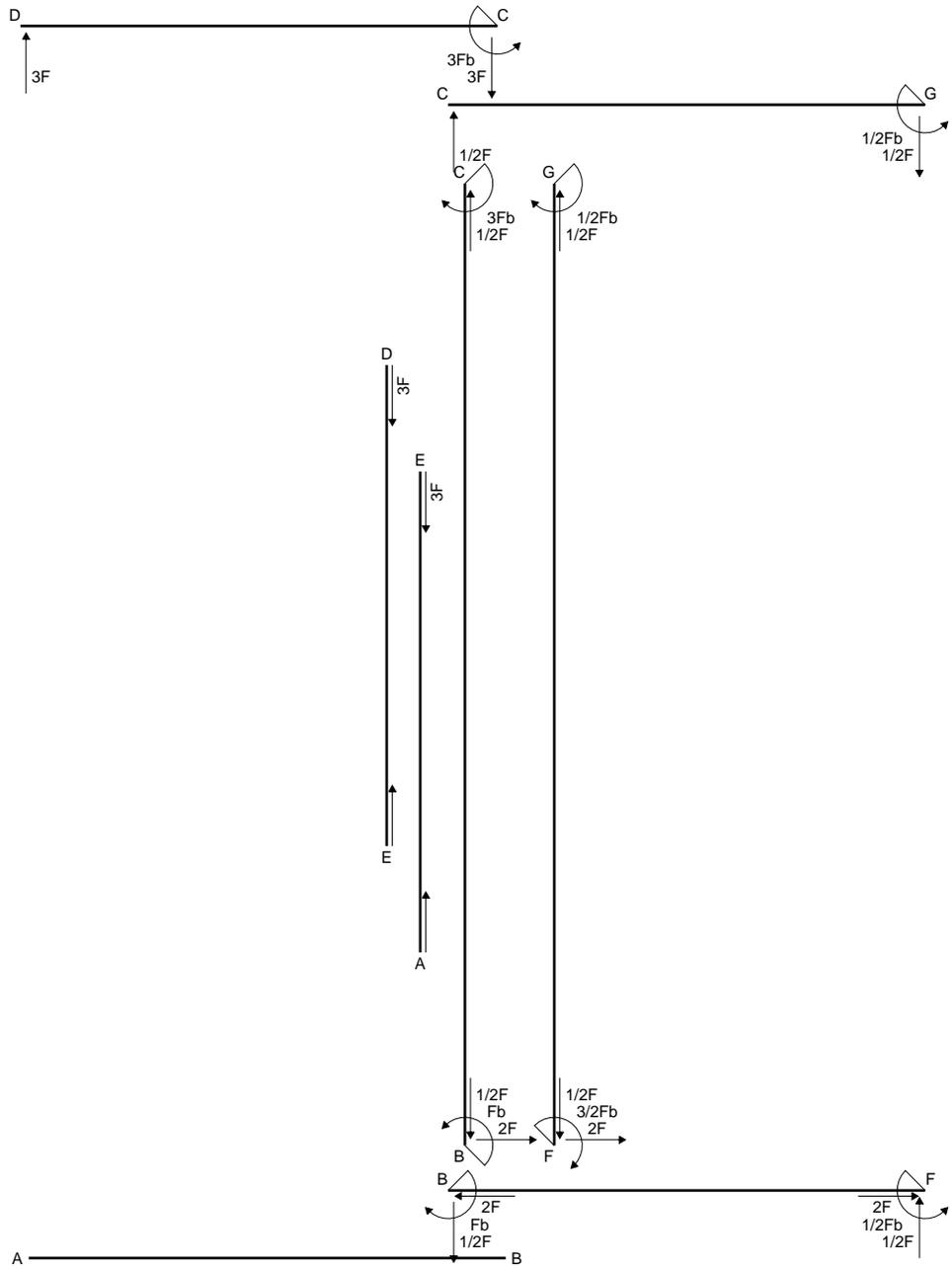
$$L_{GF}^{xo} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

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



- A = 540. mm<sup>2</sup>
- J<sub>u</sub> = 154030. mm<sup>4</sup>
- J<sub>v</sub> = 37908. mm<sup>4</sup>
- y<sub>g</sub> = 36.6 mm
- T<sub>y</sub> = 1880. N
- M<sub>x</sub> = -883600. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -36.6 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -210. N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 15. mm
- v<sub>c</sub> = -21.6 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -123.9 N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.328 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 124.3 N/mm<sup>2</sup>
- S = 2619. mm<sup>3</sup>







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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

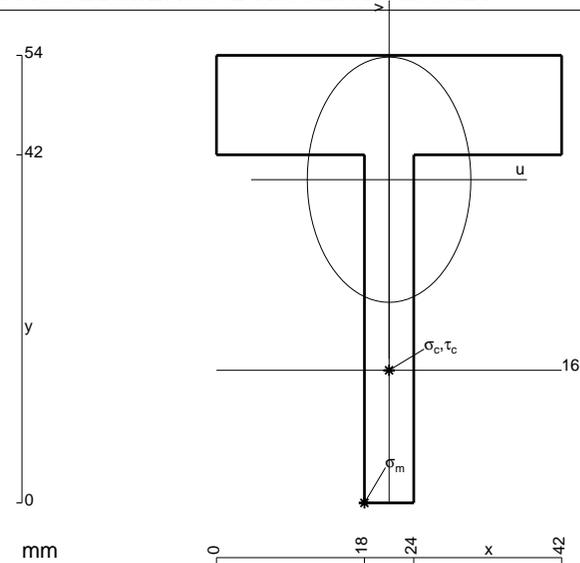
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

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

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

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

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



$$A = 756. \text{ mm}^2$$

$$J_u = 165564. \text{ mm}^4$$

$$J_v = 74844. \text{ mm}^4$$

$$y_g = 39. \text{ mm}$$

$$T_y = 1830. \text{ N}$$

$$M_x = -933300. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -39. \text{ mm}$$

$$\sigma_m = -Mv/J_u = -219.8 \text{ N/mm}^2$$

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

$$y_c = 16. \text{ mm}$$

$$v_c = -23. \text{ mm}$$

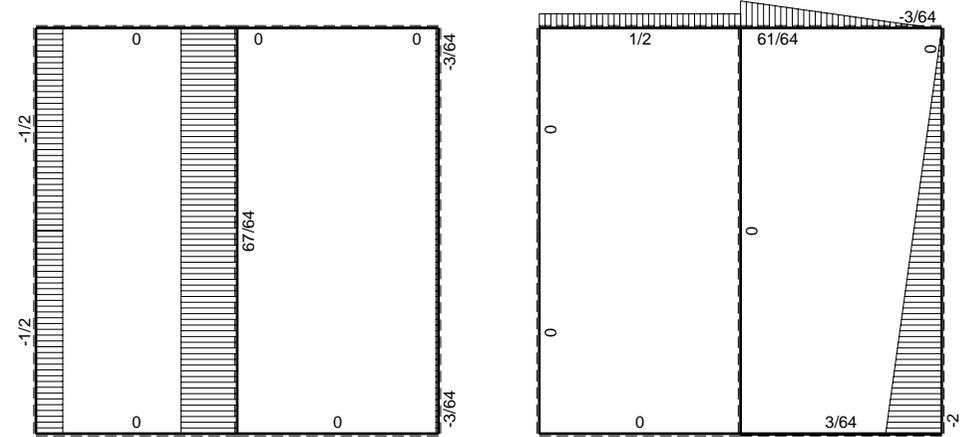
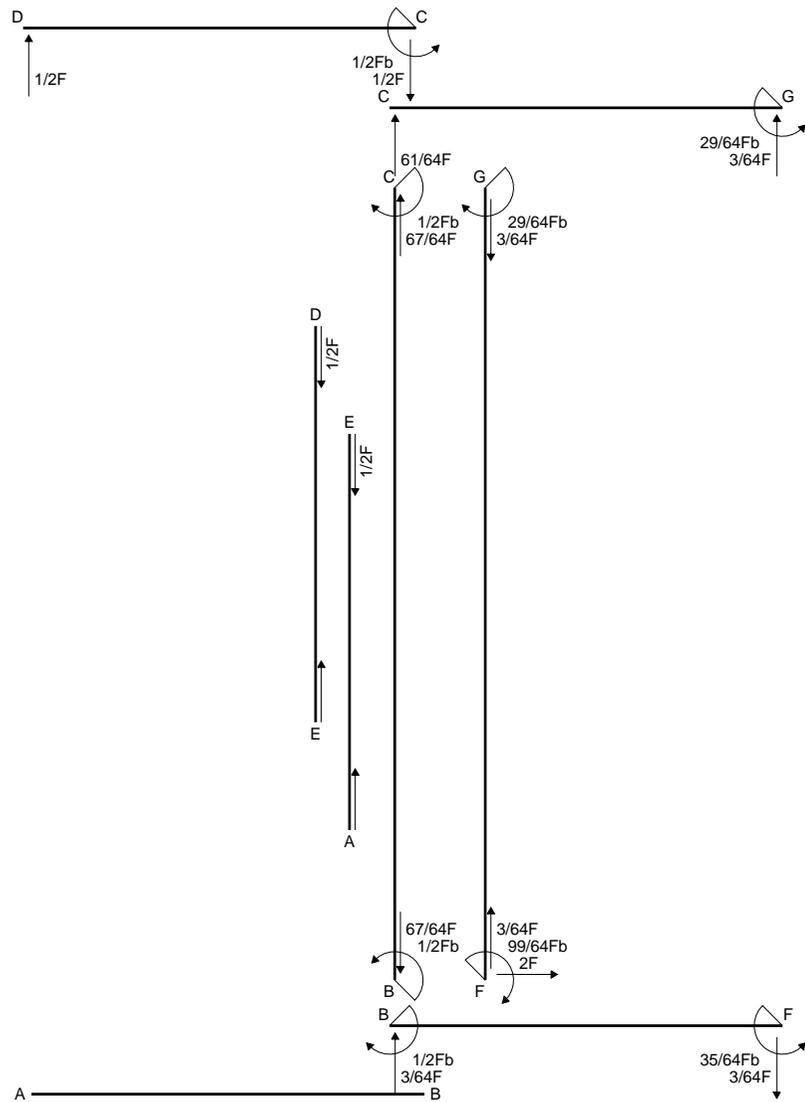
$$\sigma_c = -Mv/J_u = -129.7 \text{ N/mm}^2$$

$$\tau_c = 5.482 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma_c^2 + 3\tau_c^2} = 130. \text{ N/mm}^2$$

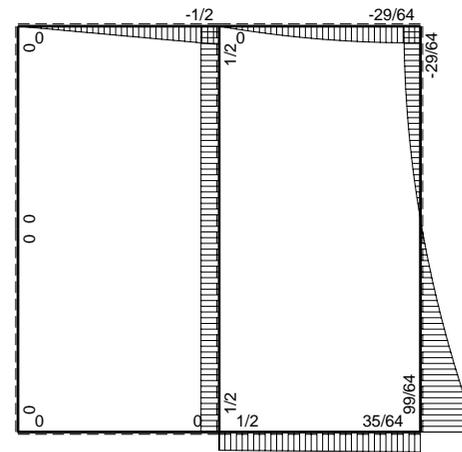
$$S = 2976. \text{ mm}^3$$



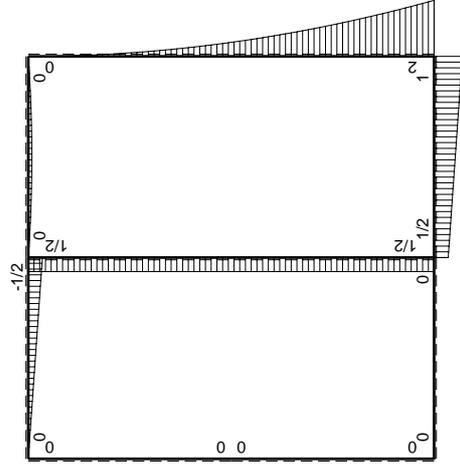
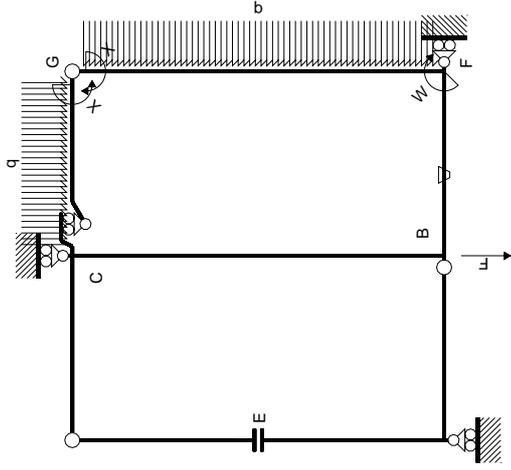


← ⊕ → F

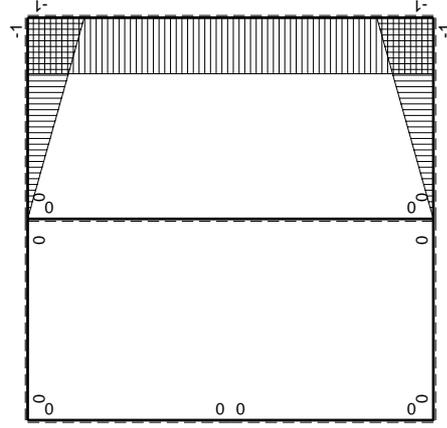
↑ ⊕ ↓ F



⊕ F<sub>b</sub>



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica X=W<sub>gc</sub>

←	M <sub>x</sub> (x)	M <sub>0</sub> (x)	θ	M <sub>x</sub> M <sub>0</sub>	M <sub>x</sub> θ	M <sub>x</sub> M <sub>x</sub>	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0+0	0
CD b	0	-1/2Fb+1/2Fx	0	0	0	0	0+0	0
DC b	0	1/2Fx	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
EA b	0	0	0	0	0	0	0+0	0
AE b	0	0	0	0	0	0	0+0	0
BF b	-x/b	1/2Fb+1/2Fx	-Fb/EJ	-1/2Fx-1/2Fx <sup>2</sup> /b	Fx/EJ	x <sup>2</sup> /b <sup>2</sup>	(-5/12+1/2)Fb <sup>2</sup> /EJ	1/3xb/EJ
FB b	1-x/b	-Fb+1/2Fx	Fb/EJ	-Fb+3/2Fx-1/2Fx <sup>2</sup> /b	Fb/EJ-Fx/EJ	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	(-5/12+1/2)Fb <sup>2</sup> /EJ	1/3xb/EJ
GC b	-1+x/b	-1/2Fx+1/2qx <sup>2</sup>	0	1/2Fx-Fx <sup>2</sup> /b+1/2qx <sup>3</sup> /b	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	(1/24+0)Fb <sup>2</sup> /EJ	1/3xb/EJ
CG b	x/b	1/2Fx-1/2qx <sup>2</sup>	0	1/2Fx <sup>2</sup> /b-1/2qx <sup>3</sup> /b	0	x <sup>2</sup> /b <sup>2</sup>	(1/24+0)Fb <sup>2</sup> /EJ	1/3xb/EJ
FG 2b	-1	2Fb-2Fx+1/2qx <sup>2</sup>	0	-2Fb+2Fx-1/2Fx <sup>2</sup> /b	0	1	(-4/3+0)Fb <sup>2</sup> /EJ	2xb/EJ
GF 2b	1	-1/2qx <sup>2</sup>	0	-1/2Fx <sup>2</sup> /b	0	1	(-4/3+0)Fb <sup>2</sup> /EJ	2xb/EJ
CB 2b	0	1/2Fb	0	0	0	0	0+0	0
BC 2b	0	-1/2Fb	0	0	0	0	0+0	0
totali							-29/24Fb <sup>2</sup> /EJ	8/3xb/EJ

iperstatica X=W<sub>gc</sub>

Sviluppi di calcolo iperstatica

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

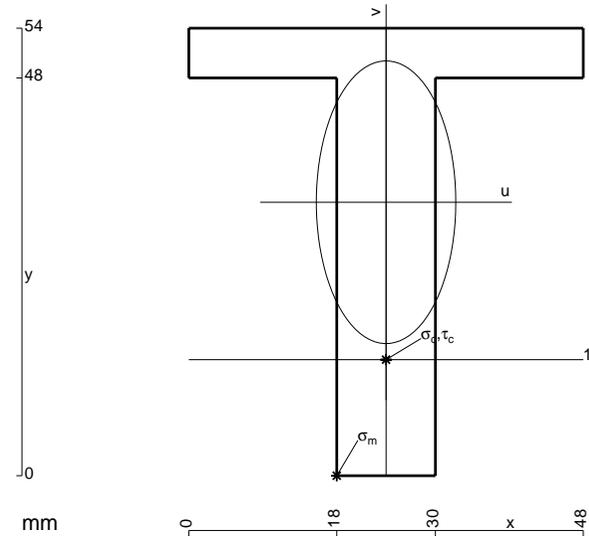
$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

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

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

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

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



$$A = 864. \text{ mm}^2$$

$$J_u = 251424. \text{ mm}^4$$

$$J_v = 62208. \text{ mm}^4$$

$$y_g = 33. \text{ mm}$$

$$T_y = 3185. \text{ N}$$

$$M_x = -1751750. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$u_m = -6. \text{ mm}$$

$$v_m = -33. \text{ mm}$$

$$\sigma_m = -Mv/J_u = -229.9 \text{ N/mm}^2$$

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

$$y_c = 14. \text{ mm}$$

$$v_c = -19. \text{ mm}$$

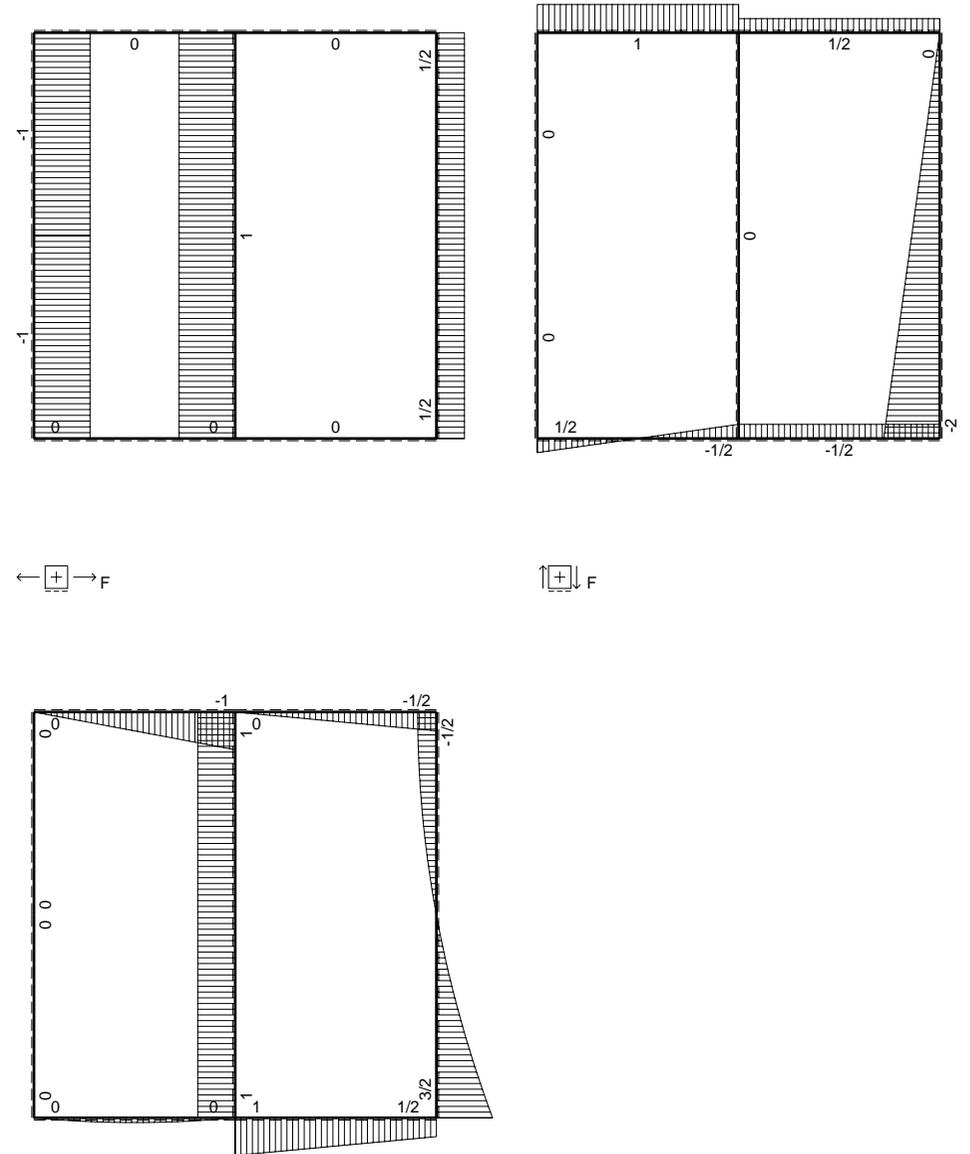
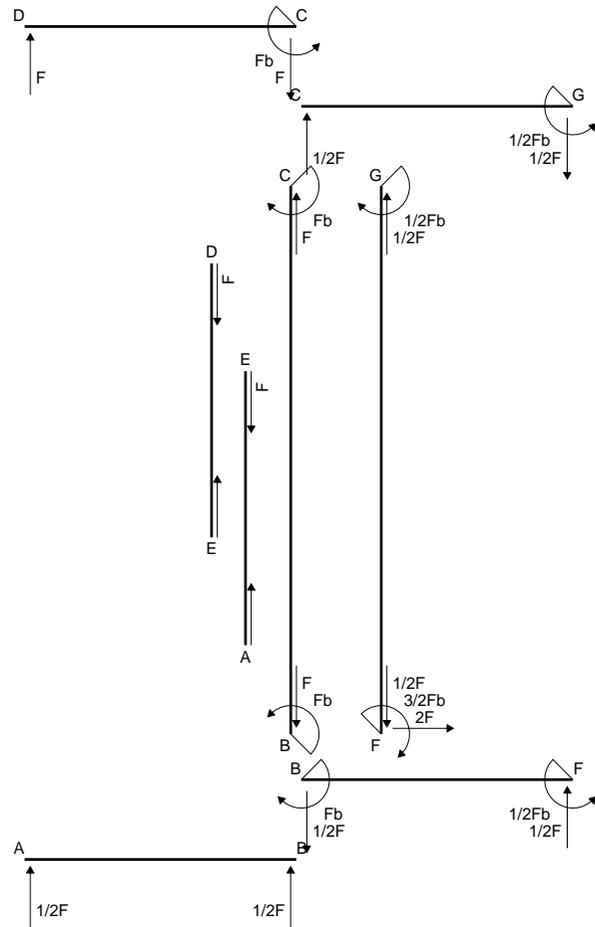
$$\sigma_c = -Mv/J_u = -132.4 \text{ N/mm}^2$$

$$\tau_c = 4.611 \text{ N/mm}^2$$

$$\sigma_\varrho = \sqrt{\sigma^2 + 3\tau^2} = 132.6 \text{ N/mm}^2$$

$$S = 4368. \text{ mm}^3$$





⊕ F<sub>b</sub>



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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

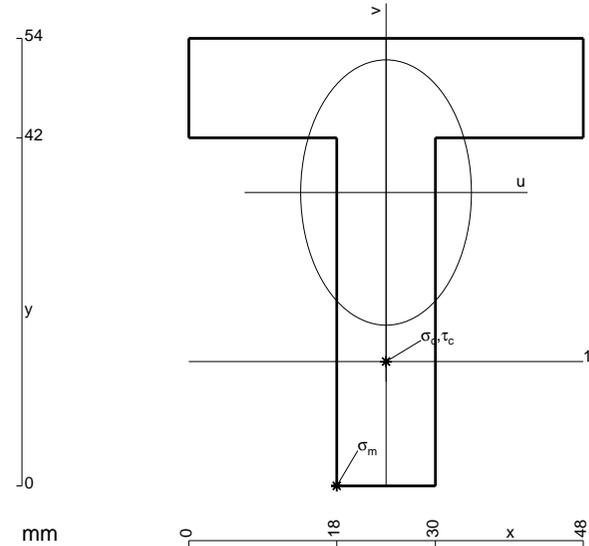
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

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

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

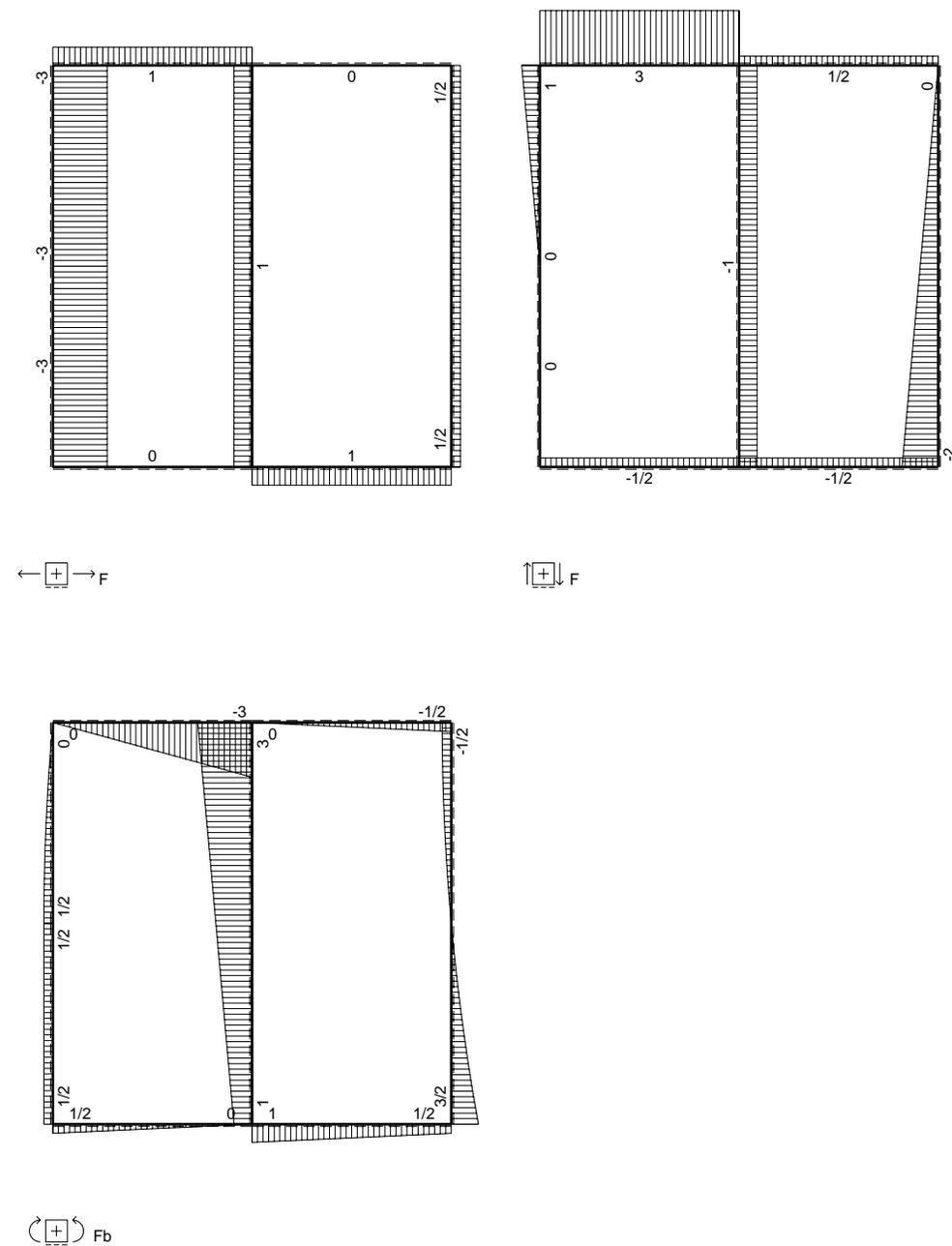
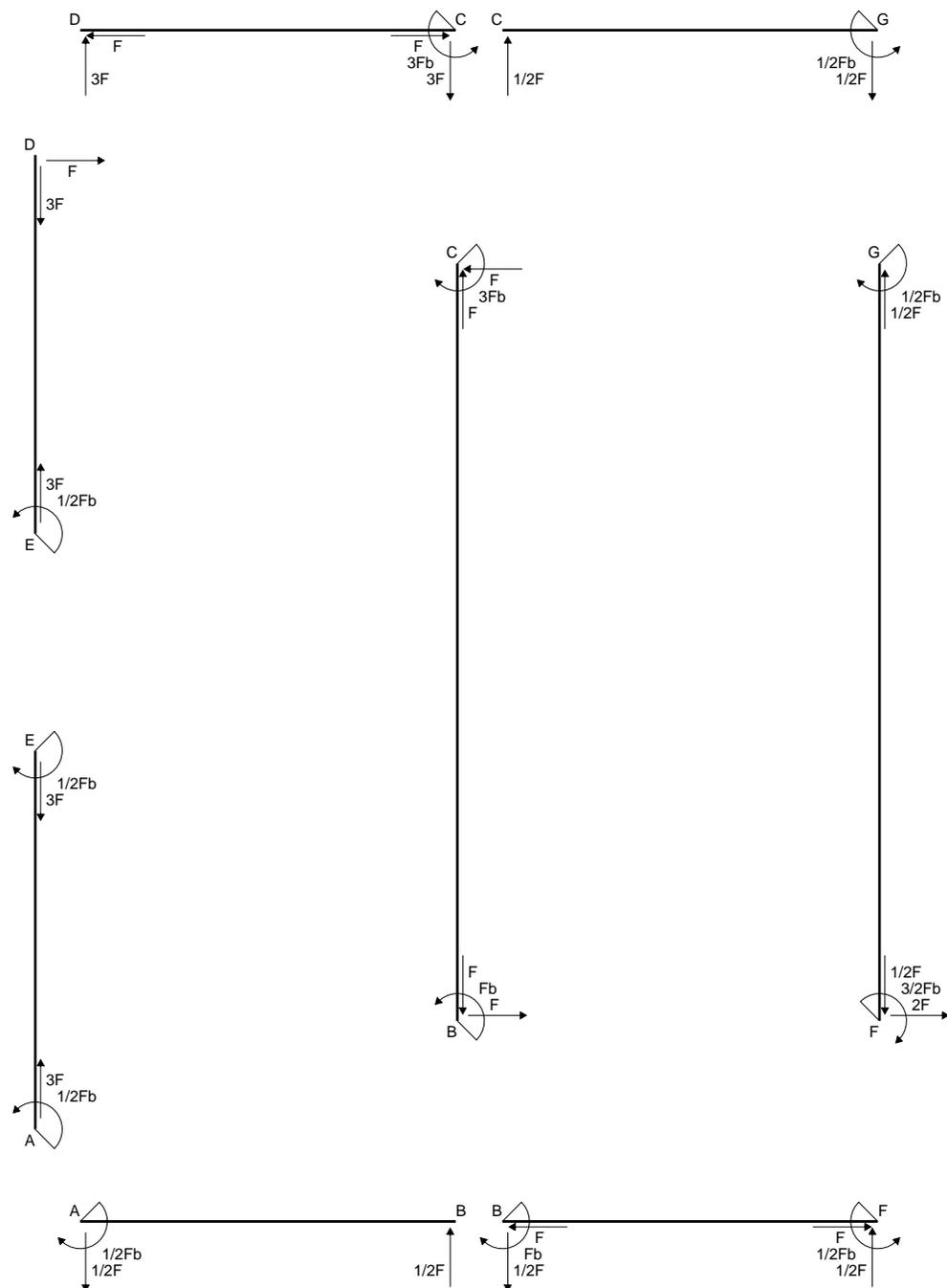
$$L_{GF}^{x\theta} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

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



- A = 1080. mm<sup>2</sup>
- J<sub>u</sub> = 276955. mm<sup>4</sup>
- J<sub>v</sub> = 116640. mm<sup>4</sup>
- y<sub>g</sub> = 35.4 mm
- T<sub>y</sub> = 3120. N
- M<sub>x</sub> = -1872000. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -35.4 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> = 15. mm
- v<sub>c</sub> = -20.4 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -137.9 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.715 N/mm<sup>2</sup>
- σ<sub>φ</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 138.1 N/mm<sup>2</sup>
- S = 5022. mm<sup>3</sup>







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

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

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

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

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

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

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

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

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

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

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

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

$$L_{BF}^{x_0} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

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

$$L_{FB}^{x_0} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

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

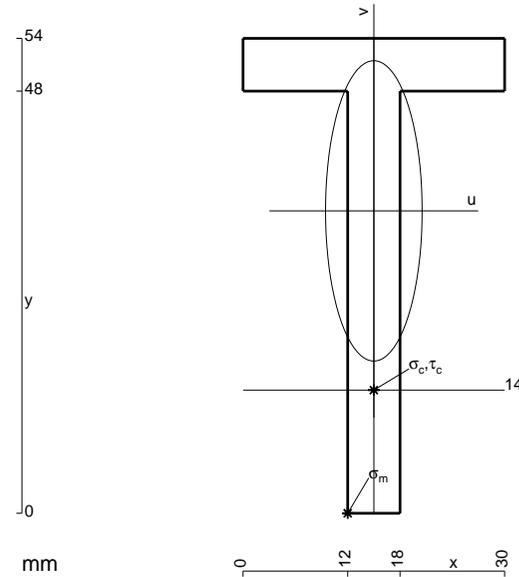
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

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

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

$$L_{GF}^{x_0} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

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



$$A = 468. \text{ mm}^2$$

$$J_u = 136587. \text{ mm}^4$$

$$J_v = 14364. \text{ mm}^4$$

$$y_g = 34.38 \text{ mm}$$

$$N = 410. \text{ N}$$

$$T_y = 1230. \text{ N}$$

$$M_x = -787200. \text{ Nmm}$$

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

$$u_m = -3. \text{ mm}$$

$$v_m = -34.38 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -197.3 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 14. \text{ mm}$$

$$v_c = -20.38 \text{ mm}$$

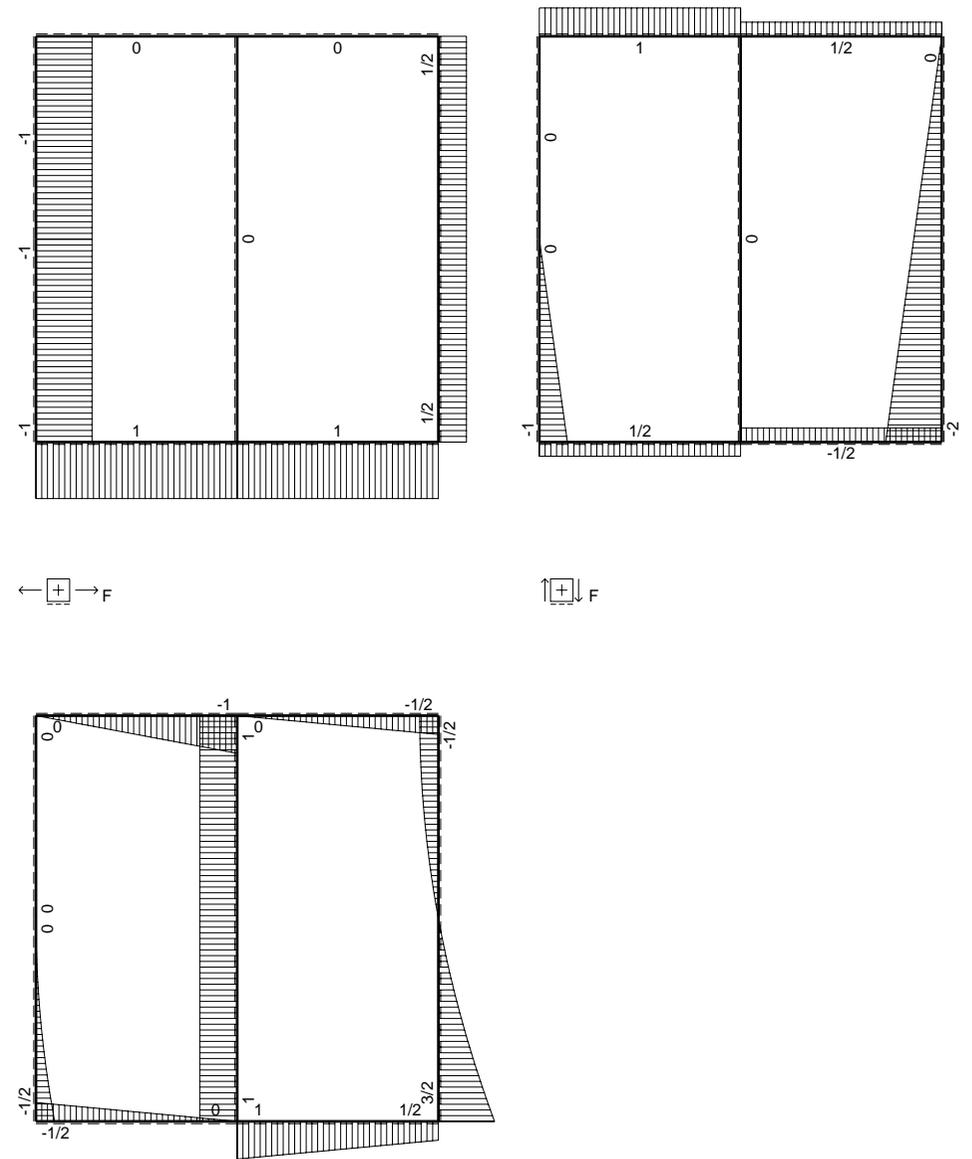
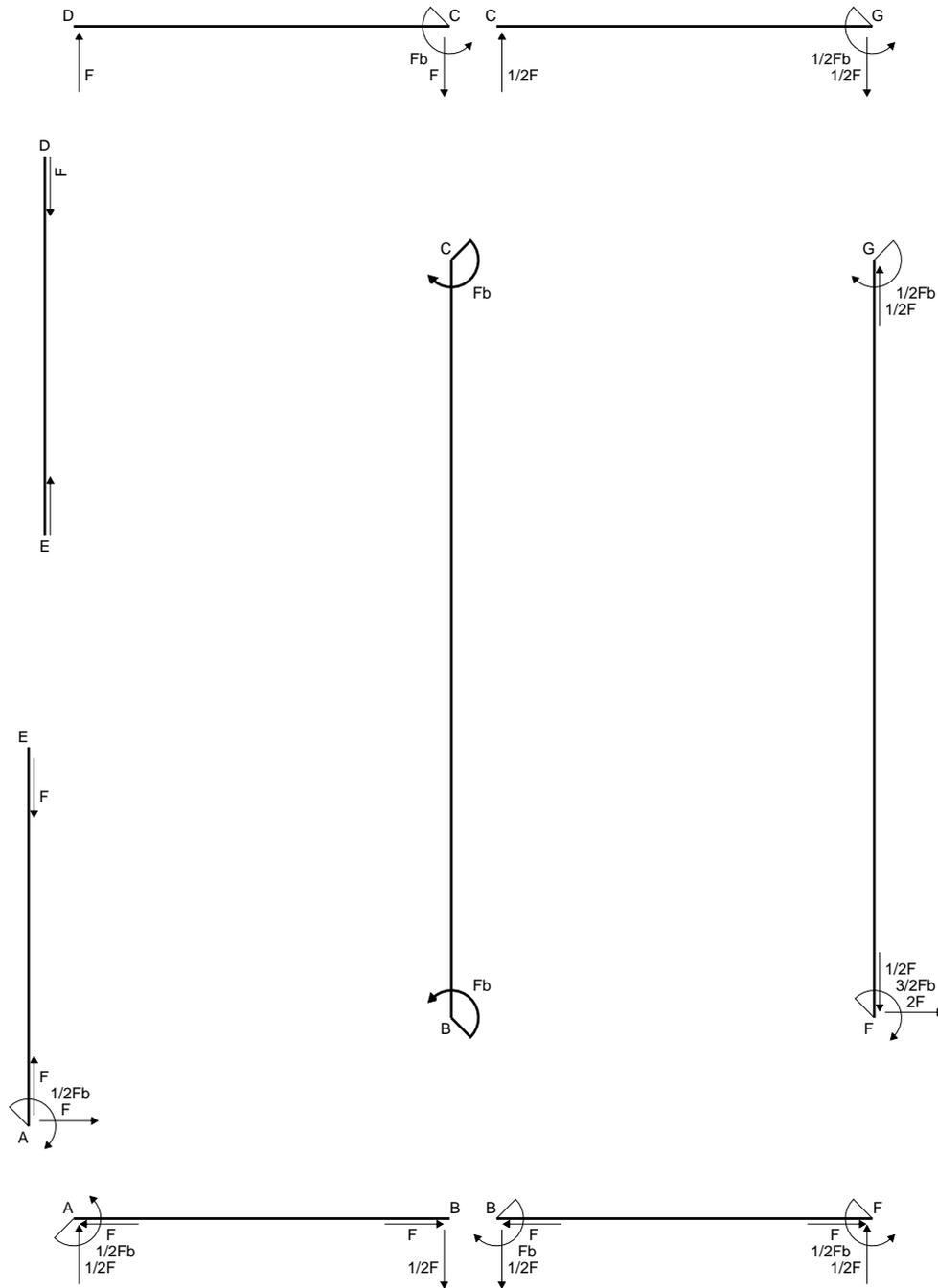
$$\sigma_c = N/A - Mv/J_u = -116.6 \text{ N/mm}^2$$

$$\tau_c = 3.452 \text{ N/mm}^2$$

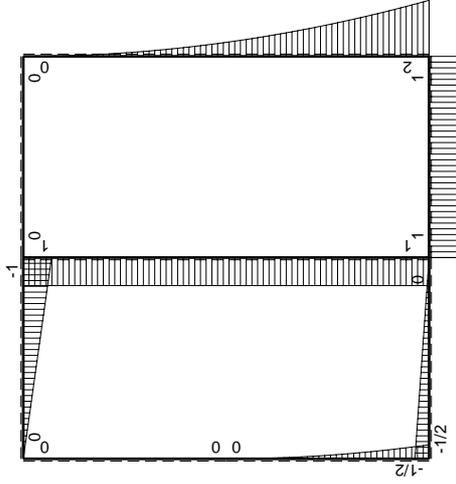
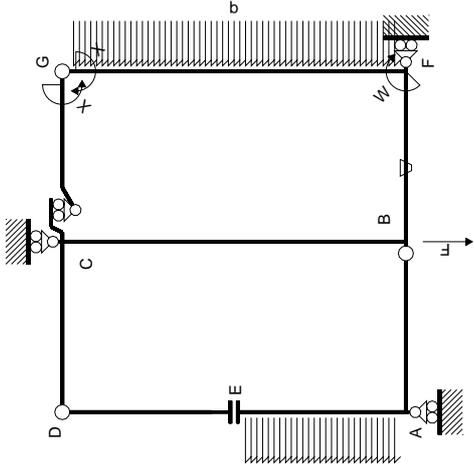
$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 116.8 \text{ N/mm}^2$$

$$S = 2300. \text{ mm}^3$$

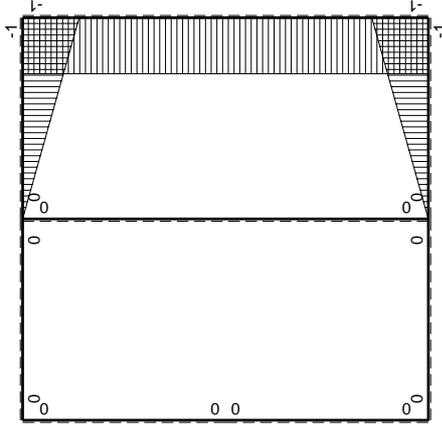




⊕ Fb



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

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

$\leftarrow$	$M(x)$	$M^0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / E dx$
AB b	0	$-1/2Fb+1/2Fx$	0	0	0	0	0+0	0
BA b	0	$1/2Fx$	0	0	0	0	0+0	0
CD b	0	$-Fb+Fx$	0	0	0	0	0+0	0
DC b	0	$Fx$	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
EA b	0	$-1/2qx^2$	0	0	0	0	0+0	0
AE b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0+0	0
BF b	$-x/b$	$Fb$	$-Fb/EJ$	$-Fx$	$Fx/EJ$	$x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$-Fb$	$Fb/EJ$	$-Fb+Fx$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	$2Fb-2Fx+1/2qx^2$	0	$-2Fb+2Fx-1/2Fx^2/b$	0	1	$(-4/3+0)Fb^2/EJ$	$2xb/EJ$
GF 2b	1	$-1/2qx^2$	0	$-1/2Fx^2/b$	0	1	$(-4/3+0)Fb^2/EJ$	$2xb/EJ$
CB 2b	0	$Fb$	0	0	0	0	0+0	0
BC 2b	0	$-Fb$	0	0	0	0	0+0	0
totali							$-4/3Fb^2/EJ$	$8/3xb/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

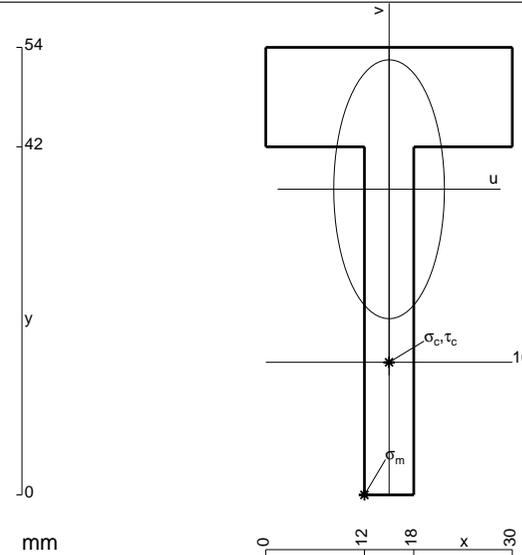
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

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

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

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

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



$$A = 612. \text{ mm}^2$$

$$J_u = 149427. \text{ mm}^4$$

$$J_v = 27756. \text{ mm}^4$$

$$y_g = 36.88 \text{ mm}$$

$$T_y = 1250. \text{ N}$$

$$M_x = -850000. \text{ Nmm}$$

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

$$u_m = -3. \text{ mm}$$

$$v_m = -36.88 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -209.8 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 16. \text{ mm}$$

$$v_c = -20.88 \text{ mm}$$

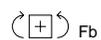
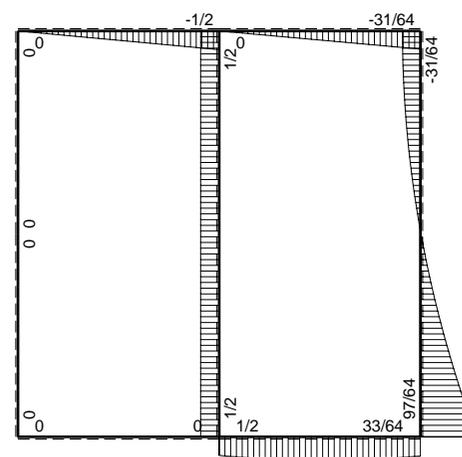
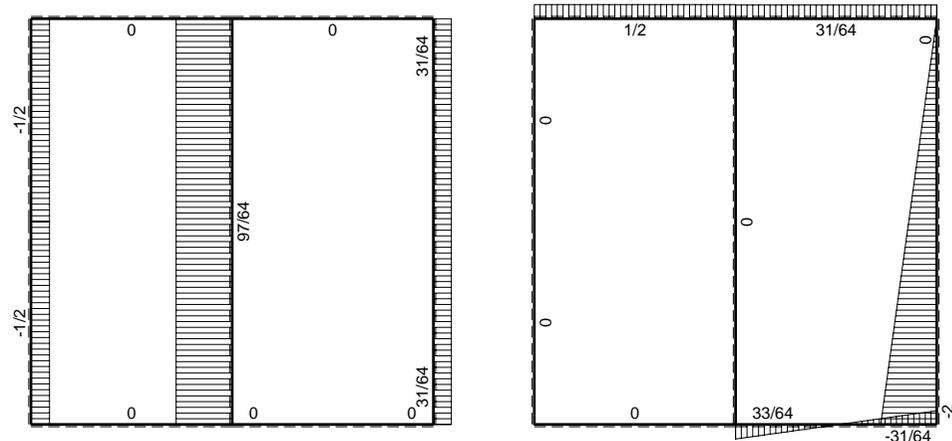
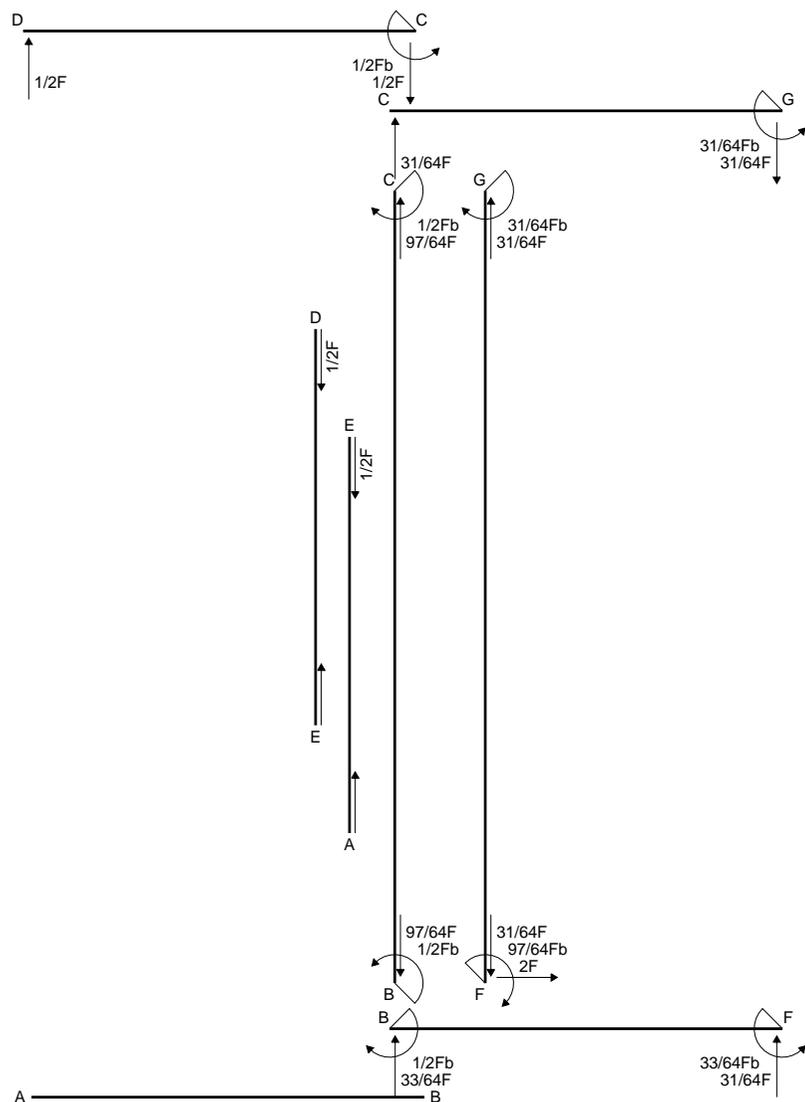
$$\sigma_c = -Mv/J_u = -118.8 \text{ N/mm}^2$$

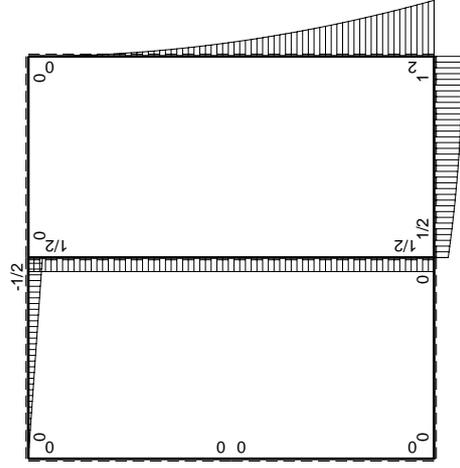
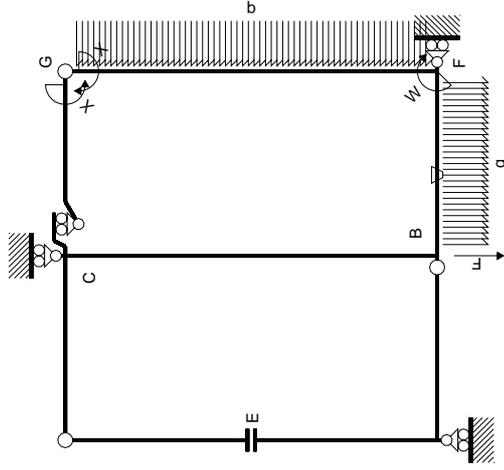
$$\tau_c = 3.866 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 119. \text{ N/mm}^2$$

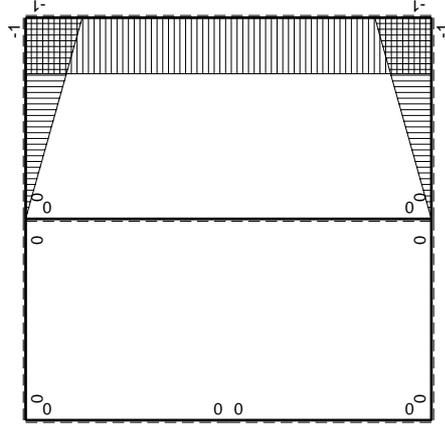
$$S = 2773. \text{ mm}^3$$







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

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

$\rightarrow$	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x(M^0/EJ+\theta)dx$	$\int M^x M_x/EJ dx$
AB b	0	0	0	0	0	0	0	0
BA b	0	0	0	0	0	0	0	0
CD b	0	$-1/2Fx$	0	0	0	0	0	0
DC b	0	$1/2Fx$	0	0	0	0	0	0
DE b	0	0	0	0	0	0	0	0
EA b	0	0	0	0	0	0	0	0
AE b	0	0	0	0	0	0	0	0
BF b	$-x/b$	$1/2Fb+Fx-1/2qx^2$	$-Fb/EJ$	$-1/2Fx-Fx^2/b+1/2qx^3/b$	$Fx/EJ$	$x^2/b^2$	$(-1/1/24+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$-Fb+1/2qx^2$	$Fb/EJ$	$-Fb+Fx+1/2Fx^2/b-1/2qx^3/b$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$(-1/1/24+1/2)Fb^2/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0	$1/3xb/EJ$
FG 2b	-1	$2Fb-2Fx+1/2qx^2$	0	$-2Fb+2Fx-1/2Fx^2/b$	0	1	$(-4/3+0)Fb^2/EJ$	$2xb/EJ$
GF 2b	1	$-1/2qx^2$	0	$-1/2Fx^2/b$	0	1	$(-4/3+0)Fb^2/EJ$	$2xb/EJ$
CB 2b	0	$1/2Fb$	0	0	0	0	0	0
BC 2b	0	$-1/2Fb$	0	0	0	0	0	0
totali							$-31/24Fb^2/EJ$	$8/3xb/EJ$
							$31/64Fb$	

Sviluppi di calcolo iperstatica

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

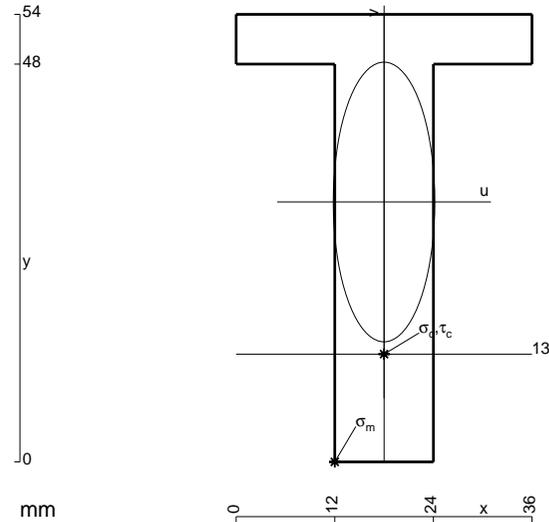
$$= (-b + 1/2 b + 1/6 b - 1/8 b) Fb 1/EJ + (-b + 1/2 b) \theta = 1/24 Fb^2/EJ$$

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

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

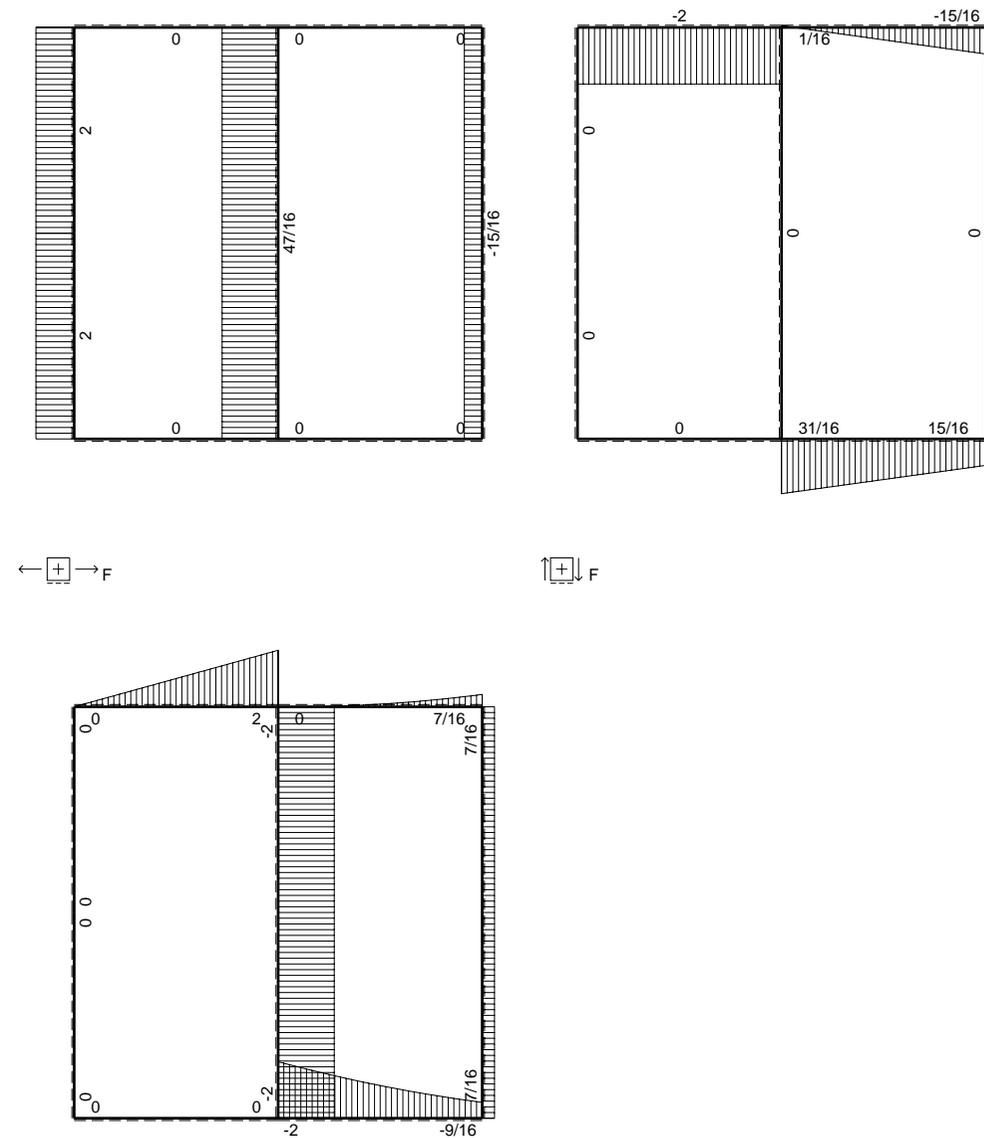
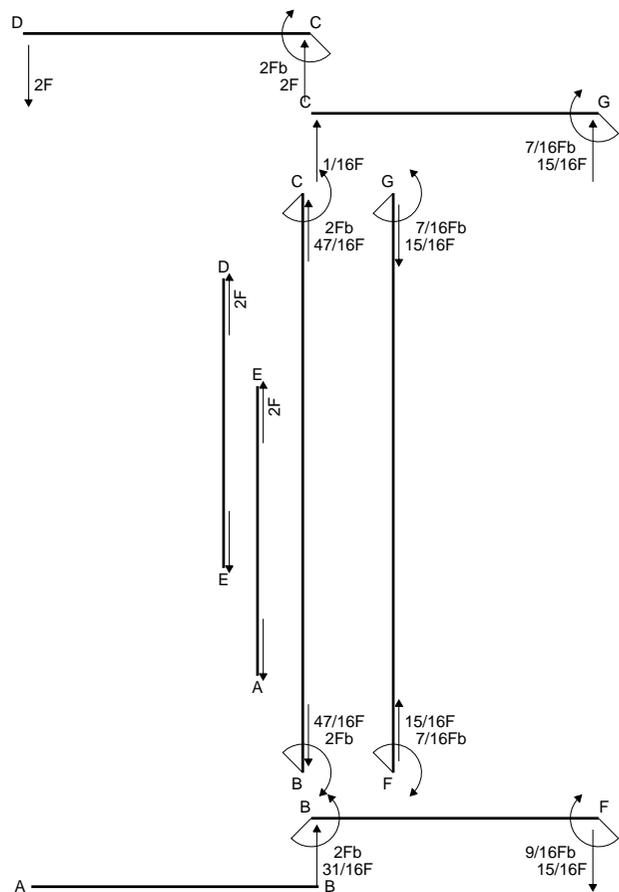
$$L_{GF}^{xo} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

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



$A = 792. \text{ mm}^2$   
 $J_u = 225759. \text{ mm}^4$   
 $J_v = 30240. \text{ mm}^4$   
 $y_g = 31.36 \text{ mm}$   
 $T_y = 2165. \text{ N}$   
 $M_x = -1580450. \text{ Nmm}$   
 $x_m = 12. \text{ mm}$   
 $u_m = -6. \text{ mm}$   
 $v_m = -31.36 \text{ mm}$   
 $\sigma_m = -Mv/J_u = -219.6 \text{ N/mm}^2$   
 $x_c = 18. \text{ mm}$   
 $y_c = 13. \text{ mm}$   
 $v_c = -18.36 \text{ mm}$   
 $\sigma_c = -Mv/J_u = -128.6 \text{ N/mm}^2$   
 $\tau_c = 3.1 \text{ N/mm}^2$   
 $\sigma_o = \sqrt{\sigma^2 + 3\tau^2} = 128.7 \text{ N/mm}^2$   
 $S = 3879. \text{ mm}^3$







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

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

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

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

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

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

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

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

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

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

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

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

$$L_{BF}^{x_0} = \int_0^b (2x/b - 3/2 x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

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

$$= (b - 1/2 b + 1/8 b) Fb 1/EJ + (1/2 b) \theta = 9/8 Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - 1/2 x/b - 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

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

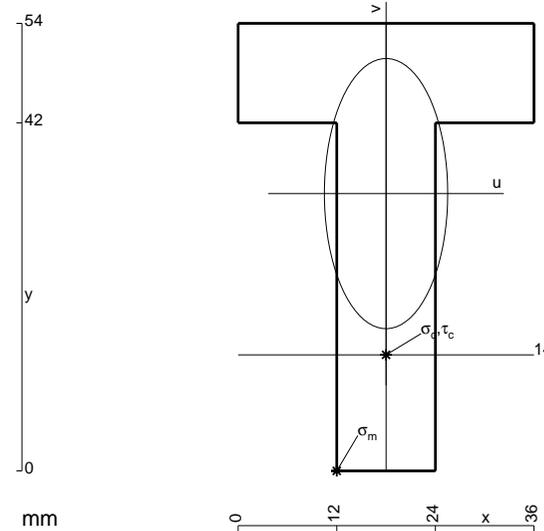
$$= (b - 1/4 b - 1/8 b) Fb 1/EJ + (-b + 1/2 b) \theta = 9/8 Fb^2/EJ$$

$$L_{GC}^{x_0} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

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

$$L_{CG}^{x_0} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$



$$A = 936. \text{ mm}^2$$

$$J_u = 248849. \text{ mm}^4$$

$$J_v = 52704. \text{ mm}^4$$

$$y_g = 33.46 \text{ mm}$$

$$T_y = -2220. \text{ N}$$

$$M_x = 1709400. \text{ Nmm}$$

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

$$u_m = -6. \text{ mm}$$

$$v_m = -33.46 \text{ mm}$$

$$\sigma_m = -Mv/J_u = 229.9 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 14. \text{ mm}$$

$$v_c = -19.46 \text{ mm}$$

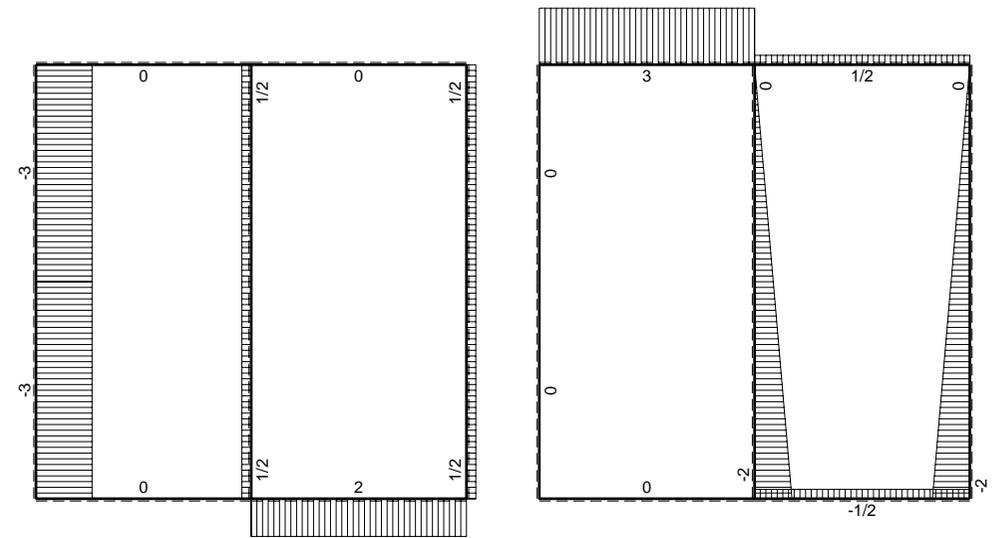
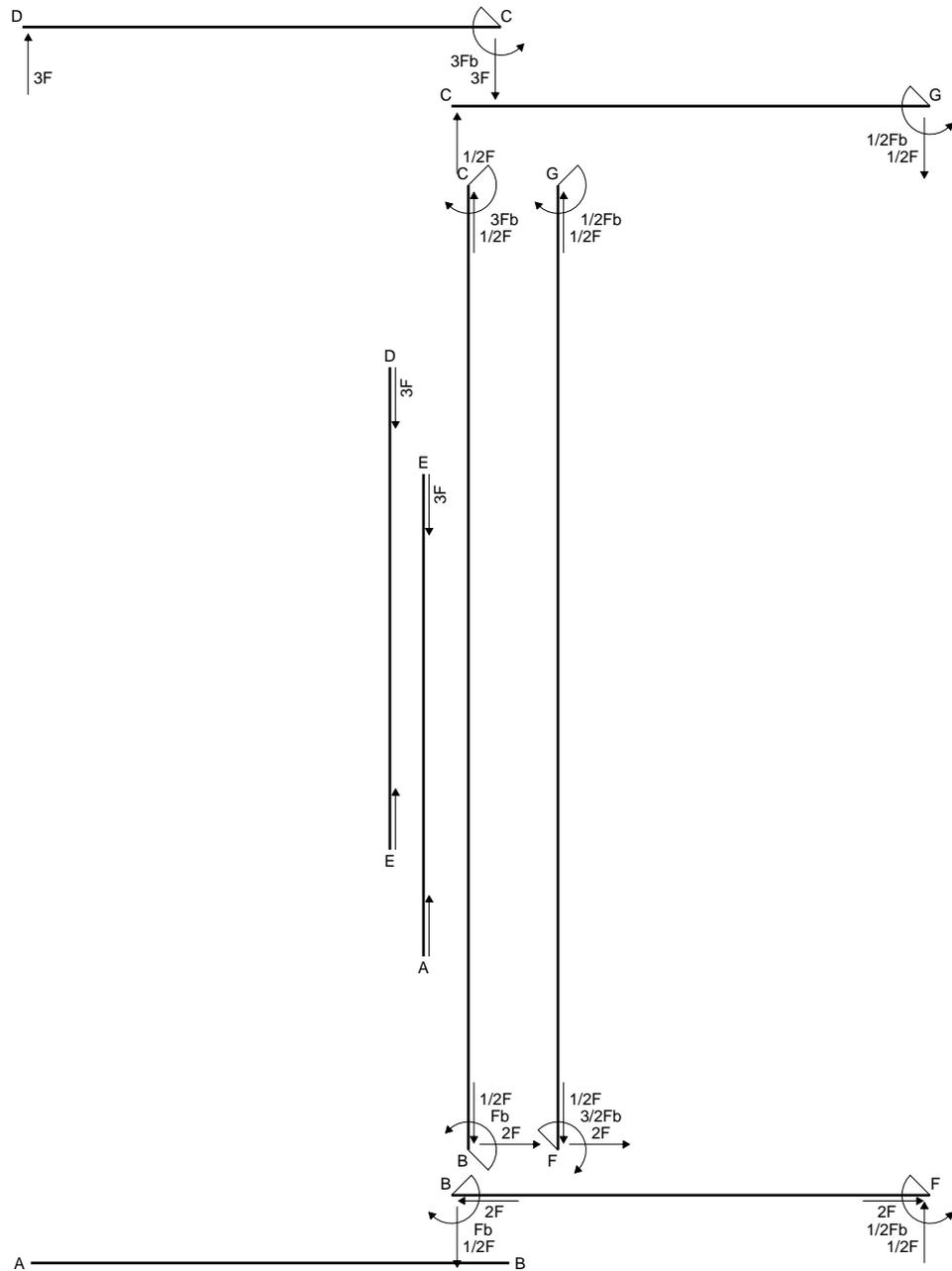
$$\sigma_c = -Mv/J_u = 133.7 \text{ N/mm}^2$$

$$\tau_c = 3.305 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 133.8 \text{ N/mm}^2$$

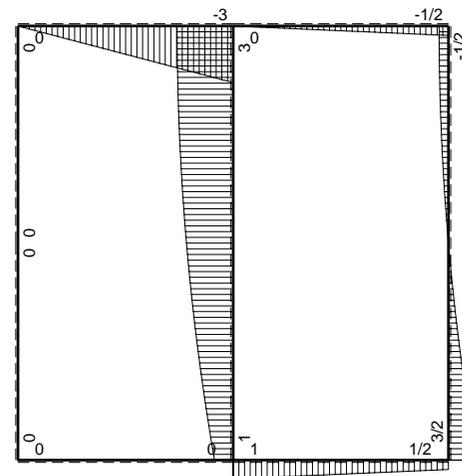
$$S = 4446. \text{ mm}^3$$





← ⊕ → F

↑ ⊕ ↓ F



⊕ ⊕ F<sub>b</sub>



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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

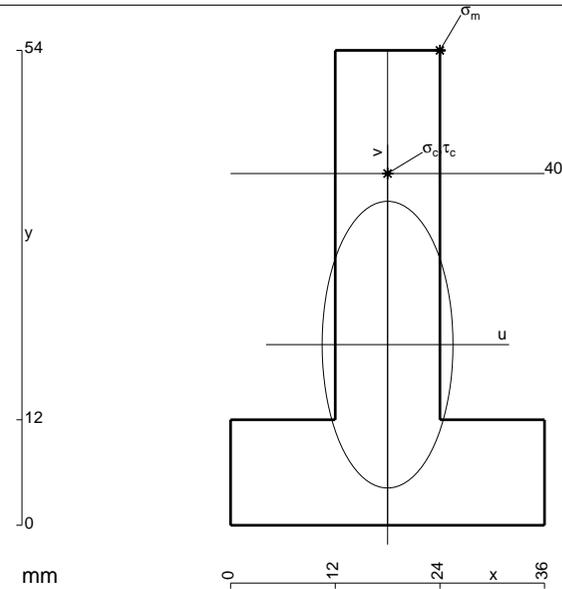
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

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

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

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

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



$$A = 936. \text{ mm}^2$$

$$J_u = 248849. \text{ mm}^4$$

$$J_v = 52704. \text{ mm}^4$$

$$y_g = 20.54 \text{ mm}$$

$$T_y = 2190. \text{ N}$$

$$M_x = -1773900. \text{ Nmm}$$

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

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

$$u_m = 6. \text{ mm}$$

$$v_m = 33.46 \text{ mm}$$

$$\sigma_m = -Mv/J_u = 238.5 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 40. \text{ mm}$$

$$v_c = 19.46 \text{ mm}$$

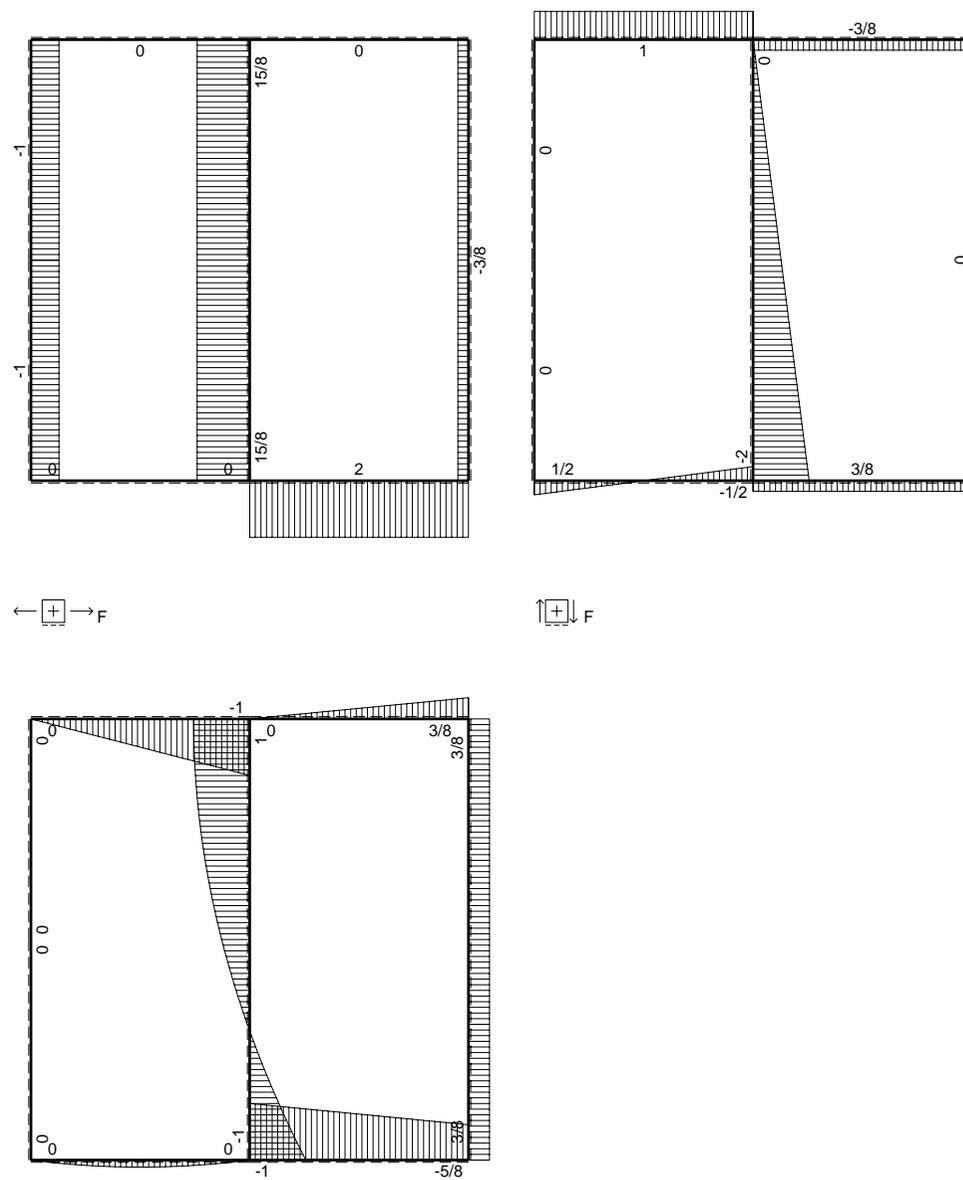
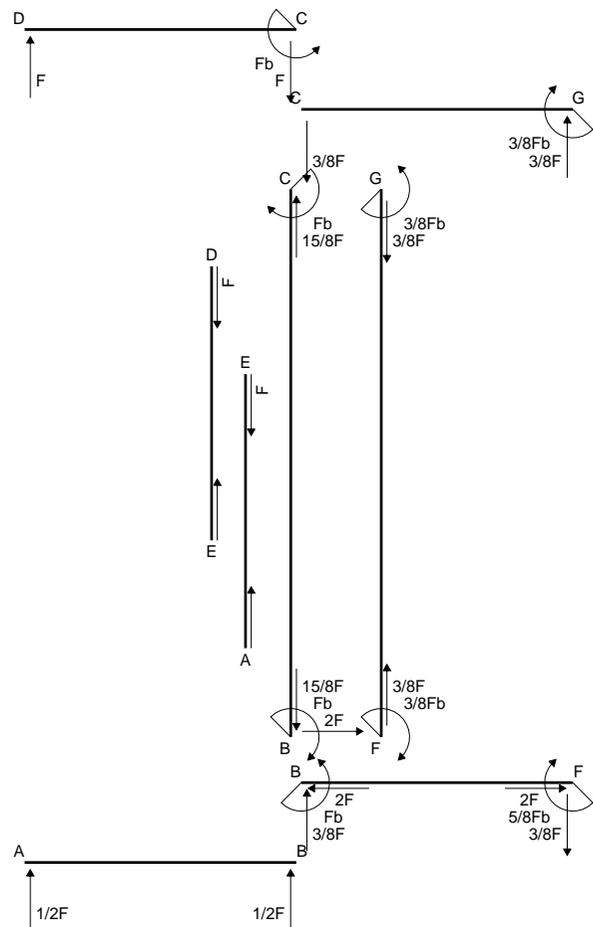
$$\sigma_c = -Mv/J_u = 138.7 \text{ N/mm}^2$$

$$\tau_c = 3.26 \text{ N/mm}^2$$

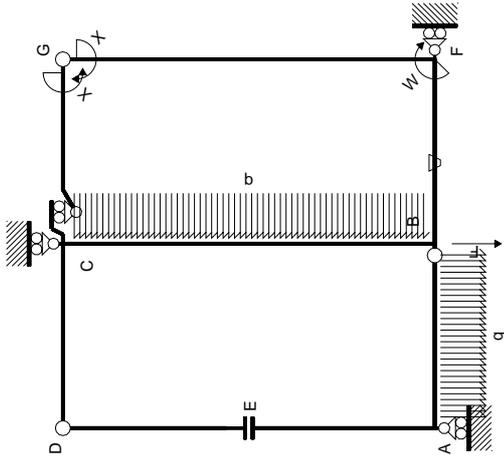
$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 138.8 \text{ N/mm}^2$$

$$S = 4446. \text{ mm}^3$$



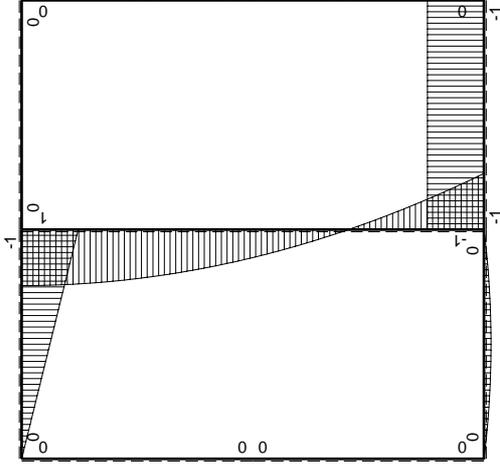


⊕  $F_b$



Schema di calcolo iperstatico

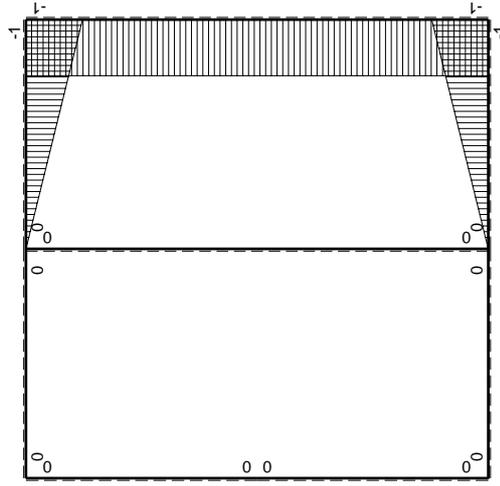
$M_0$  flessione da carichi assegnati



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

$\leftarrow$	$M^x(x)$	$M_0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x (M_0/EJ + \theta) dx$	$\int M^x M_x/EJ dx$
AB b	0	$1/2Fx - 1/2qx^2$	0	0	0	0	0+0	0
BA b	0	$-1/2Fx + 1/2qx^2$	0	0	0	0	0+0	0
CD b	0	$-Fb + Fx$	0	0	0	0	0+0	0
DC b	0	$Fx$	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
EA b	0	0	0	0	0	0	0+0	0
AE b	0	0	0	0	0	0	0+0	0
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb-Fx$	$Fb/EJ - Fx/EJ$	$1-2x/b+x^2/b^2$	$1/3xb/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2xb/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2xb/EJ$
CB 2b	0	$Fb - 1/2qx^2$	0	0	0	0	0+0	0
BC 2b	0	$Fb - 2Fx + 1/2qx^2$	0	0	0	0	0+0	0
totali								$Fb^2/EJ$
								$8/3xb/EJ$

Sviluppi di calcolo iperstatica



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

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

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

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

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

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

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

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

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

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

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

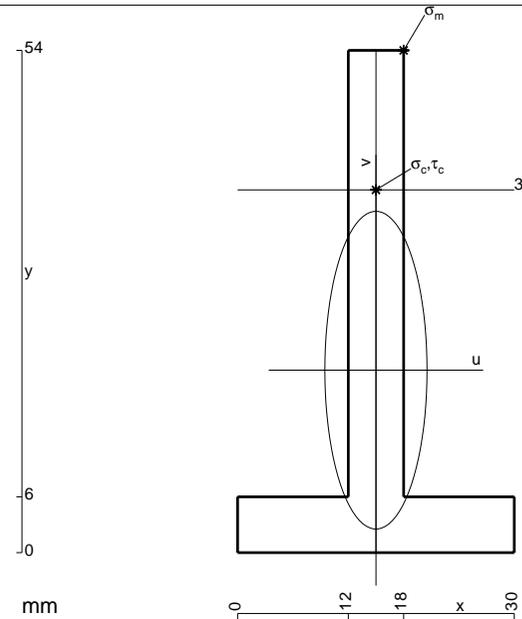
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

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

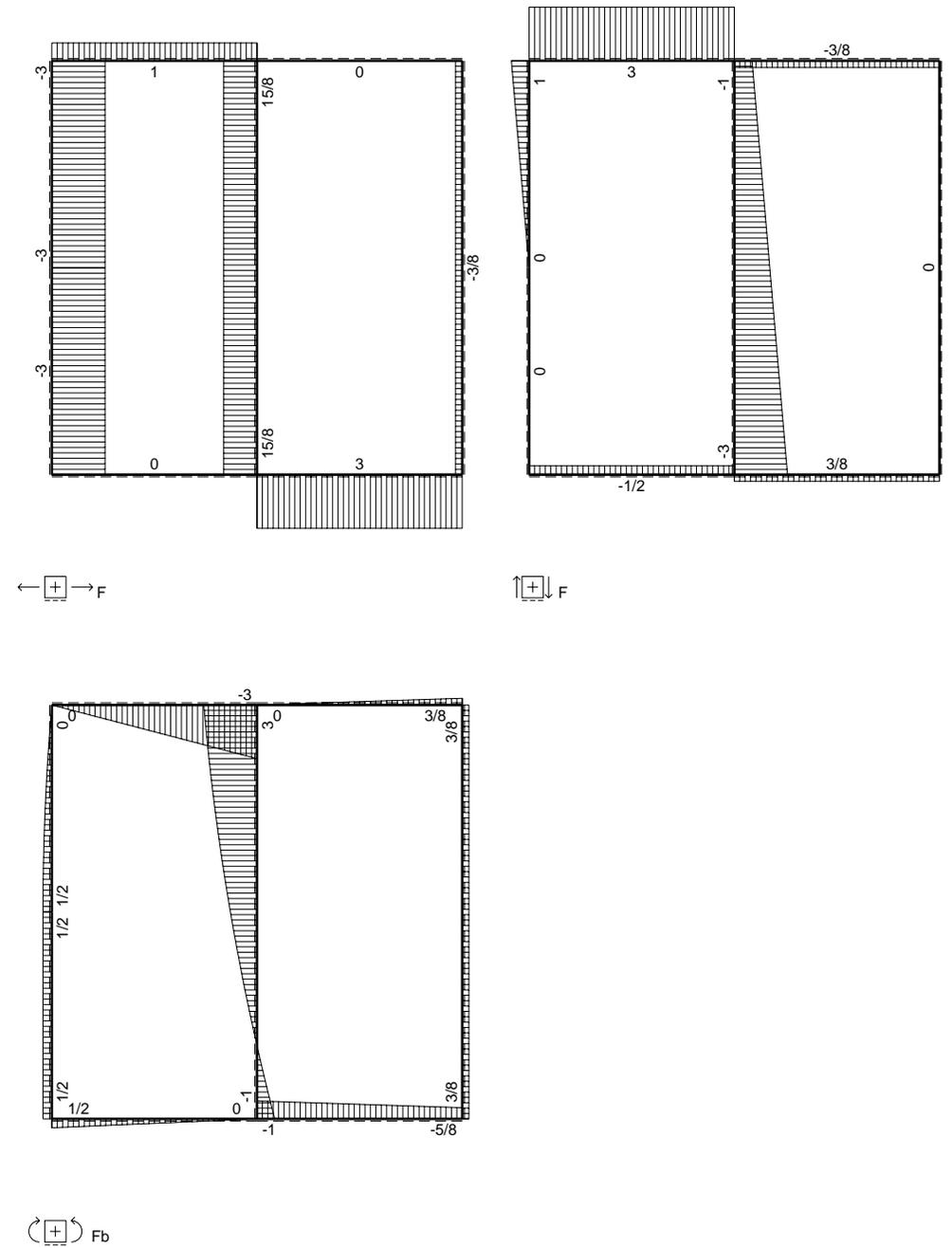
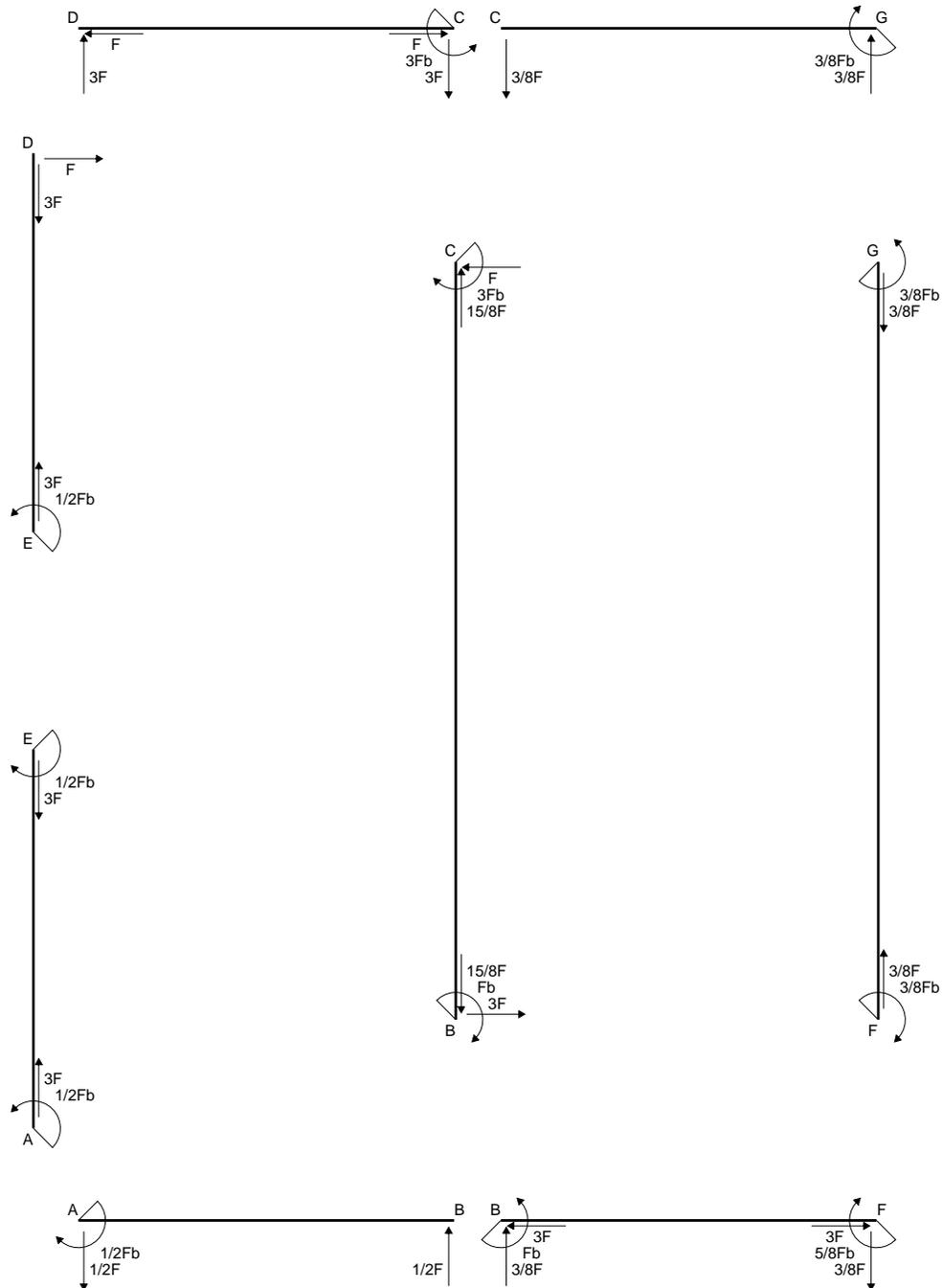
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

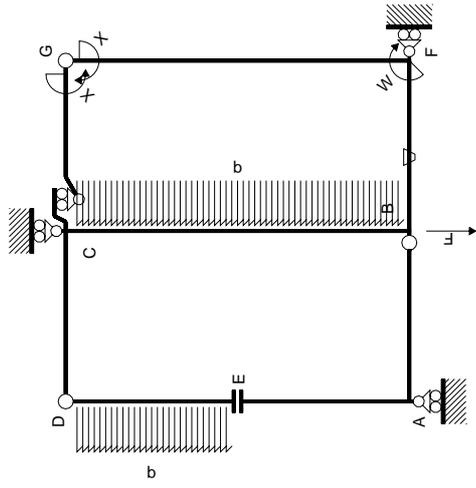
$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



- A = 468. mm<sup>2</sup>
- J<sub>u</sub> = 136587. mm<sup>4</sup>
- J<sub>v</sub> = 14364. mm<sup>4</sup>
- y<sub>g</sub> = 19.62 mm
- N = 3338. N
- T<sub>y</sub> = -3560. N
- M<sub>x</sub> = -765400. Nmm
- x<sub>m</sub> = 18. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 3. mm
- v<sub>m</sub> = 34.38 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = 199.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 15. mm
- y<sub>c</sub> = 39. mm
- v<sub>c</sub> = 19.38 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = 115.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 10.51 N/mm<sup>2</sup>
- σ<sub>φ</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 117.2 N/mm<sup>2</sup>
- S = 2420. mm<sup>3</sup>

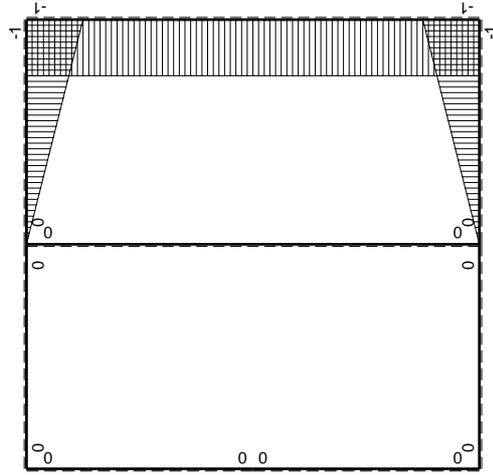






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

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

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / Edx$
AB b	0	$1/2Fb - 1/2Fx$	0	0	0	0	0+0	0
BA b	0	$-1/2Fx$	0	0	0	0	0+0	0
CD b	0	$-3Fb + 3Fx$	0	0	0	0	0+0	0
DC b	0	$3Fx$	0	0	0	0	0+0	0
DE b	0	$Fx - 1/2qx^2$	0	0	0	0	0+0	0
ED b	0	$-1/2Fb + 1/2qx^2$	0	0	0	0	0+0	0
EA b	0	$1/2Fb$	0	0	0	0	0+0	0
AE b	0	$-1/2Fb$	0	0	0	0	0+0	0
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$Fb/EJ - Fx/EJ$	$(1/2 + 1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb - Fx$	$Fb/EJ - Fx/EJ$	$Fb/EJ - Fx/EJ$	$1-2x/b + x^2/b^2$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	0	$-1-2x/b + x^2/b^2$	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	0	$x^2/b^2$	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	0	1	$2xb/EJ$
GF 2b	1	0	0	0	0	0	1	$2xb/EJ$
CB 2b	0	$3Fb - Fx - 1/2qx^2$	0	0	0	0	0+0	0
BC 2b	0	$Fb - 3Fx + 1/2qx^2$	0	0	0	0	0+0	0
totali								$8/3xb/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

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

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

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

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

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

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

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

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

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

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

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

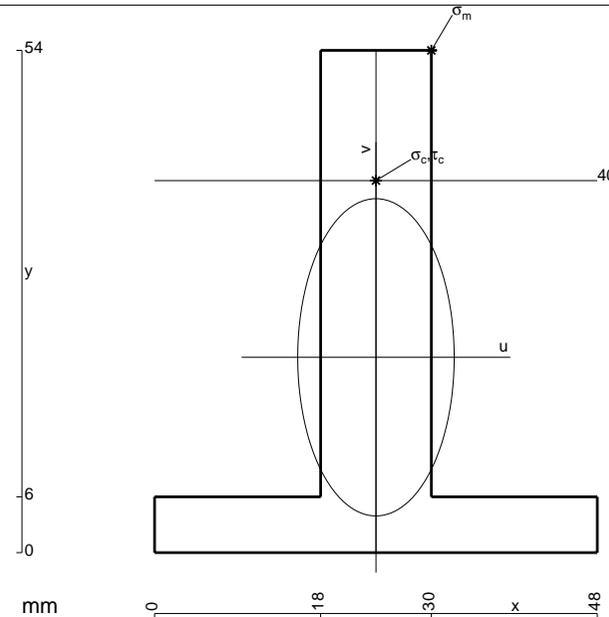
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

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

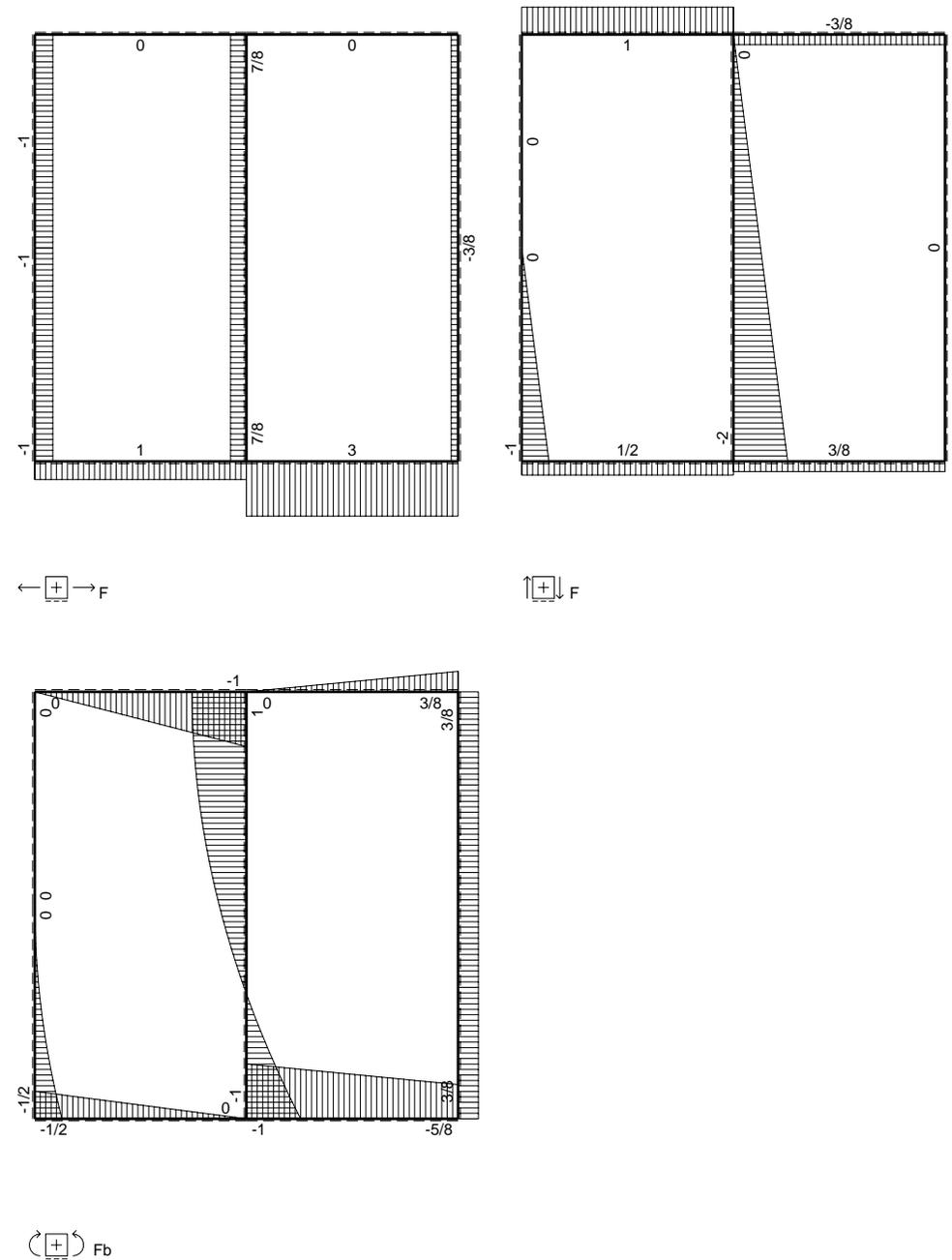
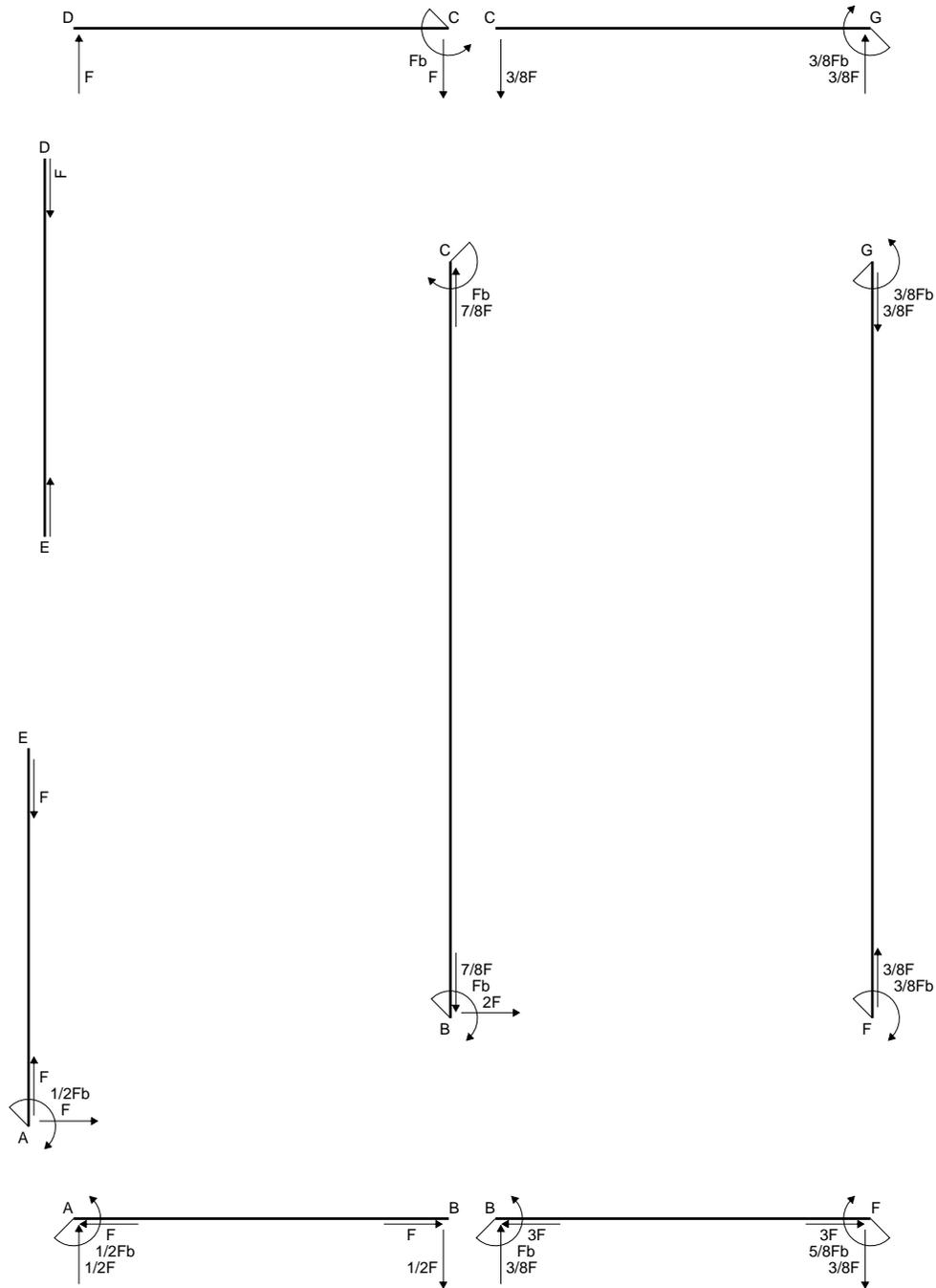
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

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



- A = 864. mm<sup>2</sup>
- J<sub>u</sub> = 251424. mm<sup>4</sup>
- J<sub>v</sub> = 62208. mm<sup>4</sup>
- y<sub>g</sub> = 21. mm
- N = 1120. N
- T<sub>y</sub> = 3360. N
- M<sub>x</sub> = -1579200. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 33. mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = 208.6 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 40. mm
- v<sub>c</sub> = 19. mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = 120.6 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.864 N/mm<sup>2</sup>
- σ<sub>σ</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 120.9 N/mm<sup>2</sup>
- S = 4368. mm<sup>3</sup>







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

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

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

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

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

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

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

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

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

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

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

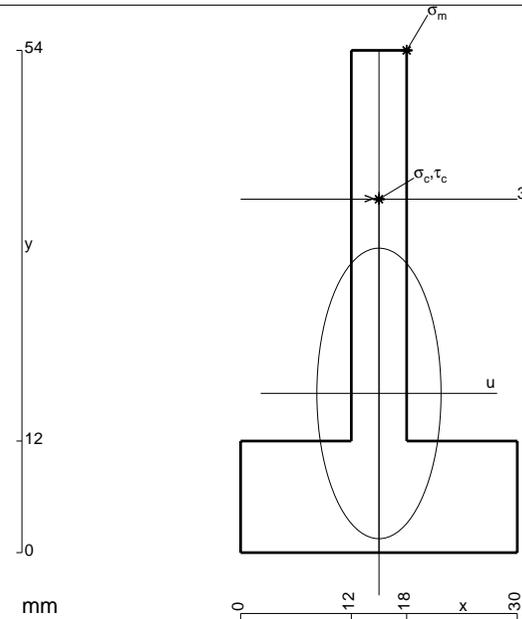
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

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

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

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



$$A = 612. \text{ mm}^2$$

$$J_u = 149428. \text{ mm}^4$$

$$J_v = 27756. \text{ mm}^4$$

$$y_g = 17.12 \text{ mm}$$

$$N = 1505. \text{ N}$$

$$T_y = -3440. \text{ N}$$

$$M_x = -877200. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

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

$$u_m = 3. \text{ mm}$$

$$v_m = 36.88 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 219. \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 38. \text{ mm}$$

$$v_c = 20.88 \text{ mm}$$

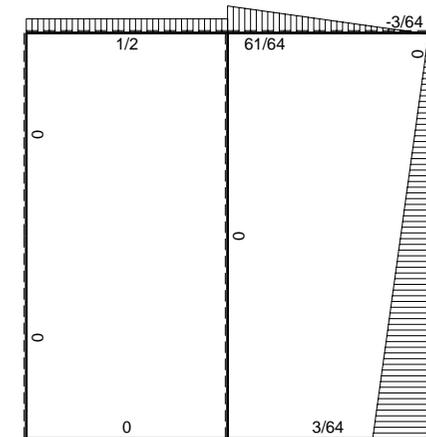
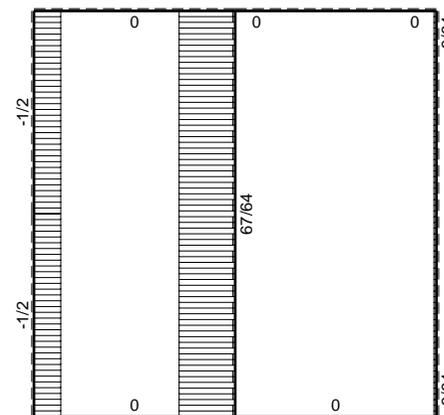
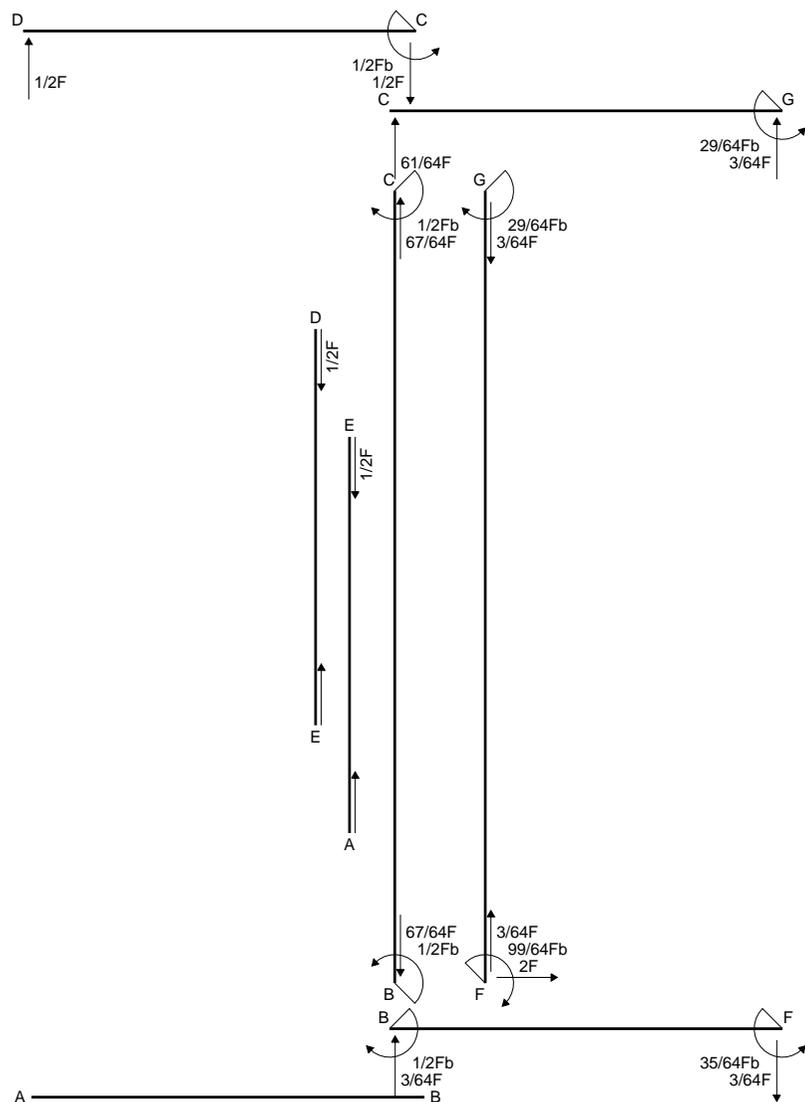
$$\sigma_c = N/A - Mv/J_u = 125. \text{ N/mm}^2$$

$$\tau_c = 10.64 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 126.4 \text{ N/mm}^2$$

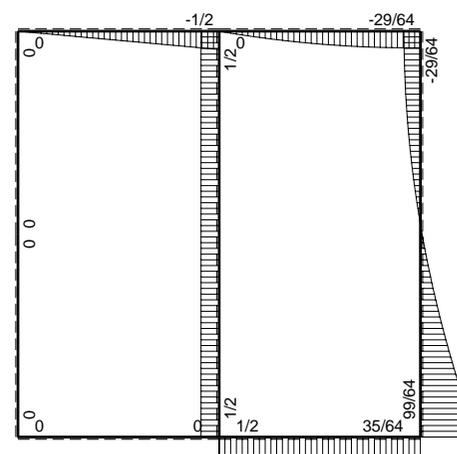
$$S = 2773. \text{ mm}^3$$





← ⊕ → F

↑ ⊕ ↓ F



⊕ F<sub>b</sub>



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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

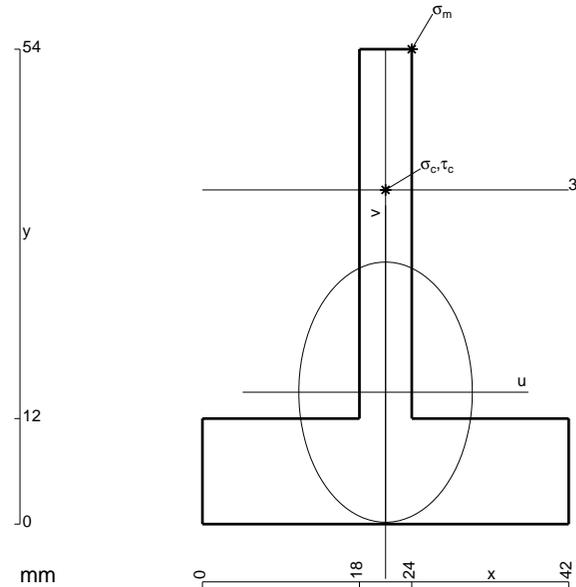
$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

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

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

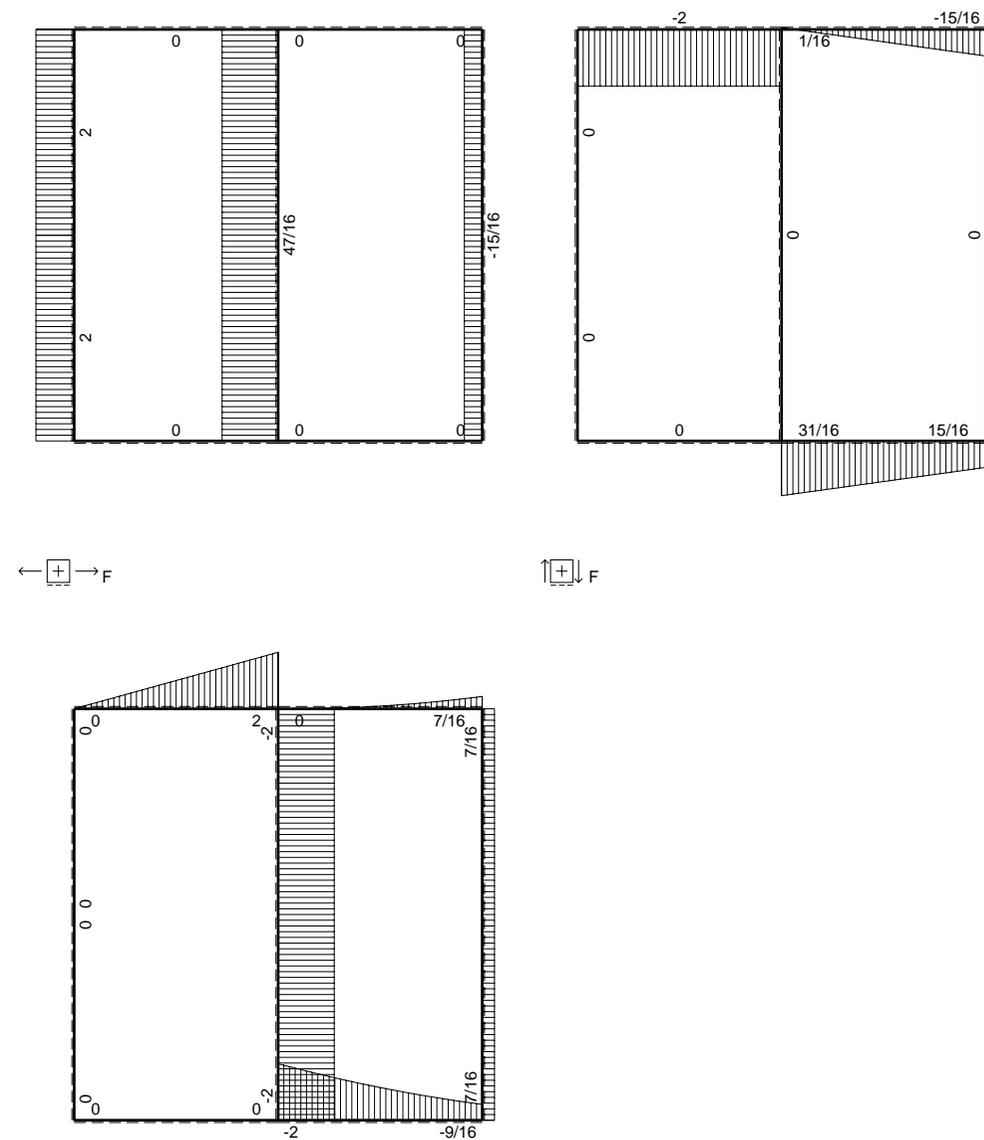
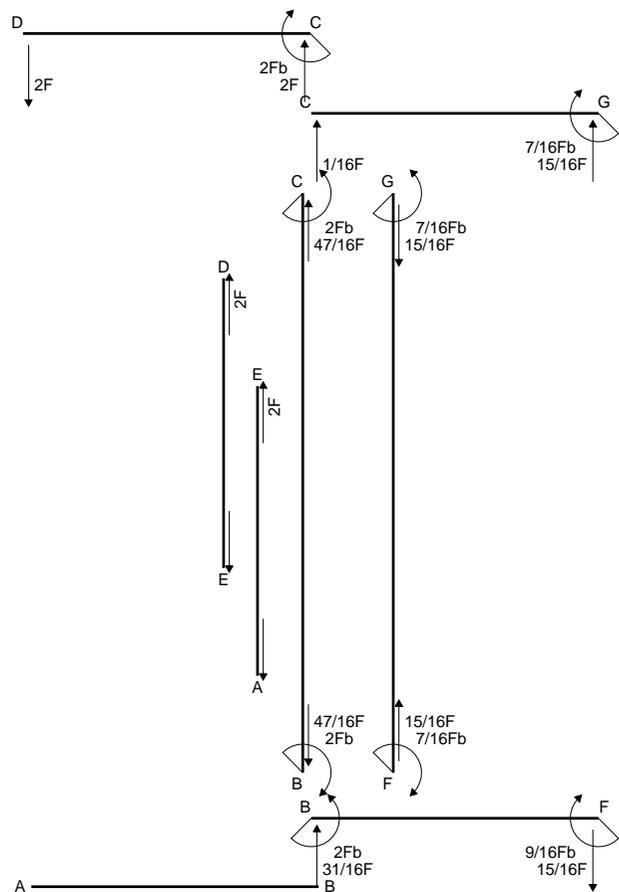
$$L_{GF}^{xo} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

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



- A = 756. mm<sup>2</sup>
- J<sub>u</sub> = 165564. mm<sup>4</sup>
- J<sub>v</sub> = 74844. mm<sup>4</sup>
- y<sub>g</sub> = 15. mm
- T<sub>y</sub> = 1775. N
- M<sub>x</sub> = -976250. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 3. mm
- v<sub>m</sub> = 39. mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 230. N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 38. mm
- v<sub>c</sub> = 23. mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 135.6 N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.318 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 135.9 N/mm<sup>2</sup>
- S = 2976. mm<sup>3</sup>







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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$= (b - 1/2 b + 1/8 b) Fb 1/EJ + (1/2 b) \theta = 9/8 Fb^2/EJ$$

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

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

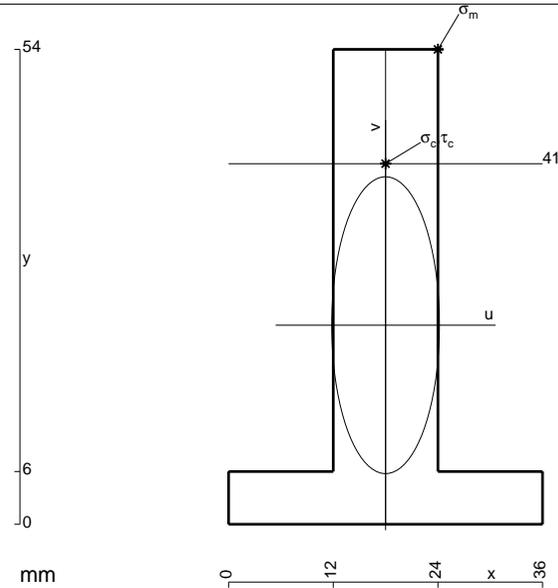
$$= (b - 1/4 b - 1/8 b) Fb 1/EJ + (-b + 1/2 b) \theta = 9/8 Fb^2/EJ$$

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

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

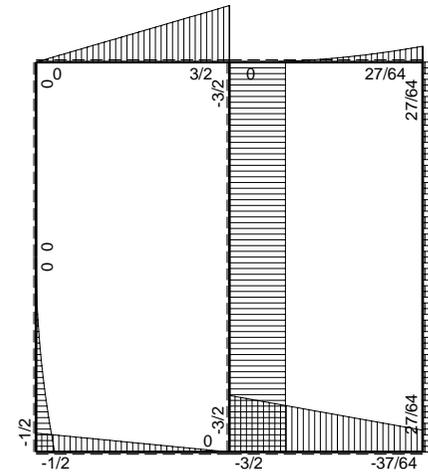
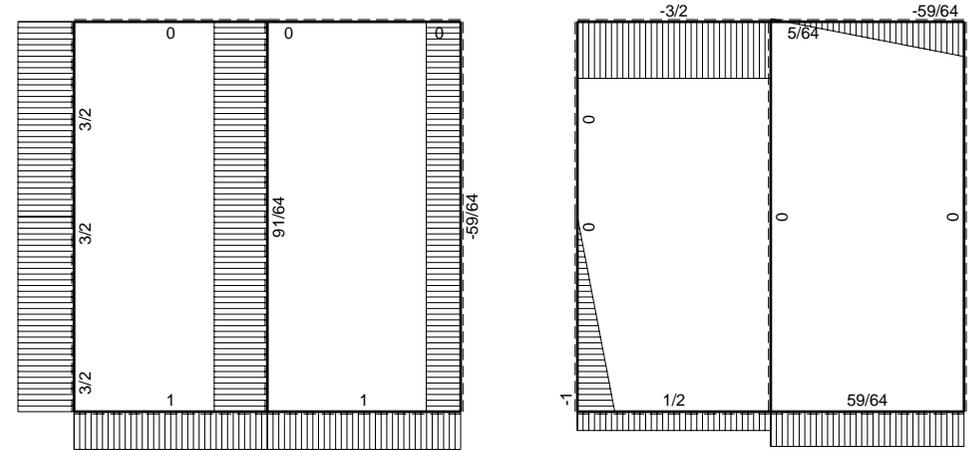
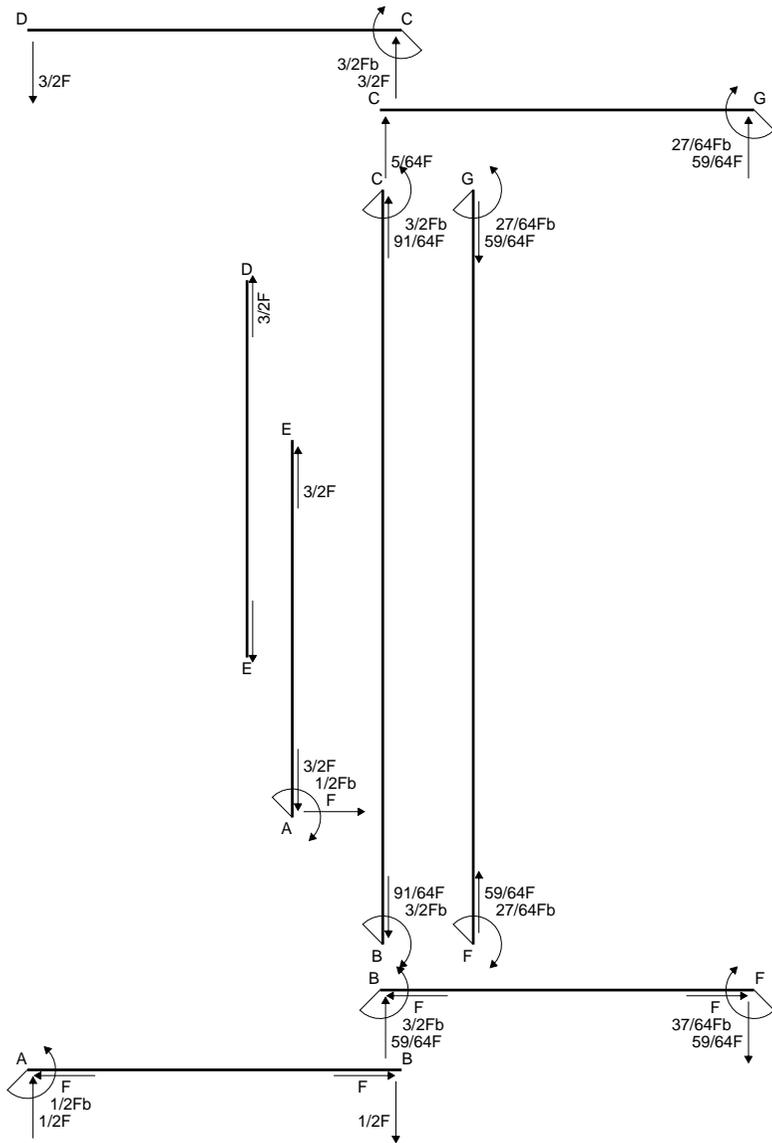
$$L_{CG}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

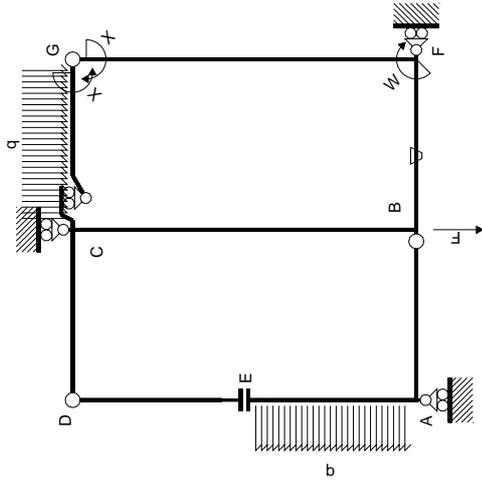
$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$



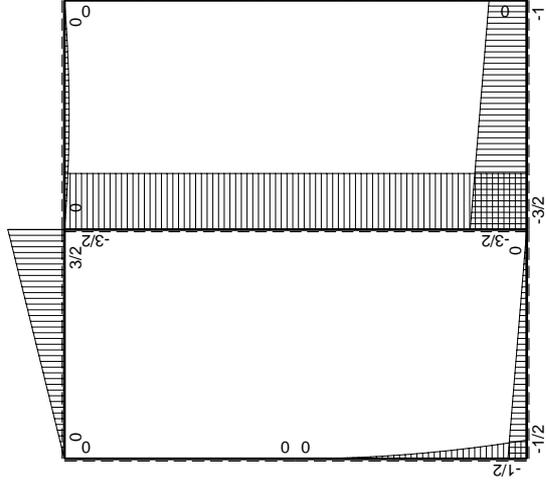
- A = 792. mm<sup>2</sup>
- J<sub>u</sub> = 225759. mm<sup>4</sup>
- J<sub>v</sub> = 30240. mm<sup>4</sup>
- y<sub>g</sub> = 22.64 mm
- T<sub>y</sub> = -2860. N
- M<sub>x</sub> = 1716000. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 31.36 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -238.4 N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 41. mm
- v<sub>c</sub> = 18.36 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -139.6 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.095 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 139.8 N/mm<sup>2</sup>
- S = 3879. mm<sup>3</sup>



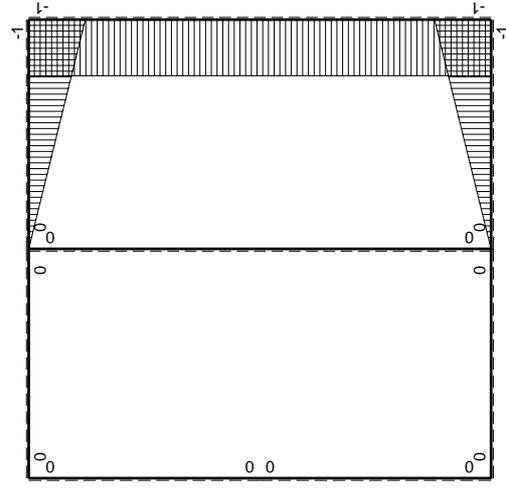




Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica X=W<sub>gc</sub>

←	$M_x(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / E dx$
AB b	0	$-1/2Fb + 1/2Fx$	0	0	0	0	0+0	0
BA b	0	$1/2Fx$	0	0	0	0	0+0	0
CD b	0	$3/2Fb - 3/2Fx$	0	0	0	0	0+0	0
DC b	0	$-3/2Fx$	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
EA b	0	$-1/2qx^2$	0	0	0	0	0+0	0
AE b	0	$1/2Fb - Fx + 1/2qx^2$	0	0	0	0	0+0	0
BF b	$-x/b$	$-3/2Fb + 1/2Fx$	$-Fb/EJ$	$3/2Fx - 1/2Fx^2/b$	$Fx/EJ$	$x^2/b^2$	$(7/12 + 1/2)Fb^2/EJ$	$1/3Xb/EJ$
FB b	$1-x/b$	$Fb + 1/2Fx$	$Fb/EJ$	$Fb - 1/2Fx - 1/2Fx^2/b$	$Fb/EJ - Fx/EJ$	$1 - 2x/b + x^2/b^2$	$(7/12 + 1/2)Fb^2/EJ$	$1/3Xb/EJ$
GC b	$-1+x/b$	$-1/2Fx + 1/2qx^2$	0	$1/2Fx - Fx^2/b + 1/2qx^3/b$	0	$1 - 2x/b + x^2/b^2$	$(1/24 + 0)Fb^2/EJ$	$1/3Xb/EJ$
CG b	$x/b$	$1/2Fx - 1/2qx^2$	0	$1/2Fx^2/b - 1/2qx^3/b$	0	$x^2/b^2$	$(1/24 + 0)Fb^2/EJ$	$1/3Xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2Xb/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$
CB 2b	0	$-3/2Fb$	0	0	0	0	0+0	0
BC 2b	0	$3/2Fb$	0	0	0	0	0+0	0
totali								
							$9/8Fb^2/EJ$	$8/3Xb/EJ$
								$-27/64Fb$

Sviluppi di calcolo iperstatica

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$= (3/4 b - 1/6 b) Fb 1/EJ + (1/2 b) \theta = 13/12 Fb^2/EJ$$

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

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

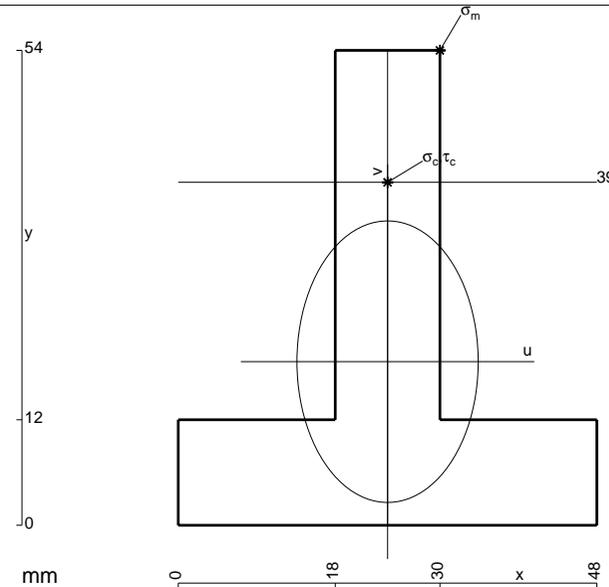
$$= (b - 1/4 b - 1/6 b) Fb 1/EJ + (-b + 1/2 b) \theta = 13/12 Fb^2/EJ$$

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

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

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

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$



$$A = 1080. \text{ mm}^2$$

$$J_u = 276955. \text{ mm}^4$$

$$J_v = 116640. \text{ mm}^4$$

$$y_g = 18.6 \text{ mm}$$

$$T_y = -2430. \text{ N}$$

$$M_x = 1555200. \text{ Nmm}$$

$$x_m = 30. \text{ mm}$$

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

$$u_m = 6. \text{ mm}$$

$$v_m = 35.4 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -198.8 \text{ N/mm}^2$$

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

$$y_c = 39. \text{ mm}$$

$$v_c = 20.4 \text{ mm}$$

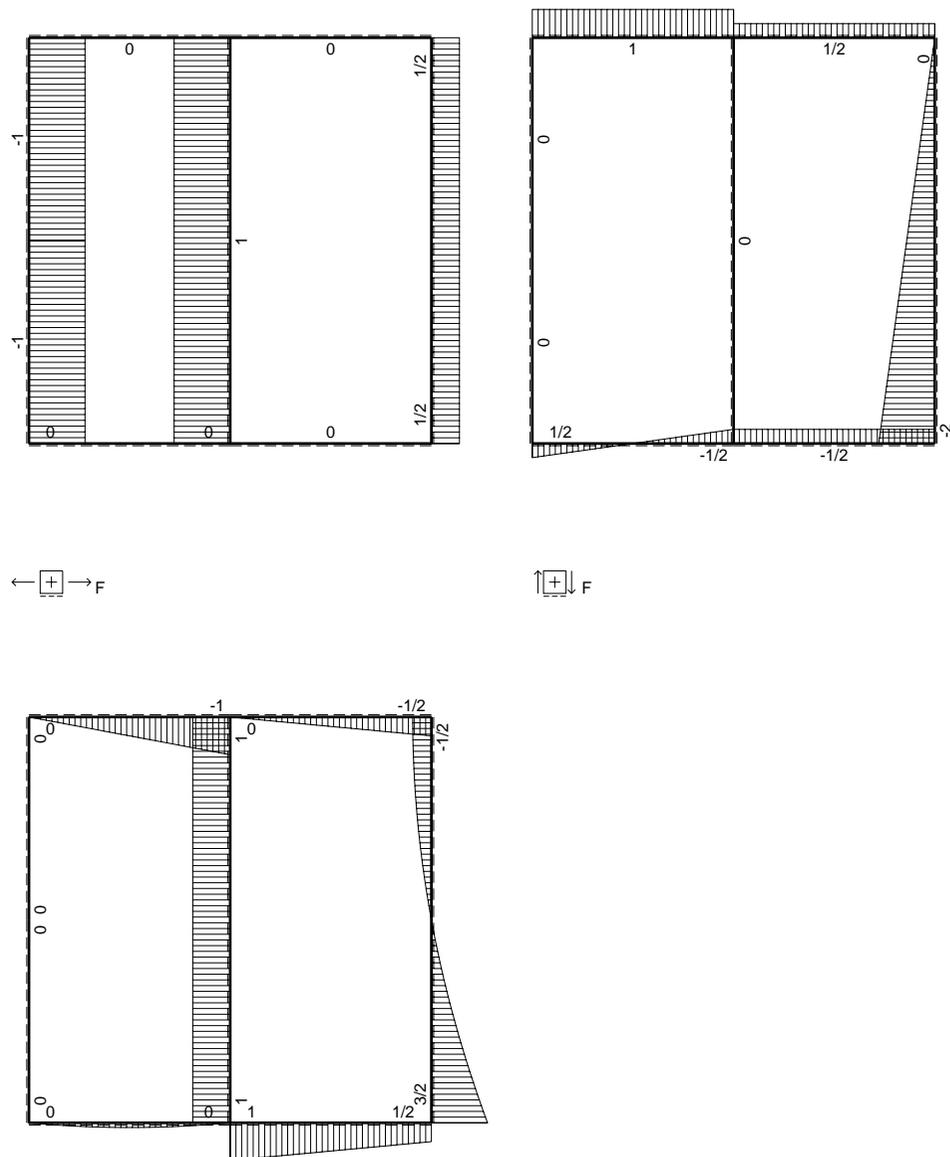
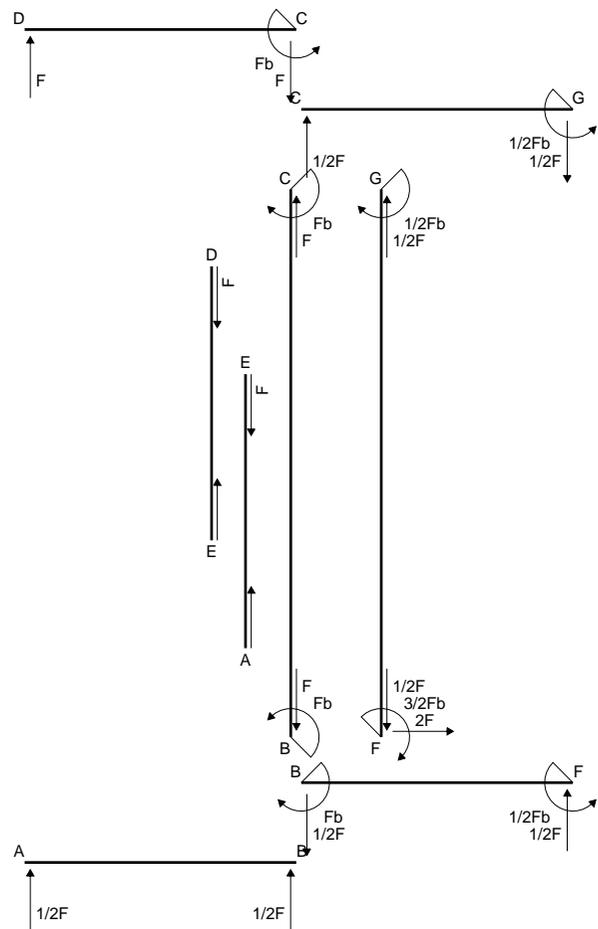
$$\sigma_c = -Mv/J_u = -114.6 \text{ N/mm}^2$$

$$\tau_c = 3.672 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 114.7 \text{ N/mm}^2$$

$$S = 5022. \text{ mm}^3$$





$\left[ \oplus \right] \downarrow F_b$



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

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

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

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

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

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

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

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

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

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

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

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

$$L_{BF}^{x_0} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

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

$$L_{FB}^{x_0} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

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

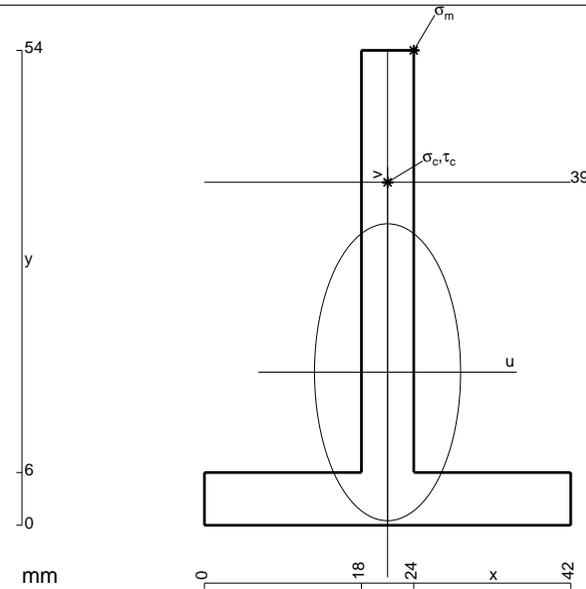
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

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

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

$$L_{GF}^{x_0} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

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



$$A = 540. \text{ mm}^2$$

$$J_u = 154030. \text{ mm}^4$$

$$J_v = 37908. \text{ mm}^4$$

$$y_g = 17.4 \text{ mm}$$

$$T_y = 1290. \text{ N}$$

$$M_x = -877200. \text{ Nmm}$$

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

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

$$u_m = 3. \text{ mm}$$

$$v_m = 36.6 \text{ mm}$$

$$\sigma_m = -Mv/J_u = 208.4 \text{ N/mm}^2$$

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

$$y_c = 39. \text{ mm}$$

$$v_c = 21.6 \text{ mm}$$

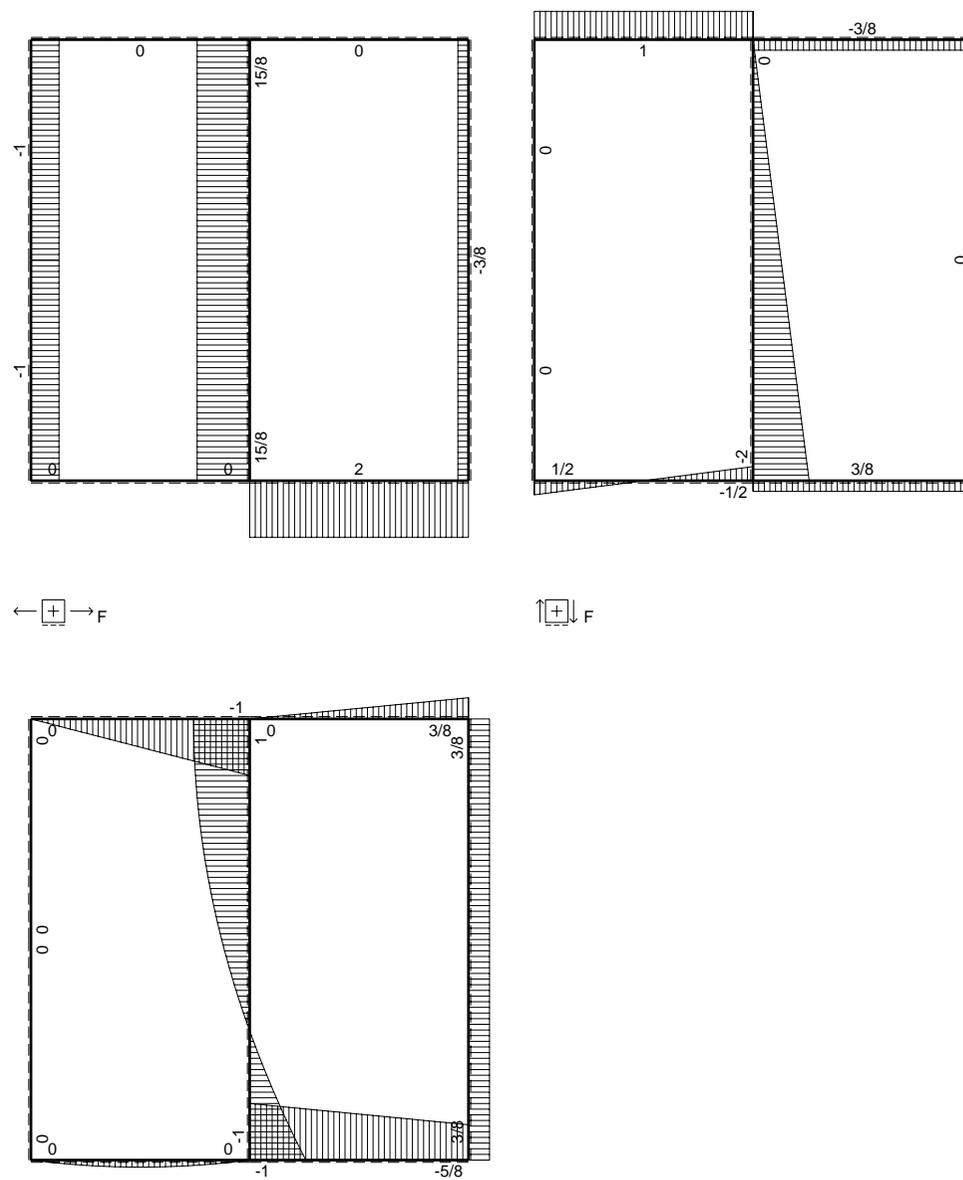
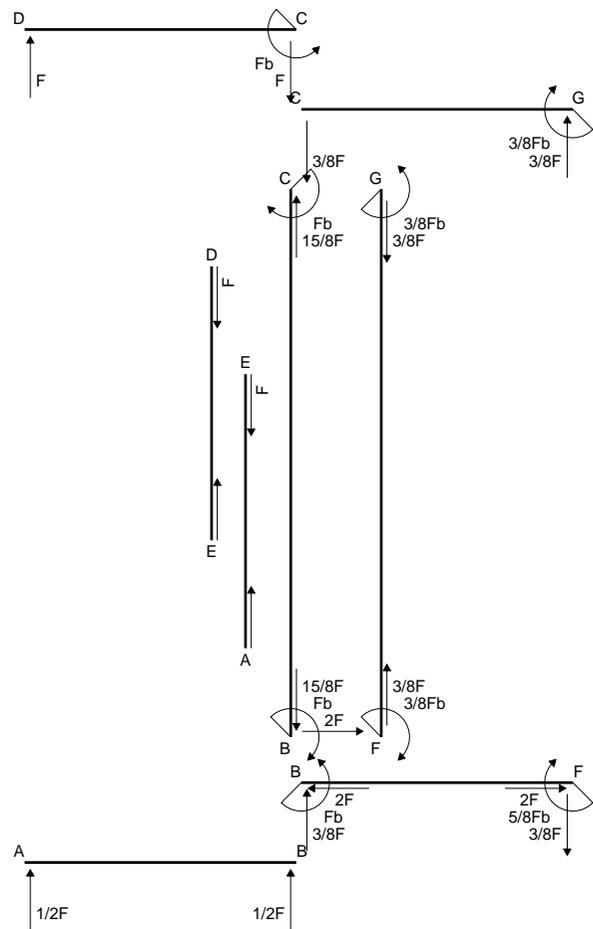
$$\sigma_c = -Mv/J_u = 123. \text{ N/mm}^2$$

$$\tau_c = 3.656 \text{ N/mm}^2$$

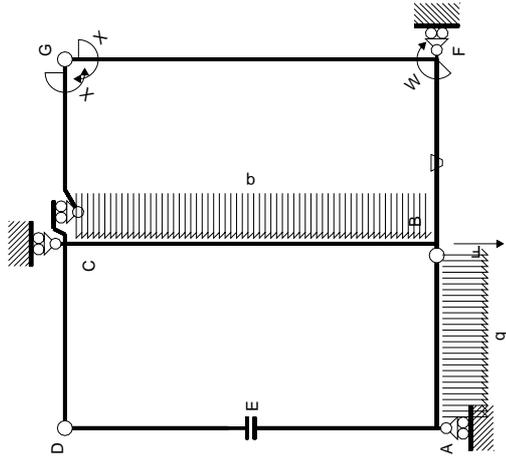
$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 123.2 \text{ N/mm}^2$$

$$S = 2619. \text{ mm}^3$$



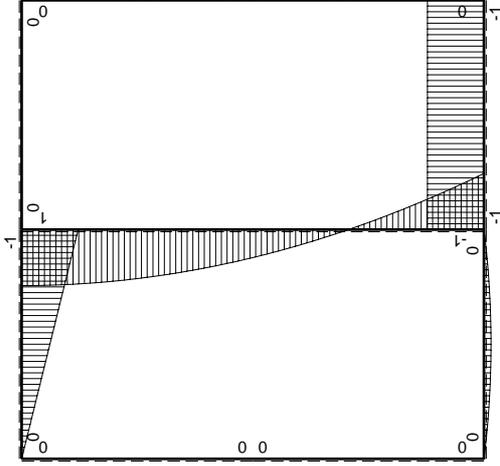


$\leftarrow \boxed{+} \rightarrow F_b$



Schema di calcolo iperstatico

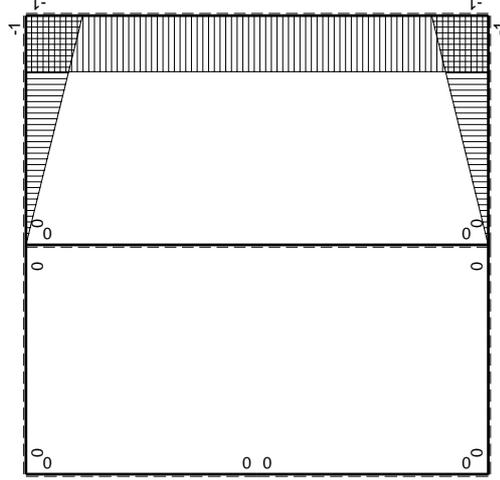
$M_0$  flessione da carichi assegnati



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

$\leftarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0
BA b	0	$-1/2Fx+1/2qx^2$	0	0	0	0	0+0	0
CD b	0	$-Fb+Fx$	0	0	0	0	0+0	0
DC b	0	$Fx$	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
EA b	0	0	0	0	0	0	0+0	0
AE b	0	0	0	0	0	0	0+0	0
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb-Fx$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$1/3xb/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2xb/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2xb/EJ$
CB 2b	0	$Fb-1/2qx^2$	0	0	0	0	0+0	0
BC 2b	0	$Fb-2Fx+1/2qx^2$	0	0	0	0	0+0	0
totali								
								$Fb^2/EJ$
								$8/3xb/EJ$

Sviluppi di calcolo iperstatica



$M_x$  flessione da iperstatica  $X=1$

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

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

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

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

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

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

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

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

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

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

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

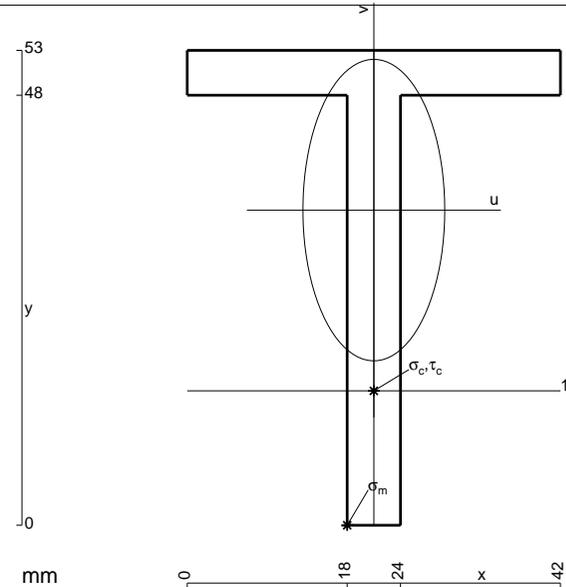
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

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

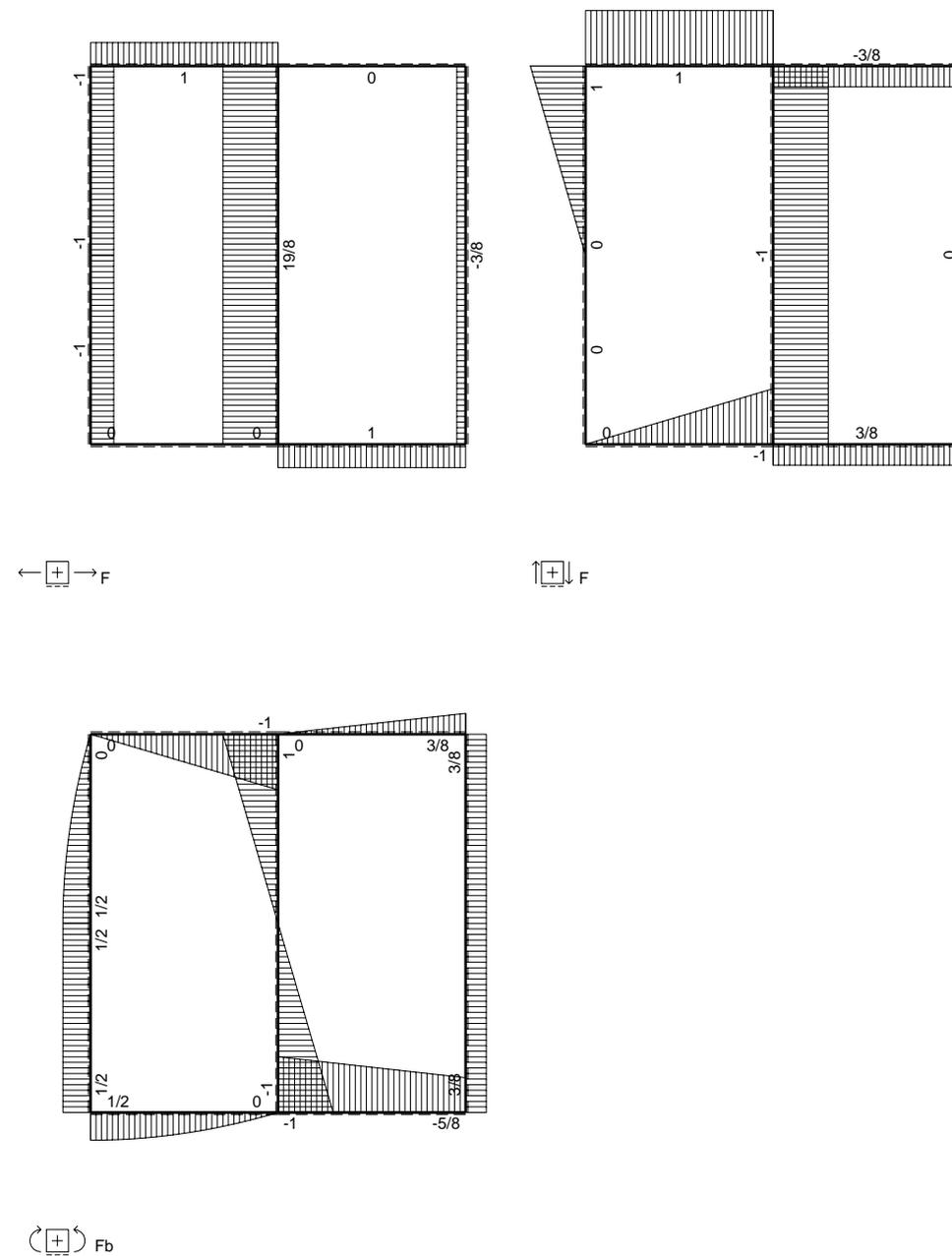
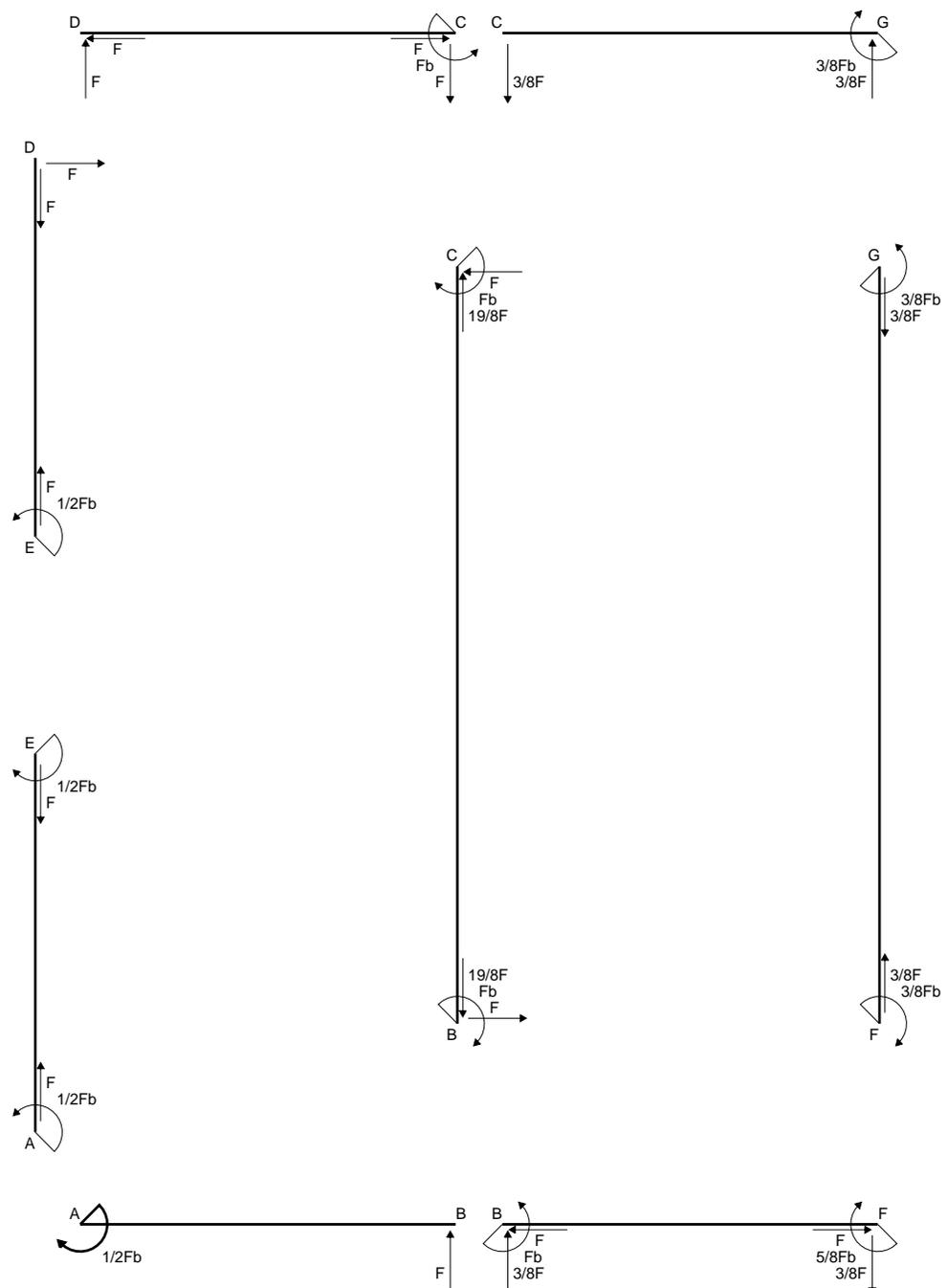
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

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



- A = 498. mm<sup>2</sup>
- J<sub>u</sub> = 141019. mm<sup>4</sup>
- J<sub>v</sub> = 31734. mm<sup>4</sup>
- y<sub>g</sub> = 35.17 mm
- N = 2363. N
- T<sub>y</sub> = -2520. N
- M<sub>x</sub> = -894600. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -35.17 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = -218.4 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 15. mm
- v<sub>c</sub> = -20.17 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = -123.2 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.418 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 123.9 N/mm<sup>2</sup>
- S = 2491. mm<sup>3</sup>







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

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

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

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

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

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

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

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

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

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

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

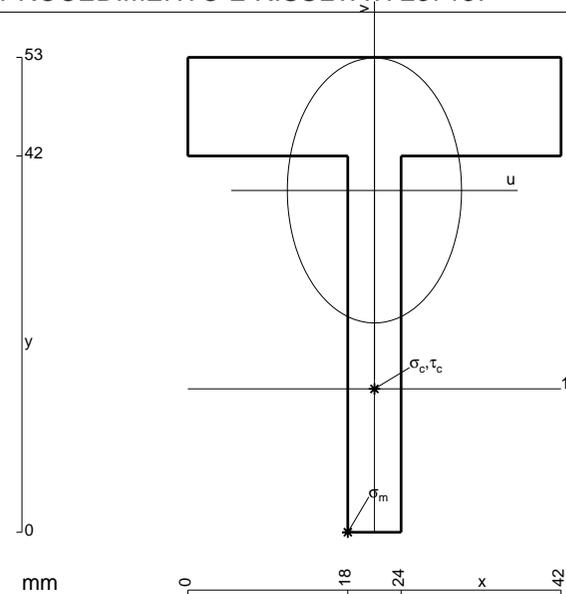
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

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

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

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



$$A = 714. \text{ mm}^2$$

$$J_u = 156210. \text{ mm}^4$$

$$J_v = 68670. \text{ mm}^4$$

$$y_g = 38.15 \text{ mm}$$

$$N = 2921. \text{ N}$$

$$T_y = -1230. \text{ N}$$

$$M_x = 922500. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -38.15 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 229.4 \text{ N/mm}^2$$

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

$$y_c = 16. \text{ mm}$$

$$v_c = -22.15 \text{ mm}$$

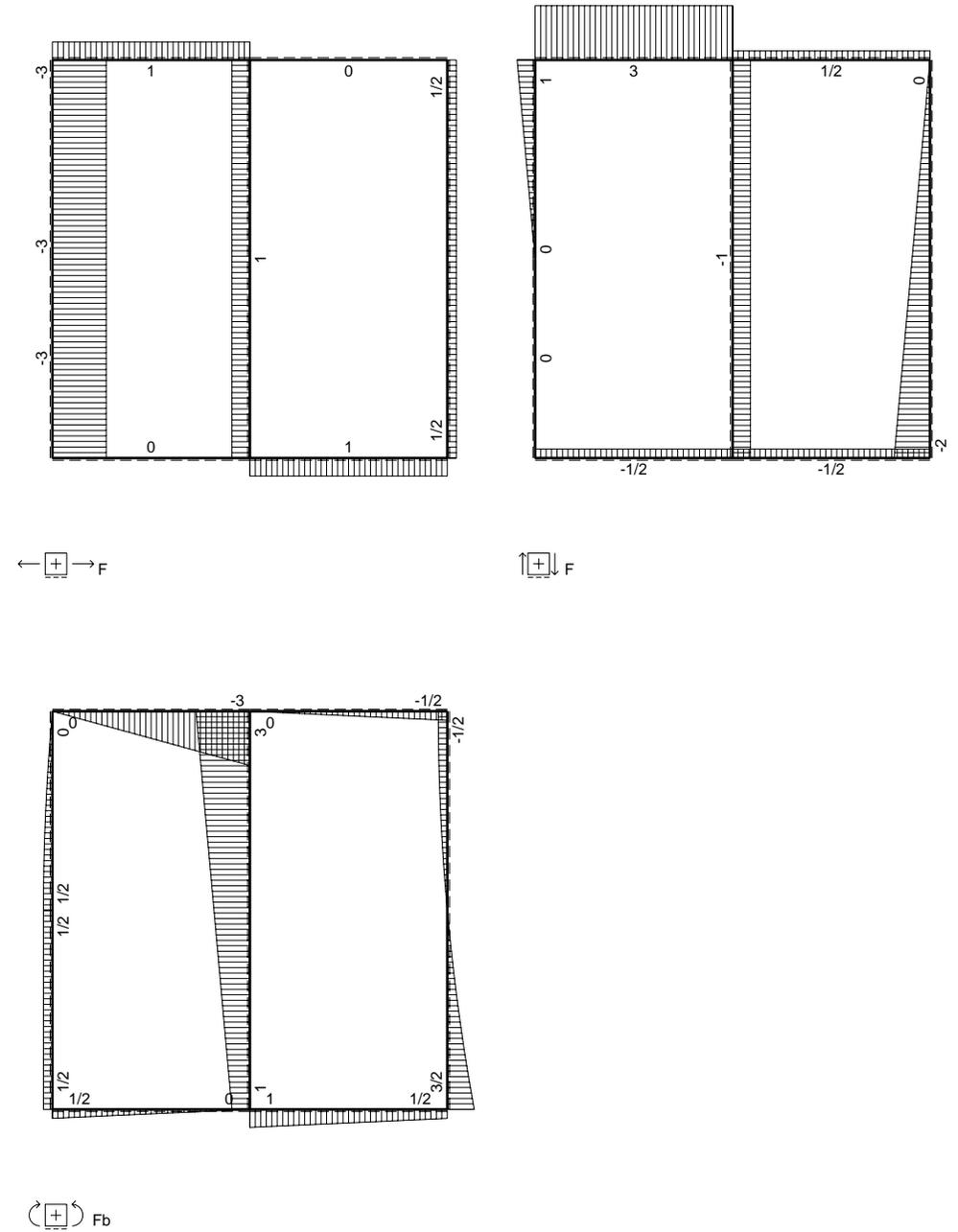
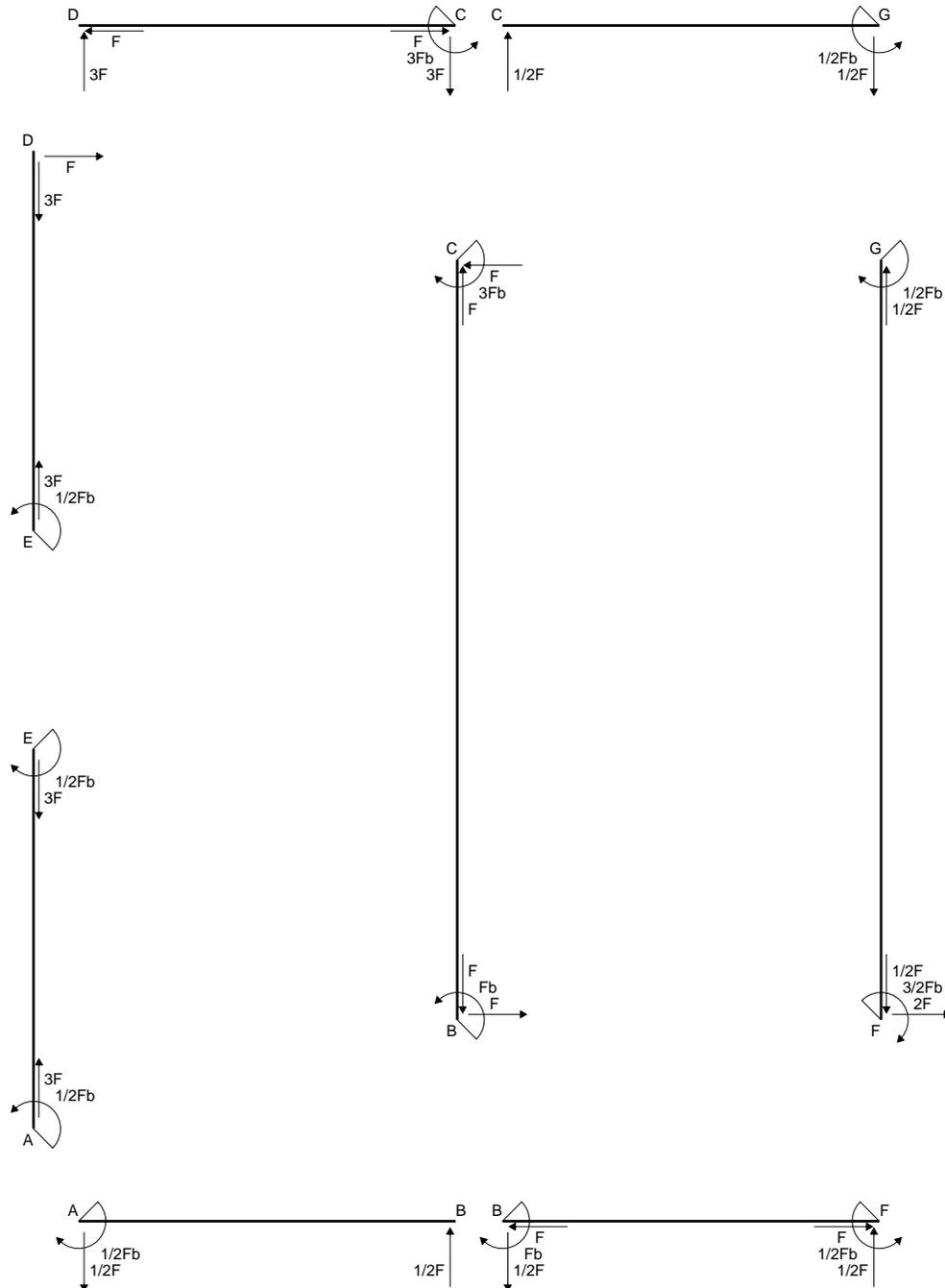
$$\sigma_c = N/A - Mv/J_u = 134.9 \text{ N/mm}^2$$

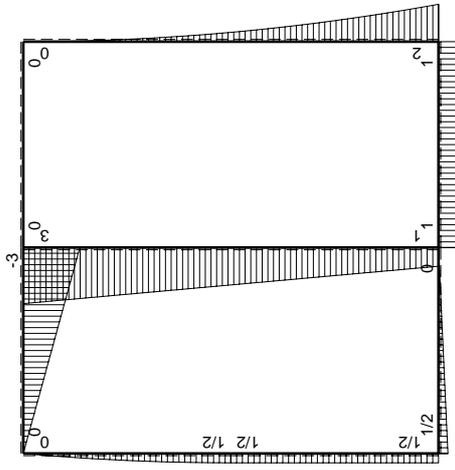
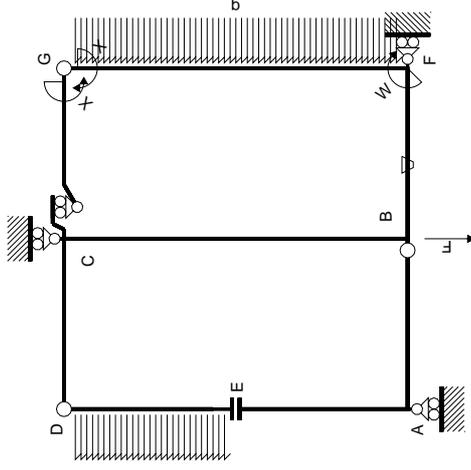
$$\tau_c = 3.798 \text{ N/mm}^2$$

$$\sigma_\varphi = \sqrt{\sigma^2 + 3\tau^2} = 135. \text{ N/mm}^2$$

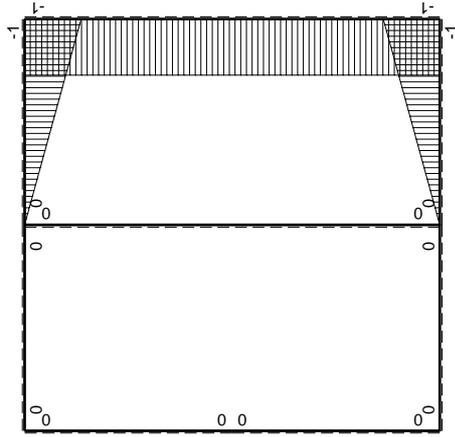
$$S = 2894. \text{ mm}^3$$







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica $X=W_{gc}$		iperstatica $X=W_{gc}$						
$\rightarrow$	$M(x)$	$M^0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	0	$1/2Fb-1/2Fx$	0	0	0	0	0+0	0
BA b	0	$-1/2Fx$	0	0	0	0	0+0	0
CD b	0	$-3Fb+3Fx$	0	0	0	0	0+0	0
DC b	0	$3Fx$	0	0	0	0	0+0	0
DE b	0	$Fx-1/2qx^2$	0	0	0	0	0+0	0
ED b	0	$-1/2Fb+1/2qx^2$	0	0	0	0	0+0	0
EA b	0	$1/2Fb$	0	0	0	0	0+0	0
AE b	0	$-1/2Fb$	0	0	0	0	0+0	0
BF b	$-x/b$	$Fb$	$-Fb/EJ$	$-Fx$	$Fx/EJ$	$x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$-Fb$	$Fb/EJ$	$-Fb+Fx$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	$2Fb-2Fx+1/2qx^2$	0	$-2Fb+2Fx-1/2Fx^2/b$	0	1	$(-4/3+0)Fb^2/EJ$	$2xb/EJ$
GF 2b	1	$-1/2qx^2$	0	$-1/2Fx^2/b$	0	1	$(-4/3+0)Fb^2/EJ$	$2xb/EJ$
CB 2b	0	$3Fb-Fx$	0	0	0	0	0+0	0
BC 2b	0	$-Fb-Fx$	0	0	0	0	0+0	0
totali							$-4/3Fb^2/EJ$	$8/3xb/EJ$

Sviluppi di calcolo iperstatica

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

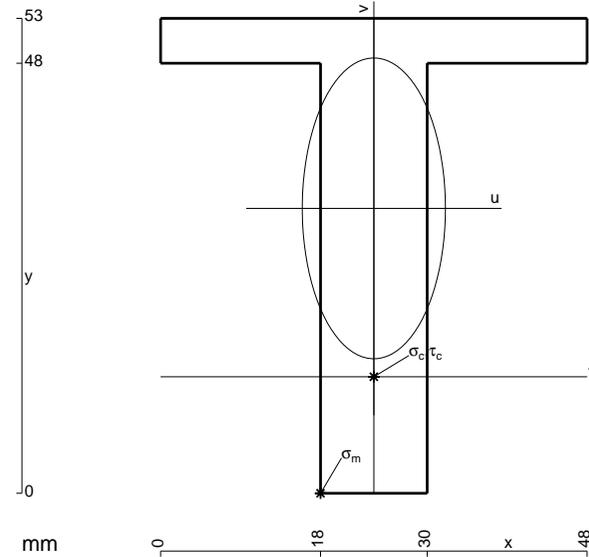
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

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

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

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

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



- A = 816. mm<sup>2</sup>
- J<sub>u</sub> = 230061. mm<sup>4</sup>
- J<sub>v</sub> = 52992. mm<sup>4</sup>
- y<sub>g</sub> = 31.79 mm
- N = 730. N
- T<sub>y</sub> = 2190. N
- M<sub>x</sub> = -1730100. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -31.79 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = -238.2 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 13. mm
- v<sub>c</sub> = -18.79 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = -140.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.13 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 = 3946. mm<sup>3</sup>







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

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

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

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

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

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

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

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

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

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

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

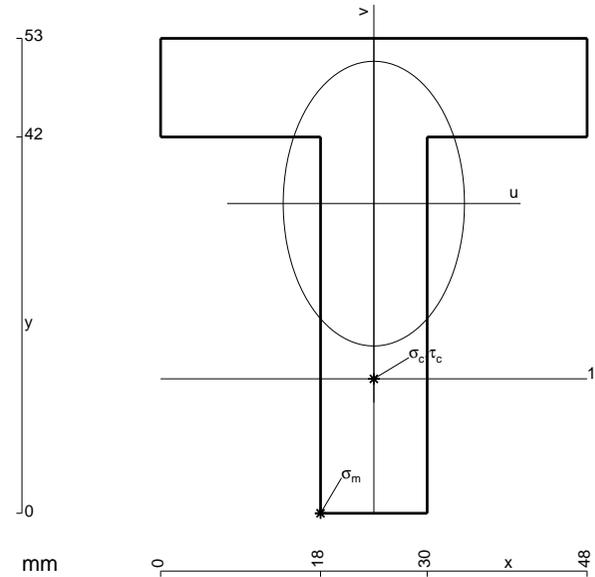
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

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

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

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



$$A = 1032. \text{ mm}^2$$

$$J_u = 260495. \text{ mm}^4$$

$$J_v = 107424. \text{ mm}^4$$

$$y_g = 34.56 \text{ mm}$$

$$N = 1200. \text{ N}$$

$$T_y = 3600. \text{ N}$$

$$M_x = -1512000. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$u_m = -6. \text{ mm}$$

$$v_m = -34.56 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -199.4 \text{ N/mm}^2$$

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

$$y_c = 15. \text{ mm}$$

$$v_c = -19.56 \text{ mm}$$

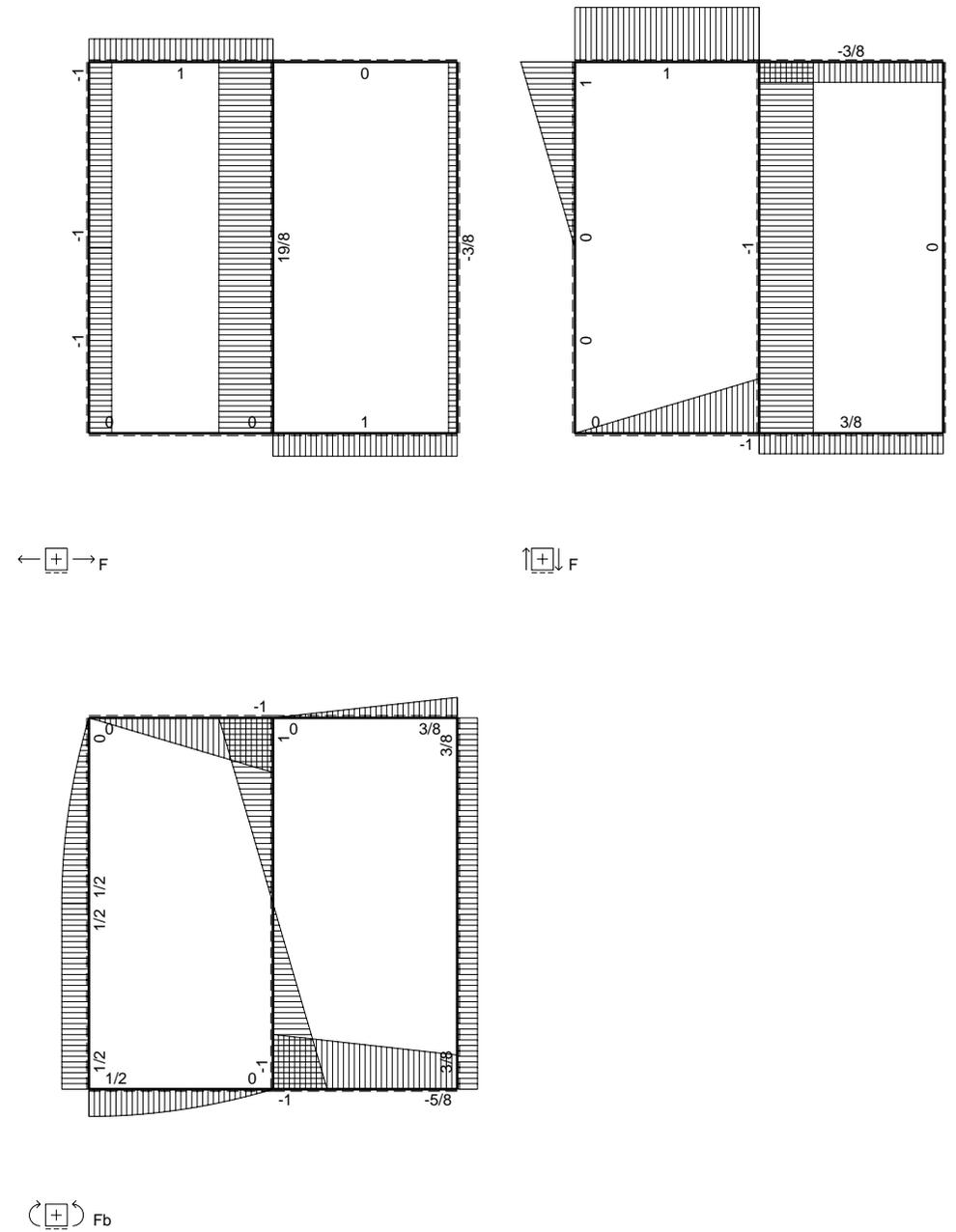
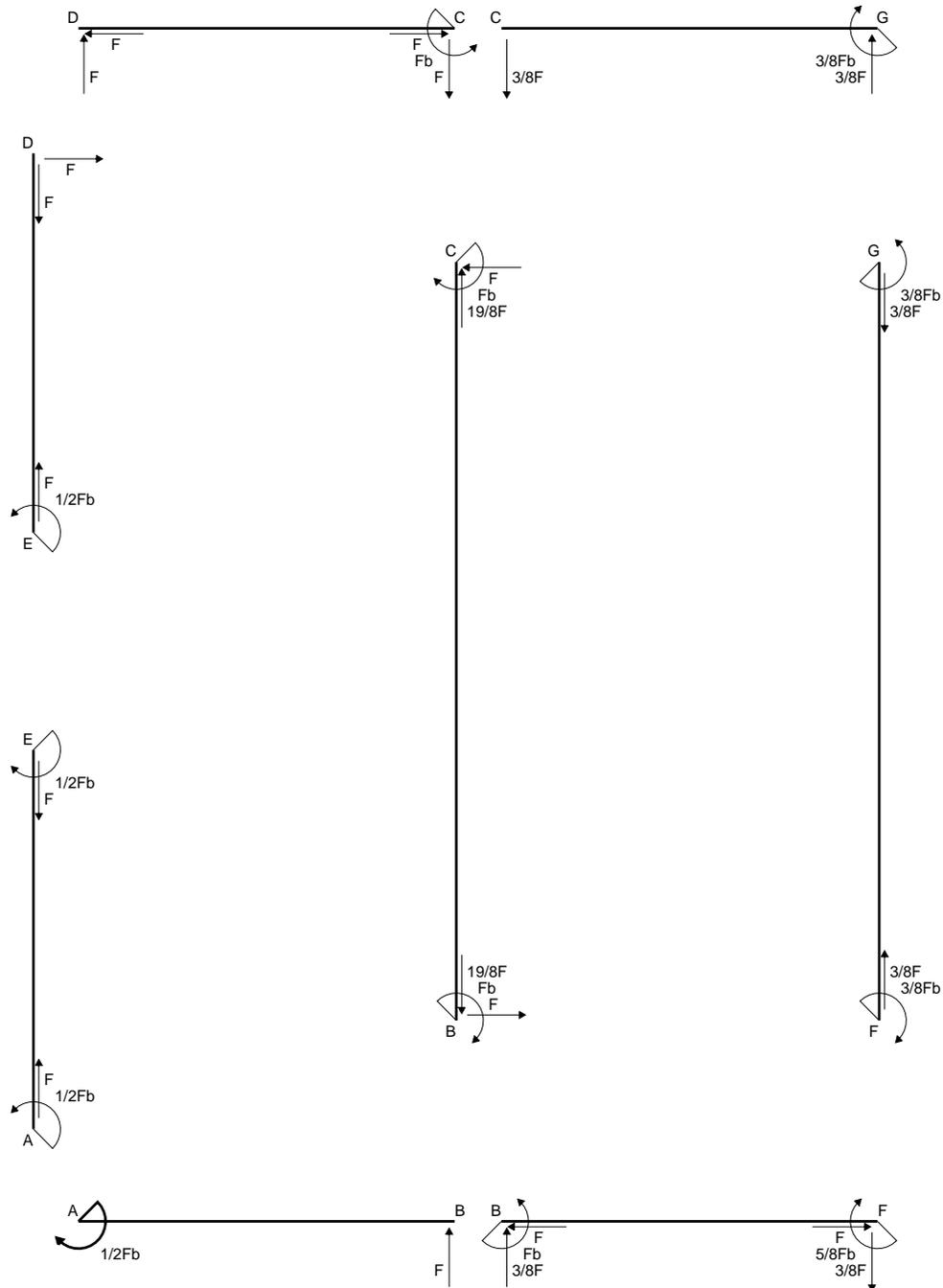
$$\sigma_c = N/A - Mv/J_u = -112.4 \text{ N/mm}^2$$

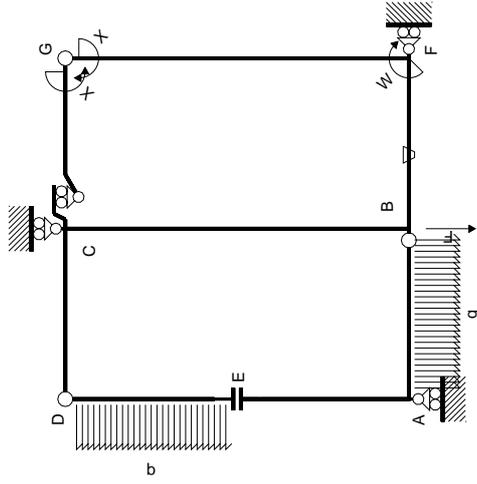
$$\tau_c = 5.609 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 112.8 \text{ N/mm}^2$$

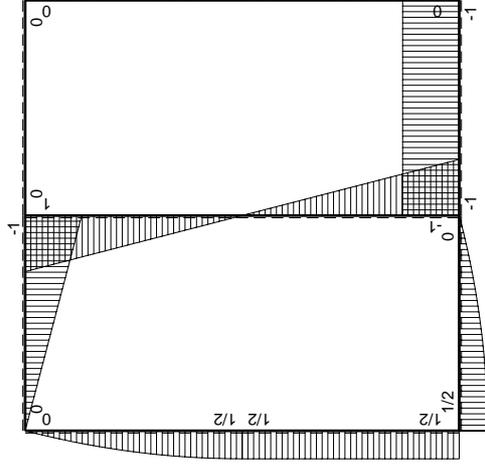
$$S = 4870. \text{ mm}^3$$



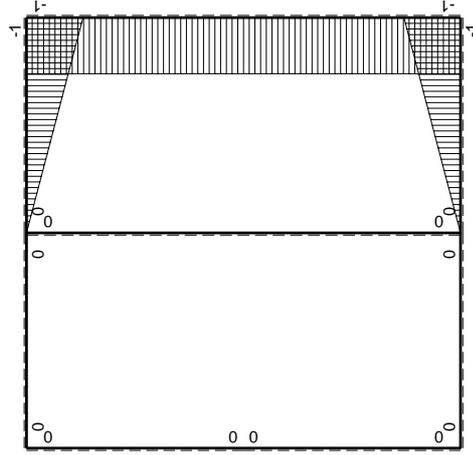




Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

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

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	$1/2Fb-1/2qx^2$	0	0	0	0	0	0+0	0
BA b	$-Fx+1/2qx^2$	0	0	0	0	0	0+0	0
CD b	$-Fb+Fx$	0	0	0	0	0	0+0	0
DC b	$Fx$	0	0	0	0	0	0+0	0
DE b	$Fx-1/2qx^2$	0	0	0	0	0	0+0	0
ED b	$-1/2Fb+1/2qx^2$	0	0	0	0	0	0+0	0
EA b	$1/2Fb$	0	0	0	0	0	0+0	0
AE b	$-1/2Fb$	0	0	0	0	0	0+0	0
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb-Fx$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$1/3xb/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2xb/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2xb/EJ$
CB 2b	0	$Fb-Fx$	0	0	0	0	0+0	0
BC 2b	0	$Fb-Fx$	0	0	0	0	0+0	0
totali								$Fb^2/EJ$
								$8/3xb/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

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

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

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

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

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

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

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

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

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

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

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

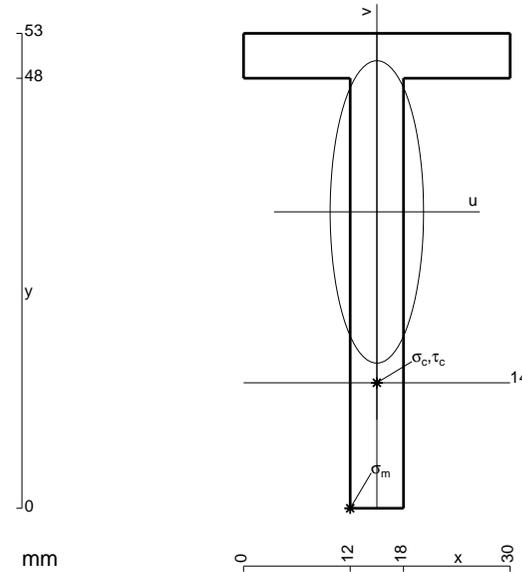
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

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

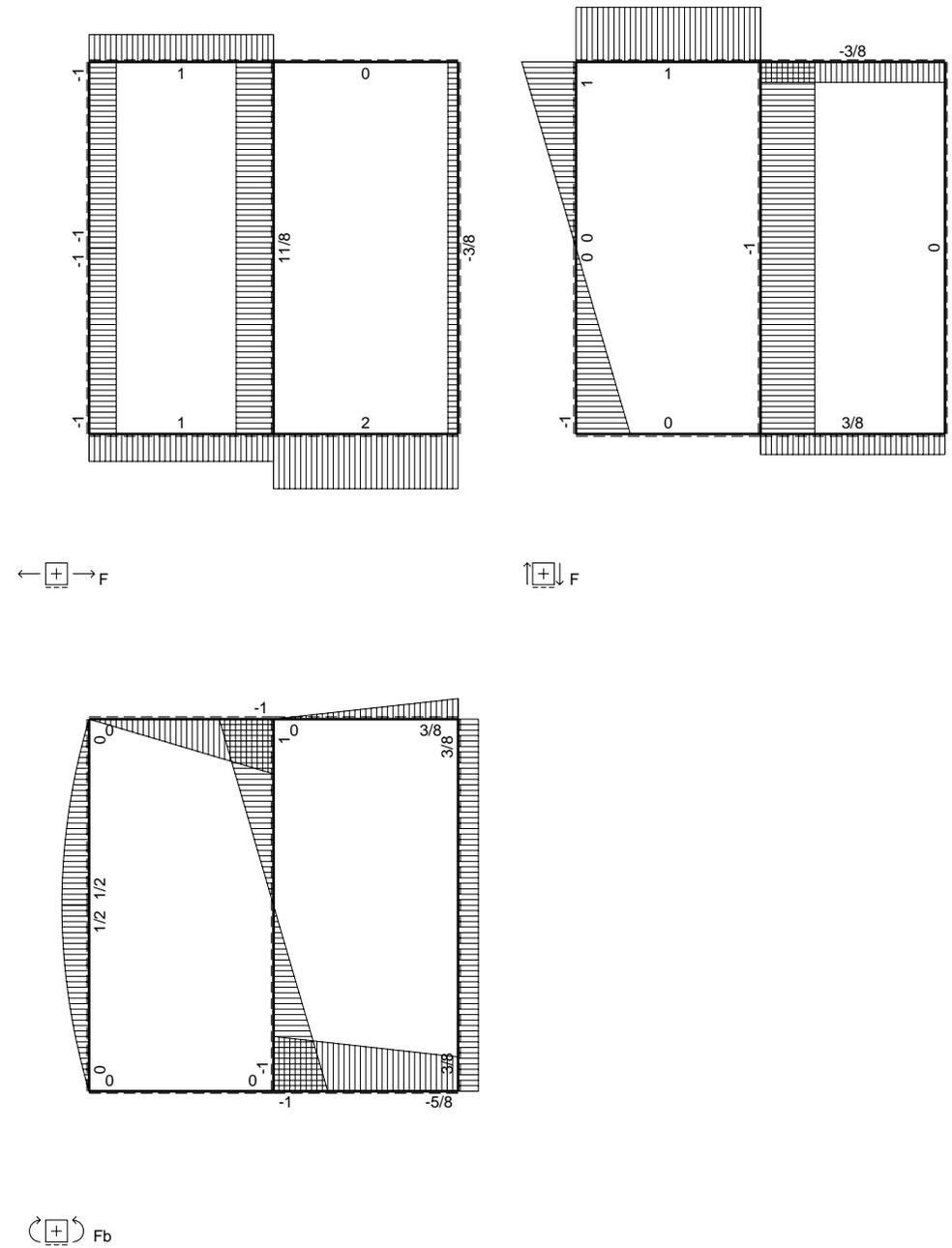
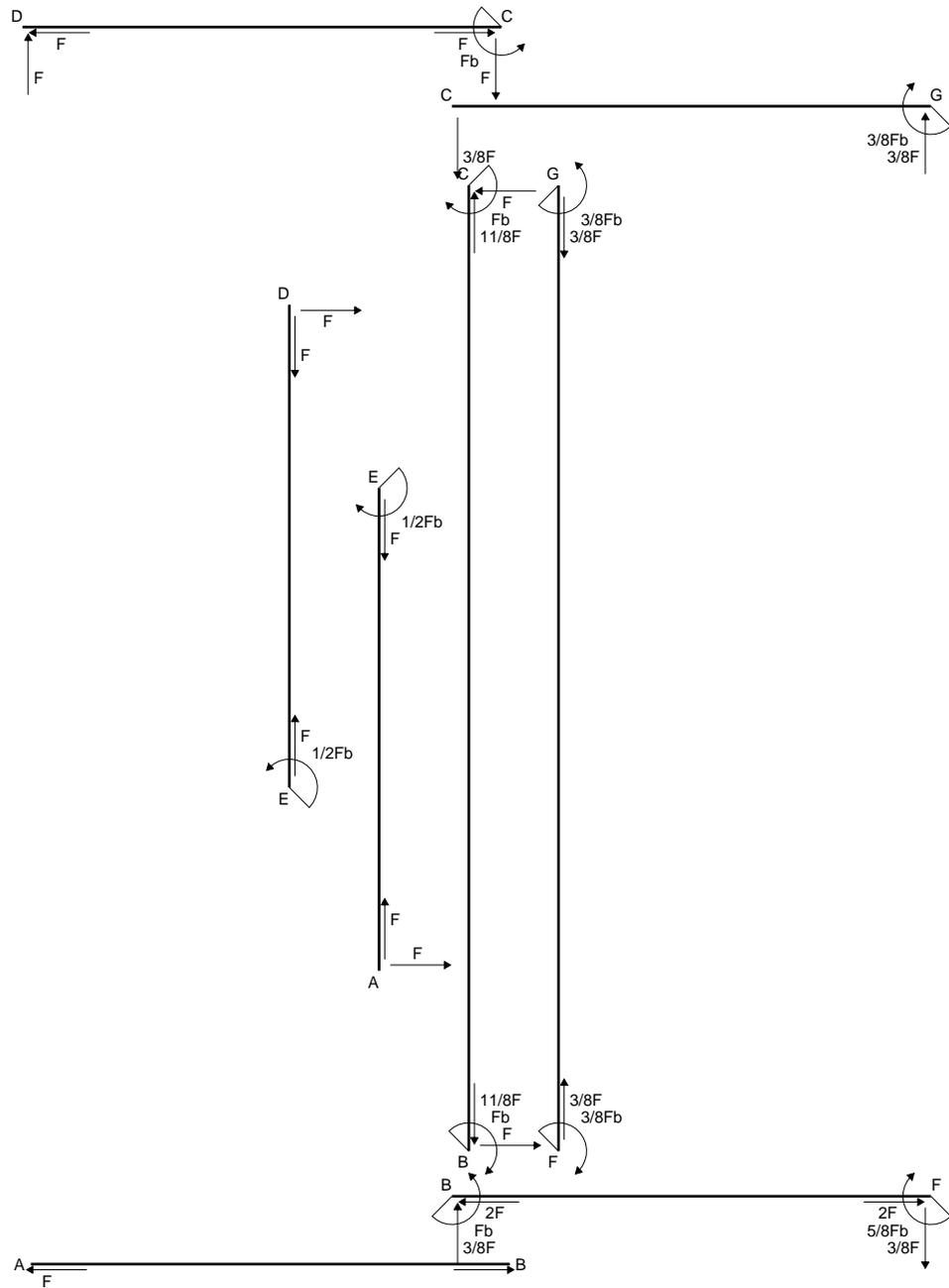
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

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



- A = 438. mm<sup>2</sup>
- J<sub>u</sub> = 124871. mm<sup>4</sup>
- J<sub>v</sub> = 12114. mm<sup>4</sup>
- y<sub>g</sub> = 33.08 mm
- N = 3919. N
- T<sub>y</sub> = -1650. N
- M<sub>x</sub> = 759000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -33.08 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = 210. N/mm<sup>2</sup>
- x<sub>c</sub> = 15. mm
- y<sub>c</sub> = 14. mm
- v<sub>c</sub> = -19.08 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = 124.9 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.824 N/mm<sup>2</sup>
- σ<sub>g</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 125.2 N/mm<sup>2</sup>
- S = 2190. mm<sup>3</sup>







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

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

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

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

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

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

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

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

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

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

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

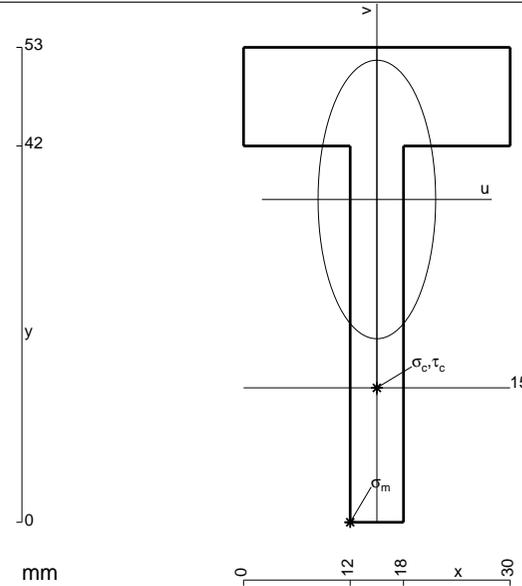
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

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

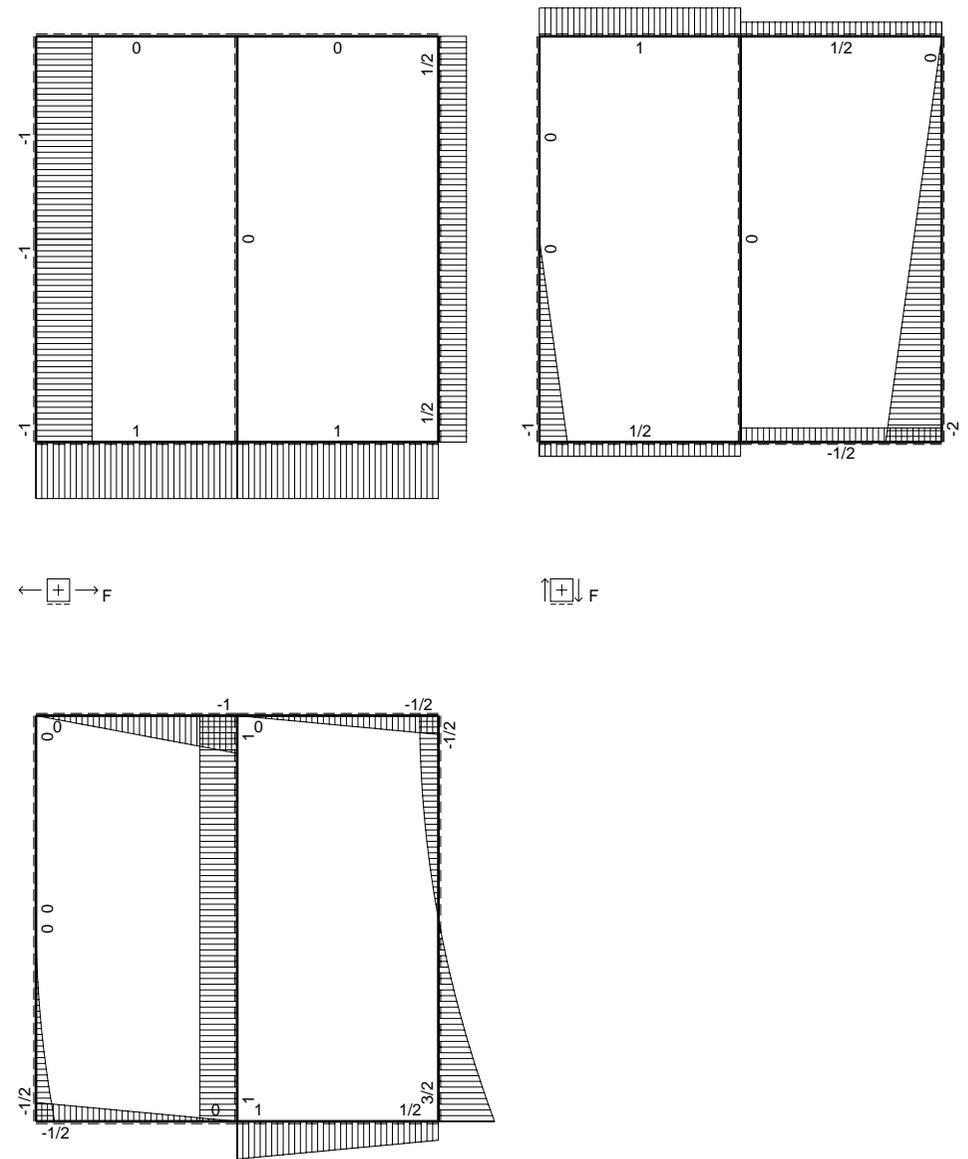
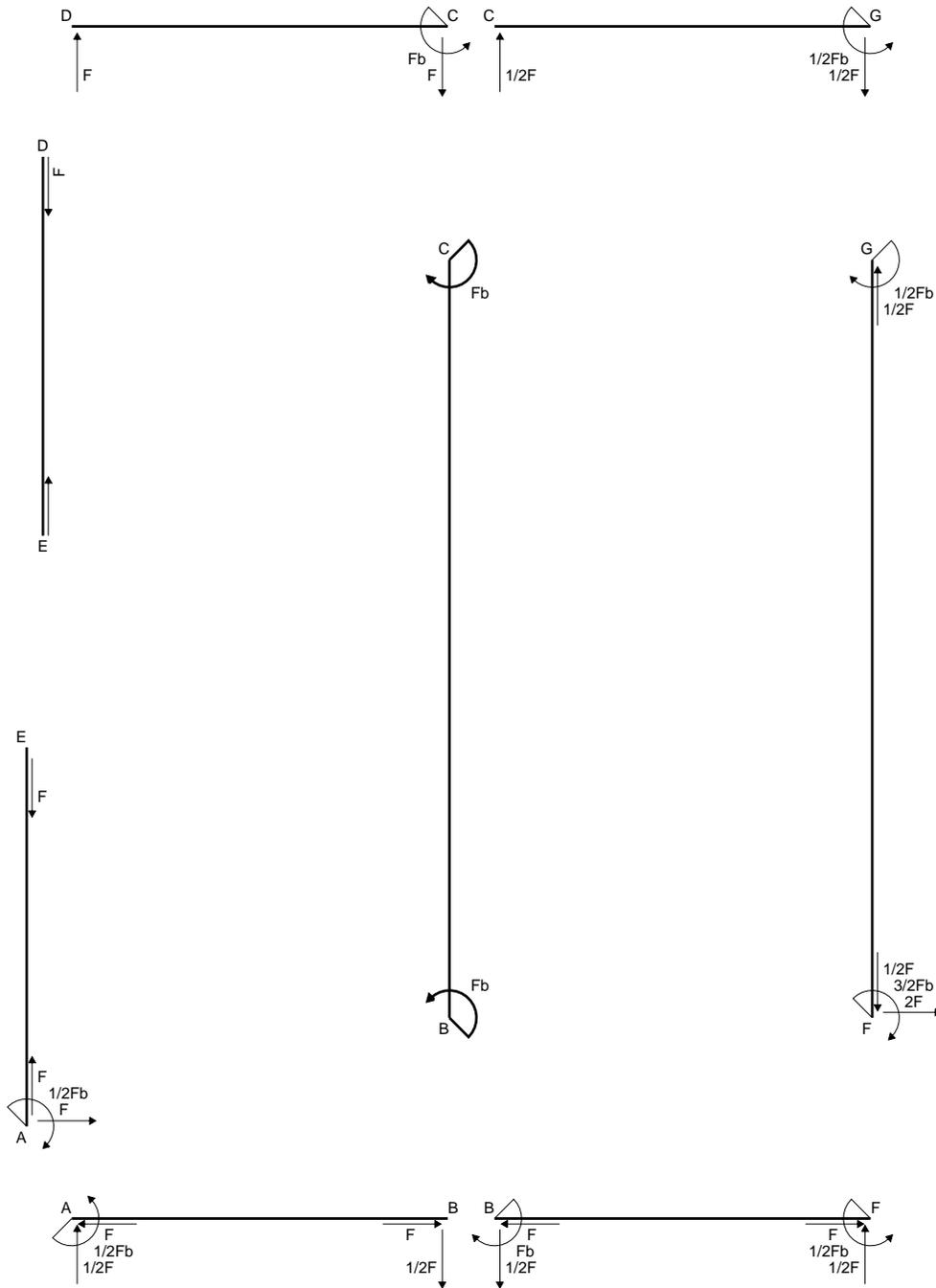
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

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



- A = 582. mm<sup>2</sup>
- J<sub>u</sub> = 140714. mm<sup>4</sup>
- J<sub>v</sub> = 25506. mm<sup>4</sup>
- y<sub>g</sub> = 36.03 mm
- N = 2310. N
- T<sub>y</sub> = -1680. N
- M<sub>x</sub> = 840000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -36.03 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = 219. N/mm<sup>2</sup>
- x<sub>c</sub> = 15. mm
- y<sub>c</sub> = 15. mm
- v<sub>c</sub> = -21.03 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = 129.5 N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.109 N/mm<sup>2</sup>
- σ<sub>g</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 129.8 N/mm<sup>2</sup>
- S = 2567. mm<sup>3</sup>





← ⊕ → F

↑ ⊕ ↓ F

⊕ ⊖ Fb



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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

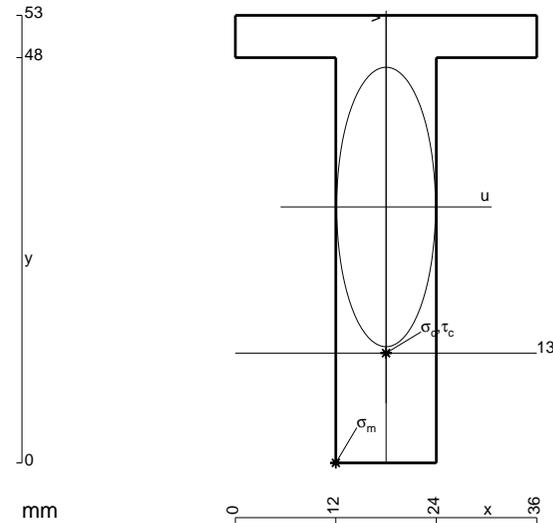
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

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

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

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

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



$$A = 756. \text{ mm}^2$$

$$J_u = 207276. \text{ mm}^4$$

$$J_v = 26352. \text{ mm}^4$$

$$y_g = 30.31 \text{ mm}$$

$$T_y = 2910. \text{ N}$$

$$M_x = -1571400. \text{ Nmm}$$

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

$$u_m = -6. \text{ mm}$$

$$v_m = -30.31 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -229.8 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

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

$$v_c = -17.31 \text{ mm}$$

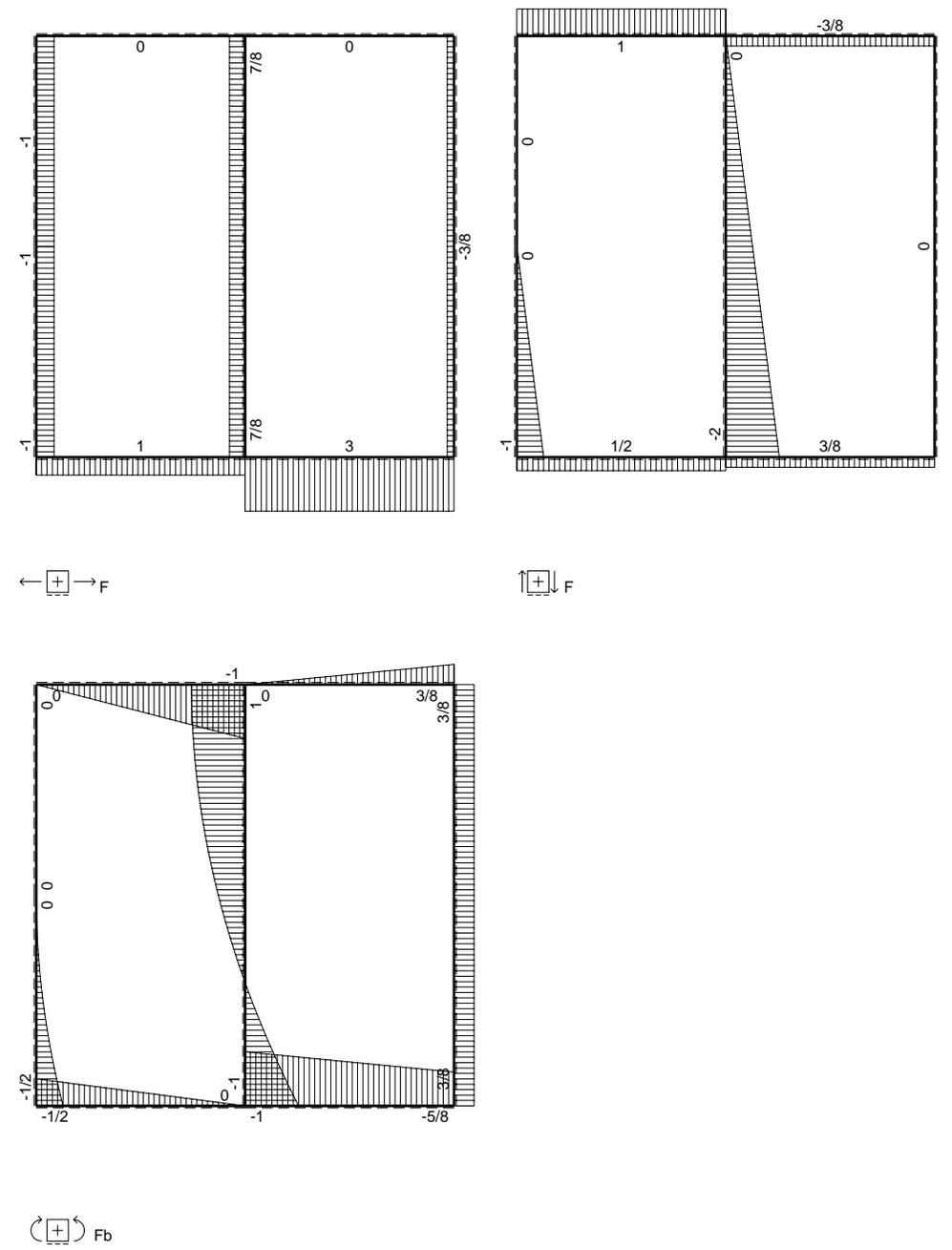
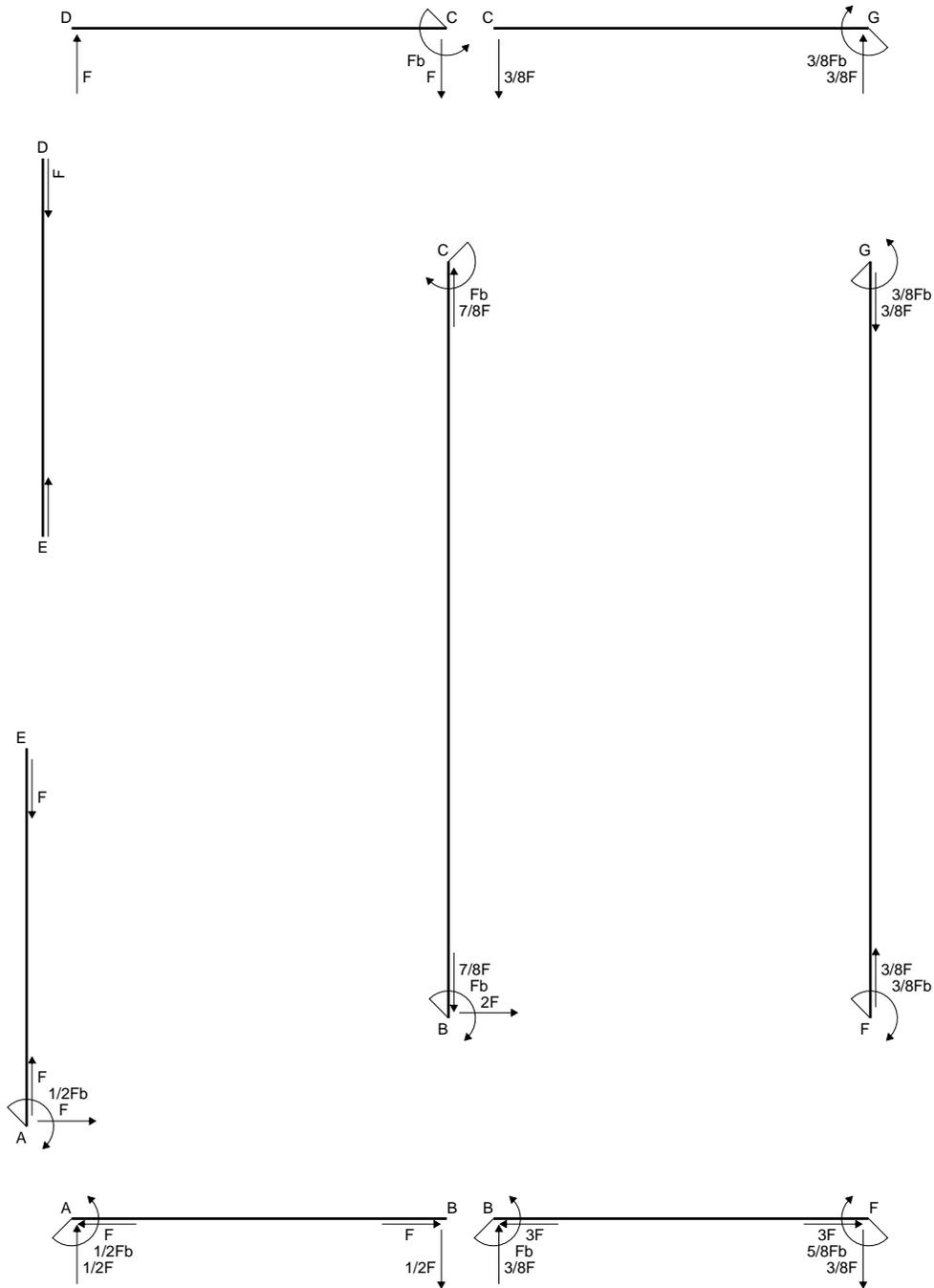
$$\sigma_c = -Mv/J_u = -131.2 \text{ N/mm}^2$$

$$\tau_c = 4.345 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 131.4 \text{ N/mm}^2$$

$$S = 3714. \text{ mm}^3$$







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

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

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

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

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

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

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

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

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

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

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

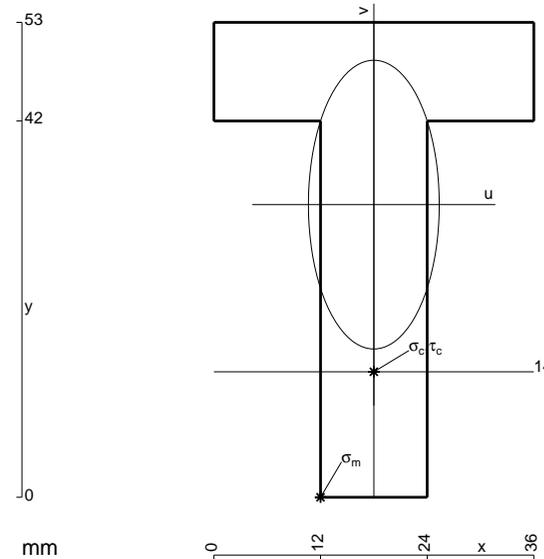
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

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

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

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



$$A = 900. \text{ mm}^2$$

$$J_u = 233812. \text{ mm}^4$$

$$J_v = 48816. \text{ mm}^4$$

$$y_g = 32.66 \text{ mm}$$

$$N = 2616. \text{ N}$$

$$T_y = -5980. \text{ N}$$

$$M_x = -1734200. \text{ Nmm}$$

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

$$u_m = -6. \text{ mm}$$

$$v_m = -32.66 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -239.3 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 14. \text{ mm}$$

$$v_c = -18.66 \text{ mm}$$

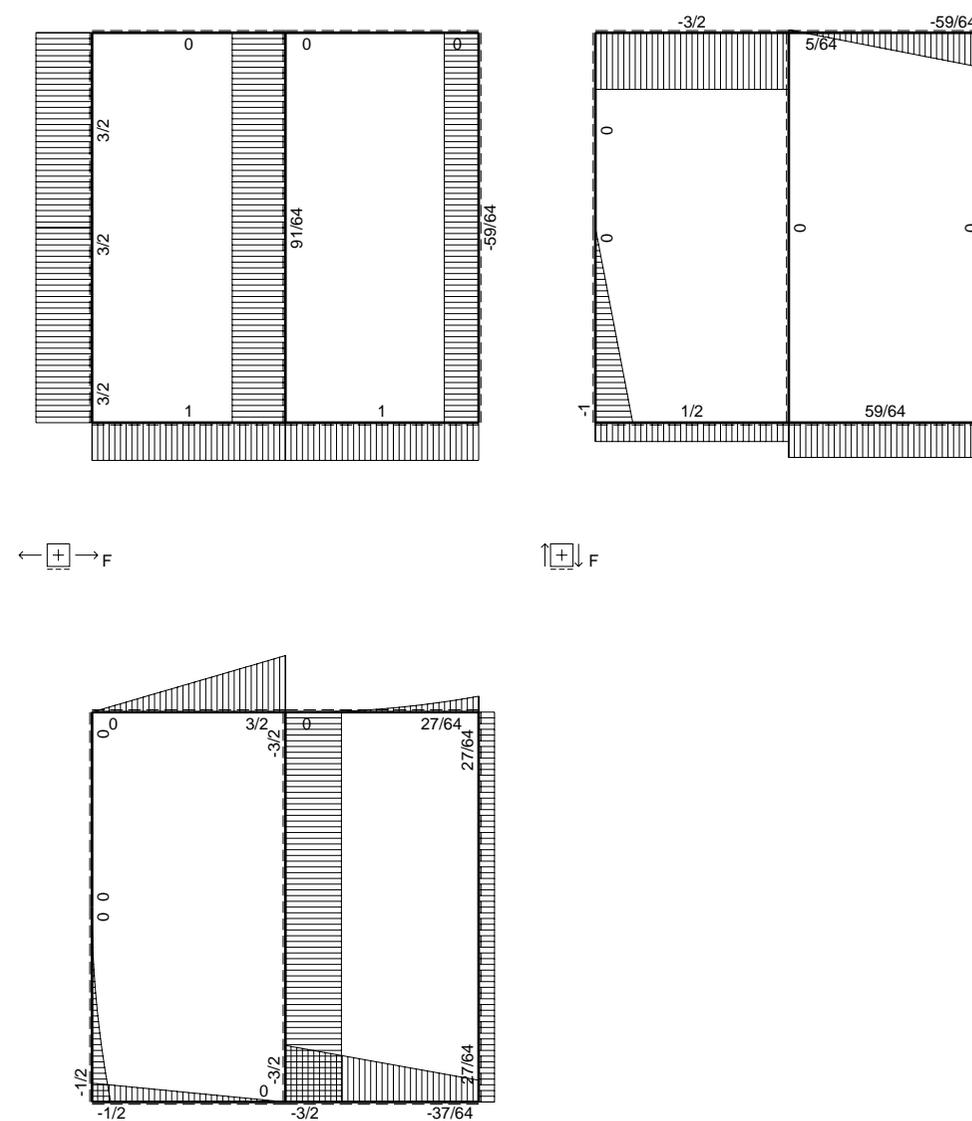
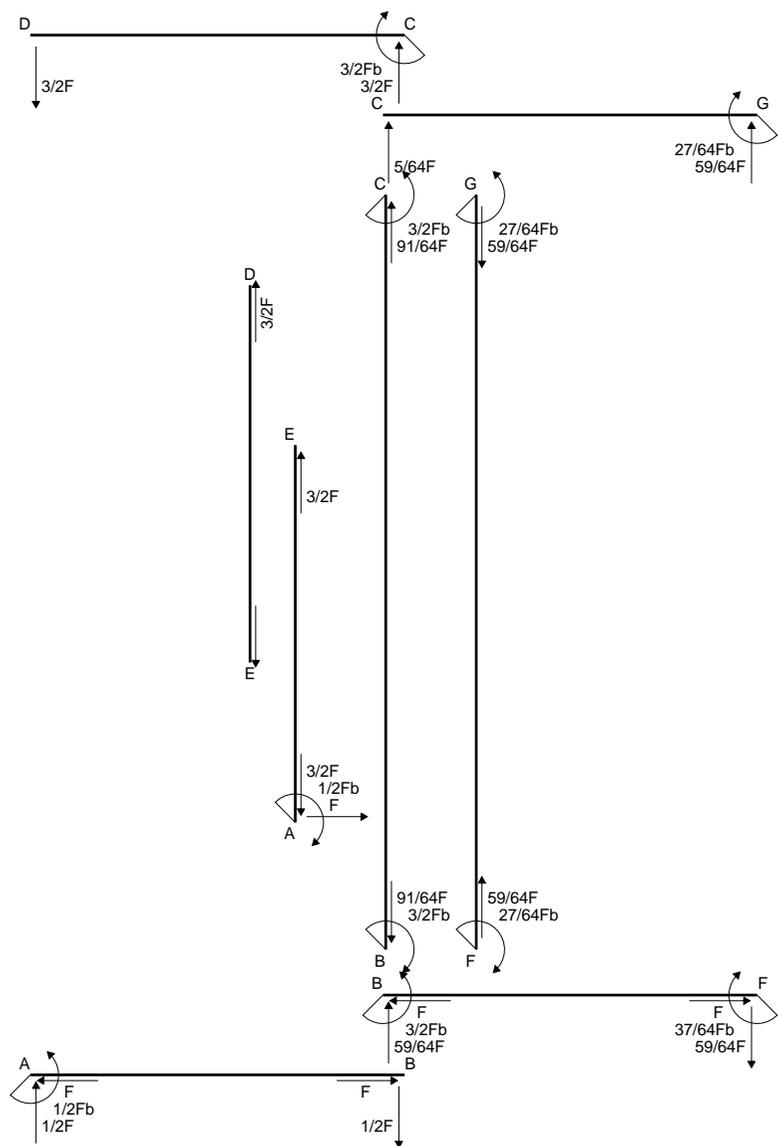
$$\sigma_c = N/A - Mv/J_u = -135.5 \text{ N/mm}^2$$

$$\tau_c = 9.188 \text{ N/mm}^2$$

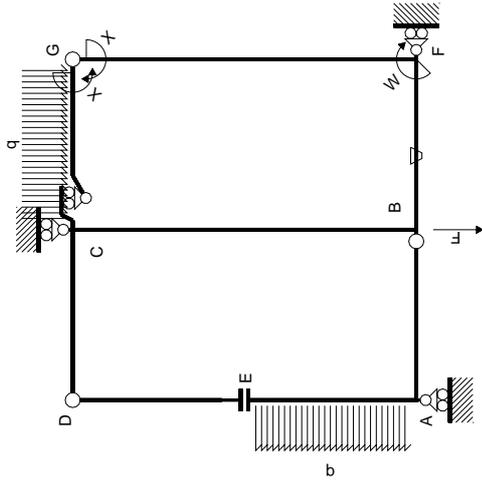
$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 136.4 \text{ N/mm}^2$$

$$S = 4311. \text{ mm}^3$$

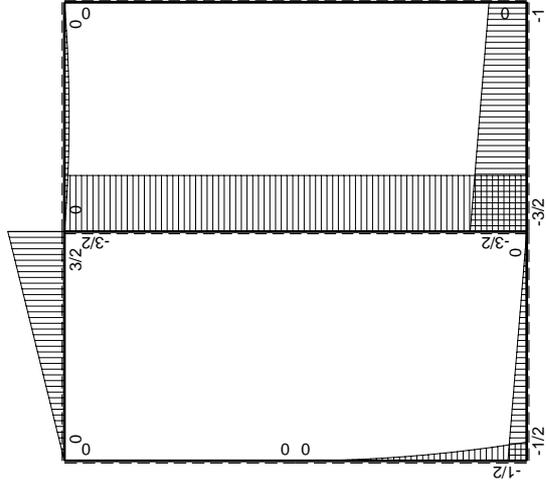




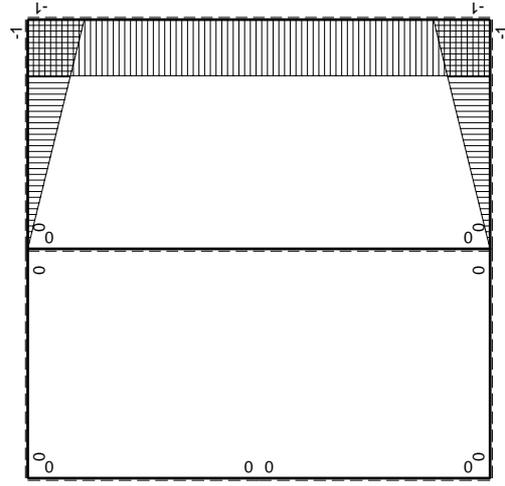
(+) Fb



Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica X=W <sub>gc</sub>		M <sup>x</sup> M <sub>x</sub>		M <sup>0</sup> M <sub>0</sub>		θ		M <sup>0</sup> (x)		M <sup>x</sup> (x)		totali	
AB B	0	0	0	0	0	0	0	0	-1/2Fb+1/2Fx	0	0	0	0
BA B	0	0	0	0	0	0	0	1/2Fx	0	0	0	0	0
CD b	0	0	0	0	0	0	0	3/2Fb-3/2Fx	0	0	0	0	0
DC b	0	0	0	0	0	0	0	-3/2Fx	0	0	0	0	0
DE b	0	0	0	0	0	0	0	0	0	0	0	0	0
EA b	0	0	0	0	0	0	0	-1/2qx <sup>2</sup>	0	0	0	0	0
AE b	0	0	0	0	0	0	0	1/2Fb-Fx+1/2qx <sup>2</sup>	0	0	0	0	0
BF b	-x/b	-3/2Fb+1/2Fx	-Fb/EJ	3/2Fx-1/2Fx <sup>2</sup> /b	Fx/EJ	0	0	-x/b	-3/2Fb+1/2Fx	-Fb/EJ	0	0	0
FB b	1-x/b	Fb+1/2Fx	Fb/EJ	Fb-1/2Fx-1/2Fx <sup>2</sup> /b	Fb/EJ-Fx/EJ	0	0	1-x/b	Fb+1/2Fx	Fb/EJ	0	0	0
GC b	-1+x/b	-1/2Fx+1/2qx <sup>2</sup>	0	1/2Fx-Fx <sup>2</sup> /b+1/2qx <sup>3</sup> /b	0	0	0	-1+x/b	-1/2Fx+1/2qx <sup>2</sup>	0	0	0	0
CG b	x/b	1/2Fx-1/2qx <sup>2</sup>	0	1/2Fx <sup>2</sup> /b-1/2qx <sup>3</sup> /b	0	0	0	x/b	1/2Fx-1/2qx <sup>2</sup>	0	0	0	0
FG 2b	-1	0	0	0	0	0	0	0	0	0	0	0	0
GF 2b	1	0	0	0	0	0	0	0	0	0	0	0	0
CB 2b	0	-3/2Fb	0	0	0	0	0	0	-3/2Fb	0	0	0	0
BC 2b	0	3/2Fb	0	0	0	0	0	0	3/2Fb	0	0	0	0
		totali											
		9/8Fb <sup>2</sup> /EJ		-27/64Fb									
		8/3Xb/EJ											

Sviluppi di calcolo iperstatica

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$= (3/4 b - 1/6 b) Fb 1/EJ + (1/2 b) \theta = 13/12 Fb^2/EJ$$

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

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

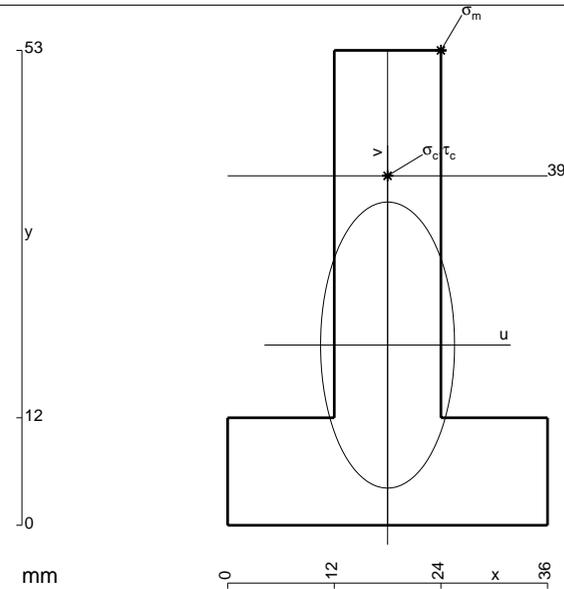
$$= (b - 1/4 b - 1/6 b) Fb 1/EJ + (-b + 1/2 b) \theta = 13/12 Fb^2/EJ$$

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

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

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

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$



$$A = 924. \text{ mm}^2$$

$$J_u = 235641. \text{ mm}^4$$

$$J_v = 52560. \text{ mm}^4$$

$$y_g = 20.11 \text{ mm}$$

$$T_y = -2265. \text{ N}$$

$$M_x = 1426950. \text{ Nmm}$$

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

$$y_m = 53. \text{ mm}$$

$$u_m = 6. \text{ mm}$$

$$v_m = 32.89 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -199.2 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 39. \text{ mm}$$

$$v_c = 18.89 \text{ mm}$$

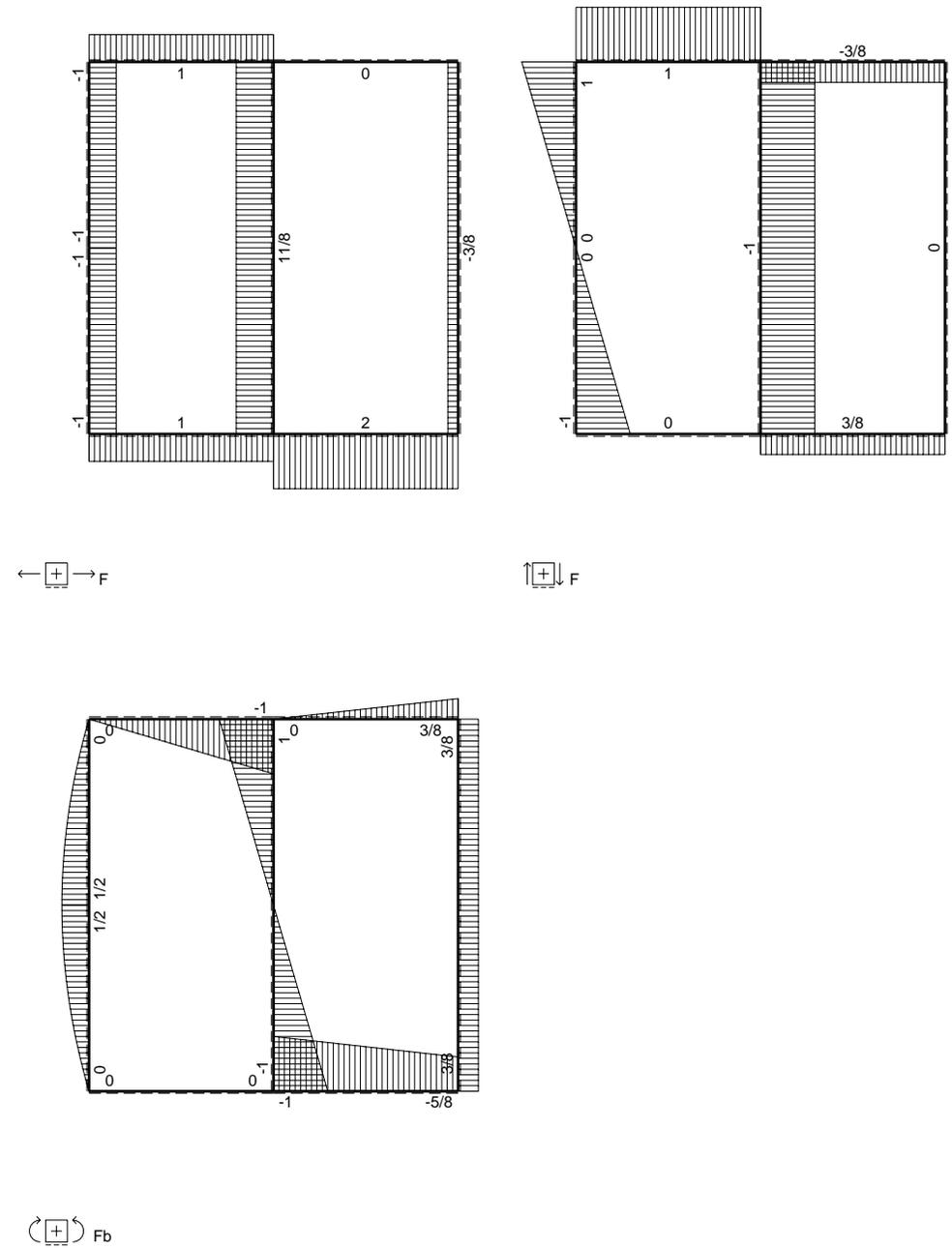
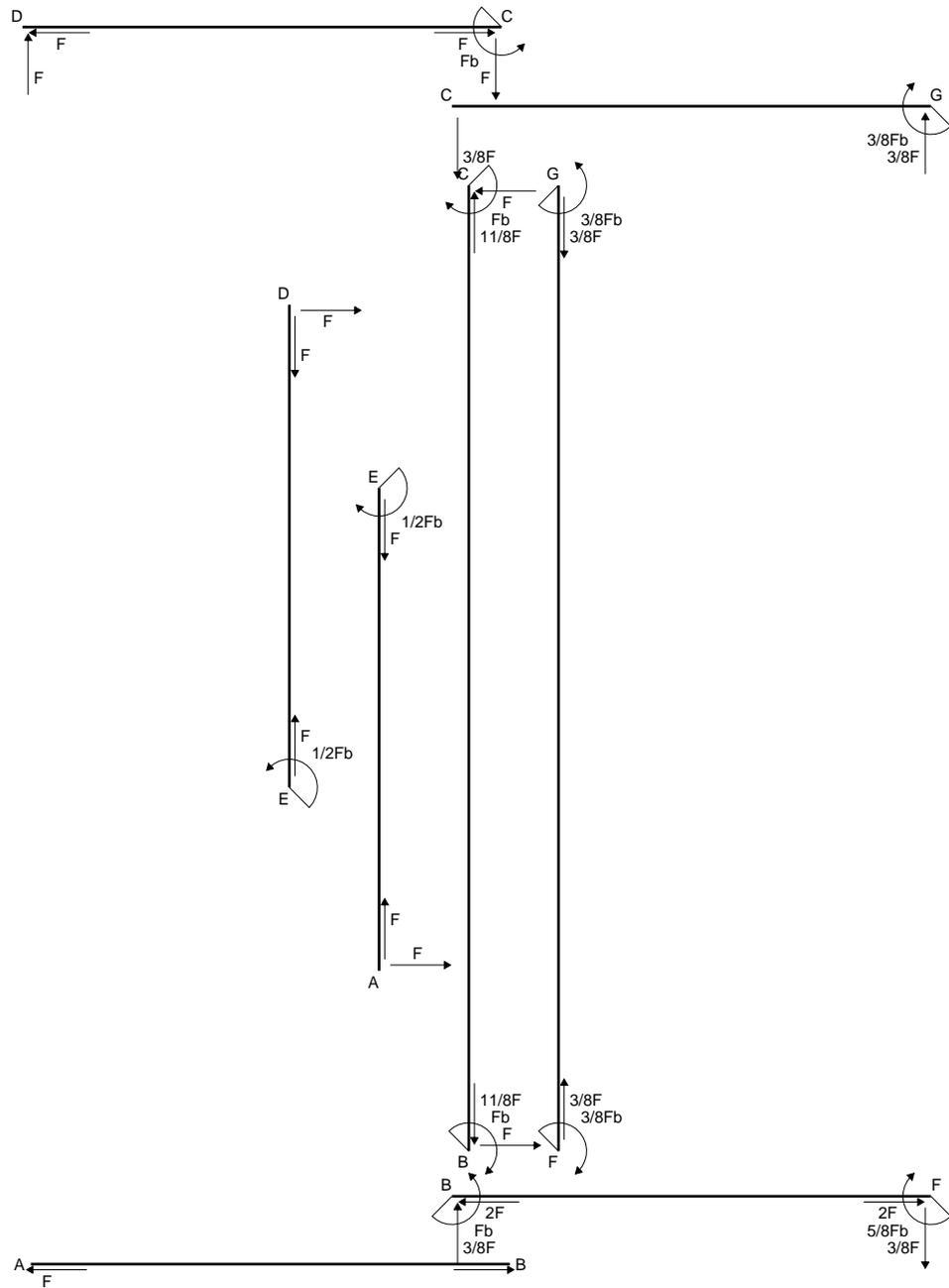
$$\sigma_c = -Mv/J_u = -114.4 \text{ N/mm}^2$$

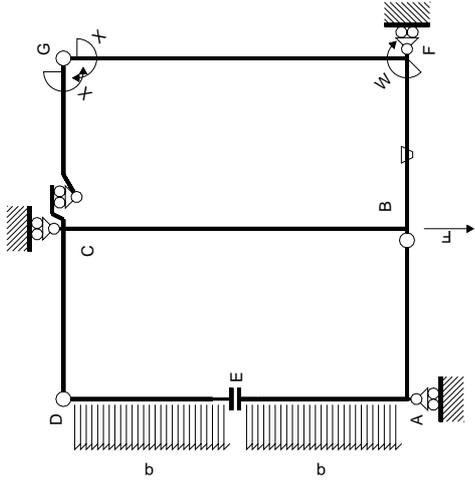
$$\tau_c = 3.484 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 114.5 \text{ N/mm}^2$$

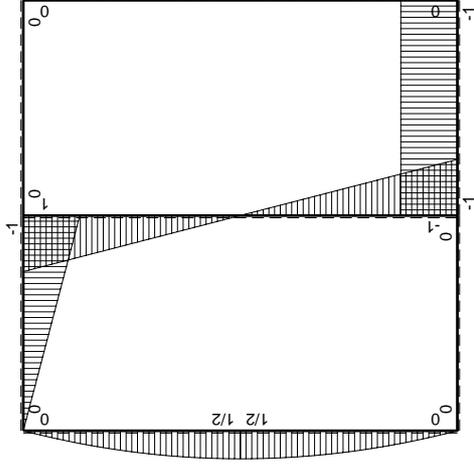
$$S = 4349. \text{ mm}^3$$



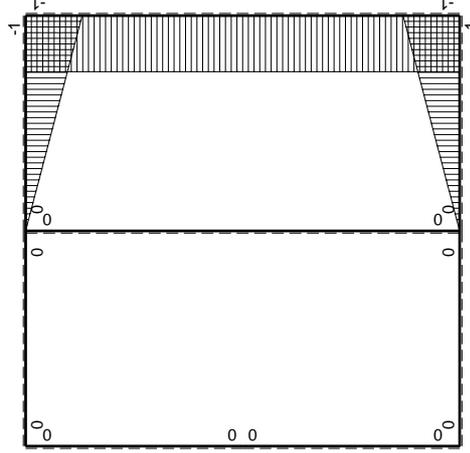




Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica X=W<sub>gc</sub>

→	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJdx$
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0+0	0
CD b	0	-Fb+Fx	0	0	0	0	0+0	0
DC b	0	Fx	0	0	0	0	0+0	0
DE b	0	Fx-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
ED b	0	-1/2Fb+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
EA b	0	1/2Fb-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
AE b	0	-Fx+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
BF b	-x/b	-Fb	-Fb/EJ	Fx	Fx/EJ	$x^2/b^2$	$(1/2+1/2)Fb^2/EJ$	1/3xb/EJ
FB b	1-x/b	Fb	Fb/EJ	Fb-Fx	Fb/EJ-Fx/EJ	$1-2x/b+x^2/b^2$	$1-2x/b+x^2/b^2$	1/3xb/EJ
GC b	-1+x/b	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	1/3xb/EJ
CG b	x/b	0	0	0	0	$x^2/b^2$	0+0	1/3xb/EJ
FG 2b	-1	0	0	0	0	1	0+0	2xb/EJ
GF 2b	1	0	0	0	0	1	0+0	2xb/EJ
CB 2b	0	Fb-Fx	0	0	0	0	0+0	0
BC 2b	0	Fb-Fx	0	0	0	0	0+0	0
totali								8/3xb/EJ

iperstatica X=W<sub>gc</sub>

Sviluppi di calcolo iperstatica

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

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

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

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

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

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

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

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

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

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

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

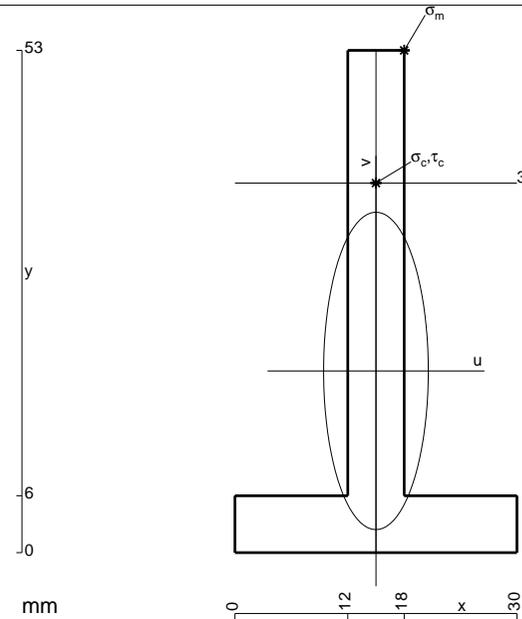
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

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

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

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



$$A = 462. \text{ mm}^2$$

$$J_u = 129608. \text{ mm}^4$$

$$J_v = 14346. \text{ mm}^4$$

$$y_g = 19.18 \text{ mm}$$

$$N = 1623. \text{ N}$$

$$T_y = -1180. \text{ N}$$

$$M_x = -790600. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$y_m = 53. \text{ mm}$$

$$u_m = 3. \text{ mm}$$

$$v_m = 33.82 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 209.8 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 39. \text{ mm}$$

$$v_c = 19.82 \text{ mm}$$

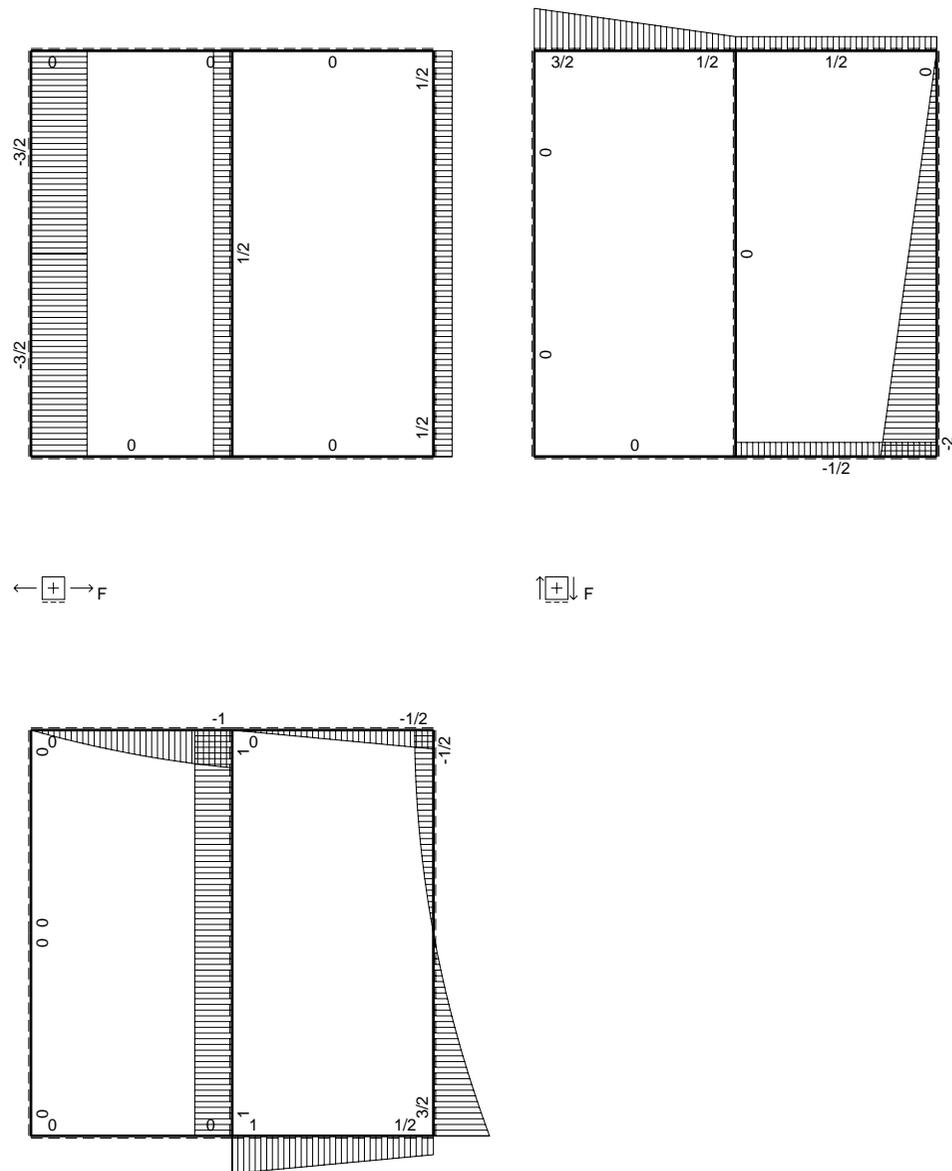
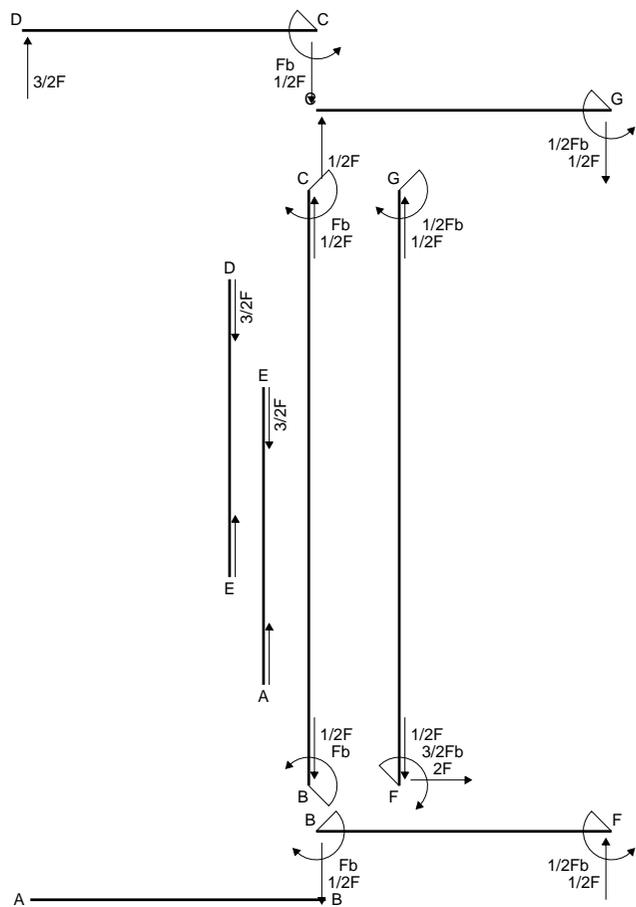
$$\sigma_c = N/A - Mv/J_u = 124.4 \text{ N/mm}^2$$

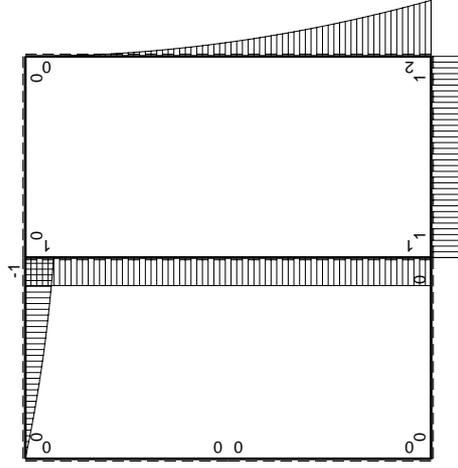
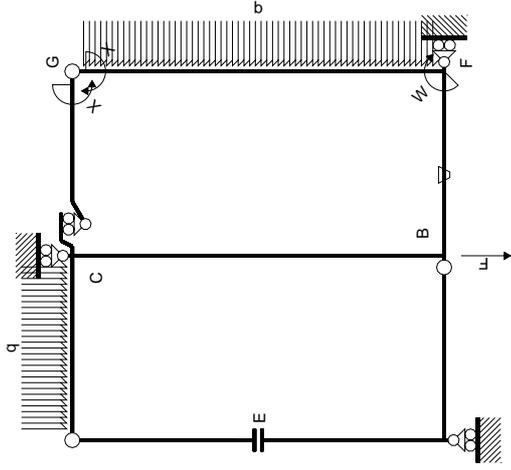
$$\tau_c = 3.419 \text{ N/mm}^2$$

$$\sigma_\varrho = \sqrt{\sigma^2 + 3\tau^2} = 124.6 \text{ N/mm}^2$$

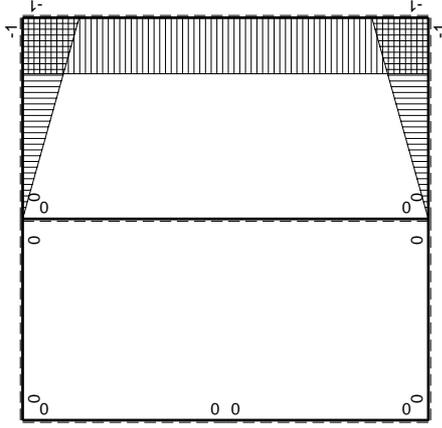
$$S = 2253. \text{ mm}^3$$







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

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

$\leftarrow$	$M_x(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0+0	0
CD b	$-Fb+1/2Fx+1/2qx^2$	0	0	0	0	0	0+0	0
DC b	$3/2Fx-1/2qx^2$	0	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
ED b	0	0	0	0	0	0	0+0	0
EA b	0	0	0	0	0	0	0+0	0
AE b	0	0	0	0	0	0	0+0	0
BF b	$-x/b$	Fb	$-Fb/EJ$	$-Fx$	$Fx/EJ$	$x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$-Fb$	$Fb/EJ$	$-Fb+Fx$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	$-1$	$2Fb-2Fx+1/2qx^2$	0	$-2Fb+2Fx-1/2Fx^2/b$	0	1	$(-4/3+0)Fb^2/EJ$	$2xb/EJ$
GF 2b	1	$-1/2qx^2$	0	$-1/2Fx^2/b$	0	1	$(-4/3+0)Fb^2/EJ$	$2xb/EJ$
CB 2b	0	Fb	0	0	0	0	0+0	0
BC 2b	0	$-Fb$	0	0	0	0	0+0	0
totali								
iperstatica $X=W_{gc}$								

Sviluppi di calcolo iperstatica

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

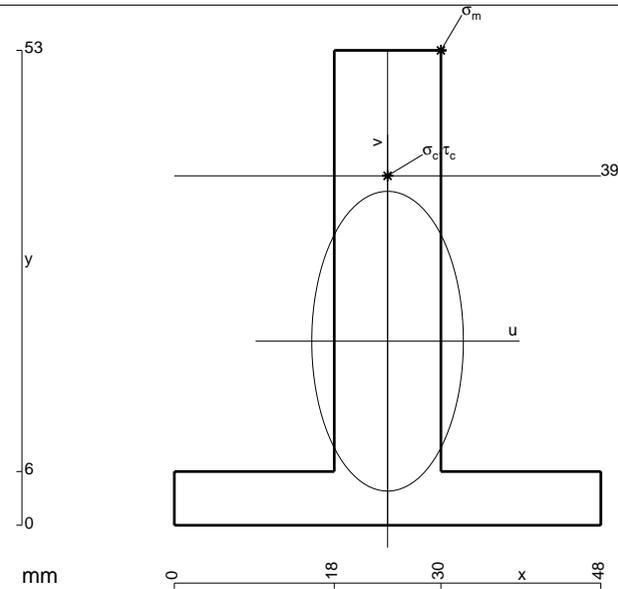
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

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

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

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

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



$$A = 852. \text{ mm}^2$$

$$J_u = 238569. \text{ mm}^4$$

$$J_v = 62064. \text{ mm}^4$$

$$y_g = 20.54 \text{ mm}$$

$$T_y = 3640. \text{ N}$$

$$M_x = -1615250. \text{ Nmm}$$

$$x_m = 30. \text{ mm}$$

$$y_m = 53. \text{ mm}$$

$$u_m = 6. \text{ mm}$$

$$v_m = 32.46 \text{ mm}$$

$$\sigma_m = -Mv/J_u = 219.8 \text{ N/mm}^2$$

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

$$y_c = 39. \text{ mm}$$

$$v_c = 18.46 \text{ mm}$$

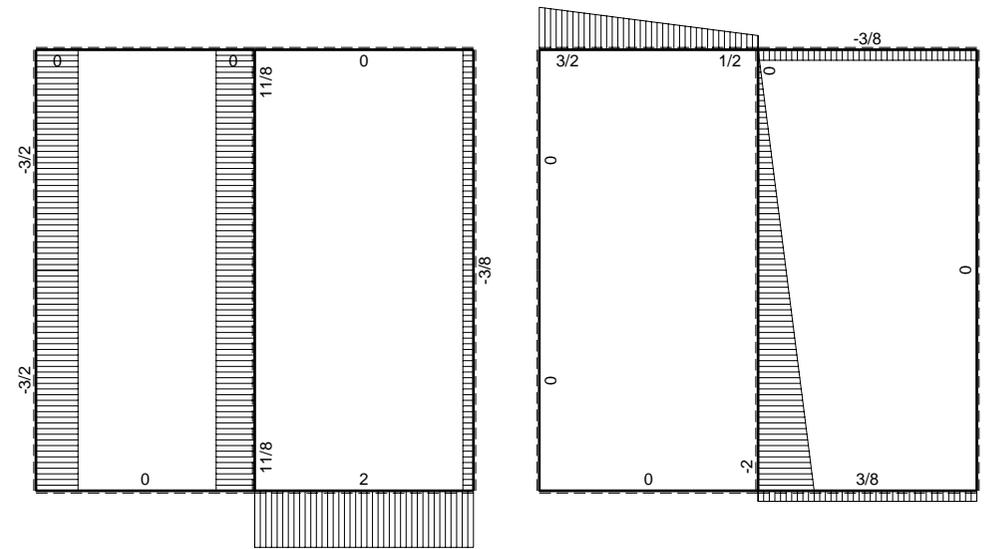
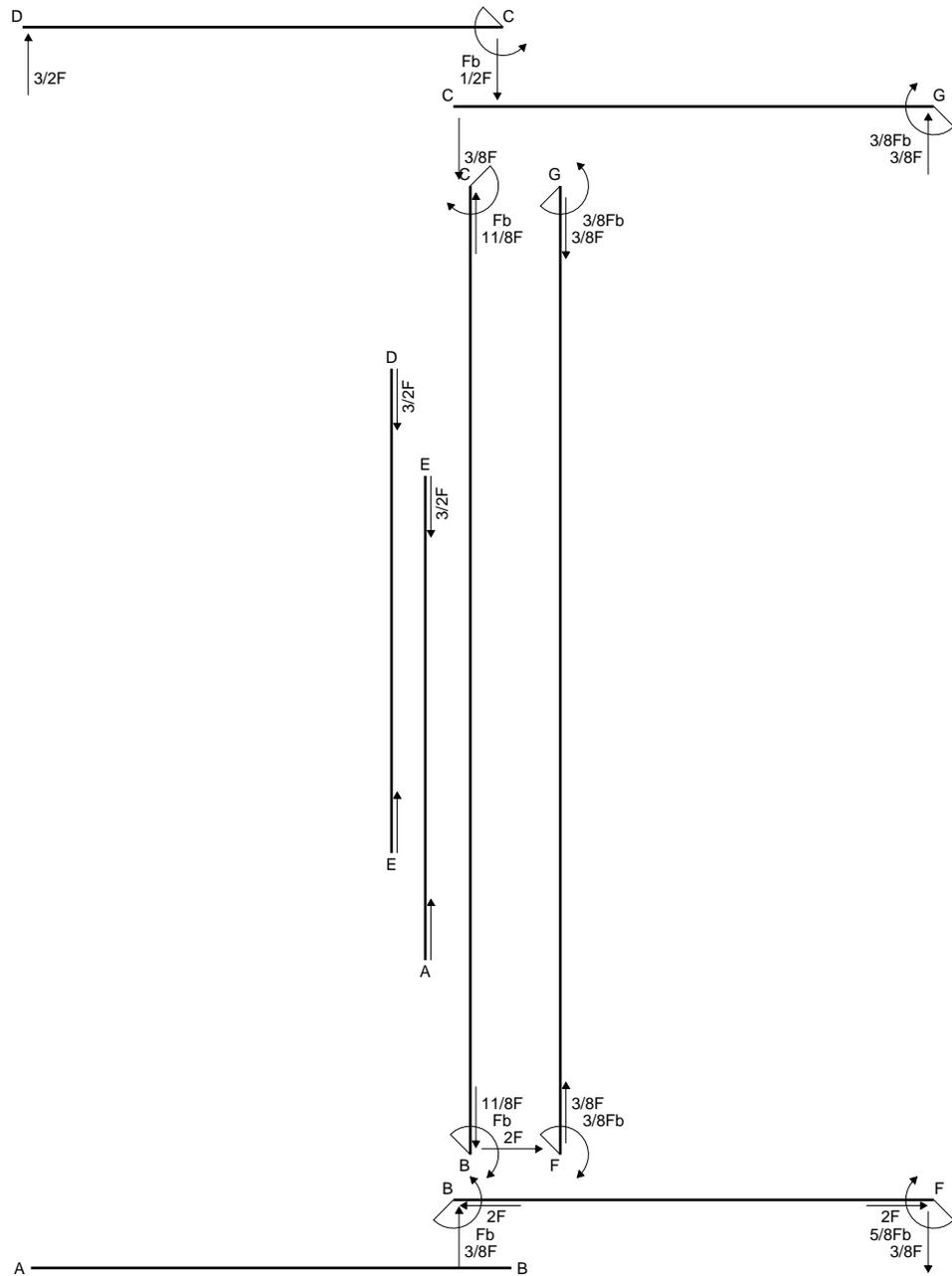
$$\sigma_c = -Mv/J_u = 125. \text{ N/mm}^2$$

$$\tau_c = 5.438 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 125.3 \text{ N/mm}^2$$

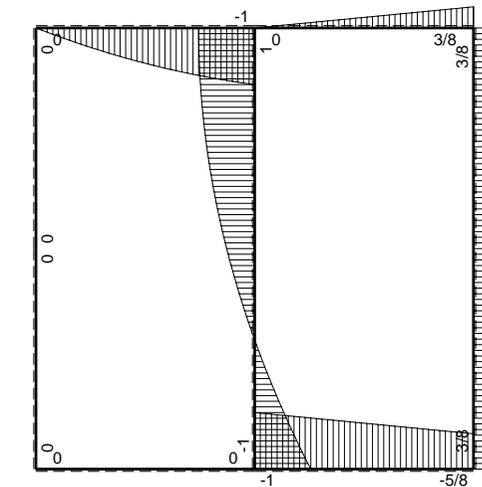
$$S = 4277. \text{ mm}^3$$





← ⊕ → F

↑ ⊕ ↓ F



⊕ ⊖ F<sub>b</sub>



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

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

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

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

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

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

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

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

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

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

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

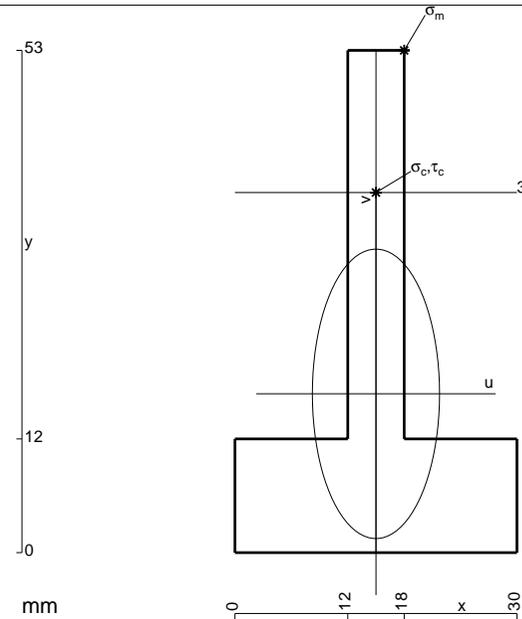
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

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

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

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



$$A = 606. \text{ mm}^2$$

$$J_u = 141406. \text{ mm}^4$$

$$J_v = 27738. \text{ mm}^4$$

$$y_g = 16.76 \text{ mm}$$

$$N = 1623. \text{ N}$$

$$T_y = -2360. \text{ N}$$

$$M_x = -885000. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$y_m = 53. \text{ mm}$$

$$u_m = 3. \text{ mm}$$

$$v_m = 36.24 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 229.5 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 38. \text{ mm}$$

$$v_c = 21.24 \text{ mm}$$

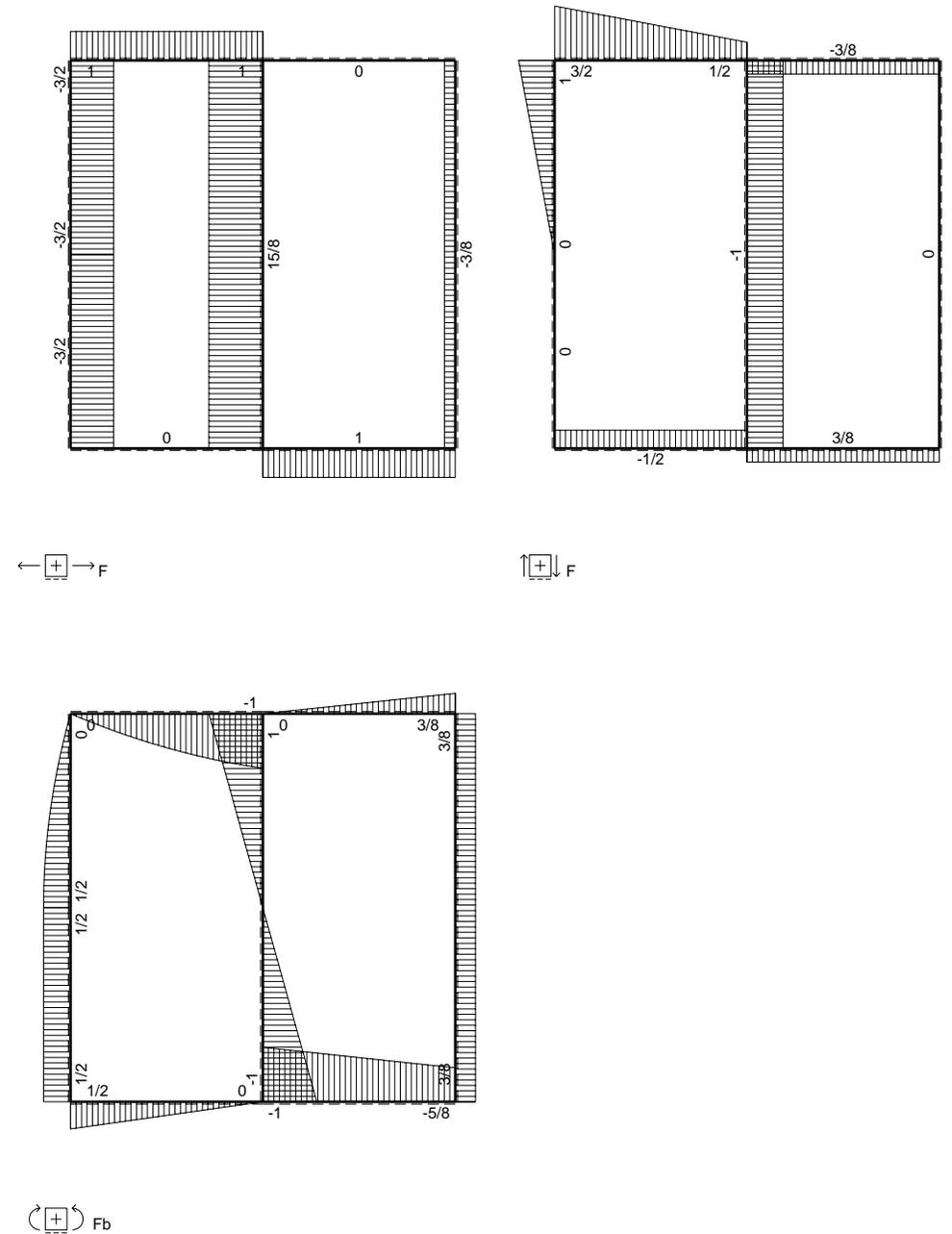
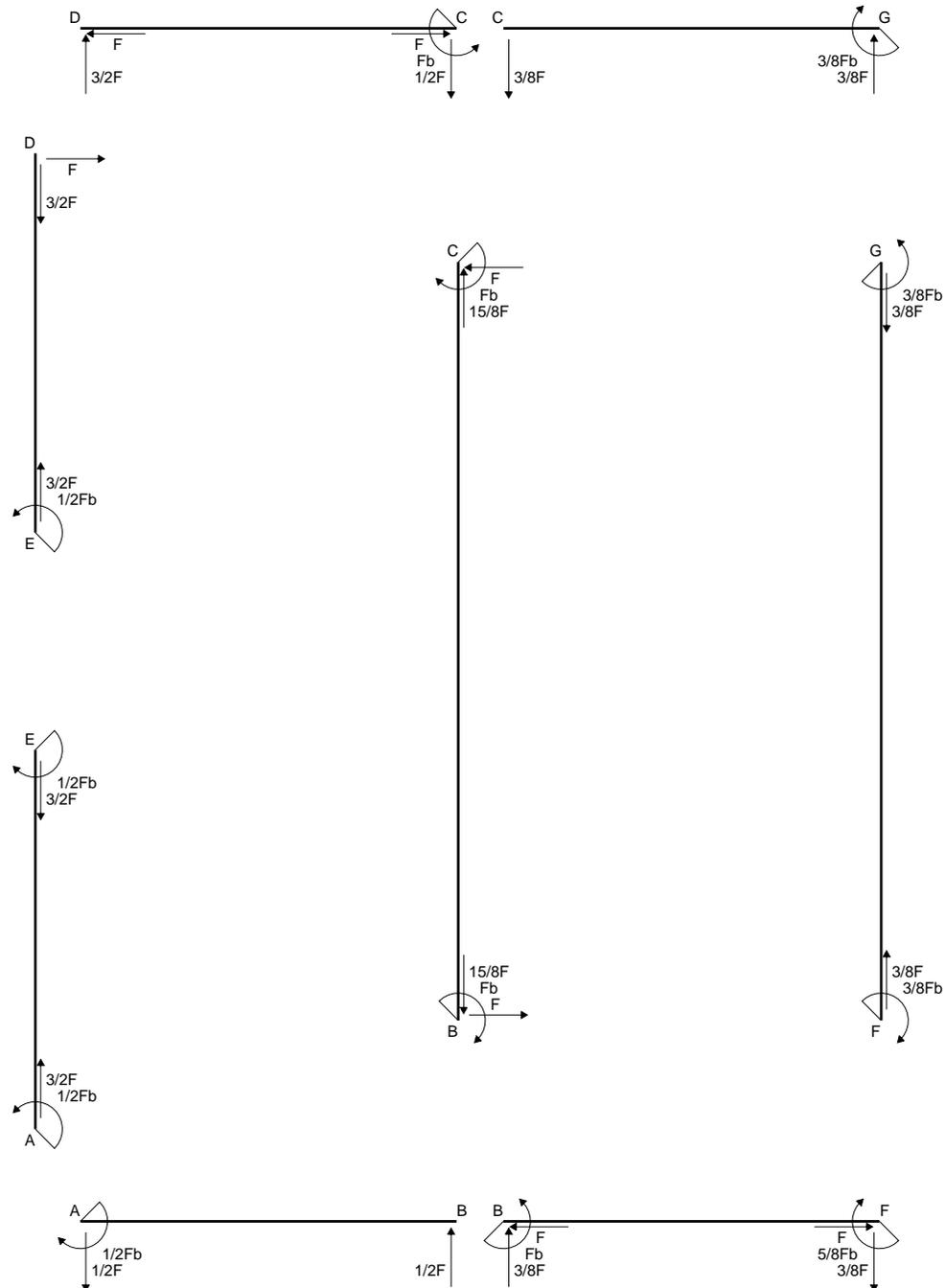
$$\sigma_c = N/A - Mv/J_u = 135.6 \text{ N/mm}^2$$

$$\tau_c = 7.195 \text{ N/mm}^2$$

$$\sigma_\varrho = \sqrt{\sigma^2 + 3\tau^2} = 136.2 \text{ N/mm}^2$$

$$S = 2587. \text{ mm}^3$$







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

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

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

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

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

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

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

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

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

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

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

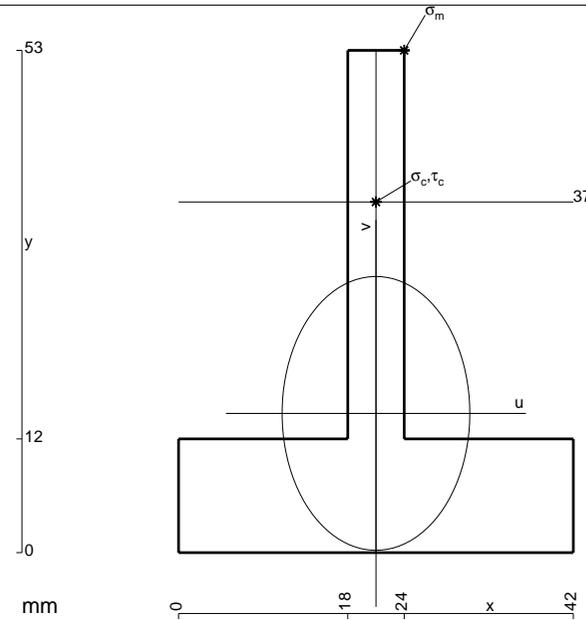
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

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

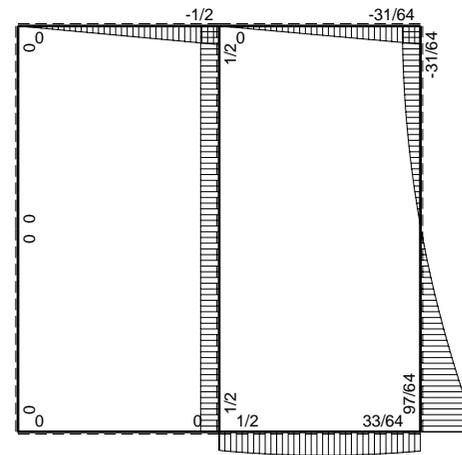
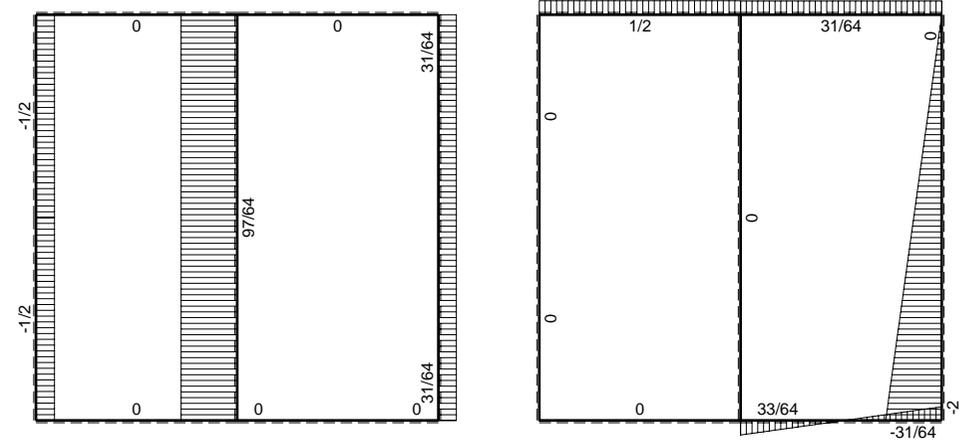
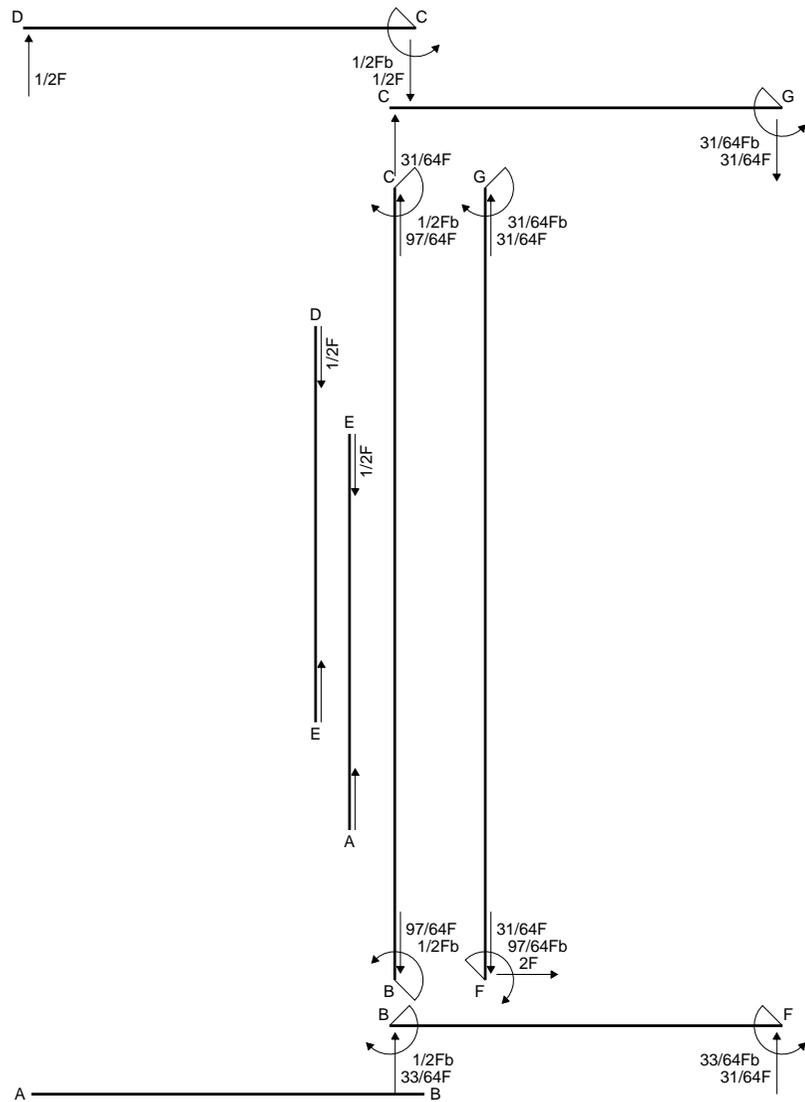
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

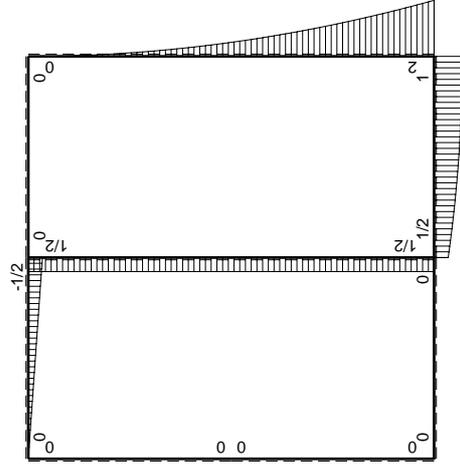
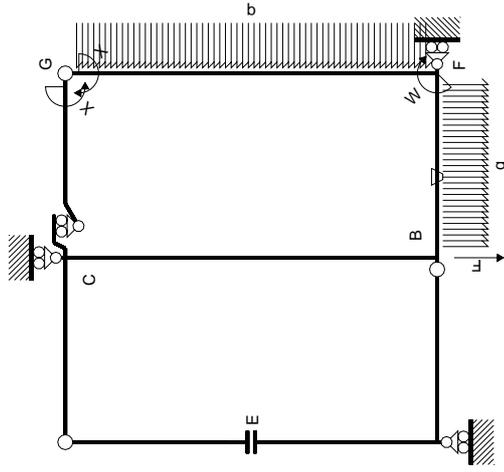
$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



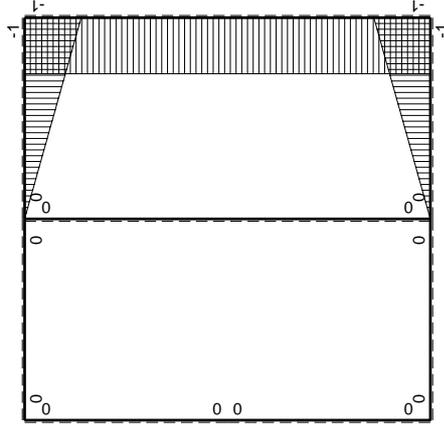
- A = 750. mm<sup>2</sup>
- J<sub>u</sub> = 156599. mm<sup>4</sup>
- J<sub>v</sub> = 74826. mm<sup>4</sup>
- y<sub>g</sub> = 14.69 mm
- N = 2288. N
- T<sub>y</sub> = -1220. N
- M<sub>x</sub> = -963800. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 53. mm
- u<sub>m</sub> = 3. mm
- v<sub>m</sub> = 38.31 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = 238.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 37. mm
- v<sub>c</sub> = 22.31 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = 140.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.778 N/mm<sup>2</sup>
- σ<sub>σ</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 140.5 N/mm<sup>2</sup>
- S = 2910. mm<sup>3</sup>







$M_0$ , flessione da carichi assegnati



$M_x$ , flessione da iperstatica  $X=1$

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

$\rightarrow$	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x (M^0/EJ + \theta) dx$	$\int M^x M^x/EJ dx$
AB b	0	0	0	0	0	0	0	0
BA b	0	0	0	0	0	0	0	0
CD b	0	$-1/2Fx + 1/2Fx$	0	0	0	0	0	0
DC b	0	$1/2Fx$	0	0	0	0	0	0
DE b	0	0	0	0	0	0	0	0
EA b	0	0	0	0	0	0	0	0
AE b	0	0	0	0	0	0	0	0
BF b	$-x/b$	$1/2Fb + Fx - 1/2qx^2$	$-Fb/EJ$	$-1/2Fx - Fx^2/b + 1/2qx^3/b$	$Fx/EJ$	$x^2/b^2$	$(-1/1/24 + 1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$-Fb + 1/2qx^2$	$Fb/EJ$	$-Fb + Fx + 1/2Fx^2/b - 1/2qx^3/b$	$Fb/EJ - Fx/EJ$	$1-2x/b + x^2/b^2$	$(-1/1/24 + 1/2)Fb^2/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b + x^2/b^2$	0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0	$1/3xb/EJ$
FG 2b	-1	$2Fb - 2Fx + 1/2qx^2$	0	$-2Fb + 2Fx - 1/2Fx^2/b$	0	1	$(-4/3 + 0)Fb^2/EJ$	$2xb/EJ$
GF 2b	1	$-1/2qx^2$	0	$-1/2Fx^2/b$	0	1	$(-4/3 + 0)Fb^2/EJ$	$2xb/EJ$
CB 2b	0	$1/2Fb$	0	0	0	0	0	0
BC 2b	0	$-1/2Fb$	0	0	0	0	0	0
totali							$-31/24Fb^2/EJ$	$8/3xb/EJ$
							$31/64Fb$	

Sviluppi di calcolo iperstatica

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

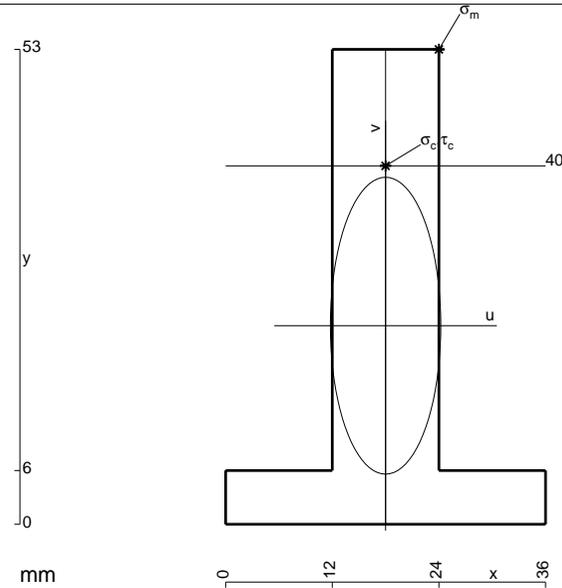
$$= (-b + 1/2 b + 1/6 b - 1/8 b) Fb 1/EJ + (-b + 1/2 b) \theta = 1/24 Fb^2/EJ$$

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

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

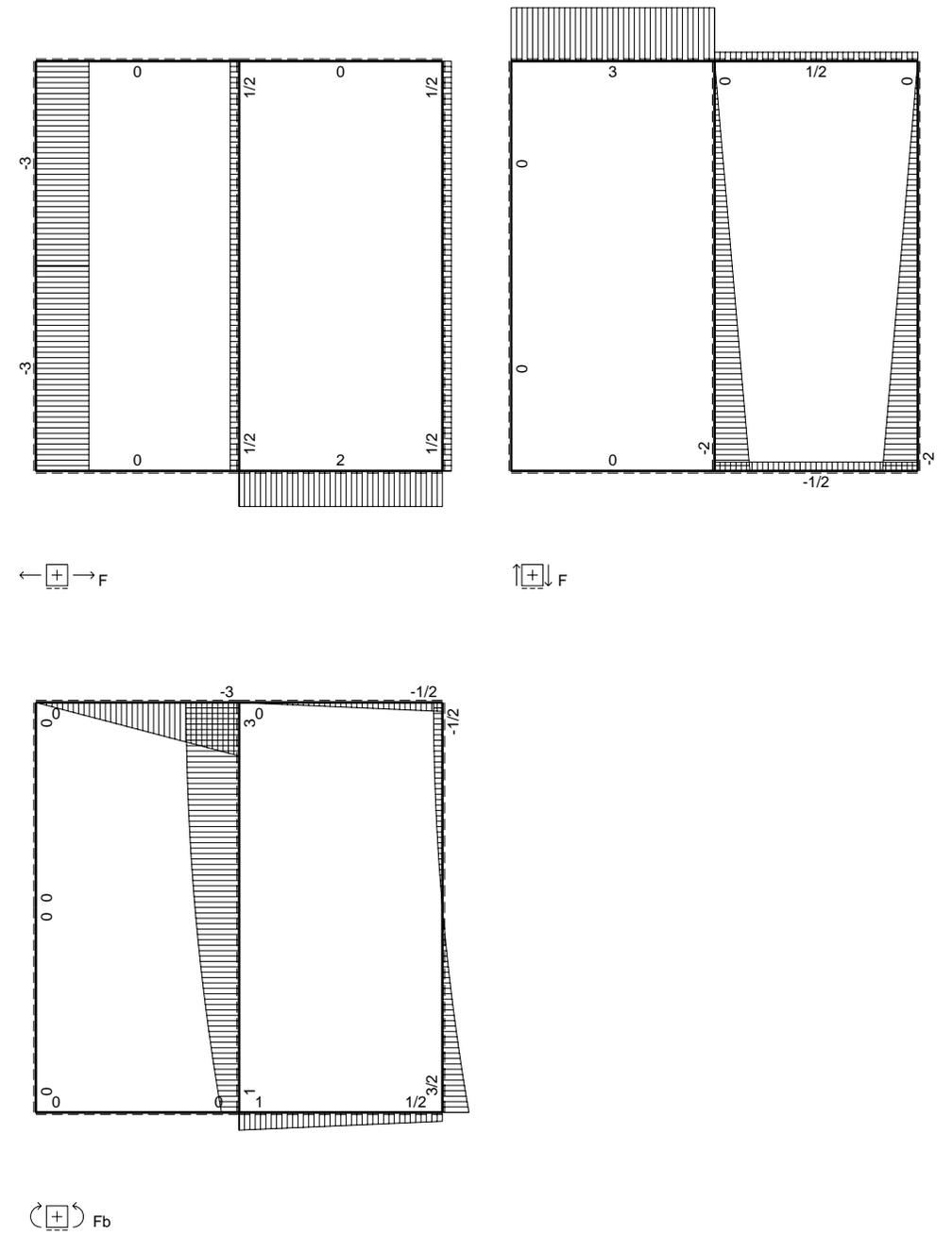
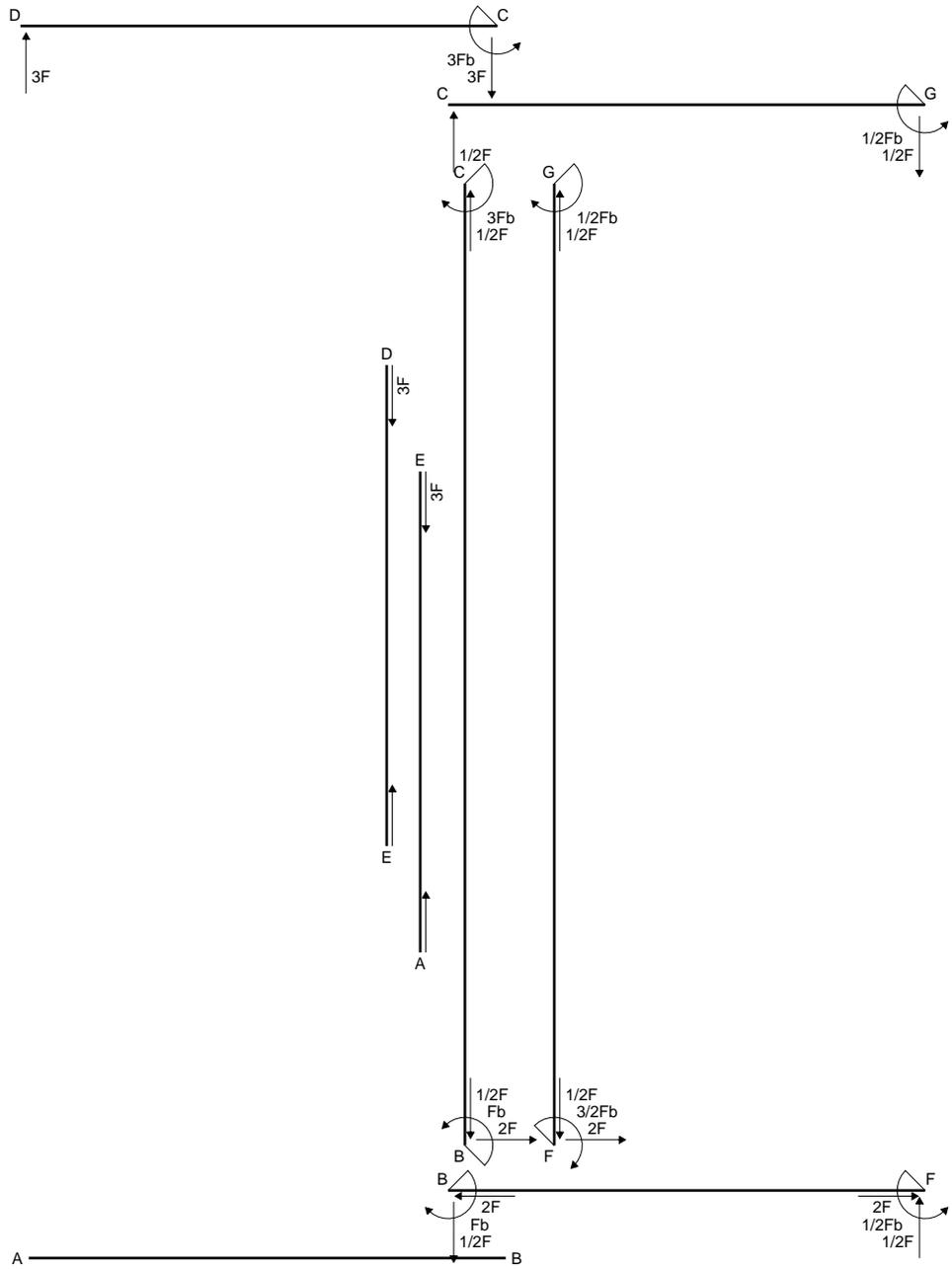
$$L_{GF}^{xo} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

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



- A = 780. mm<sup>2</sup>
- J<sub>u</sub> = 214152. mm<sup>4</sup>
- J<sub>v</sub> = 30096. mm<sup>4</sup>
- y<sub>g</sub> = 22.16 mm
- T<sub>y</sub> = 3305. N
- M<sub>x</sub> = -1388100. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 53. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 30.84 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 199.9 N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 40. mm
- v<sub>c</sub> = 17.84 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 115.6 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.883 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 115.9 N/mm<sup>2</sup>
- S = 3797. mm<sup>3</sup>







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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

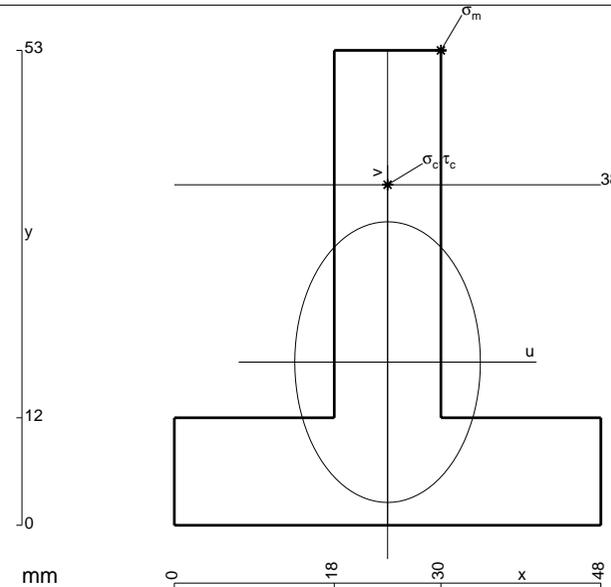
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

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

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

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

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



$$A = 1068. \text{ mm}^2$$

$$J_u = 262174. \text{ mm}^4$$

$$J_v = 116496. \text{ mm}^4$$

$$y_g = 18.21 \text{ mm}$$

$$T_y = 3420. \text{ N}$$

$$M_x = -1573200. \text{ Nmm}$$

$$x_m = 30. \text{ mm}$$

$$y_m = 53. \text{ mm}$$

$$u_m = 6. \text{ mm}$$

$$v_m = 34.79 \text{ mm}$$

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

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

$$y_c = 38. \text{ mm}$$

$$v_c = 19.79 \text{ mm}$$

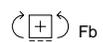
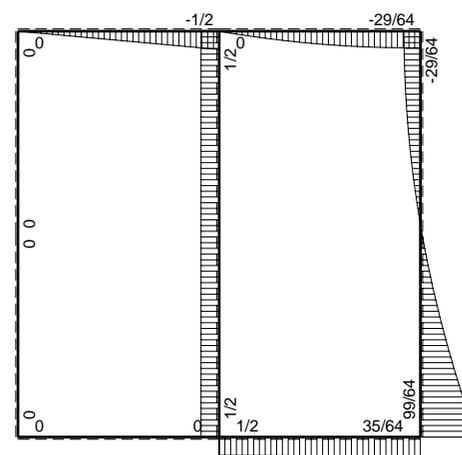
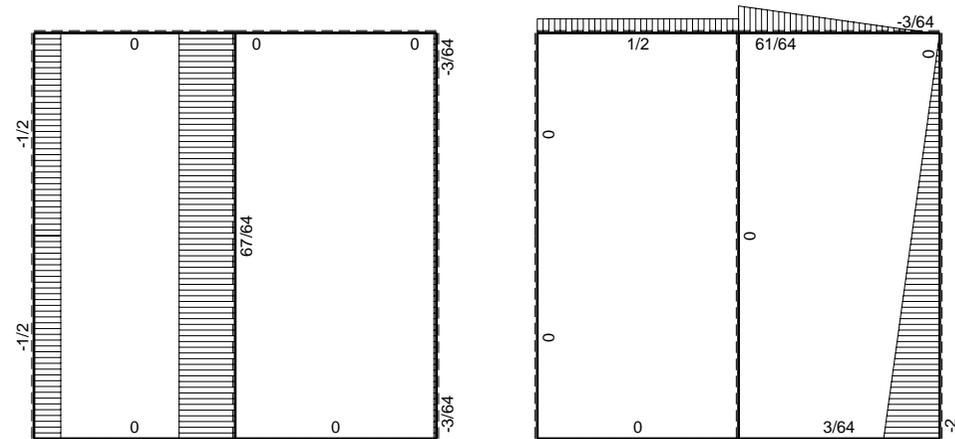
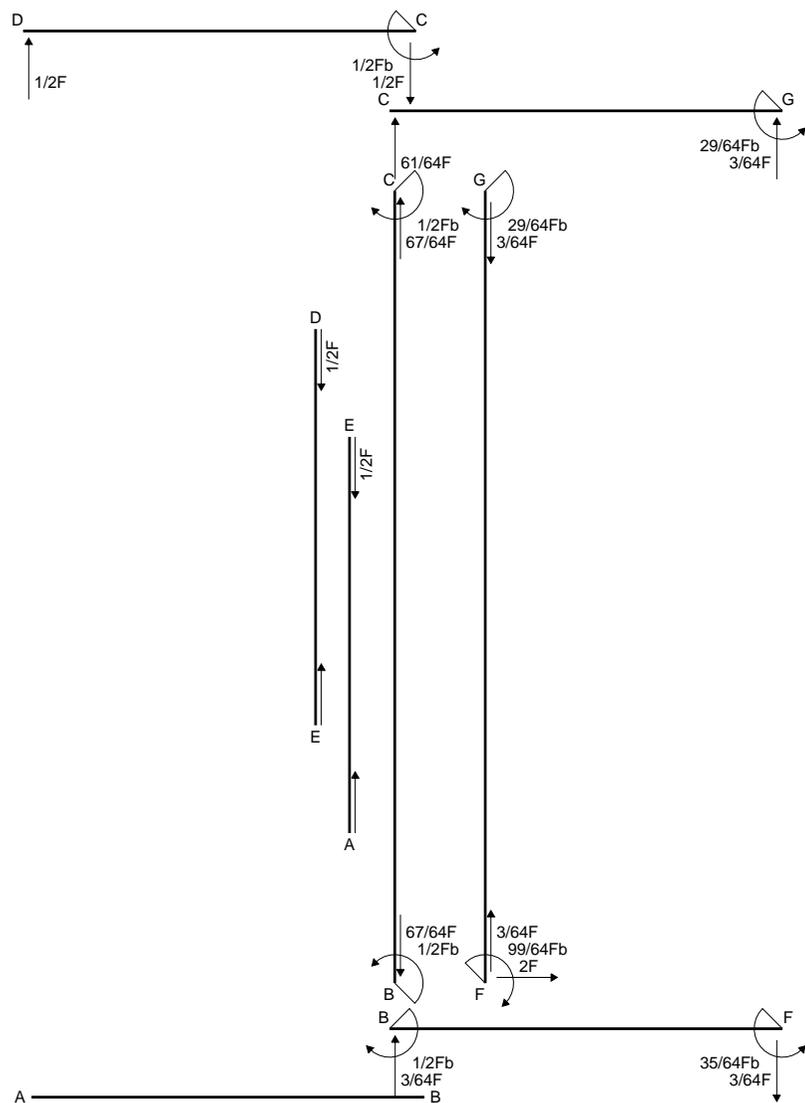
$$\sigma_c = -Mv/J_u = 118.8 \text{ N/mm}^2$$

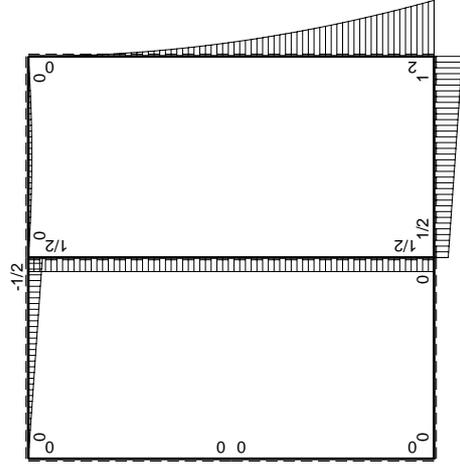
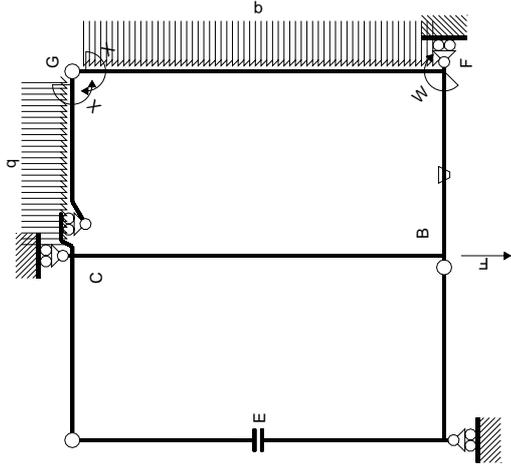
$$\tau_c = 5.34 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 119.1 \text{ N/mm}^2$$

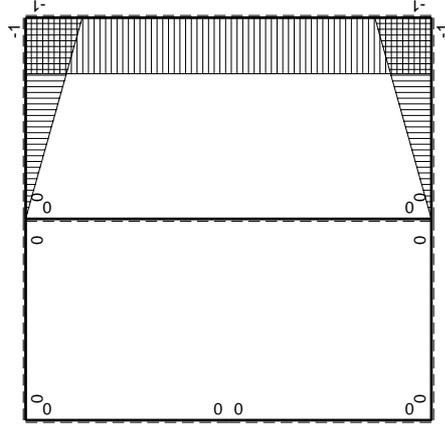
$$S = 4913. \text{ mm}^3$$







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

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

$\leftarrow$	$M_x(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0+0	0
CD b	0	$-1/2Fb+1/2Fx$	0	0	0	0	0+0	0
DC b	0	$1/2Fx$	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
EA b	0	0	0	0	0	0	0+0	0
AE b	0	0	0	0	0	0	0+0	0
BF b	$-x/b$	$1/2Fb+1/2Fx$	$-Fb/EJ$	$-1/2Fx-1/2Fx^2/b$	$Fx/EJ$	$x^2/b^2$	$(-5/12+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$-Fb+1/2Fx$	$Fb/EJ$	$-Fb+3/2Fx-1/2Fx^2/b$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$(1/24+0)Fb^2/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	$-1/2Fx+1/2qx^2$	0	$1/2Fx-Fx^2/b+1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(1/24+0)Fb^2/EJ$	$1/3xb/EJ$
CG b	$x/b$	$1/2Fx-1/2qx^2$	0	$1/2Fx^2/b-1/2qx^3/b$	0	$x^2/b^2$	$(1/24+0)Fb^2/EJ$	$1/3xb/EJ$
FG 2b	-1	$2Fb-2Fx+1/2qx^2$	0	$-2Fb+2Fx-1/2Fx^2/b$	0	1	$(-4/3+0)Fb^2/EJ$	$2xb/EJ$
GF 2b	1	$-1/2qx^2$	0	$-1/2Fx^2/b$	0	1	$(-4/3+0)Fb^2/EJ$	$2xb/EJ$
CB 2b	0	$1/2Fb$	0	0	0	0	0+0	0
BC 2b	0	$-1/2Fb$	0	0	0	0	0+0	0
totali							$-29/24Fb^2/EJ$	$8/3xb/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

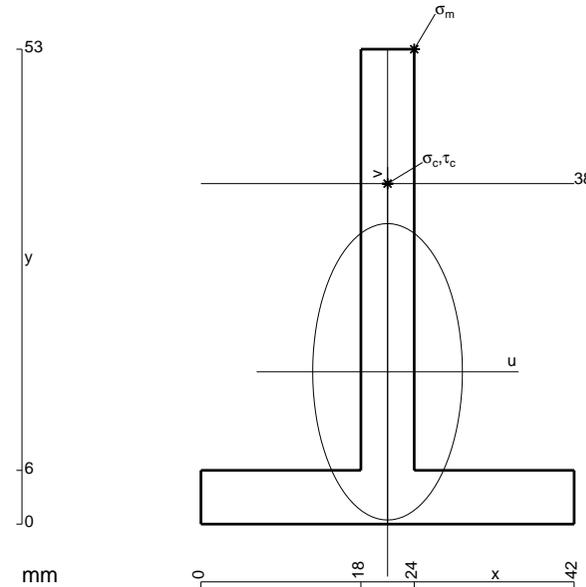
$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

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

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

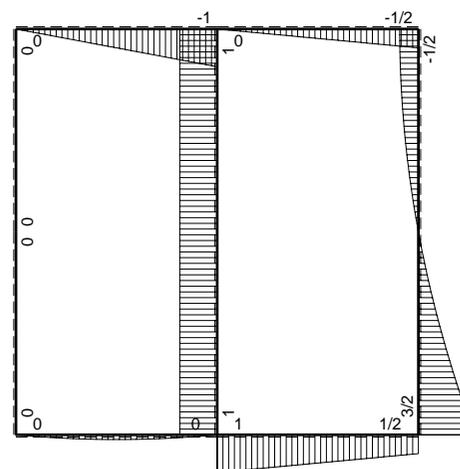
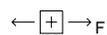
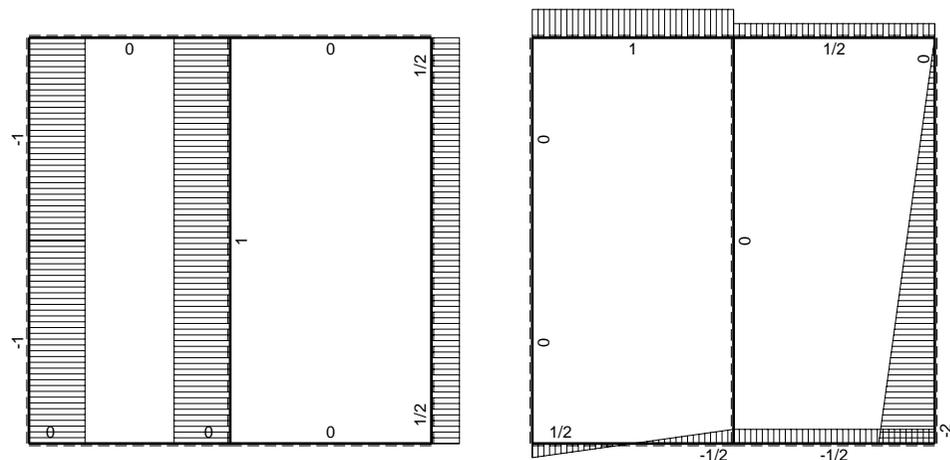
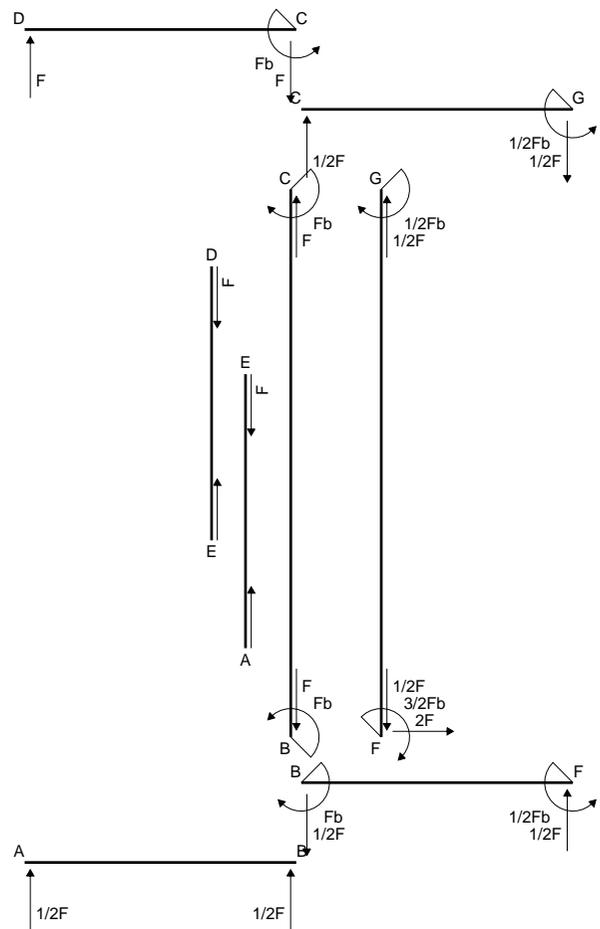
$$L_{GF}^{x\theta} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

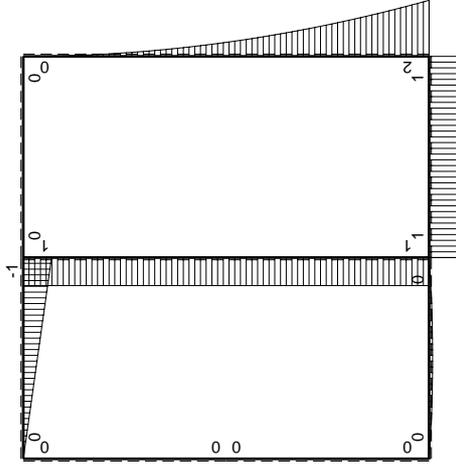
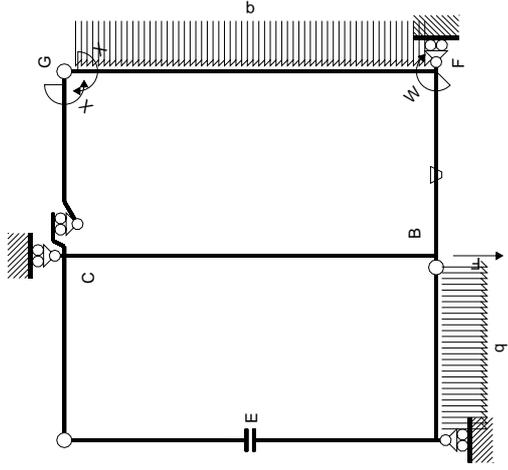
$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



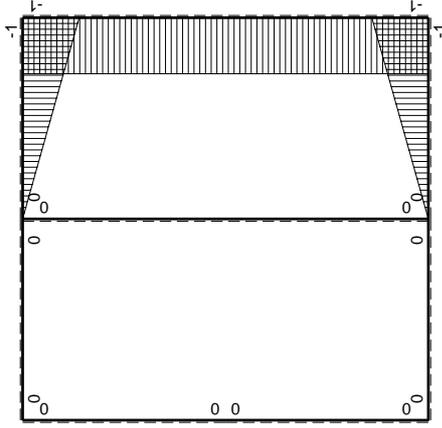
- A = 534. mm<sup>2</sup>
- J<sub>u</sub> = 146122. mm<sup>4</sup>
- J<sub>v</sub> = 37890. mm<sup>4</sup>
- y<sub>g</sub> = 16.99 mm
- T<sub>y</sub> = 1785. N
- M<sub>x</sub> = -892500. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 53. mm
- u<sub>m</sub> = 3. mm
- v<sub>m</sub> = 36.01 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 219.9 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 38. mm
- v<sub>c</sub> = 21.01 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 128.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.223 N/mm<sup>2</sup>
- σ<sub>σ</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 128.6 N/mm<sup>2</sup>
- S = 2566. mm<sup>3</sup>







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica X=W<sub>gc</sub>

←	M <sup>0</sup> (x)	M <sup>0</sup> (x)	θ	M <sup>x</sup> M <sub>0</sub>	M <sup>x</sup> θ	M <sup>x</sup> M <sub>x</sub>	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJdx$
AB b	0	1/2Fx-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
BA b	0	-1/2Fx+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
CD b	0	-b+Fx	0	0	0	0	0+0	0
DC b	0	Fx	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
ED b	0	0	0	0	0	0	0+0	0
EA b	0	0	0	0	0	0	0+0	0
AE b	0	0	0	0	0	0	0+0	0
BF b	-x/b	Fb	-Fb/EJ	-Fx	Fx/EJ	$x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	1/3xb/EJ
FB b	1-x/b	-Fb	Fb/EJ	-Fb+Fx	Fb/EJ-Fx/EJ	$1-2x/b+x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	1/3xb/EJ
GC b	-1+x/b	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	1/3xb/EJ
CG b	x/b	0	0	0	0	$x^2/b^2$	0+0	1/3xb/EJ
FG 2b	-1	2Fb-2Fx+1/2qx <sup>2</sup>	0	-2Fb+2Fx-1/2Fx <sup>2</sup> /b	0	1	$(-4/3+0)Fb^2/EJ$	2xb/EJ
GF 2b	1	-1/2qx <sup>2</sup>	0	-1/2Fx <sup>2</sup> /b	0	1	$(-4/3+0)Fb^2/EJ$	2xb/EJ
CB 2b	0	Fb	0	0	0	0	0+0	0
BC 2b	0	-Fb	0	0	0	0	0+0	0
totali								8/3xb/EJ

iperstatica X=W<sub>gc</sub>

Sviluppi di calcolo iperstatica

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

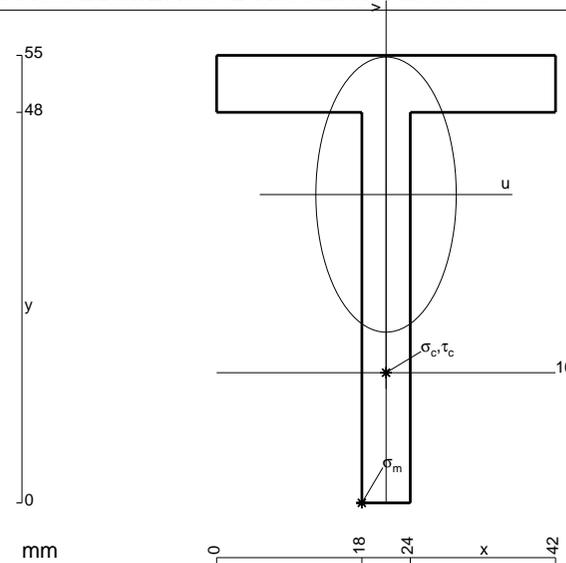
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

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

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

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

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



$$A = 582. \text{ mm}^2$$

$$J_u = 166519. \text{ mm}^4$$

$$J_v = 44082. \text{ mm}^4$$

$$y_g = 37.89 \text{ mm}$$

$$T_y = 1770. \text{ N}$$

$$M_x = -1008900. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -37.89 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -229.6 \text{ N/mm}^2$$

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

$$y_c = 16. \text{ mm}$$

$$v_c = -21.89 \text{ mm}$$

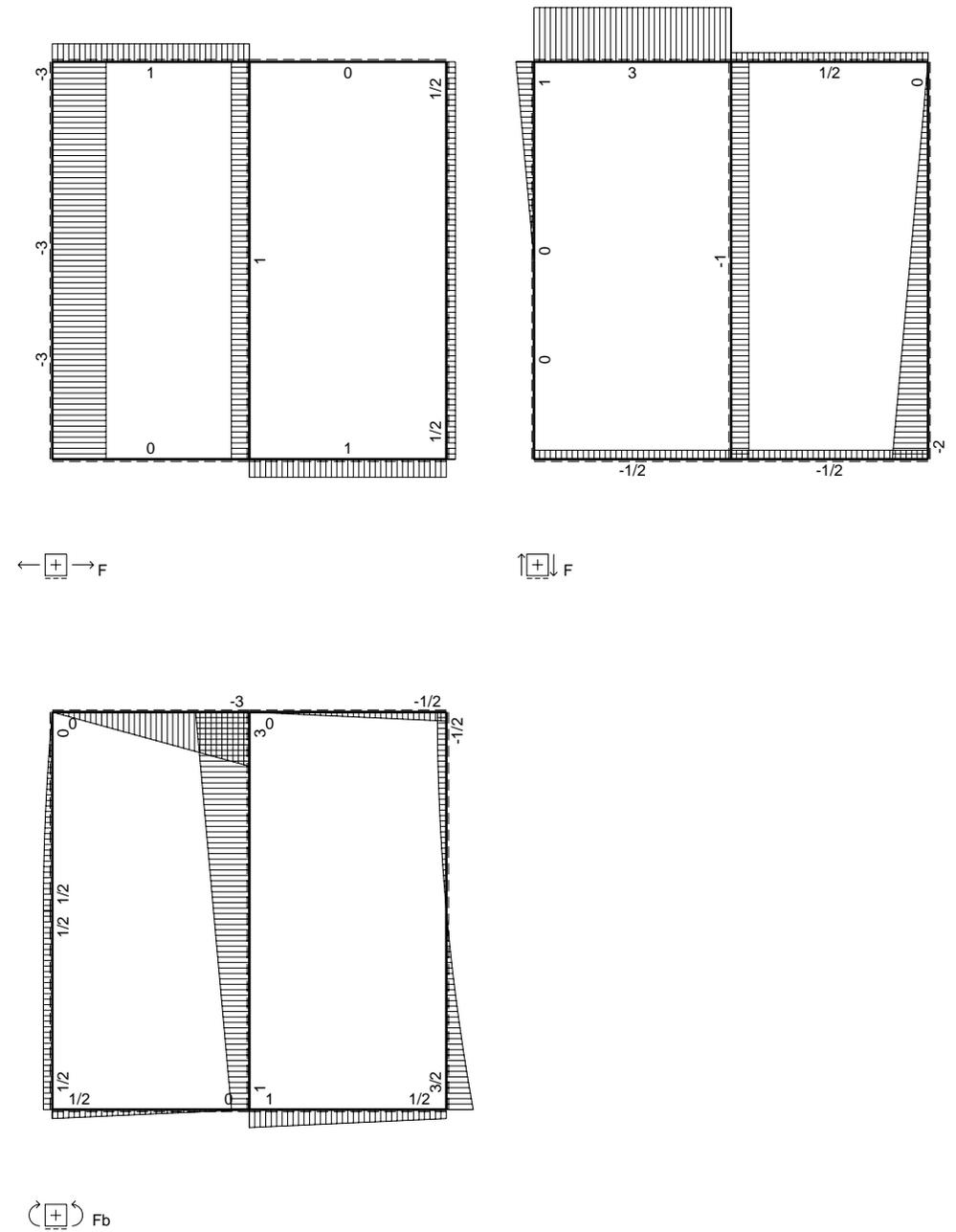
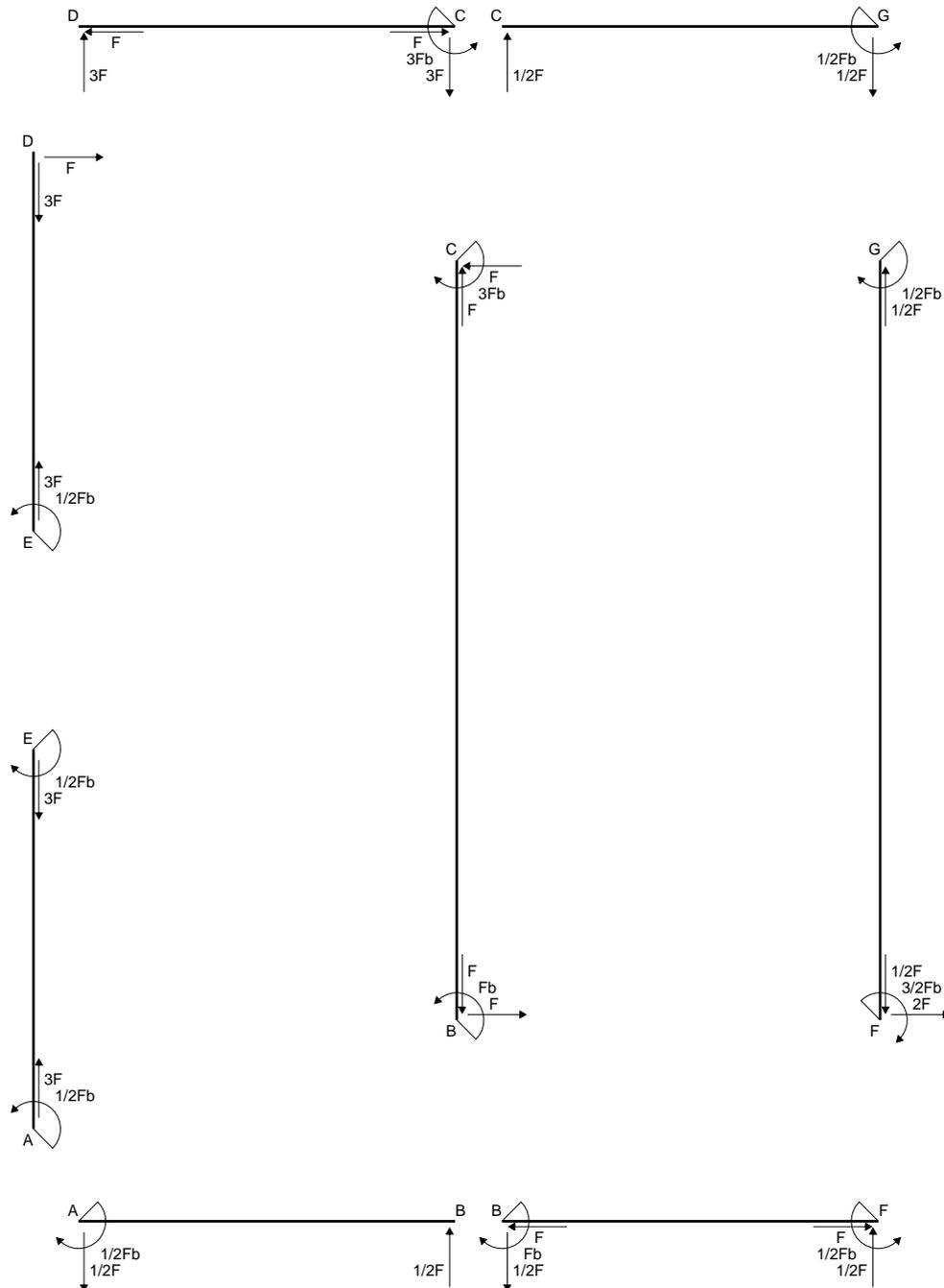
$$\sigma_c = -Mv/J_u = -132.6 \text{ N/mm}^2$$

$$\tau_c = 5.084 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 132.9 \text{ N/mm}^2$$

$$S = 2870. \text{ mm}^3$$







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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

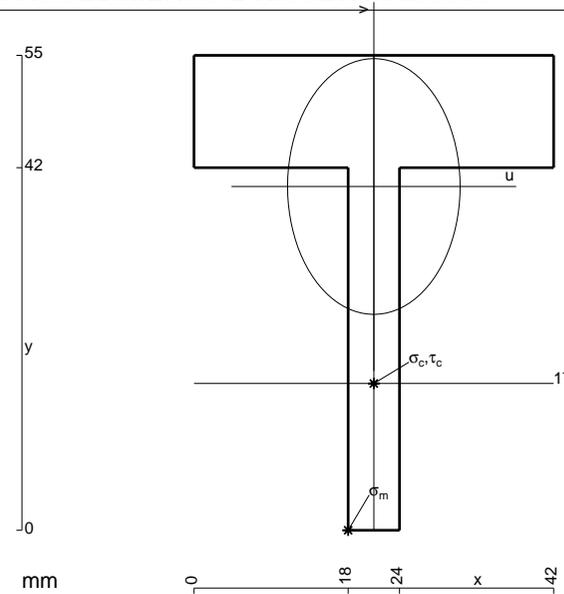
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

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

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

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

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



$$A = 798. \text{ mm}^2$$

$$J_u = 175127. \text{ mm}^4$$

$$J_v = 81018. \text{ mm}^4$$

$$y_g = 39.82 \text{ mm}$$

$$N = 570. \text{ N}$$

$$T_y = 1710. \text{ N}$$

$$M_x = -1043100. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -39.82 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -236.4 \text{ N/mm}^2$$

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

$$y_c = 17. \text{ mm}$$

$$v_c = -22.82 \text{ mm}$$

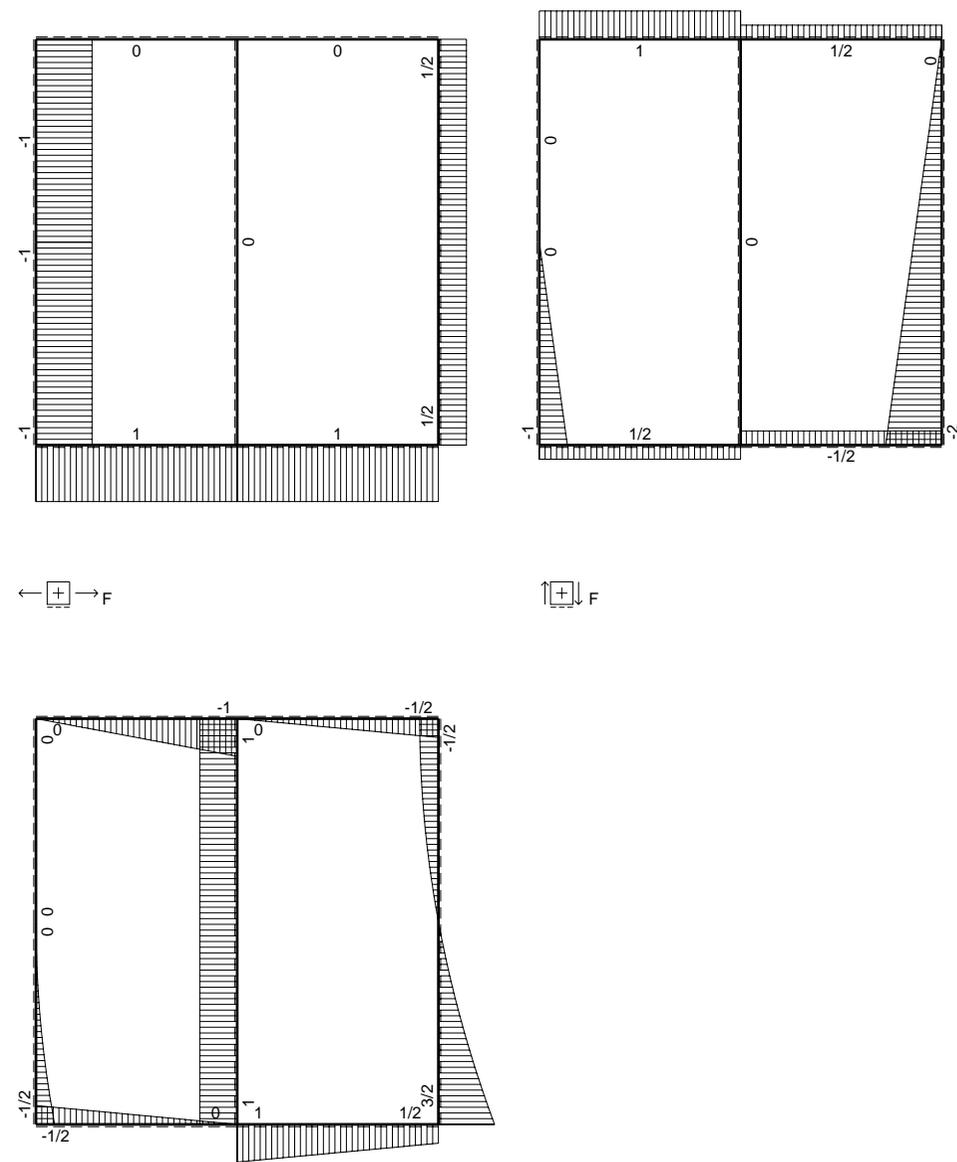
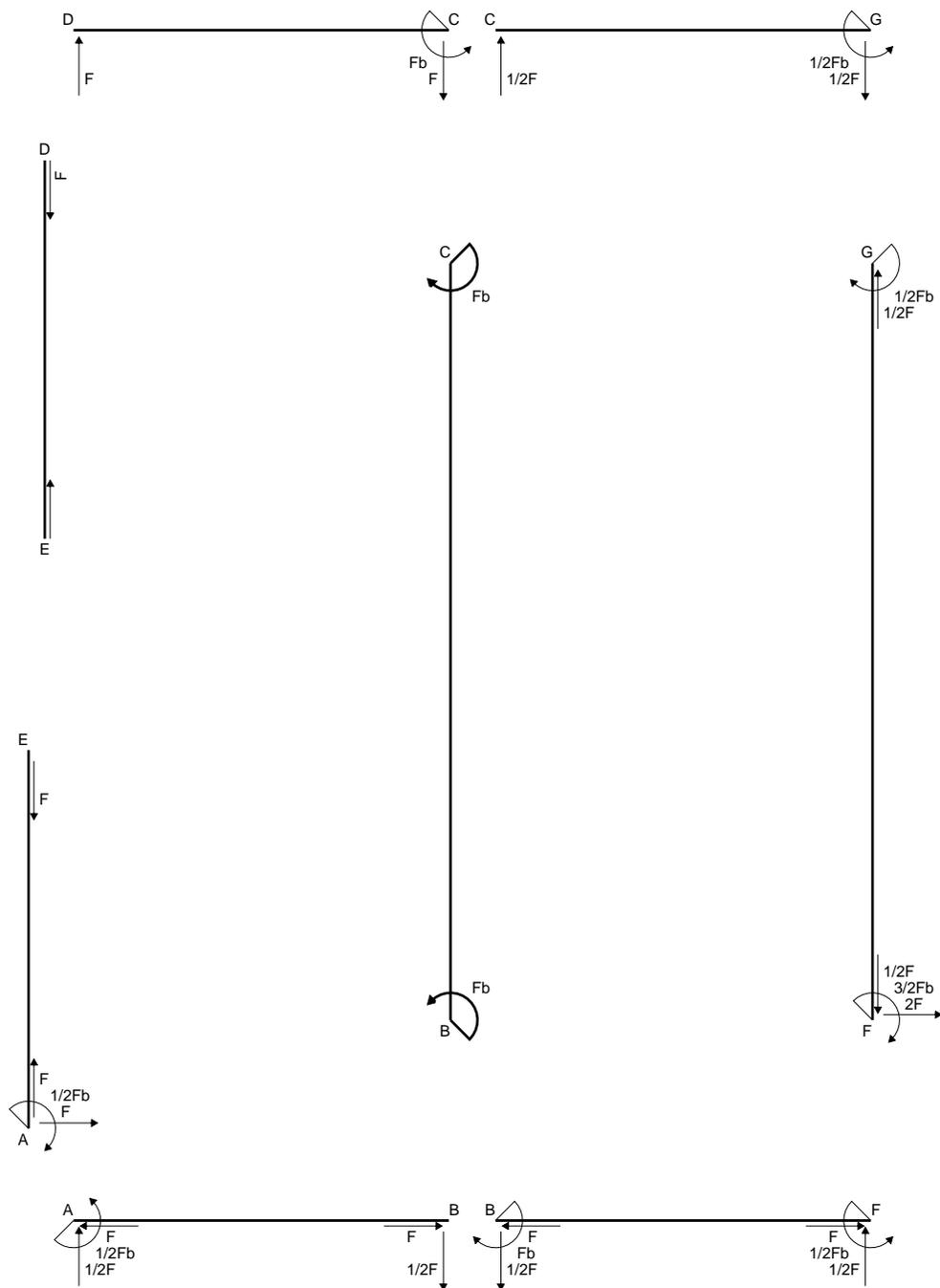
$$\sigma_c = N/A - Mv/J_u = -135.2 \text{ N/mm}^2$$

$$\tau_c = 5.198 \text{ N/mm}^2$$

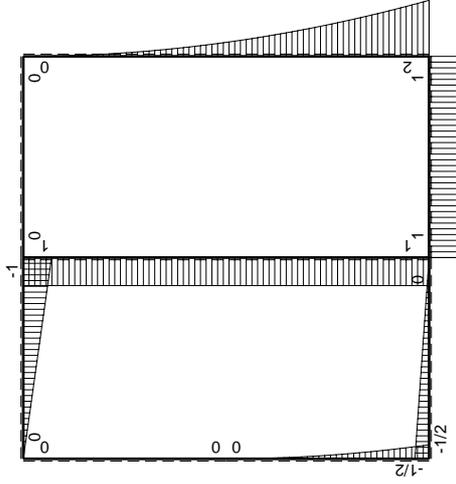
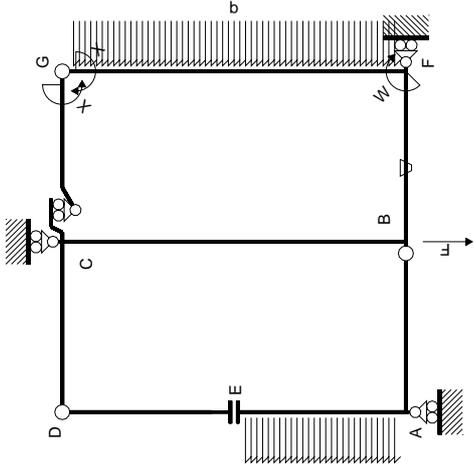
$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 135.5 \text{ N/mm}^2$$

$$S = 3194. \text{ mm}^3$$

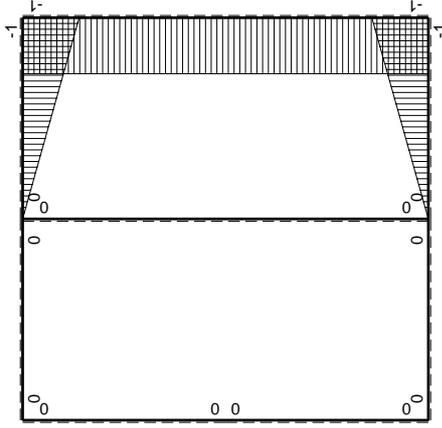




$\oplus \oplus \oplus F_b$



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

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

$\leftarrow$	$M(x)$	$M^0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / E dx$
AB b	0	$-1/2Fb + 1/2Fx$	0	0	0	0	0+0	0
BA b	0	$1/2Fx$	0	0	0	0	0+0	0
CD b	0	$-Fb + Fx$	0	0	0	0	0+0	0
DC b	0	$Fx$	0	0	0	0	0+0	0
ED b	0	0	0	0	0	0	0+0	0
EA b	0	$-1/2qx^2$	0	0	0	0	0+0	0
AE b	0	$1/2Fb - Fx + 1/2qx^2$	0	0	0	0	0+0	0
BF b	$-x/b$	$Fb$	$-Fb/EJ$	$-Fx$	$Fx/EJ$	$x^2/b^2$	$(-1/2 + 1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$-Fb$	$Fb/EJ$	$-Fb + Fx$	$Fb/EJ - Fx/EJ$	$1-2x/b + x^2/b^2$	$(-1/2 + 1/2)Fb^2/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b + x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	$2Fb - 2Fx + 1/2qx^2$	0	$-2Fb + 2Fx - 1/2Fx^2/b$	0	1	$(-4/3 + 0)Fb^2/EJ$	$2xb/EJ$
GF 2b	1	$-1/2qx^2$	0	$-1/2Fx^2/b$	0	1	$(-4/3 + 0)Fb^2/EJ$	$2xb/EJ$
CB 2b	0	$Fb$	0	0	0	0	0+0	0
BC 2b	0	$-Fb$	0	0	0	0	0+0	0
totali							$-4/3Fb^2/EJ$	$8/3xb/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

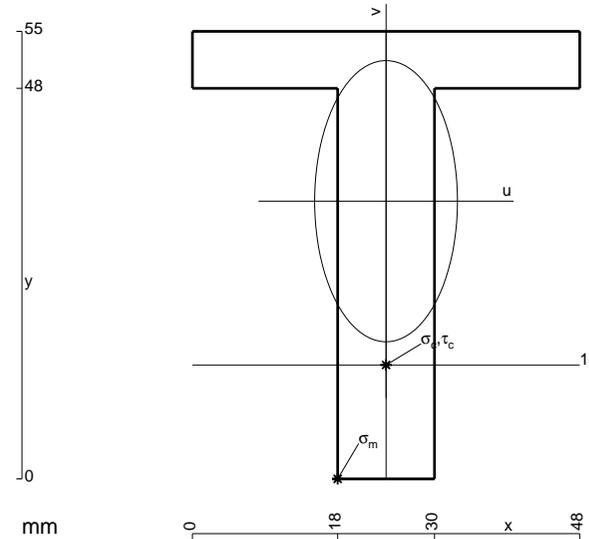
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

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

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

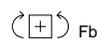
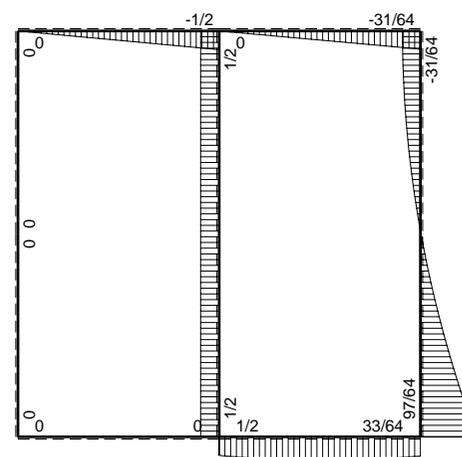
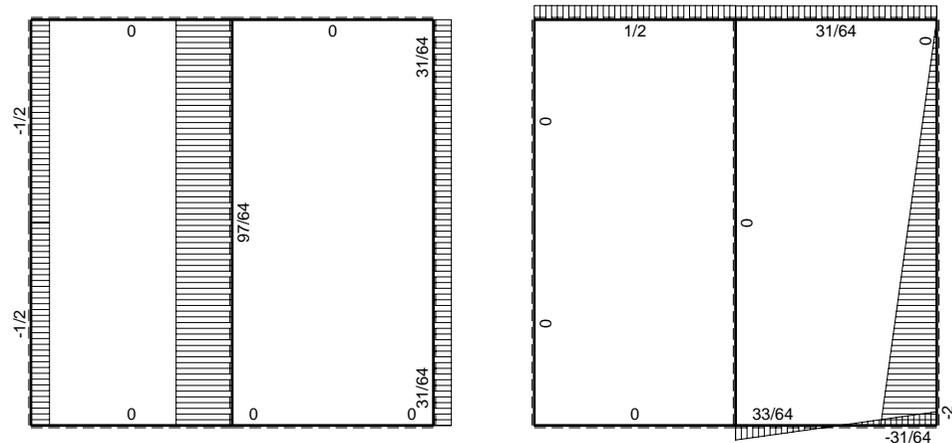
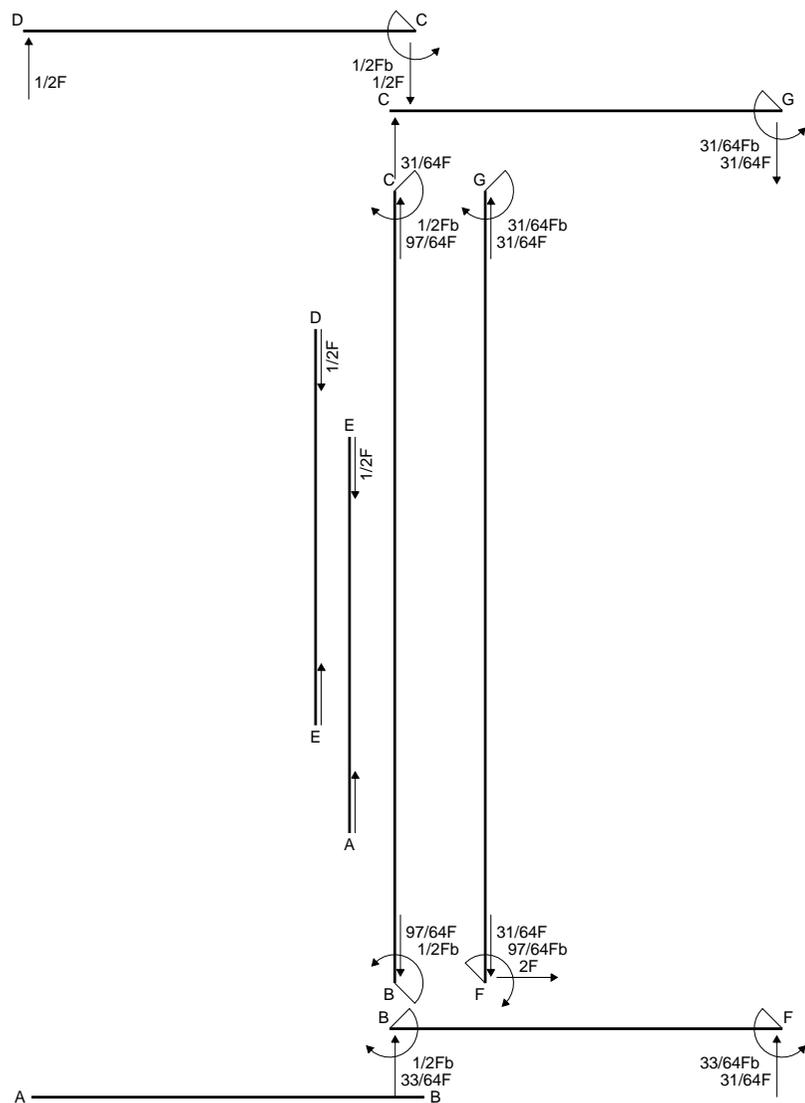
$$L_{GF}^{x\theta} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

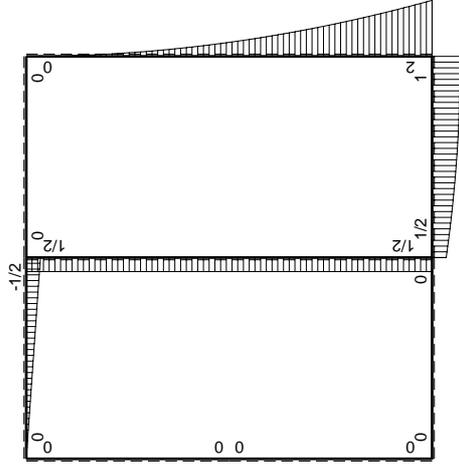
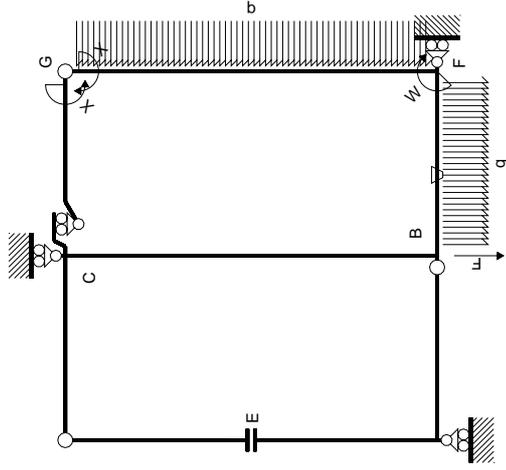
$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



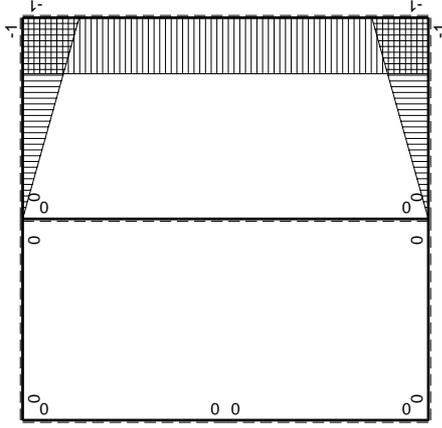
- A = 912. mm<sup>2</sup>
- J<sub>u</sub> = 272448. mm<sup>4</sup>
- J<sub>v</sub> = 71424. mm<sup>4</sup>
- y<sub>g</sub> = 34.13 mm
- T<sub>y</sub> = 2410. N
- M<sub>x</sub> = -1590600. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -34.13 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -199.3 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 14. mm
- v<sub>c</sub> = -20.13 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -117.5 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.36 N/mm<sup>2</sup>
- σ<sub>ρ</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 117.7 N/mm<sup>2</sup>
- S = 4558. mm<sup>3</sup>







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

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

$\rightarrow$	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x (M^0/EJ + \theta) dx$	$\int M^x M_x / E dx$
AB b	0	0	0	0	0	0	0	0
BA b	0	0	0	0	0	0	0	0
CD b	0	$-1/2Fx + 1/2Fx$	0	0	0	0	0	0
DC b	0	$1/2Fx$	0	0	0	0	0	0
DE b	0	0	0	0	0	0	0	0
EA b	0	0	0	0	0	0	0	0
AE b	0	0	0	0	0	0	0	0
BF b	$-x/b$	$1/2Fb + Fx - 1/2qx^2$	$-Fb/EJ$	$-1/2Fx - Fx^2/b + 1/2qx^3/b$	$Fx/EJ$	$x^2/b^2$	$(-1/11/24 + 1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$-Fb + 1/2qx^2$	$Fb/EJ$	$-Fb + Fx + 1/2Fx^2/b - 1/2qx^3/b$	$Fb/EJ - Fx/EJ$	$1-2x/b + x^2/b^2$	$(-1/11/24 + 1/2)Fb^2/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b + x^2/b^2$	0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0	$1/3xb/EJ$
FG 2b	-1	$2Fb - 2Fx + 1/2qx^2$	0	$-2Fb + 2Fx - 1/2Fx^2/b$	0	1	$(-4/3 + 0)Fb^2/EJ$	$2xb/EJ$
GF 2b	1	$-1/2qx^2$	0	$-1/2Fx^2/b$	0	1	$(-4/3 + 0)Fb^2/EJ$	$2xb/EJ$
CB 2b	0	$1/2Fb$	0	0	0	0	0	0
BC 2b	0	$-1/2Fb$	0	0	0	0	0	0
totali							$-31/24Fb^2/EJ$	$8/3xb/EJ$
							$31/64Fb$	

Sviluppi di calcolo iperstatica

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

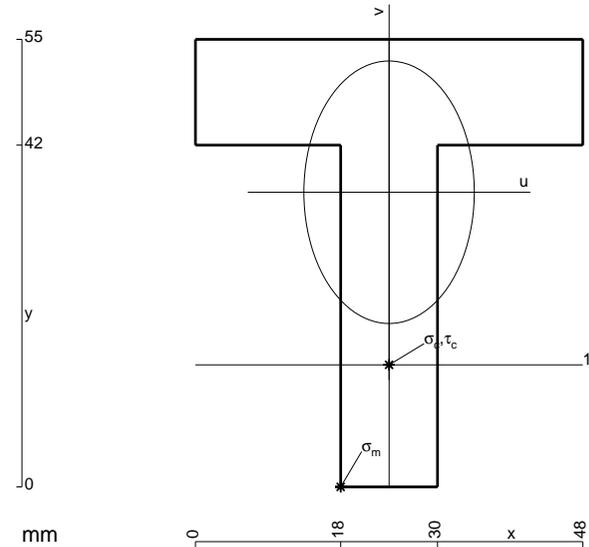
$$= (-b + 1/2 b + 1/6 b - 1/8 b) Fb 1/EJ + (-b + 1/2 b) \theta = 1/24 Fb^2/EJ$$

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

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

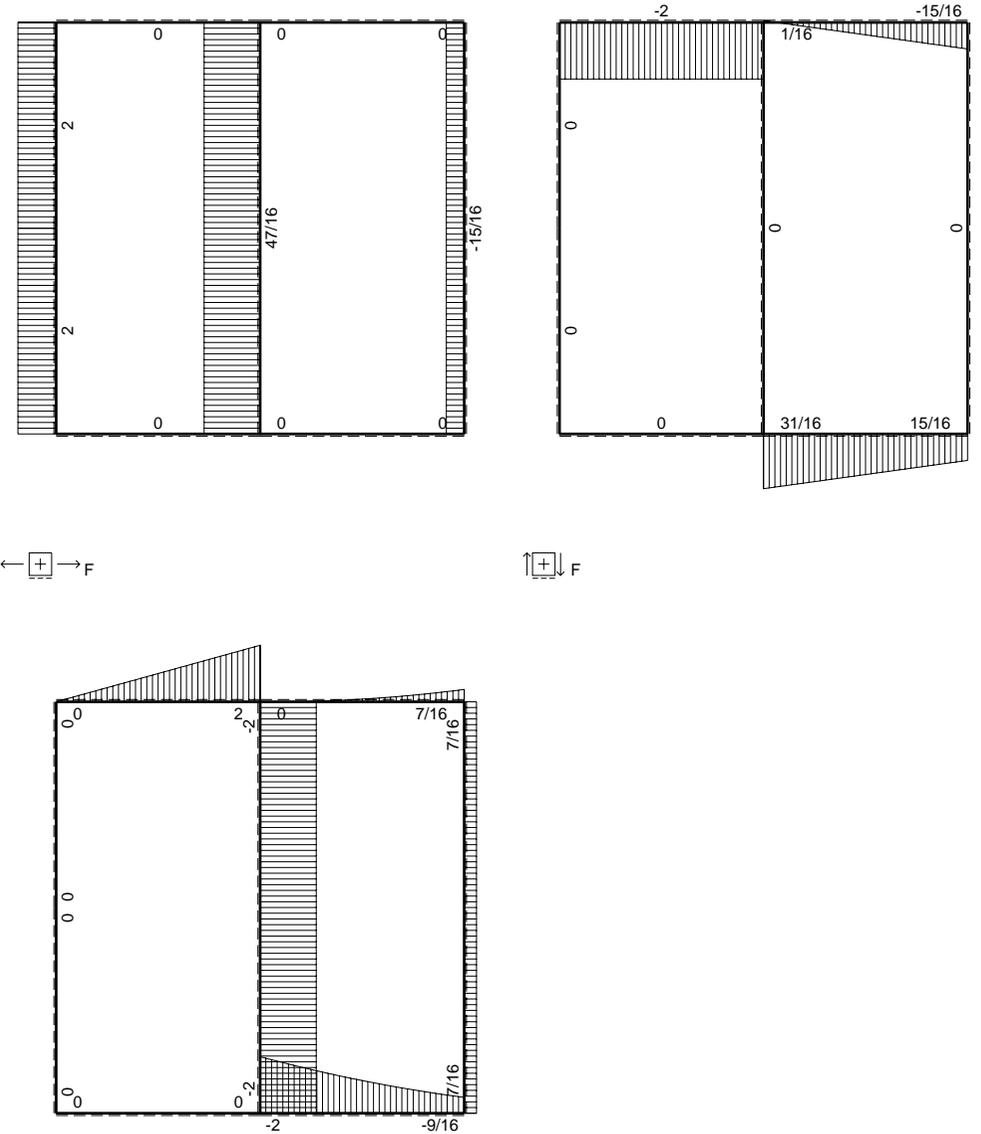
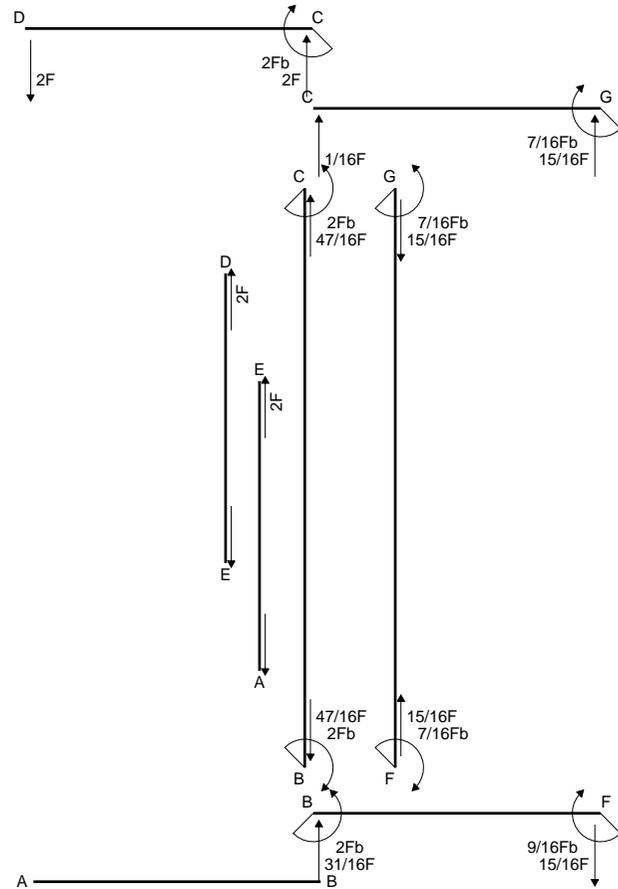
$$L_{GF}^{x\theta} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

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



- A = 1128. mm<sup>2</sup>
- J<sub>u</sub> = 293725. mm<sup>4</sup>
- J<sub>v</sub> = 125856. mm<sup>4</sup>
- y<sub>g</sub> = 36.21 mm
- T<sub>y</sub> = 2430. N
- M<sub>x</sub> = -1701000. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -36.21 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> = 15. mm
- v<sub>c</sub> = -21.21 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -122.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.563 N/mm<sup>2</sup>
- σ<sub>ρ</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 123. N/mm<sup>2</sup>
- S = 5168. mm<sup>3</sup>







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

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

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

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

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

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

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

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

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

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

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

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

$$L_{BF}^{x_0} = \int_0^b (2x/b - 3/2 x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

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

$$= (b - 1/2 b + 1/8 b) Fb 1/EJ + (1/2 b) \theta = 9/8 Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - 1/2 x/b - 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

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

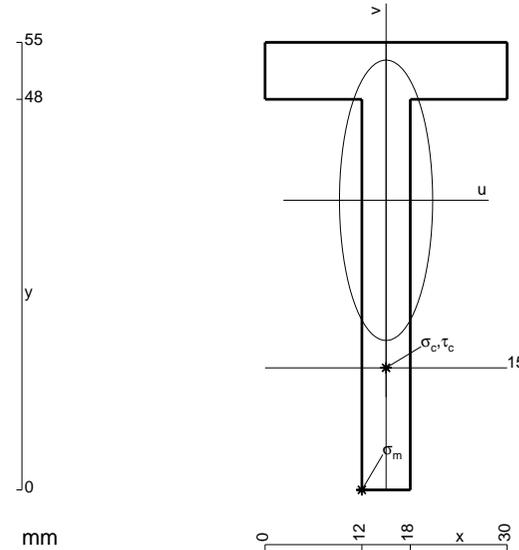
$$= (b - 1/4 b - 1/8 b) Fb 1/EJ + (-b + 1/2 b) \theta = 9/8 Fb^2/EJ$$

$$L_{GC}^{x_0} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

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

$$L_{CG}^{x_0} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$



$$A = 498. \text{ mm}^2$$

$$J_u = 147997. \text{ mm}^4$$

$$J_v = 16614. \text{ mm}^4$$

$$y_g = 35.6 \text{ mm}$$

$$T_y = -1220. \text{ N}$$

$$M_x = 902800. \text{ Nmm}$$

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

$$u_m = -3. \text{ mm}$$

$$v_m = -35.6 \text{ mm}$$

$$\sigma_m = -Mv/J_u = 217.1 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 15. \text{ mm}$$

$$v_c = -20.6 \text{ mm}$$

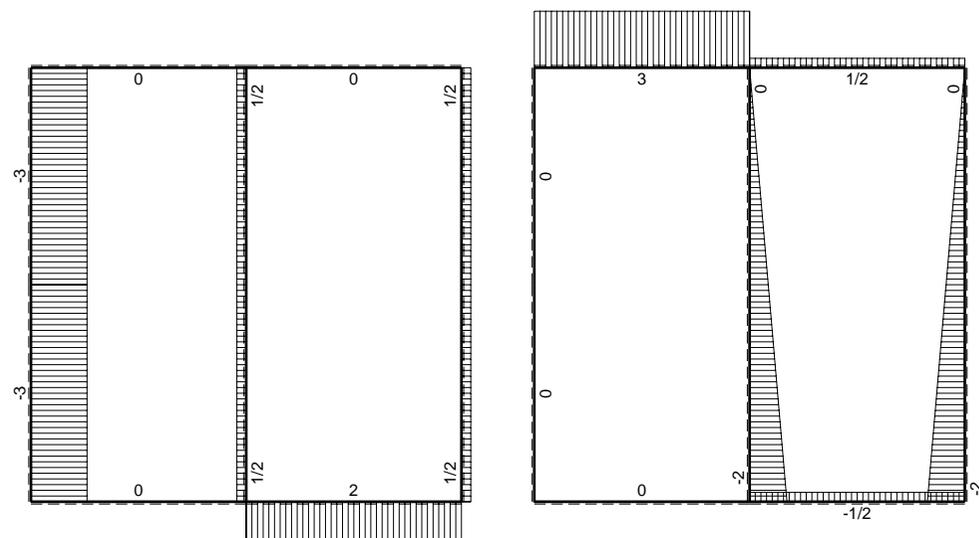
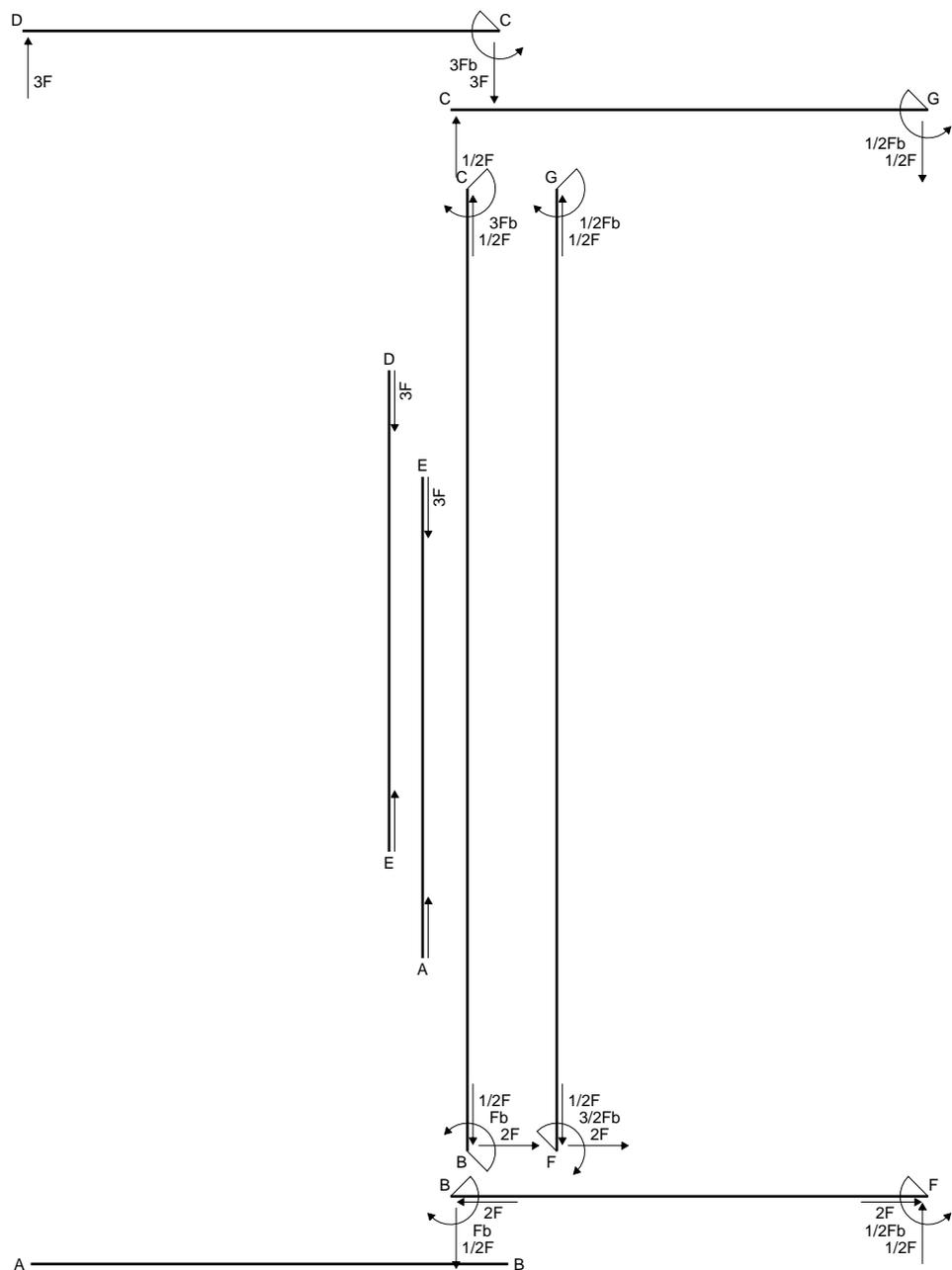
$$\sigma_c = -Mv/J_u = 125.6 \text{ N/mm}^2$$

$$\tau_c = 3.474 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 125.8 \text{ N/mm}^2$$

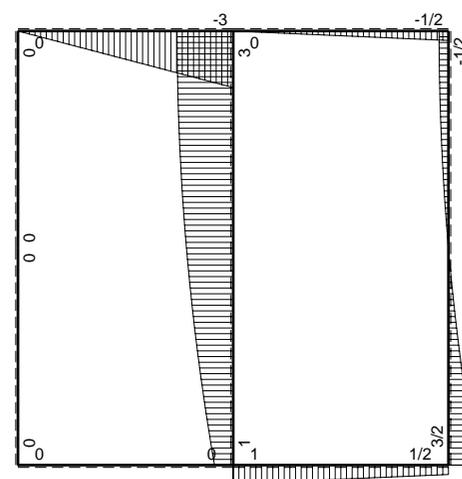
$$S = 2529. \text{ mm}^3$$



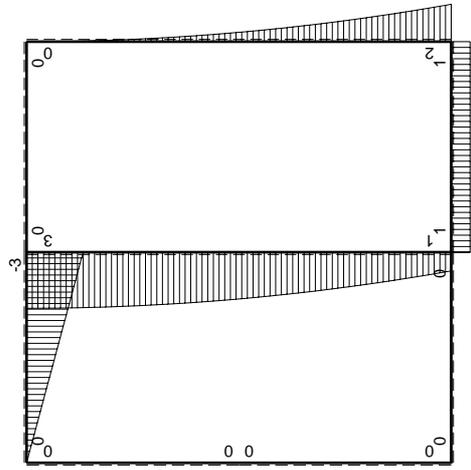
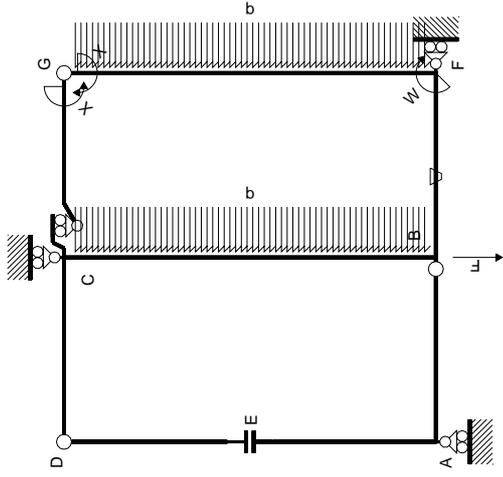


← ⊕ → F

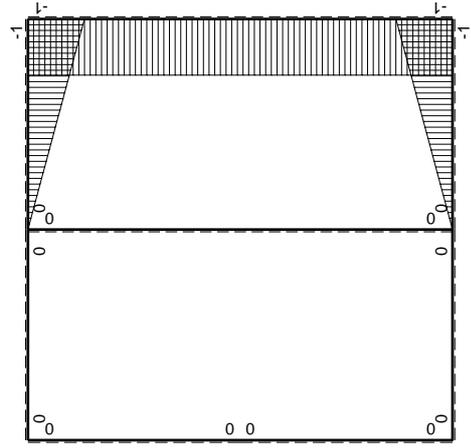
↑ ⊕ ↓ F



⊕ ⊖ Fb



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

←	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x (M_0/EJ + \theta) dx$	$\int M^x M_x/EJ dx$	iperstatica X=W <sub>gc</sub>	
									totali	
AB b	0	0	0	0	0	0	0	0	0	0
BA b	0	0	0	0	0	0	0	0	0	0
CD b	0	-3Fb+3Fx	0	0	0	0	0	0	0	0
DC b	0	3Fx	0	0	0	0	0	0	0	0
DE b	0	0	0	0	0	0	0	0	0	0
ED b	0	0	0	0	0	0	0	0	0	0
EA b	0	0	0	0	0	0	0	0	0	0
AE b	0	0	0	0	0	0	0	0	0	0
BF b	-x/b	Fb	-Fb/EJ	-Fx	Fx/EJ	$x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$	0+0	0
FB b	1-x/b	-Fb	Fb/EJ	-Fb+Fx	Fb/EJ-Fx/EJ	$1-2x/b+x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$	0+0	0
GC b	-1+x/b	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$	0	0
CG b	x/b	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$	0	0
FG 2b	-1	$2Fb-2Fx+1/2qx^2$	0	$-2Fb+2Fx-1/2Fx^2/b$	0	1	$(-4/3+0)Fb^2/EJ$	$2xb/EJ$	0+0	0
GF 2b	1	$-1/2qx^2$	0	$-1/2Fx^2/b$	0	1	$(-4/3+0)Fb^2/EJ$	$2xb/EJ$	0+0	0
CB 2b	0	$3Fb-1/2qx^2$	0	0	0	0	0	$8/3xb/EJ$	0	0
BC 2b	0	$-Fb-2Fx+1/2qx^2$	0	0	0	0	0	$8/3xb/EJ$	0	0
totali										

Sviluppi di calcolo iperstatica

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

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

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

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

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

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

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

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

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

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

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

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

$$L_{BF}^{x_0} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

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

$$L_{FB}^{x_0} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

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

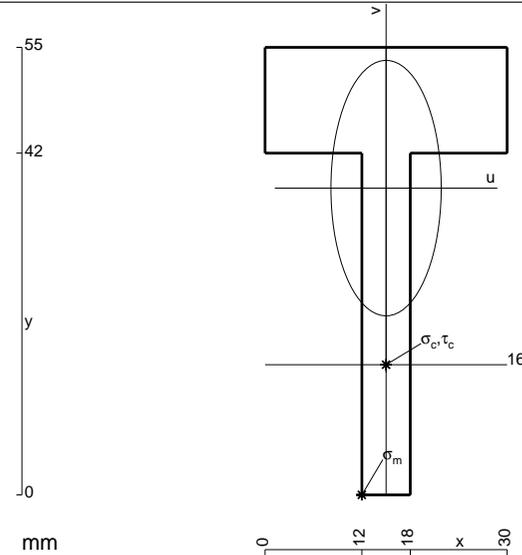
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

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

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

$$L_{GF}^{x_0} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

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



$$A = 642. \text{ mm}^2$$

$$J_u = 158306. \text{ mm}^4$$

$$J_v = 30006. \text{ mm}^4$$

$$y_g = 37.71 \text{ mm}$$

$$T_y = 1200. \text{ N}$$

$$M_x = -948000. \text{ Nmm}$$

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

$$u_m = -3. \text{ mm}$$

$$v_m = -37.71 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -225.8 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 16. \text{ mm}$$

$$v_c = -21.71 \text{ mm}$$

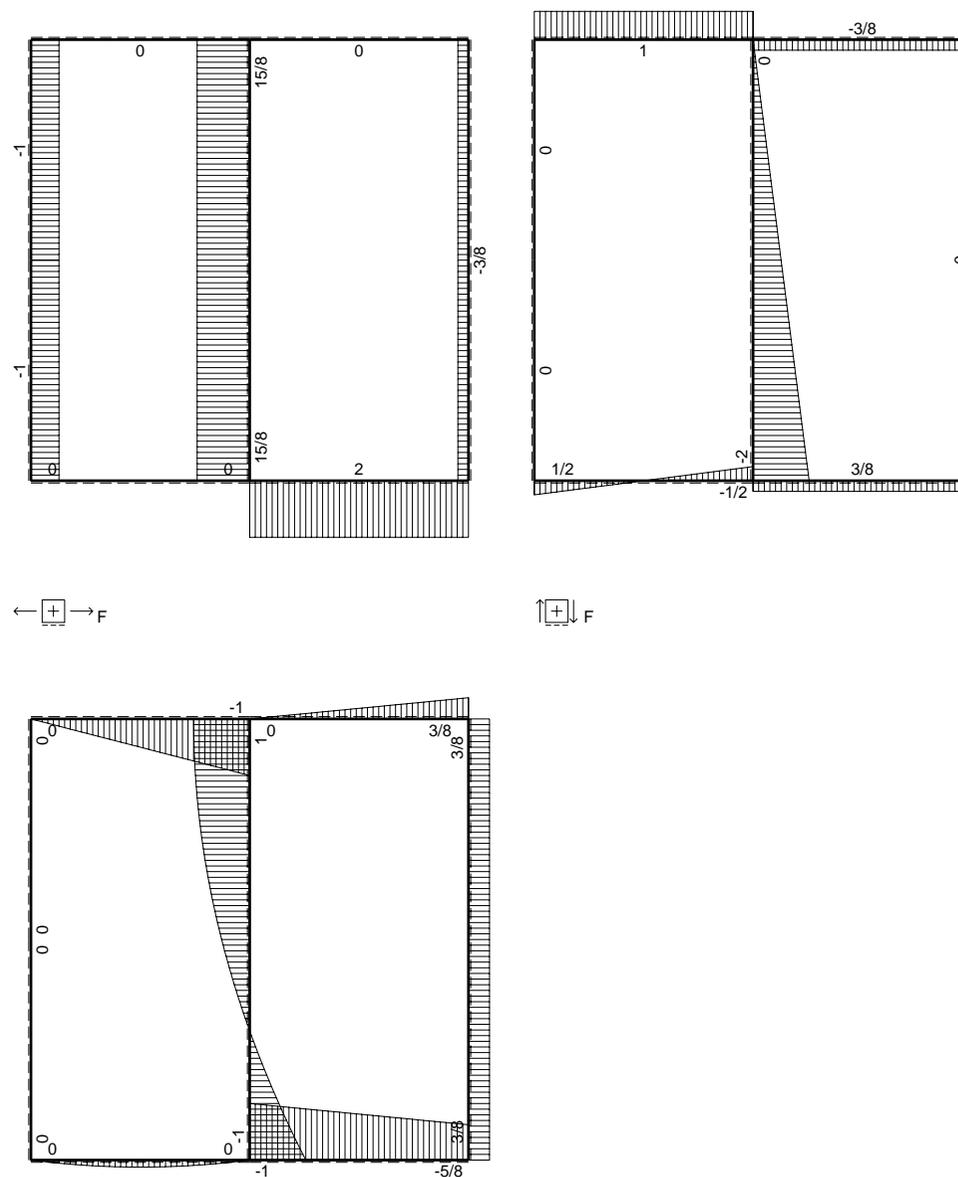
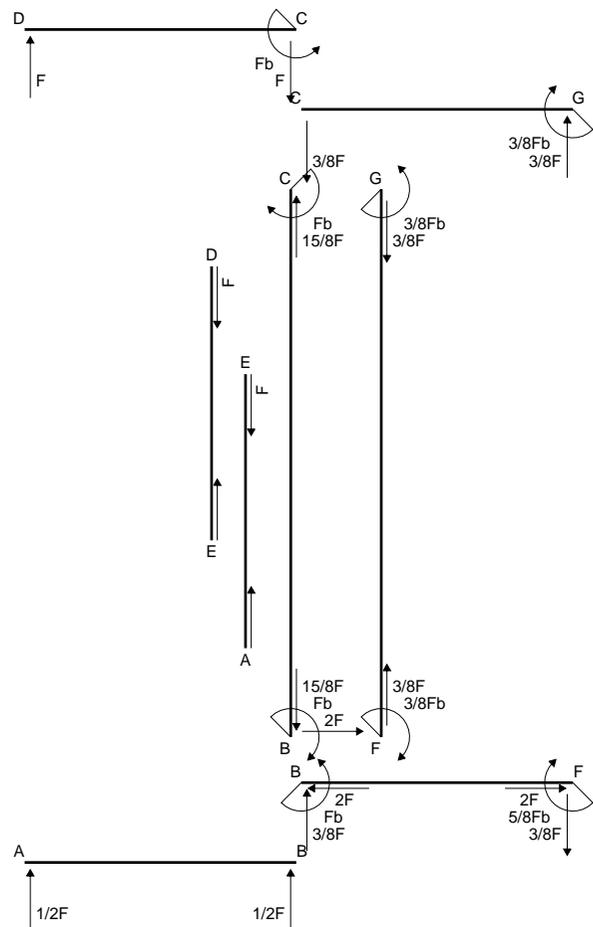
$$\sigma_c = -Mv/J_u = -130. \text{ N/mm}^2$$

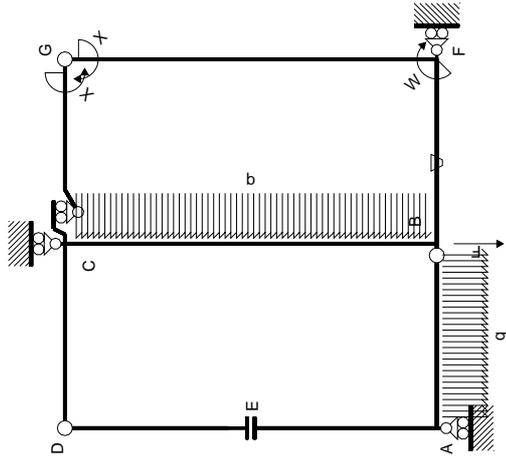
$$\tau_c = 3.603 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 130.1 \text{ N/mm}^2$$

$$S = 2852. \text{ mm}^3$$

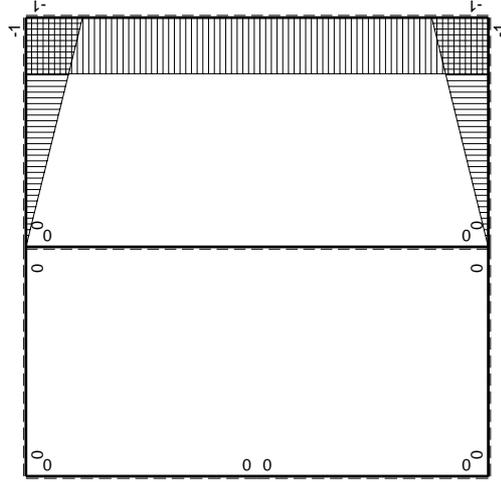






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

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

$\leftarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / EJ dx$
AB b	0	$1/2Fx - 1/2qx^2$	0	0	0	0	0+0	0
BA b	0	$-1/2Fx + 1/2qx^2$	0	0	0	0	0+0	0
CD b	0	$-Fb + Fx$	0	0	0	0	0+0	0
DC b	0	$Fx$	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
EA b	0	0	0	0	0	0	0+0	0
AE b	0	0	0	0	0	0	0+0	0
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb-Fx$	$Fb/EJ - Fx/EJ$	$1-2x/b+x^2/b^2$	$1/3xb/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2xb/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2xb/EJ$
CB 2b	0	$Fb - 1/2qx^2$	0	0	0	0	0+0	0
BC 2b	0	$Fb - 2Fx + 1/2qx^2$	0	0	0	0	0+0	0
totali								$8/3xb/EJ$
								$-3/8Fb$

Sviluppi di calcolo iperstatica

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

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

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

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

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

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

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

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

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

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

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

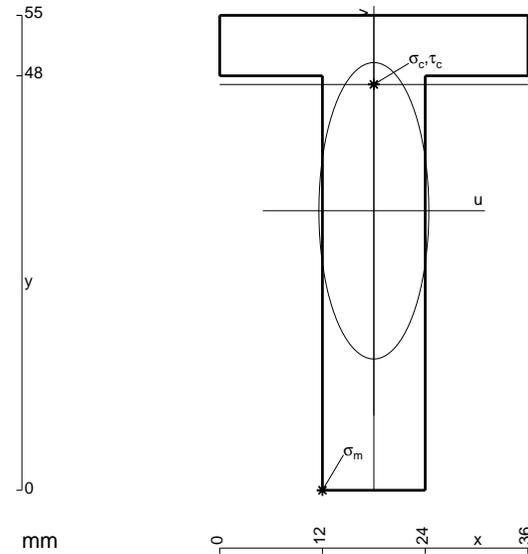
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

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

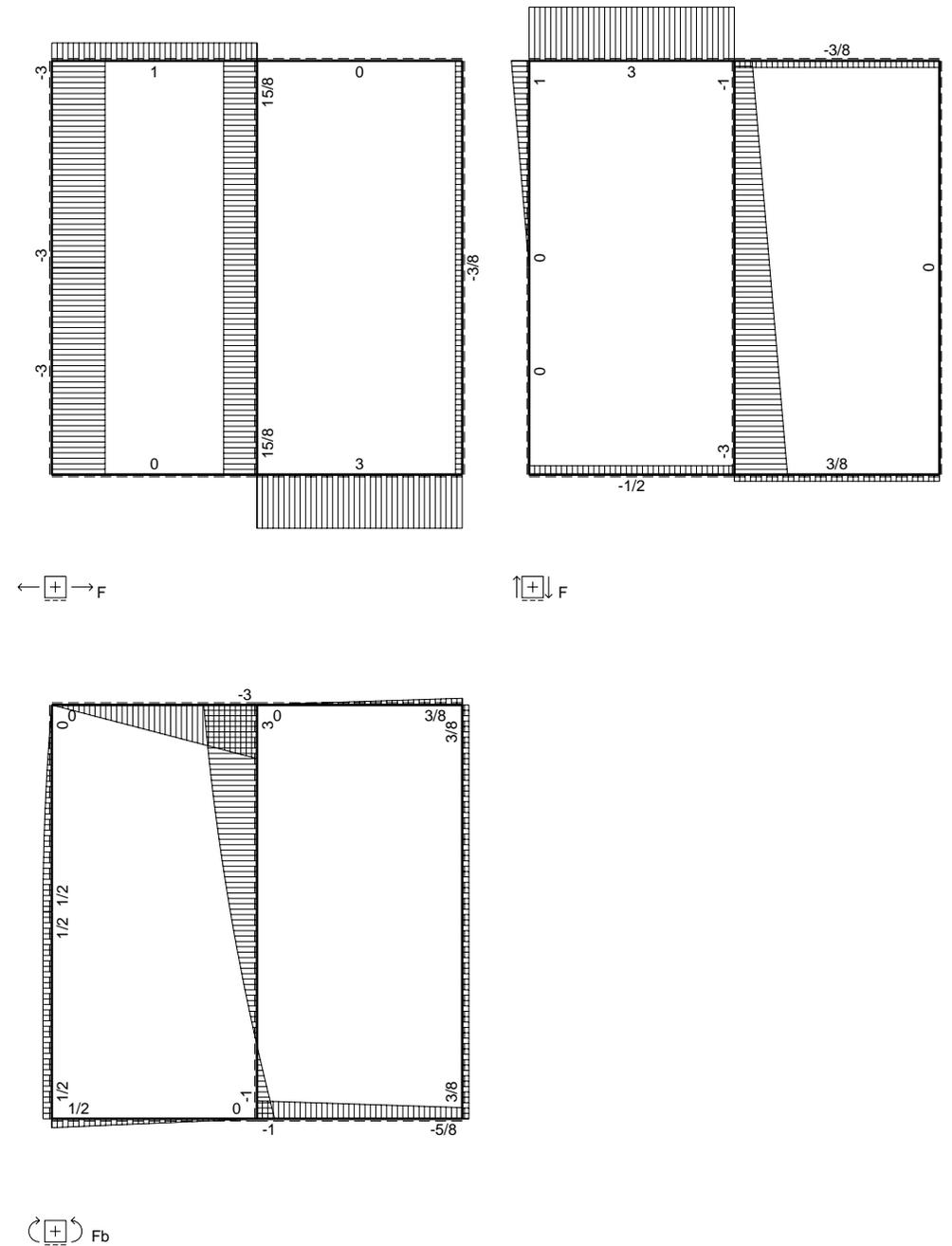
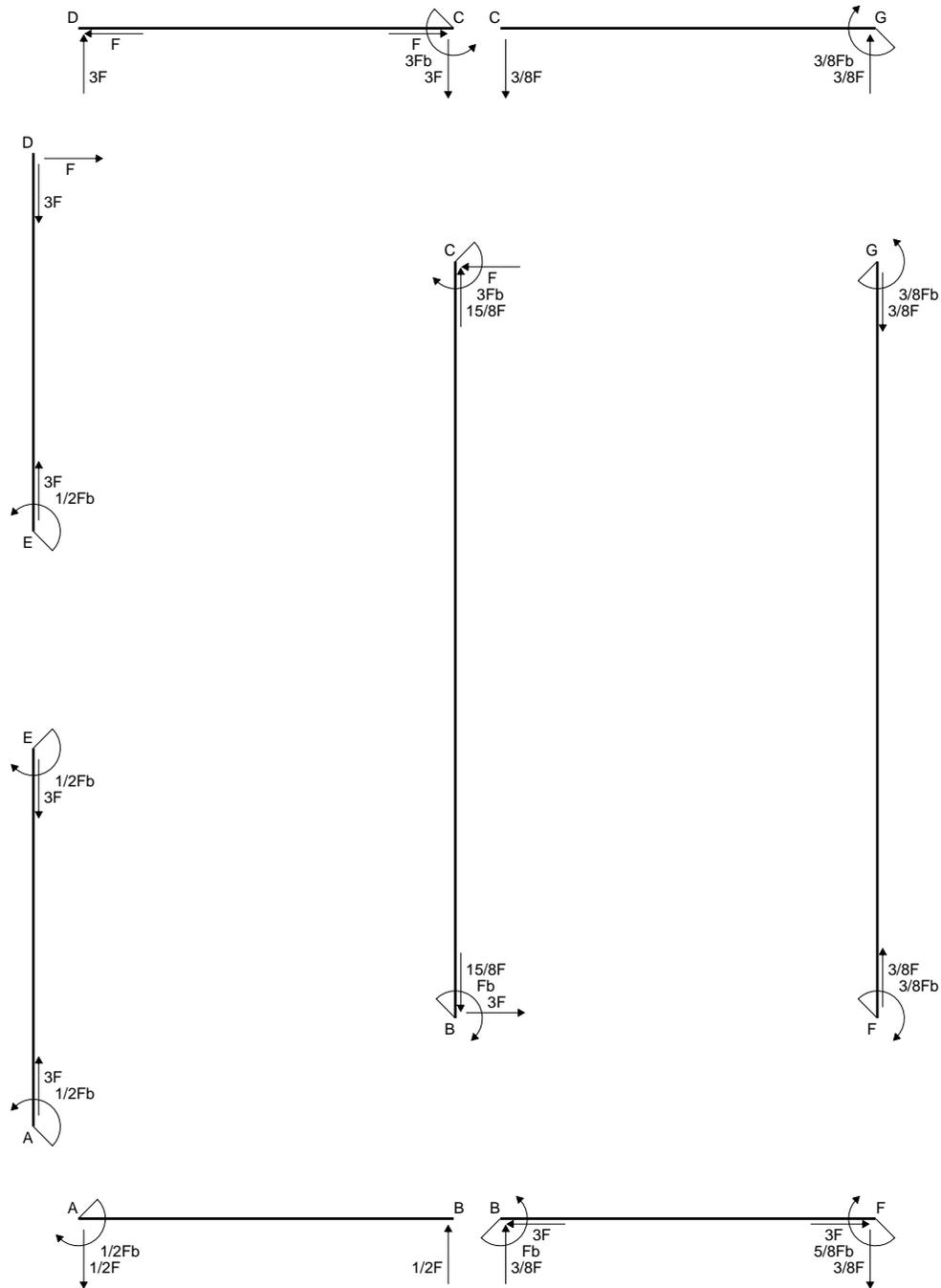
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

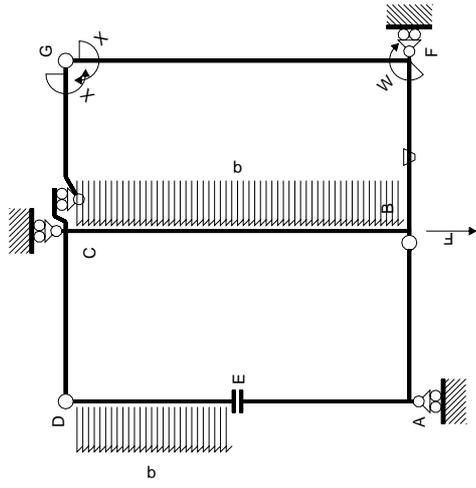
$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



- A = 828. mm<sup>2</sup>
- J<sub>u</sub> = 244195. mm<sup>4</sup>
- J<sub>v</sub> = 34128. mm<sup>4</sup>
- y<sub>g</sub> = 32.37 mm
- N = 4163. N
- T<sub>y</sub> = -4440. N
- M<sub>x</sub> = -1842600. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -32.37 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = -239.2 N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 47. mm
- v<sub>c</sub> = 14.63 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = 115.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.58 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 116.2 N/mm<sup>2</sup>
- S = 5002. mm<sup>3</sup>

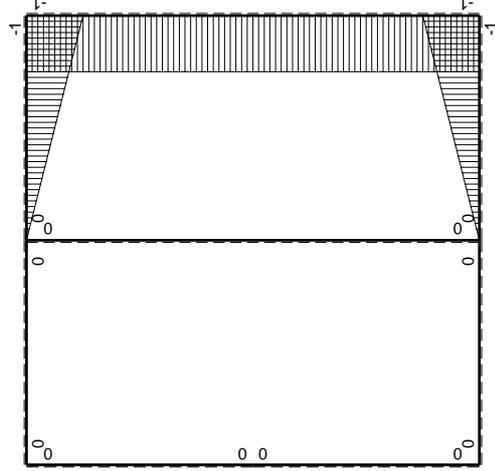
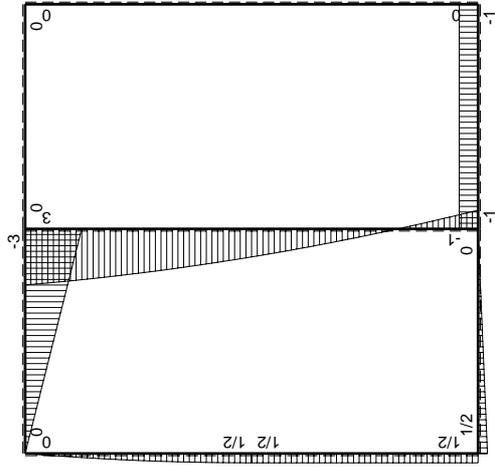






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

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

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / EJ dx$
AB b	0	$1/2Fb - 1/2Fx$	0	0	0	0	0+0	0
BA b	0	$-1/2Fx$	0	0	0	0	0+0	0
CD b	0	$-3Fb + 3Fx$	0	0	0	0	0+0	0
DC b	0	$3Fx$	0	0	0	0	0+0	0
DE b	0	$Fx - 1/2qx^2$	0	0	0	0	0+0	0
EA b	0	$1/2Fb$	0	0	0	0	0+0	0
AE b	0	$-1/2Fb$	0	0	0	0	0+0	0
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2 + 1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb - Fx$	$Fb/EJ - Fx/EJ$	$1 - 2x/b + x^2/b^2$	$1/3xb/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1 - 2x/b + x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2xb/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2xb/EJ$
CB 2b	0	$3Fb - Fx - 1/2qx^2$	0	0	0	0	0+0	0
BC 2b	0	$Fb - 3Fx + 1/2qx^2$	0	0	0	0	0+0	0
totali								$Fb^2/EJ$
								$8/3xb/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

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

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

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

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

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

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

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

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

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

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

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

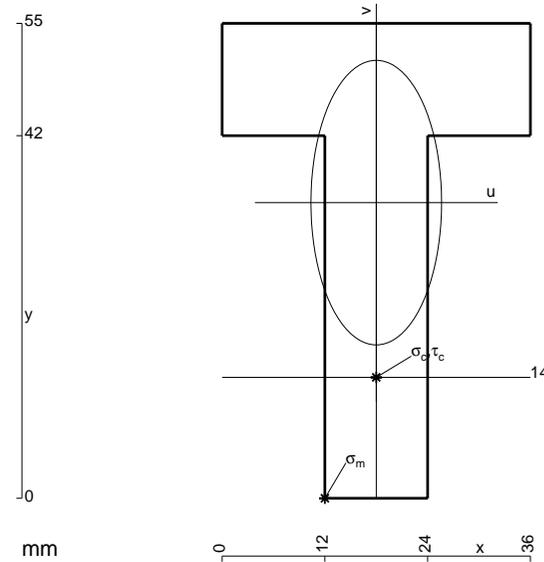
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

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

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

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



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

$$J_u = 264196. \text{ mm}^4$$

$$J_v = 56592. \text{ mm}^4$$

$$y_g = 34.24 \text{ mm}$$

$$N = 1170. \text{ N}$$

$$T_y = 3510. \text{ N}$$

$$M_x = -1544400. \text{ Nmm}$$

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

$$u_m = -6. \text{ mm}$$

$$v_m = -34.24 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -199. \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 14. \text{ mm}$$

$$v_c = -20.24 \text{ mm}$$

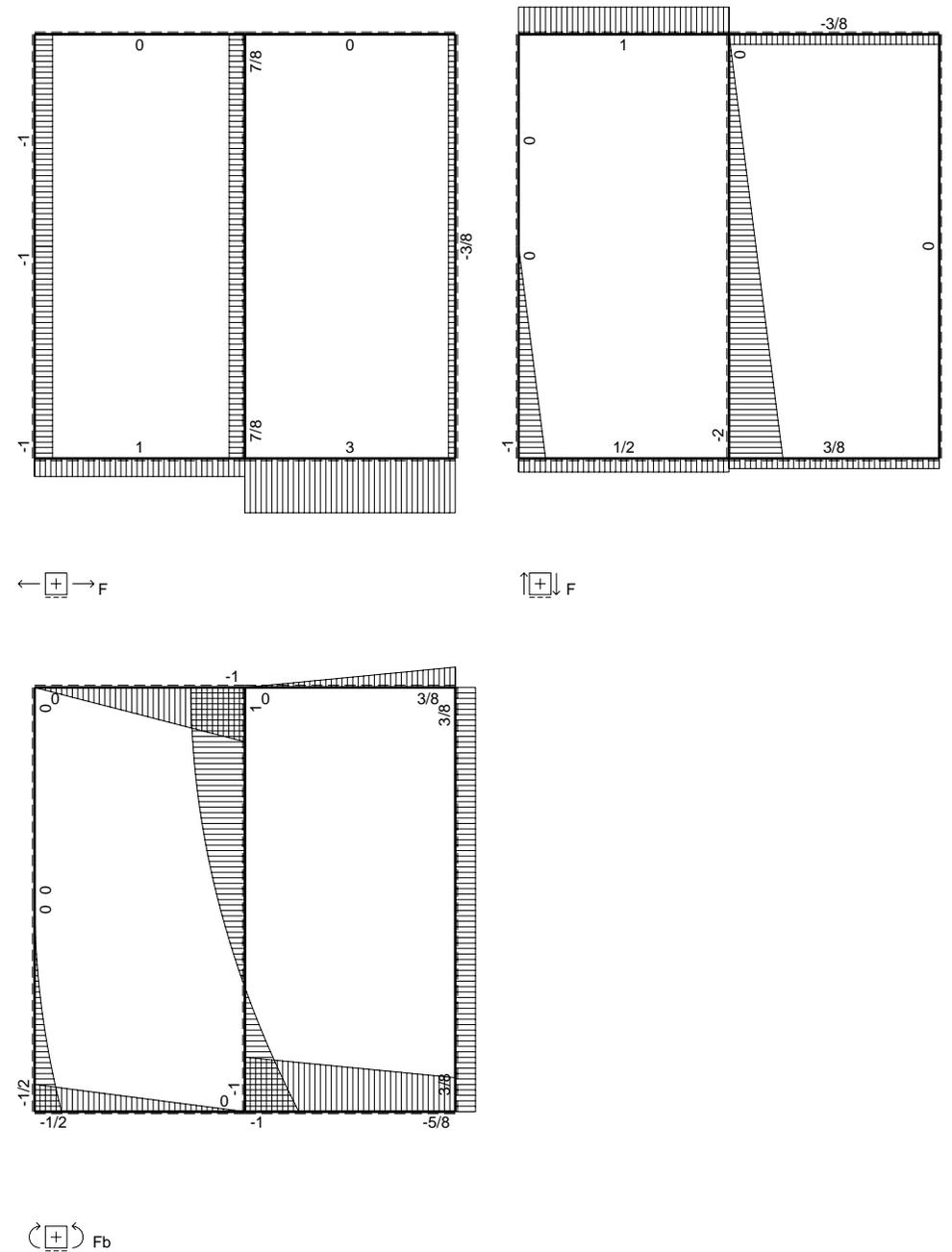
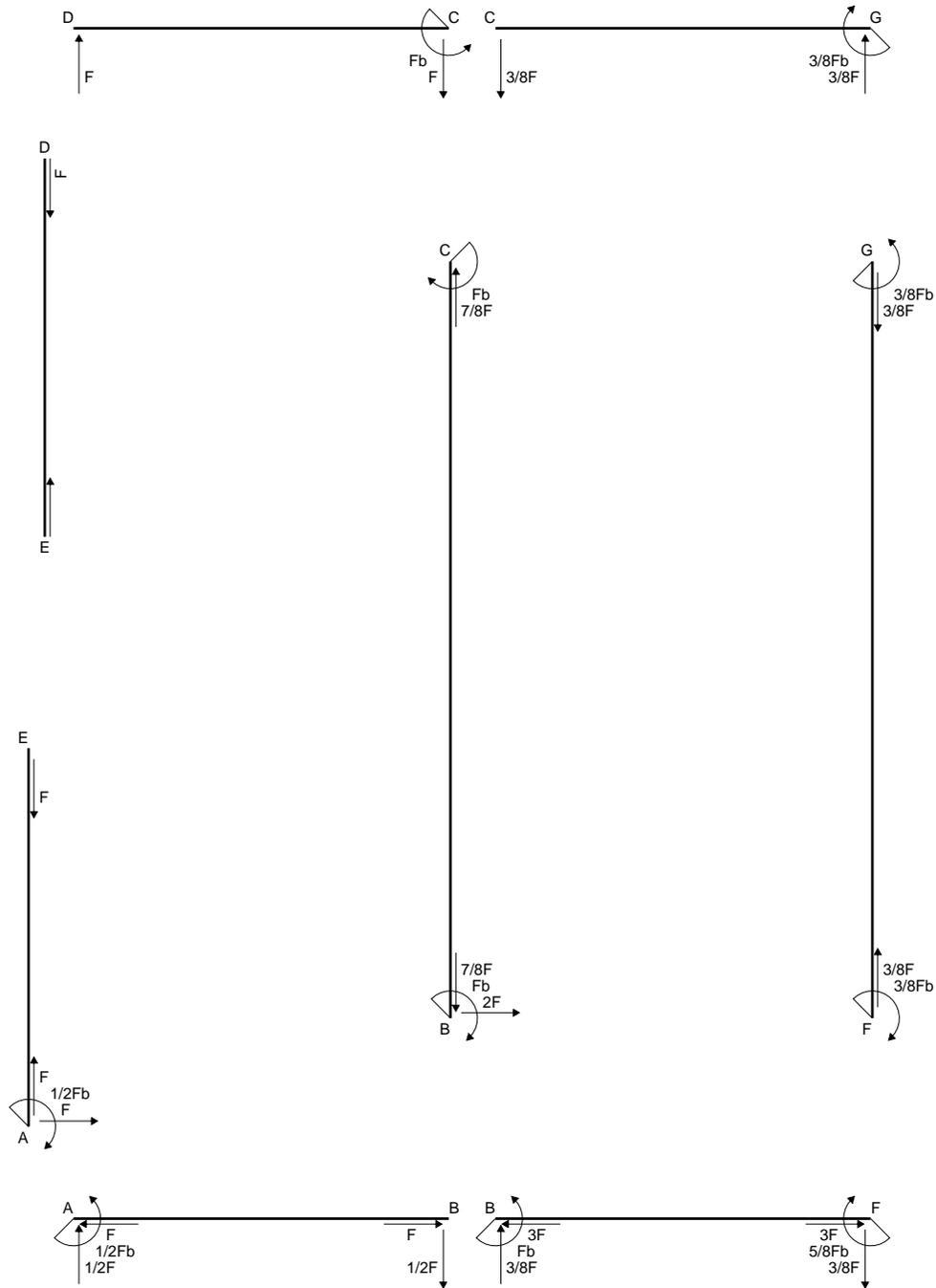
$$\sigma_c = N/A - Mv/J_u = -117.1 \text{ N/mm}^2$$

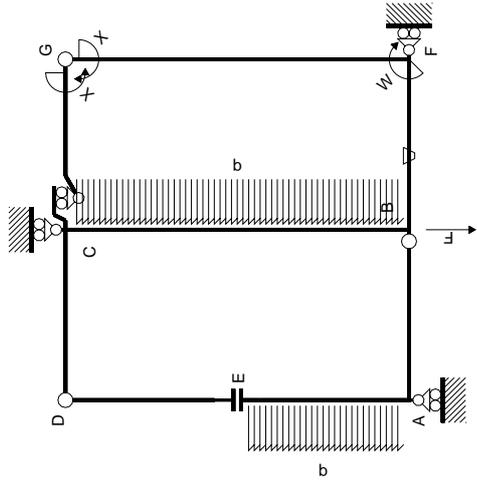
$$\tau_c = 5.067 \text{ N/mm}^2$$

$$\sigma_g = \sqrt{\sigma^2 + 3\tau^2} = 117.4 \text{ N/mm}^2$$

$$S = 4576. \text{ mm}^3$$

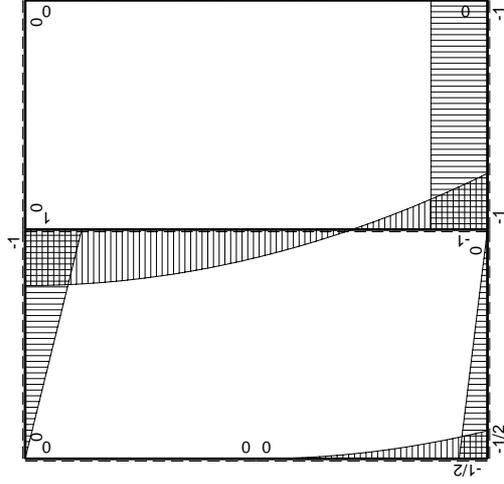






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



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

$\rightarrow$	$M^x(x)$	$M(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB B	0	$-1/2Fx$	0	0	0	0	0+0	0
BA B	0	$1/2Fx$	0	0	0	0	0+0	0
CD B	0	$-Fb+Fx$	0	0	0	0	0+0	0
DC B	0	$Fx$	0	0	0	0	0+0	0
ED B	0	0	0	0	0	0	0+0	0
EAB	0	$-1/2qx^2$	0	0	0	0	0+0	0
AE B	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0+0	0
BF B	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$Fb/EJ-Fx/EJ$	$(1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB B	$1-x/b$	$Fb$	$Fb/EJ$	$Fb-Fx$	$Fb/EJ-Fx/EJ$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$1/3xb/EJ$
GC B	$-1+x/b$	0	0	0	0	0	$1-2x/b+x^2/b^2$	$1/3xb/EJ$
CG B	$x/b$	0	0	0	0	0	$x^2/b^2$	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	0	0+0	$2xb/EJ$
GF 2b	1	0	0	0	0	0	0+0	$2xb/EJ$
CB 2b	0	$Fb-1/2qx^2$	0	0	0	0	0+0	0
BC 2b	0	$Fb-2Fx+1/2qx^2$	0	0	0	0	0+0	0
totali								$Fb^2/EJ$
								$8/3xb/EJ$

Sviluppi di calcolo iperstatica

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

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

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

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

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

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

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

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

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

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

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

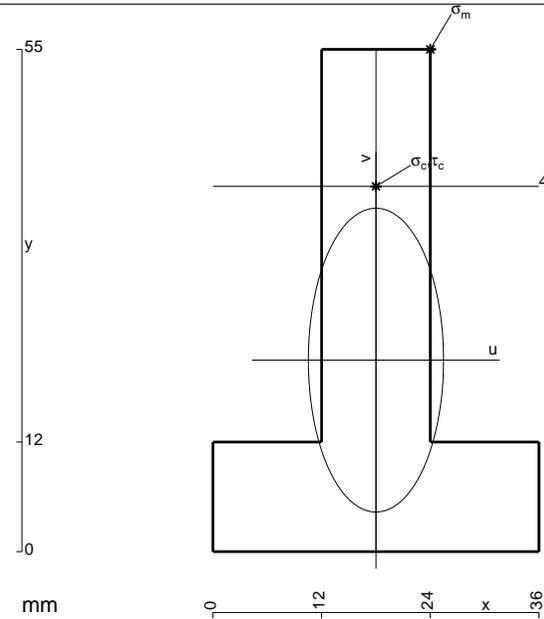
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

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

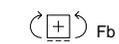
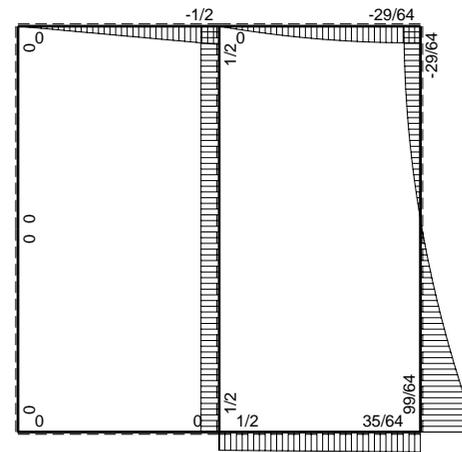
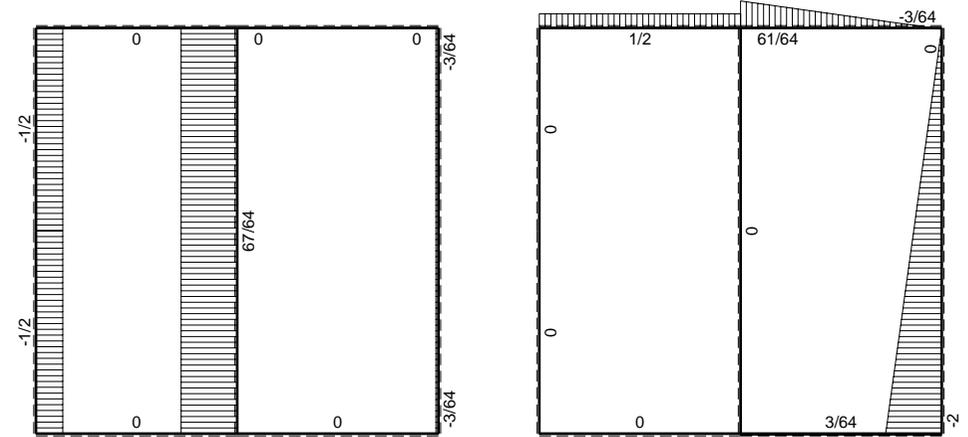
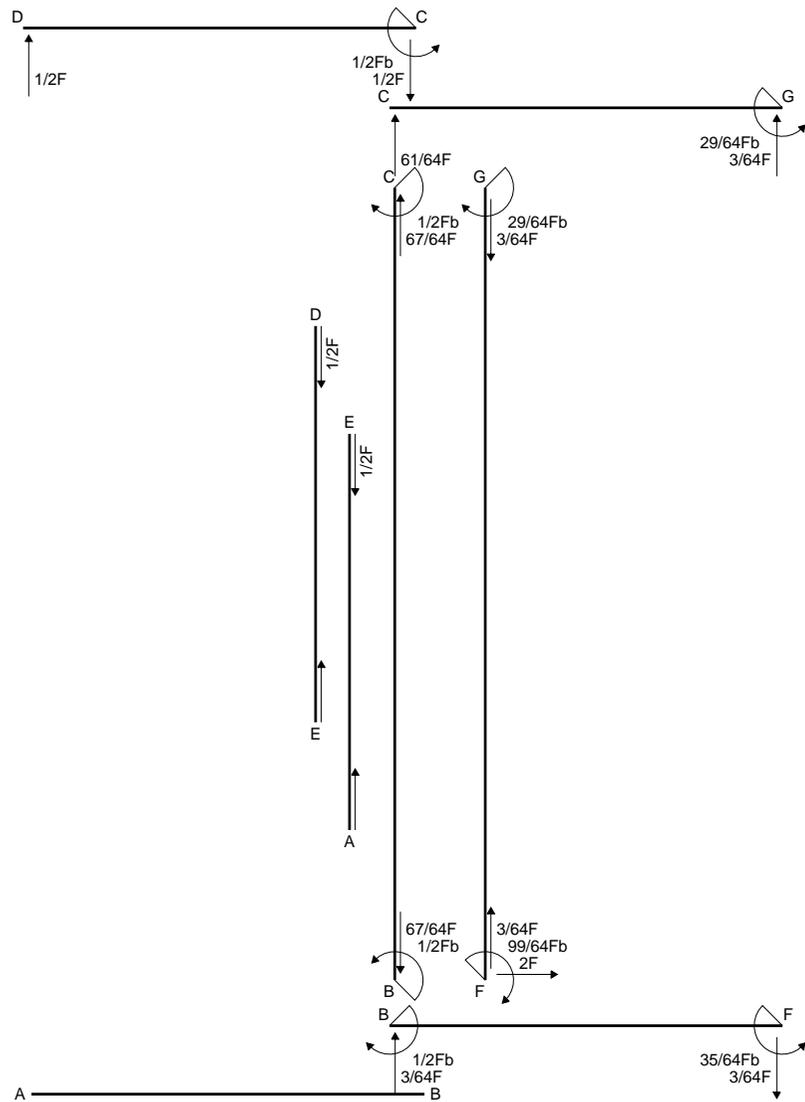
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

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



- A = 948. mm<sup>2</sup>
- J<sub>u</sub> = 262515. mm<sup>4</sup>
- J<sub>v</sub> = 52848. mm<sup>4</sup>
- y<sub>g</sub> = 20.97 mm
- N = 2905. N
- T<sub>y</sub> = -6640. N
- M<sub>x</sub> = -1593600. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 55. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 34.03 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = 209.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 40. mm
- v<sub>c</sub> = 19.03 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = 118.6 N/mm<sup>2</sup>
- τ<sub>c</sub> = 10.07 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 119.9 N/mm<sup>2</sup>
- S = 4776. mm<sup>3</sup>







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

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

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

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

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

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

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

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

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

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

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

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

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

$$= [-1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/4 b - 1/6 b) Fb 1/EJ + (1/2 b) \theta = 1/12 Fb^2/EJ$$

$$L_{FB}^{xo} = \int_0^b (-1 + 3/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 3/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (-b + 3/4 b - 1/6 b) Fb 1/EJ + (-b + 1/2 b) \theta = 1/12 Fb^2/EJ$$

$$L_{GC}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{CG}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

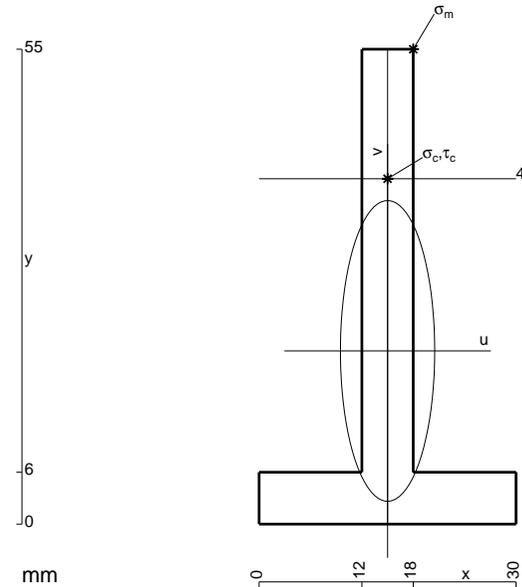
$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{FG}^{xo} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

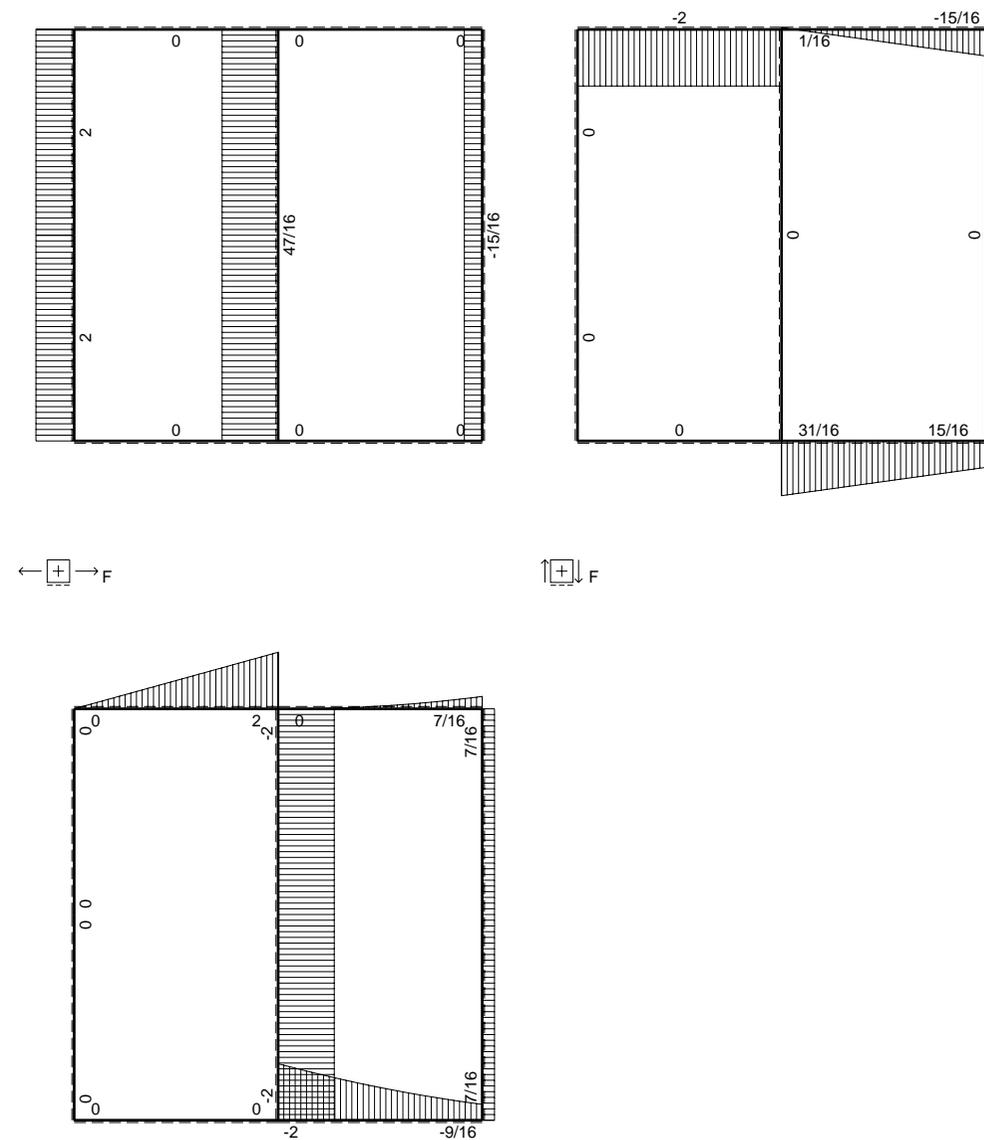
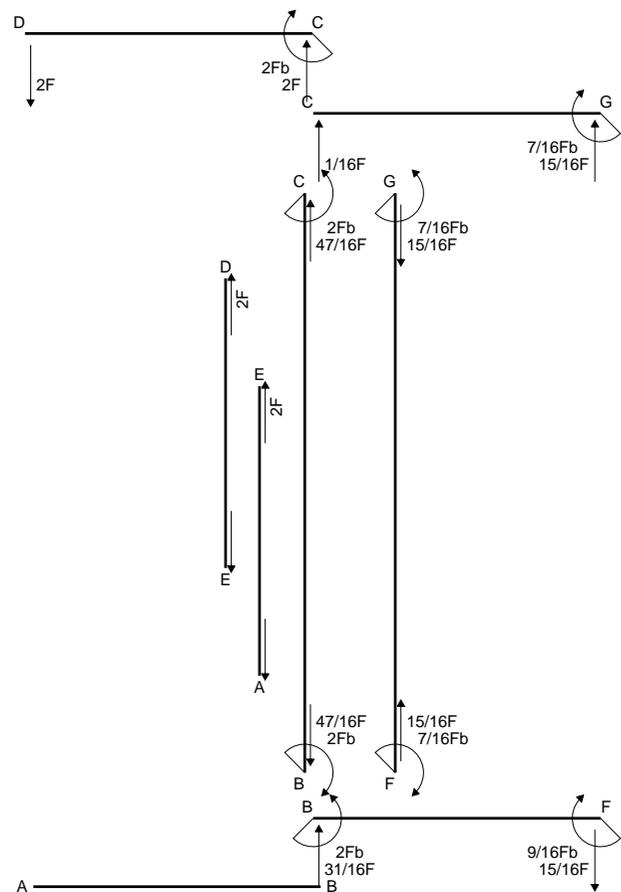
$$L_{GF}^{xo} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



- A = 474. mm<sup>2</sup>
- J<sub>u</sub> = 143796. mm<sup>4</sup>
- J<sub>v</sub> = 14382. mm<sup>4</sup>
- y<sub>g</sub> = 20.06 mm
- T<sub>y</sub> = 1740. N
- M<sub>x</sub> = -904800. Nmm
- x<sub>m</sub> = 18. mm
- y<sub>m</sub> = 55. mm
- u<sub>m</sub> = 3. mm
- v<sub>m</sub> = 34.94 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 219.9 N/mm<sup>2</sup>
- x<sub>c</sub> = 15. mm
- y<sub>c</sub> = 40. mm
- v<sub>c</sub> = 19.94 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 125.5 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.981 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 125.8 N/mm<sup>2</sup>
- S = 2470. mm<sup>3</sup>







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{xo} = \int_0^b (2x/b - 3/2 x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

$$= [x^2/b - 1/2 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b + 1/8 b) Fb 1/EJ + (1/2 b) \theta = 9/8 Fb^2/EJ$$

$$L_{FB}^{xo} = \int_0^b (1 - 1/2 x/b - 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [x - 1/4 x^2/b - 1/8 x^4/b^3]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

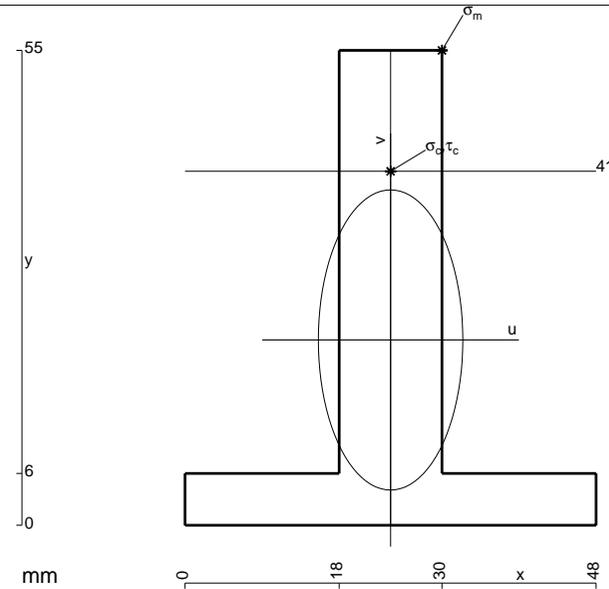
$$= (b - 1/4 b - 1/8 b) Fb 1/EJ + (-b + 1/2 b) \theta = 9/8 Fb^2/EJ$$

$$L_{GC}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

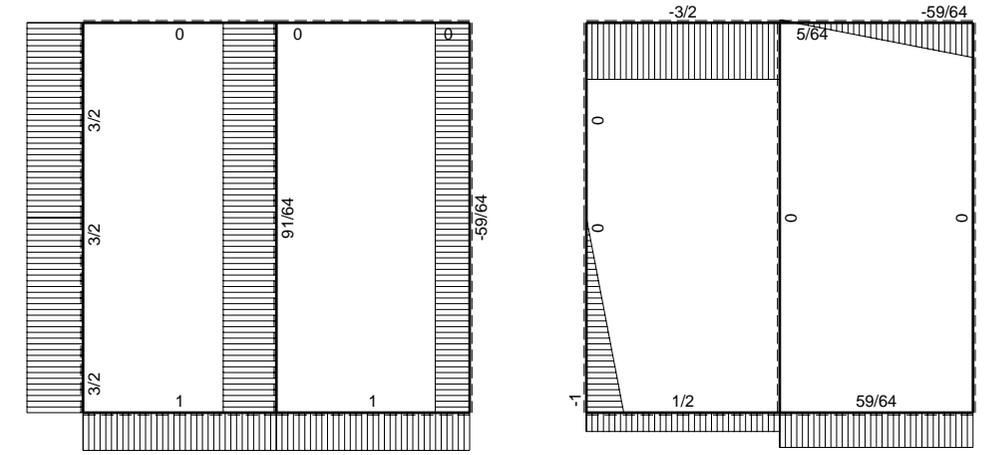
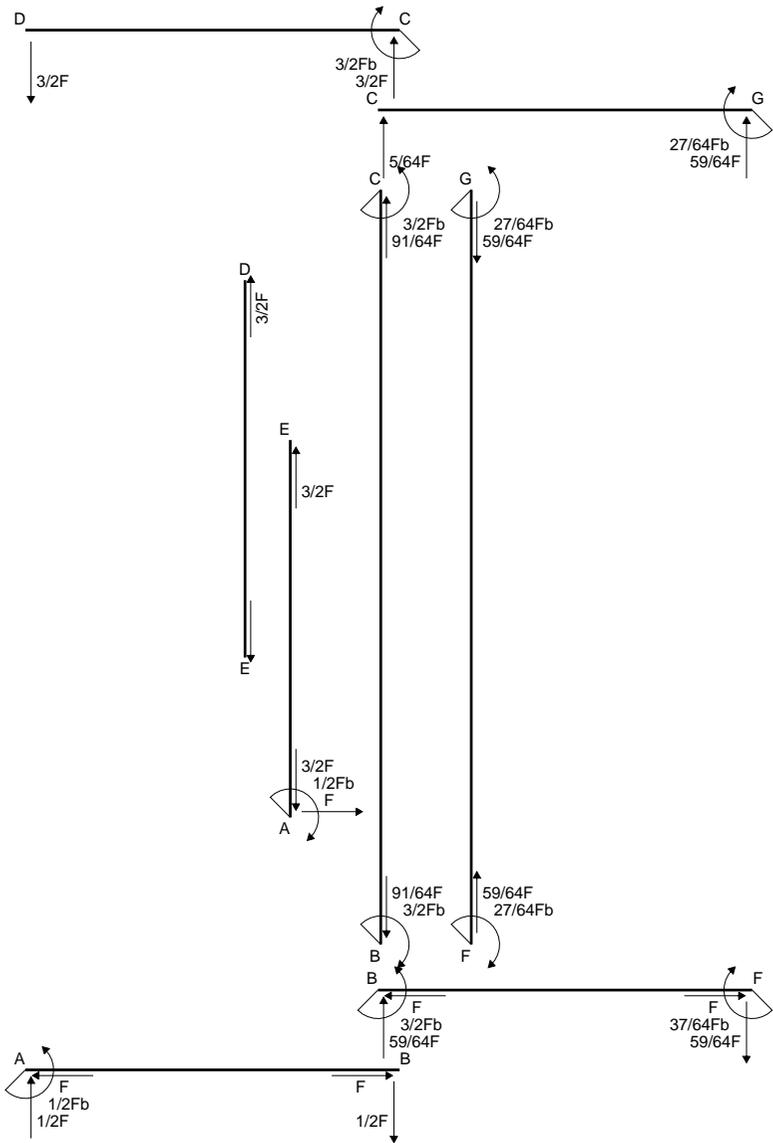
$$L_{CG}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$



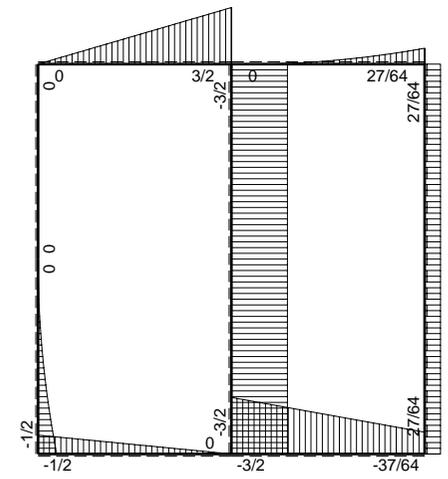
- A = 876. mm<sup>2</sup>
- J<sub>u</sub> = 264708. mm<sup>4</sup>
- J<sub>v</sub> = 62352. mm<sup>4</sup>
- y<sub>g</sub> = 21.46 mm
- T<sub>y</sub> = -3180. N
- M<sub>x</sub> = 1812600. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 55. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 33.54 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -229.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 41. mm
- v<sub>c</sub> = 19.54 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -133.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.464 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 134. N/mm<sup>2</sup>
- S = 4459. mm<sup>3</sup>



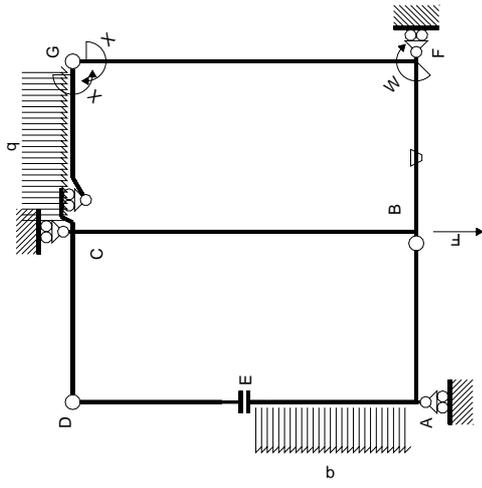


← ⊕ → F

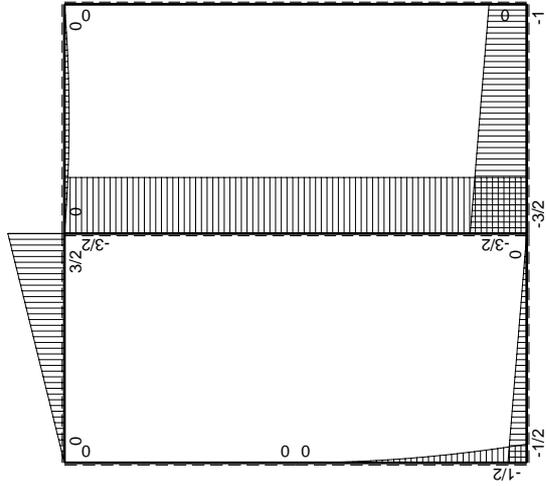
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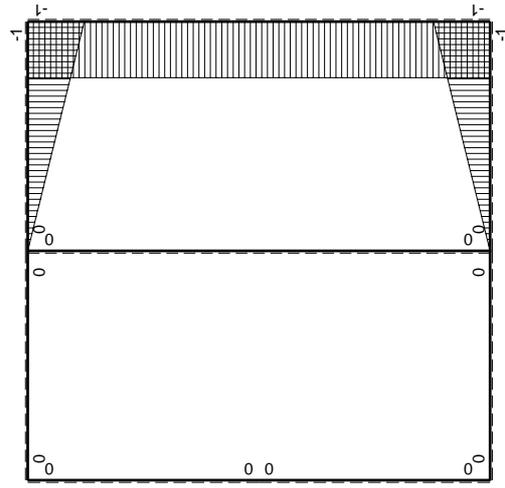
⊕ ⊖ Fb



Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica X=W<sub>gc</sub>

←	M <sub>0</sub> (x)	M <sub>0</sub> (x)	θ	M <sub>0</sub> M <sub>0</sub>	M <sub>0</sub> θ	M <sub>0</sub> M <sub>x</sub>	∫M <sub>0</sub> (M <sub>0</sub> /EJ+θ)dx	∫M <sub>0</sub> M <sub>x</sub> /EJdx
AB b	0	-1/2Fb+1/2Fx	0	0	0	0	0+0	0
BA b	0	1/2Fx	0	0	0	0	0+0	0
CD b	0	3/2Fb-3/2Fx	0	0	0	0	0+0	0
DC b	0	-3/2Fx	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
EA b	0	-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
AE b	0	1/2Fb-Fx+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
BF b	-x/b	-3/2Fb+1/2Fx	-Fb/EJ	3/2Fx-1/2Fx <sup>2</sup> /b	Fx/EJ	x <sup>2</sup> /b <sup>2</sup>	(7/12+1/2)Fb <sup>2</sup> /EJ	1/3Xb/EJ
FB b	1-x/b	Fb+1/2Fx	Fb/EJ	Fb-1/2Fx-1/2Fx <sup>2</sup> /b	Fb/EJ-Fx/EJ	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	(7/12+1/2)Fb <sup>2</sup> /EJ	1/3Xb/EJ
GC b	-1+x/b	-1/2Fx+1/2qx <sup>2</sup>	0	1/2Fx-Fx <sup>2</sup> /b+1/2qx <sup>3</sup> /b	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	(1/24+0)Fb <sup>2</sup> /EJ	1/3Xb/EJ
CG b	x/b	1/2Fx-1/2qx <sup>2</sup>	0	1/2Fx <sup>2</sup> /b-1/2qx <sup>3</sup> /b	0	x <sup>2</sup> /b <sup>2</sup>	(1/24+0)Fb <sup>2</sup> /EJ	1/3Xb/EJ
FG 2b	-1	0	0	0	0	1	0+0	2Xb/EJ
GF 2b	1	0	0	0	0	1	0+0	2Xb/EJ
CB 2b	0	-3/2Fb	0	0	0	0	0+0	0
BC 2b	0	3/2Fb	0	0	0	0	0+0	0
totali								8/3Xb/EJ
								-27/64Fb

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{xo} = \int_0^b (3/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

$$= [3/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (3/4 b - 1/6 b) Fb 1/EJ + (1/2 b) \theta = 13/12 Fb^2/EJ$$

$$L_{FB}^{xo} = \int_0^b (1 - 1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [x - 1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

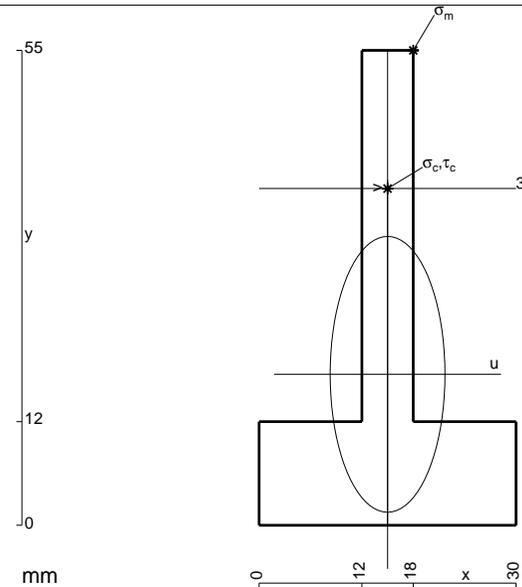
$$= (b - 1/4 b - 1/6 b) Fb 1/EJ + (-b + 1/2 b) \theta = 13/12 Fb^2/EJ$$

$$L_{GC}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{CG}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$



$$A = 618. \text{ mm}^2$$

$$J_u = 157731. \text{ mm}^4$$

$$J_v = 27774. \text{ mm}^4$$

$$y_g = 17.48 \text{ mm}$$

$$T_y = -1650. \text{ N}$$

$$M_x = 1006500. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$y_m = 55. \text{ mm}$$

$$u_m = 3. \text{ mm}$$

$$v_m = 37.52 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -239.4 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 39. \text{ mm}$$

$$v_c = 21.52 \text{ mm}$$

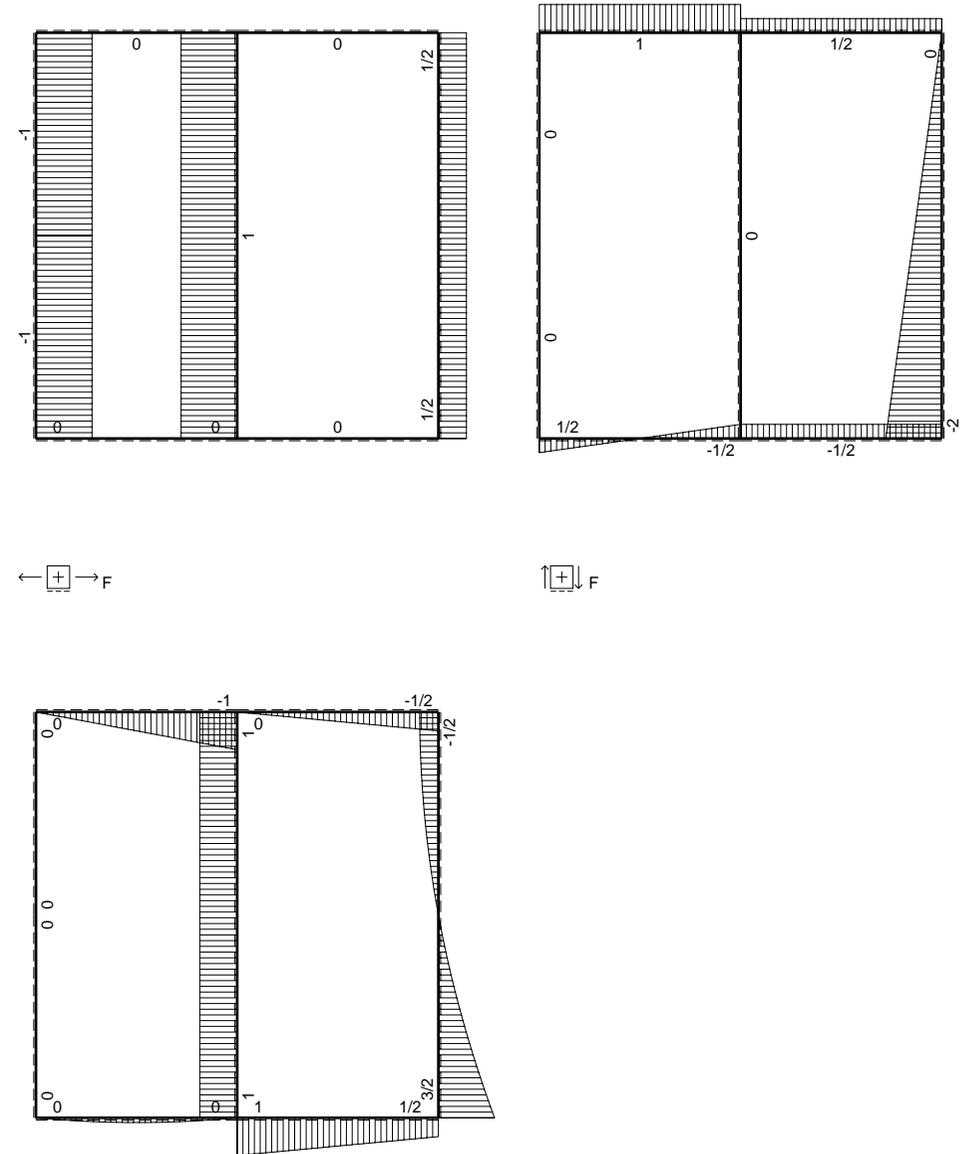
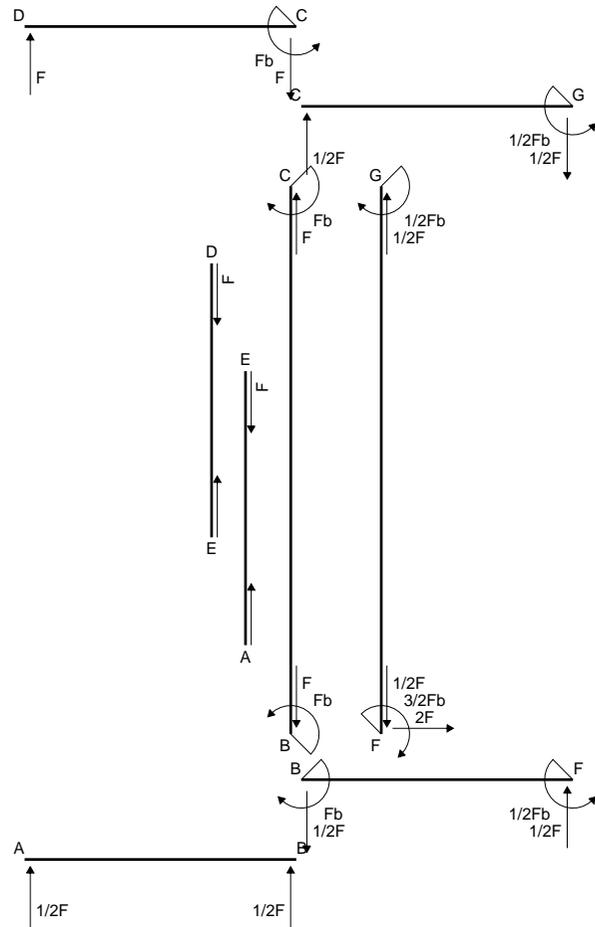
$$\sigma_c = -Mv/J_u = -137.3 \text{ N/mm}^2$$

$$\tau_c = 4.941 \text{ N/mm}^2$$

$$\sigma_\varphi = \sqrt{\sigma^2 + 3\tau^2} = 137.6 \text{ N/mm}^2$$

$$S = 2834. \text{ mm}^3$$







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x_0} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

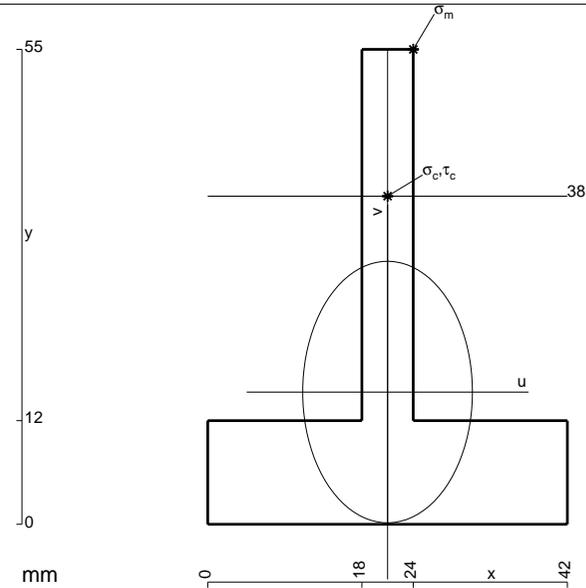
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x_0} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

$$L_{GF}^{x_0} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



$$A = 762. \text{ mm}^2$$

$$J_u = 174852. \text{ mm}^4$$

$$J_v = 74862. \text{ mm}^4$$

$$y_g = 15.31 \text{ mm}$$

$$T_y = 1330. \text{ N}$$

$$M_x = -877800. \text{ Nmm}$$

$$x_m = 24. \text{ mm}$$

$$y_m = 55. \text{ mm}$$

$$u_m = 3. \text{ mm}$$

$$v_m = 39.69 \text{ mm}$$

$$\sigma_m = -Mv/J_u = 199.2 \text{ N/mm}^2$$

$$x_c = 21. \text{ mm}$$

$$y_c = 38. \text{ mm}$$

$$v_c = 22.69 \text{ mm}$$

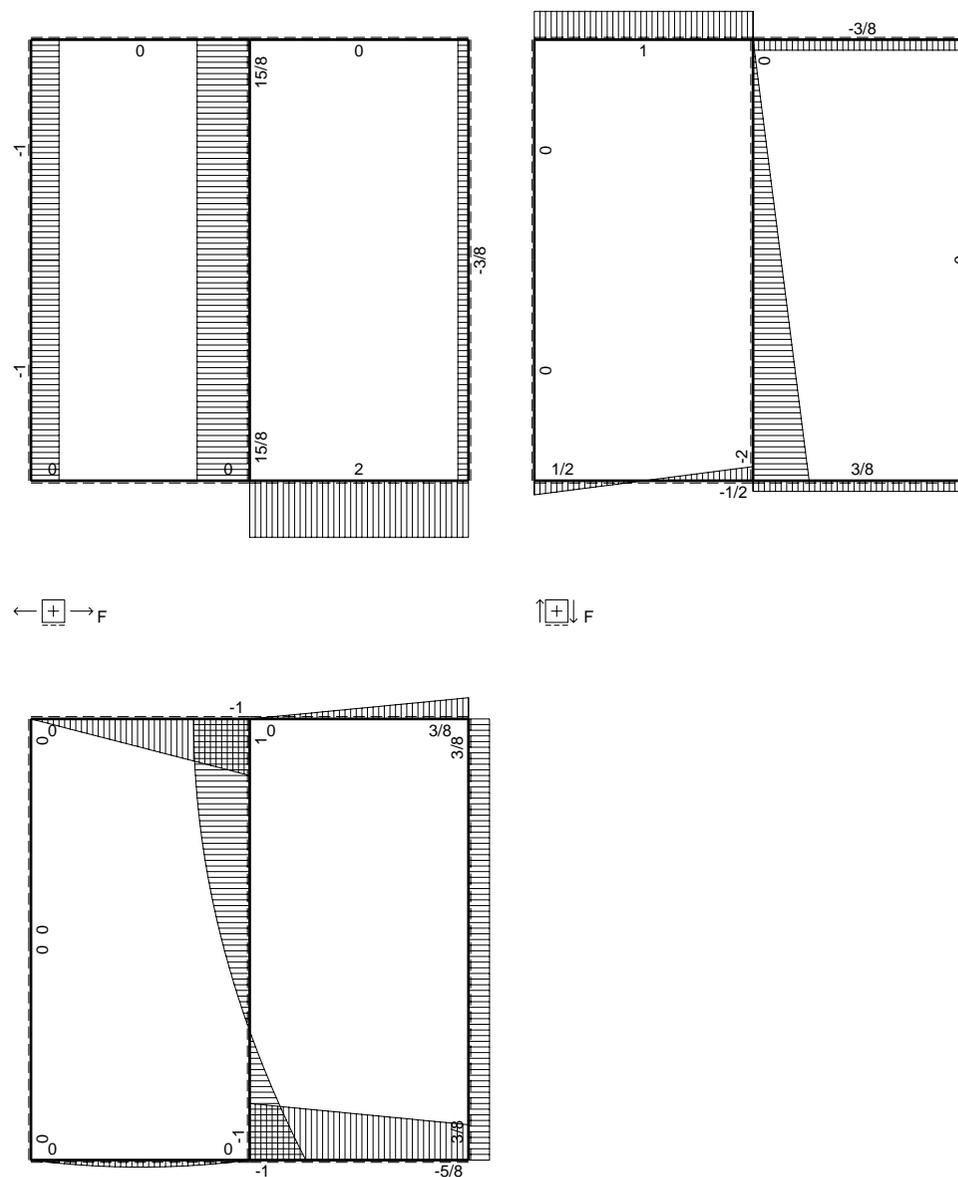
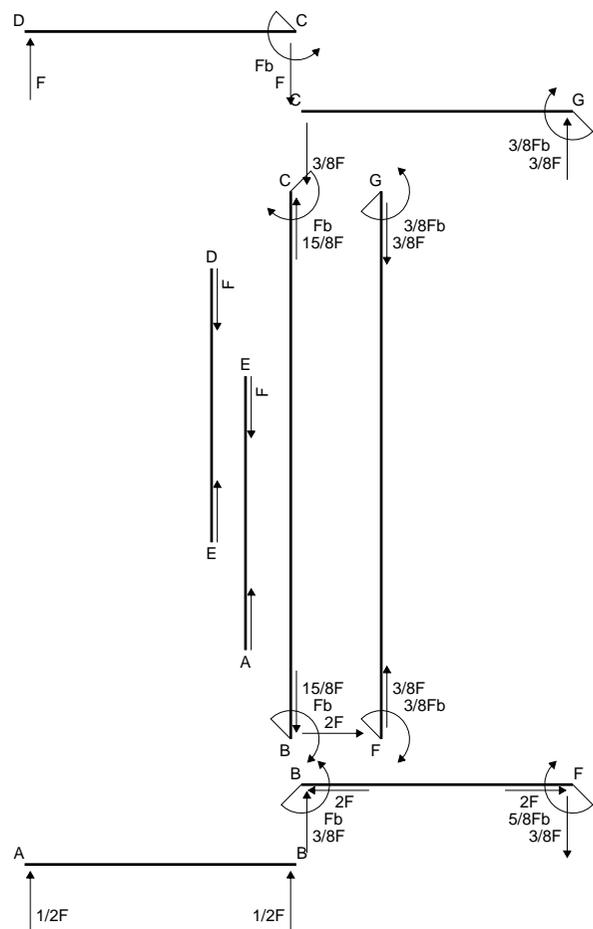
$$\sigma_c = -Mv/J_u = 113.9 \text{ N/mm}^2$$

$$\tau_c = 4.033 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 114.1 \text{ N/mm}^2$$

$$S = 3181. \text{ mm}^3$$





⊕ Fb



$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

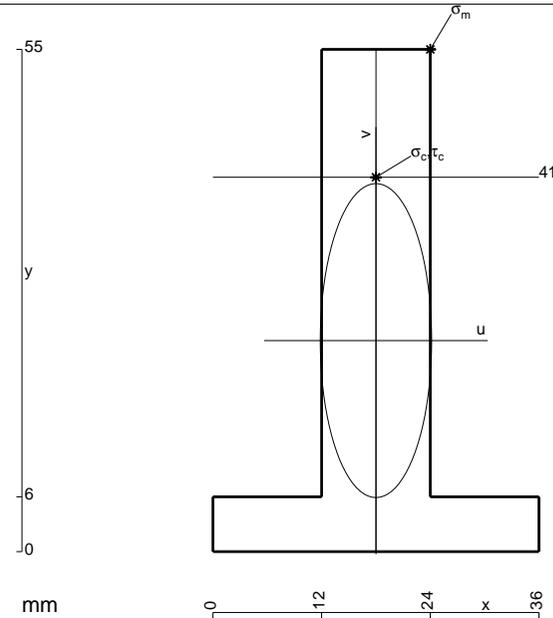
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



$$A = 804. \text{ mm}^2$$

$$J_u = 237762. \text{ mm}^4$$

$$J_v = 30384. \text{ mm}^4$$

$$y_g = 23.11 \text{ mm}$$

$$N = 4088. \text{ N}$$

$$T_y = -4360. \text{ N}$$

$$M_x = -1526000. \text{ Nmm}$$

$$x_m = 24. \text{ mm}$$

$$y_m = 55. \text{ mm}$$

$$u_m = 6. \text{ mm}$$

$$v_m = 31.89 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 209.7 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 41. \text{ mm}$$

$$v_c = 17.89 \text{ mm}$$

$$\sigma_c = N/A - Mv/J_u = 119.9 \text{ N/mm}^2$$

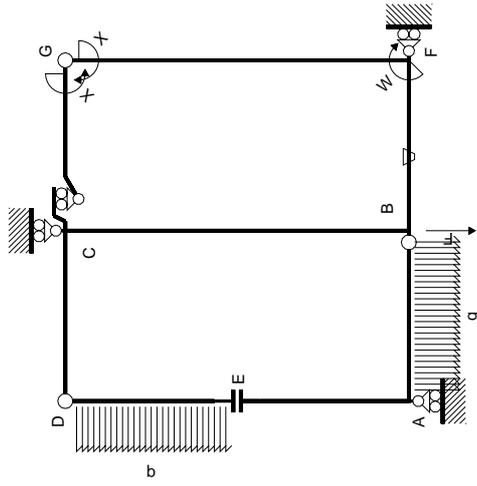
$$\tau_c = 6.389 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 120.4 \text{ N/mm}^2$$

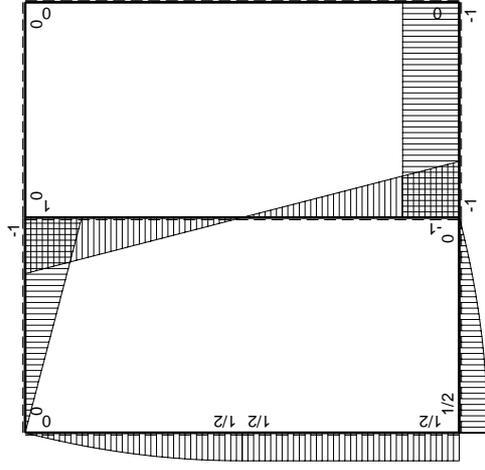
$$S = 4181. \text{ mm}^3$$



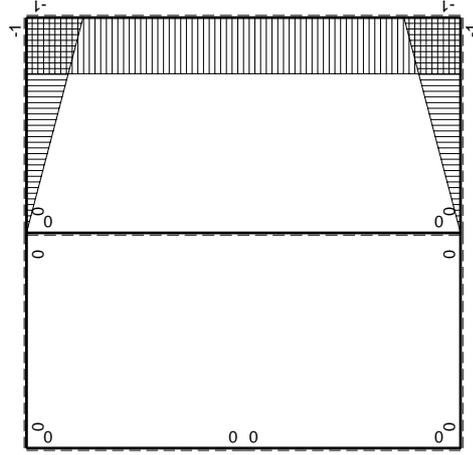




Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	$1/2Fb-1/2qx^2$	0	0	0	0	0	0+0	0
BA b	$-Fx+1/2qx^2$	0	0	0	0	0	0+0	0
CD b	$-Fb+Fx$	0	0	0	0	0	0+0	0
DC b	$Fx$	0	0	0	0	0	0+0	0
DE b	$Fx-1/2qx^2$	0	0	0	0	0	0+0	0
ED b	$-1/2Fb+1/2qx^2$	0	0	0	0	0	0+0	0
EA b	$1/2Fb$	0	0	0	0	0	0+0	0
AE b	$-1/2Fb$	0	0	0	0	0	0+0	0
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb-Fx$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$1/3xb/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2xb/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2xb/EJ$
CB 2b	0	$Fb-Fx$	0	0	0	0	0+0	0
BC 2b	0	$Fb-Fx$	0	0	0	0	0+0	0
totali								$Fb^2/EJ$
								$8/3xb/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

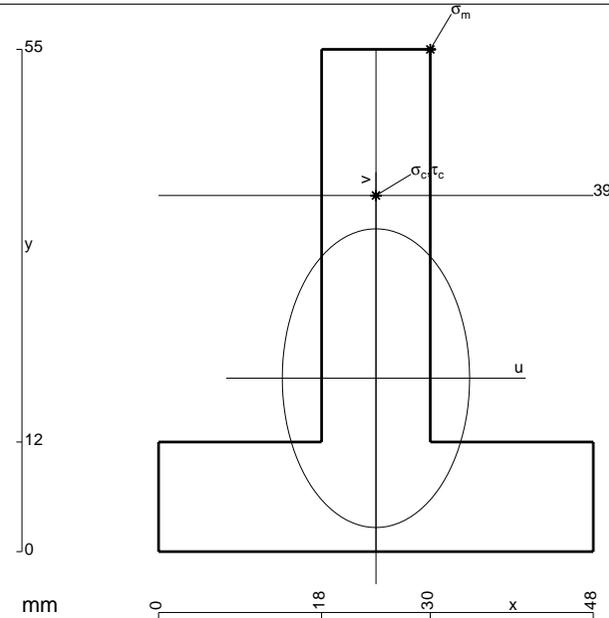
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



$$A = 1092. \text{ mm}^2$$

$$J_u = 292252. \text{ mm}^4$$

$$J_v = 116784. \text{ mm}^4$$

$$y_g = 18.99 \text{ mm}$$

$$N = 5581. \text{ N}$$

$$T_y = -2350. \text{ N}$$

$$M_x = -1739000. \text{ Nmm}$$

$$x_m = 30. \text{ mm}$$

$$y_m = 55. \text{ mm}$$

$$u_m = 6. \text{ mm}$$

$$v_m = 36.01 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 219.4 \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 39. \text{ mm}$$

$$v_c = 20.01 \text{ mm}$$

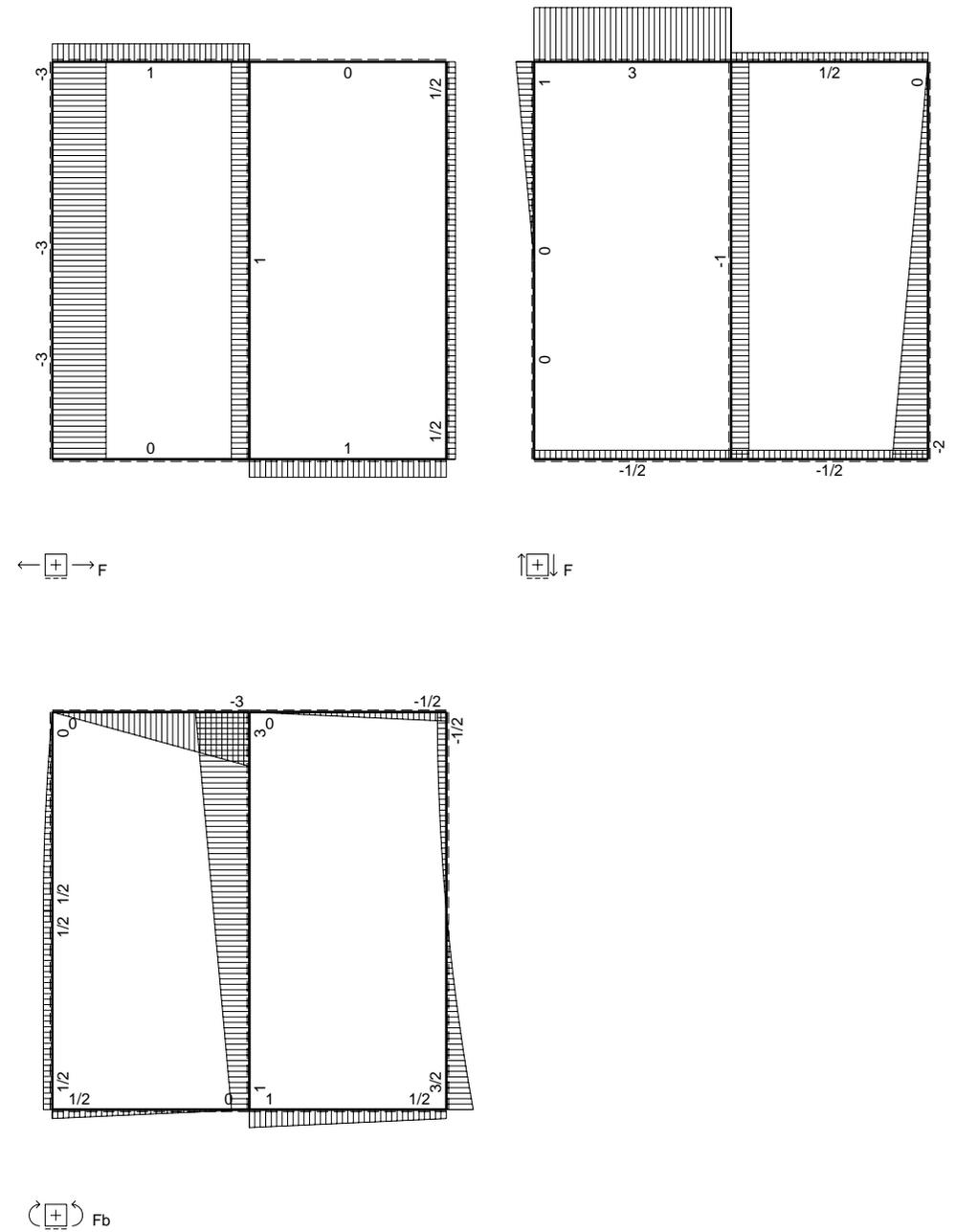
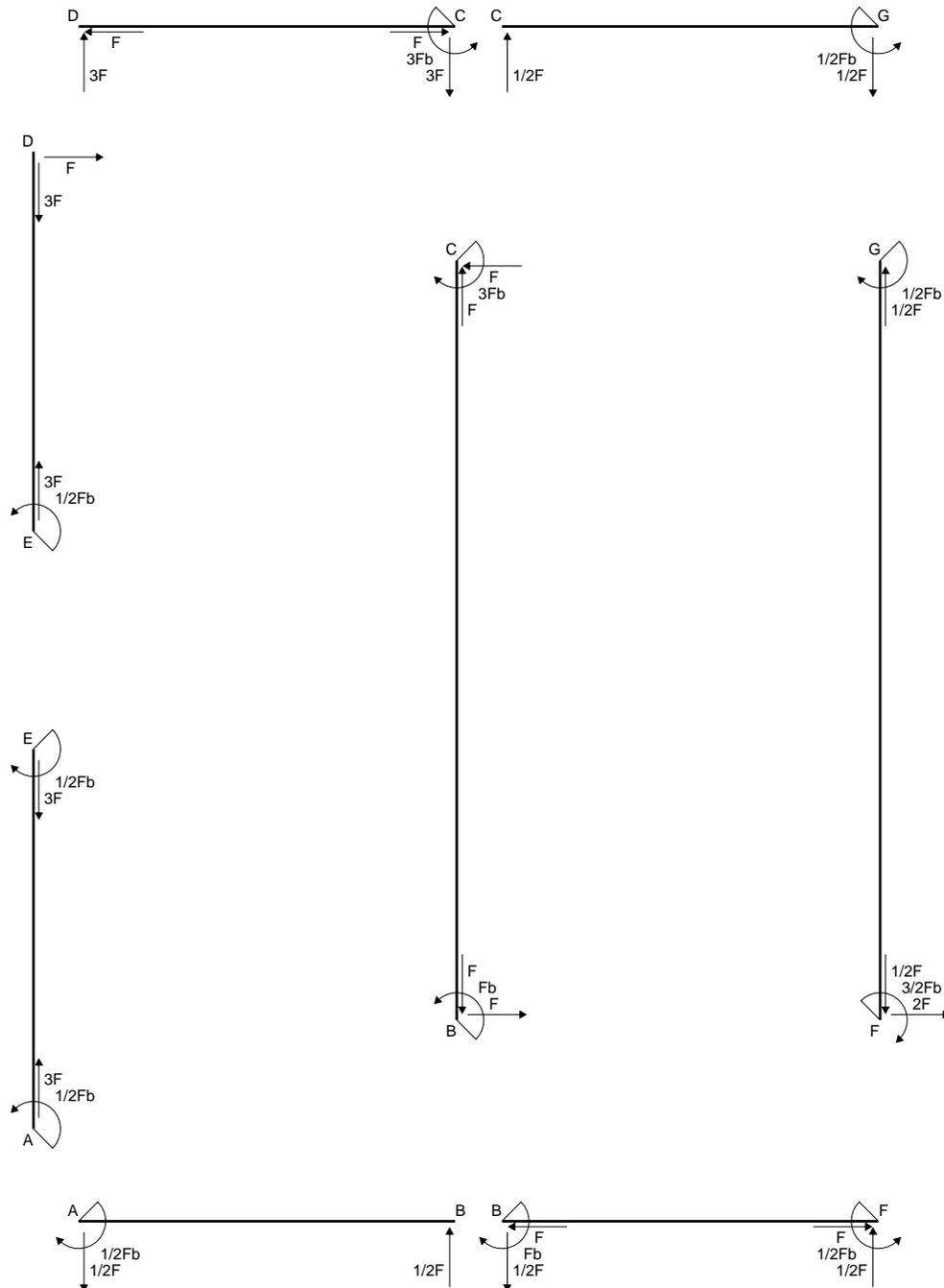
$$\sigma_c = N/A - Mv/J_u = 124.2 \text{ N/mm}^2$$

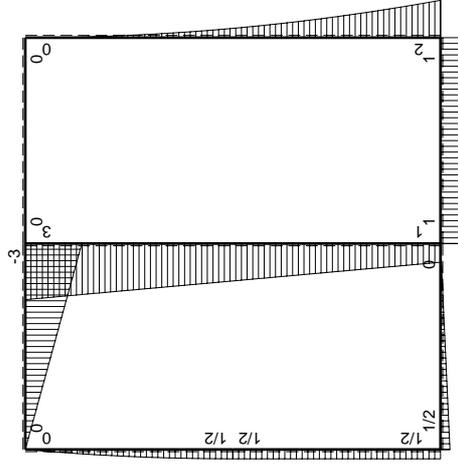
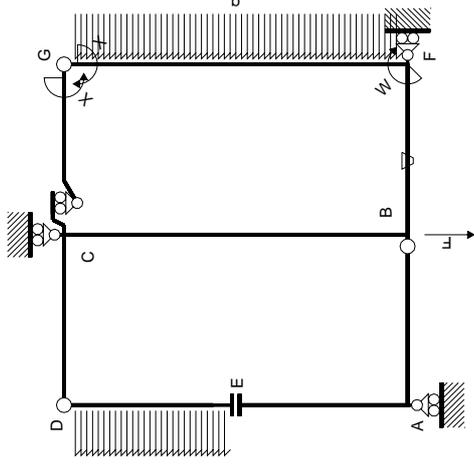
$$\tau_c = 3.603 \text{ N/mm}^2$$

$$\sigma_\varrho = \sqrt{\sigma^2 + 3\tau^2} = 124.3 \text{ N/mm}^2$$

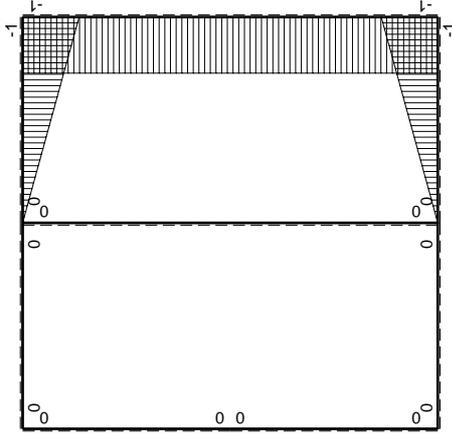
$$S = 5377. \text{ mm}^3$$







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M(x)$	$M^0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / E dx$
AB b	0	$1/2Fb - 1/2Fx$	0	0	0	0	0+0	0
BA b	0	$-1/2Fx$	0	0	0	0	0+0	0
CD b	0	$-3Fb + 3Fx$	0	0	0	0	0+0	0
DC b	0	$3Fx$	0	0	0	0	0+0	0
DE b	0	$Fx - 1/2qx^2$	0	0	0	0	0+0	0
ED b	0	$-1/2Fb + 1/2qx^2$	0	0	0	0	0+0	0
EA b	0	$1/2Fb$	0	0	0	0	0+0	0
AE b	0	$-1/2Fb$	0	0	0	0	0+0	0
BF b	$-x/b$	$Fb$	$-Fb/EJ$	$-Fx$	$Fx/EJ$	$x^2/b^2$	$(-1/2 + 1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$-Fb$	$Fb/EJ$	$-Fb + Fx$	$Fb/EJ - Fx/EJ$	$1 - 2x/b + x^2/b^2$	$(-1/2 + 1/2)Fb^2/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1 - 2x/b + x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	$2Fb - 2Fx + 1/2qx^2$	0	$-2Fb + 2Fx - 1/2Fx^2/b$	0	1	$(-4/3 + 0)Fb^2/EJ$	$2xb/EJ$
GF 2b	1	$-1/2qx^2$	0	$-1/2Fx^2/b$	0	1	$(-4/3 + 0)Fb^2/EJ$	$2xb/EJ$
CB 2b	0	$3Fb - Fx$	0	0	0	0	0+0	0
BC 2b	0	$-Fb - Fx$	0	0	0	0	0+0	0
totali							$-4/3Fb^2/EJ$	$8/3xb/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x_0} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

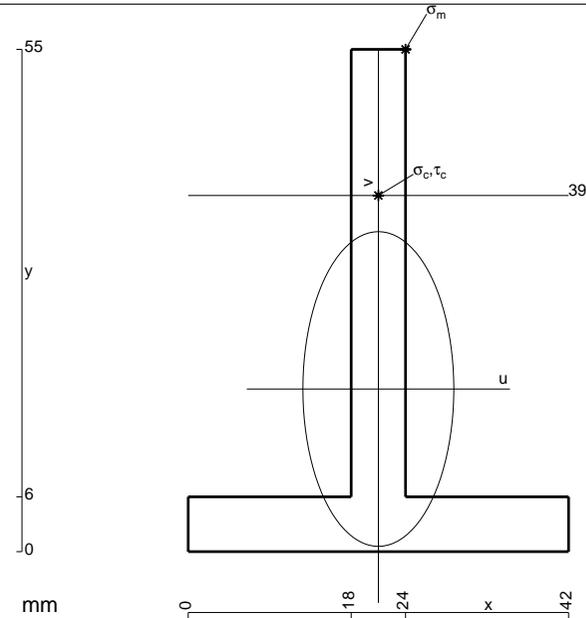
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x_0} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

$$L_{GF}^{x_0} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



$$A = 546. \text{ mm}^2$$

$$J_u = 162198. \text{ mm}^4$$

$$J_v = 37926. \text{ mm}^4$$

$$y_g = 17.81 \text{ mm}$$

$$N = 420. \text{ N}$$

$$T_y = 1260. \text{ N}$$

$$M_x = -995400. \text{ Nmm}$$

$$x_m = 24. \text{ mm}$$

$$y_m = 55. \text{ mm}$$

$$u_m = 3. \text{ mm}$$

$$v_m = 37.19 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 229. \text{ N/mm}^2$$

$$x_c = 21. \text{ mm}$$

$$y_c = 39. \text{ mm}$$

$$v_c = 21.19 \text{ mm}$$

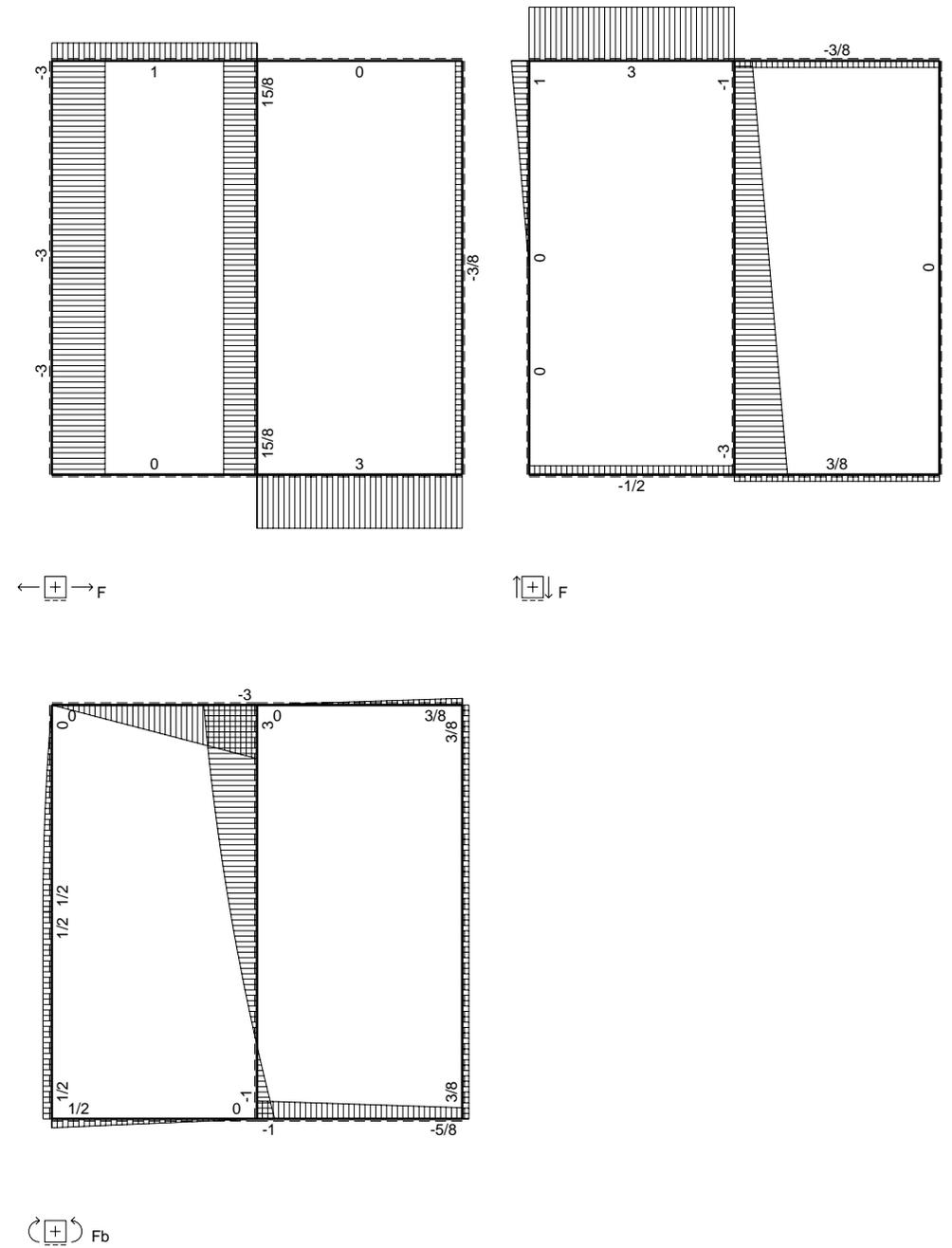
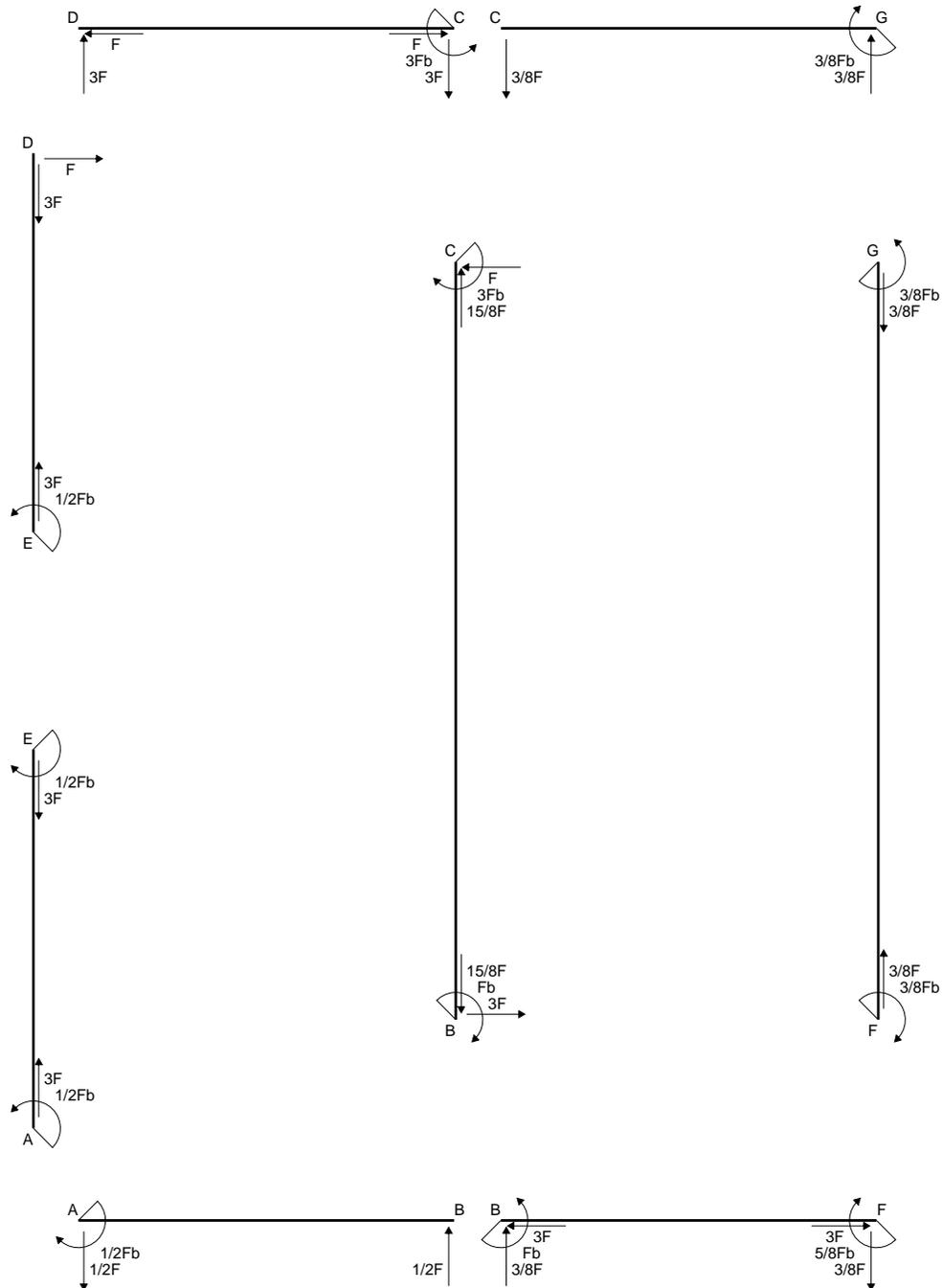
$$\sigma_c = N/A - Mv/J_u = 130.8 \text{ N/mm}^2$$

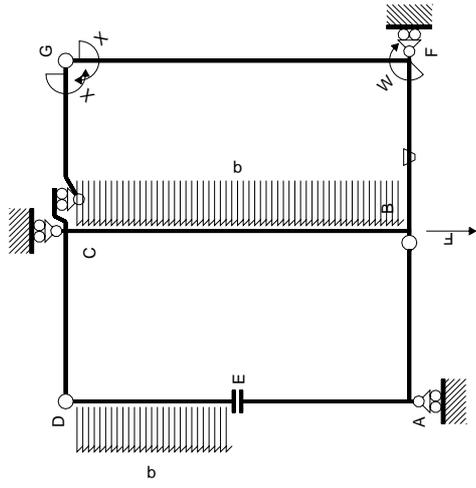
$$\tau_c = 3.628 \text{ N/mm}^2$$

$$\sigma_0 = \sqrt{\sigma^2 + 3\tau^2} = 131. \text{ N/mm}^2$$

$$S = 2802. \text{ mm}^3$$

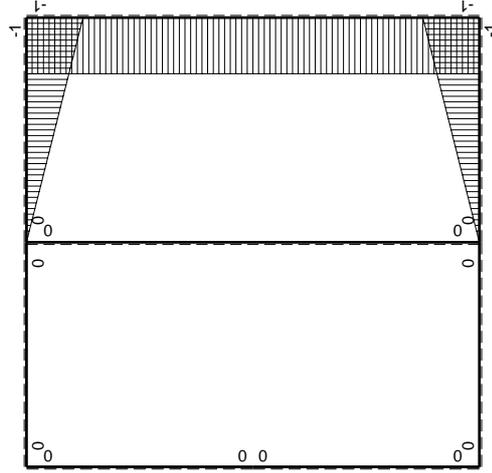
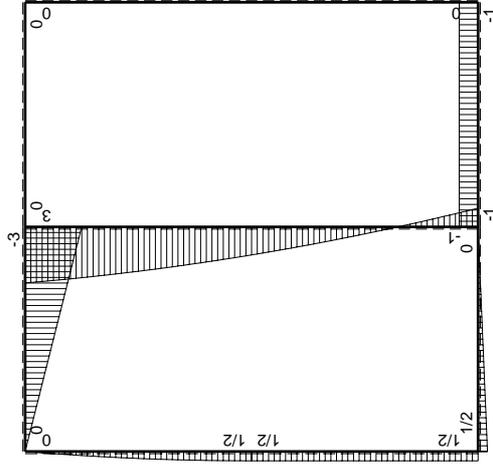






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / EJ dx$
AB b	0	$1/2Fb - 1/2Fx$	0	0	0	0	0+0	0
BA b	0	$-1/2Fx$	0	0	0	0	0+0	0
CD b	0	$-3Fb + 3Fx$	0	0	0	0	0+0	0
DC b	0	$3Fx$	0	0	0	0	0+0	0
DE b	0	$Fx - 1/2qx^2$	0	0	0	0	0+0	0
ED b	0	$-1/2Fb + 1/2qx^2$	0	0	0	0	0+0	0
EA b	0	$1/2Fb$	0	0	0	0	0+0	0
AE b	0	$-1/2Fb$	0	0	0	0	0+0	0
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2 + 1/2)Fb^2/EJ$	$1/3x^3/EJ$
FB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb - Fx$	$Fb/EJ - Fx/EJ$	$1 - 2x/b + x^2/b^2$	$1/3x^3/EJ$	$1/3x^3/EJ$
GC b	$-1+x/b$	0	0	0	0	$1 - 2x/b + x^2/b^2$	0+0	$1/3x^3/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3x^3/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2x^2/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2x^2/EJ$
CB 2b	0	$3Fb - Fx - 1/2qx^2$	0	0	0	0	0+0	0
BC 2b	0	$Fb - 3Fx + 1/2qx^2$	0	0	0	0	0+0	0
totali								$8/3x^3/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

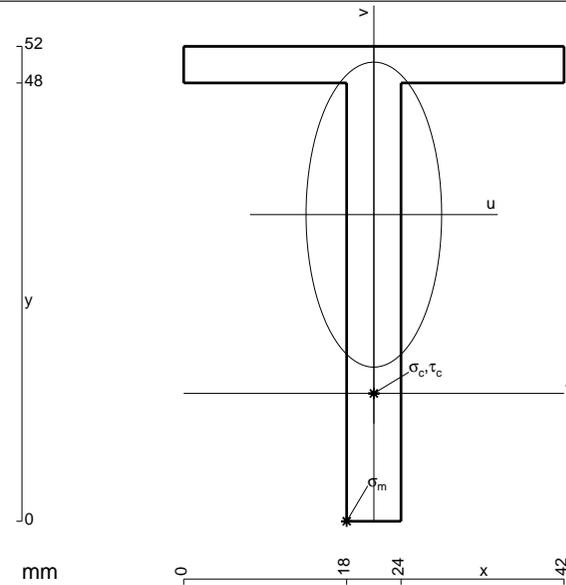
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

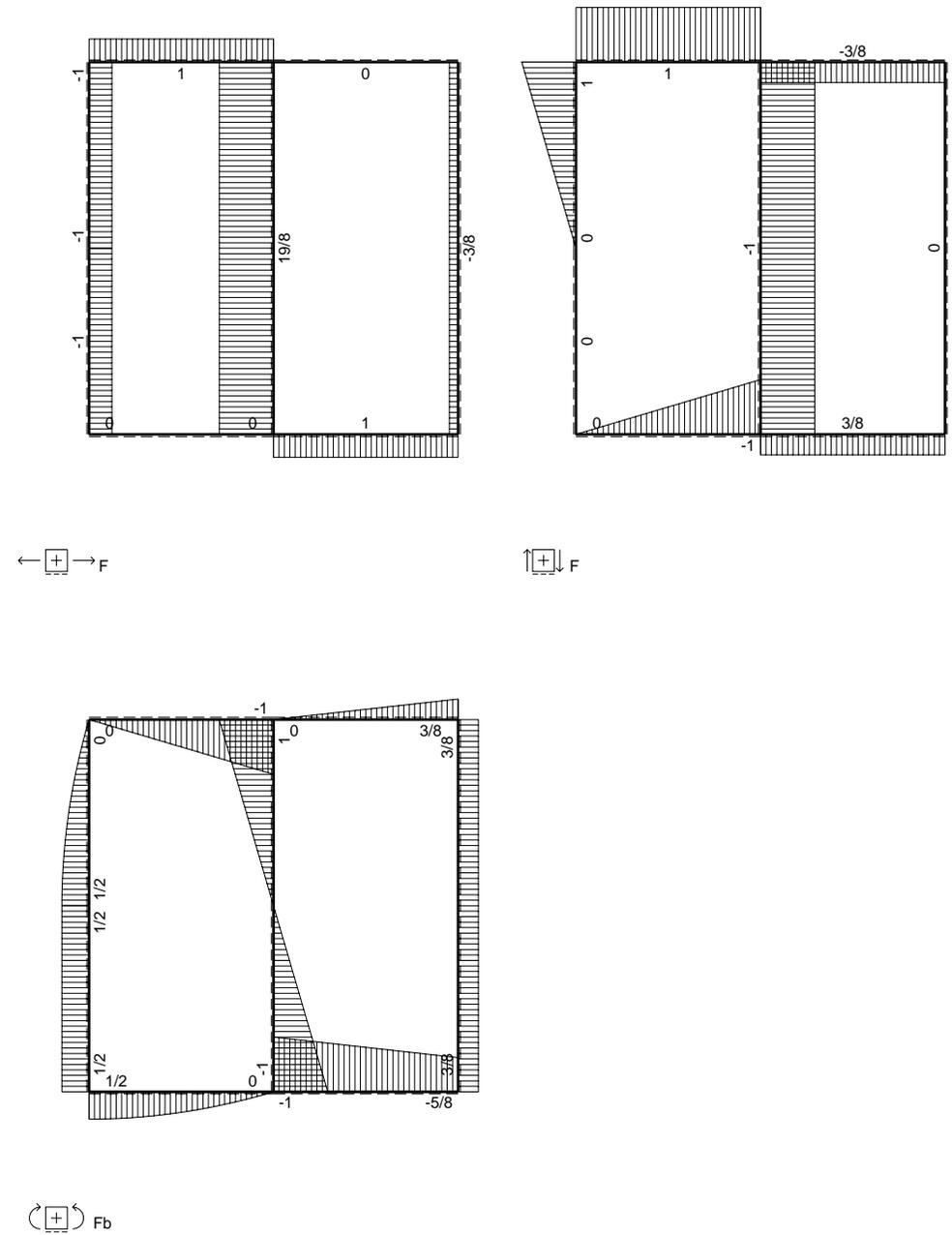
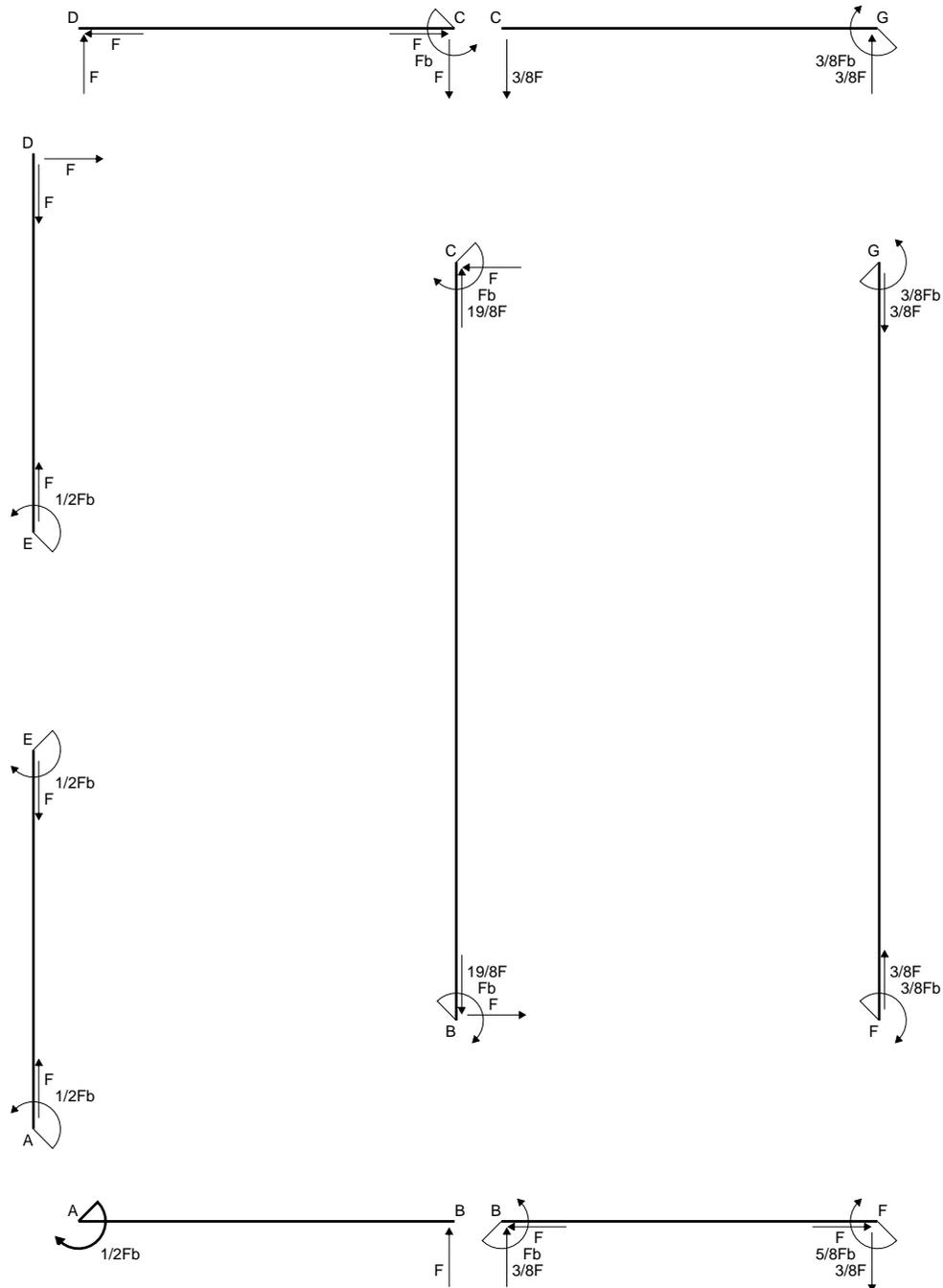
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

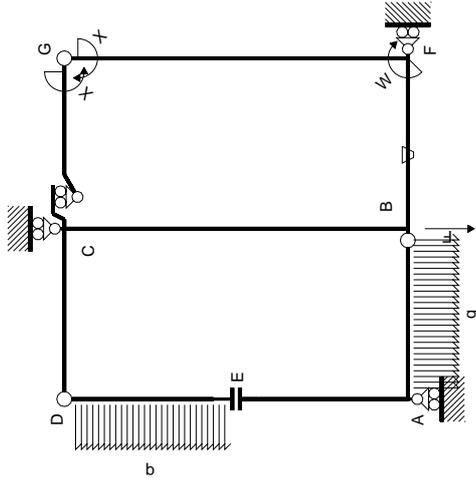
$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



- A = 456. mm<sup>2</sup>
- J<sub>u</sub> = 127247. mm<sup>4</sup>
- J<sub>v</sub> = 25560. mm<sup>4</sup>
- y<sub>g</sub> = 33.58 mm
- N = 390. N
- T<sub>y</sub> = 1170. N
- M<sub>x</sub> = -900900. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -33.58 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = -236.9 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 14. mm
- v<sub>c</sub> = -19.58 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = -137.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.421 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 137.9 N/mm<sup>2</sup>
- S = 2233. mm<sup>3</sup>

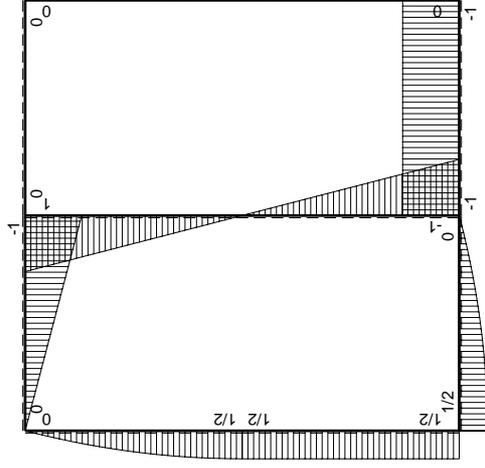






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	$1/2Fb-1/2qx^2$	0	0	0	0	0	0+0	0
BA b	$-Fx+1/2qx^2$	0	0	0	0	0	0+0	0
CD b	$-Fb+Fx$	0	0	0	0	0	0+0	0
DC b	$Fx$	0	0	0	0	0	0+0	0
DE b	$Fx-1/2qx^2$	0	0	0	0	0	0+0	0
ED b	$-1/2Fb+1/2qx^2$	0	0	0	0	0	0+0	0
EA b	$1/2Fb$	0	0	0	0	0	0+0	0
AE b	$-1/2Fb$	0	0	0	0	0	0+0	0
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb-Fx$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$1/3xb/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2xb/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2xb/EJ$
CB 2b	0	$Fb-Fx$	0	0	0	0	0+0	0
BC 2b	0	$Fb-Fx$	0	0	0	0	0+0	0
totali								$Fb^2/EJ$
								$8/3xb/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

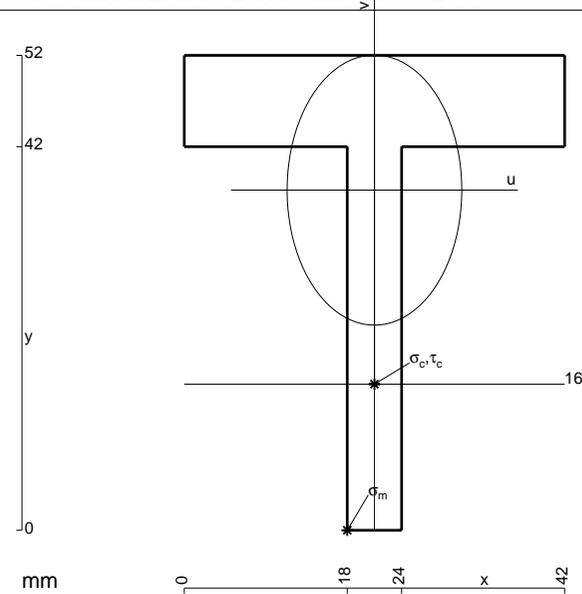
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



$$A = 672. \text{ mm}^2$$

$$J_u = 147014. \text{ mm}^4$$

$$J_v = 62496. \text{ mm}^4$$

$$y_g = 37.25 \text{ mm}$$

$$N = 4418. \text{ N}$$

$$T_y = -1860. \text{ N}$$

$$M_x = 762600. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -37.25 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 199.8 \text{ N/mm}^2$$

$$x_c = 21. \text{ mm}$$

$$y_c = 16. \text{ mm}$$

$$v_c = -21.25 \text{ mm}$$

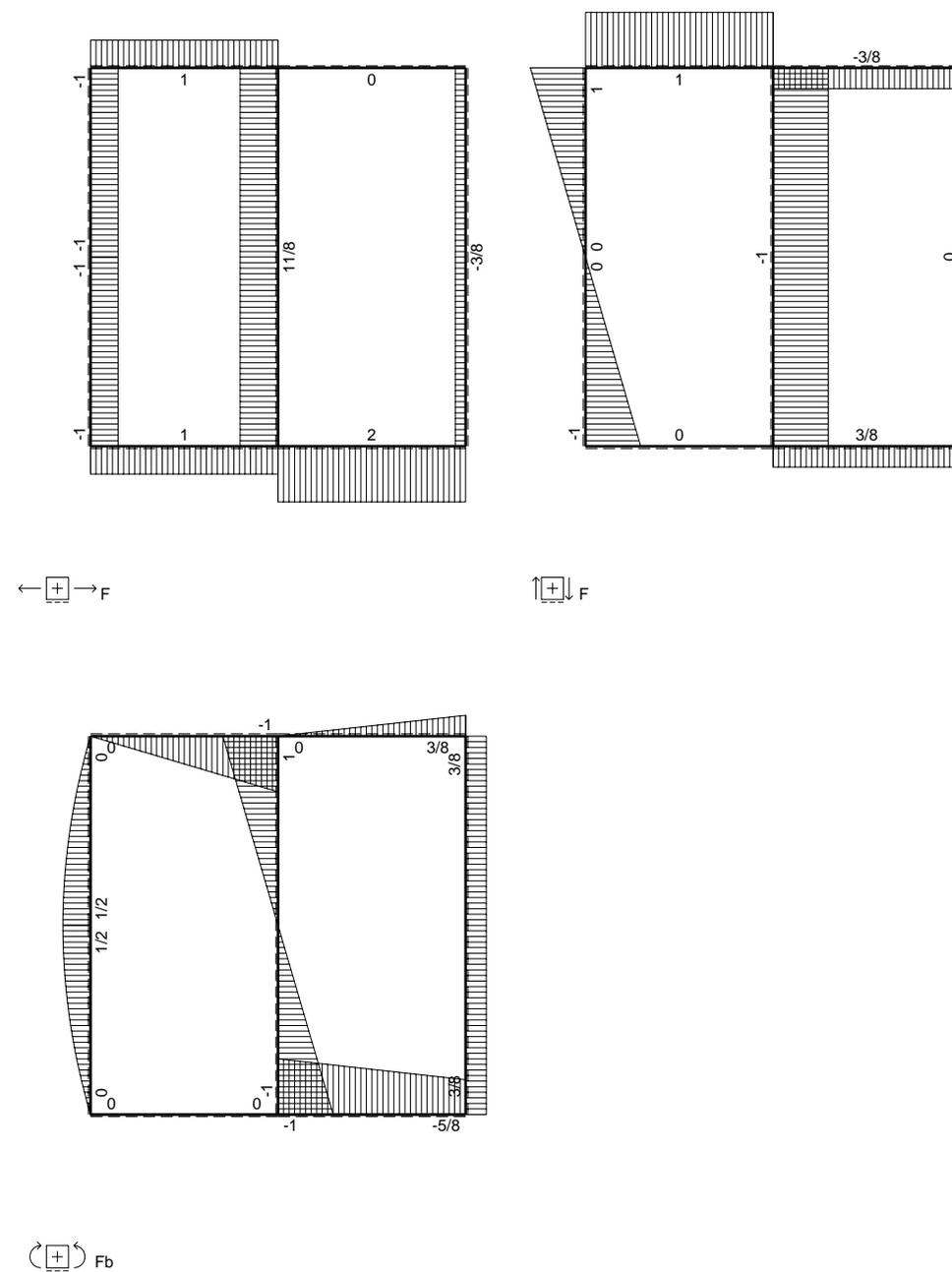
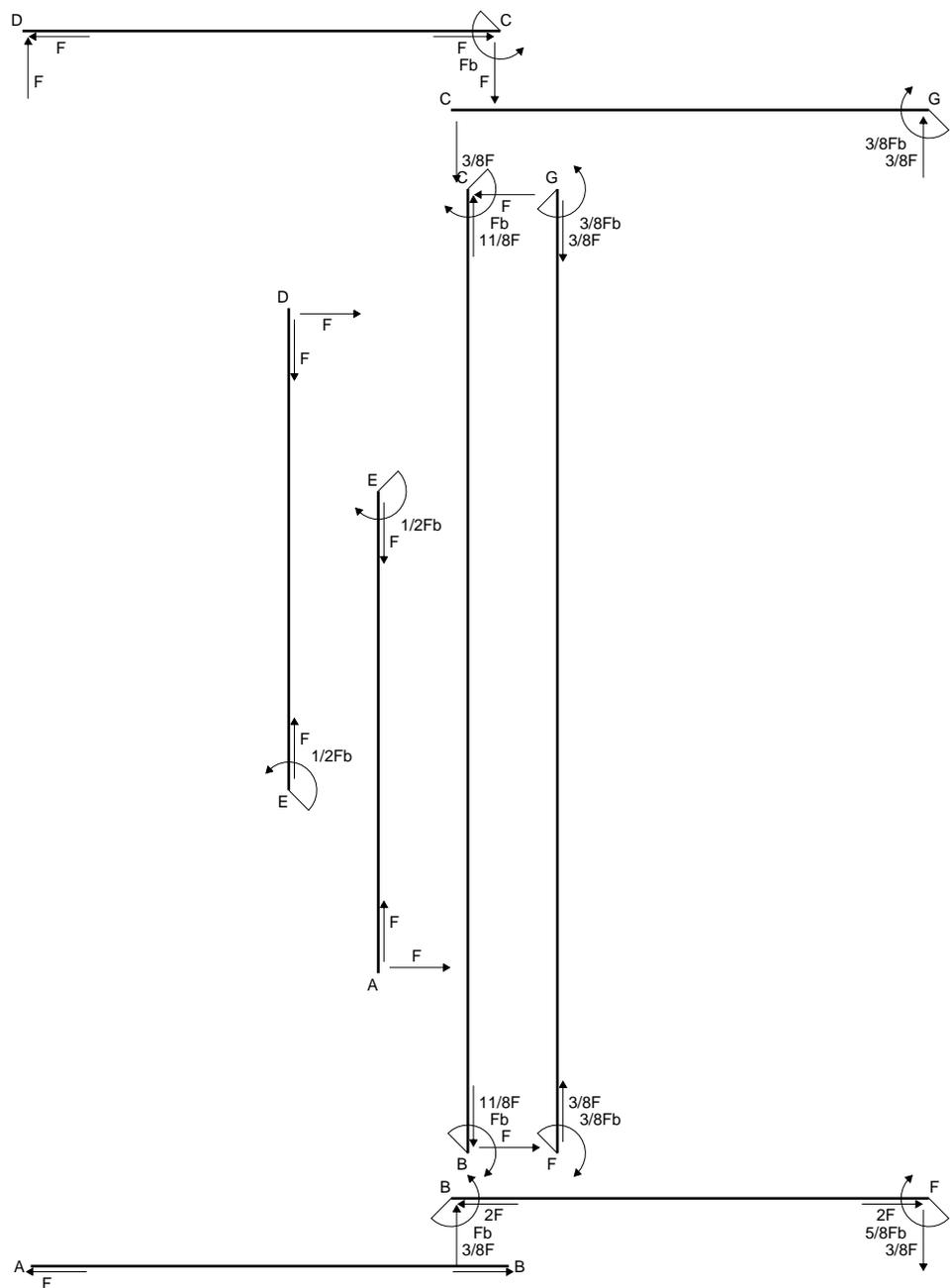
$$\sigma_c = N/A - Mv/J_u = 116.8 \text{ N/mm}^2$$

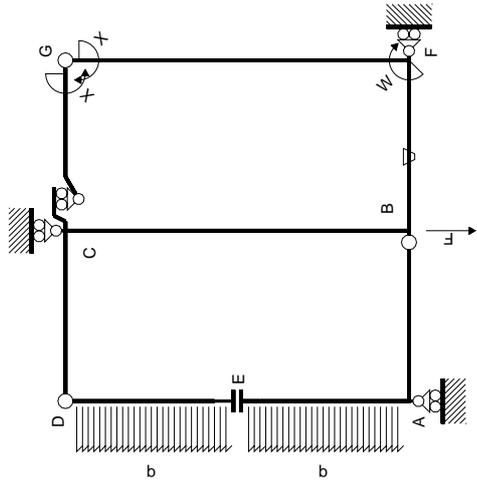
$$\tau_c = 5.921 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 117.3 \text{ N/mm}^2$$

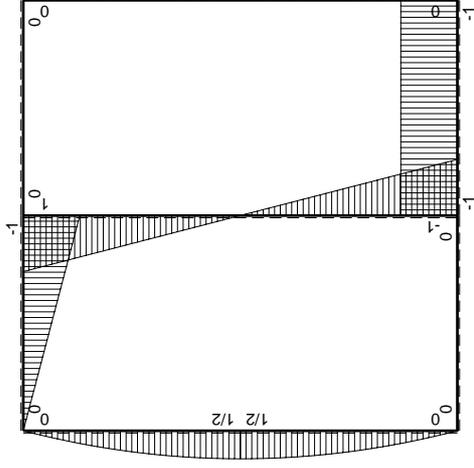
$$S = 2808. \text{ mm}^3$$



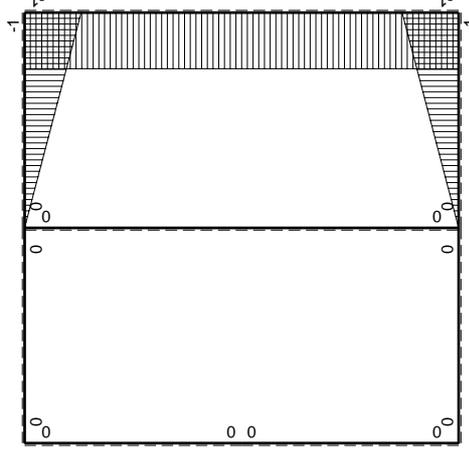




Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0+0	0
CD b	0	-Fb+Fx	0	0	0	0	0+0	0
DC b	0	Fx	0	0	0	0	0+0	0
DE b	0	Fx-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
ED b	0	-1/2Fb+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
EA b	0	1/2Fb-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
AE b	0	-Fx+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
BF b	-x/b	-Fb	-Fb/EJ	Fx	Fx/EJ	$x^2/b^2$	$(1/2+1/2)Fb^2/EJ$	1/3xb/EJ
FB b	1-x/b	Fb	Fb/EJ	Fb-Fx	Fb/EJ-Fx/EJ	$1-2x/b+x^2/b^2$	$1/2+1/2)Fb^2/EJ$	1/3xb/EJ
GC b	-1+x/b	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	1/3xb/EJ
CG b	x/b	0	0	0	0	$x^2/b^2$	0+0	1/3xb/EJ
FG 2b	-1	0	0	0	0	1	0+0	2xb/EJ
GF 2b	1	0	0	0	0	1	0+0	2xb/EJ
CB 2b	0	Fb-Fx	0	0	0	0	0+0	0
BC 2b	0	Fb-Fx	0	0	0	0	0+0	0
totali								8/3xb/EJ

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

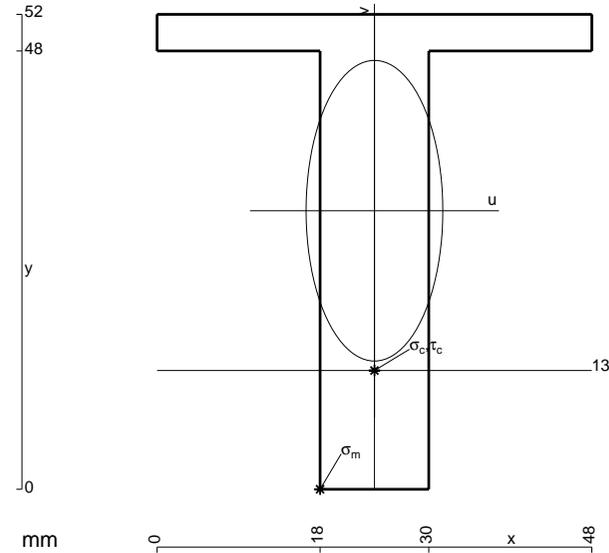
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



$$A = 768. \text{ mm}^2$$

$$J_u = 208192. \text{ mm}^4$$

$$J_v = 43776. \text{ mm}^4$$

$$y_g = 30.5 \text{ mm}$$

$$N = 4263. \text{ N}$$

$$T_y = -3100. \text{ N}$$

$$M_x = 1395000. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$u_m = -6. \text{ mm}$$

$$v_m = -30.5 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 209.9 \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 13. \text{ mm}$$

$$v_c = -17.5 \text{ mm}$$

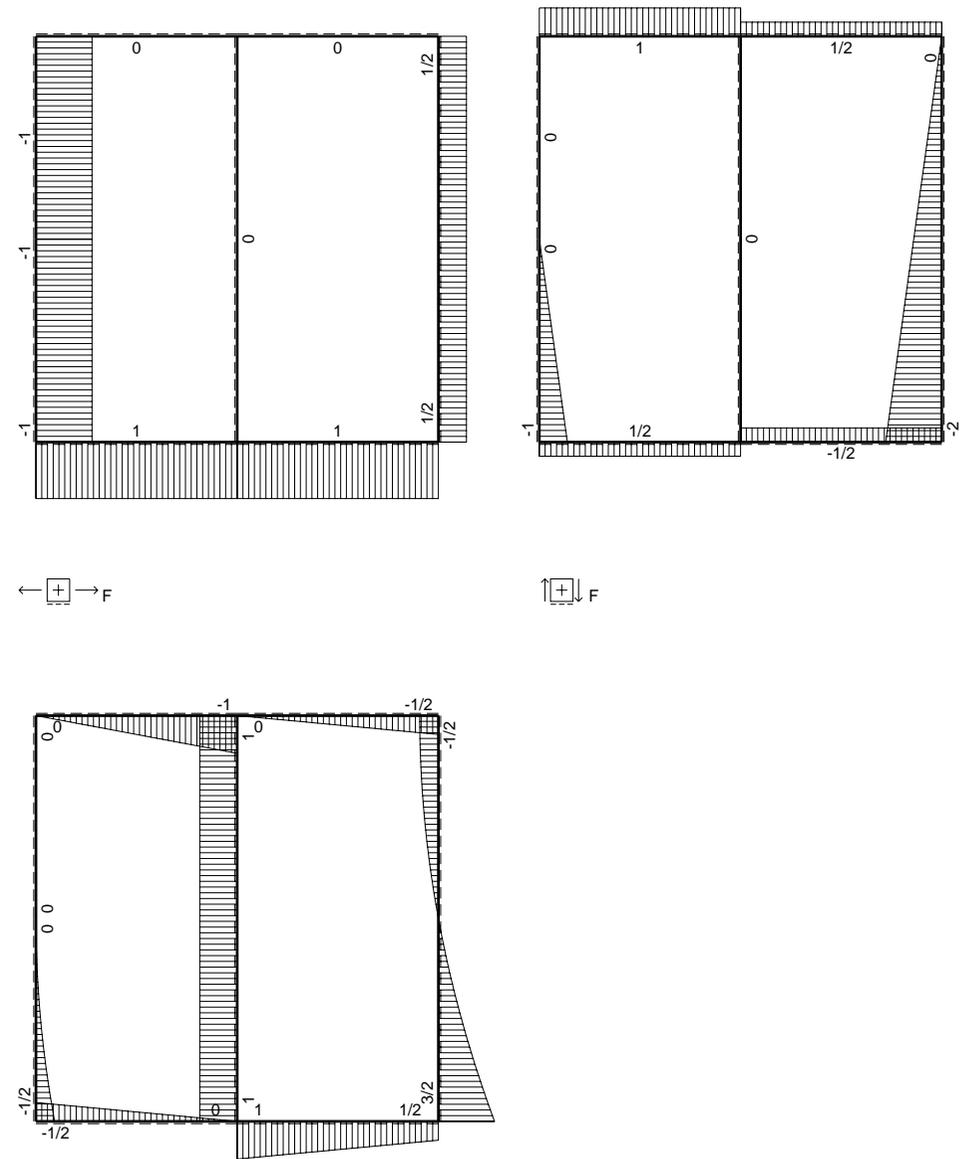
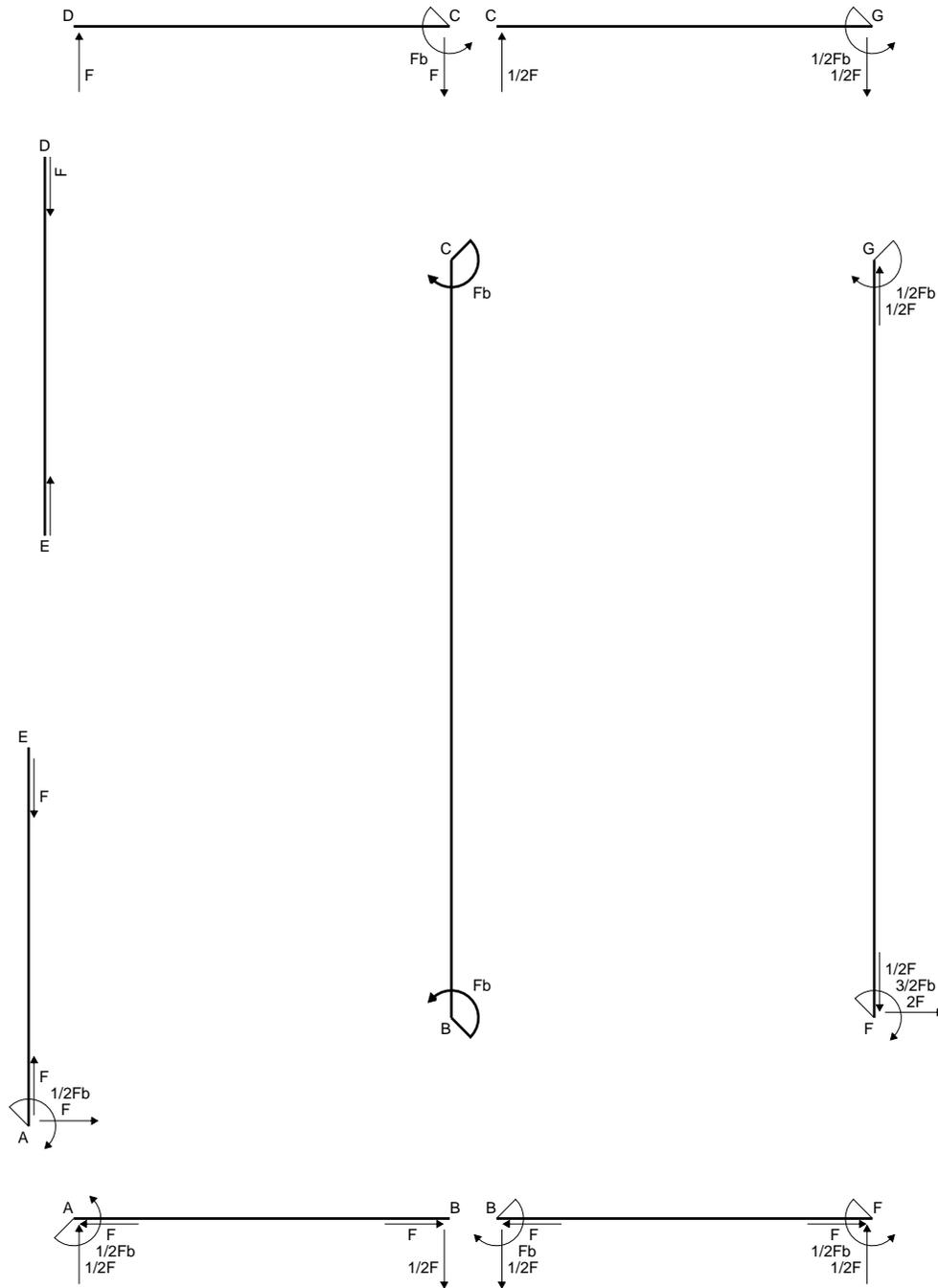
$$\sigma_c = N/A - Mv/J_u = 122.8 \text{ N/mm}^2$$

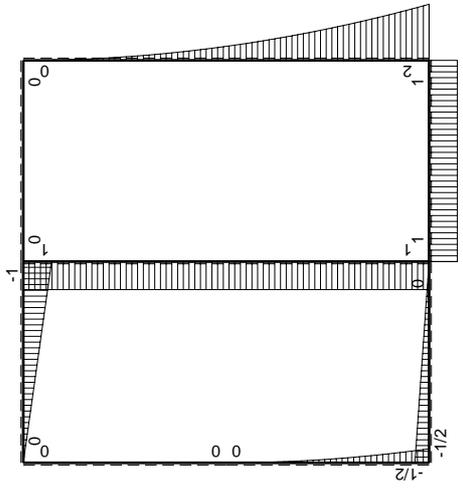
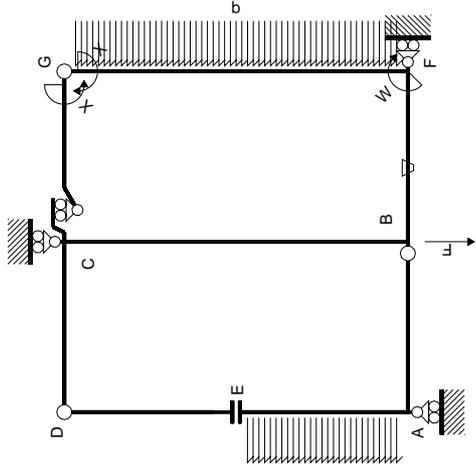
$$\tau_c = 4.646 \text{ N/mm}^2$$

$$\sigma_\varphi = \sqrt{\sigma^2 + 3\tau^2} = 123.1 \text{ N/mm}^2$$

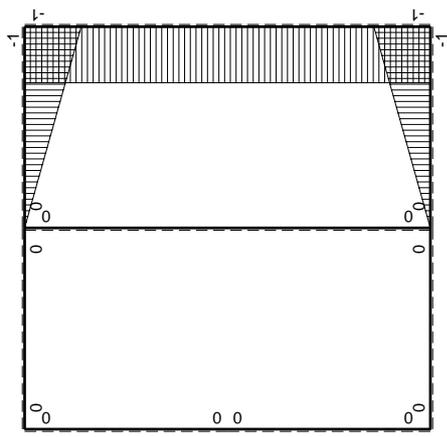
$$S = 3744. \text{ mm}^3$$







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica X=W<sup>gc</sup>

←	M <sup>x</sup> (x)	M <sup>0</sup> (x)	θ	M <sup>x</sup> M <sub>0</sub>	M <sup>x</sup> θ	M <sup>x</sup> M <sub>x</sub>	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	0	-1/2Fb+1/2Fx	0	0	0	0	0+0	0
BA b	0	1/2Fx	0	0	0	0	0+0	0
CD b	0	-Fb+Fx	0	0	0	0	0+0	0
DC b	0	Fx	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
ED b	0	0	0	0	0	0	0+0	0
EA b	0	-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
AE b	0	1/2Fb-Fx+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
BF b	-x/b	Fb	-Fb/EJ	-Fx	Fx/EJ	x <sup>2</sup> /b <sup>2</sup>	$(-1/2+1/2)Fb^2/EJ$	1/3xb/EJ
FB b	1-x/b	-Fb	Fb/EJ	-Fb+Fx	Fb/EJ-Fx/EJ	$1-2x/b+x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	1/3xb/EJ
GC b	-1+x/b	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	1/3xb/EJ
CG b	x/b	0	0	0	0	x <sup>2</sup> /b <sup>2</sup>	0+0	1/3xb/EJ
FG 2b	-1	2Fb-2Fx+1/2qx <sup>2</sup>	0	-2Fb+2Fx-1/2Fx <sup>2</sup> /b	0	1	$(-4/3+0)Fb^2/EJ$	2xb/EJ
GF 2b	1	-1/2qx <sup>2</sup>	0	-1/2Fx <sup>2</sup> /b	0	1	0+0	0
CB 2b	0	Fb	0	0	0	0	0+0	0
BC 2b	0	-Fb	0	0	0	0	-4/3Fb <sup>2</sup> /EJ	8/3xb/EJ
totali								
iperstatica X=W <sup>gc</sup>								

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{xo} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{xo} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

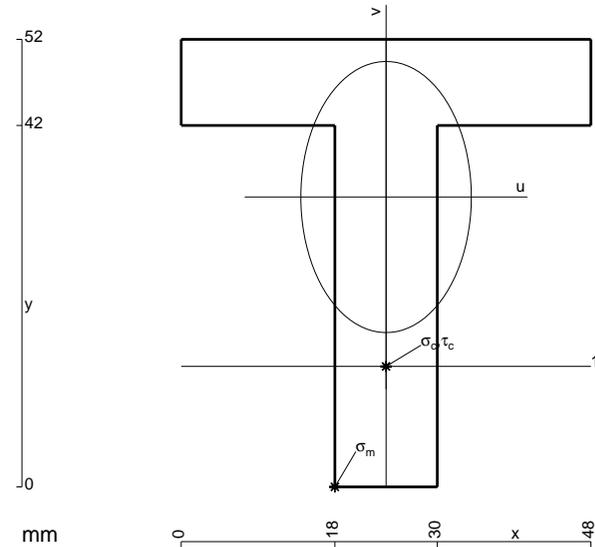
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{xo} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

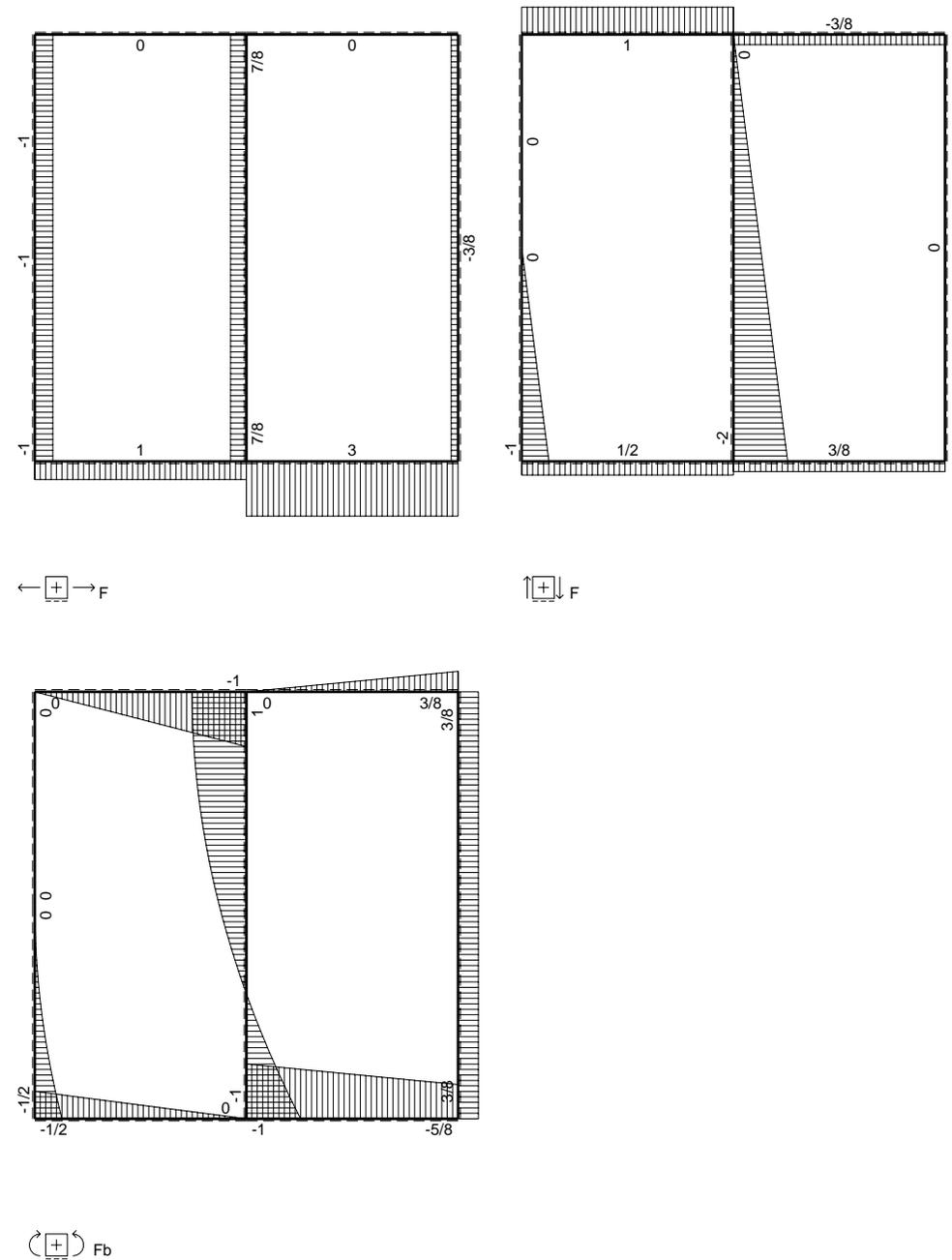
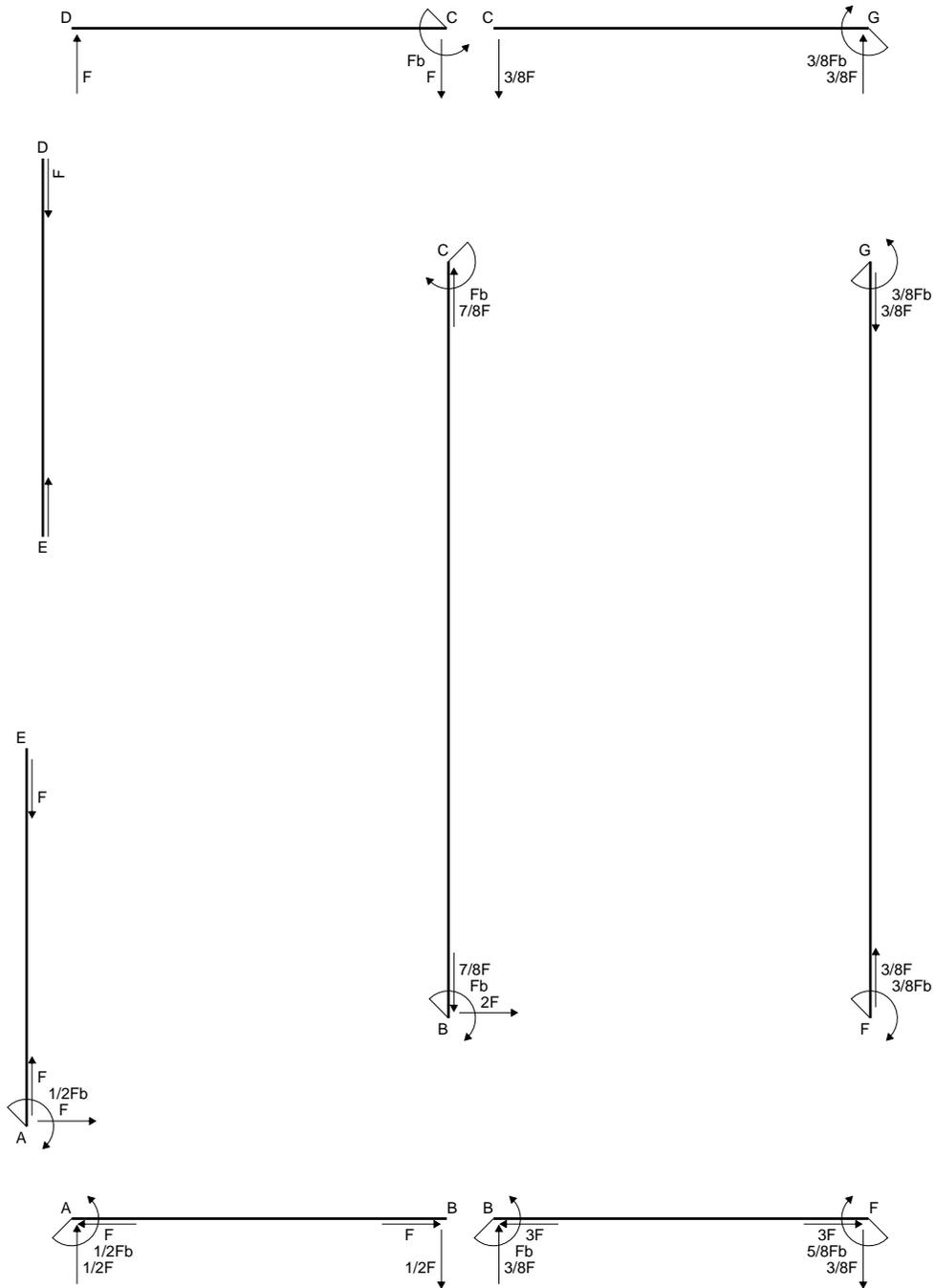
$$L_{GF}^{xo} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



- A = 984. mm<sup>2</sup>
- J<sub>u</sub> = 244285. mm<sup>4</sup>
- J<sub>v</sub> = 98208. mm<sup>4</sup>
- y<sub>g</sub> = 33.68 mm
- T<sub>y</sub> = 3250. N
- M<sub>x</sub> = -1592500. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -33.68 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -219.6 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 14. mm
- v<sub>c</sub> = -19.68 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -128.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.97 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 128.6 N/mm<sup>2</sup>
- S = 4483. mm<sup>3</sup>







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

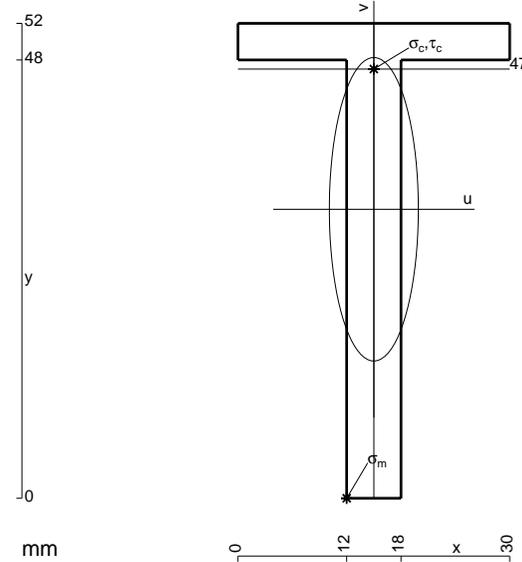
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

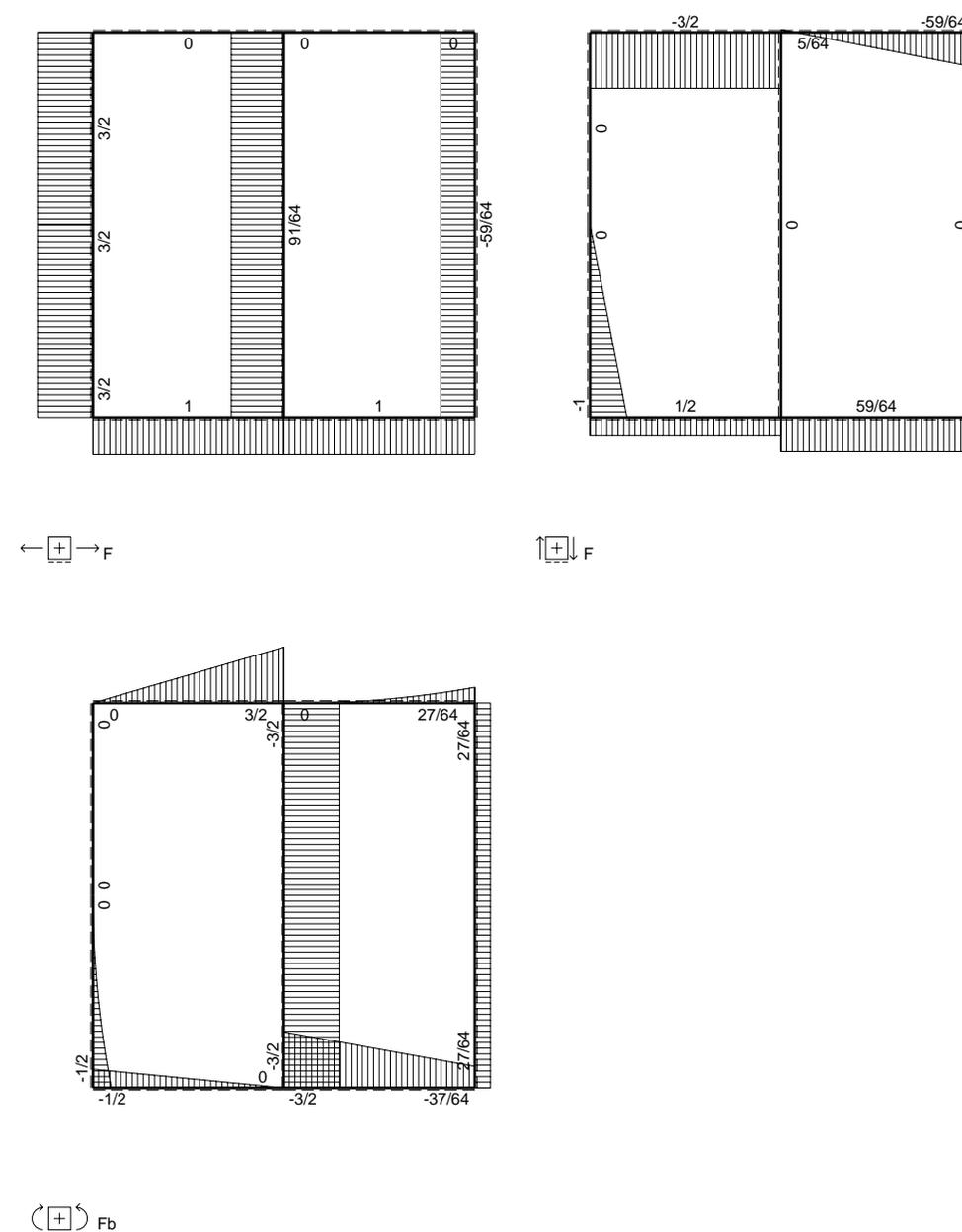
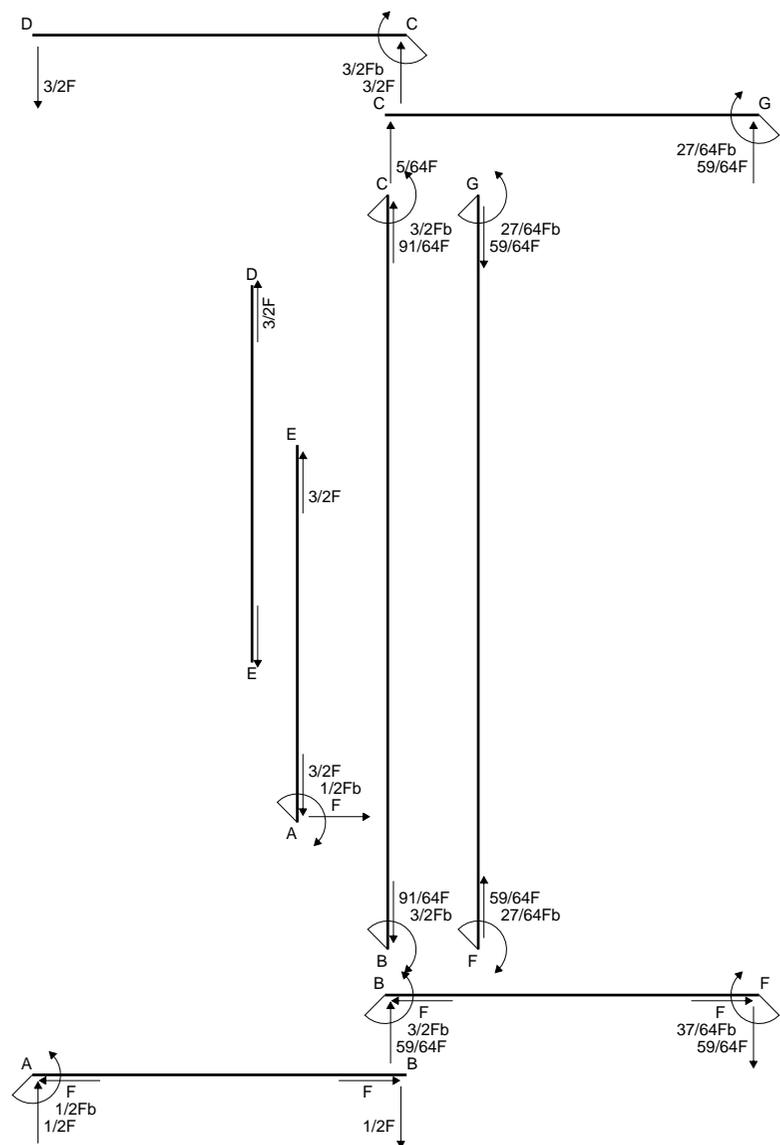
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

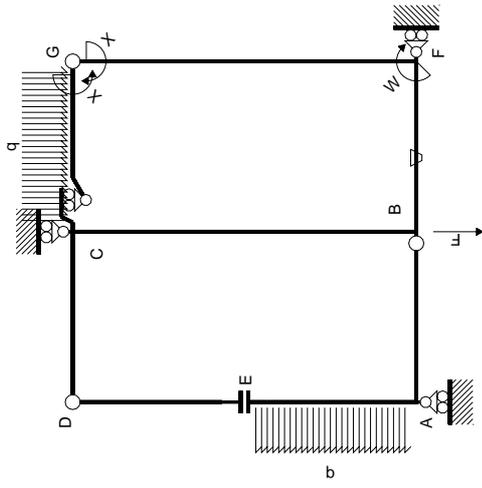
$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



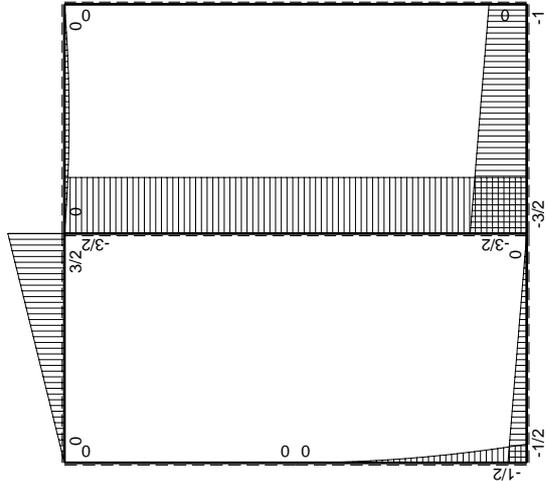
- A = 408. mm<sup>2</sup>
- J<sub>u</sub> = 112717. mm<sup>4</sup>
- J<sub>v</sub> = 9864. mm<sup>4</sup>
- y<sub>g</sub> = 31.65 mm
- N = 1365. N
- T<sub>y</sub> = -3120. N
- M<sub>x</sub> = -826800. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -31.65 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = -228.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 15. mm
- y<sub>c</sub> = 47. mm
- v<sub>c</sub> = 15.35 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = 116. N/mm<sup>2</sup>
- τ<sub>c</sub> = 10.6 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 117.4 N/mm<sup>2</sup>
- S = 2297. mm<sup>3</sup>



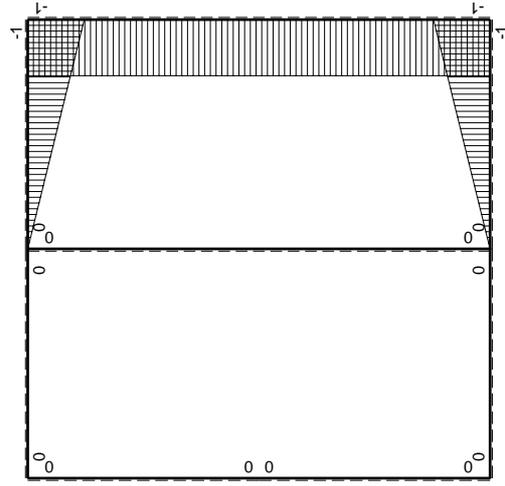




Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica X=W<sub>gc</sub>

←	M <sub>0</sub> (x)	M <sub>0</sub> (x)	θ	M <sub>0</sub> M <sub>0</sub>	M <sub>0</sub> θ	M <sub>x</sub> M <sub>x</sub>	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	0	-1/2Fb+1/2Fx	0	0	0	0	0+0	0
BA b	0	1/2Fx	0	0	0	0	0+0	0
CD b	0	3/2Fb-3/2Fx	0	0	0	0	0+0	0
DC b	0	-3/2Fx	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
EA b	0	-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
AE b	0	1/2Fb-Fx+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
BF b	-x/b	-3/2Fb+1/2Fx	-Fb/EJ	3/2Fx-1/2Fx <sup>2</sup> /b	Fx/EJ	x <sup>2</sup> /b <sup>2</sup>	(7/12+1/2)Fb <sup>2</sup> /EJ	1/3Xb/EJ
FB b	1-x/b	Fb+1/2Fx	Fb/EJ	Fb-1/2Fx-1/2Fx <sup>2</sup> /b	Fb/EJ-Fx/EJ	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	(7/12+1/2)Fb <sup>2</sup> /EJ	1/3Xb/EJ
GC b	-1+x/b	-1/2Fx+1/2qx <sup>2</sup>	0	1/2Fx-Fx <sup>2</sup> /b+1/2qx <sup>3</sup> /b	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	(1/24+0)Fb <sup>2</sup> /EJ	1/3Xb/EJ
CG b	x/b	1/2Fx-1/2qx <sup>2</sup>	0	1/2Fx <sup>2</sup> /b-1/2qx <sup>3</sup> /b	0	x <sup>2</sup> /b <sup>2</sup>	(1/24+0)Fb <sup>2</sup> /EJ	1/3Xb/EJ
FG 2b	-1	0	0	0	0	1	0+0	2Xb/EJ
GF 2b	1	0	0	0	0	1	0+0	2Xb/EJ
CB 2b	0	-3/2Fb	0	0	0	0	0+0	0
BC 2b	0	3/2Fb	0	0	0	0	0+0	0
totali								
							9/8Fb <sup>2</sup> /EJ	8/3Xb/EJ
								-27/64Fb

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{xo} = \int_0^b (3/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

$$= [3/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (3/4 b - 1/6 b) Fb 1/EJ + (1/2 b) \theta = 13/12 Fb^2/EJ$$

$$L_{FB}^{xo} = \int_0^b (1 - 1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [x - 1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

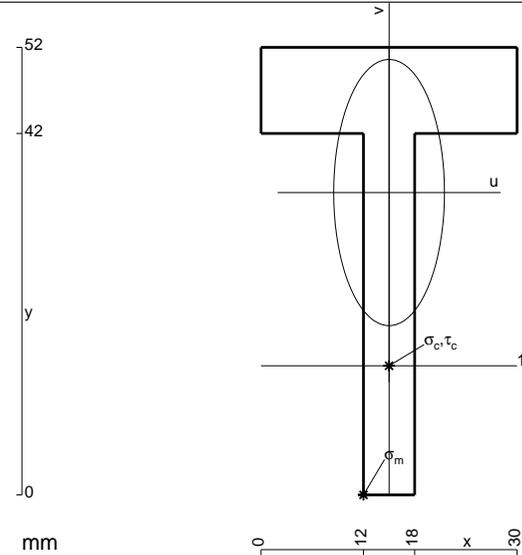
$$= (b - 1/4 b - 1/6 b) Fb 1/EJ + (-b + 1/2 b) \theta = 13/12 Fb^2/EJ$$

$$L_{GC}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{CG}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$



$$A = 552. \text{ mm}^2$$

$$J_u = 132127. \text{ mm}^4$$

$$J_v = 23256. \text{ mm}^4$$

$$y_g = 35.13 \text{ mm}$$

$$T_y = -1575. \text{ N}$$

$$M_x = 897750. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -35.13 \text{ mm}$$

$$\sigma_m = -Mv/J_u = 238.7 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 15. \text{ mm}$$

$$v_c = -20.13 \text{ mm}$$

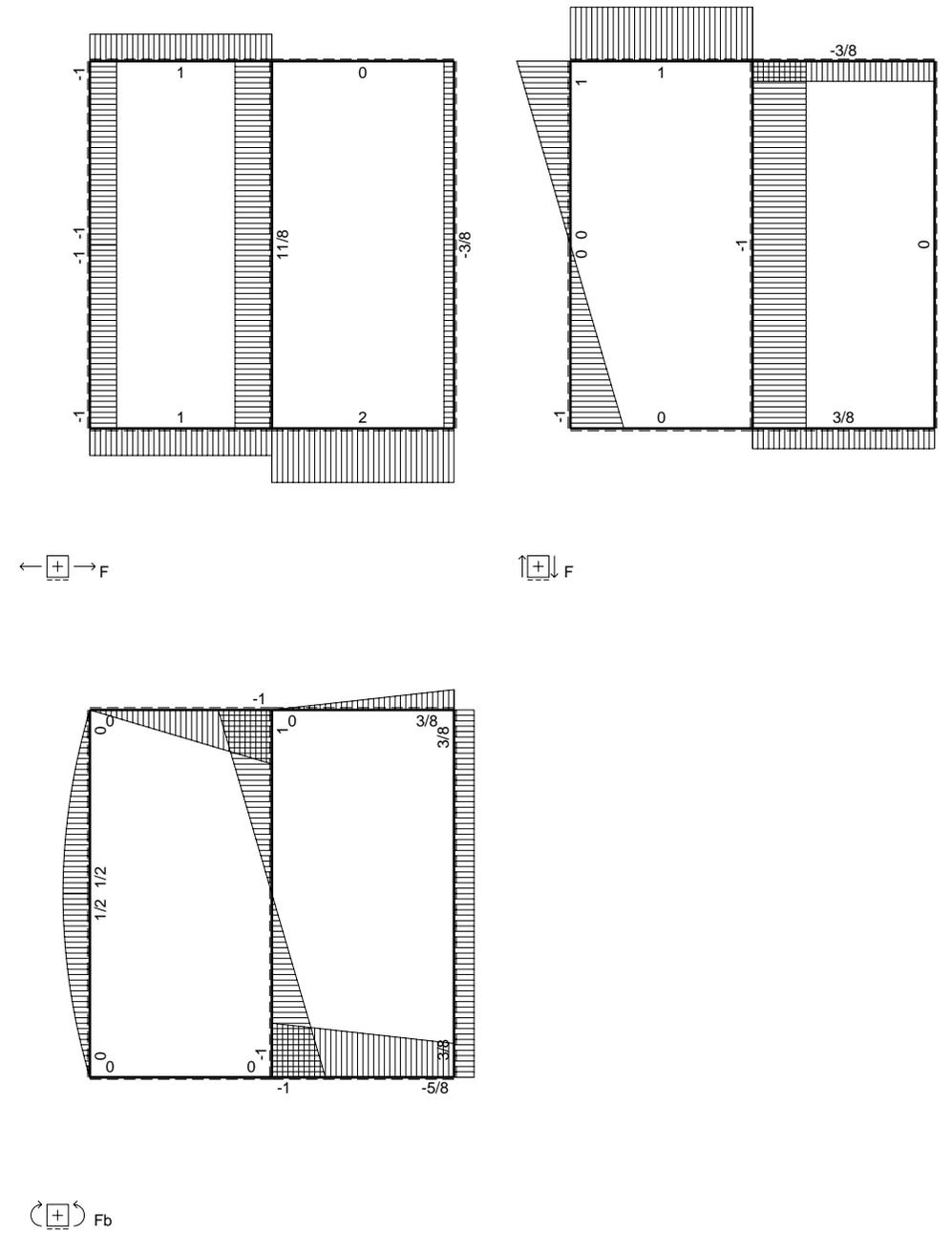
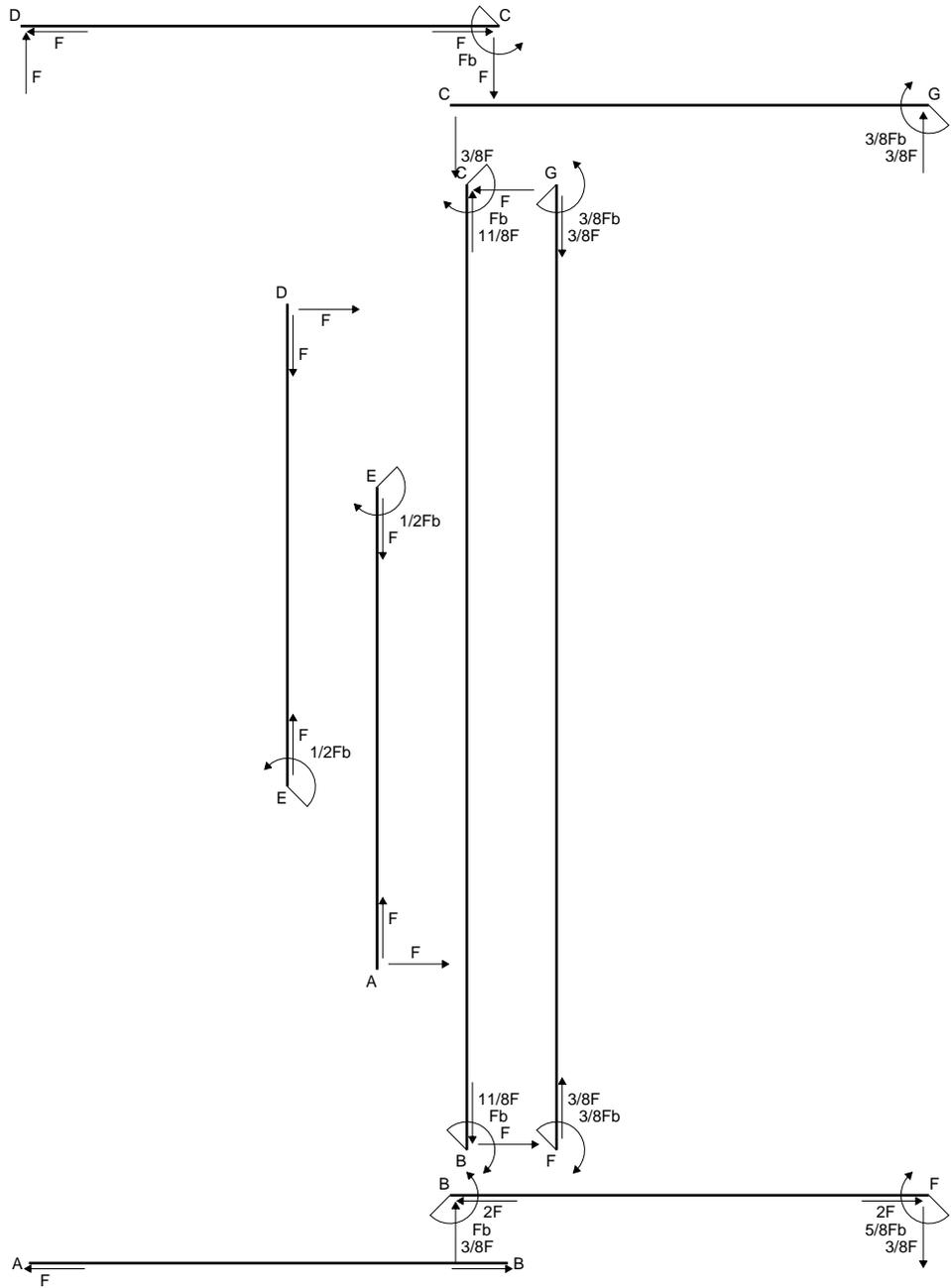
$$\sigma_c = -Mv/J_u = 136.8 \text{ N/mm}^2$$

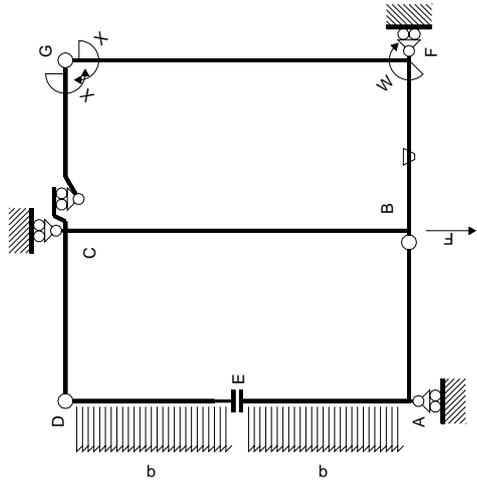
$$\tau_c = 4.94 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 137. \text{ N/mm}^2$$

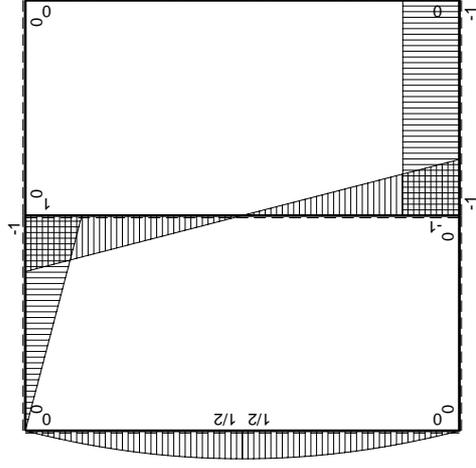
$$S = 2487. \text{ mm}^3$$



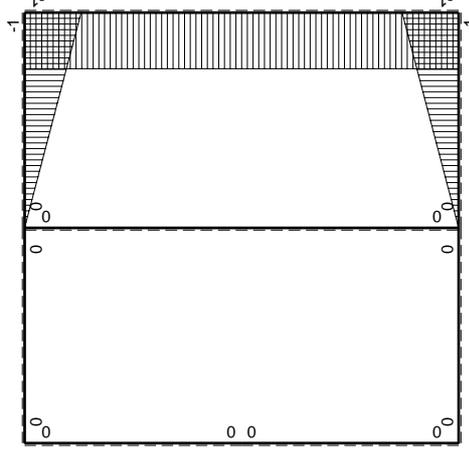




Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica X=W<sub>gc</sub>

→	M <sub>0</sub> (x)	M <sub>0</sub> (x)	θ	M <sub>0</sub> M <sub>0</sub>	M <sub>0</sub> θ	M <sub>0</sub> M <sub>x</sub>	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0+0	0
CD b	0	-Fb+Fx	0	0	0	0	0+0	0
DC b	0	Fx	0	0	0	0	0+0	0
DE b	0	Fx-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
ED b	0	-1/2Fb+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
EA b	0	1/2Fb-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
AE b	0	-Fx+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
BF b	-x/b	-Fb	-Fb/EJ	Fx	Fx/EJ	x <sup>2</sup> /b <sup>2</sup>	(1/2+1/2)Fb <sup>2</sup> /EJ	1/3xb/EJ
FB b	1-x/b	Fb	Fb/EJ	Fb-Fx	Fb/EJ-Fx/EJ	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	1/3xb/EJ	1/3xb/EJ
GC b	-1+x/b	0	0	0	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	0+0	1/3xb/EJ
CG b	x/b	0	0	0	0	x <sup>2</sup> /b <sup>2</sup>	0+0	2xb/EJ
FG 2b	-1	0	0	0	0	1	0+0	0
GF 2b	1	0	0	0	0	1	0+0	0
CB 2b	0	Fb-Fx	0	0	0	0	0+0	8/3xb/EJ
BC 2b	0	Fb-Fx	0	0	0	0	0+0	0
totali								

iperstatica X=W<sub>gc</sub>

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

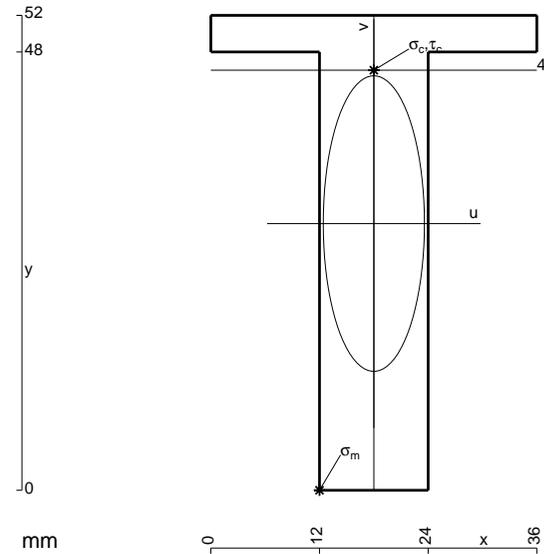
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

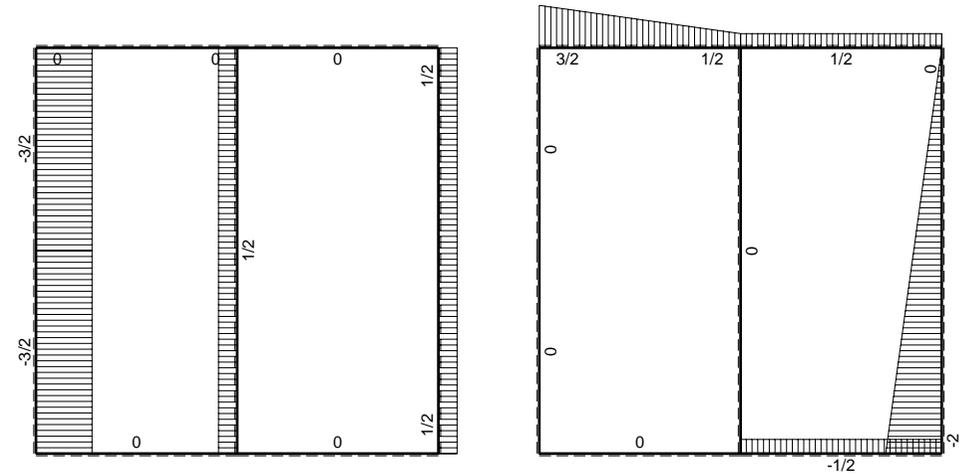
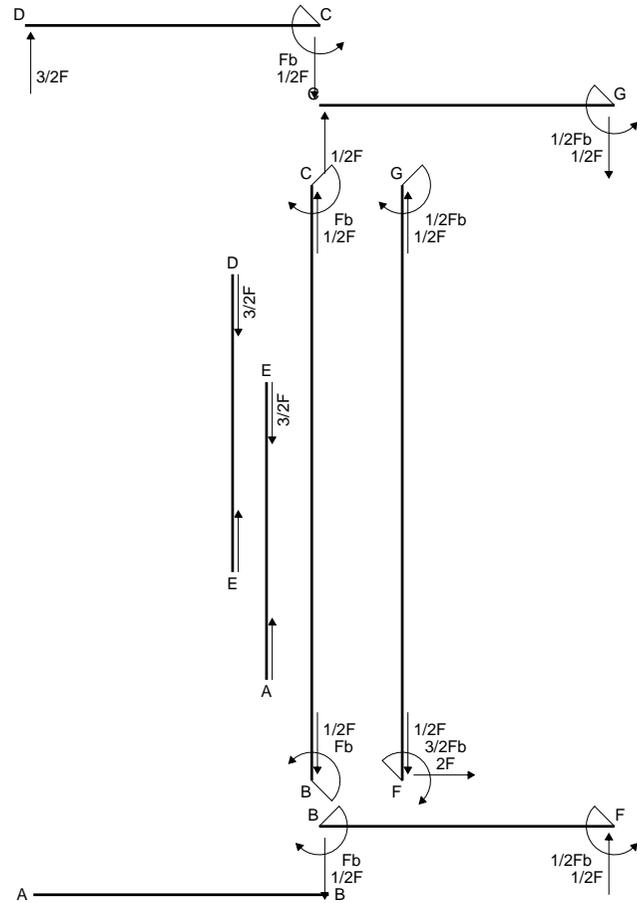
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



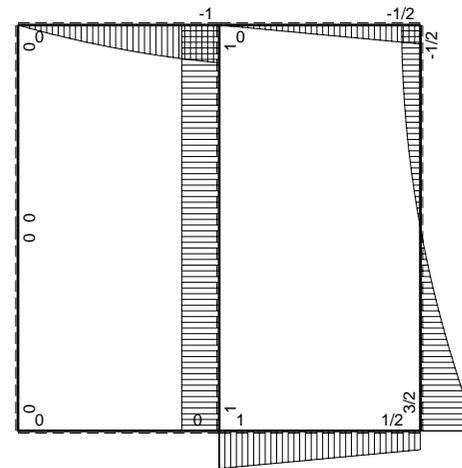
- A = 720. mm<sup>2</sup>
- J<sub>u</sub> = 188659. mm<sup>4</sup>
- J<sub>v</sub> = 22464. mm<sup>4</sup>
- y<sub>g</sub> = 29.2 mm
- N = 2970. N
- T<sub>y</sub> = -2160. N
- M<sub>x</sub> = -1317600. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -29.2 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = -199.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 46. mm
- v<sub>c</sub> = 16.8 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = 121.5 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.265 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup>+3τ<sup>2</sup>) = 121.6 N/mm<sup>2</sup>
- S = 3422. mm<sup>3</sup>





← ⊕ → F

↑ ⊕ ↓ Fb



⊕ Fb



$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x\theta} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x\theta} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

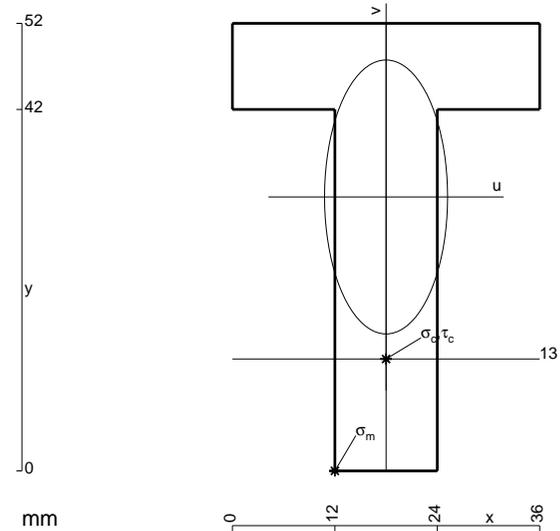
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x\theta} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

$$L_{GF}^{x\theta} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



$$A = 864. \text{ mm}^2$$

$$J_u = 219048. \text{ mm}^4$$

$$J_v = 44928. \text{ mm}^4$$

$$y_g = 31.83 \text{ mm}$$

$$T_y = 3550. \text{ N}$$

$$M_x = -1442190. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -6. \text{ mm}$$

$$v_m = -31.83 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -209.6 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 13. \text{ mm}$$

$$v_c = -18.83 \text{ mm}$$

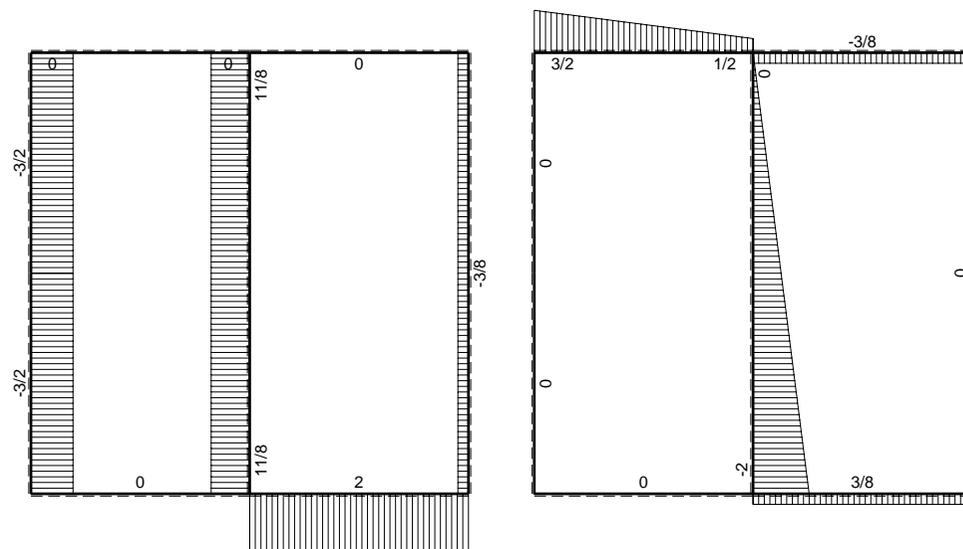
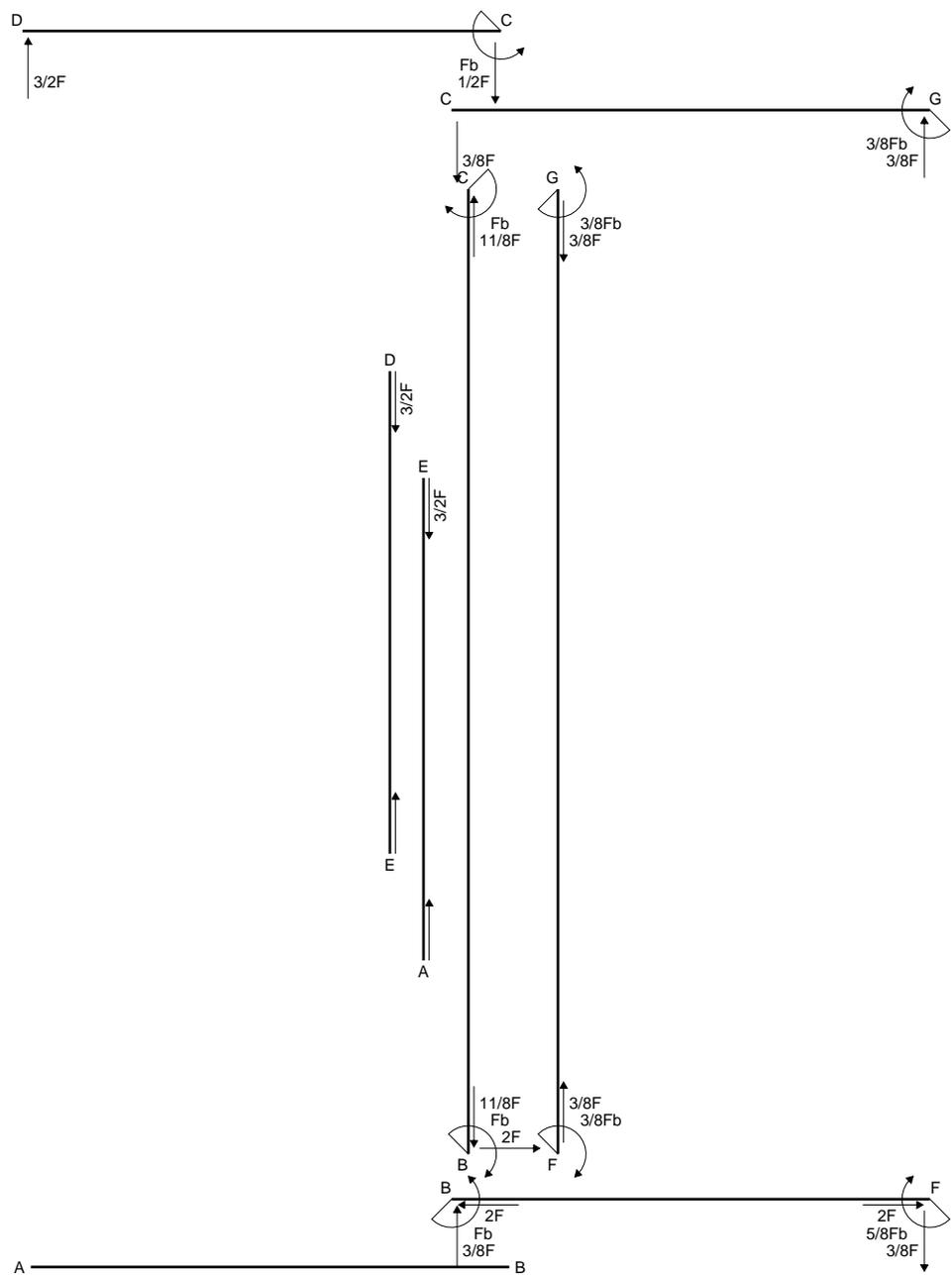
$$\sigma_c = -Mv/J_u = -124. \text{ N/mm}^2$$

$$\tau_c = 5.337 \text{ N/mm}^2$$

$$\sigma_o = \sqrt{\sigma^2 + 3\tau^2} = 124.3 \text{ N/mm}^2$$

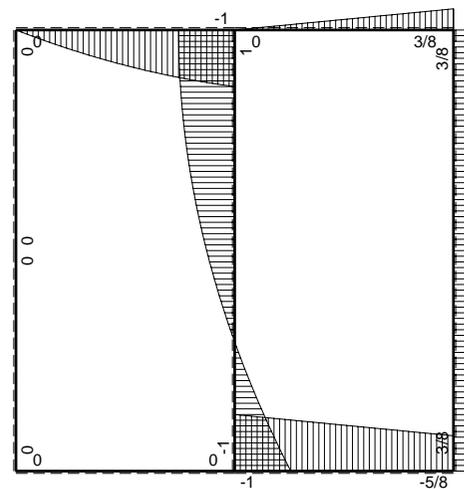
$$S = 3952. \text{ mm}^3$$





← (+) → F

↑ (+) ↓ F



⊙ (+) ⊙ Fb



$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

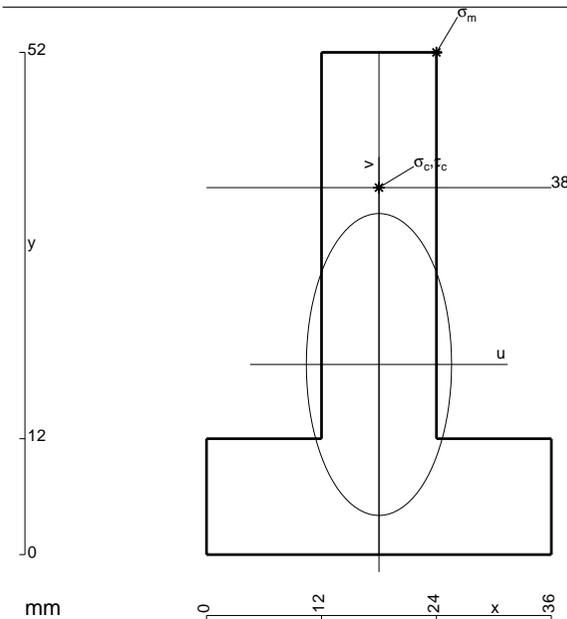
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



$$A = 912. \text{ mm}^2$$

$$J_u = 222885. \text{ mm}^4$$

$$J_v = 52416. \text{ mm}^4$$

$$y_g = 19.68 \text{ mm}$$

$$N = 2970. \text{ N}$$

$$T_y = -4320. \text{ N}$$

$$M_x = -1490400. \text{ Nmm}$$

$$x_m = 24. \text{ mm}$$

$$y_m = 52. \text{ mm}$$

$$u_m = 6. \text{ mm}$$

$$v_m = 32.32 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 219.3 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 38. \text{ mm}$$

$$v_c = 18.32 \text{ mm}$$

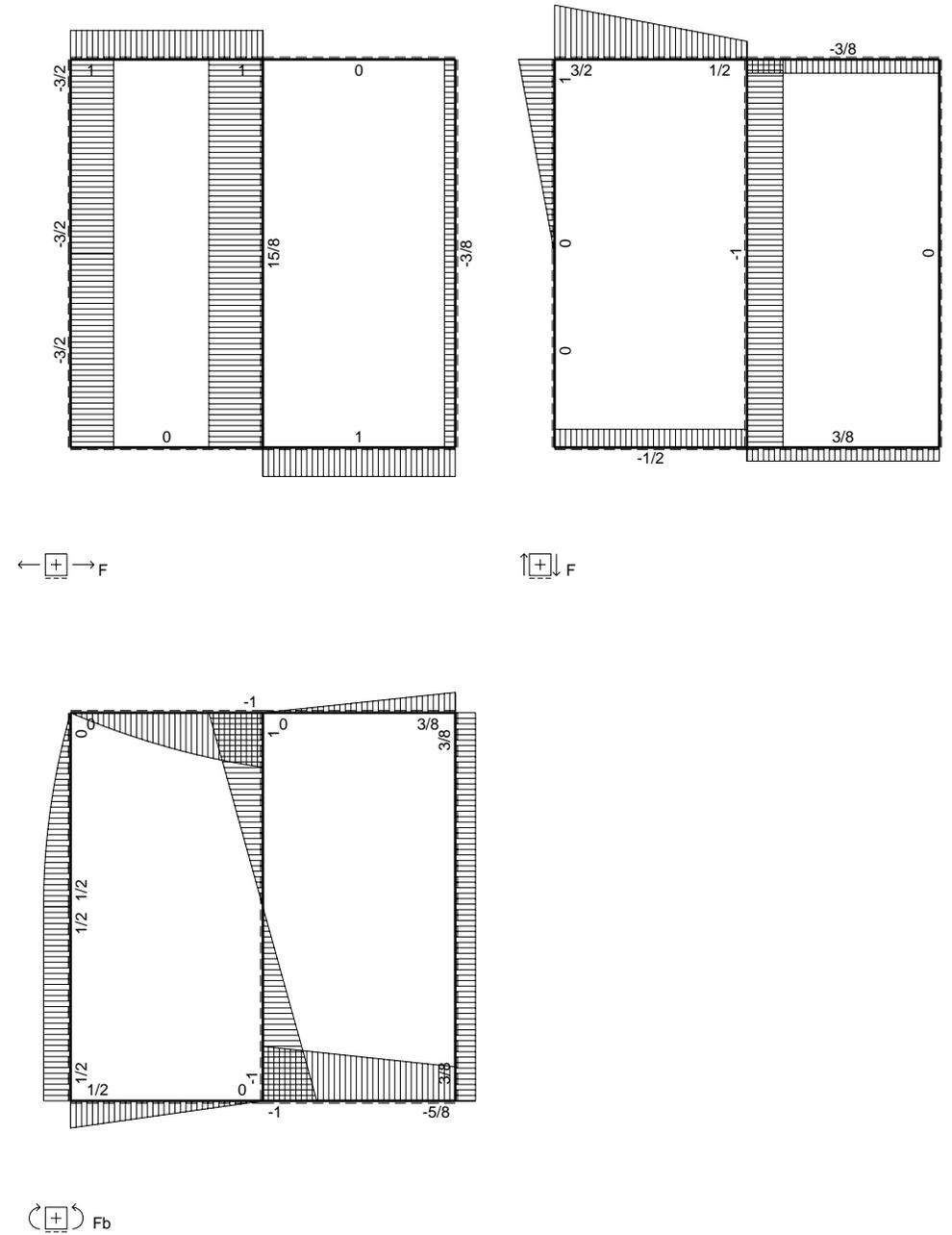
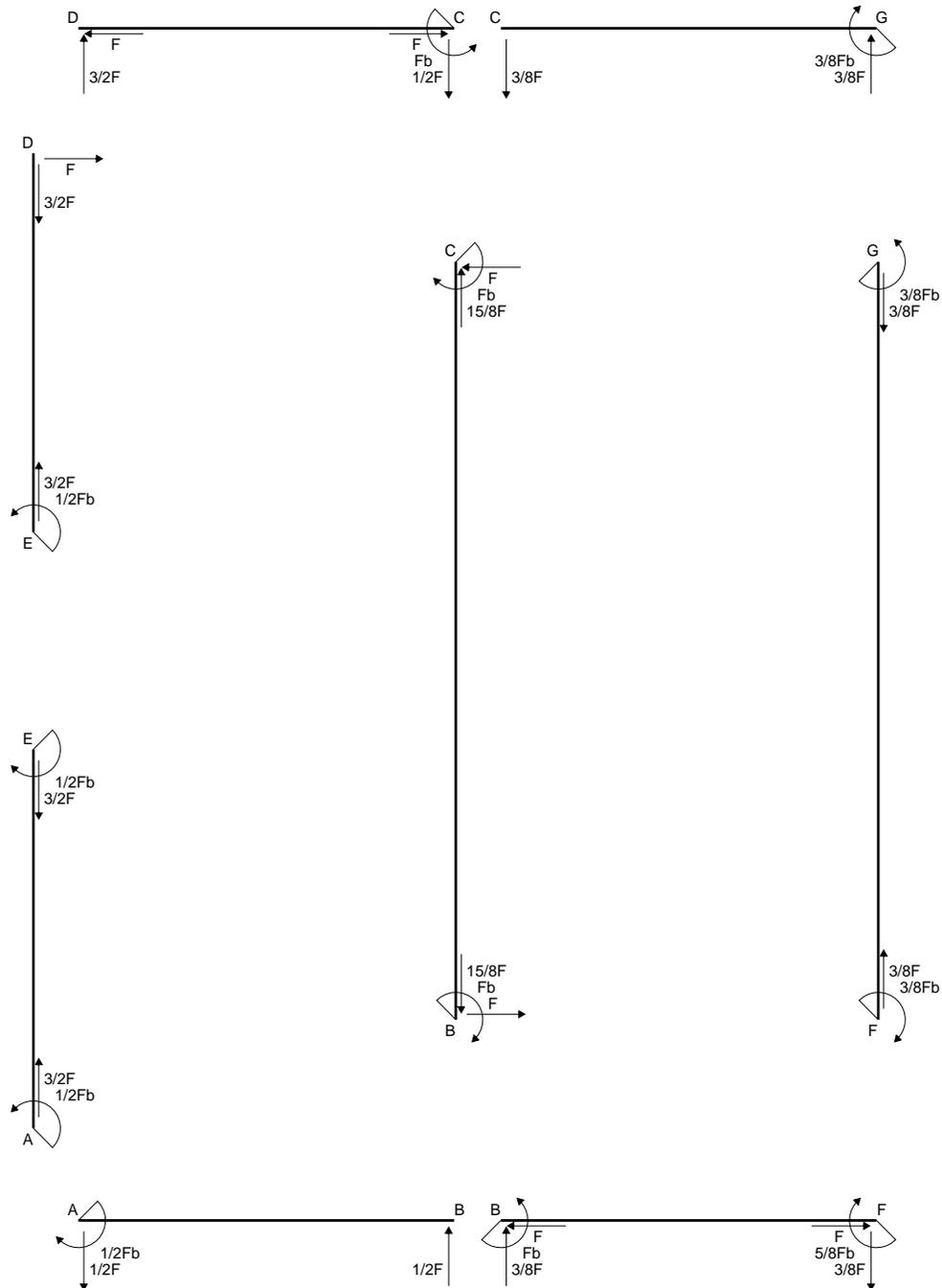
$$\sigma_c = N/A - Mv/J_u = 125.7 \text{ N/mm}^2$$

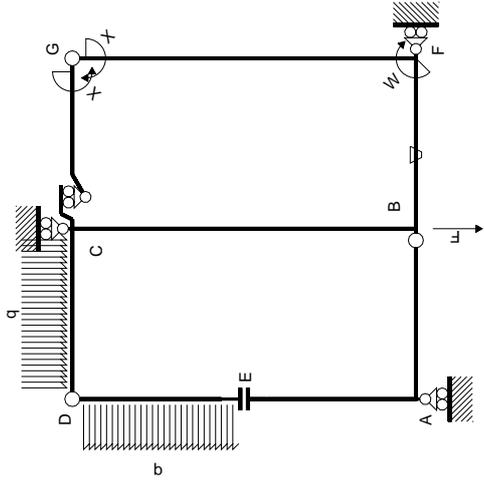
$$\tau_c = 6.869 \text{ N/mm}^2$$

$$\sigma_\varrho = \sqrt{\sigma^2 + 3\tau^2} = 126.3 \text{ N/mm}^2$$

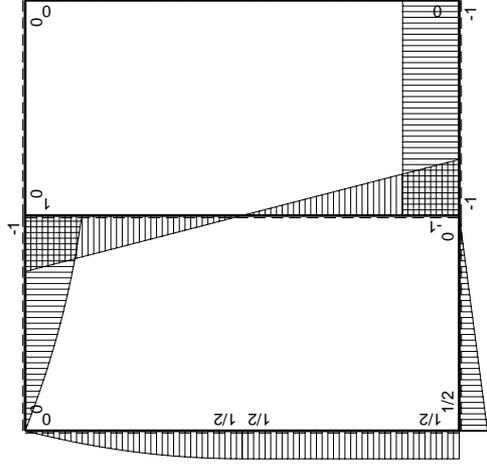
$$S = 4253. \text{ mm}^3$$



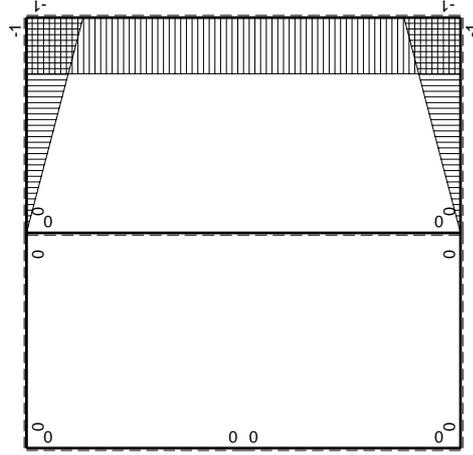




Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\leftarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	0	$1/2Fb-1/2Fx$	0	0	0	0	0+0	0
BA b	0	$-1/2Fx$	0	0	0	0	0+0	0
CD b	0	$-b+1/2Fx+1/2qx^2$	0	0	0	0	0+0	0
DC b	0	$3/2Fx-1/2qx^2$	0	0	0	0	0+0	0
DE b	0	$Fx-1/2qx^2$	0	0	0	0	0+0	0
ED b	0	$-1/2Fb+1/2qx^2$	0	0	0	0	0+0	0
EA b	0	$1/2Fb$	0	0	0	0	0+0	0
AE b	0	$-1/2Fb$	0	0	0	0	0+0	0
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FBB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb-Fx$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$1/3xb/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2xb/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2xb/EJ$
CB 2b	0	$Fb-Fx$	0	0	0	0	0+0	0
BC 2b	0	$Fb-Fx$	0	0	0	0	0+0	0
totali								$Fb^2/EJ$
								$8/3xb/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

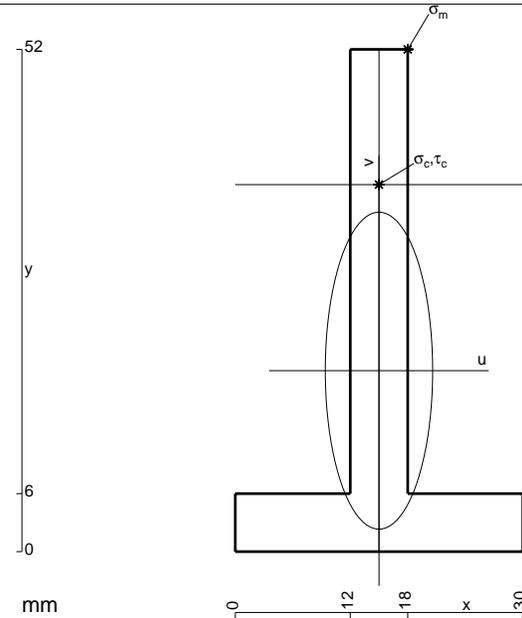
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

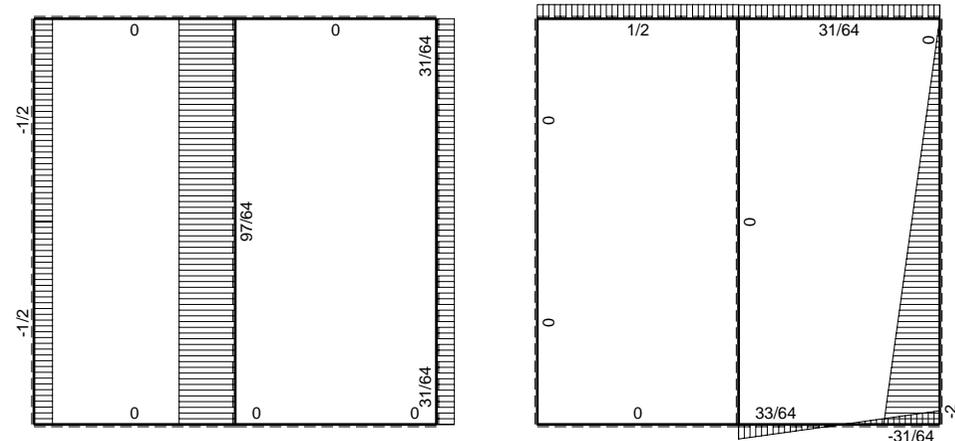
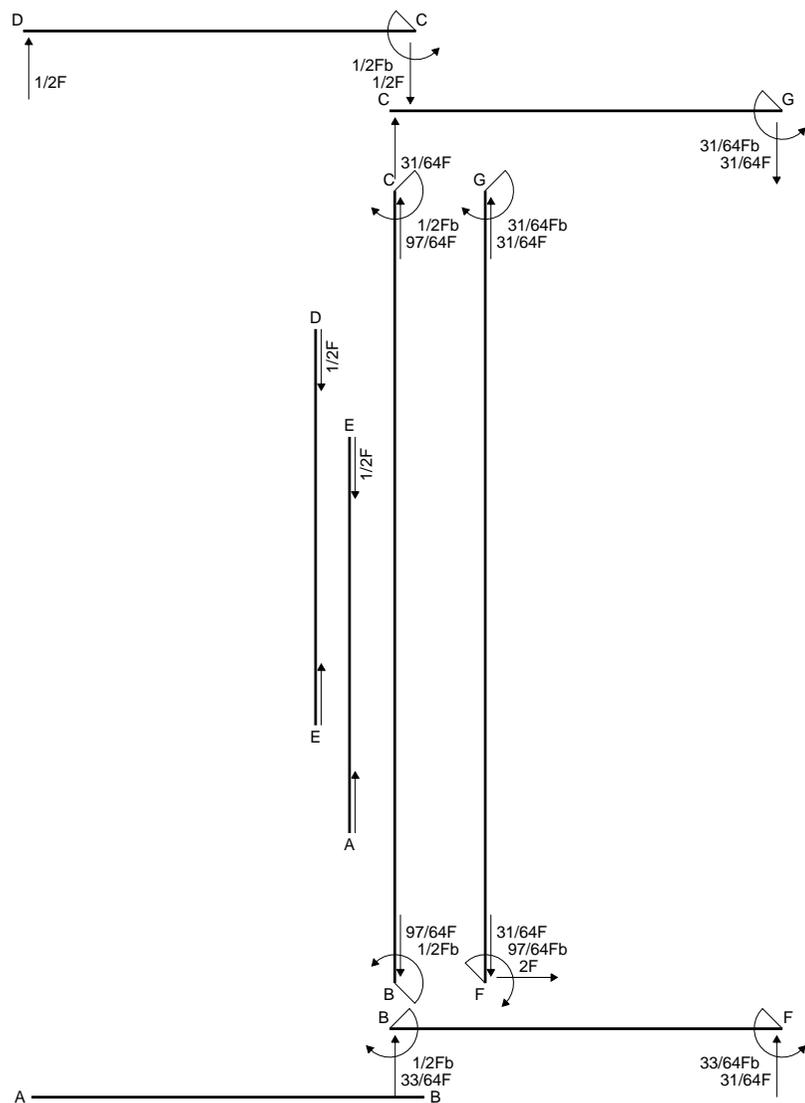
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



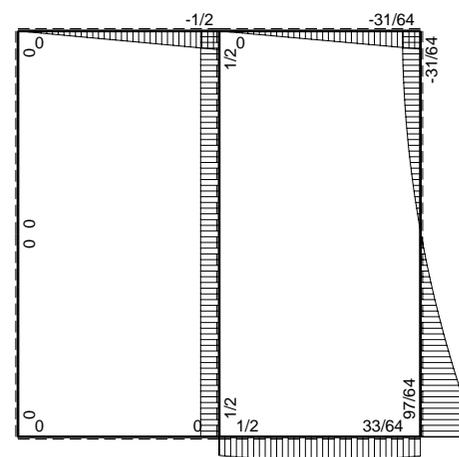
- A = 456. mm<sup>2</sup>
- J<sub>u</sub> = 122856. mm<sup>4</sup>
- J<sub>v</sub> = 14328. mm<sup>4</sup>
- y<sub>g</sub> = 18.74 mm
- N = 2119. N
- T<sub>y</sub> = -1130. N
- M<sub>x</sub> = -824900. Nmm
- x<sub>m</sub> = 18. mm
- y<sub>m</sub> = 52. mm
- u<sub>m</sub> = 3. mm
- v<sub>m</sub> = 33.26 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = 228. N/mm<sup>2</sup>
- x<sub>c</sub> = 15. mm
- y<sub>c</sub> = 38. mm
- v<sub>c</sub> = 19.26 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = 134. N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.382 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 134.1 N/mm<sup>2</sup>
- S = 2206. mm<sup>3</sup>



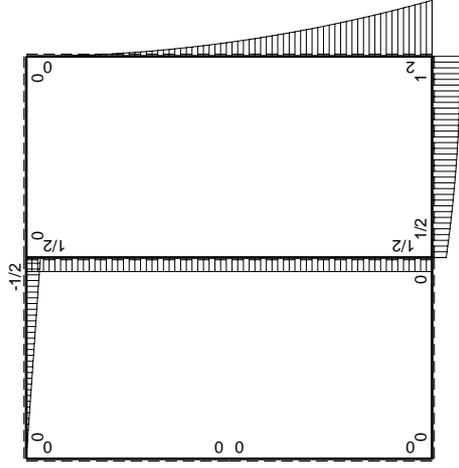
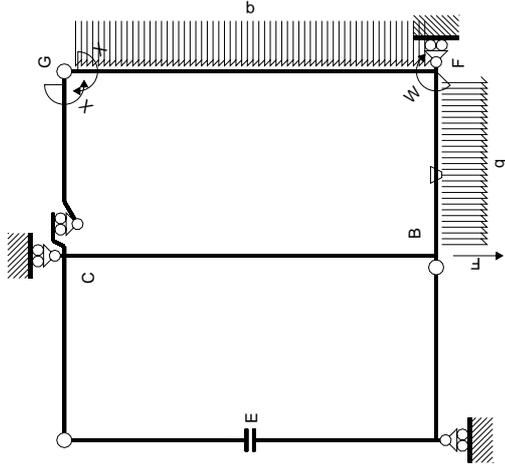


← ⊕ → F

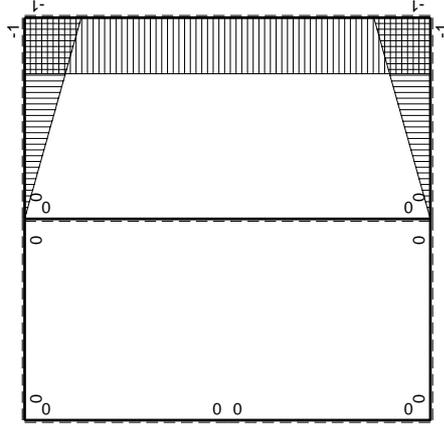
↑ ⊕ ↓ F



⊕ F<sub>b</sub>



$M_x$  flessione da carichi assegnati



$M_0$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica X=W <sup>gc</sup>		iperstatica X=W <sup>gc</sup>							
←	M <sup>x</sup> (x)	M <sup>0</sup> (x)	θ	M <sup>x</sup> M <sub>0</sub>	M <sup>x</sup> θ	M <sup>x</sup> M <sub>x</sub>	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJdx$	
AB b	0	0	0	0	0	0	0+0	0	0
BA b	0	0	0	0	0	0	0+0	0	0
CD b	0	-1/2Fb+1/2Fx	0	0	0	0	0+0	0	0
DC b	0	1/2Fx	0	0	0	0	0+0	0	0
DE b	0	0	0	0	0	0	0+0	0	0
EA b	0	0	0	0	0	0	0+0	0	0
AE b	0	0	0	0	0	0	0+0	0	0
BF b	-x/b	1/2Fb+Fx-1/2qx <sup>2</sup>	-Fb/EJ	-1/2Fx-Fx <sup>2</sup> /b+1/2qx <sup>3</sup> /b	Fx/EJ	x <sup>2</sup> /b <sup>2</sup>	(-1/1/24+1/2)Fb <sup>2</sup> /EJ	1/3xb/EJ	1/3xb/EJ
FB b	1-x/b	-Fb+1/2qx <sup>2</sup>	Fb/EJ	-Fb+Fx+1/2Fx <sup>2</sup> /b-1/2qx <sup>3</sup> /b	Fb/EJ-Fx/EJ	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	-1/1/24+1/2)Fb <sup>2</sup> /EJ	1/3xb/EJ	1/3xb/EJ
GC b	-1+x/b	0	0	0	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	0+0	1/3xb/EJ	1/3xb/EJ
CG b	x/b	0	0	0	0	x <sup>2</sup> /b <sup>2</sup>	0+0	1/3xb/EJ	1/3xb/EJ
FG 2b	-1	2Fb-2Fx+1/2qx <sup>2</sup>	0	-2Fb+2Fx-1/2Fx <sup>2</sup> /b	0	1	(-4/3+0)Fb <sup>2</sup> /EJ	2xb/EJ	2xb/EJ
GF 2b	1	-1/2qx <sup>2</sup>	0	-1/2Fx <sup>2</sup> /b	0	1	(-4/3+0)Fb <sup>2</sup> /EJ	2xb/EJ	2xb/EJ
CB 2b	0	1/2Fb	0	0	0	0	0+0	8/3xb/EJ	8/3xb/EJ
BC 2b	0	-1/2Fb	0	0	0	0	0+0	8/3xb/EJ	8/3xb/EJ
totali									
									31/64Fb

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{xo} = \int_0^b (-1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

$$= [-1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/4 b - 1/3 b + 1/8 b) Fb 1/EJ + (1/2 b) \theta = 1/24 Fb^2/EJ$$

$$L_{FB}^{xo} = \int_0^b (-1 + x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

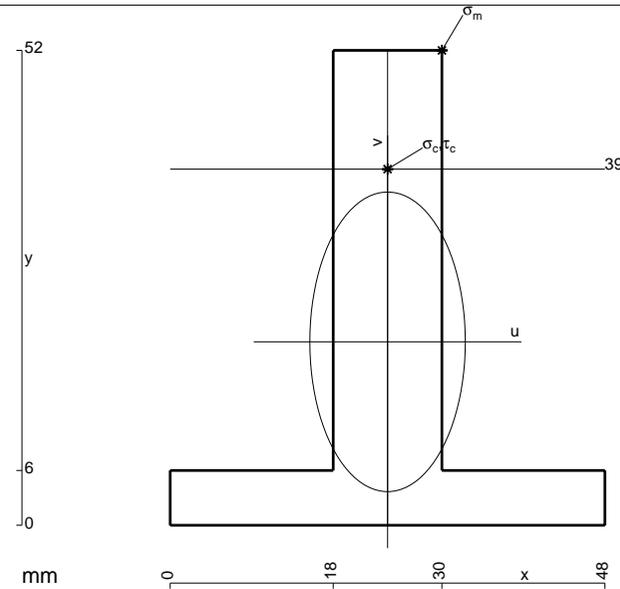
$$= (-b + 1/2 b + 1/6 b - 1/8 b) Fb 1/EJ + (-b + 1/2 b) \theta = 1/24 Fb^2/EJ$$

$$L_{FG}^{xo} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

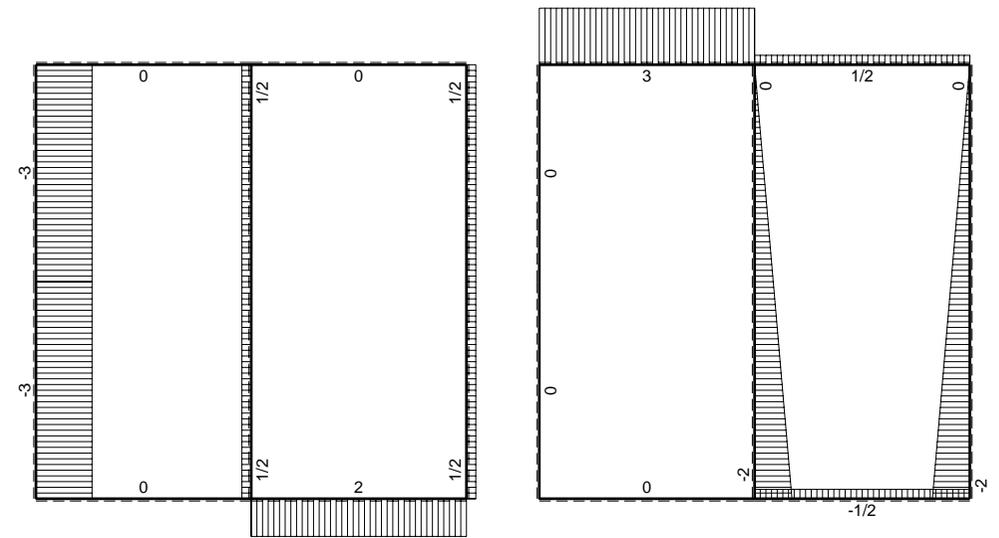
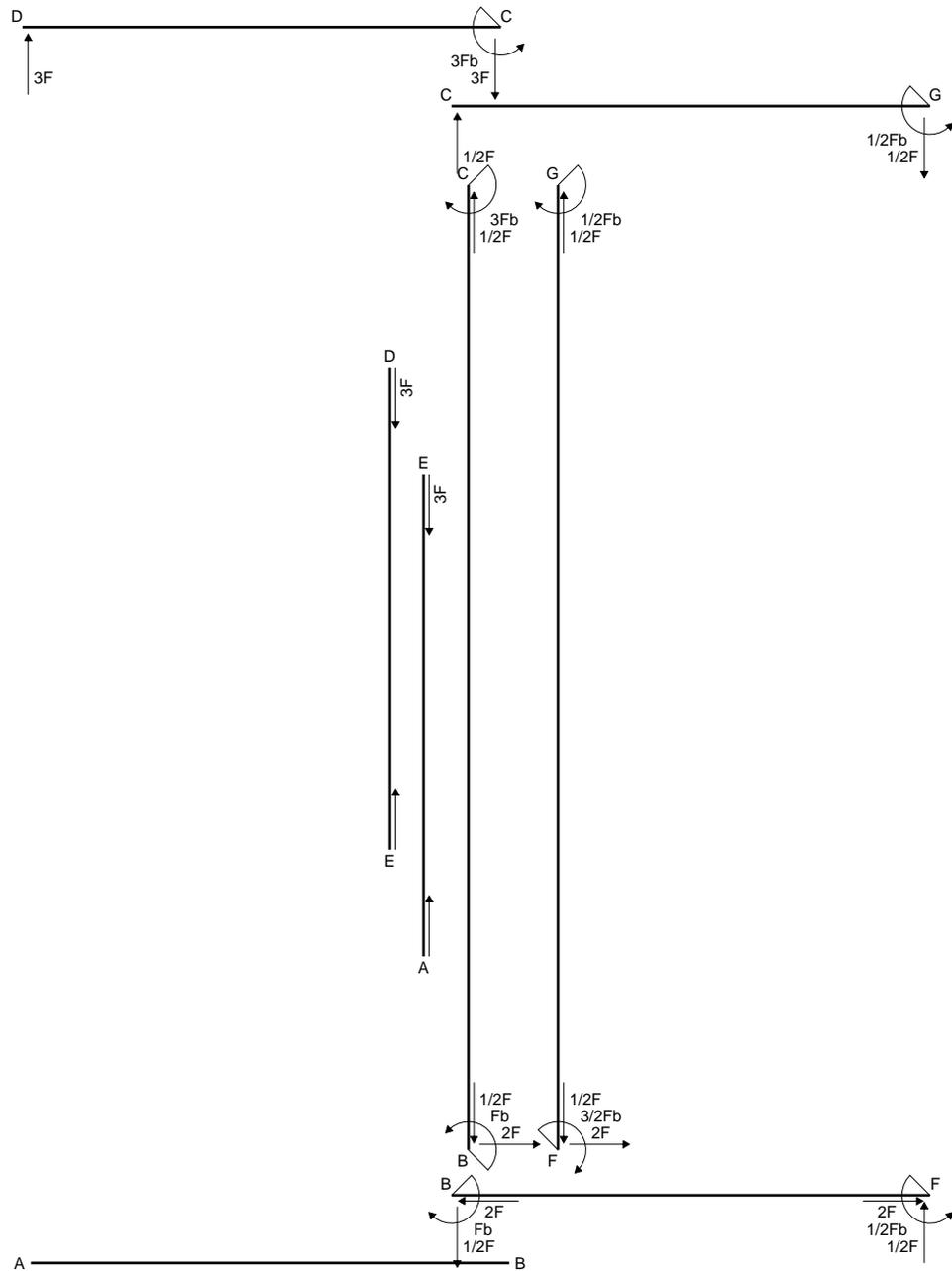
$$L_{GF}^{xo} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



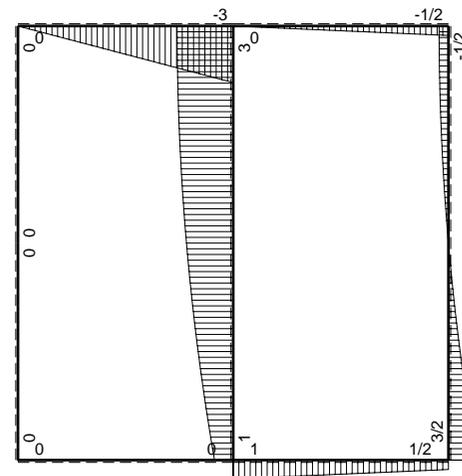
- A = 840. mm<sup>2</sup>
- J<sub>u</sub> = 226138. mm<sup>4</sup>
- J<sub>v</sub> = 61920. mm<sup>4</sup>
- y<sub>g</sub> = 20.09 mm
- T<sub>y</sub> = 2205. N
- M<sub>x</sub> = -1697850. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 52. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 31.91 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 239.6 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 39. mm
- v<sub>c</sub> = 18.91 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 142. N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.221 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 142.1 N/mm<sup>2</sup>
- S = 3965. mm<sup>3</sup>





← ⊕ → F

↑ ⊕ ↓ F



⊕ ⊖ F<sub>b</sub>



$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x\theta} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x\theta} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

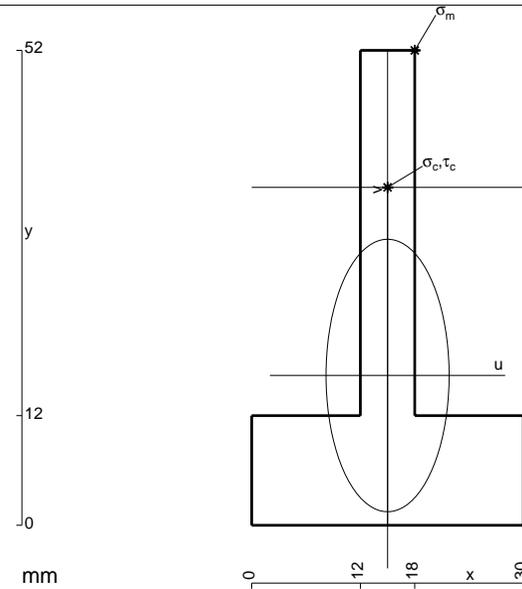
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x\theta} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

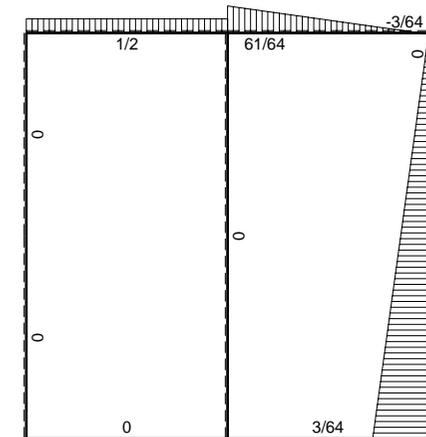
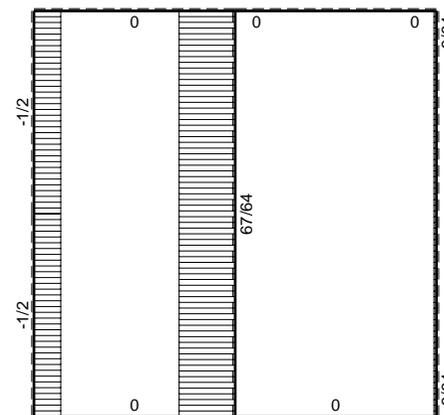
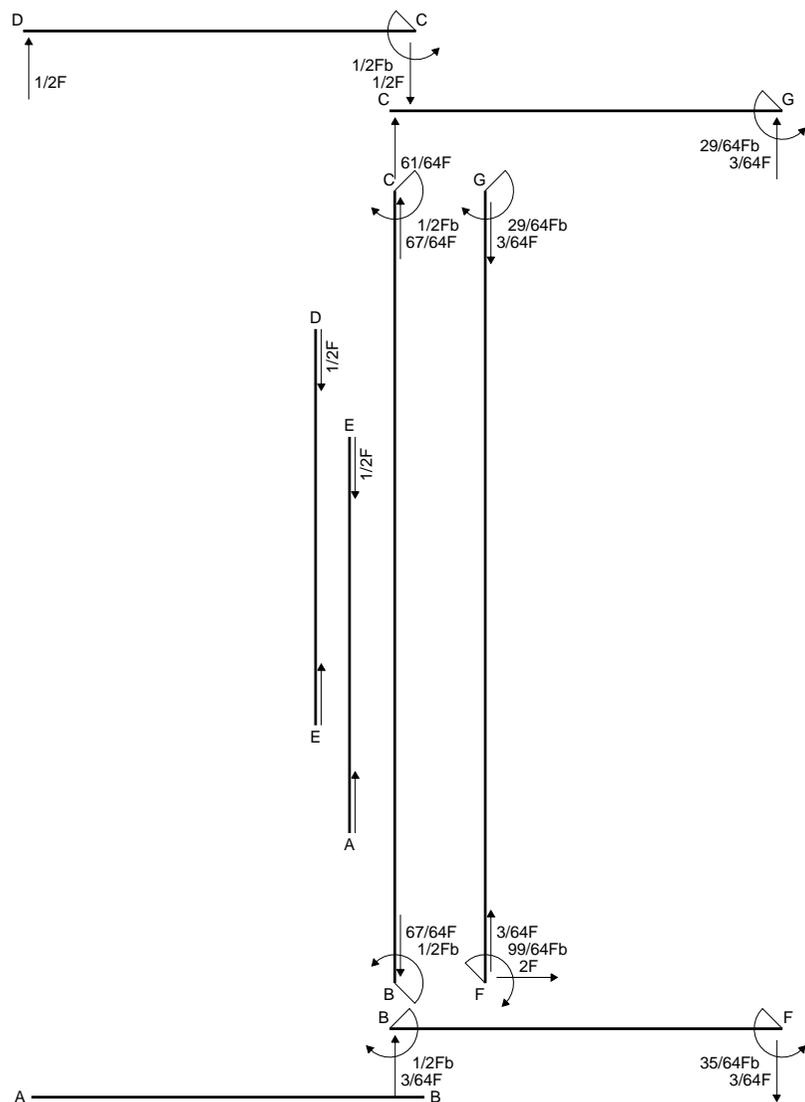
$$L_{GF}^{x\theta} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



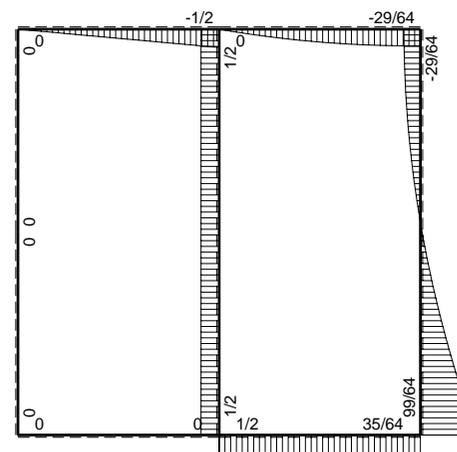
- A = 600. mm<sup>2</sup>
- J<sub>u</sub> = 133664. mm<sup>4</sup>
- J<sub>v</sub> = 27720. mm<sup>4</sup>
- y<sub>g</sub> = 16.4 mm
- T<sub>y</sub> = 1830. N
- M<sub>x</sub> = -750300. Nmm
- x<sub>m</sub> = 18. mm
- y<sub>m</sub> = 52. mm
- u<sub>m</sub> = 3. mm
- v<sub>m</sub> = 35.6 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 199.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 15. mm
- y<sub>c</sub> = 37. mm
- v<sub>c</sub> = 20.6 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 115.6 N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.771 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 116.1 N/mm<sup>2</sup>
- S = 2529. mm<sup>3</sup>



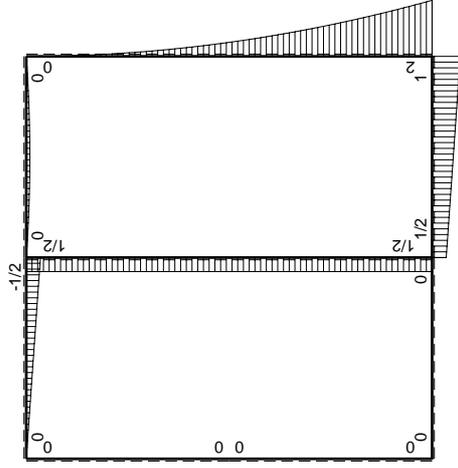
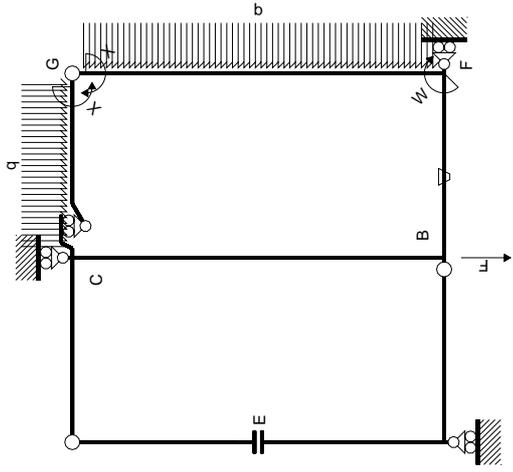


← ⊕ → F

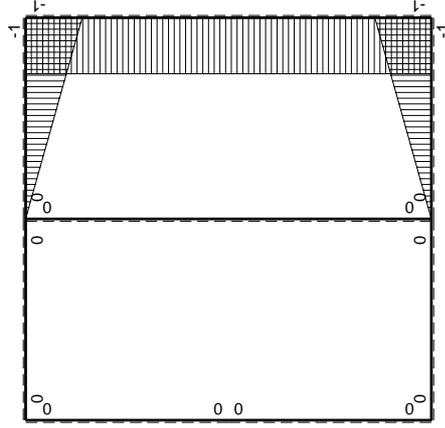
↑ ⊕ ↓ F



⊕ F<sub>b</sub>



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica $X=W_{gc}$		$M_x(x)$		$M_0(x)$		$\theta$		$M_x M_0$		$M_x \theta$		$M_x M_x$		$\int M_x(M_0/EJ+\theta)dx$		$\int M_x M_x/EJ dx$		
AB b	0	0	0	0	0	0	0	0	0	0	0	0	0	0+0	0	0	0	
BA b	0	0	0	0	0	0	0	0	0	0	0	0	0	0+0	0	0	0	
CD b	0	-1/2Fb+1/2Fx	0	0	0	0	0	0	0	0	0	0	0	0+0	0	0	0	
DC b	0	1/2Fx	0	0	0	0	0	0	0	0	0	0	0	0+0	0	0	0	
DE b	0	0	0	0	0	0	0	0	0	0	0	0	0	0+0	0	0	0	
EA b	0	0	0	0	0	0	0	0	0	0	0	0	0	0+0	0	0	0	
AE b	0	0	0	0	0	0	0	0	0	0	0	0	0	0+0	0	0	0	
BF b	-x/b	1/2Fb+1/2Fx	-Fb/EJ	-1/2Fx-1/2Fx <sup>2</sup> /b	Fx/EJ	Fx/EJ	x <sup>2</sup> /b <sup>2</sup>	(-5/12+1/2)Fb <sup>2</sup> /EJ	1/3xb/EJ	0	0	0	0	0+0	0	0	0	
FB b	1-x/b	-Fb+1/2Fx	Fb/EJ	-Fb+3/2Fx-1/2Fx <sup>2</sup> /b	Fb/EJ-Fx/EJ	Fb/EJ-Fx/EJ	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	(-5/12+1/2)Fb <sup>2</sup> /EJ	1/3xb/EJ	0	0	0	0	0+0	0	0	0	
GC b	-1+x/b	-1/2Fx+1/2qx <sup>2</sup>	0	1/2Fx-Fx <sup>2</sup> /b+1/2qx <sup>3</sup> /b	0	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	(1/24+0)Fb <sup>2</sup> /EJ	1/3xb/EJ	0	0	0	0	0+0	0	0	0	
CG b	x/b	1/2Fx-1/2qx <sup>2</sup>	0	1/2Fx <sup>2</sup> /b-1/2qx <sup>3</sup> /b	0	0	x <sup>2</sup> /b <sup>2</sup>	(1/24+0)Fb <sup>2</sup> /EJ	1/3xb/EJ	0	0	0	0	0+0	0	0	0	
FG 2b	-1	2Fb-2Fx+1/2qx <sup>2</sup>	0	-2Fb+2Fx-1/2Fx <sup>2</sup> /b	0	0	1	(-4/3+0)Fb <sup>2</sup> /EJ	2xb/EJ	0	0	0	0	0+0	0	0	0	
GF 2b	1	-1/2qx <sup>2</sup>	0	-1/2Fx <sup>2</sup> /b	0	0	1	(-4/3+0)Fb <sup>2</sup> /EJ	2xb/EJ	0	0	0	0	0+0	0	0	0	
CB 2b	0	1/2Fb	0	0	0	0	0	-29/24Fb <sup>2</sup> /EJ	8/3xb/EJ	0	0	0	0	0+0	0	0	0	
BC 2b	0	-1/2Fb	0	0	0	0	0	-29/24Fb <sup>2</sup> /EJ	8/3xb/EJ	0	0	0	0	0+0	0	0	0	
totali																		

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x\theta} = \int_0^b (-1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

$$= [-1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/4 b - 1/6 b) Fb 1/EJ + (1/2 b) \theta = 1/12 Fb^2/EJ$$

$$L_{FB}^{x\theta} = \int_0^b (-1 + 3/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 3/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (-b + 3/4 b - 1/6 b) Fb 1/EJ + (-b + 1/2 b) \theta = 1/12 Fb^2/EJ$$

$$L_{GC}^{x\theta} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{CG}^{x\theta} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

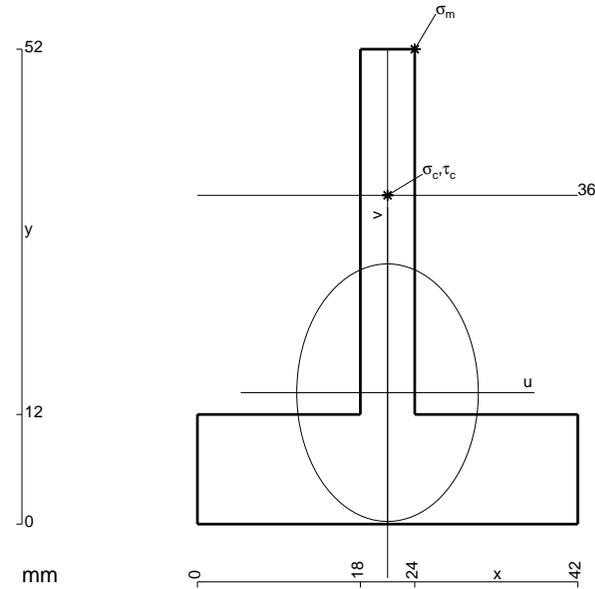
$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{FG}^{x\theta} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

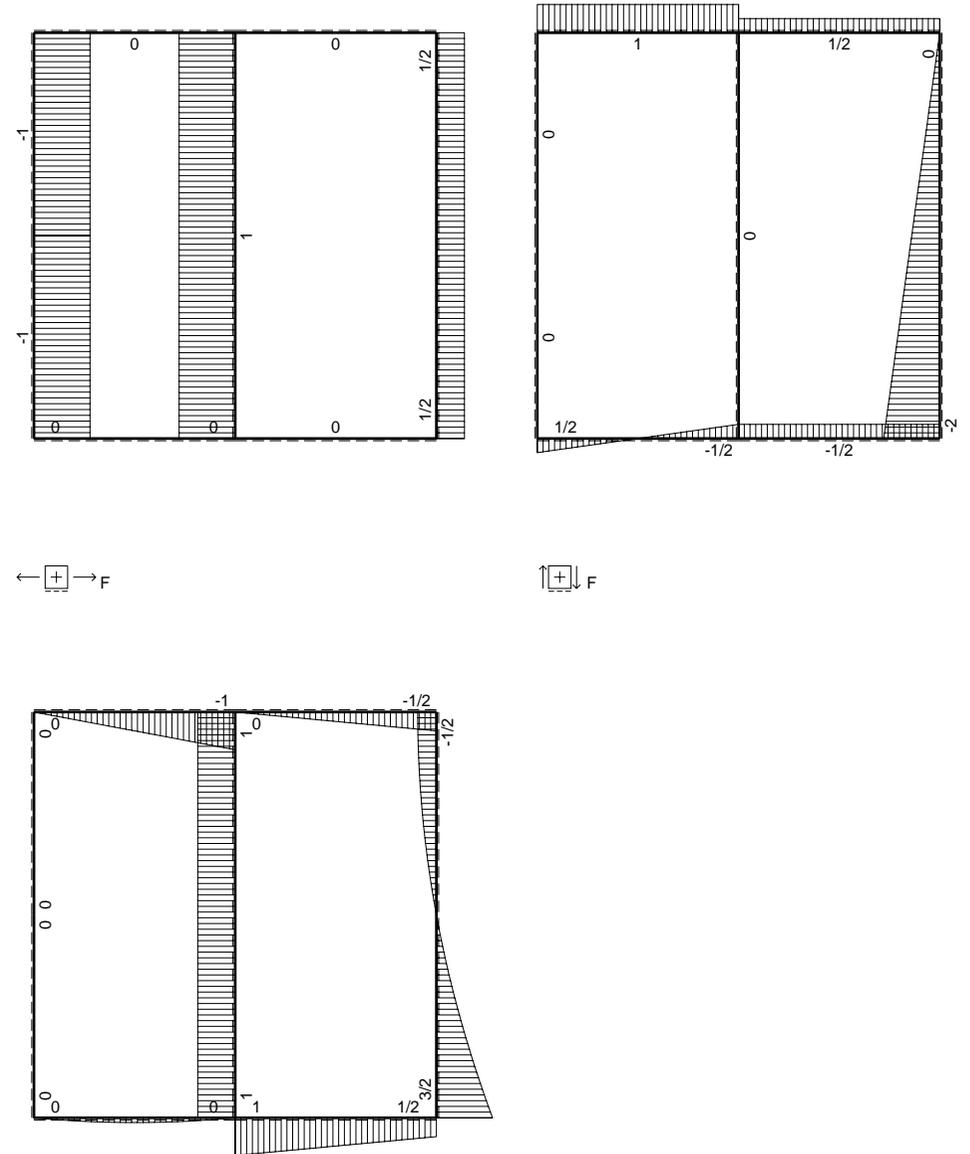
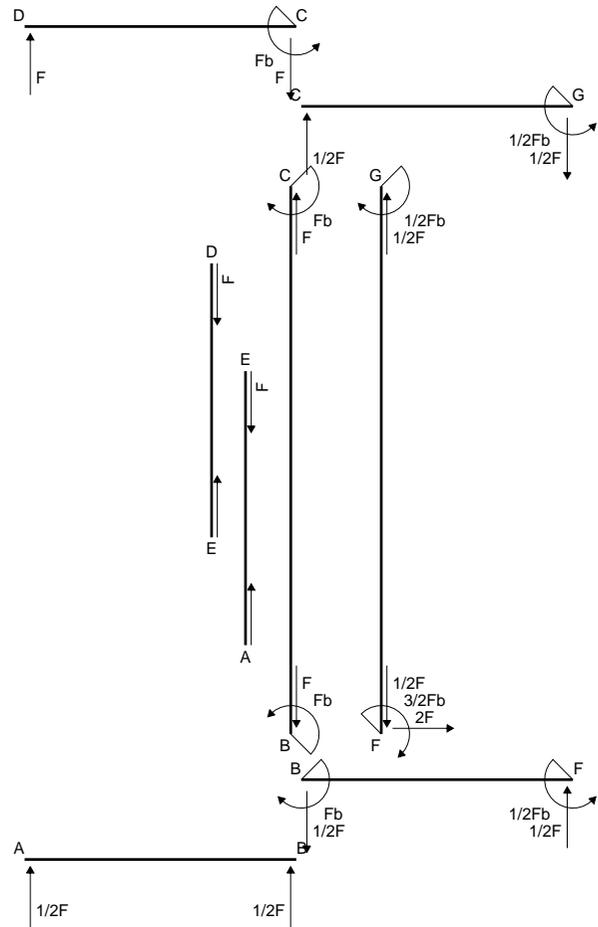
$$L_{GF}^{x\theta} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

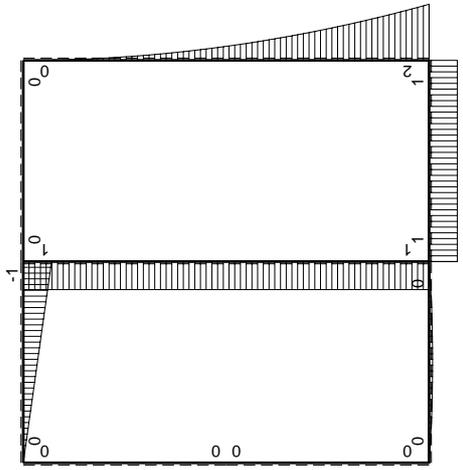
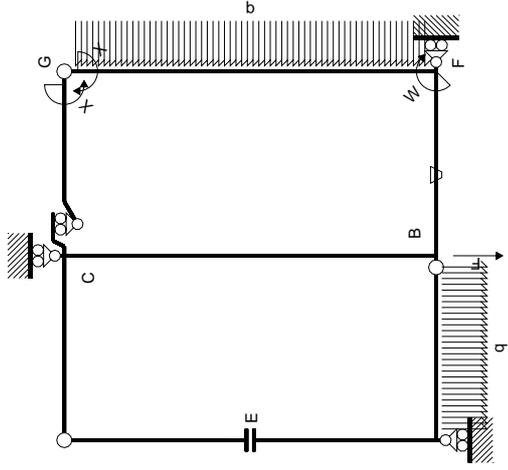
$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



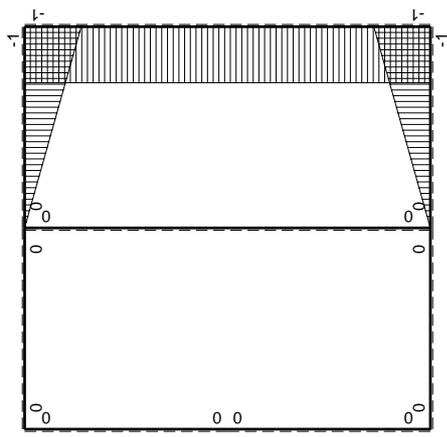
$A = 744. \text{ mm}^2$   
 $J_u = 147953. \text{ mm}^4$   
 $J_v = 74808. \text{ mm}^4$   
 $y_g = 14.39 \text{ mm}$   
 $T_y = 1835. \text{ N}$   
 $M_x = -825750. \text{ Nmm}$   
 $x_m = 24. \text{ mm}$   
 $y_m = 52. \text{ mm}$   
 $u_m = 3. \text{ mm}$   
 $v_m = 37.61 \text{ mm}$   
 $\sigma_m = -Mv/J_u = 209.9 \text{ N/mm}^2$   
 $x_c = 21. \text{ mm}$   
 $y_c = 36. \text{ mm}$   
 $v_c = 21.61 \text{ mm}$   
 $\sigma_c = -Mv/J_u = 120.6 \text{ N/mm}^2$   
 $\tau_c = 5.876 \text{ N/mm}^2$   
 $\sigma_\theta = \sqrt{\sigma^2 + 3\tau^2} = 121.1 \text{ N/mm}^2$   
 $S = 2843. \text{ mm}^3$







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica X=W <sub>gc</sub>		M <sup>0</sup> (x)		θ		M <sup>0</sup> <sub>0</sub>		M <sup>x</sup> θ		M <sup>x</sup> M <sub>x</sub>		∫M <sup>x</sup> (M <sub>0</sub> /EJ+θ)dx		∫M <sup>x</sup> M <sub>x</sub> /EJdx	
AB b	0	1/2Fx-1/2qx <sup>2</sup>	0	0	0	0	0	0	0	0	0	0	0	0	0
BA b	0	-1/2Fx+1/2qx <sup>2</sup>	0	0	0	0	0	0	0	0	0	0	0	0	0
CD b	0	-b+Fx	0	0	0	0	0	0	0	0	0	0	0	0	0
DC b	0	Fx	0	0	0	0	0	0	0	0	0	0	0	0	0
DE b	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ED b	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EA b	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AE b	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BF b	-x/b	Fb	-Fb/EJ	-Fx	Fx/EJ	-1-2x/b+x <sup>2</sup> /b <sup>2</sup>	x <sup>2</sup> /b <sup>2</sup>	-1/2+1/2(Fb <sup>2</sup> /EJ)	1/3xb/EJ	0	0	0	0	0	0
FB b	1-x/b	-Fb	Fb/EJ	-Fb+Fx	Fb/EJ-Fx/EJ	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	x <sup>2</sup> /b <sup>2</sup>	(-1/2+1/2)Fb <sup>2</sup> /EJ	1/3xb/EJ	0	0	0	0	0	0
GC b	-1+x/b	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CG b	x/b	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FG 2b	-1	2Fb-2Fx+1/2qx <sup>2</sup>	0	-2Fb+2Fx-1/2Fx <sup>2</sup> /b	0	1	1	(-4/3+0)Fb <sup>2</sup> /EJ	2xb/EJ	0	0	0	0	0	0
GF 2b	1	-1/2qx <sup>2</sup>	0	-1/2Fx <sup>2</sup> /b	0	1	1	(-4/3+0)Fb <sup>2</sup> /EJ	2xb/EJ	0	0	0	0	0	0
CB 2b	0	Fb	0	0	0	0	0	0	0	0	0	0	0	0	0
BC 2b	0	-Fb	0	0	0	0	0	0	0	0	0	0	0	0	0
totali															
iperstatica X=W <sub>gc</sub>															

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x\theta} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x\theta} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

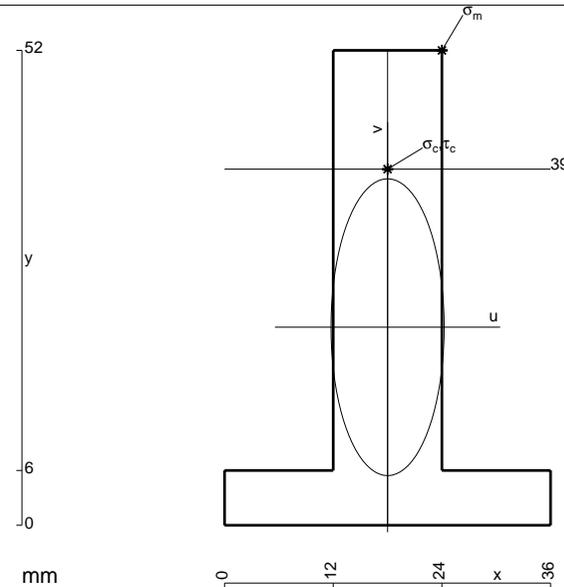
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x\theta} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

$$L_{GF}^{x\theta} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



$$A = 768. \text{ mm}^2$$

$$J_u = 202933. \text{ mm}^4$$

$$J_v = 29952. \text{ mm}^4$$

$$y_g = 21.69 \text{ mm}$$

$$T_y = 3000. \text{ N}$$

$$M_x = -1470000. \text{ Nmm}$$

$$x_m = 24. \text{ mm}$$

$$y_m = 52. \text{ mm}$$

$$u_m = 6. \text{ mm}$$

$$v_m = 30.31 \text{ mm}$$

$$\sigma_m = -Mv/J_u = 219.6 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 39. \text{ mm}$$

$$v_c = 17.31 \text{ mm}$$

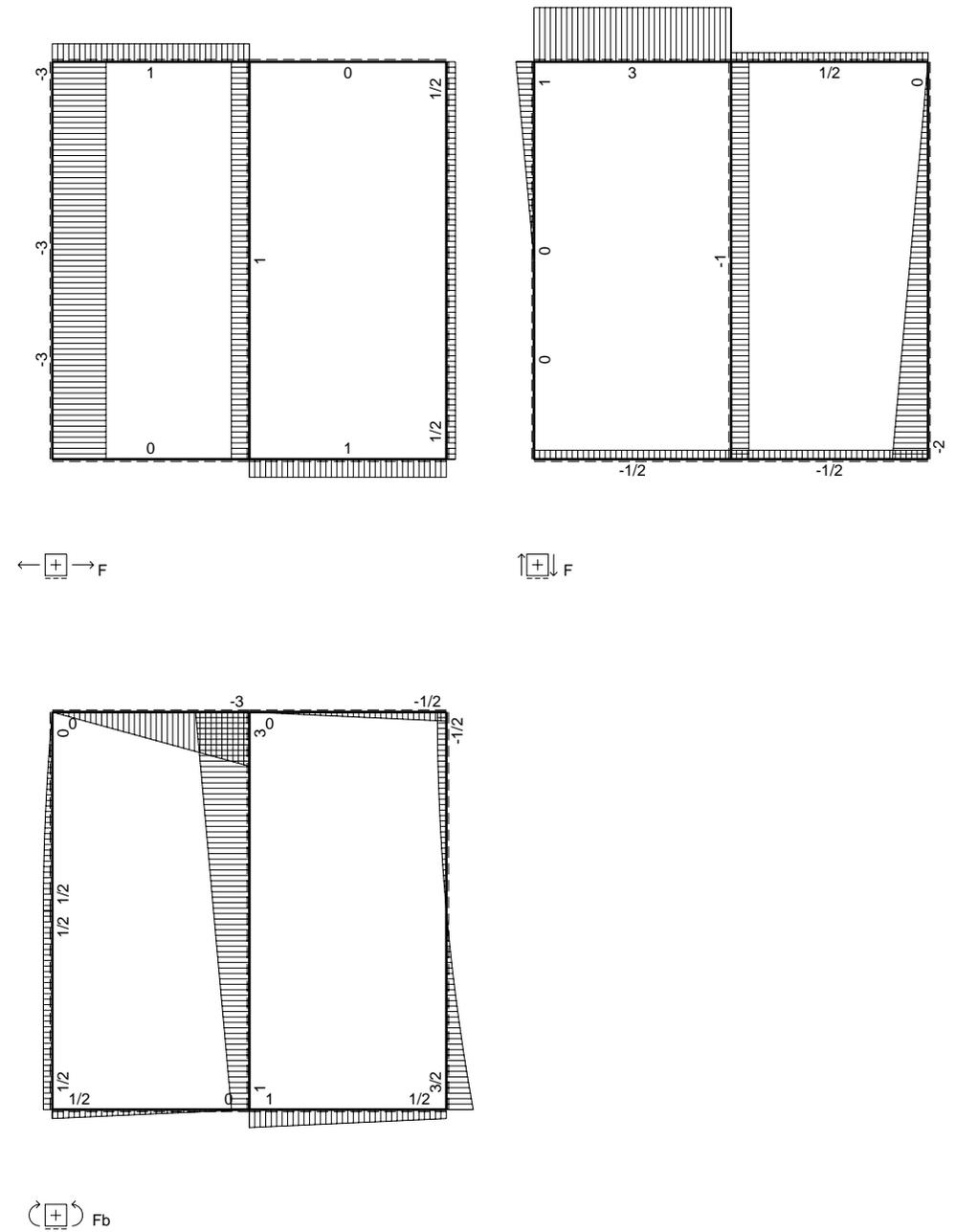
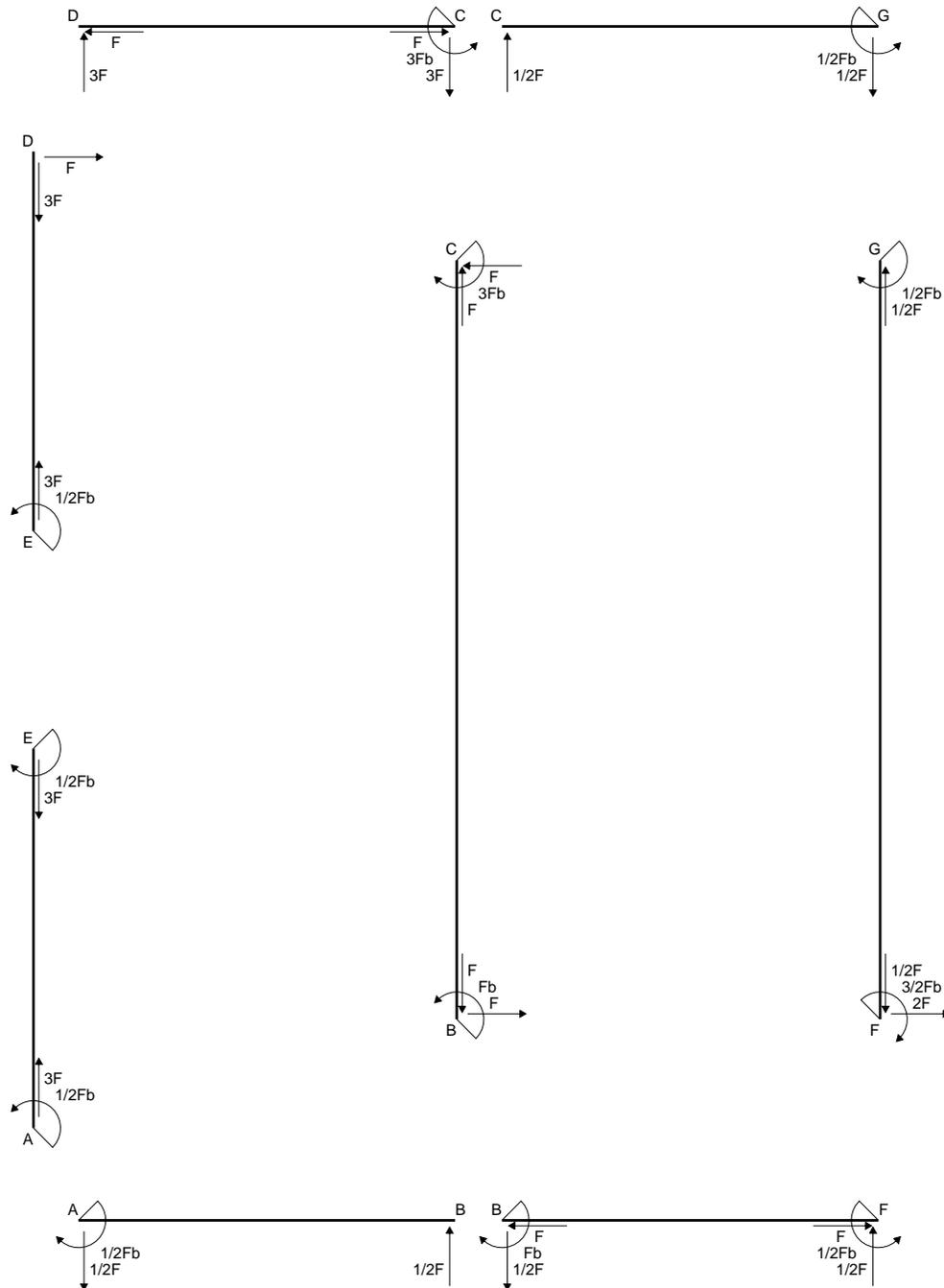
$$\sigma_c = -Mv/J_u = 125.4 \text{ N/mm}^2$$

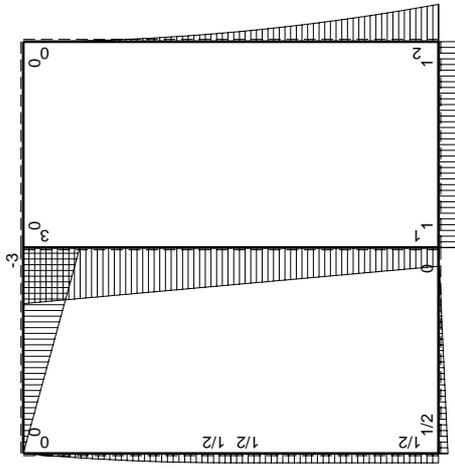
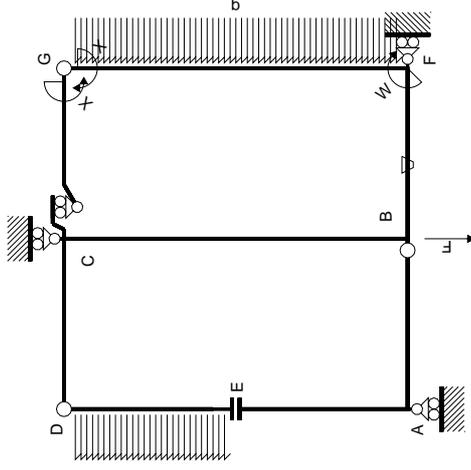
$$\tau_c = 4.576 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 125.7 \text{ N/mm}^2$$

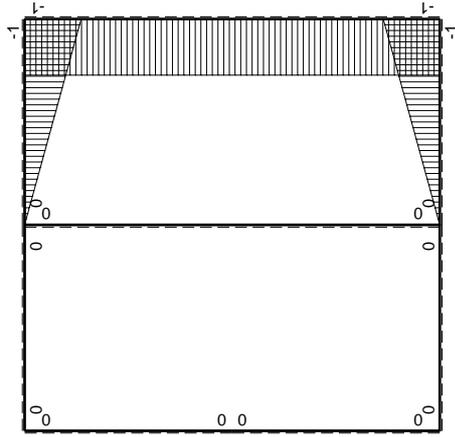
$$S = 3715. \text{ mm}^3$$







$M_x$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M^0(x)$	$M^0(x)$	$\theta$	$M^0 M_0$	$M^0 \theta$	$M^0 M_x$	$\int M^0 (M_0/EJ + \theta) dx$	$\int M^0 M_x/EJ dx$
AB b	0	$1/2Fb-1/2Fx$	0	0	0	0	0+0	0
BA b	0	$-1/2Fx$	0	0	0	0	0+0	0
CD b	0	$-3Fb+3Fx$	0	0	0	0	0+0	0
DC b	0	$3Fx$	0	0	0	0	0+0	0
DE b	0	$Fx-1/2qx^2$	0	0	0	0	0+0	0
ED b	0	$-1/2Fb+1/2qx^2$	0	0	0	0	0+0	0
EA b	0	$1/2Fb$	0	0	0	0	0+0	0
AE b	0	$-1/2Fb$	0	0	0	0	0+0	0
BF b	$-x/b$	$Fb$	$-Fb/EJ$	$-Fx$	$Fx/EJ$	$x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$-Fb$	$Fb/EJ$	$-Fb+Fx$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	$2Fb-2Fx+1/2qx^2$	0	$-2Fb+2Fx-1/2Fx^2/b$	0	1	$(-4/3+0)Fb^2/EJ$	$2xb/EJ$
GF 2b	1	$-1/2qx^2$	0	$-1/2Fx^2/b$	0	1	$(-4/3+0)Fb^2/EJ$	$2xb/EJ$
CB 2b	0	$3Fb-Fx$	0	0	0	0	0+0	0
BC 2b	0	$-Fb-Fx$	0	0	0	0	0+0	0
totali							$-4/3Fb^2/EJ$	$8/3xb/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x_0} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

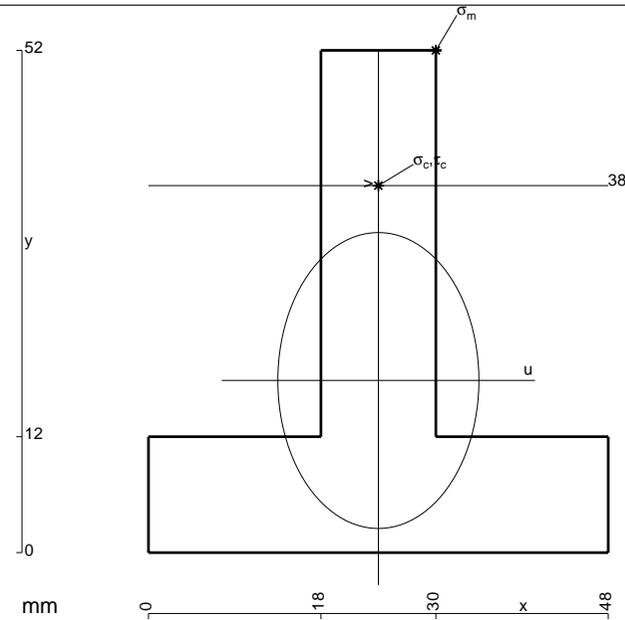
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x_0} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

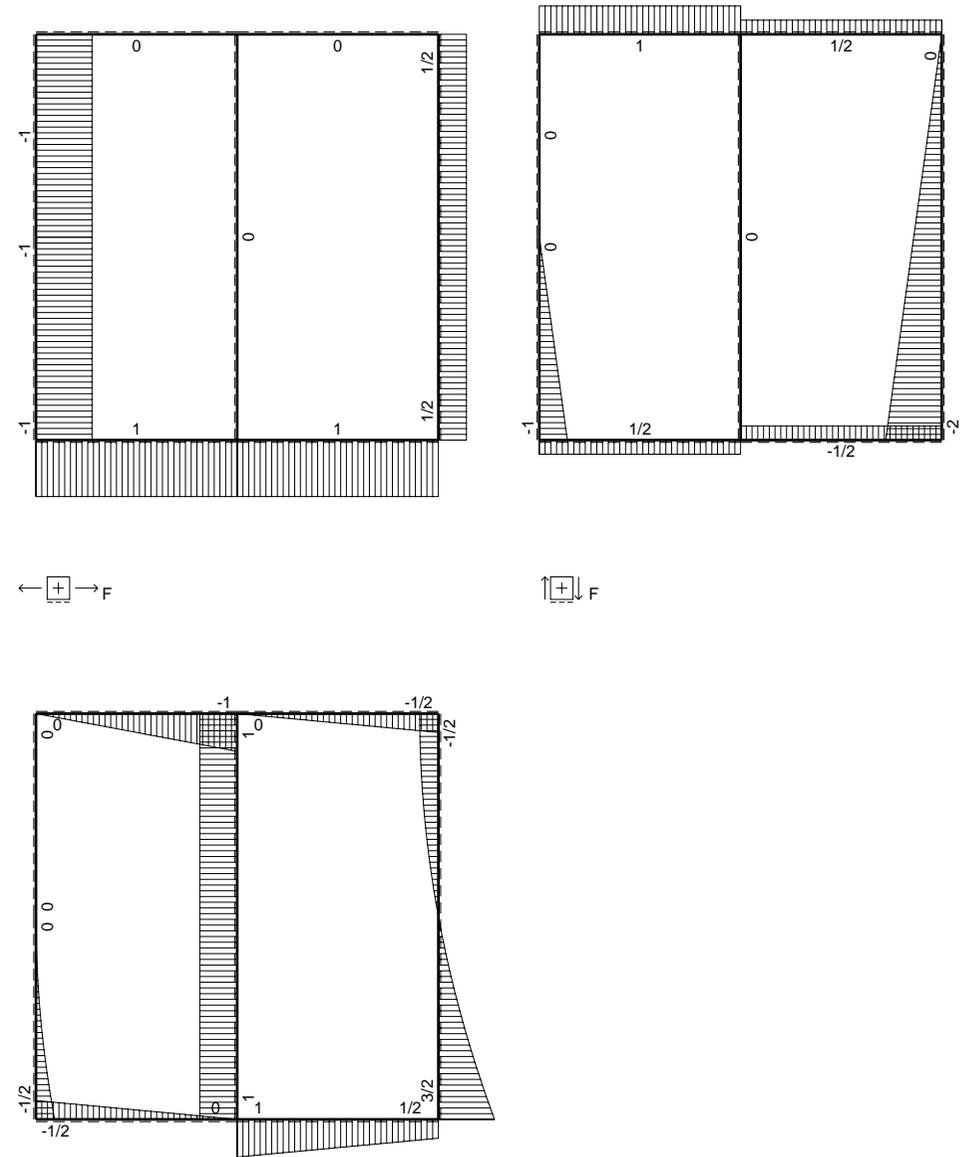
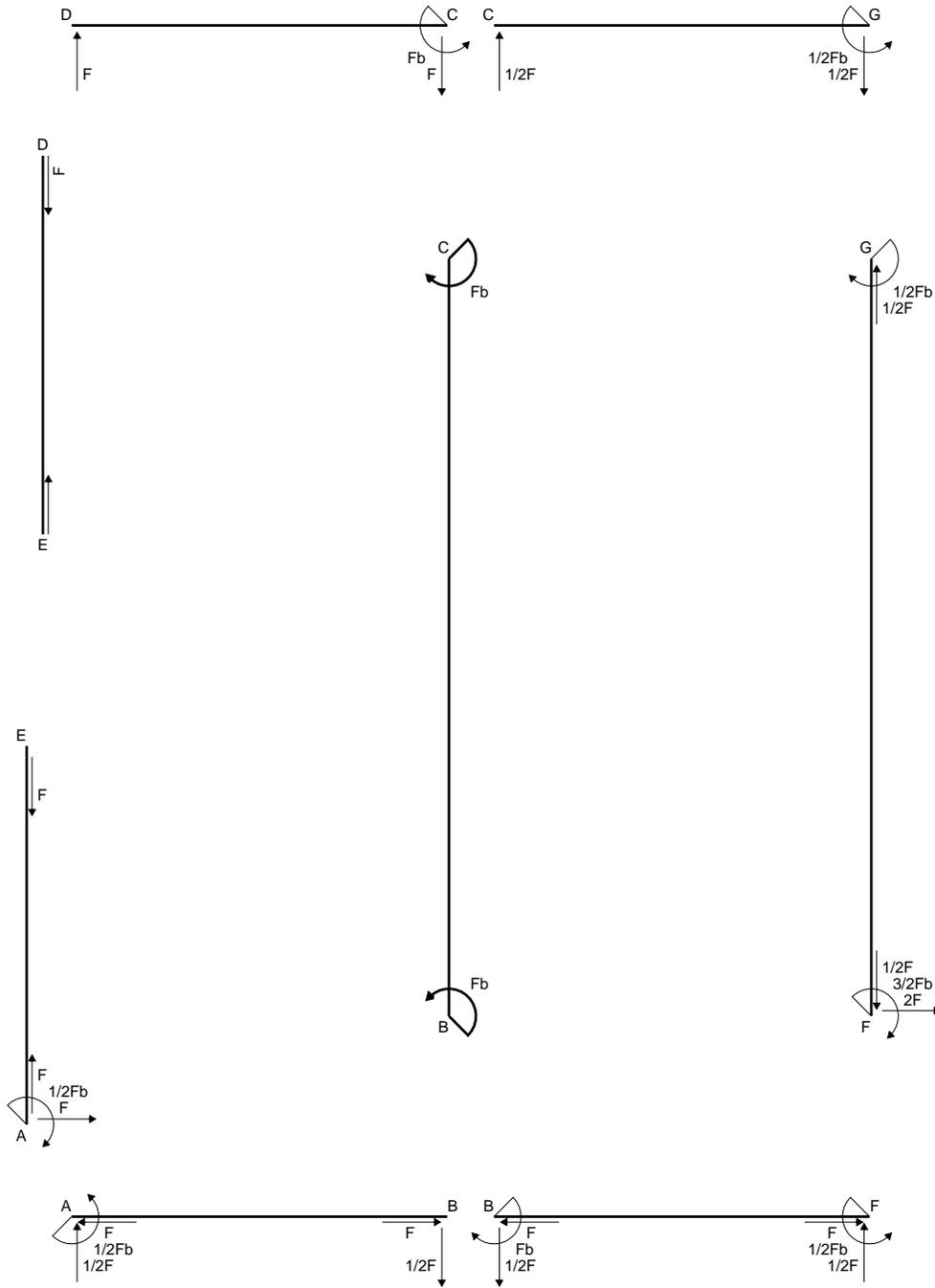
$$L_{GF}^{x_0} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

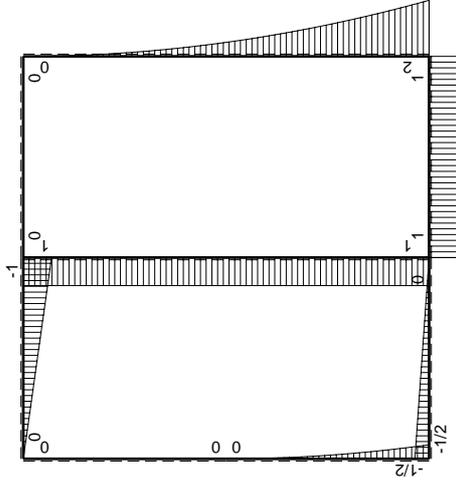
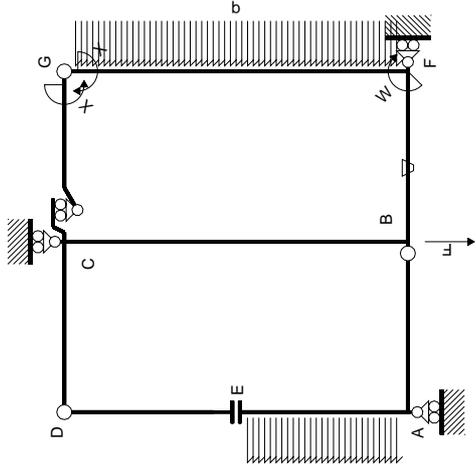
$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



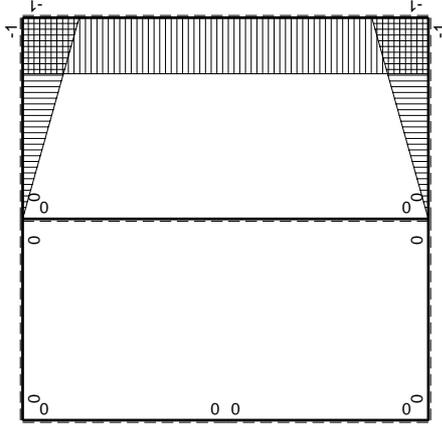
- A = 1056. mm<sup>2</sup>
- J<sub>y</sub> = 247901. mm<sup>4</sup>
- J<sub>x</sub> = 116352. mm<sup>4</sup>
- y<sub>g</sub> = 17.82 mm
- N = 1040. N
- T<sub>y</sub> = 3120. N
- M<sub>x</sub> = -1653600. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 52. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 34.18 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = 229. N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 38. mm
- v<sub>c</sub> = 20.18 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = 135.6 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.789 N/mm<sup>2</sup>
- σ<sub>0</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 135.9 N/mm<sup>2</sup>
- S = 4567. mm<sup>3</sup>







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\leftarrow$	$M(x)$	$M^0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	0	$-1/2Fb+1/2Fx$	0	0	0	0	0+0	0
BA b	0	$1/2Fx$	0	0	0	0	0+0	0
CD b	0	$-Fb+Fx$	0	0	0	0	0+0	0
DC b	0	$Fx$	0	0	0	0	0+0	0
ED b	0	0	0	0	0	0	0+0	0
EA b	0	$-1/2qx^2$	0	0	0	0	0+0	0
AE b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0+0	0
BF b	$-x/b$	$Fb$	$-Fb/EJ$	$-Fx$	$Fx/EJ$	$x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$-Fb$	$Fb/EJ$	$-Fb+Fx$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	$2Fb-2Fx+1/2qx^2$	0	$-2Fb+2Fx-1/2Fx^2/b$	0	1	$(-4/3+0)Fb^2/EJ$	$2xb/EJ$
GF 2b	1	$-1/2qx^2$	0	$-1/2Fx^2/b$	0	1	$(-4/3+0)Fb^2/EJ$	$2xb/EJ$
CB 2b	0	$Fb$	0	0	0	0	0+0	0
BC 2b	0	$-Fb$	0	0	0	0	0+0	0
totali							$-4/3Fb^2/EJ$	$8/3xb/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x_0} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

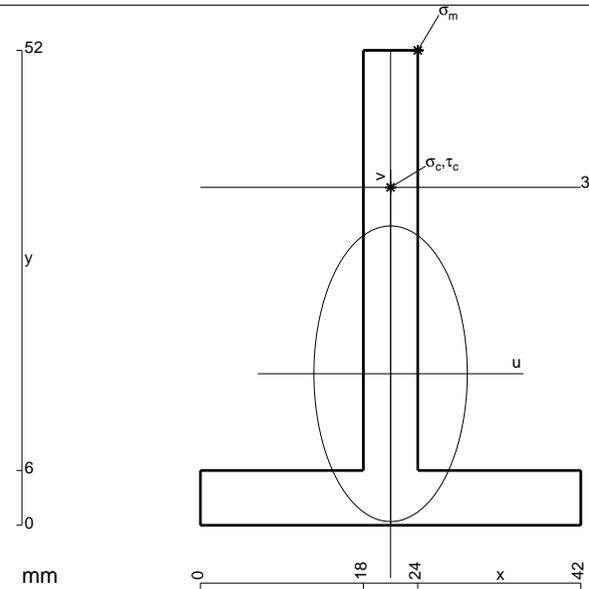
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x_0} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

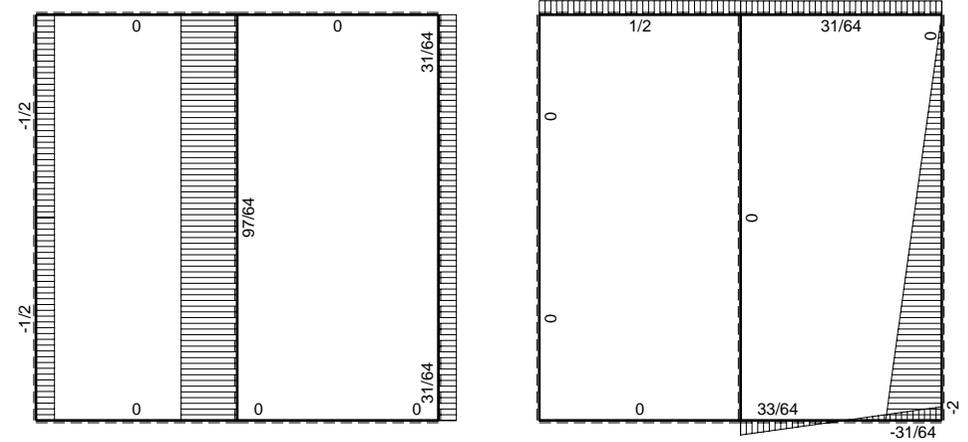
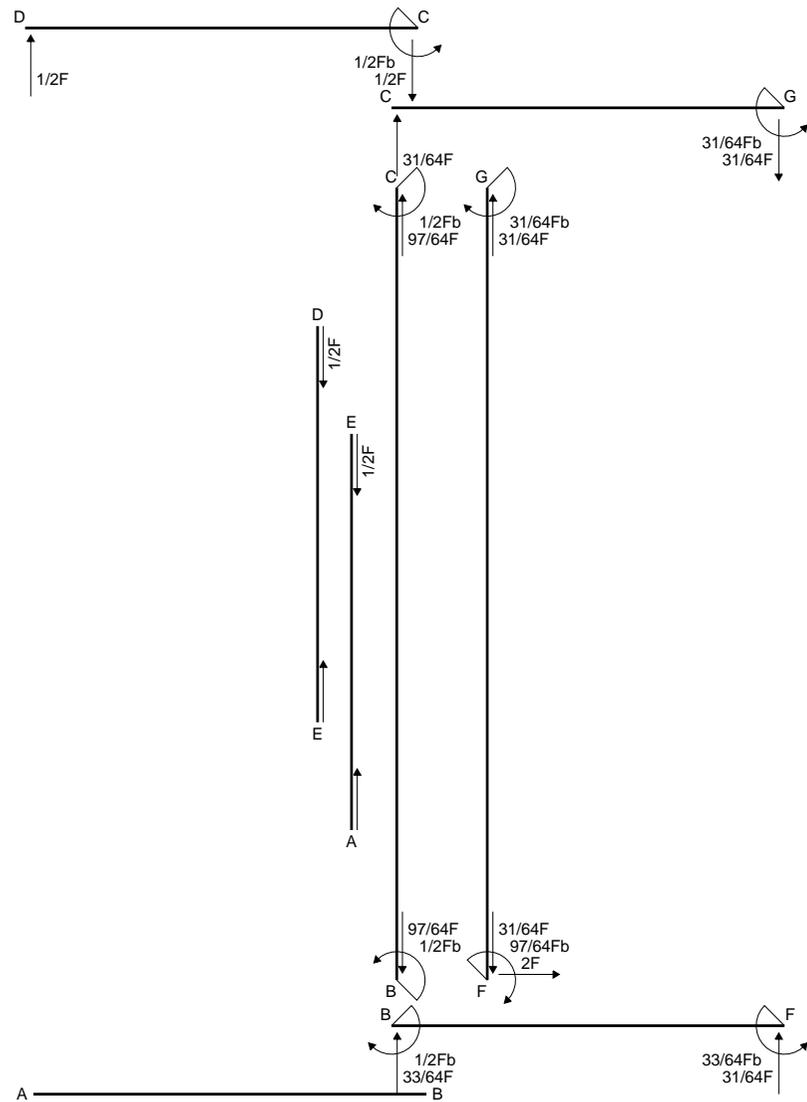
$$L_{GF}^{x_0} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



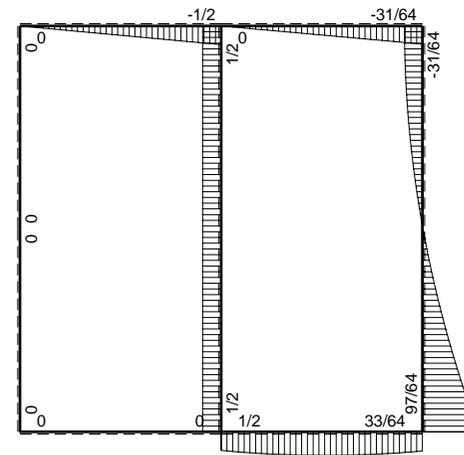
- A = 528. mm<sup>2</sup>
- J<sub>u</sub> = 138472. mm<sup>4</sup>
- J<sub>v</sub> = 37872. mm<sup>4</sup>
- y<sub>g</sub> = 16.59 mm
- T<sub>y</sub> = 1640. N
- M<sub>x</sub> = -934800. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 52. mm
- u<sub>m</sub> = 3. mm
- v<sub>m</sub> = 35.41 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 239. N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 37. mm
- v<sub>c</sub> = 20.41 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 137.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.958 N/mm<sup>2</sup>
- σ<sub>φ</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 138. N/mm<sup>2</sup>
- S = 2512. mm<sup>3</sup>



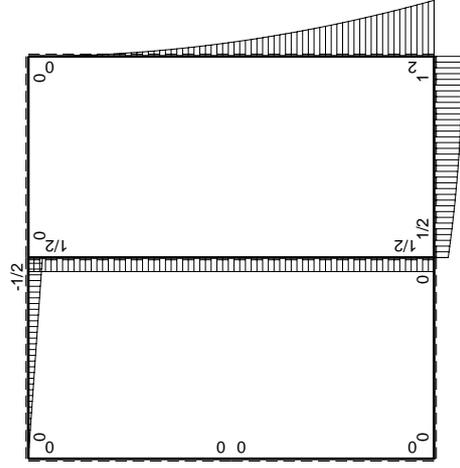
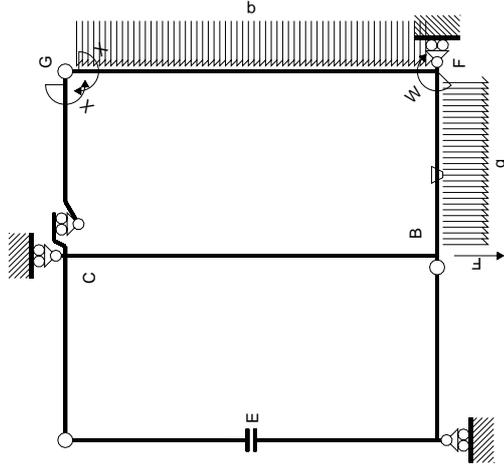


← ⊕ → F

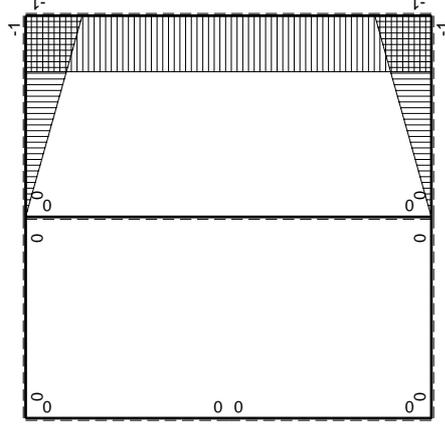
↑ ⊕ ↓ F



⊕ F<sub>b</sub>



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

←	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x (M^0/EJ + \theta) dx$	$\int M^x M^x/EJ dx$	iperstatica X=W <sup>gc</sup>		
									totali	31/64Fb	
AB b	0	0	0	0	0	0	0+0	0	0	0	
BA b	0	0	0	0	0	0	0+0	0	0	0	
CD b	0	-1/2Fb+1/2Fx	0	0	0	0	0+0	0	0	0	
DC b	0	1/2Fx	0	0	0	0	0+0	0	0	0	
DE b	0	0	0	0	0	0	0+0	0	0	0	
EA b	0	0	0	0	0	0	0+0	0	0	0	
AE b	0	0	0	0	0	0	0+0	0	0	0	
BF b	-x/b	1/2Fb+Fx-1/2qx <sup>2</sup>	-Fb/EJ	-1/2Fx-Fx <sup>2</sup> /b+1/2qx <sup>3</sup> /b	Fx/EJ	x <sup>2</sup> /b <sup>2</sup>	(-11/24+1/2)Fb <sup>2</sup> /EJ	1/3xb/EJ	1-x/b	-b+1/2qx <sup>2</sup>	
FB b	1-x/b	-b+1/2qx <sup>2</sup>	Fb/EJ	-b+Fx+1/2Fx <sup>2</sup> /b-1/2qx <sup>3</sup> /b	Fb/EJ-Fx/EJ	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	1/3xb/EJ	1/3xb/EJ	1-x/b	-b+1/2qx <sup>2</sup>	
GC b	-1+x/b	0	0	0	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	0+0	1/3xb/EJ	-1+x/b	0	
CG b	x/b	0	0	0	0	x <sup>2</sup> /b <sup>2</sup>	0+0	1/3xb/EJ	x/b	0	
FG 2b	-1	2Fb-2Fx+1/2qx <sup>2</sup>	0	-2Fb+2Fx-1/2Fx <sup>2</sup> /b	0	1	(-4/3+0)Fb <sup>2</sup> /EJ	2xb/EJ	-1	2Fb-2Fx+1/2qx <sup>2</sup>	
GF 2b	1	-1/2qx <sup>2</sup>	0	-1/2Fx <sup>2</sup> /b	0	1	(-4/3+0)Fb <sup>2</sup> /EJ	2xb/EJ	1	-1/2qx <sup>2</sup>	
CB 2b	0	1/2Fb	0	0	0	0	0+0	8/3xb/EJ	0	1/2Fb	
BC 2b	0	-1/2Fb	0	0	0	0	0+0	8/3xb/EJ	0	-1/2Fb	
totali											

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x\theta} = \int_0^b (-1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

$$= [-1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/4 b - 1/3 b + 1/8 b) Fb 1/EJ + (1/2 b) \theta = 1/24 Fb^2/EJ$$

$$L_{FB}^{x\theta} = \int_0^b (-1 + x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

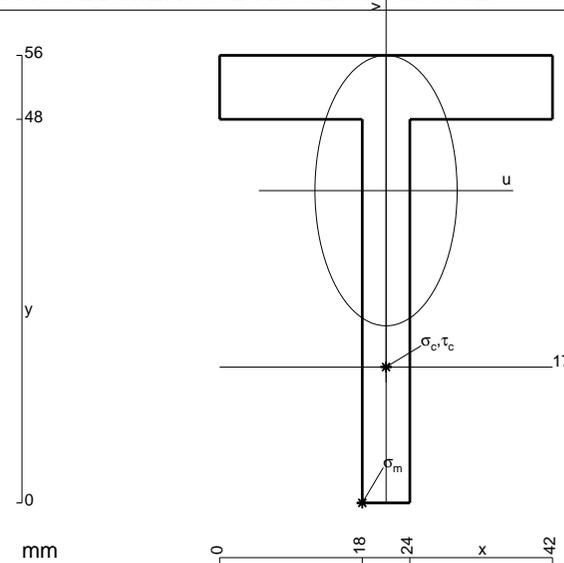
$$= (-b + 1/2 b + 1/6 b - 1/8 b) Fb 1/EJ + (-b + 1/2 b) \theta = 1/24 Fb^2/EJ$$

$$L_{FG}^{x\theta} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

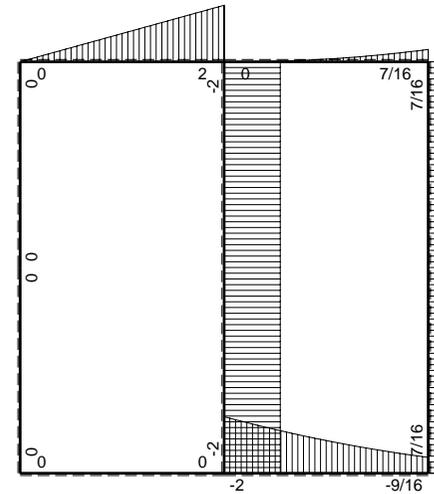
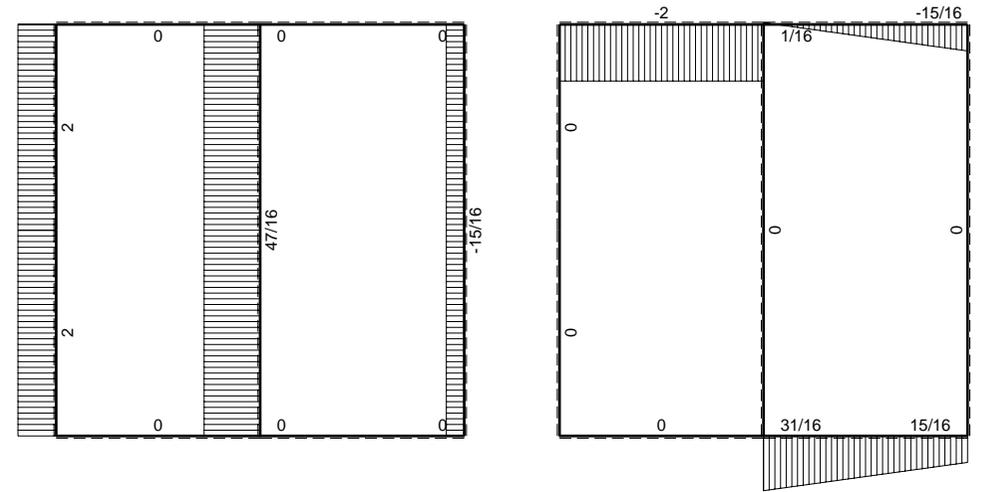
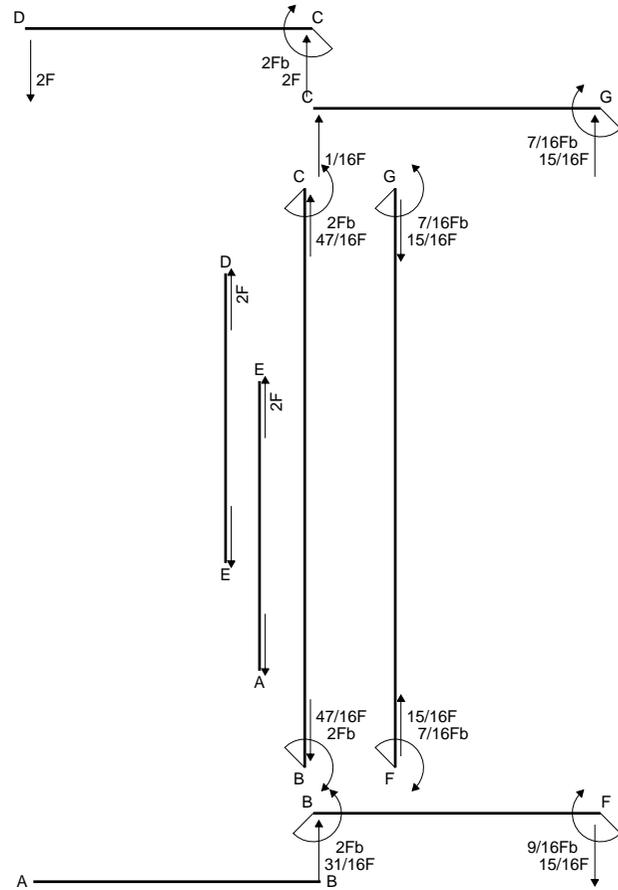
$$L_{GF}^{x\theta} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



$A = 624. \text{ mm}^2$   
 $J_u = 178668. \text{ mm}^4$   
 $J_v = 50256. \text{ mm}^4$   
 $y_g = 39.08 \text{ mm}$   
 $T_y = 1385. \text{ N}$   
 $M_x = -914100. \text{ Nmm}$   
 $x_m = 18. \text{ mm}$   
 $u_m = -3. \text{ mm}$   
 $v_m = -39.08 \text{ mm}$   
 $\sigma_m = -Mv/J_u = -199.9 \text{ N/mm}^2$   
 $x_c = 21. \text{ mm}$   
 $y_c = 17. \text{ mm}$   
 $v_c = -22.08 \text{ mm}$   
 $\sigma_c = -Mv/J_u = -112.9 \text{ N/mm}^2$   
 $\tau_c = 4.029 \text{ N/mm}^2$   
 $\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 113.2 \text{ N/mm}^2$   
 $S = 3119. \text{ mm}^3$







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{xo} = \int_0^b (2x/b - 3/2 x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

$$= [x^2/b - 1/2 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b + 1/8 b) Fb 1/EJ + (1/2 b) \theta = 9/8 Fb^2/EJ$$

$$L_{FB}^{xo} = \int_0^b (1 - 1/2 x/b - 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [x - 1/4 x^2/b - 1/8 x^4/b^3]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

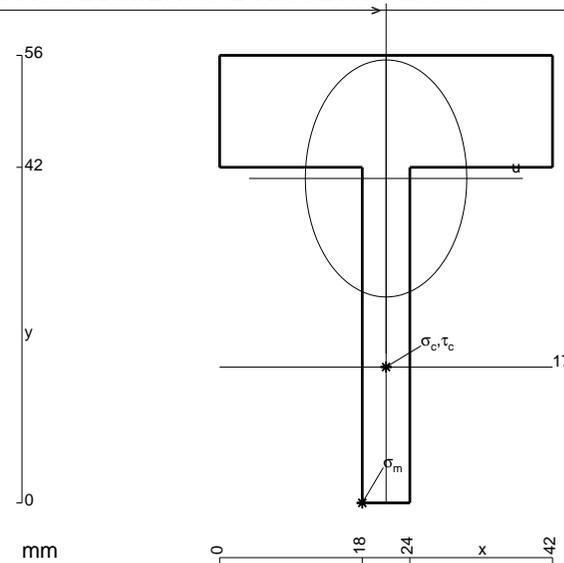
$$= (b - 1/4 b - 1/8 b) Fb 1/EJ + (-b + 1/2 b) \theta = 9/8 Fb^2/EJ$$

$$L_{GC}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

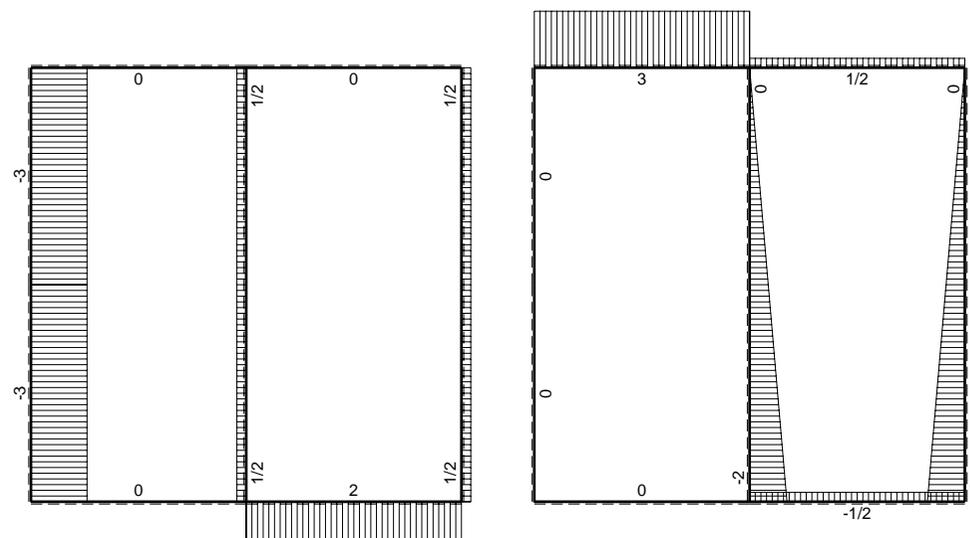
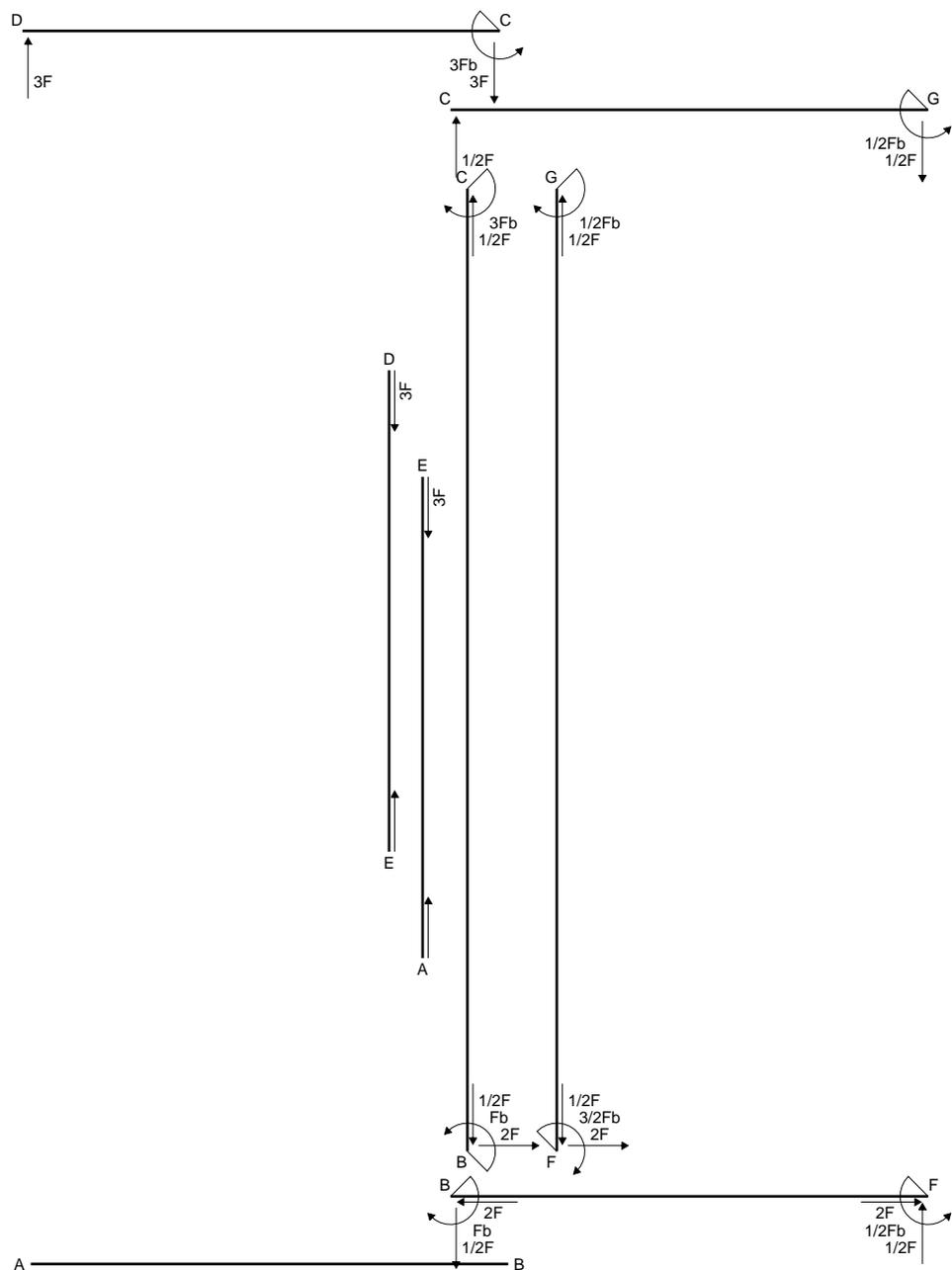
$$L_{CG}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$



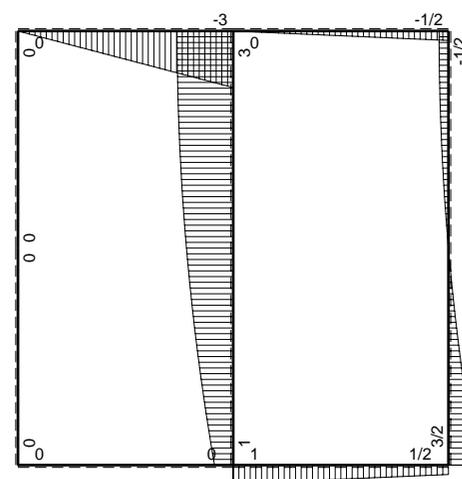
- A = 840. mm<sup>2</sup>
- J<sub>u</sub> = 184946. mm<sup>4</sup>
- J<sub>v</sub> = 87192. mm<sup>4</sup>
- y<sub>g</sub> = 40.6 mm
- T<sub>y</sub> = -1360. N
- M<sub>x</sub> = 952000. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -40.6 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 209. N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 17. mm
- v<sub>c</sub> = -23.6 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 121.5 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.013 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 121.7 N/mm<sup>2</sup>
- S = 3274. mm<sup>3</sup>





← ⊕ → F

↑ ⊕ ↓ F



⊕ Fb



$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x\theta} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x\theta} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

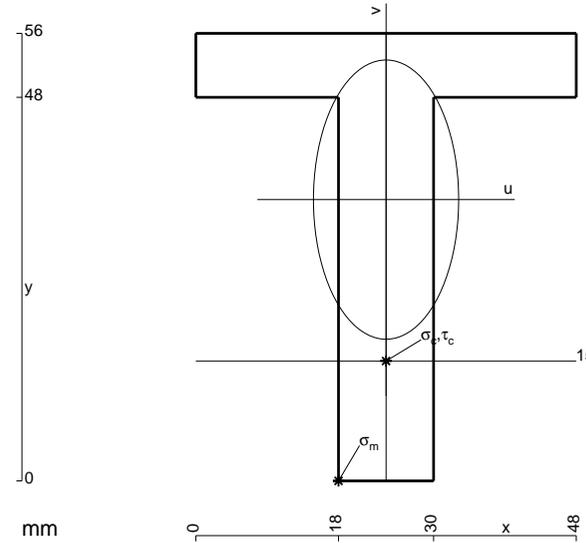
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x\theta} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

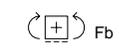
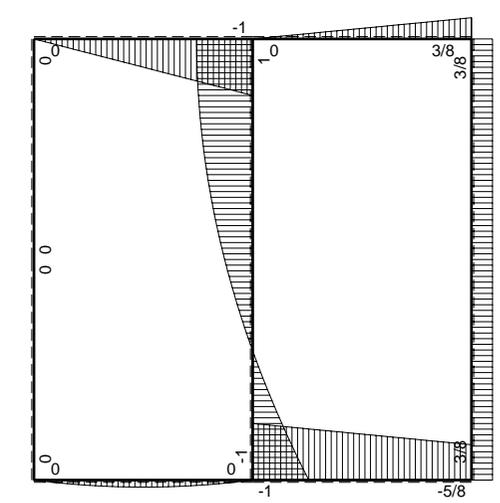
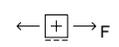
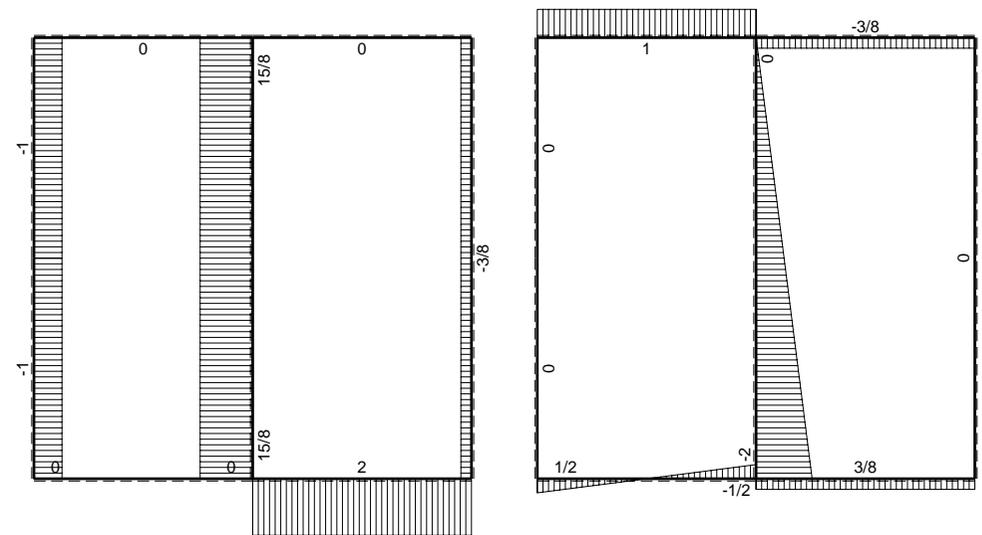
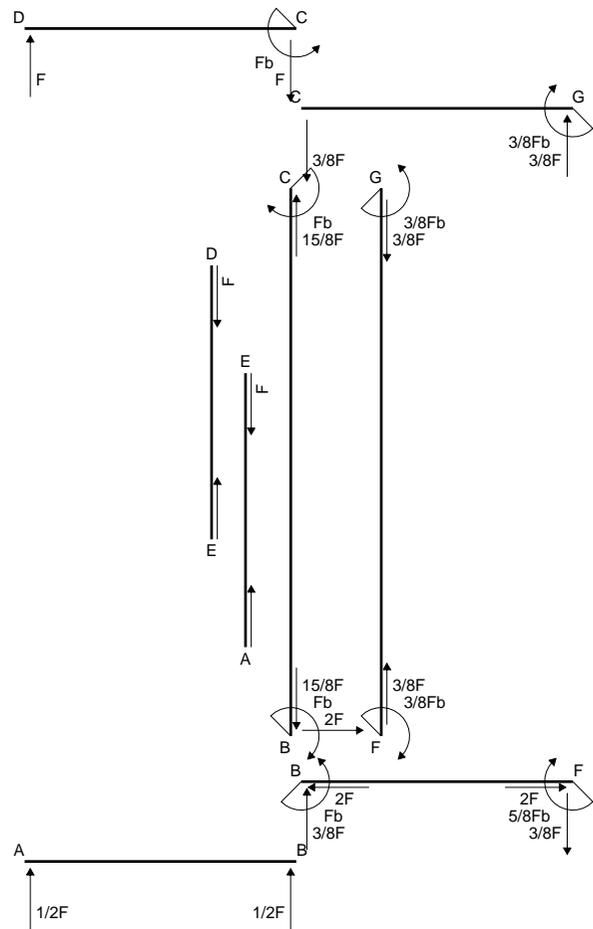
$$L_{GF}^{x\theta} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

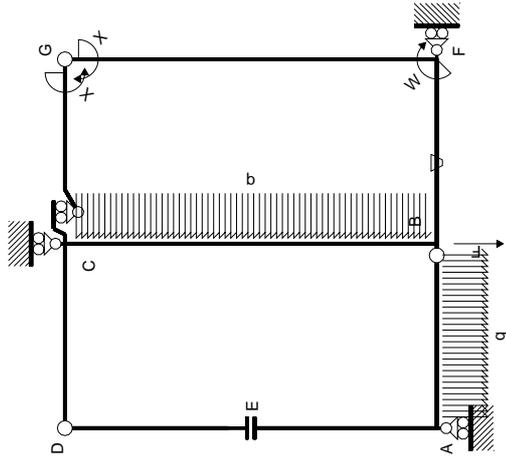
$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



- A = 960. mm<sup>2</sup>
- J<sub>u</sub> = 293274. mm<sup>4</sup>
- J<sub>v</sub> = 80640. mm<sup>4</sup>
- y<sub>g</sub> = 35.2 mm
- T<sub>y</sub> = 2460. N
- M<sub>x</sub> = -1820400. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -35.2 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -218.5 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 15. mm
- v<sub>c</sub> = -20.2 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -125.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.485 N/mm<sup>2</sup>
- σ<sub>ρ</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 125.5 N/mm<sup>2</sup>
- S = 4986. mm<sup>3</sup>

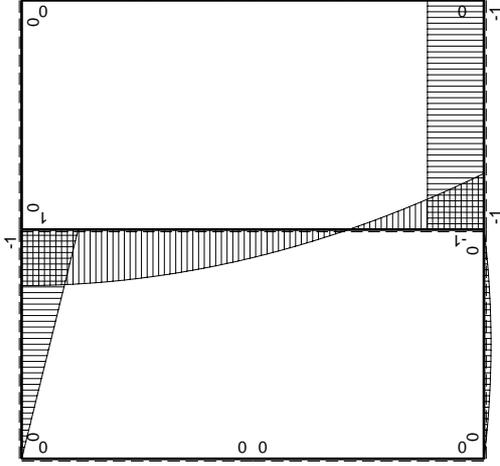






Schema di calcolo iperstatico

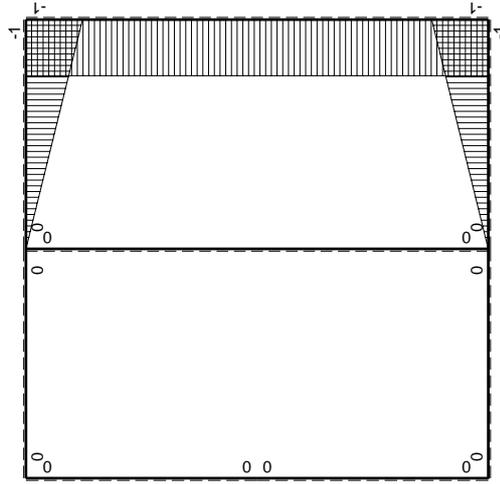
$M_0$  flessione da carichi assegnati



Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M^x(x)$	$M_0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x (M_0/EJ + \theta) dx$	$\int M^x M_x/EJ dx$
AB b	0	$1/2Fx - 1/2qx^2$	0	0	0	0	0+0	0
BA b	0	$-1/2Fx + 1/2qx^2$	0	0	0	0	0+0	0
CD b	0	$-Fb + Fx$	0	0	0	0	0+0	0
DC b	0	$Fx$	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
EA b	0	0	0	0	0	0	0+0	0
AE b	0	0	0	0	0	0	0+0	0
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb-Fx$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$1/3xb/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2xb/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2xb/EJ$
CB 2b	0	$Fb - 1/2qx^2$	0	0	0	0	0+0	0
BC 2b	0	$Fb - 2Fx + 1/2qx^2$	0	0	0	0	0+0	0
totali								$Fb^2/EJ$
								$8/3xb/EJ$

Sviluppi di calcolo iperstatica



$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

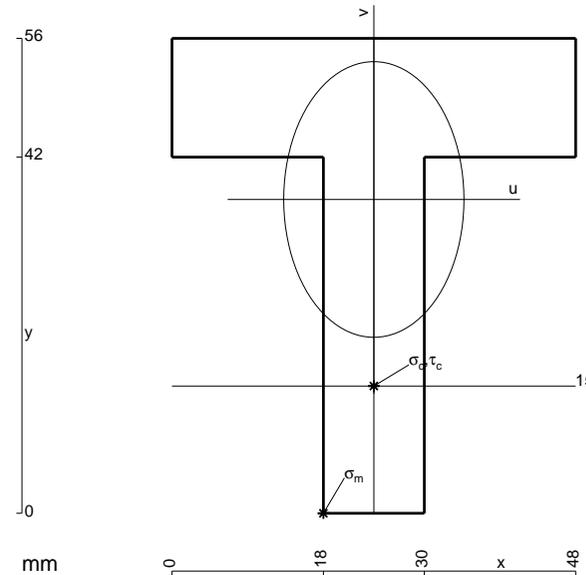
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



$$A = 1176. \text{ mm}^2$$

$$J_u = 310856. \text{ mm}^4$$

$$J_v = 135072. \text{ mm}^4$$

$$y_g = 37. \text{ mm}$$

$$N = 4650. \text{ N}$$

$$T_y = -4960. \text{ N}$$

$$M_x = -1959200. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$u_m = -6. \text{ mm}$$

$$v_m = -37. \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -229.2 \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 15. \text{ mm}$$

$$v_c = -22. \text{ mm}$$

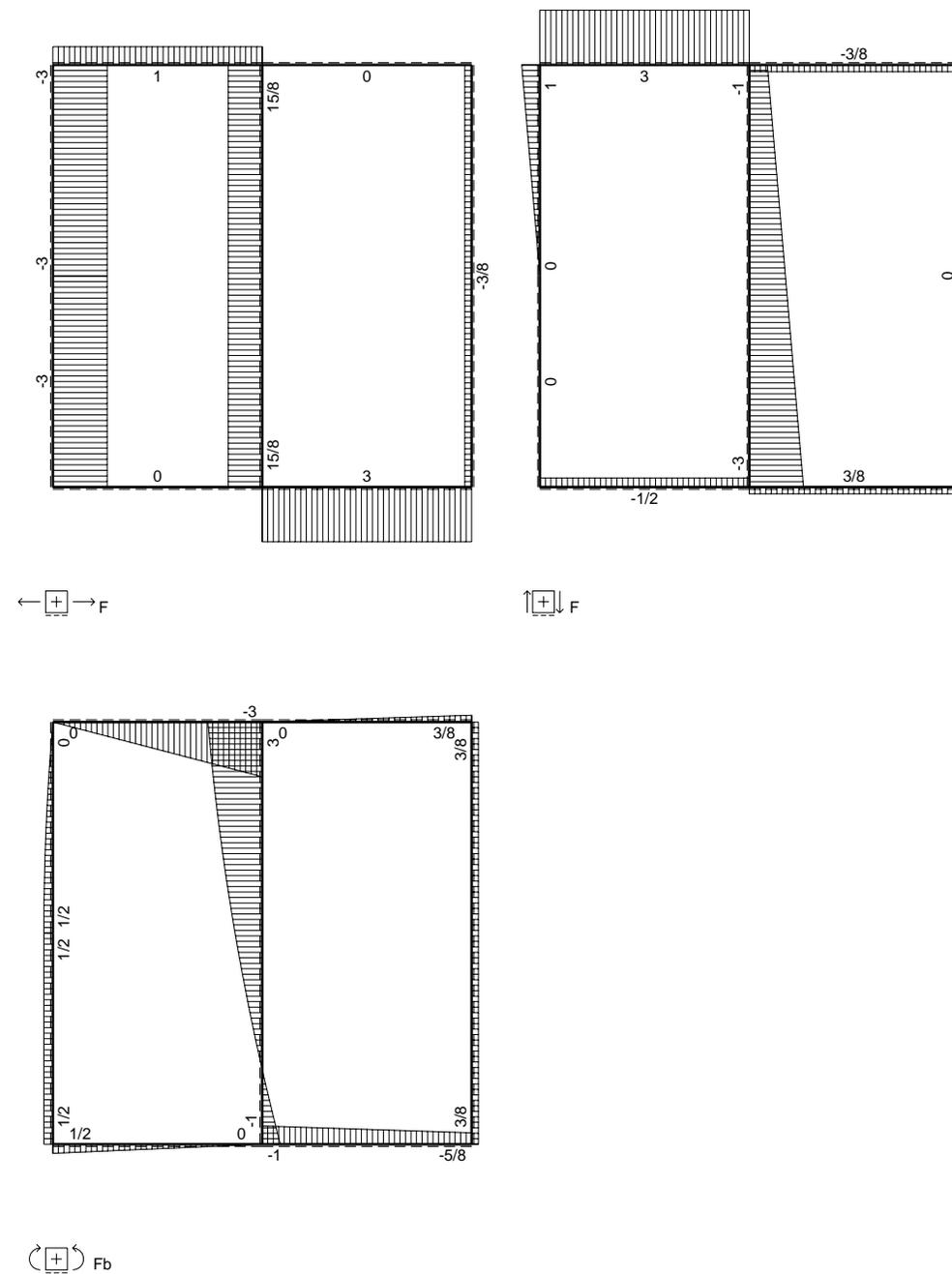
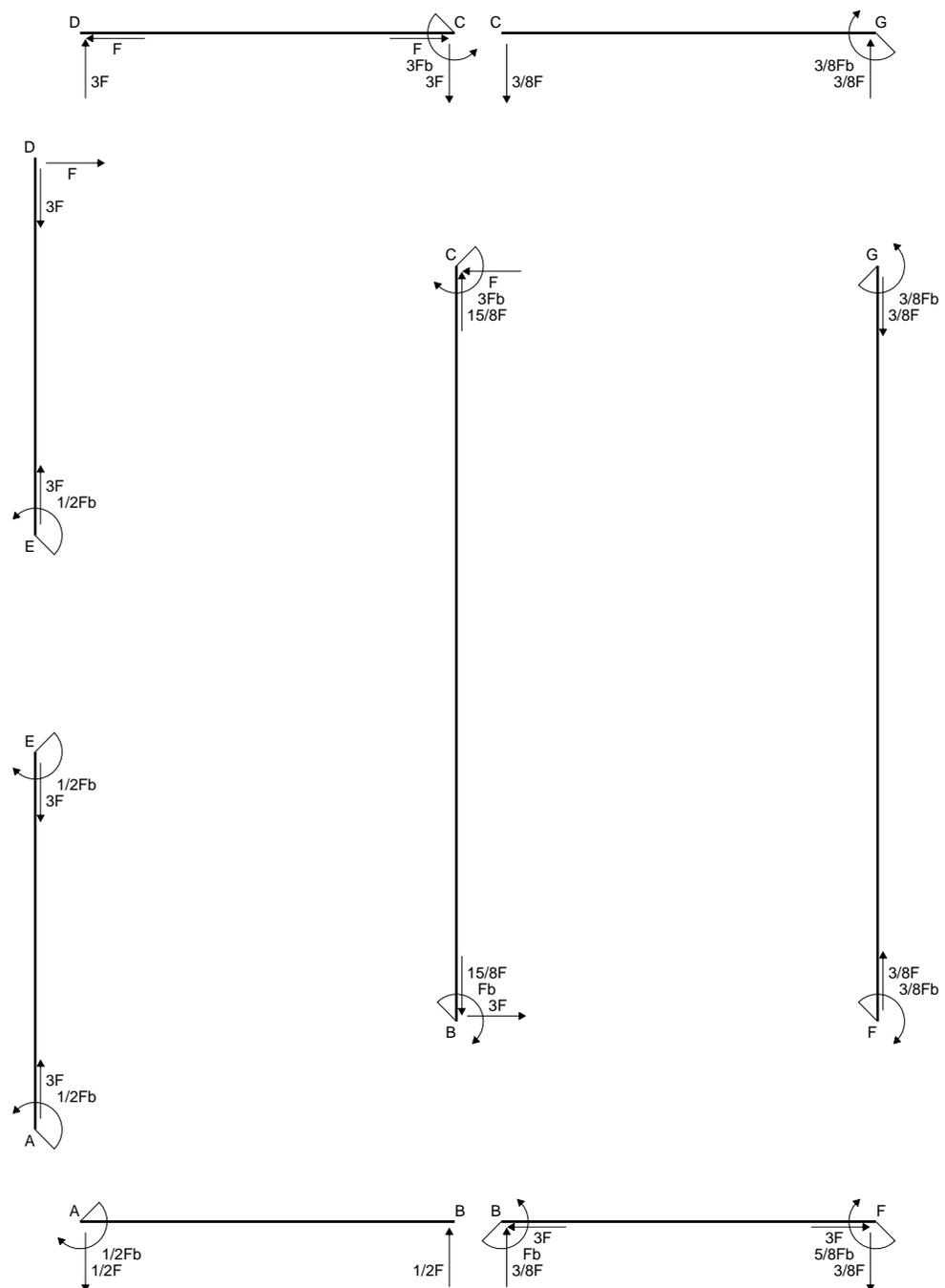
$$\sigma_c = N/A - Mv/J_u = -134.7 \text{ N/mm}^2$$

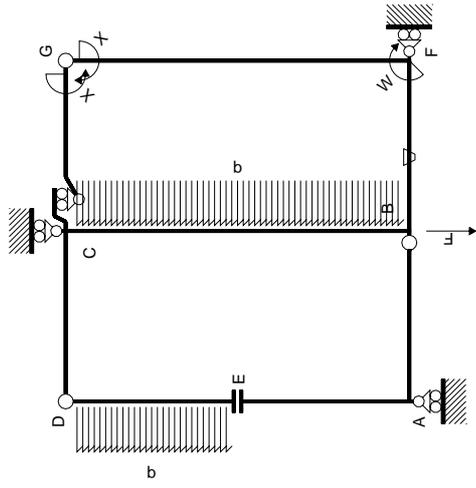
$$\tau_c = 7.061 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 135.3 \text{ N/mm}^2$$

$$S = 5310. \text{ mm}^3$$

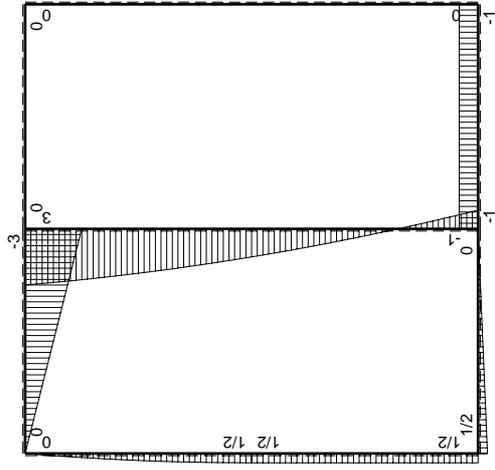






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / EJ dx$
AB b	0	$1/2Fb - 1/2Fx$	0	0	0	0	0+0	0
BA b	0	$-1/2Fx$	0	0	0	0	0+0	0
CD b	0	$-3Fb + 3Fx$	0	0	0	0	0+0	0
DC b	0	$3Fx$	0	0	0	0	0+0	0
DE b	0	$Fx - 1/2qx^2$	0	0	0	0	0+0	0
ED b	0	$-1/2Fb + 1/2qx^2$	0	0	0	0	0+0	0
EA b	0	$1/2Fb$	0	0	0	0	0+0	0
AE b	0	$-1/2Fb$	0	0	0	0	0+0	0
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$Fb/EJ - Fx/EJ$	$(1/2 + 1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb - Fx$	$Fb/EJ - Fx/EJ$	$Fb/EJ - Fx/EJ$	$1-2x/b + x^2/b^2$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	0	$1-2x/b + x^2/b^2$	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	0	$x^2/b^2$	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	0	0+0	$2xb/EJ$
GF 2b	1	0	0	0	0	0	0+0	$2xb/EJ$
CB 2b	0	$3Fb - Fx - 1/2qx^2$	0	0	0	0	0+0	0
BC 2b	0	$Fb - 3Fx + 1/2qx^2$	0	0	0	0	0+0	0
totali								$Fb^2/EJ$
								$8/3xb/EJ$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

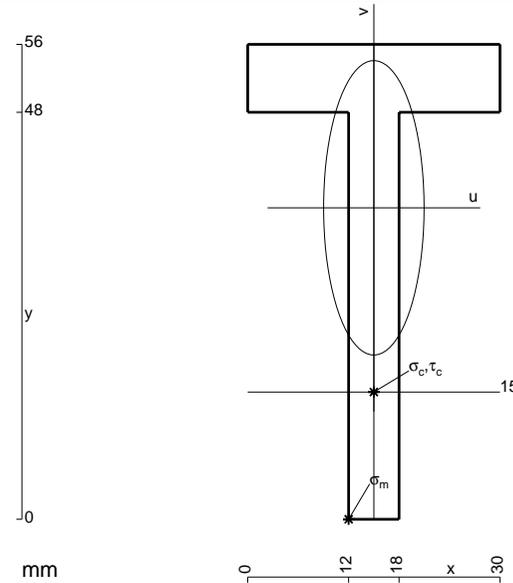
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



$$A = 528. \text{ mm}^2$$

$$J_u = 159209. \text{ mm}^4$$

$$J_v = 18864. \text{ mm}^4$$

$$y_g = 36.73 \text{ mm}$$

$$N = 410. \text{ N}$$

$$T_y = 1230. \text{ N}$$

$$M_x = -1020900. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -36.73 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -234.7 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = -21.73 \text{ mm}$$

$$v_c = -21.73 \text{ mm}$$

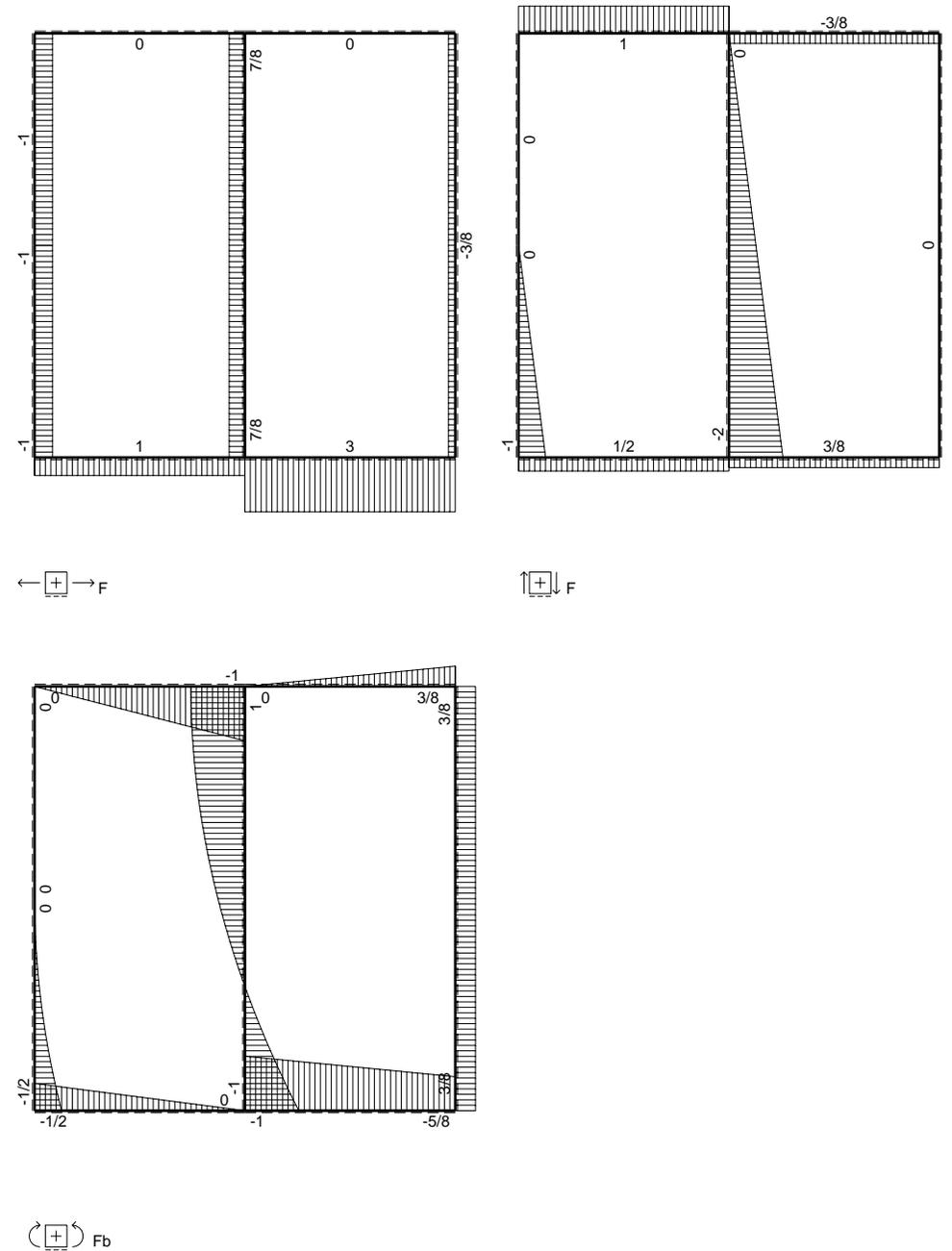
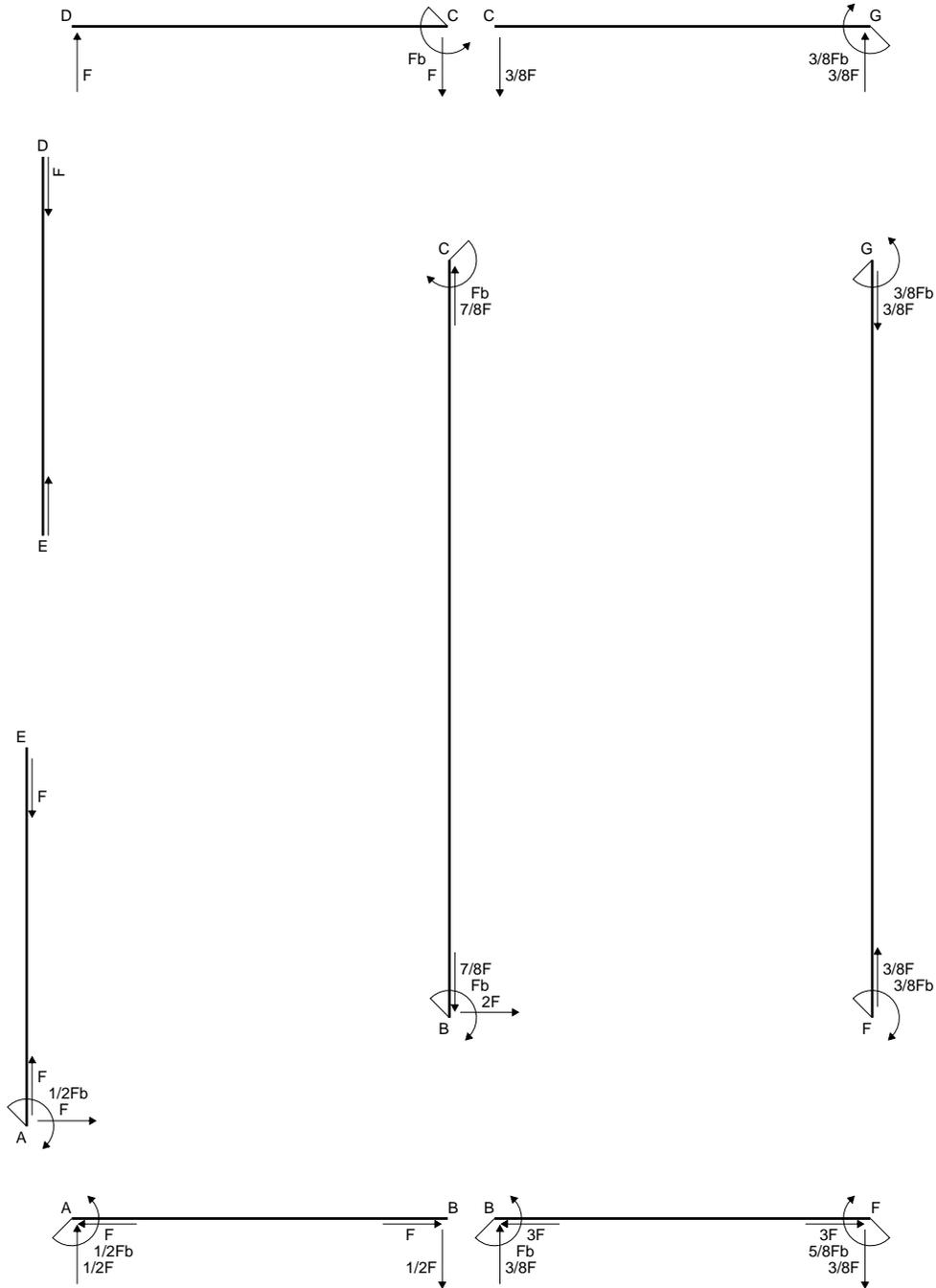
$$\sigma_c = N/A - Mv/J_u = -138.5 \text{ N/mm}^2$$

$$\tau_c = 3.387 \text{ N/mm}^2$$

$$\sigma_x = \sqrt{\sigma^2 + 3\tau^2} = 138.7 \text{ N/mm}^2$$

$$S = 2630. \text{ mm}^3$$







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

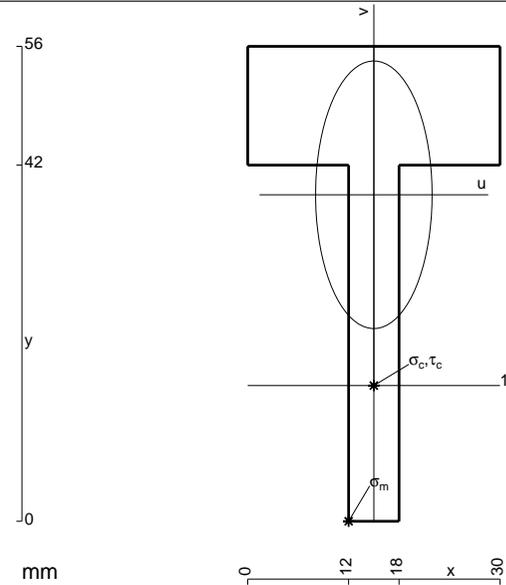
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

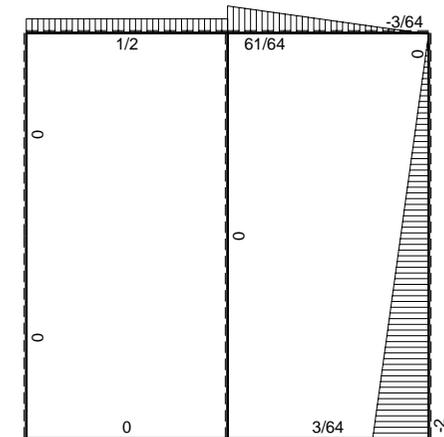
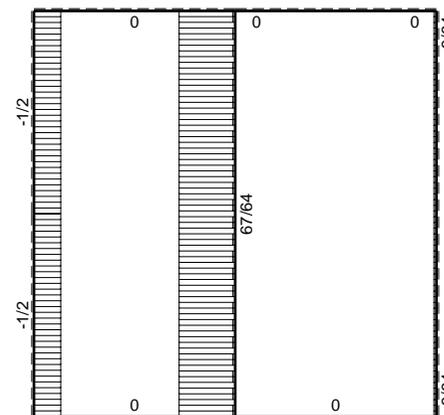
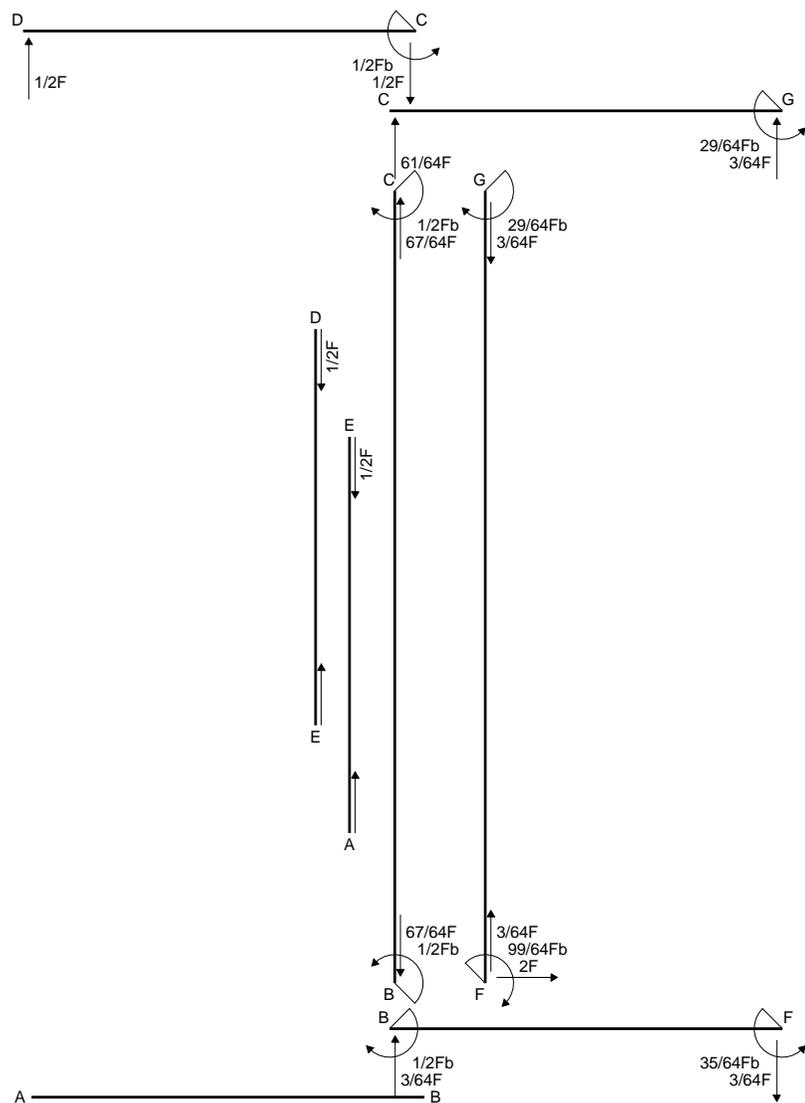
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



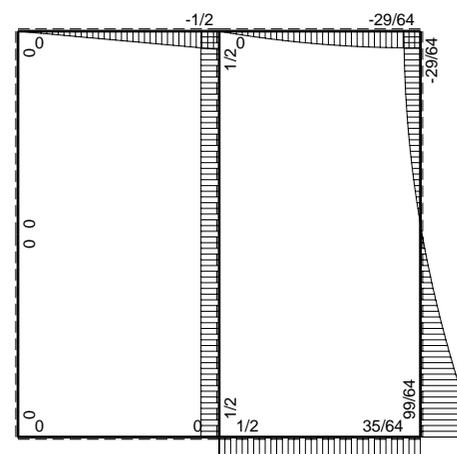
- A = 672. mm<sup>2</sup>
- J<sub>u</sub> = 167384. mm<sup>4</sup>
- J<sub>v</sub> = 32256. mm<sup>4</sup>
- y<sub>g</sub> = 38.5 mm
- N = 1750. N
- T<sub>y</sub> = -4000. N
- M<sub>x</sub> = -880000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -38.5 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = -199.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 15. mm
- y<sub>c</sub> = 16. mm
- v<sub>c</sub> = -22.5 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = -115.7 N/mm<sup>2</sup>
- τ<sub>c</sub> = 11.66 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 117.4 N/mm<sup>2</sup>
- S = 2928. mm<sup>3</sup>





← ⊕ → F

↑ ⊕ ↓ F



⊕ F<sub>b</sub>



$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{xo} = \int_0^b (-1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

$$= [-1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/4 b - 1/6 b) Fb 1/EJ + (1/2 b) \theta = 1/12 Fb^2/EJ$$

$$L_{FB}^{xo} = \int_0^b (-1 + 3/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 3/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (-b + 3/4 b - 1/6 b) Fb 1/EJ + (-b + 1/2 b) \theta = 1/12 Fb^2/EJ$$

$$L_{GC}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{CG}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

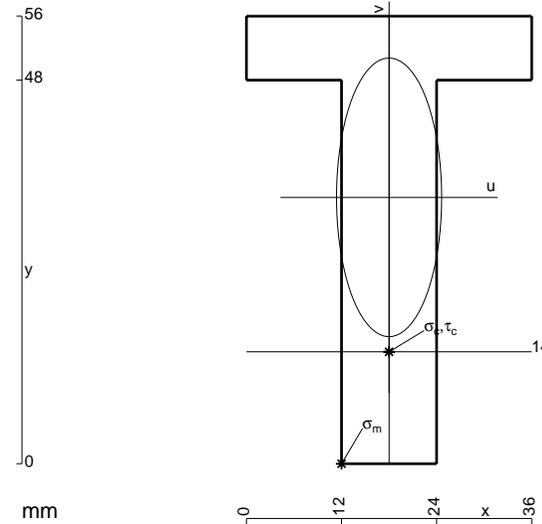
$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{FG}^{xo} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

$$L_{GF}^{xo} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



$$A = 864. \text{ mm}^2$$

$$J_u = 262656. \text{ mm}^4$$

$$J_v = 38016. \text{ mm}^4$$

$$y_g = 33.33 \text{ mm}$$

$$T_y = 3445. \text{ N}$$

$$M_x = -1653600. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -6. \text{ mm}$$

$$v_m = -33.33 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -209.9 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 14. \text{ mm}$$

$$v_c = -19.33 \text{ mm}$$

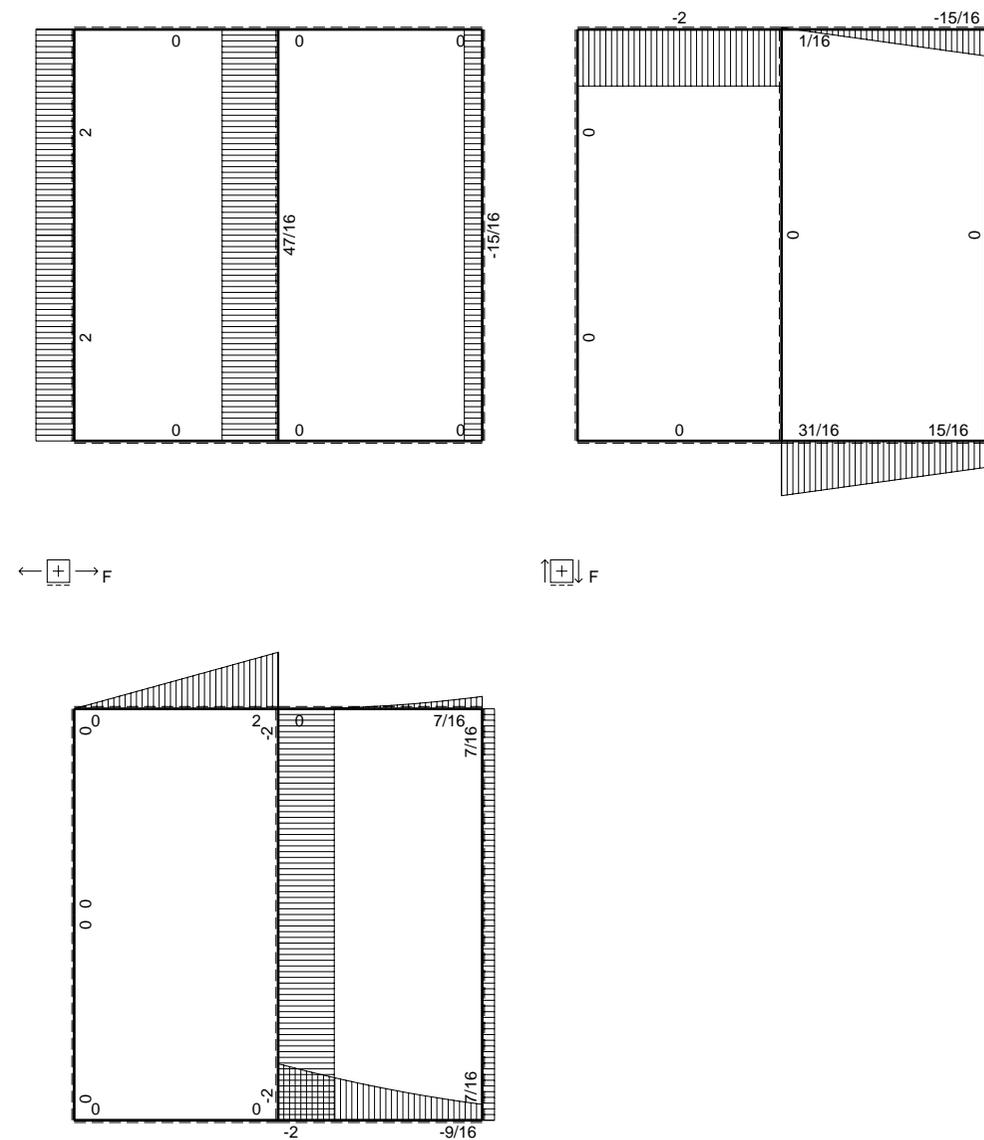
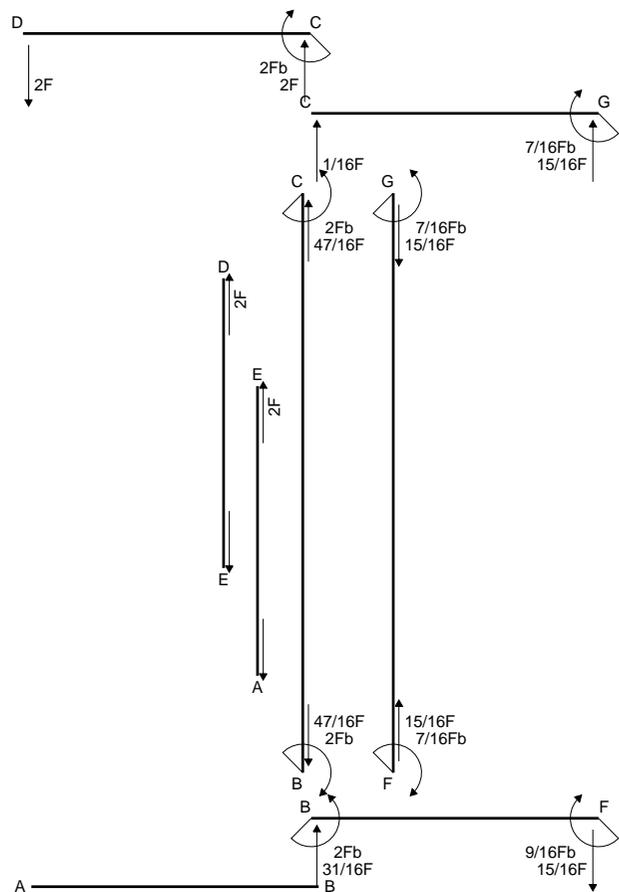
$$\sigma_c = -Mv/J_u = -121.7 \text{ N/mm}^2$$

$$\tau_c = 4.835 \text{ N/mm}^2$$

$$\sigma_o = \sqrt{\sigma^2 + 3\tau^2} = 122. \text{ N/mm}^2$$

$$S = 4424. \text{ mm}^3$$







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{xo} = \int_0^b (2x/b - 3/2 x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

$$= [x^2/b - 1/2 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b + 1/8 b) Fb 1/EJ + (1/2 b) \theta = 9/8 Fb^2/EJ$$

$$L_{FB}^{xo} = \int_0^b (1 - 1/2 x/b - 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [x - 1/4 x^2/b - 1/8 x^4/b^3]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

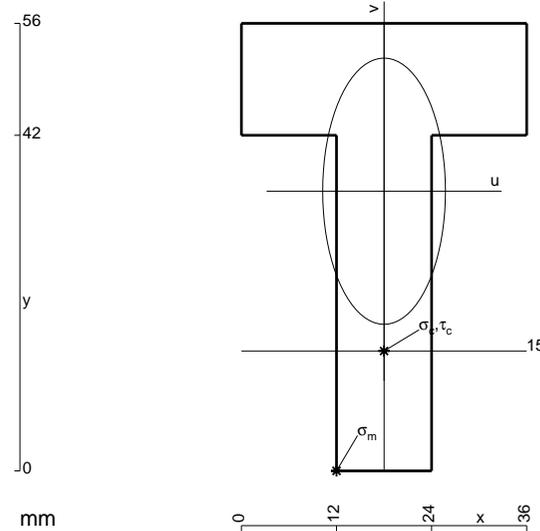
$$= (b - 1/4 b - 1/8 b) Fb 1/EJ + (-b + 1/2 b) \theta = 9/8 Fb^2/EJ$$

$$L_{GC}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

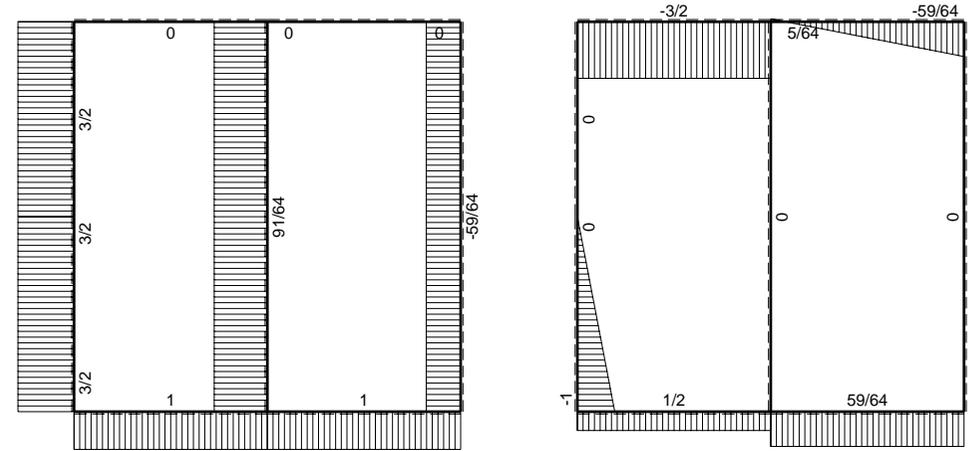
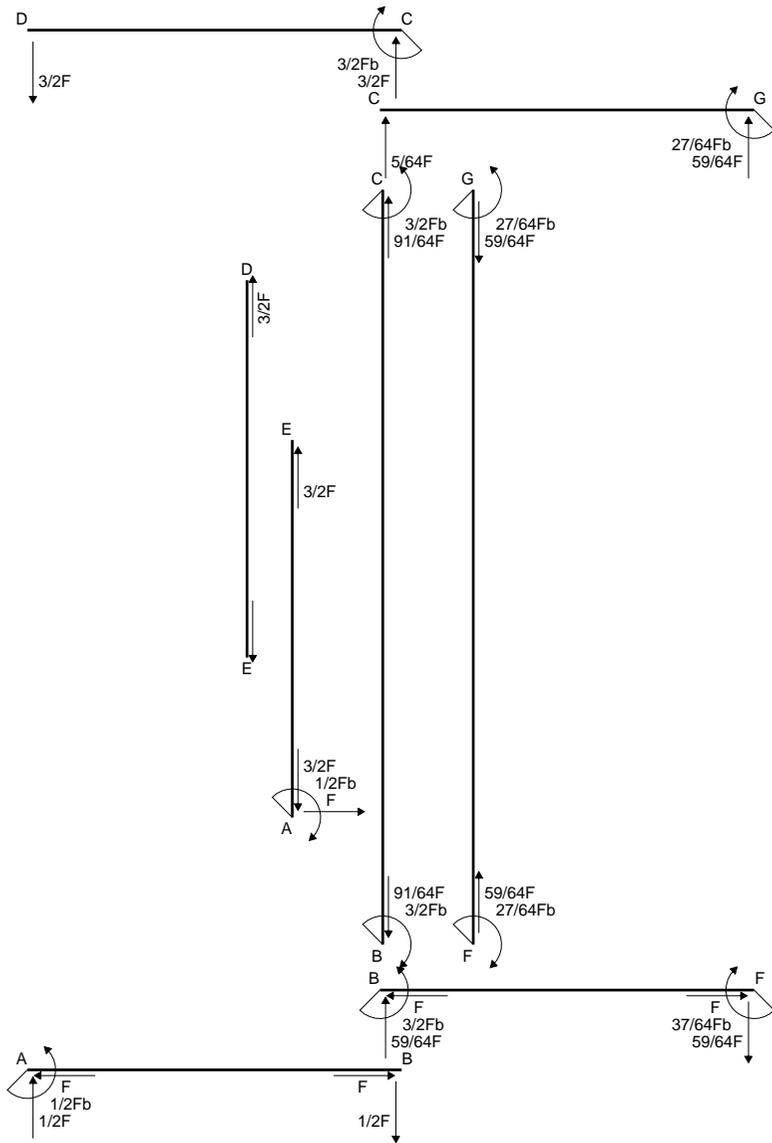
$$L_{CG}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$



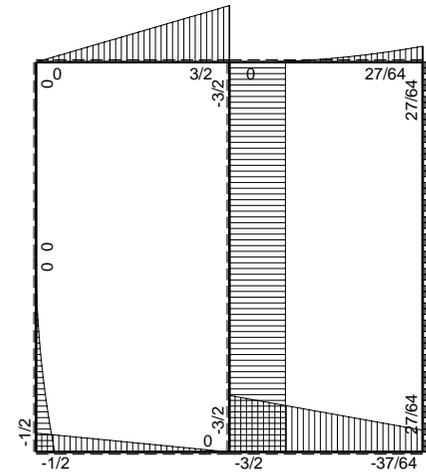
- A = 1008. mm<sup>2</sup>
- J<sub>u</sub> = 279888. mm<sup>4</sup>
- J<sub>v</sub> = 60480. mm<sup>4</sup>
- y<sub>g</sub> = 35. mm
- T<sub>y</sub> = -3380. N
- M<sub>x</sub> = 1757600. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -35. mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 219.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 15. mm
- v<sub>c</sub> = -20. mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 125.6 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.981 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 125.9 N/mm<sup>2</sup>
- S = 4950. mm<sup>3</sup>





← ⊕ → F

↑ ⊕ ↓ F



⊕ ⊖ F<sub>b</sub>



$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{xo} = \int_0^b (3/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

$$= [3/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (3/4 b - 1/6 b) Fb 1/EJ + (1/2 b) \theta = 13/12 Fb^2/EJ$$

$$L_{FB}^{xo} = \int_0^b (1 - 1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [x - 1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

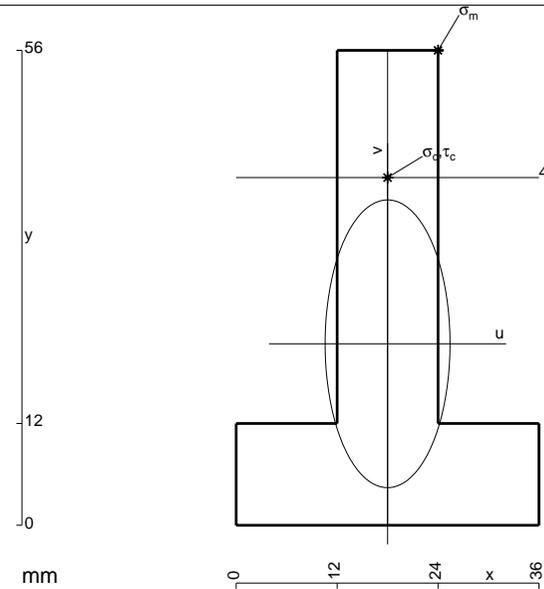
$$= (b - 1/4 b - 1/6 b) Fb 1/EJ + (-b + 1/2 b) \theta = 13/12 Fb^2/EJ$$

$$L_{GC}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

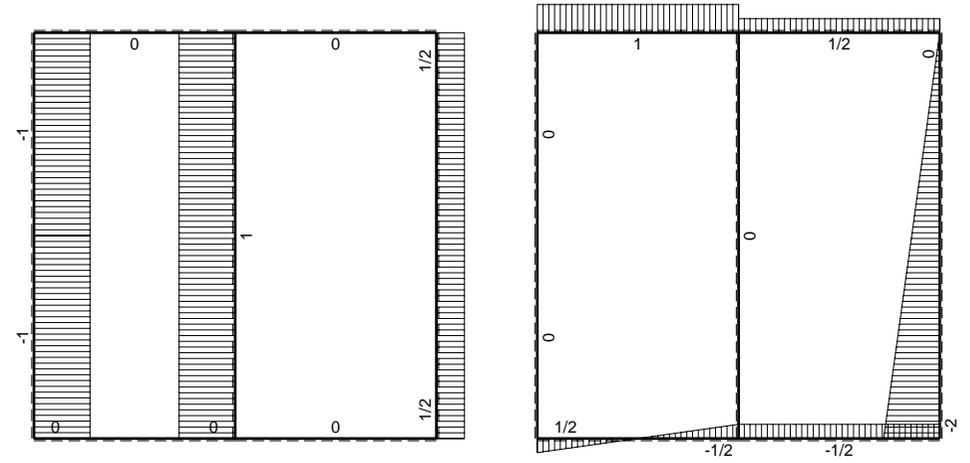
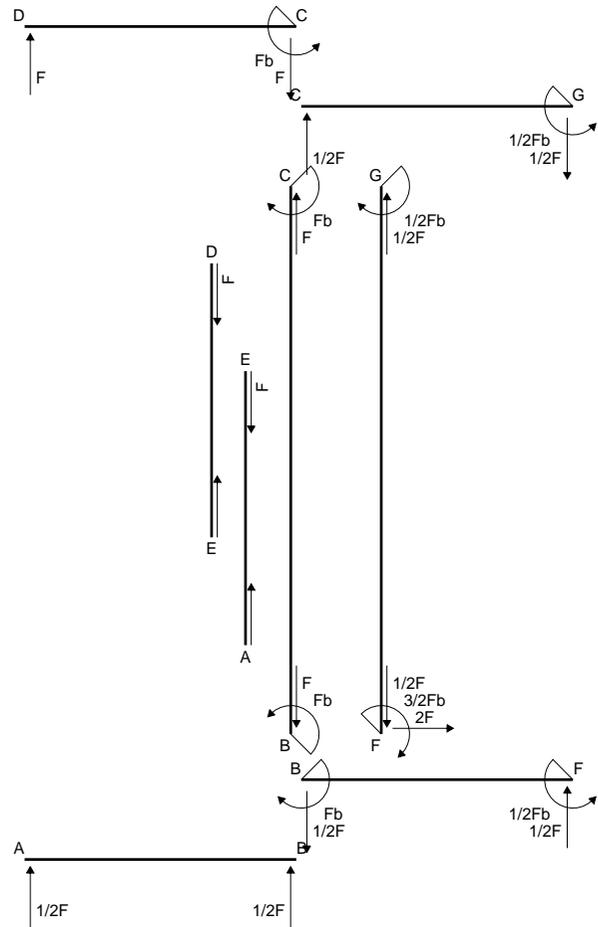
$$L_{CG}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$



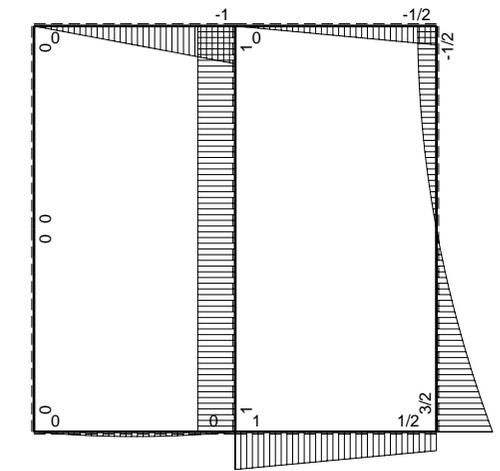
- A = 960. mm<sup>2</sup>
- J<sub>u</sub> = 276646. mm<sup>4</sup>
- J<sub>v</sub> = 52992. mm<sup>4</sup>
- y<sub>g</sub> = 21.4 mm
- T<sub>y</sub> = -3225. N
- M<sub>x</sub> = 1838250. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 56. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 34.6 mm
- σ<sub>m</sub> = -M<sub>v</sub>/J<sub>u</sub> = -229.9 N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 41. mm
- v<sub>c</sub> = 19.6 mm
- σ<sub>c</sub> = -M<sub>v</sub>/J<sub>u</sub> = -130.2 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.739 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 = 4878. mm<sup>3</sup>





← ⊕ → F

↑ ⊕ ↓ F



⊕ ⊖ F<sub>b</sub>



$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x_0} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

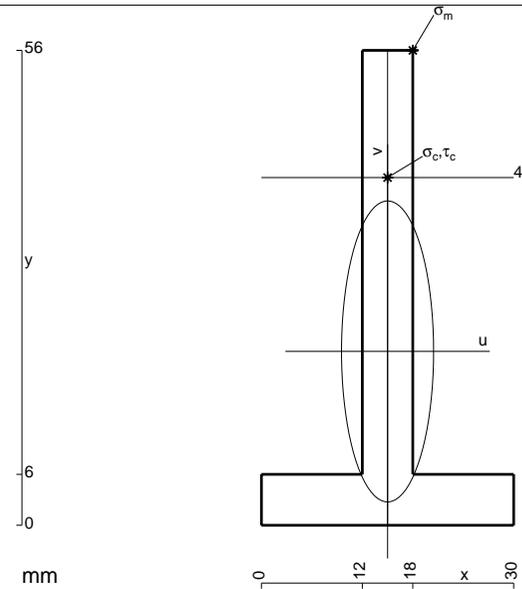
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x_0} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

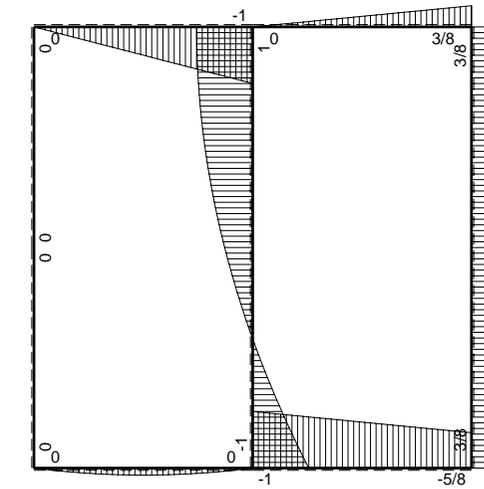
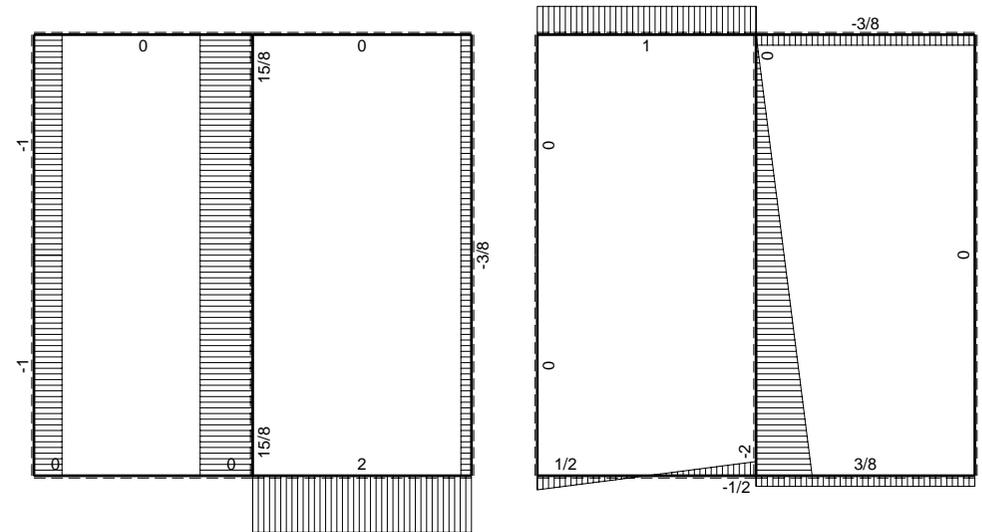
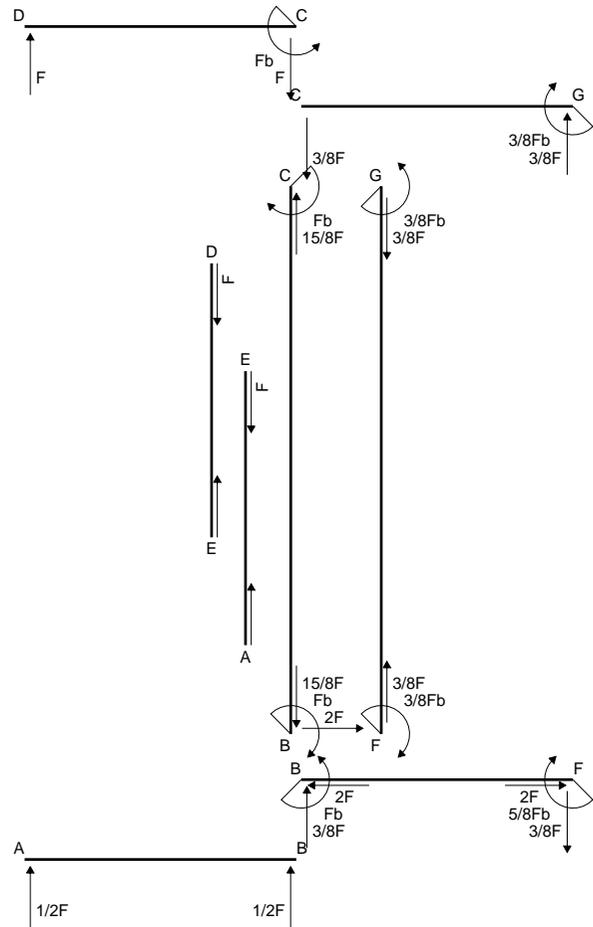
$$L_{GF}^{x_0} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

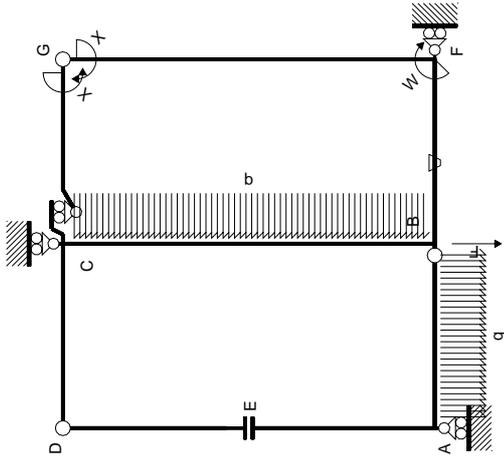
$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



- A = 480. mm<sup>2</sup>
- J<sub>u</sub> = 151240. mm<sup>4</sup>
- J<sub>v</sub> = 14400. mm<sup>4</sup>
- y<sub>g</sub> = 20.5 mm
- T<sub>y</sub> = 1670. N
- M<sub>x</sub> = -1018700. Nmm
- x<sub>m</sub> = 18. mm
- y<sub>m</sub> = 56. mm
- u<sub>m</sub> = 3. mm
- v<sub>m</sub> = 35.5 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 239.1 N/mm<sup>2</sup>
- x<sub>c</sub> = 15. mm
- y<sub>c</sub> = 41. mm
- v<sub>c</sub> = 20.5 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 138.1 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.638 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 = 2520. mm<sup>3</sup>

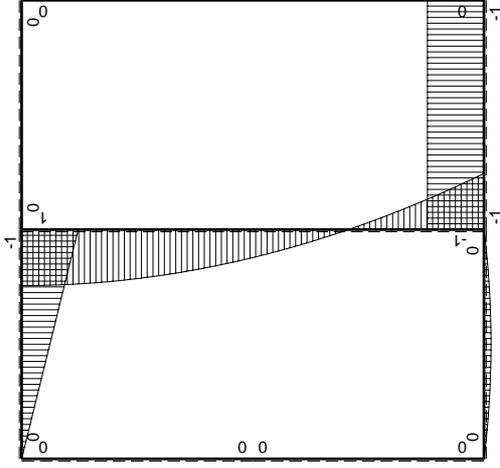






Schema di calcolo iperstatico

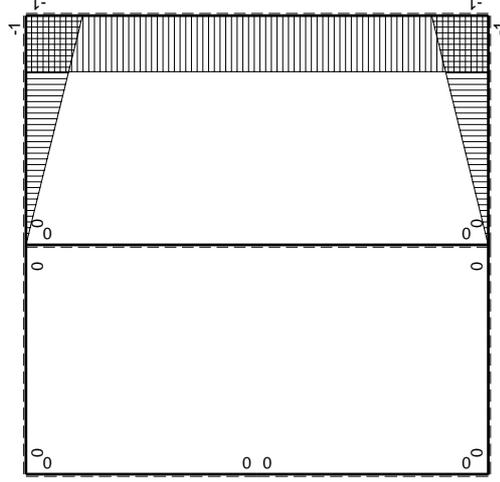
$M_0$  flessione da carichi assegnati



Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M^x(x)$	$M_0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x (M_0/EJ + \theta) dx$	$\int M^x M_x/EJ dx$
AB b	0	$1/2Fx - 1/2qx^2$	0	0	0	0	0+0	0
BA b	0	$-1/2Fx + 1/2qx^2$	0	0	0	0	0+0	0
CD b	0	$-Fb + Fx$	0	0	0	0	0+0	0
DC b	0	$Fx$	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
EA b	0	0	0	0	0	0	0+0	0
AE b	0	0	0	0	0	0	0+0	0
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb-Fx$	$Fb/EJ - Fx/EJ$	$1-2x/b+x^2/b^2$	$1/3xb/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2xb/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2xb/EJ$
CB 2b	0	$Fb - 1/2qx^2$	0	0	0	0	0+0	0
BC 2b	0	$Fb - 2Fx + 1/2qx^2$	0	0	0	0	0+0	0
totali								$Fb^2/EJ$
								$8/3xb/EJ$

Sviluppi di calcolo iperstatica



$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

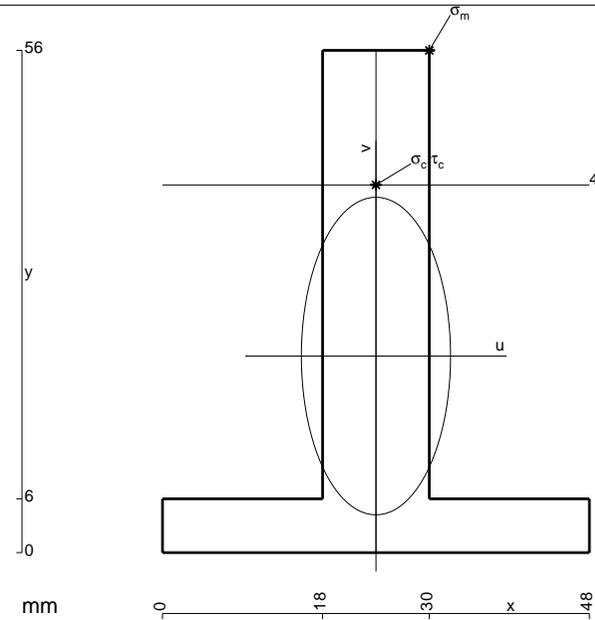
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



$$A = 888. \text{ mm}^2$$

$$J_u = 278426. \text{ mm}^4$$

$$J_v = 62496. \text{ mm}^4$$

$$y_g = 21.92 \text{ mm}$$

$$N = 4519. \text{ N}$$

$$T_y = -4820. \text{ N}$$

$$M_x = -1590600. \text{ Nmm}$$

$$x_m = 30. \text{ mm}$$

$$y_m = 56. \text{ mm}$$

$$u_m = 6. \text{ mm}$$

$$v_m = 34.08 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 199.8 \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 41. \text{ mm}$$

$$v_c = 19.08 \text{ mm}$$

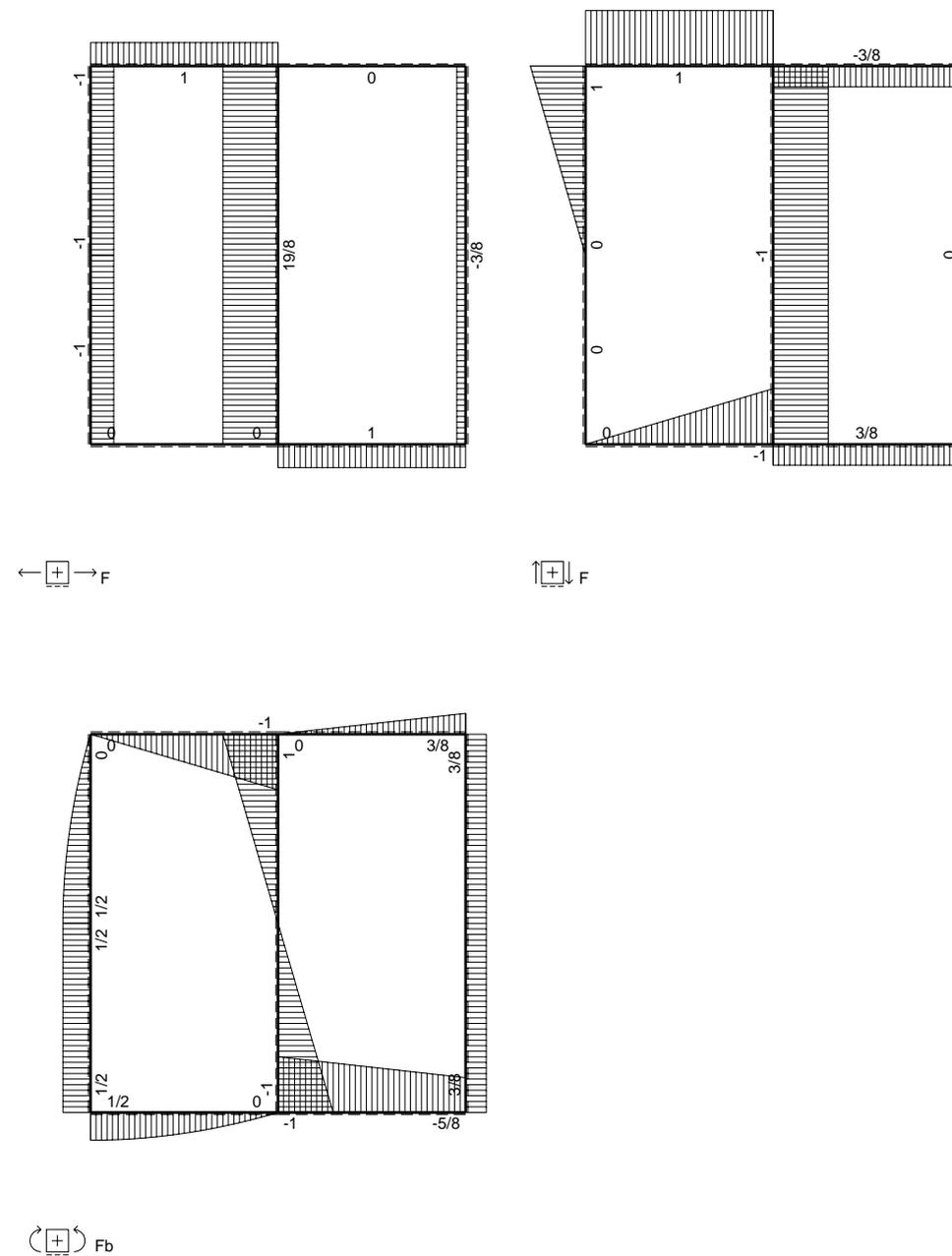
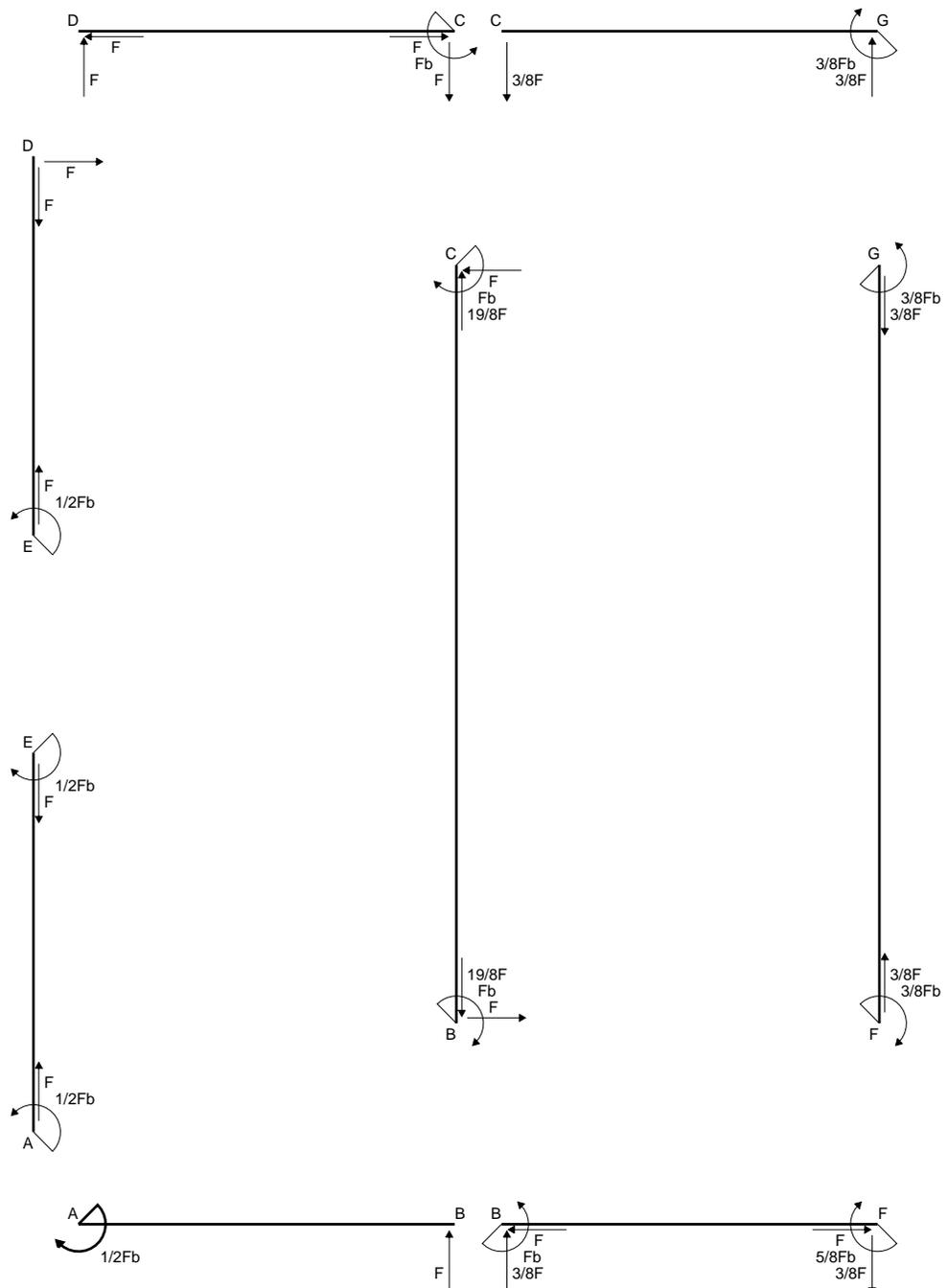
$$\sigma_c = N/A - Mv/J_u = 114.1 \text{ N/mm}^2$$

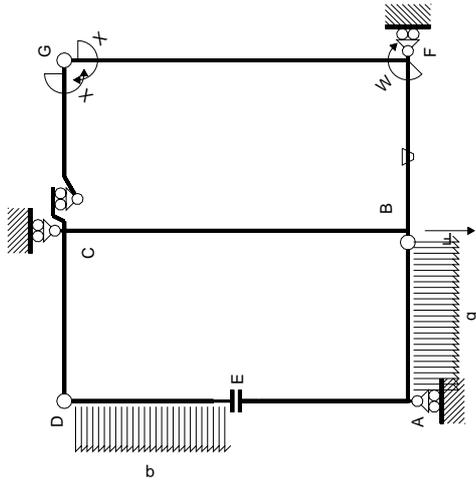
$$\tau_c = 6.902 \text{ N/mm}^2$$

$$\sigma_\varrho = \sqrt{\sigma^2 + 3\tau^2} = 114.7 \text{ N/mm}^2$$

$$S = 4785. \text{ mm}^3$$

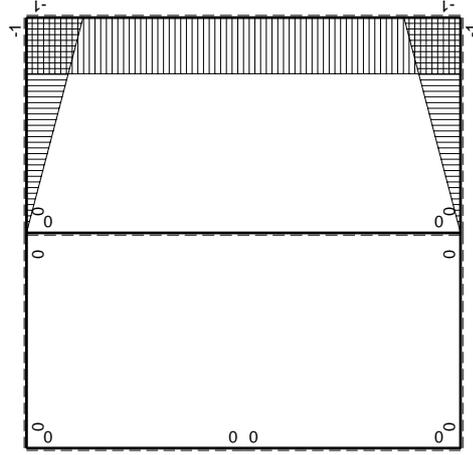
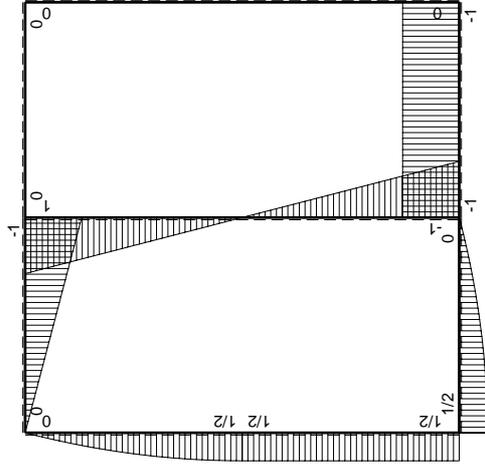






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	$1/2Fb-1/2qx^2$	0	0	0	0	0	0+0	0
BA b	$-Fx+1/2qx^2$	0	0	0	0	0	0+0	0
CD b	$-Fb+Fx$	0	0	0	0	0	0+0	0
DC b	$Fx$	0	0	0	0	0	0+0	0
DE b	$Fx-1/2qx^2$	0	0	0	0	0	0+0	0
ED b	$-1/2Fb+1/2qx^2$	0	0	0	0	0	0+0	0
EA b	$1/2Fb$	0	0	0	0	0	0+0	0
AE b	$-1/2Fb$	0	0	0	0	0	0+0	0
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb-Fx$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$1/3xb/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2xb/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2xb/EJ$
CB 2b	0	$Fb-Fx$	0	0	0	0	0+0	0
BC 2b	0	$Fb-Fx$	0	0	0	0	0+0	0
totali								$Fb^2/EJ$
								$8/3xb/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

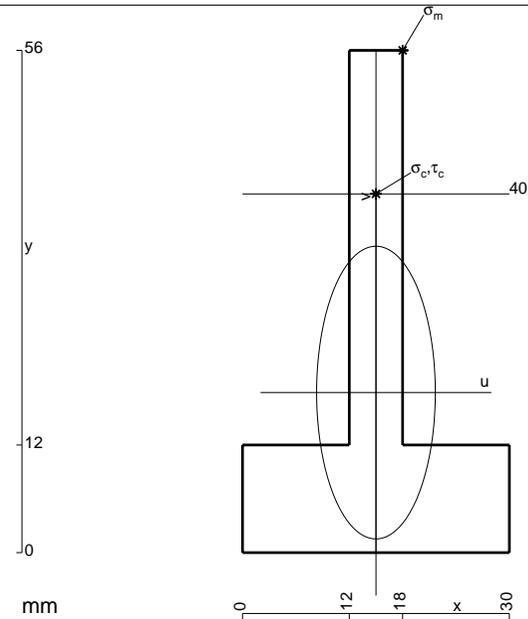
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



$$A = 624. \text{ mm}^2$$

$$J_u = 166321. \text{ mm}^4$$

$$J_v = 27792. \text{ mm}^4$$

$$y_g = 17.85 \text{ mm}$$

$$N = 3016. \text{ N}$$

$$T_y = -1270. \text{ N}$$

$$M_x = -889000. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$y_m = 56. \text{ mm}$$

$$u_m = 3. \text{ mm}$$

$$v_m = 38.15 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 208.8 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 40. \text{ mm}$$

$$v_c = 22.15 \text{ mm}$$

$$\sigma_c = N/A - Mv/J_u = 123.2 \text{ N/mm}^2$$

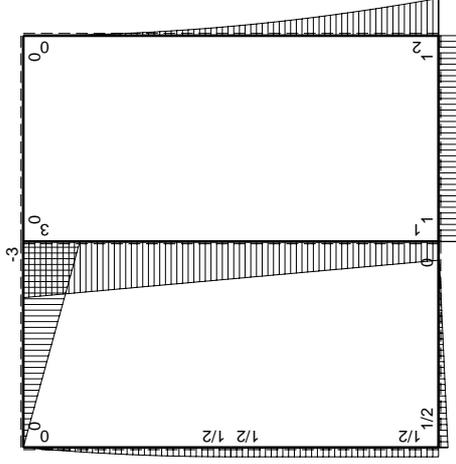
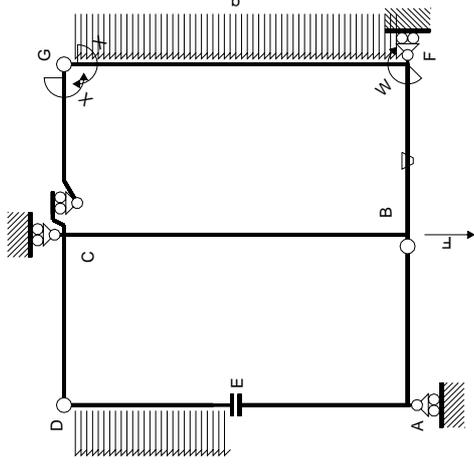
$$\tau_c = 3.684 \text{ N/mm}^2$$

$$\sigma_\varphi = \sqrt{\sigma^2 + 3\tau^2} = 123.4 \text{ N/mm}^2$$

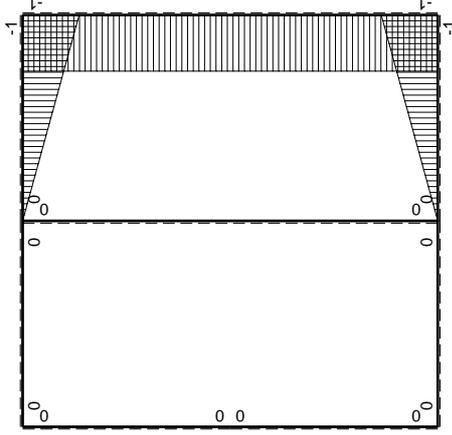
$$S = 2895. \text{ mm}^3$$







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	0	$1/2Fb-1/2Fx$	0	0	0	0	0+0	0
BA b	0	$-1/2Fx$	0	0	0	0	0+0	0
CD b	0	$-3Fb+3Fx$	0	0	0	0	0+0	0
DC b	0	$3Fx$	0	0	0	0	0+0	0
DE b	0	$Fx-1/2qx^2$	0	0	0	0	0+0	0
ED b	0	$-1/2Fb+1/2qx^2$	0	0	0	0	0+0	0
EA b	0	$1/2Fb$	0	0	0	0	0+0	0
AE b	0	$-1/2Fb$	0	0	0	0	0+0	0
BF b	$-x/b$	$Fb$	$-Fb/EJ$	$-Fx$	$Fx/EJ$	$x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$-Fb$	$Fb/EJ$	$-Fb+Fx$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	$2Fb-2Fx+1/2qx^2$	0	$-2Fb+2Fx-1/2Fx^2/b$	0	1	$(-4/3+0)Fb^2/EJ$	$2xb/EJ$
GF 2b	1	$-1/2qx^2$	0	$-1/2Fx^2/b$	0	1	$(-4/3+0)Fb^2/EJ$	$2xb/EJ$
CB 2b	0	$3Fb-Fx$	0	0	0	0	0+0	0
BC 2b	0	$-Fb-Fx$	0	0	0	0	0+0	0
totali							$-4/3Fb^2/EJ$	$8/3xb/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x_0} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

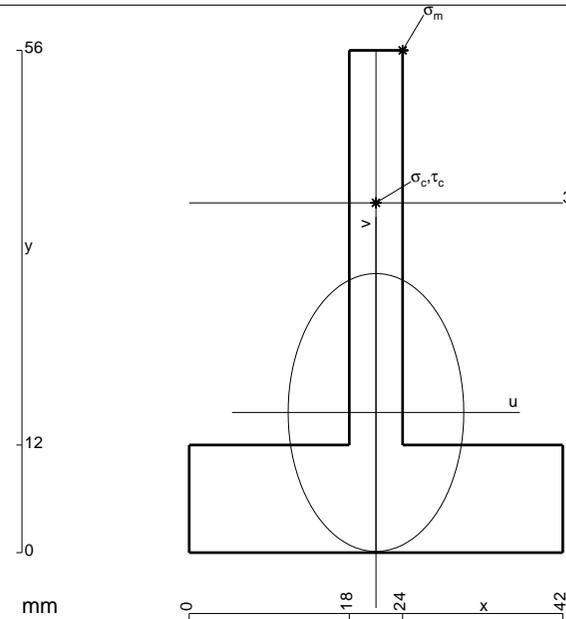
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x_0} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

$$L_{GF}^{x_0} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



$$A = 768. \text{ mm}^2$$

$$J_u = 184468. \text{ mm}^4$$

$$J_v = 74880. \text{ mm}^4$$

$$y_g = 15.63 \text{ mm}$$

$$N = 450. \text{ N}$$

$$T_y = 1350. \text{ N}$$

$$M_x = -999000. \text{ Nmm}$$

$$x_m = 24. \text{ mm}$$

$$y_m = 56. \text{ mm}$$

$$u_m = 3. \text{ mm}$$

$$v_m = 40.38 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 219.2 \text{ N/mm}^2$$

$$x_c = 21. \text{ mm}$$

$$y_c = 39. \text{ mm}$$

$$v_c = 23.38 \text{ mm}$$

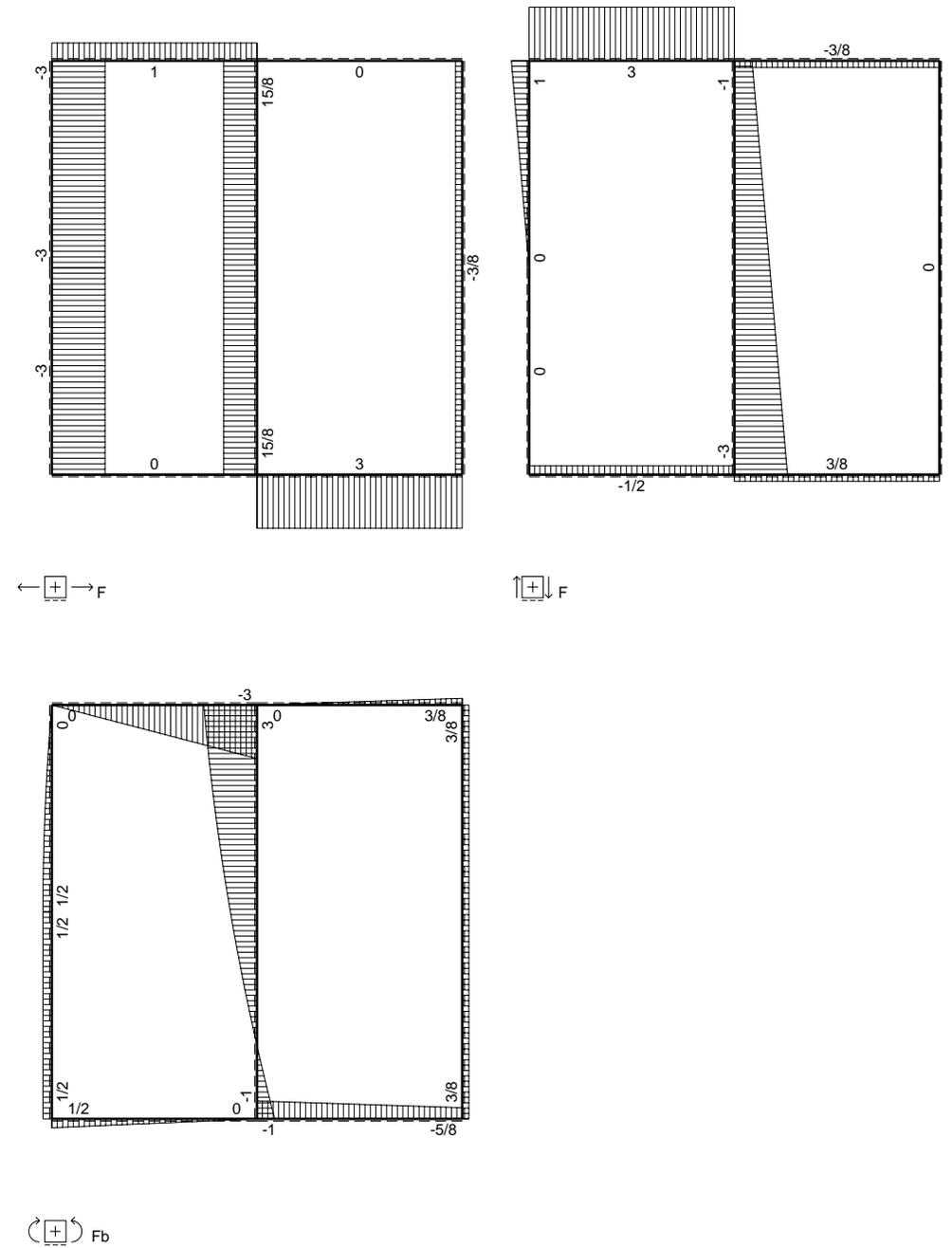
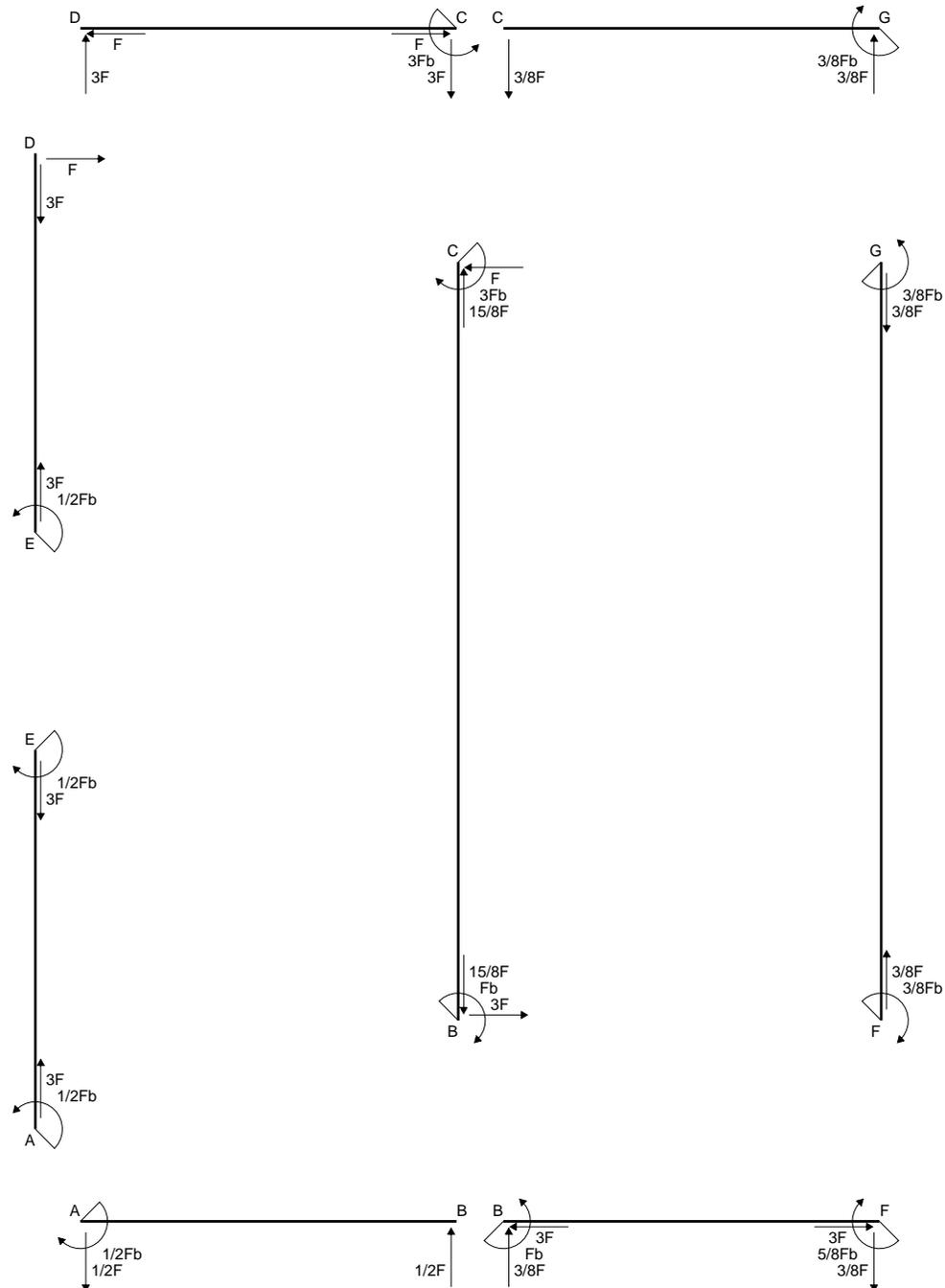
$$\sigma_c = N/A - Mv/J_u = 127.2 \text{ N/mm}^2$$

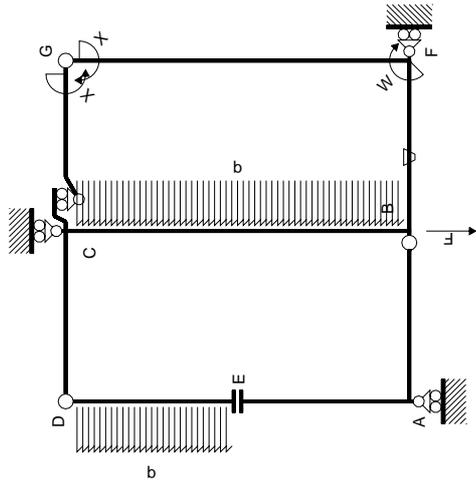
$$\tau_c = 3.966 \text{ N/mm}^2$$

$$\sigma_\varphi = \sqrt{\sigma^2 + 3\tau^2} = 127.4 \text{ N/mm}^2$$

$$S = 3251. \text{ mm}^3$$

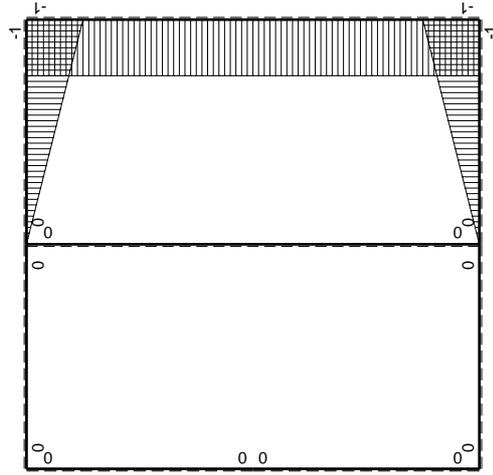
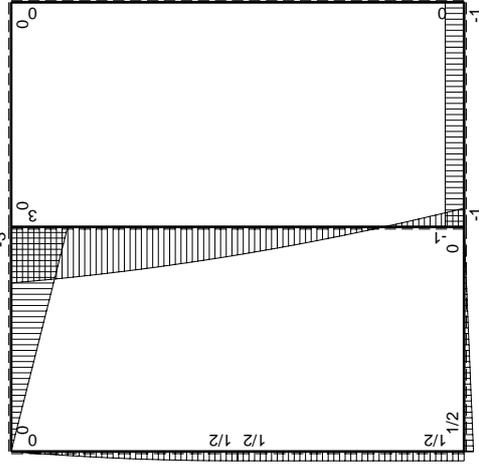






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / EJ dx$
AB b	0	$1/2Fb - 1/2Fx$	0	0	0	0	0+0	0
BA b	0	$-1/2Fx$	0	0	0	0	0+0	0
CD b	0	$-3Fb + 3Fx$	0	0	0	0	0+0	0
DC b	0	$3Fx$	0	0	0	0	0+0	0
DE b	0	$Fx - 1/2qx^2$	0	0	0	0	0+0	0
ED b	0	$-1/2Fb + 1/2qx^2$	0	0	0	0	0+0	0
EA b	0	$1/2Fb$	0	0	0	0	0+0	0
AE b	0	$-1/2Fb$	0	0	0	0	0+0	0
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$Fb/EJ - Fx/EJ$	$(1/2 + 1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb - Fx$	$Fb/EJ - Fx/EJ$	$Fb/EJ - Fx/EJ$	$1-2x/b + x^2/b^2$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	0	$-1-2x/b + x^2/b^2$	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	0	$x^2/b^2$	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	0	1	$2xb/EJ$
GF 2b	1	0	0	0	0	0	1	$2xb/EJ$
CB 2b	0	$3Fb - Fx - 1/2qx^2$	0	0	0	0	0+0	0
BC 2b	0	$Fb - 3Fx + 1/2qx^2$	0	0	0	0	0+0	0
totali								$8/3xb/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

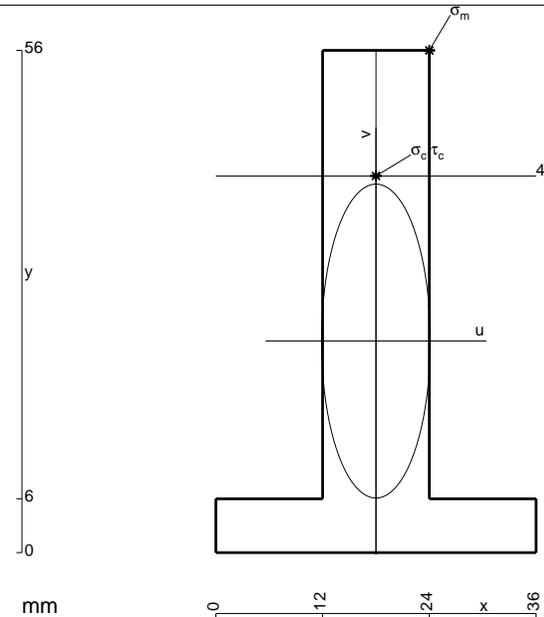
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

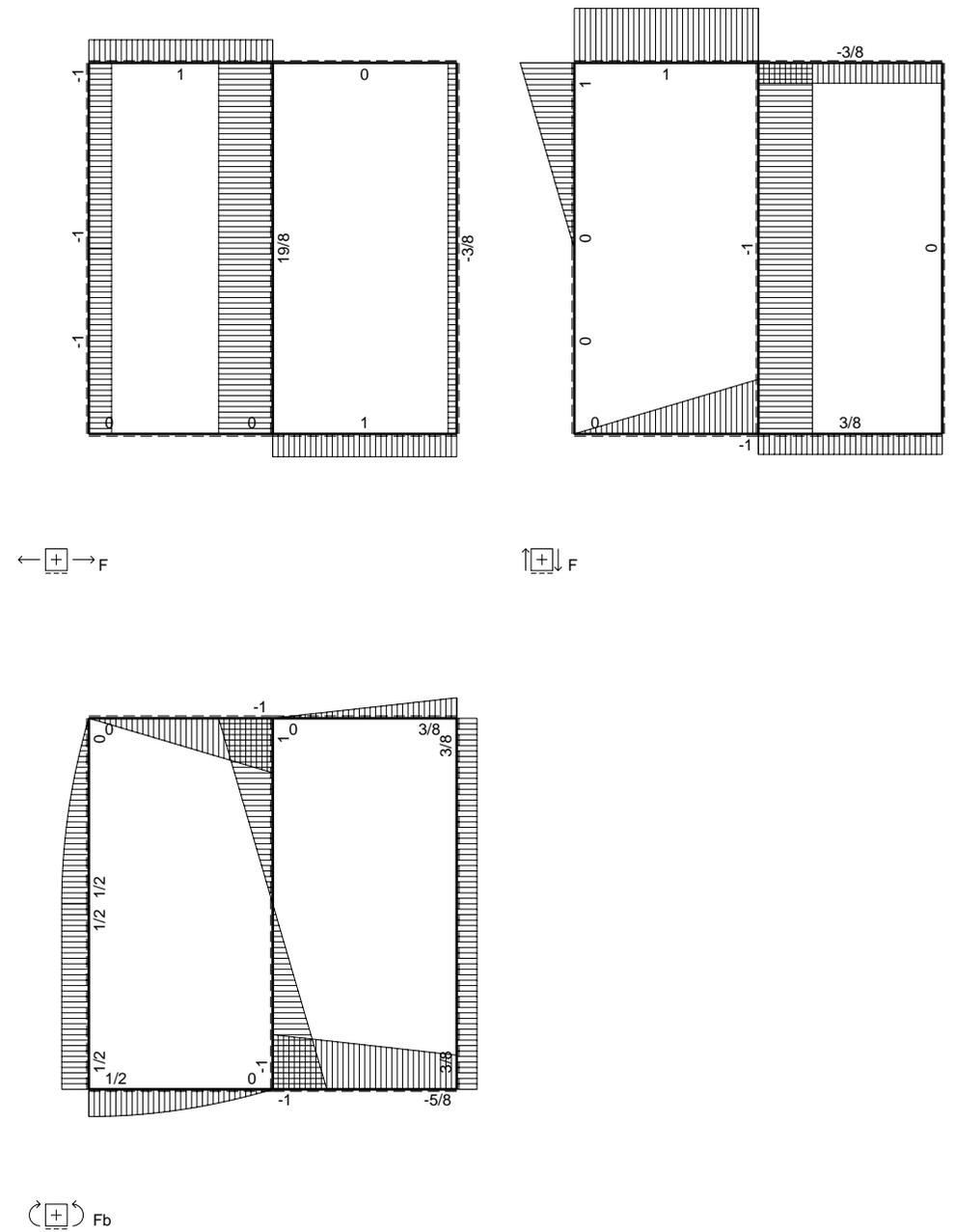
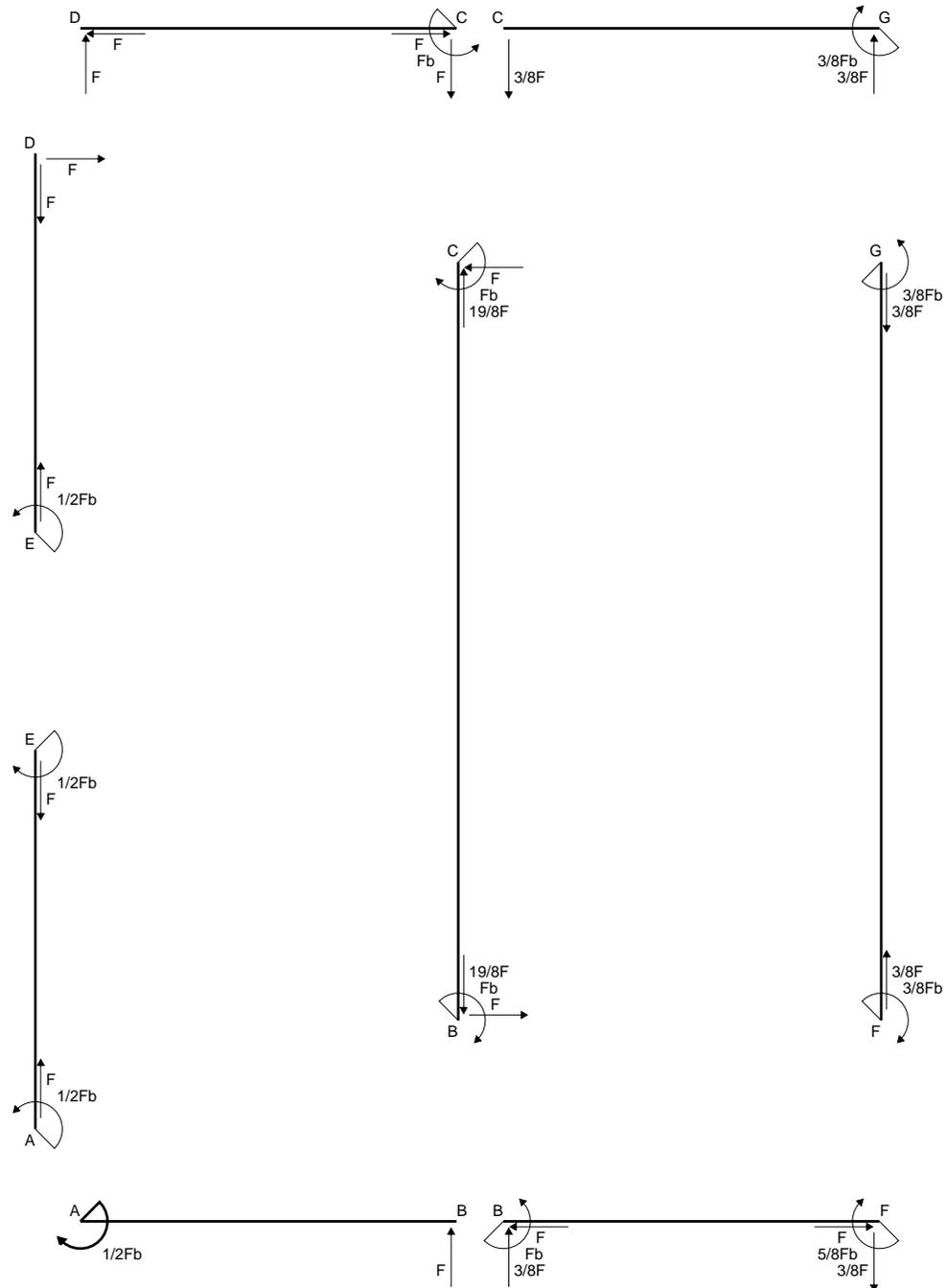
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

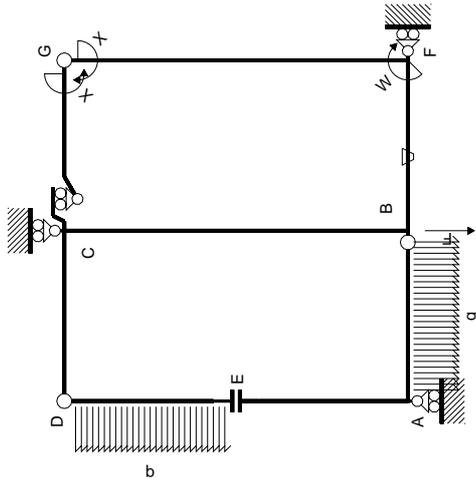
$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



- A = 816. mm<sup>2</sup>
- J<sub>u</sub> = 250166. mm<sup>4</sup>
- J<sub>v</sub> = 30528. mm<sup>4</sup>
- y<sub>g</sub> = 23.59 mm
- N = 740. N
- T<sub>y</sub> = 2220. N
- M<sub>x</sub> = -1753800. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 56. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 32.41 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = 228.1 N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 42. mm
- v<sub>c</sub> = 18.41 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = 130. N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.157 N/mm<sup>2</sup>
- σ<sub>0</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 130.1 N/mm<sup>2</sup>
- S = 4269. mm<sup>3</sup>

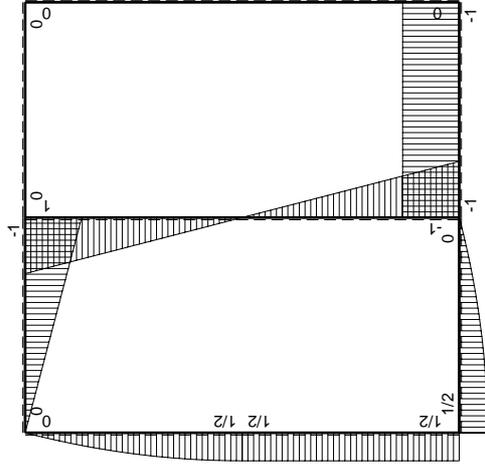






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	$1/2Fb-1/2qx^2$	0	0	0	0	0	0+0	0
BA b	$-Fx+1/2qx^2$	0	0	0	0	0	0+0	0
CD b	$-Fb+Fx$	0	0	0	0	0	0+0	0
DC b	$Fx$	0	0	0	0	0	0+0	0
DE b	$Fx-1/2qx^2$	0	0	0	0	0	0+0	0
ED b	$-1/2Fb+1/2qx^2$	0	0	0	0	0	0+0	0
EA b	$1/2Fb$	0	0	0	0	0	0+0	0
AE b	$-1/2Fb$	0	0	0	0	0	0+0	0
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb-Fx$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$1/3xb/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2xb/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2xb/EJ$
CB 2b	0	$Fb-Fx$	0	0	0	0	0+0	0
BC 2b	0	$Fb-Fx$	0	0	0	0	0+0	0
totali								$Fb^2/EJ$
								$8/3xb/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

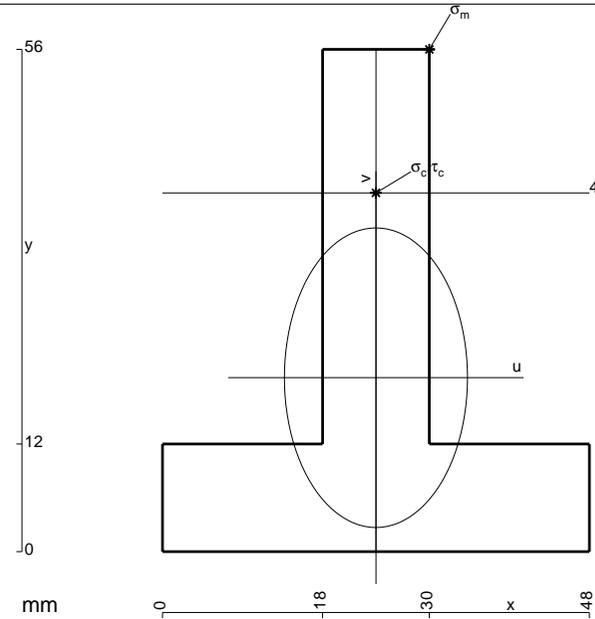
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

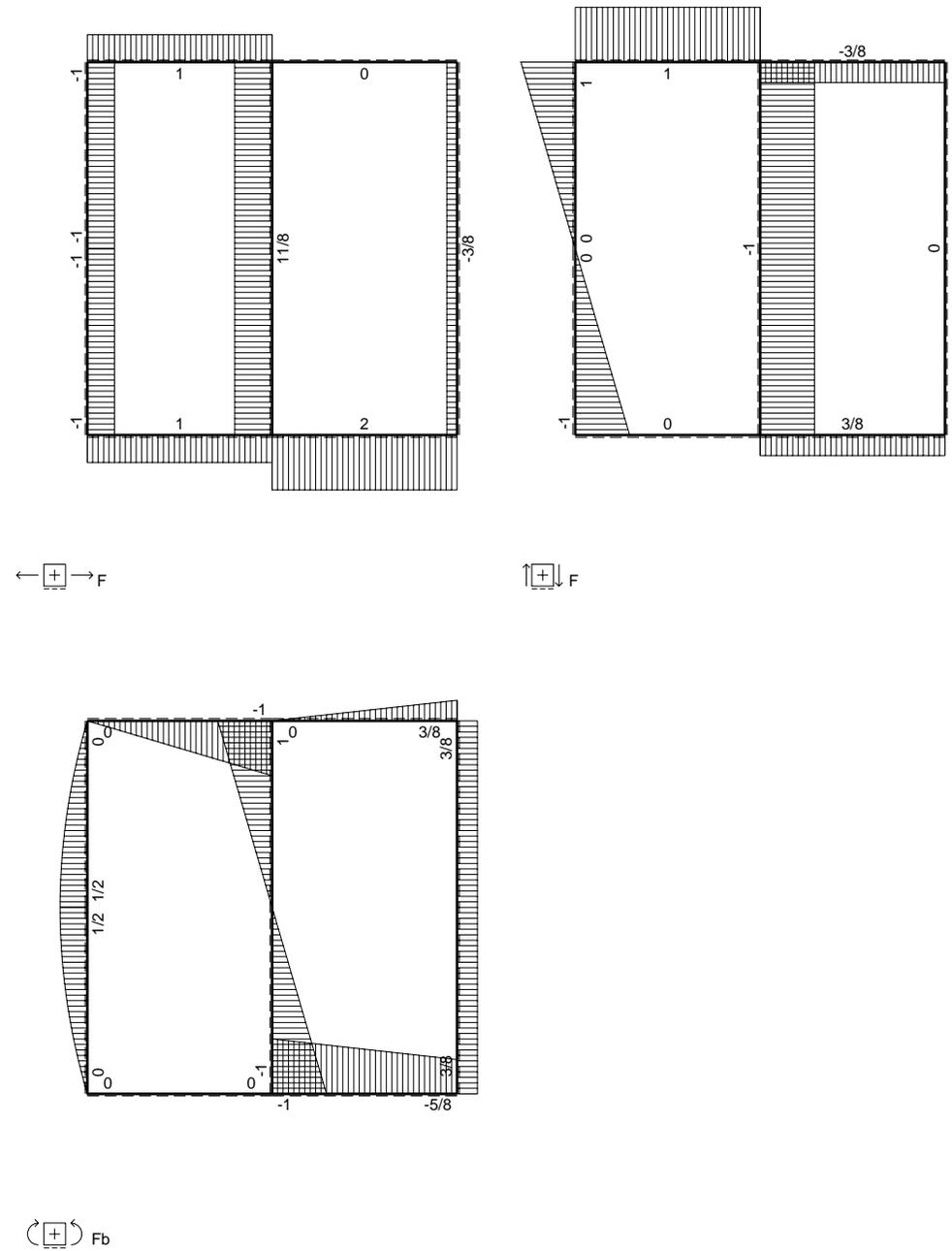
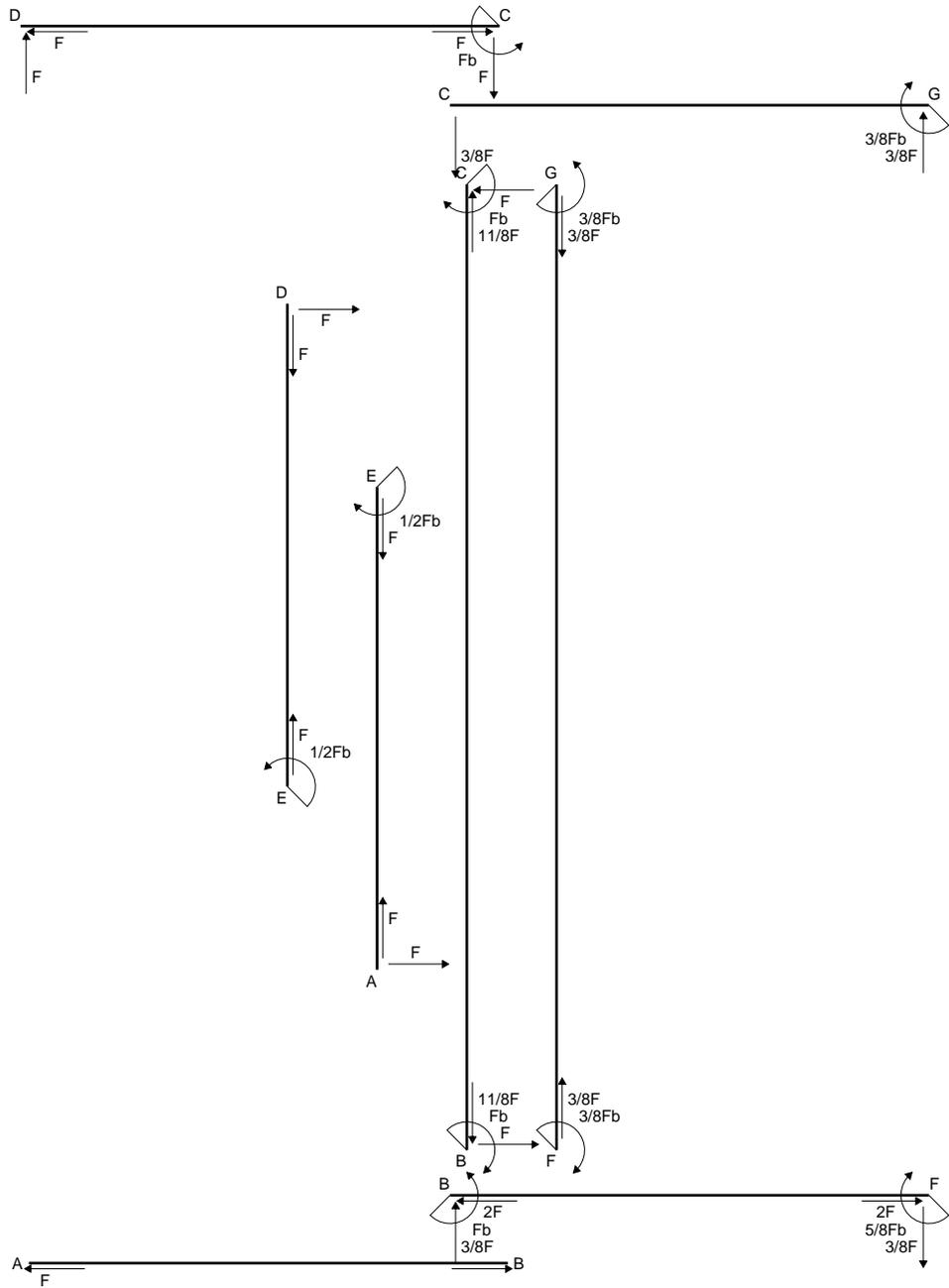
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

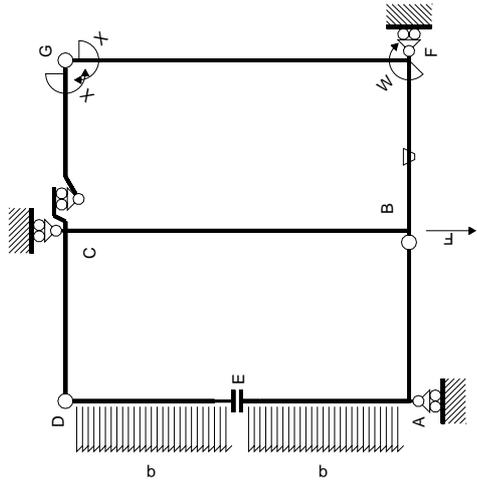
$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



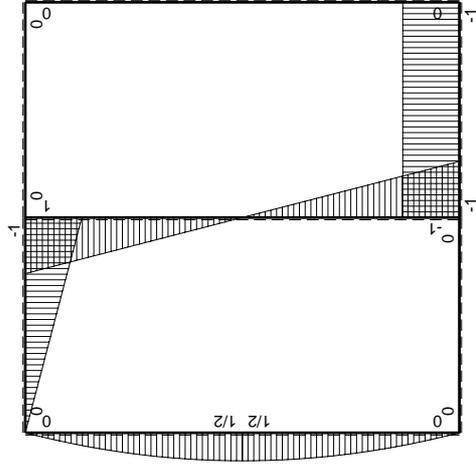
- A = 1104. mm<sup>2</sup>
- J<sub>u</sub> = 308071. mm<sup>4</sup>
- J<sub>v</sub> = 116928. mm<sup>4</sup>
- y<sub>g</sub> = 19.39 mm
- N = 5653. N
- T<sub>y</sub> = -2380. N
- M<sub>x</sub> = -1975400. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 56. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 36.61 mm
- σ<sub>m</sub> = N/A - 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> = 20.61 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = 137.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.536 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 137.4 N/mm<sup>2</sup>
- S = 5493. mm<sup>3</sup>



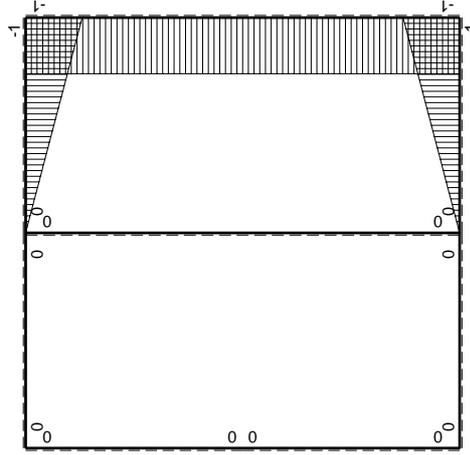




Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica X=W<sub>gc</sub>

→	M <sup>x</sup> (x)	M <sub>0</sub> (x)	θ	M <sub>0</sub> M <sub>0</sub>	M <sub>0</sub> θ	M <sub>0</sub> M <sub>x</sub>	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJdx$
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0+0	0
CD b	0	-Fb+Fx	0	0	0	0	0+0	0
DC b	0	Fx	0	0	0	0	0+0	0
DE b	0	Fx-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
ED b	0	-1/2Fb+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
EA b	0	1/2Fb-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
AE b	0	-Fx+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
BF b	-x/b	-Fb	-Fb/EJ	Fx	Fx/EJ	x <sup>2</sup> /b <sup>2</sup>	(1/2+1/2)Fb <sup>2</sup> /EJ	1/3xb/EJ
FB b	1-x/b	Fb	Fb/EJ	Fb-Fx	Fb/EJ-Fx/EJ	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	1/3xb/EJ	1/3xb/EJ
GC b	-1+x/b	0	0	0	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	0+0	1/3xb/EJ
CG b	x/b	0	0	0	0	x <sup>2</sup> /b <sup>2</sup>	0+0	2xb/EJ
FG 2b	-1	0	0	0	0	1	0+0	0
GF 2b	1	0	0	0	0	1	0+0	0
CB 2b	0	Fb-Fx	0	0	0	0	0+0	8/3xb/EJ
BC 2b	0	Fb-Fx	0	0	0	0	0+0	0
totali								

iperstatica X=W<sub>gc</sub>

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

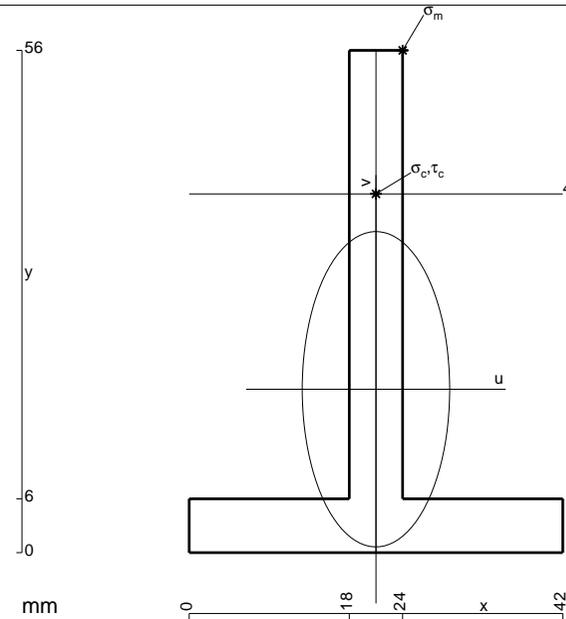
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

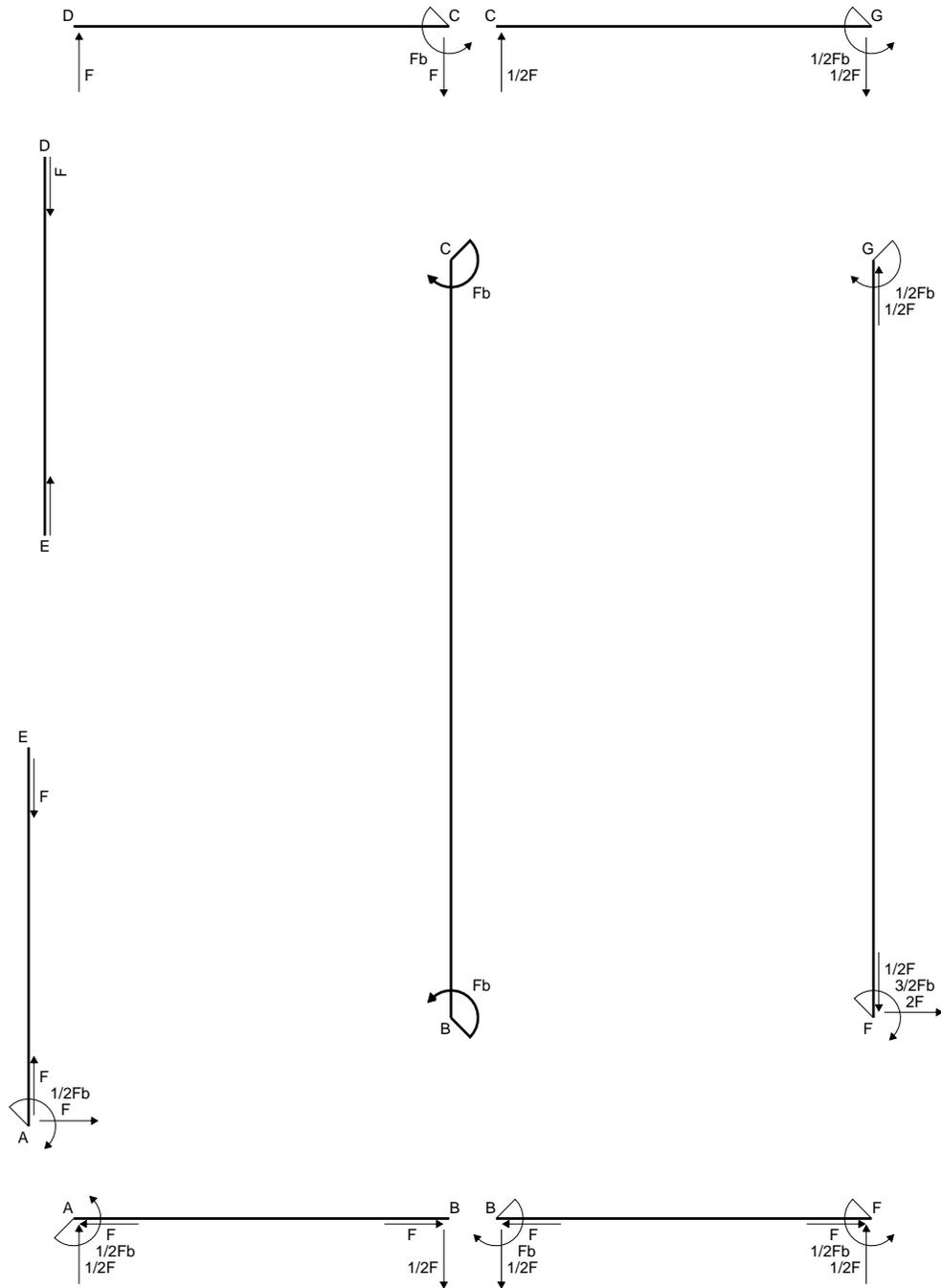
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



- A = 552. mm<sup>2</sup>
- J<sub>u</sub> = 170630. mm<sup>4</sup>
- J<sub>v</sub> = 37944. mm<sup>4</sup>
- y<sub>g</sub> = 18.22 mm
- N = 2750. N
- T<sub>y</sub> = -2000. N
- M<sub>x</sub> = -880000. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 56. mm
- u<sub>m</sub> = 3. mm
- v<sub>m</sub> = 37.78 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = 199.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 40. mm
- v<sub>c</sub> = 21.78 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = 117.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.585 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 117.7 N/mm<sup>2</sup>
- S = 2859. mm<sup>3</sup>







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x\theta} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x\theta} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

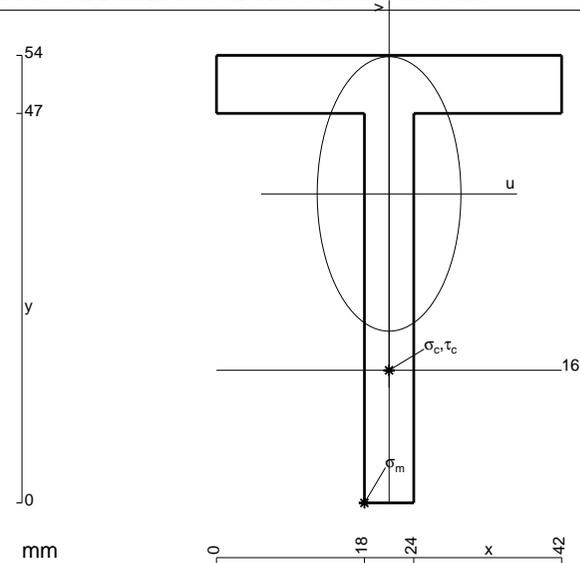
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x\theta} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

$$L_{GF}^{x\theta} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



$$A = 576. \text{ mm}^2$$

$$J_u = 158042. \text{ mm}^4$$

$$J_v = 44064. \text{ mm}^4$$

$$y_g = 37.28 \text{ mm}$$

$$T_y = 1890. \text{ N}$$

$$M_x = -888300. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -37.28 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -209.5 \text{ N/mm}^2$$

$$x_c = 21. \text{ mm}$$

$$y_c = 16. \text{ mm}$$

$$v_c = -21.28 \text{ mm}$$

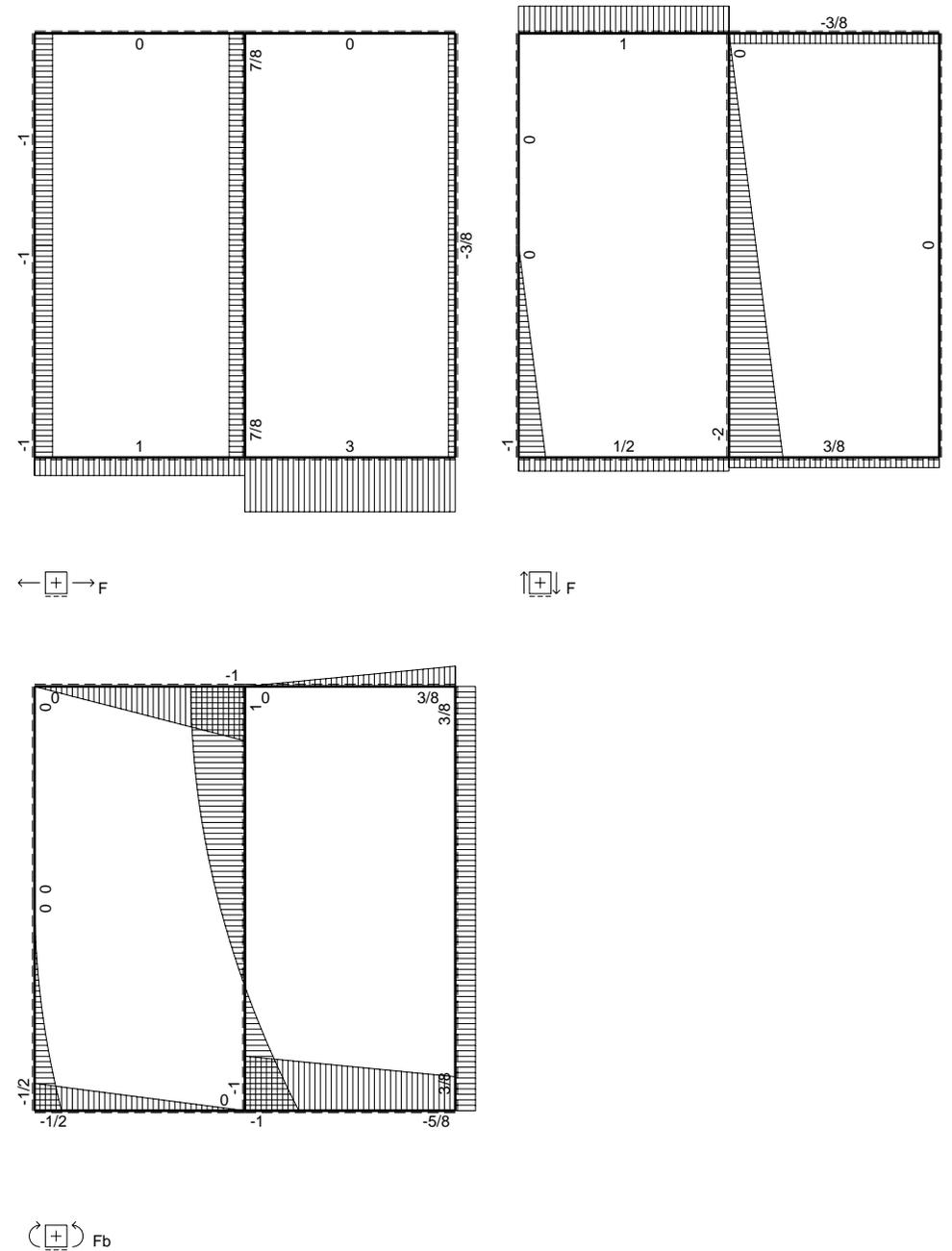
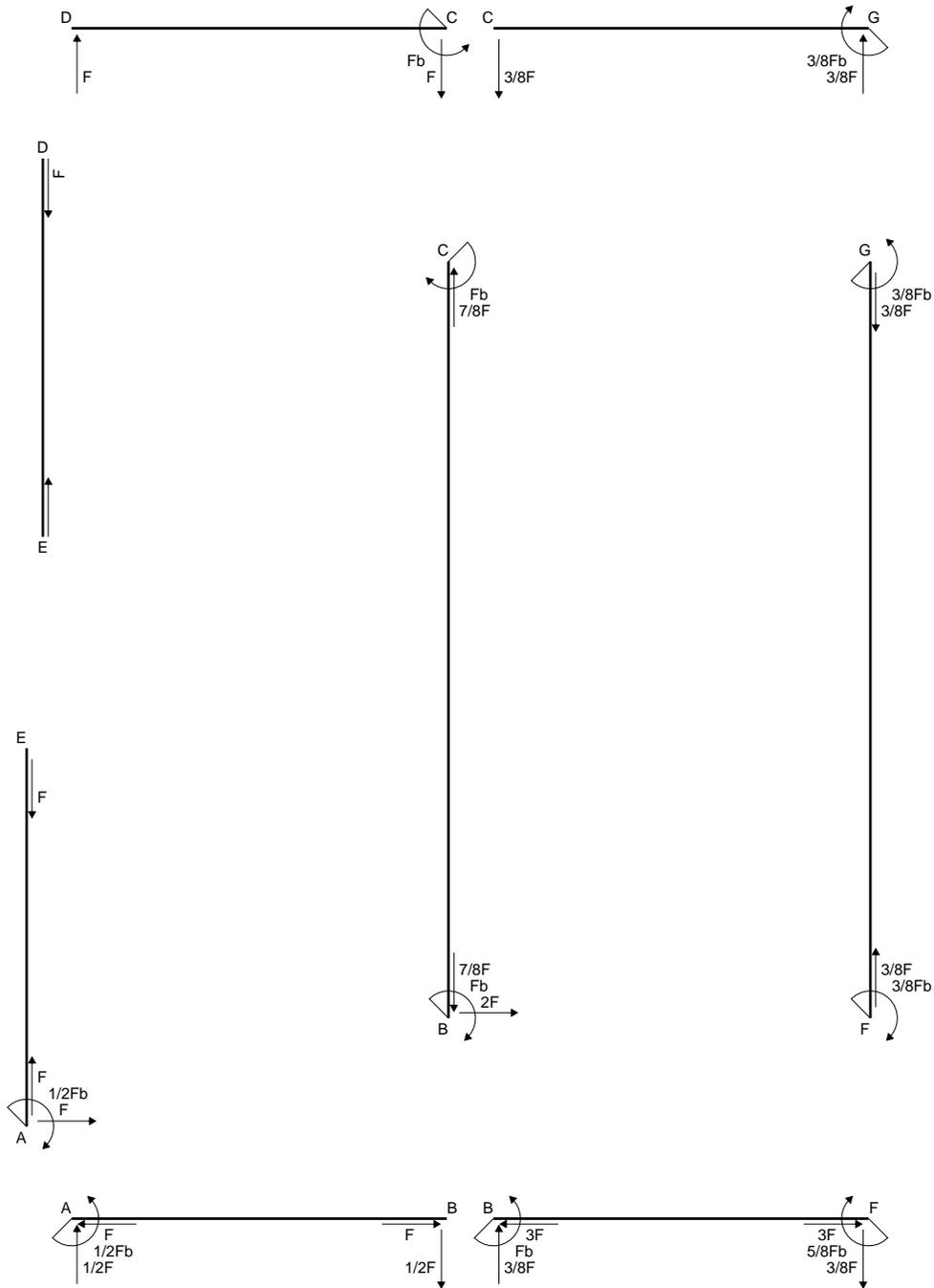
$$\sigma_c = -Mv/J_u = -119.6 \text{ N/mm}^2$$

$$\tau_c = 5.603 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 120. \text{ N/mm}^2$$

$$S = 2811. \text{ mm}^3$$







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

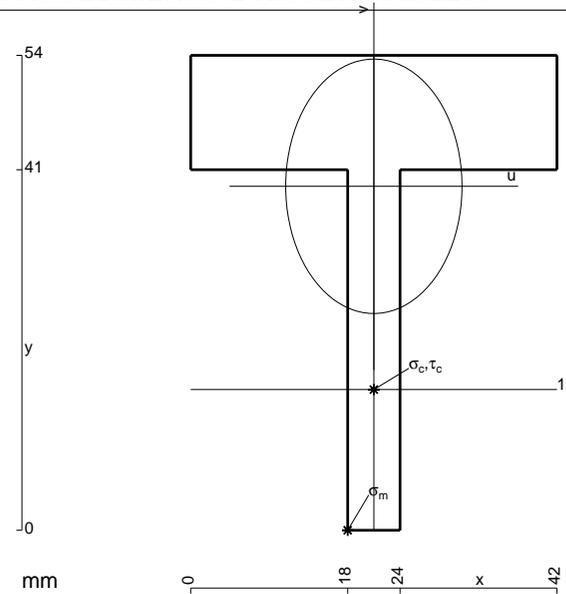
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

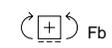
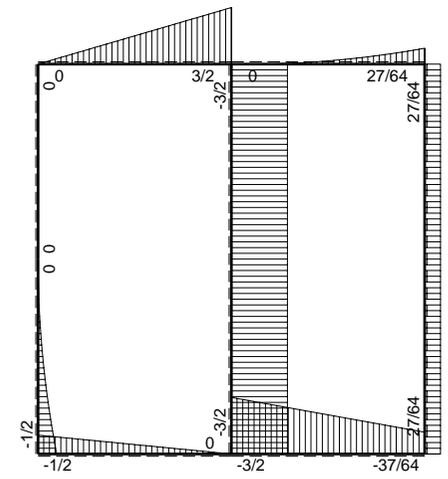
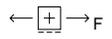
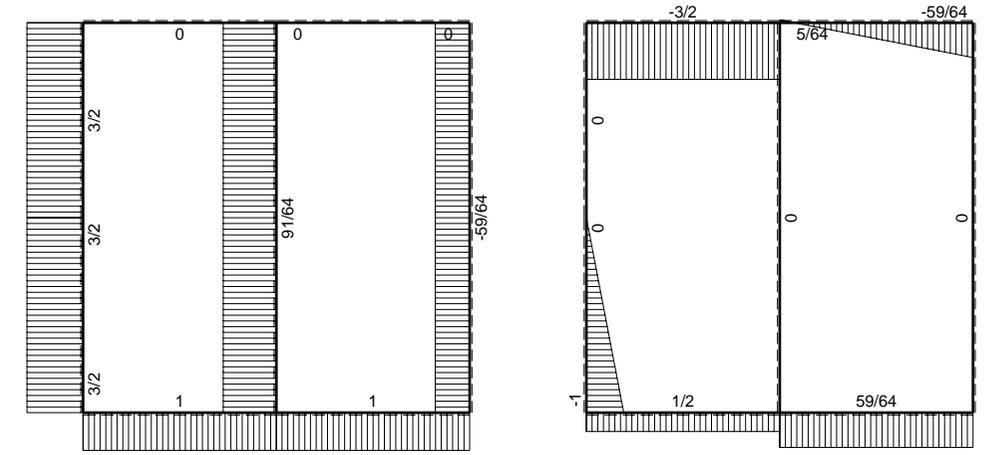
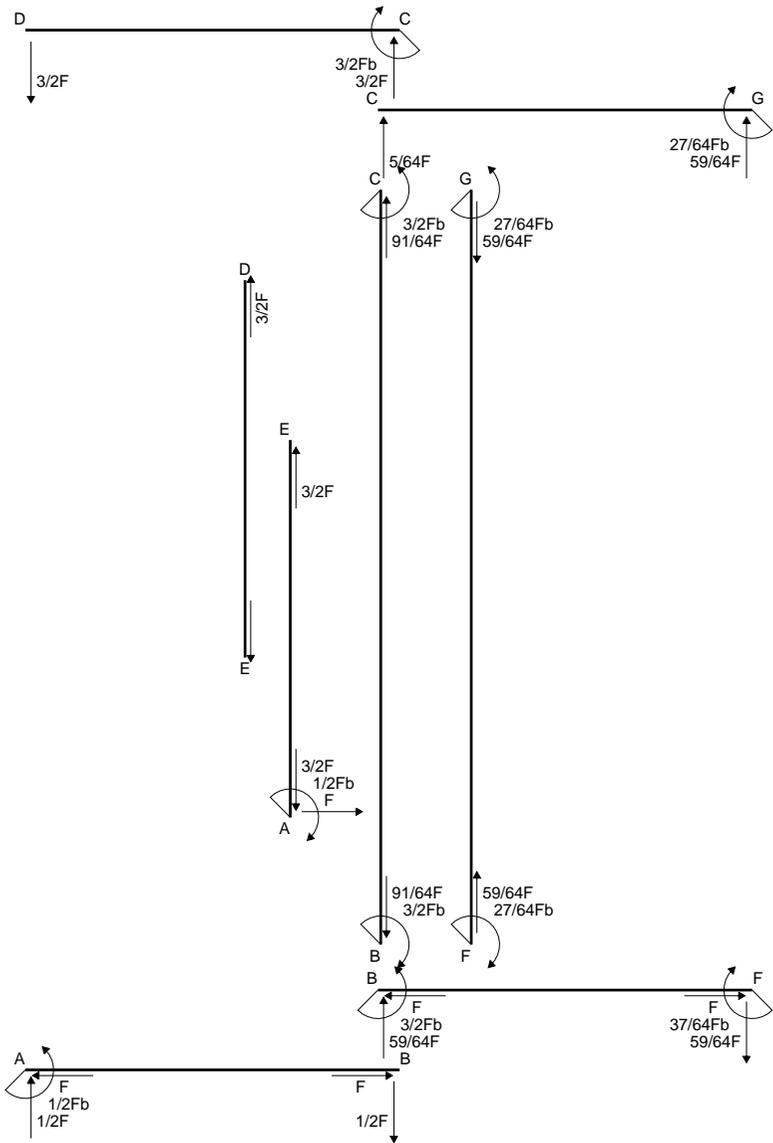
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

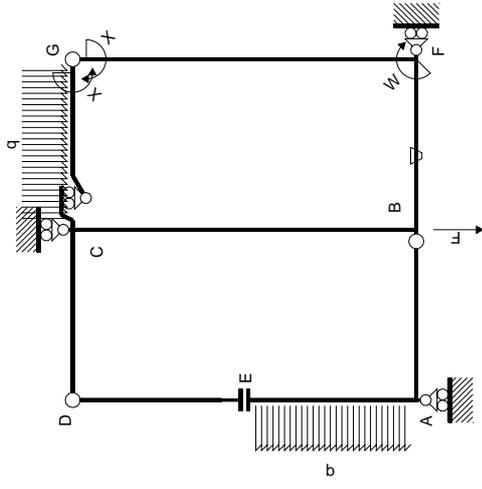
$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



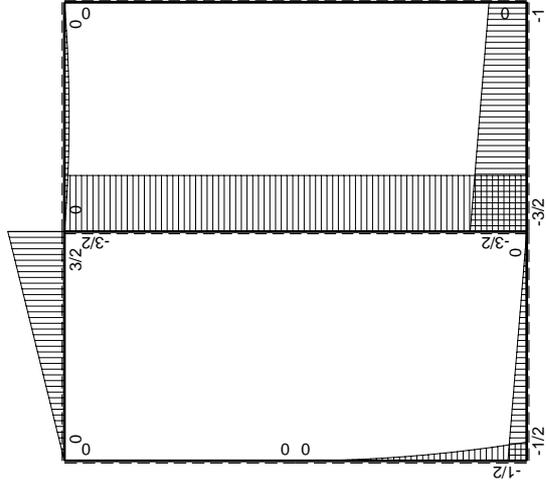
- A = 792. mm<sup>2</sup>
- J<sub>u</sub> = 165782. mm<sup>4</sup>
- J<sub>v</sub> = 81000. mm<sup>4</sup>
- y<sub>g</sub> = 39.11 mm
- N = 1610. N
- T<sub>y</sub> = -3680. N
- M<sub>x</sub> = -938400. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -39.11 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = -219.4 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 16. mm
- v<sub>c</sub> = -23.11 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = -128.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 11.05 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 130.2 N/mm<sup>2</sup>
- S = 2987. mm<sup>3</sup>



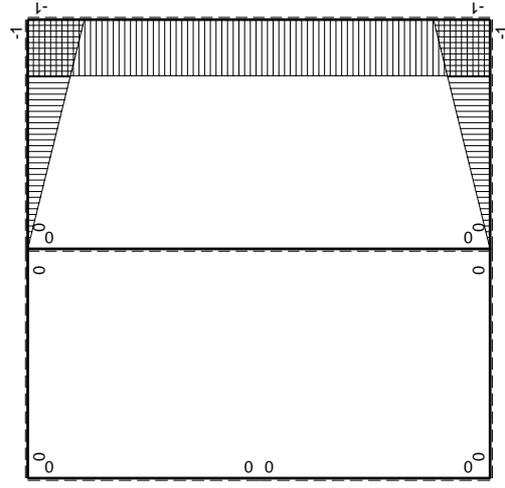




Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica X=W <sub>gc</sub>		Sviluppi di calcolo iperstatica					
←	M <sub>0</sub> (x)	M <sub>0</sub> (x)	θ	M <sub>0</sub> M <sub>0</sub>	M <sub>0</sub> θ	M <sub>0</sub> M <sub>x</sub>	$\int M_x(M_0/EJ+\theta)dx$
AB b	0	-1/2Fb+1/2Fx	0	0	0	0	0+0
BA b	0	1/2Fx	0	0	0	0	0+0
CD b	0	3/2Fb-3/2Fx	0	0	0	0	0+0
DC b	0	-3/2Fx	0	0	0	0	0+0
DE b	0	0	0	0	0	0	0+0
EA b	0	-1/2qx <sup>2</sup>	0	0	0	0	0+0
AE b	0	1/2Fb-Fx+1/2qx <sup>2</sup>	0	0	0	0	0+0
BF b	-x/b	-3/2Fb+1/2Fx	-Fb/EJ	3/2Fx-1/2Fx <sup>2</sup> /b	Fx/EJ	x <sup>2</sup> /b <sup>2</sup>	(7/12+1/2)Fb <sup>2</sup> /EJ
FB b	1-x/b	Fb+1/2Fx	Fb/EJ	Fb-1/2Fx-1/2Fx <sup>2</sup> /b	Fb/EJ-Fx/EJ	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	1/3xb/EJ
GC b	-1+x/b	-1/2Fx+1/2qx <sup>2</sup>	0	1/2Fx-Fx <sup>2</sup> /b+1/2qx <sup>3</sup> /b	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	1/3xb/EJ
CG b	x/b	1/2Fx-1/2qx <sup>2</sup>	0	1/2Fx <sup>2</sup> /b-1/2qx <sup>3</sup> /b	0	x <sup>2</sup> /b <sup>2</sup>	(1/24+0)Fb <sup>2</sup> /EJ
FG 2b	-1	0	0	0	0	1	0+0
GF 2b	1	0	0	0	0	1	2xb/EJ
CB 2b	0	-3/2Fb	0	0	0	0	0+0
BC 2b	0	3/2Fb	0	0	0	0	8/3xb/EJ
totali							
		iperstatica X=W <sub>gc</sub>					

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{xo} = \int_0^b (3/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

$$= [3/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (3/4 b - 1/6 b) Fb 1/EJ + (1/2 b) \theta = 13/12 Fb^2/EJ$$

$$L_{FB}^{xo} = \int_0^b (1 - 1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [x - 1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

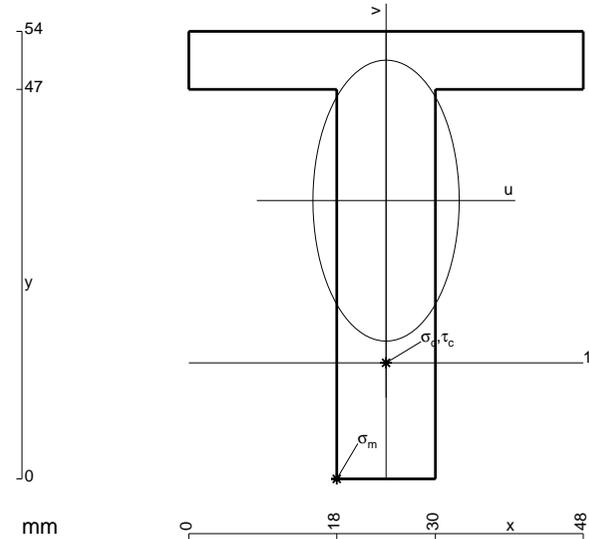
$$= (b - 1/4 b - 1/6 b) Fb 1/EJ + (-b + 1/2 b) \theta = 13/12 Fb^2/EJ$$

$$L_{GC}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{CG}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

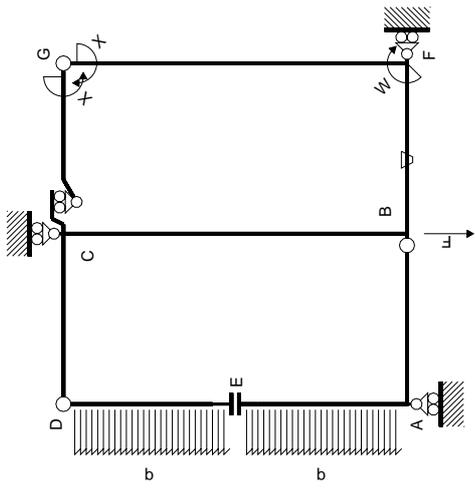
$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$



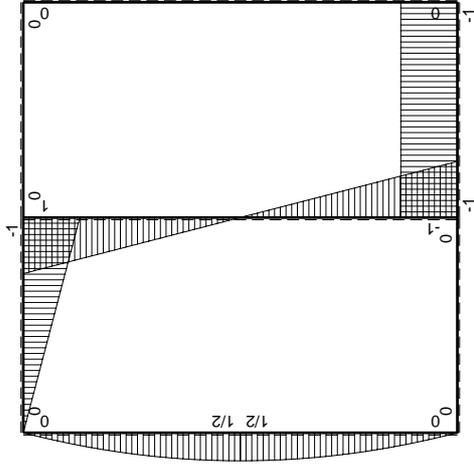
$A = 900. \text{ mm}^2$   
 $J_u = 258693. \text{ mm}^4$   
 $J_v = 71280. \text{ mm}^4$   
 $y_g = 33.58 \text{ mm}$   
 $T_y = -3210. \text{ N}$   
 $M_x = 1765500. \text{ Nmm}$   
 $x_m = 18. \text{ mm}$   
 $u_m = -6. \text{ mm}$   
 $v_m = -33.58 \text{ mm}$   
 $\sigma_m = -Mv/J_u = 229.2 \text{ N/mm}^2$   
 $x_c = 24. \text{ mm}$   
 $y_c = 14. \text{ mm}$   
 $v_c = -19.58 \text{ mm}$   
 $\sigma_c = -Mv/J_u = 133.6 \text{ N/mm}^2$   
 $\tau_c = 4.617 \text{ N/mm}^2$   
 $\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 133.9 \text{ N/mm}^2$   
 $S = 4465. \text{ mm}^3$



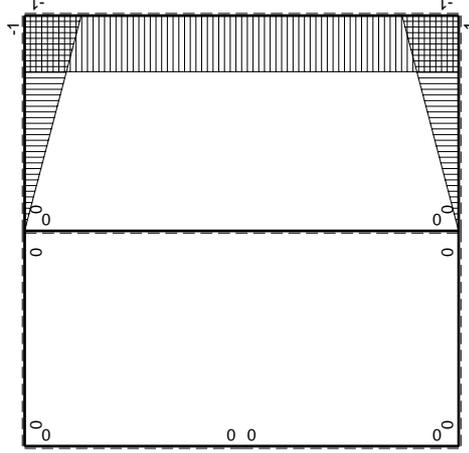




Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica X=W<sub>gc</sub>

←	$M^x(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / EJ dx$
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0+0	0
CD b	0	-Fb+Fx	0	0	0	0	0+0	0
DC b	0	Fx	0	0	0	0	0+0	0
DE b	0	Fx-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
ED b	0	-1/2Fb+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
EA b	0	1/2Fb-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
AE b	0	-Fx+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
BF b	-x/b	-Fb	-Fb/EJ	Fx	Fx/EJ	$x^2/b^2$	$(1/2+1/2)Fb^2/EJ$	1/3xb/EJ
FB b	1-x/b	Fb	Fb/EJ	Fb-Fx	Fb/EJ-Fx/EJ	$1-2x/b+x^2/b^2$	$1/2+1/2)Fb^2/EJ$	1/3xb/EJ
GC b	-1+x/b	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	1/3xb/EJ
CG b	x/b	0	0	0	0	$x^2/b^2$	0+0	1/3xb/EJ
FG 2b	-1	0	0	0	0	1	0+0	2xb/EJ
GF 2b	1	0	0	0	0	1	0+0	2xb/EJ
CB 2b	0	Fb-Fx	0	0	0	0	0+0	0
BC 2b	0	Fb-Fx	0	0	0	0	0+0	0
totali								8/3xb/EJ

iperstatica X=W<sub>gc</sub>

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

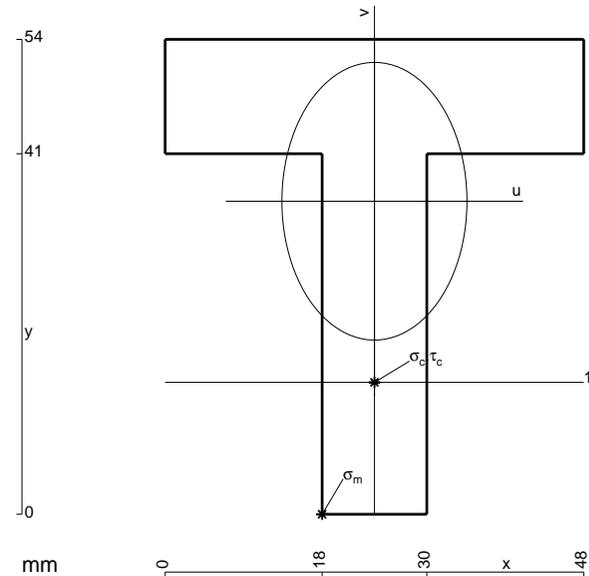
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

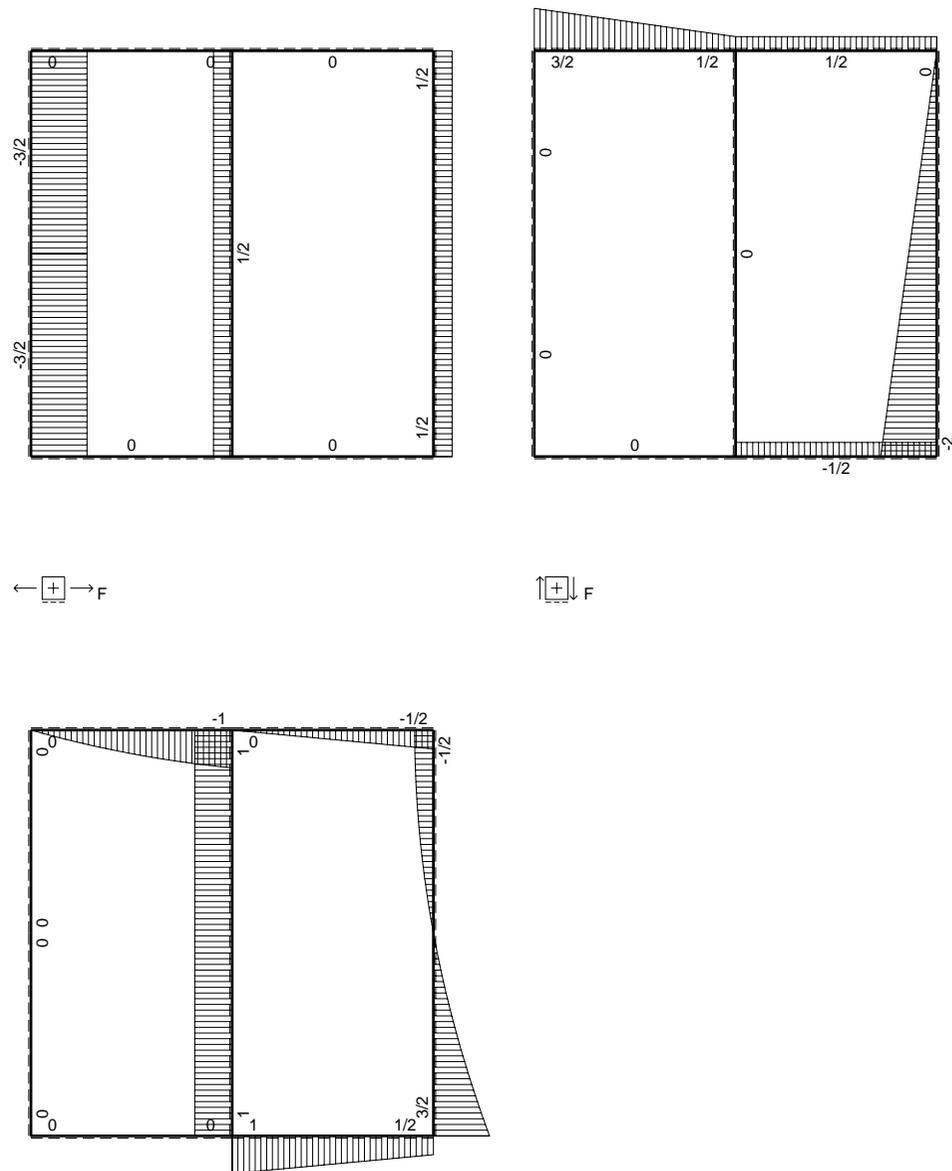
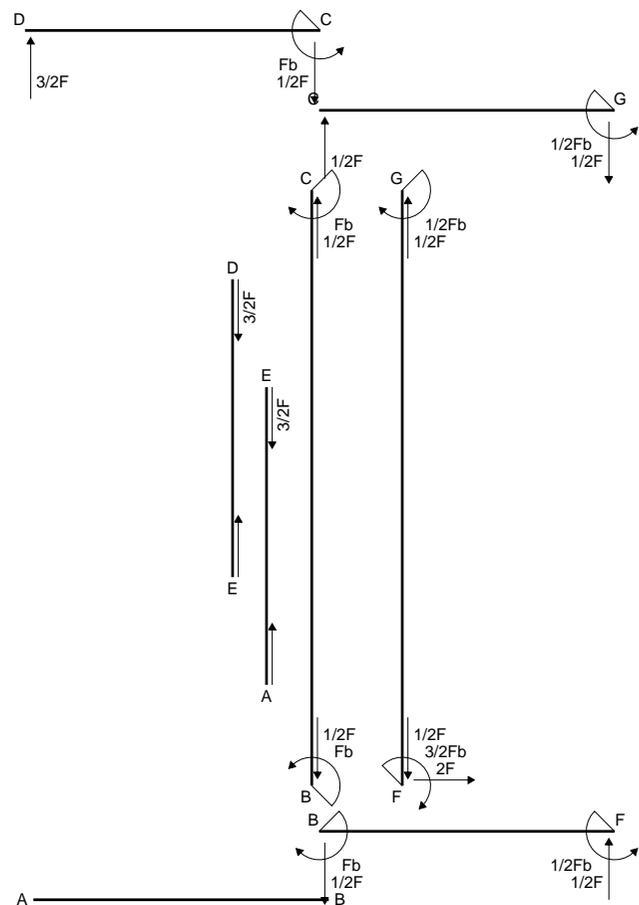
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

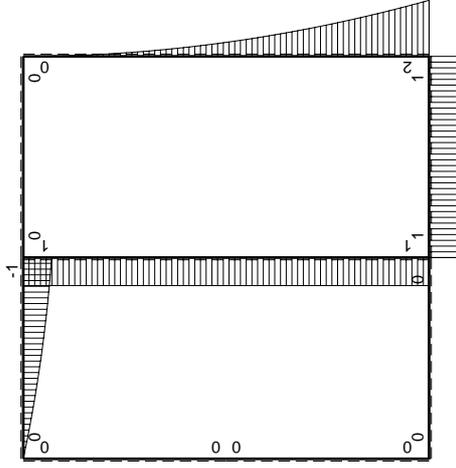
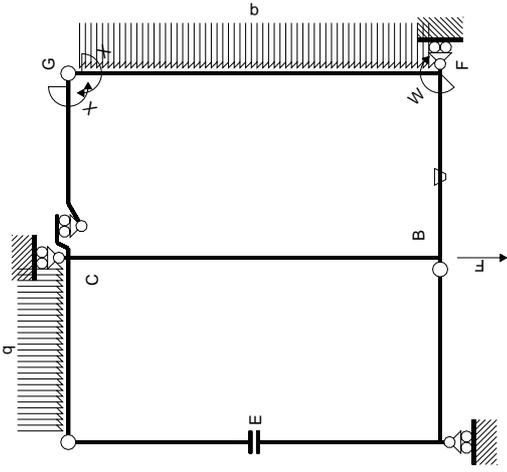
$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



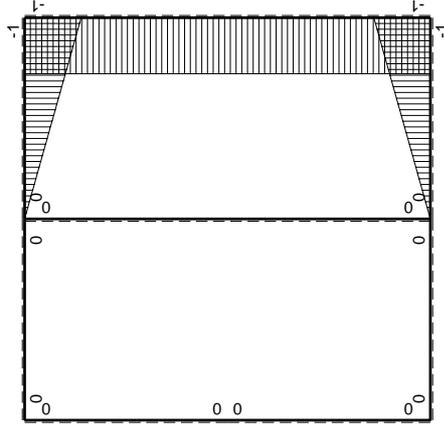
- A = 1116. mm<sup>2</sup>
- J<sub>u</sub> = 278254. mm<sup>4</sup>
- J<sub>v</sub> = 125712. mm<sup>4</sup>
- y<sub>g</sub> = 35.6 mm
- N = 4221. N
- T<sub>y</sub> = -3070. N
- M<sub>x</sub> = 1842000. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -35.6 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = 239.4 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 15. mm
- v<sub>c</sub> = -20.6 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = 140.1 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.65 N/mm<sup>2</sup>
- σ<sub>φ</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 140.4 N/mm<sup>2</sup>
- S = 5057. mm<sup>3</sup>







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica $X=W_{gc}$		Sviluppi di calcolo iperstatica						
$\leftarrow$	$M_x(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0+0	0
CD b	0	$-Fb+1/2Fx+1/2qx^2$	0	0	0	0	0+0	0
DC b	0	$3/2Fx-1/2qx^2$	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
ED b	0	0	0	0	0	0	0+0	0
EA b	0	0	0	0	0	0	0+0	0
AE b	0	0	0	0	0	0	0+0	0
BF b	$-x/b$	Fb	$-Fb/EJ$	$-Fx$	$Fx/EJ$	$x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$-Fb$	Fb/EJ	$-Fb+Fx$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	$2Fb-2Fx+1/2qx^2$	0	$-2Fb+2Fx-1/2Fx^2/b$	0	1	$(-4/3+0)Fb^2/EJ$	$2xb/EJ$
GF 2b	1	$-1/2qx^2$	0	$-1/2Fx^2/b$	0	1	$(-4/3+0)Fb^2/EJ$	$2xb/EJ$
CB 2b	0	Fb	0	0	0	0	0+0	0
BC 2b	0	$-Fb$	0	0	0	0	0+0	0
totali							$-4/3Fb^2/EJ$	$8/3xb/EJ$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{xo} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{xo} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

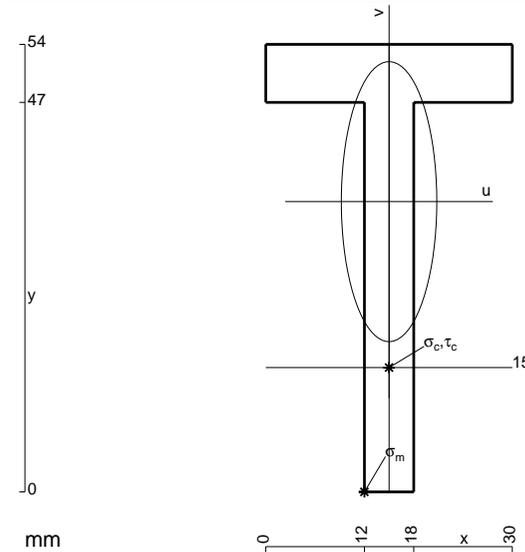
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{xo} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

$$L_{GF}^{xo} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



- A = 492. mm<sup>2</sup>
- J<sub>u</sub> = 140516. mm<sup>4</sup>
- J<sub>v</sub> = 16596. mm<sup>4</sup>
- y<sub>g</sub> = 35.02 mm
- T<sub>y</sub> = 2000. N
- M<sub>x</sub> = -800000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -35.02 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -199.4 N/mm<sup>2</sup>
- x<sub>c</sub> = 15. mm
- y<sub>c</sub> = 15. mm
- v<sub>c</sub> = -20.02 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -114. N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.876 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 114.5 N/mm<sup>2</sup>
- S = 2477. mm<sup>3</sup>







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

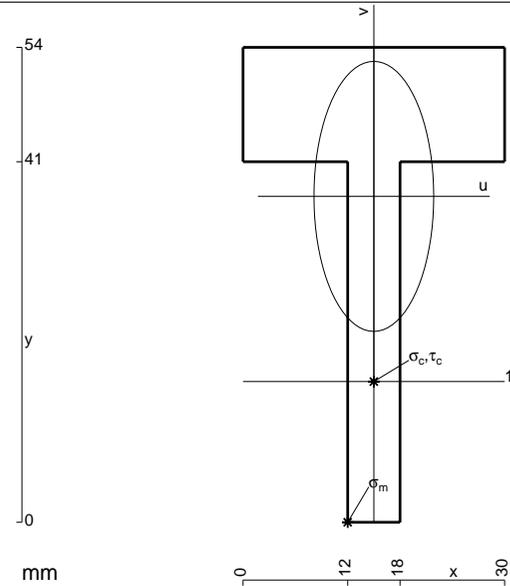
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

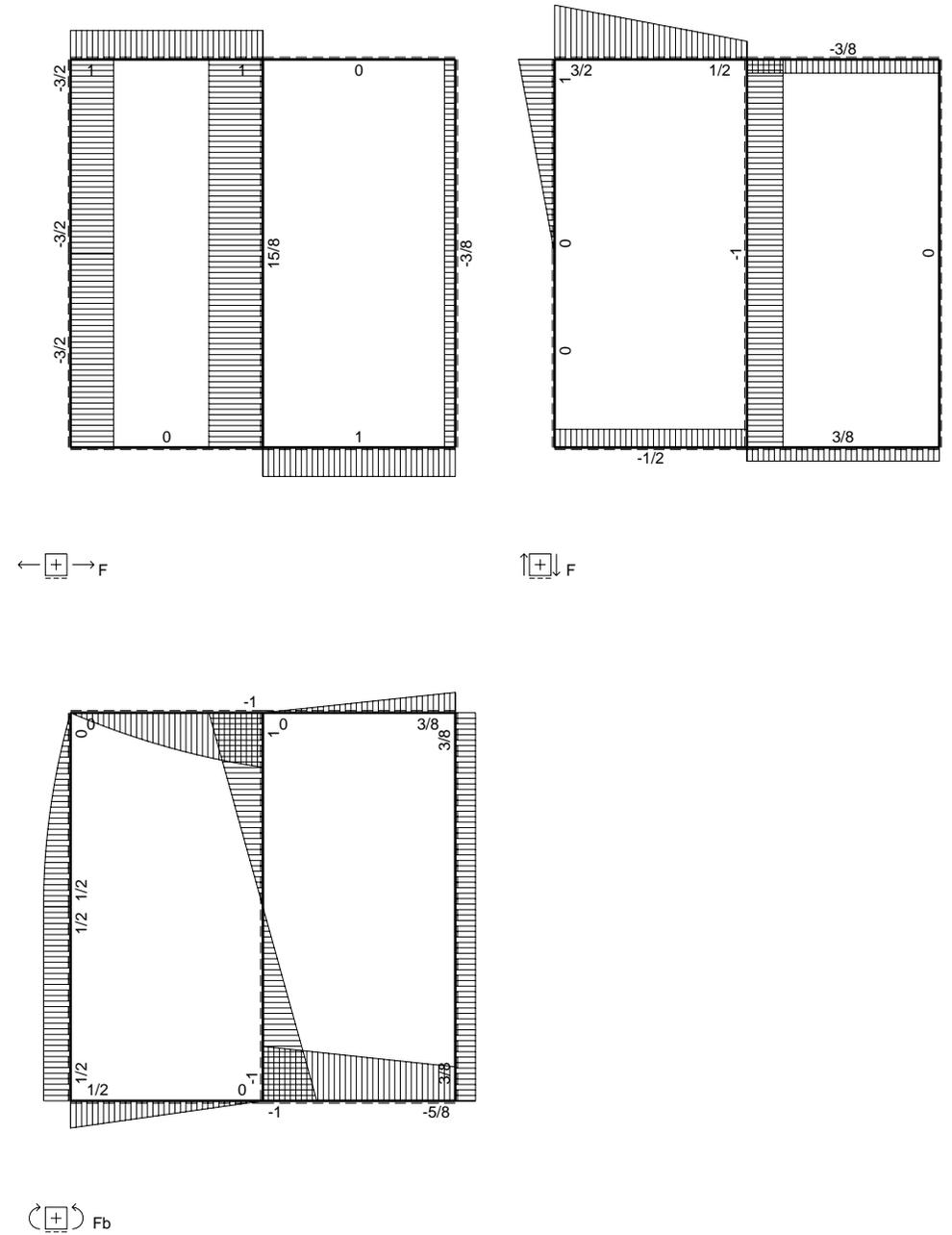
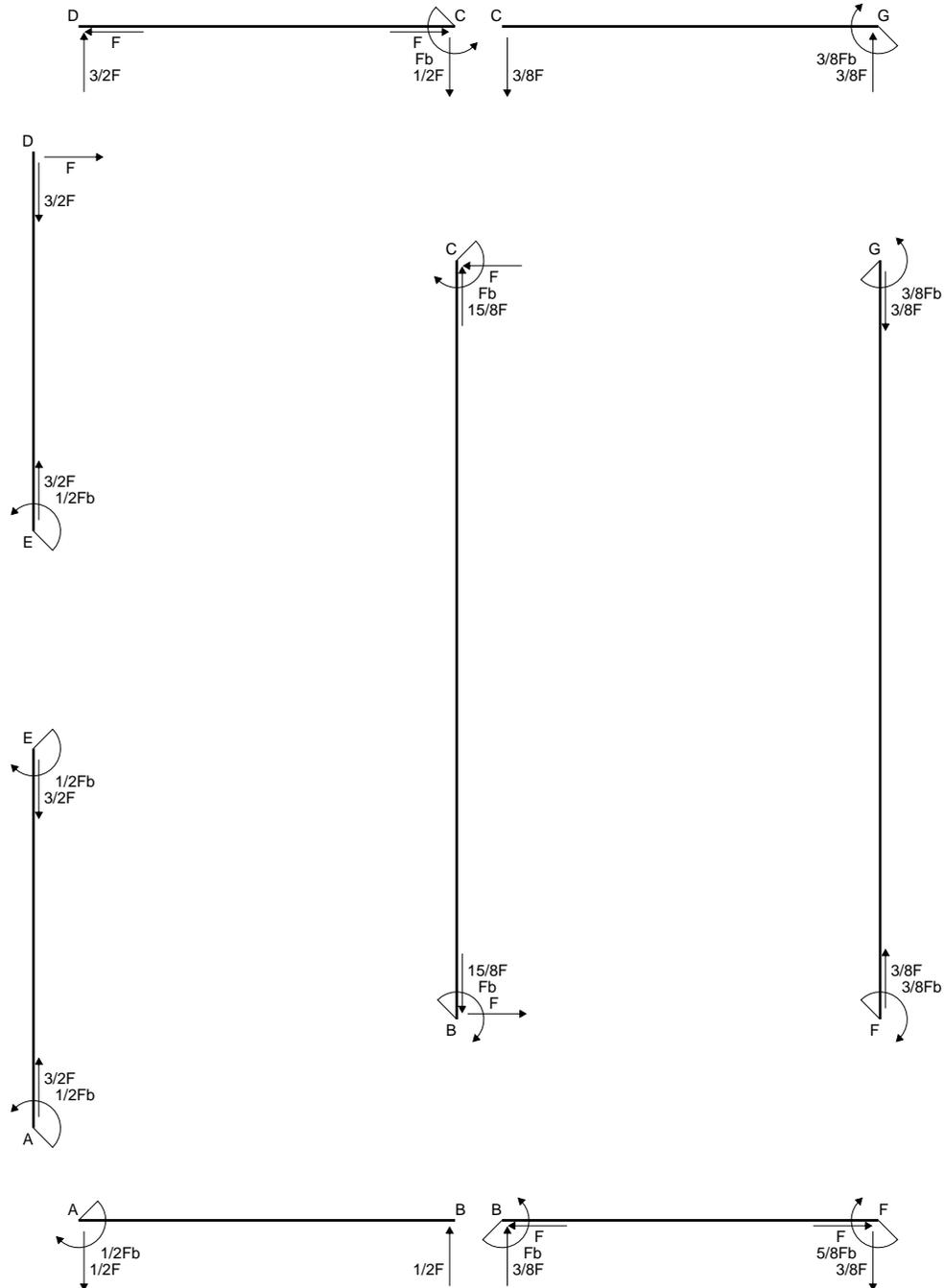
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

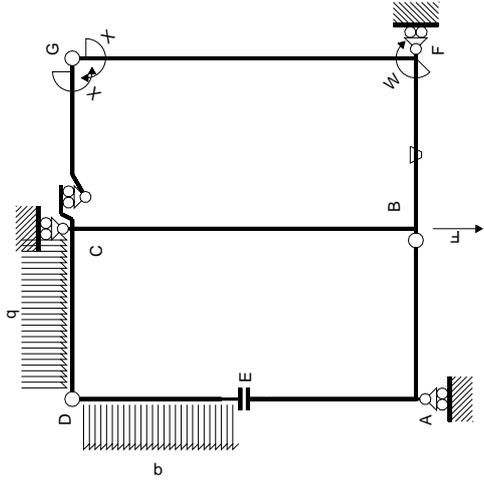
$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



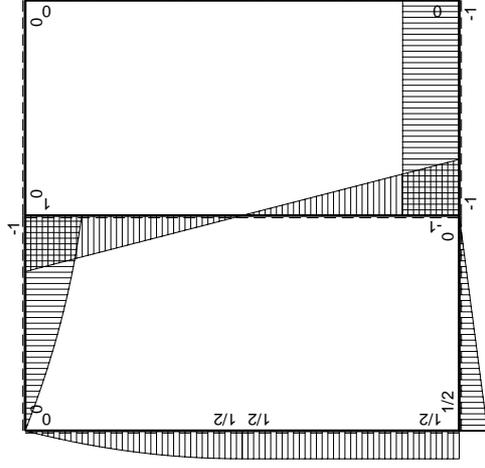
- A = 636. mm<sup>2</sup>
- J<sub>u</sub> = 149922. mm<sup>4</sup>
- J<sub>v</sub> = 29988. mm<sup>4</sup>
- y<sub>g</sub> = 37.06 mm
- N = 1733. N
- T<sub>y</sub> = -2520. N
- M<sub>x</sub> = -856800. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -37.06 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = -209.1 N/mm<sup>2</sup>
- x<sub>c</sub> = 15. mm
- y<sub>c</sub> = 16. mm
- v<sub>c</sub> = -21.06 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = -117.6 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.814 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 118.4 N/mm<sup>2</sup>
- S = 2789. mm<sup>3</sup>



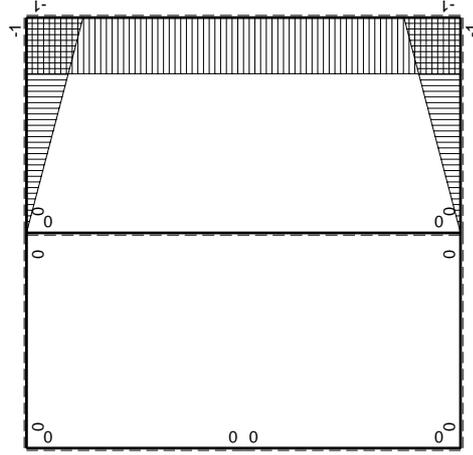




Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / EJ dx$
AB b	0	$1/2Fb - 1/2Fx$	0	0	0	0	0+0	0
BA b	0	$-1/2Fx$	0	0	0	0	0+0	0
CD b	0	$-Fb + 1/2Fx + 1/2qx^2$	0	0	0	0	0+0	0
DC b	0	$3/2Fx - 1/2qx^2$	0	0	0	0	0+0	0
DE b	0	$Fx - 1/2qx^2$	0	0	0	0	0+0	0
ED b	0	$-1/2Fb + 1/2qx^2$	0	0	0	0	0+0	0
EA b	0	$1/2Fb$	0	0	0	0	0+0	0
AE b	0	$-1/2Fb$	0	0	0	0	0+0	0
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2 + 1/2)Fb^2/EJ$	$1/3xb/EJ$
FBB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb-Fx$	$Fb-Fx/EJ$	$1-2x/b+x^2/b^2$	$1/3xb/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2xb/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2xb/EJ$
CB 2b	0	$Fb-Fx$	0	0	0	0	0+0	0
BC 2b	0	$Fb-Fx$	0	0	0	0	0+0	0
totali								$Fb^2/EJ$
								$8/3xb/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

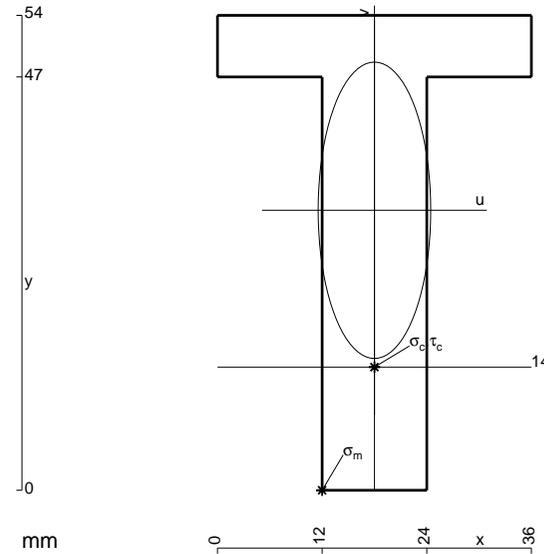
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



$$A = 816. \text{ mm}^2$$

$$J_u = 231827. \text{ mm}^4$$

$$J_v = 33984. \text{ mm}^4$$

$$y_g = 31.84 \text{ mm}$$

$$N = 4013. \text{ N}$$

$$T_y = -2140. \text{ N}$$

$$M_x = 1562200. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -6. \text{ mm}$$

$$v_m = -31.84 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 219.5 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 14. \text{ mm}$$

$$v_c = -17.84 \text{ mm}$$

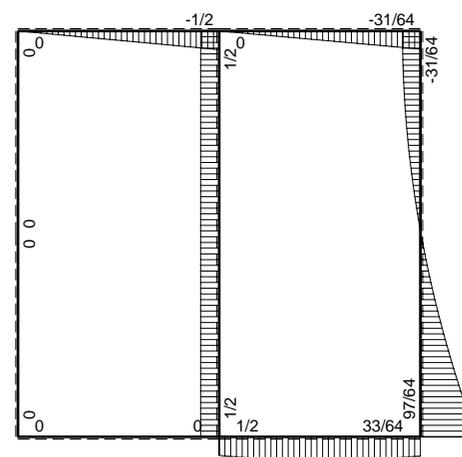
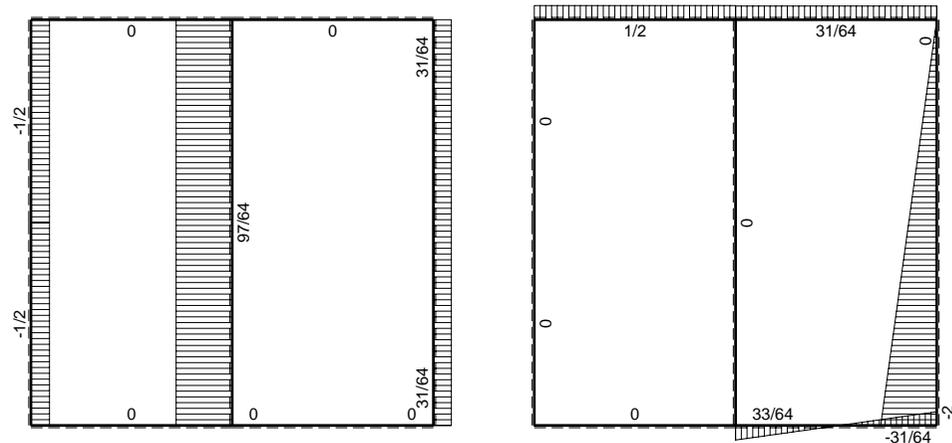
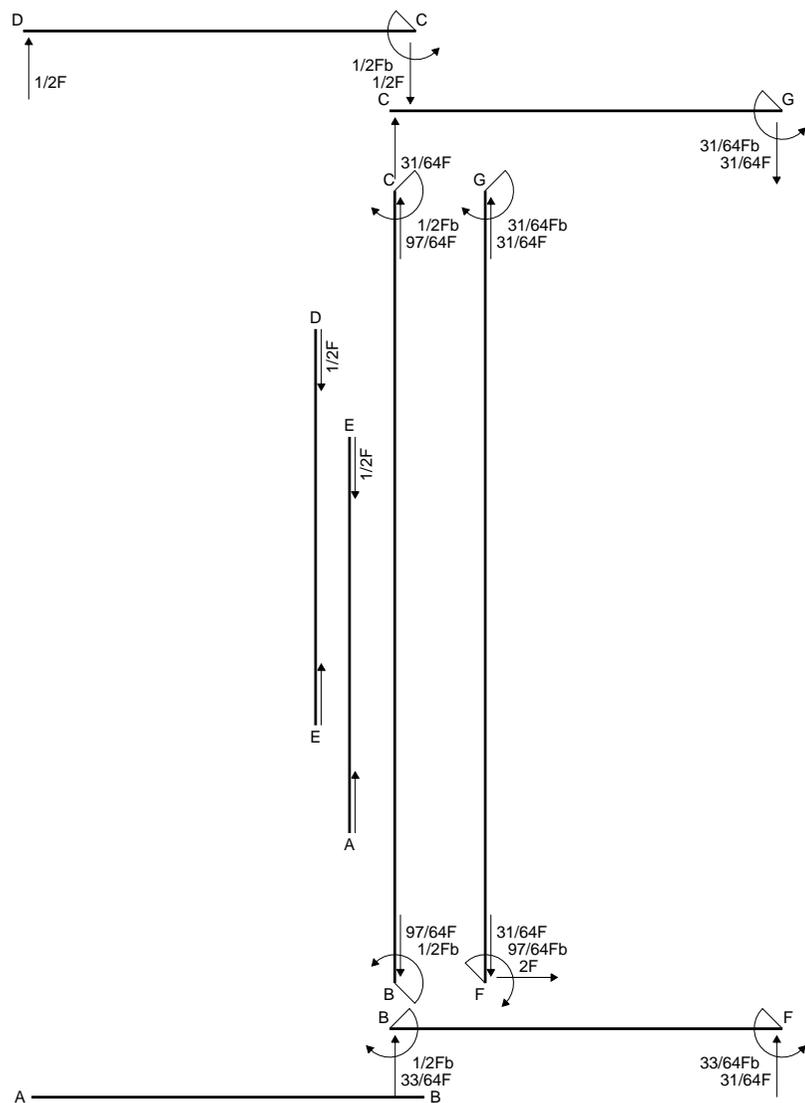
$$\sigma_c = N/A - Mv/J_u = 125.1 \text{ N/mm}^2$$

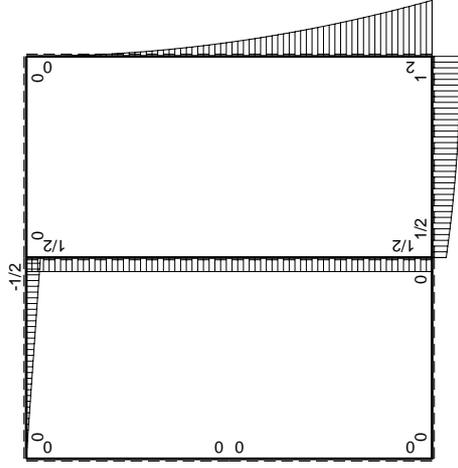
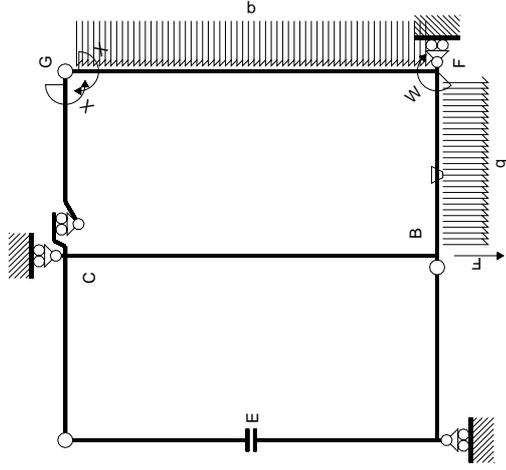
$$\tau_c = 3.21 \text{ N/mm}^2$$

$$\sigma_\varphi = \sqrt{\sigma^2 + 3\tau^2} = 125.2 \text{ N/mm}^2$$

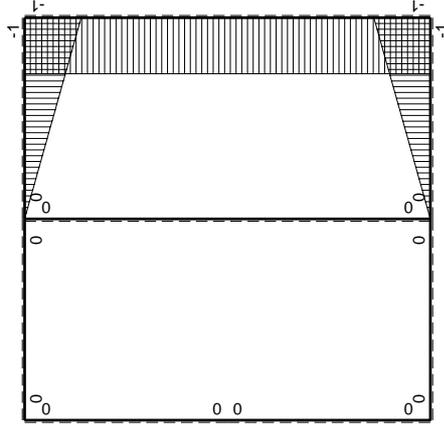
$$S = 4173. \text{ mm}^3$$







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica X=W<sup>gc</sup>

←	M <sup>x</sup> (x)	M <sup>0</sup> (x)	θ	M <sup>x</sup> M <sub>0</sub>	M <sup>x</sup> θ	M <sup>x</sup> M <sub>x</sub>	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJdx$
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0+0	0
CD b	0	-1/2Fx	0	0	0	0	0+0	0
DC b	0	1/2Fx	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
EA b	0	0	0	0	0	0	0+0	0
AE b	0	0	0	0	0	0	0+0	0
BF b	-x/b	1/2Fb+Fx-1/2qx <sup>2</sup>	-Fb/EJ	-1/2Fx-Fx <sup>2</sup> /b+1/2qx <sup>3</sup> /b	Fx/EJ	x <sup>2</sup> /b <sup>2</sup>	(-1/1/24+1/2)Fb <sup>2</sup> /EJ	1/3xb/EJ
FB b	1-x/b	-Fb+1/2qx <sup>2</sup>	Fb/EJ	-Fb+Fx+1/2Fx <sup>2</sup> /b-1/2qx <sup>3</sup> /b	Fb/EJ-Fx/EJ	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	1/3xb/EJ	1/3xb/EJ
GC b	-1+x/b	0	0	0	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	0+0	1/3xb/EJ
CG b	x/b	0	0	0	0	x <sup>2</sup> /b <sup>2</sup>	0+0	1/3xb/EJ
FG 2b	-1	2Fb-2Fx+1/2qx <sup>2</sup>	0	-2Fb+2Fx-1/2Fx <sup>2</sup> /b	0	1	(-4/3+0)Fb <sup>2</sup> /EJ	2xb/EJ
GF 2b	1	-1/2qx <sup>2</sup>	0	-1/2Fx <sup>2</sup> /b	0	1	0+0	2xb/EJ
CB 2b	0	1/2Fb	0	0	0	0	0+0	0
BC 2b	0	-1/2Fb	0	0	0	0	0+0	0
totali							-31/24Fb <sup>2</sup> /EJ	8/3xb/EJ
							31/64Fb	

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{xo} = \int_0^b (-1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

$$= [-1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/4 b - 1/3 b + 1/8 b) Fb 1/EJ + (1/2 b) \theta = 1/24 Fb^2/EJ$$

$$L_{FB}^{xo} = \int_0^b (-1 + x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

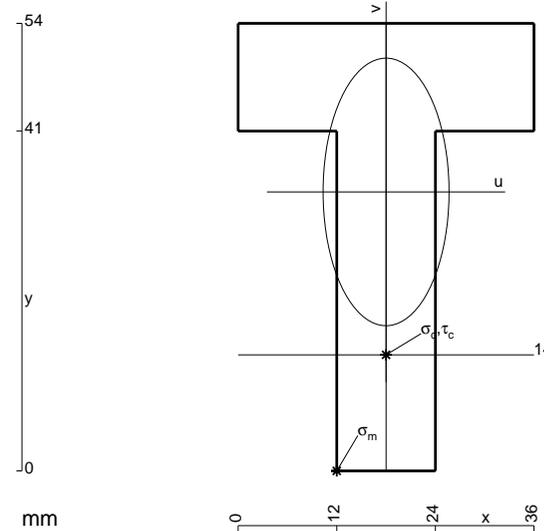
$$= (-b + 1/2 b + 1/6 b - 1/8 b) Fb 1/EJ + (-b + 1/2 b) \theta = 1/24 Fb^2/EJ$$

$$L_{FG}^{xo} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

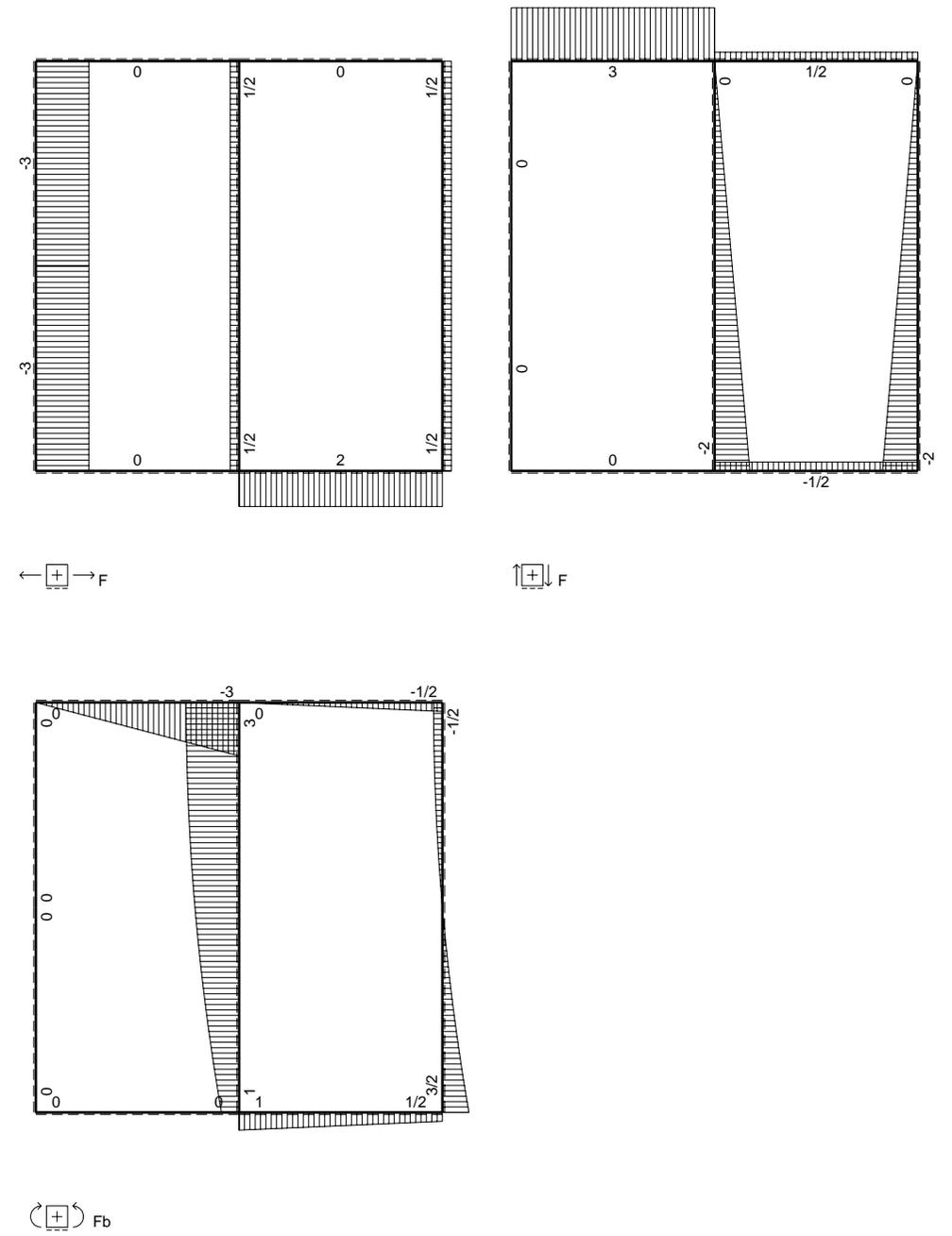
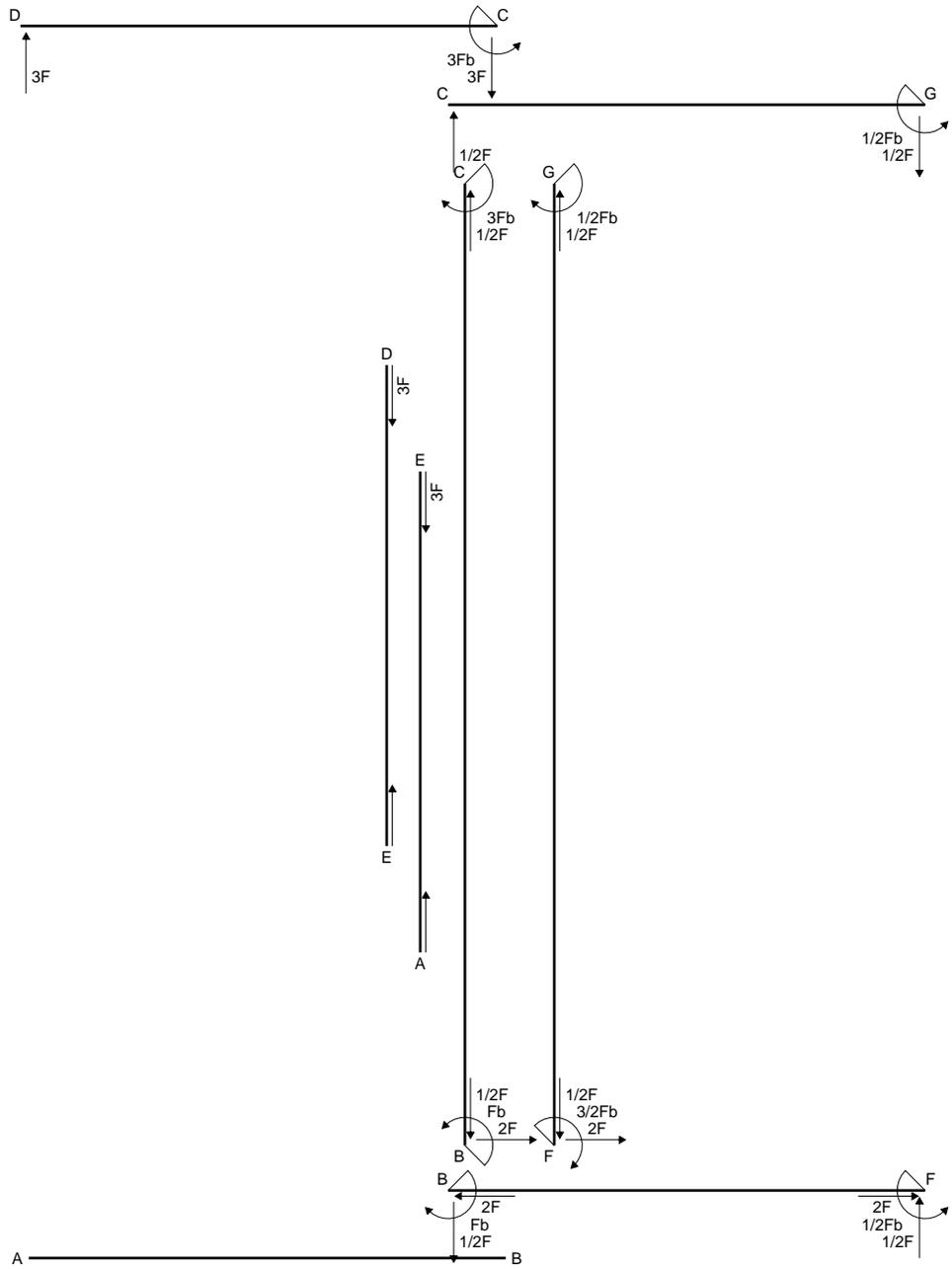
$$L_{GF}^{xo} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



- A = 960. mm<sup>2</sup>
- J<sub>u</sub> = 250363. mm<sup>4</sup>
- J<sub>v</sub> = 56448. mm<sup>4</sup>
- y<sub>g</sub> = 33.66 mm
- T<sub>y</sub> = 2220. N
- M<sub>x</sub> = -1709400. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -33.66 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -229.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 14. mm
- v<sub>c</sub> = -19.66 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -134.2 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.31 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 134.4 N/mm<sup>2</sup>
- S = 4479. mm<sup>3</sup>







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x\theta} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x\theta} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

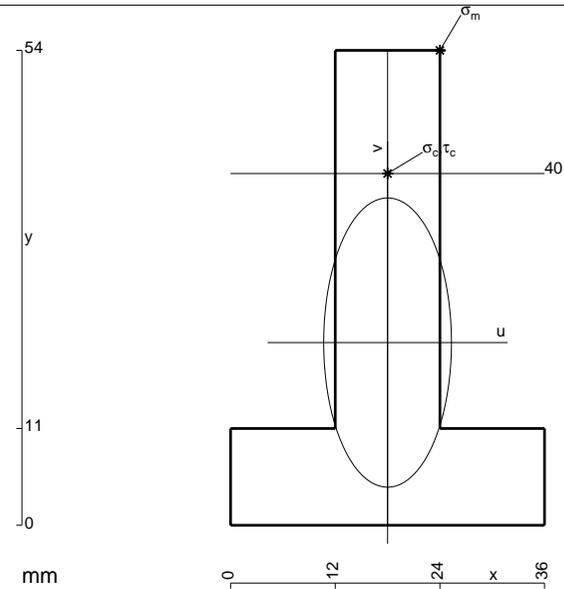
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x\theta} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

$$L_{GF}^{x\theta} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



$$A = 912. \text{ mm}^2$$

$$J_u = 246834. \text{ mm}^4$$

$$J_v = 48960. \text{ mm}^4$$

$$y_g = 20.78 \text{ mm}$$

$$T_y = 2190. \text{ N}$$

$$M_x = -1773900. \text{ Nmm}$$

$$x_m = 24. \text{ mm}$$

$$y_m = 54. \text{ mm}$$

$$u_m = 6. \text{ mm}$$

$$v_m = 33.22 \text{ mm}$$

$$\sigma_m = -Mv/J_u = 238.8 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 40. \text{ mm}$$

$$v_c = 19.22 \text{ mm}$$

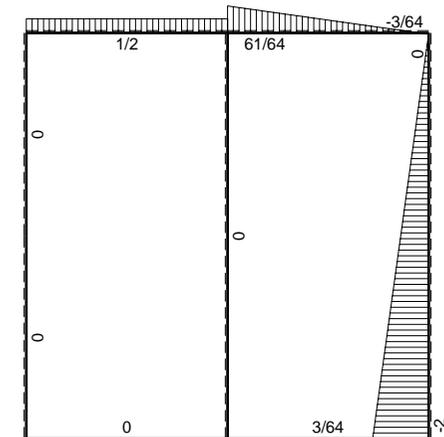
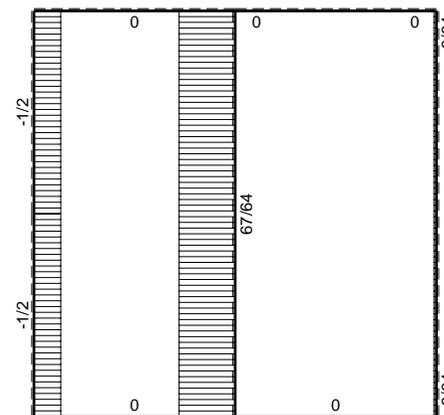
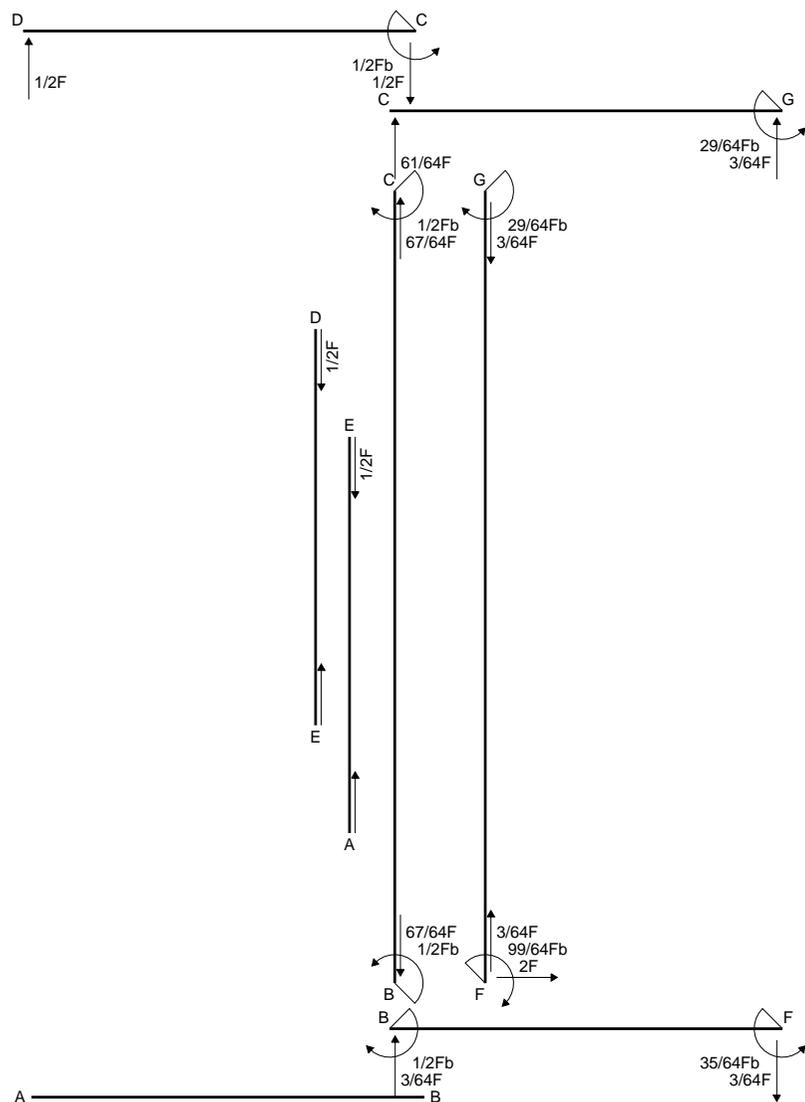
$$\sigma_c = -Mv/J_u = 138.2 \text{ N/mm}^2$$

$$\tau_c = 3.257 \text{ N/mm}^2$$

$$\sigma_\varrho = \sqrt{\sigma^2 + 3\tau^2} = 138.3 \text{ N/mm}^2$$

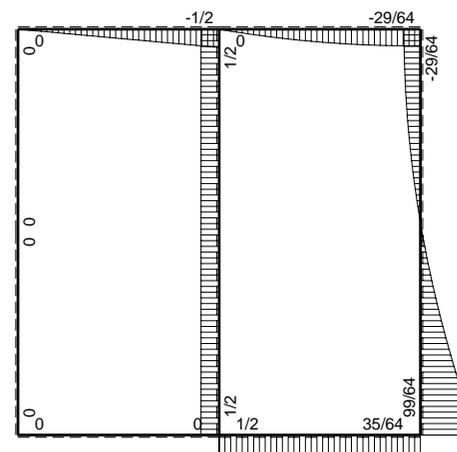
$$S = 4406. \text{ mm}^3$$



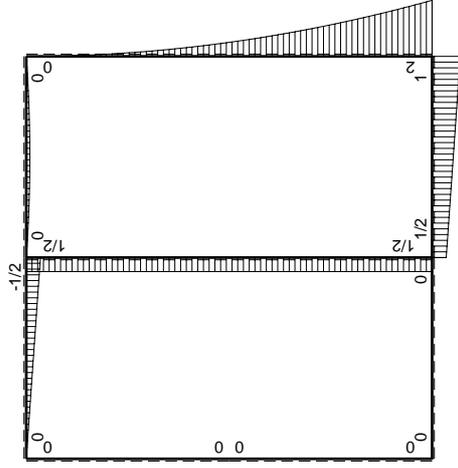
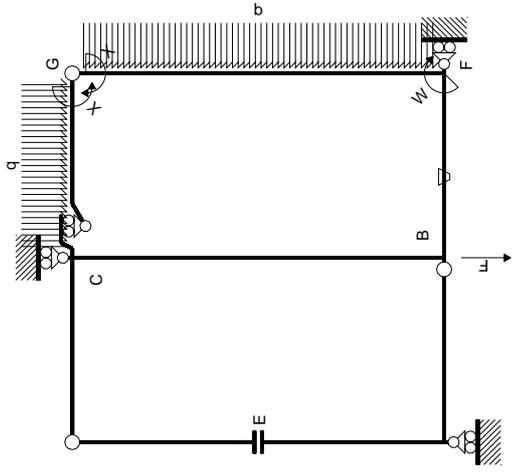


← ⊕ → F

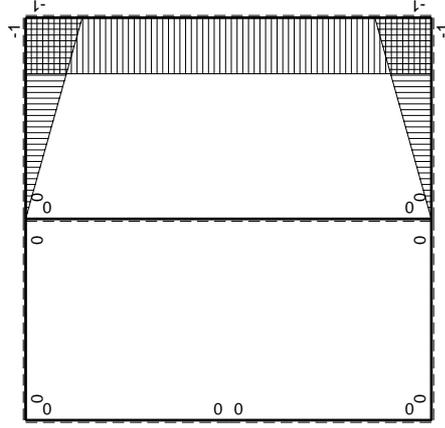
↑ ⊕ ↓ F



⊕ F<sub>b</sub>



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\leftarrow$	$M_x(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0+0	0
CD b	0	$-1/2Fb+1/2Fx$	0	0	0	0	0+0	0
DC b	0	$1/2Fx$	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
EA b	0	0	0	0	0	0	0+0	0
AE b	0	0	0	0	0	0	0+0	0
BF b	$-x/b$	$1/2Fb+1/2Fx$	$-Fb/EJ$	$-1/2Fx-1/2Fx^2/b$	$Fx/EJ$	$x^2/b^2$	$(-5/12+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$-Fb+1/2Fx$	$Fb/EJ$	$-Fb+3/2Fx-1/2Fx^2/b$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$(1/24+0)Fb^2/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	$-1/2Fx+1/2qx^2$	0	$1/2Fx-Fx^2/b+1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(1/24+0)Fb^2/EJ$	$1/3xb/EJ$
CG b	$x/b$	$1/2Fx-1/2qx^2$	0	$1/2Fx^2/b-1/2qx^3/b$	0	$x^2/b^2$	$(1/24+0)Fb^2/EJ$	$1/3xb/EJ$
FG 2b	-1	$2Fb-2Fx+1/2qx^2$	0	$-2Fb+2Fx-1/2Fx^2/b$	0	1	$(-4/3+0)Fb^2/EJ$	$2xb/EJ$
GF 2b	1	$-1/2qx^2$	0	$-1/2Fx^2/b$	0	1	$(-4/3+0)Fb^2/EJ$	$2xb/EJ$
CB 2b	0	$1/2Fb$	0	0	0	0	0+0	0
BC 2b	0	$-1/2Fb$	0	0	0	0	0+0	0
totali							$-29/24Fb^2/EJ$	$8/3xb/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (-1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

$$= [-1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/4 b - 1/6 b) Fb 1/EJ + (1/2 b) \theta = 1/12 Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (-1 + 3/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 3/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (-b + 3/4 b - 1/6 b) Fb 1/EJ + (-b + 1/2 b) \theta = 1/12 Fb^2/EJ$$

$$L_{GC}^{x_0} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{CG}^{x_0} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

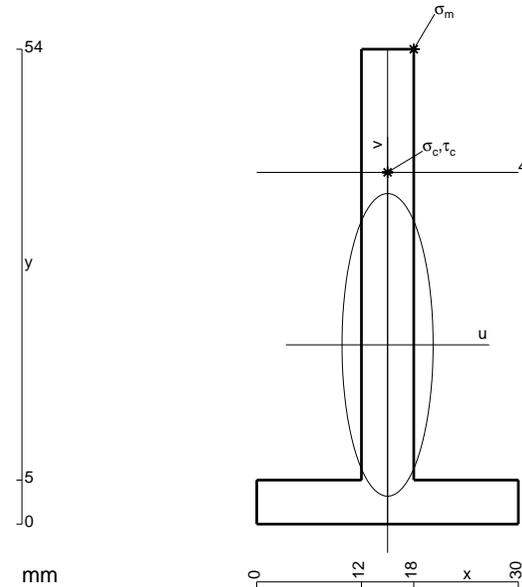
$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{FG}^{x_0} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

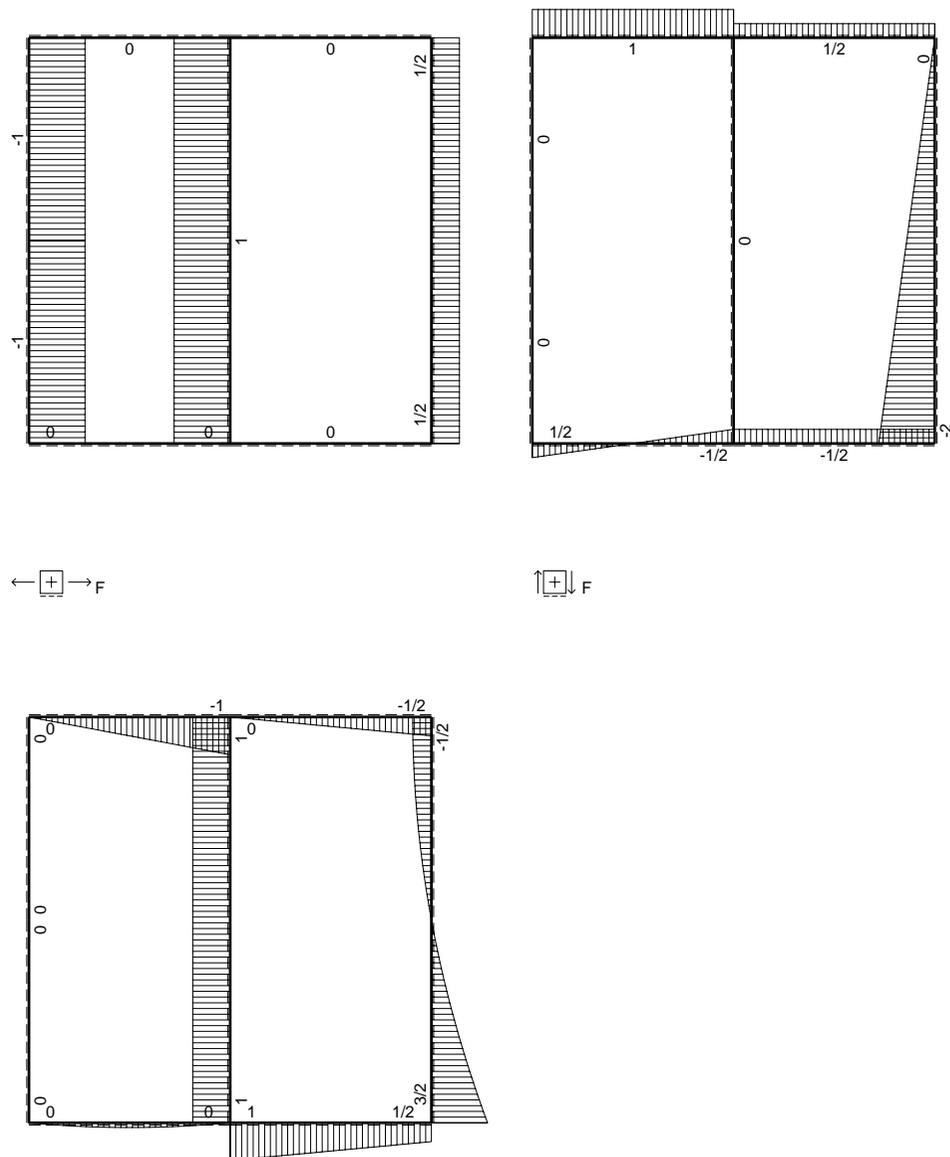
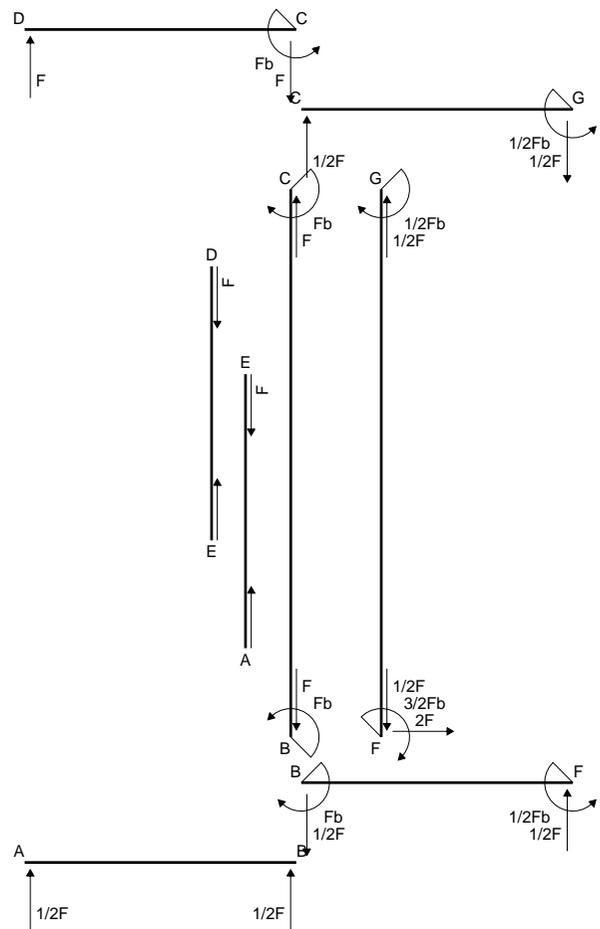
$$L_{GF}^{x_0} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



- A = 444. mm<sup>2</sup>
- J<sub>u</sub> = 131544. mm<sup>4</sup>
- J<sub>v</sub> = 12132. mm<sup>4</sup>
- y<sub>g</sub> = 20.38 mm
- T<sub>y</sub> = 1815. N
- M<sub>x</sub> = -780450. Nmm
- x<sub>m</sub> = 18. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 3. mm
- v<sub>m</sub> = 33.62 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 199.5 N/mm<sup>2</sup>
- x<sub>c</sub> = 15. mm
- y<sub>c</sub> = 40. mm
- v<sub>c</sub> = 19.62 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 116.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.142 N/mm<sup>2</sup>
- σ<sub>0</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 116.8 N/mm<sup>2</sup>
- S = 2236. mm<sup>3</sup>





$\oplus \curvearrowright F_b$



$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x\theta} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x\theta} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

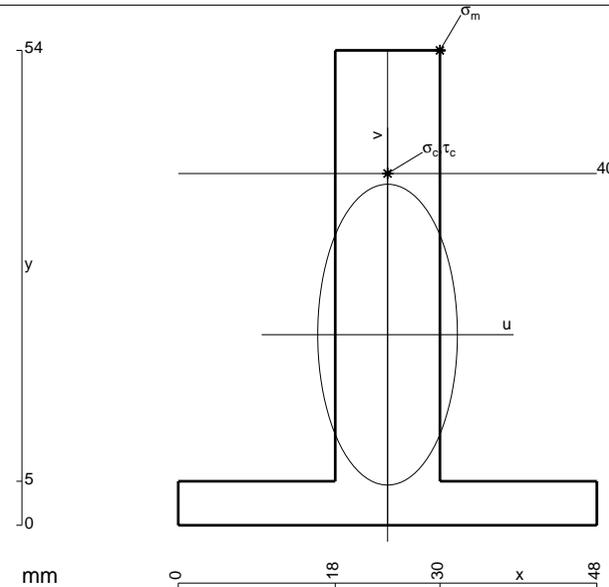
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x\theta} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

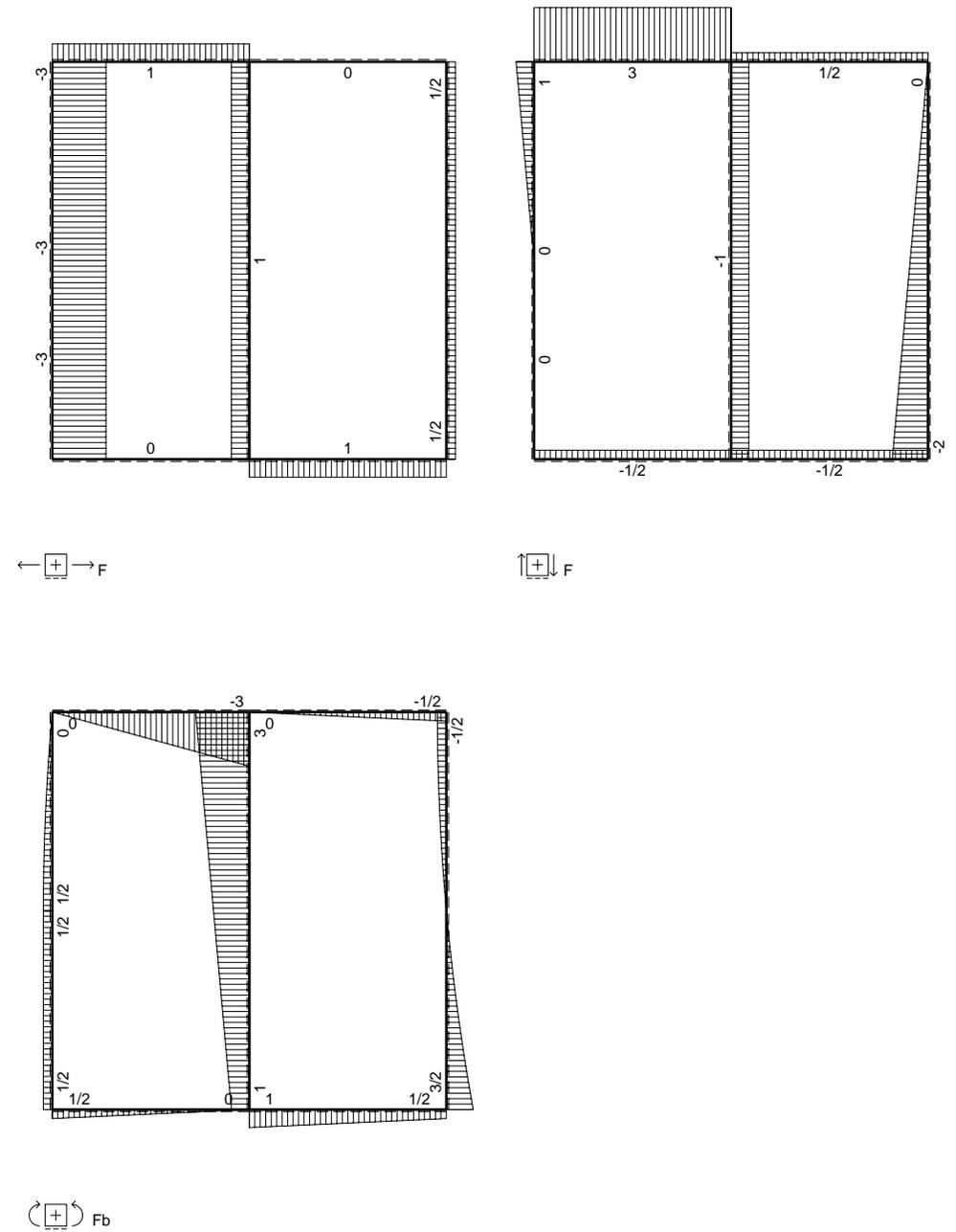
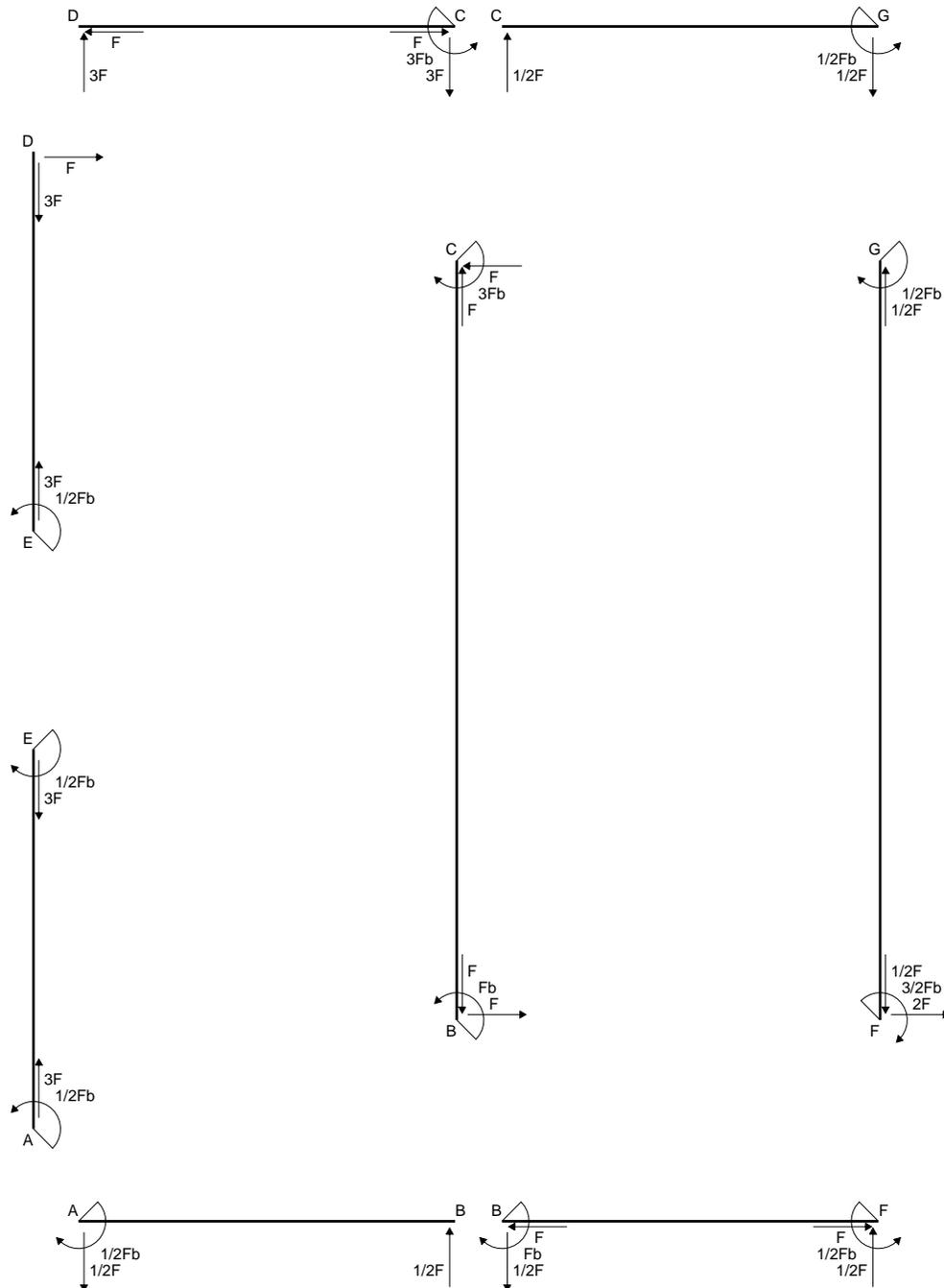
$$L_{GF}^{x\theta} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



- A = 828. mm<sup>2</sup>
- J<sub>u</sub> = 242396. mm<sup>4</sup>
- J<sub>v</sub> = 53136. mm<sup>4</sup>
- y<sub>g</sub> = 21.67 mm
- T<sub>y</sub> = 3350. N
- M<sub>x</sub> = -1574500. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 32.33 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> = 40. mm
- v<sub>c</sub> = 18.33 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 119. N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.9 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 119.3 N/mm<sup>2</sup>
- S = 4255. mm<sup>3</sup>







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x_0} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

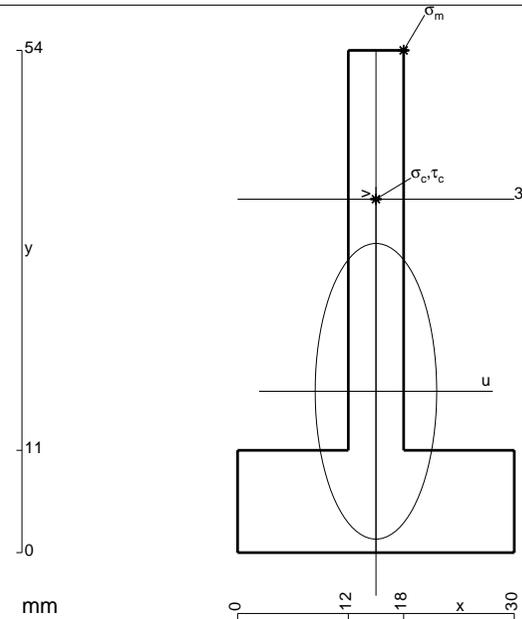
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x_0} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

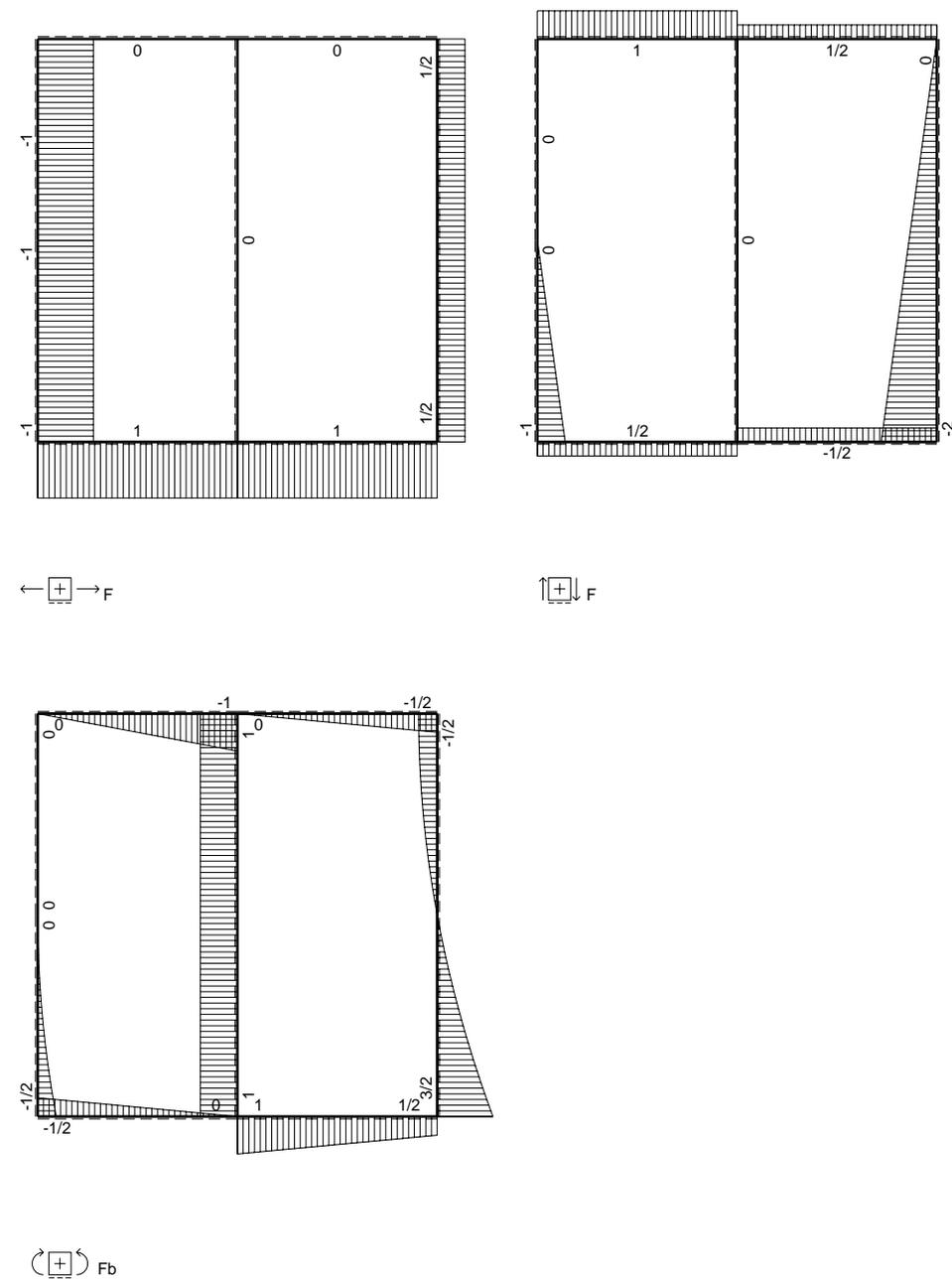
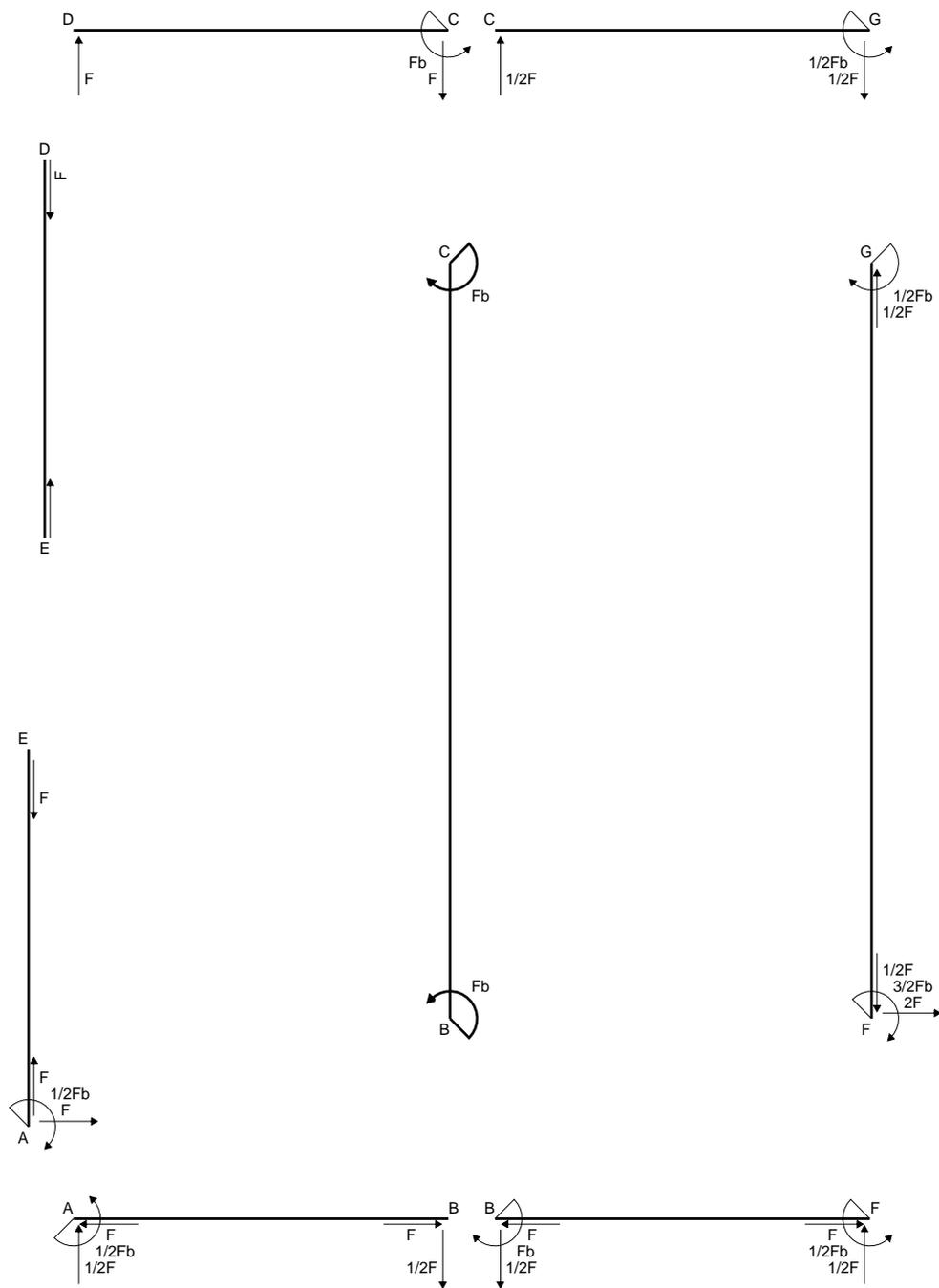
$$L_{GF}^{x_0} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



- A = 588. mm<sup>2</sup>
- J<sub>u</sub> = 148637. mm<sup>4</sup>
- J<sub>v</sub> = 25524. mm<sup>4</sup>
- y<sub>g</sub> = 17.35 mm
- N = 580. N
- T<sub>y</sub> = 1740. N
- M<sub>x</sub> = -887400. Nmm
- x<sub>m</sub> = 18. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 3. mm
- v<sub>m</sub> = 36.65 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = 219.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 15. mm
- y<sub>c</sub> = 38. mm
- v<sub>c</sub> = 20.65 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = 124.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.367 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 124.6 N/mm<sup>2</sup>
- S = 2751. mm<sup>3</sup>







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x_0} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

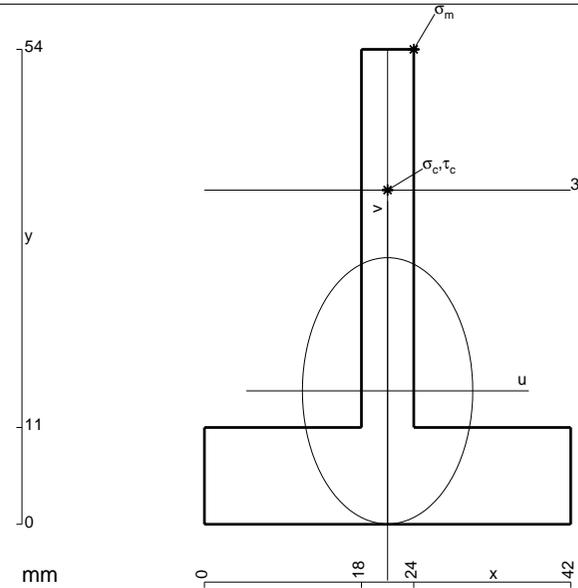
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x_0} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

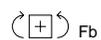
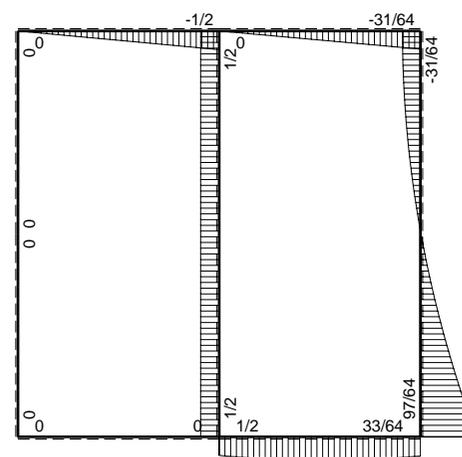
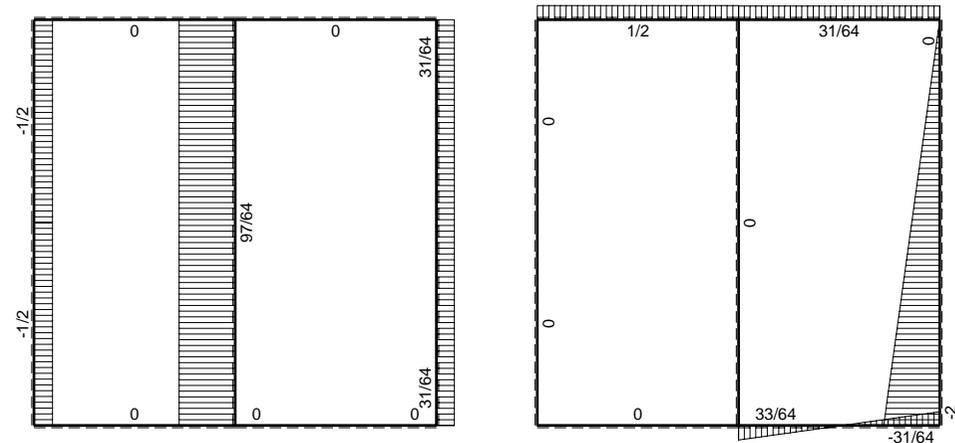
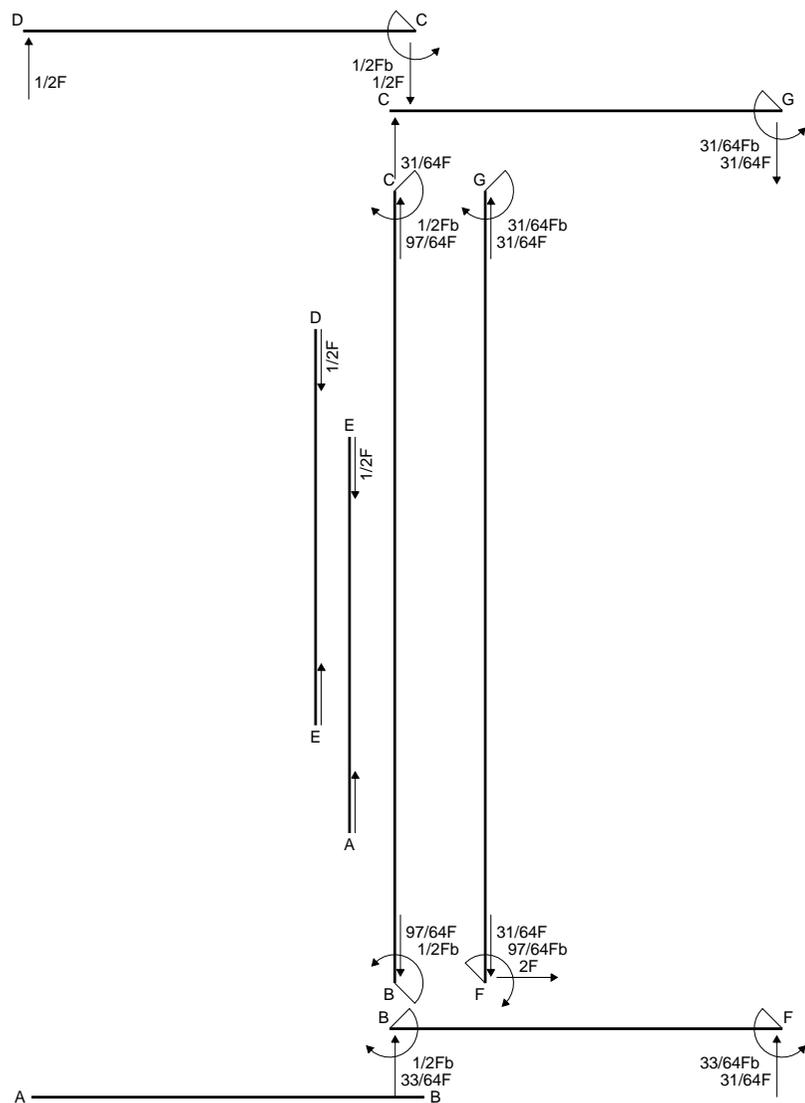
$$L_{GF}^{x_0} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

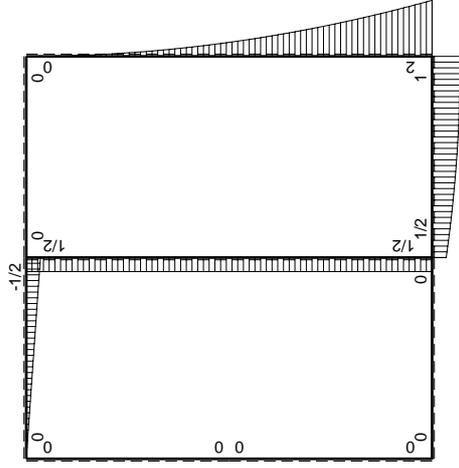
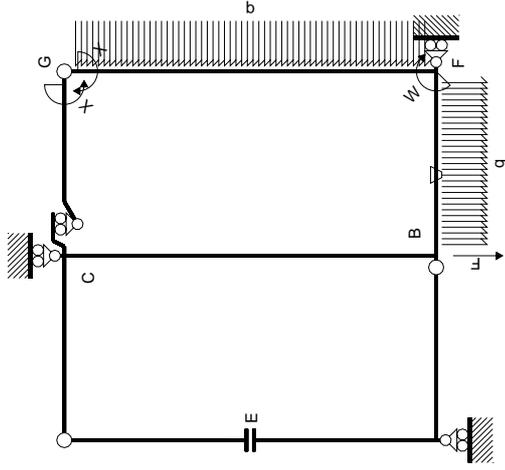
$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



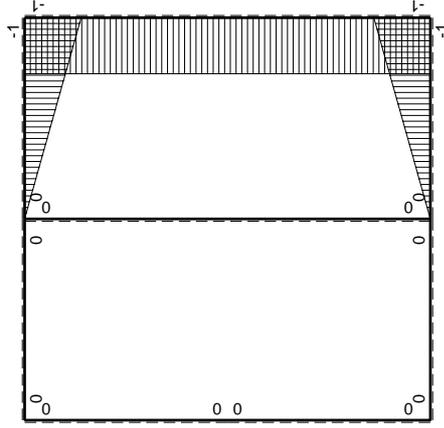
- A = 720. mm<sup>2</sup>
- J<sub>u</sub> = 165098. mm<sup>4</sup>
- J<sub>v</sub> = 68688. mm<sup>4</sup>
- y<sub>g</sub> = 15.18 mm
- T<sub>y</sub> = 1770. N
- M<sub>x</sub> = -973500. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 3. mm
- v<sub>m</sub> = 38.83 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 228.9 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 38. mm
- v<sub>c</sub> = 22.83 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 134.6 N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.288 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 134.9 N/mm<sup>2</sup>
- S = 2959. mm<sup>3</sup>







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica X=W<sup>gc</sup>

←	M <sup>x</sup> (x)	M <sup>0</sup> (x)	θ	M <sup>x</sup> M <sub>0</sub>	M <sup>x</sup> θ	M <sup>x</sup> M <sub>x</sub>	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJdx$
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0+0	0
CD b	0	-1/2Fb+1/2Fx	0	0	0	0	0+0	0
DC b	0	1/2Fx	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
EA b	0	0	0	0	0	0	0+0	0
AE b	0	0	0	0	0	0	0+0	0
BF b	-x/b	1/2Fb+Fx-1/2qx <sup>2</sup>	-Fb/EJ	-1/2Fx-Fx <sup>2</sup> /b+1/2qx <sup>3</sup> /b	Fx/EJ	x <sup>2</sup> /b <sup>2</sup>	(-1/1/24+1/2)Fb <sup>2</sup> /EJ	1/3xb/EJ
FB b	1-x/b	-Fb+1/2qx <sup>2</sup>	Fb/EJ	-Fb+Fx+1/2Fx <sup>2</sup> /b-1/2qx <sup>3</sup> /b	Fb/EJ-Fx/EJ	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	-1/1/24+1/2)Fb <sup>2</sup> /EJ	1/3xb/EJ
GC b	-1+x/b	0	0	0	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	0+0	1/3xb/EJ
CG b	x/b	0	0	0	0	x <sup>2</sup> /b <sup>2</sup>	0+0	1/3xb/EJ
FG 2b	-1	2Fb-2Fx+1/2qx <sup>2</sup>	0	-2Fb+2Fx-1/2Fx <sup>2</sup> /b	0	1	(-4/3+0)Fb <sup>2</sup> /EJ	2xb/EJ
GF 2b	1	-1/2qx <sup>2</sup>	0	-1/2Fx <sup>2</sup> /b	0	1	-4/3+0)Fb <sup>2</sup> /EJ	2xb/EJ
CB 2b	0	1/2Fb	0	0	0	0	0+0	0
BC 2b	0	-1/2Fb	0	0	0	0	0+0	0
totali							-31/24Fb <sup>2</sup> /EJ	8/3xb/EJ
								31/64Fb

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x\theta} = \int_0^b (-1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

$$= [-1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/4 b - 1/3 b + 1/8 b) Fb 1/EJ + (1/2 b) \theta = 1/24 Fb^2/EJ$$

$$L_{FB}^{x\theta} = \int_0^b (-1 + x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

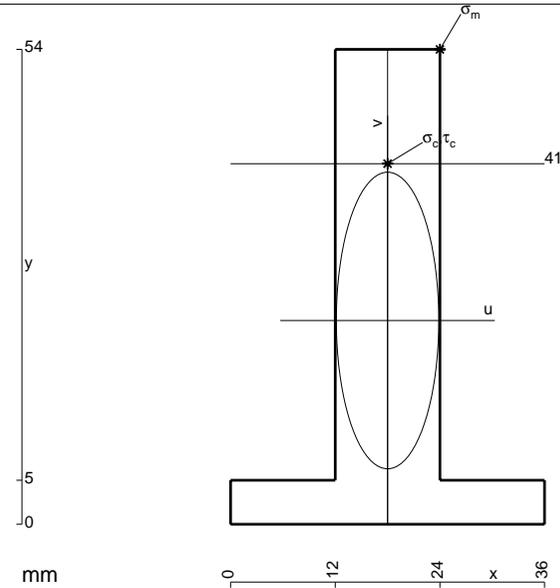
$$= (-b + 1/2 b + 1/6 b - 1/8 b) Fb 1/EJ + (-b + 1/2 b) \theta = 1/24 Fb^2/EJ$$

$$L_{FG}^{x\theta} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

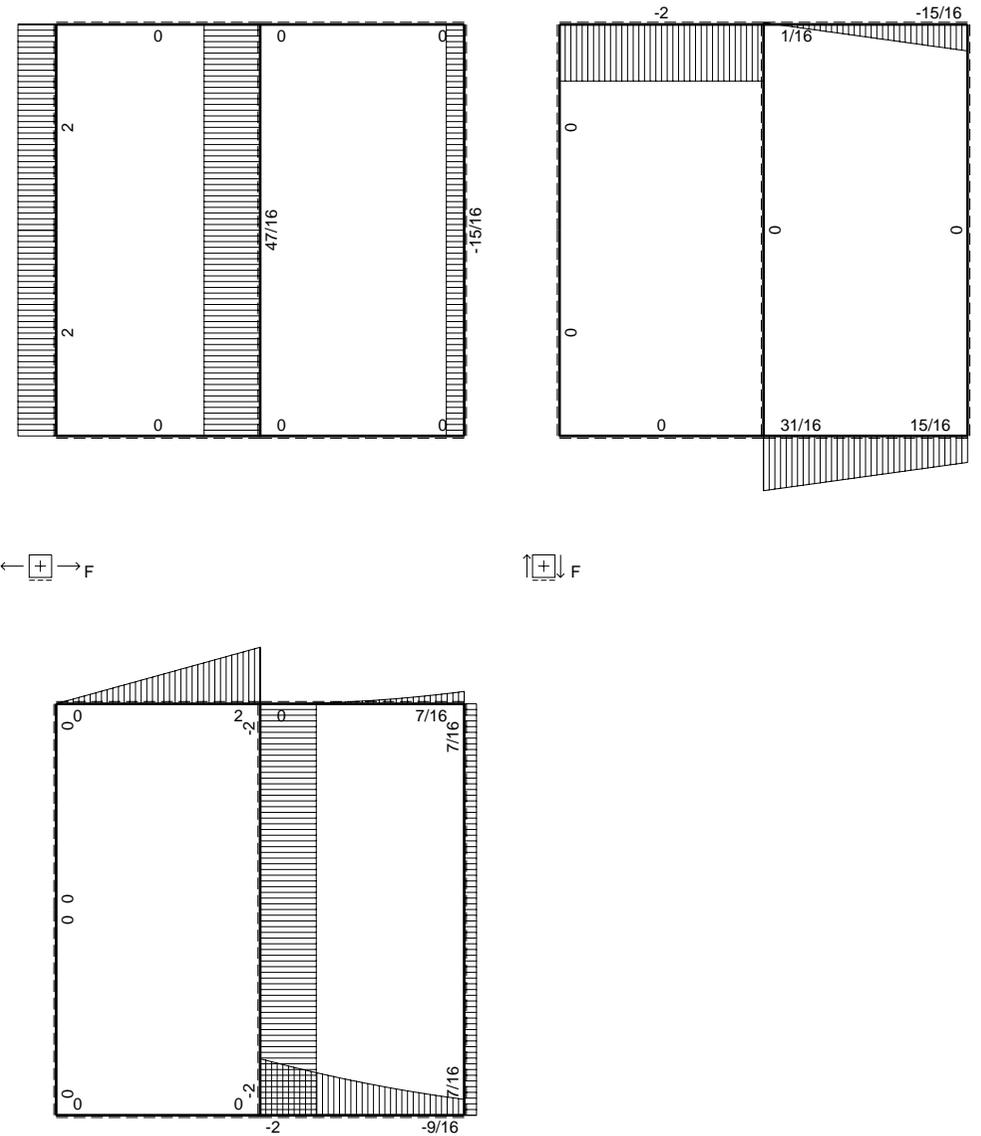
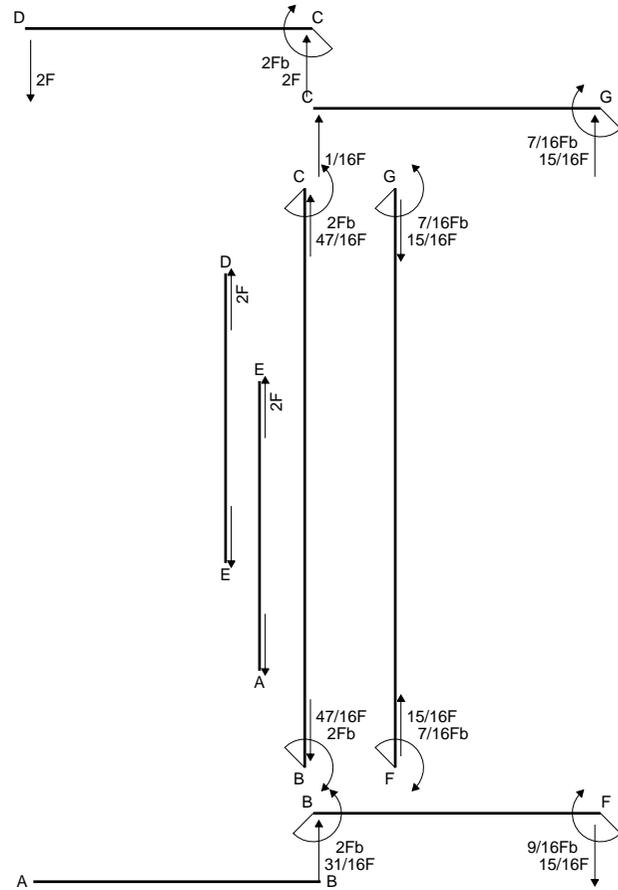
$$L_{GF}^{x\theta} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



- A = 768. mm<sup>2</sup>
- J<sub>u</sub> = 218489. mm<sup>4</sup>
- J<sub>v</sub> = 26496. mm<sup>4</sup>
- y<sub>g</sub> = 23.17 mm
- T<sub>y</sub> = 2830. N
- M<sub>x</sub> = -1698000. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 30.83 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 239.6 N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 41. mm
- v<sub>c</sub> = 17.83 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 138.6 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.096 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 138.7 N/mm<sup>2</sup>
- S = 3795. mm<sup>3</sup>







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{xo} = \int_0^b (2x/b - 3/2 x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

$$= [x^2/b - 1/2 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b + 1/8 b) Fb 1/EJ + (1/2 b) \theta = 9/8 Fb^2/EJ$$

$$L_{FB}^{xo} = \int_0^b (1 - 1/2 x/b - 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [x - 1/4 x^2/b - 1/8 x^4/b^3]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

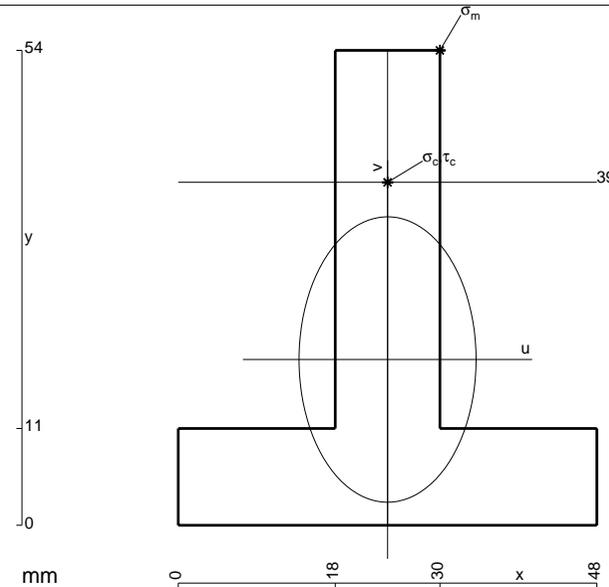
$$= (b - 1/4 b - 1/8 b) Fb 1/EJ + (-b + 1/2 b) \theta = 9/8 Fb^2/EJ$$

$$L_{GC}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{CG}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$



$$A = 1044. \text{ mm}^2$$

$$J_u = 275075. \text{ mm}^4$$

$$J_v = 107568. \text{ mm}^4$$

$$y_g = 18.84 \text{ mm}$$

$$T_y = -2440. \text{ N}$$

$$M_x = 1561600. \text{ Nmm}$$

$$x_m = 30. \text{ mm}$$

$$y_m = 54. \text{ mm}$$

$$u_m = 6. \text{ mm}$$

$$v_m = 35.16 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -199.6 \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 39. \text{ mm}$$

$$v_c = 20.16 \text{ mm}$$

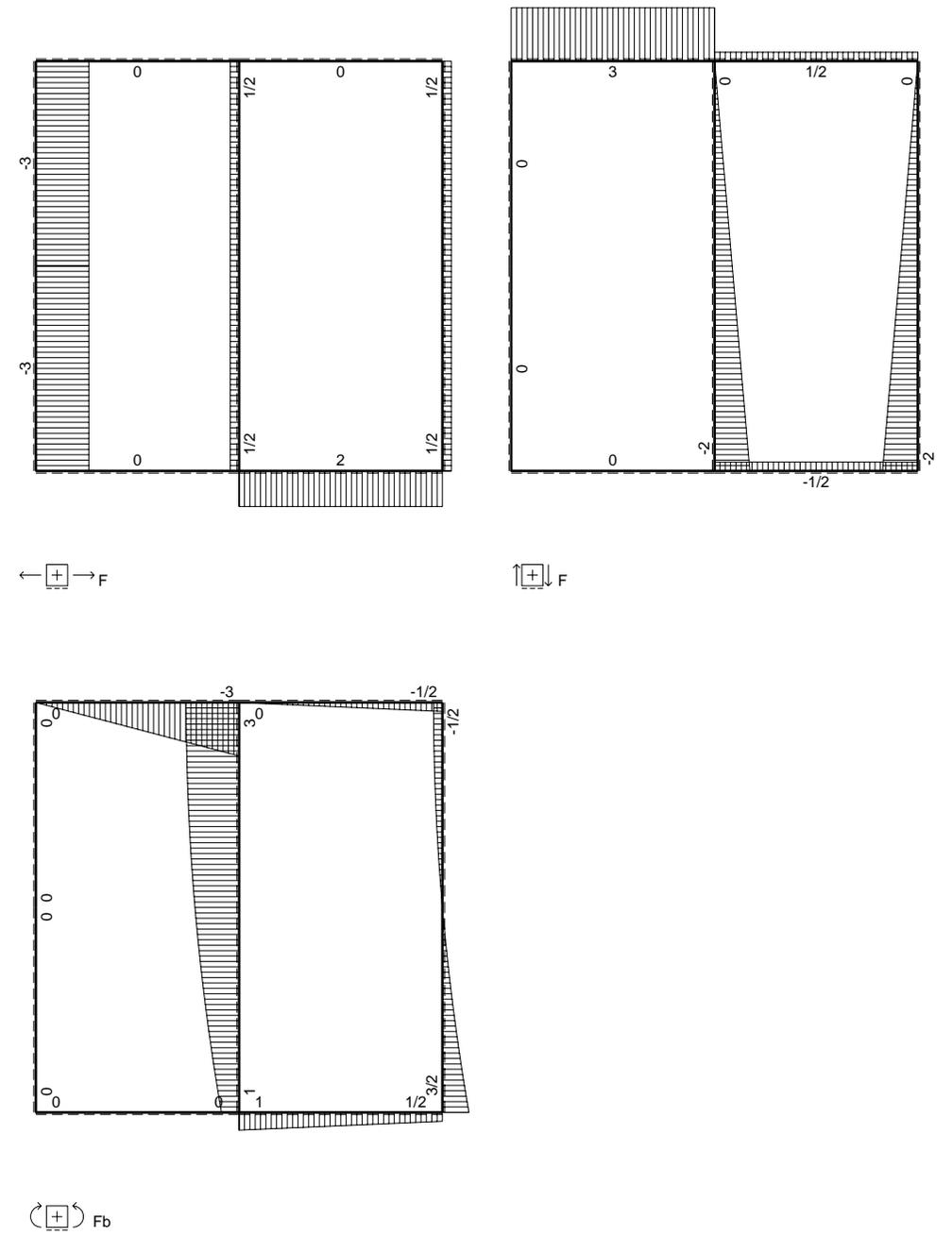
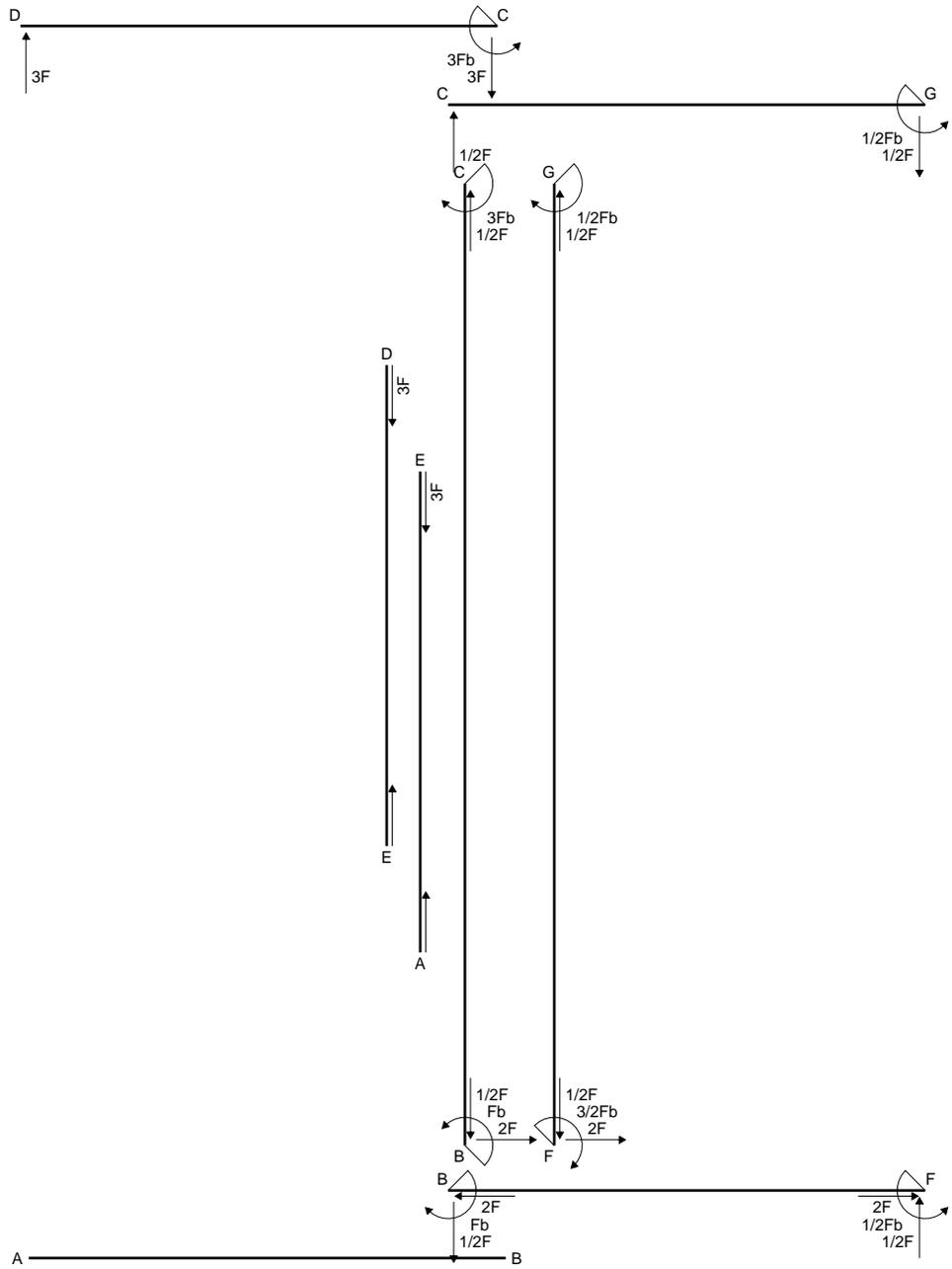
$$\sigma_c = -Mv/J_u = -114.4 \text{ N/mm}^2$$

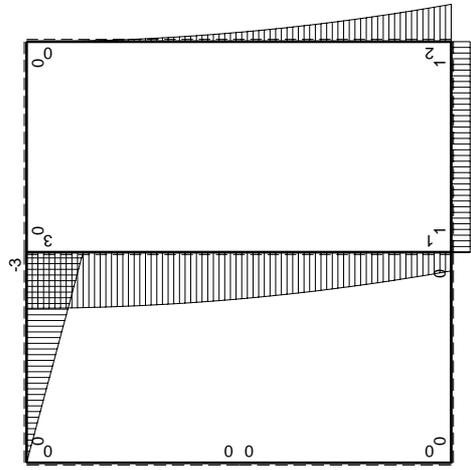
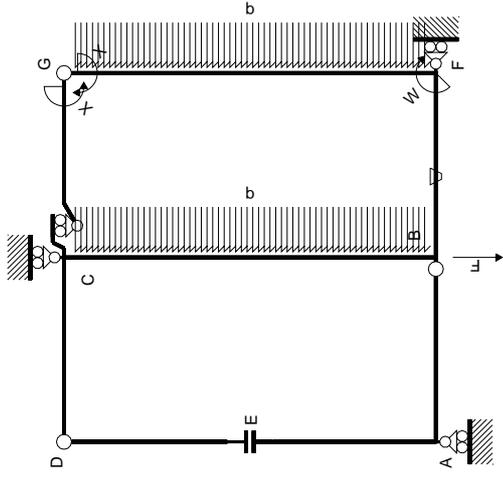
$$\tau_c = 3.68 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 114.6 \text{ N/mm}^2$$

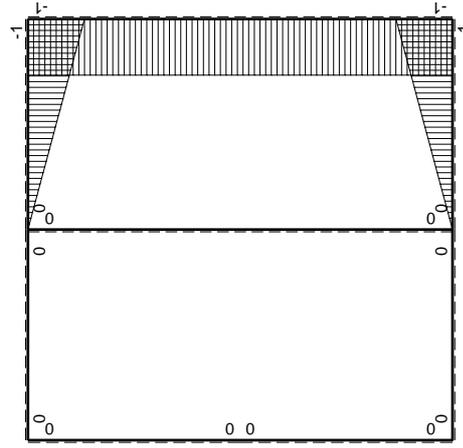
$$S = 4978. \text{ mm}^3$$







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica X=W<sub>gc</sub>

←	M <sup>x</sup> (x)	M <sup>0</sup> (x)	θ	M <sup>x</sup> M <sub>0</sub>	M <sup>x</sup> θ	M <sup>x</sup> M <sub>x</sub>	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0+0	0
CD b	0	-3Fb+3Fx	0	0	0	0	0+0	0
DC b	0	3Fx	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
ED b	0	0	0	0	0	0	0+0	0
EA b	0	0	0	0	0	0	0+0	0
AE b	0	0	0	0	0	0	0+0	0
BF b	-x/b	Fb	-Fb/EJ	-Fx	Fx/EJ	$x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	1/3xb/EJ
FB b	1-x/b	-Fb	Fb/EJ	-Fb+Fx	Fb/EJ-Fx/EJ	$1-2x/b+x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	1/3xb/EJ
GC b	-1+x/b	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	1/3xb/EJ
CG b	x/b	0	0	0	0	$x^2/b^2$	0+0	1/3xb/EJ
FG 2b	-1	$2Fb-2Fx+1/2qx^2$	0	$-2Fb+2Fx-1/2Fx^2/b$	0	1	$(-4/3+0)Fb^2/EJ$	2xb/EJ
GF 2b	1	$-1/2qx^2$	0	$-1/2Fx^2/b$	0	1	$(-4/3+0)Fb^2/EJ$	2xb/EJ
CB 2b	0	$3Fb-1/2qx^2$	0	0	0	0	0+0	0
BC 2b	0	$-Fb-2Fx+1/2qx^2$	0	0	0	0	0+0	0
totali							$-4/3Fb^2/EJ$	8/3xb/EJ

iperstatica X=W<sub>gc</sub>

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x_0} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

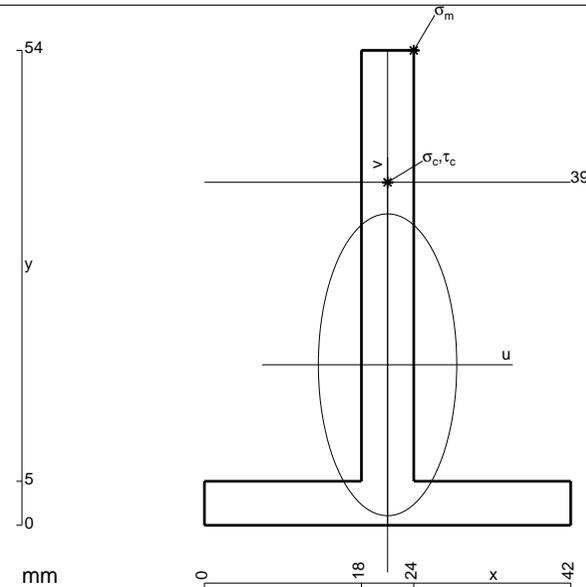
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x_0} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

$$L_{GF}^{x_0} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



$$A = 504. \text{ mm}^2$$

$$J_u = 148565. \text{ mm}^4$$

$$J_v = 31752. \text{ mm}^4$$

$$y_g = 18.25 \text{ mm}$$

$$T_y = 1260. \text{ N}$$

$$M_x = -856800. \text{ Nmm}$$

$$x_m = 24. \text{ mm}$$

$$y_m = 54. \text{ mm}$$

$$u_m = 3. \text{ mm}$$

$$v_m = 35.75 \text{ mm}$$

$$\sigma_m = -Mv/J_u = 206.2 \text{ N/mm}^2$$

$$x_c = 21. \text{ mm}$$

$$y_c = 39. \text{ mm}$$

$$v_c = 20.75 \text{ mm}$$

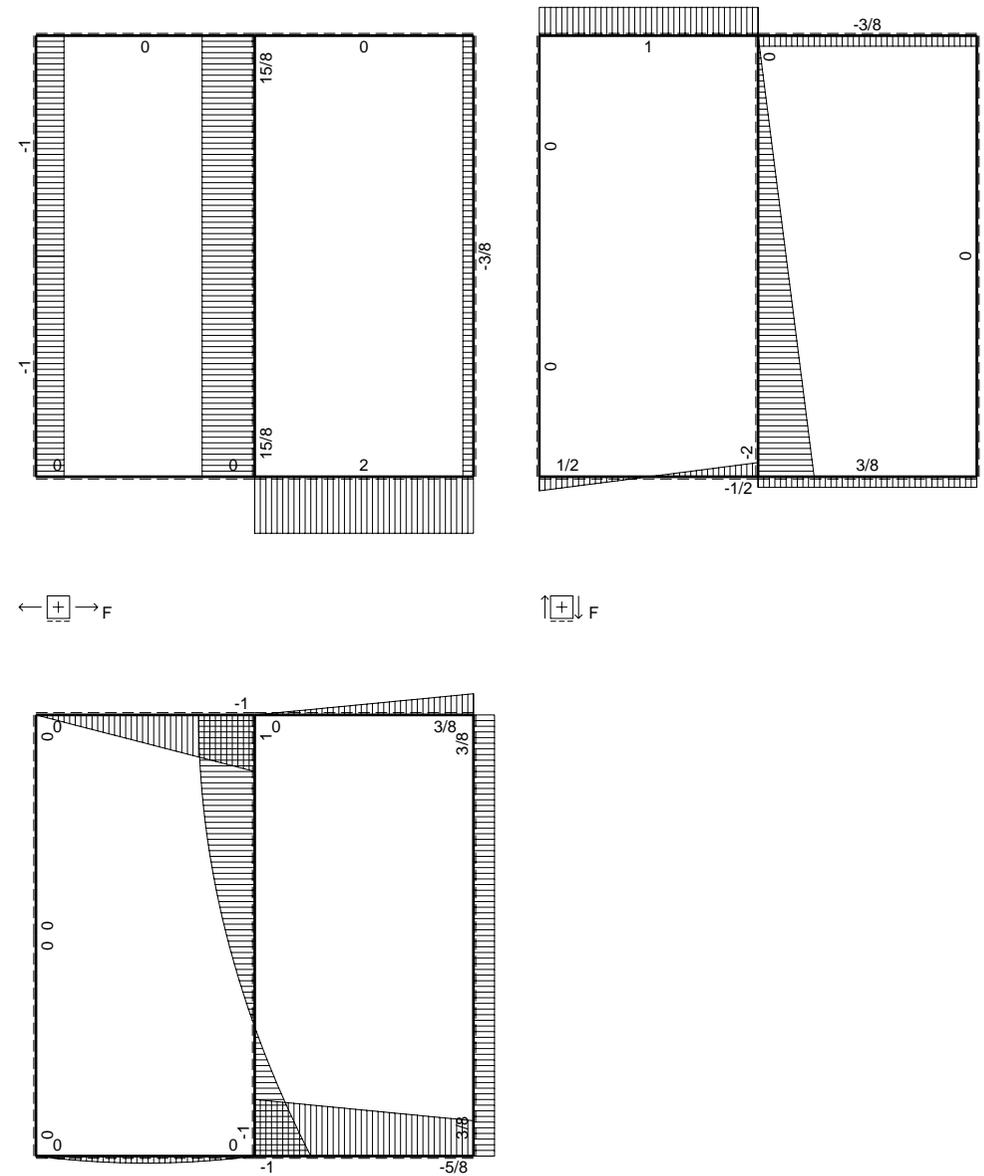
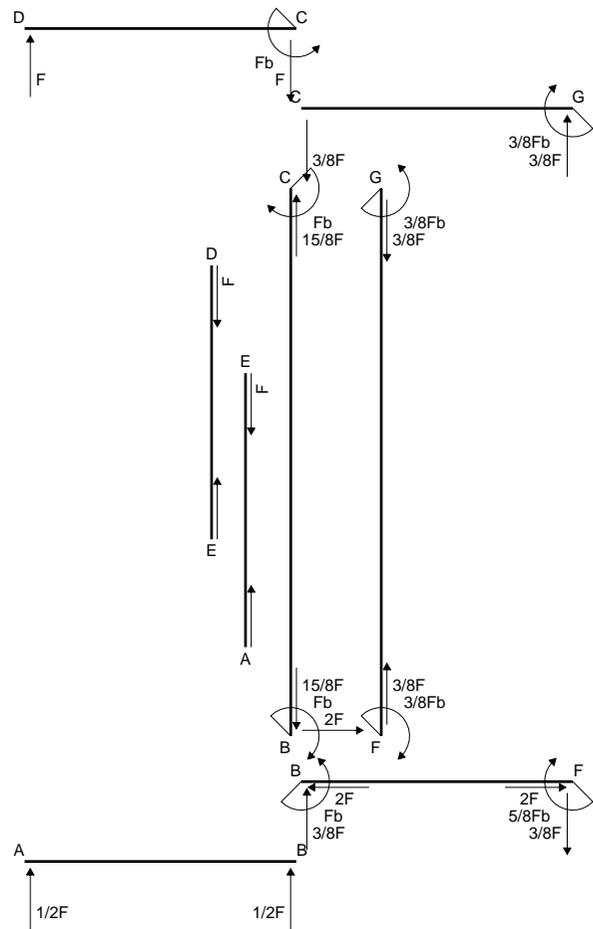
$$\sigma_c = -Mv/J_u = 119.7 \text{ N/mm}^2$$

$$\tau_c = 3.594 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 119.8 \text{ N/mm}^2$$

$$S = 2543. \text{ mm}^3$$





$\oplus$   $F_b$



$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

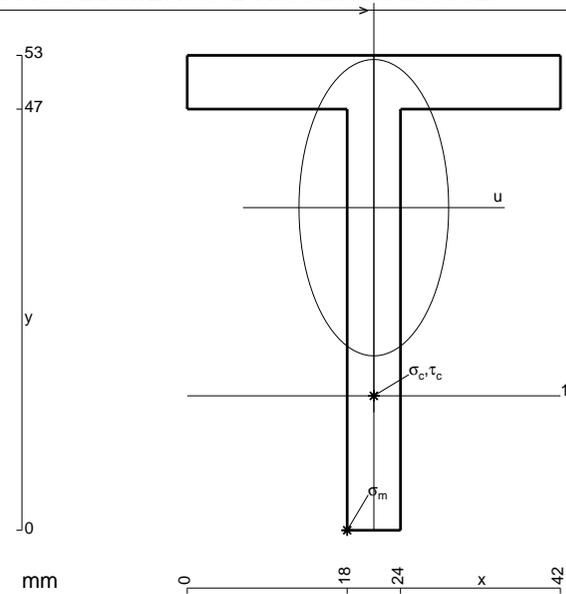
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

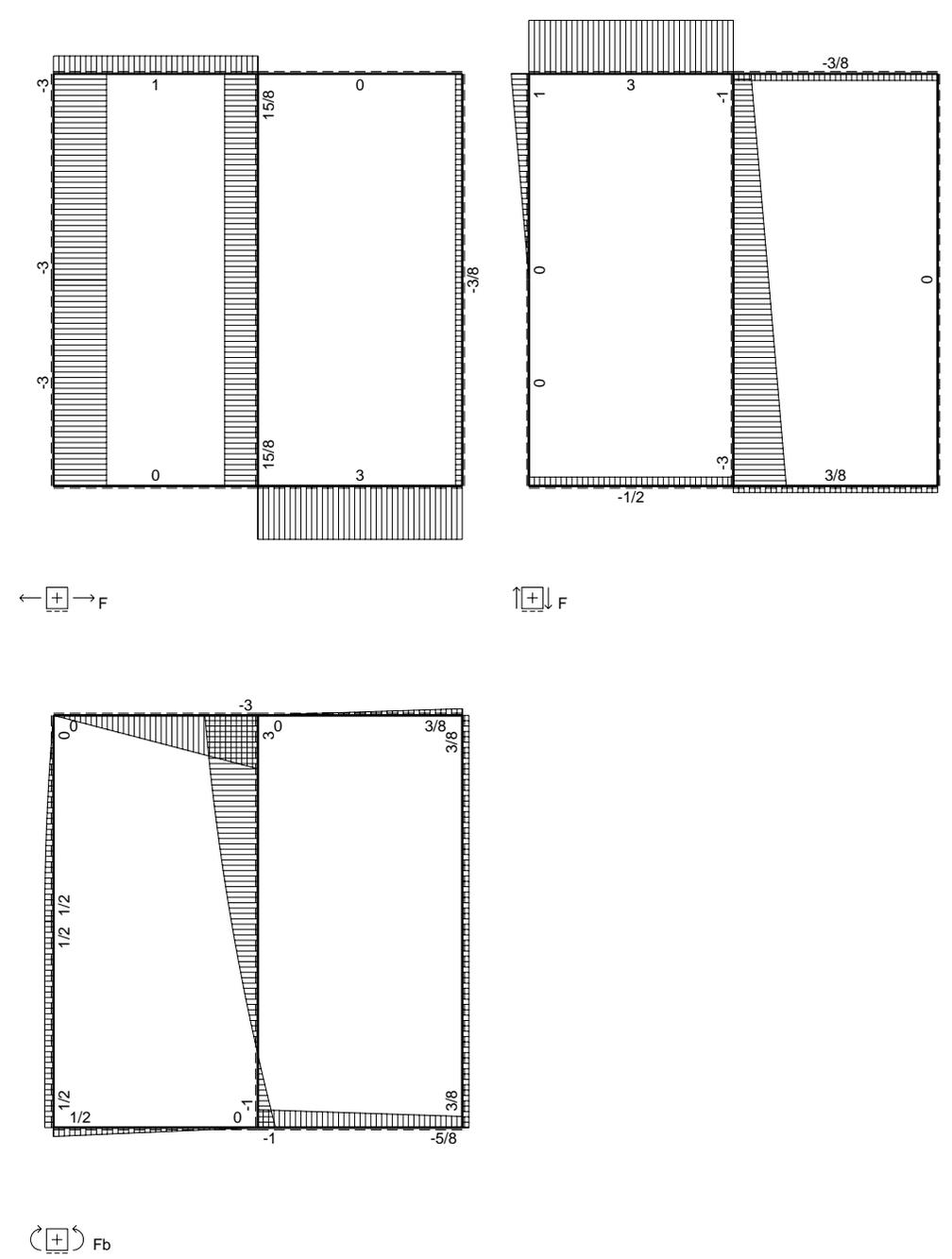
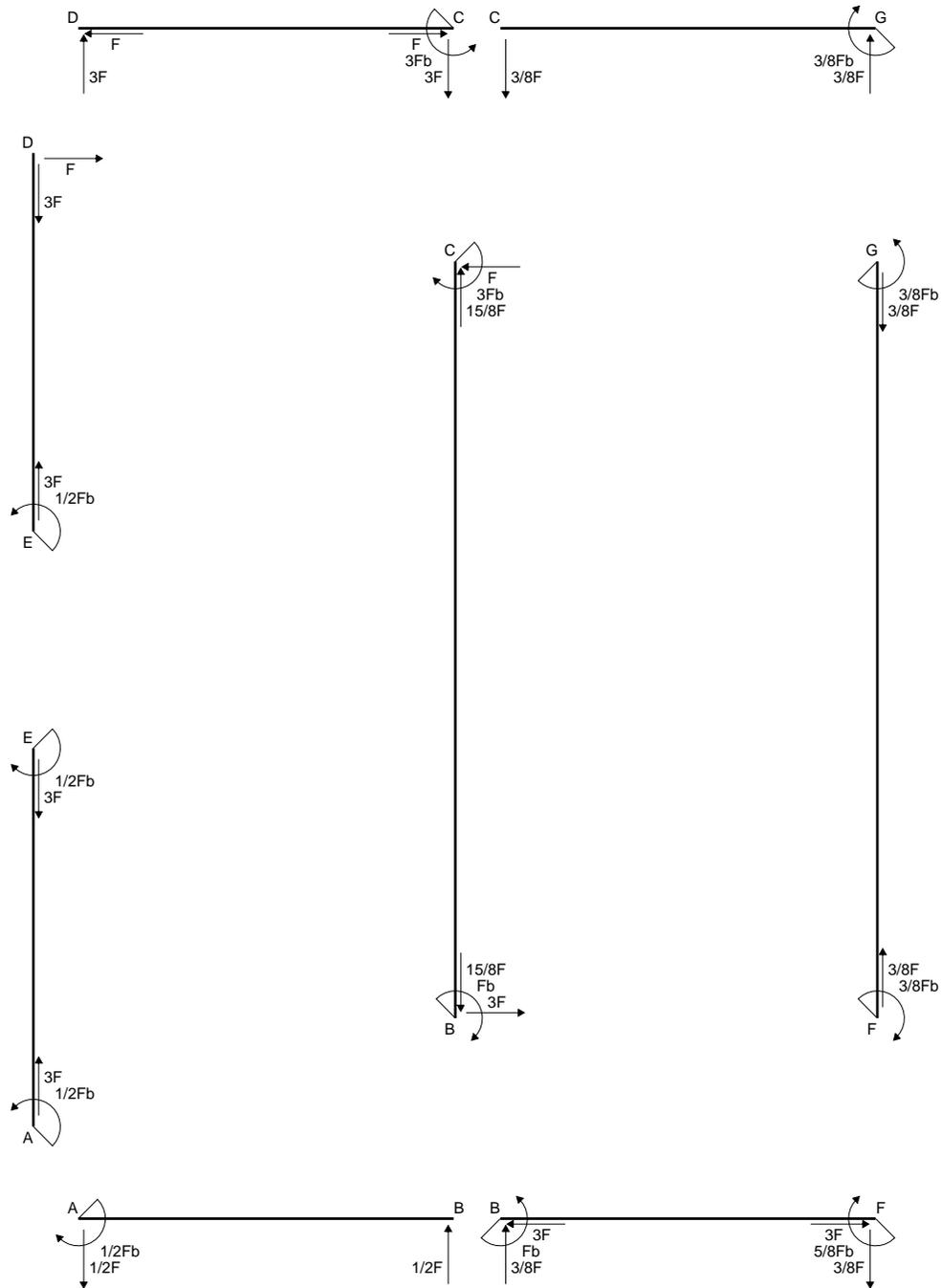
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



- A = 534. mm<sup>2</sup>
- J<sub>u</sub> = 146122. mm<sup>4</sup>
- J<sub>v</sub> = 37890. mm<sup>4</sup>
- y<sub>g</sub> = 36.01 mm
- N = 2400. N
- T<sub>y</sub> = -2560. N
- M<sub>x</sub> = -908800. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -36.01 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = -219.4 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 15. mm
- v<sub>c</sub> = -21.01 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = -126.1 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.491 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 126.8 N/mm<sup>2</sup>
- S = 2566. mm<sup>3</sup>







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

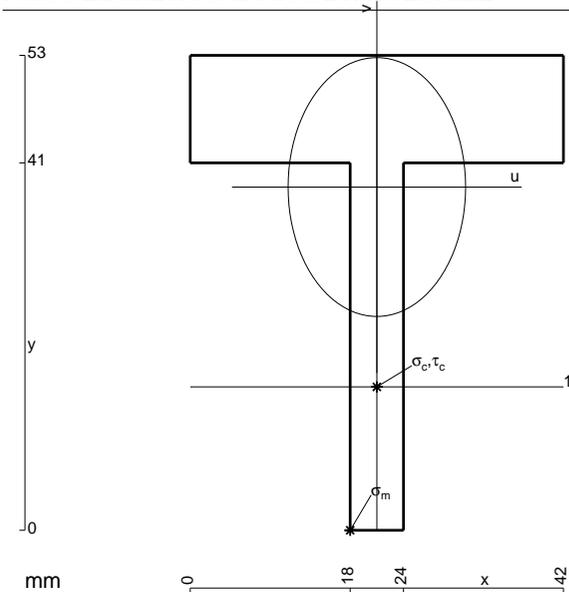
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

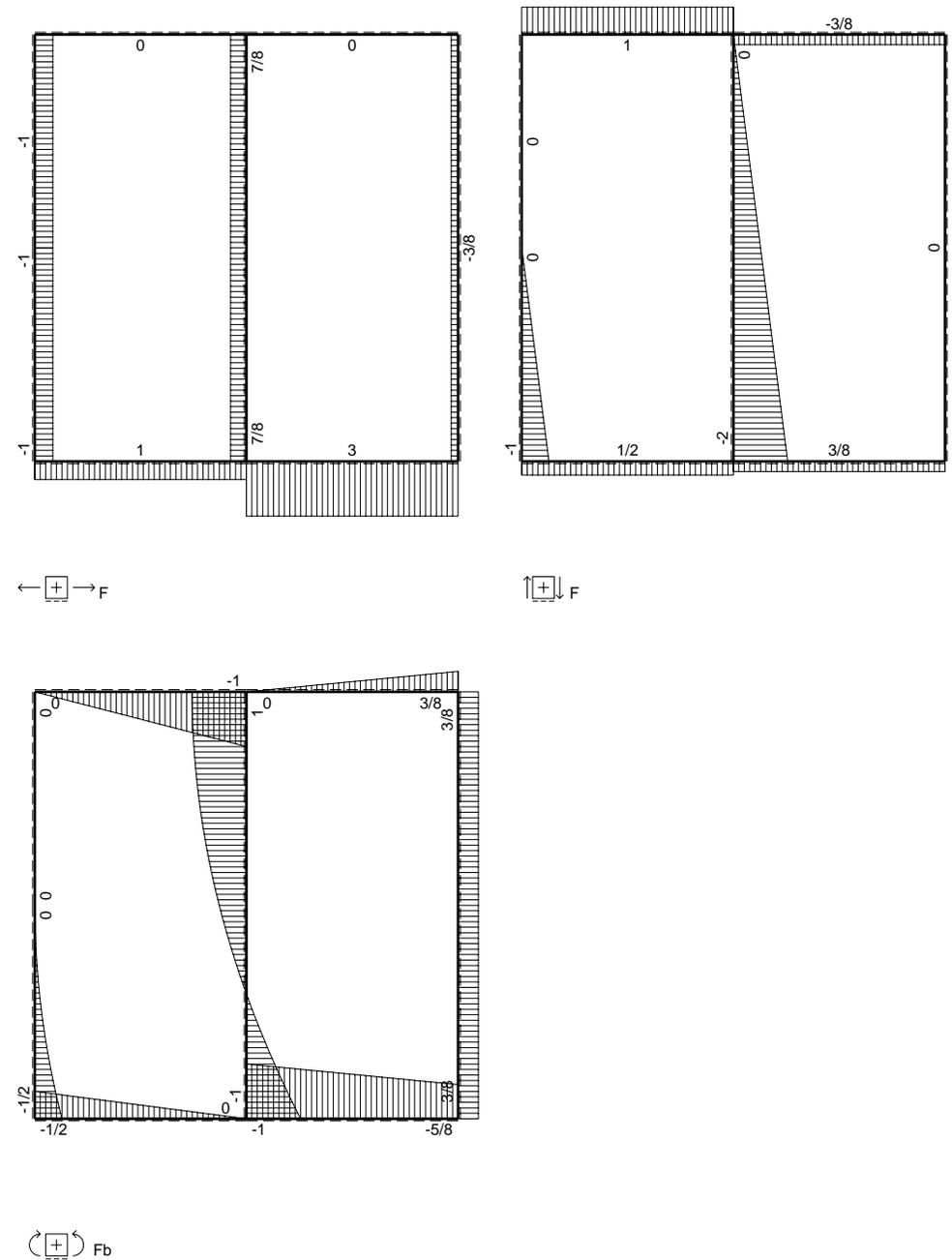
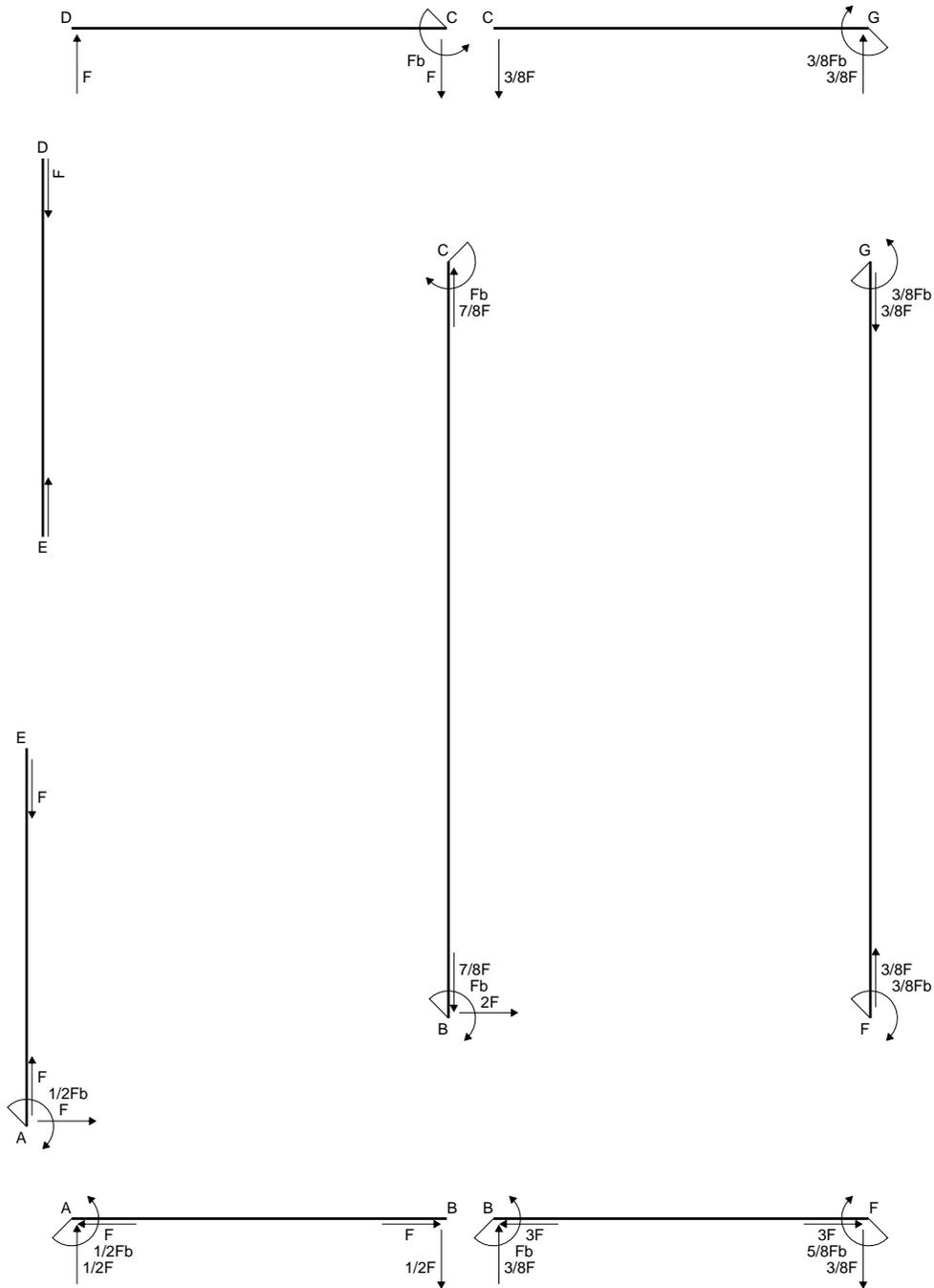
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



- A = 750. mm<sup>2</sup>
- J<sub>u</sub> = 156599. mm<sup>4</sup>
- J<sub>v</sub> = 74826. mm<sup>4</sup>
- y<sub>g</sub> = 38.31 mm
- N = 410. N
- T<sub>y</sub> = 1230. N
- M<sub>x</sub> = -922500. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -38.31 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = -225.1 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 16. mm
- v<sub>c</sub> = -22.31 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = -130.9 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.809 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 131. N/mm<sup>2</sup>
- S = 2910. mm<sup>3</sup>







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

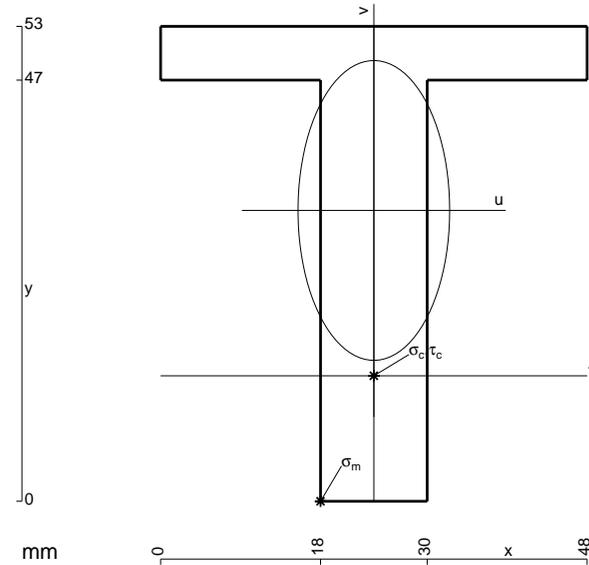
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

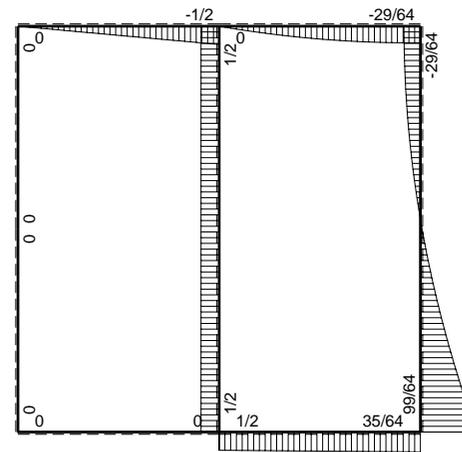
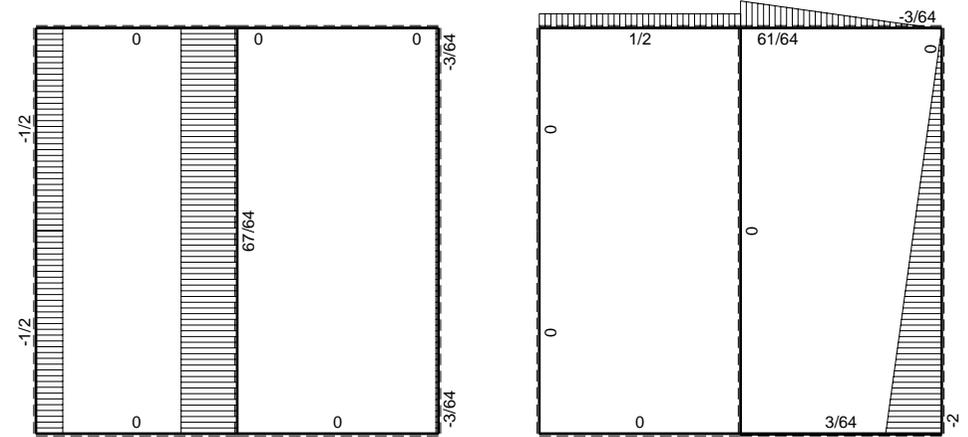
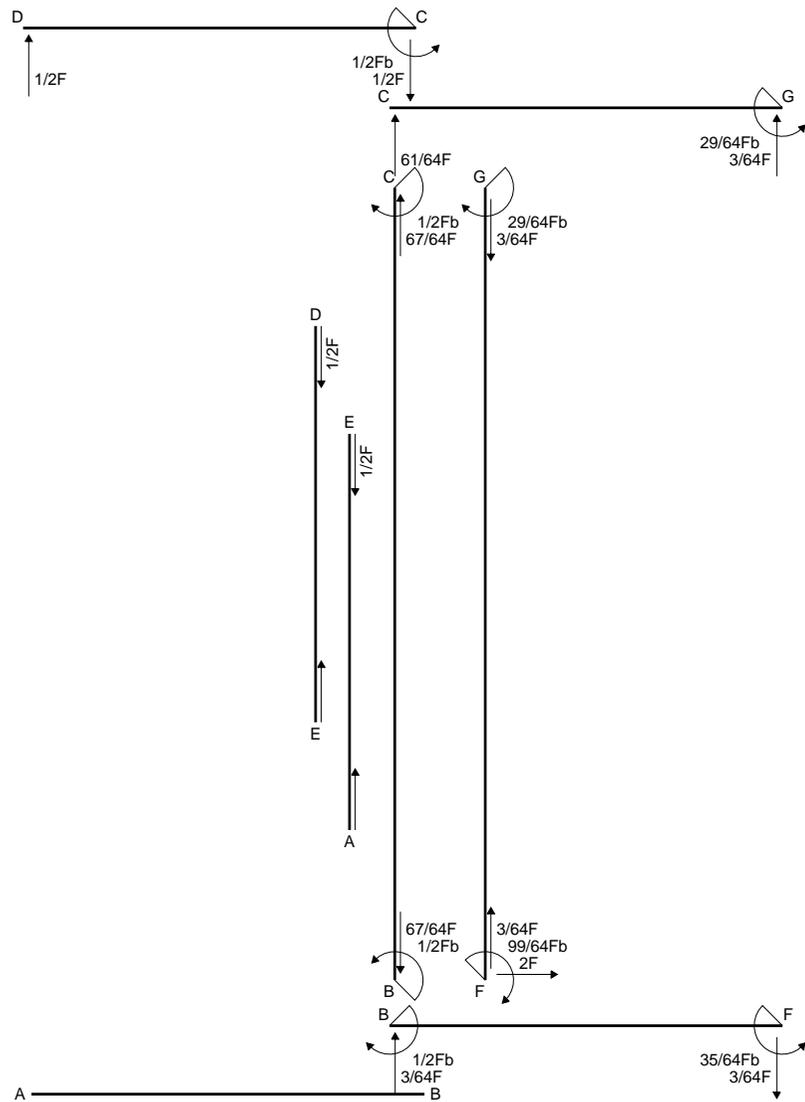
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

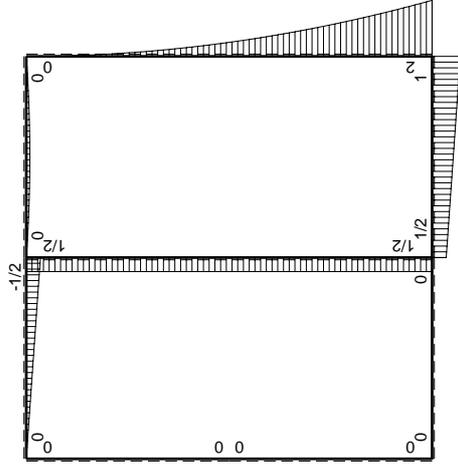
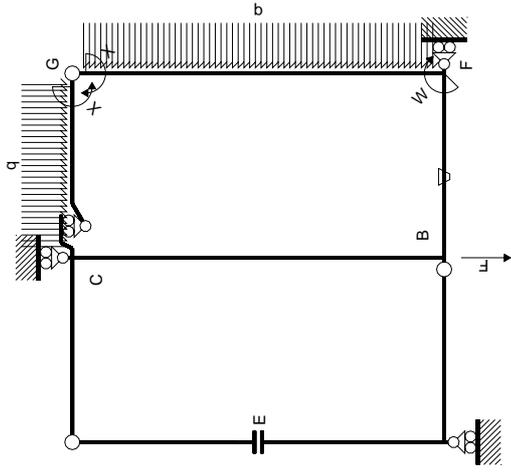
$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



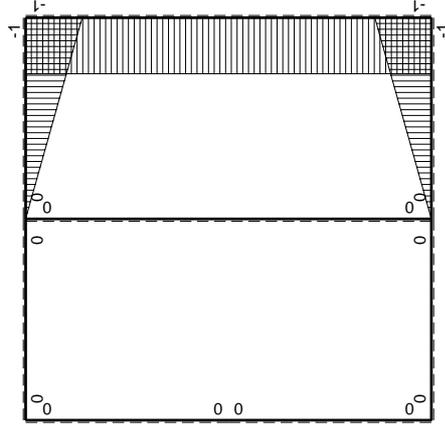
- A = 852. mm<sup>2</sup>
- J<sub>u</sub> = 238570. mm<sup>4</sup>
- J<sub>v</sub> = 62064. mm<sup>4</sup>
- y<sub>g</sub> = 32.46 mm
- N = 1969. N
- T<sub>y</sub> = -4500. N
- M<sub>x</sub> = -1777500. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -32.46 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = -239.5 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 14. mm
- v<sub>c</sub> = -18.46 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = -135.2 N/mm<sup>2</sup>
- τ<sub>c</sub> = 6.723 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 135.7 N/mm<sup>2</sup>
- S = 4277. mm<sup>3</sup>







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica $X=W_{gc}$		$M_x(x)$		$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int X M_x M_0 / E J dx$
AB b	0	0	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0	0	0+0	0
CD b	0	-1/2Fb+1/2Fx	0	0	0	0	0	0	0+0	0
DC b	0	1/2Fx	0	0	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0	0	0+0	0
EA b	0	0	0	0	0	0	0	0	0+0	0
AE b	0	0	0	0	0	0	0	0	0+0	0
BF b	-x/b	1/2Fb+1/2Fx	-Fb/EJ	-Fb/EJ	-1/2Fx-1/2Fx <sup>2</sup> /b	Fx/EJ	x <sup>2</sup> /b <sup>2</sup>	(-5/12+1/2)Fb <sup>2</sup> /EJ	1/3xb/EJ	1/3xb/EJ
FB b	1-x/b	-Fb+1/2Fx	Fb/EJ	Fb/EJ	-Fb+3/2Fx-1/2Fx <sup>2</sup> /b	Fb/EJ-Fx/EJ	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	(1/24+0)Fb <sup>2</sup> /EJ	1/3xb/EJ	1/3xb/EJ
GC b	-1+x/b	-1/2Fx+1/2qx <sup>2</sup>	0	0	1/2Fx-Fx <sup>2</sup> /b+1/2qx <sup>3</sup> /b	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	(1/24+0)Fb <sup>2</sup> /EJ	1/3xb/EJ	1/3xb/EJ
CG b	x/b	1/2Fx-1/2qx <sup>2</sup>	0	0	1/2Fx <sup>2</sup> /b-1/2qx <sup>3</sup> /b	0	x <sup>2</sup> /b <sup>2</sup>	(-4/3+0)Fb <sup>2</sup> /EJ	2xb/EJ	2xb/EJ
FG 2b	-1	2Fb-2Fx+1/2qx <sup>2</sup>	0	0	-2Fb+2Fx-1/2Fx <sup>2</sup> /b	0	1	(-4/3+0)Fb <sup>2</sup> /EJ	2xb/EJ	2xb/EJ
GF 2b	1	-1/2qx <sup>2</sup>	0	0	-1/2Fx <sup>2</sup> /b	0	1	(-4/3+0)Fb <sup>2</sup> /EJ	2xb/EJ	2xb/EJ
CB 2b	0	1/2Fb	0	0	0	0	0	0+0	8/3xb/EJ	8/3xb/EJ
BC 2b	0	-1/2Fb	0	0	0	0	0	0+0	8/3xb/EJ	8/3xb/EJ
totali										
iperstatica $X=W_{gc}$										

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{xo} = \int_0^b (-1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

$$= [-1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/4 b - 1/6 b) Fb 1/EJ + (1/2 b) \theta = 1/12 Fb^2/EJ$$

$$L_{FB}^{xo} = \int_0^b (-1 + 3/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 3/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (-b + 3/4 b - 1/6 b) Fb 1/EJ + (-b + 1/2 b) \theta = 1/12 Fb^2/EJ$$

$$L_{GC}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{CG}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

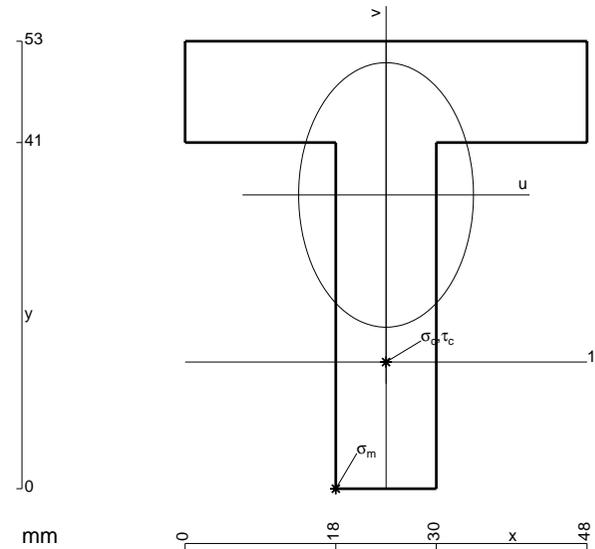
$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{FG}^{xo} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

$$L_{GF}^{xo} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



$$A = 1068. \text{ mm}^2$$

$$J_u = 262174. \text{ mm}^4$$

$$J_v = 116496. \text{ mm}^4$$

$$y_g = 34.79 \text{ mm}$$

$$T_y = 3585. \text{ N}$$

$$M_x = -1505700. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$u_m = -6. \text{ mm}$$

$$v_m = -34.79 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -199.8 \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 15. \text{ mm}$$

$$v_c = -19.79 \text{ mm}$$

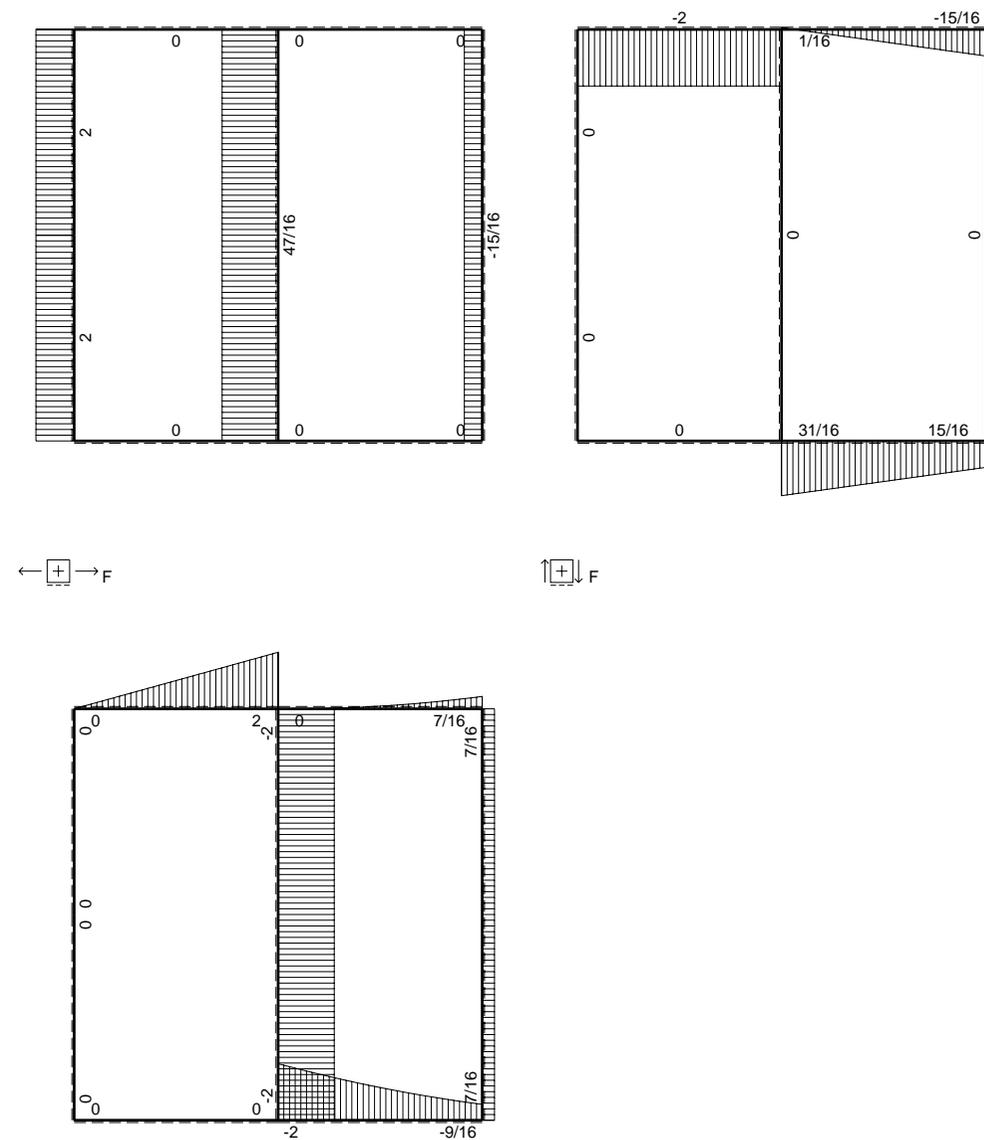
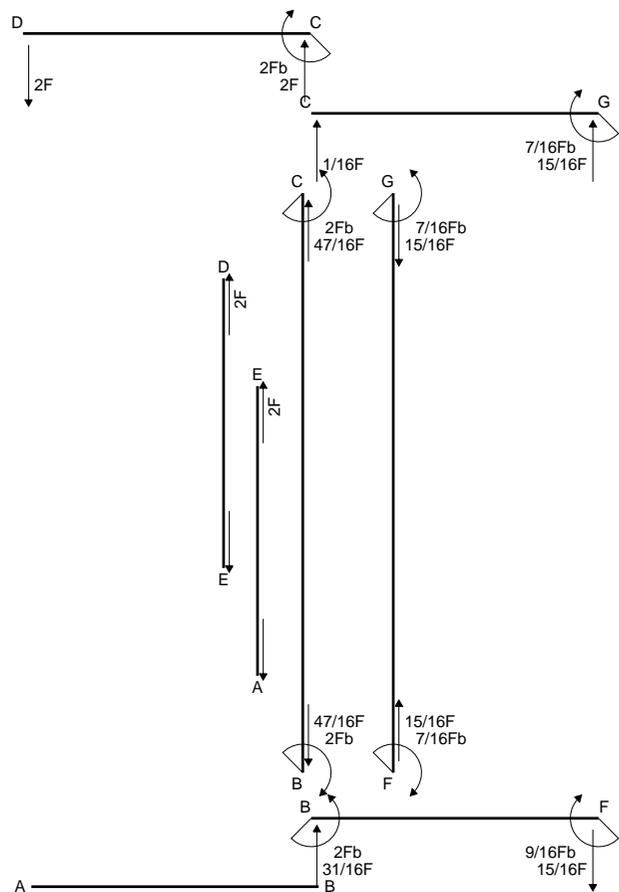
$$\sigma_c = -Mv/J_u = -113.7 \text{ N/mm}^2$$

$$\tau_c = 5.598 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 114.1 \text{ N/mm}^2$$

$$S = 4913. \text{ mm}^3$$







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (2x/b - 3/2 x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

$$= [x^2/b - 1/2 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b + 1/8 b) Fb 1/EJ + (1/2 b) \theta = 9/8 Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - 1/2 x/b - 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [x - 1/4 x^2/b - 1/8 x^4/b^3]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

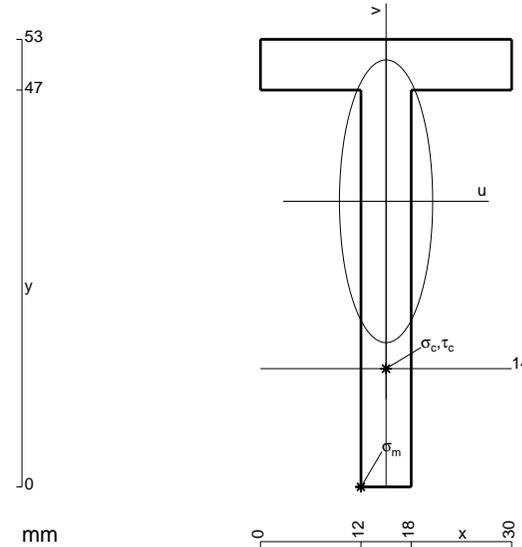
$$= (b - 1/4 b - 1/8 b) Fb 1/EJ + (-b + 1/2 b) \theta = 9/8 Fb^2/EJ$$

$$L_{GC}^{x_0} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{CG}^{x_0} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$



$$A = 462. \text{ mm}^2$$

$$J_u = 129608. \text{ mm}^4$$

$$J_v = 14346. \text{ mm}^4$$

$$y_g = 33.82 \text{ mm}$$

$$T_y = -1740. \text{ N}$$

$$M_x = 800400. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -33.82 \text{ mm}$$

$$\sigma_m = -Mv/J_u = 208.9 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 14. \text{ mm}$$

$$v_c = -19.82 \text{ mm}$$

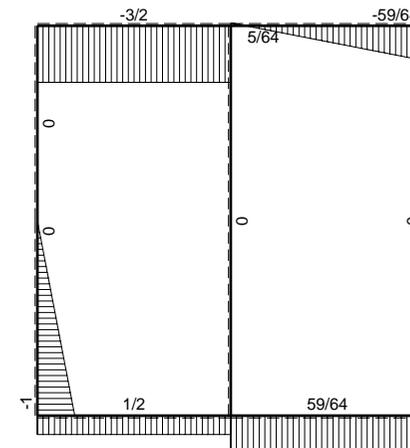
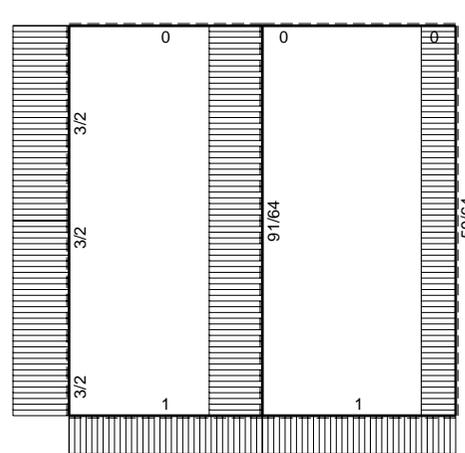
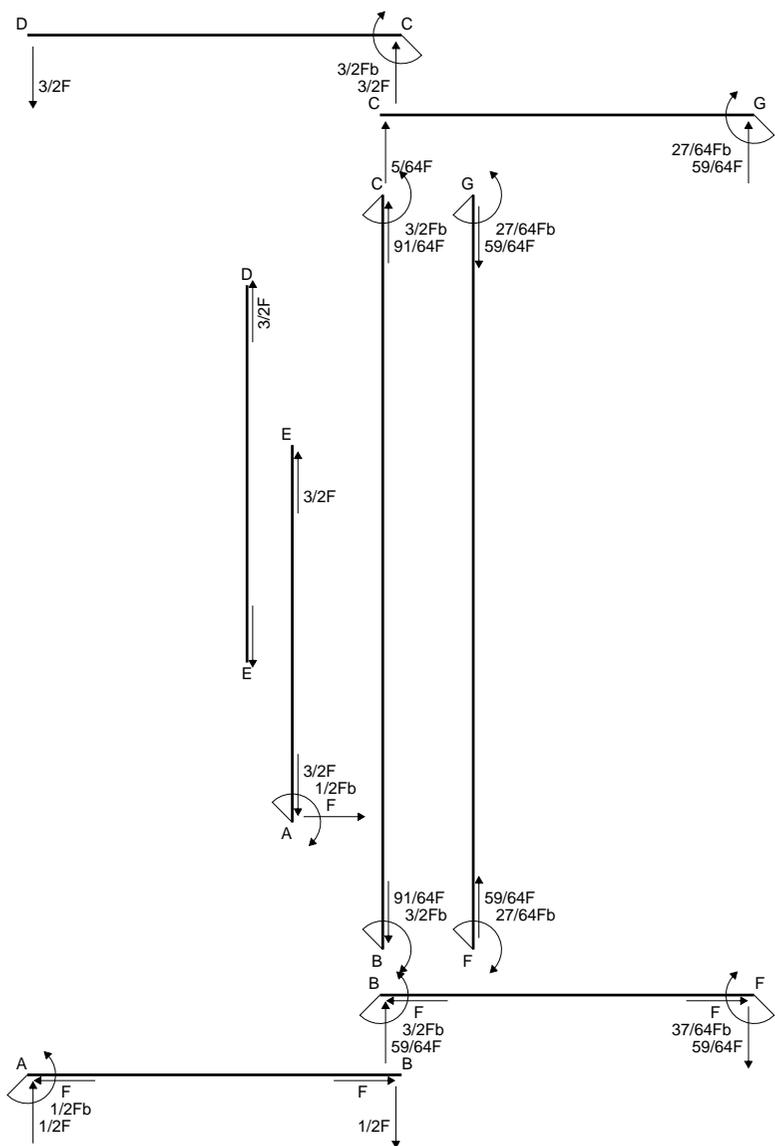
$$\sigma_c = -Mv/J_u = 122.4 \text{ N/mm}^2$$

$$\tau_c = 5.042 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 122.7 \text{ N/mm}^2$$

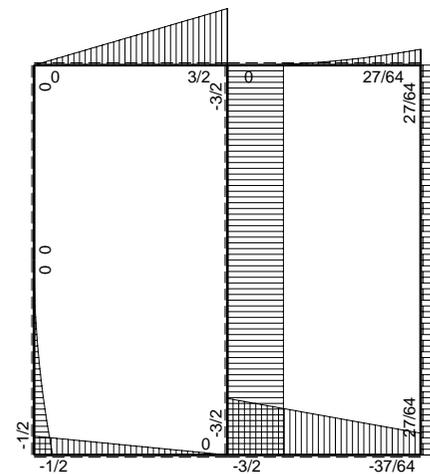
$$S = 2253. \text{ mm}^3$$



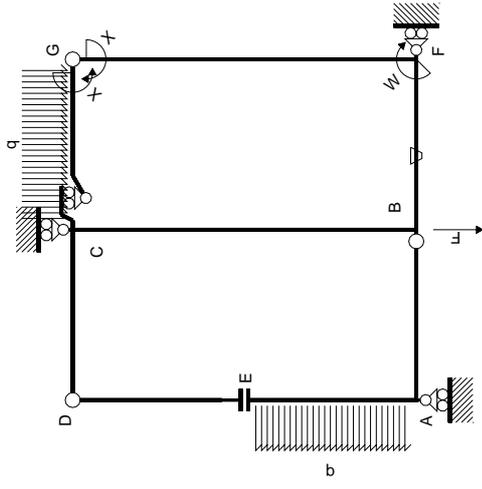


← ⊕ → F

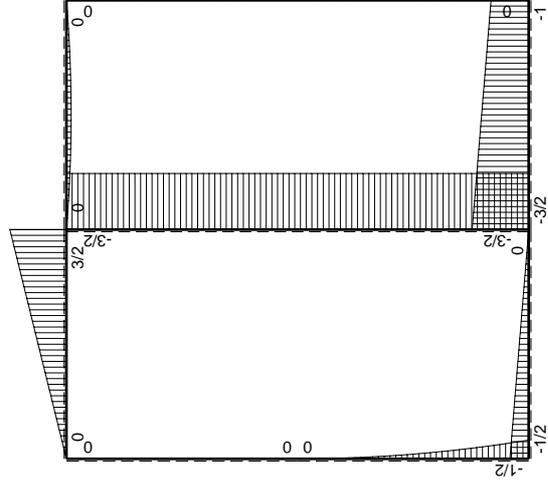
↑ ⊕ ↓ F



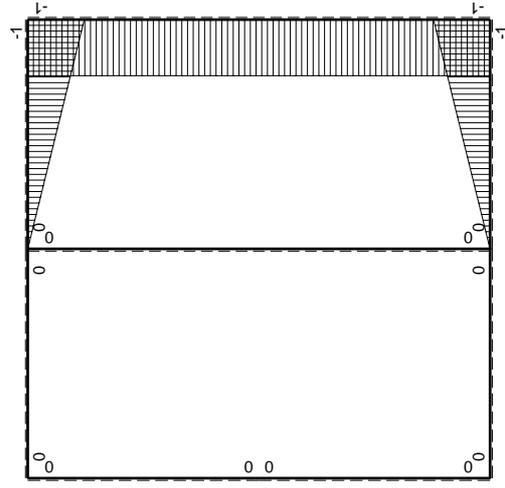
⊕ ⊖ F<sub>b</sub>



Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica $X=W_{gc}$		Sviluppi di calcolo iperstatica						
$\leftarrow$	$M_x(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int X M_x M_x / E J dx$
AB b	0	$-1/2 F b + 1/2 F x$	0	0	0	0	0+0	0
BA b	0	$1/2 F x$	0	0	0	0	0+0	0
CD b	0	$3/2 F b - 3/2 F x$	0	0	0	0	0+0	0
DC b	0	$-3/2 F x$	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
EA b	0	$-1/2 q x^2$	0	0	0	0	0+0	0
AE b	0	$1/2 F b - F x + 1/2 q x^2$	0	0	0	0	0+0	0
BF b	$-x/b$	$-3/2 F b + 1/2 F x$	$-F b/EJ$	$3/2 F x - 1/2 F x^2/b$	$F x/EJ$	$x^2/b^2$	$(7/12 + 1/2) F b^2/EJ$	$1/3 X b/EJ$
FB b	$1-x/b$	$F b + 1/2 F x$	$F b/EJ$	$F b - 1/2 F x - 1/2 F x^2/b$	$F b/EJ - F x/EJ$	$1 - 2x/b + x^2/b^2$	$(7/12 + 1/2) F b^2/EJ$	$1/3 X b/EJ$
GC b	$-1+x/b$	$-1/2 F x + 1/2 q x^2$	0	$1/2 F x - F x^2/b + 1/2 q x^3/b$	0	$1 - 2x/b + x^2/b^2$	$(1/24 + 0) F b^2/EJ$	$1/3 X b/EJ$
CG b	$x/b$	$1/2 F x - 1/2 q x^2$	0	$1/2 F x^2/b - 1/2 q x^3/b$	0	$x^2/b^2$	$(1/24 + 0) F b^2/EJ$	$1/3 X b/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2 X b/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2 X b/EJ$
CB 2b	0	$-3/2 F b$	0	0	0	0	0+0	0
BC 2b	0	$3/2 F b$	0	0	0	0	0+0	0
totali							$9/8 F b^2/EJ$	$8/3 X b/EJ$
								$-27/64 F b$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{xo} = \int_0^b (3/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

$$= [3/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (3/4 b - 1/6 b) Fb 1/EJ + (1/2 b) \theta = 13/12 Fb^2/EJ$$

$$L_{FB}^{xo} = \int_0^b (1 - 1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [x - 1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

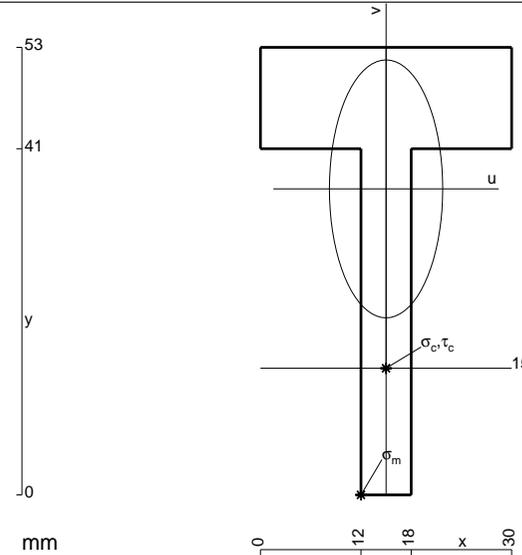
$$= (b - 1/4 b - 1/6 b) Fb 1/EJ + (-b + 1/2 b) \theta = 13/12 Fb^2/EJ$$

$$L_{GC}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{CG}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$



$$A = 606. \text{ mm}^2$$

$$J_u = 141406. \text{ mm}^4$$

$$J_v = 27738. \text{ mm}^4$$

$$y_g = 36.24 \text{ mm}$$

$$T_y = -1710. \text{ N}$$

$$M_x = 855000. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -36.24 \text{ mm}$$

$$\sigma_m = -Mv/J_u = 219.1 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 15. \text{ mm}$$

$$v_c = -21.24 \text{ mm}$$

$$\sigma_c = -Mv/J_u = 128.4 \text{ N/mm}^2$$

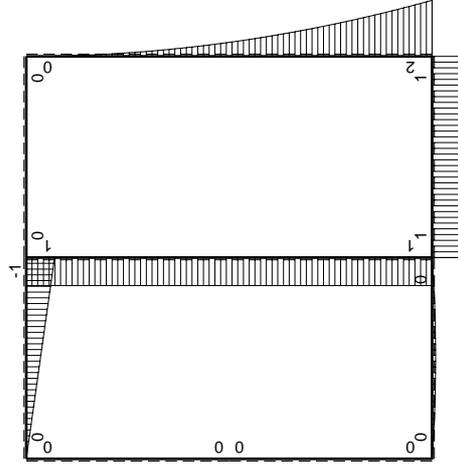
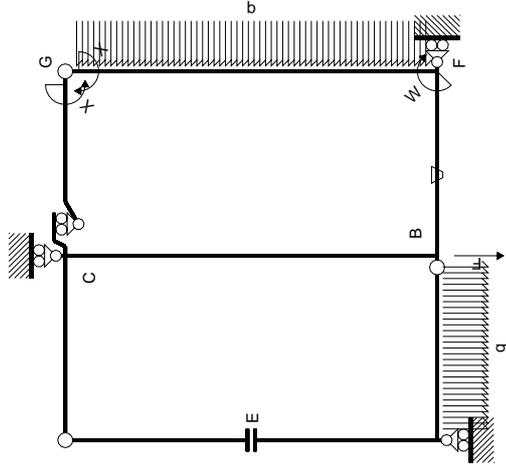
$$\tau_c = 5.214 \text{ N/mm}^2$$

$$\sigma_o = \sqrt{\sigma^2 + 3\tau^2} = 128.8 \text{ N/mm}^2$$

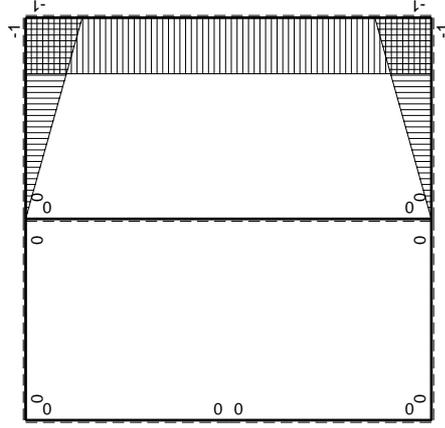
$$S = 2587. \text{ mm}^3$$







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica X=W<sub>gc</sub>

←	M <sup>0</sup> (x)	θ	M <sup>x</sup> M <sub>0</sub>	M <sup>x</sup> θ	M <sup>x</sup> M <sub>x</sub>	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJdx$
AB b	0	0	0	0	0	0	0
BA b	0	0	0	0	0	0	0
CD b	0	0	0	0	0	0	0
DC b	0	0	0	0	0	0	0
DE b	0	0	0	0	0	0	0
ED b	0	0	0	0	0	0	0
EA b	0	0	0	0	0	0	0
AE b	0	0	0	0	0	0	0
BF b	-x/b	-Fb/EJ	-Fx	Fx/EJ	$x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	1/3xb/EJ
FB b	1-x/b	Fb/EJ	-Fx	Fb/EJ-Fx/EJ	$1-2x/b+x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	1/3xb/EJ
GC b	-1+x/b	0	0	0	$1-2x/b+x^2/b^2$	0+0	1/3xb/EJ
CG b	x/b	0	0	0	$x^2/b^2$	0+0	1/3xb/EJ
FG 2b	-1	0	0	0	1	$(-4/3+0)Fb^2/EJ$	2xb/EJ
GF 2b	1	0	0	0	1	$(-4/3+0)Fb^2/EJ$	2xb/EJ
CB 2b	0	0	0	0	0	0+0	0
BC 2b	0	0	0	0	0	0+0	0
totali	0	0	0	0	0	$-4/3Fb^2/EJ$	8/3xb/EJ

iperstatica X=W<sub>gc</sub>

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{xo} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{xo} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

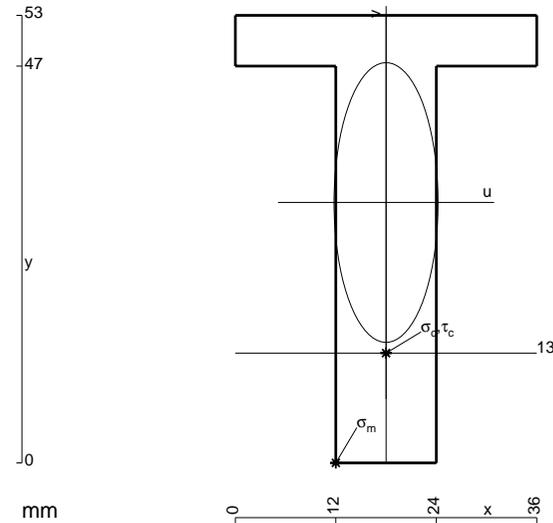
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{xo} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

$$L_{GF}^{xo} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



$$A = 780. \text{ mm}^2$$

$$J_u = 214152. \text{ mm}^4$$

$$J_v = 30096. \text{ mm}^4$$

$$y_g = 30.84 \text{ mm}$$

$$T_y = 2950. \text{ N}$$

$$M_x = -1593000. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -6. \text{ mm}$$

$$v_m = -30.84 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -229.4 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 13. \text{ mm}$$

$$v_c = -17.84 \text{ mm}$$

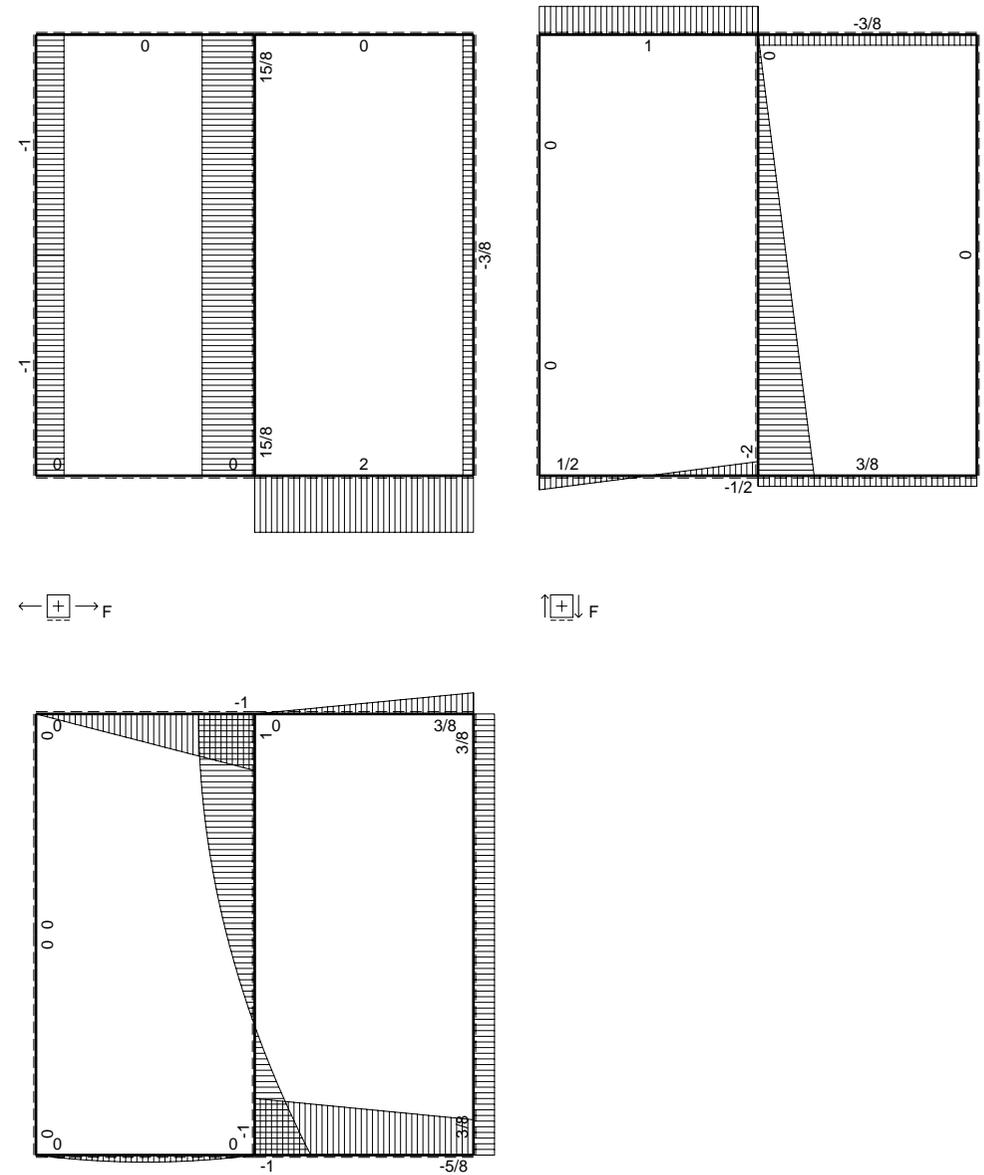
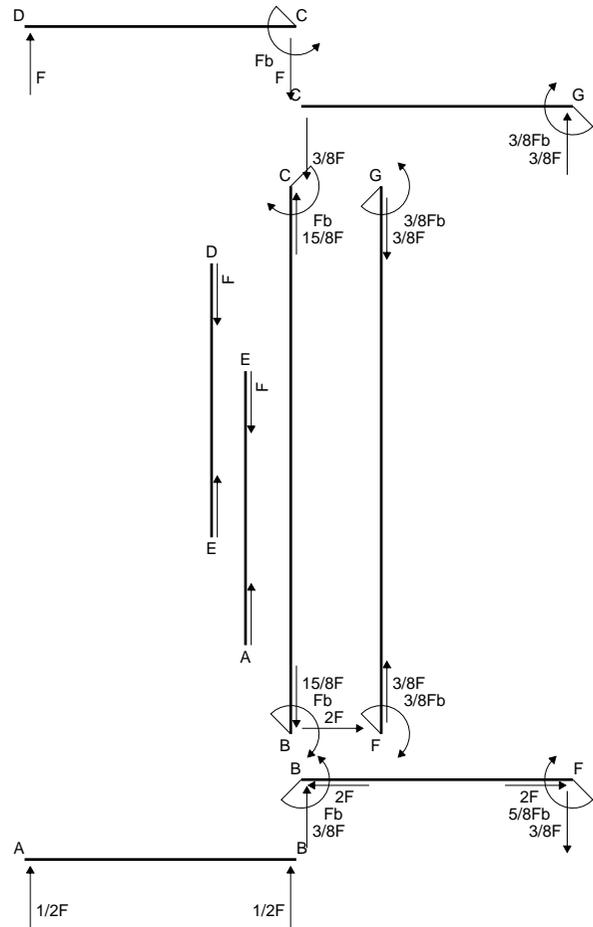
$$\sigma_c = -Mv/J_u = -132.7 \text{ N/mm}^2$$

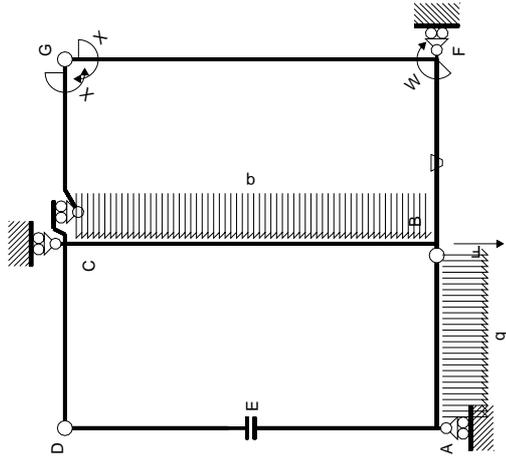
$$\tau_c = 4.359 \text{ N/mm}^2$$

$$\sigma_o = \sqrt{\sigma^2 + 3\tau^2} = 132.9 \text{ N/mm}^2$$

$$S = 3797. \text{ mm}^3$$

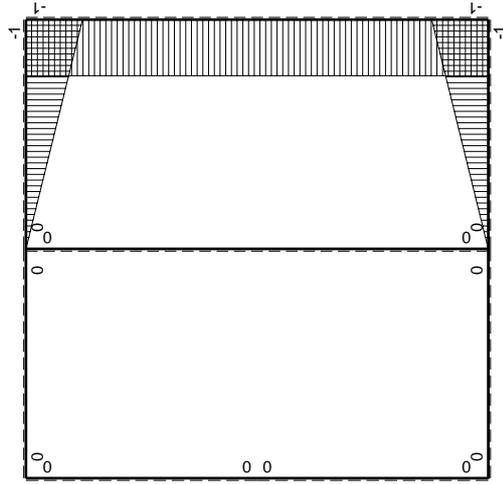






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / EJ dx$
AB b	0	$1/2Fx - 1/2qx^2$	0	0	0	0	0+0	0
BA b	0	$-1/2Fx + 1/2qx^2$	0	0	0	0	0+0	0
CD b	0	$-Fb + Fx$	0	0	0	0	0+0	0
DC b	0	$Fx$	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
EA b	0	0	0	0	0	0	0+0	0
AE b	0	0	0	0	0	0	0+0	0
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb-Fx$	$Fb/EJ - Fx/EJ$	$1-2x/b+x^2/b^2$	$1/3xb/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2xb/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2xb/EJ$
CB 2b	0	$Fb - 1/2qx^2$	0	0	0	0	0+0	0
BC 2b	0	$Fb - 2Fx + 1/2qx^2$	0	0	0	0	0+0	0
totali								$Fb^2/EJ$
								$8/3xb/EJ$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

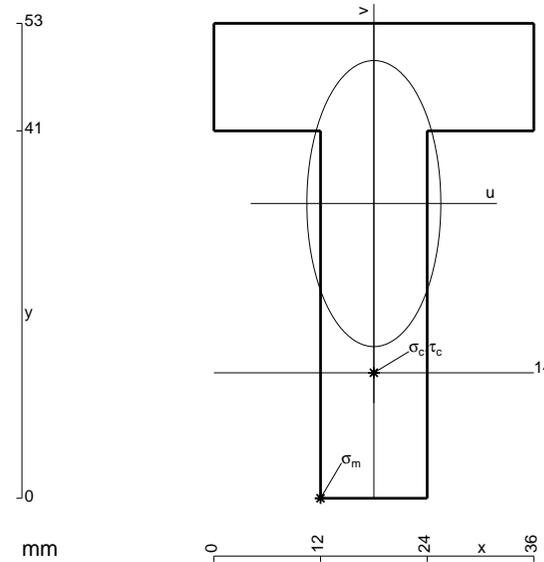
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

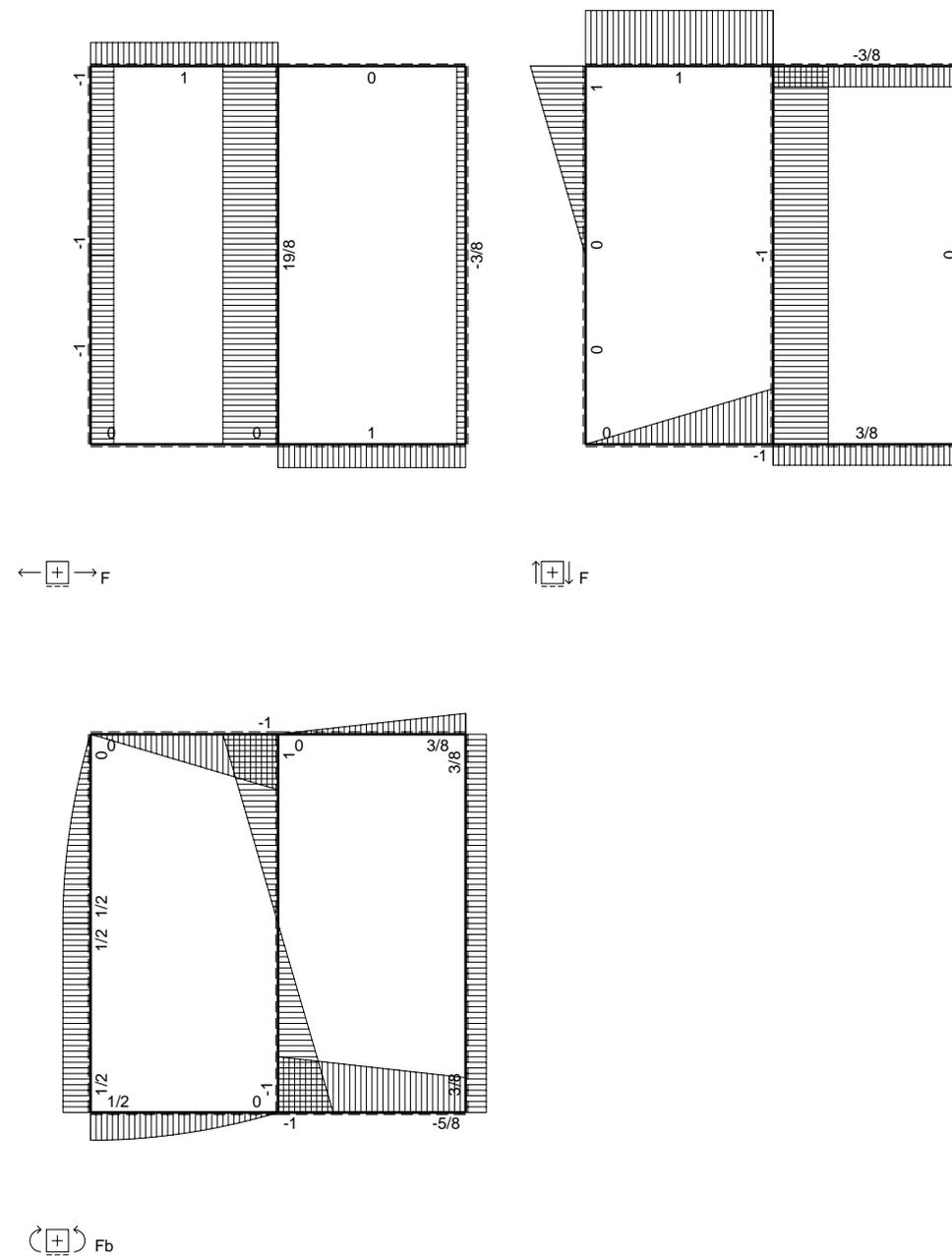
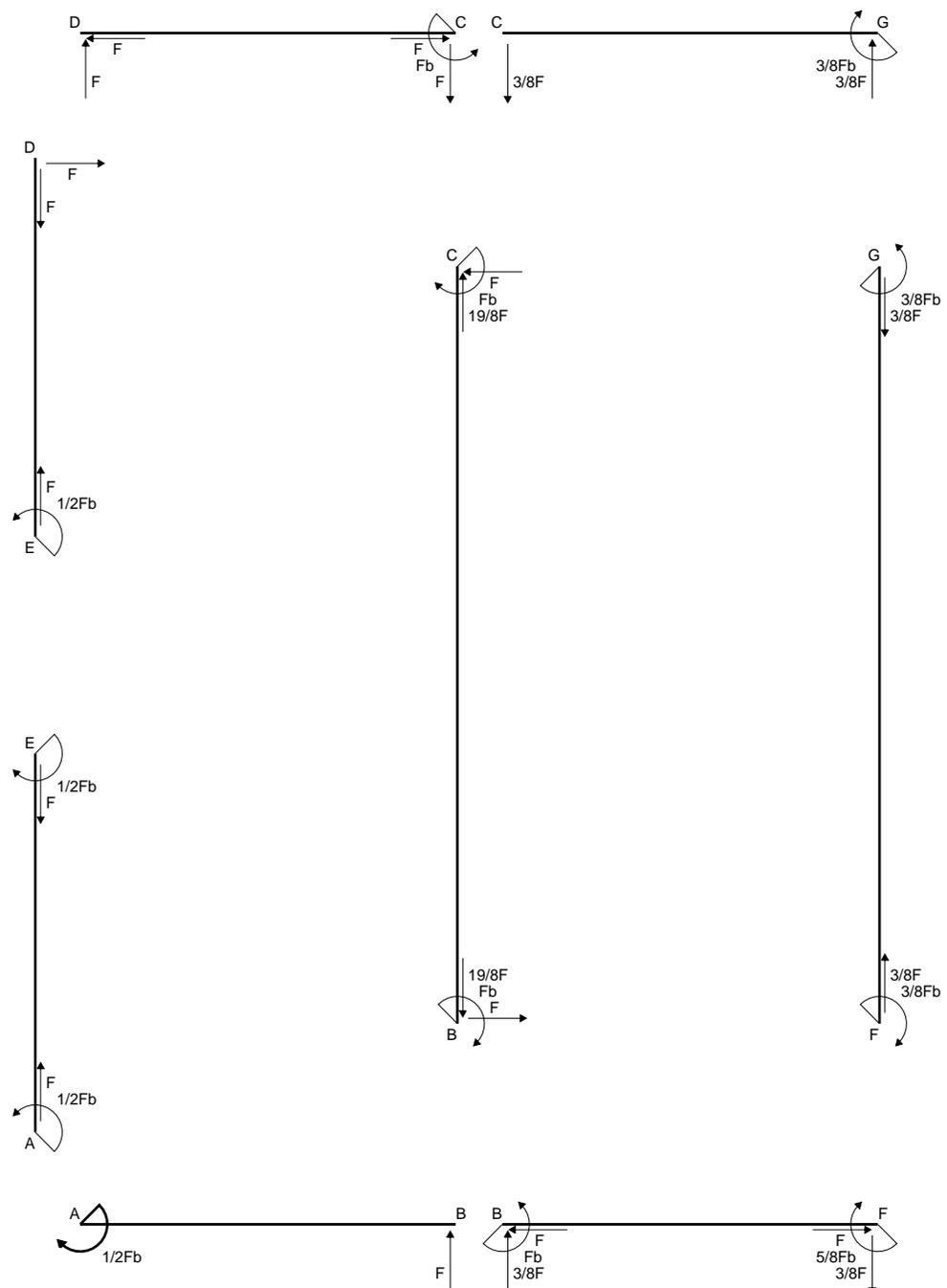
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



- A = 924. mm<sup>2</sup>
- J<sub>u</sub> = 235641. mm<sup>4</sup>
- J<sub>v</sub> = 52560. mm<sup>4</sup>
- y<sub>g</sub> = 32.89 mm
- N = 5700. N
- T<sub>y</sub> = -6080. N
- M<sub>x</sub> = -1763200. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -32.89 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = -239.9 N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 14. mm
- v<sub>c</sub> = -18.89 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = -135.2 N/mm<sup>2</sup>
- τ<sub>c</sub> = 9.352 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 136.1 N/mm<sup>2</sup>
- S = 4349. mm<sup>3</sup>







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

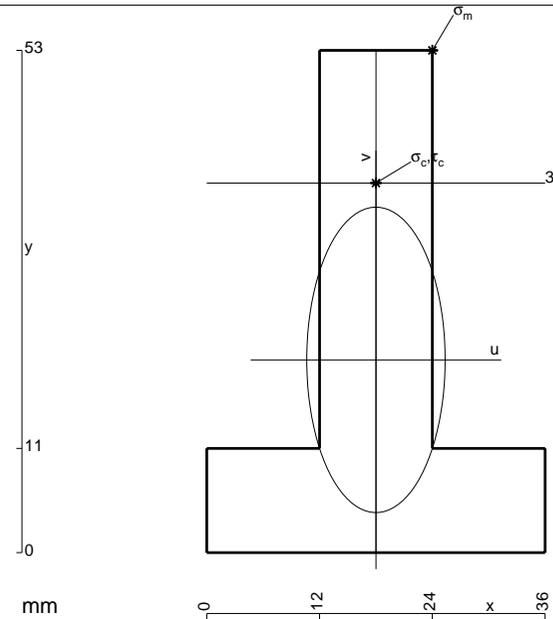
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



$$A = 900. \text{ mm}^2$$

$$J_u = 233812. \text{ mm}^4$$

$$J_v = 48816. \text{ mm}^4$$

$$y_g = 20.34 \text{ mm}$$

$$N = 5225. \text{ N}$$

$$T_y = -2200. \text{ N}$$

$$M_x = -1386000. \text{ Nmm}$$

$$x_m = 24. \text{ mm}$$

$$y_m = 53. \text{ mm}$$

$$u_m = 6. \text{ mm}$$

$$v_m = 32.66 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 199.4 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 39. \text{ mm}$$

$$v_c = 18.66 \text{ mm}$$

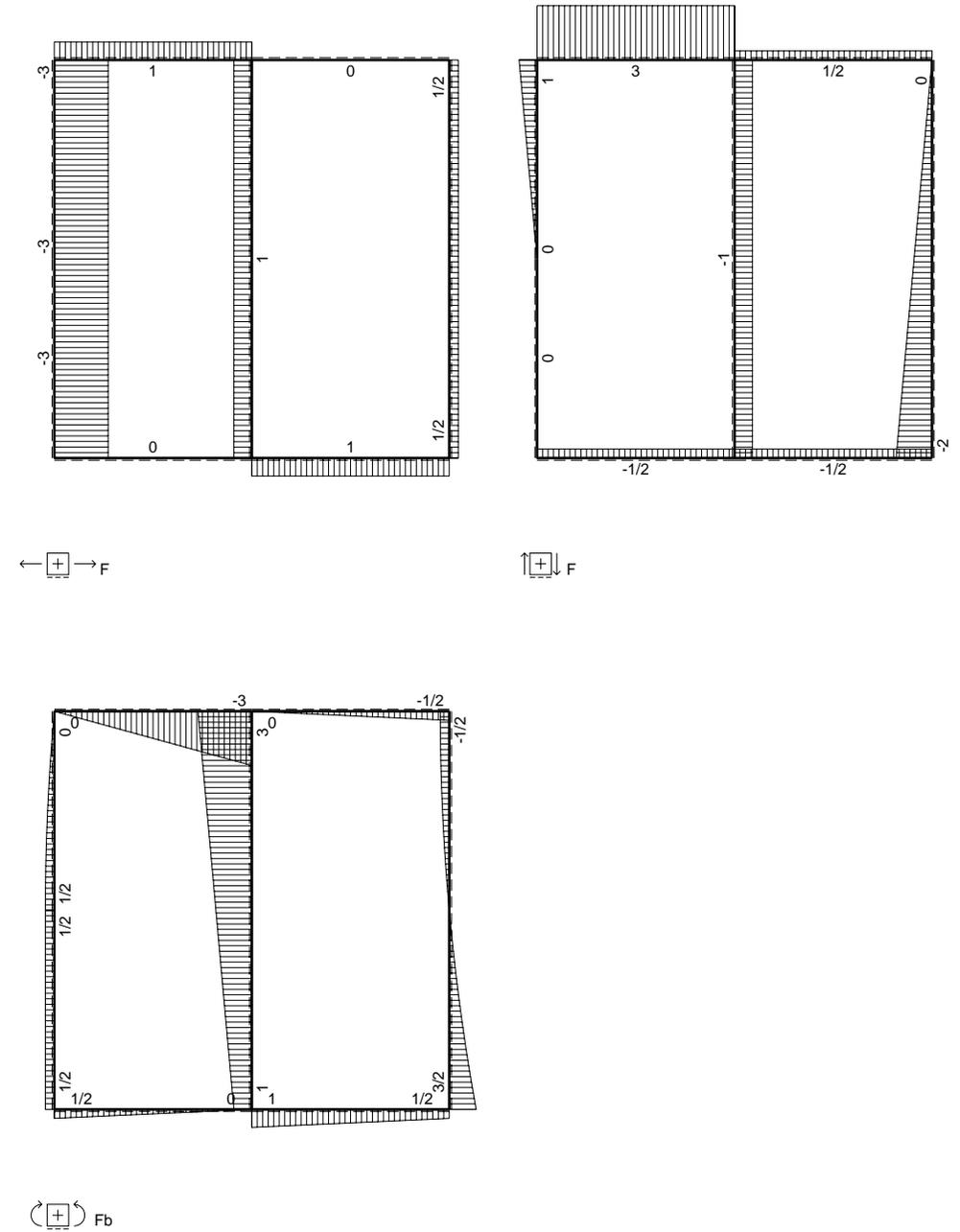
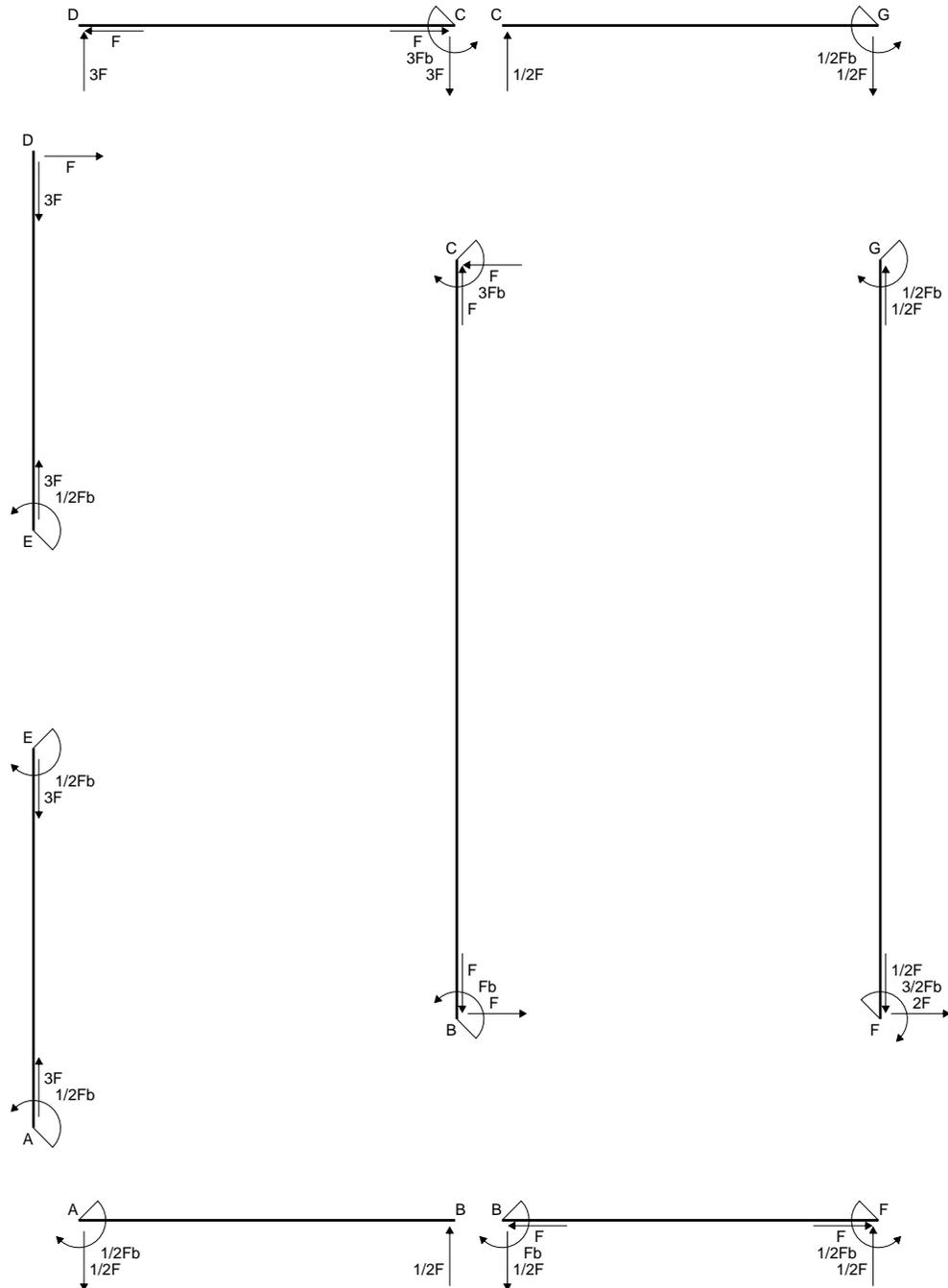
$$\sigma_c = N/A - Mv/J_u = 116.4 \text{ N/mm}^2$$

$$\tau_c = 3.38 \text{ N/mm}^2$$

$$\sigma_\varphi = \sqrt{\sigma^2 + 3\tau^2} = 116.6 \text{ N/mm}^2$$

$$S = 4311. \text{ mm}^3$$







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x_0} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

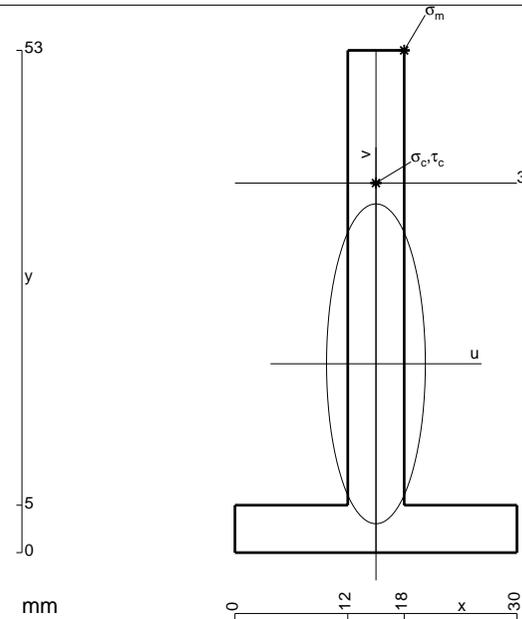
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x_0} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

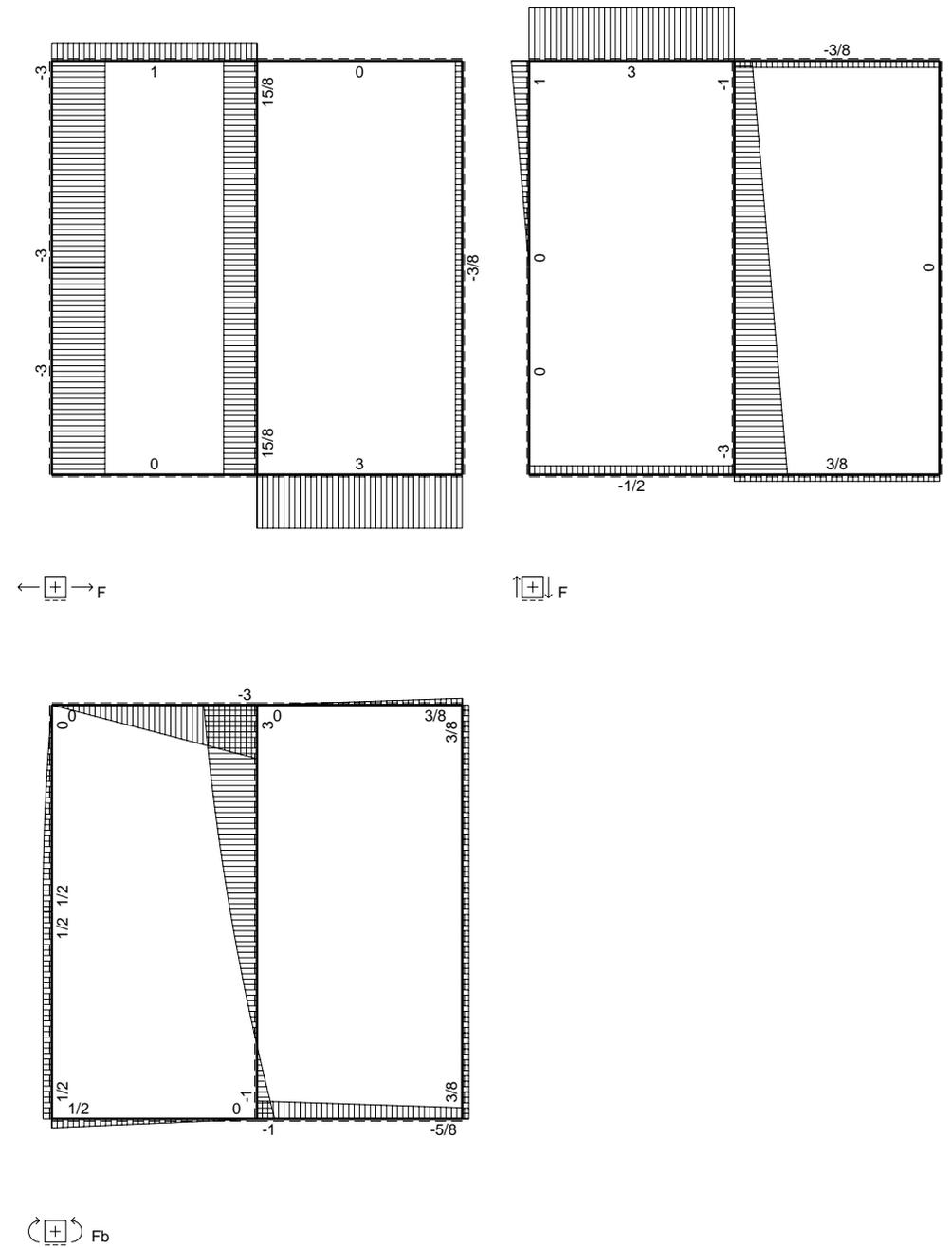
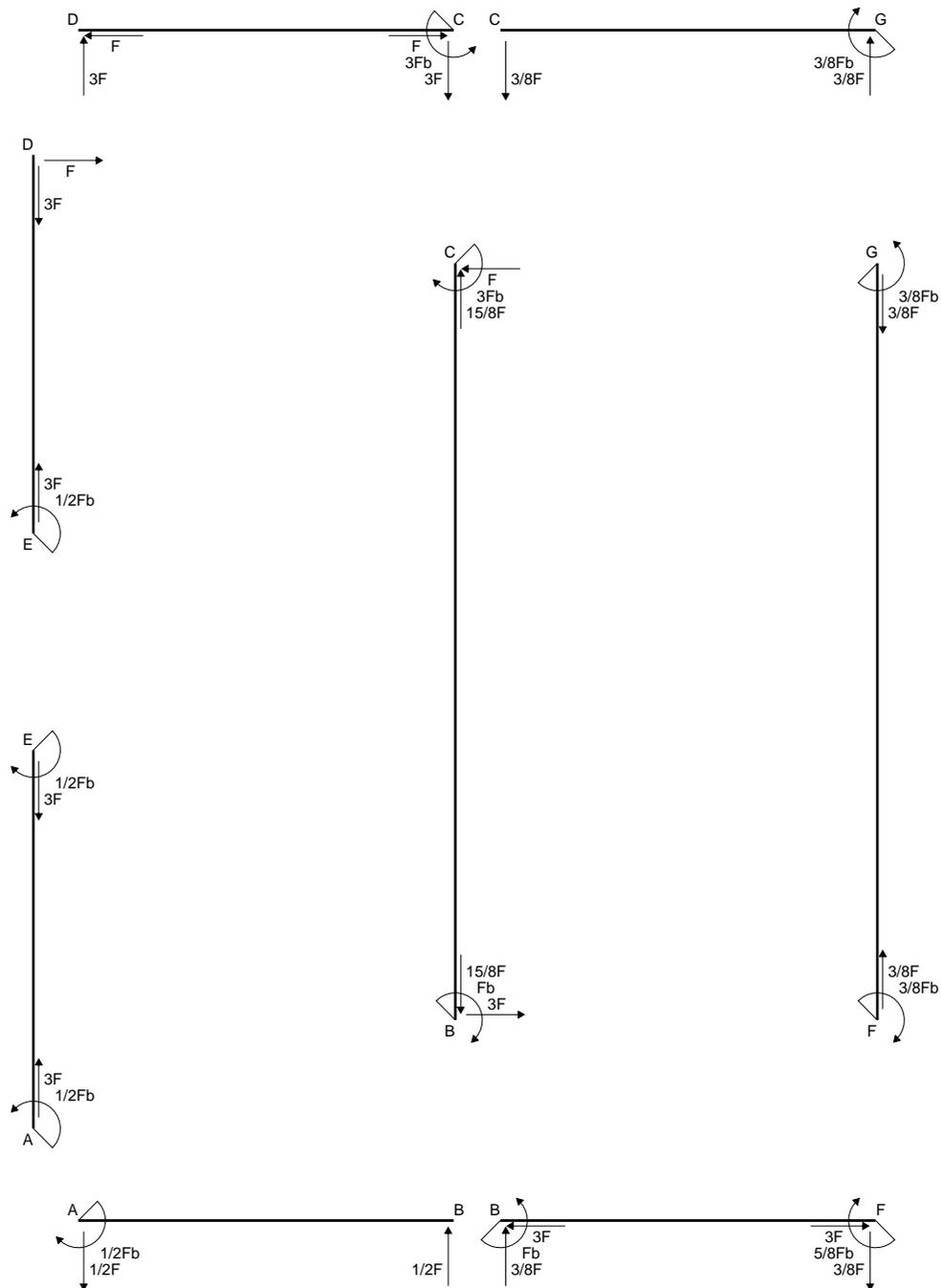
$$L_{GF}^{x_0} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

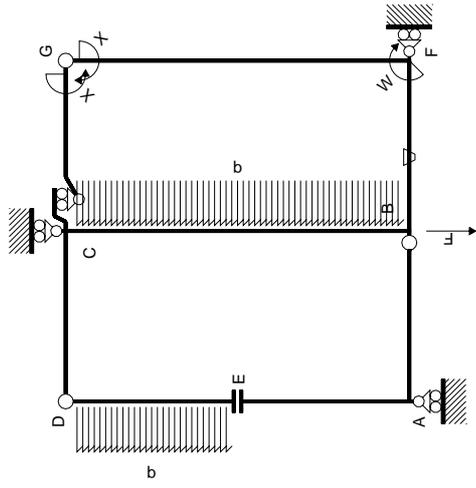
$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



- A = 438. mm<sup>2</sup>
- J<sub>u</sub> = 124872. mm<sup>4</sup>
- J<sub>v</sub> = 12114. mm<sup>4</sup>
- y<sub>g</sub> = 19.92 mm
- N = 390. N
- T<sub>y</sub> = 1170. N
- M<sub>x</sub> = -783900. Nmm
- x<sub>m</sub> = 18. mm
- y<sub>m</sub> = 53. mm
- u<sub>m</sub> = 3. mm
- v<sub>m</sub> = 33.08 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = 208.5 N/mm<sup>2</sup>
- x<sub>c</sub> = 15. mm
- y<sub>c</sub> = 39. mm
- v<sub>c</sub> = 19.08 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = 120.6 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.42 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 120.8 N/mm<sup>2</sup>
- S = 2190. mm<sup>3</sup>

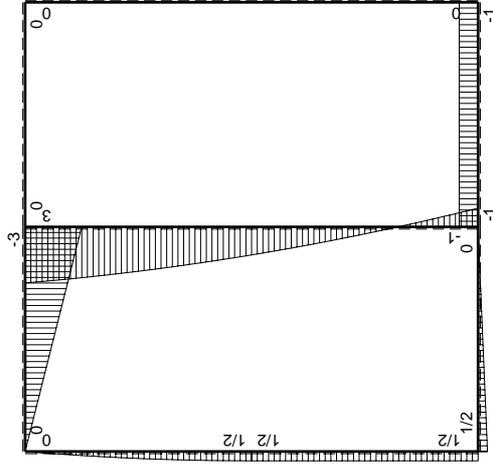






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati

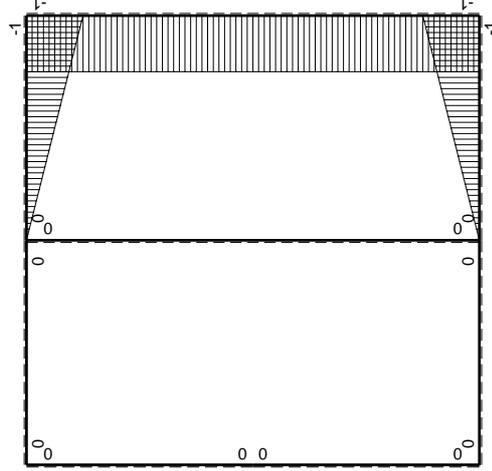


Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / EJ dx$
AB b	0	$1/2 Fb - 1/2 Fx$	0	0	0	0	0+0	0
BA b	0	$-1/2 Fx$	0	0	0	0	0+0	0
CD b	0	$-3Fb + 3Fx$	0	0	0	0	0+0	0
DC b	0	$3Fx$	0	0	0	0	0+0	0
DE b	0	$Fx - 1/2 qx^2$	0	0	0	0	0+0	0
ED b	0	$-1/2 Fb + 1/2 qx^2$	0	0	0	0	0+0	0
EA b	0	$1/2 Fb$	0	0	0	0	0+0	0
AE b	0	$-1/2 Fb$	0	0	0	0	0+0	0
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2 + 1/2) Fb^2/EJ$	$1/3 x b^3/EJ$
FB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb - Fx$	$Fb/EJ - Fx/EJ$	$1 - 2x/b + x^2/b^2$	$1/3 x b^3/EJ$	$1/3 x b^3/EJ$
GC b	$-1+x/b$	0	0	0	0	$1 - 2x/b + x^2/b^2$	0+0	$1/3 x b^3/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3 x b^3/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2x b^3/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2x b^3/EJ$
CB 2b	0	$3Fb - Fx - 1/2 qx^2$	0	0	0	0	0+0	0
BC 2b	0	$Fb - 3Fx + 1/2 qx^2$	0	0	0	0	0+0	0
totali								$8/3 x b^3/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica



$M_x$  flessione da iperstatica  $X=1$

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

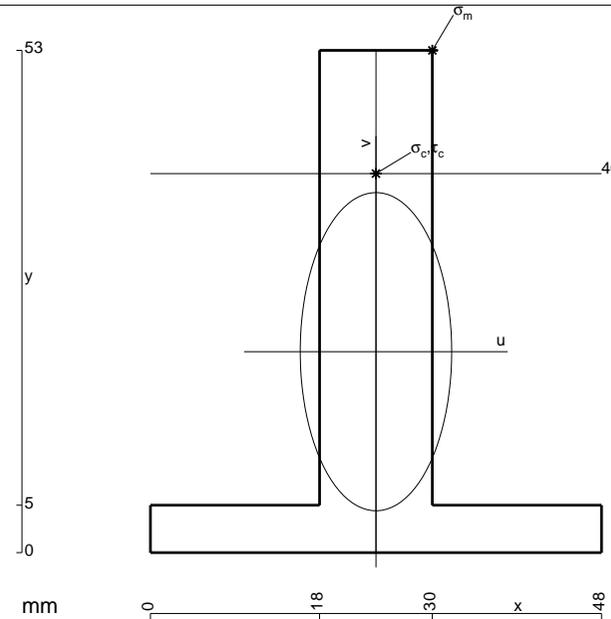
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

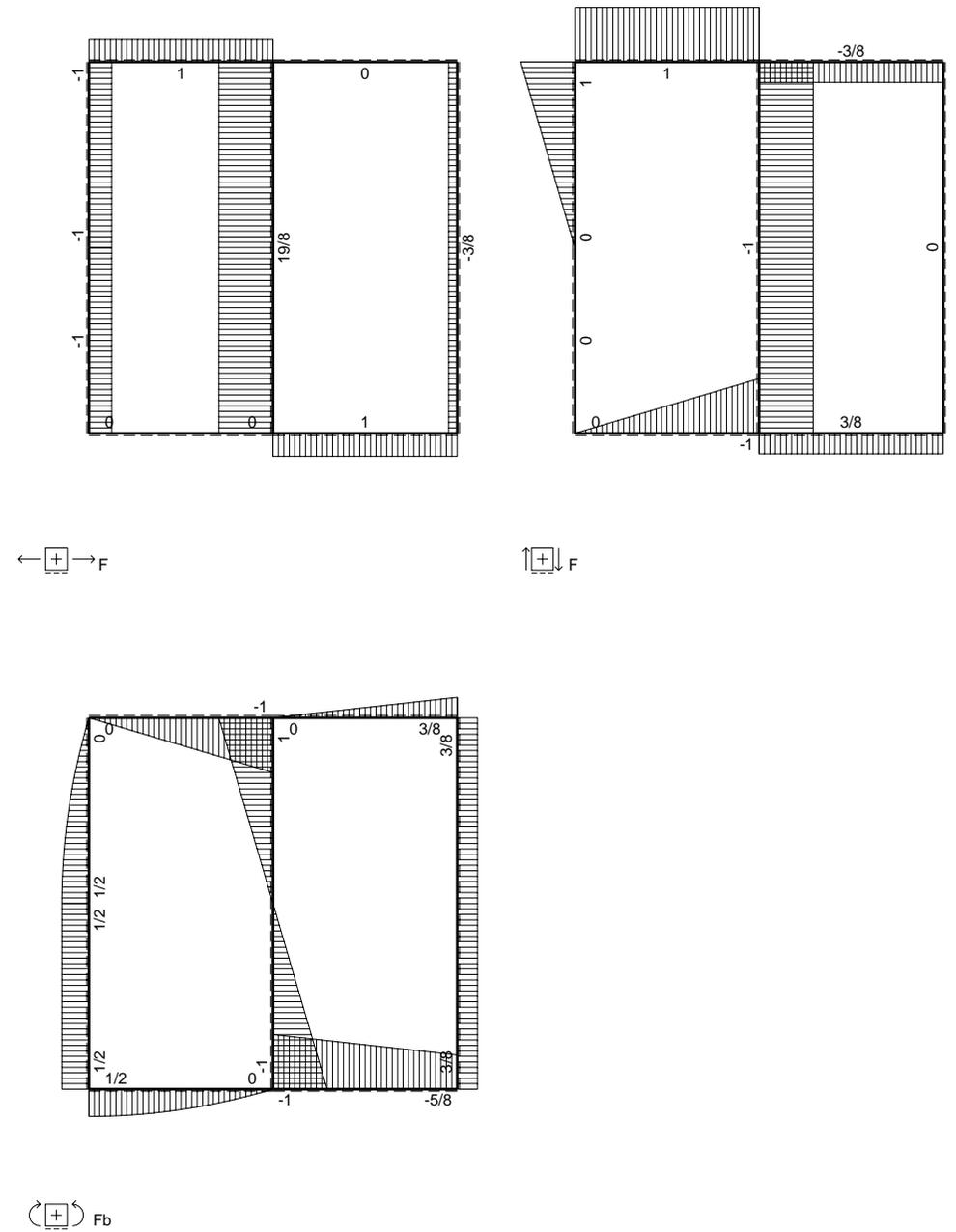
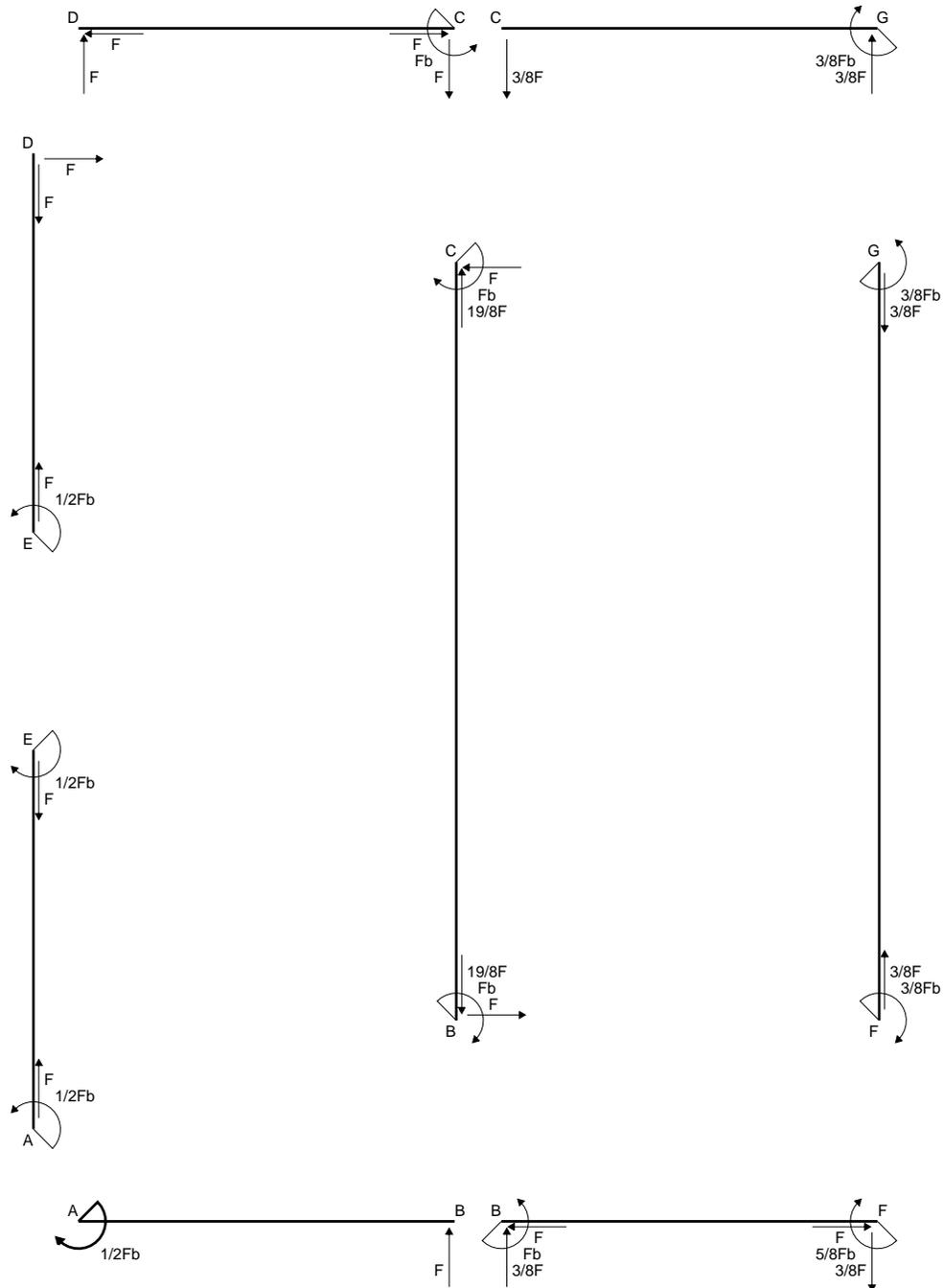
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



- A = 816. mm<sup>2</sup>
- J<sub>u</sub> = 230061. mm<sup>4</sup>
- J<sub>v</sub> = 52992. mm<sup>4</sup>
- y<sub>g</sub> = 21.21 mm
- N = 740. N
- T<sub>y</sub> = 2220. N
- M<sub>x</sub> = -1576200. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 53. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 31.79 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = 218.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 40. mm
- v<sub>c</sub> = 18.79 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = 129.7 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.173 N/mm<sup>2</sup>
- σ<sub>σ</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 129.8 N/mm<sup>2</sup>
- S = 3946. mm<sup>3</sup>







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

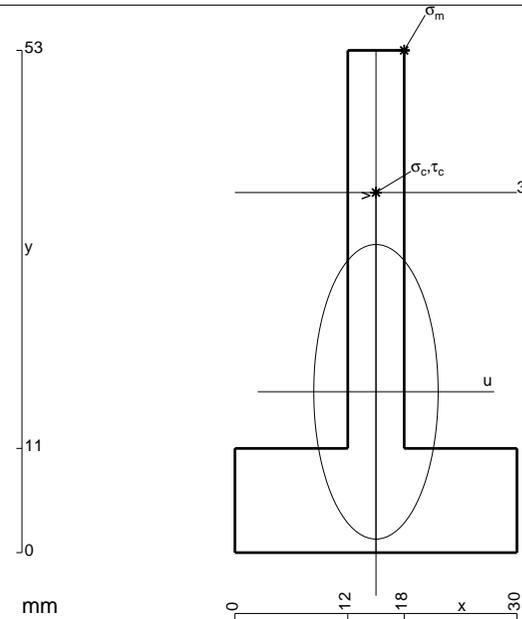
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

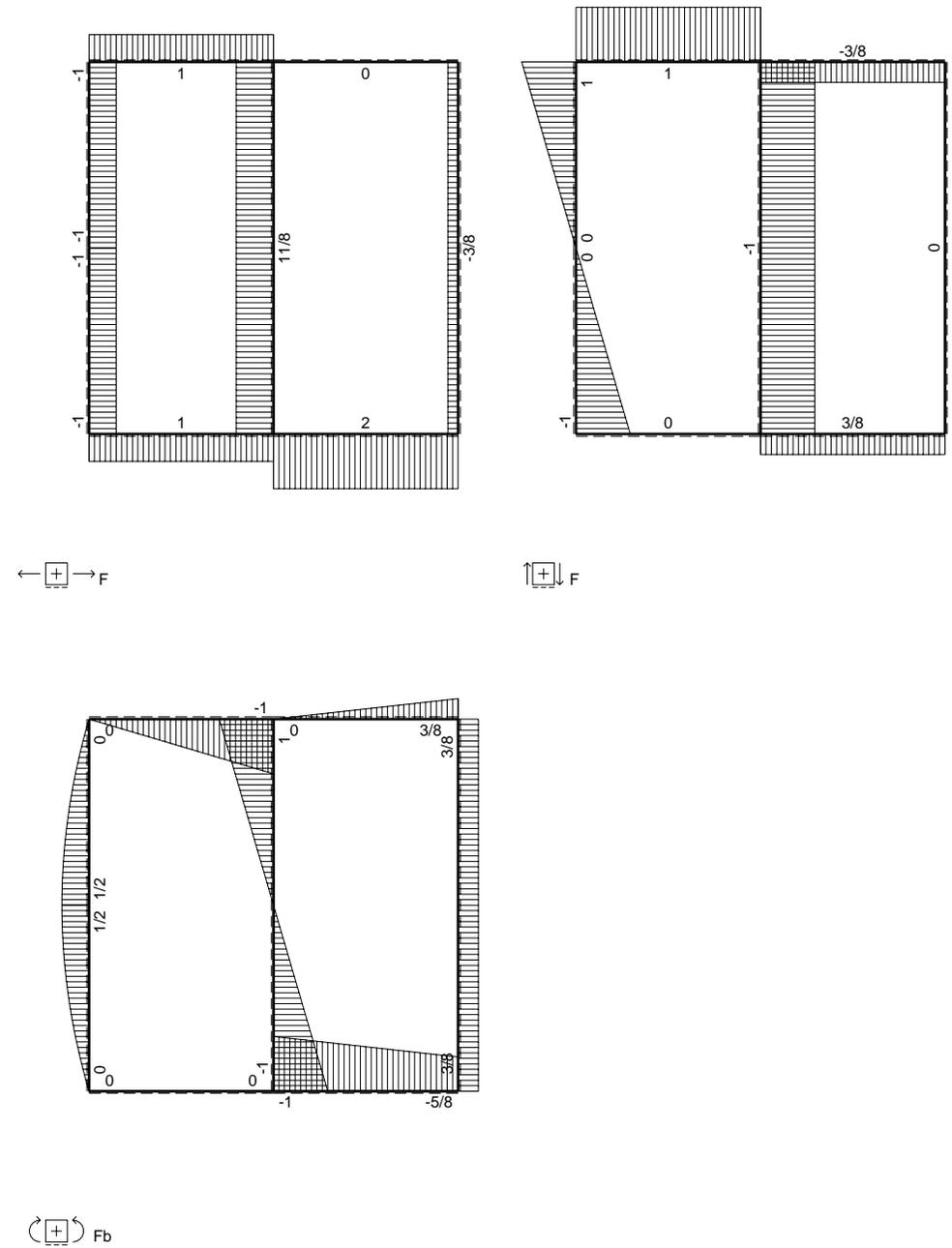
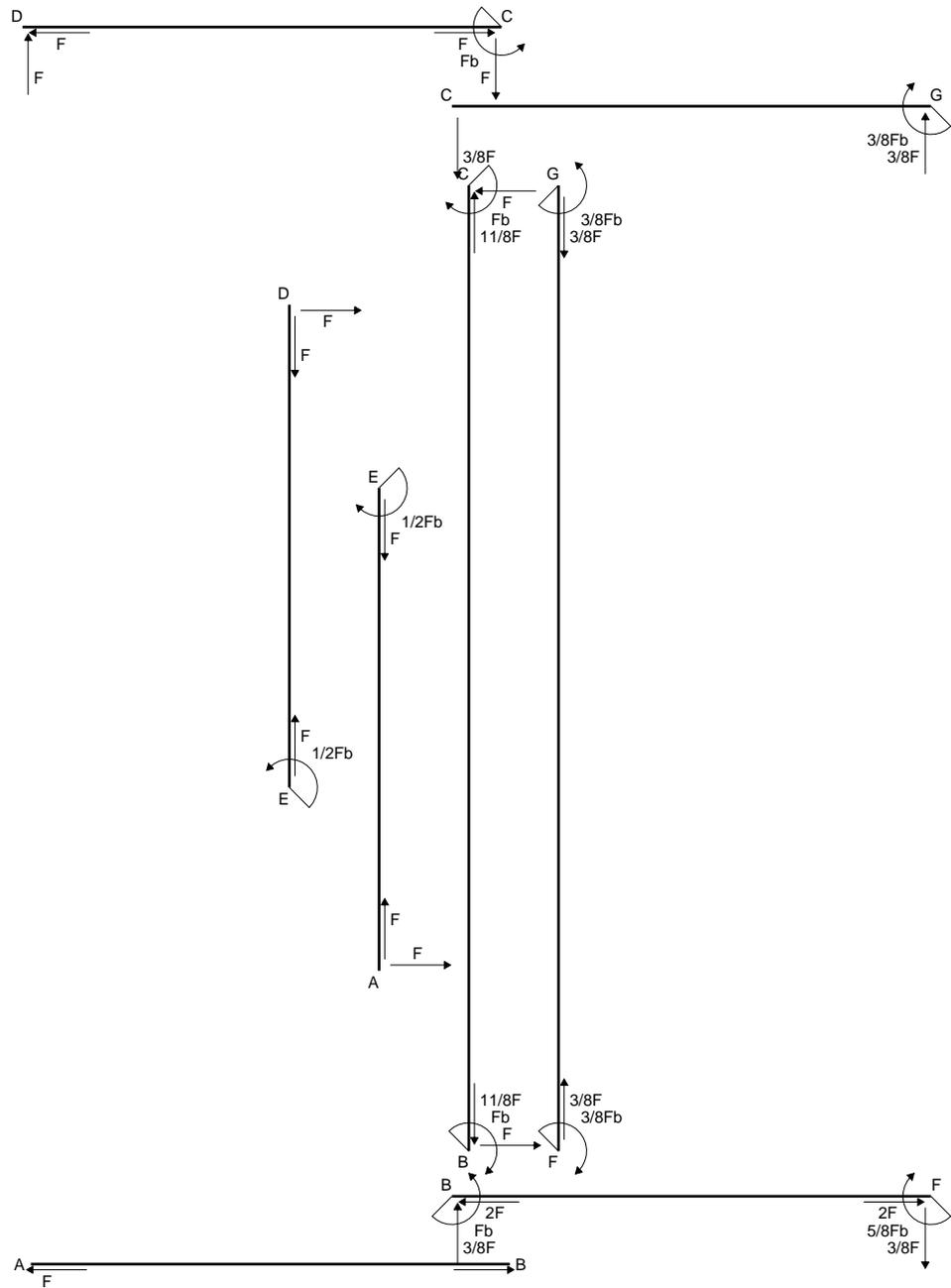
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



- A = 582. mm<sup>2</sup>
- J<sub>u</sub> = 140714. mm<sup>4</sup>
- J<sub>v</sub> = 25506. mm<sup>4</sup>
- y<sub>g</sub> = 16.97 mm
- N = 2779. N
- T<sub>y</sub> = -1170. N
- M<sub>x</sub> = -877500. Nmm
- x<sub>m</sub> = 18. mm
- y<sub>m</sub> = 53. mm
- u<sub>m</sub> = 3. mm
- v<sub>m</sub> = 36.03 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = 229.4 N/mm<sup>2</sup>
- x<sub>c</sub> = 15. mm
- y<sub>c</sub> = 38. mm
- v<sub>c</sub> = 21.03 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = 135.9 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.558 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 136. N/mm<sup>2</sup>
- S = 2567. mm<sup>3</sup>







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

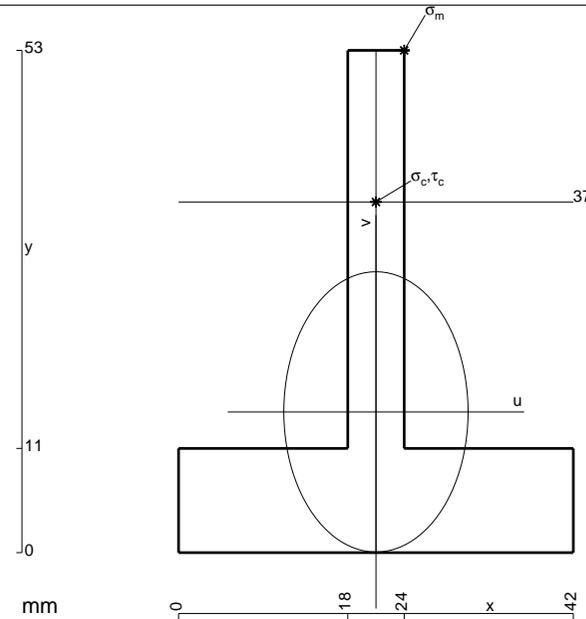
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

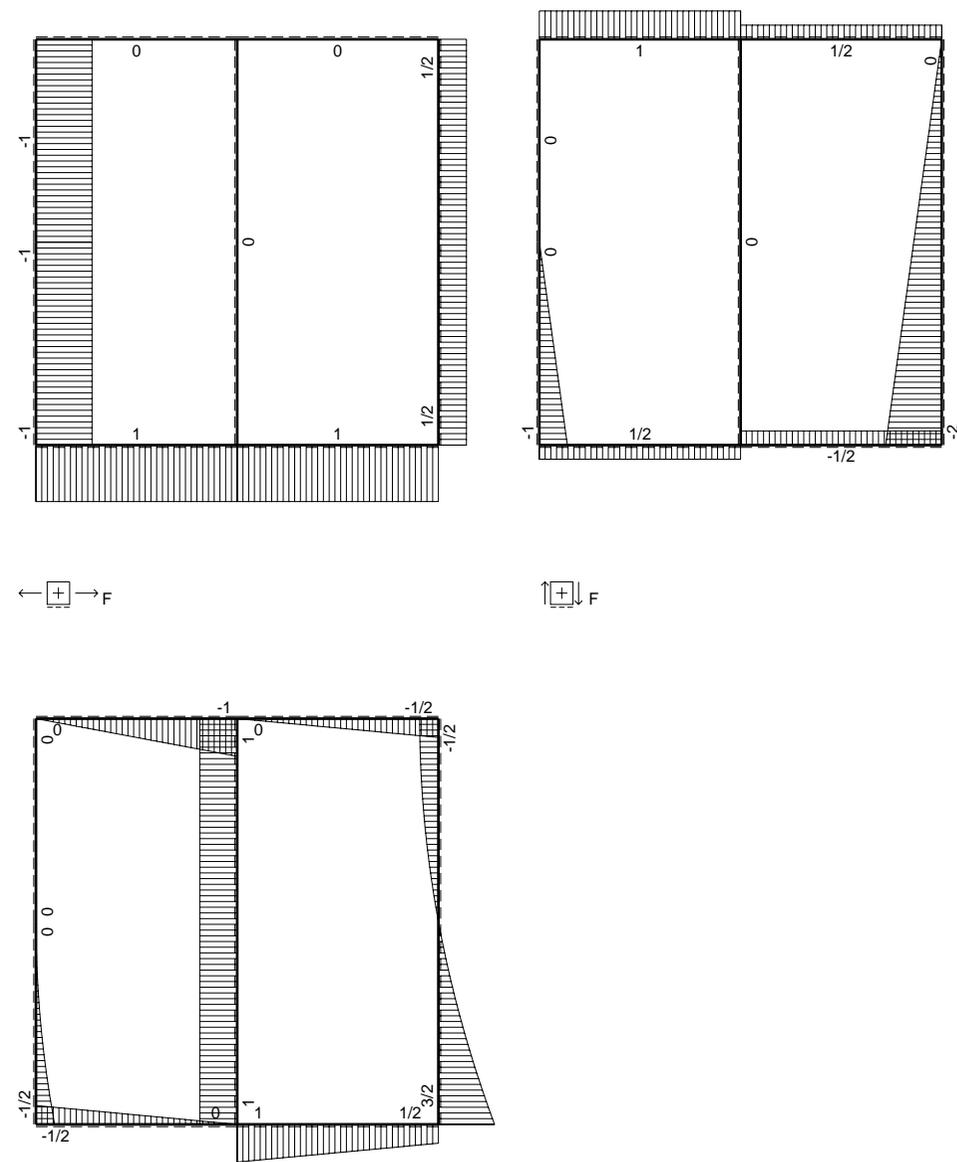
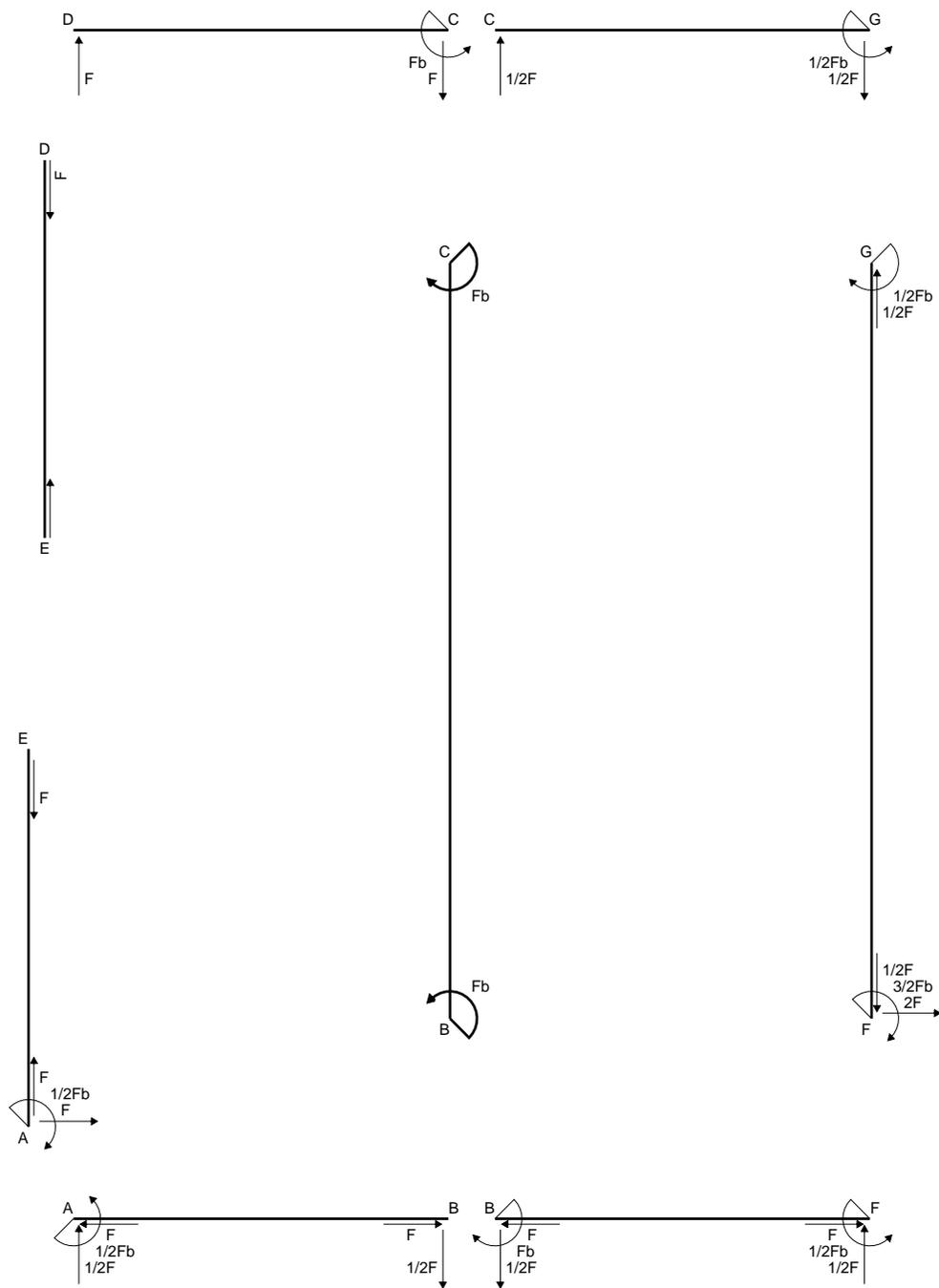
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

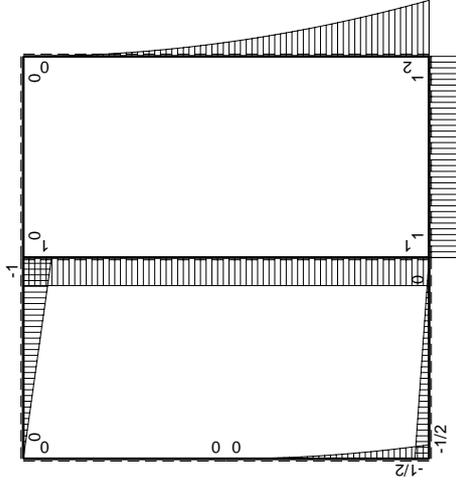
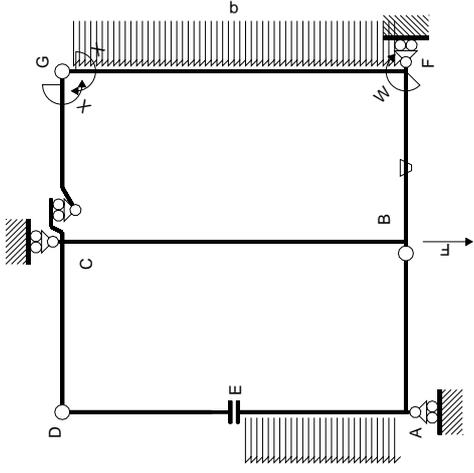
$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



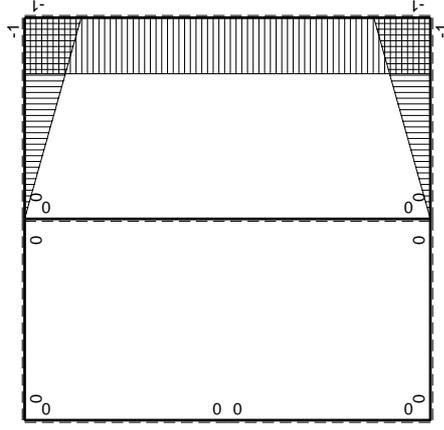
- A = 714. mm<sup>2</sup>
- J<sub>u</sub> = 156211. mm<sup>4</sup>
- J<sub>v</sub> = 68670. mm<sup>4</sup>
- y<sub>g</sub> = 14.85 mm
- N = 1691. N
- T<sub>y</sub> = -1230. N
- M<sub>x</sub> = -971700. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 53. mm
- u<sub>m</sub> = 3. mm
- v<sub>m</sub> = 38.15 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = 239.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 37. mm
- v<sub>c</sub> = 22.15 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = 140.1 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.798 N/mm<sup>2</sup>
- σ<sub>σ</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 140.3 N/mm<sup>2</sup>
- S = 2894. mm<sup>3</sup>







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\leftarrow$	$M(x)$	$M^0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	0	$-1/2Fb+1/2Fx$	0	0	0	0	0+0	0
BA b	0	$1/2Fx$	0	0	0	0	0+0	0
CD b	0	$-Fb+Fx$	0	0	0	0	0+0	0
DC b	0	$Fx$	0	0	0	0	0+0	0
ED b	0	0	0	0	0	0	0+0	0
EA b	0	$-1/2qx^2$	0	0	0	0	0+0	0
AE b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0+0	0
BF b	$-x/b$	$Fb$	$-Fb/EJ$	$-Fx$	$Fx/EJ$	$x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$-Fb$	$Fb/EJ$	$-Fb+Fx$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	$2Fb-2Fx+1/2qx^2$	0	$-2Fb+2Fx-1/2Fx^2/b$	0	1	$(-4/3+0)Fb^2/EJ$	$2xb/EJ$
GF 2b	1	$-1/2qx^2$	0	$-1/2Fx^2/b$	0	1	$(-4/3+0)Fb^2/EJ$	$2xb/EJ$
CB 2b	0	$Fb$	0	0	0	0	0+0	0
BC 2b	0	$-Fb$	0	0	0	0	0+0	0
totali							$-4/3Fb^2/EJ$	$8/3xb/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x_0} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

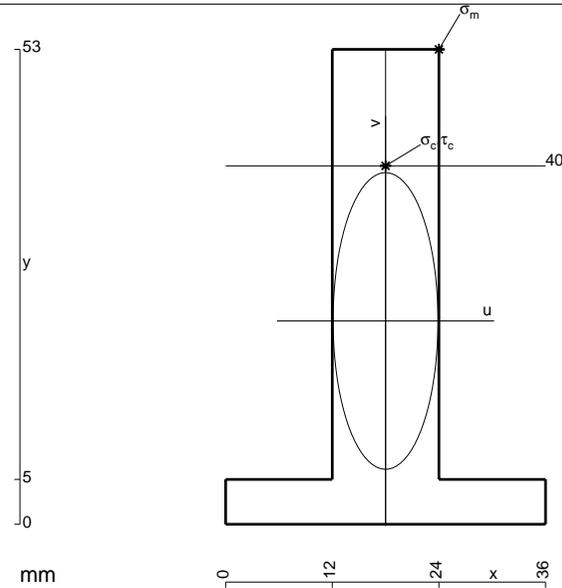
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x_0} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

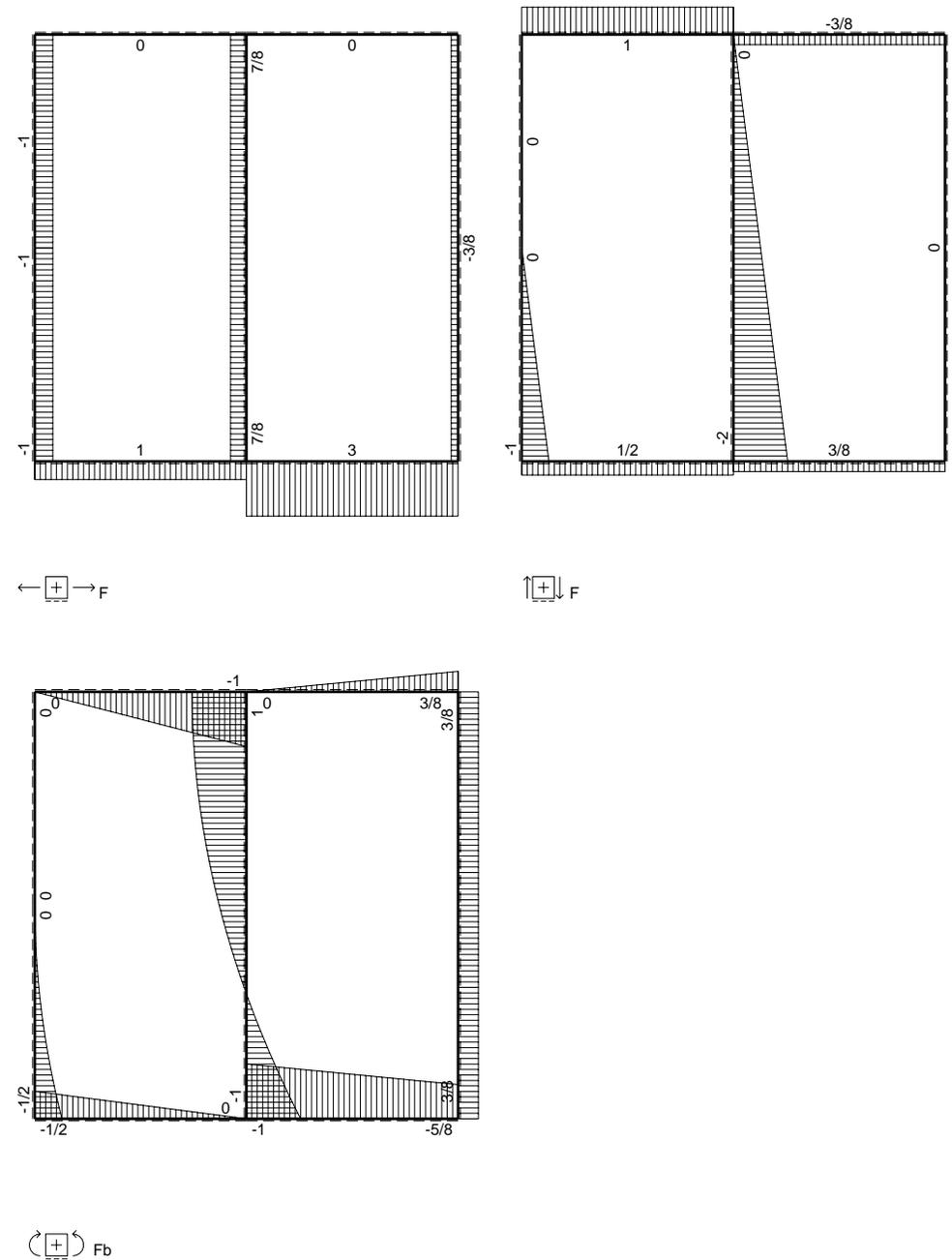
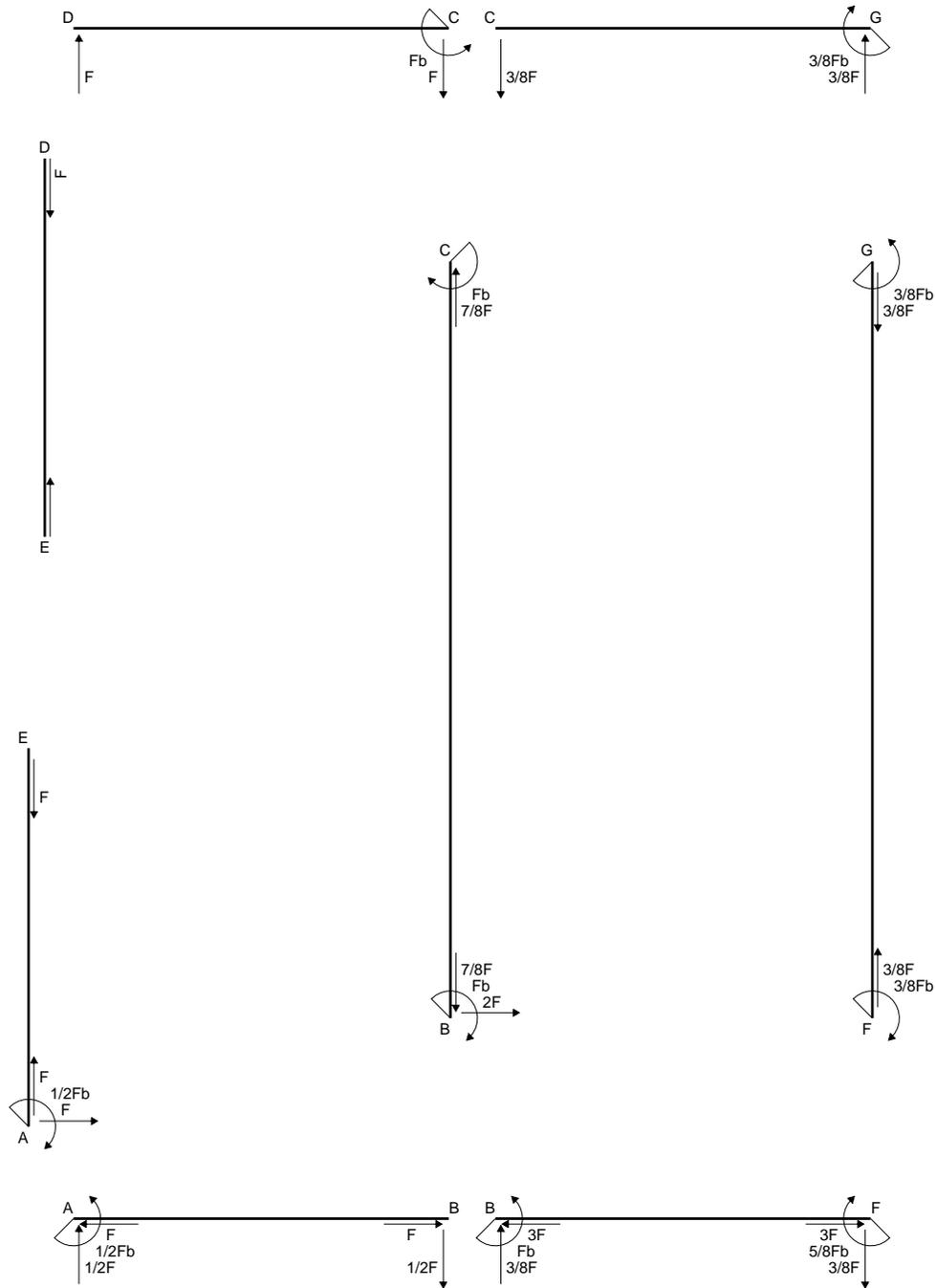
$$L_{GF}^{x_0} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

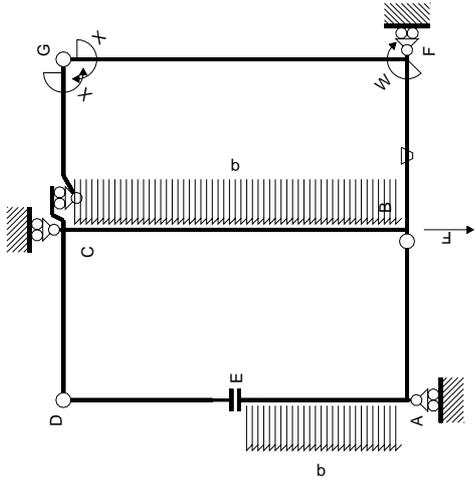
$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



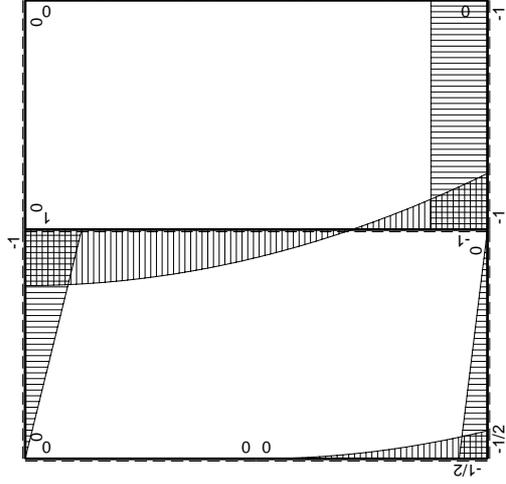
- A = 756. mm<sup>2</sup>
- J<sub>u</sub> = 207276. mm<sup>4</sup>
- J<sub>v</sub> = 26352. mm<sup>4</sup>
- y<sub>g</sub> = 22.69 mm
- T<sub>y</sub> = 3250. N
- M<sub>x</sub> = -1365000. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 53. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 30.31 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 199.6 N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 40. mm
- v<sub>c</sub> = 17.31 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 114. N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.853 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 114.3 N/mm<sup>2</sup>
- S = 3714. mm<sup>3</sup>



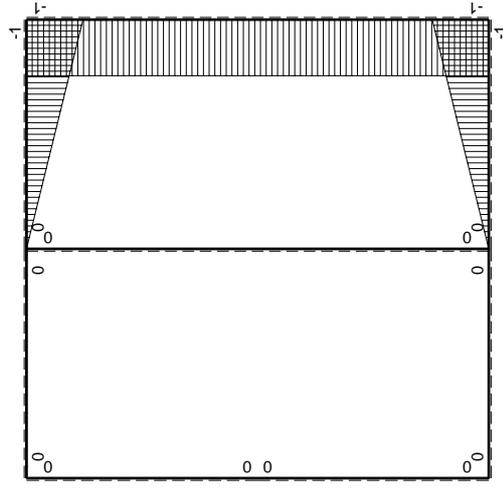




Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M(x)$	$M(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / EJ dx$
AB b	0	$-1/2Fx$	0	0	0	0	0+0	0
BA b	0	$1/2Fx$	0	0	0	0	0+0	0
CD b	0	$-Fb+Fx$	0	0	0	0	0+0	0
DC b	0	$Fx$	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
EA b	0	$-1/2qx^2$	0	0	0	0	0+0	0
AE b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0+0	0
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb-Fx$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$1/3xb/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2xb/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2xb/EJ$
CB 2b	0	$Fb-1/2qx^2$	0	0	0	0	0+0	0
BC 2b	0	$Fb-2Fx+1/2qx^2$	0	0	0	0	0+0	0
totali								$Fb^2/EJ$
								$8/3xb/EJ$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

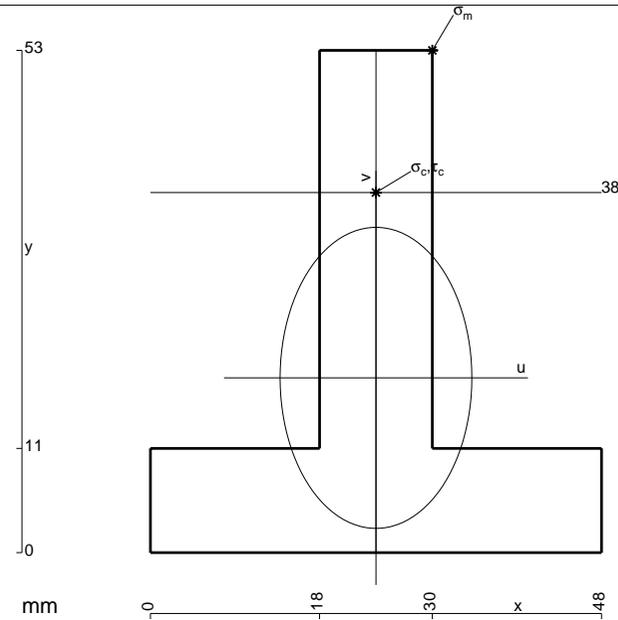
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



$$A = 1032. \text{ mm}^2$$

$$J_u = 260495. \text{ mm}^4$$

$$J_v = 107424. \text{ mm}^4$$

$$y_g = 18.44 \text{ mm}$$

$$N = 2966. \text{ N}$$

$$T_y = -6780. \text{ Nmm}$$

$$M_x = -1559400. \text{ Nmm}$$

$$x_m = 30. \text{ mm}$$

$$y_m = 53. \text{ mm}$$

$$u_m = 6. \text{ mm}$$

$$v_m = 34.56 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 209.8 \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 38. \text{ mm}$$

$$v_c = 19.56 \text{ mm}$$

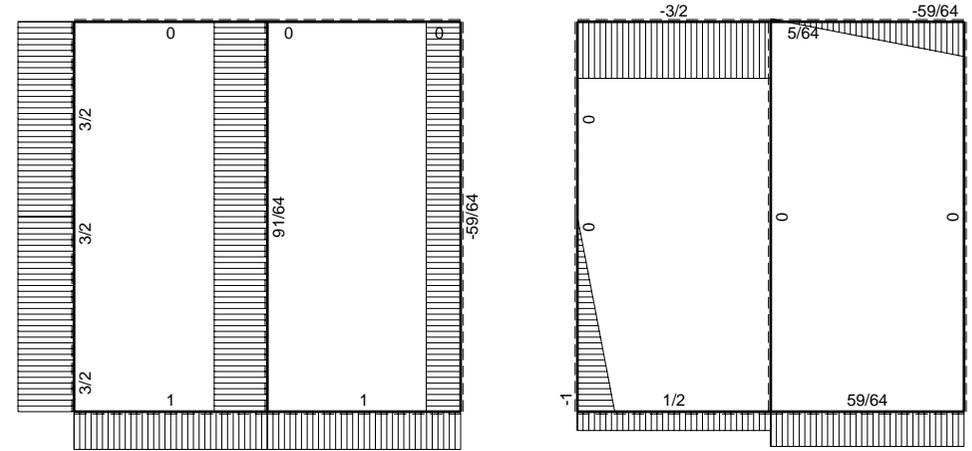
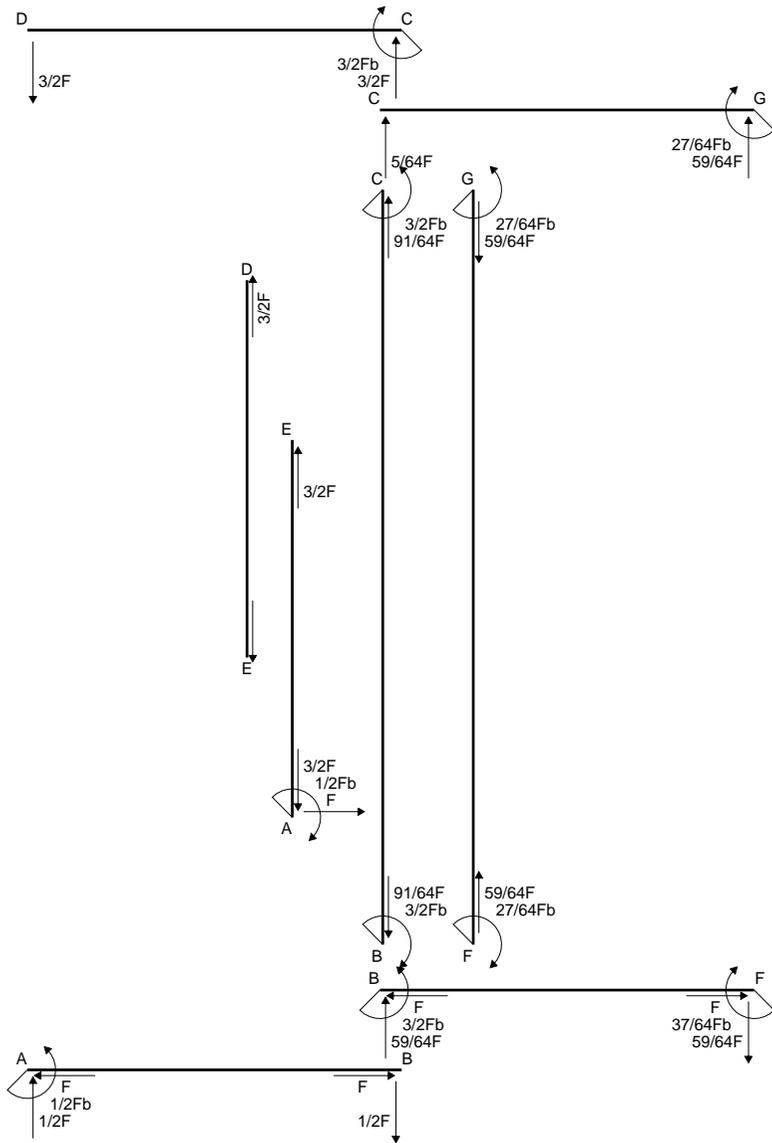
$$\sigma_c = N/A - Mv/J_u = 120. \text{ N/mm}^2$$

$$\tau_c = 10.56 \text{ N/mm}^2$$

$$\sigma_\varrho = \sqrt{\sigma^2 + 3\tau^2} = 121.3 \text{ N/mm}^2$$

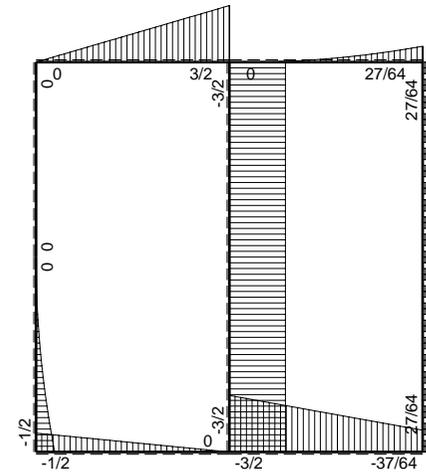
$$S = 4870. \text{ mm}^3$$



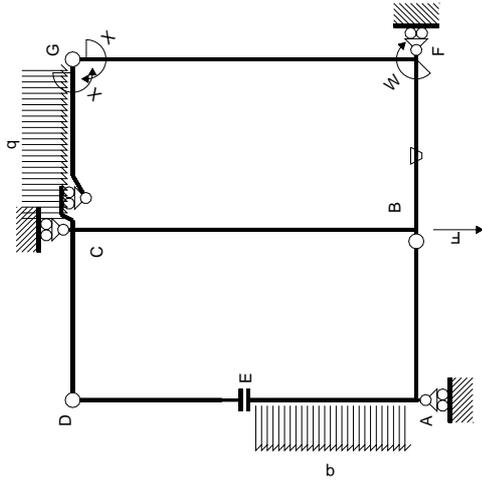


← ⊕ → F

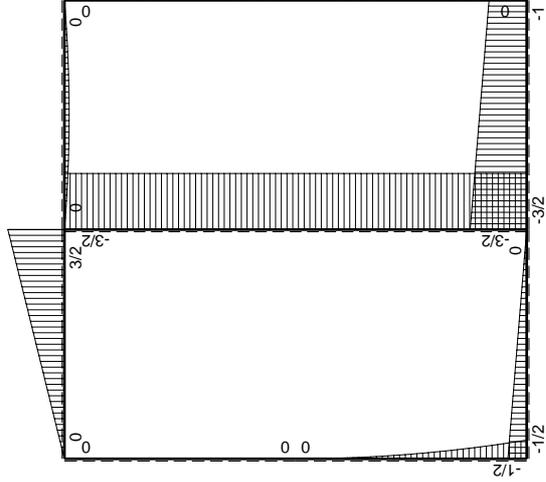
↑ ⊕ ↓ F



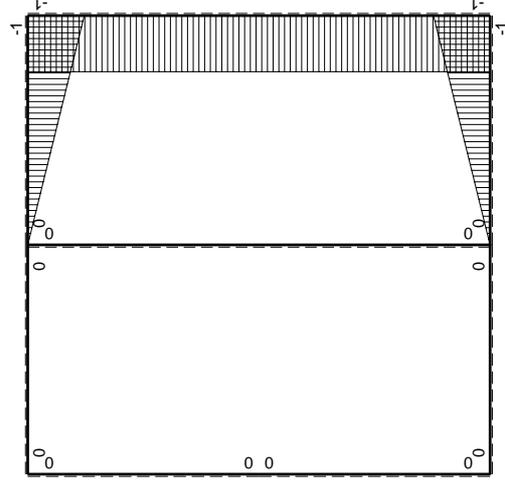
⊕ ⊖ F<sub>b</sub>



Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x (M^0/EJ + \theta) dx$	$\int X M^x M^0/EJ dx$
AB b	0	$-1/2Fb+1/2Fx$	0	0	0	0	0+0	0
BA b	0	$1/2Fx$	0	0	0	0	0+0	0
CD b	0	$3/2Fb-3/2Fx$	0	0	0	0	0+0	0
DC b	0	$-3/2Fx$	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
EA b	0	$-1/2qx^2$	0	0	0	0	0+0	0
AE b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0+0	0
BF b	$-x/b$	$-3/2Fb+1/2Fx$	$-Fb/EJ$	$3/2Fx-1/2Fx^2/b$	$Fx/EJ$	$x^2/b^2$	$(7/12+1/2)Fb^2/EJ$	$1/3Xb/EJ$
FB b	$1-x/b$	$Fb+1/2Fx$	$Fb/EJ$	$Fb-1/2Fx-1/2Fx^2/b$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$(7/12+1/2)Fb^2/EJ$	$1/3Xb/EJ$
GC b	$-1+x/b$	$-1/2Fx+1/2qx^2$	0	$1/2Fx-Fx^2/b+1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(1/24+0)Fb^2/EJ$	$1/3Xb/EJ$
CG b	$x/b$	$1/2Fx-1/2qx^2$	0	$1/2Fx^2/b-1/2qx^3/b$	0	$x^2/b^2$	$(1/24+0)Fb^2/EJ$	$1/3Xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2Xb/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$
CB 2b	0	$-3/2Fb$	0	0	0	0	0+0	0
BC 2b	0	$3/2Fb$	0	0	0	0	0+0	0
totali								
							$9/8Fb^2/EJ$	$8/3Xb/EJ$
								$-27/64Fb$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{xo} = \int_0^b (3/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

$$= [3/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (3/4 b - 1/6 b) Fb 1/EJ + (1/2 b) \theta = 13/12 Fb^2/EJ$$

$$L_{FB}^{xo} = \int_0^b (1 - 1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [x - 1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

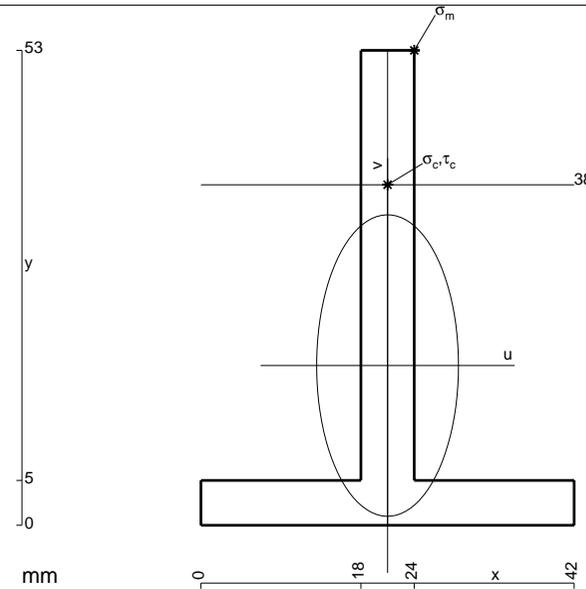
$$= (b - 1/4 b - 1/6 b) Fb 1/EJ + (-b + 1/2 b) \theta = 13/12 Fb^2/EJ$$

$$L_{GC}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{CG}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$



$$A = 498. \text{ mm}^2$$

$$J_u = 141019. \text{ mm}^4$$

$$J_v = 31734. \text{ mm}^4$$

$$y_g = 17.83 \text{ mm}$$

$$T_y = -1755. \text{ N}$$

$$M_x = 877500. \text{ Nmm}$$

$$x_m = 24. \text{ mm}$$

$$y_m = 53. \text{ mm}$$

$$u_m = 3. \text{ mm}$$

$$v_m = 35.17 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -218.9 \text{ N/mm}^2$$

$$x_c = 21. \text{ mm}$$

$$y_c = 38. \text{ mm}$$

$$v_c = 20.17 \text{ mm}$$

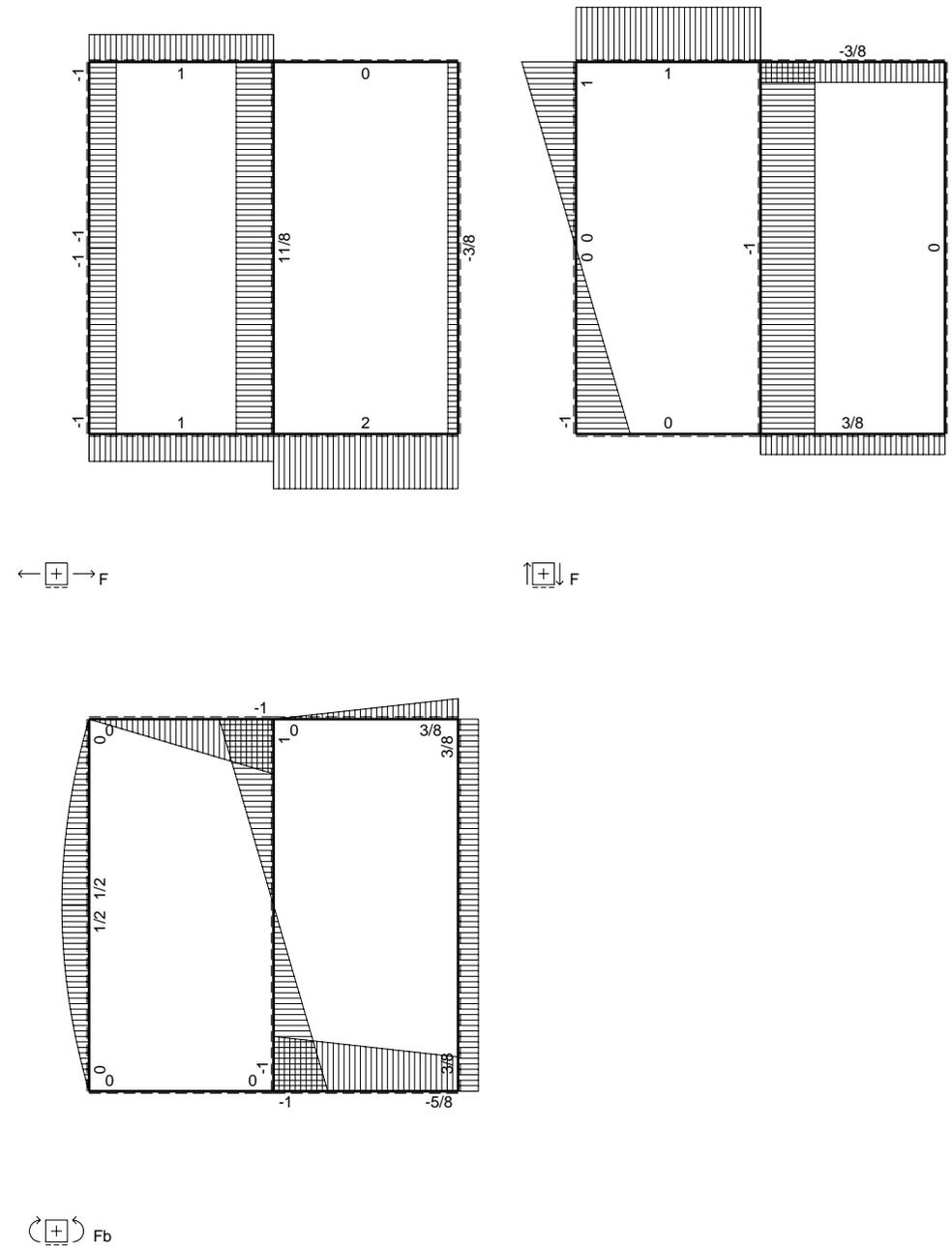
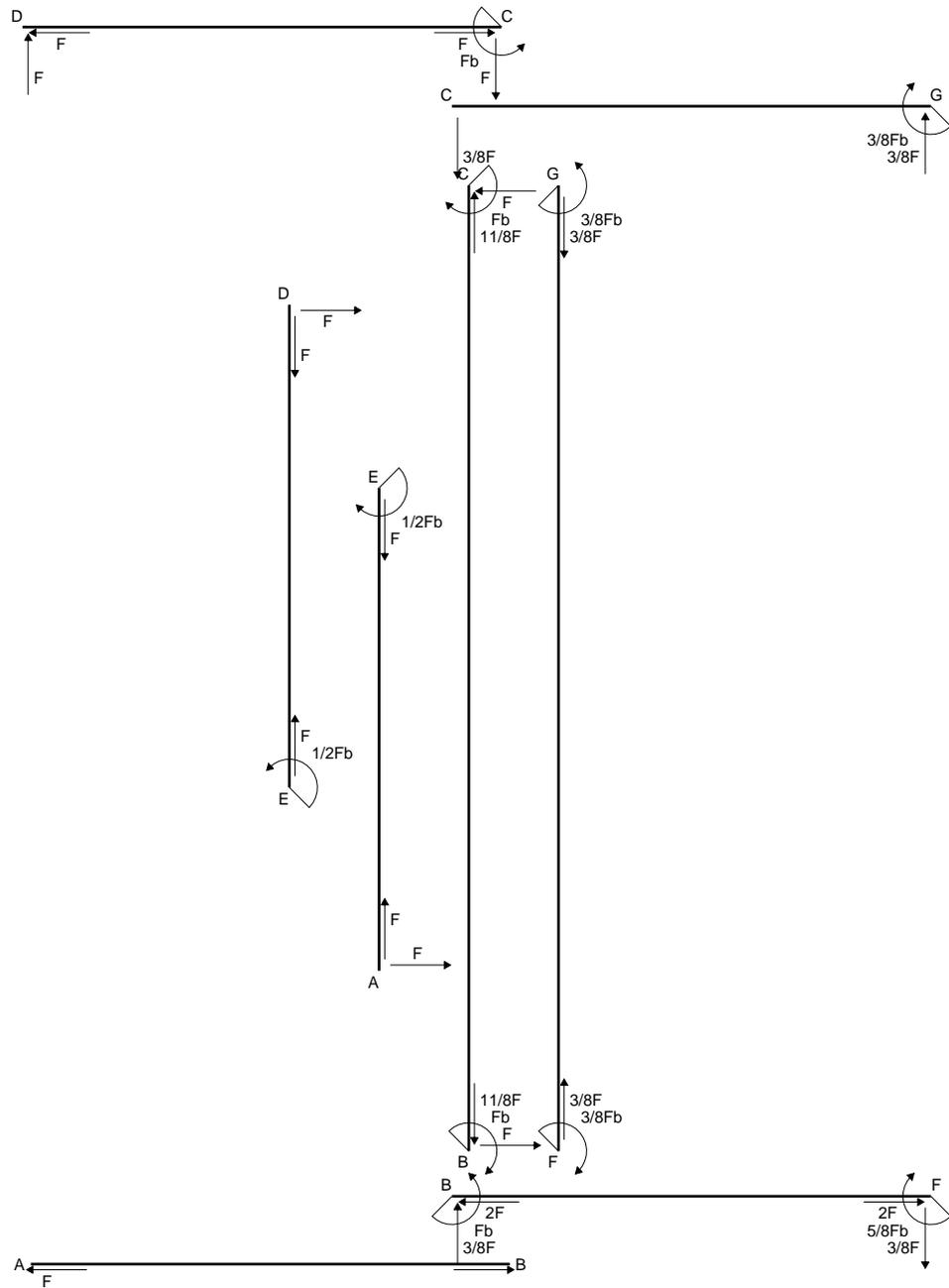
$$\sigma_c = -Mv/J_u = -125.5 \text{ N/mm}^2$$

$$\tau_c = 5.166 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 125.9 \text{ N/mm}^2$$

$$S = 2491. \text{ mm}^3$$







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

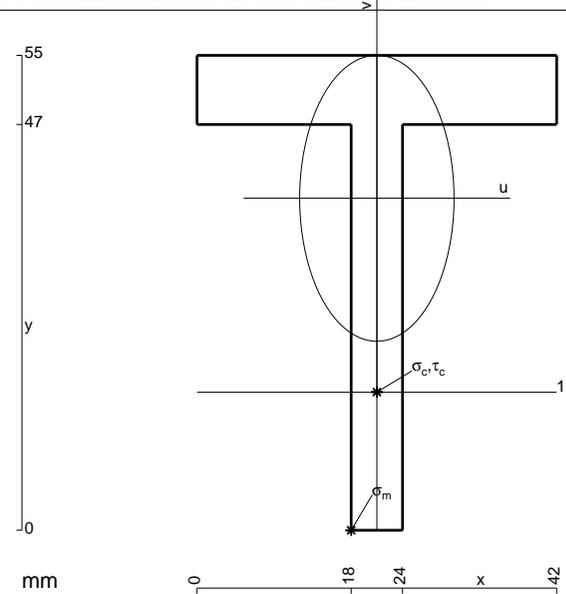
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



$$A = 618. \text{ mm}^2$$

$$J_u = 169652. \text{ mm}^4$$

$$J_v = 50238. \text{ mm}^4$$

$$y_g = 38.45 \text{ mm}$$

$$N = 2406. \text{ N}$$

$$T_y = -1750. \text{ N}$$

$$M_x = 997500. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -38.45 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 230. \text{ N/mm}^2$$

$$x_c = 21. \text{ mm}$$

$$y_c = 16. \text{ mm}$$

$$v_c = -22.45 \text{ mm}$$

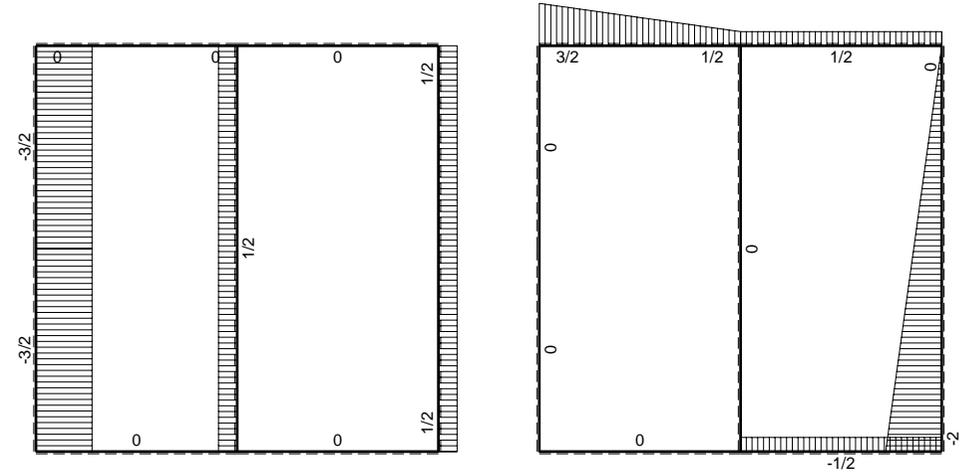
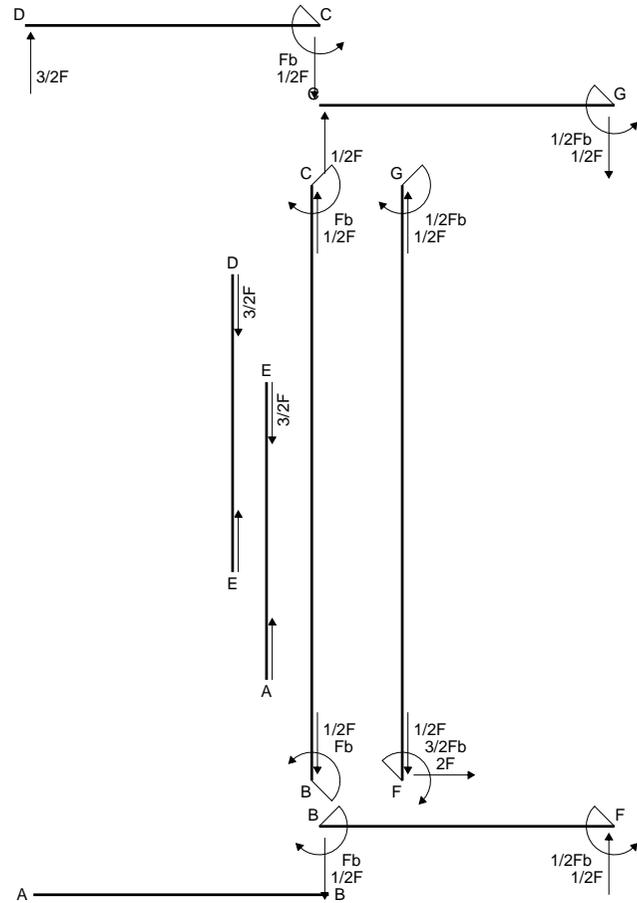
$$\sigma_c = N/A - Mv/J_u = 135.9 \text{ N/mm}^2$$

$$\tau_c = 5.026 \text{ N/mm}^2$$

$$\sigma_g = \sqrt{\sigma^2 + 3\tau^2} = 136.2 \text{ N/mm}^2$$

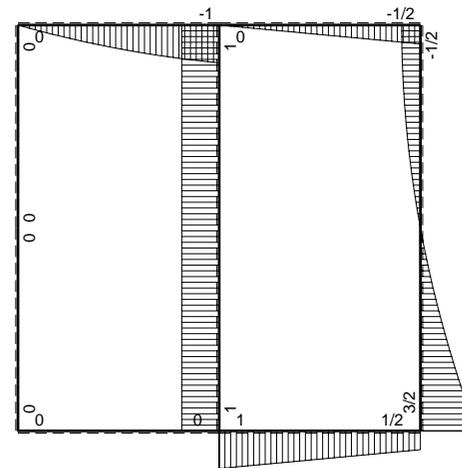
$$S = 2923. \text{ mm}^3$$



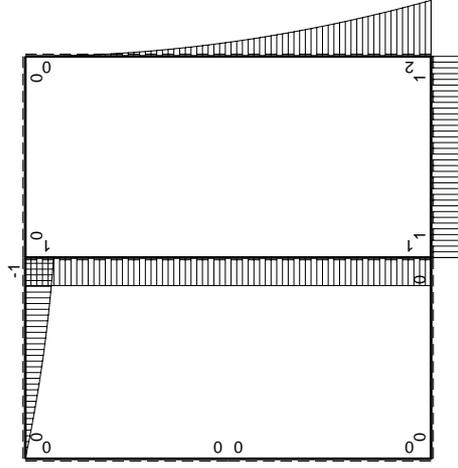
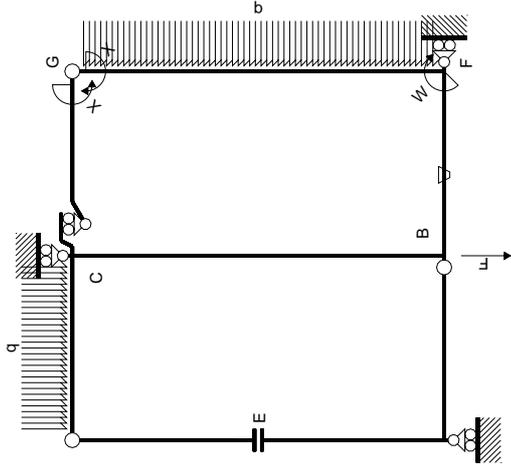


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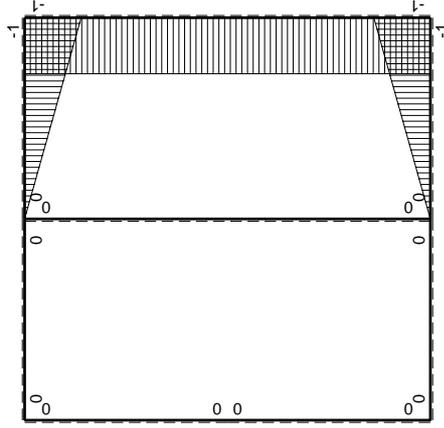
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⊕ F<sub>b</sub>



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica X=W <sup>gc</sup>		Sviluppi di calcolo iperstatica							
←	M <sup>x</sup> (x)	M <sub>0</sub> (x)	θ	M <sup>x</sup> M <sub>0</sub>	M <sup>x</sup> θ	M <sup>x</sup> M <sub>x</sub>	∫M <sup>x</sup> (M <sub>0</sub> /EJ+θ)dx	∫M <sup>x</sup> M <sub>x</sub> /EJdx	
AB b	0	0	0	0	0	0	0	0	
BA b	0	0	0	0	0	0	0	0	
CD b	-Fb+1/2Fx+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	
DE b	0	0	0	0	0	0	0	0	
ED b	0	0	0	0	0	0	0	0	
EA b	0	0	0	0	0	0	0	0	
AE b	0	0	0	0	0	0	0	0	
BF b	-x/b	Fb	-Fb/EJ	-Fx	Fx/EJ	x <sup>2</sup> /b <sup>2</sup>	(-1/2+1/2)Fb <sup>2</sup> /EJ	1/3xb/EJ	
FB b	1-x/b	-Fb	Fb/EJ	-Fb+Fx	Fb/EJ-Fx/EJ	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	(-1/2+1/2)Fb <sup>2</sup> /EJ	1/3xb/EJ	
GC b	-1+x/b	0	0	0	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	0+0	1/3xb/EJ	
CG b	x/b	0	0	0	0	x <sup>2</sup> /b <sup>2</sup>	0+0	1/3xb/EJ	
FG 2b	-1	2Fb-2Fx+1/2qx <sup>2</sup>	0	-2Fb+2Fx-1/2Fx <sup>2</sup> /b	0	1	(-4/3+0)Fb <sup>2</sup> /EJ	2xb/EJ	
GF 2b	1	-1/2qx <sup>2</sup>	0	-1/2Fx <sup>2</sup> /b	0	1	(-4/3+0)Fb <sup>2</sup> /EJ	2xb/EJ	
CB 2b	0	Fb	0	0	0	0	0+0	0	
BC 2b	0	-Fb	0	0	0	0	0+0	0	
totali								-4/3Fb <sup>2</sup> /EJ	8/3xb/EJ
								1/2Fb	

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{xo} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{xo} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

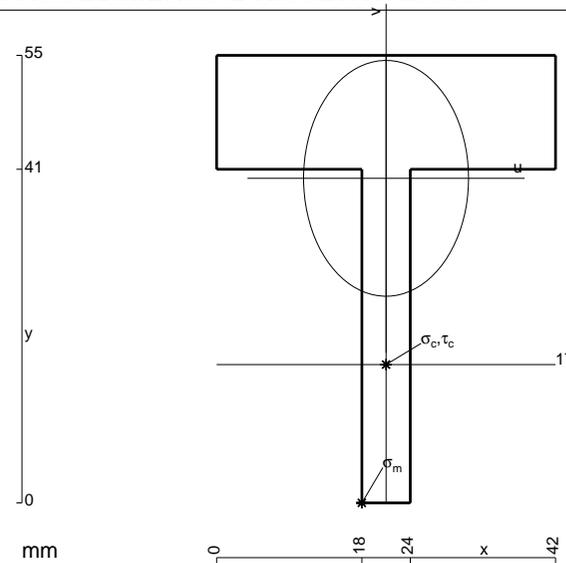
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{xo} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

$$L_{GF}^{xo} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



$$A = 834. \text{ mm}^2$$

$$J_u = 175228. \text{ mm}^4$$

$$J_v = 87174. \text{ mm}^4$$

$$y_g = 39.89 \text{ mm}$$

$$T_y = 2760. \text{ N}$$

$$M_x = -1052250. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -39.89 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -239.5 \text{ N/mm}^2$$

$$x_c = 21. \text{ mm}$$

$$y_c = 17. \text{ mm}$$

$$v_c = -22.89 \text{ mm}$$

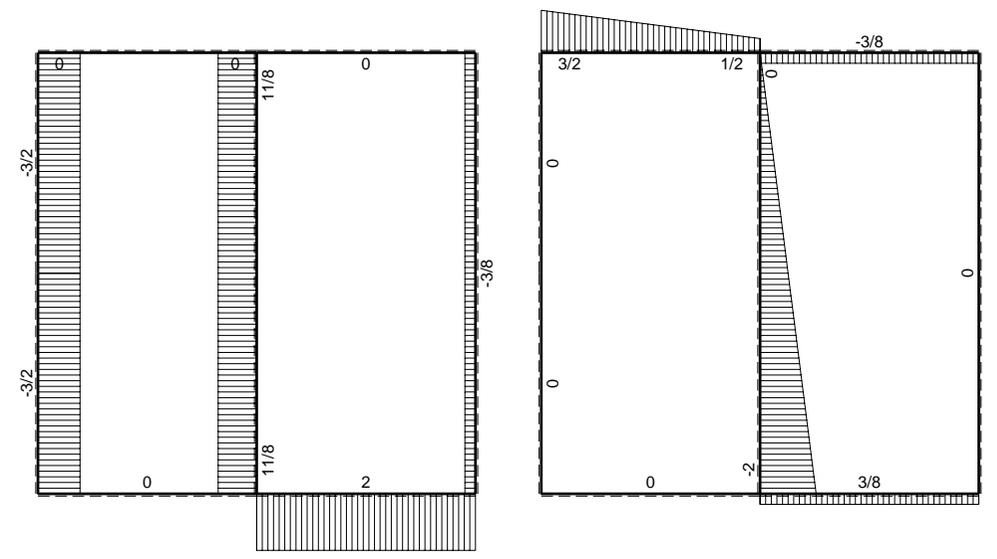
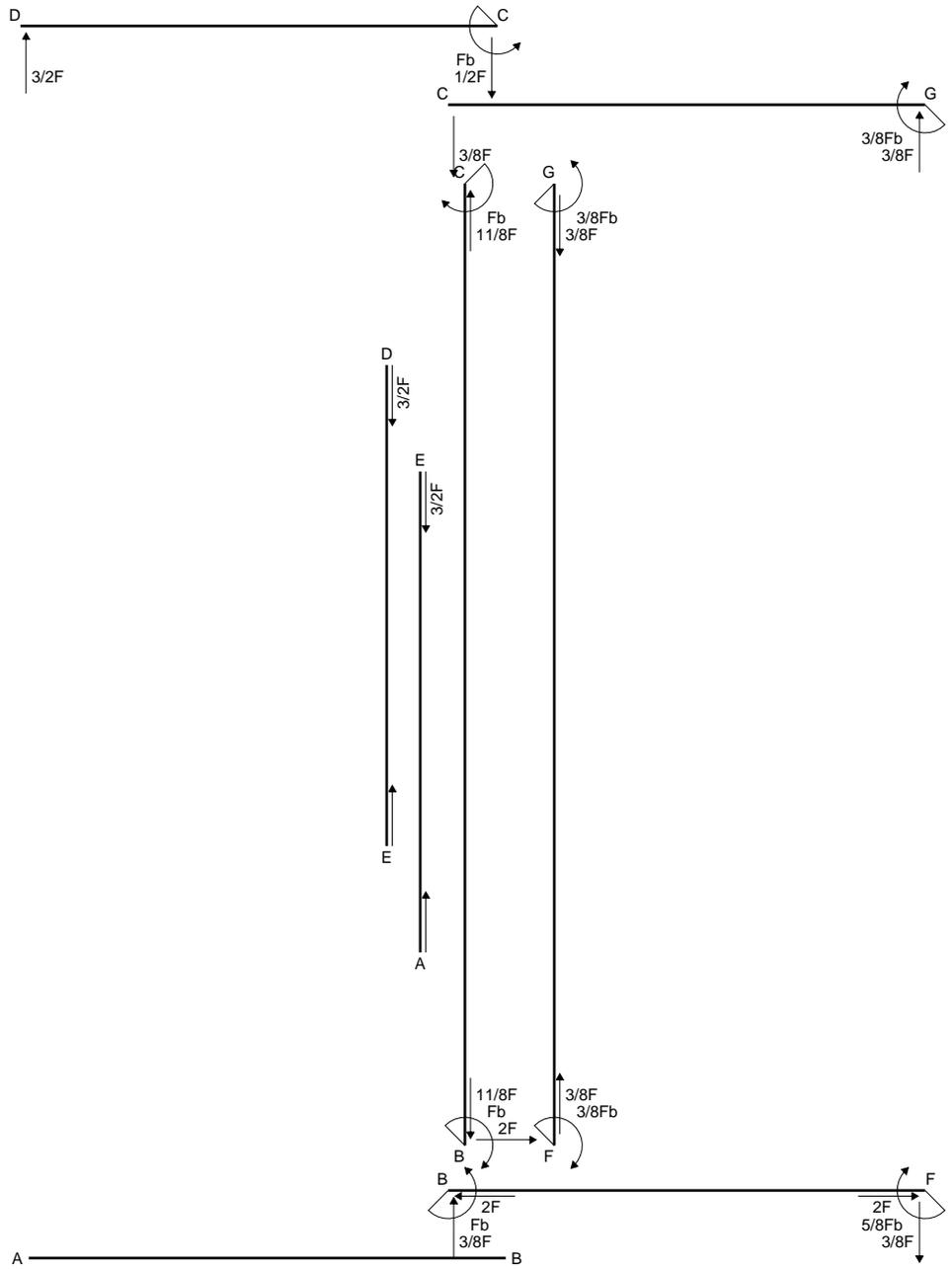
$$\sigma_c = -Mv/J_u = -137.4 \text{ N/mm}^2$$

$$\tau_c = 8.405 \text{ N/mm}^2$$

$$\sigma_o = \sqrt{\sigma^2 + 3\tau^2} = 138.2 \text{ N/mm}^2$$

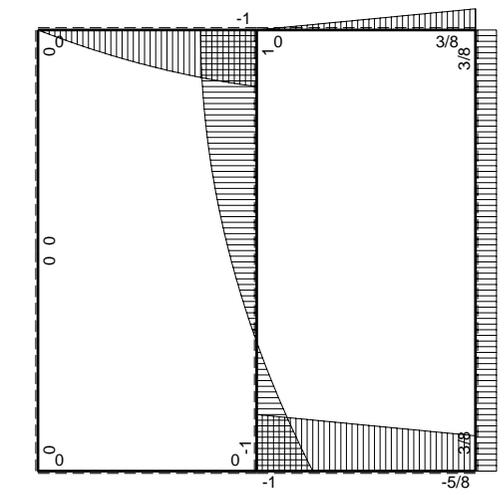
$$S = 3202. \text{ mm}^3$$



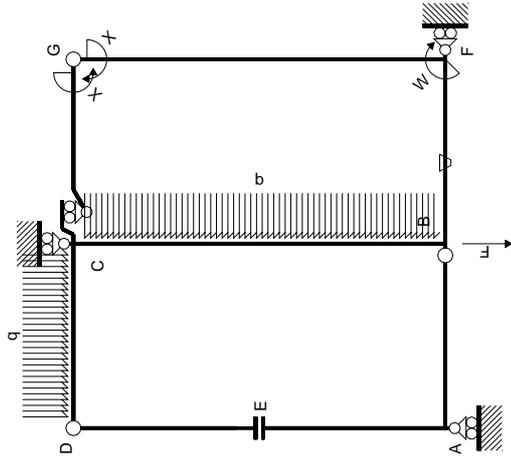


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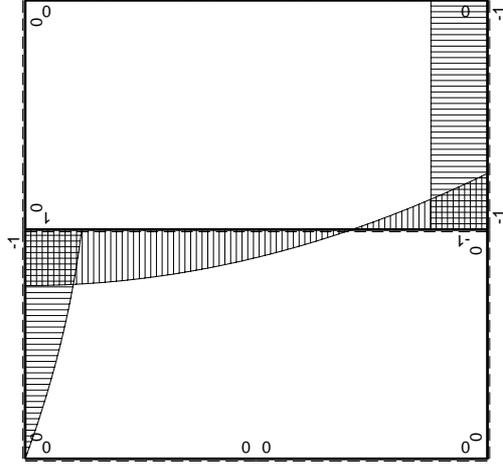
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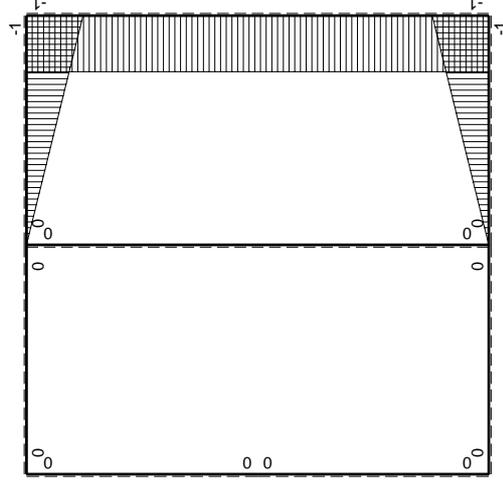
⊕ ⊖ F<sub>b</sub>



Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\leftarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJdx$
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0+0	0
CD b	0	$-b+1/2Fx+1/2qx^2$	0	0	0	0	0+0	0
DC b	0	$3/2Fx-1/2qx^2$	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
ED b	0	0	0	0	0	0	0+0	0
EA b	0	0	0	0	0	0	0+0	0
AE b	0	0	0	0	0	0	0+0	0
BF b	-x/b	-Fb	-Fb/EJ	Fx	Fx/EJ	$x^2/b^2$	$(1/2+1/2)Fb^2/EJ$	$1/3xb^2/EJ$
FBB b	1-x/b	Fb	Fb/EJ	Fb-Fx	Fb/EJ-Fx/EJ	$1-2x/b+x^2/b^2$	$1/2+1/2)Fb^2/EJ$	$1/3xb^2/EJ$
GCB b	-1+x/b	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb^2/EJ$
CG b	x/b	0	0	0	0	$x^2/b^2$	0+0	$1/3xb^2/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2xb^2/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2xb^2/EJ$
CB 2b	0	$Fb-1/2qx^2$	0	0	0	0	0+0	0
BC 2b	0	$Fb-2Fx+1/2qx^2$	0	0	0	0	0+0	0
totali								$8/3xb^2/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

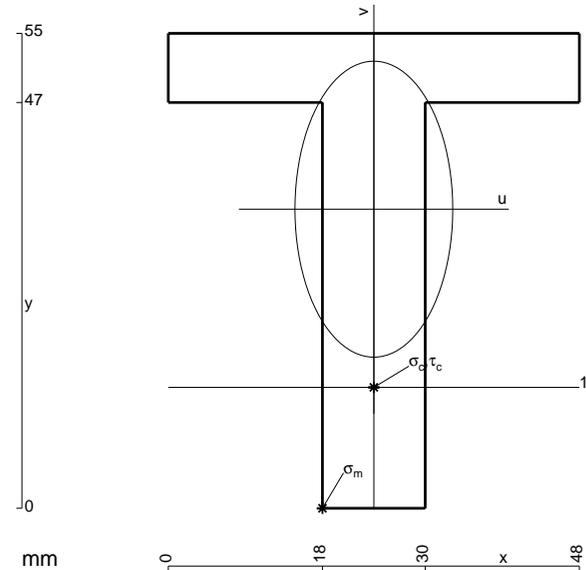
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



$$A = 948. \text{ mm}^2$$

$$J_u = 278641. \text{ mm}^4$$

$$J_v = 80496. \text{ mm}^4$$

$$y_g = 34.64 \text{ mm}$$

$$N = 3410. \text{ N}$$

$$T_y = -4960. \text{ Nmm}$$

$$M_x = -1636800. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$u_m = -6. \text{ mm}$$

$$v_m = -34.64 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -199.9 \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 14. \text{ mm}$$

$$v_c = -20.64 \text{ mm}$$

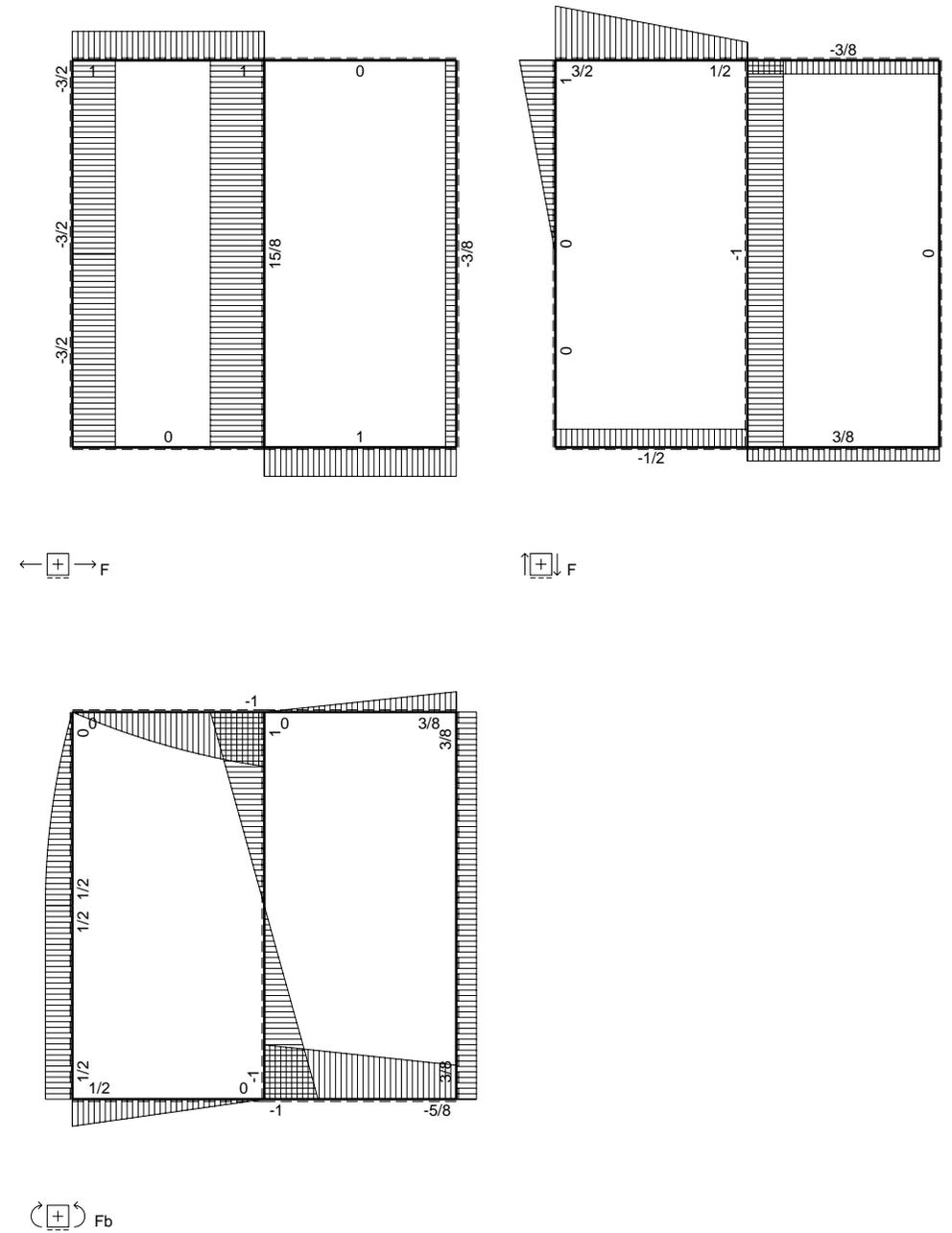
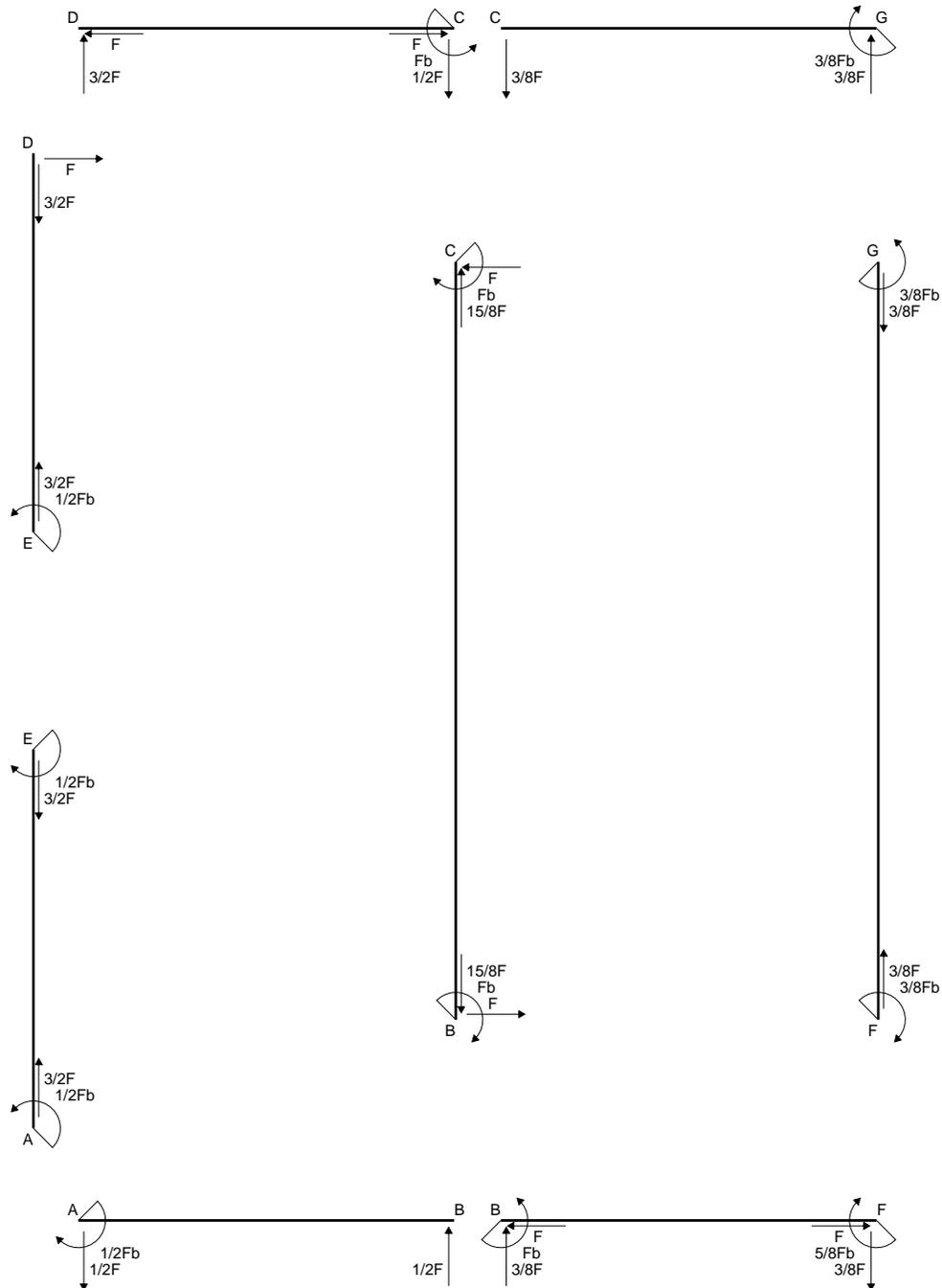
$$\sigma_c = N/A - Mv/J_u = -117.6 \text{ N/mm}^2$$

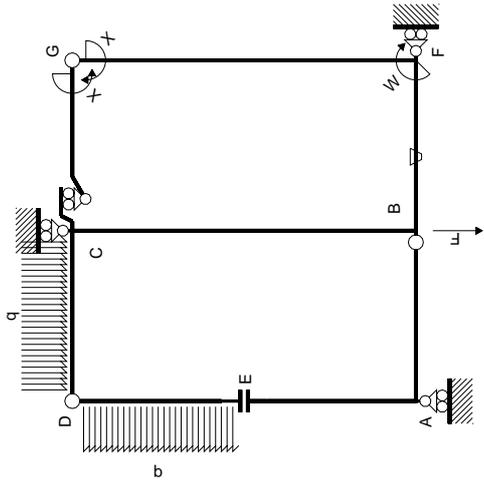
$$\tau_c = 6.888 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 118.2 \text{ N/mm}^2$$

$$S = 4643. \text{ mm}^3$$

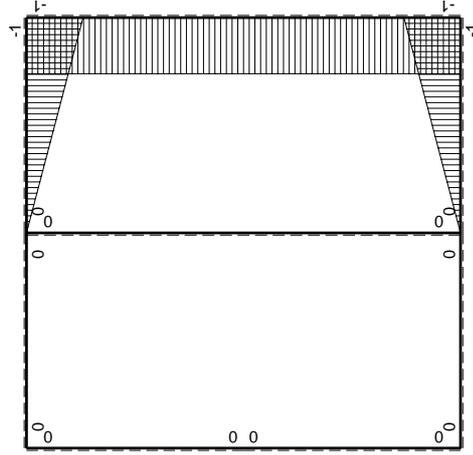
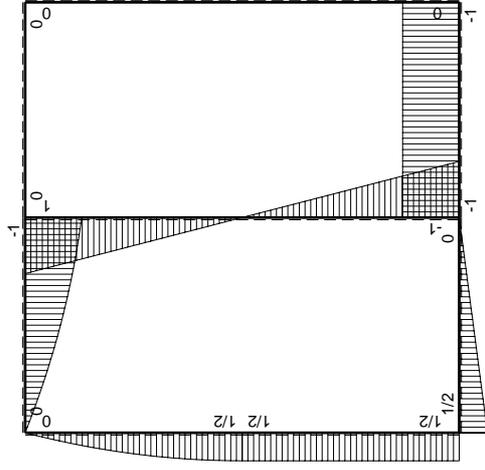






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\leftarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$	
AB b	0	$1/2Fb-1/2Fx$	0	0	0	0	0+0	0	
BA b	0	$-1/2Fx$	0	0	0	0	0+0	0	
CD b	0	$-Fb+1/2Fx+1/2qx^2$	0	0	0	0	0+0	0	
DC b	0	$3/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
DE b	0	$Fx-1/2qx^2$	0	0	0	0	0+0	0	
ED b	0	$-1/2Fb+1/2qx^2$	0	0	0	0	0+0	0	
EA b	0	$1/2Fb$	0	0	0	0	0+0	0	
AE b	0	$-1/2Fb$	0	0	0	0	0+0	0	
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$	
FBB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb-Fx$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$1/3xb/EJ$	$1/3xb/EJ$	
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$	
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$	
FG 2b	-1	0	0	0	0	1	0+0	$2xb/EJ$	
GF 2b	1	0	0	0	0	1	0+0	$2xb/EJ$	
CB 2b	0	$Fb-Fx$	0	0	0	0	0+0	0	
BC 2b	0	$Fb-Fx$	0	0	0	0	0+0	0	
totali									
		iperstatica $X=W_{gc}$							
								$8/3xb/EJ$	
								$-3/8Fb$	

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

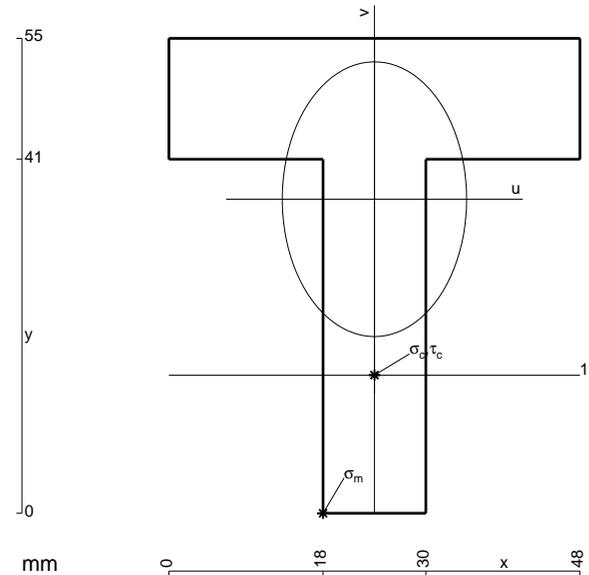
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



$$A = 1164. \text{ mm}^2$$

$$J_u = 294703. \text{ mm}^4$$

$$J_v = 134928. \text{ mm}^4$$

$$y_g = 36.38 \text{ mm}$$

$$N = 4463. \text{ N}$$

$$T_y = -2380. \text{ N}$$

$$M_x = 1666000. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$u_m = -6. \text{ mm}$$

$$v_m = -36.38 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 209.5 \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 16. \text{ mm}$$

$$v_c = -20.38 \text{ mm}$$

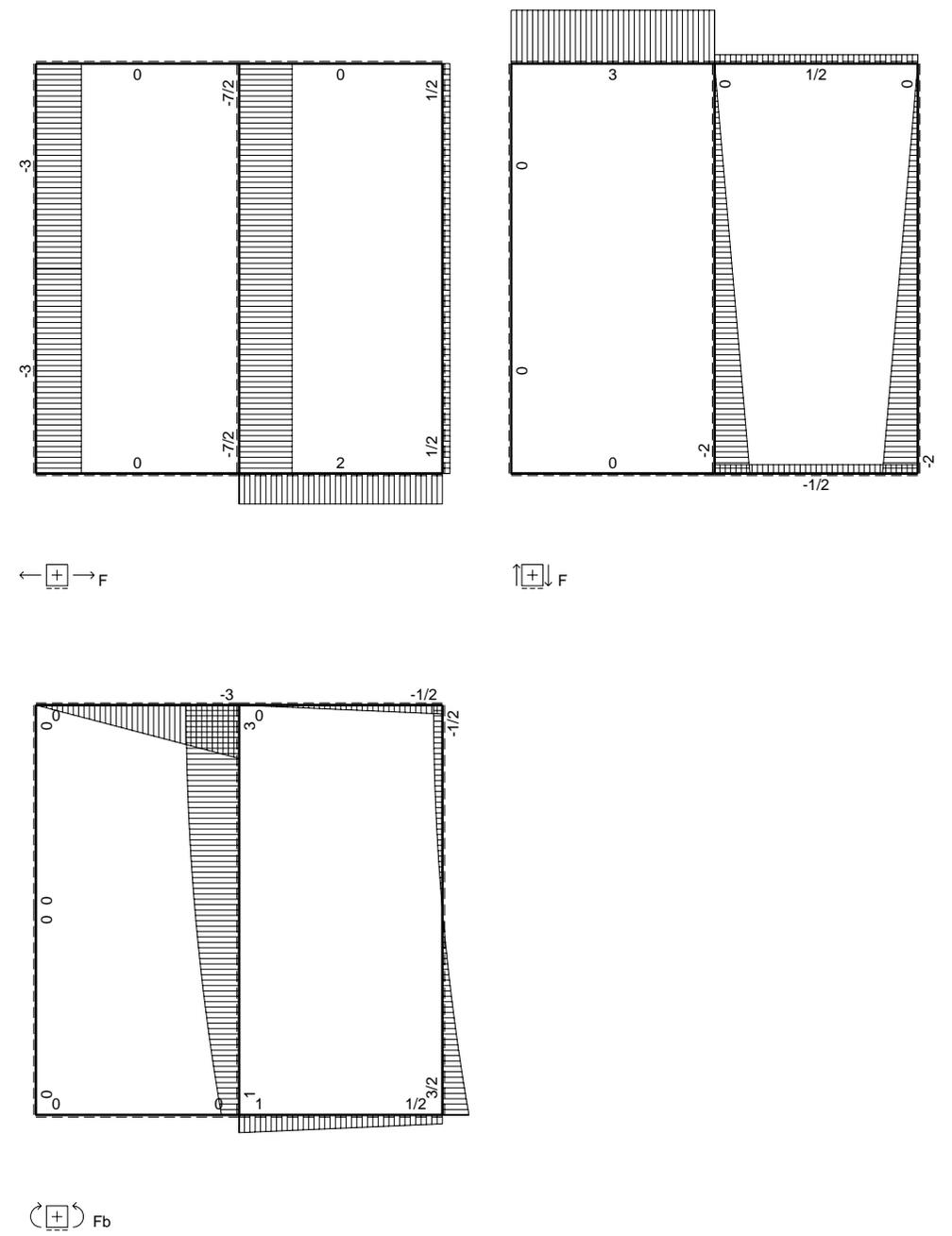
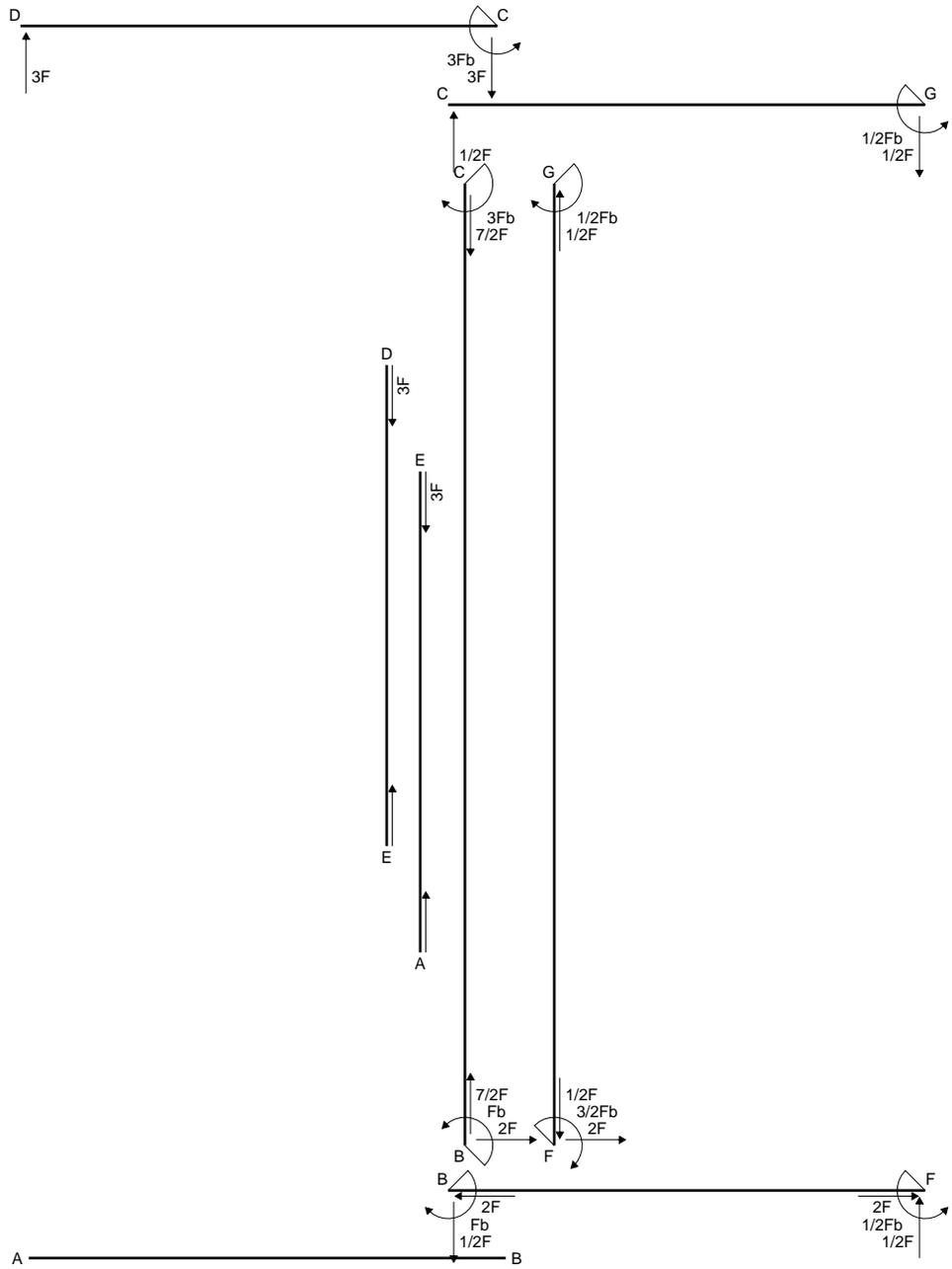
$$\sigma_c = N/A - Mv/J_u = 119. \text{ N/mm}^2$$

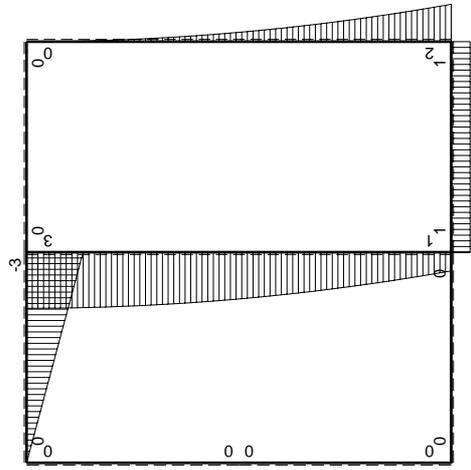
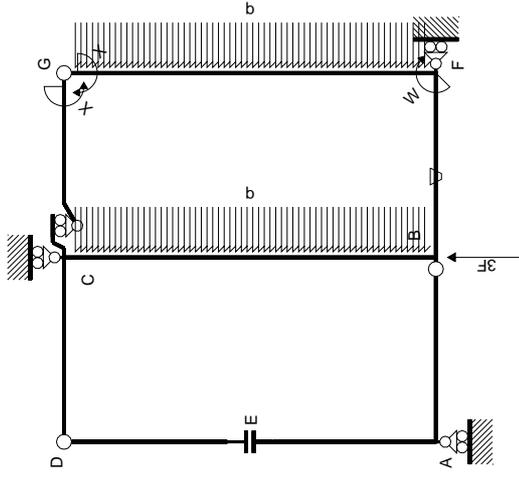
$$\tau_c = 3.667 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 119.2 \text{ N/mm}^2$$

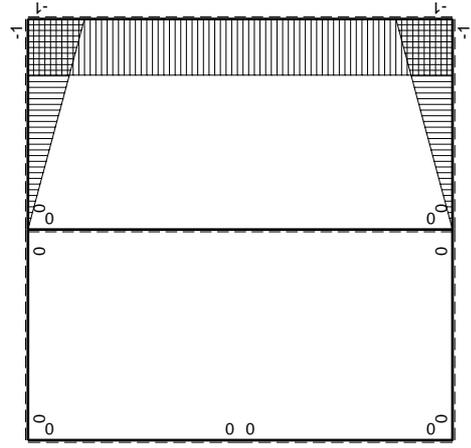
$$S = 5448. \text{ mm}^3$$







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

←	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x (M_0/EJ + \theta) dx$	$\int M^x M_x / EJ dx$	iperstatica X=W <sub>gc</sub>	
									totali	
AB b	0	0	0	0	0	0	0	0	0	0
BA b	0	0	0	0	0	0	0	0	0	0
CD b	0	-3Fb+3Fx	0	0	0	0	0	0	0	0
DC b	0	3Fx	0	0	0	0	0	0	0	0
DE b	0	0	0	0	0	0	0	0	0	0
ED b	0	0	0	0	0	0	0	0	0	0
EA b	0	0	0	0	0	0	0	0	0	0
AE b	0	0	0	0	0	0	0	0	0	0
BF b	-x/b	Fb	-Fb/EJ	-Fx	Fx/EJ	$x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	1/3xb/EJ	1/3xb/EJ	1/2Fb
FB b	1-x/b	-Fb	Fb/EJ	-Fb+Fx	Fb/EJ-Fx/EJ	$1-2x/b+x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	1/3xb/EJ	1/3xb/EJ	1/2Fb
GC b	-1+x/b	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	1/3xb/EJ	1/3xb/EJ	1/2Fb
CG b	x/b	0	0	0	0	$x^2/b^2$	0+0	1/3xb/EJ	1/3xb/EJ	1/2Fb
FG 2b	-1	$2Fb-2Fx+1/2qx^2$	0	$-2Fb+2Fx-1/2Fx^2/b$	0	1	$(-4/3+0)Fb^2/EJ$	2xb/EJ	2xb/EJ	1/2Fb
GF 2b	1	$-1/2qx^2$	0	$-1/2Fx^2/b$	0	1	$(-4/3+0)Fb^2/EJ$	2xb/EJ	2xb/EJ	1/2Fb
CB 2b	0	$3Fb-1/2qx^2$	0	0	0	0	0+0	8/3xb/EJ	8/3xb/EJ	1/2Fb
BC 2b	0	$-Fb-2Fx+1/2qx^2$	0	0	0	0	0+0	8/3xb/EJ	8/3xb/EJ	1/2Fb
totali										

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{xo} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{xo} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

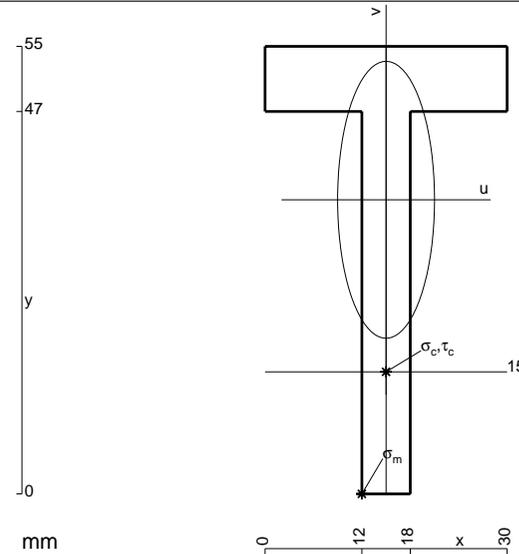
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{xo} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

$$L_{GF}^{xo} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



$$A = 522. \text{ mm}^2$$

$$J_u = 151243. \text{ mm}^4$$

$$J_v = 18846. \text{ mm}^4$$

$$y_g = 36.14 \text{ mm}$$

$$T_y = 1230. \text{ N}$$

$$M_x = -910200. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -36.14 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -217.5 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 15. \text{ mm}$$

$$v_c = -21.14 \text{ mm}$$

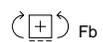
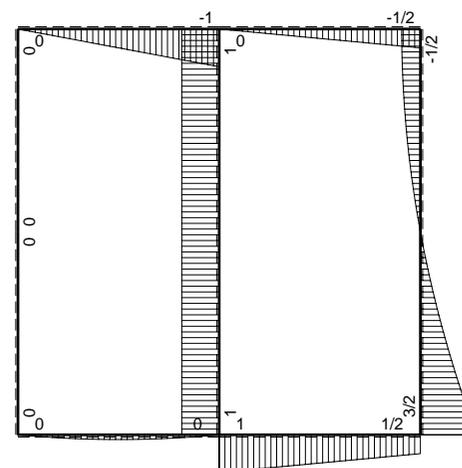
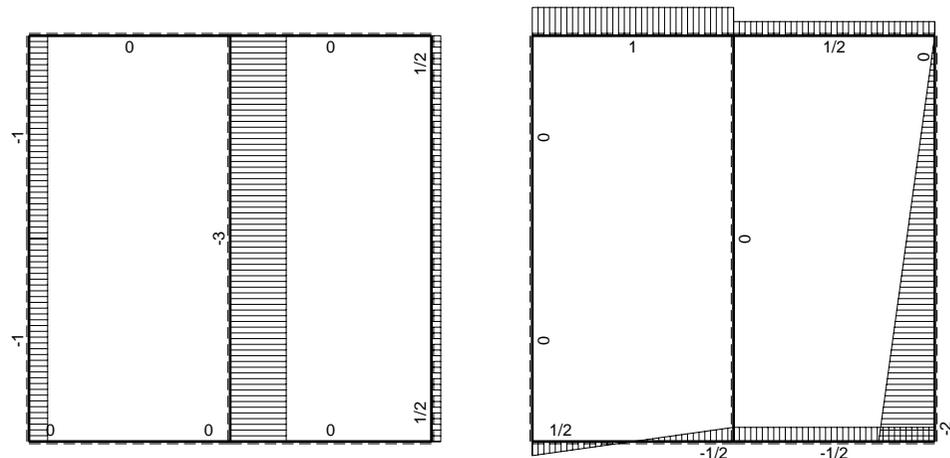
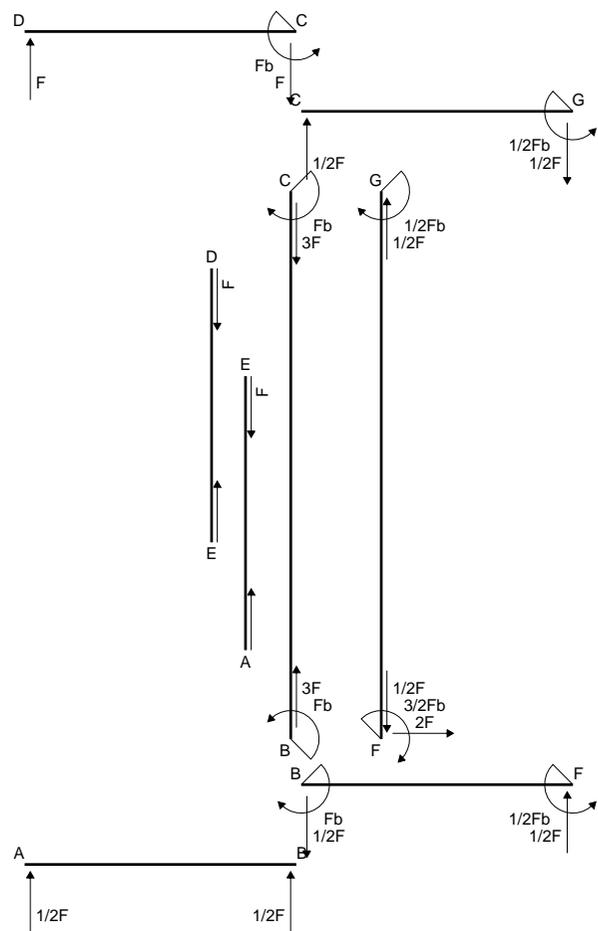
$$\sigma_c = -Mv/J_u = -127.2 \text{ N/mm}^2$$

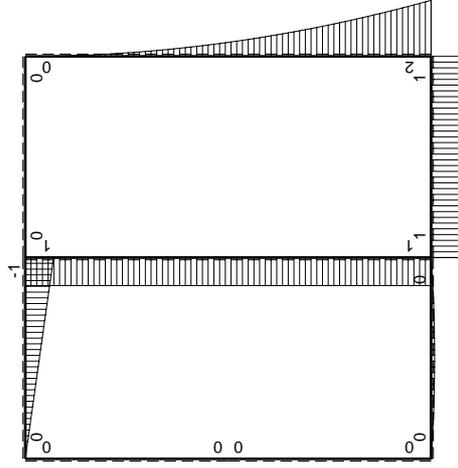
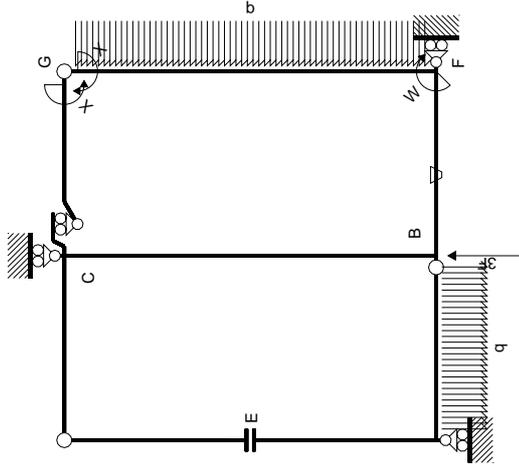
$$\tau_c = 3.494 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 127.4 \text{ N/mm}^2$$

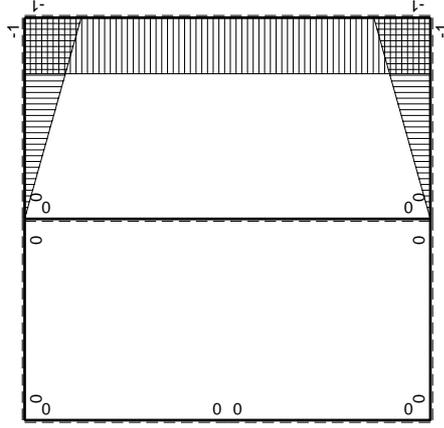
$$S = 2578. \text{ mm}^3$$







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica X=W <sub>gc</sub>		iperstatica X=W <sub>gc</sub>						
←	M <sup>0</sup> (x)	M <sup>0</sup> (x)	θ	M <sup>x</sup> M <sub>0</sub>	M <sup>x</sup> θ	M <sup>x</sup> M <sub>x</sub>	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJdx$
AB b	0	1/2Fx-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
BA b	0	-1/2Fx+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
CD b	0	-b+Fx	0	0	0	0	0+0	0
DC b	0	Fx	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
ED b	0	0	0	0	0	0	0+0	0
EA b	0	0	0	0	0	0	0+0	0
AE b	0	0	0	0	0	0	0+0	0
BF b	-x/b	Fb	-Fb/EJ	-Fx	Fx/EJ	x <sup>2</sup> /b <sup>2</sup>	$(-1/2+1/2)Fb^2/EJ$	1/3xb/EJ
FB b	1-x/b	-Fb	Fb/EJ	-Fb+Fx	Fb/EJ-Fx/EJ	$1-2x/b+x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	1/3xb/EJ
GC b	-1+x/b	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	1/3xb/EJ
CG b	x/b	0	0	0	0	x <sup>2</sup> /b <sup>2</sup>	0+0	1/3xb/EJ
FG 2b	-1	2Fb-2Fx+1/2qx <sup>2</sup>	0	-2Fb+2Fx-1/2Fx <sup>2</sup> /b	0	1	$(-4/3+0)Fb^2/EJ$	2xb/EJ
GF 2b	1	-1/2qx <sup>2</sup>	0	-1/2Fx <sup>2</sup> /b	0	1	$(-4/3+0)Fb^2/EJ$	2xb/EJ
CB 2b	0	Fb	0	0	0	0	0+0	0
BC 2b	0	-Fb	0	0	0	0	0+0	0
totali							-4/3Fb <sup>2</sup> /EJ	8/3xb/EJ

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{xo} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{xo} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

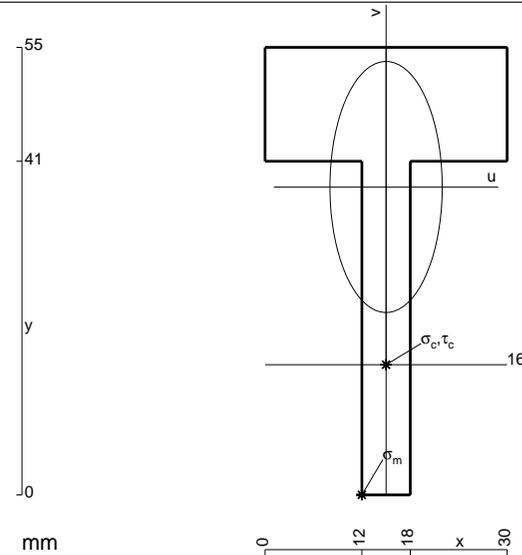
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{xo} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

$$L_{GF}^{xo} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



$$A = 666. \text{ mm}^2$$

$$J_u = 158641. \text{ mm}^4$$

$$J_v = 32238. \text{ mm}^4$$

$$y_g = 37.84 \text{ mm}$$

$$T_y = 1220. \text{ N}$$

$$M_x = -963800. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -37.84 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -229.9 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 16. \text{ mm}$$

$$v_c = -21.84 \text{ mm}$$

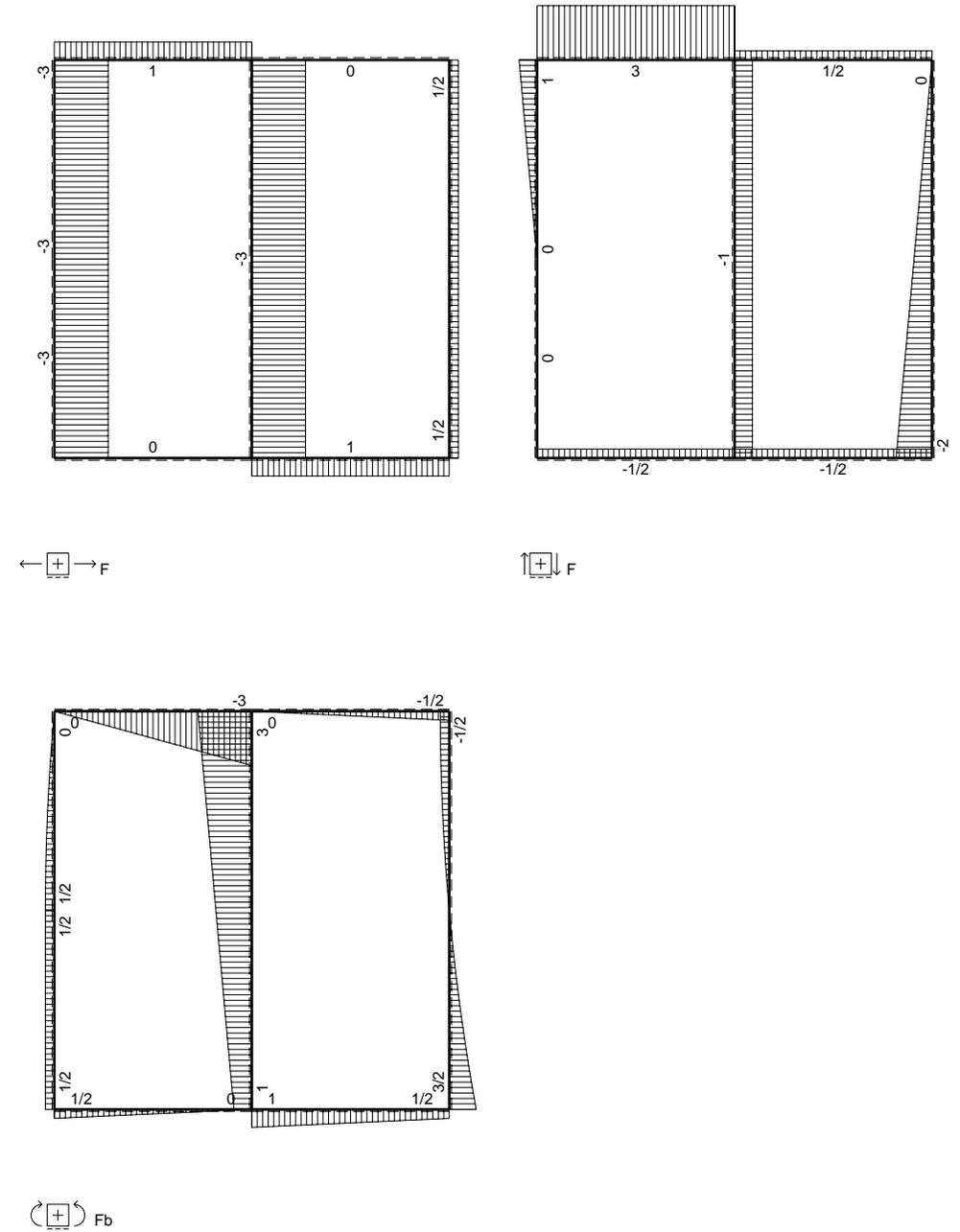
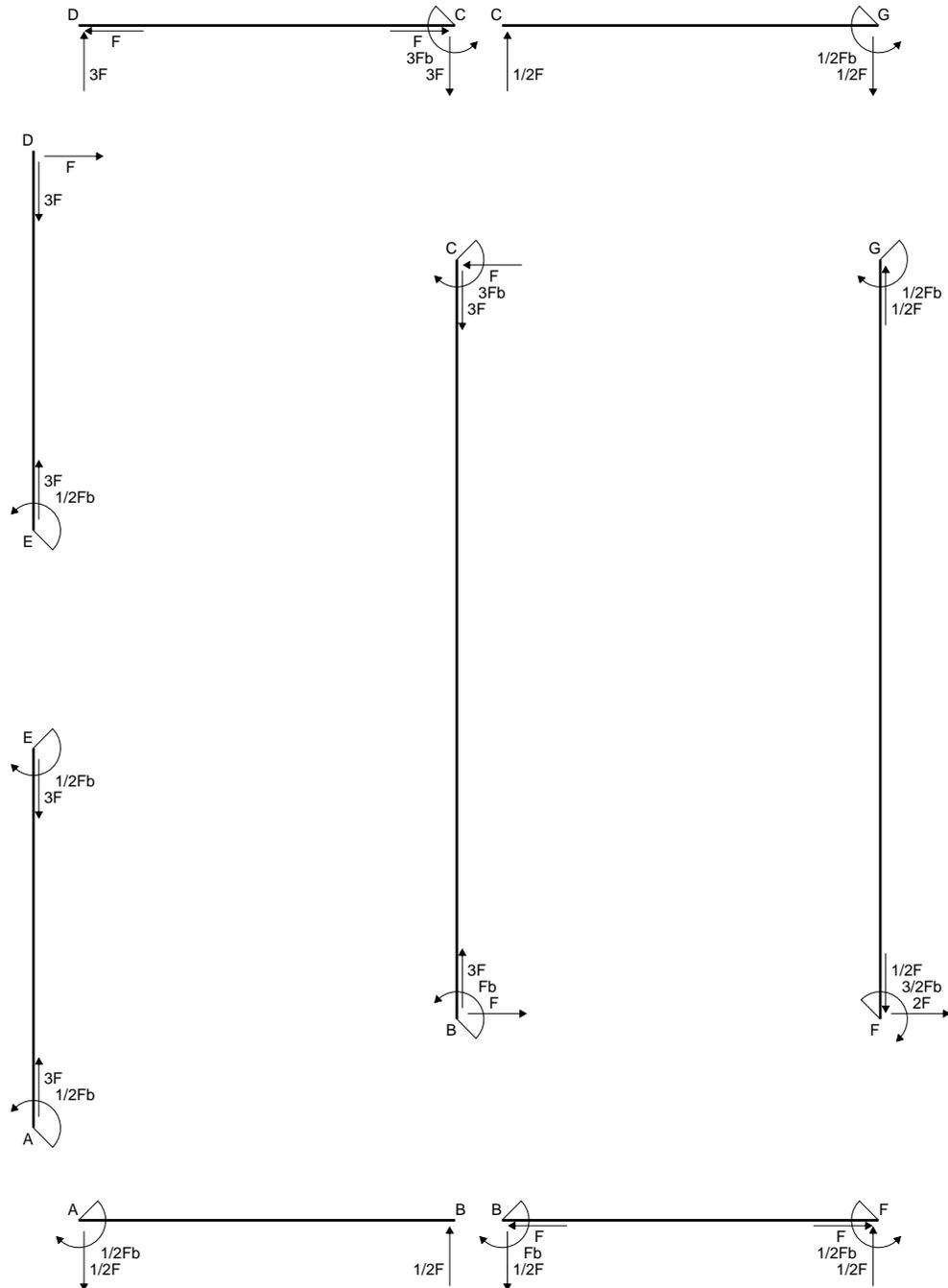
$$\sigma_c = -Mv/J_u = -132.7 \text{ N/mm}^2$$

$$\tau_c = 3.672 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 132.9 \text{ N/mm}^2$$

$$S = 2865. \text{ mm}^3$$







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{xo} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{xo} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

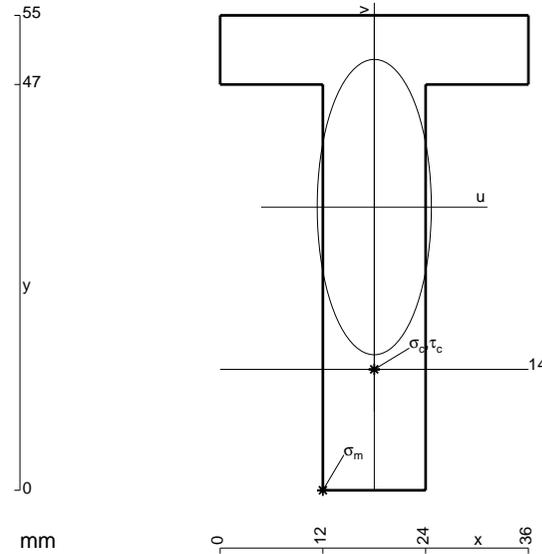
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{xo} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

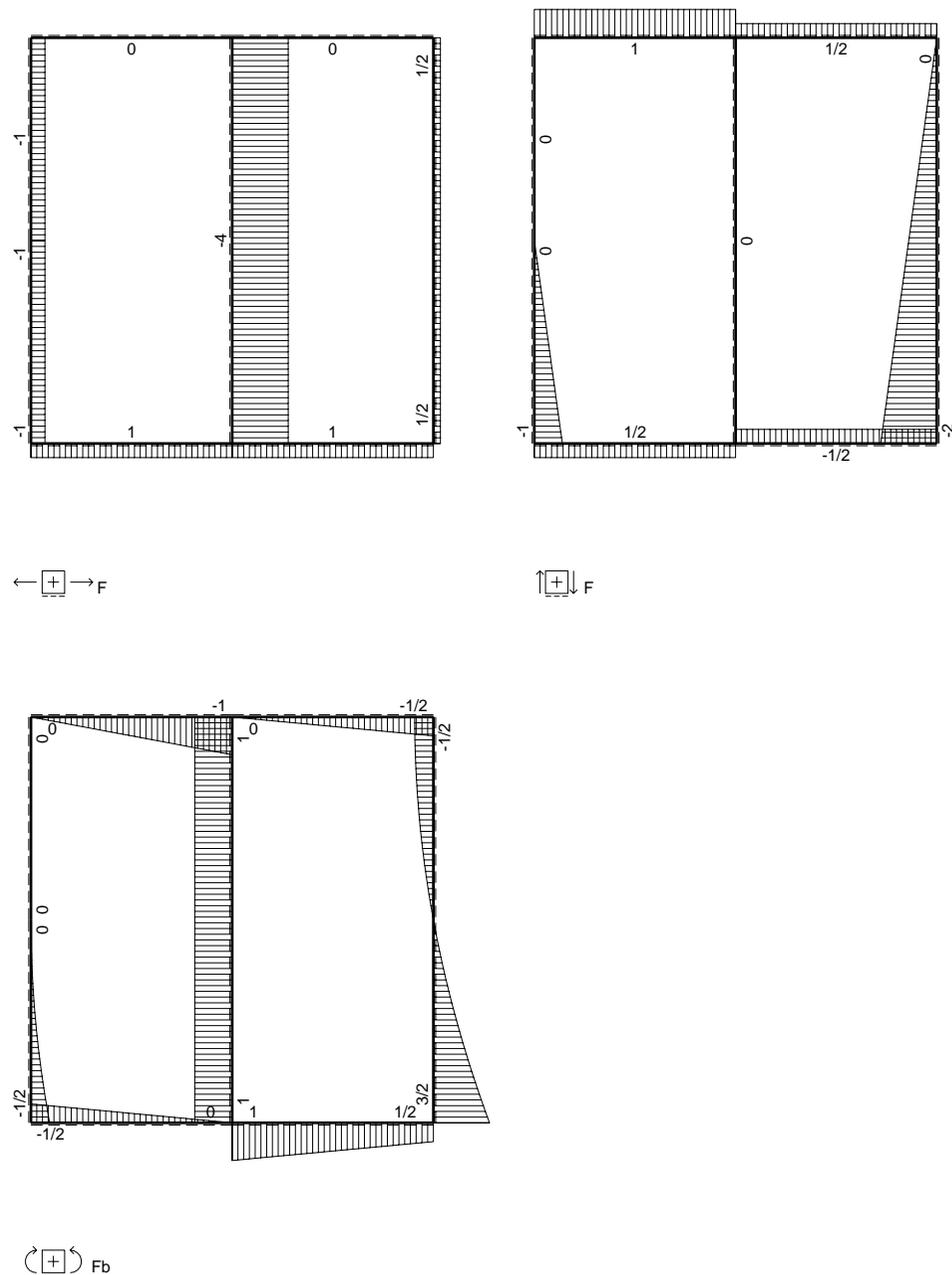
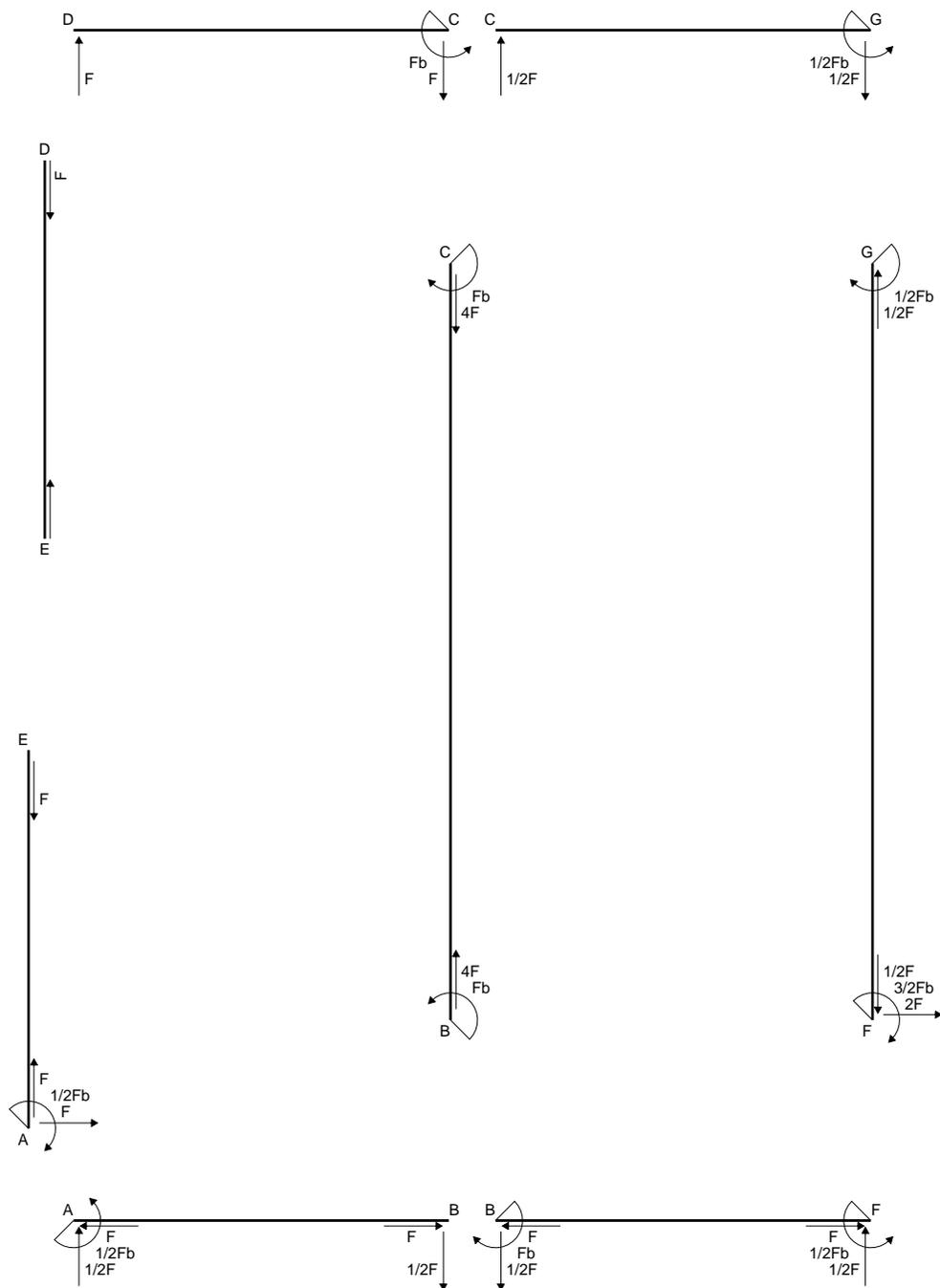
$$L_{GF}^{xo} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

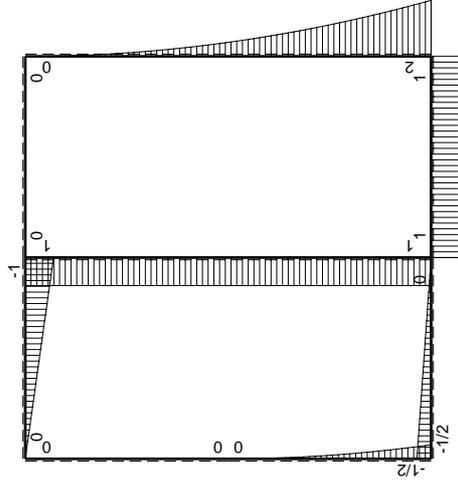
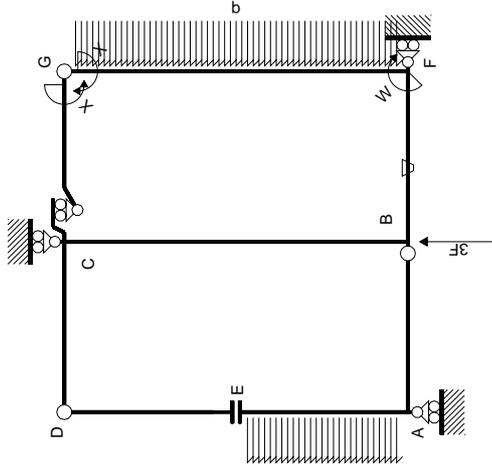
$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



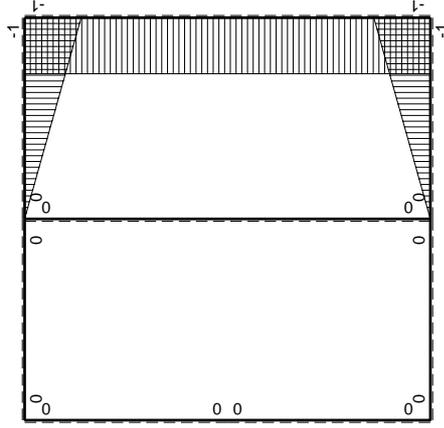
- A = 852. mm<sup>2</sup>
- J<sub>u</sub> = 249536. mm<sup>4</sup>
- J<sub>v</sub> = 37872. mm<sup>4</sup>
- y<sub>g</sub> = 32.8 mm
- N = 730. N
- T<sub>y</sub> = 2190. N
- M<sub>x</sub> = -1817700. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -32.8 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = -238. N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 14. mm
- v<sub>c</sub> = -18.8 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = -136.1 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.169 N/mm<sup>2</sup>
- σ<sub>g</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 136.2 N/mm<sup>2</sup>
- S<sup>i</sup> = 4334. mm<sup>3</sup>







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\leftarrow$	$M(x)$	$M^0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / E dx$
AB b	0	$-1/2Fb + 1/2Fx$	0	0	0	0	0+0	0
BA b	0	$1/2Fx$	0	0	0	0	0+0	0
CD b	0	$-Fb + Fx$	0	0	0	0	0+0	0
DC b	0	$Fx$	0	0	0	0	0+0	0
ED b	0	0	0	0	0	0	0+0	0
EA b	0	$-1/2qx^2$	0	0	0	0	0+0	0
AE b	0	$1/2Fb - Fx + 1/2qx^2$	0	0	0	0	0+0	0
BF b	$-x/b$	$Fb$	$-Fb/EJ$	$-Fx$	$Fx/EJ$	$x^2/b^2$	$(-1/2 + 1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$-Fb$	$Fb/EJ$	$-Fb + Fx$	$Fb/EJ - Fx/EJ$	$1-2x/b + x^2/b^2$	$(-1/2 + 1/2)Fb^2/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b + x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	$2Fb - 2Fx + 1/2qx^2$	0	$-2Fb + 2Fx - 1/2Fx^2/b$	0	1	$(-4/3 + 0)Fb^2/EJ$	$2xb/EJ$
GF 2b	1	$-1/2qx^2$	0	$-1/2Fx^2/b$	0	1	$(-4/3 + 0)Fb^2/EJ$	$2xb/EJ$
CB 2b	0	$Fb$	0	0	0	0	0+0	0
BC 2b	0	$-Fb$	0	0	0	0	0+0	0
totali							$-4/3Fb^2/EJ$	$8/3xb/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x\theta} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x\theta} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

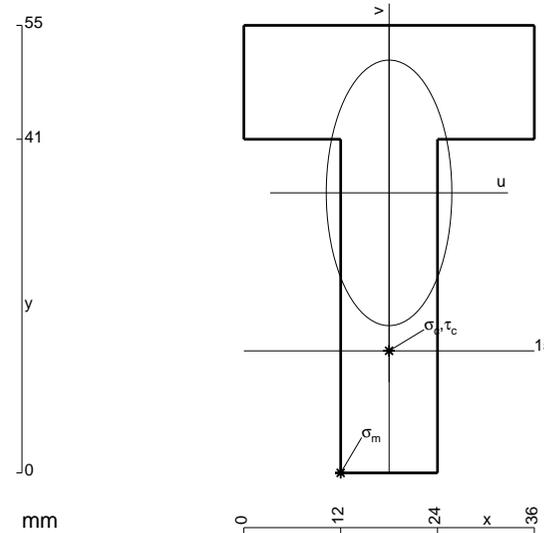
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x\theta} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

$$L_{GF}^{x\theta} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



$$A = 996. \text{ mm}^2$$

$$J_u = 265432. \text{ mm}^4$$

$$J_v = 60336. \text{ mm}^4$$

$$y_g = 34.42 \text{ mm}$$

$$T_y = 3500. \text{ N}$$

$$M_x = -1540000. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -6. \text{ mm}$$

$$v_m = -34.42 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -199.7 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 15. \text{ mm}$$

$$v_c = -19.42 \text{ mm}$$

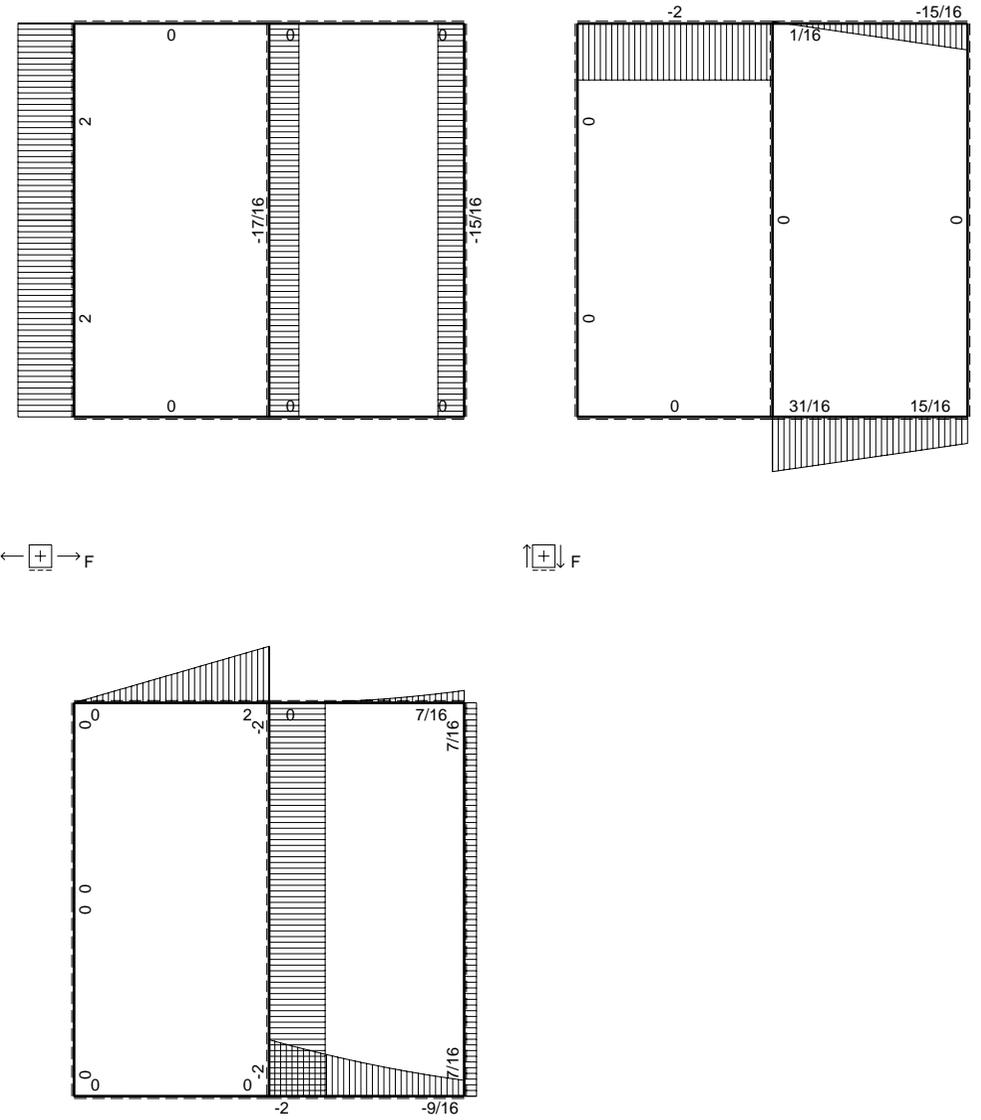
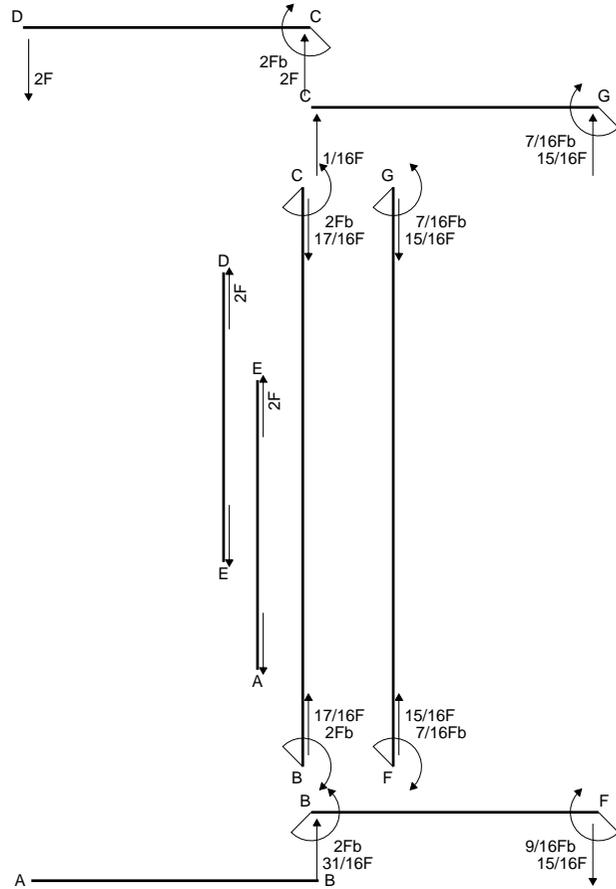
$$\sigma_c = -Mv/J_u = -112.6 \text{ N/mm}^2$$

$$\tau_c = 5.324 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 113. \text{ N/mm}^2$$

$$S = 4845. \text{ mm}^3$$







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x\theta} = \int_0^b (2x/b - 3/2 x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

$$= [x^2/b - 1/2 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b + 1/8 b) Fb 1/EJ + (1/2 b) \theta = 9/8 Fb^2/EJ$$

$$L_{FB}^{x\theta} = \int_0^b (1 - 1/2 x/b - 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [x - 1/4 x^2/b - 1/8 x^4/b^3]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

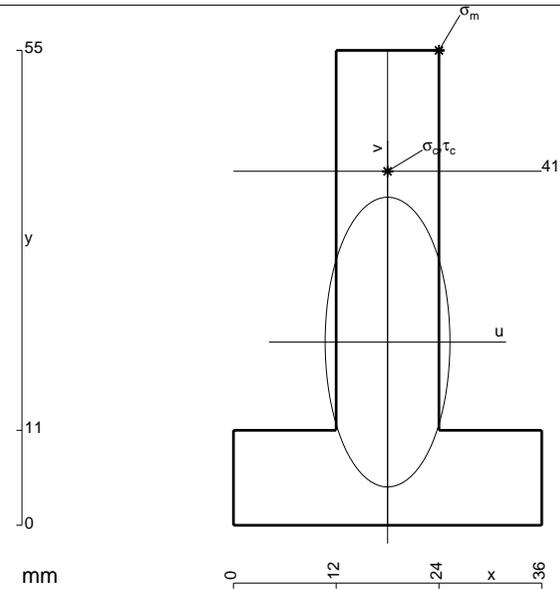
$$= (b - 1/4 b - 1/8 b) Fb 1/EJ + (-b + 1/2 b) \theta = 9/8 Fb^2/EJ$$

$$L_{GC}^{x\theta} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

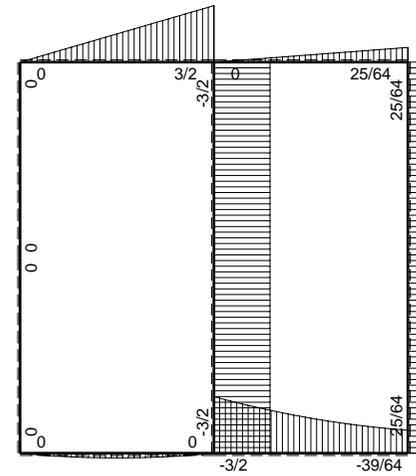
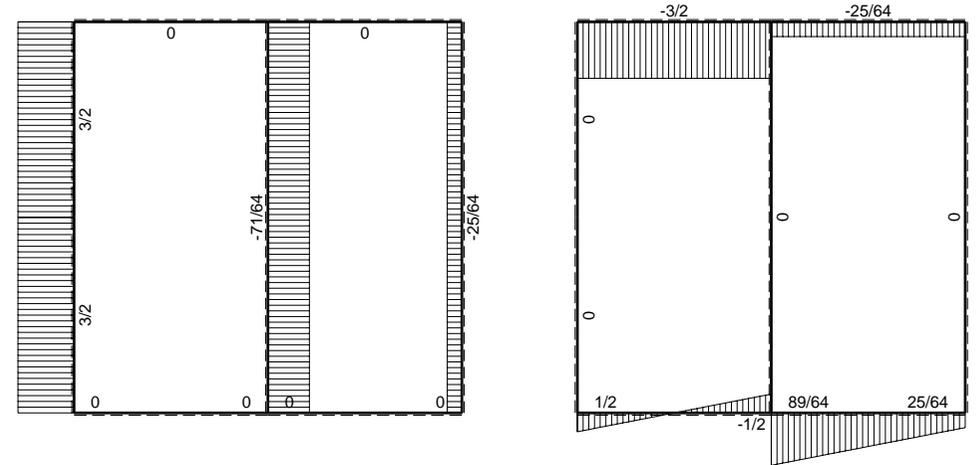
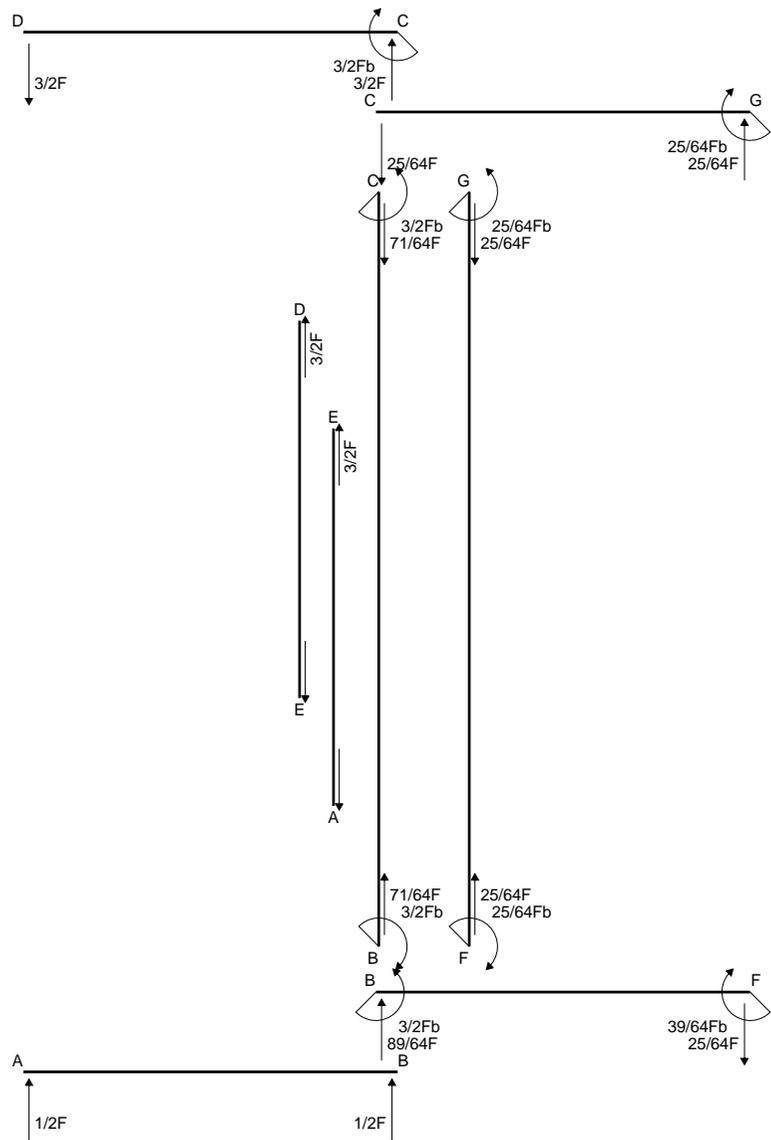
$$L_{CG}^{x\theta} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

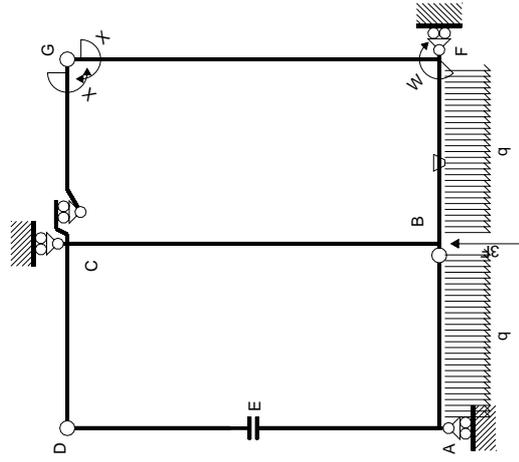
$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$



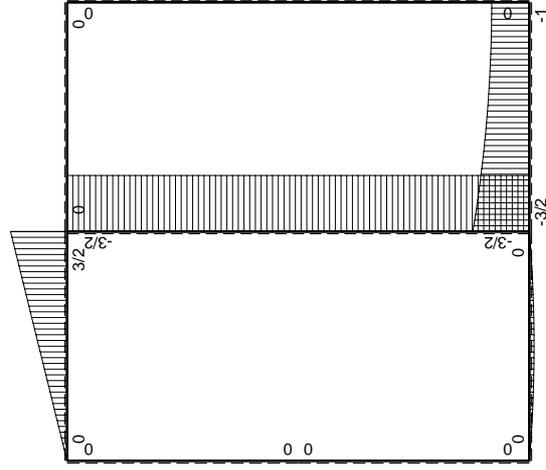
- A = 924. mm<sup>2</sup>
- J<sub>u</sub> = 260306. mm<sup>4</sup>
- J<sub>v</sub> = 49104. mm<sup>4</sup>
- y<sub>g</sub> = 21.21 mm
- T<sub>y</sub> = -3360. N
- M<sub>x</sub> = 1612800. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 55. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 33.79 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -209.3 N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 41. mm
- v<sub>c</sub> = 19.79 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -122.6 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.84 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 122.9 N/mm<sup>2</sup>
- S = 4500. mm<sup>3</sup>



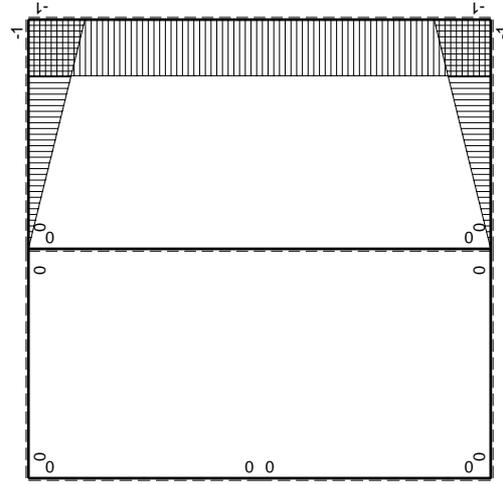




Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x(M^0/EJ+\theta)dx$	$\int M^x M_x/EJ dx$
AB b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0
BA b	0	$-1/2Fx+1/2qx^2$	0	0	0	0	0+0	0
CD b	0	$3/2Fb-3/2Fx$	0	0	0	0	0+0	0
DC b	0	$-3/2Fx$	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
ED b	0	0	0	0	0	0	0+0	0
EA b	0	0	0	0	0	0	0+0	0
AE b	0	0	0	0	0	0	0+0	0
BF b	$-x/b$	$-3/2Fb+Fx-1/2qx^2$	$-Fb/EJ$	$3/2Fx-Fx^2/b+1/2qx^3/b$	$Fx/EJ$	$x^2/b^2$	$(13/24+1/2)Fb^2/EJ$	$1/3Xb/EJ$
Fb b	$1-x/b$	$Fb+1/2qx^2$	$Fb/EJ$	$Fb-Fx+1/2Fx^2/b-1/2qx^3/b$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$1/3Xb/EJ$	$1/3Xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3Xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$2Xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	0
GF 2b	1	0	0	0	0	1	0+0	0
CB 2b	0	$-3/2Fb$	0	0	0	0	0+0	0
BC 2b	0	$3/2Fb$	0	0	0	0	$25/24Fb^2/EJ$	$8/3Xb/EJ$
totali								
								iperstatica $X=W_{gc}$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (3/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

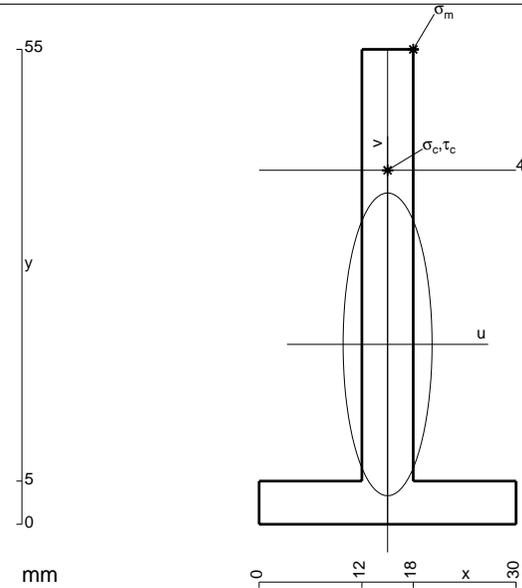
$$= [3/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (3/4 b - 1/3 b + 1/8 b) Fb 1/EJ + (1/2 b) \theta = 25/24 Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

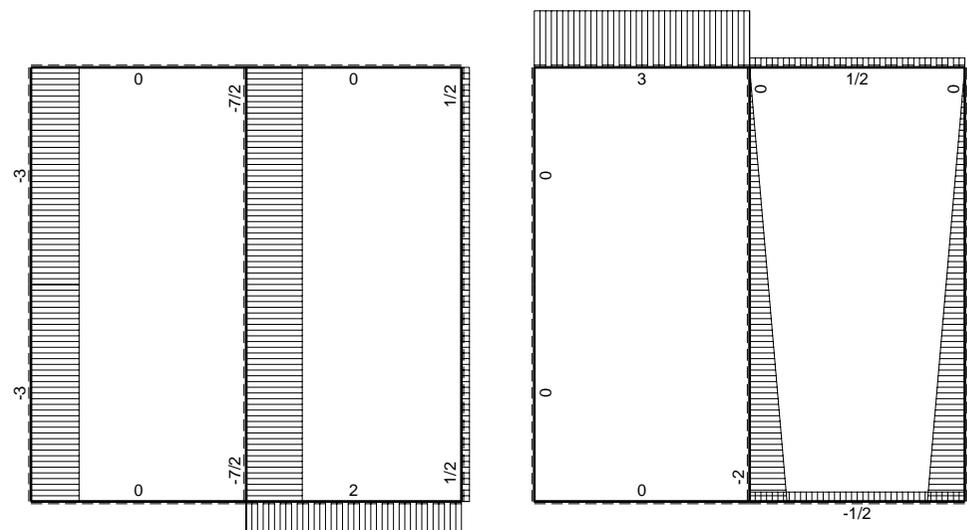
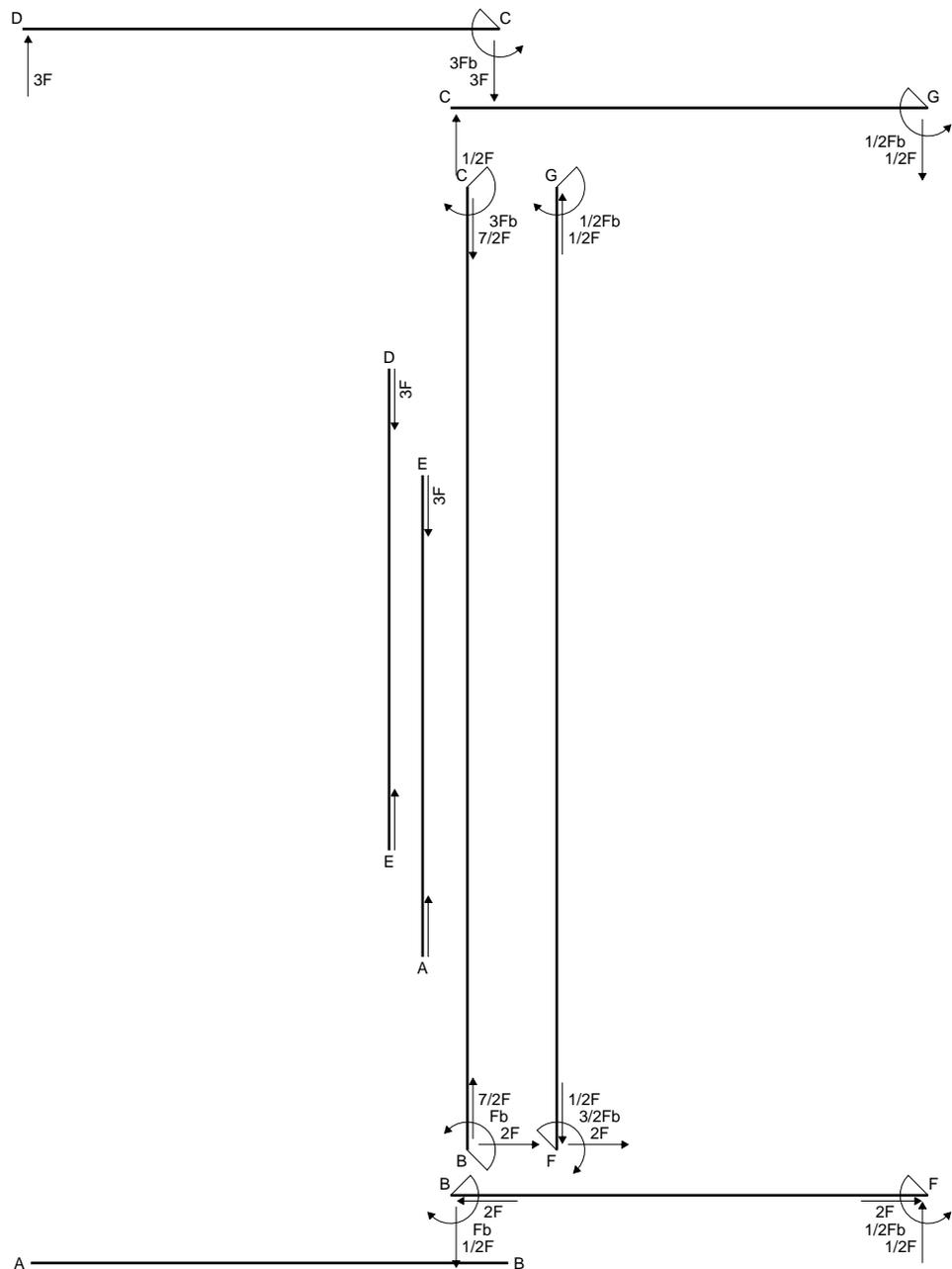
$$= [x - 1/2 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b + 1/6 b - 1/8 b) Fb 1/EJ + (-b + 1/2 b) \theta = 25/24 Fb^2/EJ$$



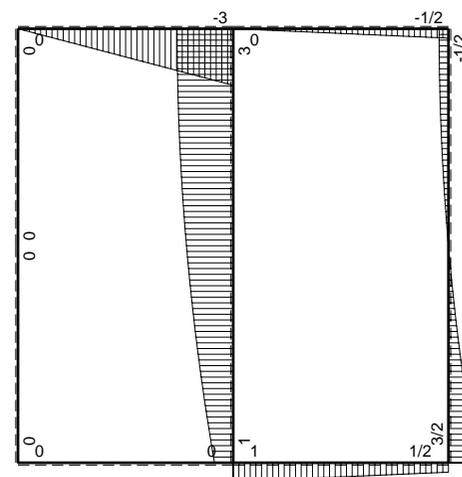
- A = 450. mm<sup>2</sup>
- J<sub>u</sub> = 138437. mm<sup>4</sup>
- J<sub>v</sub> = 12150. mm<sup>4</sup>
- y<sub>g</sub> = 20.83 mm
- T<sub>y</sub> = -1710. N
- M<sub>x</sub> = 889200. Nmm
- x<sub>m</sub> = 18. mm
- y<sub>m</sub> = 55. mm
- u<sub>m</sub> = 3. mm
- v<sub>m</sub> = 34.17 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -219.5 N/mm<sup>2</sup>
- x<sub>c</sub> = 15. mm
- y<sub>c</sub> = 41. mm
- v<sub>c</sub> = 20.17 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -129.5 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.698 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 129.8 N/mm<sup>2</sup>
- S = 2282. mm<sup>3</sup>



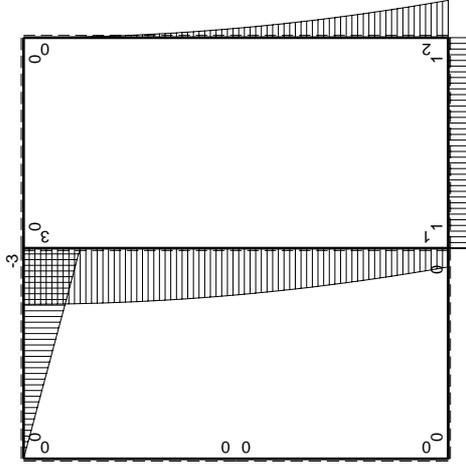
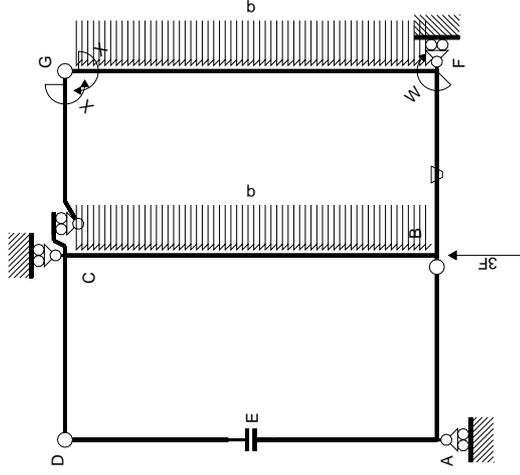


← ⊕ → F

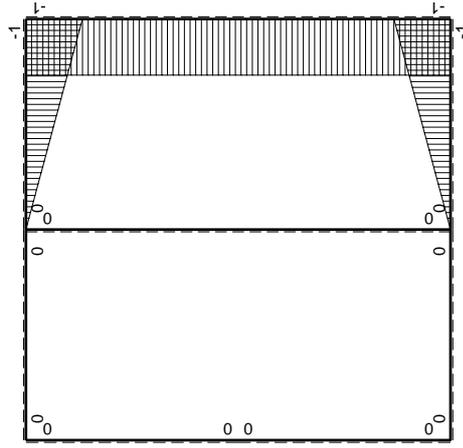
↑ ⊕ ↓ F



⊕ ⊖ F<sub>b</sub>



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

←	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x(M_0/EJ+\theta)dx$	$\int M^x M_x/EJ dx$	iperstatica X=W <sup>gc</sup>	
									totali	
AB b	0	0	0	0	0	0	0	0	0	0
BA b	0	0	0	0	0	0	0	0	0	0
CD b	0	-3Fb+3Fx	0	0	0	0	0	0	0	0
DC b	0	3Fx	0	0	0	0	0	0	0	0
DE b	0	0	0	0	0	0	0	0	0	0
ED b	0	0	0	0	0	0	0	0	0	0
EA b	0	0	0	0	0	0	0	0	0	0
AE b	0	0	0	0	0	0	0	0	0	0
BF b	-x/b	Fb	-Fb/EJ	-Fx	Fx/EJ	$x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	1/3xb/EJ	1	$(-4/3+0)Fb^2/EJ$
FB b	1-x/b	-Fb	Fb/EJ	-Fb+Fx	Fb/EJ-Fx/EJ	$1-2x/b+x^2/b^2$	$-1/2+1/2)Fb^2/EJ$	1/3xb/EJ	1	$(-4/3+0)Fb^2/EJ$
GC b	-1+x/b	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	1/3xb/EJ	0	0+0
CG b	x/b	0	0	0	0	$x^2/b^2$	0+0	1/3xb/EJ	0	0+0
FG 2b	-1	$2Fb-2Fx+1/2qx^2$	0	$-2Fb+2Fx-1/2Fx^2/b$	0	1	$(-4/3+0)Fb^2/EJ$	2xb/EJ	1	$(-4/3+0)Fb^2/EJ$
GF 2b	1	$-1/2qx^2$	0	$-1/2Fx^2/b$	0	1	$(-4/3+0)Fb^2/EJ$	2xb/EJ	1	$(-4/3+0)Fb^2/EJ$
CB 2b	0	$3Fb-1/2qx^2$	0	0	0	0	0+0	8/3xb/EJ	0	0+0
BC 2b	0	$-Fb-2Fx+1/2qx^2$	0	0	0	0	0+0	8/3xb/EJ	0	0+0
totali										

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x_0} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

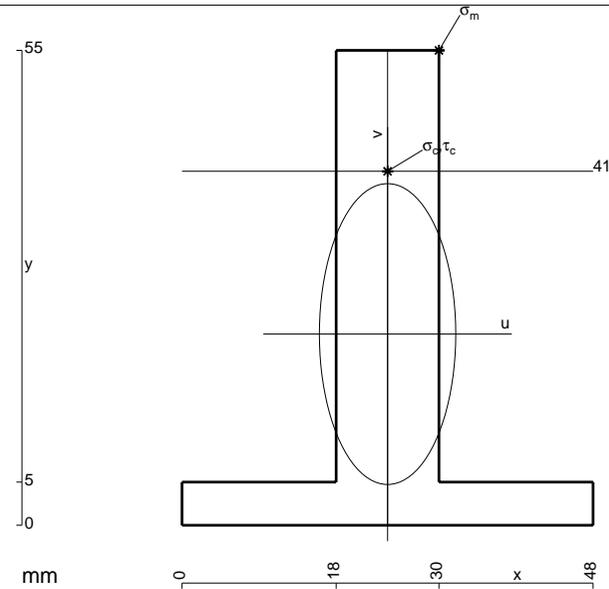
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x_0} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

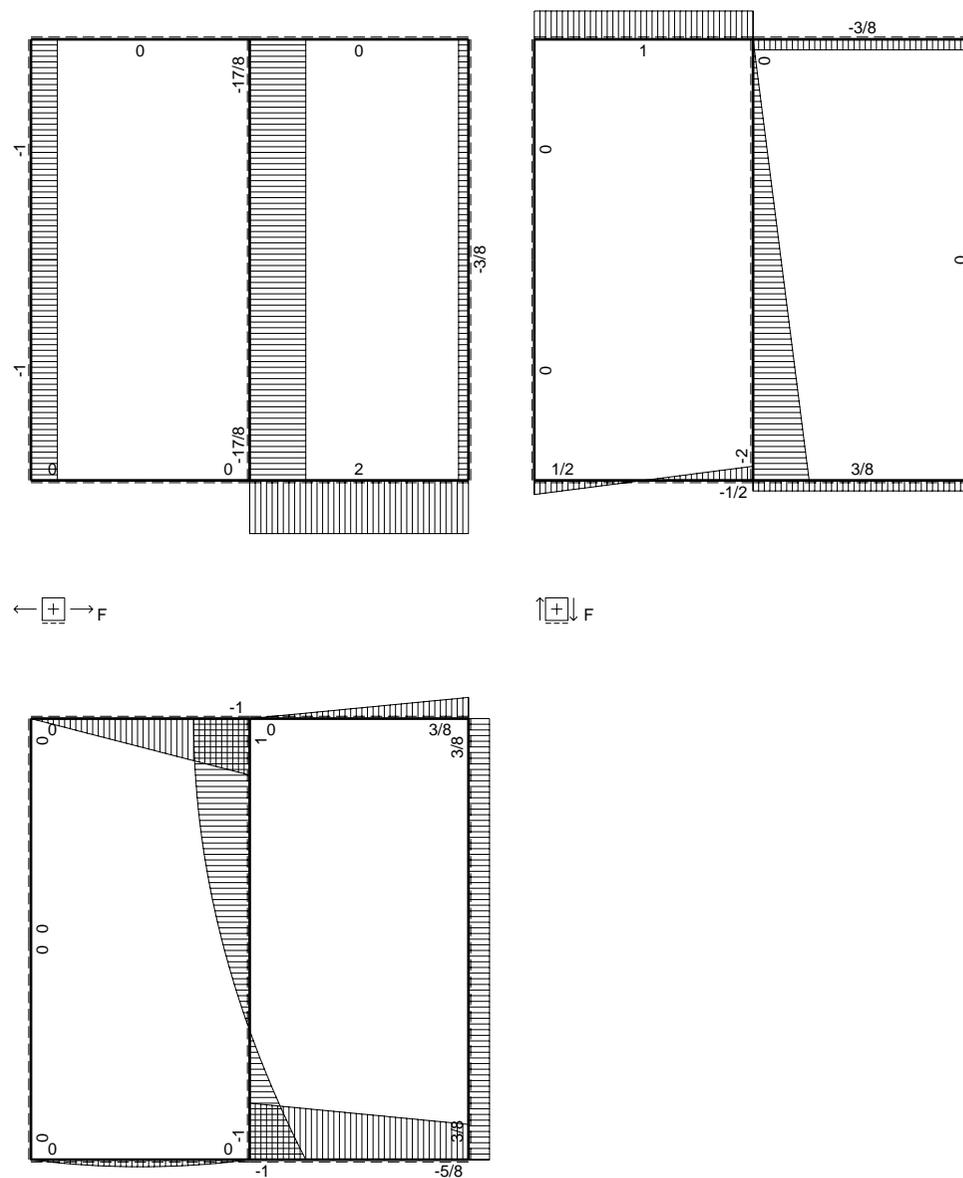
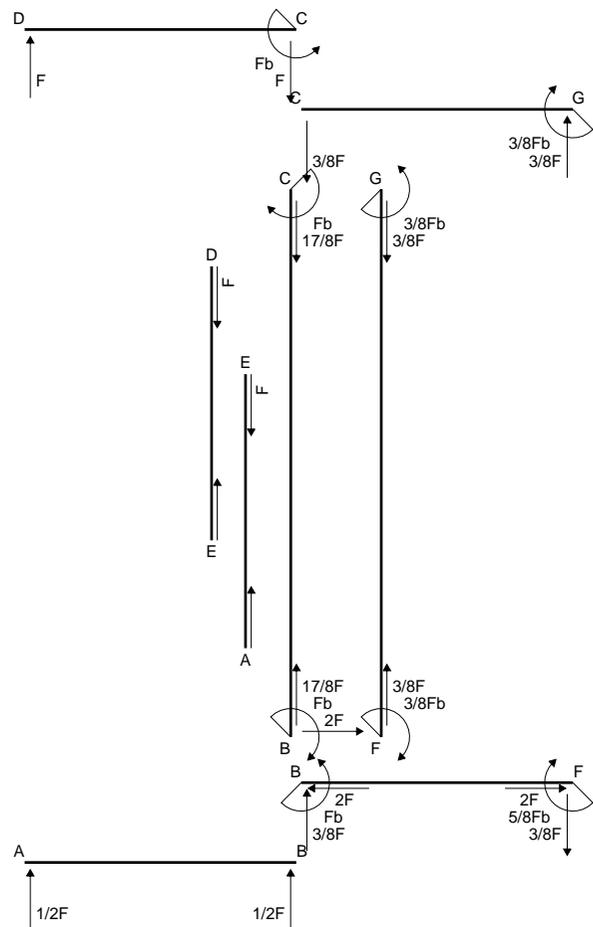
$$L_{GF}^{x_0} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

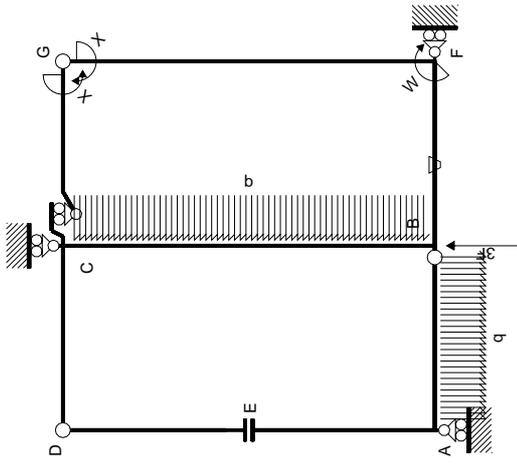


- A = 840. mm<sup>2</sup>
- J<sub>u</sub> = 255143. mm<sup>4</sup>
- J<sub>v</sub> = 53280. mm<sup>4</sup>
- y<sub>g</sub> = 22.14 mm
- T<sub>y</sub> = 3120. N
- M<sub>x</sub> = -1778400. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 55. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 32.86 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 229. N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 41. mm
- v<sub>c</sub> = 18.86 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 131.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.427 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 131.7 N/mm<sup>2</sup>
- S = 4344. mm<sup>3</sup>

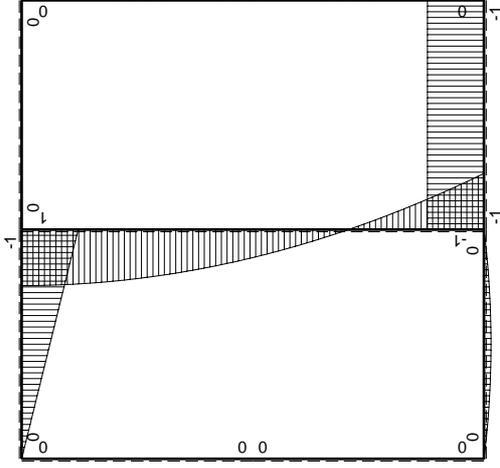




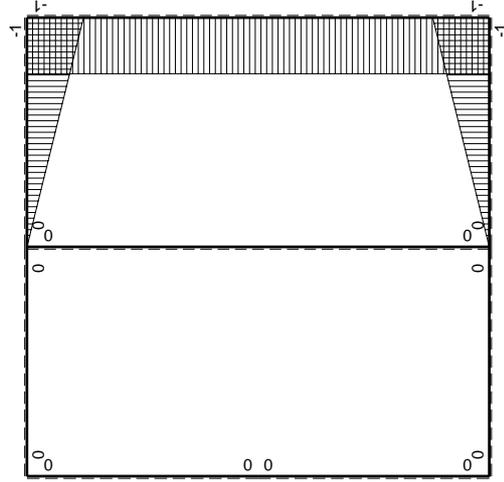
⊕  $Fb$



Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / EJ dx$
AB b	0	$1/2Fx - 1/2qx^2$	0	0	0	0	0+0	0
BA b	0	$-1/2Fx + 1/2qx^2$	0	0	0	0	0+0	0
CD b	0	$-Fb + Fx$	0	0	0	0	0+0	0
DC b	0	$Fx$	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
EA b	0	0	0	0	0	0	0+0	0
AE b	0	0	0	0	0	0	0+0	0
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb-Fx$	$Fb/EJ - Fx/EJ$	$1-2x/b+x^2/b^2$	$1/3xb/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2xb/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2xb/EJ$
CB 2b	0	$Fb - 1/2qx^2$	0	0	0	0	0+0	0
BC 2b	0	$Fb - 2Fx + 1/2qx^2$	0	0	0	0	0+0	0
totali								$Fb^2/EJ$
								$8/3xb/EJ$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

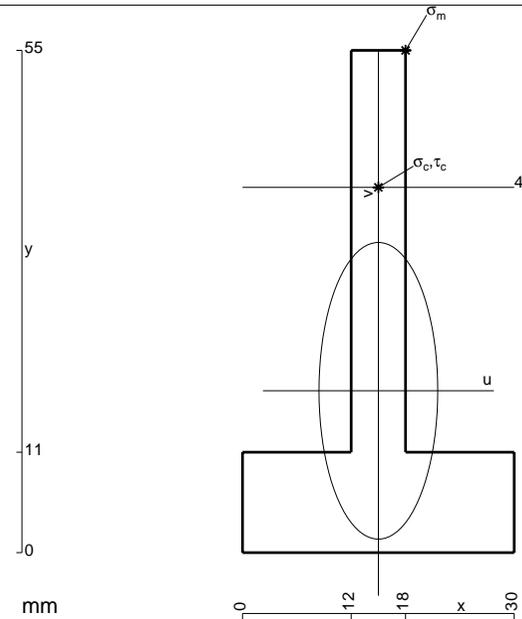
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



$$A = 594. \text{ mm}^2$$

$$J_u = 156836. \text{ mm}^4$$

$$J_v = 25542. \text{ mm}^4$$

$$y_g = 17.72 \text{ mm}$$

$$N = -3591. \text{ N}$$

$$T_y = -3380. \text{ N}$$

$$M_x = -1030900. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$y_m = 55. \text{ mm}$$

$$u_m = 3. \text{ mm}$$

$$v_m = 37.28 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 239. \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 40. \text{ mm}$$

$$v_c = 22.28 \text{ mm}$$

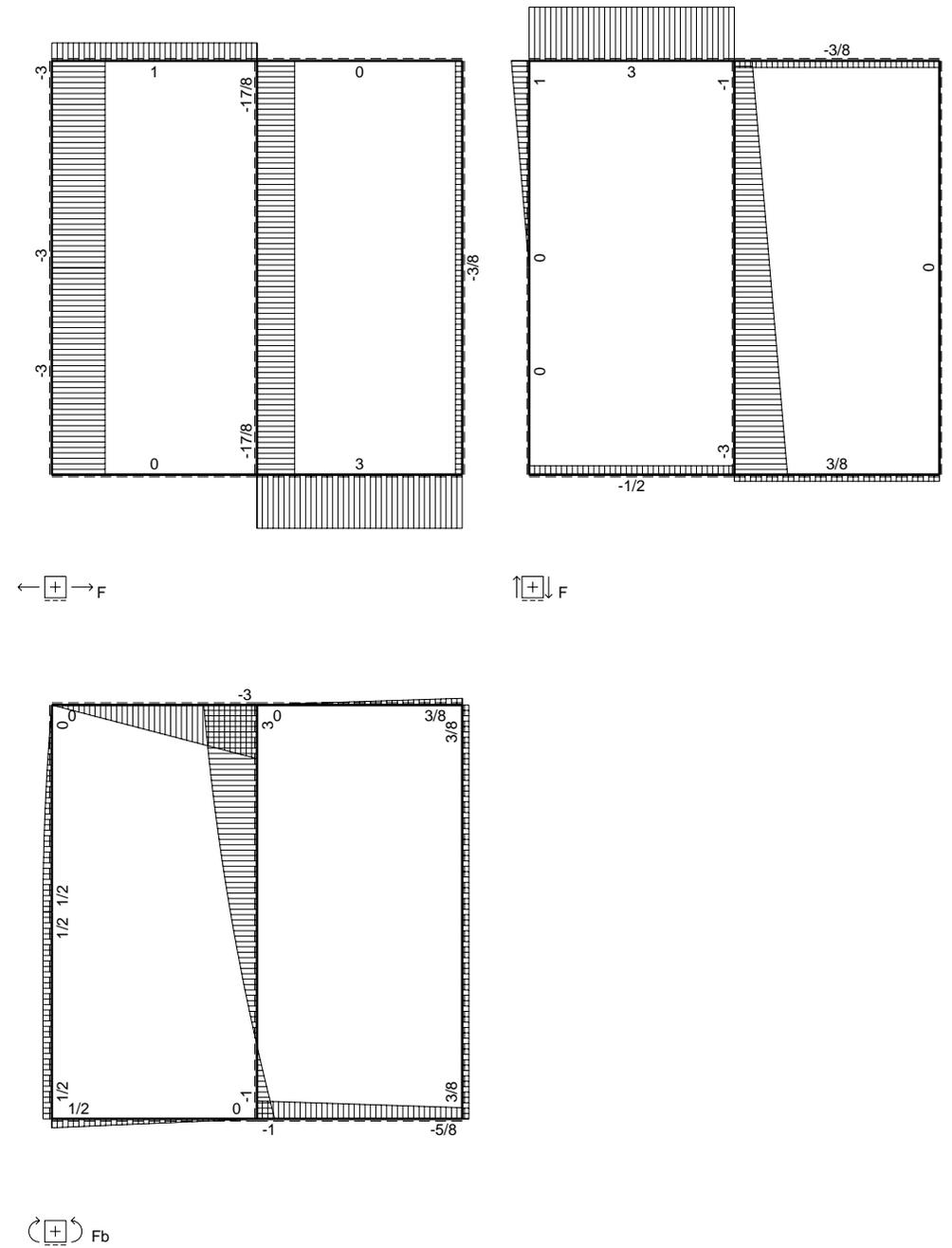
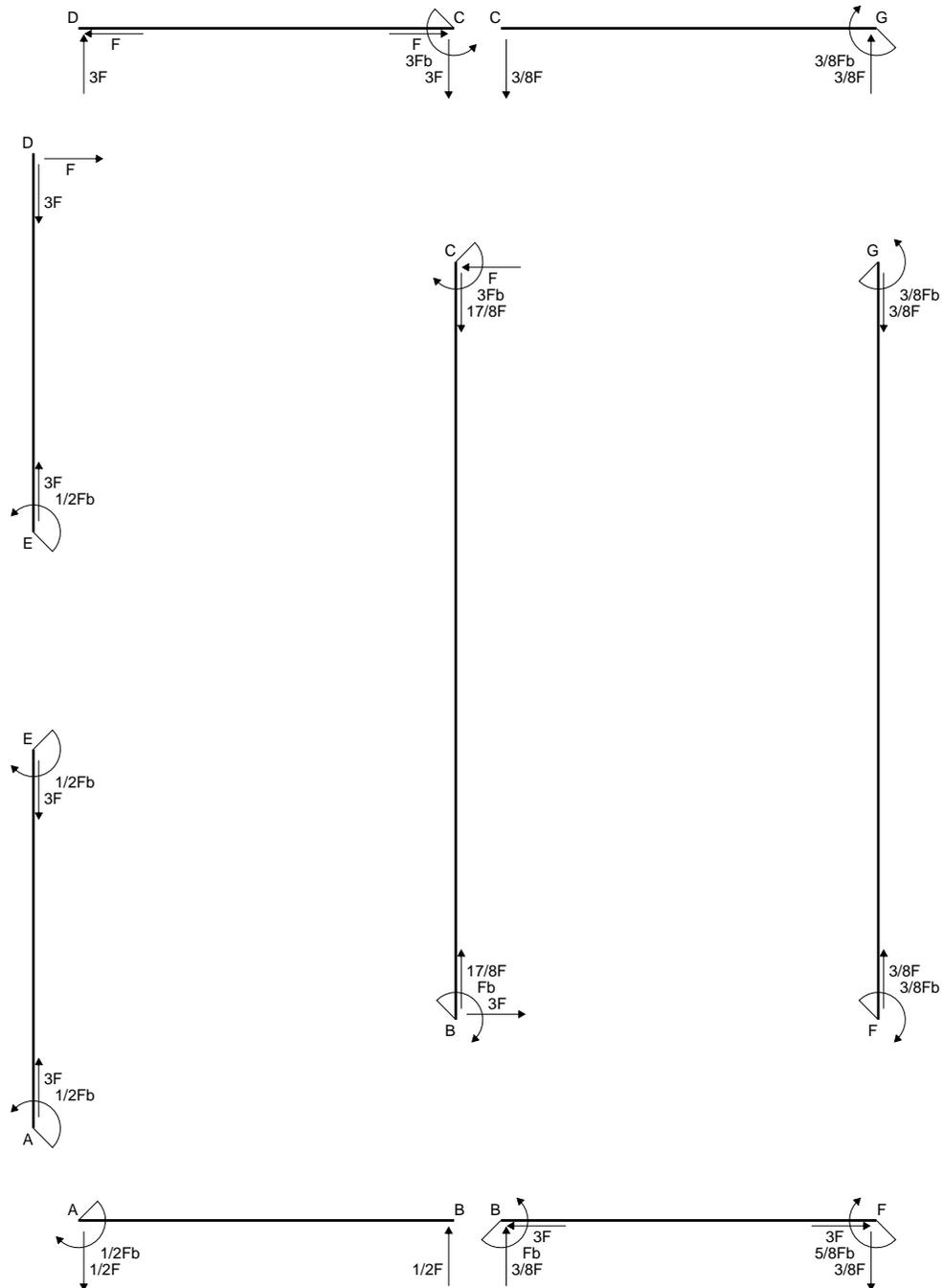
$$\sigma_c = N/A - Mv/J_u = 140.4 \text{ N/mm}^2$$

$$\tau_c = 9.626 \text{ N/mm}^2$$

$$\sigma_0 = \sqrt{\sigma^2 + 3\tau^2} = 141.4 \text{ N/mm}^2$$

$$S = 2680. \text{ mm}^3$$







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

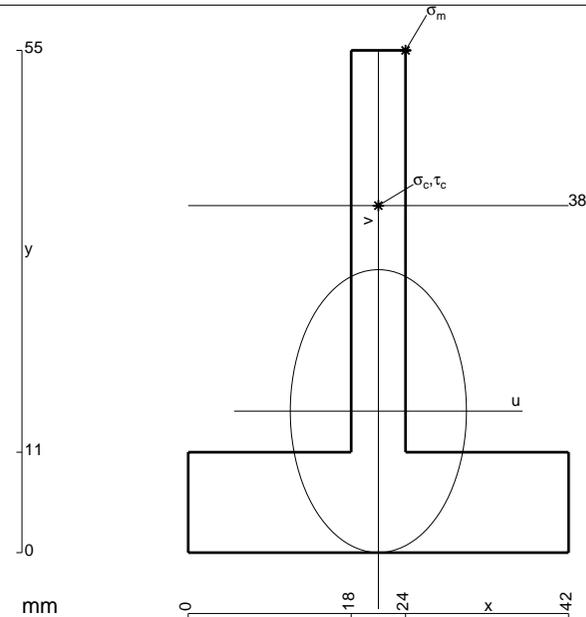
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

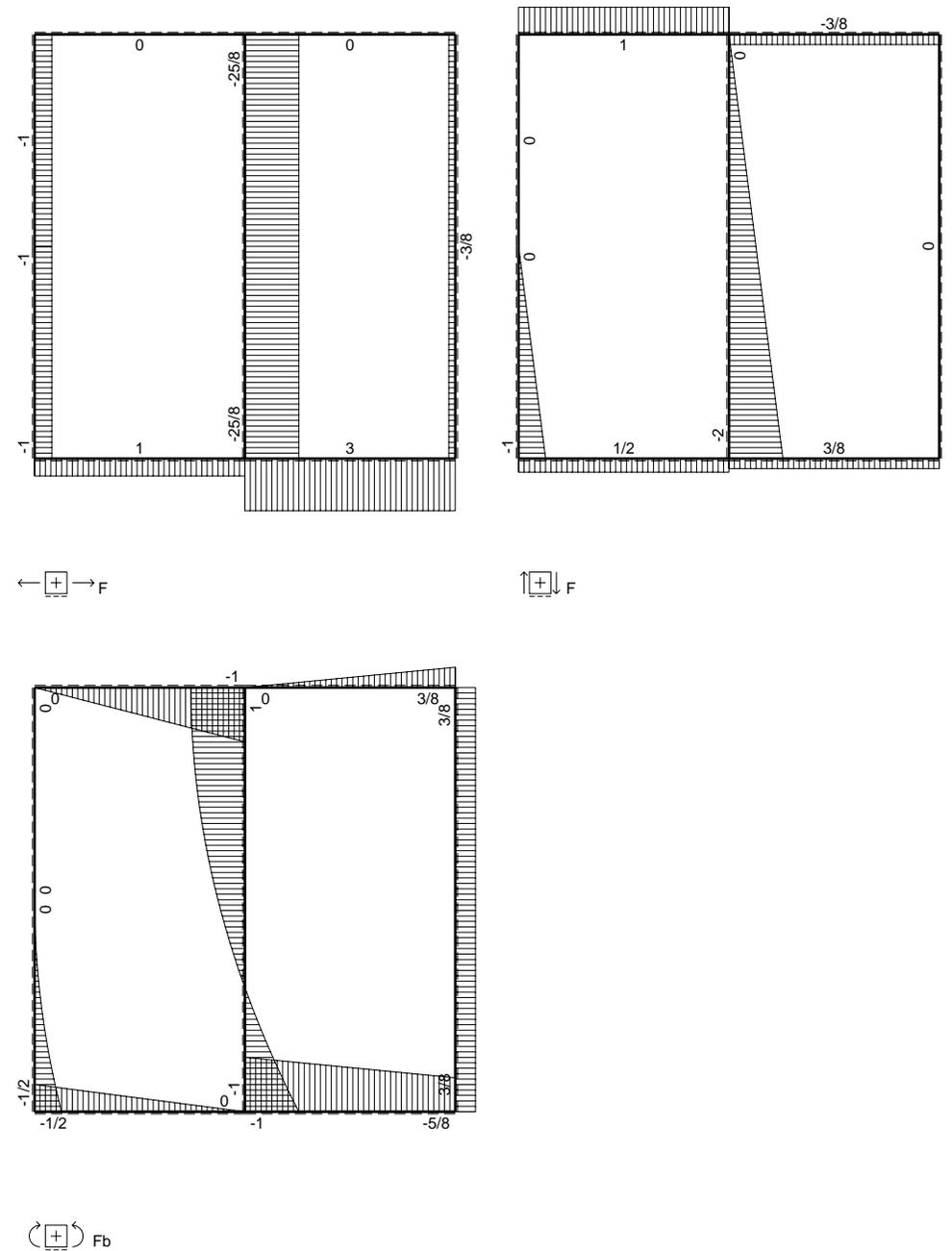
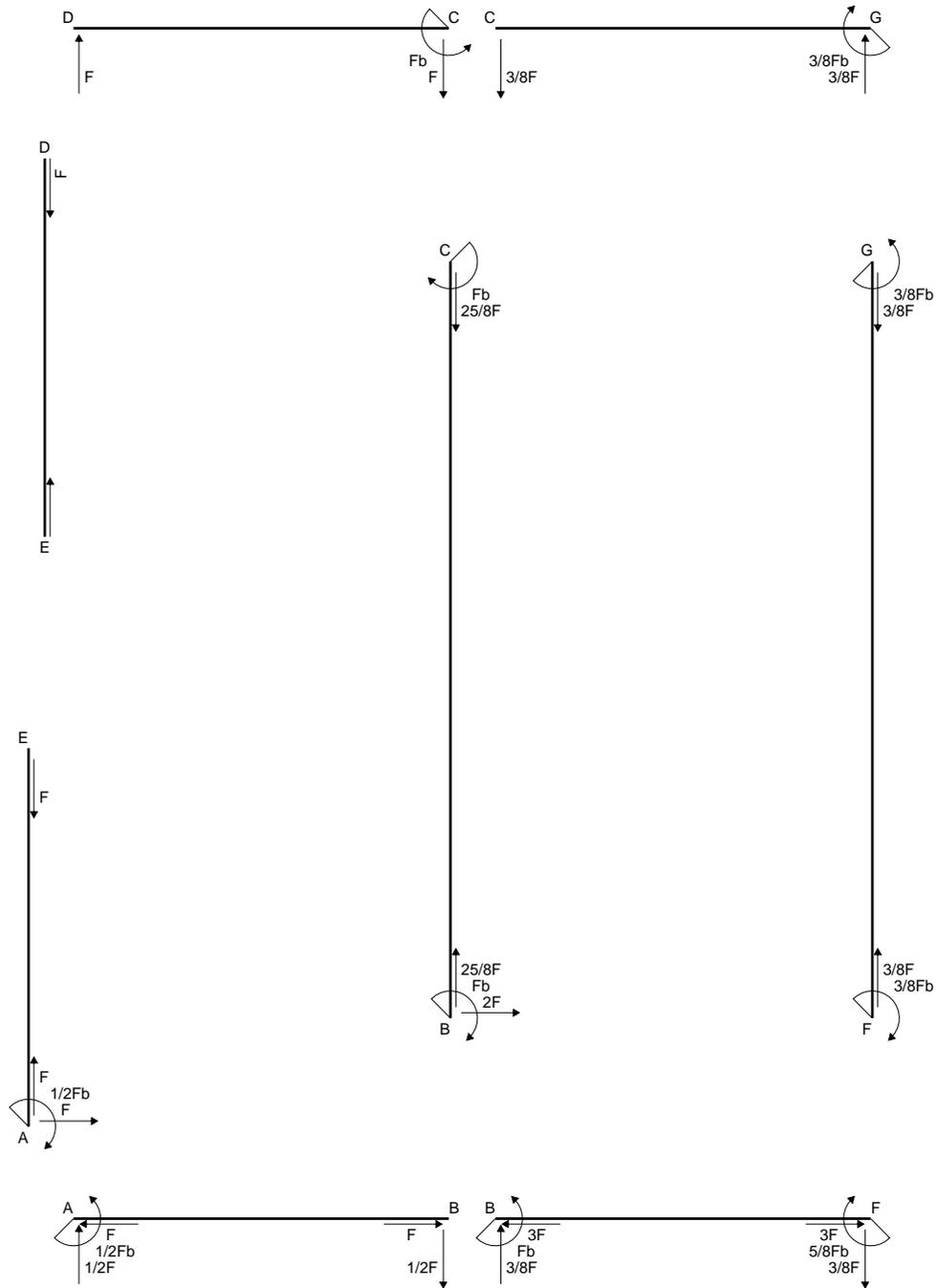
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



- A = 726. mm<sup>2</sup>
- J<sub>v</sub> = 174301. mm<sup>4</sup>
- J<sub>w</sub> = 68706. mm<sup>4</sup>
- y<sub>g</sub> = 15.5 mm
- N = 440. N
- T<sub>y</sub> = 1320. N
- M<sub>x</sub> = -871200. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 55. mm
- u<sub>m</sub> = 3. mm
- v<sub>m</sub> = 39.5 mm
- v<sub>c</sub> = 39.5 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>v</sub> = 198. N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 38. mm
- v<sub>c</sub> = 22.5 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>v</sub> = 113.1 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.991 N/mm<sup>2</sup>
- σ<sub>0</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 113.3 N/mm<sup>2</sup>
- S = 3162. mm<sup>3</sup>







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

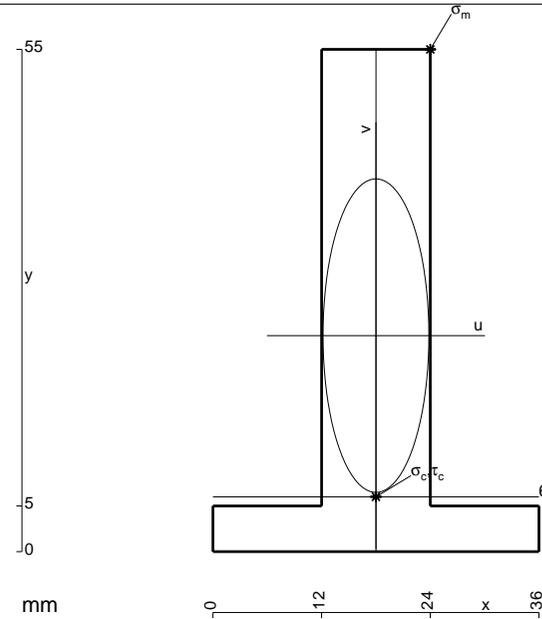
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

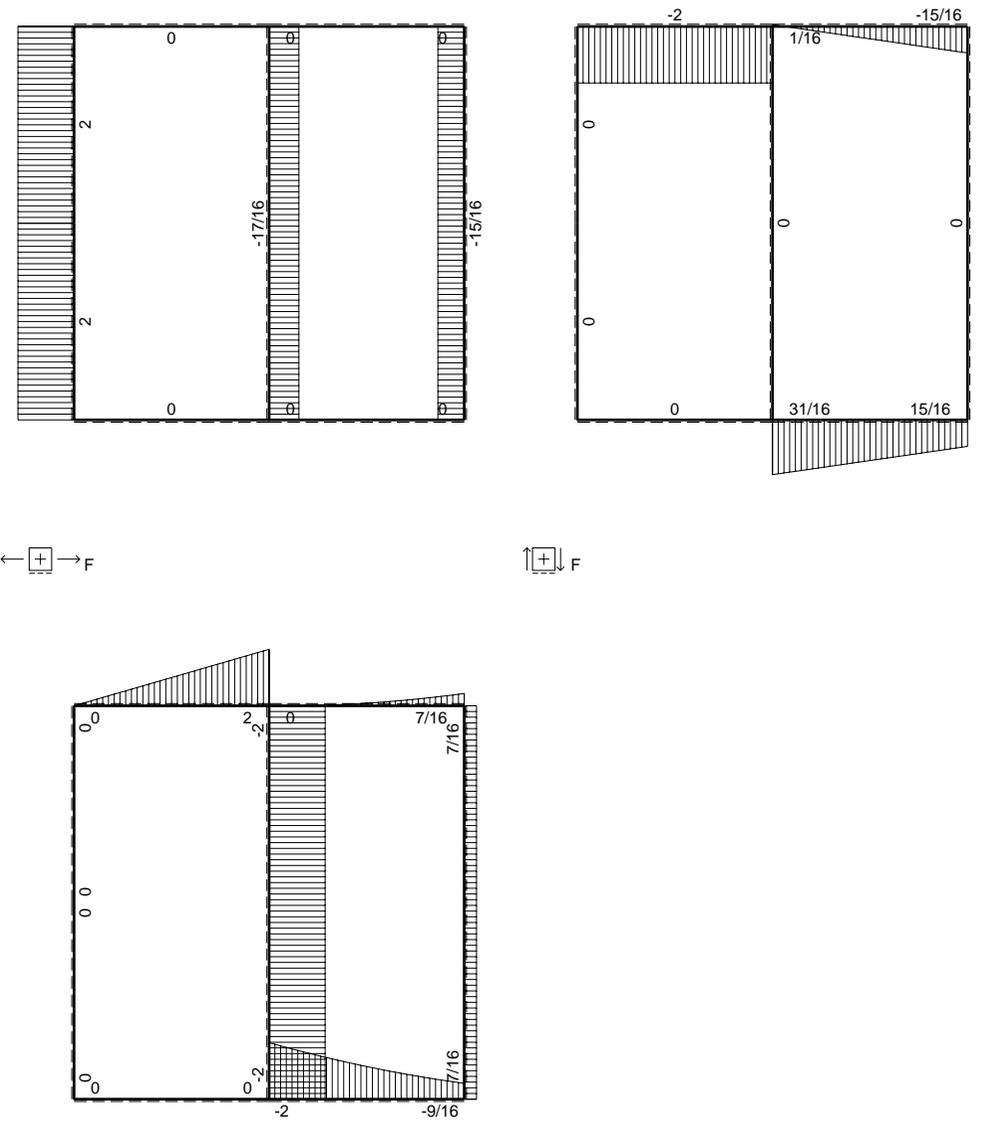
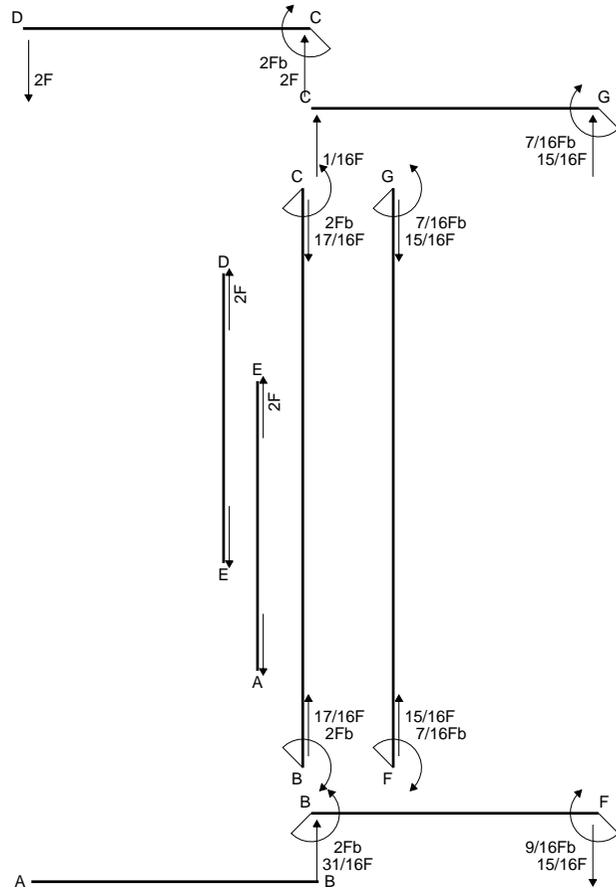
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



- A = 780. mm<sup>2</sup>
- J<sub>u</sub> = 230087. mm<sup>4</sup>
- J<sub>v</sub> = 26640. mm<sup>4</sup>
- y<sub>g</sub> = 23.65 mm
- N = -7156. N
- T<sub>y</sub> = -4580. N
- M<sub>x</sub> = -1603000. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 55. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 31.35 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = 209.2 N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 6. mm
- v<sub>c</sub> = -17.65 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = -132.2 N/mm<sup>2</sup>
- τ<sub>c</sub> = 6.678 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 = 4026. mm<sup>3</sup>







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{xo} = \int_0^b (2x/b - 3/2 x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

$$= [x^2/b - 1/2 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b + 1/8 b) Fb 1/EJ + (1/2 b) \theta = 9/8 Fb^2/EJ$$

$$L_{FB}^{xo} = \int_0^b (1 - 1/2 x/b - 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [x - 1/4 x^2/b - 1/8 x^4/b^3]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

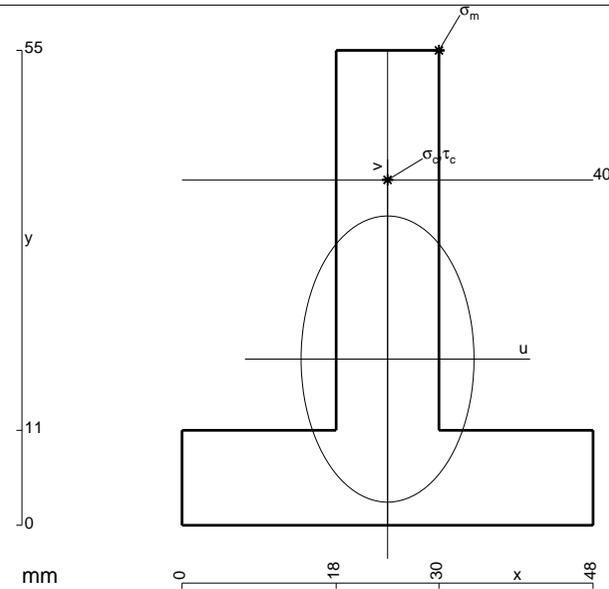
$$= (b - 1/4 b - 1/8 b) Fb 1/EJ + (-b + 1/2 b) \theta = 9/8 Fb^2/EJ$$

$$L_{GC}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

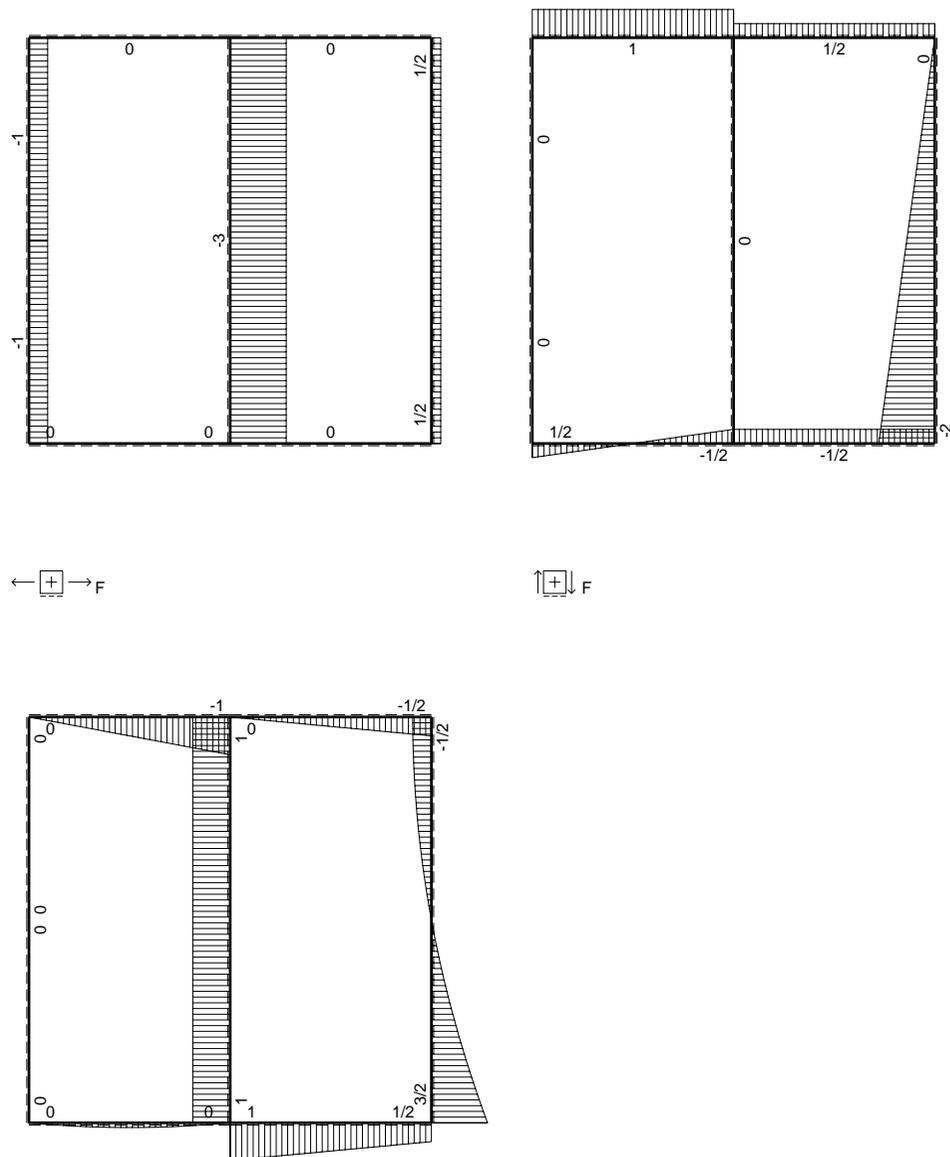
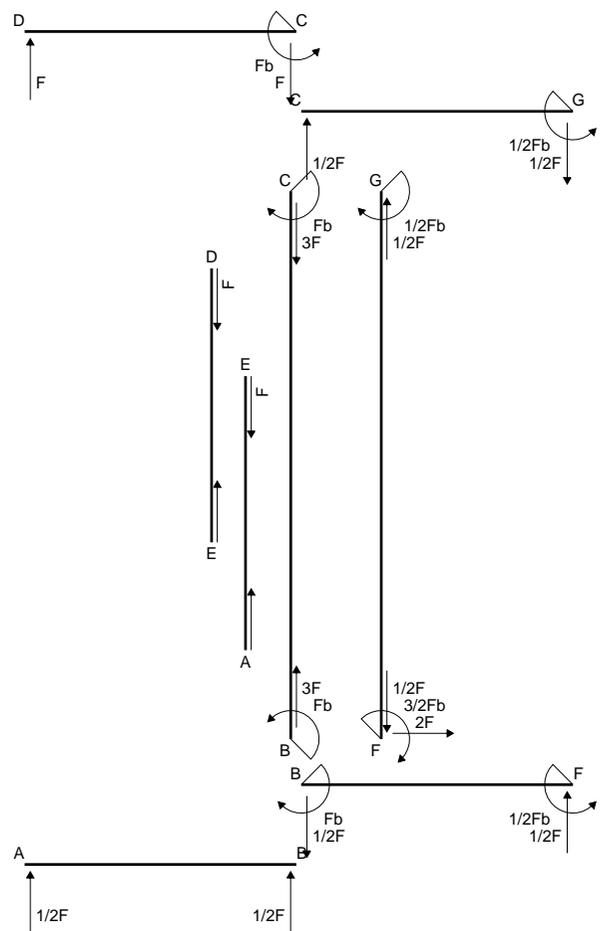
$$L_{CG}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

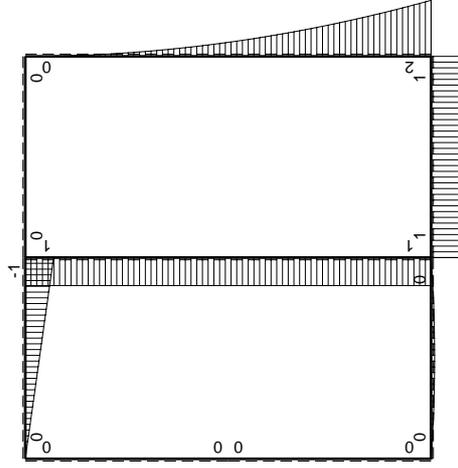
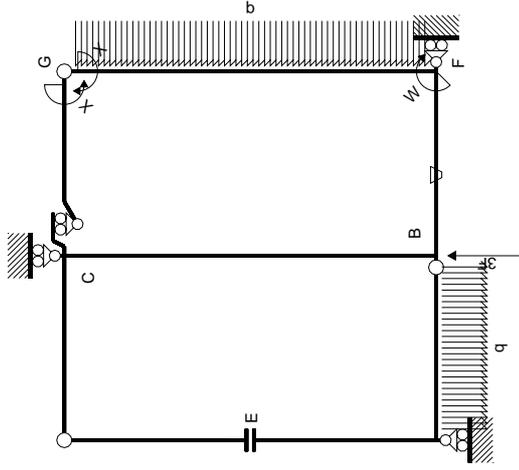
$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$



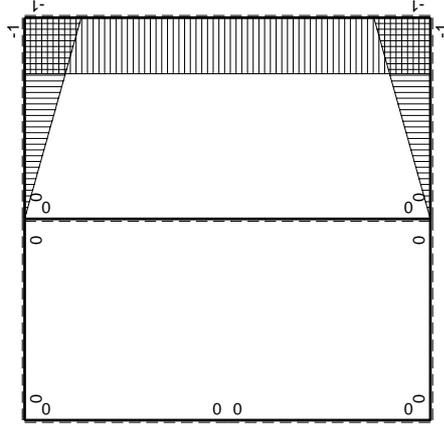
- A = 1056. mm<sup>2</sup>
- J<sub>u</sub> = 290158. mm<sup>4</sup>
- J<sub>v</sub> = 107712. mm<sup>4</sup>
- y<sub>g</sub> = 19.25 mm
- T<sub>y</sub> = -2400. N
- M<sub>x</sub> = 1776000. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 55. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 35.75 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -218.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 40. mm
- v<sub>c</sub> = 20.75 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -127. N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.505 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 127.2 N/mm<sup>2</sup>
- S = 5085. mm<sup>3</sup>







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica X=W<sub>gc</sub>

←	M <sup>0</sup> (x)	θ	M <sup>x</sup> M <sub>0</sub>	M <sup>x</sup> θ	M <sup>x</sup> M <sub>x</sub>	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJdx$
AB b	0	0	0	0	0	0	0
BA b	0	0	0	0	0	0	0
CD b	0	0	0	0	0	0	0
DC b	0	0	0	0	0	0	0
DE b	0	0	0	0	0	0	0
ED b	0	0	0	0	0	0	0
EA b	0	0	0	0	0	0	0
AE b	0	0	0	0	0	0	0
BF b	-x/b	-b/EJ	-Fx	Fx/EJ	$x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	1/3xb/EJ
FB b	1-x/b	Fb/EJ	-b+Fx	Fb/EJ-Fx/EJ	$1-2x/b+x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	1/3xb/EJ
GC b	-1+x/b	0	0	0	$1-2x/b+x^2/b^2$	0+0	1/3xb/EJ
CG b	x/b	0	0	0	$x^2/b^2$	0+0	1/3xb/EJ
FG 2b	-1	0	0	0	1	$(-4/3+0)Fb^2/EJ$	2xb/EJ
GF 2b	1	0	0	0	1	$(-4/3+0)Fb^2/EJ$	2xb/EJ
CB 2b	0	0	0	0	0	0+0	0
BC 2b	0	0	0	0	0	0+0	0
totali	0	0	0	0	0	-4/3Fb <sup>2</sup> /EJ	8/3xb/EJ

iperstatica X=W<sub>gc</sub>

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x_0} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

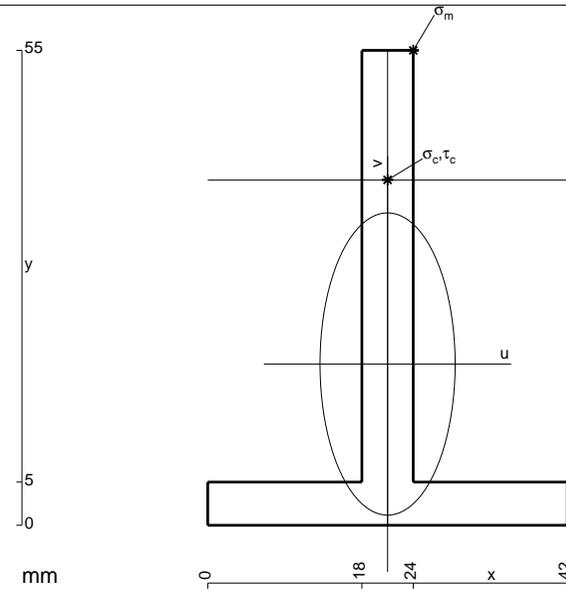
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x_0} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

$$L_{GF}^{x_0} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



$$A = 510. \text{ mm}^2$$

$$J_u = 156357. \text{ mm}^4$$

$$J_v = 31770. \text{ mm}^4$$

$$y_g = 18.68 \text{ mm}$$

$$T_y = 1250. \text{ N}$$

$$M_x = -987500. \text{ Nmm}$$

$$x_m = 24. \text{ mm}$$

$$y_m = 55. \text{ mm}$$

$$u_m = 3. \text{ mm}$$

$$v_m = 36.32 \text{ mm}$$

$$\sigma_m = -Mv/J_u = 229.4 \text{ N/mm}^2$$

$$x_c = 21. \text{ mm}$$

$$y_c = 40. \text{ mm}$$

$$v_c = 21.32 \text{ mm}$$

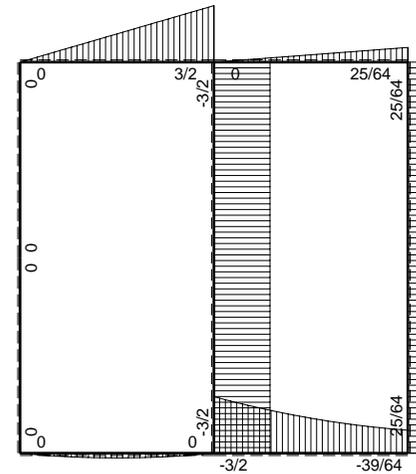
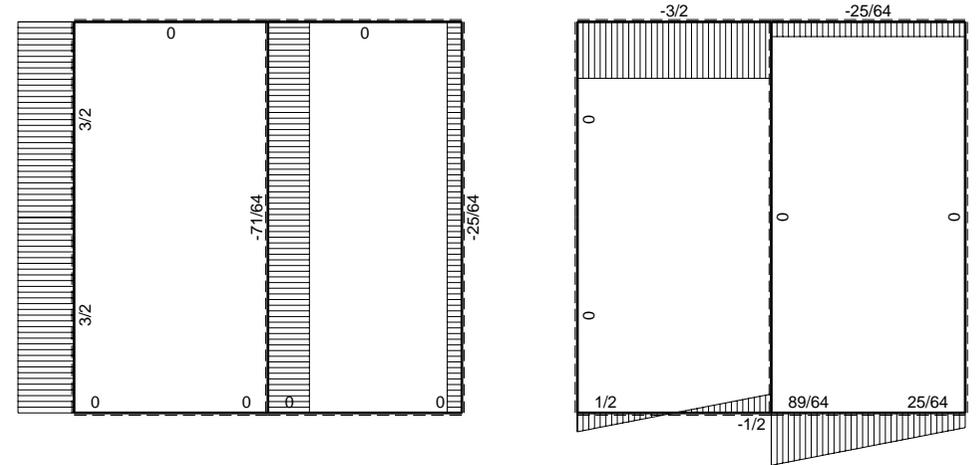
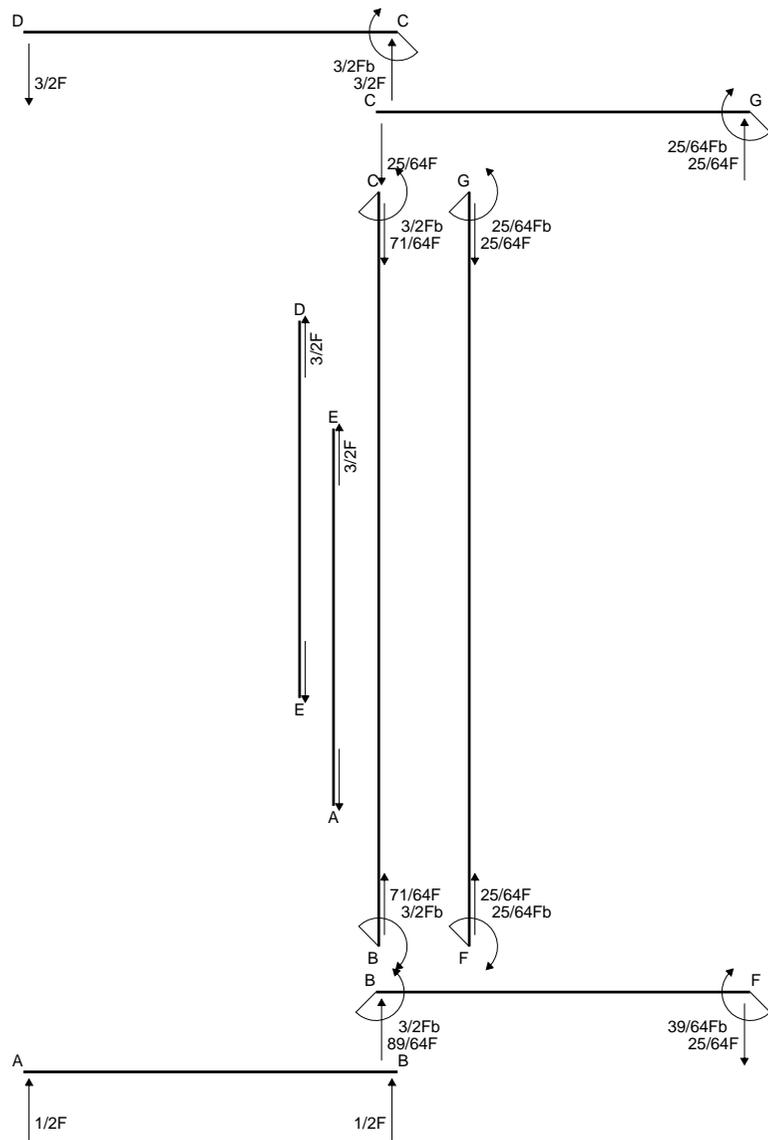
$$\sigma_c = -Mv/J_u = 134.7 \text{ N/mm}^2$$

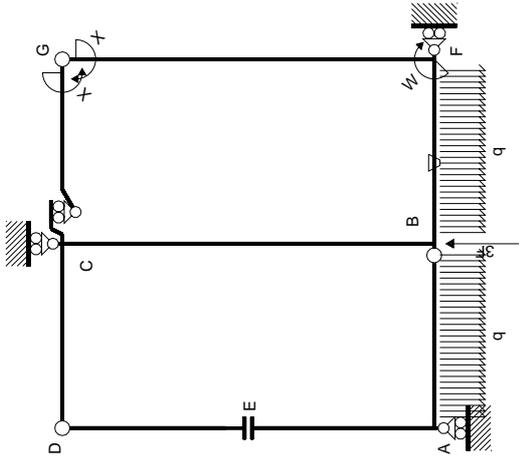
$$\tau_c = 3.456 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 134.8 \text{ N/mm}^2$$

$$S = 2594. \text{ mm}^3$$

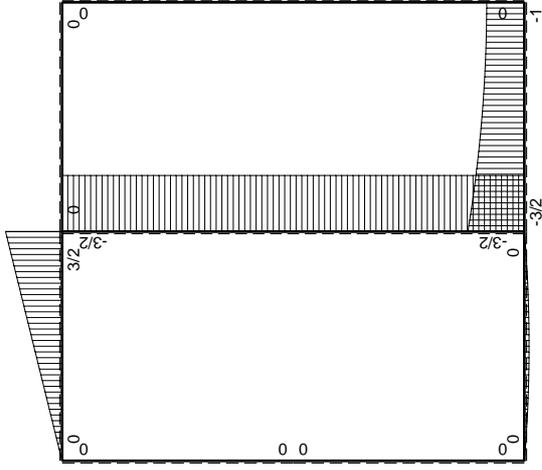






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati

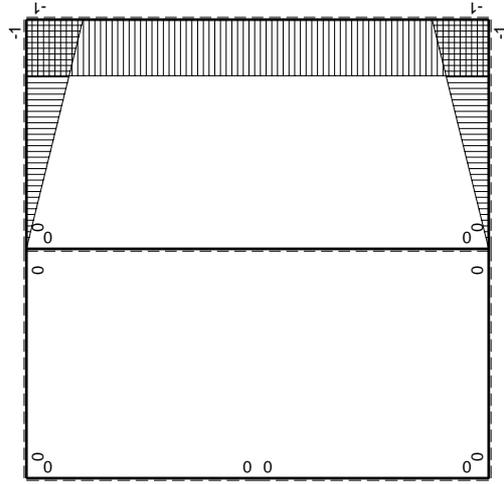


Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x(M^0/EJ+\theta)dx$	$\int M^x M_x/EJ dx$
AB b	$0$	$1/2Fx-1/2qx^2$	$0$	$0$	$0$	$0$	$0+0$	$0$
BA b	$0$	$-1/2Fx+1/2qx^2$	$0$	$0$	$0$	$0$	$0+0$	$0$
CD b	$0$	$3/2Fb-3/2Fx$	$0$	$0$	$0$	$0$	$0+0$	$0$
DC b	$0$	$-3/2Fx$	$0$	$0$	$0$	$0$	$0+0$	$0$
DE b	$0$	$0$	$0$	$0$	$0$	$0$	$0+0$	$0$
ED b	$0$	$0$	$0$	$0$	$0$	$0$	$0+0$	$0$
EA b	$0$	$0$	$0$	$0$	$0$	$0$	$0+0$	$0$
AE b	$0$	$0$	$0$	$0$	$0$	$0$	$0+0$	$0$
BF b	$-x/b$	$-3/2Fb+Fx-1/2qx^2$	$-Fb/EJ$	$3/2Fx-Fx^2/b+1/2qx^3/b$	$Fx/EJ$	$x^2/b^2$	$(13/24+1/2)Fb^2/EJ$	$1/3Xb/EJ$
Fb b	$1-x/b$	$Fb+1/2qx^2$	$Fb/EJ$	$Fb-Fx+1/2Fx^2/b-1/2qx^3/b$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$25/24Fb^2/EJ$	$8/3Xb/EJ$
GC b	$-1+x/b$	$0$	$0$	$0$	$0$	$x^2/b^2$	$0+0$	$1/3Xb/EJ$
CG b	$x/b$	$0$	$0$	$0$	$0$	$x^2/b^2$	$0+0$	$1/3Xb/EJ$
FG 2b	$-1$	$0$	$0$	$0$	$0$	$1$	$0+0$	$2Xb/EJ$
GF 2b	$1$	$0$	$0$	$0$	$0$	$1$	$0+0$	$2Xb/EJ$
CB 2b	$0$	$-3/2Fb$	$0$	$0$	$0$	$0$	$0+0$	$0$
BC 2b	$0$	$3/2Fb$	$0$	$0$	$0$	$0$	$0+0$	$0$
totali								
iperstatica $X=W_{gc}$								

Sviluppi di calcolo iperstatica

$M_x$  flessione da iperstatica  $X=1$



$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x\theta} = \int_0^b (3/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

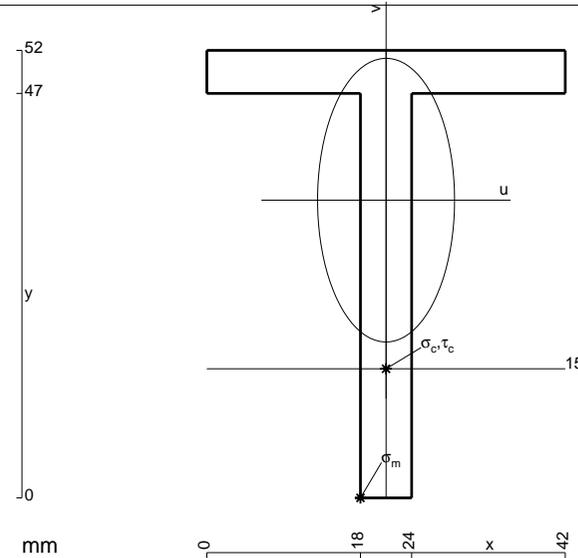
$$= [3/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (3/4 b - 1/3 b + 1/8 b) Fb 1/EJ + (1/2 b) \theta = 25/24 Fb^2/EJ$$

$$L_{FB}^{x\theta} = \int_0^b (1 - x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

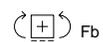
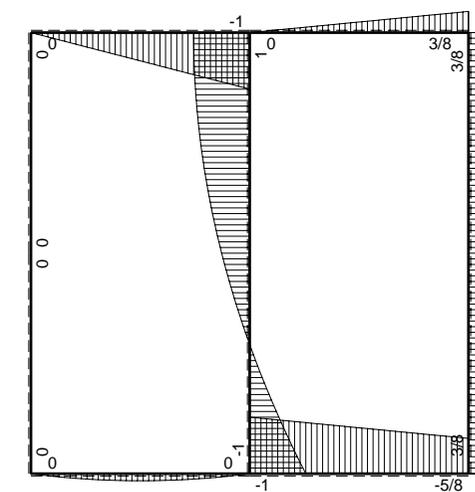
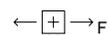
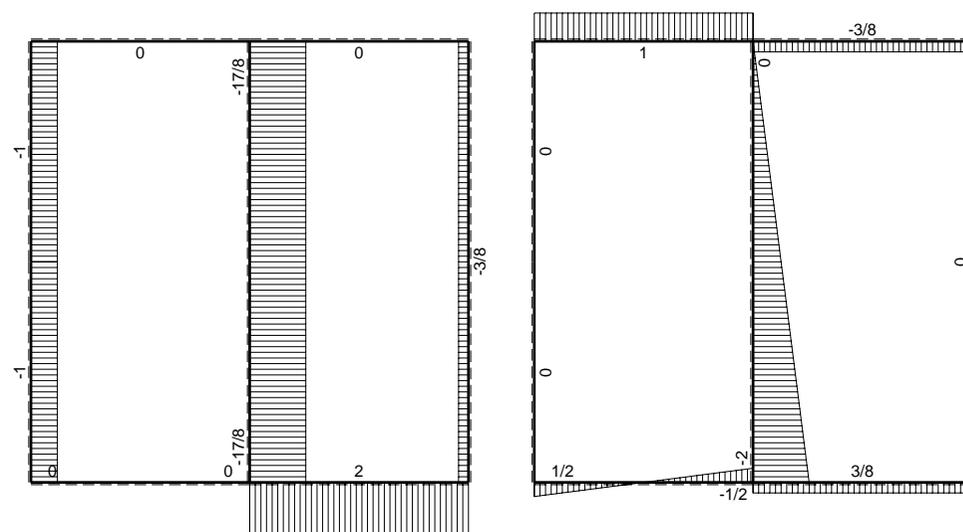
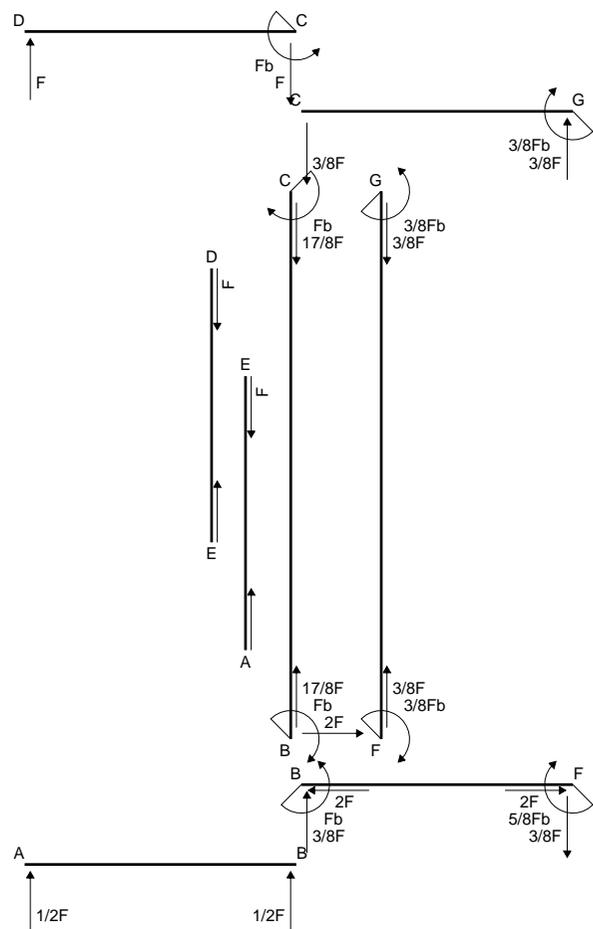
$$= [x - 1/2 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

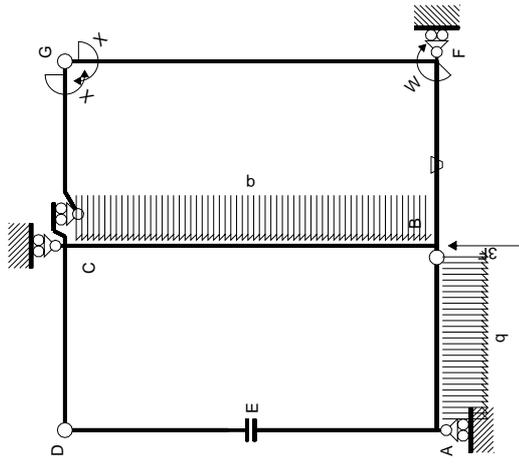
$$= (b - 1/2 b + 1/6 b - 1/8 b) Fb 1/EJ + (-b + 1/2 b) \theta = 25/24 Fb^2/EJ$$



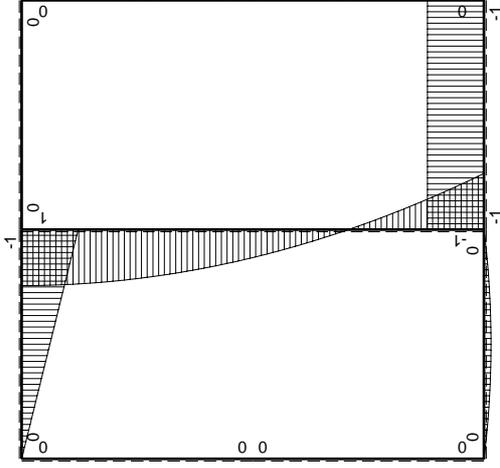
- A = 492. mm<sup>2</sup>
- J<sub>u</sub> = 133716. mm<sup>4</sup>
- J<sub>v</sub> = 31716. mm<sup>4</sup>
- y<sub>g</sub> = 34.6 mm
- T<sub>y</sub> = -1200. N
- M<sub>x</sub> = 924000. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -34.6 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 239.1 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 15. mm
- v<sub>c</sub> = -19.6 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 135.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.648 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 135.6 N/mm<sup>2</sup>
- S = 2439. mm<sup>3</sup>



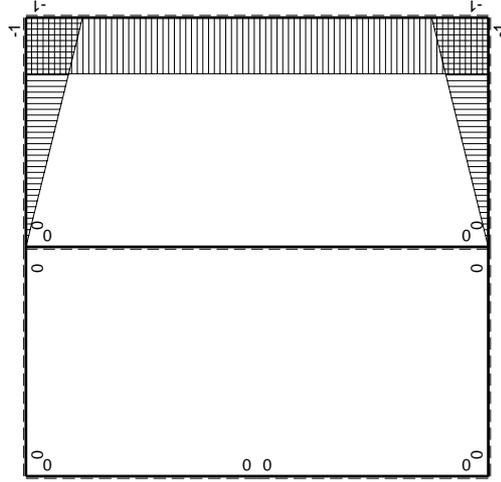




Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / EJ dx$
AB b	0	$1/2Fx - 1/2qx^2$	0	0	0	0	0+0	0
BA b	0	$-1/2Fx + 1/2qx^2$	0	0	0	0	0+0	0
CD b	0	$-Fb + Fx$	0	0	0	0	0+0	0
DC b	0	$Fx$	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
EA b	0	0	0	0	0	0	0+0	0
AF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb-Fx$	$Fb/EJ - Fx/EJ$	$1-2x/b+x^2/b^2$	$1/3xb/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2xb/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2xb/EJ$
CB 2b	0	$Fb - 1/2qx^2$	0	0	0	0	0+0	0
BC 2b	0	$Fb - 2Fx + 1/2qx^2$	0	0	0	0	0+0	0
totali								$Fb^2/EJ$
								$8/3xb/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

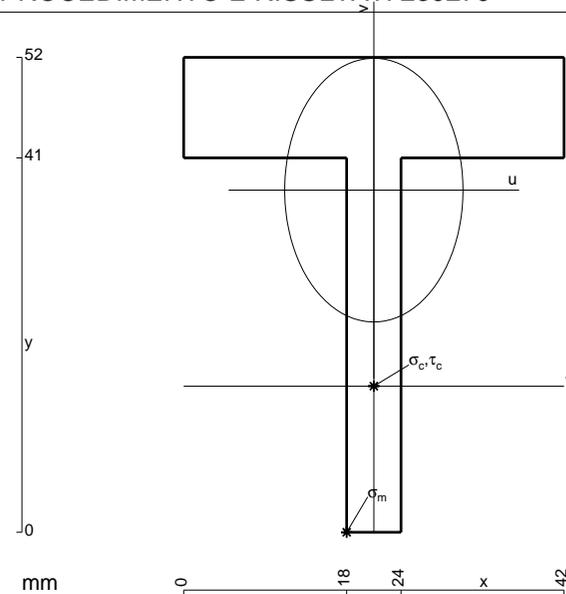
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

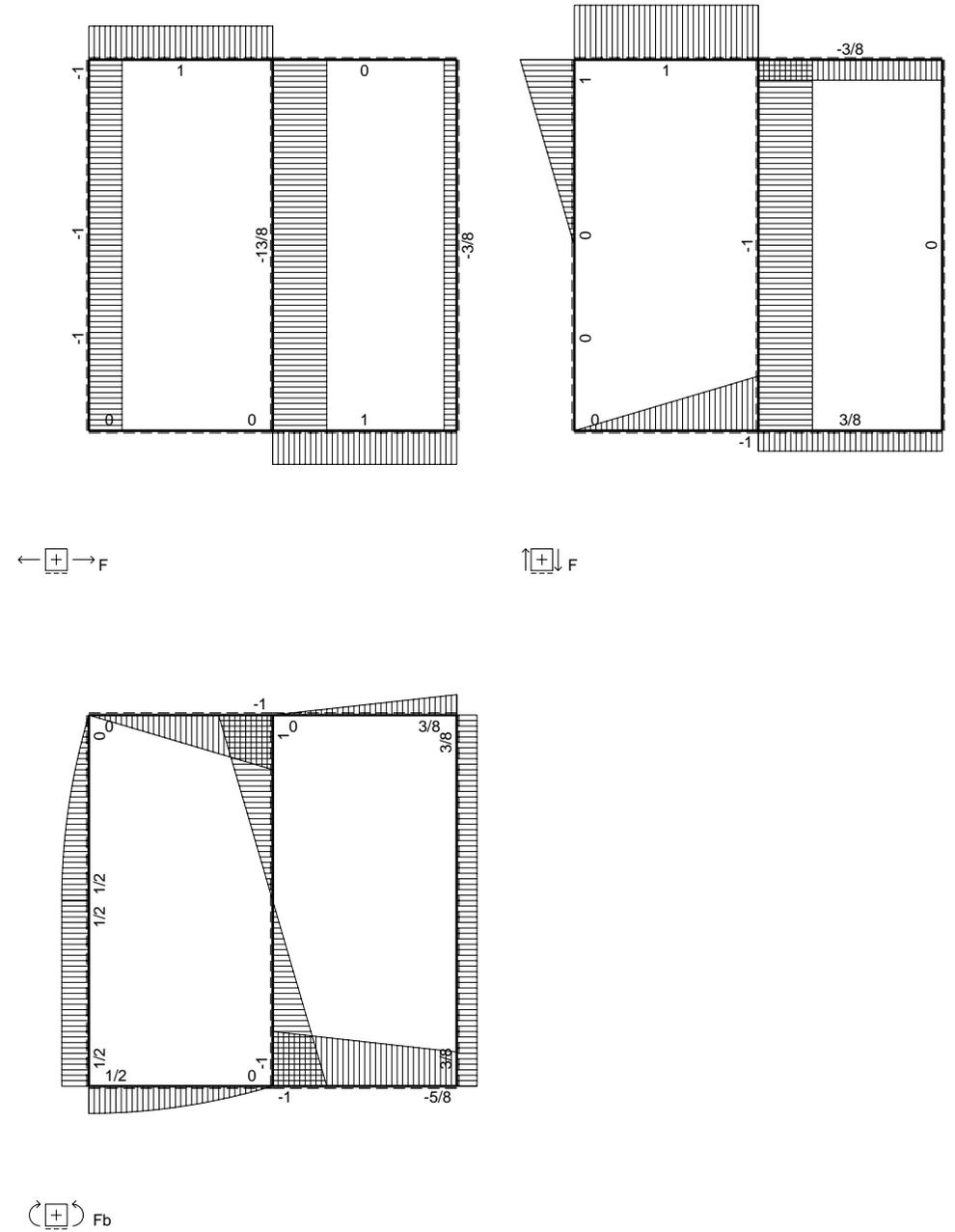
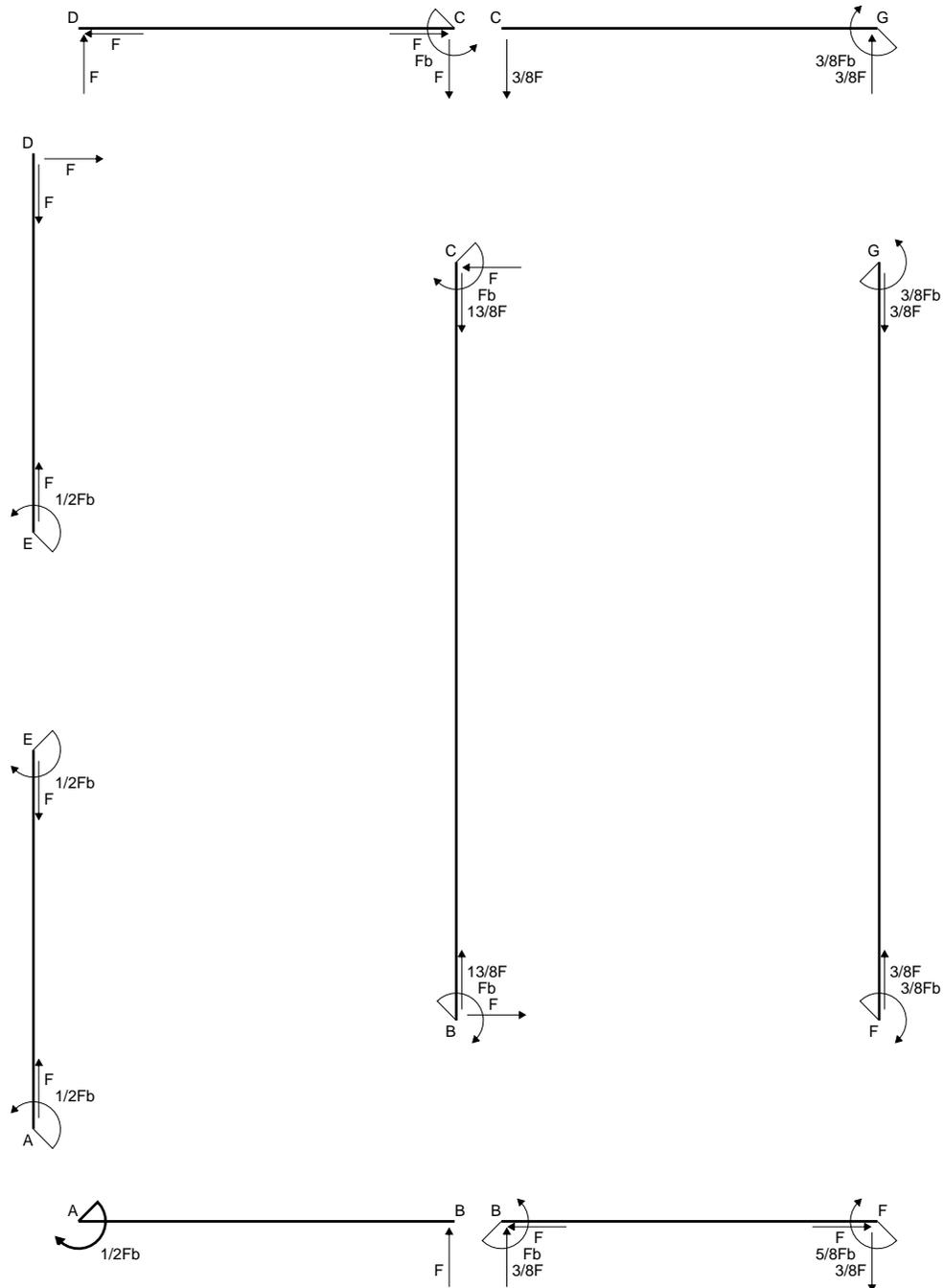
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

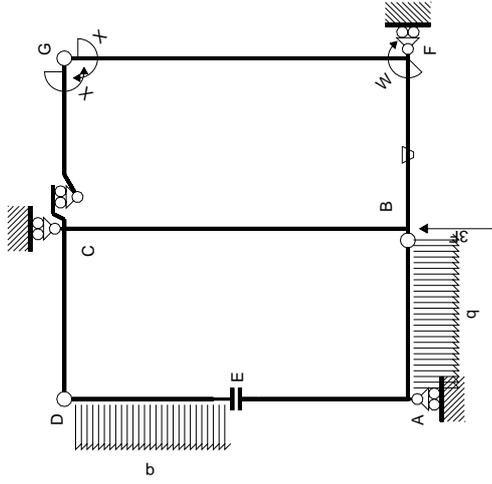
$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



- A = 708. mm<sup>2</sup>
- J<sub>u</sub> = 147634. mm<sup>4</sup>
- J<sub>v</sub> = 68652. mm<sup>4</sup>
- y<sub>g</sub> = 37.47 mm
- N = -3953. N
- T<sub>y</sub> = -3720. N
- M<sub>x</sub> = -762600. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -37.47 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = -199.1 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 16. mm
- v<sub>c</sub> = -21.47 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = -116.5 N/mm<sup>2</sup>
- τ<sub>c</sub> = 11.88 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 118.3 N/mm<sup>2</sup>
- S = 2829. mm<sup>3</sup>

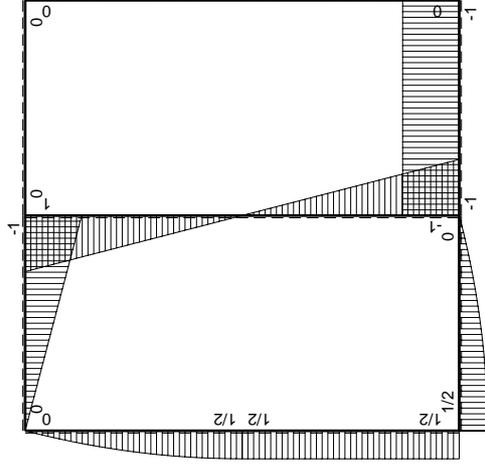






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	$1/2Fb-1/2qx^2$	0	0	0	0	0	0+0	0
BA b	$-Fx+1/2qx^2$	0	0	0	0	0	0+0	0
CD b	$-Fb+Fx$	0	0	0	0	0	0+0	0
DC b	$Fx$	0	0	0	0	0	0+0	0
DE b	$Fx-1/2qx^2$	0	0	0	0	0	0+0	0
ED b	$-1/2Fb+1/2qx^2$	0	0	0	0	0	0+0	0
EA b	$1/2Fb$	0	0	0	0	0	0+0	0
AE b	$-1/2Fb$	0	0	0	0	0	0+0	0
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb-Fx$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$1/3xb/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2xb/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2xb/EJ$
CB 2b	0	$Fb-Fx$	0	0	0	0	0+0	0
BC 2b	0	$Fb-Fx$	0	0	0	0	0+0	0
totali								$Fb^2/EJ$
								$8/3xb/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

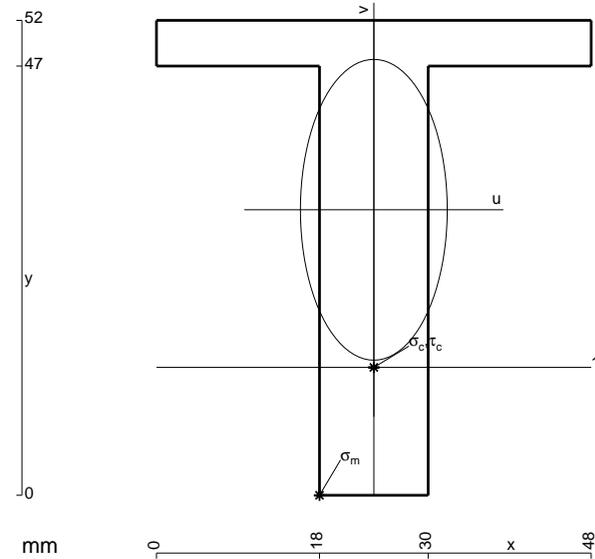
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



- A = 804. mm<sup>2</sup>
- J<sub>u</sub> = 218133. mm<sup>4</sup>
- J<sub>v</sub> = 52848. mm<sup>4</sup>
- y<sub>g</sub> = 31.26 mm
- N = -5119. N
- T<sub>y</sub> = -3150. N
- M<sub>x</sub> = -1417500. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -31.26 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = -209.5 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 14. mm
- v<sub>c</sub> = -17.26 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = -118.5 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.905 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 118.8 N/mm<sup>2</sup>
- S = 4076. mm<sup>3</sup>







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x\theta} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x\theta} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

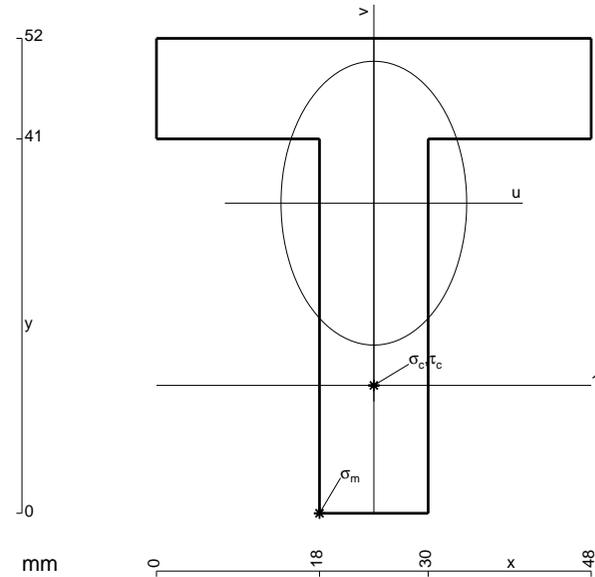
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x\theta} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

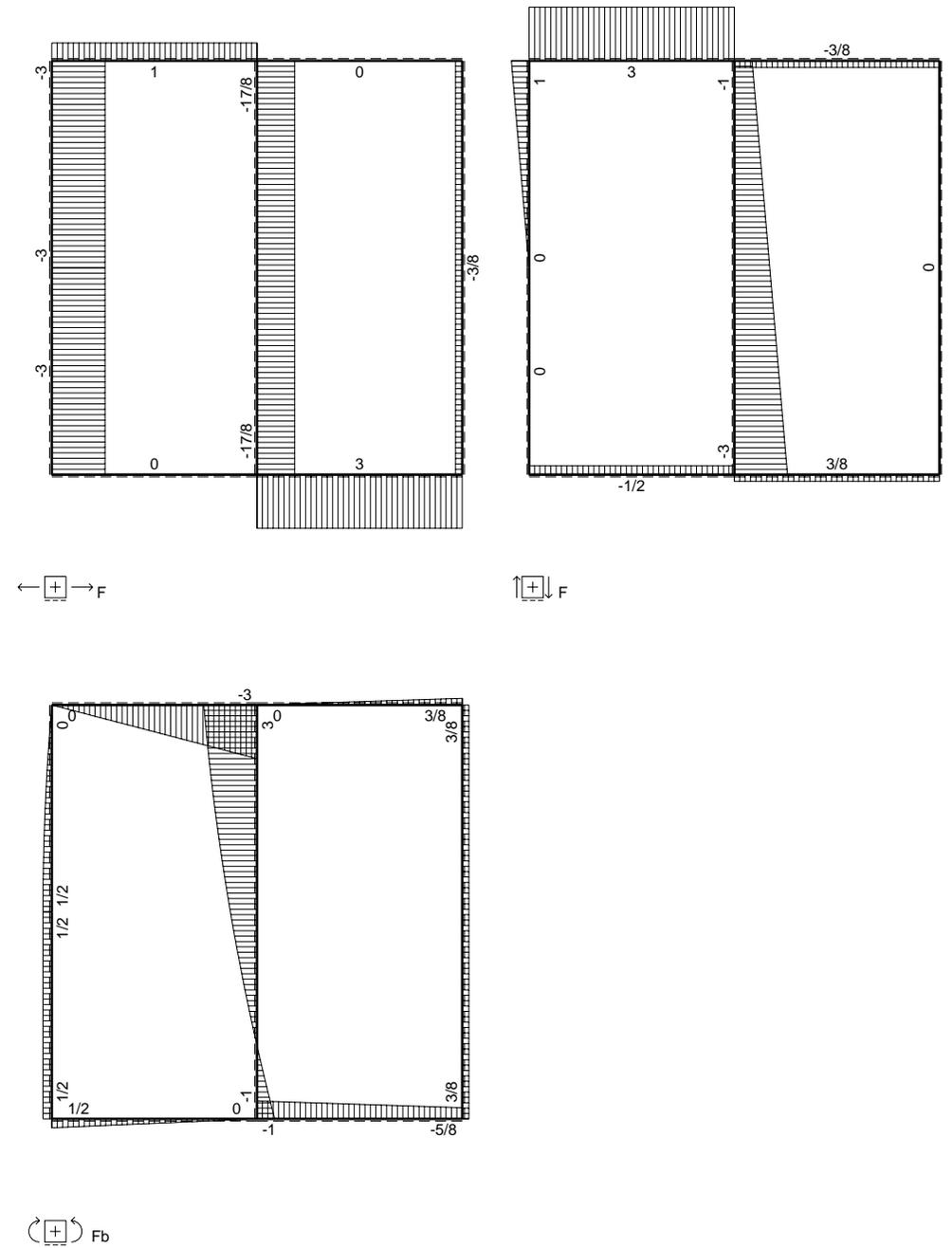
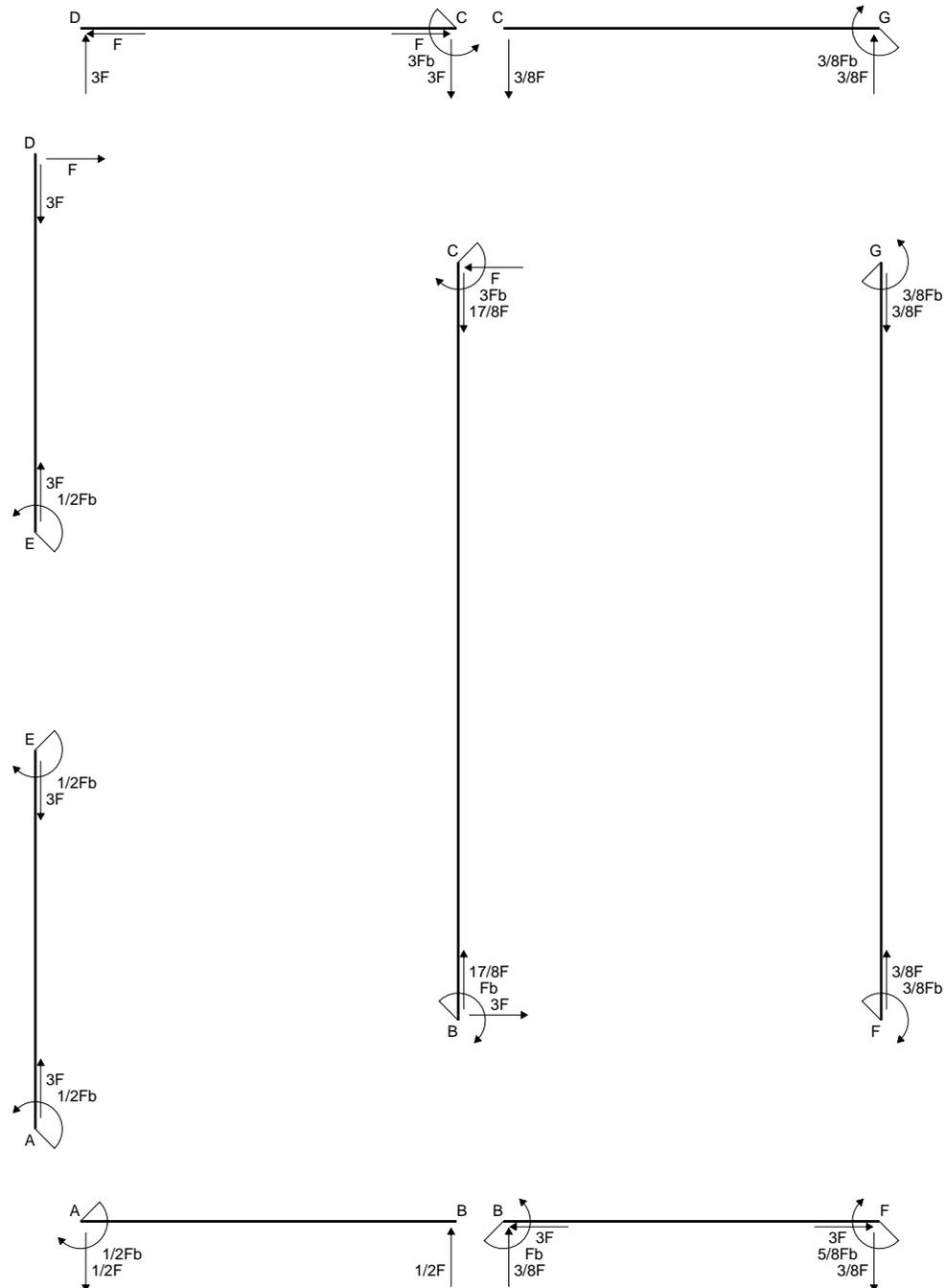
$$L_{GF}^{x\theta} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

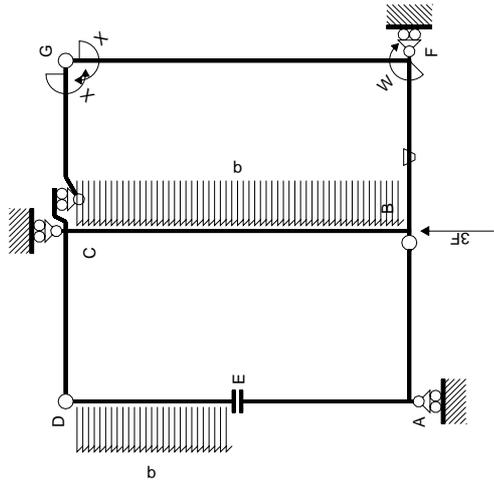
$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



- A = 1020. mm<sup>2</sup>
- J<sub>u</sub> = 246410. mm<sup>4</sup>
- J<sub>v</sub> = 107280. mm<sup>4</sup>
- y<sub>g</sub> = 33.96 mm
- N = 1090. N
- T<sub>y</sub> = 3270. N
- M<sub>x</sub> = -1602300. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -33.96 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = -219.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 14. mm
- v<sub>c</sub> = -19.96 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = -128.7 N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.009 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 129. N/mm<sup>2</sup>
- S = 4529. mm<sup>3</sup>

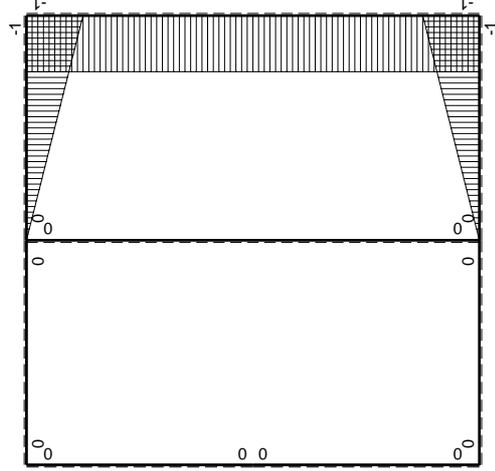
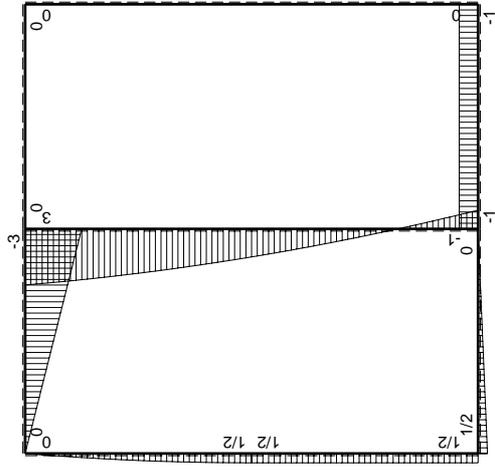






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / EJ dx$
AB b	0	$1/2Fb - 1/2Fx$	0	0	0	0	0+0	0
BA b	0	$-1/2Fx$	0	0	0	0	0+0	0
CD b	0	$-3Fb + 3Fx$	0	0	0	0	0+0	0
DC b	0	$3Fx$	0	0	0	0	0+0	0
DE b	0	$Fx - 1/2qx^2$	0	0	0	0	0+0	0
ED b	0	$-1/2Fb + 1/2qx^2$	0	0	0	0	0+0	0
EA b	0	$1/2Fb$	0	0	0	0	0+0	0
AE b	0	$-1/2Fb$	0	0	0	0	0+0	0
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2 + 1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb - Fx$	$Fb/EJ - Fx/EJ$	$1 - 2x/b + x^2/b^2$	$1/3xb/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	0	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	0	0+0	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	0	0+0	$2xb/EJ$
GF 2b	1	0	0	0	0	0	0+0	$2xb/EJ$
CB 2b	0	$3Fb - Fx - 1/2qx^2$	0	0	0	0	0+0	0
BC 2b	0	$Fb - 3Fx + 1/2qx^2$	0	0	0	0	0+0	0
totali								$Fb^2/EJ$
								$8/3xb/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

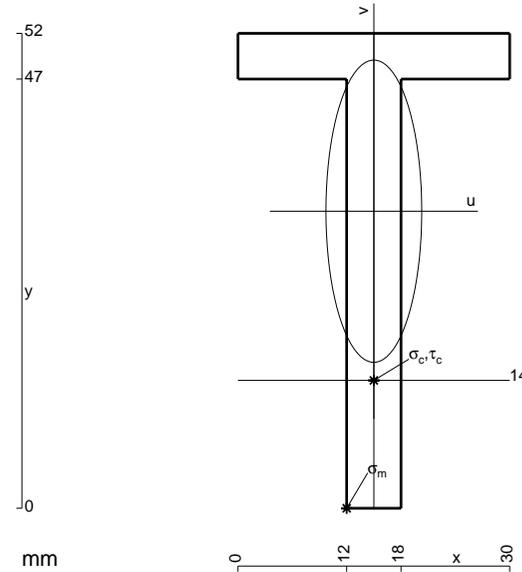
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

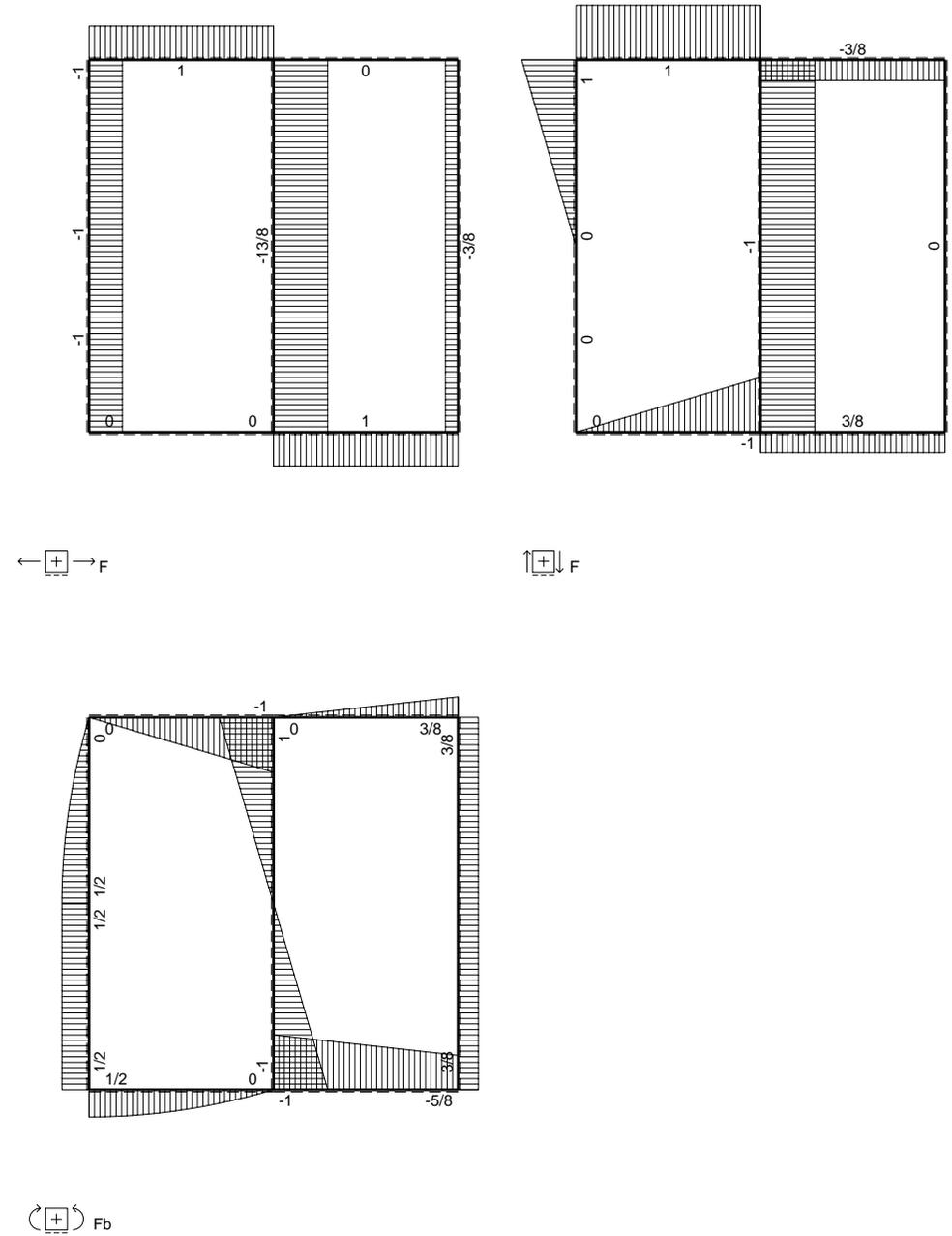
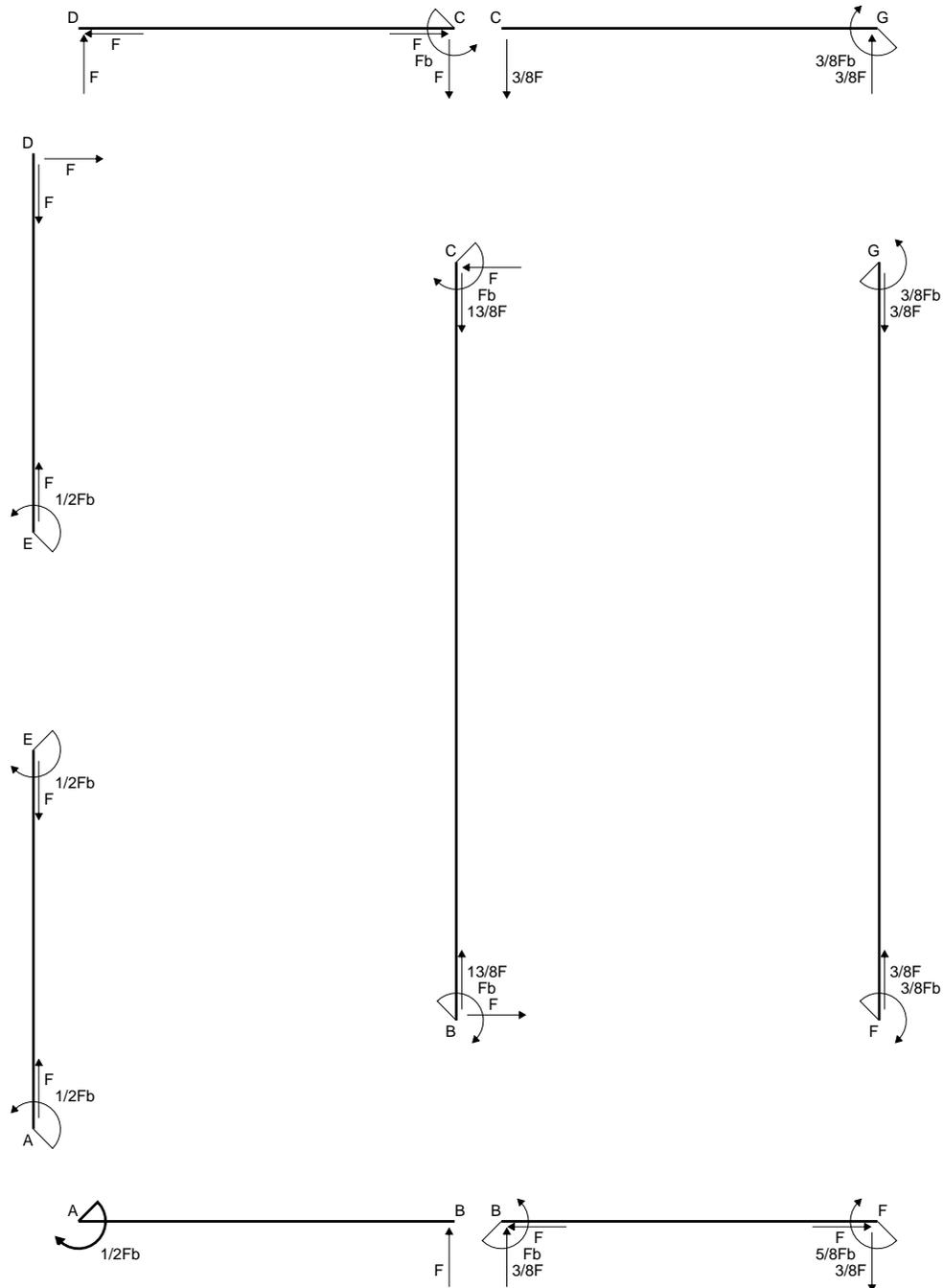
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

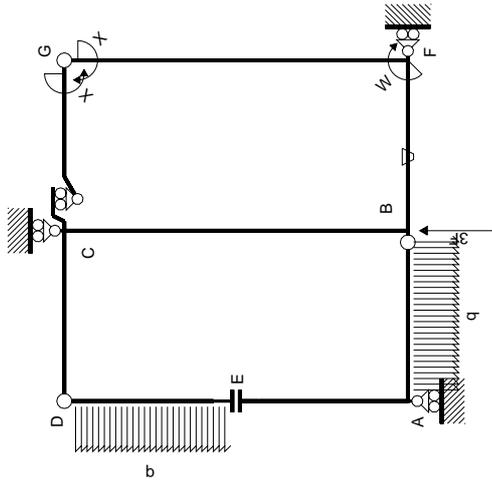
$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



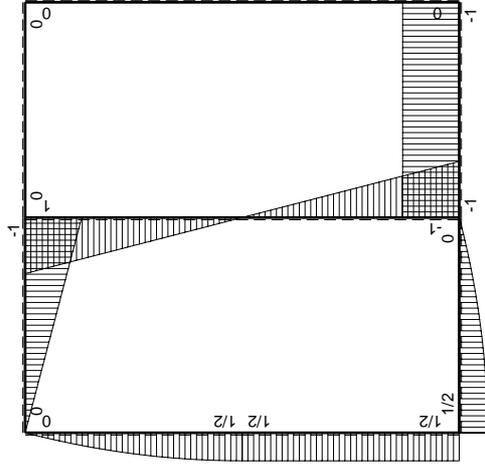
- A = 432. mm<sup>2</sup>
- J<sub>u</sub> = 118416. mm<sup>4</sup>
- J<sub>v</sub> = 12096. mm<sup>4</sup>
- y<sub>g</sub> = 32.53 mm
- N = 520. N
- T<sub>y</sub> = 1560. N
- M<sub>x</sub> = -826800. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -32.53 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = -225.9 N/mm<sup>2</sup>
- x<sub>c</sub> = 15. mm
- y<sub>c</sub> = 14. mm
- v<sub>c</sub> = -18.53 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = -128.2 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.708 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 128.4 N/mm<sup>2</sup>
- S = 2144. mm<sup>3</sup>



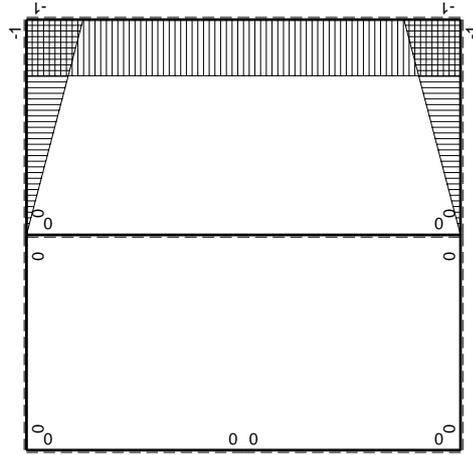




Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	$1/2Fb-1/2qx^2$	0	0	0	0	0	0+0	0
BA b	$-Fx+1/2qx^2$	0	0	0	0	0	0+0	0
CD b	$-Fb+Fx$	0	0	0	0	0	0+0	0
DC b	$Fx$	0	0	0	0	0	0+0	0
DE b	$Fx-1/2qx^2$	0	0	0	0	0	0+0	0
ED b	$-1/2Fb+1/2qx^2$	0	0	0	0	0	0+0	0
EA b	$1/2Fb$	0	0	0	0	0	0+0	0
AE b	$-1/2Fb$	0	0	0	0	0	0+0	0
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb-Fx$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2xb/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2xb/EJ$
CB 2b	0	$Fb-Fx$	0	0	0	0	0+0	0
BC 2b	0	$Fb-Fx$	0	0	0	0	0+0	0
totali								$Fb^2/EJ$
								$8/3xb/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

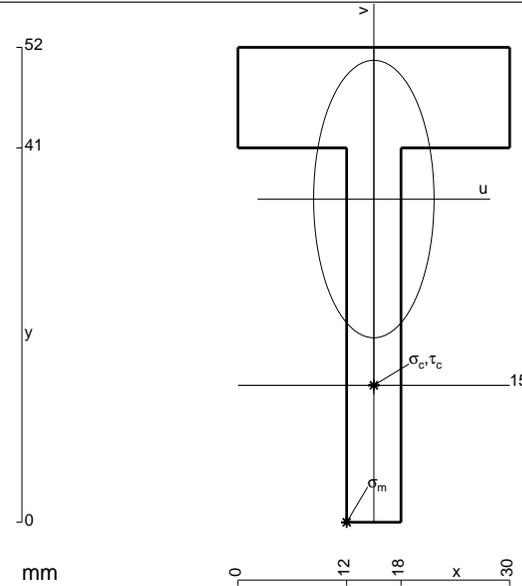
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

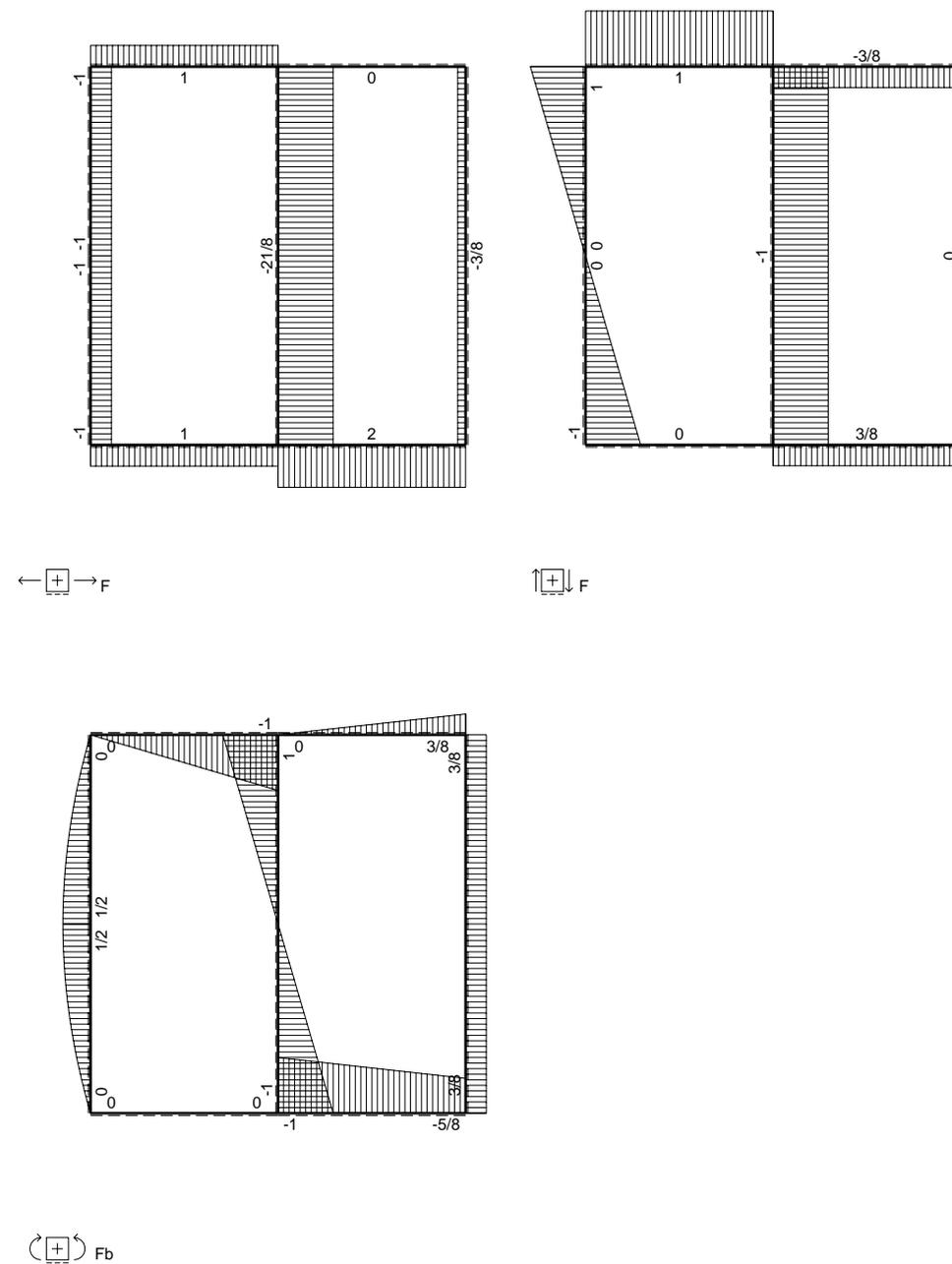
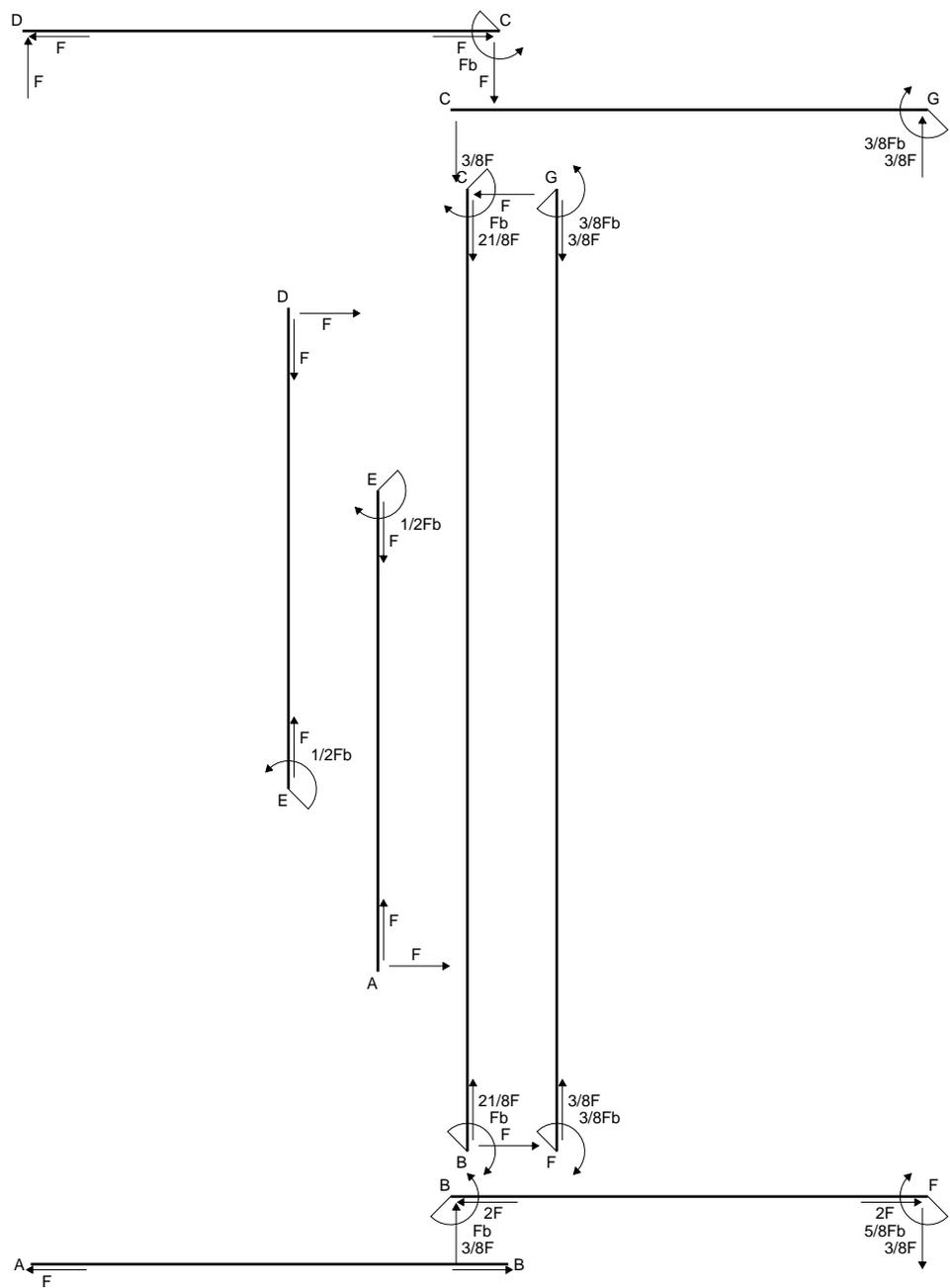
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

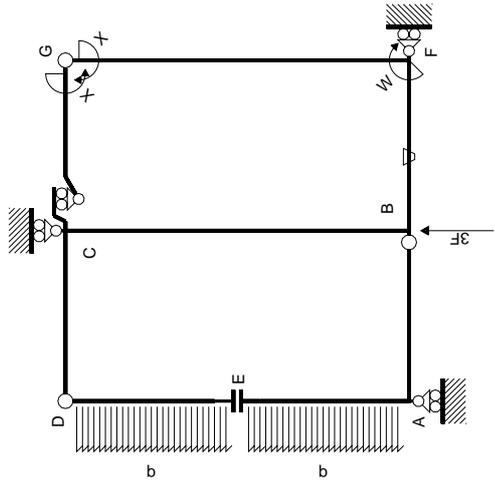
$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



- A = 576. mm<sup>2</sup>
- J<sub>u</sub> = 133062. mm<sup>4</sup>
- J<sub>v</sub> = 25488. mm<sup>4</sup>
- y<sub>g</sub> = 35.4 mm
- N = -2519. N
- T<sub>y</sub> = -1550. N
- M<sub>x</sub> = -883500. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -35.4 mm
- σ<sub>m</sub> = N/A - M<sub>v</sub>/J<sub>u</sub> = -239.4 N/mm<sup>2</sup>
- x<sub>c</sub> = 15. mm
- y<sub>c</sub> = 15. mm
- v<sub>c</sub> = -20.4 mm
- σ<sub>c</sub> = N/A - M<sub>v</sub>/J<sub>u</sub> = -139.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.874 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 140.1 N/mm<sup>2</sup>
- S = 2511. mm<sup>3</sup>

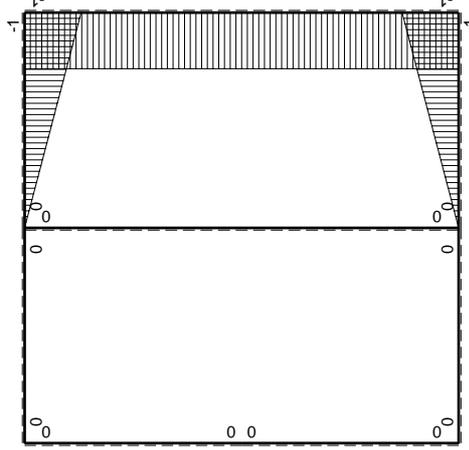
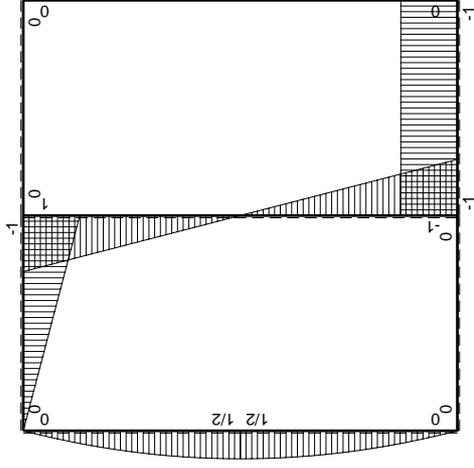






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / EJ dx$
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0+0	0
CD b	0	-Fb+Fx	0	0	0	0	0+0	0
DC b	0	Fx	0	0	0	0	0+0	0
DE b	0	Fx-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
ED b	0	-1/2Fb+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
EA b	0	1/2Fb-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
AE b	0	-Fx+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
BF b	-x/b	-Fb	-Fb/EJ	Fx	Fx/EJ	$x^2/b^2$	$(1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	1-x/b	Fb	Fb/EJ	Fb-Fx	Fb/EJ-Fx/EJ	$1-2x/b+x^2/b^2$	$1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
GC b	-1+x/b	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	x/b	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2xb/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2xb/EJ$
CB 2b	0	Fb-Fx	0	0	0	0	0+0	0
BC 2b	0	Fb-Fx	0	0	0	0	0+0	0
totali								$8/3xb/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

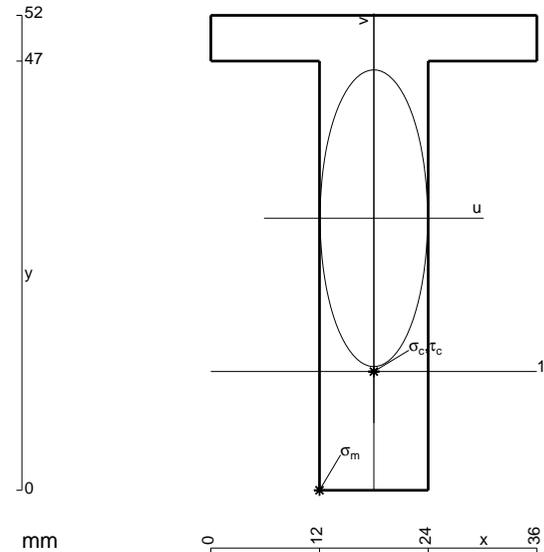
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

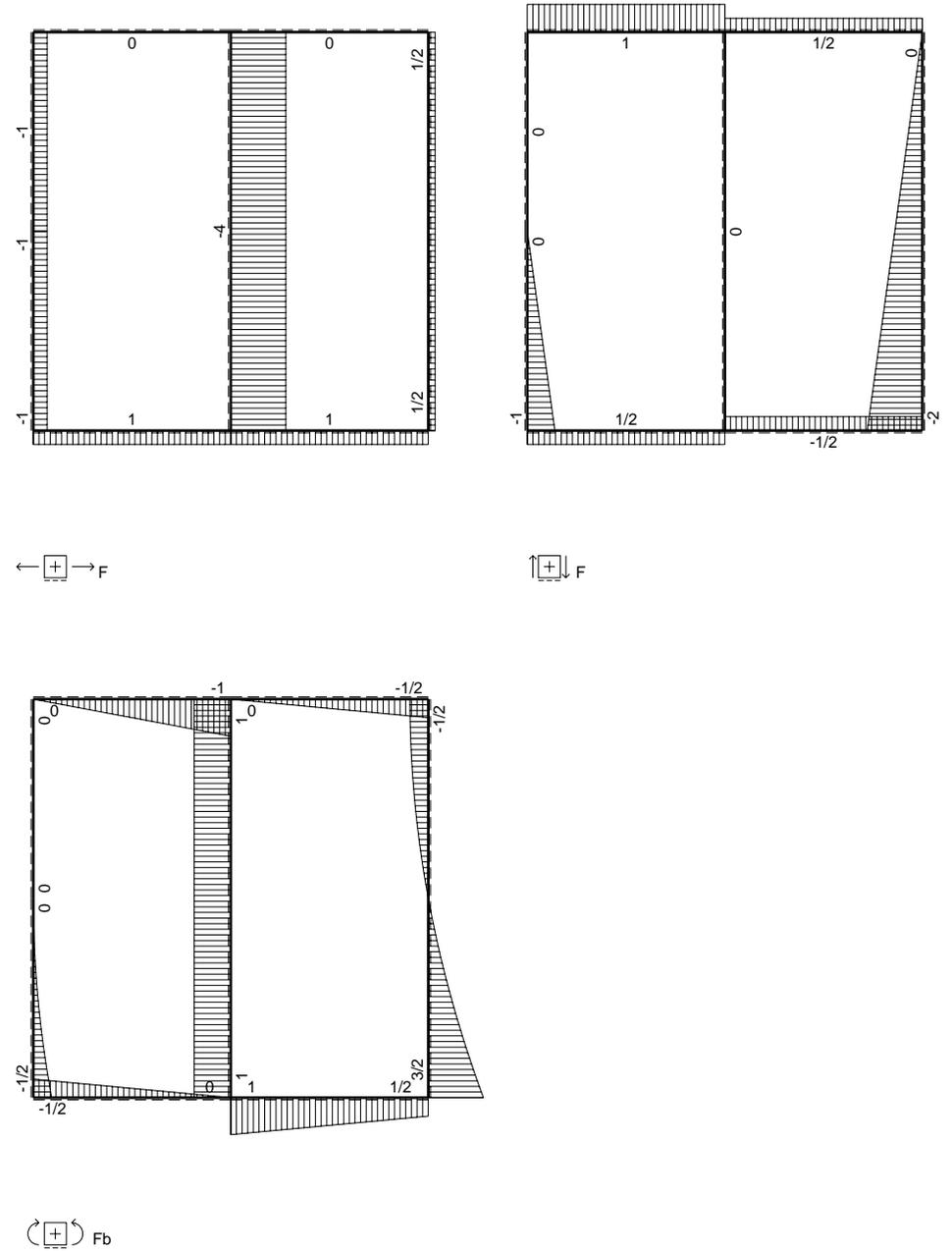
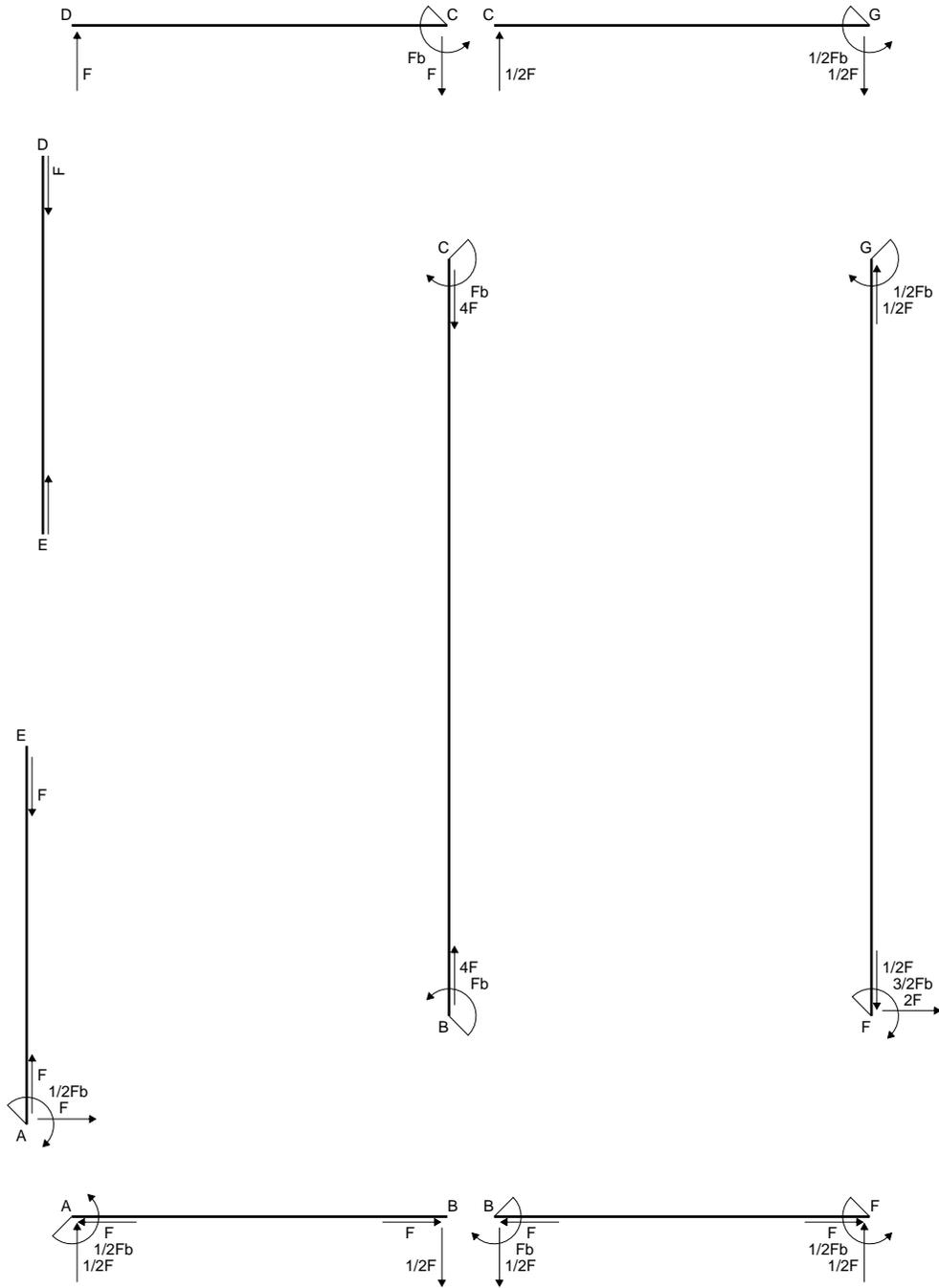
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

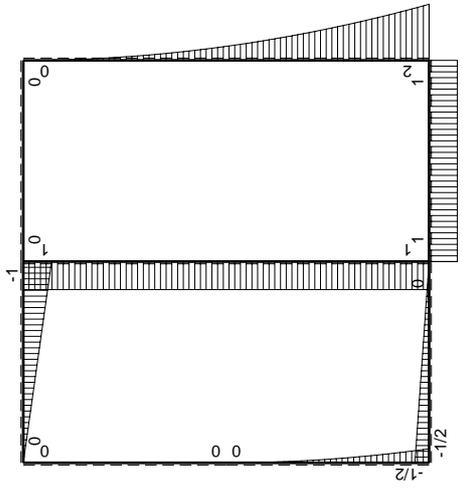
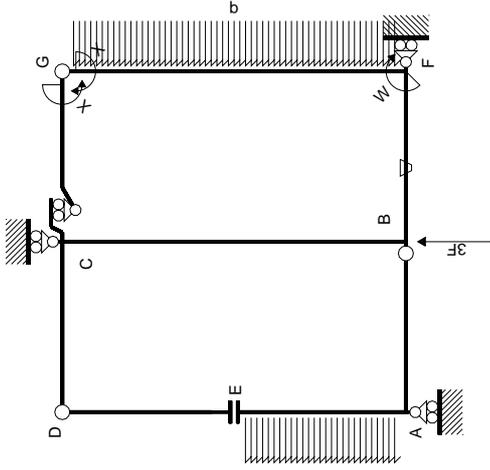
$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



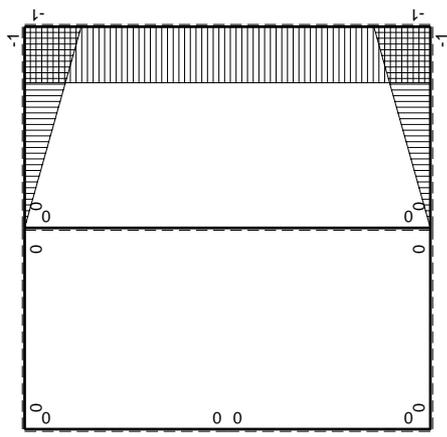
- A = 744. mm<sup>2</sup>
- J<sub>u</sub> = 196439. mm<sup>4</sup>
- J<sub>v</sub> = 26208. mm<sup>4</sup>
- y<sub>g</sub> = 29.79 mm
- N = -5460. N
- T<sub>y</sub> = -2080. N
- M<sub>x</sub> = -1268800. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -29.79 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = -199.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 13. mm
- v<sub>c</sub> = -16.79 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = -115.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.206 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 115.9 N/mm<sup>2</sup>
- S = 3633. mm<sup>3</sup>







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica $X=W_{gc}$		$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x (M_0/EJ + \theta) dx$	$\int M^x M_x / E dx$	
AB b	0	$-1/2Fb + 1/2Fx$	0	0	0	0	0	0	0	
BA b	0	$1/2Fx$	0	0	0	0	0	0	0	
CD b	0	$-Fb + Fx$	0	0	0	0	0	0	0	
DC b	0	$Fx$	0	0	0	0	0	0	0	
DE b	0	0	0	0	0	0	0	0	0	
ED b	0	0	0	0	0	0	0	0	0	
EA b	0	$-1/2qx^2$	0	0	0	0	0	0	0	
AE b	0	$1/2Fb - Fx + 1/2qx^2$	0	0	0	0	0	0	0	
BF b	$-x/b$	$Fb$	$-Fb/EJ$	$-Fx/EJ$	$-Fx$	$Fx/EJ$	$x^2/b^2$	$-1/2 + 1/2 Fb^2/EJ$	$1/3xb/EJ$	
FB b	$1-x/b$	$-Fb$	$Fb/EJ$	$-Fb + Fx$	$-Fb + Fx$	$Fb/EJ - Fx/EJ$	$1 - 2x/b + x^2/b^2$	$-1/2 + 1/2 Fb^2/EJ$	$1/3xb/EJ$	
GC b	$-1+x/b$	0	0	0	0	0	$1 - 2x/b + x^2/b^2$	0	$1/3xb/EJ$	
CG b	$x/b$	0	0	0	0	0	$x^2/b^2$	0	$1/3xb/EJ$	
FG 2b	-1	$2Fb - 2Fx + 1/2qx^2$	0	0	$-2Fb + 2Fx - 1/2Fx^2/b$	0	1	$(-4/3 + 0)Fb^2/EJ$	$2xb/EJ$	
GF 2b	1	$-1/2qx^2$	0	0	$-1/2Fx^2/b$	0	1	$(-4/3 + 0)Fb^2/EJ$	$2xb/EJ$	
CB 2b	0	$Fb$	0	0	0	0	0	0	0	
BC 2b	0	$-Fb$	0	0	0	0	0	0	0	
totali								$-4/3Fb^2/EJ$	$8/3xb/EJ$	
		iperstatica $X=W_{gc}$								

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x\theta} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x\theta} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

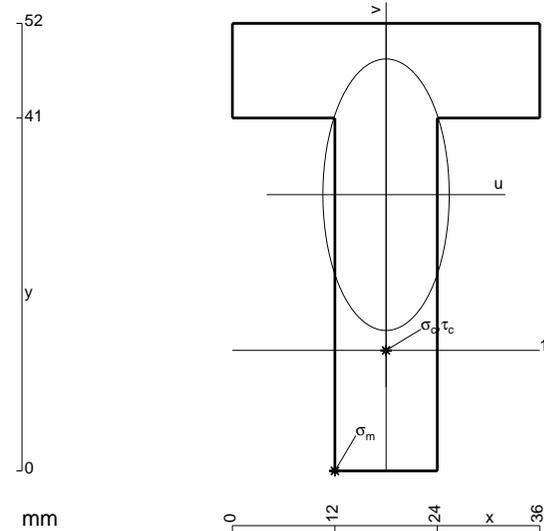
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x\theta} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

$$L_{GF}^{x\theta} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



$$A = 888. \text{ mm}^2$$

$$J_u = 221232. \text{ mm}^4$$

$$J_v = 48672. \text{ mm}^4$$

$$y_g = 32.09 \text{ mm}$$

$$T_y = 2220. \text{ N}$$

$$M_x = -1443000. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -6. \text{ mm}$$

$$v_m = -32.09 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -209.3 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 14. \text{ mm}$$

$$v_c = -18.09 \text{ mm}$$

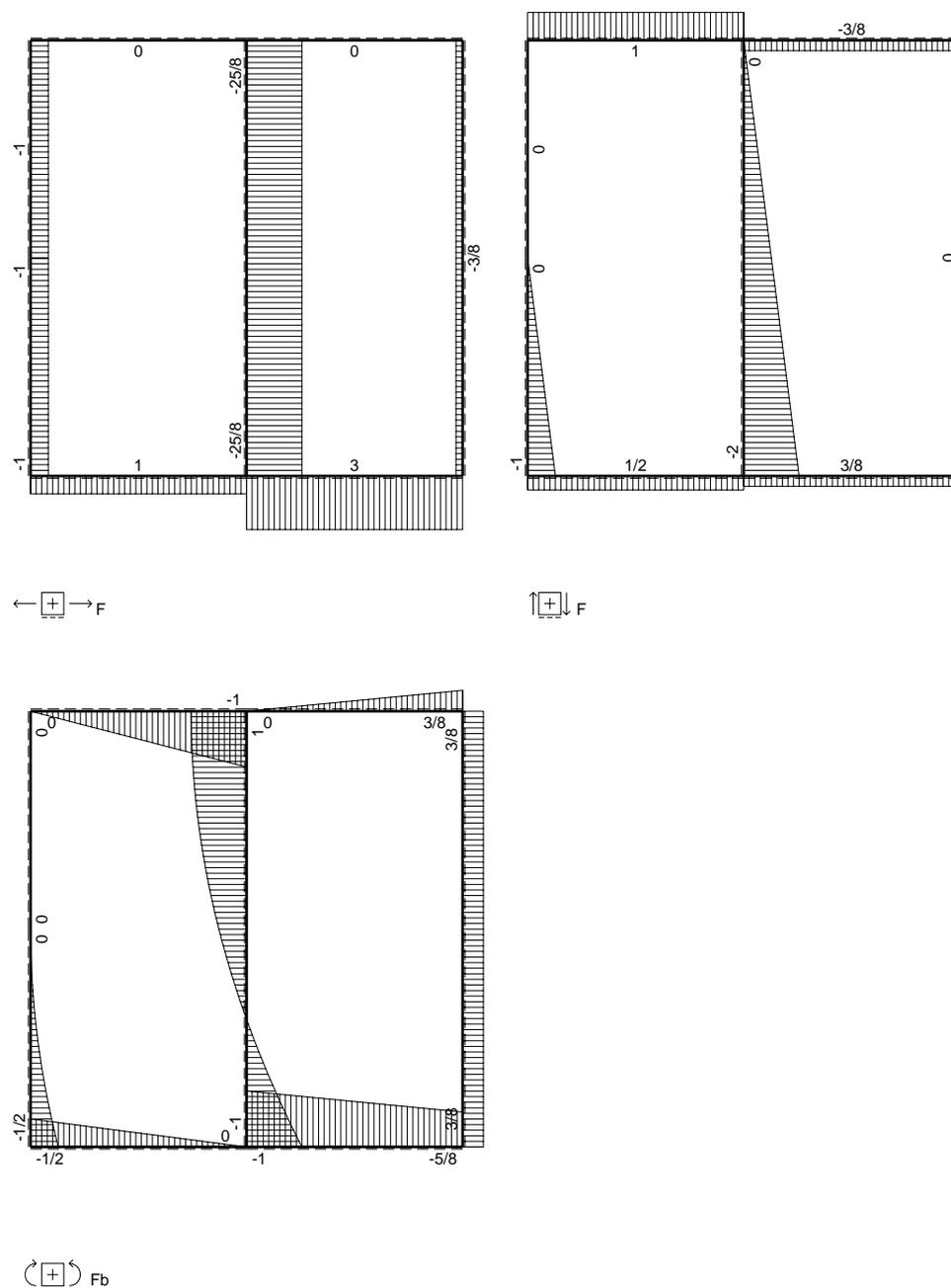
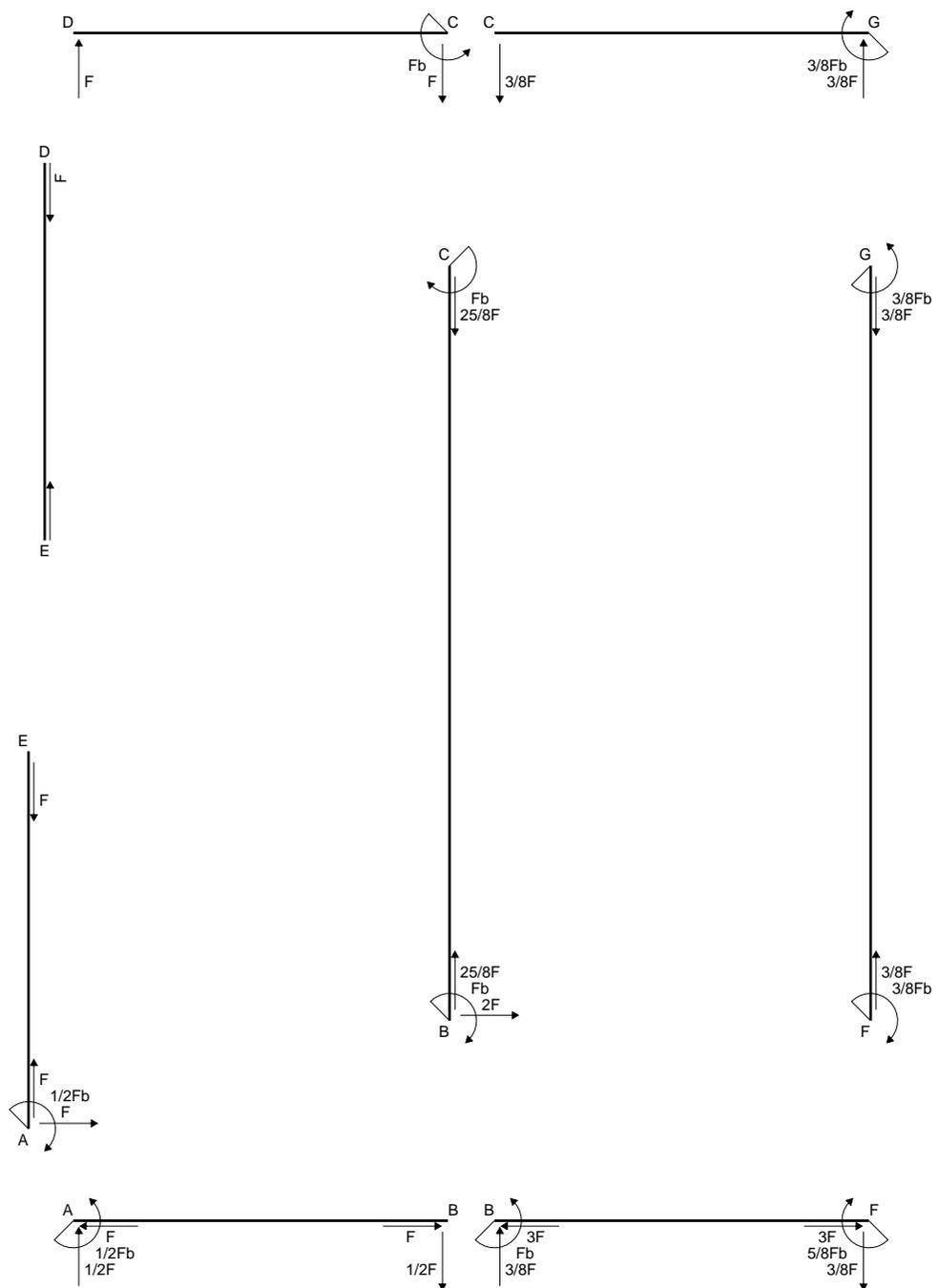
$$\sigma_c = -Mv/J_u = -118. \text{ N/mm}^2$$

$$\tau_c = 3.525 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 118.2 \text{ N/mm}^2$$

$$S = 4216. \text{ mm}^3$$







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

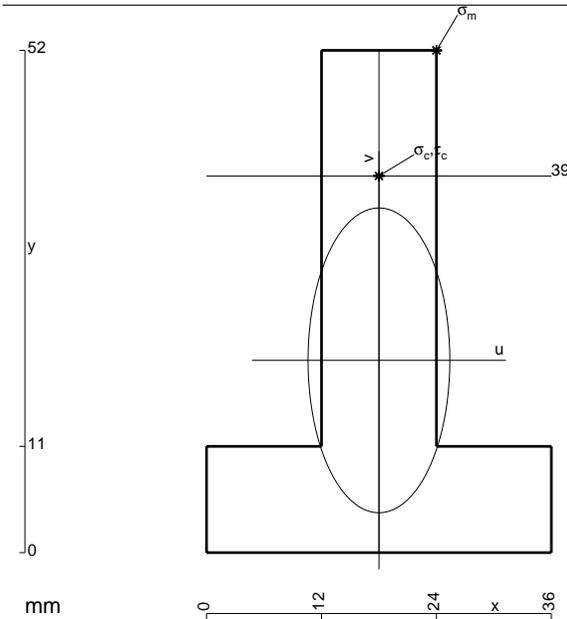
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



$$A = 888. \text{ mm}^2$$

$$J_u = 221232. \text{ mm}^4$$

$$J_v = 48672. \text{ mm}^4$$

$$y_g = 19.91 \text{ mm}$$

$$N = -7094. \text{ N}$$

$$T_y = -4540. \text{ N}$$

$$M_x = -1566300. \text{ Nmm}$$

$$x_m = 24. \text{ mm}$$

$$y_m = 52. \text{ mm}$$

$$u_m = 6. \text{ mm}$$

$$v_m = 32.09 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 219.2 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 39. \text{ mm}$$

$$v_c = 19.09 \text{ mm}$$

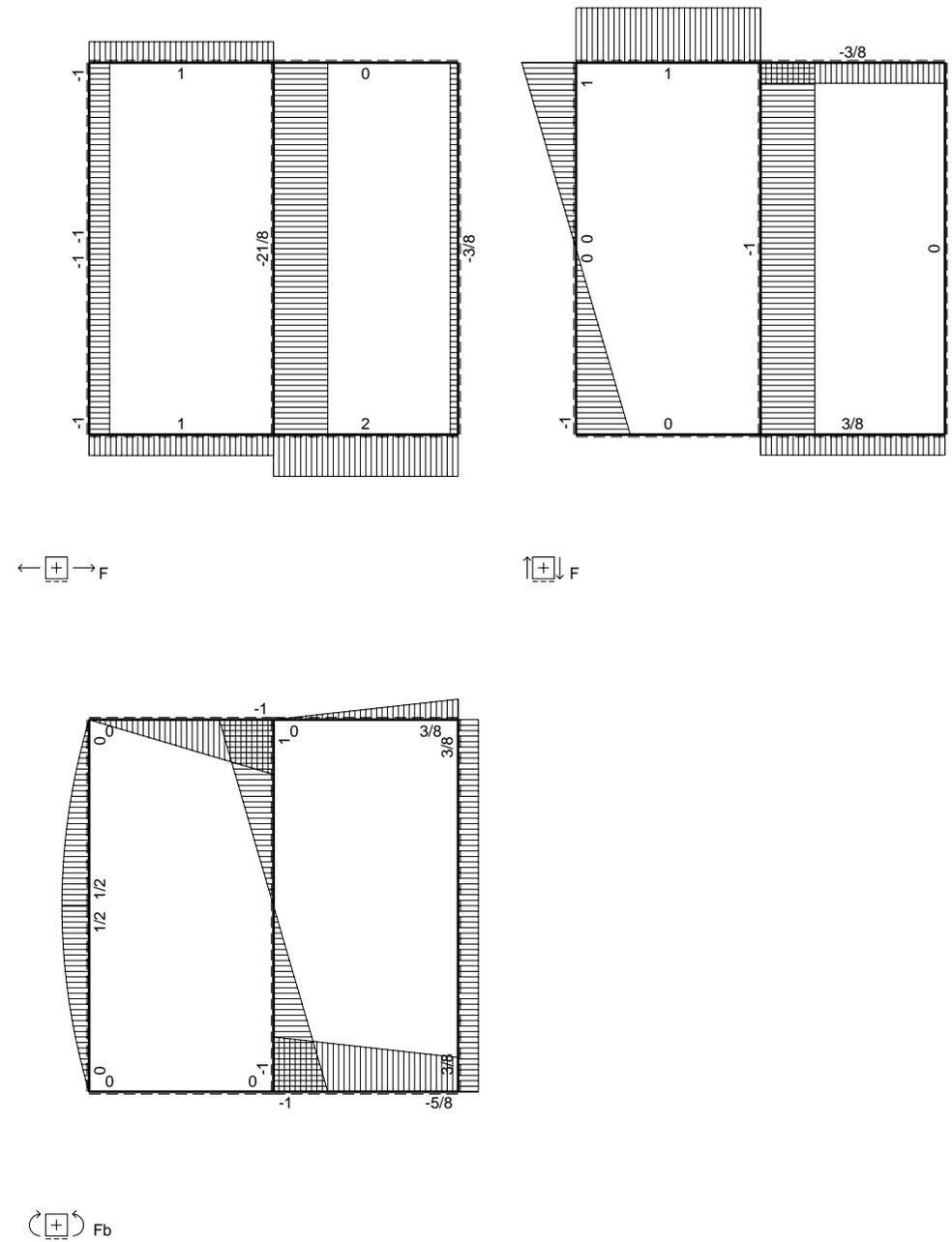
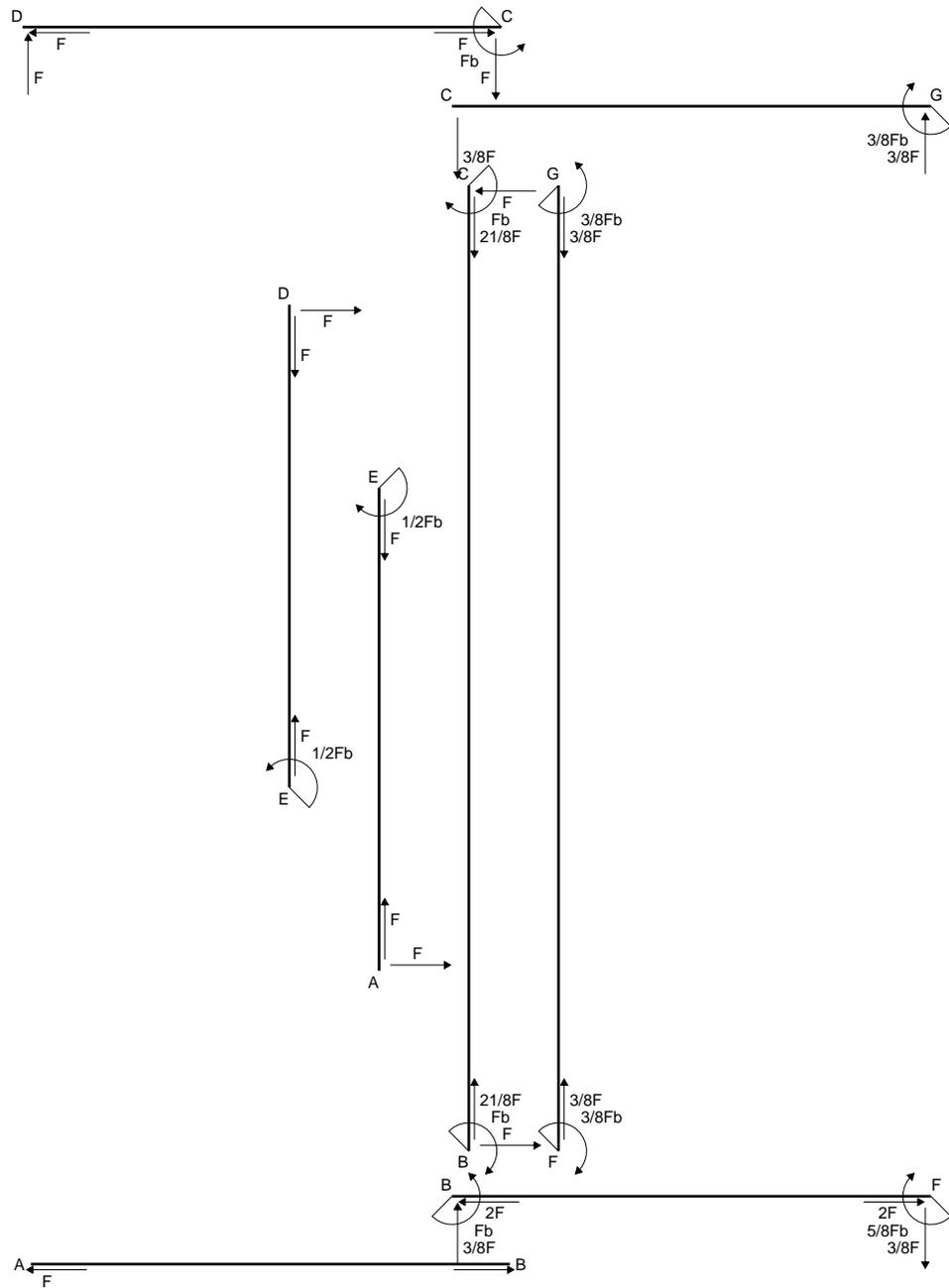
$$\sigma_c = N/A - Mv/J_u = 127.2 \text{ N/mm}^2$$

$$\tau_c = 6.828 \text{ N/mm}^2$$

$$\sigma_\varrho = \sqrt{\sigma^2 + 3\tau^2} = 127.7 \text{ N/mm}^2$$

$$S = 3993. \text{ mm}^3$$







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

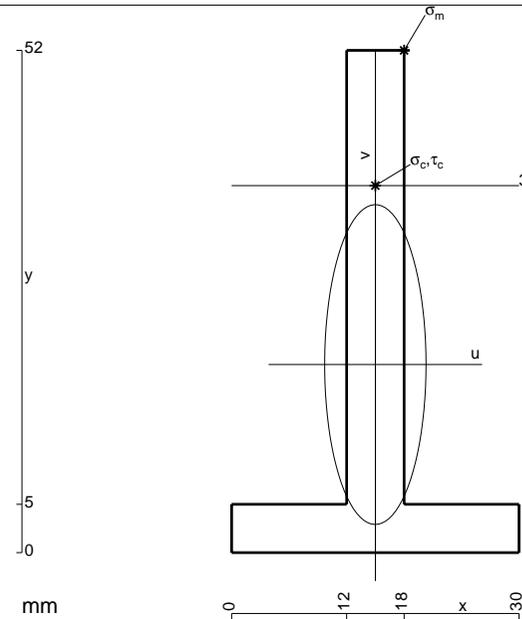
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



$$A = 432. \text{ mm}^2$$

$$J_u = 118416. \text{ mm}^4$$

$$J_v = 12096. \text{ mm}^4$$

$$y_g = 19.47 \text{ mm}$$

$$N = -2914. \text{ N}$$

$$T_y = -1110. \text{ N}$$

$$M_x = 810300. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$y_m = 52. \text{ mm}$$

$$u_m = 3. \text{ mm}$$

$$v_m = 32.53 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -229.3 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 38. \text{ mm}$$

$$v_c = 18.53 \text{ mm}$$

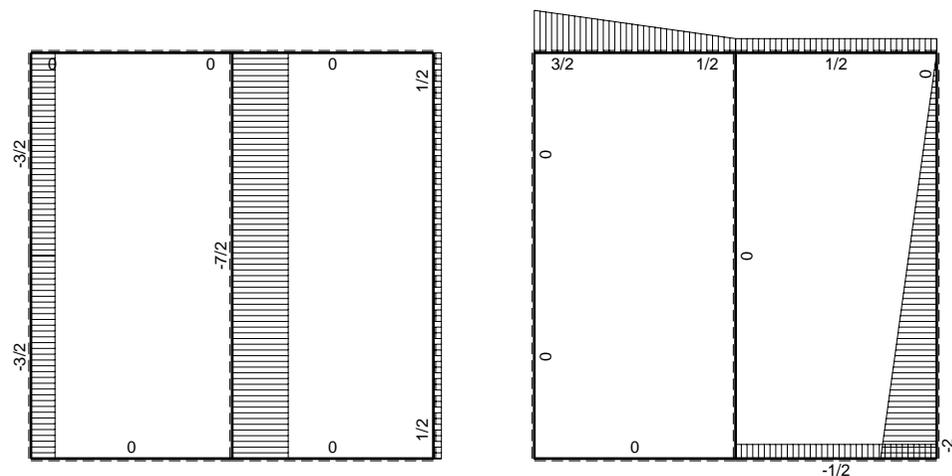
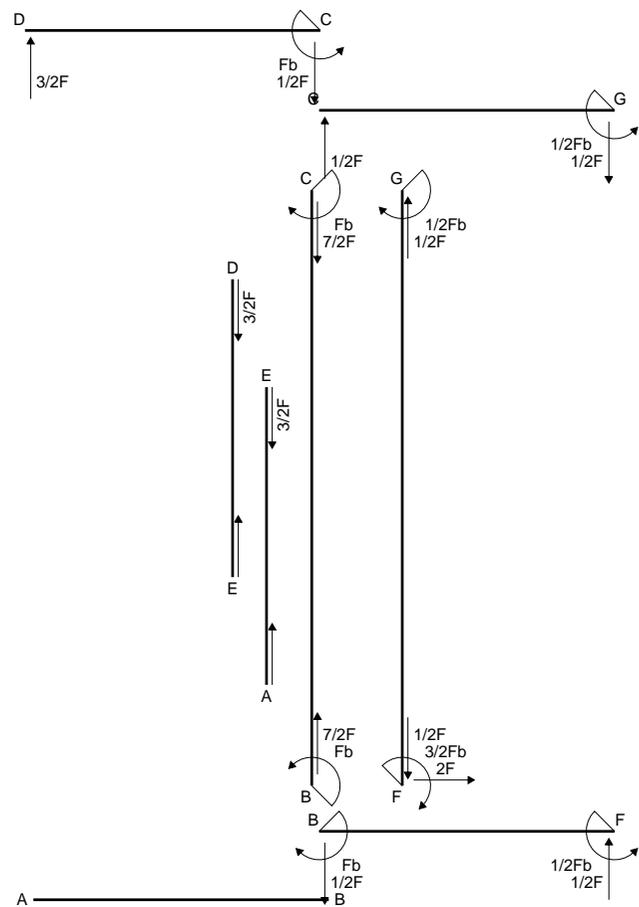
$$\sigma_c = N/A - Mv/J_u = -133.5 \text{ N/mm}^2$$

$$\tau_c = 3.35 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 133.7 \text{ N/mm}^2$$

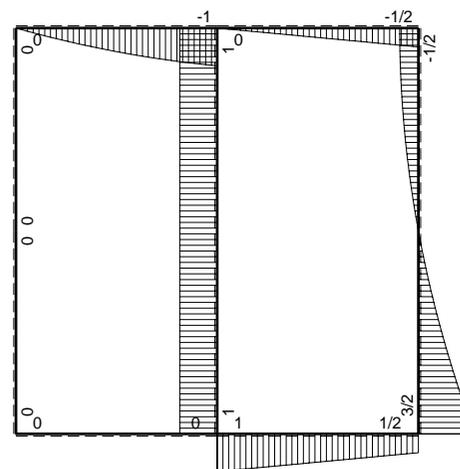
$$S = 2144. \text{ mm}^3$$





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⊕ Fb



$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x\theta} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x\theta} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

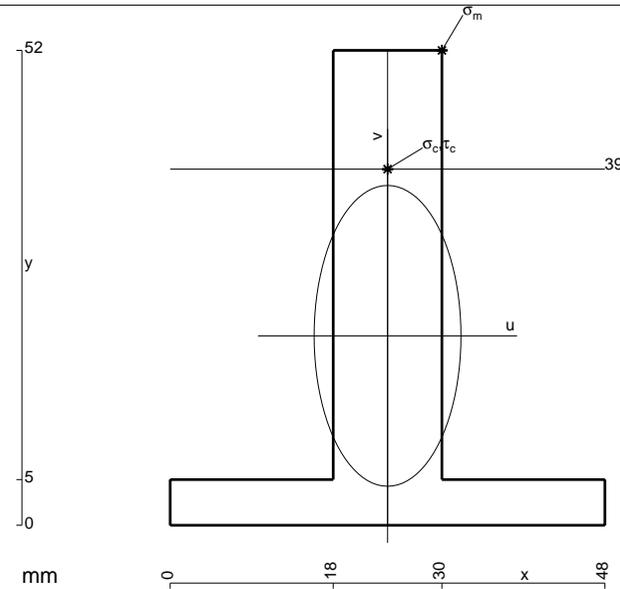
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x\theta} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

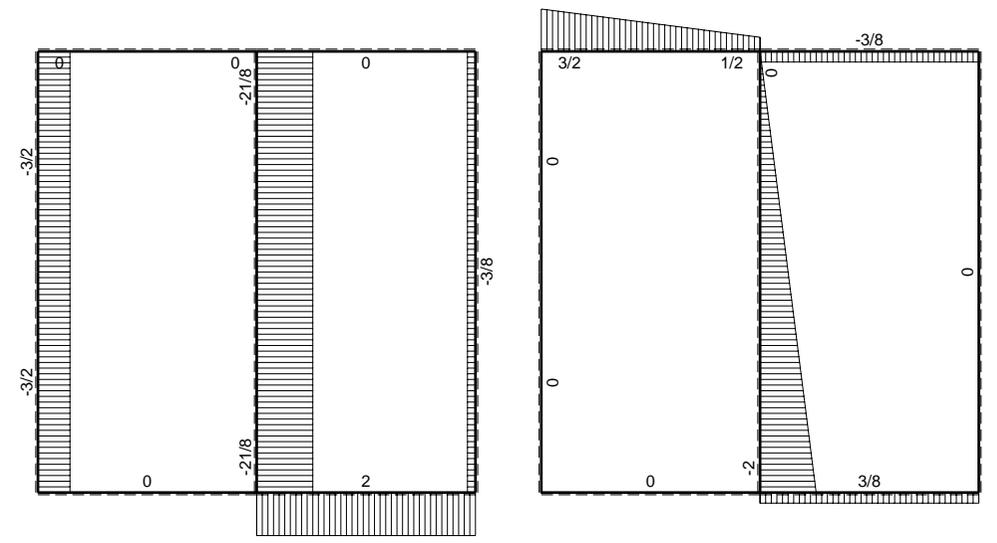
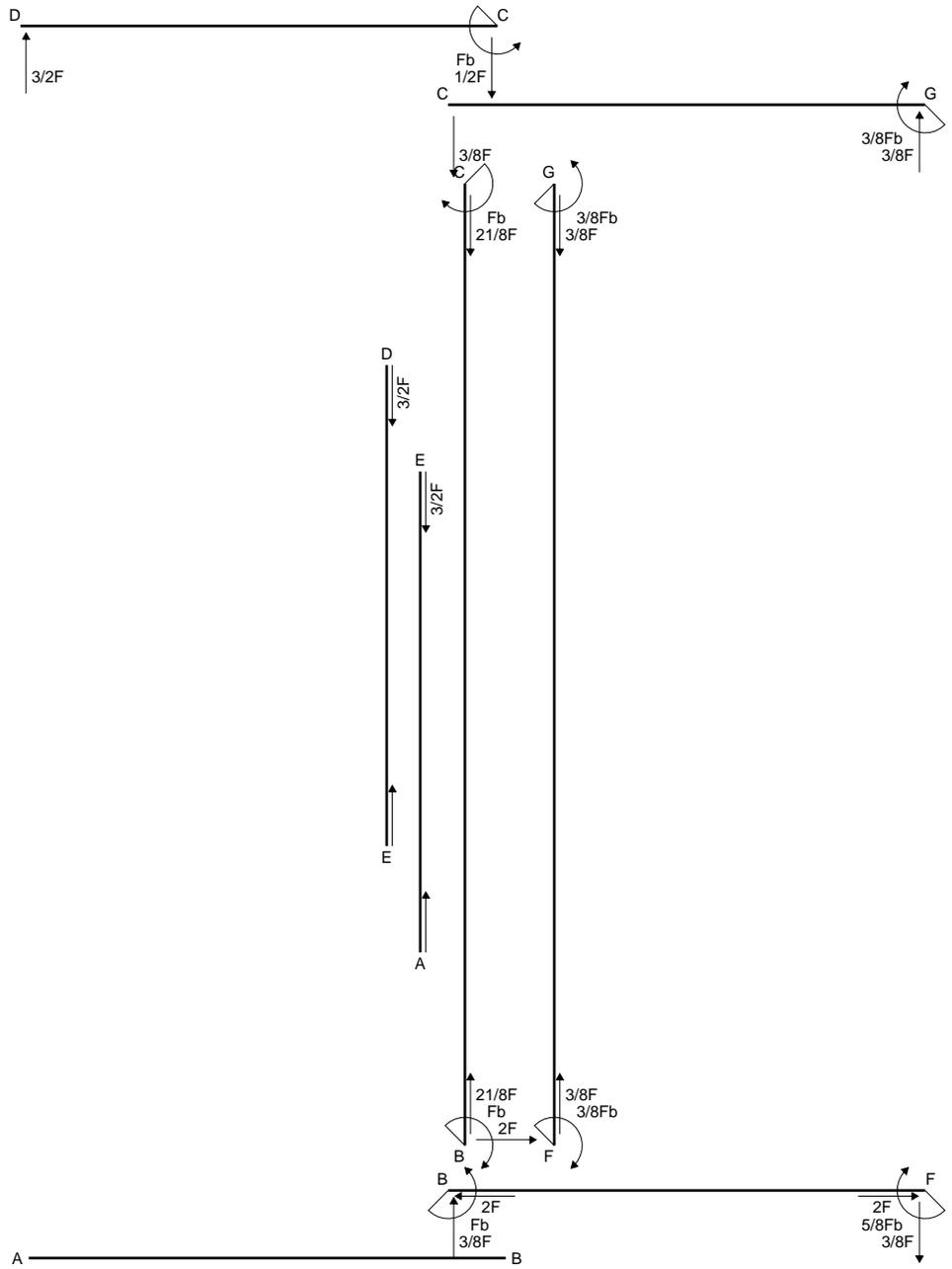
$$L_{GF}^{x\theta} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



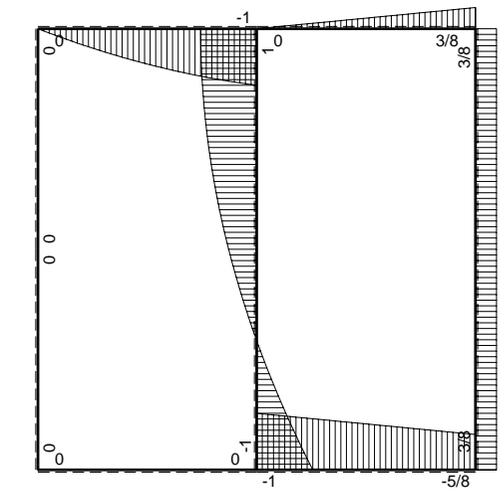
- A = 804. mm<sup>2</sup>
- J<sub>u</sub> = 218133. mm<sup>4</sup>
- J<sub>v</sub> = 52848. mm<sup>4</sup>
- y<sub>g</sub> = 20.74 mm
- T<sub>y</sub> = 3470. N
- M<sub>x</sub> = -1669940. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 52. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 31.26 mm
- σ<sub>c</sub> = -M<sub>v</sub>/J<sub>u</sub> = 239.3 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 39. mm
- v<sub>c</sub> = 18.26 mm
- σ<sub>c</sub> = -M<sub>v</sub>/J<sub>u</sub> = 139.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.121 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 140.1 N/mm<sup>2</sup>
- S = 3863. mm<sup>3</sup>



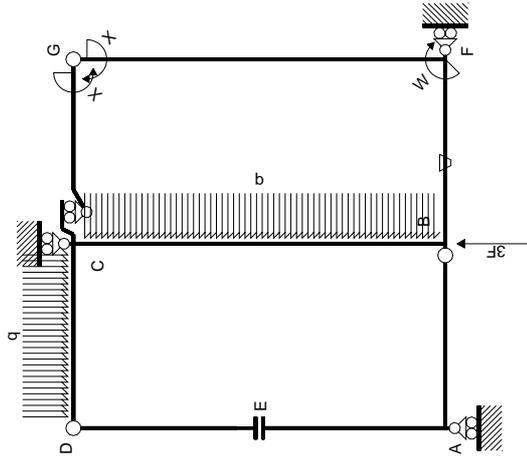


← ⊕ → F

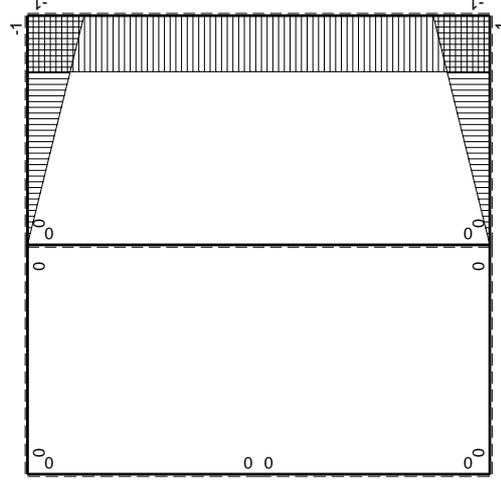
↑ ⊕ ↓ F



⊕ ⊖ F<sub>b</sub>



Schema di calcolo iperstatico



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0+0	0
CD b	$-b+1/2Fx+1/2qx^2$	0	0	0	0	0	0+0	0
DC b	$3/2Fx-1/2qx^2$	0	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
ED b	0	0	0	0	0	0	0+0	0
EA b	0	0	0	0	0	0	0+0	0
AE b	0	0	0	0	0	0	0+0	0
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FBB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb-Fx$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
GCB b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2xb/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2xb/EJ$
CB 2b	0	$Fb-1/2qx^2$	0	0	0	0	0+0	0
BC 2b	0	$Fb-2Fx+1/2qx^2$	0	0	0	0	0+0	0
totali								$Fb^2/EJ$
								$8/3xb/EJ$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

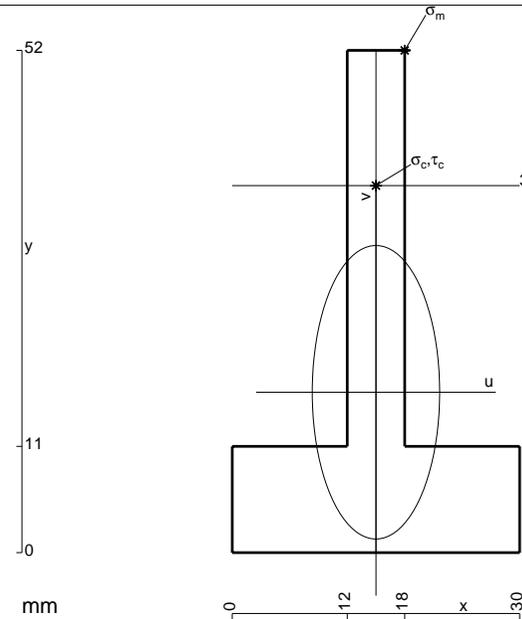
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

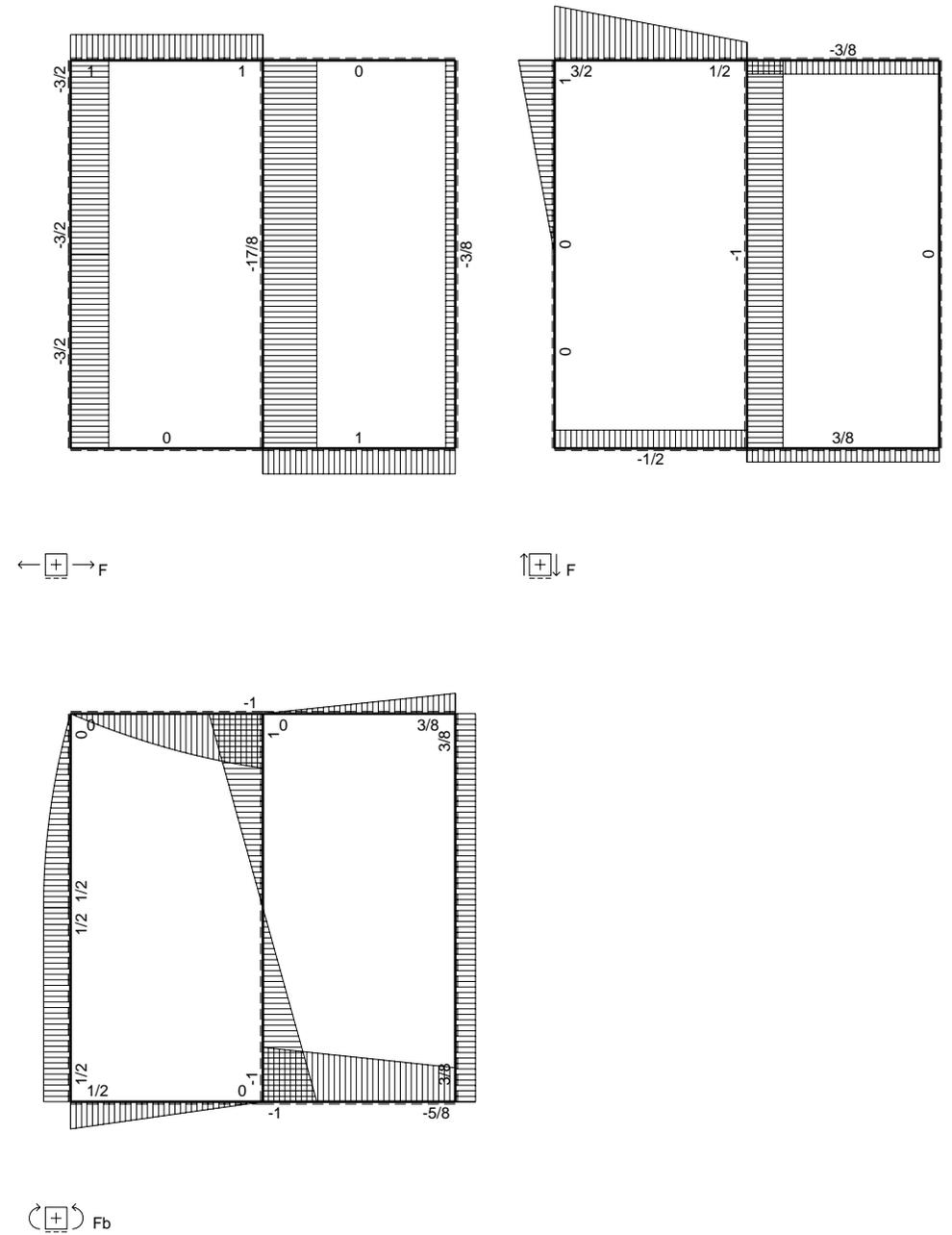
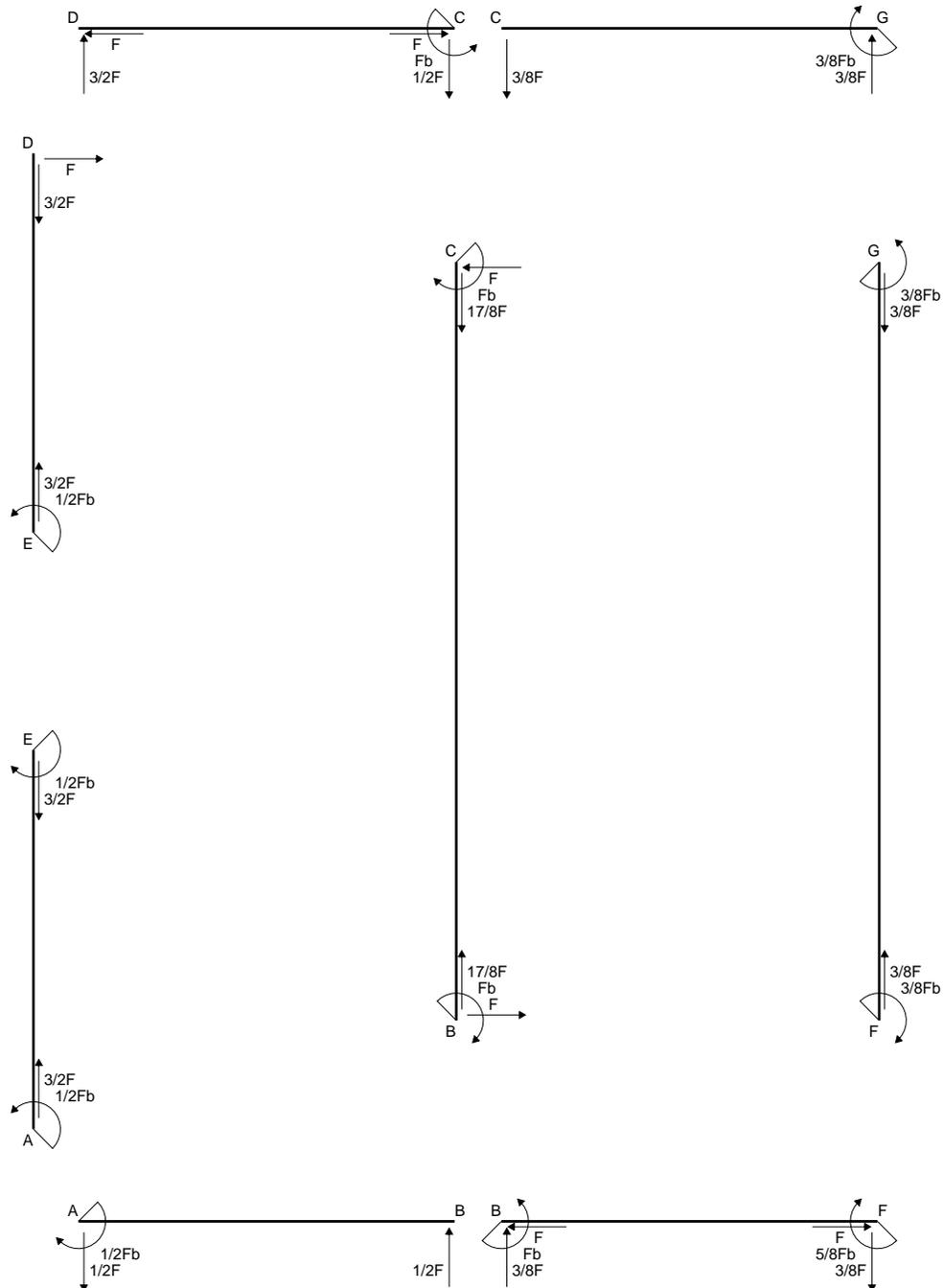
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

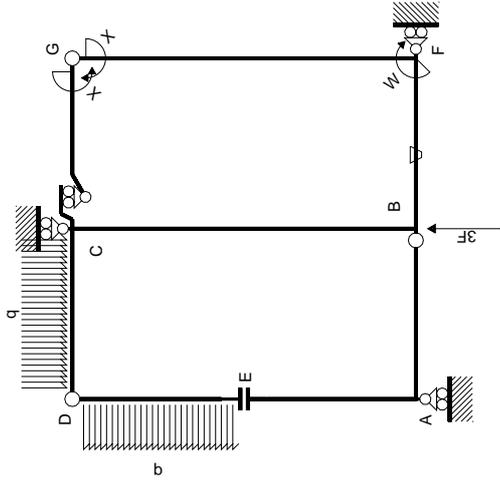
$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



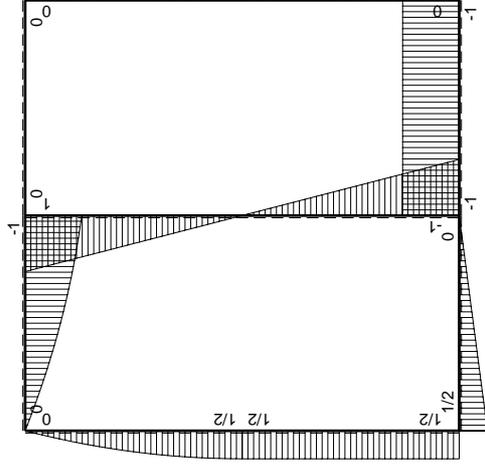
- A = 576. mm<sup>2</sup>
- J<sub>u</sub> = 133062. mm<sup>4</sup>
- J<sub>v</sub> = 25488. mm<sup>4</sup>
- y<sub>g</sub> = 16.6 mm
- N = -5014. N
- T<sub>y</sub> = -3820. N
- M<sub>x</sub> = -783100. Nmm
- x<sub>m</sub> = 18. mm
- y<sub>m</sub> = 52. mm
- u<sub>m</sub> = 3. mm
- v<sub>m</sub> = 35.4 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = 199.6 N/mm<sup>2</sup>
- x<sub>c</sub> = 15. mm
- y<sub>c</sub> = 38. mm
- v<sub>c</sub> = 21.4 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = 117.2 N/mm<sup>2</sup>
- τ<sub>c</sub> = 11.41 N/mm<sup>2</sup>
- σ<sub>σ</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 118.9 N/mm<sup>2</sup>
- S = 2385. mm<sup>3</sup>



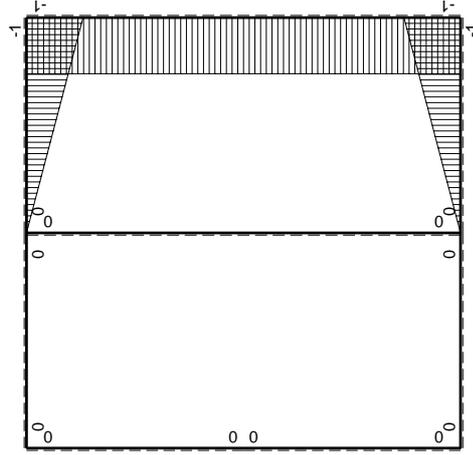




Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\leftarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / EJ dx$
AB b	0	$1/2Fb - 1/2Fx$	0	0	0	0	0+0	0
BA b	0	$-1/2Fx$	0	0	0	0	0+0	0
CD b	0	$-Fb + 1/2Fx + 1/2qx^2$	0	0	0	0	0+0	0
DC b	0	$3/2Fx - 1/2qx^2$	0	0	0	0	0+0	0
DE b	0	$Fx - 1/2qx^2$	0	0	0	0	0+0	0
ED b	0	$-1/2Fb + 1/2qx^2$	0	0	0	0	0+0	0
EA b	0	$1/2Fb$	0	0	0	0	0+0	0
AE b	0	$-1/2Fb$	0	0	0	0	0+0	0
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2 + 1/2)Fb^2/EJ$	$1/3xb/EJ$
FBB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb-Fx$	$Fb/EJ - Fx/EJ$	$1-2x/b + x^2/b^2$	$1/3xb/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b + x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2xb/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2xb/EJ$
CB 2b	0	$Fb-Fx$	0	0	0	0	0+0	0
BC 2b	0	$Fb-Fx$	0	0	0	0	0+0	0
totali								$Fb^2/EJ$
								$8/3xb/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

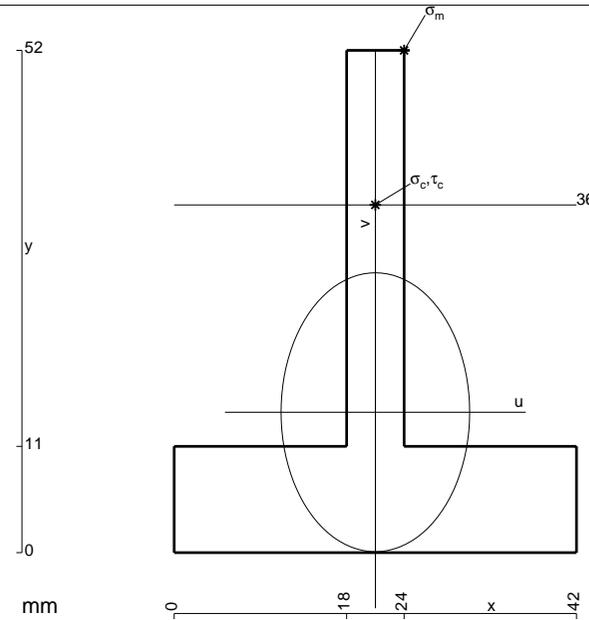
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

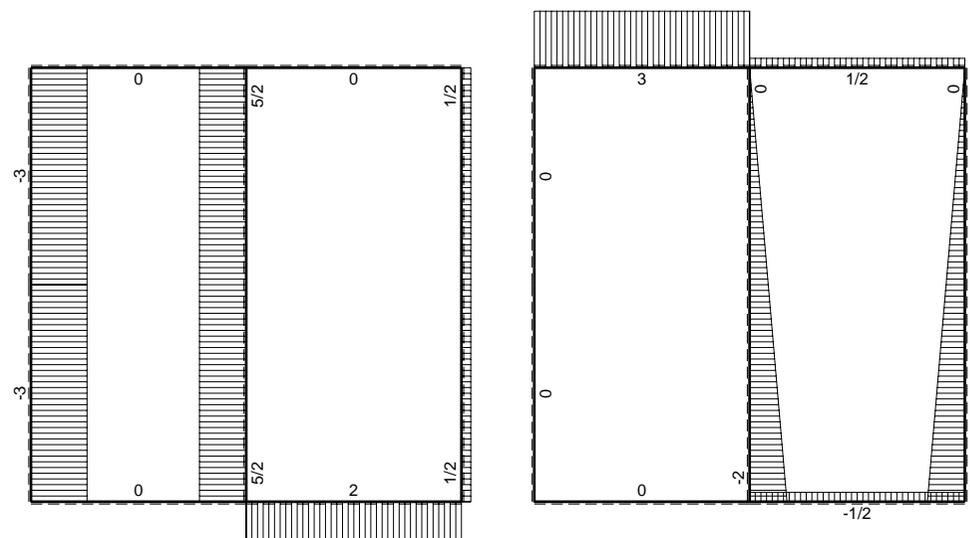
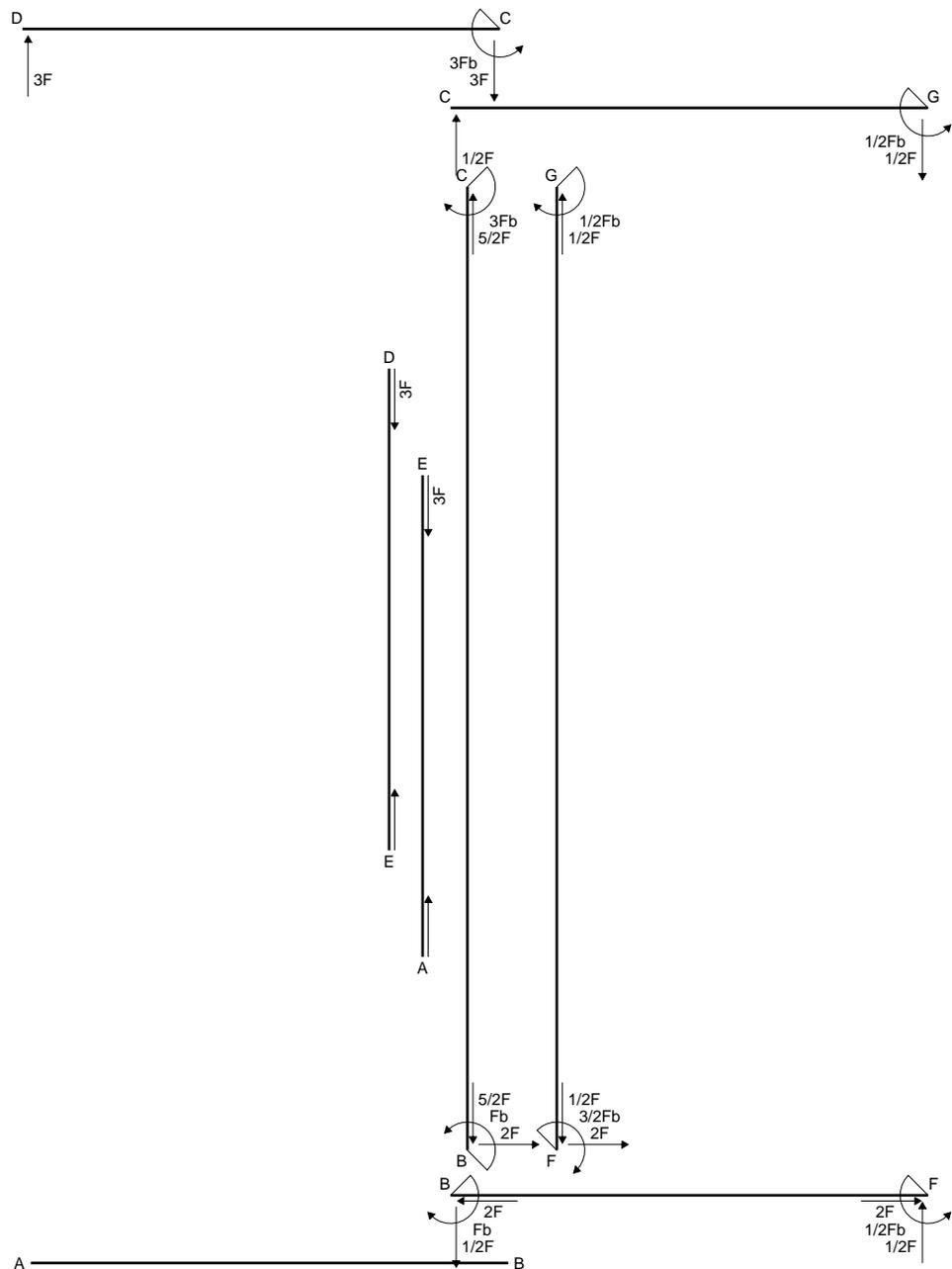
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



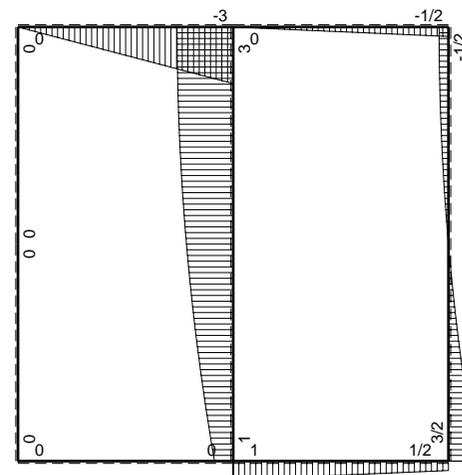
- A = 708. mm<sup>2</sup>
- J<sub>u</sub> = 147634. mm<sup>4</sup>
- J<sub>v</sub> = 68652. mm<sup>4</sup>
- y<sub>g</sub> = 14.53 mm
- N = -3804. N
- T<sub>y</sub> = -1790. N
- M<sub>x</sub> = 805500. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 52. mm
- u<sub>m</sub> = 3. mm
- v<sub>m</sub> = 37.47 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = -209.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 36. mm
- v<sub>c</sub> = 21.47 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = -122.5 N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.716 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 122.9 N/mm<sup>2</sup>
- S = 2829. mm<sup>3</sup>





← ⊕ → F

↑ ⊕ ↓ F



⊕ Fb



$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x_0} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

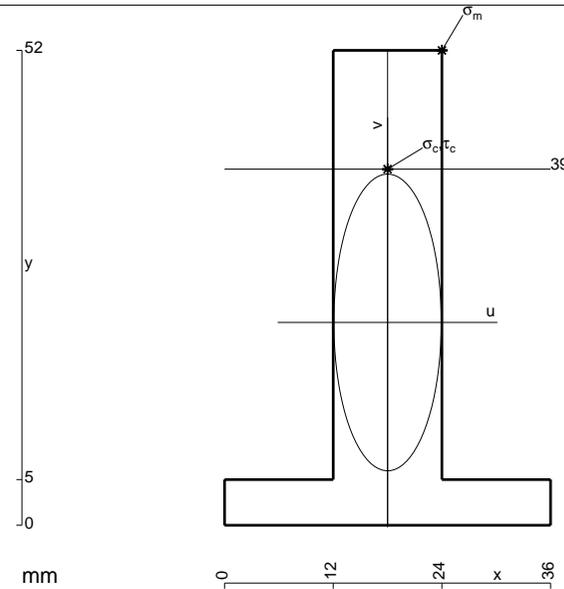
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x_0} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

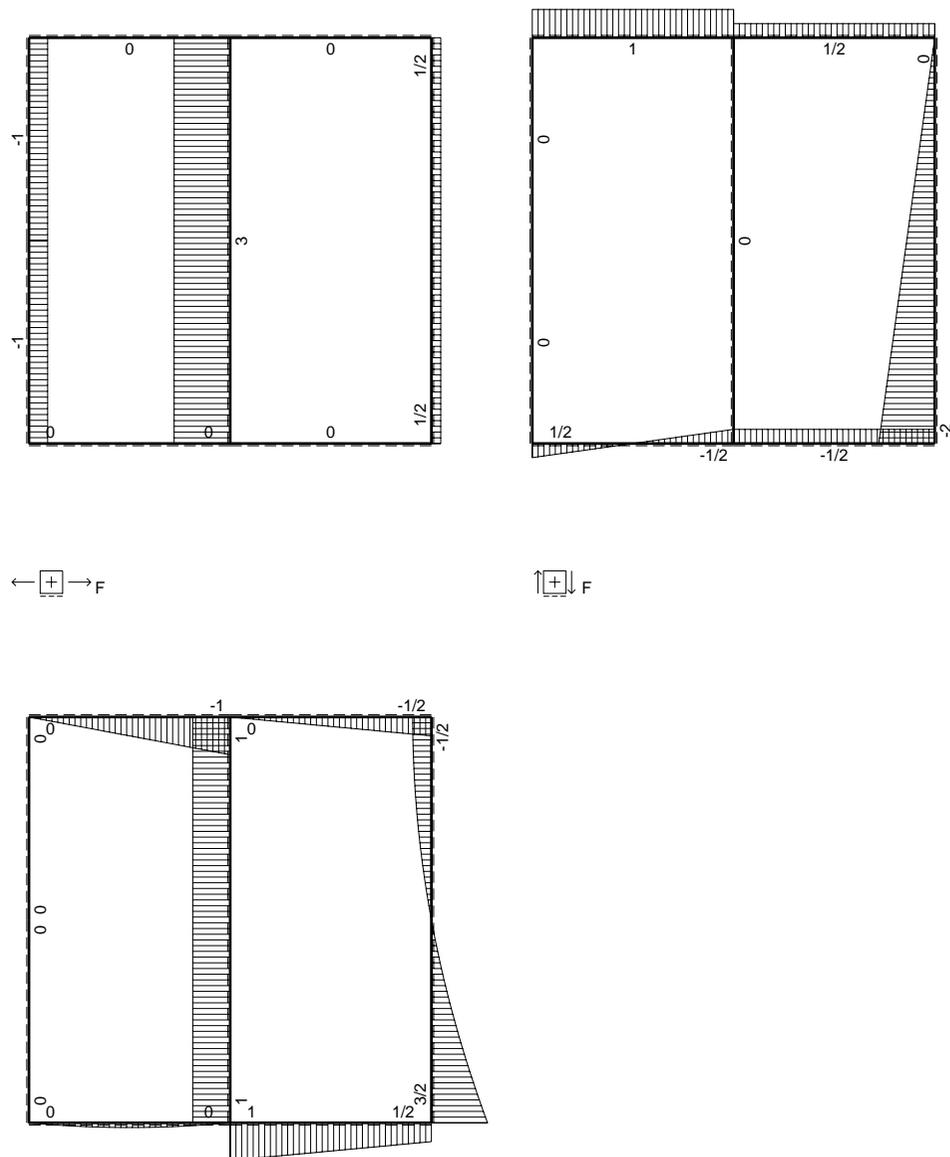
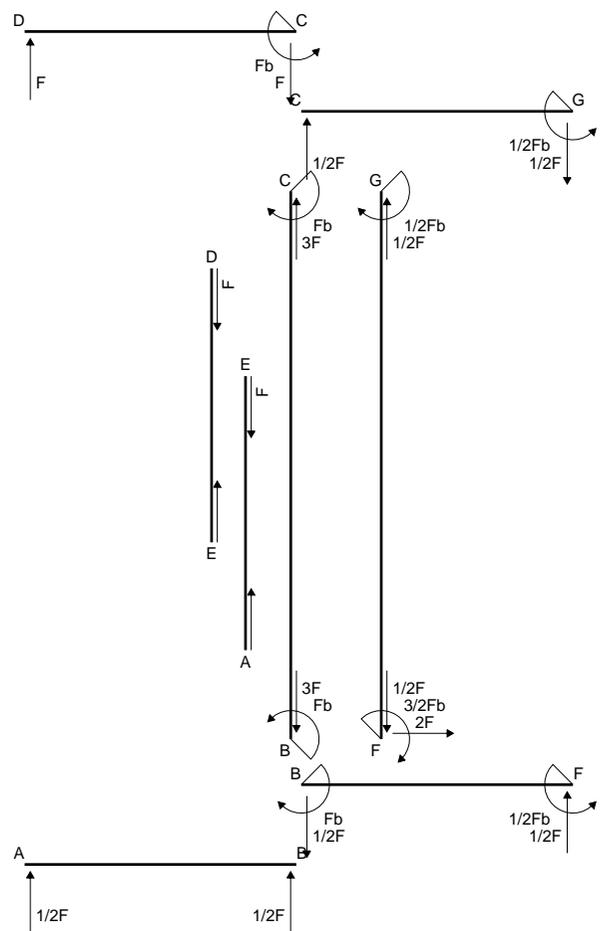
$$L_{GF}^{x_0} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

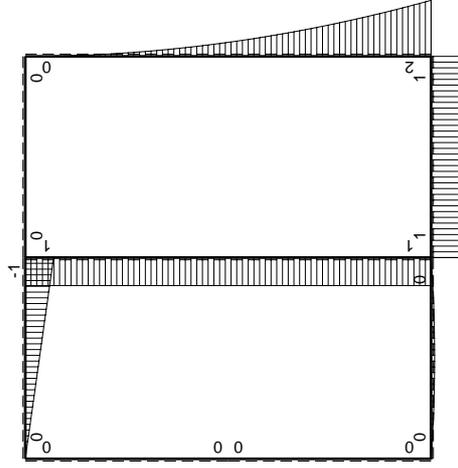
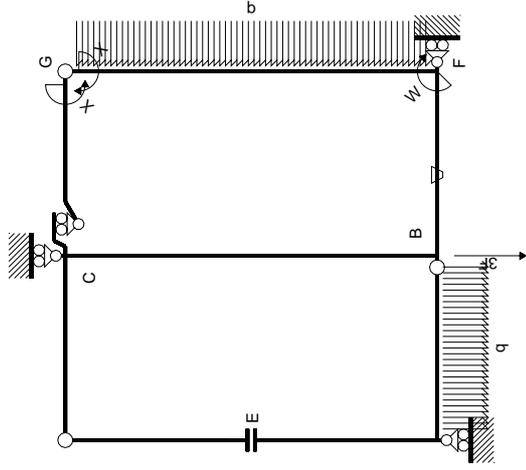


- A = 744. mm<sup>2</sup>
- J<sub>u</sub> = 196439. mm<sup>4</sup>
- J<sub>v</sub> = 26208. mm<sup>4</sup>
- y<sub>g</sub> = 22.21 mm
- T<sub>y</sub> = 2940. N
- M<sub>x</sub> = -1440600. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 52. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 29.79 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 218.5 N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 39. mm
- v<sub>c</sub> = 16.79 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 123.1 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.531 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 = 3633. mm<sup>3</sup>

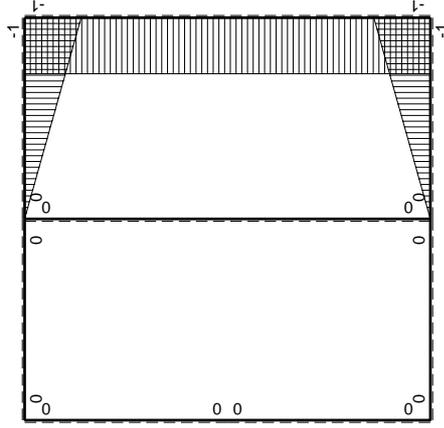




⊕  $Fb$



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica X=W<sub>gc</sub>

←	M <sup>0</sup> (x)	M <sup>0</sup> (x)	θ	M <sup>x</sup> M <sub>0</sub>	M <sup>x</sup> θ	M <sup>x</sup> M <sub>x</sub>	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJdx$
AB b	0	1/2Fx-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
BA b	0	-1/2Fx+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
CD b	0	-b+Fx	0	0	0	0	0+0	0
DC b	0	Fx	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
ED b	0	0	0	0	0	0	0+0	0
EA b	0	0	0	0	0	0	0+0	0
AE b	0	0	0	0	0	0	0+0	0
BF b	-x/b	Fb	-Fb/EJ	-Fx	Fx/EJ	x <sup>2</sup> /b <sup>2</sup>	$(-1/2+1/2)Fb^2/EJ$	1/3xb/EJ
FB b	1-x/b	-Fb	Fb/EJ	-Fb+Fx	Fb/EJ-Fx/EJ	$1-2x/b+x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	1/3xb/EJ
GC b	-1+x/b	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	1/3xb/EJ
CG b	x/b	0	0	0	0	x <sup>2</sup> /b <sup>2</sup>	0+0	1/3xb/EJ
FG 2b	-1	2Fb-2Fx+1/2qx <sup>2</sup>	0	-2Fb+2Fx-1/2Fx <sup>2</sup> /b	0	1	$(-4/3+0)Fb^2/EJ$	2xb/EJ
GF 2b	1	-1/2qx <sup>2</sup>	0	-1/2Fx <sup>2</sup> /b	0	1	$(-4/3+0)Fb^2/EJ$	2xb/EJ
CB 2b	0	Fb	0	0	0	0	0+0	0
BC 2b	0	-Fb	0	0	0	0	0+0	0
totali								8/3xb/EJ

iperstatica X=W<sub>gc</sub>

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x\theta} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x\theta} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

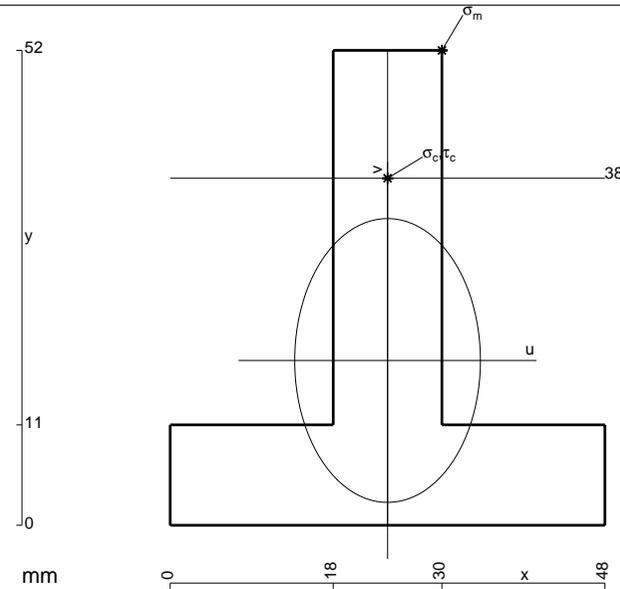
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x\theta} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

$$L_{GF}^{x\theta} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



$$A = 1020. \text{ mm}^2$$

$$J_u = 246410. \text{ mm}^4$$

$$J_v = 107280. \text{ mm}^4$$

$$y_g = 18.04 \text{ mm}$$

$$T_y = 3140. \text{ N}$$

$$M_x = -1664200. \text{ Nmm}$$

$$x_m = 30. \text{ mm}$$

$$y_m = 52. \text{ mm}$$

$$u_m = 6. \text{ mm}$$

$$v_m = 33.96 \text{ mm}$$

$$\sigma_m = -Mv/J_u = 229.4 \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 38. \text{ mm}$$

$$v_c = 19.96 \text{ mm}$$

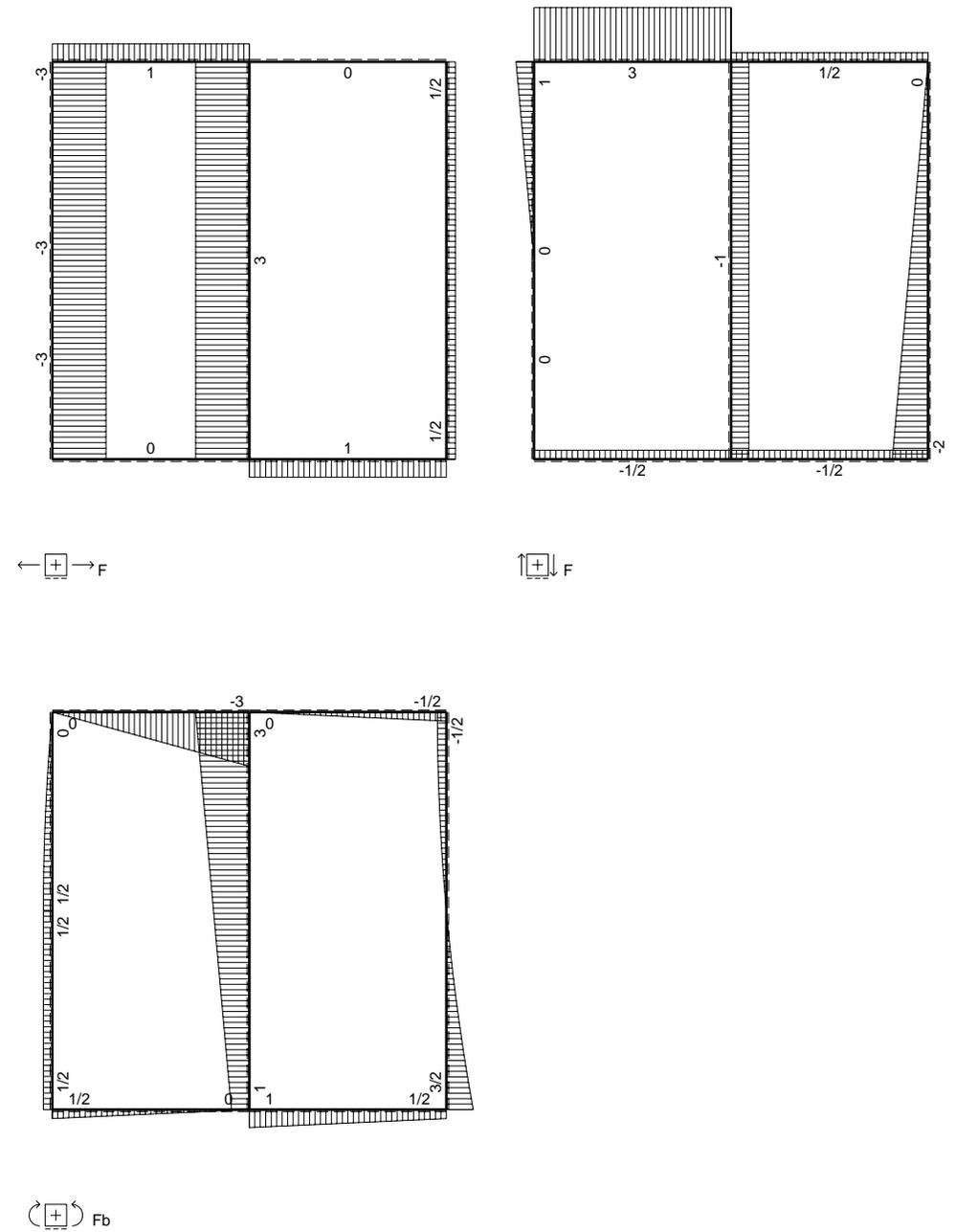
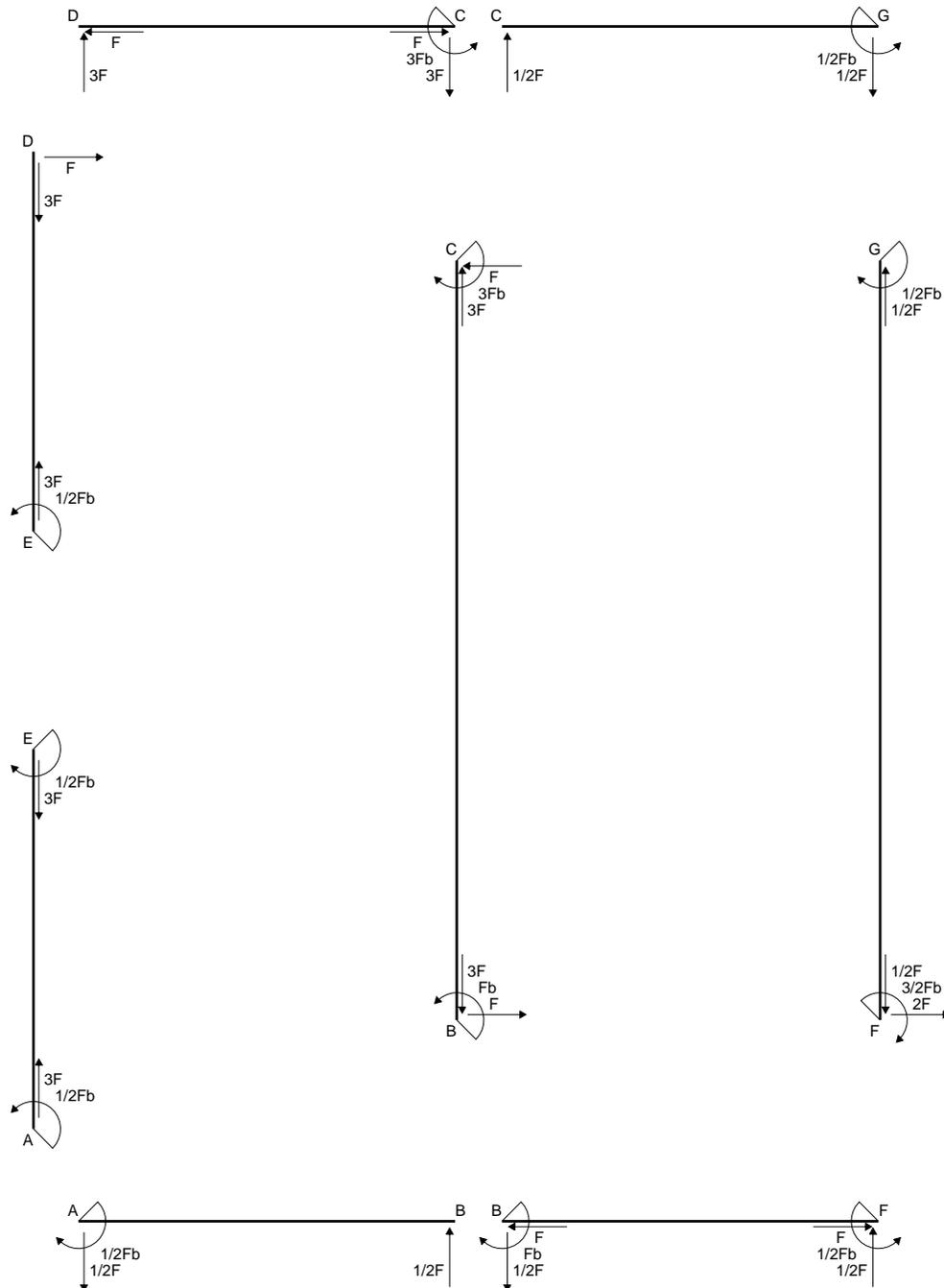
$$\sigma_c = -Mv/J_u = 134.8 \text{ N/mm}^2$$

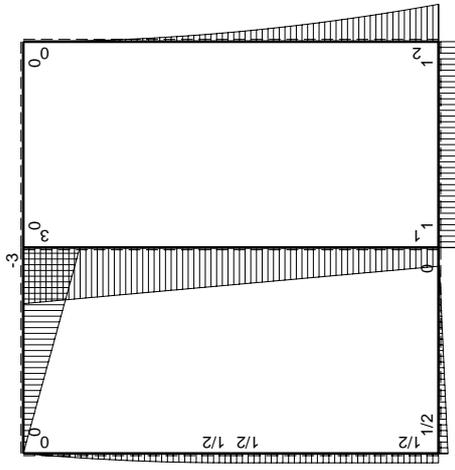
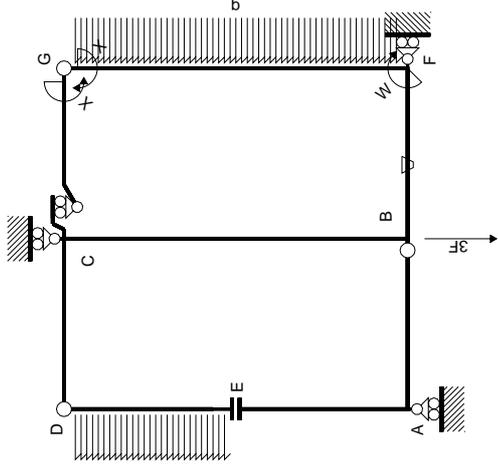
$$\tau_c = 4.81 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 135.1 \text{ N/mm}^2$$

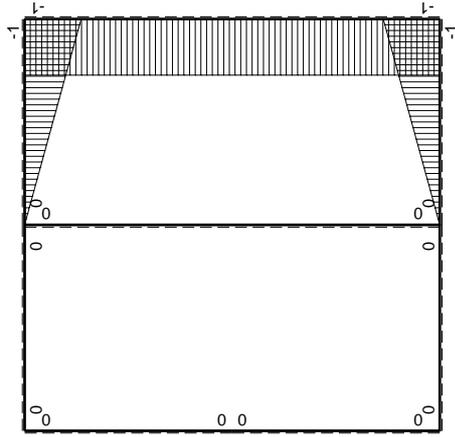
$$S = 4529. \text{ mm}^3$$







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

←	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x (M^0/EJ + \theta) dx$	$\int M^x M_x / E dx$	iperstatica X=W <sub>gc</sub>	
									totali	
AB b	0	$1/2Fb-1/2Fx$	0	0	0	0	0	0	0	$1/2Fb$
BA b	0	$-1/2Fx$	0	0	0	0	0	0	0	$-4/3Fb^2/EJ$
CD b	0	$-3Fb+3Fx$	0	0	0	0	0	0	0	$8/3Xb/EJ$
DC b	0	$3Fx$	0	0	0	0	0	0	0	$1/2Fb$
DE b	0	$Fx-1/2qx^2$	0	0	0	0	0	0	0	$1/2Fb$
ED b	0	$-1/2Fb+1/2qx^2$	0	0	0	0	0	0	0	$1/2Fb$
EA b	0	$1/2Fb$	0	0	0	0	0	0	0	$1/2Fb$
AE b	0	$-1/2Fb$	0	0	0	0	0	0	0	$1/2Fb$
BF b	$-x/b$	$Fb$	$-Fb/EJ$	$-Fx$	$Fx/EJ$	$x^2/b^2$	$-1/2+1/2)Fb^2/EJ$	$1/3Xb/EJ$	$1/3Xb/EJ$	$1/2Fb$
FB b	$1-x/b$	$-Fb$	$Fb/EJ$	$-Fb+Fx$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	$1/3Xb/EJ$	$1/3Xb/EJ$	$1/2Fb$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0	0	0	$1/2Fb$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0	0	0	$1/2Fb$
FG 2b	-1	$2Fb-2Fx+1/2qx^2$	0	$-2Fb+2Fx-1/2Fx^2/b$	0	1	$(-4/3+0)Fb^2/EJ$	$2Xb/EJ$	0	$1/2Fb$
GF 2b	1	$-1/2qx^2$	0	$-1/2Fx^2/b$	0	1	$(-4/3+0)Fb^2/EJ$	$2Xb/EJ$	0	$1/2Fb$
CB 2b	0	$3Fb-Fx$	0	0	0	0	0	0	0	$1/2Fb$
BC 2b	0	$-Fb-Fx$	0	0	0	0	0	0	0	$1/2Fb$
totali										

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x_0} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

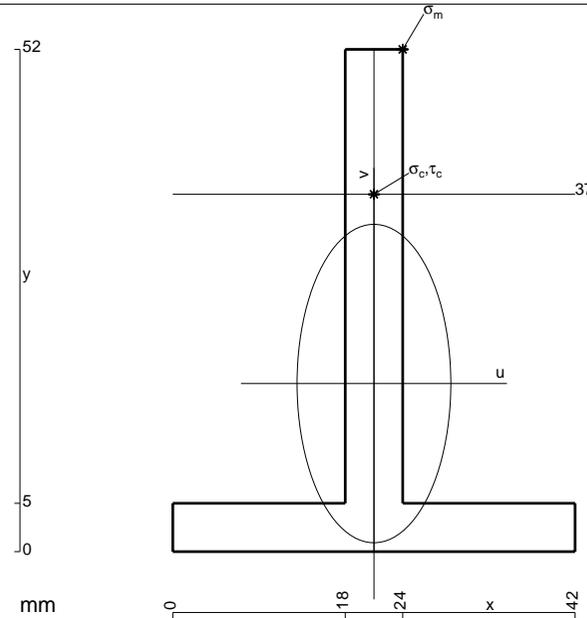
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x_0} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

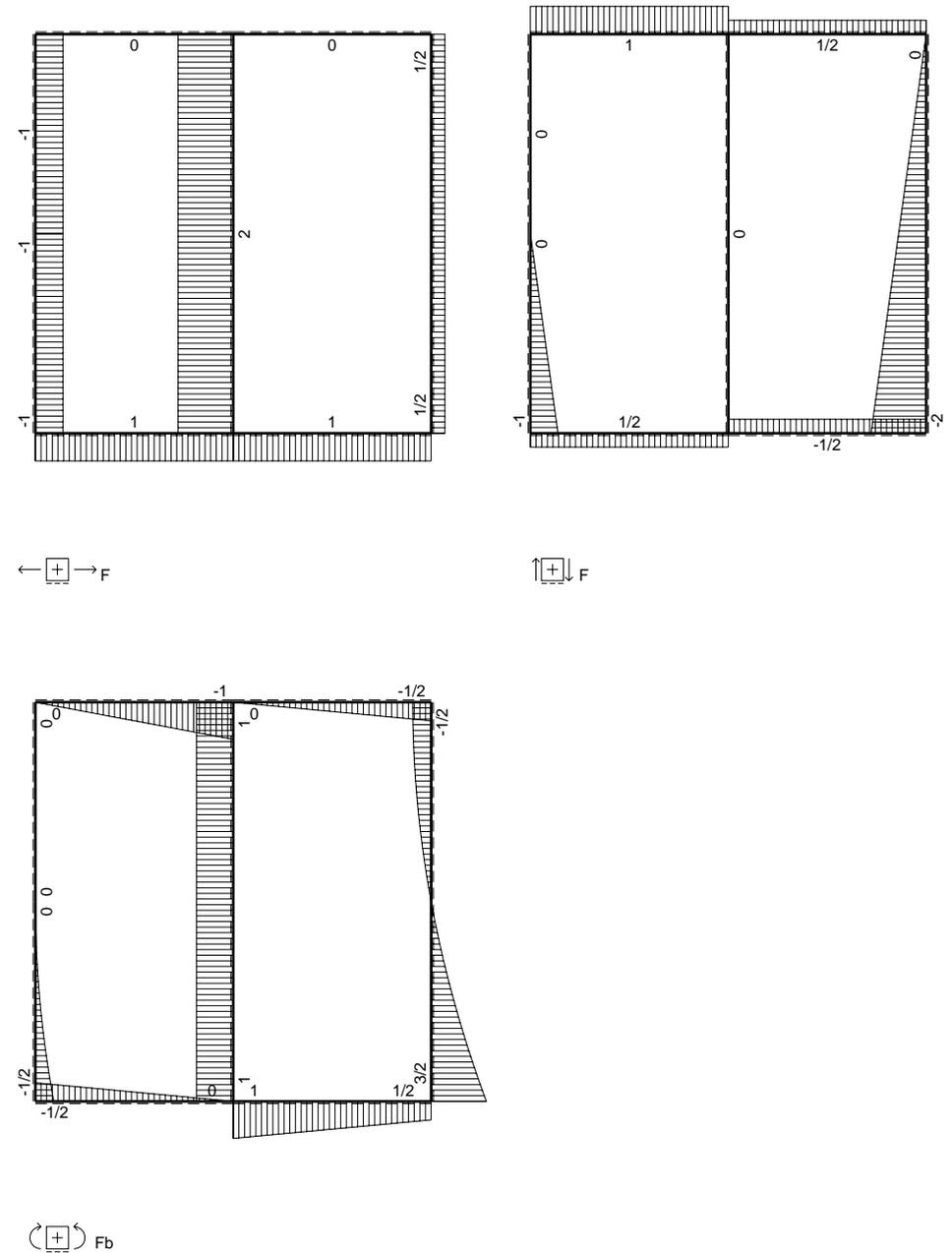
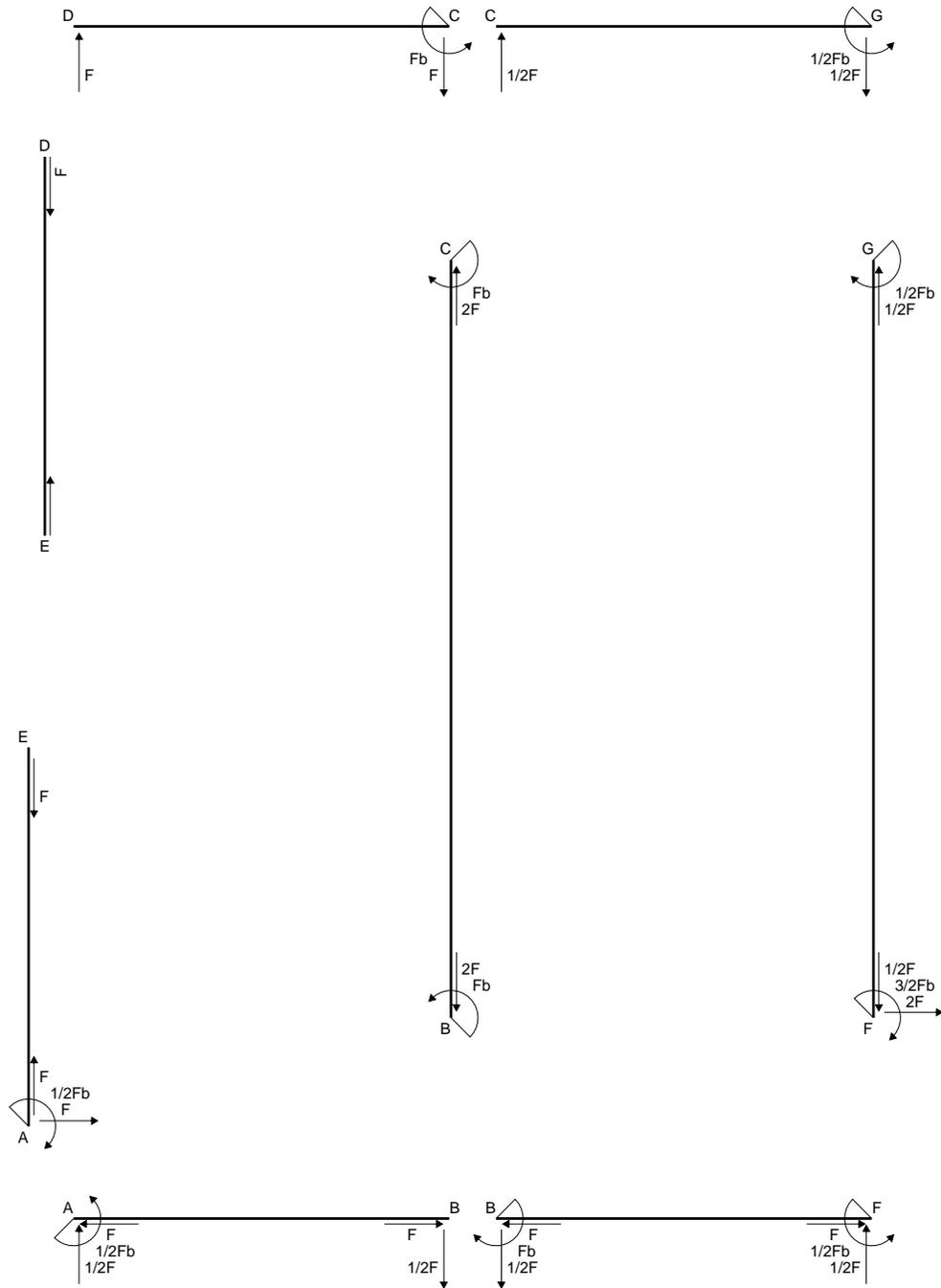
$$L_{GF}^{x_0} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

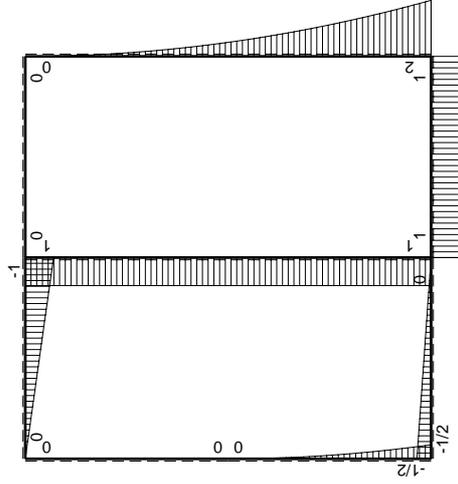
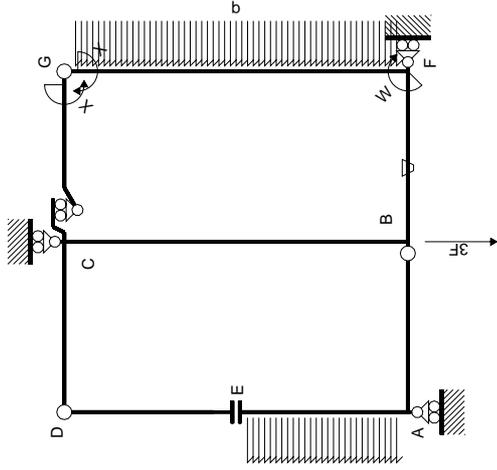
$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



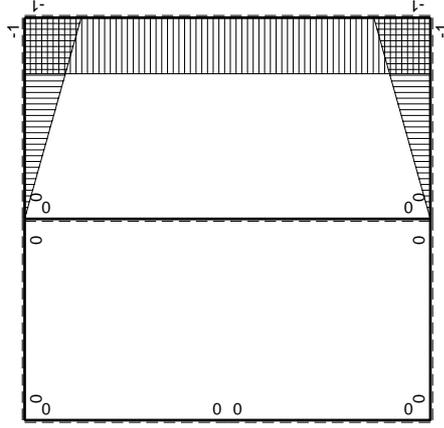
- A = 492. mm<sup>2</sup>
- J<sub>u</sub> = 133716. mm<sup>4</sup>
- J<sub>v</sub> = 31716. mm<sup>4</sup>
- y<sub>g</sub> = 17.4 mm
- N = 530. N
- T<sub>y</sub> = 1590. N
- M<sub>x</sub> = -906300. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 52. mm
- u<sub>m</sub> = 3. mm
- v<sub>m</sub> = 34.6 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = 235.6 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 37. mm
- v<sub>c</sub> = 19.6 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = 133.9 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.833 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 = 2439. mm<sup>3</sup>







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M(x)$	$M^0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	0	$-1/2Fb+1/2Fx$	0	0	0	0	0+0	0
BA b	0	$1/2Fx$	0	0	0	0	0+0	0
CD b	0	$-Fb+Fx$	0	0	0	0	0+0	0
DC b	0	$Fx$	0	0	0	0	0+0	0
ED b	0	0	0	0	0	0	0+0	0
EA b	0	$-1/2qx^2$	0	0	0	0	0+0	0
AE b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0+0	0
BF b	$-x/b$	$Fb$	$-Fb/EJ$	$-Fx$	$Fx/EJ$	$x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$-Fb$	$Fb/EJ$	$-Fb+Fx$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	$2Fb-2Fx+1/2qx^2$	0	$-2Fb+2Fx-1/2Fx^2/b$	0	1	$(-4/3+0)Fb^2/EJ$	$2xb/EJ$
GF 2b	1	$-1/2qx^2$	0	$-1/2Fx^2/b$	0	1	$(-4/3+0)Fb^2/EJ$	$2xb/EJ$
CB 2b	0	$Fb$	0	0	0	0	0+0	0
BC 2b	0	$-Fb$	0	0	0	0	0+0	0
totali							$-4/3Fb^2/EJ$	$8/3xb/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{xo} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{xo} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

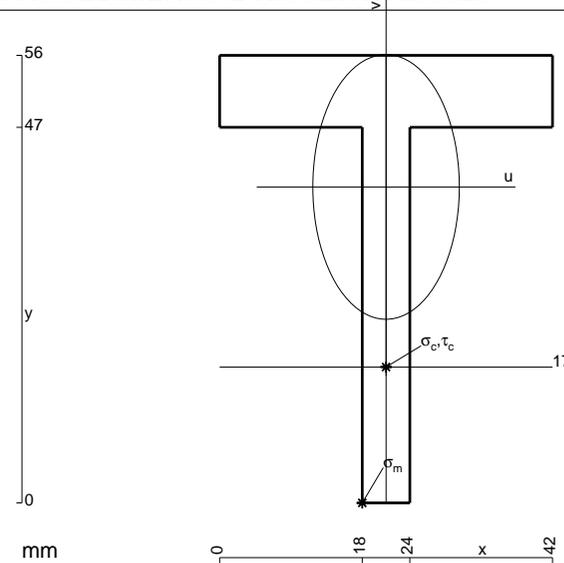
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{xo} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

$$L_{GF}^{xo} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



$$A = 660. \text{ mm}^2$$

$$J_u = 181086. \text{ mm}^4$$

$$J_v = 56412. \text{ mm}^4$$

$$y_g = 39.54 \text{ mm}$$

$$T_y = 1380. \text{ N}$$

$$M_x = -910800. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -39.54 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -198.9 \text{ N/mm}^2$$

$$x_c = 21. \text{ mm}$$

$$y_c = 17. \text{ mm}$$

$$v_c = -22.54 \text{ mm}$$

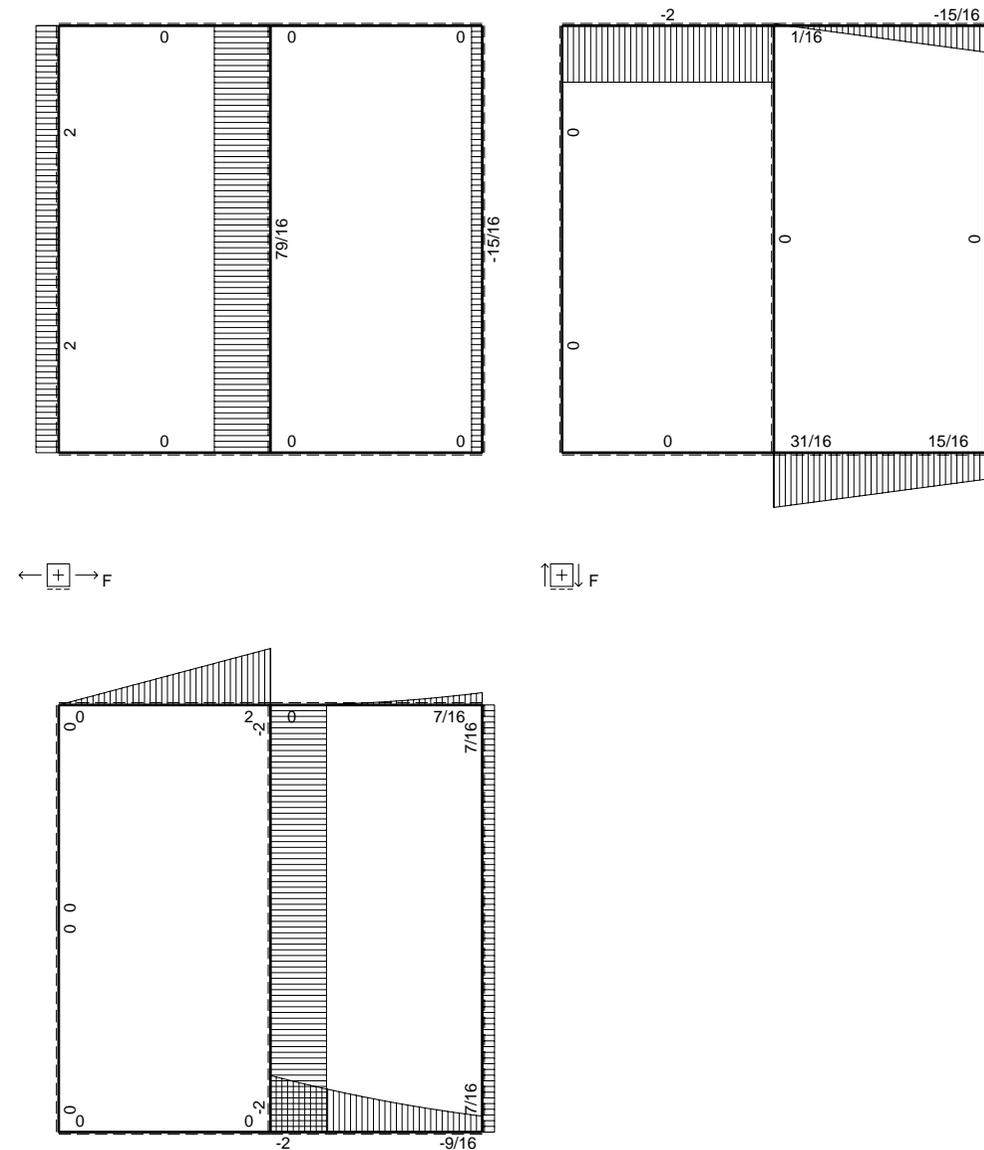
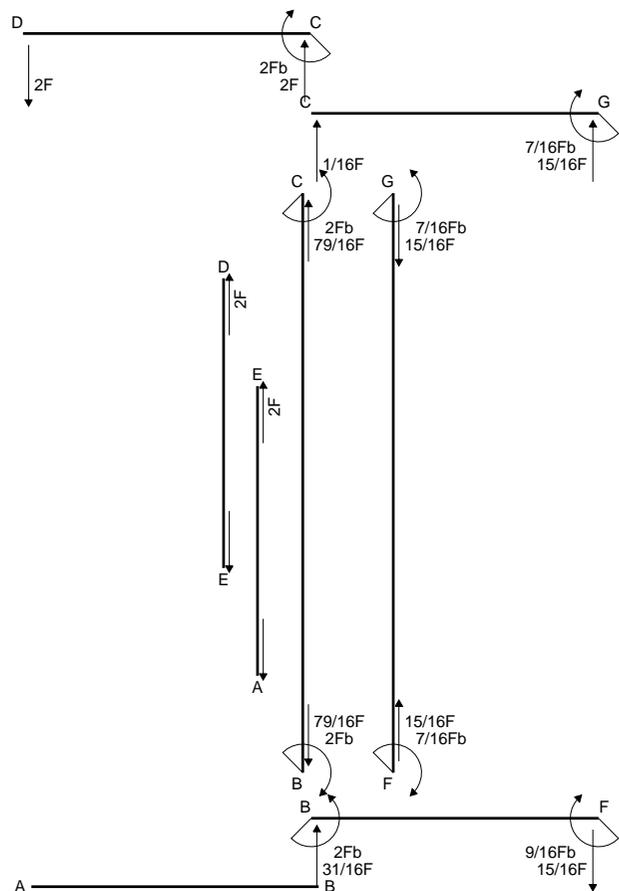
$$\sigma_c = -Mv/J_u = -113.3 \text{ N/mm}^2$$

$$\tau_c = 4.021 \text{ N/mm}^2$$

$$\sigma_o = \sqrt{\sigma^2 + 3\tau^2} = 113.6 \text{ N/mm}^2$$

$$S = 3166. \text{ mm}^3$$







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{xo} = \int_0^b (2x/b - 3/2 x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

$$= [x^2/b - 1/2 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b + 1/8 b) Fb 1/EJ + (1/2 b) \theta = 9/8 Fb^2/EJ$$

$$L_{FB}^{xo} = \int_0^b (1 - 1/2 x/b - 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [x - 1/4 x^2/b - 1/8 x^4/b^3]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

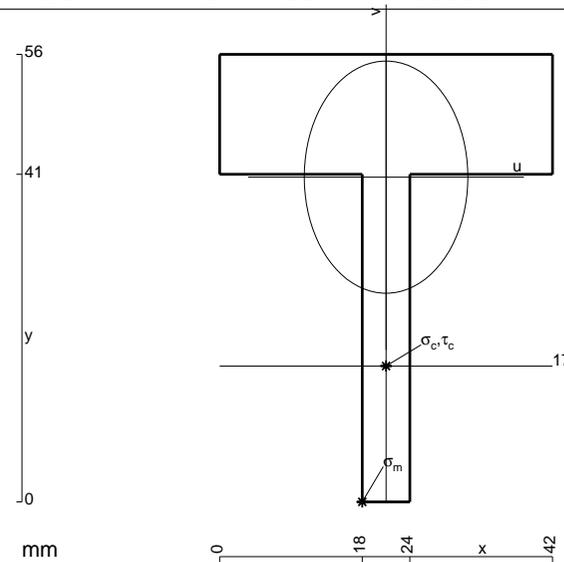
$$= (b - 1/4 b - 1/8 b) Fb 1/EJ + (-b + 1/2 b) \theta = 9/8 Fb^2/EJ$$

$$L_{GC}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

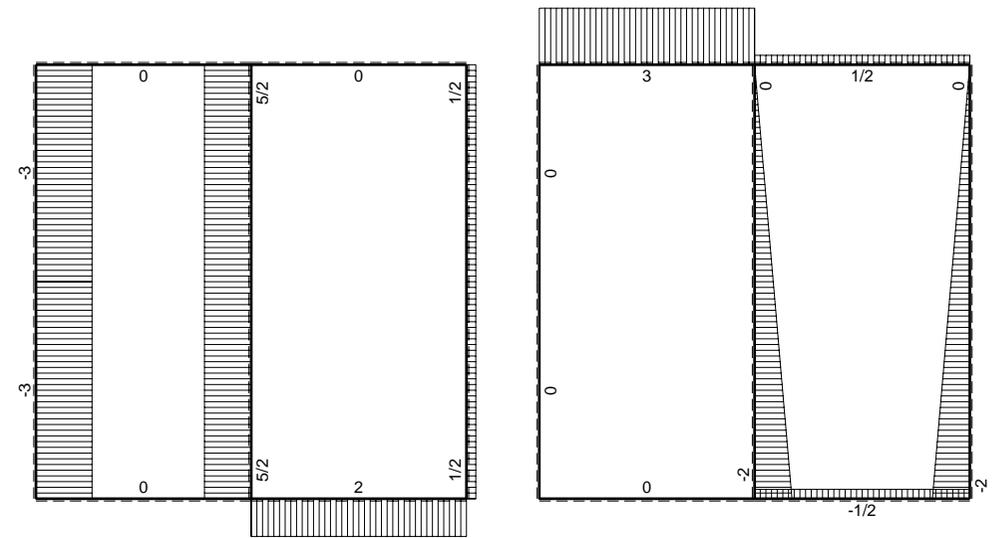
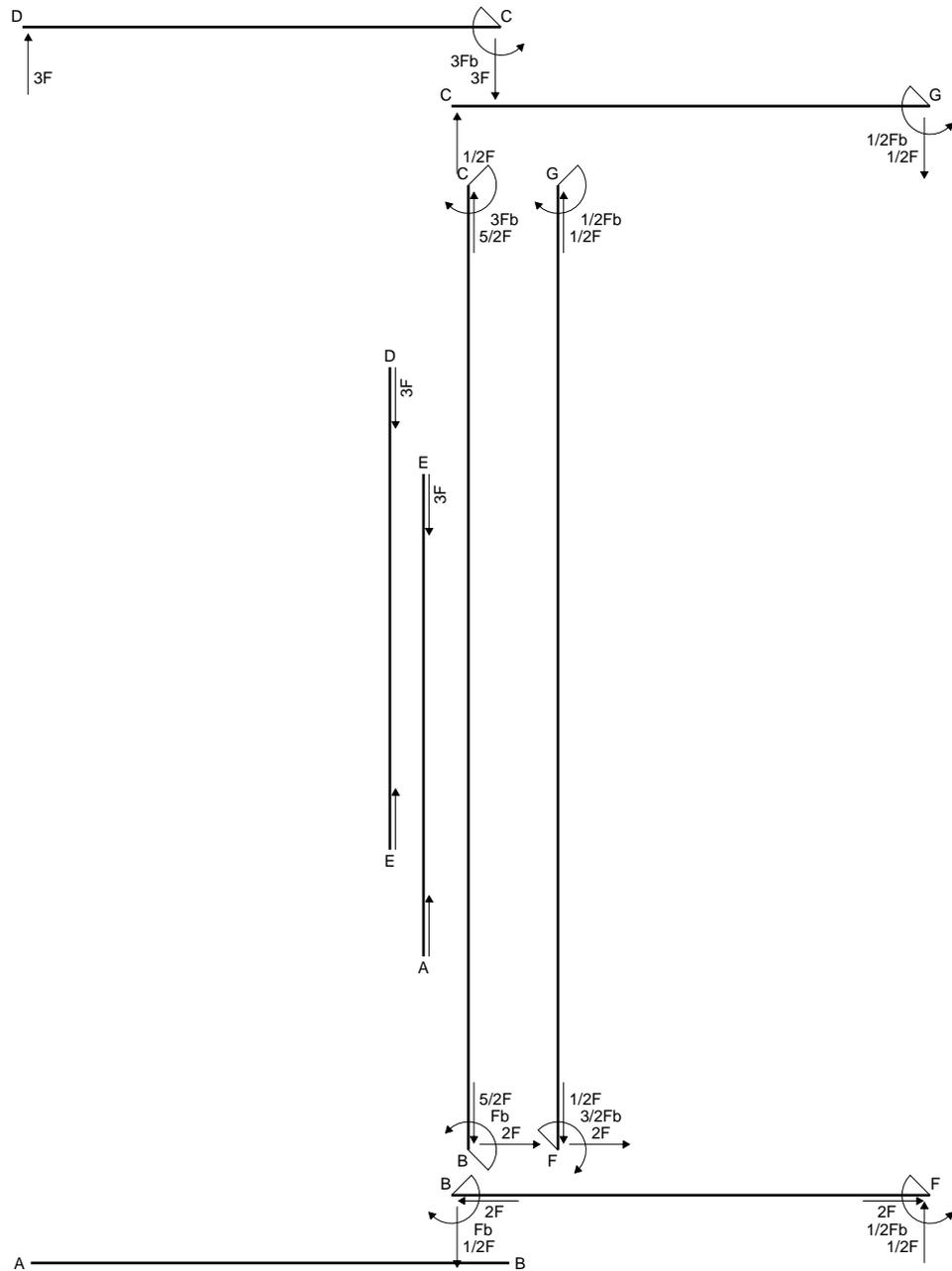
$$L_{CG}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$



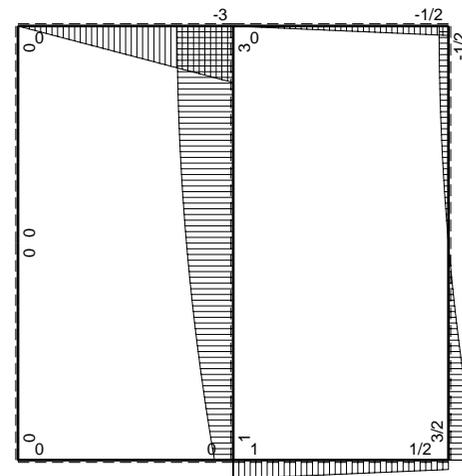
- A = 876. mm<sup>2</sup>
- J<sub>u</sub> = 184977. mm<sup>4</sup>
- J<sub>v</sub> = 93348. mm<sup>4</sup>
- y<sub>g</sub> = 40.64 mm
- T<sub>y</sub> = -1360. N
- M<sub>x</sub> = 952000. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -40.64 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 209.1 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 17. mm
- v<sub>c</sub> = -23.64 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 121.7 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.017 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 121.8 N/mm<sup>2</sup>
- S = 3278. mm<sup>3</sup>





← ⊕ →  $F$

↑ ⊕ ↓  $Fb$



⊕  $Mb$



$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x\theta} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x\theta} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

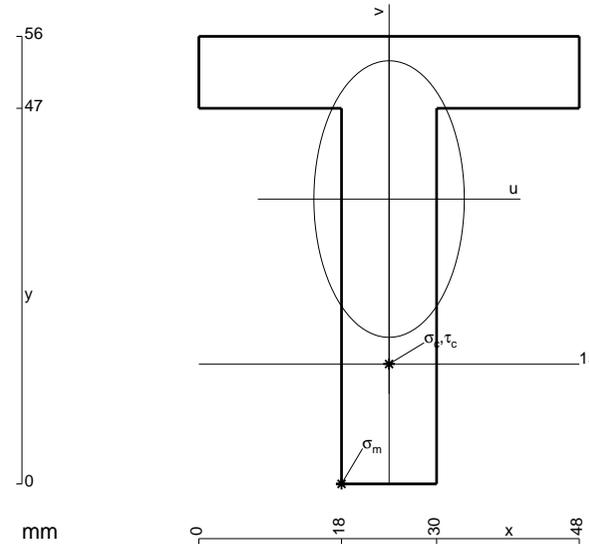
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x\theta} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

$$L_{GF}^{x\theta} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



$$A = 996. \text{ mm}^2$$

$$J_u = 298526. \text{ mm}^4$$

$$J_v = 89712. \text{ mm}^4$$

$$y_g = 35.64 \text{ mm}$$

$$T_y = 2460. \text{ N}$$

$$M_x = -1820400. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$u_m = -6. \text{ mm}$$

$$v_m = -35.64 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -217.4 \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 15. \text{ mm}$$

$$v_c = -20.64 \text{ mm}$$

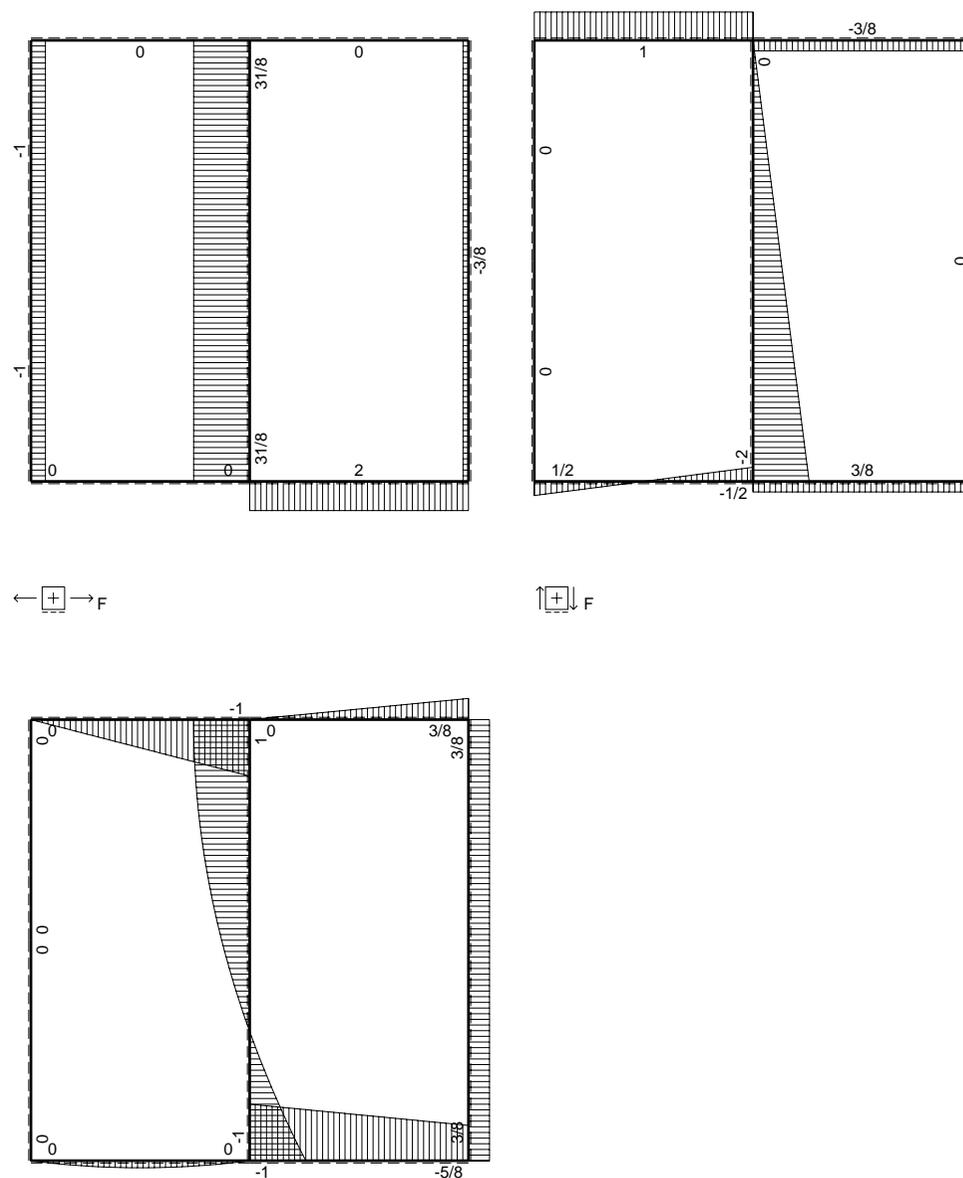
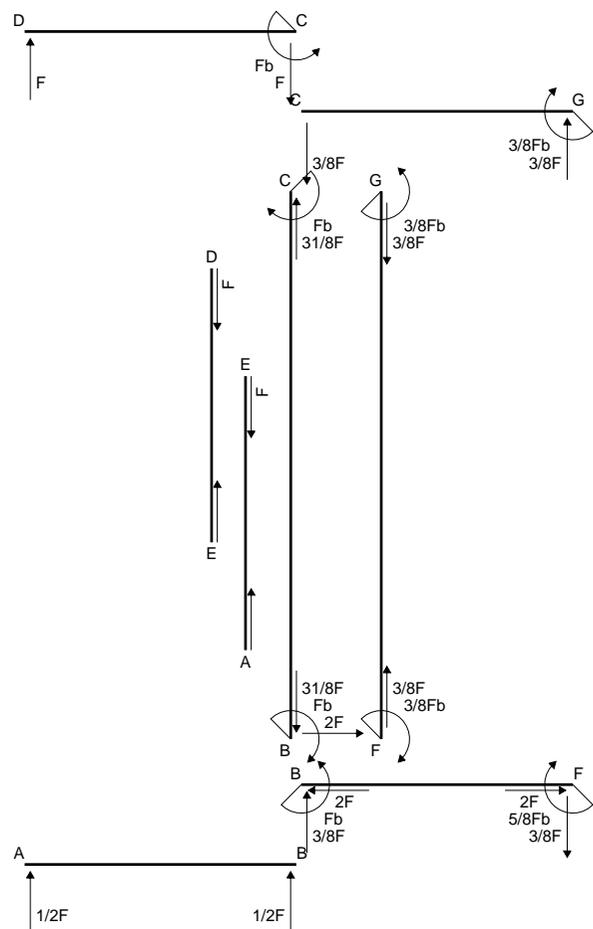
$$\sigma_c = -Mv/J_u = -125.9 \text{ N/mm}^2$$

$$\tau_c = 3.479 \text{ N/mm}^2$$

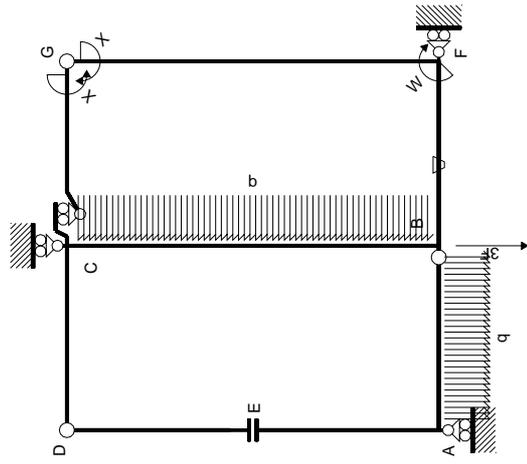
$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 126. \text{ N/mm}^2$$

$$S = 5066. \text{ mm}^3$$

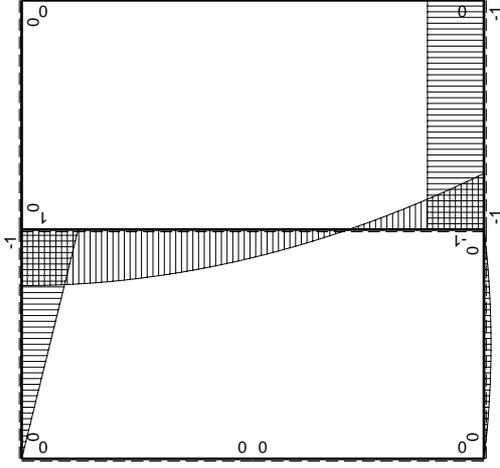




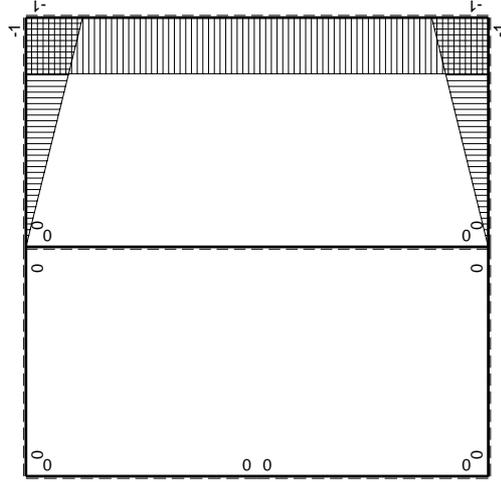
$\boxed{+}$   $F_b$



Schema di calcolo iperstatico



$M_x$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / EJ dx$
AB b	0	$1/2Fx - 1/2qx^2$	0	0	0	0	0+0	0
BA b	0	$-1/2Fx + 1/2qx^2$	0	0	0	0	0+0	0
CD b	0	$-Fb + Fx$	0	0	0	0	0+0	0
DC b	0	$Fx$	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
ED b	0	0	0	0	0	0	0+0	0
EA b	0	0	0	0	0	0	0+0	0
AE b	0	0	0	0	0	0	0+0	0
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb-Fx$	$Fb/EJ - Fx/EJ$	$1-2x/b+x^2/b^2$	$1/3xb/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2xb/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2xb/EJ$
CB 2b	0	$Fb - 1/2qx^2$	0	0	0	0	0+0	0
BC 2b	0	$Fb - 2Fx + 1/2qx^2$	0	0	0	0	0+0	0
totali								$8/3xb/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

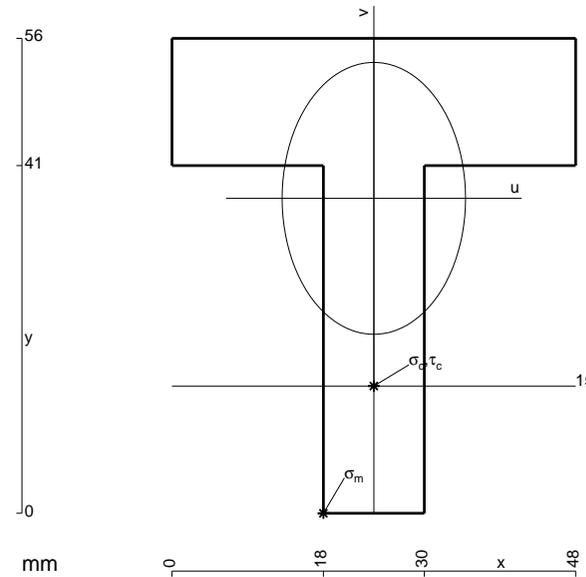
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

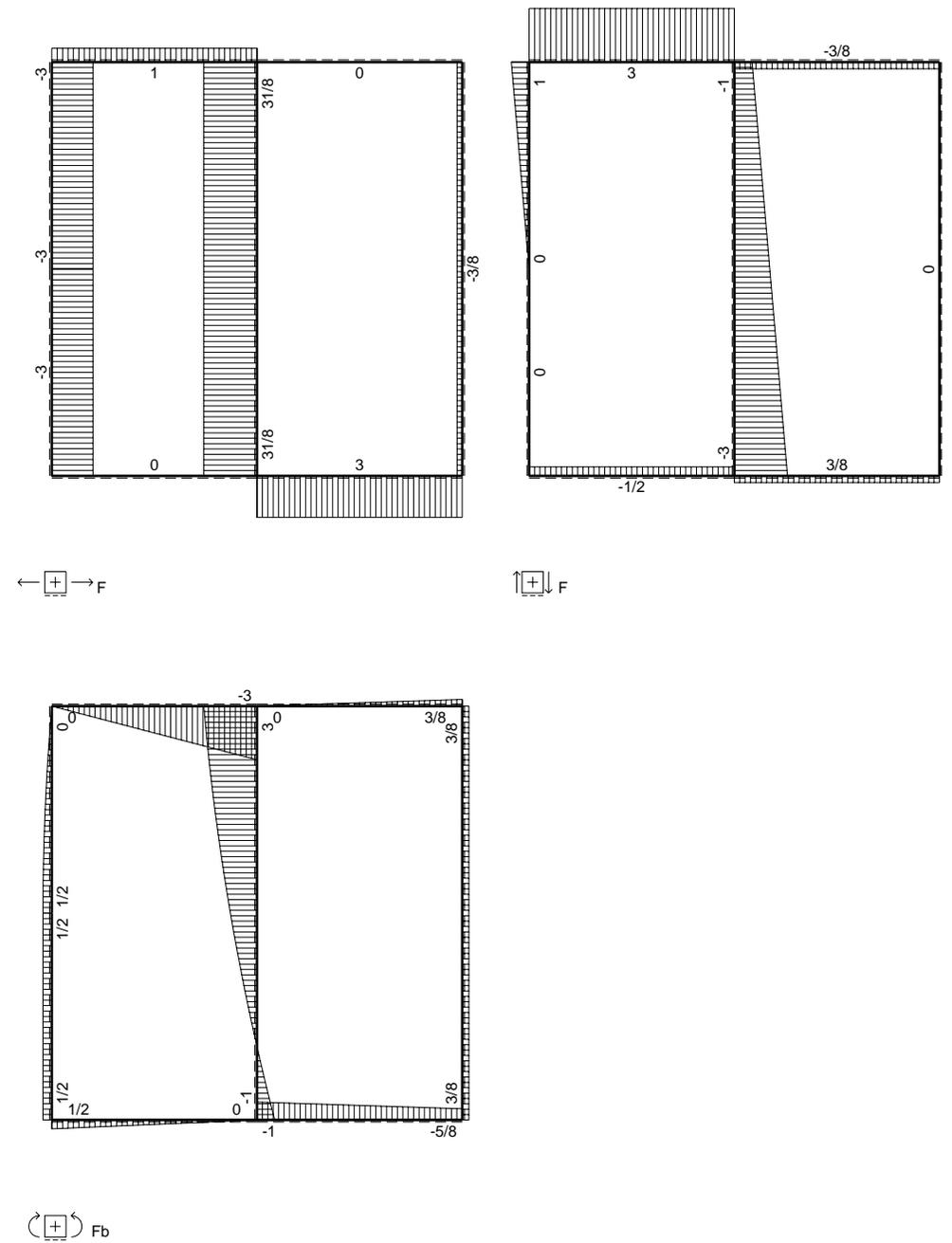
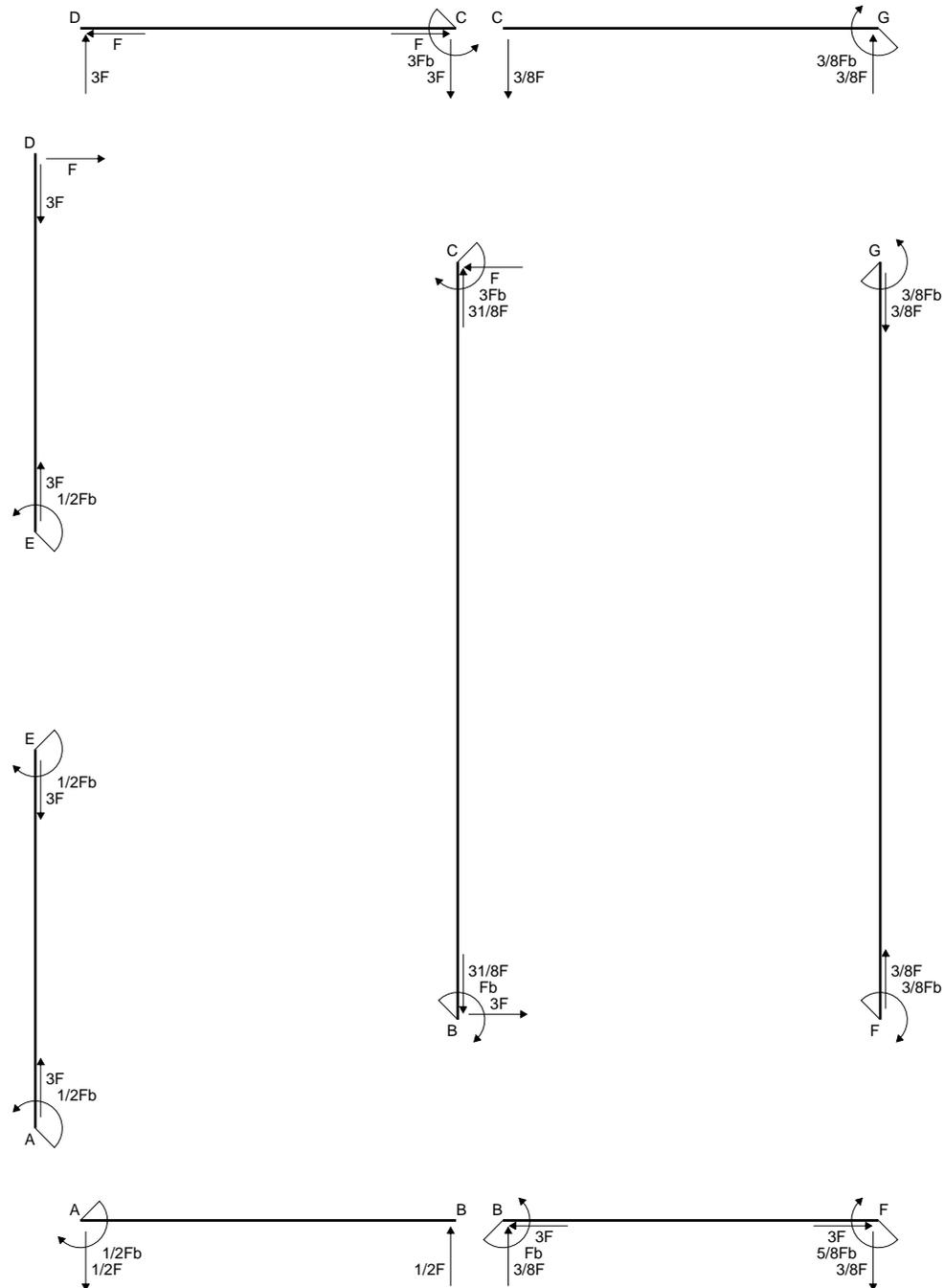
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

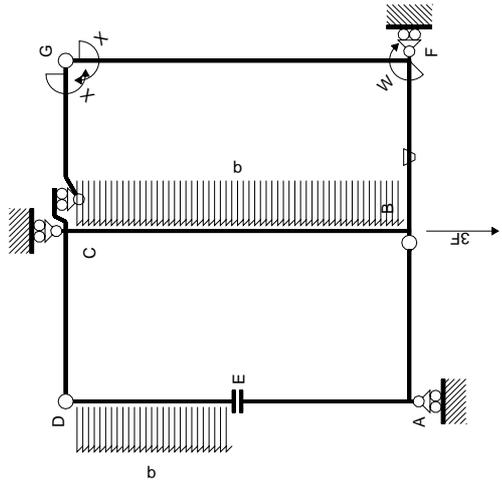
$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



- A = 1212. mm<sup>2</sup>
- J<sub>u</sub> = 311566. mm<sup>4</sup>
- J<sub>v</sub> = 144144. mm<sup>4</sup>
- y<sub>g</sub> = 37.13 mm
- N = 9765. N
- T<sub>y</sub> = -5040. N
- M<sub>x</sub> = -1990800. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -37.13 mm
- σ<sub>m</sub> = N/A - M<sub>v</sub>/J<sub>u</sub> = -229.2 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 15. mm
- v<sub>c</sub> = -22.13 mm
- σ<sub>c</sub> = N/A - M<sub>v</sub>/J<sub>u</sub> = -133.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.19 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 = 5334. mm<sup>3</sup>

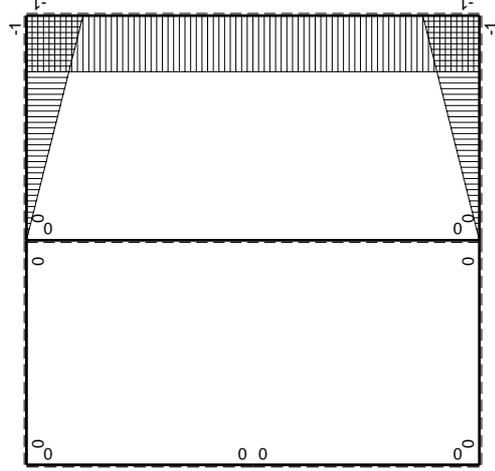
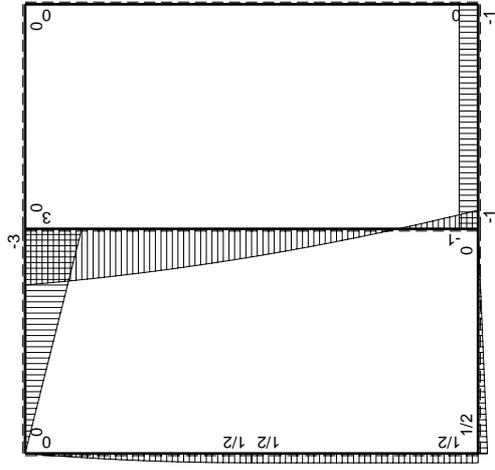






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / EJ dx$
AB b	0	$1/2Fb - 1/2Fx$	0	0	0	0	0+0	0
BA b	0	$-1/2Fx$	0	0	0	0	0+0	0
CD b	0	$-3Fb + 3Fx$	0	0	0	0	0+0	0
DC b	0	$3Fx$	0	0	0	0	0+0	0
DE b	0	$Fx - 1/2qx^2$	0	0	0	0	0+0	0
ED b	0	$-1/2Fb + 1/2qx^2$	0	0	0	0	0+0	0
EA b	0	$1/2Fb$	0	0	0	0	0+0	0
AE b	0	$-1/2Fb$	0	0	0	0	0+0	0
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2 + 1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb - Fx$	$Fb/EJ - Fx/EJ$	$1 - 2x/b + x^2/b^2$	$1/3xb/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1 - 2x/b + x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2xb/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2xb/EJ$
CB 2b	0	$3Fb - Fx - 1/2qx^2$	0	0	0	0	0+0	0
BC 2b	0	$Fb - 3Fx + 1/2qx^2$	0	0	0	0	0+0	0
totali								$Fb^2/EJ$
								$8/3xb/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

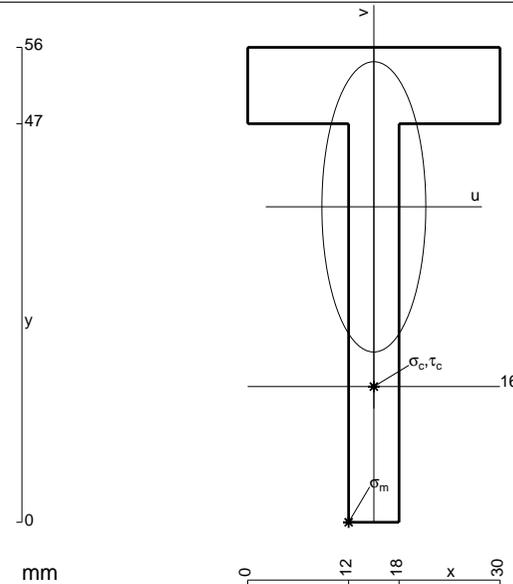
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



$$A = 552. \text{ mm}^2$$

$$J_u = 161875. \text{ mm}^4$$

$$J_v = 21096. \text{ mm}^4$$

$$y_g = 37.2 \text{ mm}$$

$$N = 420. \text{ N}$$

$$T_y = 1260. \text{ N}$$

$$M_x = -1045800. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -37.2 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -239.5 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 16. \text{ mm}$$

$$v_c = -21.2 \text{ mm}$$

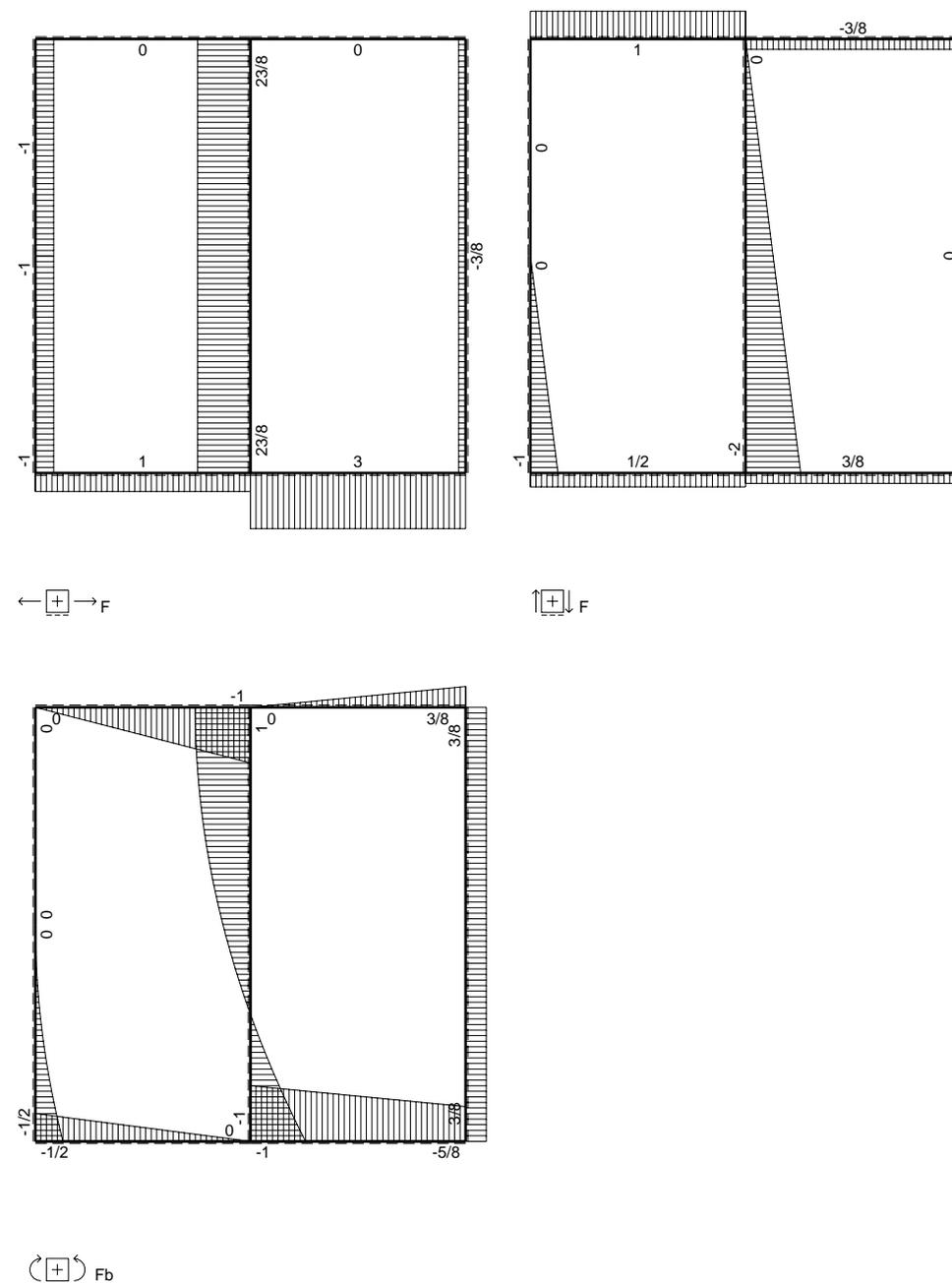
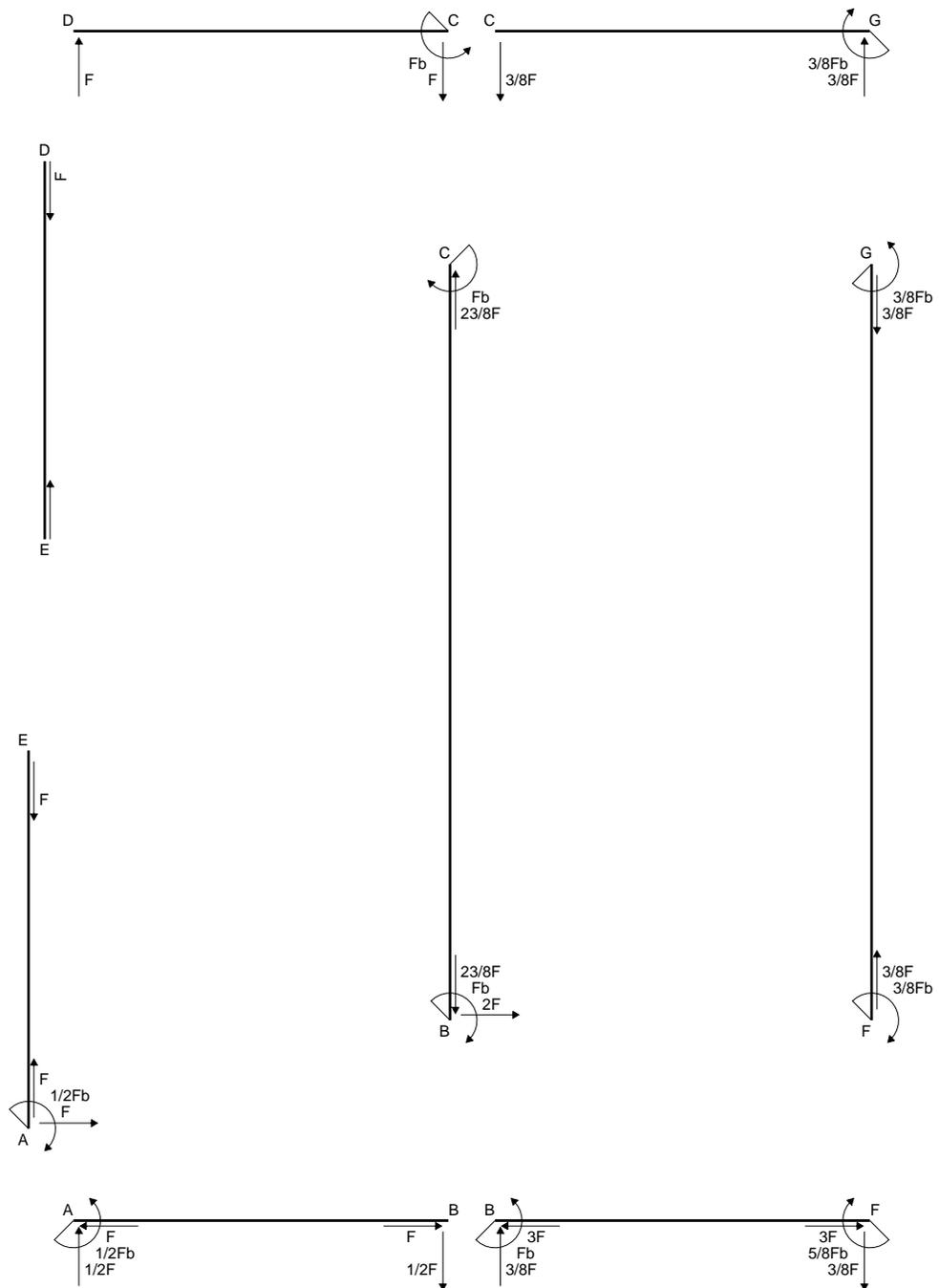
$$\sigma_c = N/A - Mv/J_u = -136.2 \text{ N/mm}^2$$

$$\tau_c = 3.636 \text{ N/mm}^2$$

$$\sigma_x = \sqrt{\sigma^2 + 3\tau^2} = 136.3 \text{ N/mm}^2$$

$$S = 2803. \text{ mm}^3$$







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

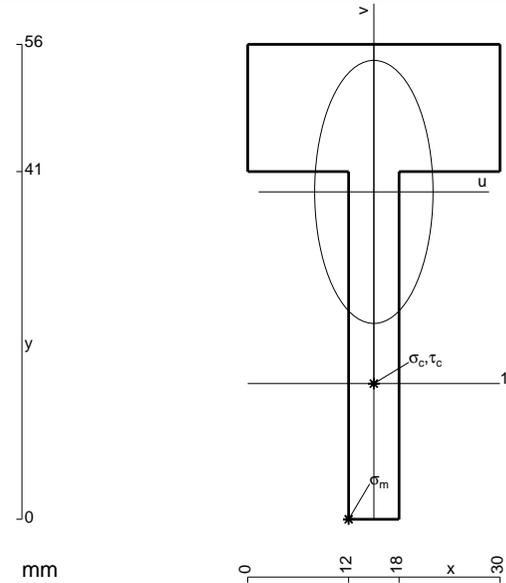
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

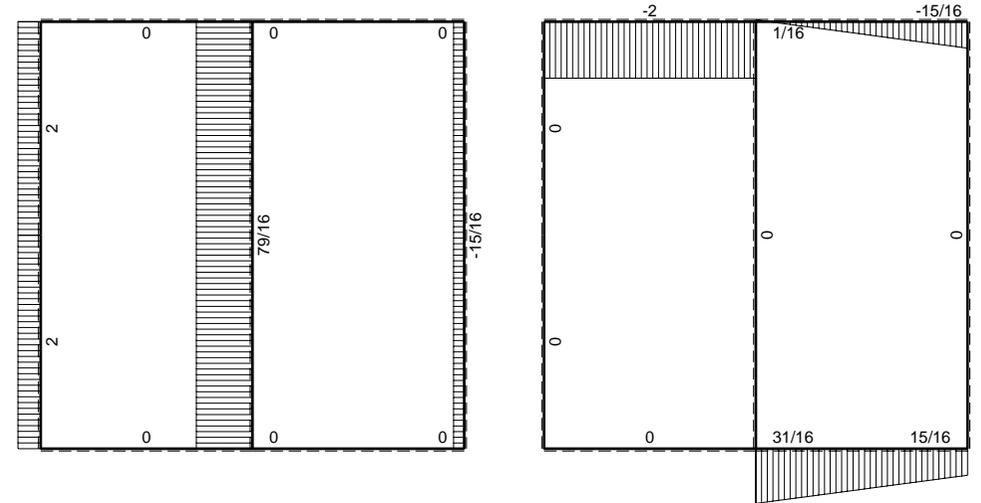
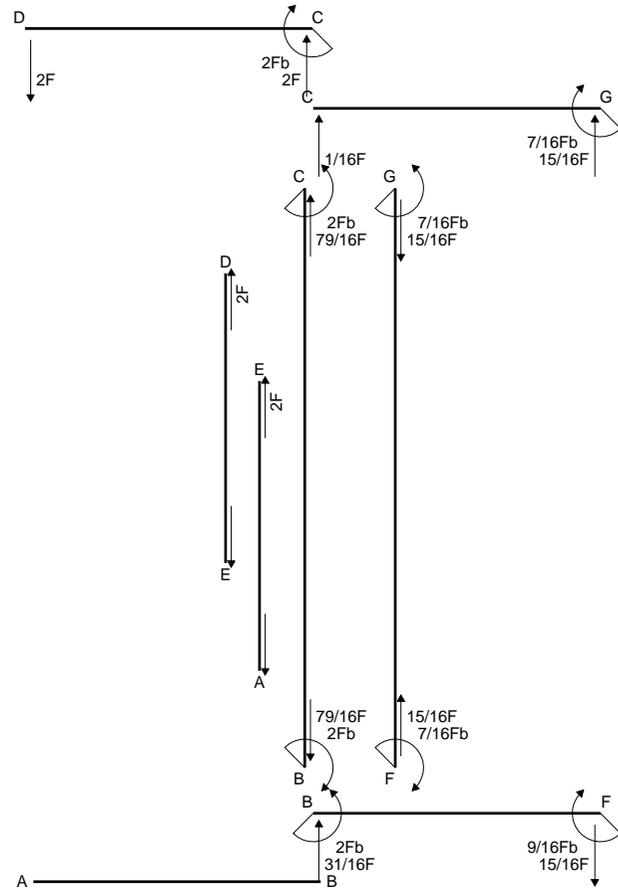
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



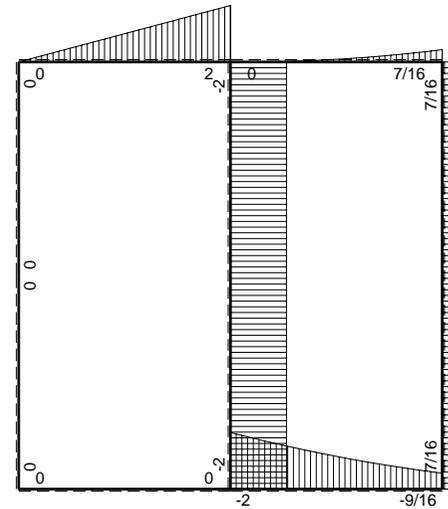
- A = 696. mm<sup>2</sup>
- J<sub>u</sub> = 167595. mm<sup>4</sup>
- J<sub>v</sub> = 34488. mm<sup>4</sup>
- y<sub>g</sub> = 38.6 mm
- N = 5894. N
- T<sub>y</sub> = -4100. N
- M<sub>x</sub> = -902000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -38.6 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = -199.3 N/mm<sup>2</sup>
- x<sub>c</sub> = 15. mm
- y<sub>c</sub> = 16. mm
- v<sub>c</sub> = -22.6 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = -113.2 N/mm<sup>2</sup>
- τ<sub>c</sub> = 11.98 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 115.1 N/mm<sup>2</sup>
- S = 2938. mm<sup>3</sup>





← ⊕ → F

↑ ⊕ ↓ F



⊕ F<sub>b</sub>



$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{xo} = \int_0^b (2x/b - 3/2 x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

$$= [x^2/b - 1/2 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b + 1/8 b) Fb 1/EJ + (1/2 b) \theta = 9/8 Fb^2/EJ$$

$$L_{FB}^{xo} = \int_0^b (1 - 1/2 x/b - 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [x - 1/4 x^2/b - 1/8 x^4/b^3]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

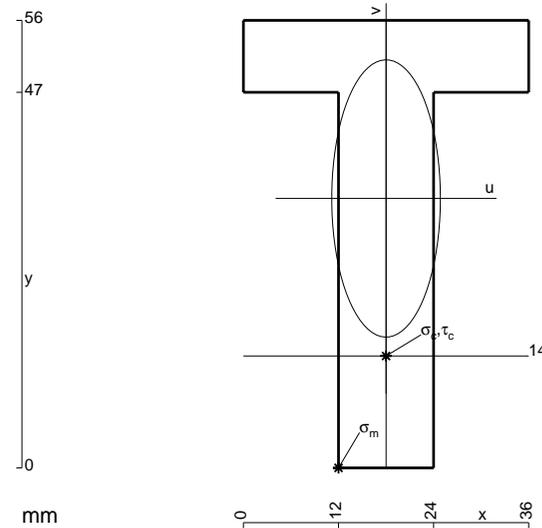
$$= (b - 1/4 b - 1/8 b) Fb 1/EJ + (-b + 1/2 b) \theta = 9/8 Fb^2/EJ$$

$$L_{GC}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

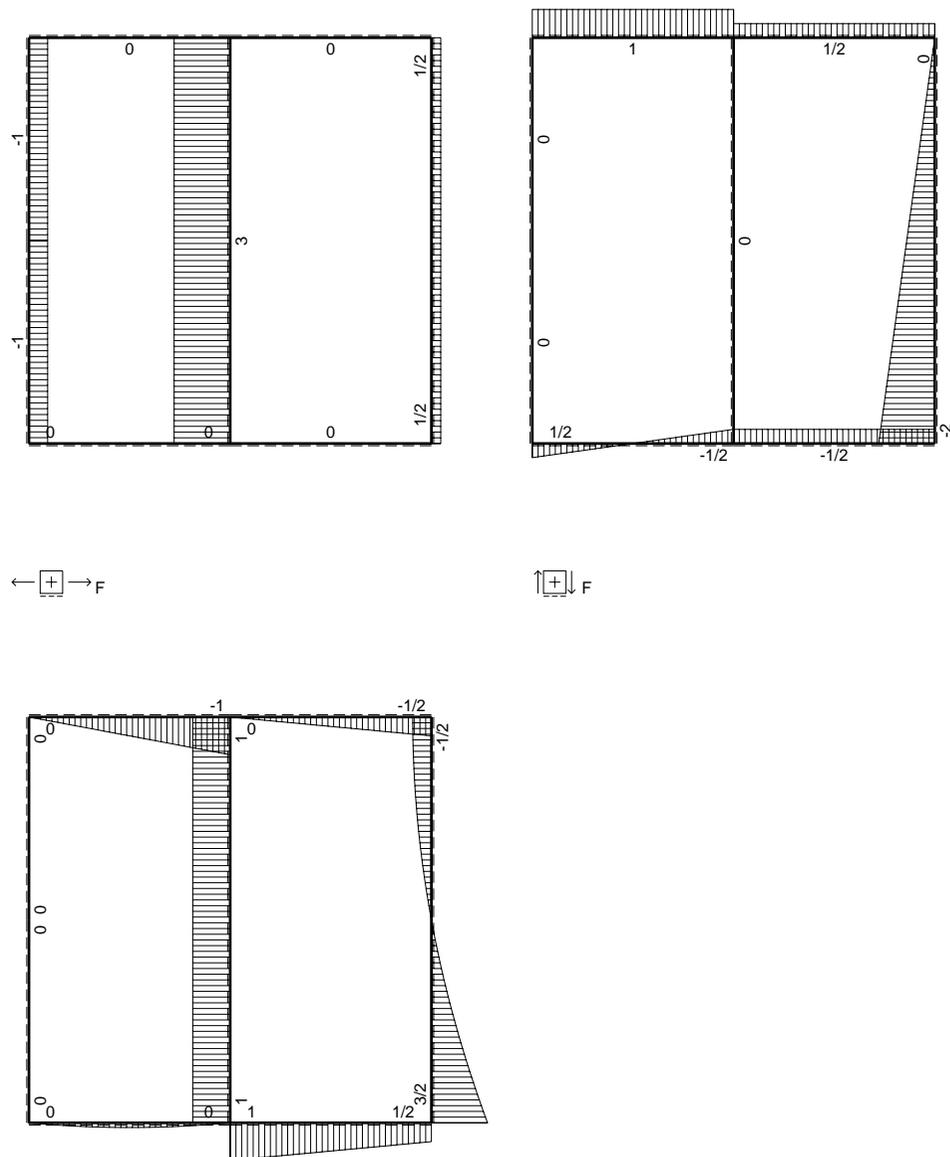
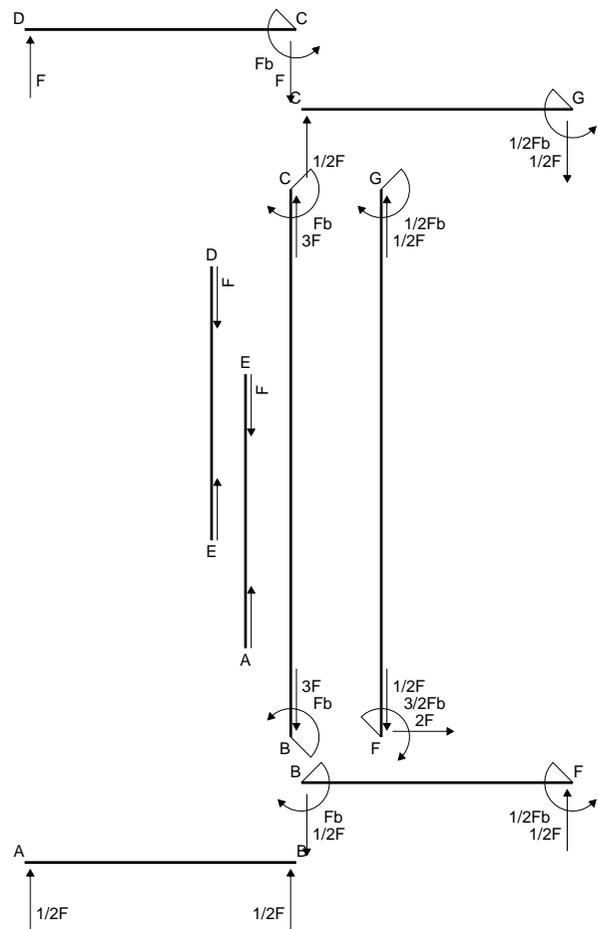
$$L_{CG}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

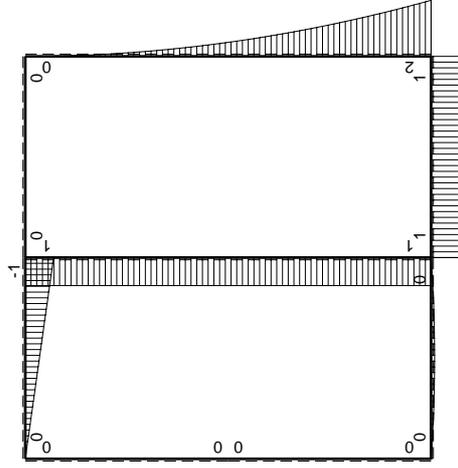
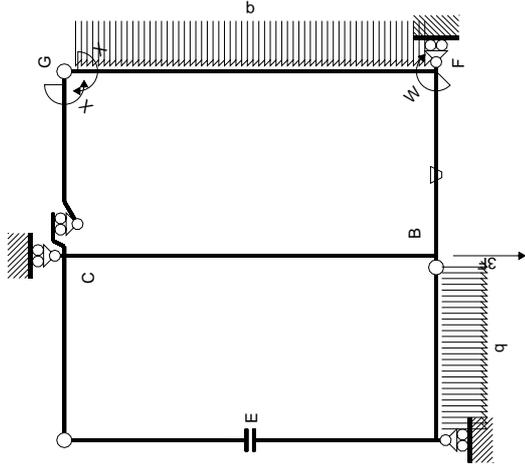


$A = 888. \text{ mm}^2$   
 $J_u = 267344. \text{ mm}^4$   
 $J_v = 41760. \text{ mm}^4$   
 $y_g = 33.72 \text{ mm}$   
 $T_y = -3460. \text{ N}$   
 $M_x = 1660800. \text{ Nmm}$   
 $x_m = 12. \text{ mm}$   
 $u_m = -6. \text{ mm}$   
 $v_m = -33.72 \text{ mm}$   
 $\sigma_m = -Mv/J_u = 209.5 \text{ N/mm}^2$   
 $x_c = 18. \text{ mm}$   
 $y_c = 14. \text{ mm}$   
 $v_c = -19.72 \text{ mm}$   
 $\sigma_c = -Mv/J_u = 122.5 \text{ N/mm}^2$   
 $\tau_c = 4.841 \text{ N/mm}^2$   
 $\sigma_o = \sqrt{\sigma^2 + 3\tau^2} = 122.8 \text{ N/mm}^2$   
 $S = 4488. \text{ mm}^3$

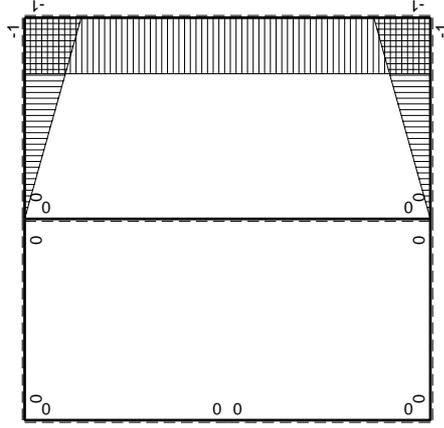




$\curvearrowright \boxed{+} F_b$



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica X=W<sub>gc</sub>

←	M <sup>0</sup> (x)	M <sup>0</sup> (x)	θ	M <sup>x</sup> M <sub>0</sub>	M <sup>x</sup> θ	M <sup>x</sup> M <sub>x</sub>	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJdx$
AB b	0	1/2Fx-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
BA b	0	-1/2Fx+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
CD b	0	-b+Fx	0	0	0	0	0+0	0
DC b	0	Fx	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
ED b	0	0	0	0	0	0	0+0	0
EA b	0	0	0	0	0	0	0+0	0
AE b	0	0	0	0	0	0	0+0	0
BF b	-x/b	Fb	-Fb/EJ	-Fx	Fx/EJ	$x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	1/3xb/EJ
FB b	1-x/b	-Fb	Fb/EJ	-Fx	Fb/EJ-Fx/EJ	$1-2x/b+x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	1/3xb/EJ
GC b	-1+x/b	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	1/3xb/EJ
CG b	x/b	0	0	0	0	$x^2/b^2$	0+0	1/3xb/EJ
FG 2b	-1	2Fb-2Fx+1/2qx <sup>2</sup>	0	-2Fb+2Fx-1/2Fx <sup>2</sup> /b	0	1	$(-4/3+0)Fb^2/EJ$	2xb/EJ
GF 2b	1	-1/2qx <sup>2</sup>	0	-1/2Fx <sup>2</sup> /b	0	1	$(-4/3+0)Fb^2/EJ$	2xb/EJ
CB 2b	0	Fb	0	0	0	0	0+0	0
BC 2b	0	-Fb	0	0	0	0	0+0	0
totali								8/3xb/EJ

iperstatica X=W<sub>gc</sub>

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{xo} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{xo} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

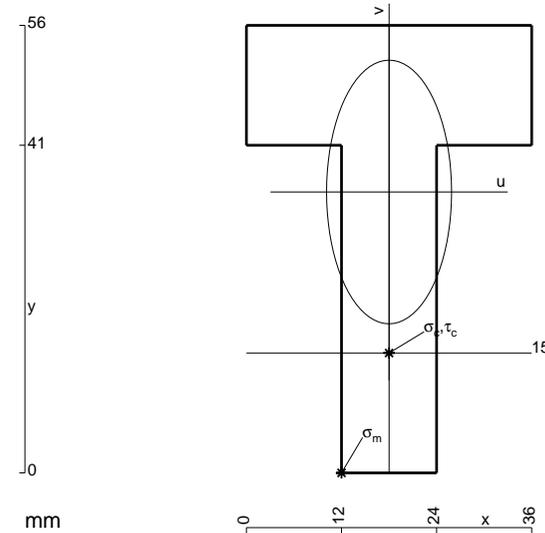
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{xo} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

$$L_{GF}^{xo} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



$$A = 1032. \text{ mm}^2$$

$$J_u = 280881. \text{ mm}^4$$

$$J_v = 64224. \text{ mm}^4$$

$$y_g = 35.15 \text{ mm}$$

$$T_y = 3380. \text{ N}$$

$$M_x = -1757600. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -6. \text{ mm}$$

$$v_m = -35.15 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -220. \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 15. \text{ mm}$$

$$v_c = -20.15 \text{ mm}$$

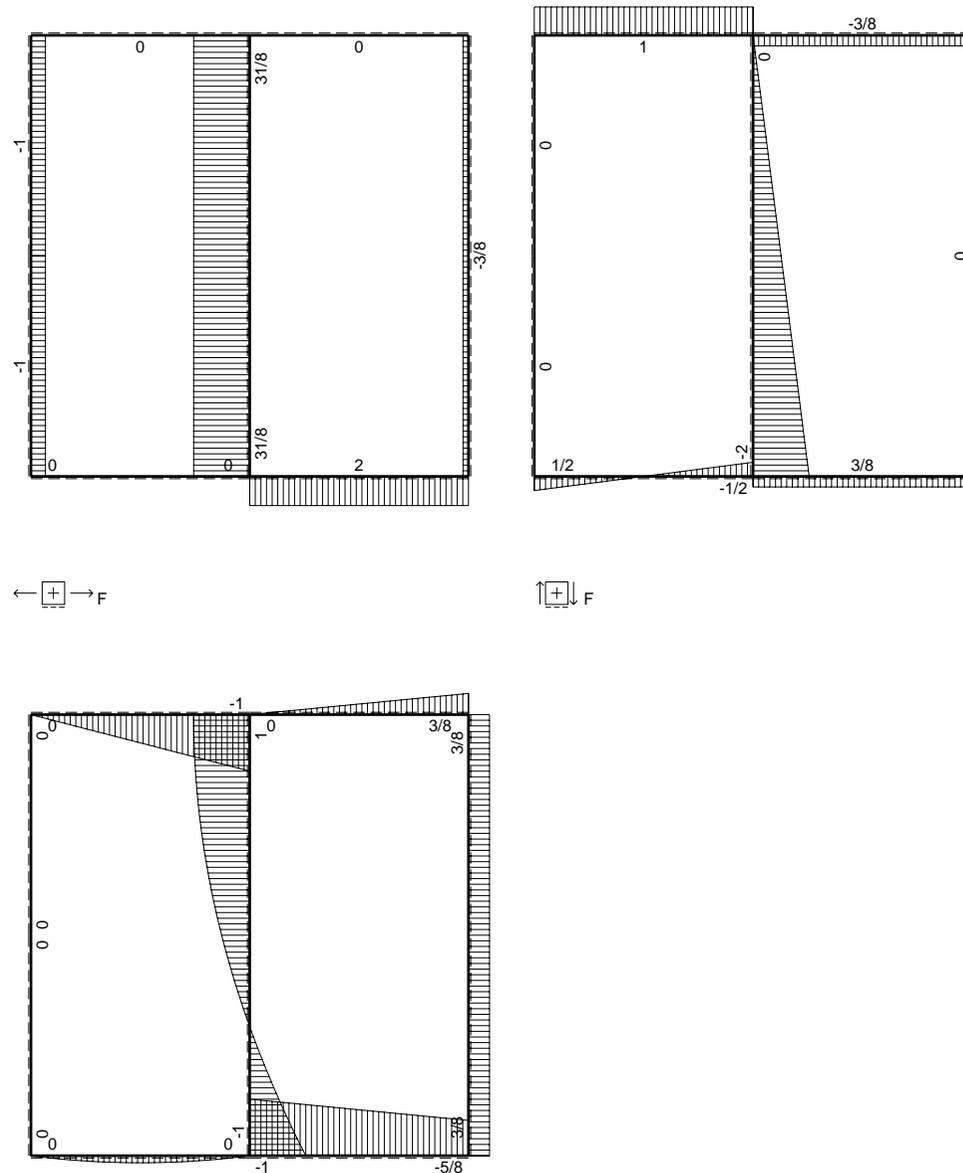
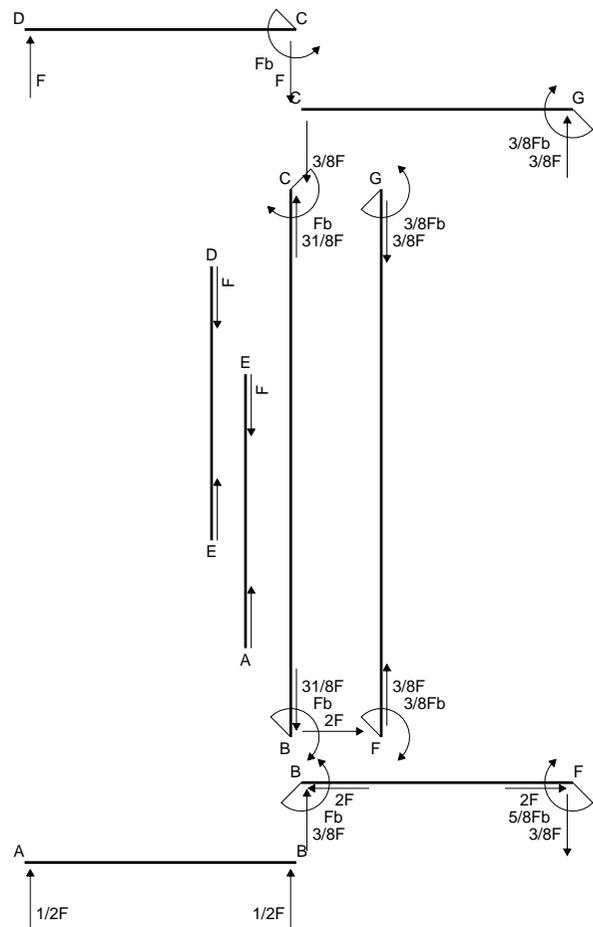
$$\sigma_c = -Mv/J_u = -126.1 \text{ N/mm}^2$$

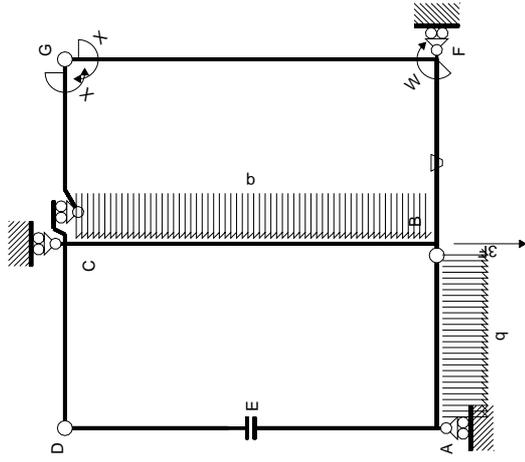
$$\tau_c = 4.991 \text{ N/mm}^2$$

$$\sigma_o = \sqrt{\sigma^2 + 3\tau^2} = 126.4 \text{ N/mm}^2$$

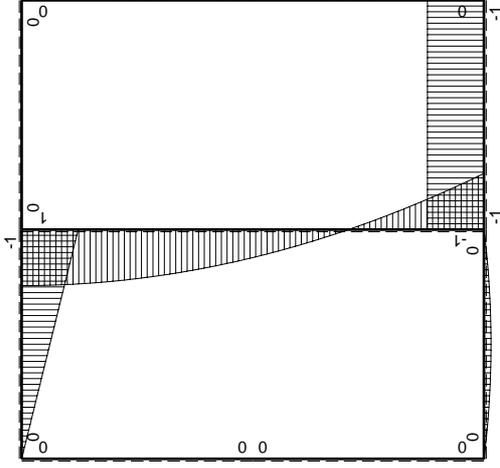
$$S = 4977. \text{ mm}^3$$



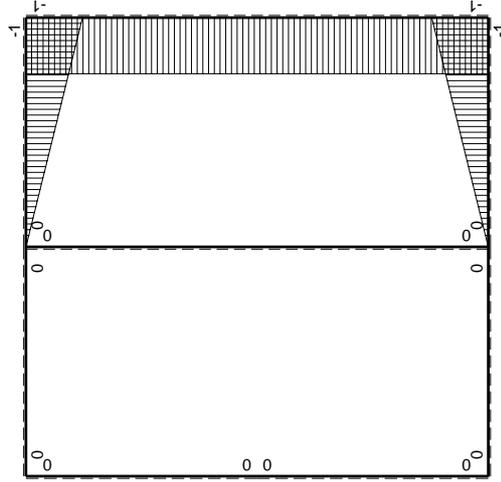




Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / EJ dx$
AB b	0	$1/2Fx - 1/2qx^2$	0	0	0	0	0+0	0
BA b	0	$-1/2Fx + 1/2qx^2$	0	0	0	0	0+0	0
CD b	0	$-Fb + Fx$	0	0	0	0	0+0	0
DC b	0	$Fx$	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
EA b	0	0	0	0	0	0	0+0	0
AB b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
BFB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb-Fx$	$Fb/EJ - Fx/EJ$	$1-2x/b+x^2/b^2$	$1/3xb/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2xb/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2xb/EJ$
CB 2b	0	$Fb - 1/2qx^2$	0	0	0	0	0+0	0
BC 2b	0	$Fb - 2Fx + 1/2qx^2$	0	0	0	0	0+0	0
totali								$8/3xb/EJ$
								$-3/8Fb$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

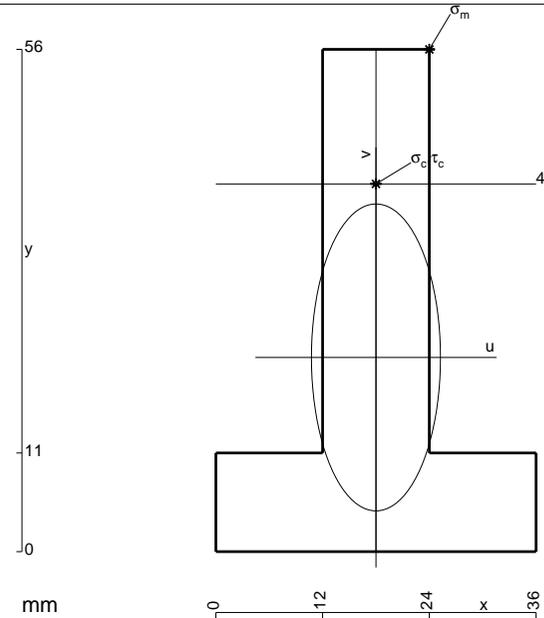
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



$$A = 936. \text{ mm}^2$$

$$J_u = 274232. \text{ mm}^4$$

$$J_v = 49248. \text{ mm}^4$$

$$y_g = 21.65 \text{ mm}$$

$$N = 11780. \text{ N}$$

$$T_y = -6080. \text{ N}$$

$$M_x = -1732800. \text{ Nmm}$$

$$x_m = 24. \text{ mm}$$

$$y_m = 56. \text{ mm}$$

$$u_m = 6. \text{ mm}$$

$$v_m = 34.35 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 229.6 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 41. \text{ mm}$$

$$v_c = 19.35 \text{ mm}$$

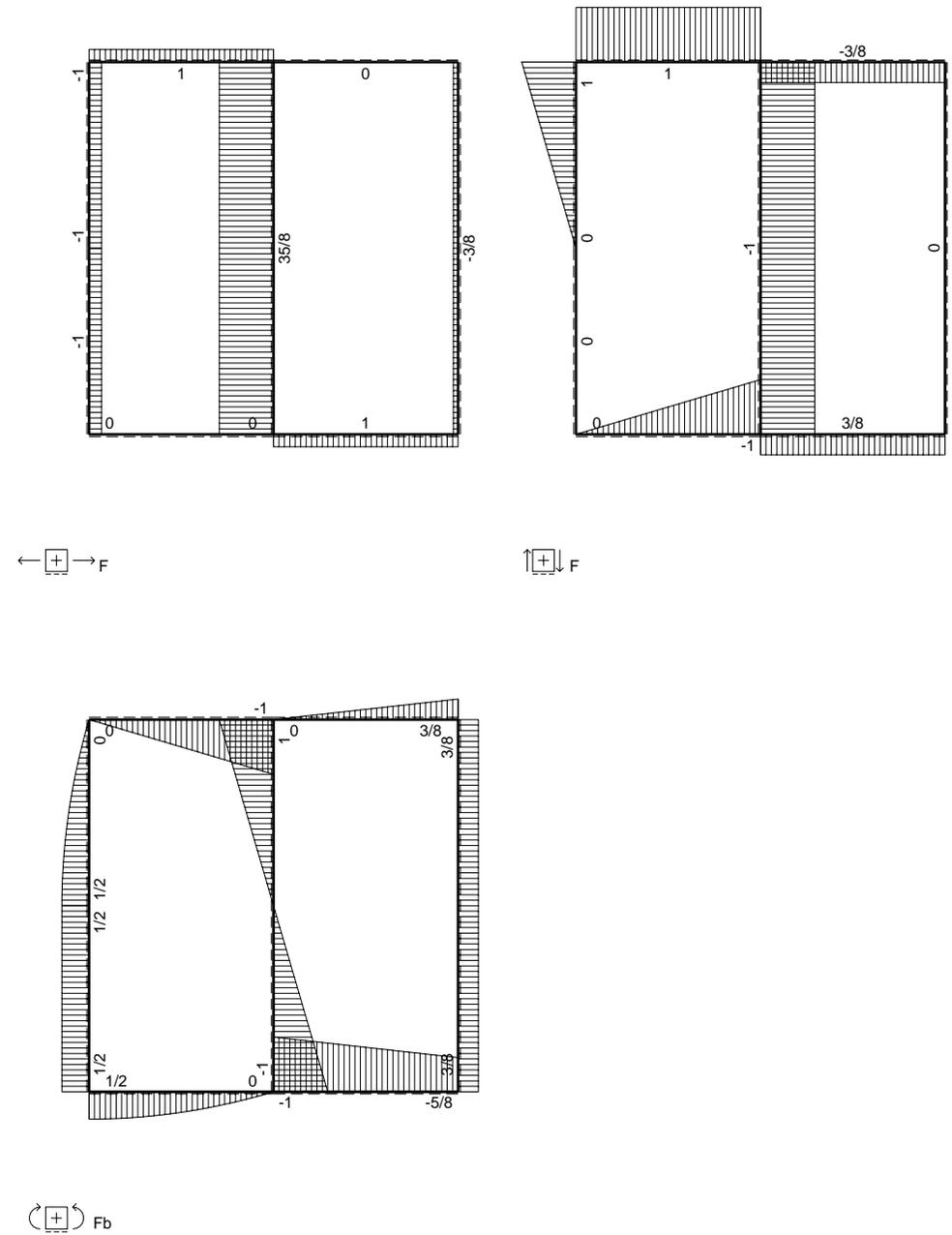
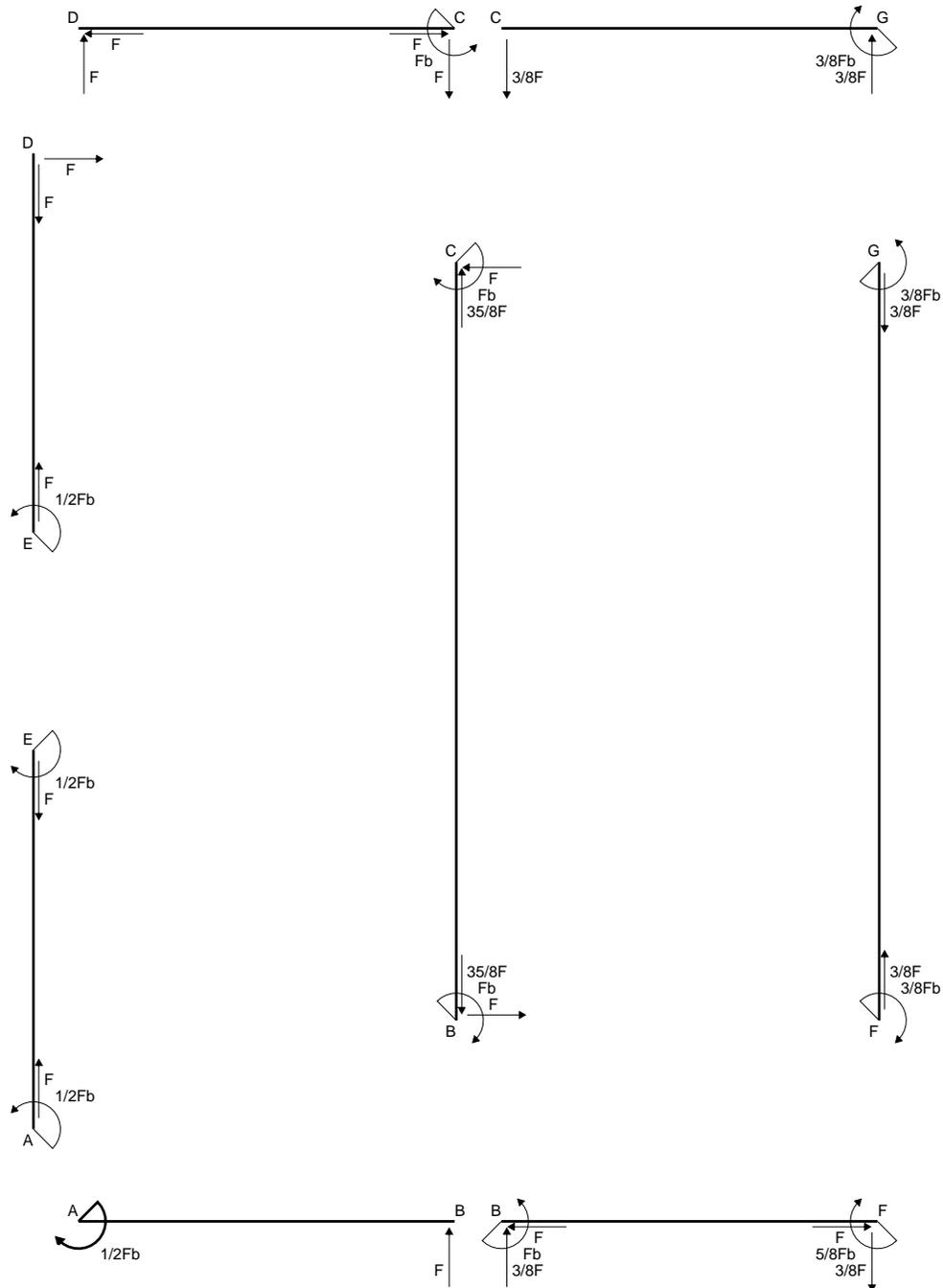
$$\sigma_c = N/A - Mv/J_u = 134.8 \text{ N/mm}^2$$

$$\tau_c = 8.928 \text{ N/mm}^2$$

$$\sigma_\varrho = \sqrt{\sigma^2 + 3\tau^2} = 135.7 \text{ N/mm}^2$$

$$S = 4832. \text{ mm}^3$$







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

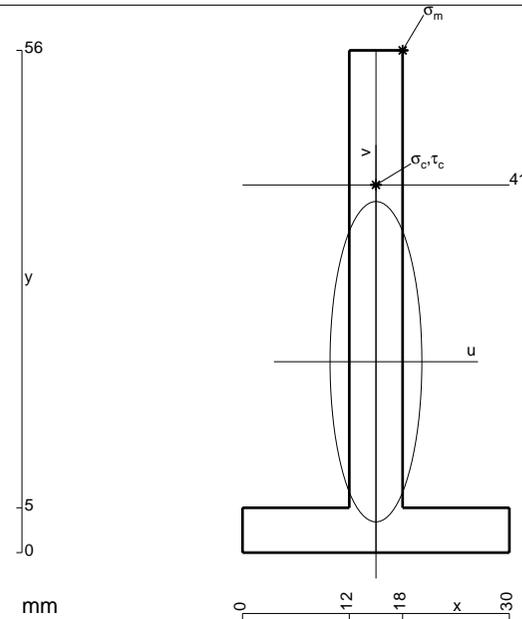
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

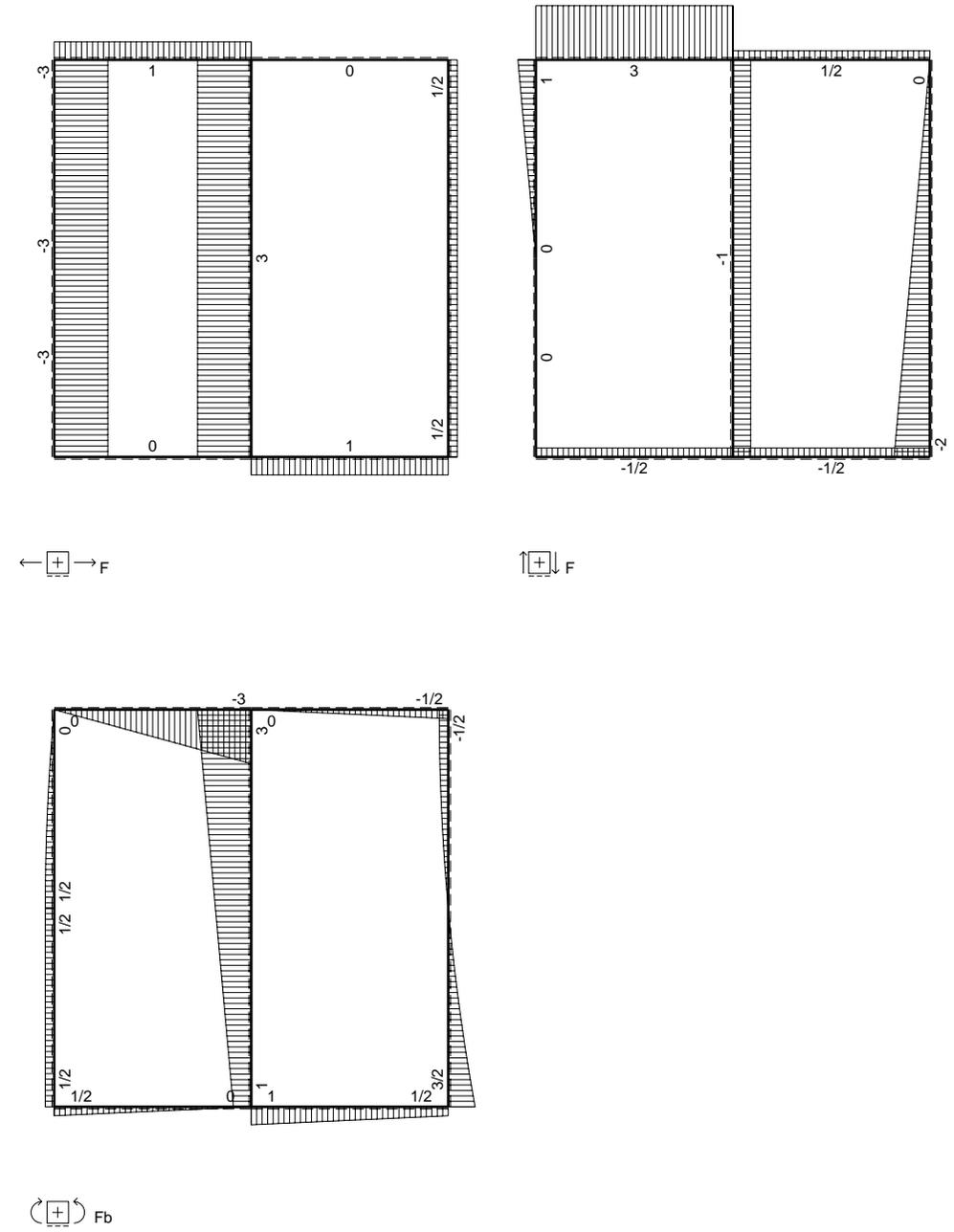
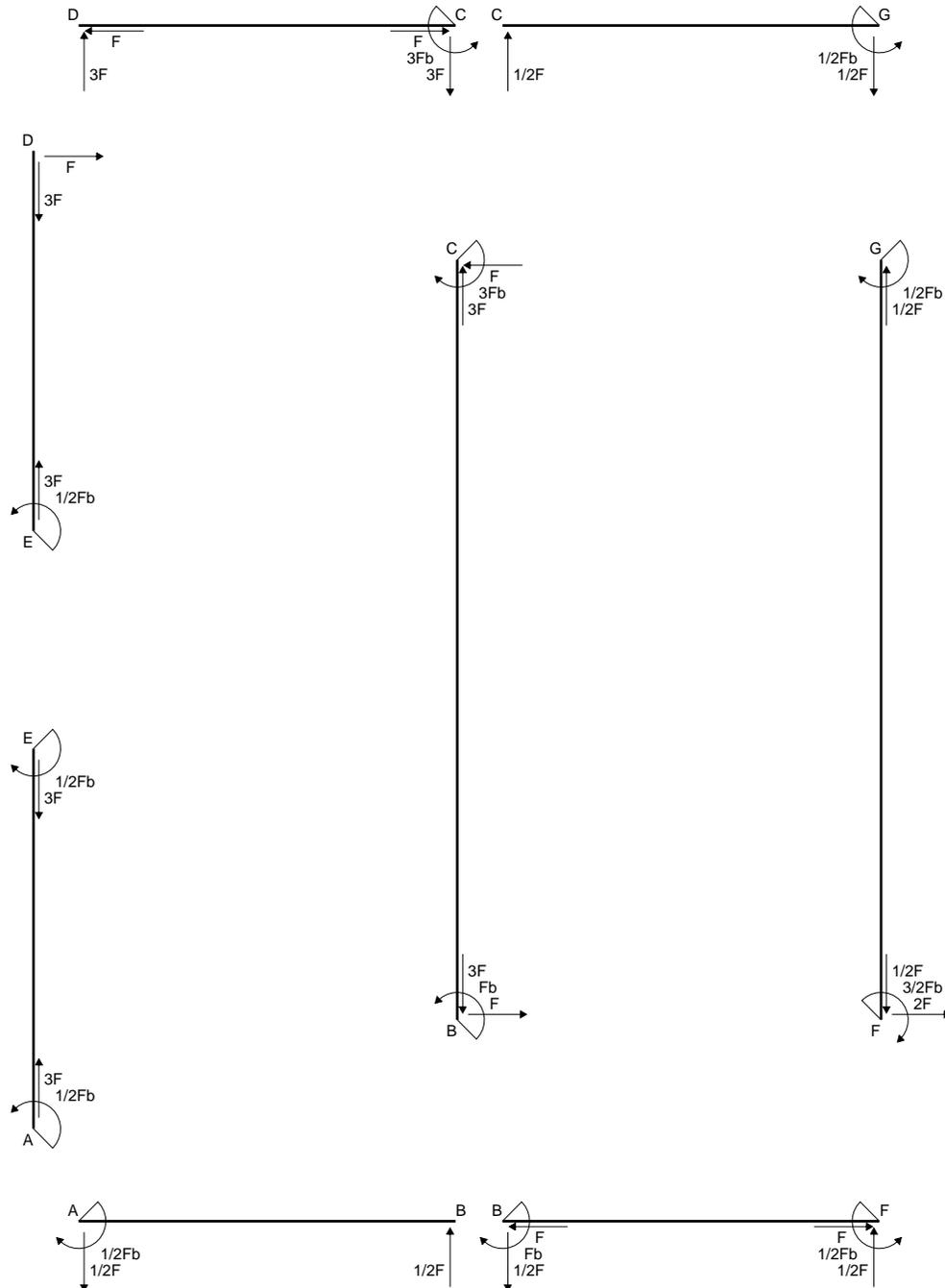
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

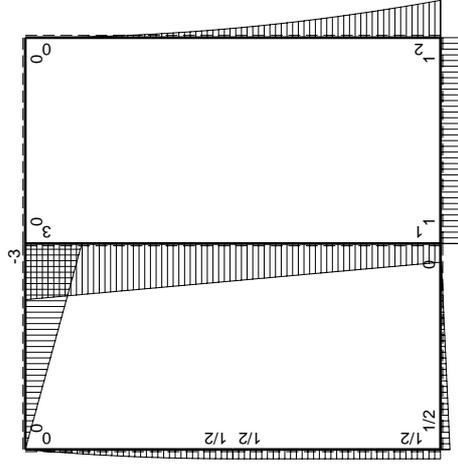
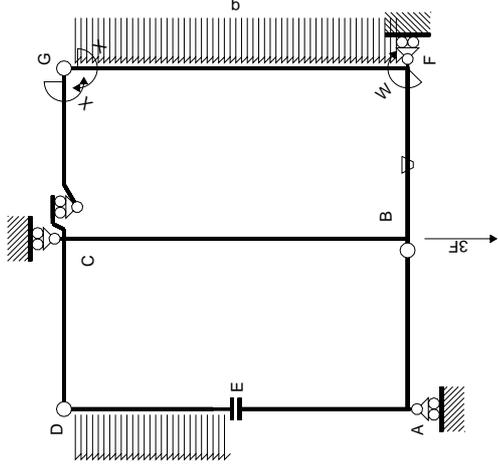
$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



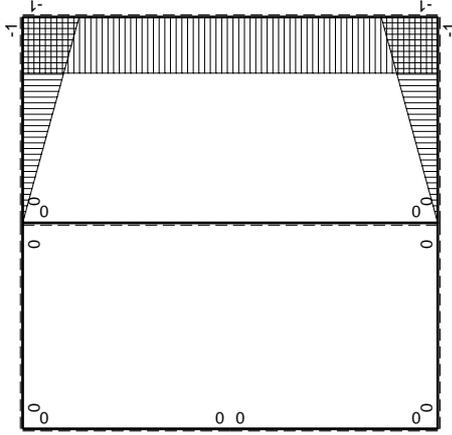
- A = 456. mm<sup>2</sup>
- J<sub>u</sub> = 145554. mm<sup>4</sup>
- J<sub>v</sub> = 12168. mm<sup>4</sup>
- y<sub>g</sub> = 21.29 mm
- N = 6738. N
- T<sub>y</sub> = -1540. N
- M<sub>x</sub> = -939400. Nmm
- x<sub>m</sub> = 18. mm
- y<sub>m</sub> = 56. mm
- u<sub>m</sub> = 3. mm
- v<sub>m</sub> = 34.71 mm
- σ<sub>m</sub> = N/A - M<sub>v</sub>/J<sub>u</sub> = 238.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 15. mm
- y<sub>c</sub> = 41. mm
- v<sub>c</sub> = 19.71 mm
- σ<sub>c</sub> = N/A - M<sub>v</sub>/J<sub>u</sub> = 142. N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.318 N/mm<sup>2</sup>
- σ<sub>φ</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 142.2 N/mm<sup>2</sup>
- S = 2449. mm<sup>3</sup>







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

←	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / E dx$	iperstatica X=W <sub>gc</sub>	
									totali	
AB b	0	$1/2Fb-1/2Fx$	0	0	0	0	0	0	0	0
BA b	0	$-1/2Fx$	0	0	0	0	0	0	0	0
CD b	0	$-3Fb+3Fx$	0	0	0	0	0	0	0	0
DC b	0	$3Fx$	0	0	0	0	0	0	0	0
DE b	0	$Fx-1/2qx^2$	0	0	0	0	0	0	0	0
ED b	0	$-1/2Fb+1/2qx^2$	0	0	0	0	0	0	0	0
EA b	0	$1/2Fb$	0	0	0	0	0	0	0	0
AE b	0	$-1/2Fb$	0	0	0	0	0	0	0	0
BF b	$-x/b$	Fb	$-Fb/EJ$	$-Fx$	$Fx/EJ$	$x^2/b^2$	$-1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$	0	0
FB b	$1-x/b$	$-Fb$	$Fb/EJ$	$-Fb+Fx$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$	0	0
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0	0	0	0
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0	0	0	0
FG 2b	-1	$2Fb-2Fx+1/2qx^2$	0	$-2Fb+2Fx-1/2Fx^2/b$	0	1	$(-4/3+0)Fb^2/EJ$	$2xb/EJ$	0	0
GF 2b	1	$-1/2qx^2$	0	$-1/2Fx^2/b$	0	1	0	0	0	0
CB 2b	0	$3Fb-Fx$	0	0	0	0	0	0	0	0
BC 2b	0	$-Fb-Fx$	0	0	0	0	0	0	0	0
totali									$-4/3Fb^2/EJ$	$8/3xb/EJ$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x_0} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

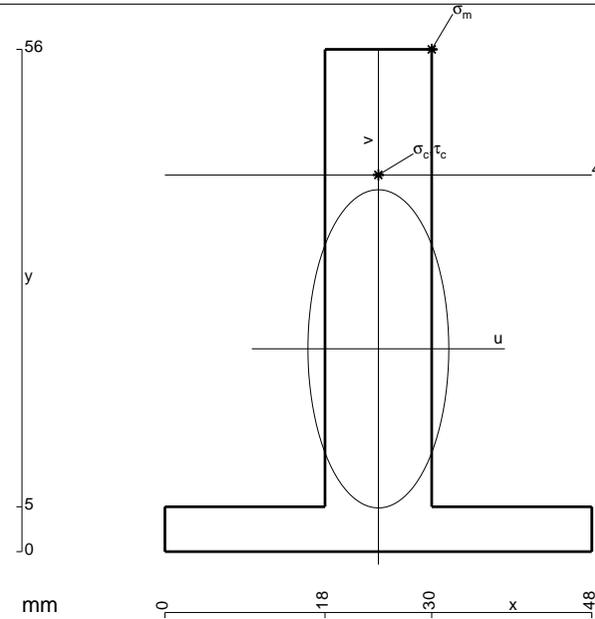
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x_0} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

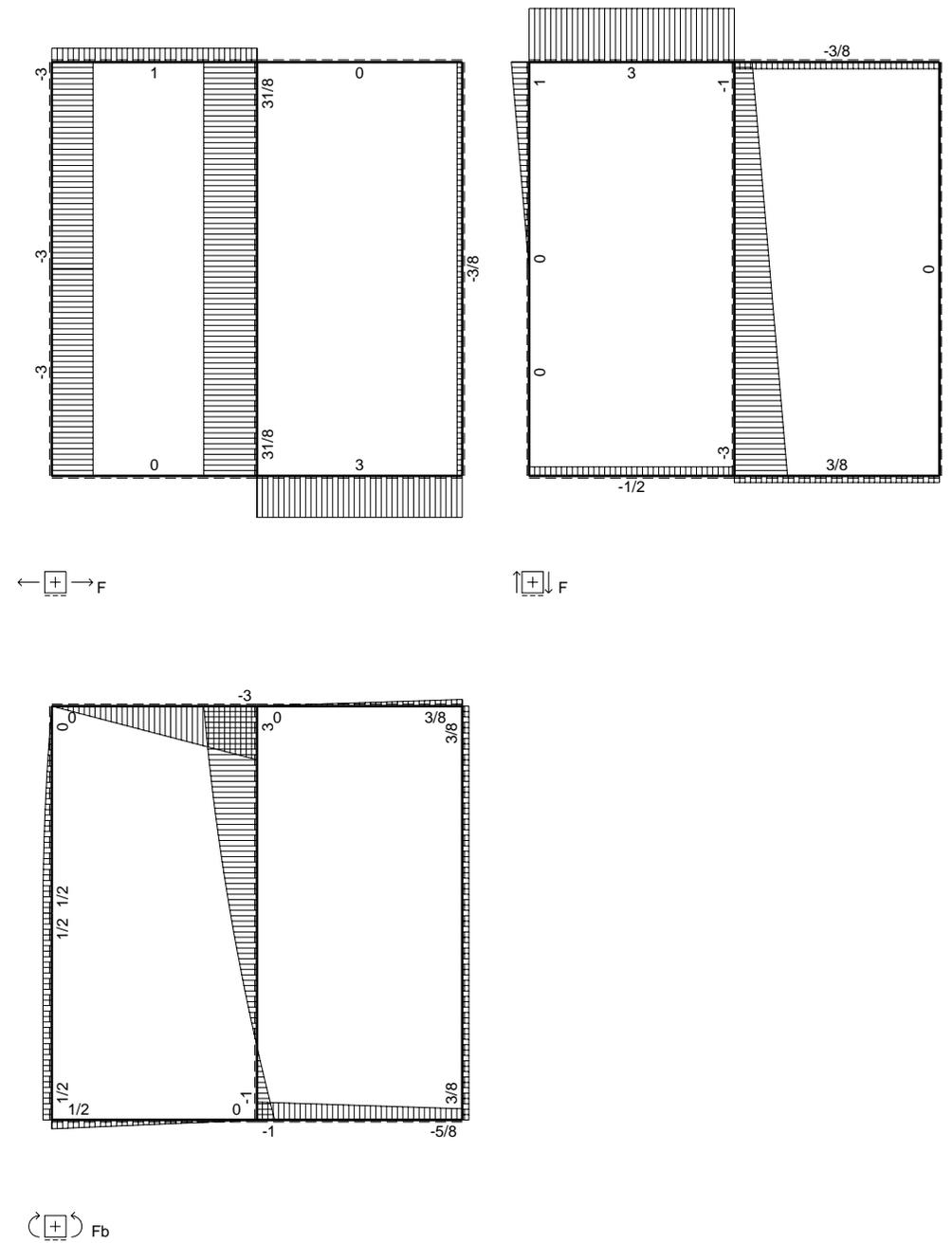
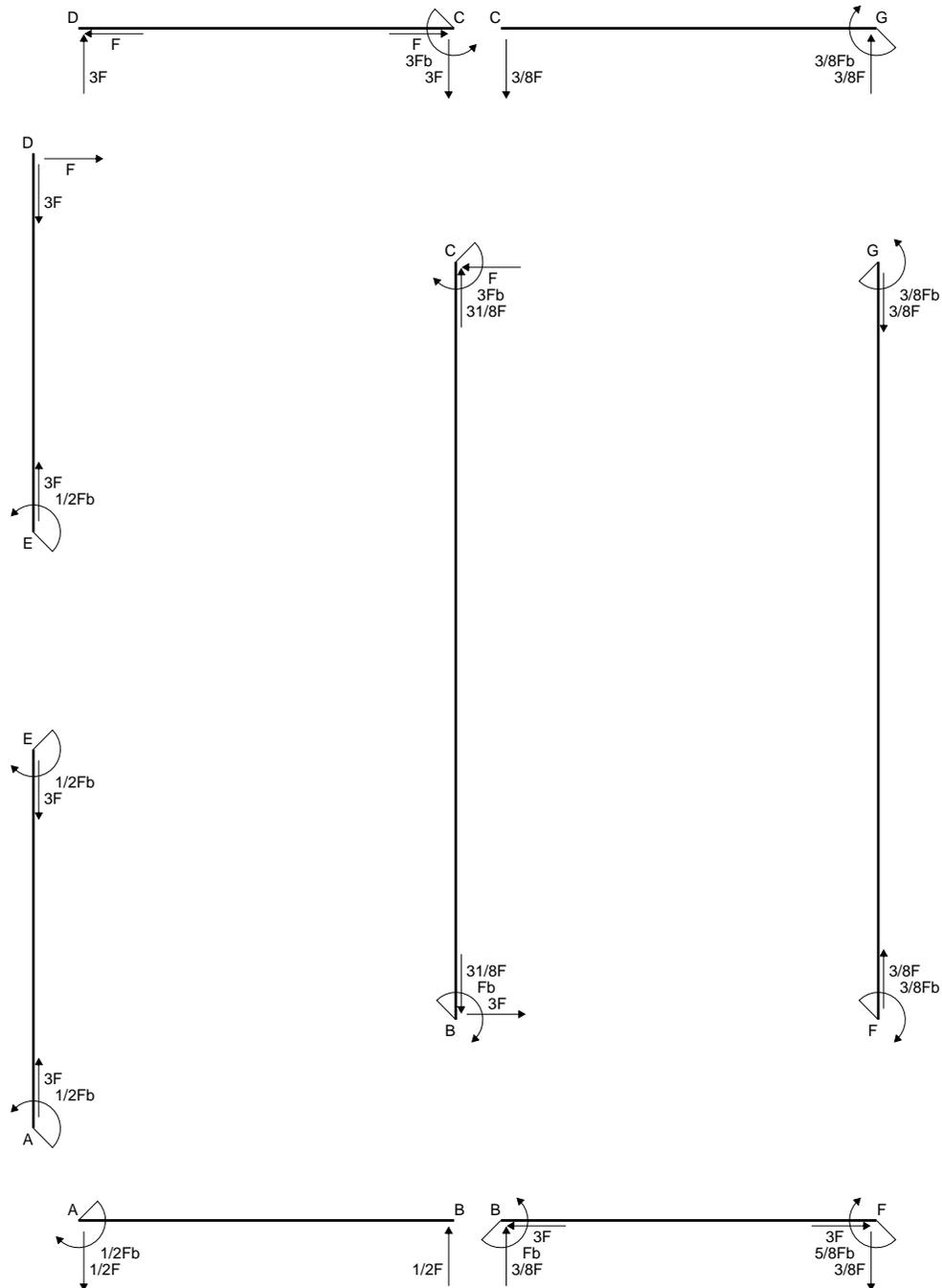
$$L_{GF}^{x_0} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

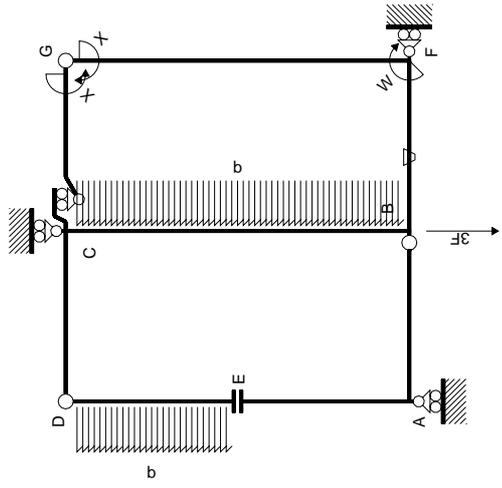
$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



- A = 852. mm<sup>2</sup>
- J<sub>u</sub> = 268308. mm<sup>4</sup>
- J<sub>v</sub> = 53424. mm<sup>4</sup>
- y<sub>g</sub> = 22.61 mm
- N = 800. N
- T<sub>y</sub> = 2400. N
- M<sub>x</sub> = -1584000. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 56. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 33.39 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = 198. N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 42. mm
- v<sub>c</sub> = 19.39 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = 115.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.304 N/mm<sup>2</sup>
- σ<sub>0</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 115.5 N/mm<sup>2</sup>
- S = 4433. mm<sup>3</sup>

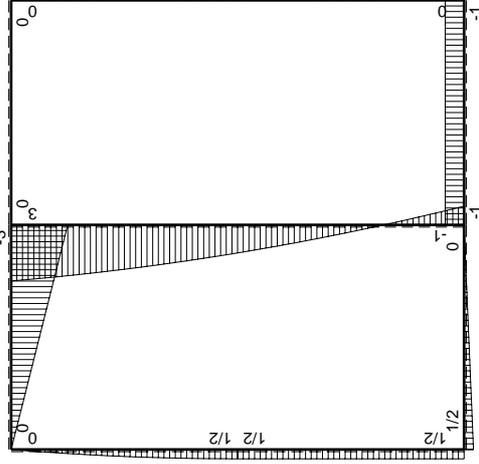






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / EJ dx$
AB b	0	$1/2Fb - 1/2Fx$	0	0	0	0	0+0	0
BA b	0	$-1/2Fx$	0	0	0	0	0+0	0
CD b	0	$-3Fb + 3Fx$	0	0	0	0	0+0	0
DC b	0	$3Fx$	0	0	0	0	0+0	0
DE b	0	$Fx - 1/2qx^2$	0	0	0	0	0+0	0
ED b	0	$-1/2Fb + 1/2qx^2$	0	0	0	0	0+0	0
EA b	0	$1/2Fb$	0	0	0	0	0+0	0
AE b	0	$-1/2Fb$	0	0	0	0	0+0	0
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2 + 1/2)Fb^2/EJ$	$1/3x^3/EJ$
FB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb - Fx$	$Fb/EJ - Fx/EJ$	$1 - 2x/b + x^2/b^2$	$1/3x^3/EJ$	$1/3x^3/EJ$
GC b	$-1+x/b$	0	0	0	0	$1 - 2x/b + x^2/b^2$	0+0	$1/3x^3/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3x^3/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2x^2/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2x^2/EJ$
CB 2b	0	$3Fb - Fx - 1/2qx^2$	0	0	0	0	0+0	0
BC 2b	0	$Fb - 3Fx + 1/2qx^2$	0	0	0	0	0+0	0
totali								$8/3x^3/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

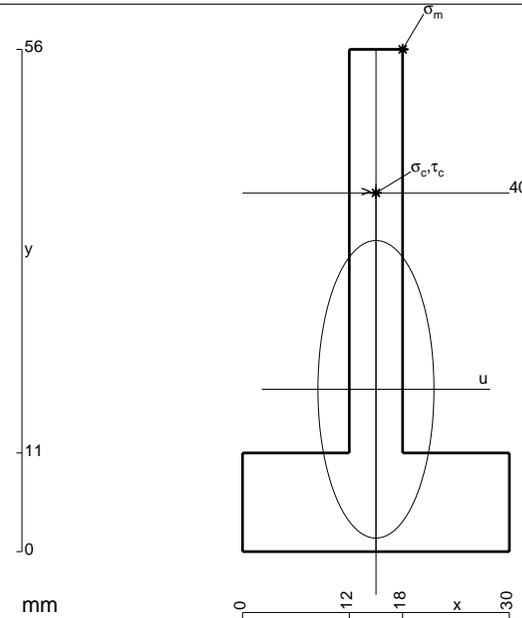
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

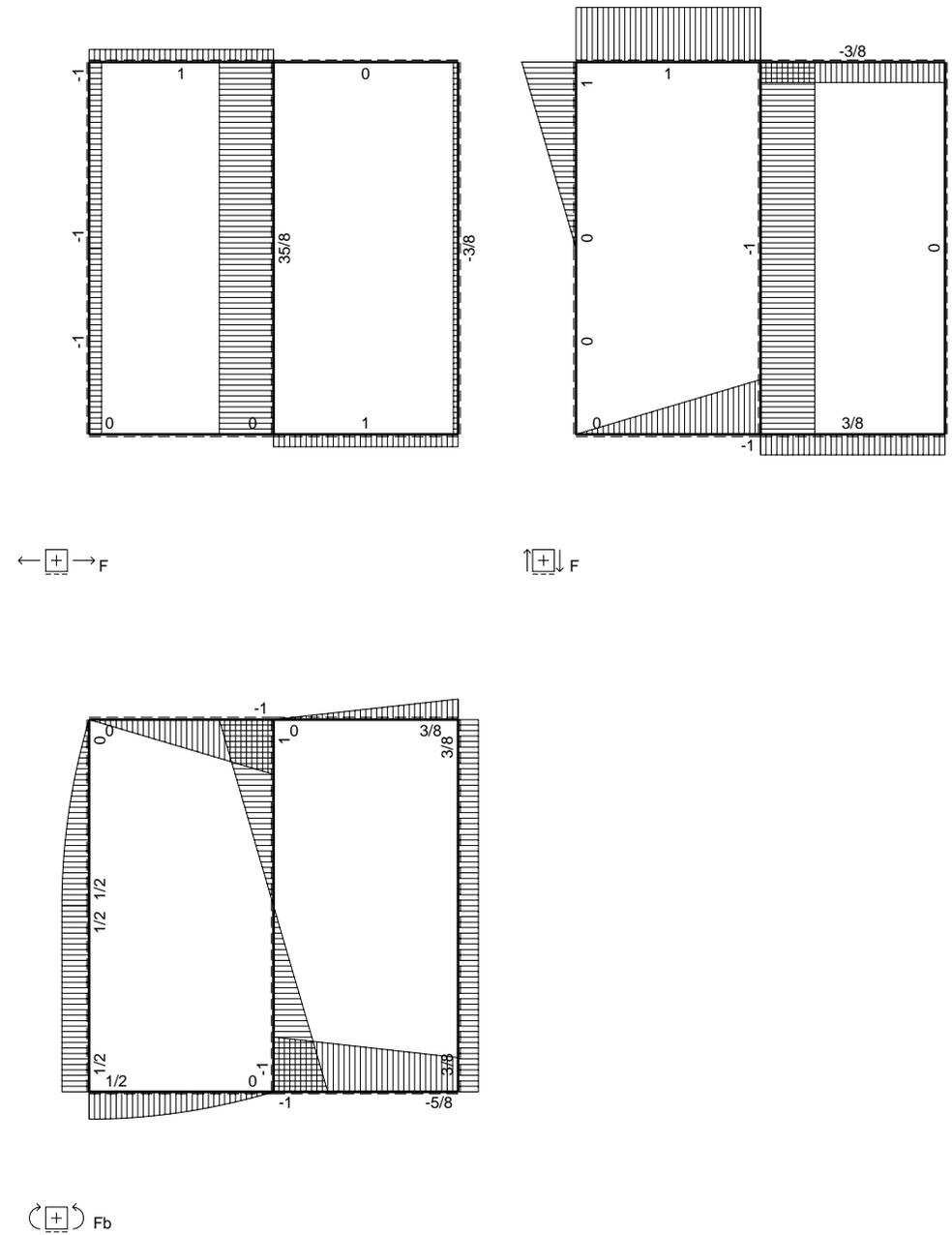
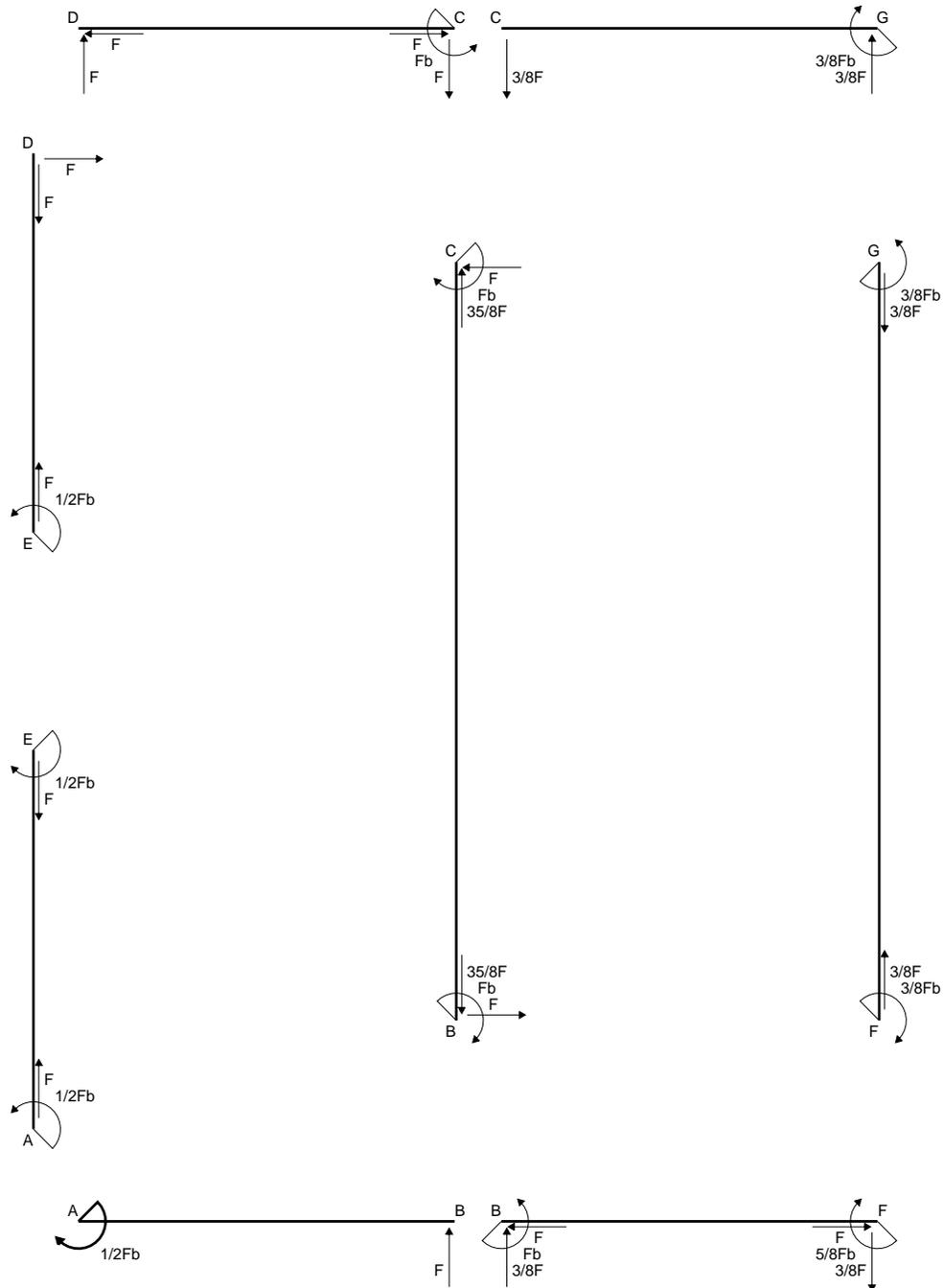
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

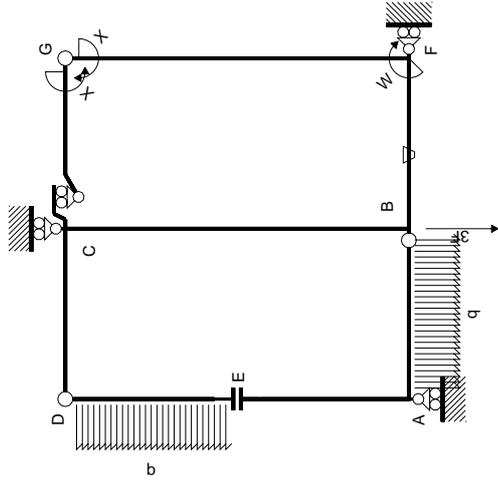
$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



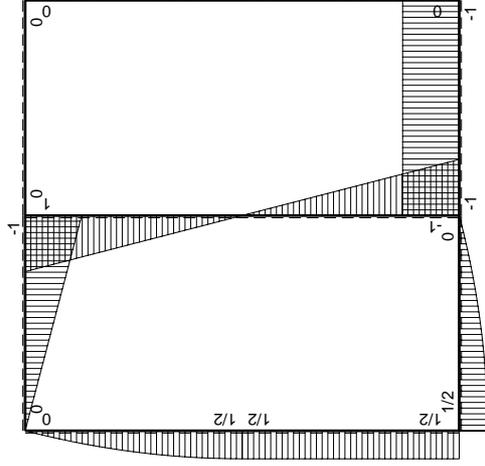
- A = 600. mm<sup>2</sup>
- J<sub>u</sub> = 165314. mm<sup>4</sup>
- J<sub>v</sub> = 25560. mm<sup>4</sup>
- y<sub>g</sub> = 18.1 mm
- N = 430. N
- T<sub>y</sub> = 1290. N
- M<sub>x</sub> = -903000. Nmm
- x<sub>m</sub> = 18. mm
- y<sub>m</sub> = 56. mm
- u<sub>m</sub> = 3. mm
- v<sub>m</sub> = 37.9 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = 207.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 15. mm
- y<sub>c</sub> = 40. mm
- v<sub>c</sub> = 21.9 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = 120.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.733 N/mm<sup>2</sup>
- σ<sub>ρ</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 120.5 N/mm<sup>2</sup>
- S = 2870. mm<sup>3</sup>



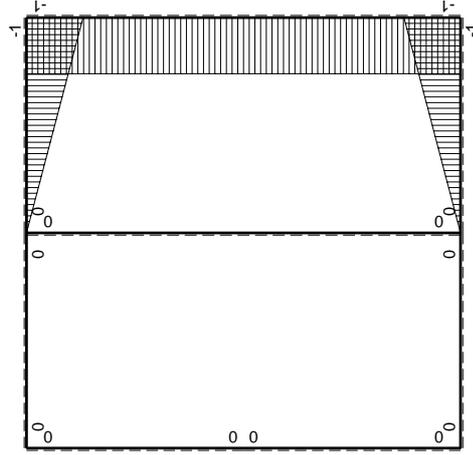




Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	$1/2Fb-1/2qx^2$	0	0	0	0	0	0+0	0
BA b	$-Fx+1/2qx^2$	0	0	0	0	0	0+0	0
CD b	$-Fb+Fx$	0	0	0	0	0	0+0	0
DC b	$Fx$	0	0	0	0	0	0+0	0
DE b	$Fx-1/2qx^2$	0	0	0	0	0	0+0	0
ED b	$-1/2Fb+1/2qx^2$	0	0	0	0	0	0+0	0
EA b	$1/2Fb$	0	0	0	0	0	0+0	0
AE b	$-1/2Fb$	0	0	0	0	0	0+0	0
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb-Fx$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$1/3xb/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2xb/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2xb/EJ$
CB 2b	0	$Fb-Fx$	0	0	0	0	0+0	0
BC 2b	0	$Fb-Fx$	0	0	0	0	0+0	0
totali								$Fb^2/EJ$
								$8/3xb/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

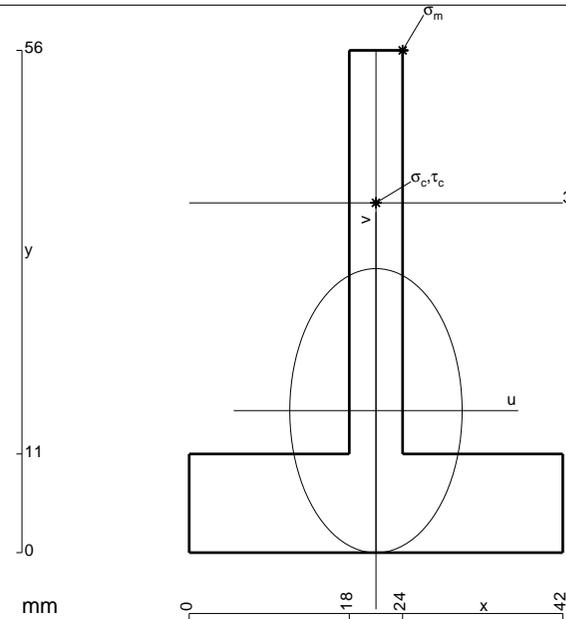
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



- A = 732. mm<sup>2</sup>
- J<sub>u</sub> = 183822. mm<sup>4</sup>
- J<sub>v</sub> = 68724. mm<sup>4</sup>
- y<sub>g</sub> = 15.83 mm
- N = 5731. N
- T<sub>y</sub> = -1310. N
- M<sub>x</sub> = -969400. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 56. mm
- u<sub>m</sub> = 3. mm
- v<sub>m</sub> = 40.17 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = 219.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 39. mm
- v<sub>c</sub> = 23.17 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = 130. N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.837 N/mm<sup>2</sup>
- σ<sub>σ</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 130.2 N/mm<sup>2</sup>
- S = 3231. mm<sup>3</sup>







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

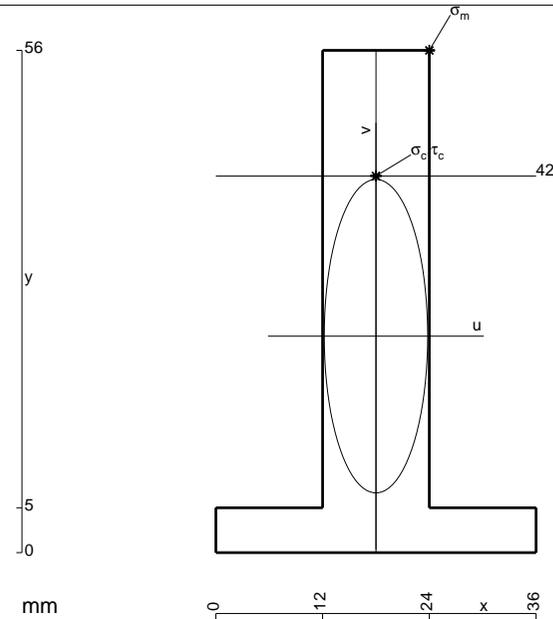
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



$$A = 792. \text{ mm}^2$$

$$J_u = 242073. \text{ mm}^4$$

$$J_v = 26784. \text{ mm}^4$$

$$y_g = 24.14 \text{ mm}$$

$$N = 7155. \text{ N}$$

$$T_y = -2120. \text{ N}$$

$$M_x = -1674800. \text{ Nmm}$$

$$x_m = 24. \text{ mm}$$

$$y_m = 56. \text{ mm}$$

$$u_m = 6. \text{ mm}$$

$$v_m = 31.86 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 229.5 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 42. \text{ mm}$$

$$v_c = 17.86 \text{ mm}$$

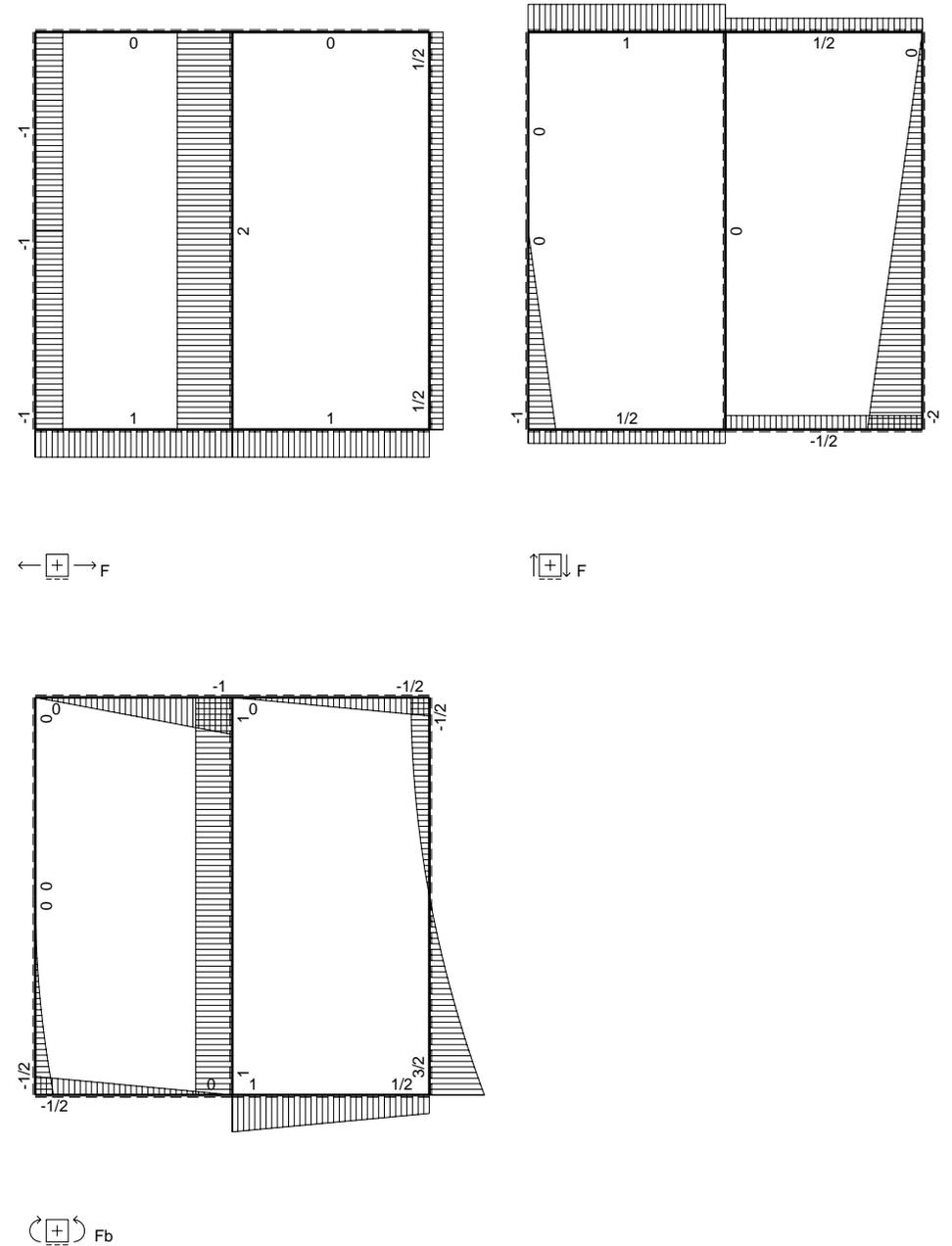
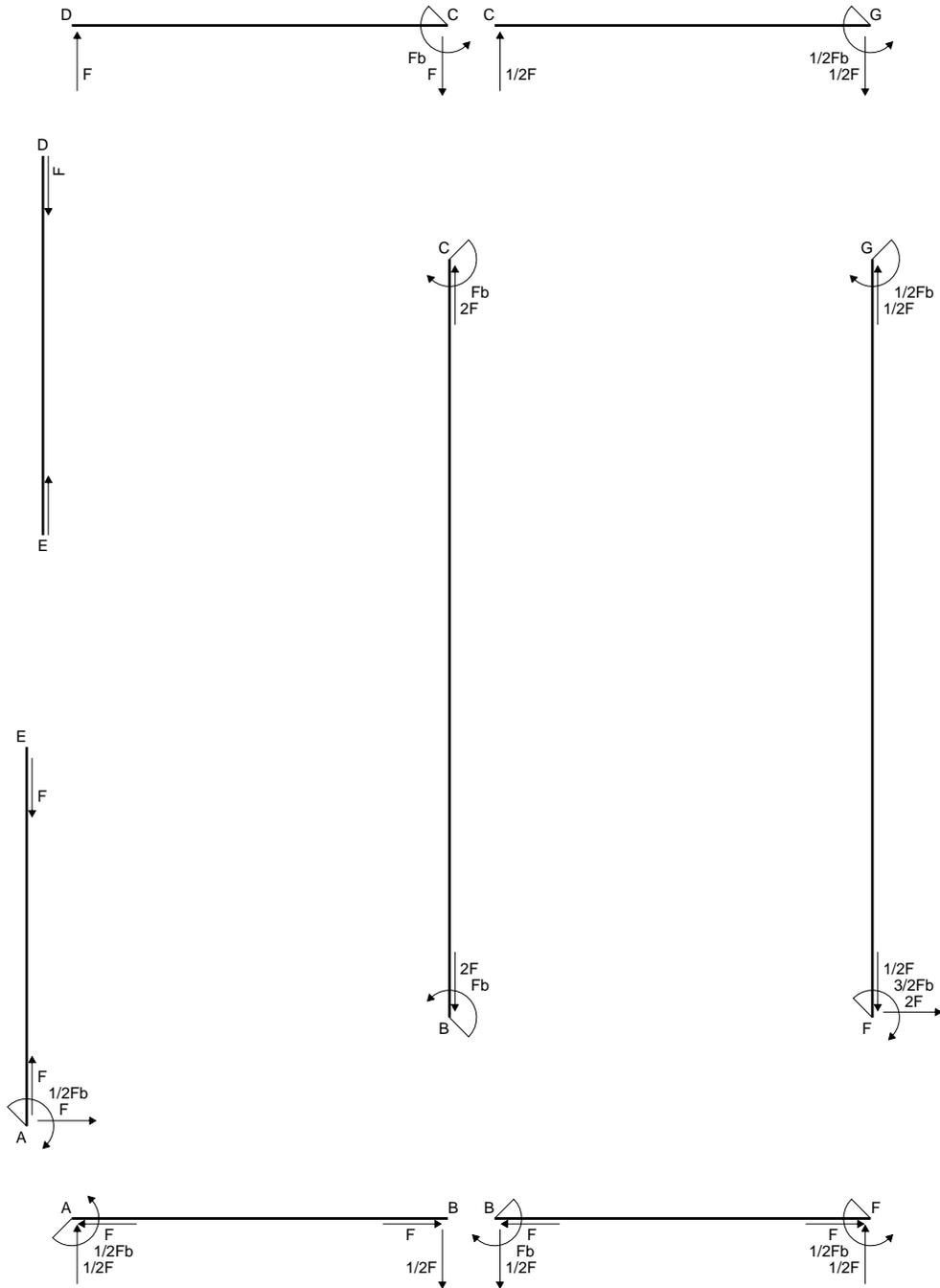
$$\sigma_c = N/A - Mv/J_u = 132.6 \text{ N/mm}^2$$

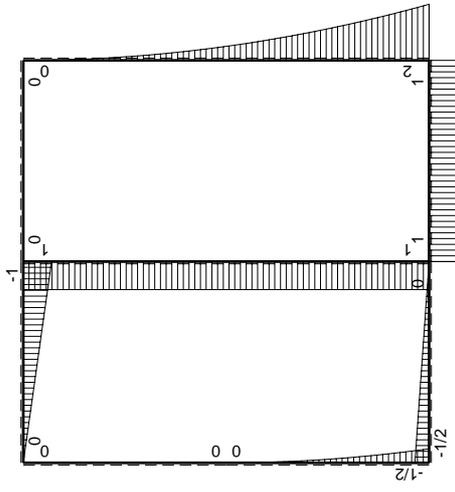
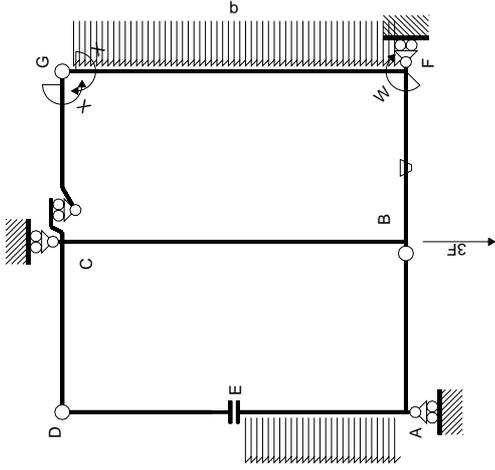
$$\tau_c = 3.048 \text{ N/mm}^2$$

$$\sigma_\varrho = \sqrt{\sigma^2 + 3\tau^2} = 132.7 \text{ N/mm}^2$$

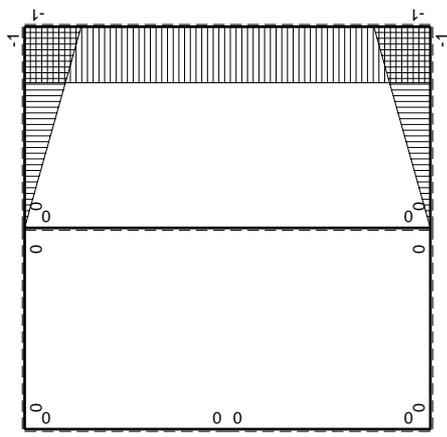
$$S = 4177. \text{ mm}^3$$







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\leftarrow$	$M(x)$	$M^0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / E dx$
AB b	0	$-1/2Fb + 1/2Fx$	0	0	0	0	0+0	0
BA b	0	$1/2Fx$	0	0	0	0	0+0	0
CD b	0	$-Fb + Fx$	0	0	0	0	0+0	0
DC b	0	$Fx$	0	0	0	0	0+0	0
ED b	0	0	0	0	0	0	0+0	0
EA b	0	$-1/2qx^2$	0	0	0	0	0+0	0
AE b	0	$1/2Fb - Fx + 1/2qx^2$	0	0	0	0	0+0	0
BF b	$-x/b$	$Fb$	$-Fb/EJ$	$-Fx$	$Fx/EJ$	$x^2/b^2$	$(-1/2 + 1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$-Fb$	$Fb/EJ$	$-Fb + Fx$	$Fb/EJ - Fx/EJ$	$1-2x/b + x^2/b^2$	$(-1/2 + 1/2)Fb^2/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b + x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	$2Fb - 2Fx + 1/2qx^2$	0	$-2Fb + 2Fx - 1/2Fx^2/b$	0	1	$(-4/3 + 0)Fb^2/EJ$	$2xb/EJ$
GF 2b	1	$-1/2qx^2$	0	$-1/2Fx^2/b$	0	1	$(-4/3 + 0)Fb^2/EJ$	$2xb/EJ$
CB 2b	0	$Fb$	0	0	0	0	0+0	0
BC 2b	0	$-Fb$	0	0	0	0	0+0	0
totali							$-4/3Fb^2/EJ$	$8/3xb/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x\theta} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x\theta} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

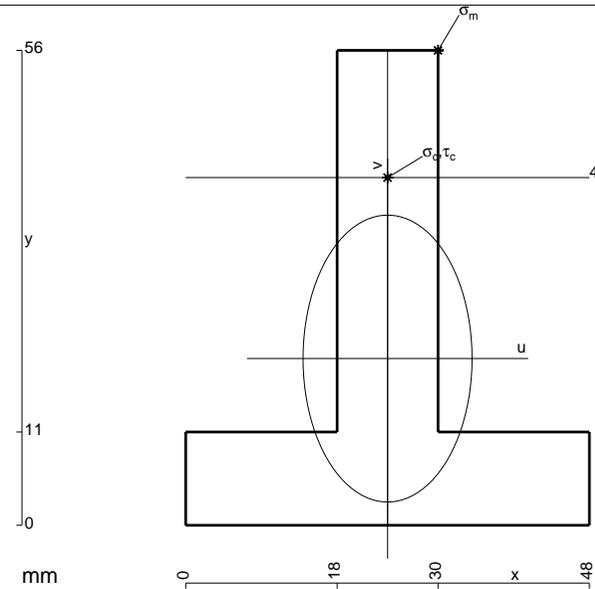
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x\theta} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

$$L_{GF}^{x\theta} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



$$A = 1068. \text{ mm}^2$$

$$J_u = 305751. \text{ mm}^4$$

$$J_v = 107856. \text{ mm}^4$$

$$y_g = 19.66 \text{ mm}$$

$$T_y = 2430. \text{ N}$$

$$M_x = -2016900. \text{ Nmm}$$

$$x_m = 30. \text{ mm}$$

$$y_m = 56. \text{ mm}$$

$$u_m = 6. \text{ mm}$$

$$v_m = 36.34 \text{ mm}$$

$$\sigma_m = -Mv/J_u = 239.7 \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 41. \text{ mm}$$

$$v_c = 21.34 \text{ mm}$$

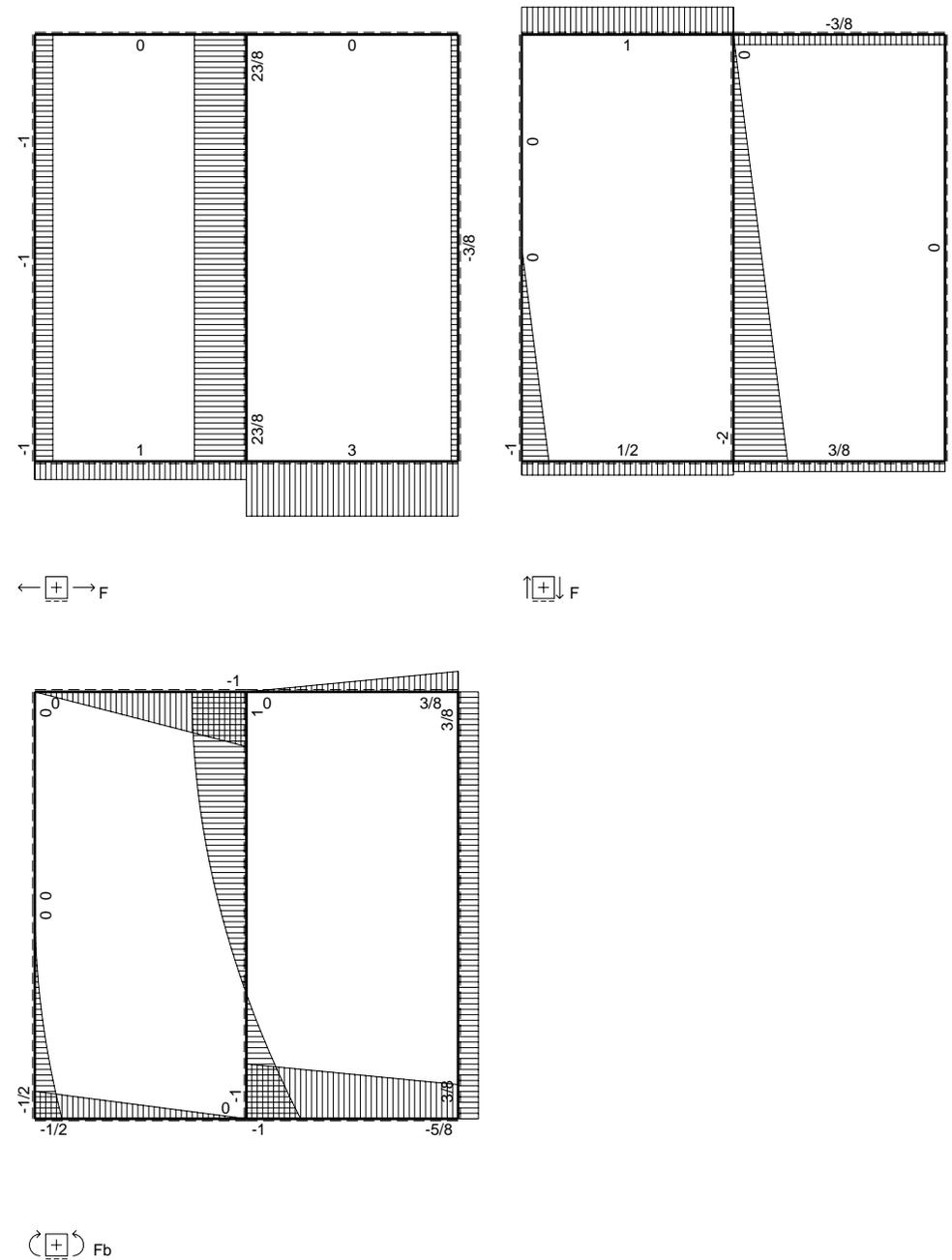
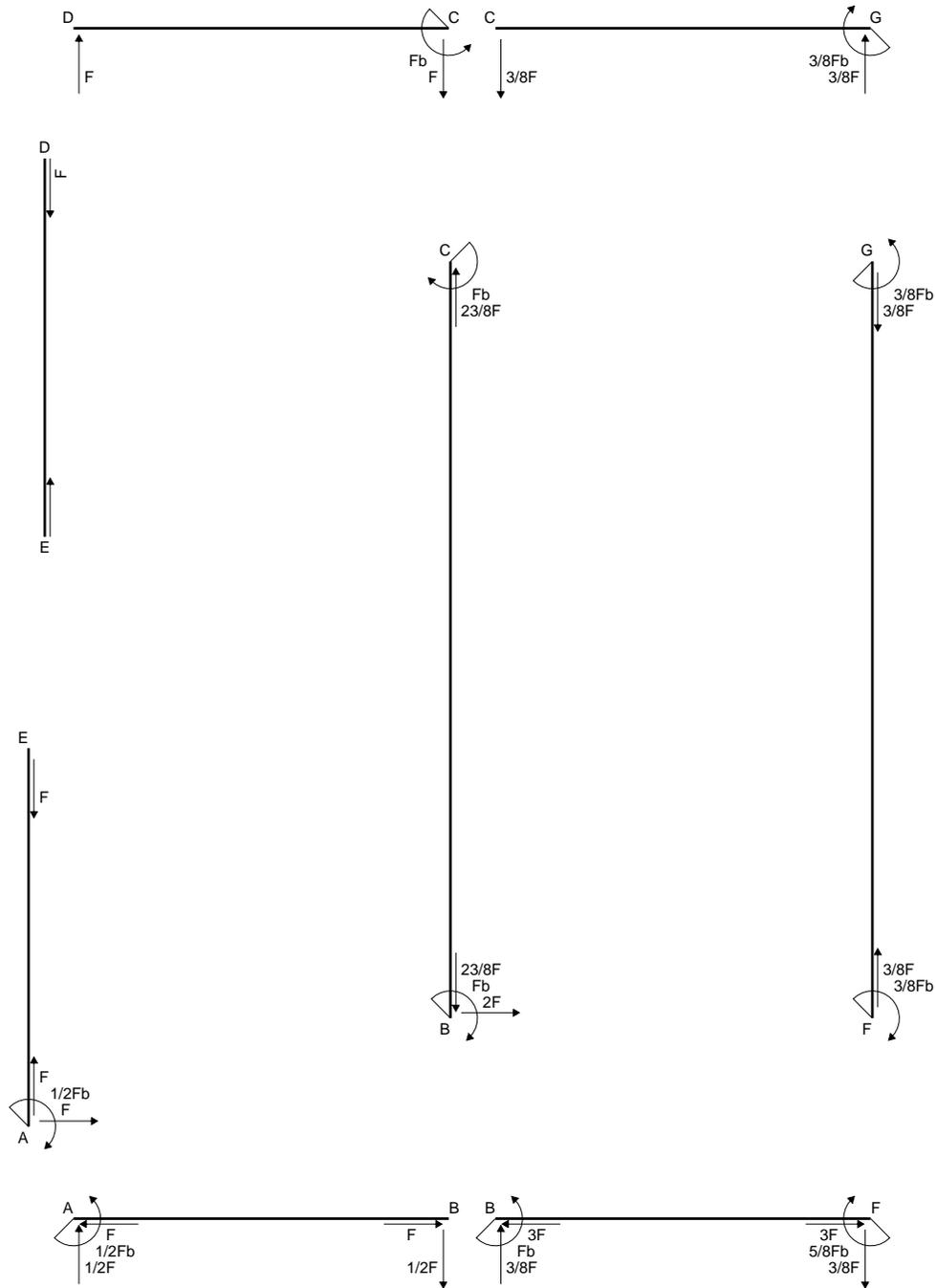
$$\sigma_c = -Mv/J_u = 140.8 \text{ N/mm}^2$$

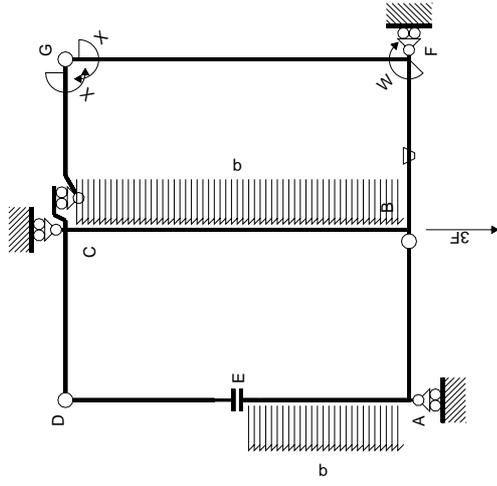
$$\tau_c = 3.438 \text{ N/mm}^2$$

$$\sigma_\varphi = \sqrt{\sigma^2 + 3\tau^2} = 140.9 \text{ N/mm}^2$$

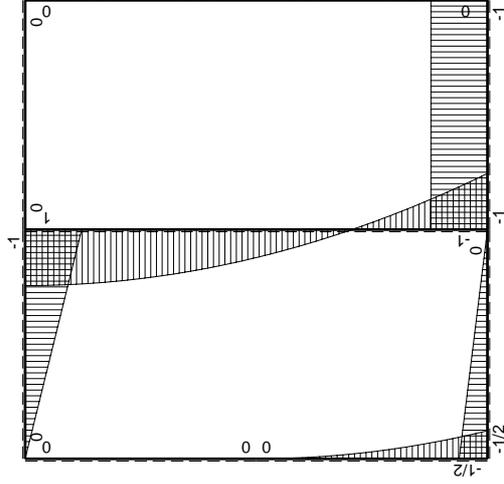
$$S = 5192. \text{ mm}^3$$



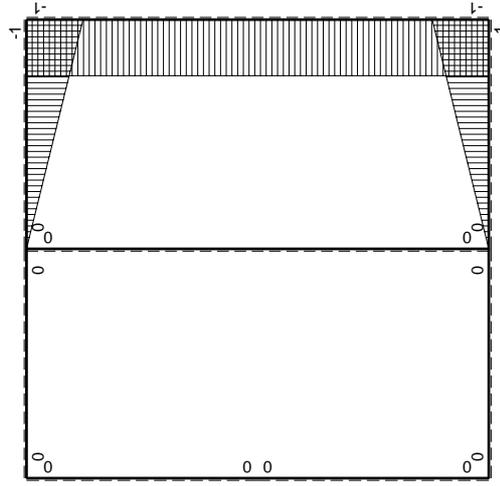




Schema di calcolo iperstatico



M<sub>0</sub> flessione da carichi assegnati



M<sub>x</sub> flessione da iperstatica X=1

Quadro contributi PLV per iperstatica X=W<sup>gc</sup>

←	M <sup>x</sup> (x)	M(x)	θ	M <sup>x</sup> M <sub>0</sub>	M <sup>x</sup> θ	M <sup>x</sup> M <sub>x</sub>	∫M <sup>x</sup> (M <sub>0</sub> /EJ+θ)dx	∫M <sup>x</sup> M <sub>x</sub> /EJdx
AB B	0	-1/2Fb+1/2Fx	0	0	0	0	0+0	0
BA B	0	1/2Fx	0	0	0	0	0+0	0
CD B	0	-Fb+Fx	0	0	0	0	0+0	0
DC B	0	Fx	0	0	0	0	0+0	0
DE B	0	0	0	0	0	0	0+0	0
ED B	0	0	0	0	0	0	0+0	0
EA B	0	-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
AE B	0	1/2Fb-Fx+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
BF B	-x/b	-Fb	-Fb/EJ	Fx	Fx/EJ	Fb/EJ-Fx/EJ	(1/2+1/2)Fb <sup>2</sup> /EJ	1/3xb/EJ
FB B	1-x/b	Fb	Fb/EJ	Fb-Fx	Fb/EJ-Fx/EJ	Fb/EJ-Fx/EJ	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	1/3xb/EJ
GC B	-1+x/b	0	0	0	0	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	1/3xb/EJ
CG B	x/b	0	0	0	0	0	x <sup>2</sup> /b <sup>2</sup>	1/3xb/EJ
FG 2b	-1	0	0	0	0	0	1	2xb/EJ
GF 2b	1	0	0	0	0	0	1	2xb/EJ
CB 2b	0	Fb-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
BC 2b	0	Fb-2Fx+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
totali								8/3xb/EJ
								-3/8Fb

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

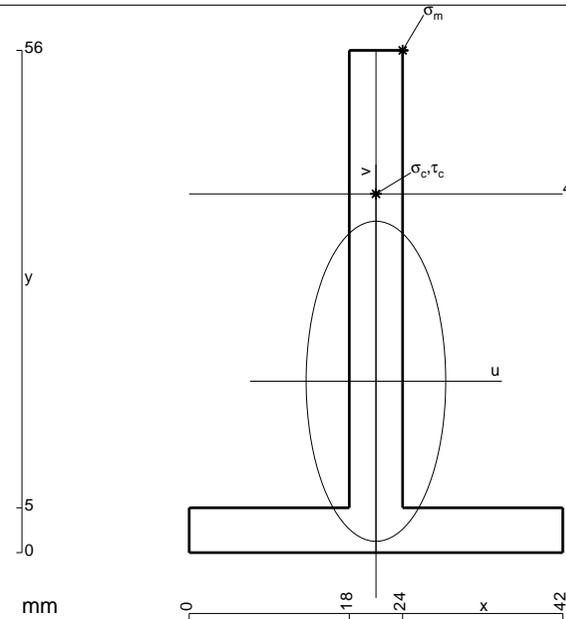
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

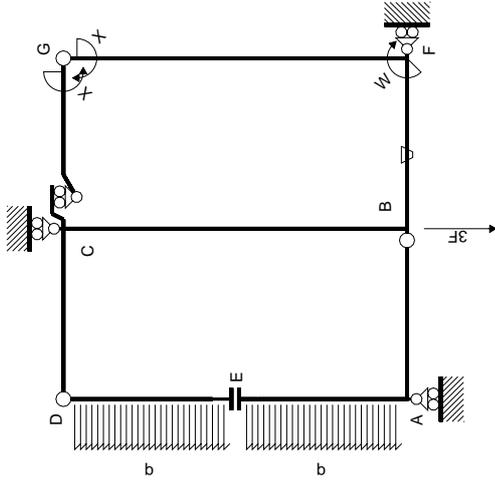
$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



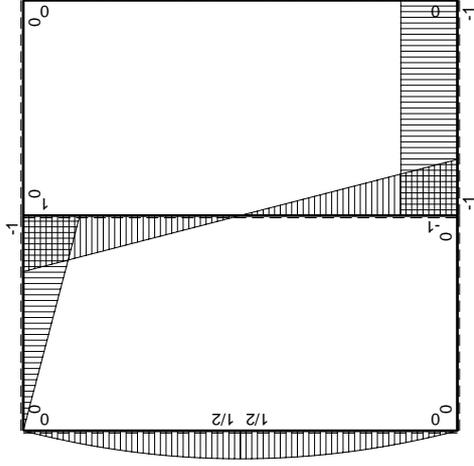
- A = 516. mm<sup>2</sup>
- J<sub>u</sub> = 164398. mm<sup>4</sup>
- J<sub>v</sub> = 31788. mm<sup>4</sup>
- y<sub>g</sub> = 19.1 mm
- N = 5491. N
- T<sub>y</sub> = -3820. N
- M<sub>x</sub> = -840400. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 56. mm
- u<sub>m</sub> = 3. mm
- v<sub>m</sub> = 36.9 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = 199.3 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 40. mm
- v<sub>c</sub> = 20.9 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = 117.5 N/mm<sup>2</sup>
- τ<sub>c</sub> = 10.74 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 118.9 N/mm<sup>2</sup>
- S = 2774. mm<sup>3</sup>



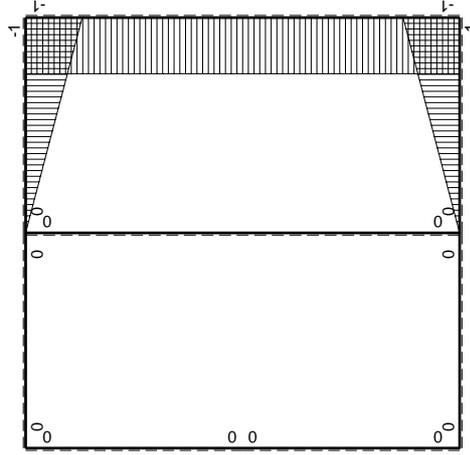




Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0+0	0
CD b	0	-Fb+Fx	0	0	0	0	0+0	0
DC b	0	Fx	0	0	0	0	0+0	0
DE b	0	Fx-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
ED b	0	-1/2Fb+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
EA b	0	1/2Fb-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
AE b	0	-Fx+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
BF b	-x/b	-Fb	-Fb/EJ	Fx	Fx/EJ	$x^2/b^2$	$(1/2+1/2)Fb^2/EJ$	1/3xb/EJ
FB b	1-x/b	Fb	Fb/EJ	Fb-Fx	Fb/EJ-Fx/EJ	$1-2x/b+x^2/b^2$	$1-2x/b+x^2/b^2$	1/3xb/EJ
GC b	-1+x/b	0	0	0	0	0	0+0	1/3xb/EJ
CG b	x/b	0	0	0	0	0	0+0	1/3xb/EJ
FG 2b	-1	0	0	0	0	0	0+0	2xb/EJ
GF 2b	1	0	0	0	0	0	0+0	2xb/EJ
CB 2b	0	Fb-Fx	0	0	0	0	0+0	0
BC 2b	0	Fb-Fx	0	0	0	0	0+0	0
totali								8/3xb/EJ

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

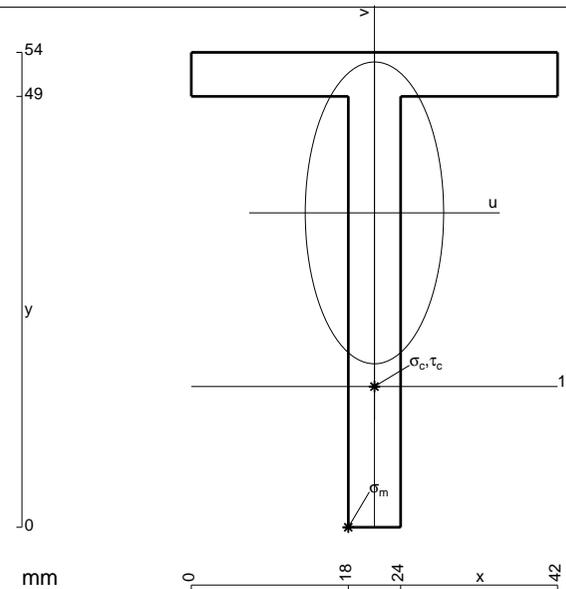
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



$$A = 504. \text{ mm}^2$$

$$J_u = 148565. \text{ mm}^4$$

$$J_v = 31752. \text{ mm}^4$$

$$y_g = 35.75 \text{ mm}$$

$$N = 5906. \text{ N}$$

$$T_y = -1750. \text{ N}$$

$$M_x = 822500. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -35.75 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 209.6 \text{ N/mm}^2$$

$$x_c = 21. \text{ mm}$$

$$y_c = 16. \text{ mm}$$

$$v_c = -19.75 \text{ mm}$$

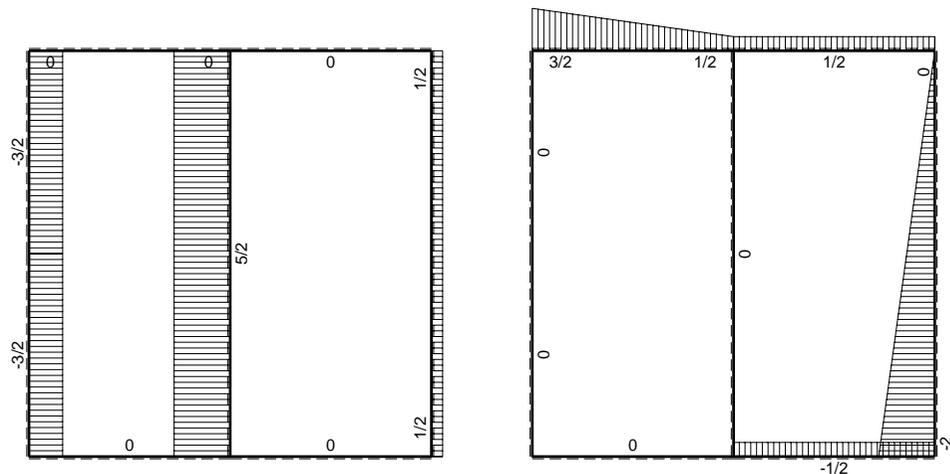
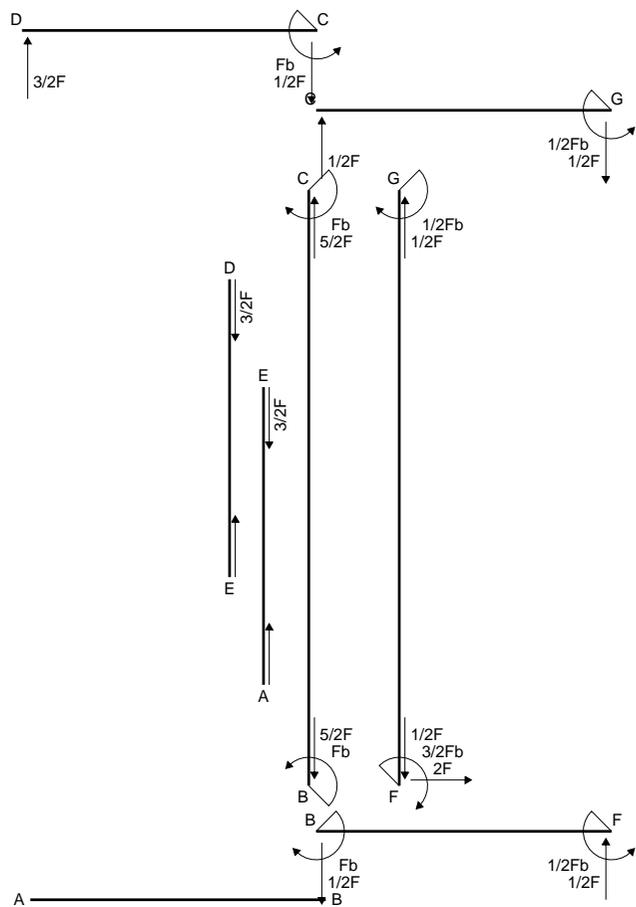
$$\sigma_c = N/A - Mv/J_u = 121.1 \text{ N/mm}^2$$

$$\tau_c = 5.23 \text{ N/mm}^2$$

$$\sigma_\varphi = \sqrt{\sigma^2 + 3\tau^2} = 121.4 \text{ N/mm}^2$$

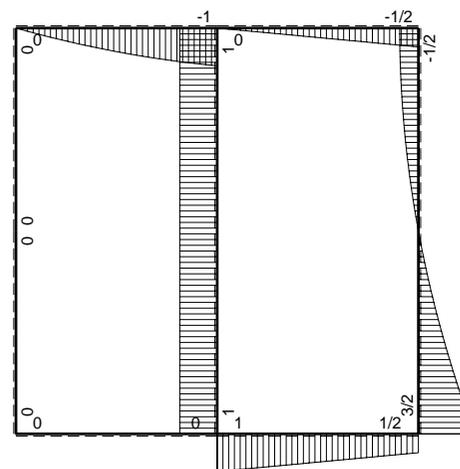
$$S = 2664. \text{ mm}^3$$





← ⊕ → F

↑ ⊕ ↓ Fb



⊕ Fb



$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x\theta} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x\theta} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

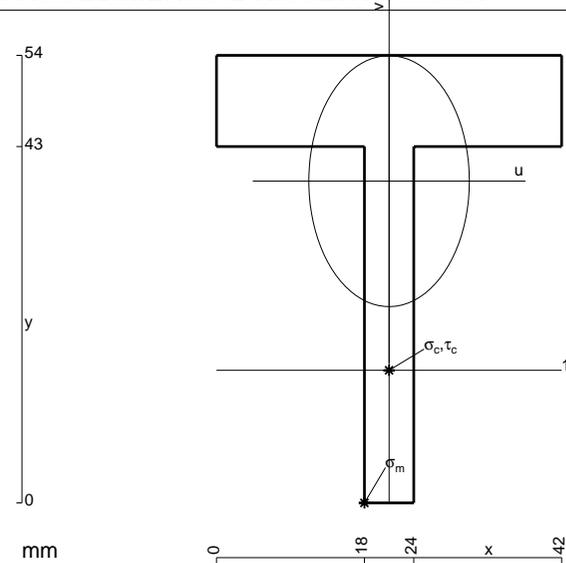
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x\theta} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

$$L_{GF}^{x\theta} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



$$A = 720. \text{ mm}^2$$

$$J_u = 165098. \text{ mm}^4$$

$$J_v = 68688. \text{ mm}^4$$

$$y_g = 38.83 \text{ mm}$$

$$T_y = 2930. \text{ N}$$

$$M_x = -933938. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -38.83 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -219.6 \text{ N/mm}^2$$

$$x_c = 21. \text{ mm}$$

$$y_c = 16. \text{ mm}$$

$$v_c = -22.83 \text{ mm}$$

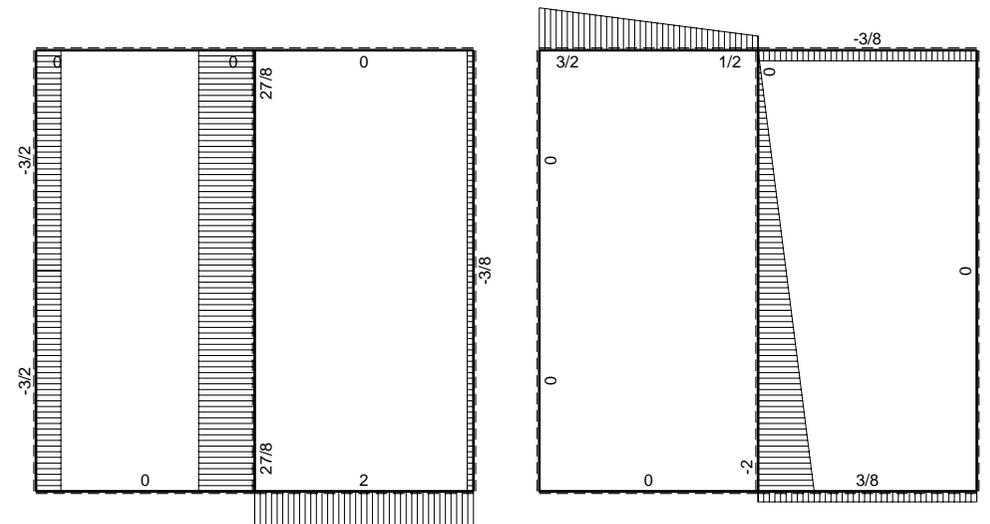
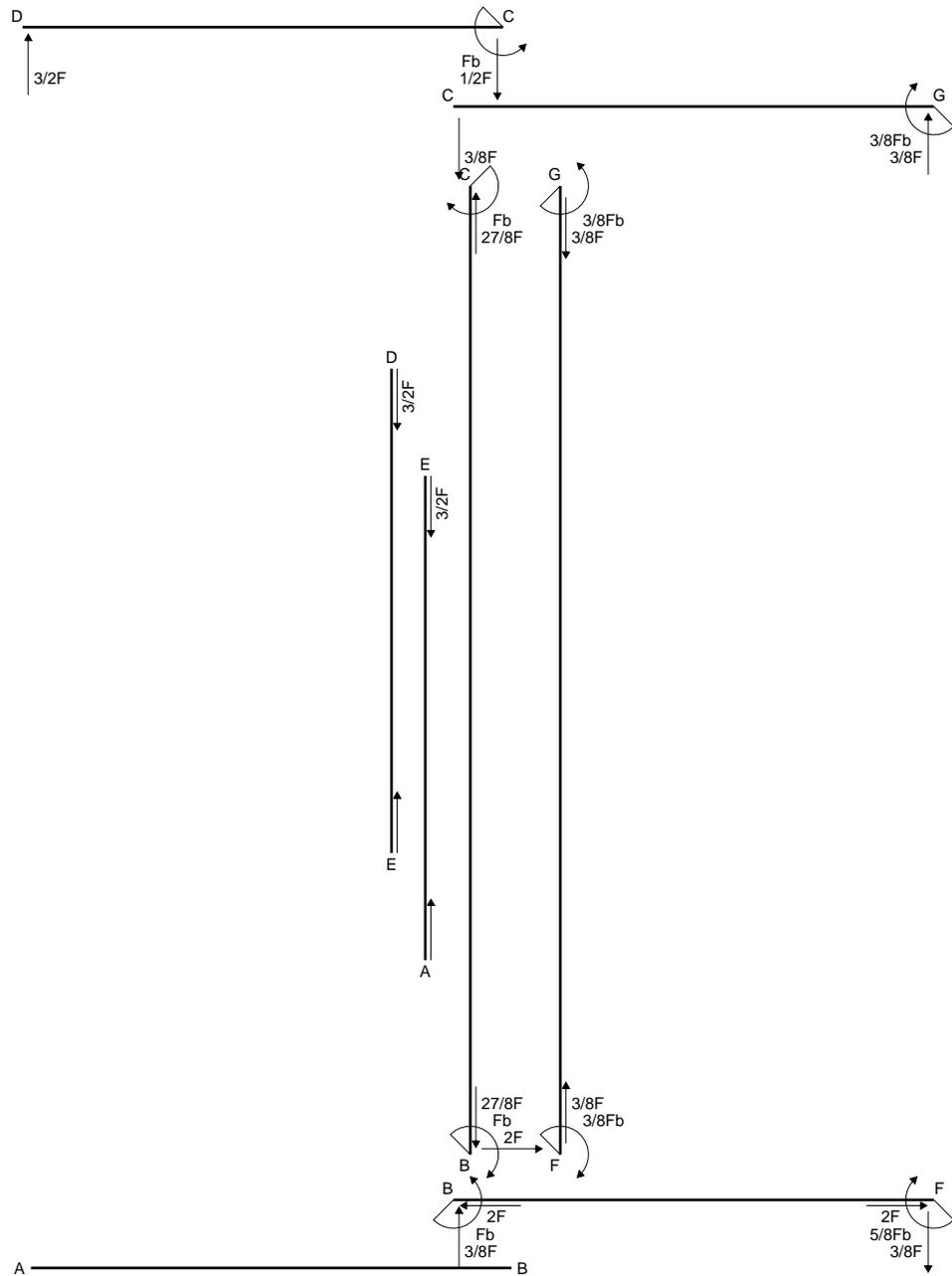
$$\sigma_c = -Mv/J_u = -129.1 \text{ N/mm}^2$$

$$\tau_c = 8.753 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 130. \text{ N/mm}^2$$

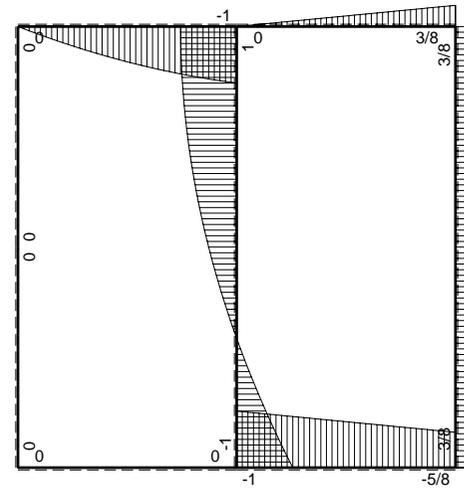
$$S = 2959. \text{ mm}^3$$





← ⊕ → F

↑ ⊕ ↓ F



⊕ Fb



$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

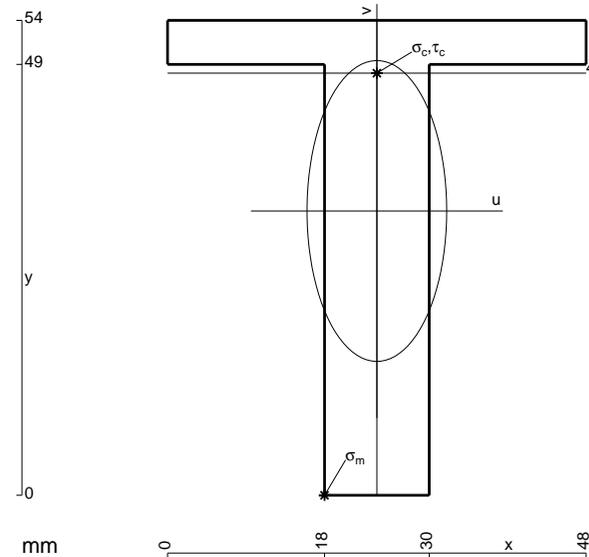
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



$$A = 828. \text{ mm}^2$$

$$J_u = 242396. \text{ mm}^4$$

$$J_v = 53136. \text{ mm}^4$$

$$y_g = 32.33 \text{ mm}$$

$$N = 11205. \text{ N}$$

$$T_y = -6640. \text{ N}$$

$$M_x = -1826000. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$u_m = -6. \text{ mm}$$

$$v_m = -32.33 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -230. \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 48. \text{ mm}$$

$$v_c = 15.67 \text{ mm}$$

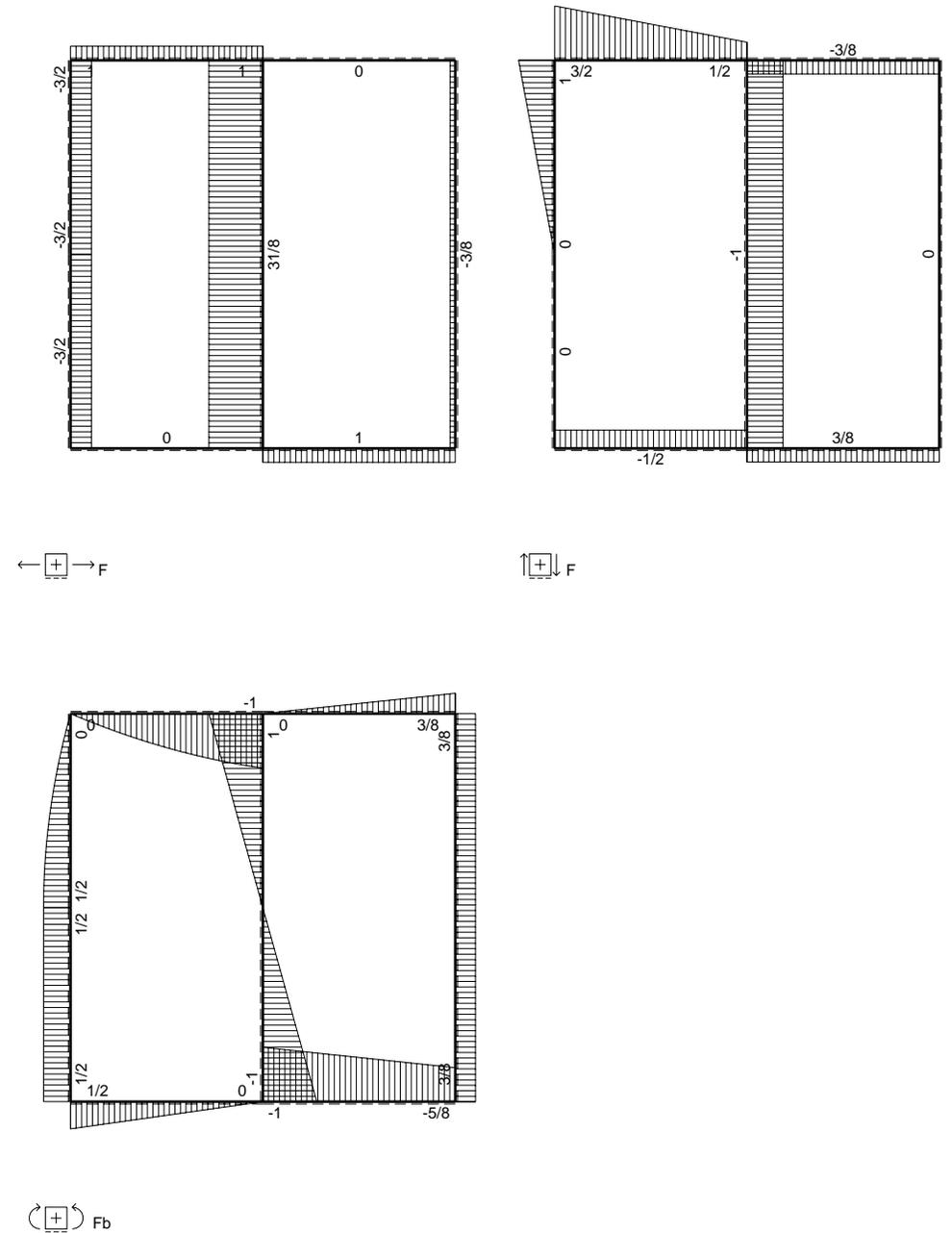
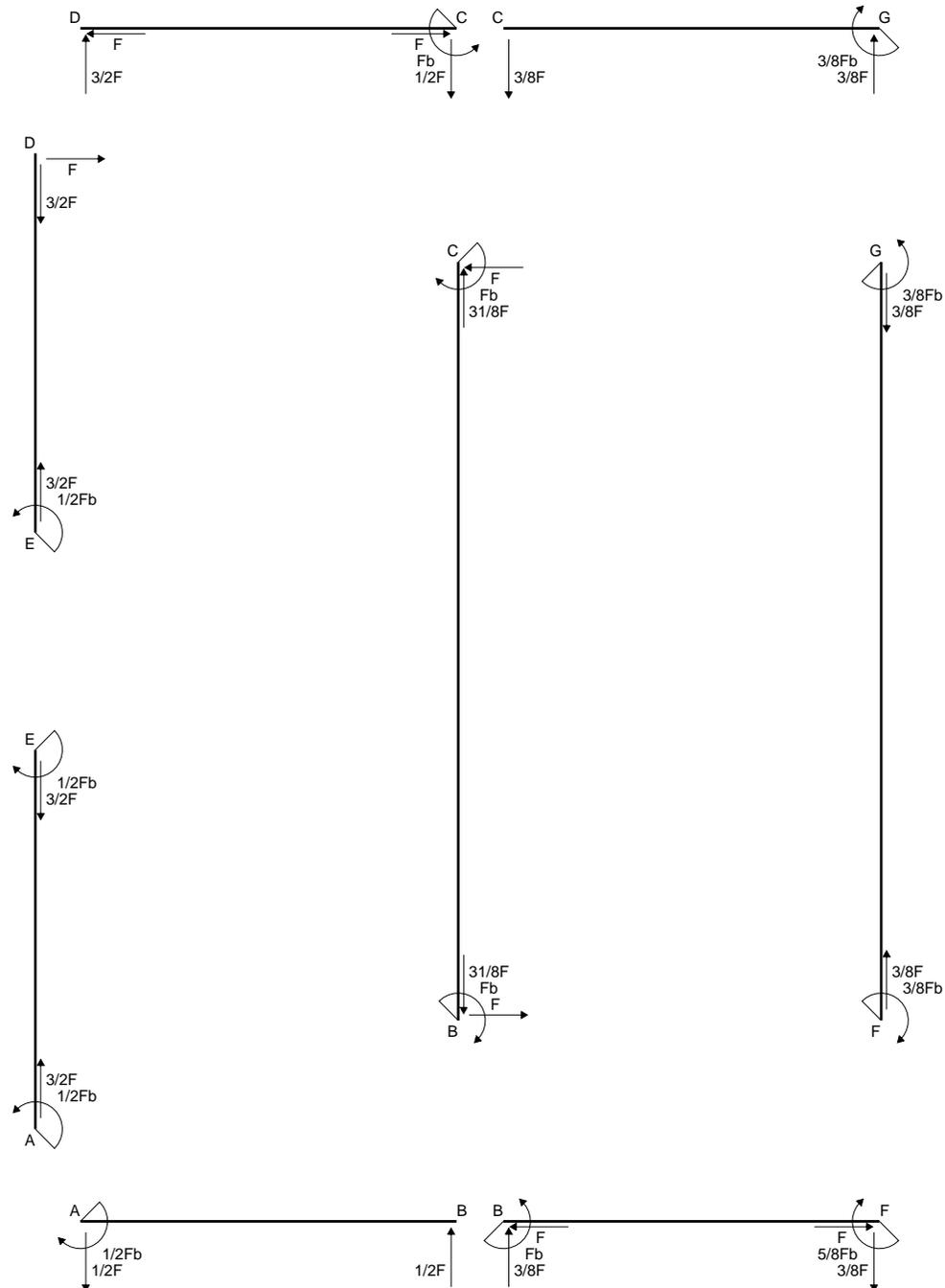
$$\sigma_c = N/A - Mv/J_u = 131.6 \text{ N/mm}^2$$

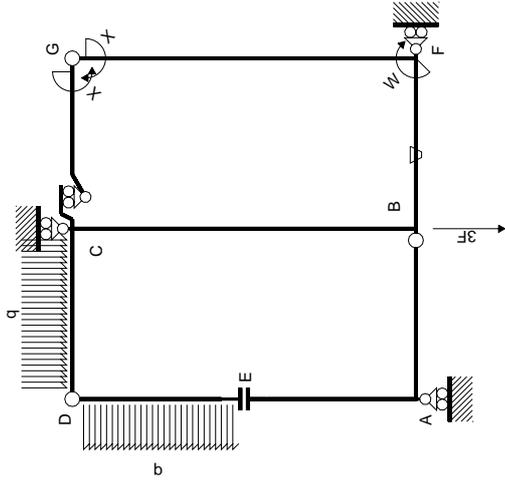
$$\tau_c = 10.95 \text{ N/mm}^2$$

$$\sigma_g = \sqrt{\sigma^2 + 3\tau^2} = 133. \text{ N/mm}^2$$

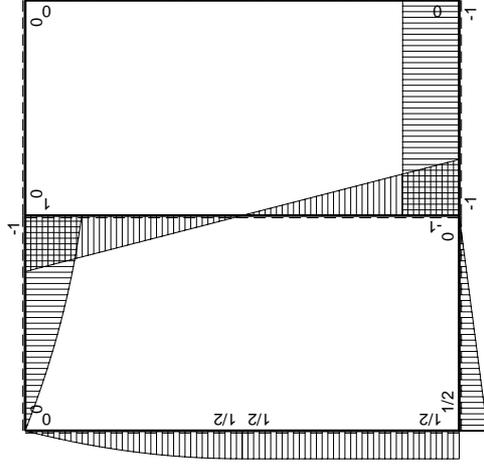
$$S = 4796. \text{ mm}^3$$



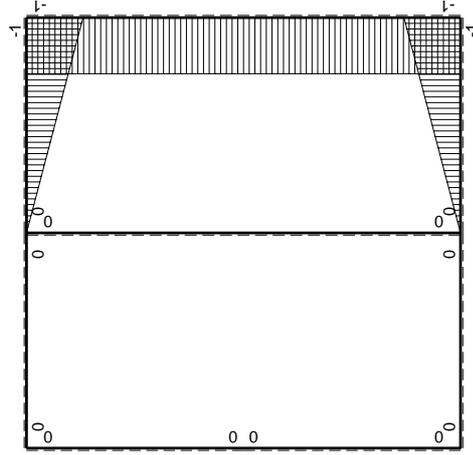




Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica X=W<sub>gc</sub>

←	M <sub>0</sub> (x)	θ	M <sub>x</sub> M <sub>0</sub>	M <sub>x</sub> θ	M <sub>x</sub> M <sub>x</sub>	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJdx$
AB b	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0+0	0
CD b	0	0	0	0	0	0+0	0
DC b	0	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0+0	0
ED b	0	0	0	0	0	0+0	0
EA b	0	0	0	0	0	0+0	0
AE b	0	0	0	0	0	0+0	0
BF b	-x/b	-Fb/EJ	Fx	Fx/EJ	$x^2/b^2$	$(1/2+1/2)Fb^2/EJ$	1/3xb/EJ
FBB b	1-x/b	Fb/EJ	Fb-Fx	Fb/EJ-Fx/EJ	$1-2x/b+x^2/b^2$		1/3xb/EJ
GC b	-1+x/b	0	0	0	$1-2x/b+x^2/b^2$	0+0	1/3xb/EJ
CG b	x/b	0	0	0	$x^2/b^2$	0+0	2xb/EJ
FG 2b	-1	0	0	0	1	0+0	2xb/EJ
GF 2b	1	0	0	0	1	0+0	2xb/EJ
CB 2b	0	0	0	0	0	0+0	8/3xb/EJ
BC 2b	0	0	0	0	0	0+0	8/3xb/EJ
totali							

iperstatica X=W<sub>gc</sub>

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

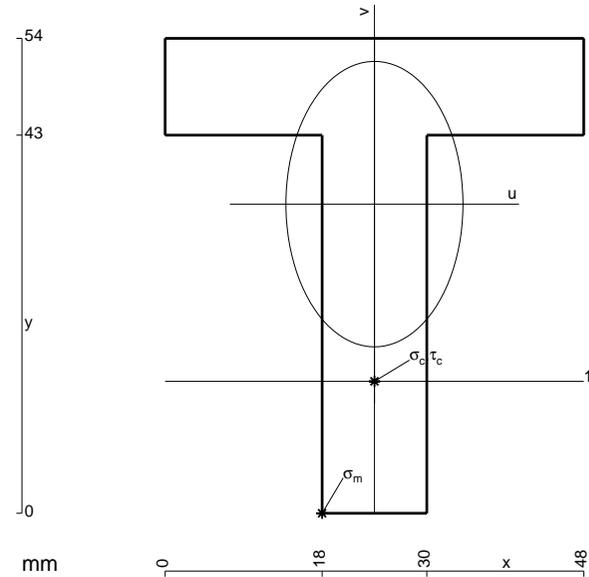
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

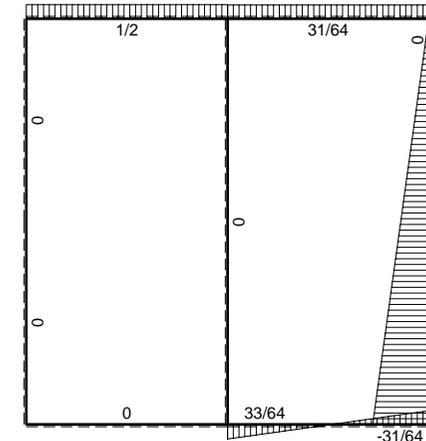
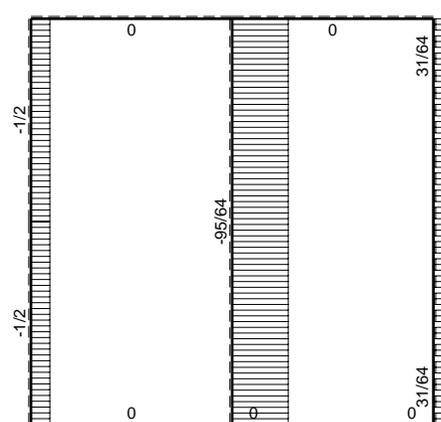
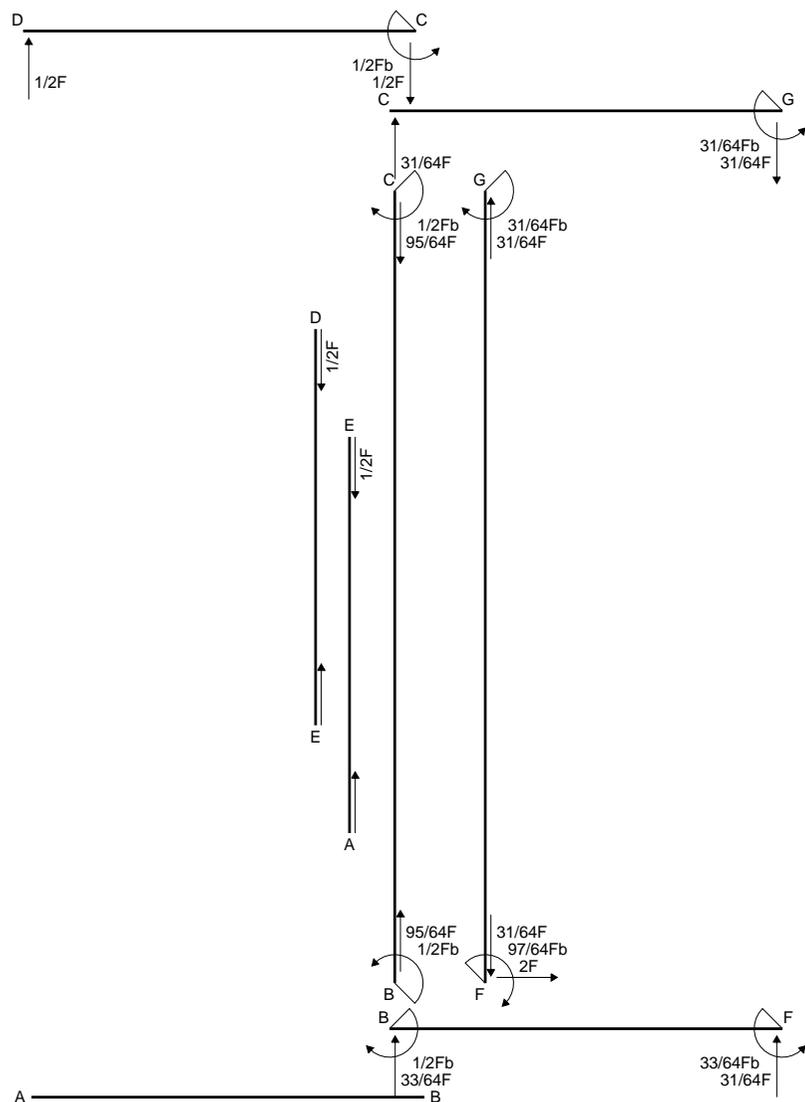
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



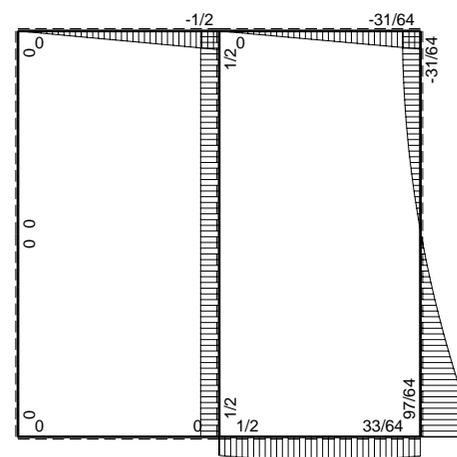
- A = 1044. mm<sup>2</sup>
- J<sub>u</sub> = 275075. mm<sup>4</sup>
- J<sub>v</sub> = 107568. mm<sup>4</sup>
- y<sub>g</sub> = 35.16 mm
- N = 11548. N
- T<sub>y</sub> = -2980. N
- M<sub>x</sub> = 1788000. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -35.16 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = 239.6 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 15. mm
- v<sub>c</sub> = -20.16 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = 142.1 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.494 N/mm<sup>2</sup>
- σ<sub>φ</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 142.3 N/mm<sup>2</sup>
- S = 4978. mm<sup>3</sup>





← ⊕ → F

↑ ⊕ ↓ F



⊕ F<sub>b</sub>



$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x\theta} = \int_0^b (-1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

$$= [-1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/4 b - 1/3 b + 1/8 b) Fb 1/EJ + (1/2 b) \theta = 1/24 Fb^2/EJ$$

$$L_{FB}^{x\theta} = \int_0^b (-1 + x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

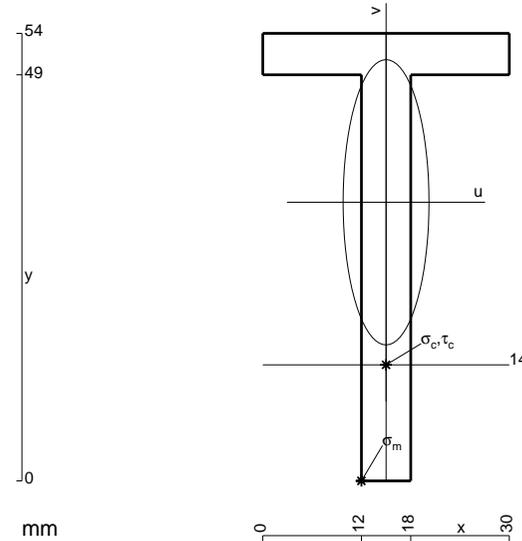
$$= (-b + 1/2 b + 1/6 b - 1/8 b) Fb 1/EJ + (-b + 1/2 b) \theta = 1/24 Fb^2/EJ$$

$$L_{FG}^{x\theta} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

$$L_{GF}^{x\theta} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



$$A = 444. \text{ mm}^2$$

$$J_u = 131544. \text{ mm}^4$$

$$J_v = 12132. \text{ mm}^4$$

$$y_g = 33.62 \text{ mm}$$

$$T_y = 1220. \text{ N}$$

$$M_x = -780800. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -33.62 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -199.6 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 14. \text{ mm}$$

$$v_c = -19.62 \text{ mm}$$

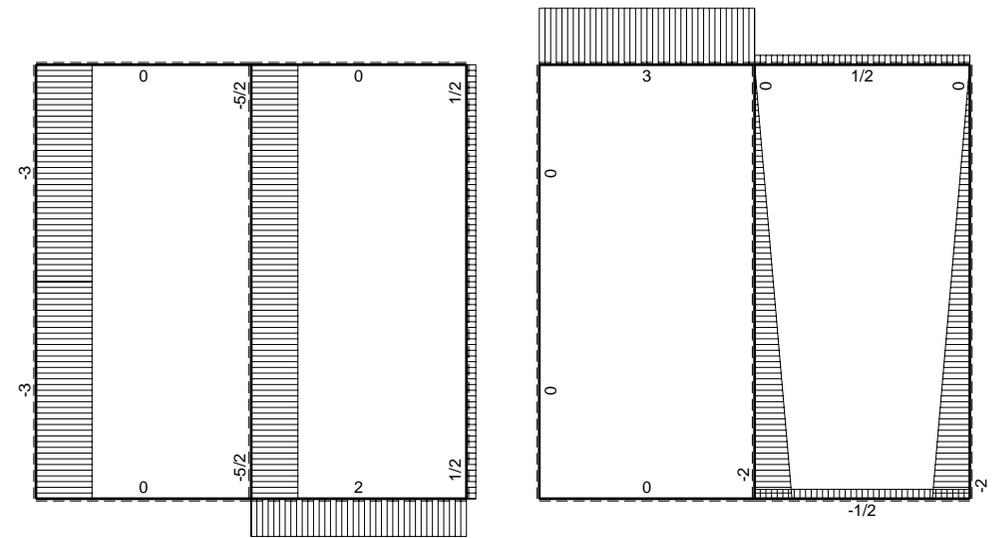
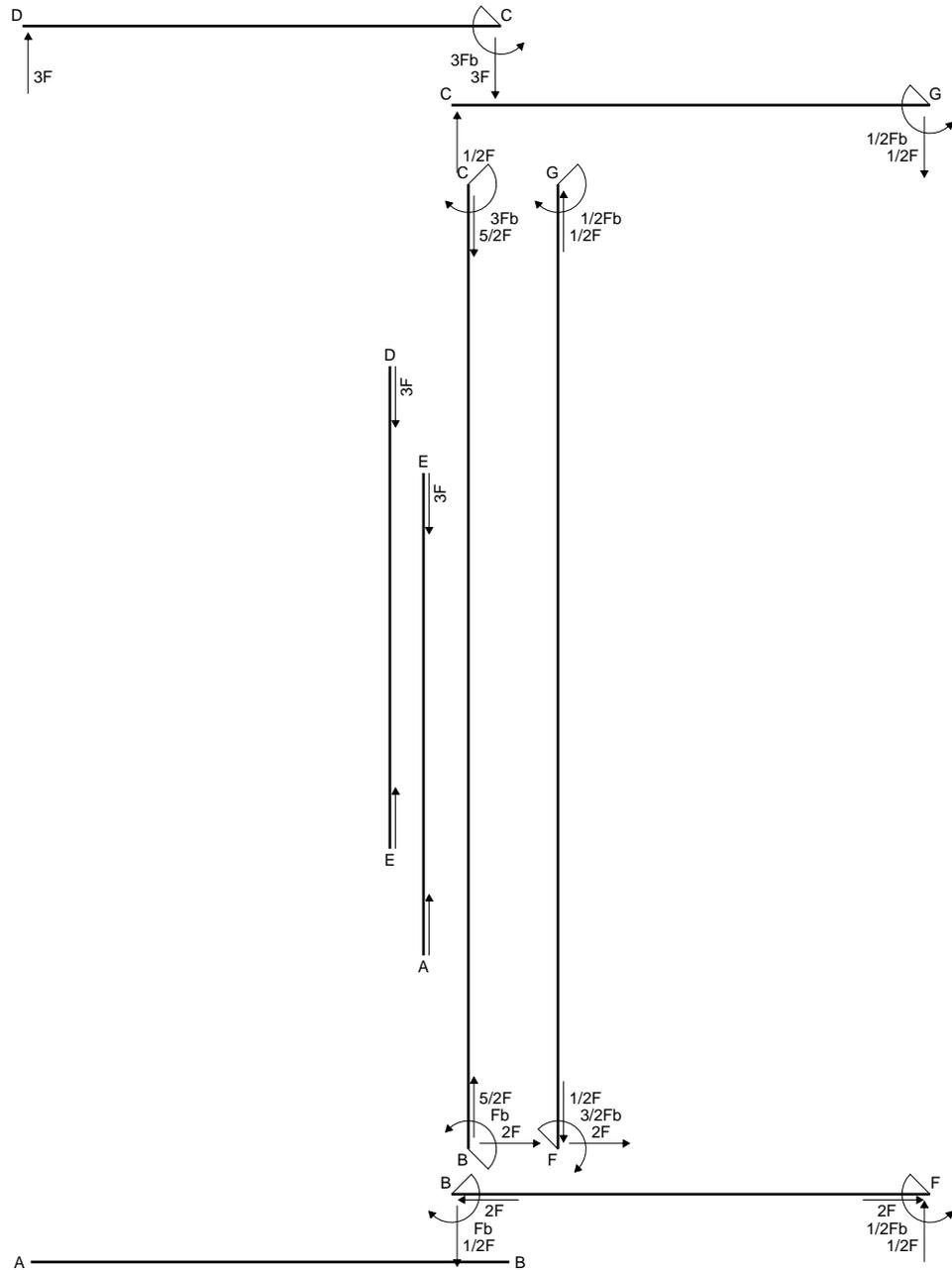
$$\sigma_c = -Mv/J_u = -116.5 \text{ N/mm}^2$$

$$\tau_c = 3.457 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 116.6 \text{ N/mm}^2$$

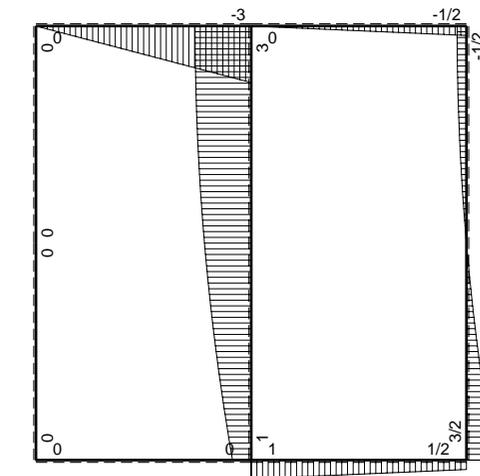
$$S = 2236. \text{ mm}^3$$



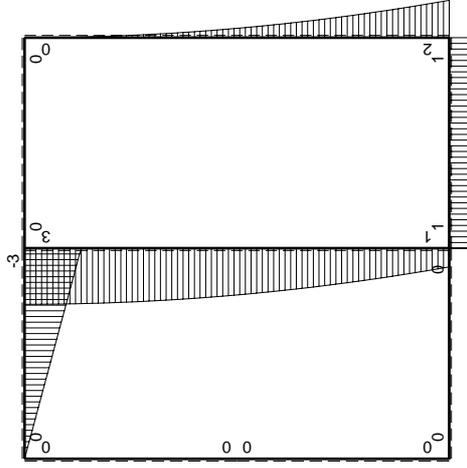
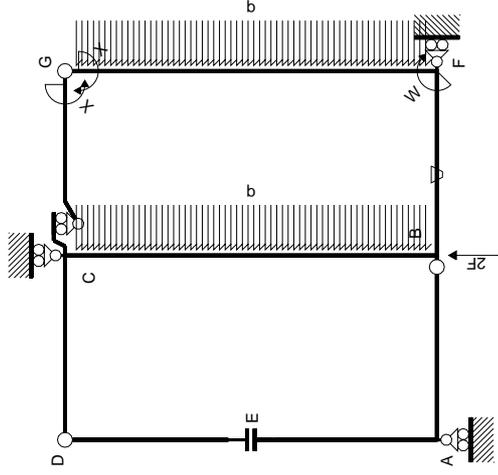


← ⊕ → F

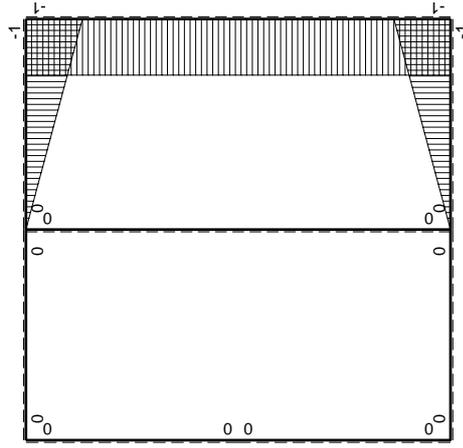
↑ ⊕ ↓ F



⊕ ⊖ F<sub>b</sub>



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

←	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M^0$	$M^x \theta$	$M^x M_x$	$\int M^x(M^0/EJ+\theta)dx$	$\int M^x M_x/EJ dx$	iperstatica X=W <sup>gc</sup>	
									totali	
AB b	0	0	0	0	0	0	0	0	0	0
BA b	0	0	0	0	0	0	0	0	0	0
CD b	0	-3Fb+3Fx	0	0	0	0	0	0	0	0
DC b	0	3Fx	0	0	0	0	0	0	0	0
DE b	0	0	0	0	0	0	0	0	0	0
ED b	0	0	0	0	0	0	0	0	0	0
EA b	0	0	0	0	0	0	0	0	0	0
AE b	0	0	0	0	0	0	0	0	0	0
BF b	-x/b	Fb	-Fb/EJ	-Fx	Fx/EJ	$x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$	$1-2x/b+x^2/b^2$	$-4/3Fb^2/EJ$
FB b	1-x/b	-Fb	Fb/EJ	-Fb+Fx	Fb/EJ-Fx/EJ	$1-2x/b+x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$	$1-2x/b+x^2/b^2$	$-4/3Fb^2/EJ$
GC b	-1+x/b	0	0	0	0	0	0	0	$x^2/b^2$	$1/2Fb$
CG b	x/b	0	0	0	0	0	0	0	0	0
FG 2b	-1	$2Fb-2Fx+1/2qx^2$	0	$-2Fb+2Fx-1/2Fx^2/b$	0	1	$(-4/3+0)Fb^2/EJ$	$2xb/EJ$	1	0
GF 2b	1	$-1/2qx^2$	0	$-1/2Fx^2/b$	0	1	$(-4/3+0)Fb^2/EJ$	$2xb/EJ$	1	0
CB 2b	0	$3Fb-1/2qx^2$	0	0	0	0	0	0	0	0
BC 2b	0	$-Fb-2Fx+1/2qx^2$	0	0	0	0	0	0	0	0
totali										

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x\theta} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x\theta} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

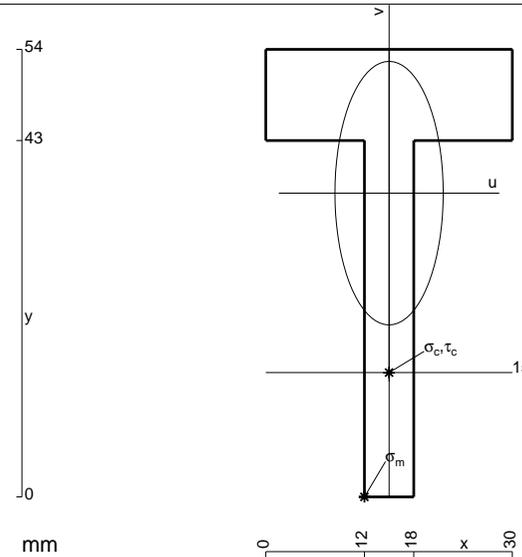
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x\theta} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

$$L_{GF}^{x\theta} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



$$A = 588. \text{ mm}^2$$

$$J_u = 148637. \text{ mm}^4$$

$$J_v = 25524. \text{ mm}^4$$

$$y_g = 36.65 \text{ mm}$$

$$T_y = 1230. \text{ N}$$

$$M_x = -836400. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -36.65 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -206.3 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 15. \text{ mm}$$

$$v_c = -21.65 \text{ mm}$$

$$\sigma_c = -Mv/J_u = -121.8 \text{ N/mm}^2$$

$$\tau_c = 3.619 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 122. \text{ N/mm}^2$$

$$S = 2624. \text{ mm}^3$$







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x_0} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

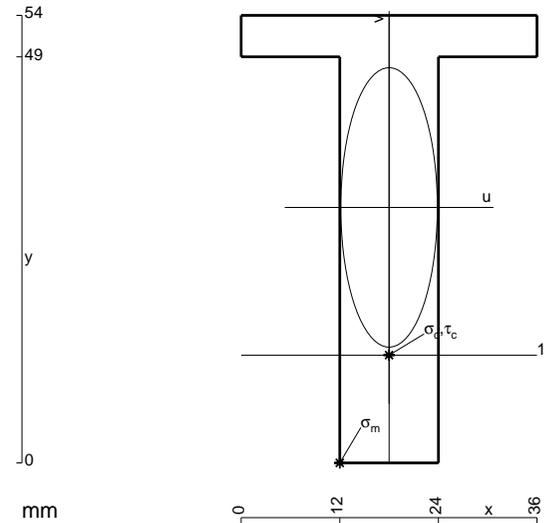
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x_0} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

$$L_{GF}^{x_0} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



$$A = 768. \text{ mm}^2$$

$$J_u = 218489. \text{ mm}^4$$

$$J_v = 26496. \text{ mm}^4$$

$$y_g = 30.83 \text{ mm}$$

$$T_y = 2130. \text{ N}$$

$$M_x = -1554900. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -6. \text{ mm}$$

$$v_m = -30.83 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -219.4 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 13. \text{ mm}$$

$$v_c = -17.83 \text{ mm}$$

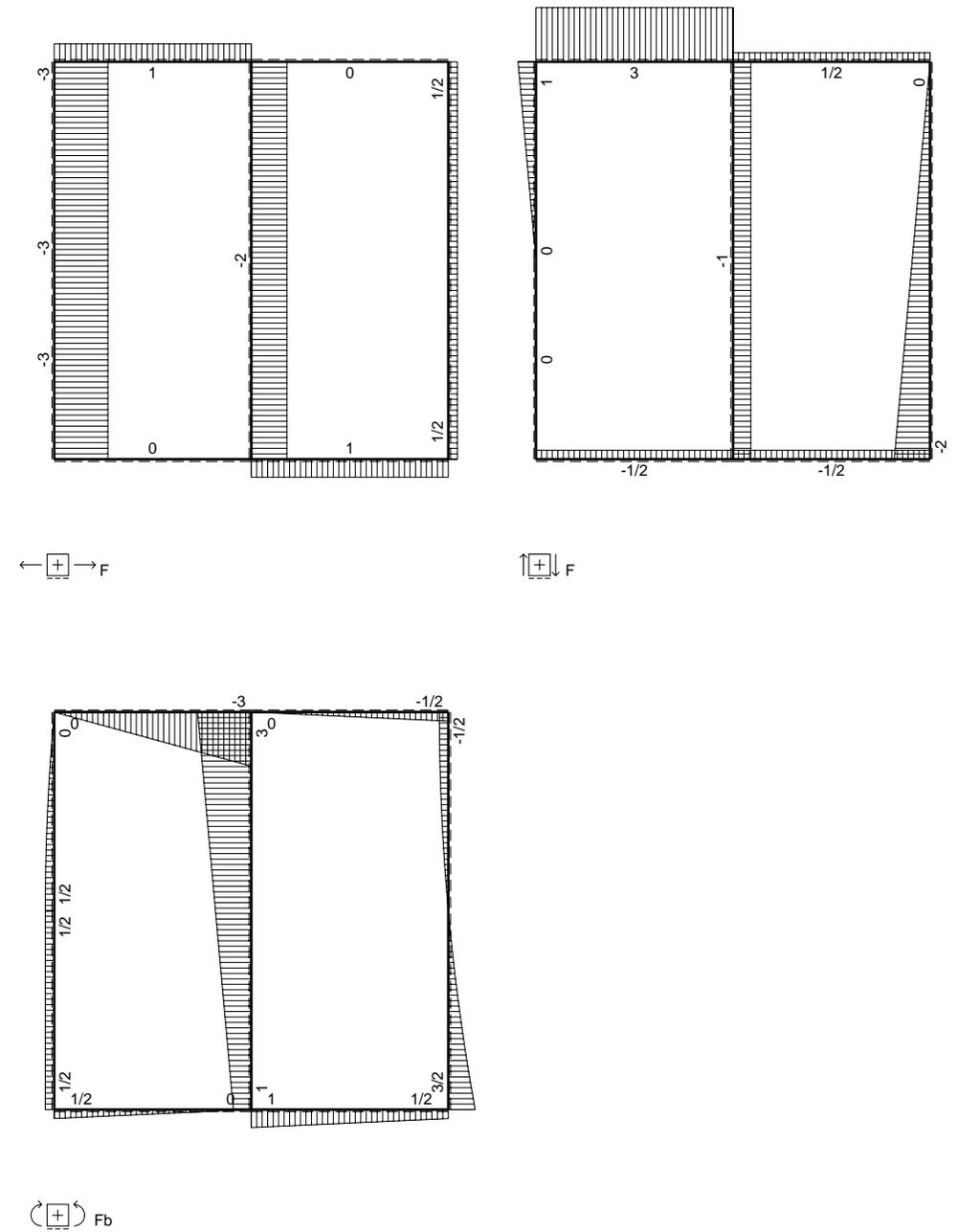
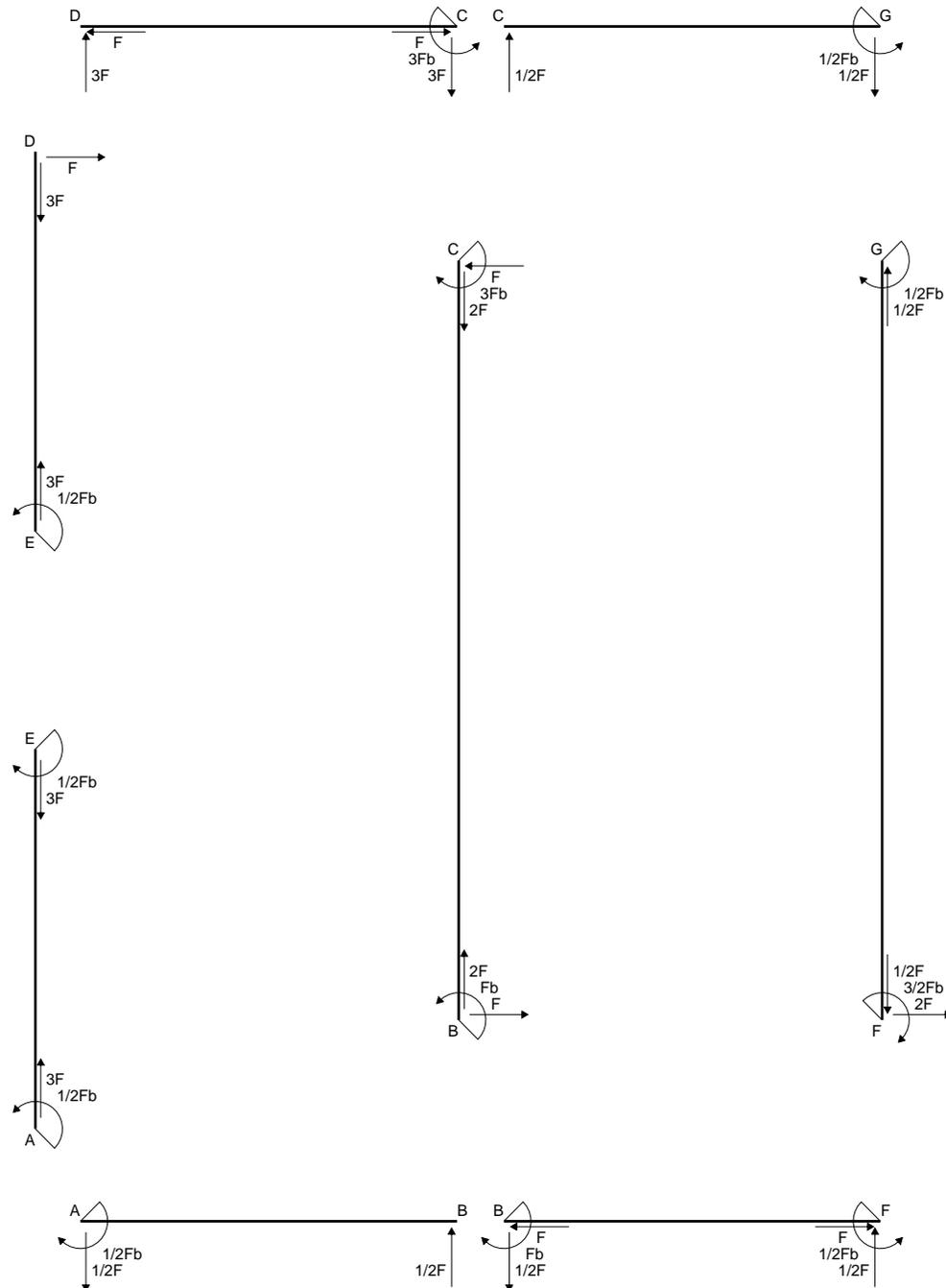
$$\sigma_c = -Mv/J_u = -126.9 \text{ N/mm}^2$$

$$\tau_c = 3.083 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 127. \text{ N/mm}^2$$

$$S = 3795. \text{ mm}^3$$







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x\theta} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x\theta} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

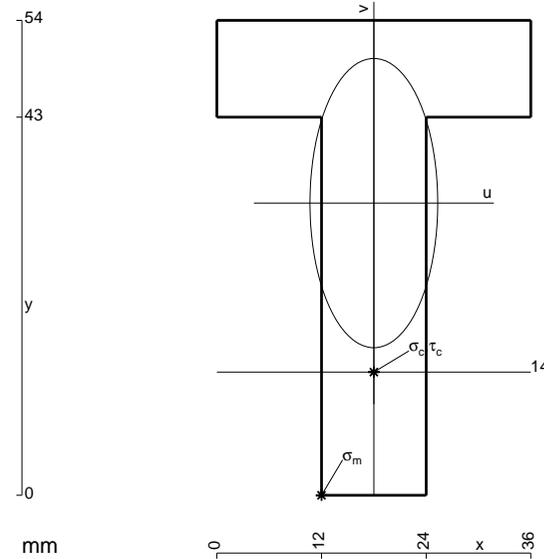
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x\theta} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

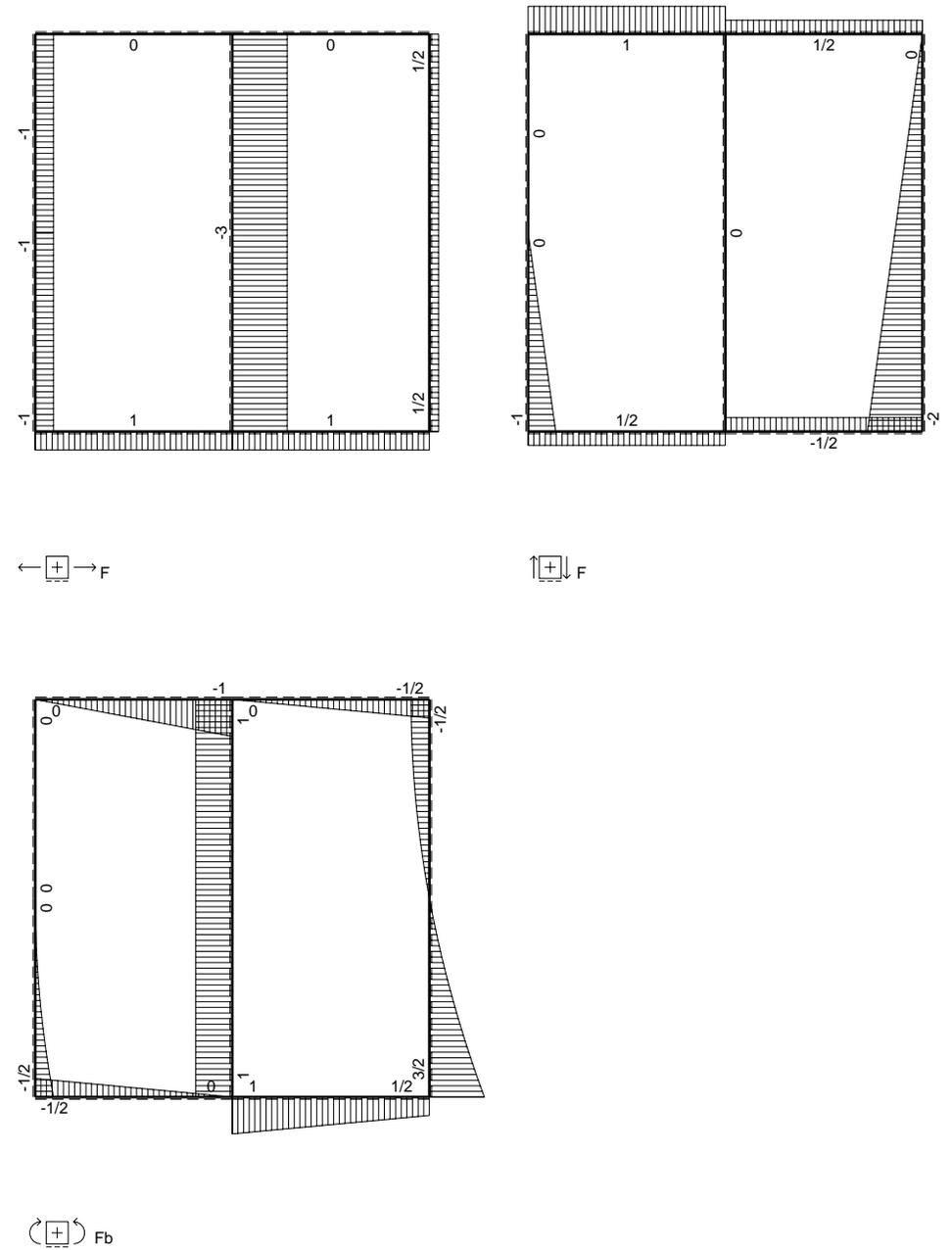
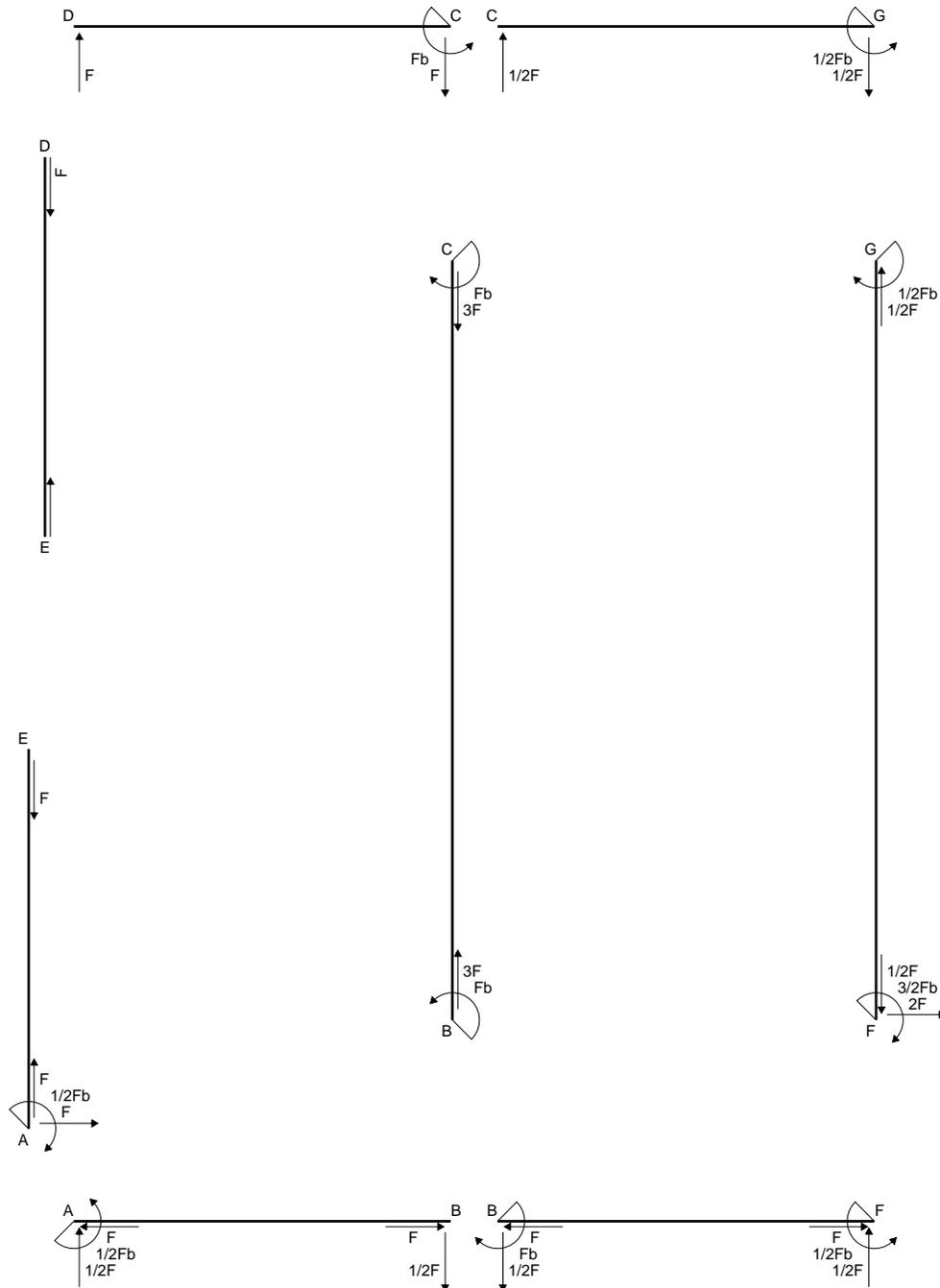
$$L_{GF}^{x\theta} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



- A = 912. mm<sup>2</sup>
- J<sub>u</sub> = 246834. mm<sup>4</sup>
- J<sub>v</sub> = 48960. mm<sup>4</sup>
- y<sub>g</sub> = 33.22 mm
- N = 740. N
- T<sub>y</sub> = 2220. N
- M<sub>x</sub> = -1709400. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -33.22 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = -229.3 N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 14. mm
- v<sub>c</sub> = -19.22 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = -132.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.302 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 = 4406. mm<sup>3</sup>







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x\theta} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x\theta} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

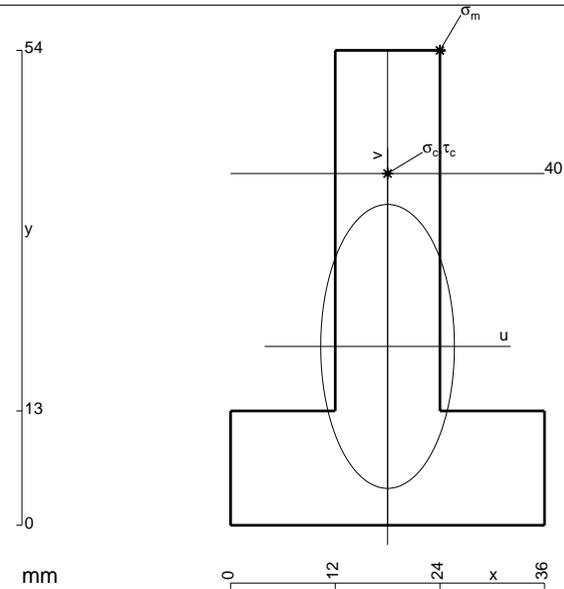
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x\theta} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

$$L_{GF}^{x\theta} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



$$A = 960. \text{ mm}^2$$

$$J_u = 250363. \text{ mm}^4$$

$$J_v = 56448. \text{ mm}^4$$

$$y_g = 20.34 \text{ mm}$$

$$T_y = 2200. \text{ N}$$

$$M_x = -1782000. \text{ Nmm}$$

$$x_m = 24. \text{ mm}$$

$$y_m = 54. \text{ mm}$$

$$u_m = 6. \text{ mm}$$

$$v_m = 33.66 \text{ mm}$$

$$\sigma_m = -Mv/J_u = 239.6 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 40. \text{ mm}$$

$$v_c = 19.66 \text{ mm}$$

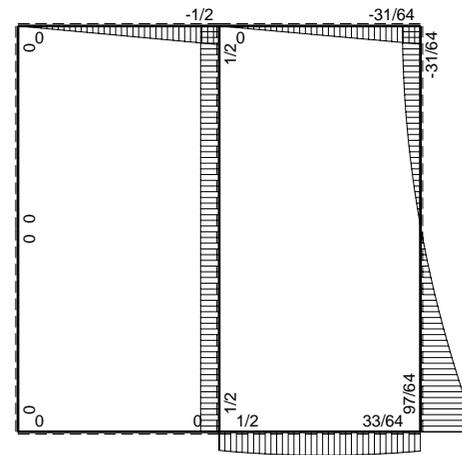
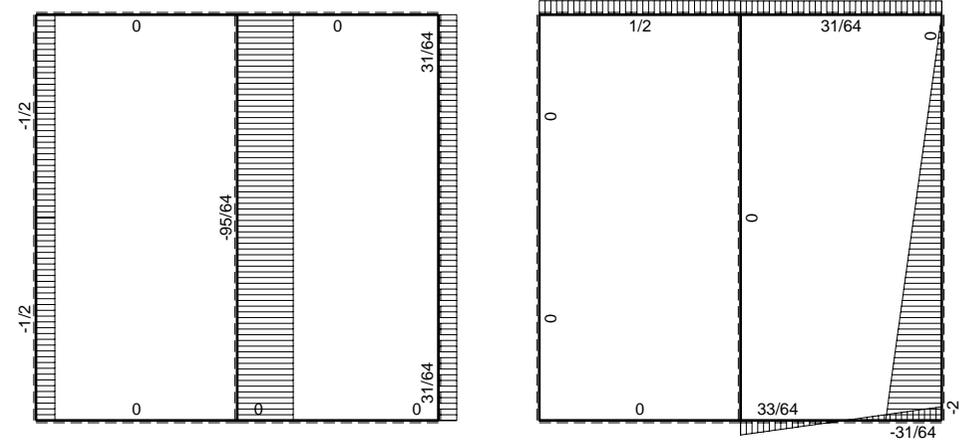
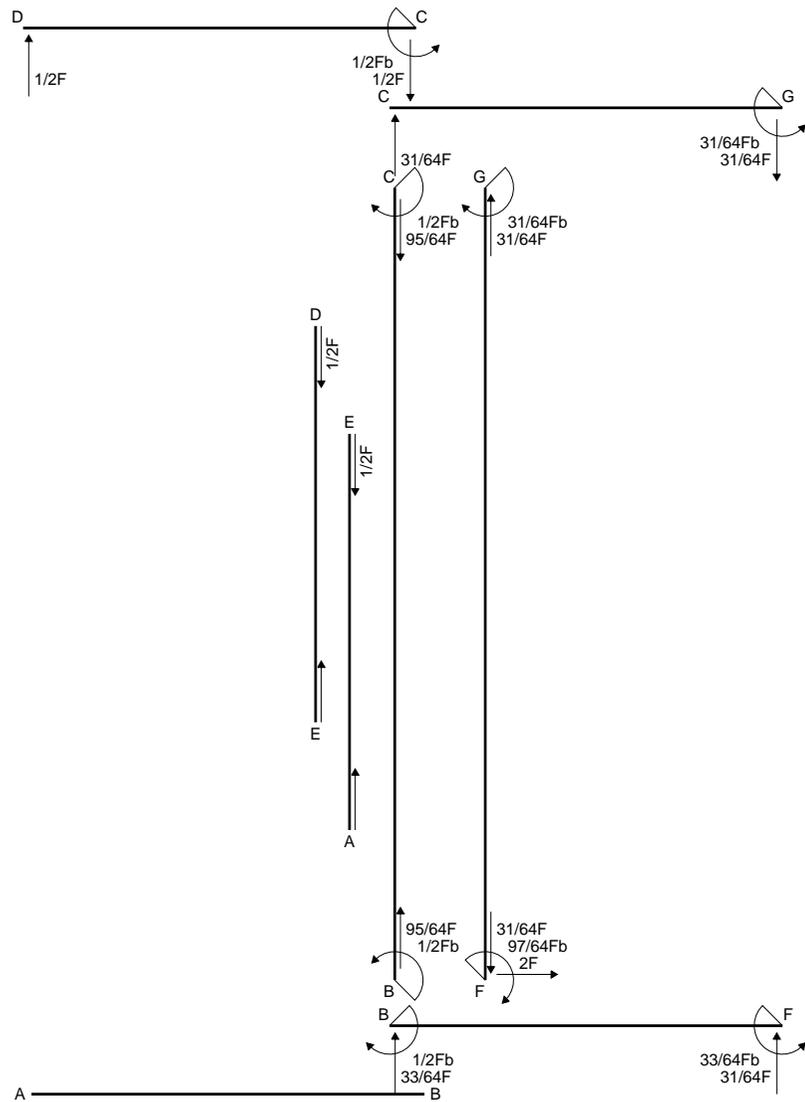
$$\sigma_c = -Mv/J_u = 140. \text{ N/mm}^2$$

$$\tau_c = 3.28 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 140.1 \text{ N/mm}^2$$

$$S = 4479. \text{ mm}^3$$







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (-1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

$$= [-1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/4 b - 1/3 b + 1/8 b) Fb 1/EJ + (1/2 b) \theta = 1/24 Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (-1 + x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

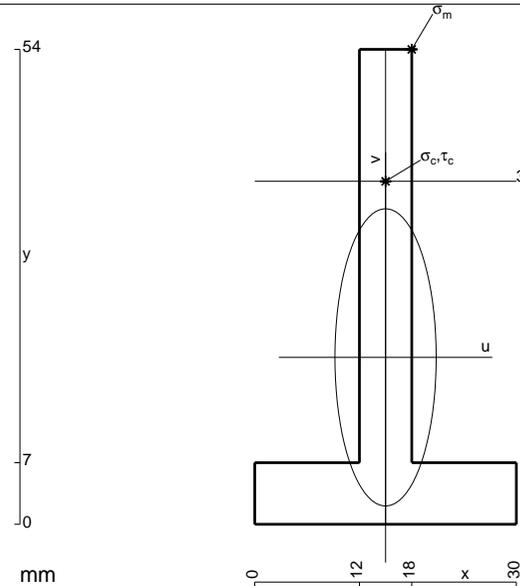
$$= (-b + 1/2 b + 1/6 b - 1/8 b) Fb 1/EJ + (-b + 1/2 b) \theta = 1/24 Fb^2/EJ$$

$$L_{FG}^{x_0} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

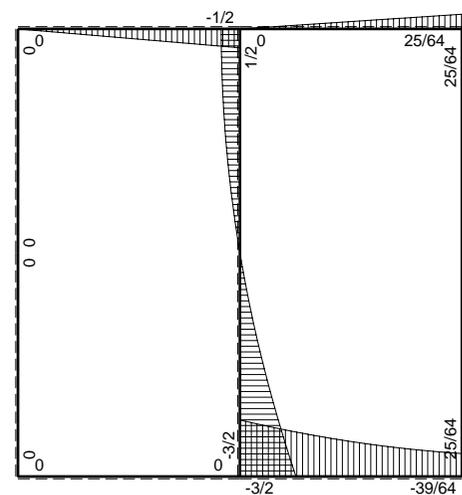
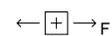
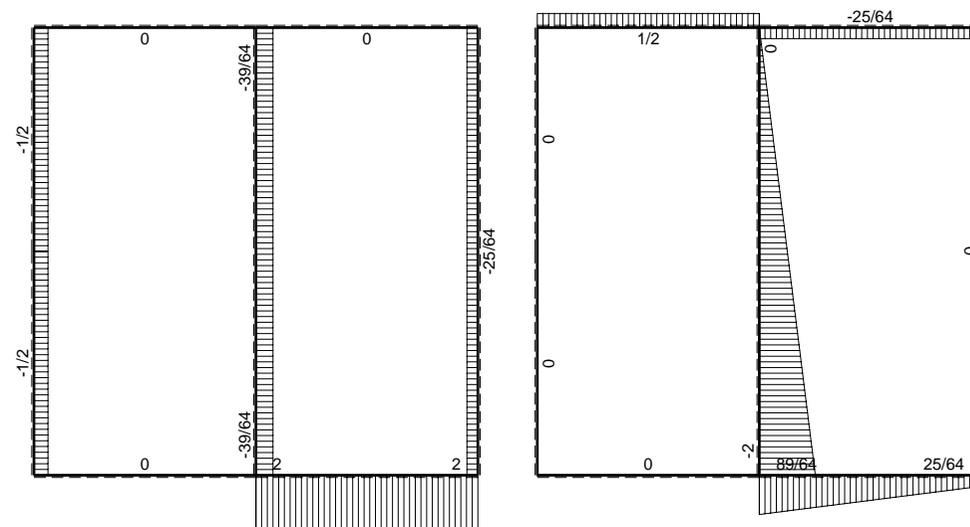
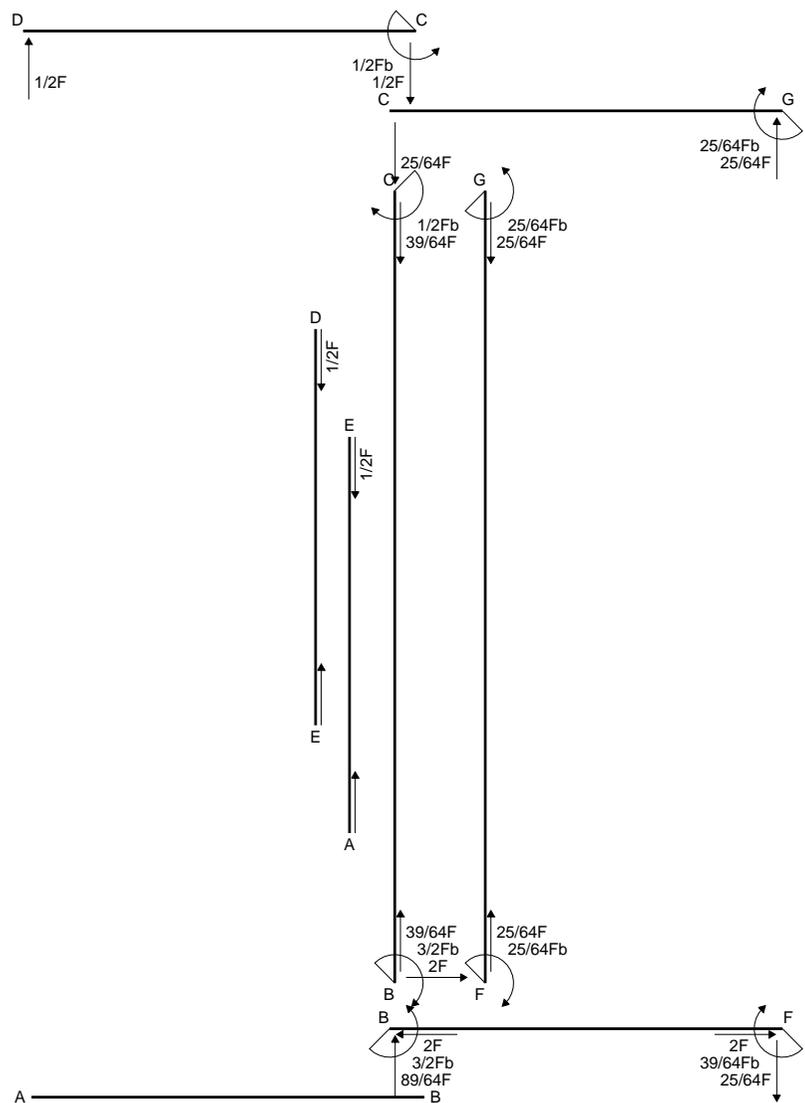
$$L_{GF}^{x_0} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

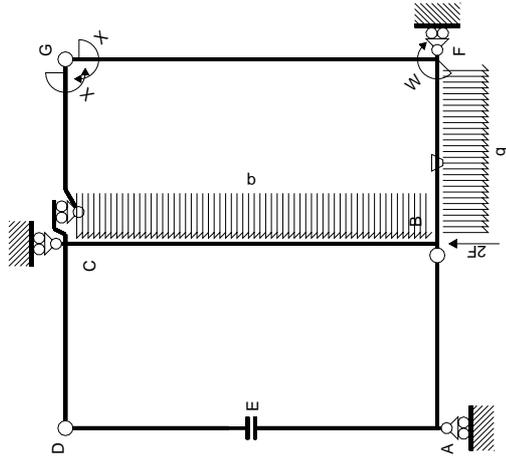
$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



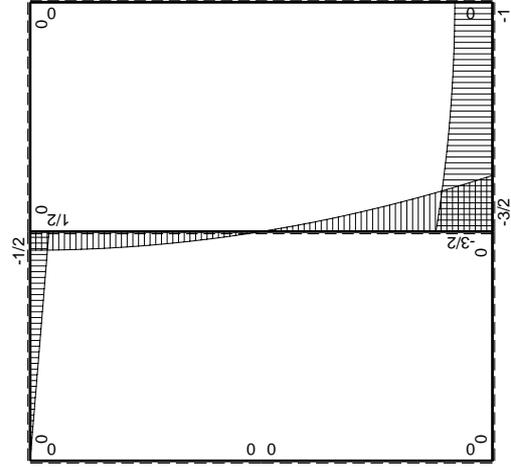
- A = 492. mm<sup>2</sup>
- J<sub>u</sub> = 140516. mm<sup>4</sup>
- J<sub>v</sub> = 16596. mm<sup>4</sup>
- y<sub>g</sub> = 18.98 mm
- T<sub>y</sub> = 1865. N
- M<sub>x</sub> = -801950. Nmm
- x<sub>m</sub> = 18. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 3. mm
- v<sub>m</sub> = 35.02 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 199.9 N/mm<sup>2</sup>
- x<sub>c</sub> = 15. mm
- y<sub>c</sub> = 39. mm
- v<sub>c</sub> = 20.02 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 114.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.48 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 114.7 N/mm<sup>2</sup>
- S = 2477. mm<sup>3</sup>



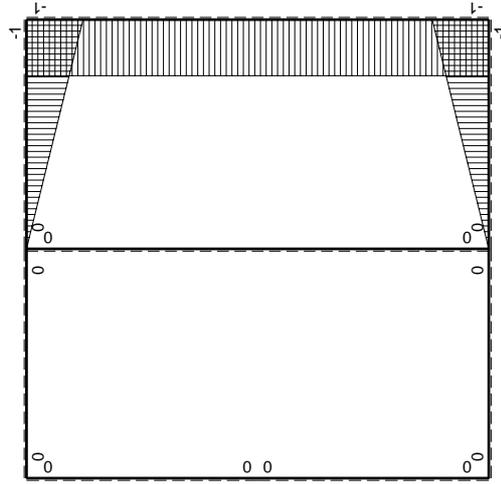




Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica X=W <sub>gc</sub>		M <sup>x</sup> (x)		M <sup>0</sup> (x)		θ		M <sup>x</sup> M <sub>0</sub>		M <sup>x</sup> θ		M <sup>x</sup> M <sub>x</sub>		∫M <sup>x</sup> (M <sub>0</sub> /EJ+θ)dx		∫M <sup>x</sup> M <sub>x</sub> /EJdx	
AB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CD	0	-1/2Fb+1/2Fx	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DC	0	1/2Fx	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ED	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BF	-x/b	-3/2Fb+Fx-1/2qx <sup>2</sup>	-Fb/EJ	3/2Fx-Fx <sup>2</sup> /b+1/2qx <sup>3</sup> /b	Fx/EJ	x <sup>2</sup> /b <sup>2</sup>	(13/24+1/2)Fb <sup>2</sup> /EJ	1/3Xb/EJ	0	0	0	0	0	0	0	0	0
FB	1-x/b	Fb+1/2qx <sup>2</sup>	Fb/EJ	Fb-Fx+1/2Fx <sup>2</sup> /b-1/2qx <sup>3</sup> /b	Fb/EJ-Fx/EJ	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	1/3Xb/EJ	1/3Xb/EJ	0	0	0	0	0	0	0	0	0
GC	-1+x/b	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CG	x/b	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FG	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GF	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CB	0	1/2Fb-1/2qx <sup>2</sup>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BC	0	3/2Fb-2Fx+1/2qx <sup>2</sup>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
totali																	
		iperstatica X=W <sub>gc</sub>															
		25/24Fb <sup>2</sup> /EJ		-25/64Fb													
		8/3Xb/EJ															

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x\theta} = \int_0^b (3/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

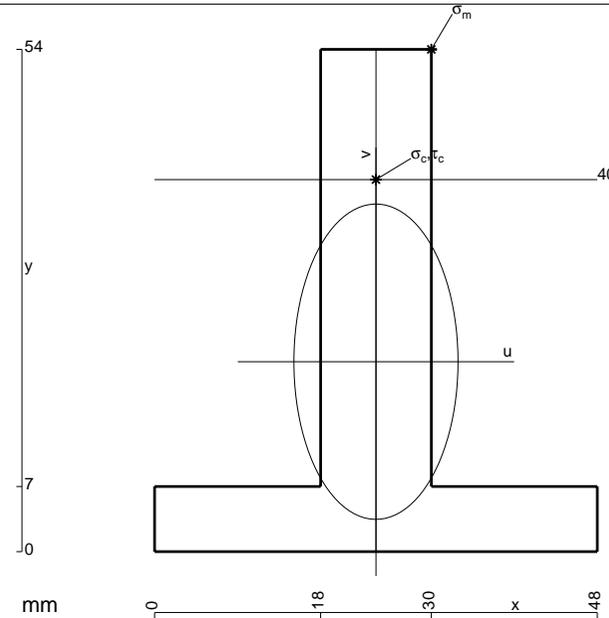
$$= [3/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (3/4 b - 1/3 b + 1/8 b) Fb 1/EJ + (1/2 b) \theta = 25/24 Fb^2/EJ$$

$$L_{FB}^{x\theta} = \int_0^b (1 - x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [x - 1/2 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b + 1/6 b - 1/8 b) Fb 1/EJ + (-b + 1/2 b) \theta = 25/24 Fb^2/EJ$$



- A = 900. mm<sup>2</sup>
- J<sub>u</sub> = 258693. mm<sup>4</sup>
- J<sub>v</sub> = 71280. mm<sup>4</sup>
- y<sub>g</sub> = 20.42 mm
- N = -1408. N
- T<sub>y</sub> = -4620. N
- M<sub>x</sub> = -1628550. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 33.58 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = 209.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 40. mm
- v<sub>c</sub> = 19.58 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = 121.7 N/mm<sup>2</sup>
- τ<sub>c</sub> = 6.646 N/mm<sup>2</sup>
- σ<sub>σ</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 122.2 N/mm<sup>2</sup>
- S = 4465. mm<sup>3</sup>







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (2x/b - 3/2 x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

$$= [x^2/b - 1/2 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b + 1/8 b) Fb 1/EJ + (1/2 b) \theta = 9/8 Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - 1/2 x/b - 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [x - 1/4 x^2/b - 1/8 x^4/b^3]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

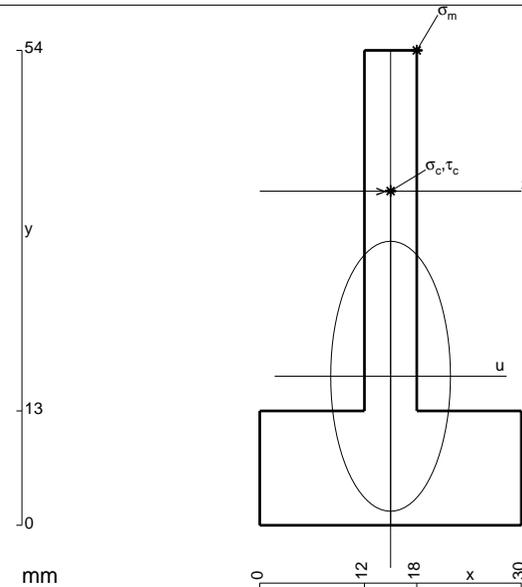
$$= (b - 1/4 b - 1/8 b) Fb 1/EJ + (-b + 1/2 b) \theta = 9/8 Fb^2/EJ$$

$$L_{GC}^{x_0} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{CG}^{x_0} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$



$$A = 636. \text{ mm}^2$$

$$J_u = 149922. \text{ mm}^4$$

$$J_v = 29988. \text{ mm}^4$$

$$y_g = 16.94 \text{ mm}$$

$$T_y = -1740. \text{ N}$$

$$M_x = 887400. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$y_m = 54. \text{ mm}$$

$$u_m = 3. \text{ mm}$$

$$v_m = 37.06 \text{ mm}$$

$$\sigma_c = -Mv/J_u = -219.3 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 38. \text{ mm}$$

$$v_c = 21.06 \text{ mm}$$

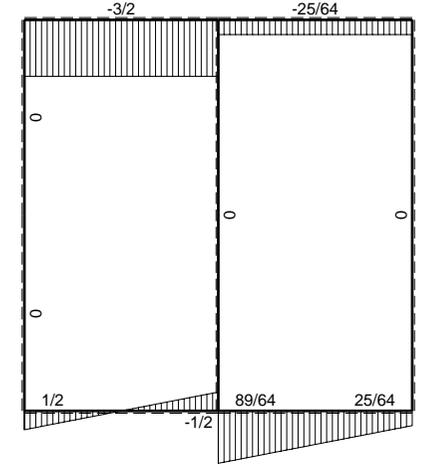
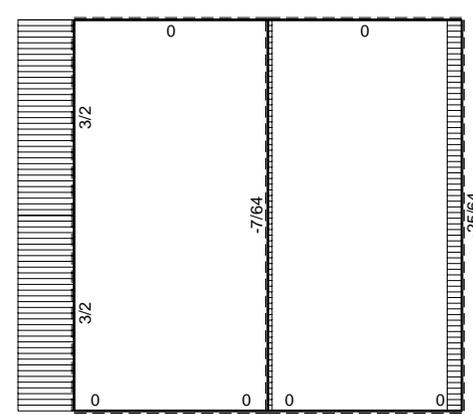
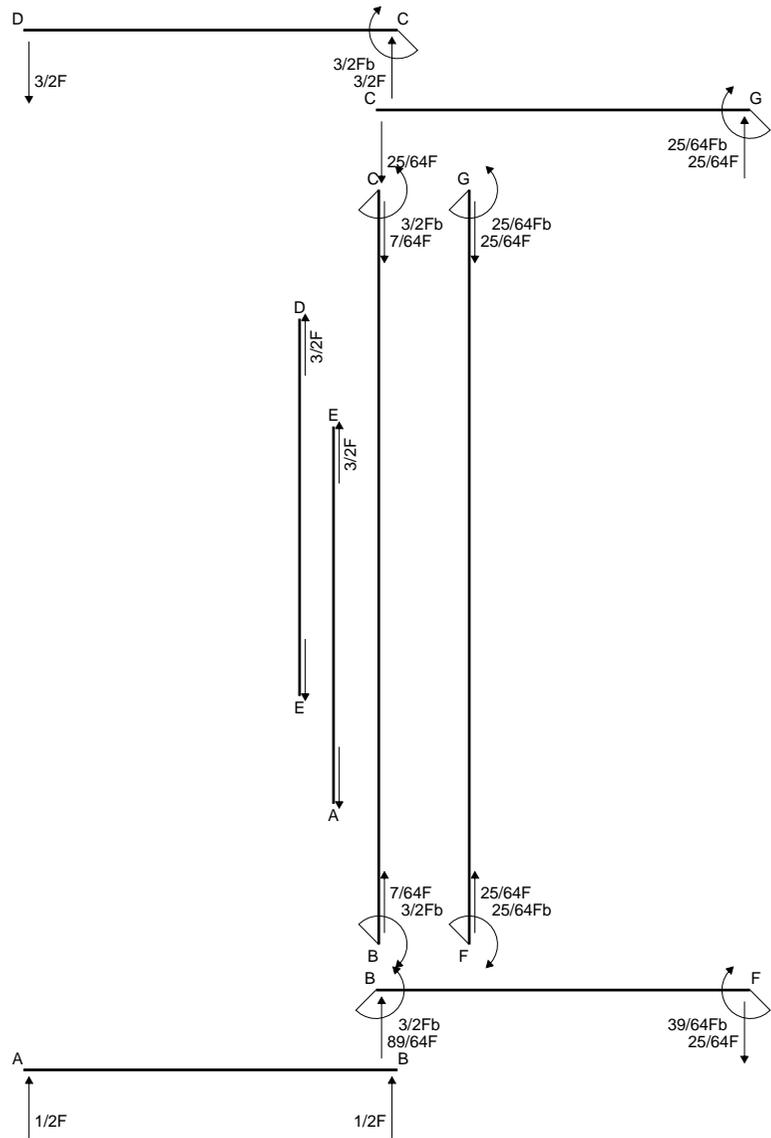
$$\sigma_c = -Mv/J_u = -124.6 \text{ N/mm}^2$$

$$\tau_c = 5.396 \text{ N/mm}^2$$

$$\sigma_\varphi = \sqrt{\sigma^2 + 3\tau^2} = 125. \text{ N/mm}^2$$

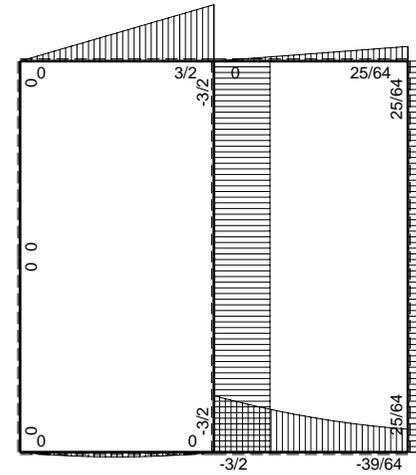
$$S = 2789. \text{ mm}^3$$



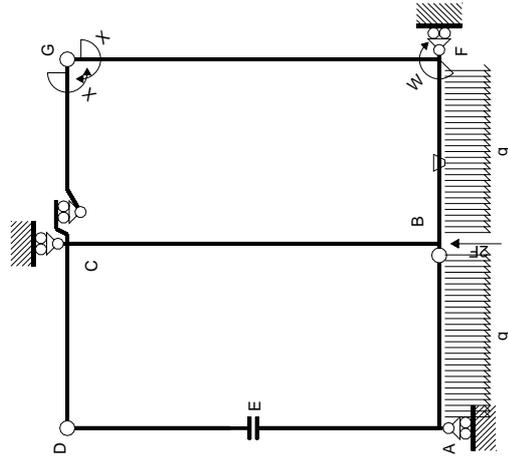


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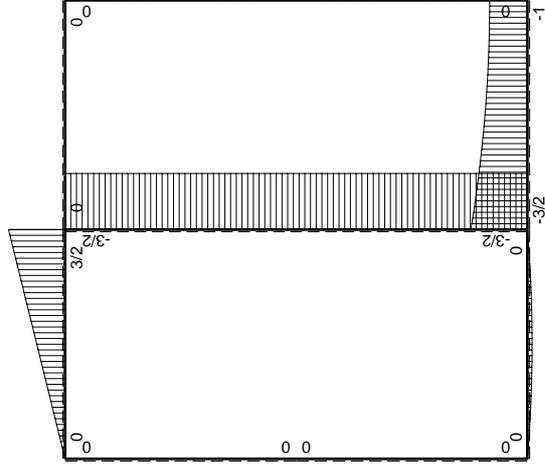
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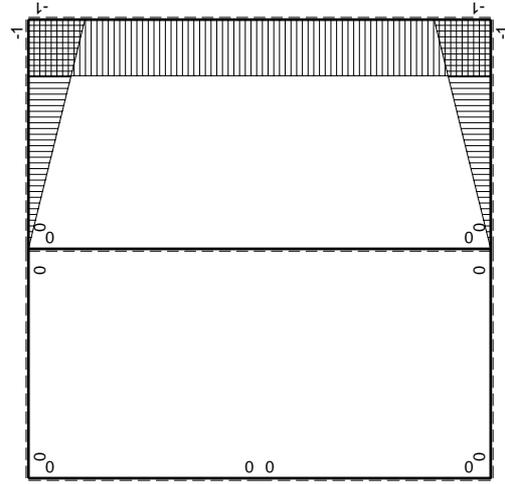
⊕ ⊖ F<sub>b</sub>



Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M_x(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0
BA b	0	$-1/2Fx+1/2qx^2$	0	0	0	0	0+0	0
CD b	0	$3/2Fb-3/2Fx$	0	0	0	0	0+0	0
DC b	0	$-3/2Fx$	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
ED b	0	0	0	0	0	0	0+0	0
EA b	0	0	0	0	0	0	0+0	0
AE b	0	0	0	0	0	0	0+0	0
BF b	$-x/b$	$-3/2Fb+Fx-1/2qx^2$	$-Fb/EJ$	$3/2Fx-Fx^2/b+1/2qx^3/b$	$Fx/EJ$	$x^2/b^2$	$(1/3/24+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$Fb+1/2qx^2$	$Fb/EJ$	$Fb-Fx+1/2Fx^2/b-1/2qx^3/b$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$25/24Fb^2/EJ$	$8/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	0	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2xb/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2xb/EJ$
CB 2b	0	$-3/2Fb$	0	0	0	0	0+0	0
BC 2b	0	$3/2Fb$	0	0	0	0	0+0	0
totali								
iperstatica $X=W_{gc}$								

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (3/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

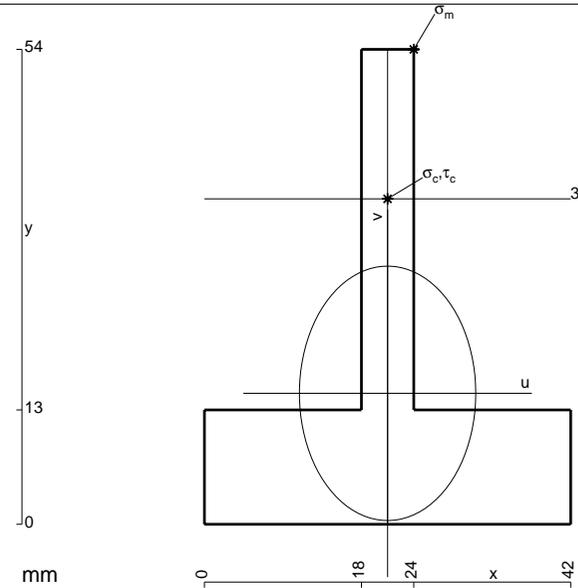
$$= [3/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (3/4 b - 1/3 b + 1/8 b) Fb 1/EJ + (1/2 b) \theta = 25/24 Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

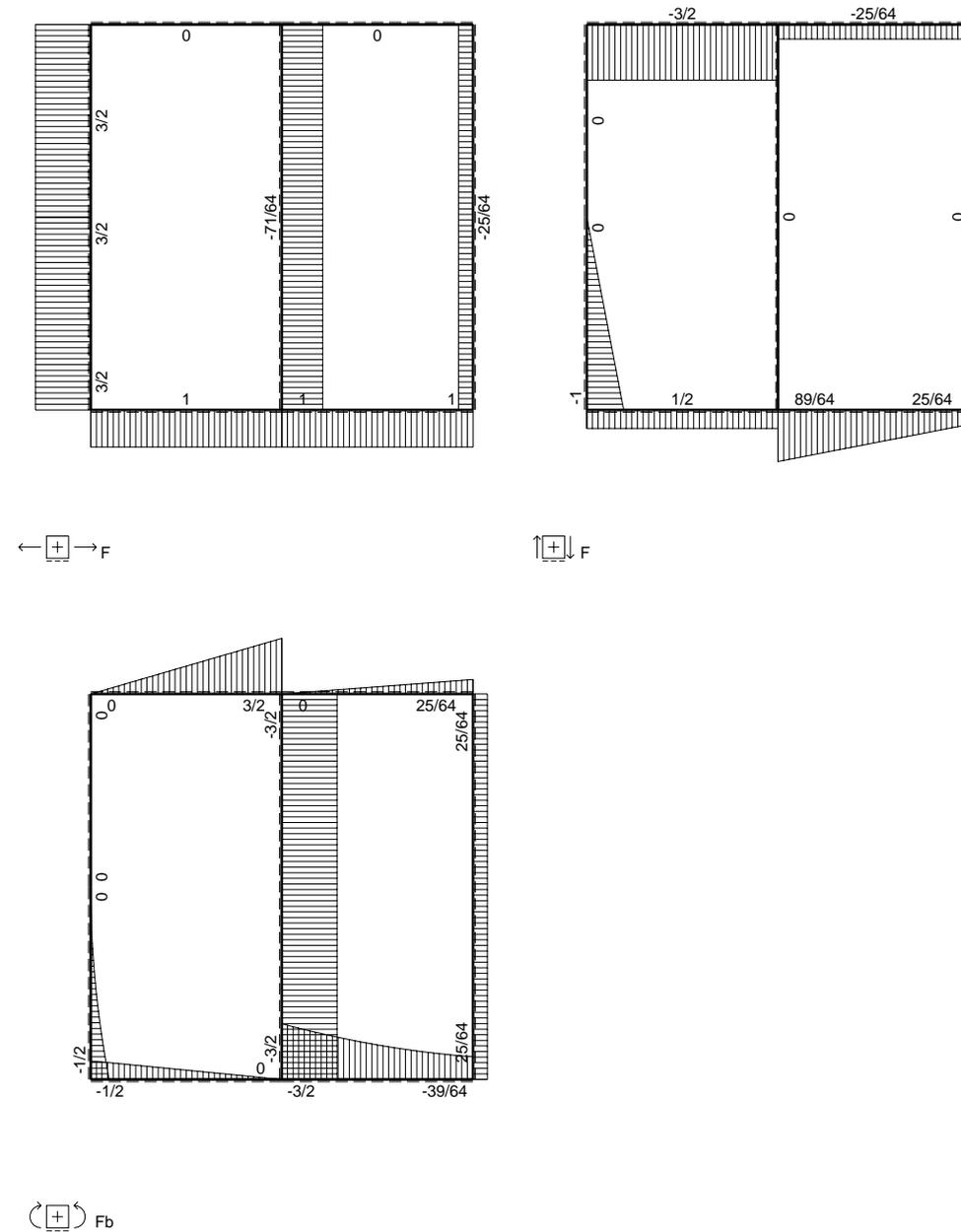
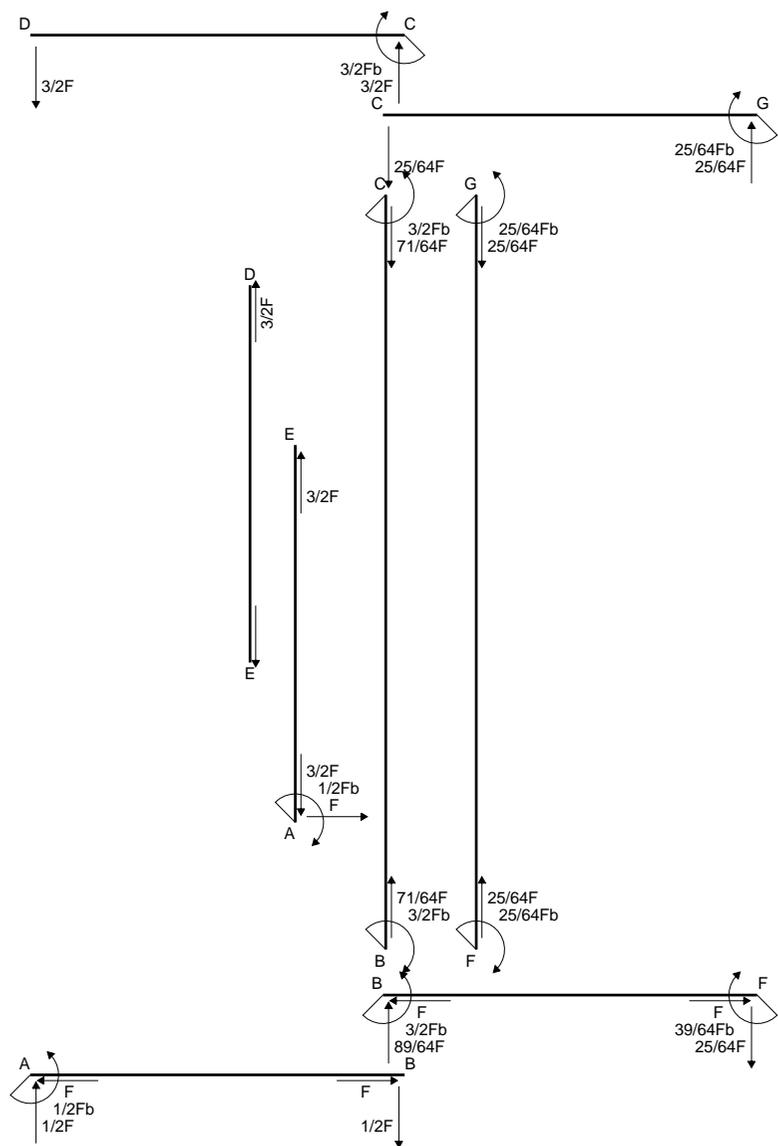
$$= [x - 1/2 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b + 1/6 b - 1/8 b) Fb 1/EJ + (-b + 1/2 b) \theta = 25/24 Fb^2/EJ$$

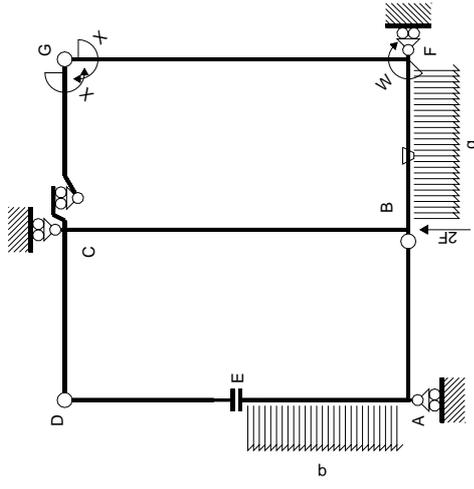


- A = 792. mm<sup>2</sup>
- J<sub>u</sub> = 165782. mm<sup>4</sup>
- J<sub>v</sub> = 81000. mm<sup>4</sup>
- y<sub>g</sub> = 14.89 mm
- T<sub>y</sub> = -1770. N
- M<sub>x</sub> = 973500. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 3. mm
- v<sub>m</sub> = 39.11 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -229.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 37. mm
- v<sub>c</sub> = 22.11 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -129.9 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> = 130.2 N/mm<sup>2</sup>
- S = 3123. mm<sup>3</sup>

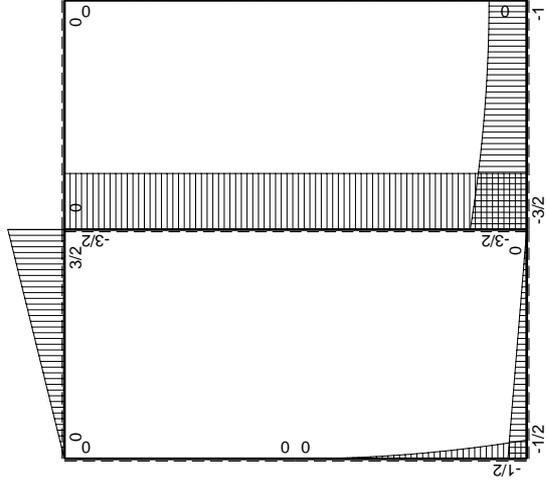




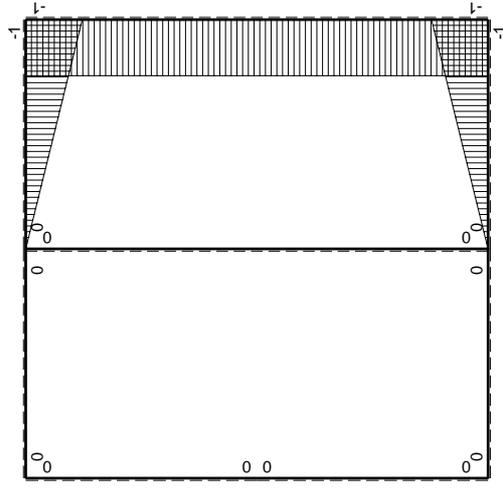
⊕ F<sub>b</sub>



Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica X=W<sub>gc</sub>

←	M <sup>x</sup> (x)	M <sup>0</sup> (x)	θ	M <sup>x</sup> M <sub>0</sub>	M <sup>x</sup> θ	M <sup>x</sup> M <sub>x</sub>	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	0	-1/2Fb+1/2Fx	0	0	0	0	0+0	0
BA b	0	1/2Fx	0	0	0	0	0+0	0
CD b	0	3/2Fb-3/2Fx	0	0	0	0	0+0	0
DC b	0	-3/2Fx	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
ED b	0	0	0	0	0	0	0+0	0
EAB b	0	-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
AE b	0	1/2Fb-Fx+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
BF b	-x/b	-3/2Fb+Fx-1/2qx <sup>2</sup>	-Fb/EJ	3/2Fx-Fx <sup>2</sup> /b+1/2qx <sup>3</sup> /b	Fx/EJ	x <sup>2</sup> /b <sup>2</sup>	(1/3/24+1/2)Fb <sup>2</sup> /EJ	1/3xb/EJ
FBB b	1-x/b	Fb+1/2qx <sup>2</sup>	Fb/EJ	Fb-Fx+1/2Fx <sup>2</sup> /b-1/2qx <sup>3</sup> /b	Fb/EJ-Fx/EJ	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	1/3xb/EJ	1/3xb/EJ
GCB b	-1+x/b	0	0	0	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	0+0	1/3xb/EJ
CG b	x/b	0	0	0	0	x <sup>2</sup> /b <sup>2</sup>	0+0	1/3xb/EJ
FG 2b	-1	0	0	0	0	1	0+0	2xb/EJ
GF 2b	1	0	0	0	0	1	0+0	2xb/EJ
CB 2b	0	-3/2Fb	0	0	0	0	0+0	0
BC 2b	0	3/2Fb	0	0	0	0	0+0	0
totali								
iperstatica X=W <sub>gc</sub>								
							25/24Fb <sup>2</sup> /EJ	8/3xb/EJ
								-25/64Fb

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x\theta} = \int_0^b (3/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

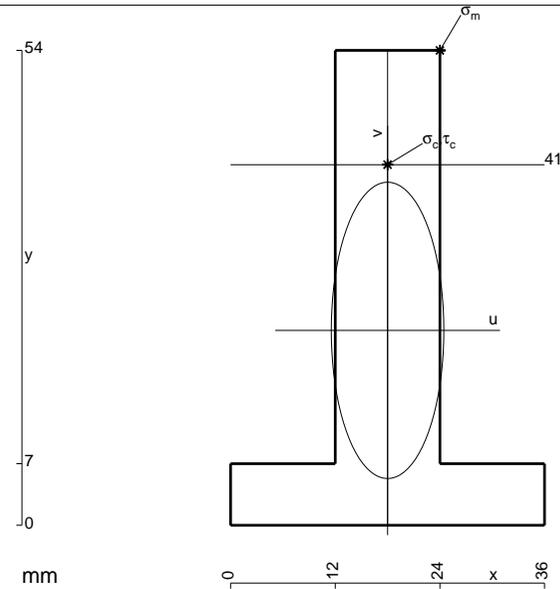
$$= [3/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (3/4 b - 1/3 b + 1/8 b) Fb 1/EJ + (1/2 b) \theta = 25/24 Fb^2/EJ$$

$$L_{FB}^{x\theta} = \int_0^b (1 - x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [x - 1/2 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b + 1/6 b - 1/8 b) Fb 1/EJ + (-b + 1/2 b) \theta = 25/24 Fb^2/EJ$$



$$A = 816. \text{ mm}^2$$

$$J_u = 231827. \text{ mm}^4$$

$$J_v = 33984. \text{ mm}^4$$

$$y_g = 22.16 \text{ mm}$$

$$T_y = -2910. \text{ N}$$

$$M_x = 1746000. \text{ Nmm}$$

$$x_m = 24. \text{ mm}$$

$$y_m = 54. \text{ mm}$$

$$u_m = 6. \text{ mm}$$

$$v_m = 31.84 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -239.8 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 41. \text{ mm}$$

$$v_c = 18.84 \text{ mm}$$

$$\sigma_c = -Mv/J_u = -141.9 \text{ N/mm}^2$$

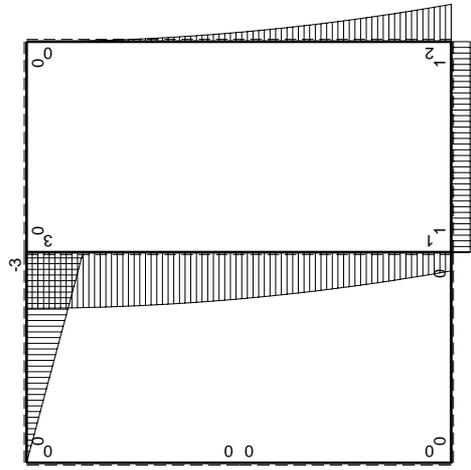
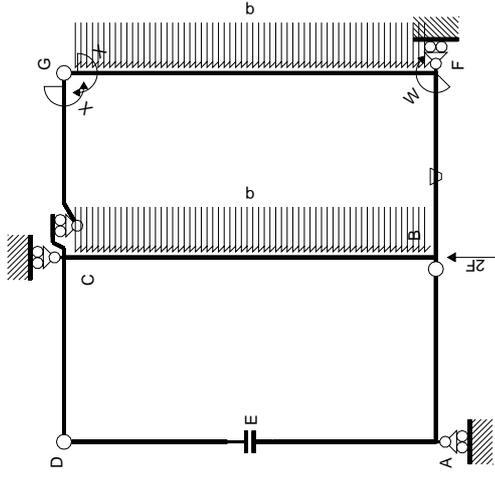
$$\tau_c = 4.135 \text{ N/mm}^2$$

$$\sigma_\varrho = \sqrt{\sigma^2 + 3\tau^2} = 142.1 \text{ N/mm}^2$$

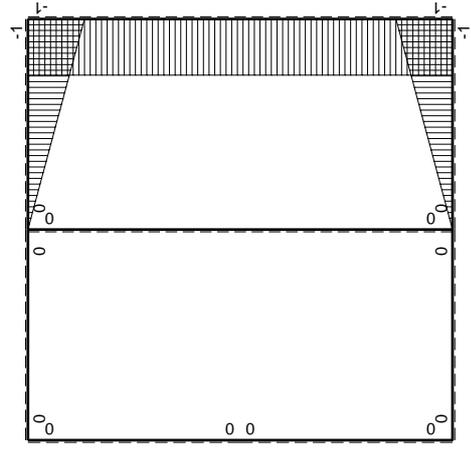
$$S = 3953. \text{ mm}^3$$







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica X=W<sub>gc</sub>

←	M <sup>x</sup> (x)	M <sup>0</sup> (x)	θ	M <sup>x</sup> M <sub>0</sub>	M <sup>x</sup> θ	M <sup>x</sup> M <sub>x</sub>	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0+0	0
CD b	0	-3Fb+3Fx	0	0	0	0	0+0	0
DC b	0	3Fx	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
ED b	0	0	0	0	0	0	0+0	0
EA b	0	0	0	0	0	0	0+0	0
AE b	0	0	0	0	0	0	0+0	0
BF b	-x/b	Fb	-Fb/EJ	-Fx	Fx/EJ	$x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	1-x/b	-Fb	Fb/EJ	-Fb+Fx	Fb/EJ-Fx/EJ	$1-2x/b+x^2/b^2$	$(-1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
GC b	-1+x/b	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	x/b	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	$2Fb-2Fx+1/2qx^2$	0	$-2Fb+2Fx-1/2Fx^2/b$	0	1	$(-4/3+0)Fb^2/EJ$	$2xb/EJ$
GF 2b	1	$-1/2qx^2$	0	$-1/2Fx^2/b$	0	1	$(-4/3+0)Fb^2/EJ$	$2xb/EJ$
CB 2b	0	$3Fb-1/2qx^2$	0	0	0	0	0+0	0
BC 2b	0	$-Fb-2Fx+1/2qx^2$	0	0	0	0	0+0	0
totali							$-4/3Fb^2/EJ$	$8/3xb/EJ$

iperstatica X=W<sub>gc</sub>

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x\theta} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x\theta} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

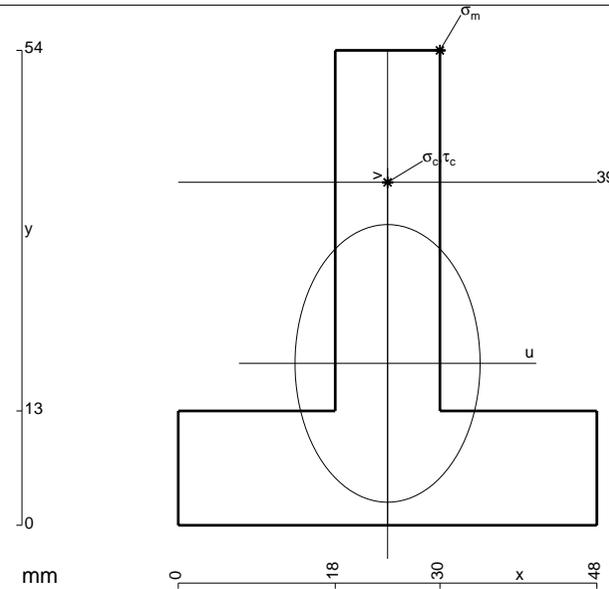
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x\theta} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

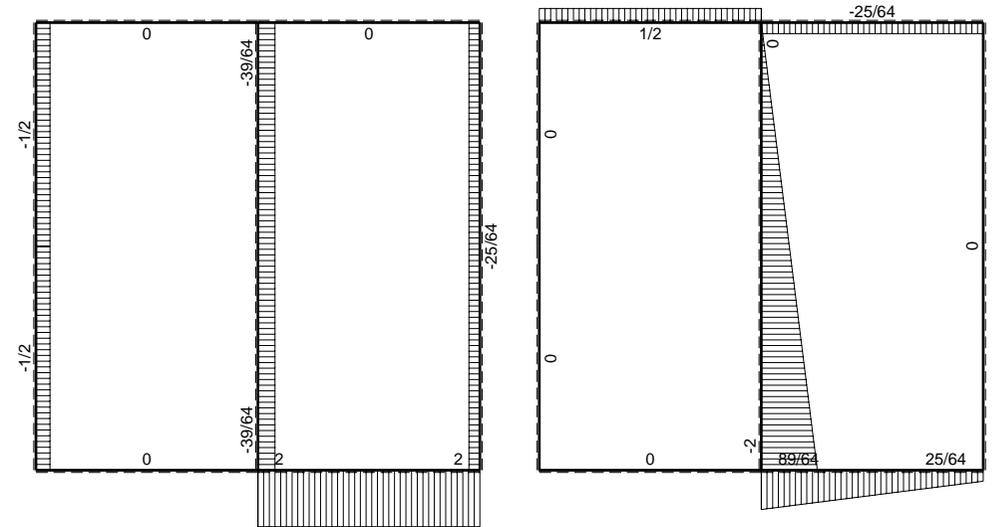
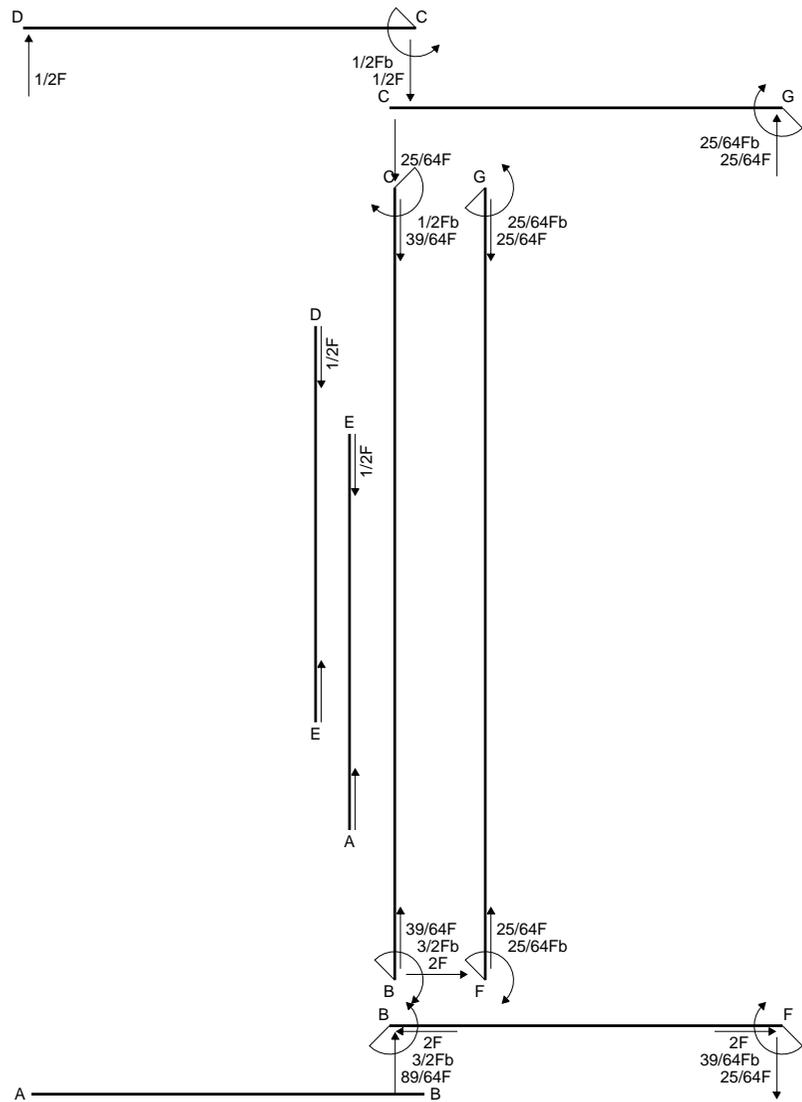
$$L_{GF}^{x\theta} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



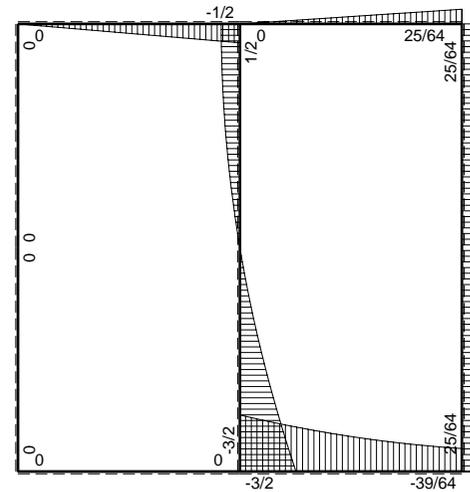
- A = 1116. mm<sup>2</sup>
- J<sub>u</sub> = 278255. mm<sup>4</sup>
- J<sub>v</sub> = 125712. mm<sup>4</sup>
- y<sub>g</sub> = 18.4 mm
- T<sub>y</sub> = 2430. N
- M<sub>x</sub> = -1555200. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 35.6 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = 199. N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 39. mm
- v<sub>c</sub> = 20.6 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 115.1 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.681 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 115.3 N/mm<sup>2</sup>
- S = 5057. mm<sup>3</sup>





← ⊕ → F

↑ ⊕ ↓ F



⊕ F<sub>b</sub>



$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (3/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

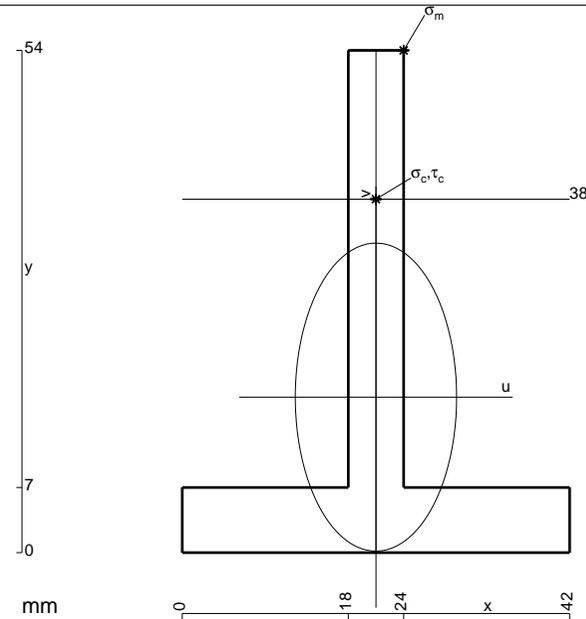
$$= [3/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (3/4 b - 1/3 b + 1/8 b) Fb 1/EJ + (1/2 b) \theta = 25/24 Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [x - 1/2 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b + 1/6 b - 1/8 b) Fb 1/EJ + (-b + 1/2 b) \theta = 25/24 Fb^2/EJ$$



$$A = 576. \text{ mm}^2$$

$$J_u = 158042. \text{ mm}^4$$

$$J_v = 44064. \text{ mm}^4$$

$$y_g = 16.72 \text{ mm}$$

$$N = -530.2 \text{ N}$$

$$T_y = -1740. \text{ N}$$

$$M_x = -887400. \text{ Nmm}$$

$$x_m = 24. \text{ mm}$$

$$y_m = 54. \text{ mm}$$

$$u_m = 3. \text{ mm}$$

$$v_m = 37.28 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 208.4 \text{ N/mm}^2$$

$$x_c = 21. \text{ mm}$$

$$y_c = 38. \text{ mm}$$

$$v_c = 21.28 \text{ mm}$$

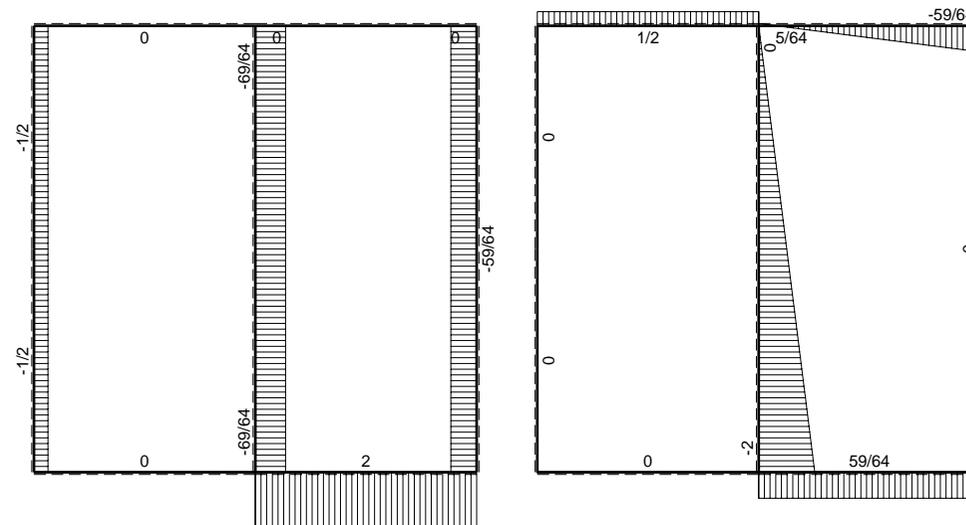
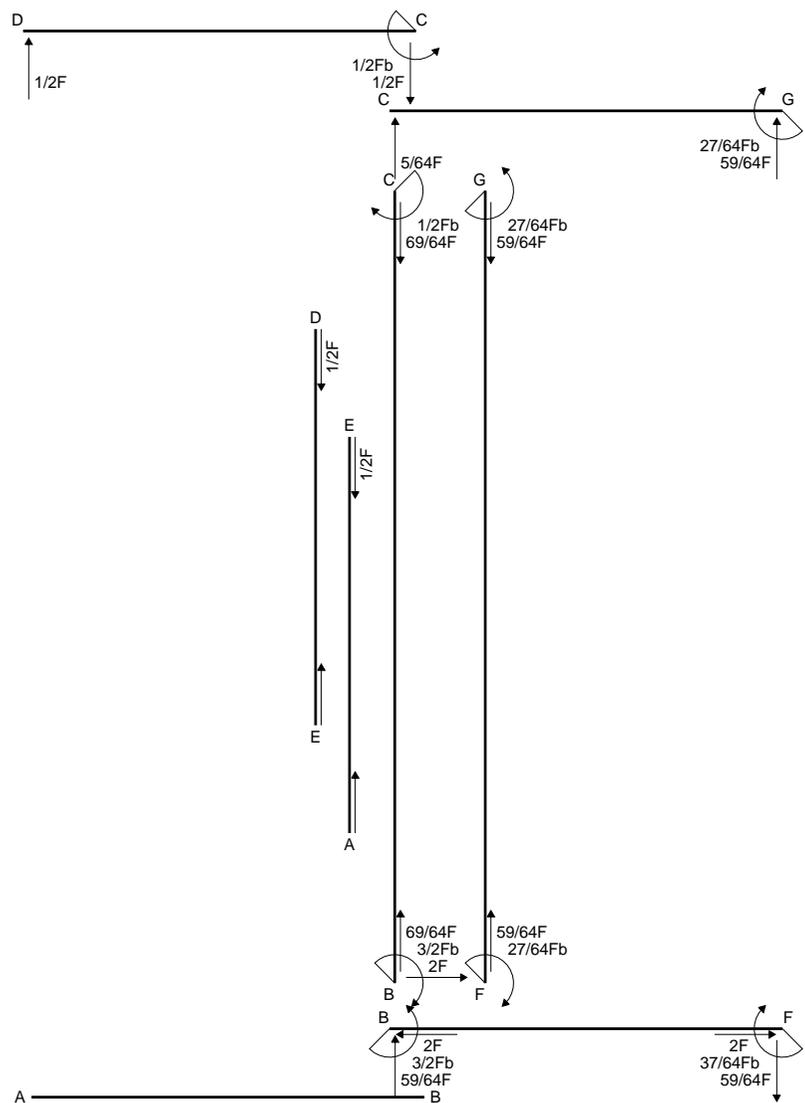
$$\sigma_c = N/A - Mv/J_u = 118.6 \text{ N/mm}^2$$

$$\tau_c = 5.158 \text{ N/mm}^2$$

$$\sigma_\varrho = \sqrt{\sigma^2 + 3\tau^2} = 118.9 \text{ N/mm}^2$$

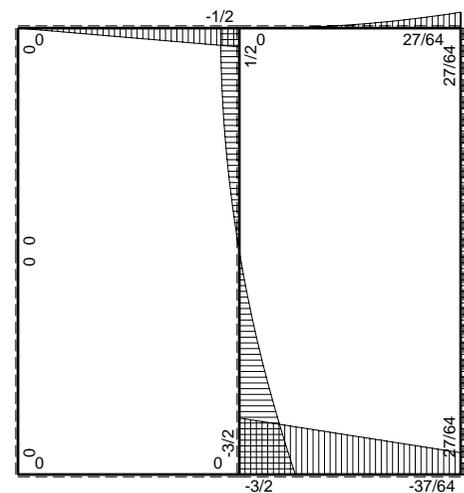
$$S = 2811. \text{ mm}^3$$



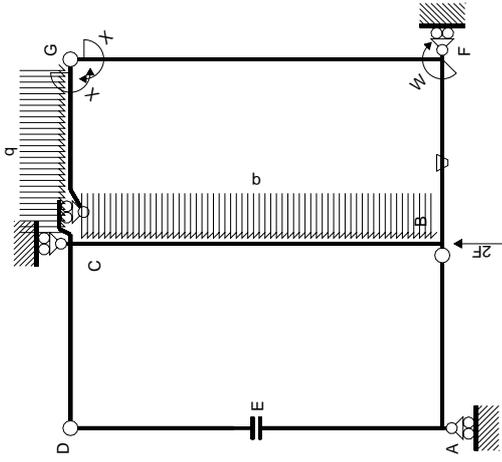


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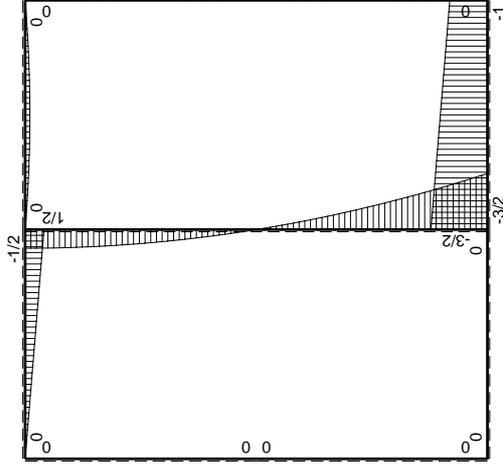


⊕ F<sub>b</sub>



Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



Quadro contributi PLV per iperstatica $X=W_{gc}$		$M_x$		$M_0$	$M_x \theta$	$M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int X M_x M_0 / EJ dx$	
AB b	0	0	0	0	0	0	0+0	0	
BA b	0	0	0	0	0	0	0+0	0	
CD b	0	$-1/2Fb+1/2Fx$	0	0	0	0	0+0	0	
DC b	0	$1/2Fx$	0	0	0	0	0+0	0	
DE b	0	0	0	0	0	0	0+0	0	
ED b	0	0	0	0	0	0	0+0	0	
EA b	0	0	0	0	0	0	0+0	0	
AE b	0	0	0	0	0	0	0+0	0	
BF b	$-x/b$	$-3/2Fb+1/2Fx$	$-Fb/EJ$	$3/2Fx-1/2Fx^2/b$	$Fx/EJ$	$x^2/b^2$	$(7/12+1/2)Fb^2/EJ$	$1/3Xb/EJ$	
FB b	$1-x/b$	$Fb+1/2Fx$	$Fb/EJ$	$Fb-1/2Fx-1/2Fx^2/b$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$(7/12+1/2)Fb^2/EJ$	$1/3Xb/EJ$	
GC b	$-1+x/b$	$-1/2Fx+1/2qx^2$	0	$1/2Fx-Fx^2/b+1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(1/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
CG b	$x/b$	$1/2Fx-1/2qx^2$	0	$1/2Fx^2/b-1/2qx^3/b$	0	$x^2/b^2$	$(1/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
FG 2b	-1	0	0	0	0	1	0+0	$2Xb/EJ$	
GF 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$	
CB 2b	0	$1/2Fb-1/2qx^2$	0	0	0	0	0+0	0	
BC 2b	0	$3/2Fb-2Fx+1/2qx^2$	0	0	0	0	0+0	0	
totali								$9/8Fb^2/EJ$	$8/3Xb/EJ$
								$-27/64Fb$	

Sviluppi di calcolo iperstatica



$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{xo} = \int_0^b (3/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

$$= [3/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (3/4 b - 1/6 b) Fb 1/EJ + (1/2 b) \theta = 13/12 Fb^2/EJ$$

$$L_{FB}^{xo} = \int_0^b (1 - 1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [x - 1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

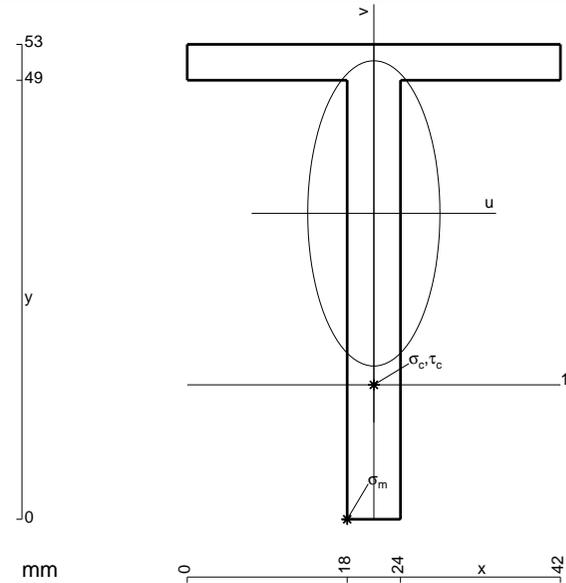
$$= (b - 1/4 b - 1/6 b) Fb 1/EJ + (-b + 1/2 b) \theta = 13/12 Fb^2/EJ$$

$$L_{GC}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

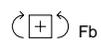
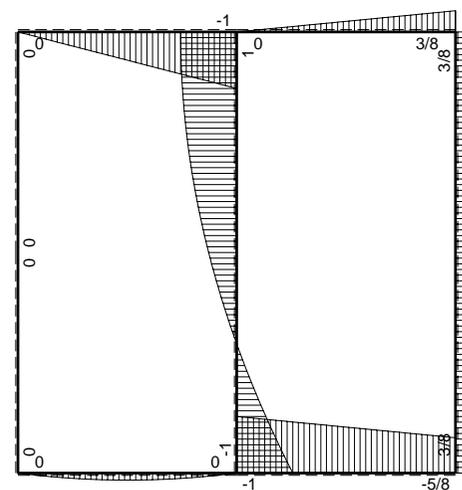
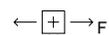
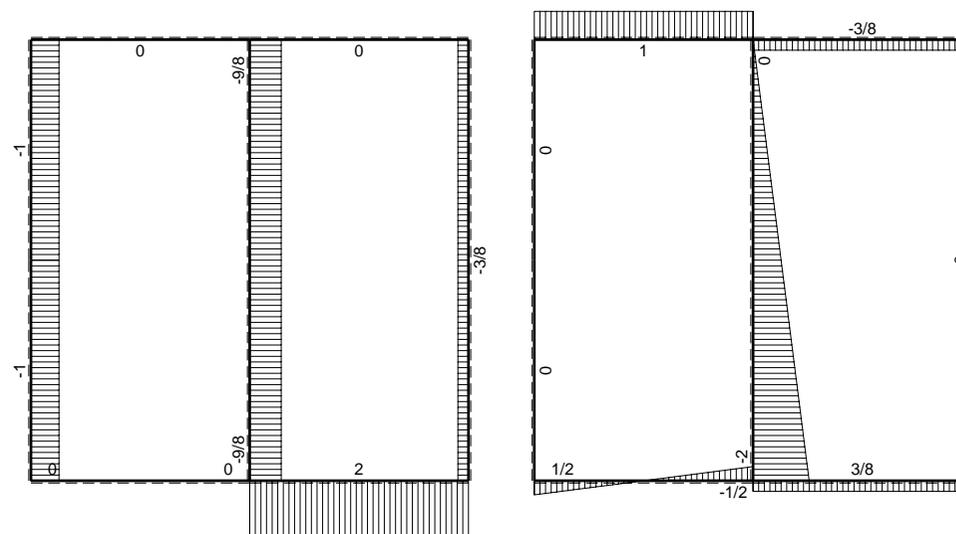
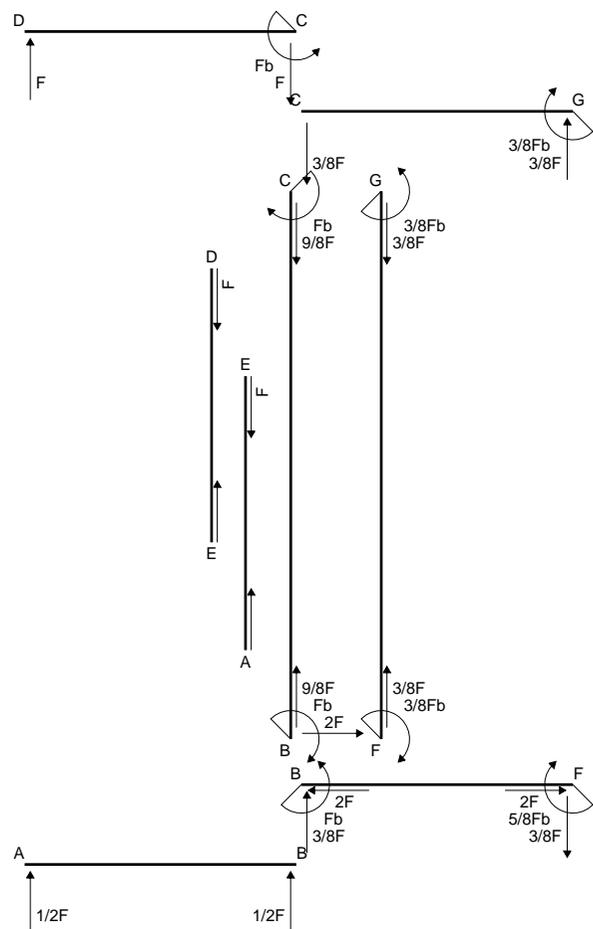
$$L_{CG}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

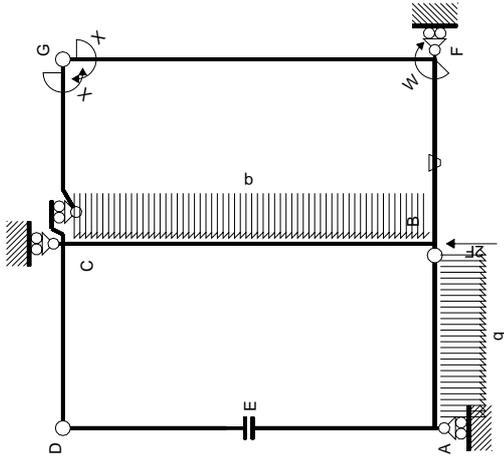
$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$



- A = 462. mm<sup>2</sup>
- J<sub>u</sub> = 134125. mm<sup>4</sup>
- J<sub>v</sub> = 25578. mm<sup>4</sup>
- y<sub>g</sub> = 34.14 mm
- N = -862.5 N
- T<sub>y</sub> = -1600. N
- M<sub>x</sub> = -852000. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -34.14 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = -218.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 15. mm
- v<sub>c</sub> = -19.14 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = -123.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 4.766 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 123.7 N/mm<sup>2</sup>
- S = 2397. mm<sup>3</sup>

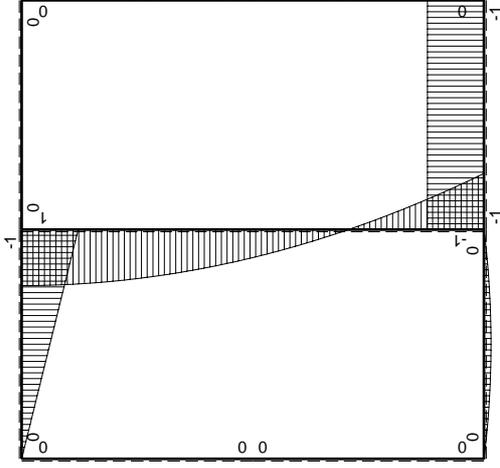






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\leftarrow$	$M^x(x)$	$M_0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x (M_0/EJ + \theta) dx$	$\int M^x M_x/EJ dx$
AB b	0	$1/2Fx - 1/2qx^2$	0	0	0	0	0+0	0
BA b	0	$-1/2Fx + 1/2qx^2$	0	0	0	0	0+0	0
CD b	0	$-Fb + Fx$	0	0	0	0	0+0	0
DC b	0	$Fx$	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
EA b	0	0	0	0	0	0	0+0	0
AE b	0	0	0	0	0	0	0+0	0
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb-Fx$	$Fb/EJ - Fx/EJ$	$1-2x/b+x^2/b^2$	$1/3xb/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2xb/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2xb/EJ$
CB 2b	0	$Fb - 1/2qx^2$	0	0	0	0	0+0	0
BC 2b	0	$Fb - 2Fx + 1/2qx^2$	0	0	0	0	0+0	0
totali								$Fb^2/EJ$
								$8/3xb/EJ$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

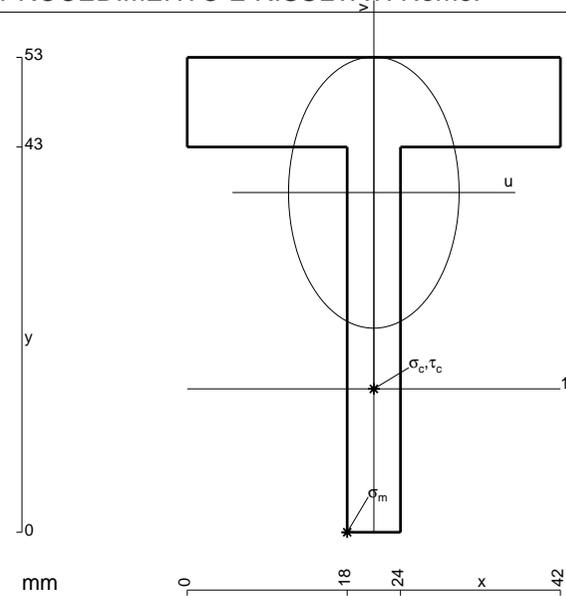
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



$$A = 678. \text{ mm}^2$$

$$J_u = 155489. \text{ mm}^4$$

$$J_v = 62514. \text{ mm}^4$$

$$y_g = 37.92 \text{ mm}$$

$$N = -1395. \text{ N}$$

$$T_y = -2480. \text{ N}$$

$$M_x = -930000. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -37.92 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -228.8 \text{ N/mm}^2$$

$$x_c = 21. \text{ mm}$$

$$y_c = 16. \text{ mm}$$

$$v_c = -21.92 \text{ mm}$$

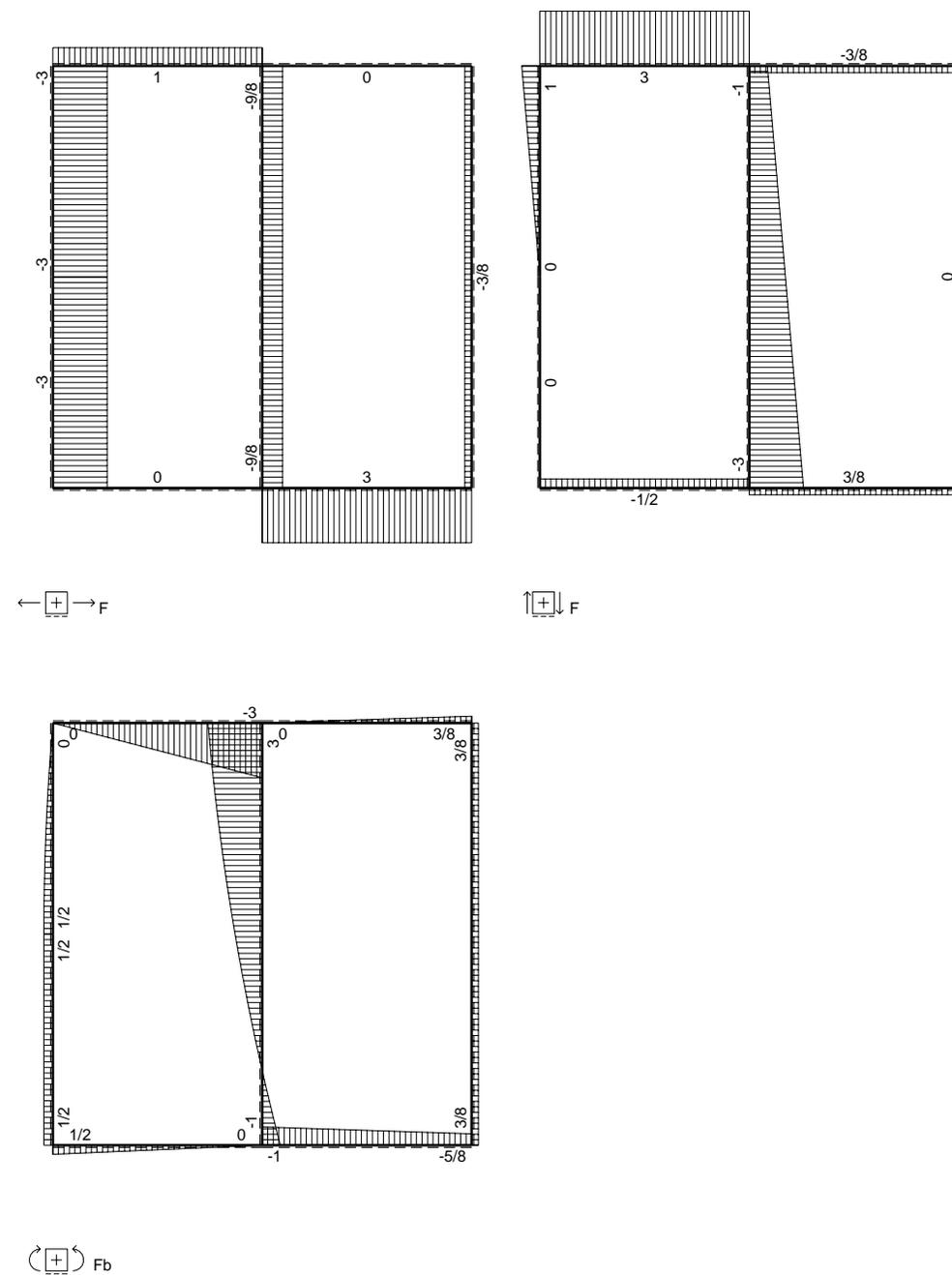
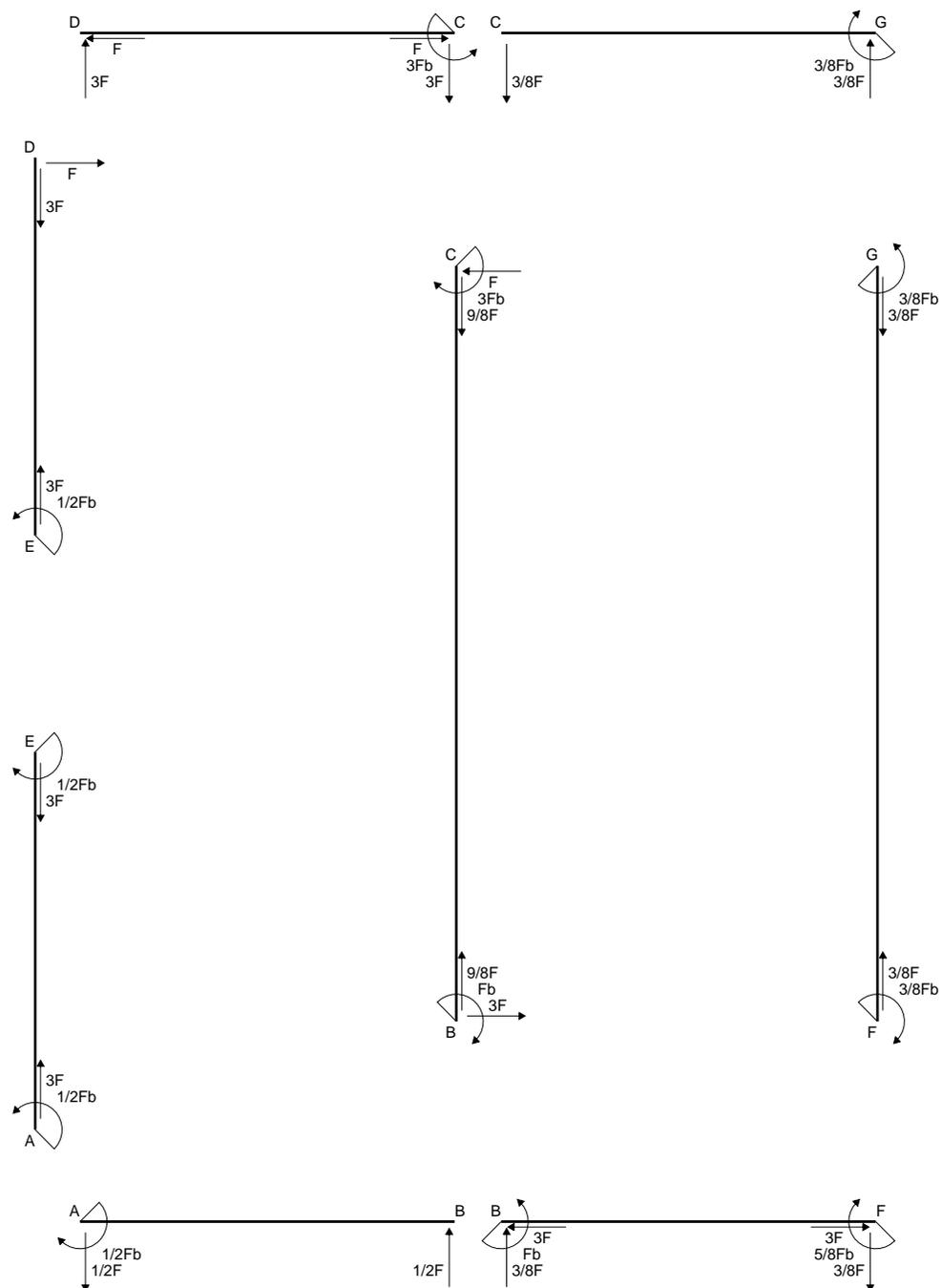
$$\sigma_c = N/A - Mv/J_u = -133.1 \text{ N/mm}^2$$

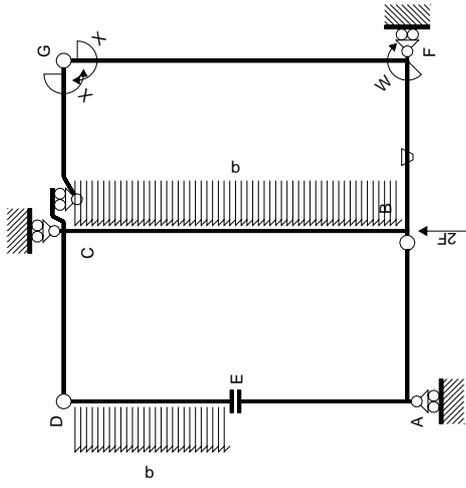
$$\tau_c = 7.634 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 133.8 \text{ N/mm}^2$$

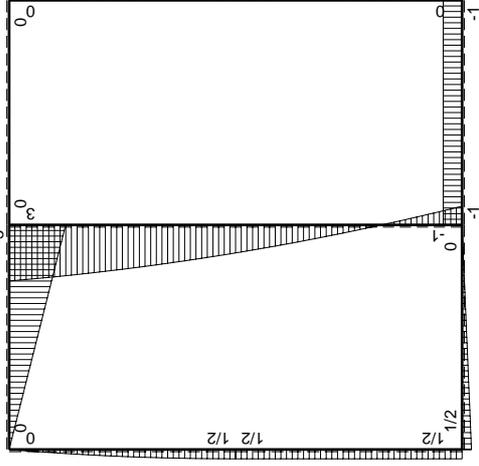
$$S = 2872. \text{ mm}^3$$



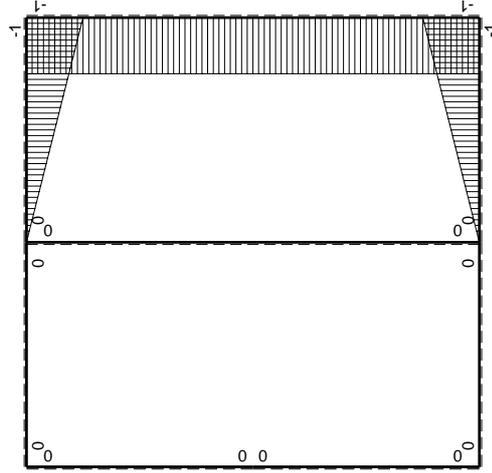




Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / EJ dx$
AB b	0	$1/2Fb - 1/2Fx$	0	0	0	0	0+0	0
BA b	0	$-1/2Fx$	0	0	0	0	0+0	0
CD b	0	$-3Fb + 3Fx$	0	0	0	0	0+0	0
DC b	0	$3Fx$	0	0	0	0	0+0	0
DE b	0	$Fx - 1/2qx^2$	0	0	0	0	0+0	0
ED b	0	$-1/2Fb + 1/2qx^2$	0	0	0	0	0+0	0
EA b	0	$1/2Fb$	0	0	0	0	0+0	0
AE b	0	$-1/2Fb$	0	0	0	0	0+0	0
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb-Fx$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$1/3xb/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2xb/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2xb/EJ$
CB 2b	0	$3Fb-Fx-1/2qx^2$	0	0	0	0	0+0	0
BC 2b	0	$Fb-3Fx+1/2qx^2$	0	0	0	0	0+0	0
totali								$Fb^2/EJ$
								$8/3xb/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

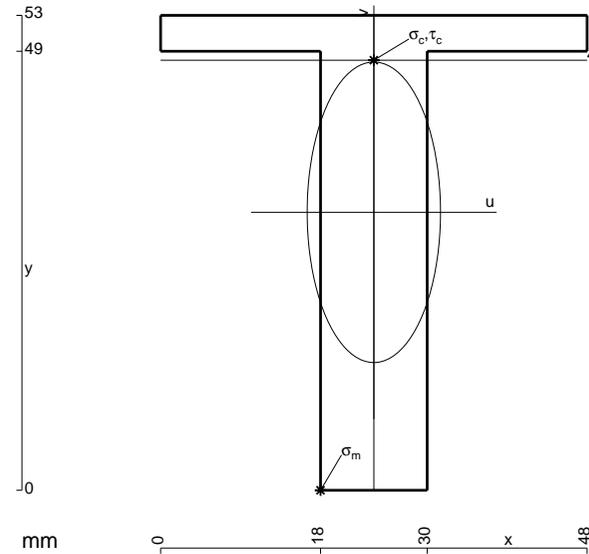
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



$$A = 780. \text{ mm}^2$$

$$J_u = 219548. \text{ mm}^4$$

$$J_v = 43920. \text{ mm}^4$$

$$y_g = 31.02 \text{ mm}$$

$$N = 710. \text{ N}$$

$$T_y = 2130. \text{ N}$$

$$M_x = -1682700. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$u_m = -6. \text{ mm}$$

$$v_m = -31.02 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -236.9 \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 48. \text{ mm}$$

$$v_c = 16.98 \text{ mm}$$

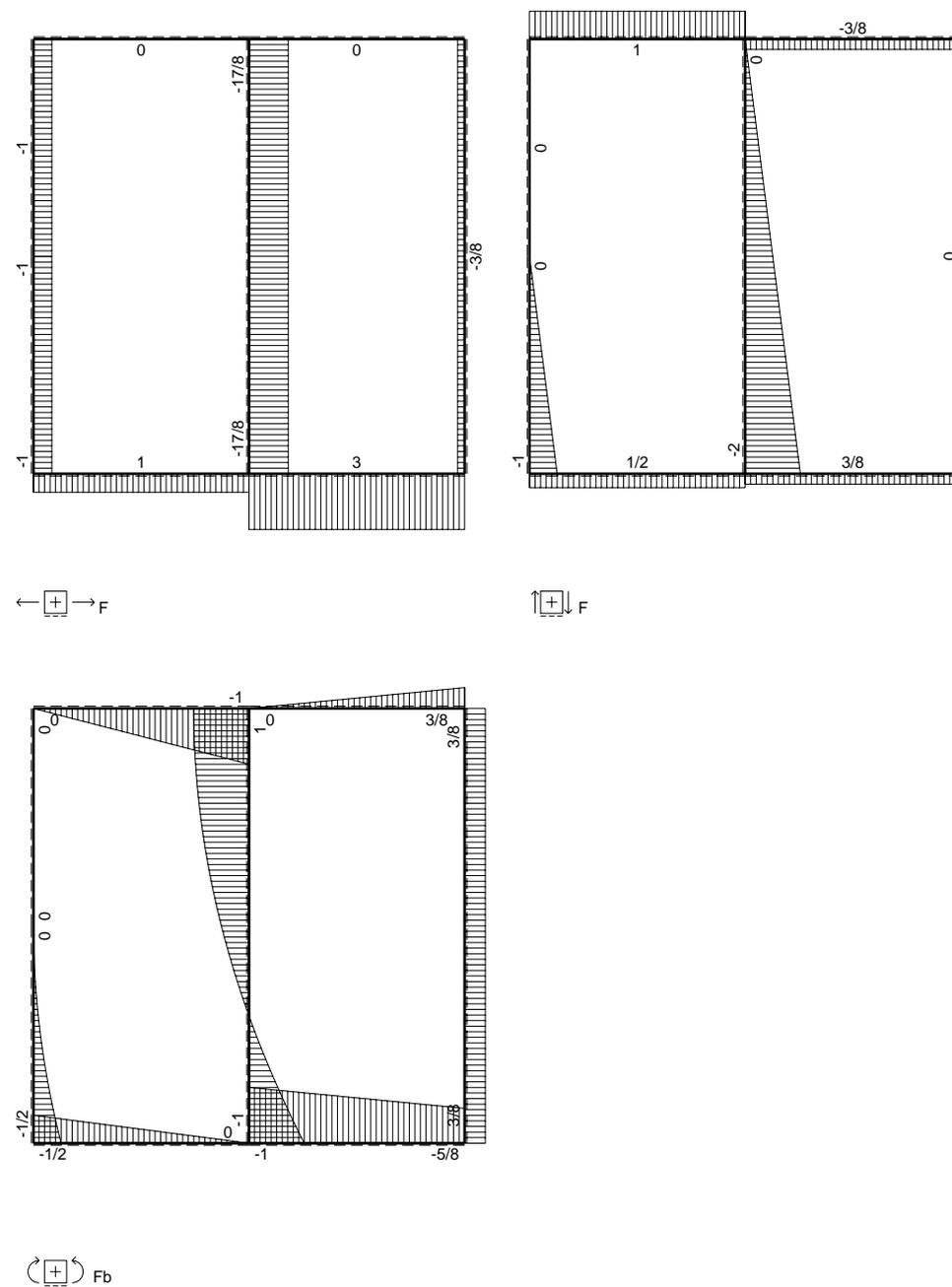
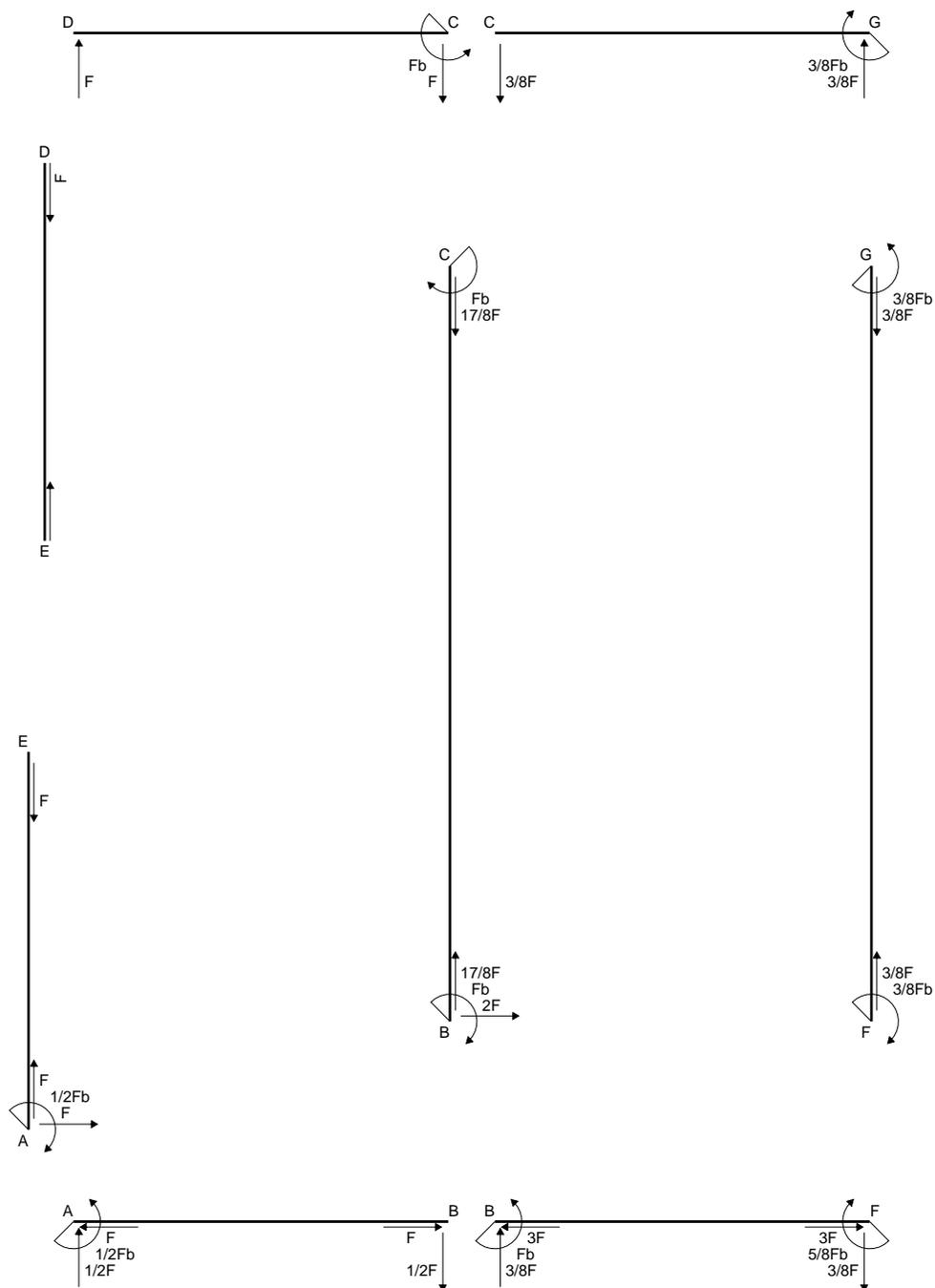
$$\sigma_c = N/A - Mv/J_u = 131. \text{ N/mm}^2$$

$$\tau_c = 3.271 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 131.2 \text{ N/mm}^2$$

$$S = 4045. \text{ mm}^3$$







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

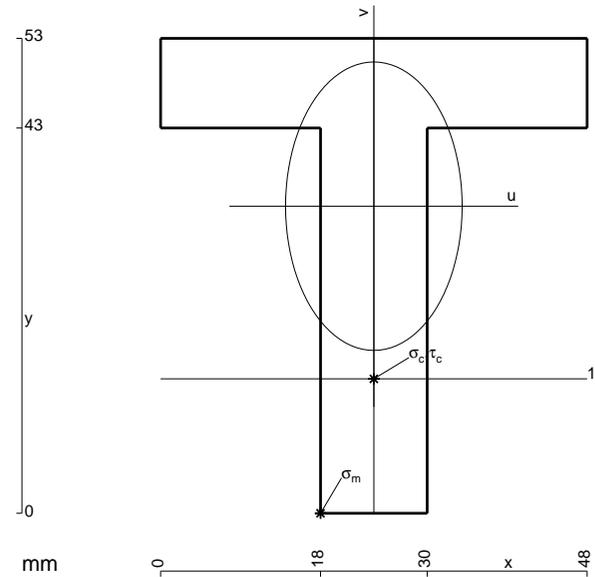
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



$$A = 996. \text{ mm}^2$$

$$J_u = 258139. \text{ mm}^4$$

$$J_v = 98352. \text{ mm}^4$$

$$y_g = 34.27 \text{ mm}$$

$$N = -7331. \text{ N}$$

$$T_y = -6900. \text{ N}$$

$$M_x = -1449000. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$u_m = -6. \text{ mm}$$

$$v_m = -34.27 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -199.7 \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 15. \text{ mm}$$

$$v_c = -19.27 \text{ mm}$$

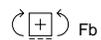
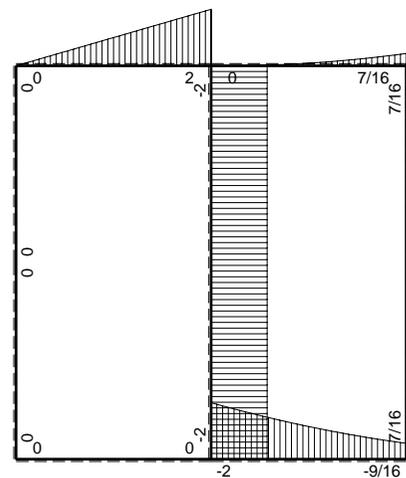
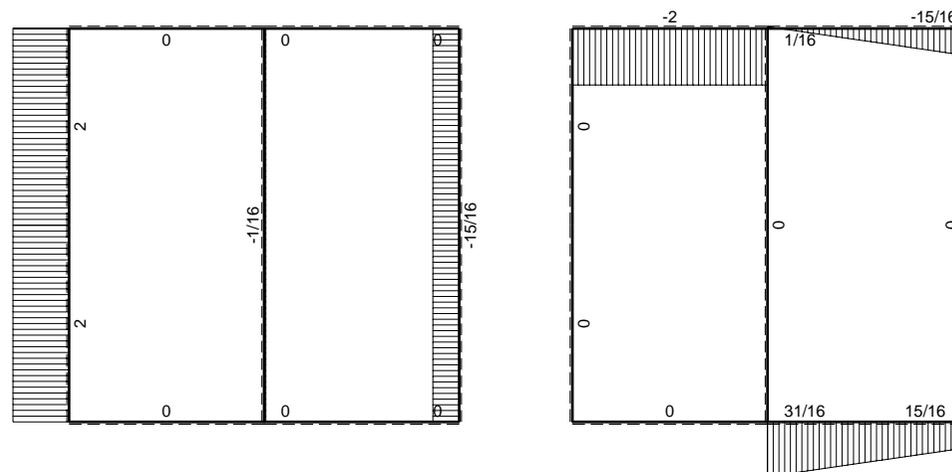
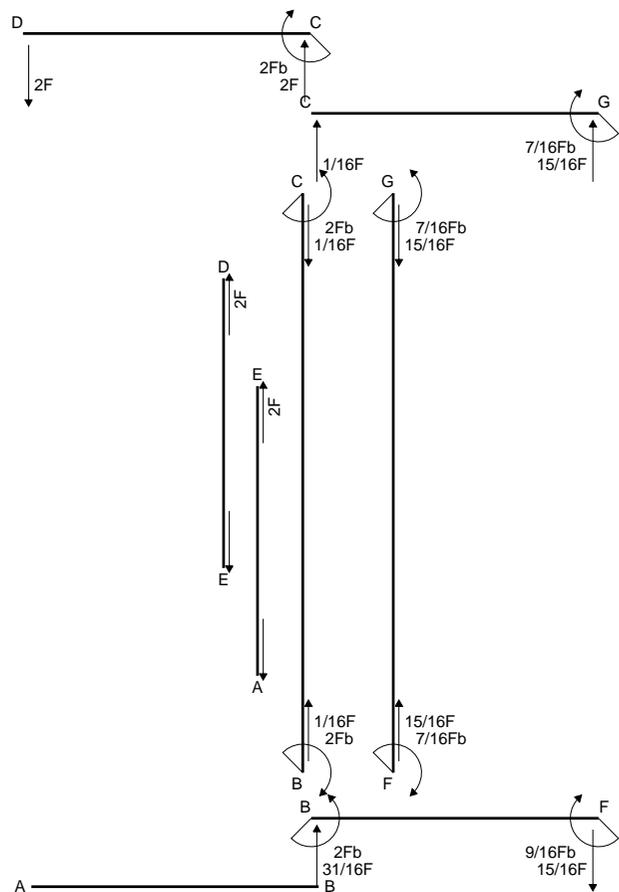
$$\sigma_c = N/A - Mv/J_u = -115.5 \text{ N/mm}^2$$

$$\tau_c = 10.73 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 117. \text{ N/mm}^2$$

$$S = 4819. \text{ mm}^3$$







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (2x/b - 3/2 x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

$$= [x^2/b - 1/2 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b + 1/8 b) Fb 1/EJ + (1/2 b) \theta = 9/8 Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - 1/2 x/b - 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [x - 1/4 x^2/b - 1/8 x^4/b^3]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

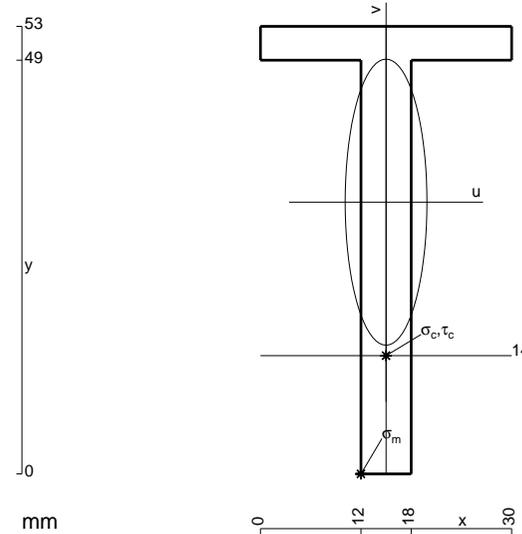
$$= (b - 1/4 b - 1/8 b) Fb 1/EJ + (-b + 1/2 b) \theta = 9/8 Fb^2/EJ$$

$$L_{GC}^{x_0} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{CG}^{x_0} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$



$$A = 414. \text{ mm}^2$$

$$J_u = 118828. \text{ mm}^4$$

$$J_v = 9882. \text{ mm}^4$$

$$y_g = 32.18 \text{ mm}$$

$$T_y = -1680. \text{ N}$$

$$M_x = 772800. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -32.18 \text{ mm}$$

$$\sigma_m = -Mv/J_u = 209.3 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 14. \text{ mm}$$

$$v_c = -18.18 \text{ mm}$$

$$\sigma_c = -Mv/J_u = 118.2 \text{ N/mm}^2$$

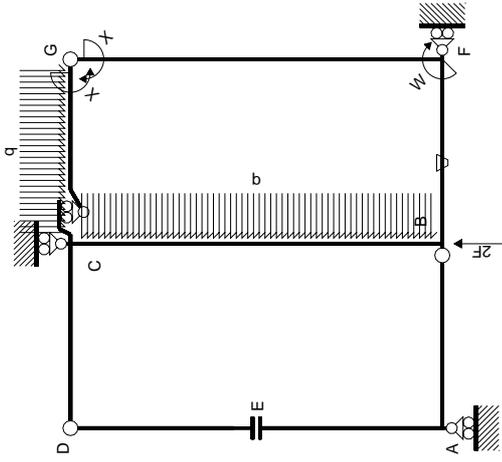
$$\tau_c = 4.984 \text{ N/mm}^2$$

$$\sigma_0 = \sqrt{\sigma^2 + 3\tau^2} = 118.6 \text{ N/mm}^2$$

$$S = 2115. \text{ mm}^3$$

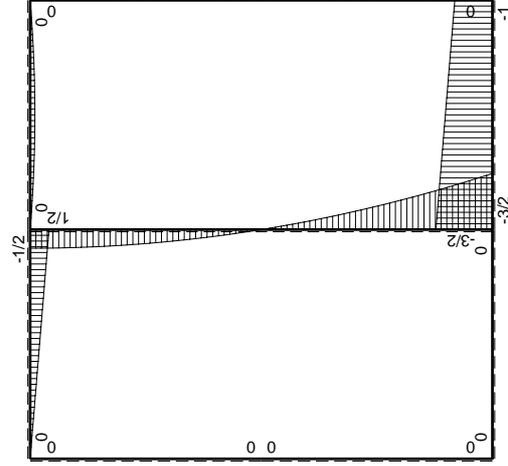






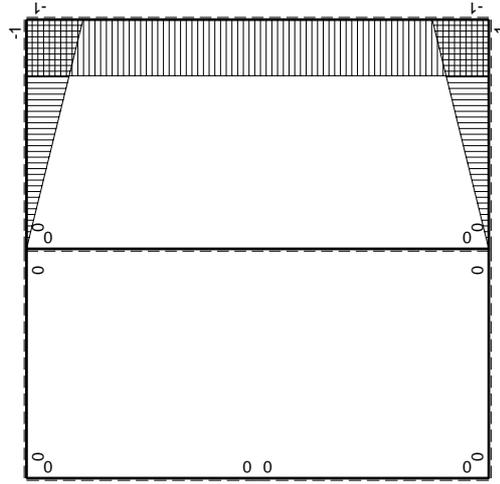
Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



Quadro contributi PLV per iperstatica $X=W_{gc}$		$M_x$		$M_x$	$M_x \theta$	$M_x M_0$	$\theta$	$M_0(x)$	$M(x)$	$\theta$	Sviluppi di calcolo iperstatica	
$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x$	$M_x \theta$	$M_x M_0$	$\theta$	$M_0(x)$	$M(x)$	$\theta$	totali	
AB b	0	0	0	0	0	0	0	0	0	0	0	AB b
BA b	0	0	0	0	0	0	0	0	0	0	0	BA b
CD b	0	$-1/2Fb+1/2Fx$	0	0	0	0	0	0	0	0	0	CD b
DC b	0	$1/2Fx$	0	0	0	0	0	0	0	0	0	DC b
DE b	0	0	0	0	0	0	0	0	0	0	0	DE b
ED b	0	0	0	0	0	0	0	0	0	0	0	ED b
EA b	0	0	0	0	0	0	0	0	0	0	0	EA b
AE b	0	0	0	0	0	0	0	0	0	0	0	AE b
BF b	$-x/b$	$-3/2Fb+1/2Fx$	$-Fb/EJ$	$x^2/b^2$	$Fx/EJ$	$Fb/EJ-Fx/EJ$	$Fb/EJ$	$3/2Fx-1/2Fx^2/b$	$Fb-1/2Fx-1/2Fx^2/b$	$-Fb/EJ$	$-3/2Fb+1/2Fx$	BF b
FB b	$1-x/b$	$Fb+1/2Fx$	$Fb/EJ$	$x^2/b^2$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$1-2x/b+x^2/b^2$	$Fb-1/2Fx-1/2Fx^2/b$	$1/2Fx-Fx^2/b+1/2qx^3/b$	$Fb/EJ$	$1/2Fx+1/2qx^2$	FB b
GC b	$-1+x/b$	$-1/2Fx+1/2qx^2$	0	$1-2x/b+x^2/b^2$	0	$1-2x/b+x^2/b^2$	0	$1/2Fx-Fx^2/b+1/2qx^3/b$	$1/2Fx^2/b-1/2qx^3/b$	0	$-1/2Fx+1/2qx^2$	GC b
CG b	$x/b$	$1/2Fx-1/2qx^2$	0	$x^2/b^2$	0	$x^2/b^2$	0	$1/2Fx^2/b-1/2qx^3/b$	$1/2Fx^2/b-1/2qx^3/b$	0	$1/2Fx-1/2qx^2$	CG b
FG 2b	-1	0	0	1	0	1	0	0	0	0	0	FG 2b
GF 2b	1	0	0	1	0	1	0	0	0	0	0	GF 2b
CB 2b	0	$1/2Fb-1/2qx^2$	0	0	0	0	0	0	0	0	0	CB 2b
BC 2b	0	$3/2Fb-2Fx+1/2qx^2$	0	0	0	0	0	0	0	0	0	BC 2b
											totali	
											$9/8Fb^2/EJ$	$8/3Xb/EJ$
											$-27/64Fb$	

$M_x$  flessione da iperstatica  $X=1$



$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (3/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

$$= [3/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (3/4 b - 1/6 b) Fb 1/EJ + (1/2 b) \theta = 13/12 Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - 1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [x - 1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

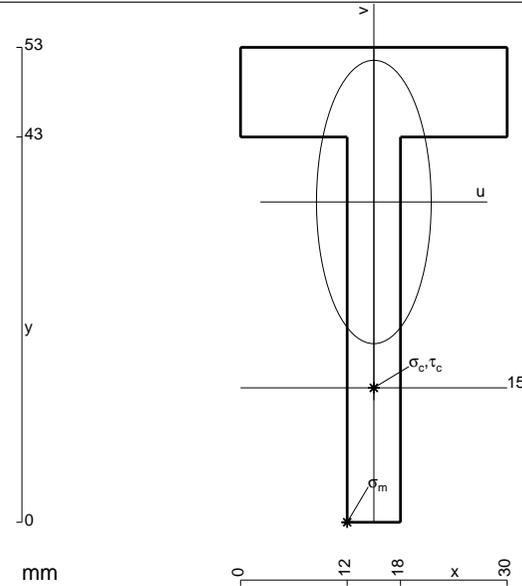
$$= (b - 1/4 b - 1/6 b) Fb 1/EJ + (-b + 1/2 b) \theta = 13/12 Fb^2/EJ$$

$$L_{GC}^{x_0} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{CG}^{x_0} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$



$$A = 558. \text{ mm}^2$$

$$J_u = 139662. \text{ mm}^4$$

$$J_v = 23274. \text{ mm}^4$$

$$y_g = 35.75 \text{ mm}$$

$$N = -1218. \text{ N}$$

$$T_y = -2260. \text{ N}$$

$$M_x = -847500. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -35.75 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -219.1 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 15. \text{ mm}$$

$$v_c = -20.75 \text{ mm}$$

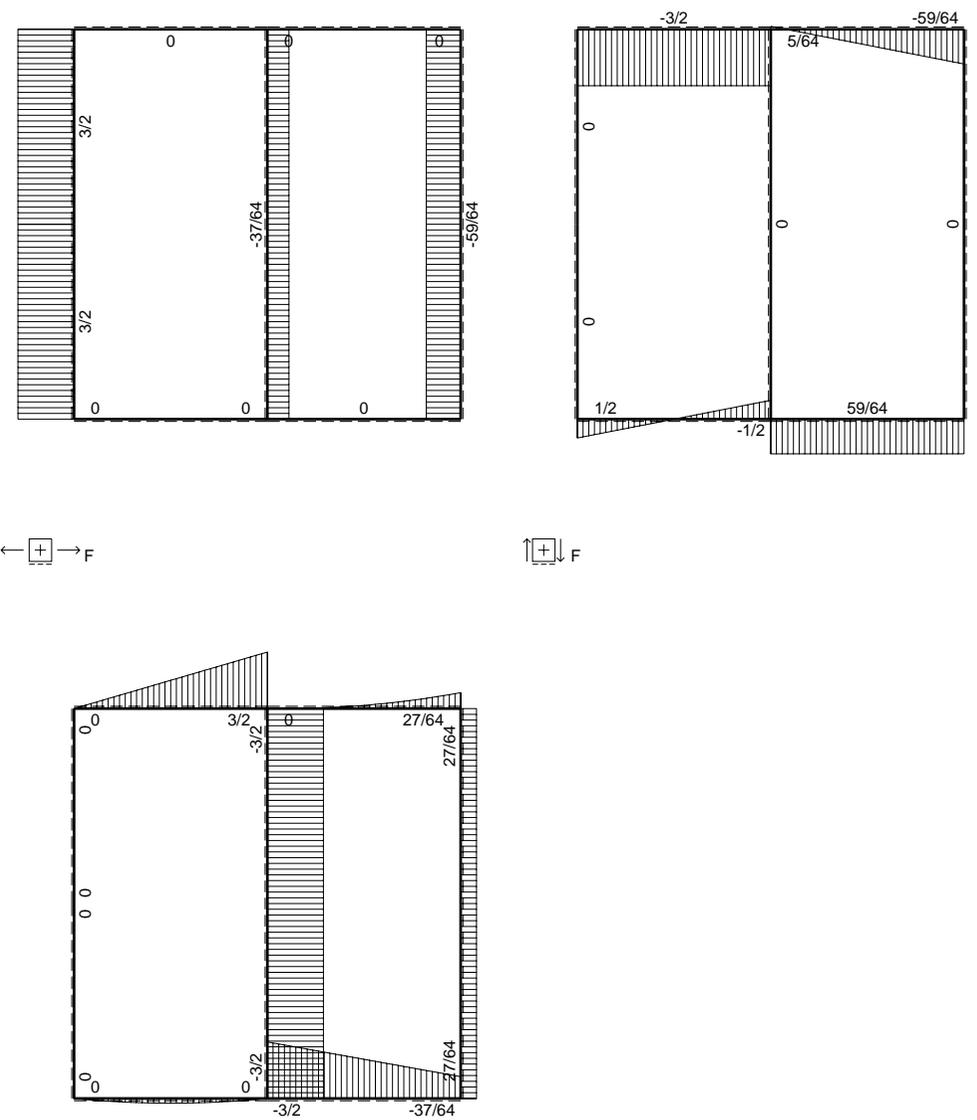
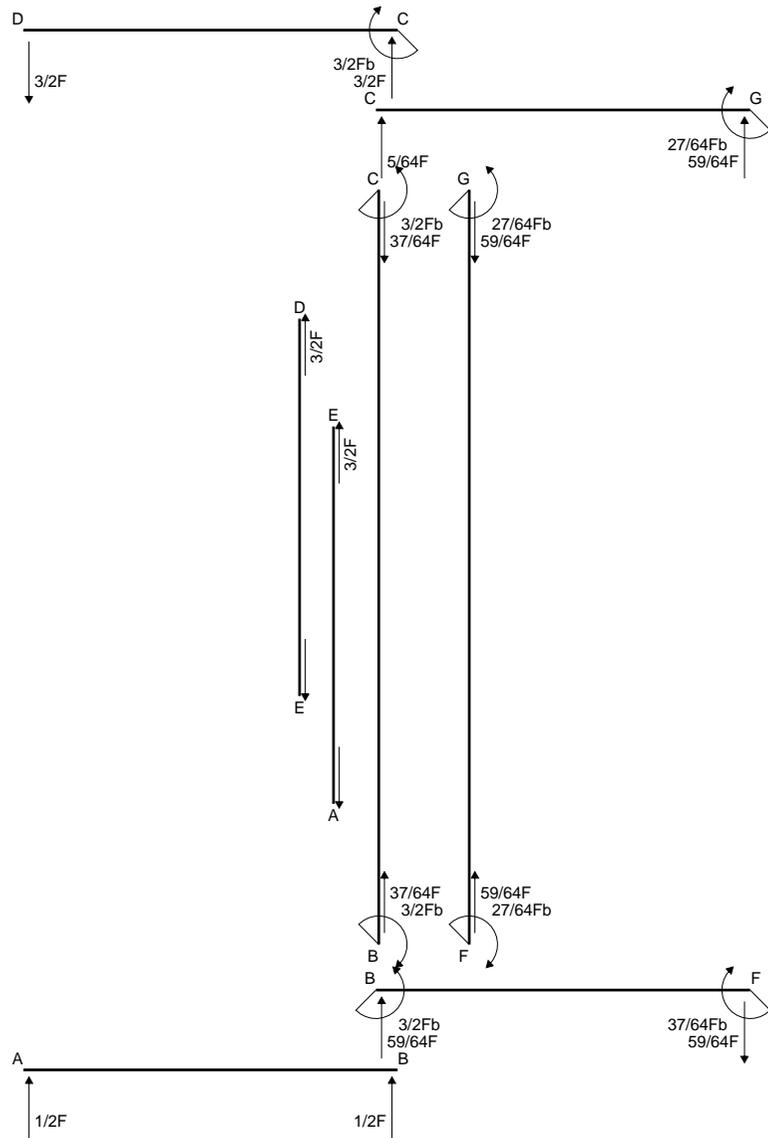
$$\sigma_c = N/A - Mv/J_u = -128.1 \text{ N/mm}^2$$

$$\tau_c = 6.856 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 128.6 \text{ N/mm}^2$$

$$S = 2542. \text{ mm}^3$$







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{xo} = \int_0^b (3/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

$$= [3/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (3/4 b - 1/6 b) Fb 1/EJ + (1/2 b) \theta = 13/12 Fb^2/EJ$$

$$L_{FB}^{xo} = \int_0^b (1 - 1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [x - 1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

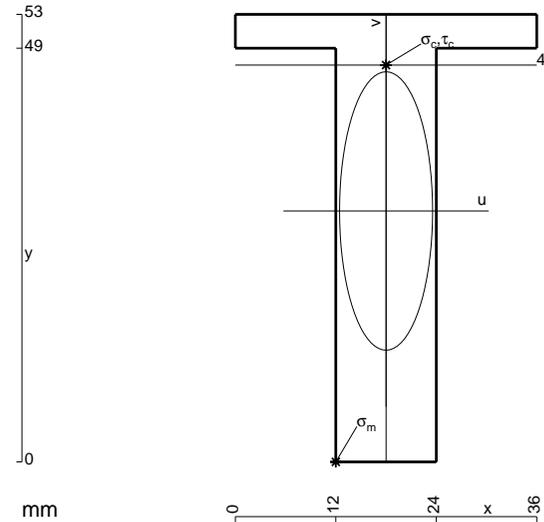
$$= (b - 1/4 b - 1/6 b) Fb 1/EJ + (-b + 1/2 b) \theta = 13/12 Fb^2/EJ$$

$$L_{GC}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

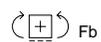
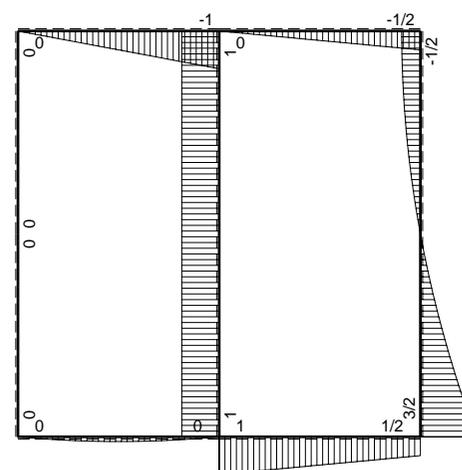
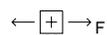
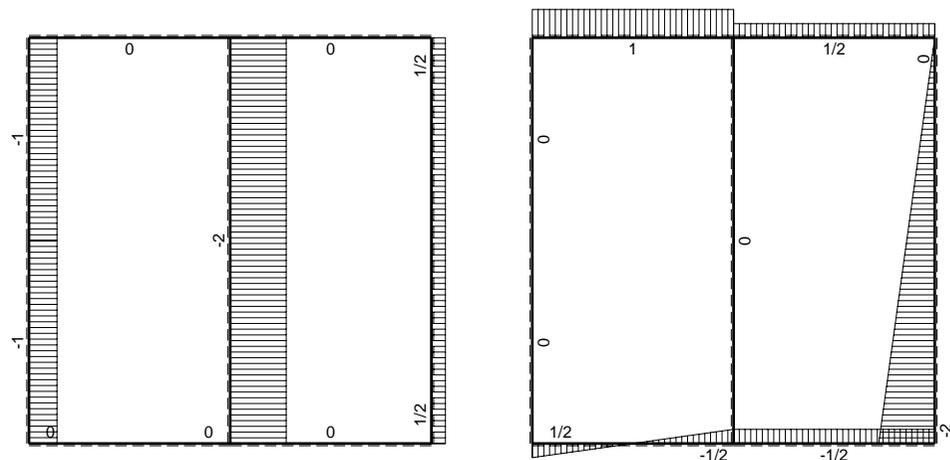
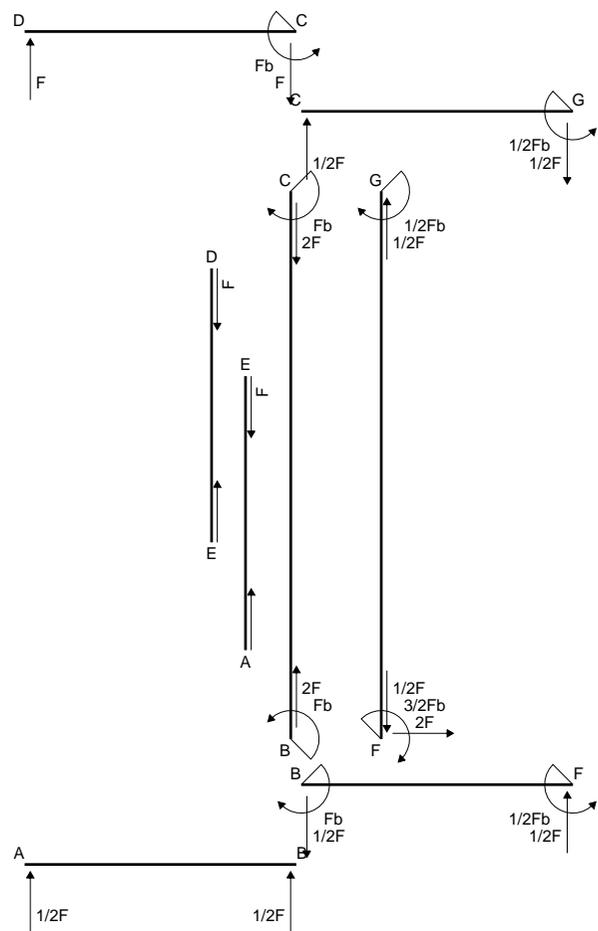
$$L_{CG}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$



$A = 732. \text{ mm}^2$   
 $J_u = 199072. \text{ mm}^4$   
 $J_v = 22608. \text{ mm}^4$   
 $y_g = 29.71 \text{ mm}$   
 $T_y = -2850. \text{ N}$   
 $M_x = 1539000. \text{ Nmm}$   
 $x_m = 12. \text{ mm}$   
 $u_m = -6. \text{ mm}$   
 $v_m = -29.71 \text{ mm}$   
 $\sigma_m = -Mv/J_u = 229.7 \text{ N/mm}^2$   
 $x_c = 18. \text{ mm}$   
 $y_c = 47. \text{ mm}$   
 $v_c = 17.29 \text{ mm}$   
 $\sigma_c = -Mv/J_u = -133.6 \text{ N/mm}^2$   
 $\tau_c = 4.181 \text{ N/mm}^2$   
 $\sigma_o = \sqrt{\sigma^2 + 3\tau^2} = 133.8 \text{ N/mm}^2$   
 $S = 3504. \text{ mm}^3$







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x\theta} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x\theta} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

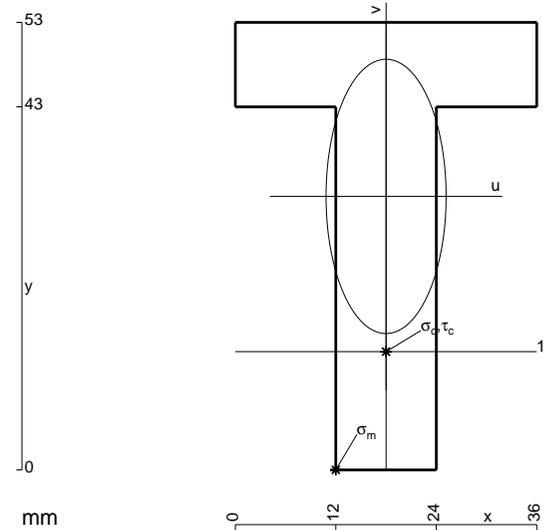
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x\theta} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

$$L_{GF}^{x\theta} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



$$A = 876. \text{ mm}^2$$

$$J_u = 231422. \text{ mm}^4$$

$$J_v = 45072. \text{ mm}^4$$

$$y_g = 32.39 \text{ mm}$$

$$T_y = 2950. \text{ N}$$

$$M_x = -1711000. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -6. \text{ mm}$$

$$v_m = -32.39 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -239.5 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 14. \text{ mm}$$

$$v_c = -18.39 \text{ mm}$$

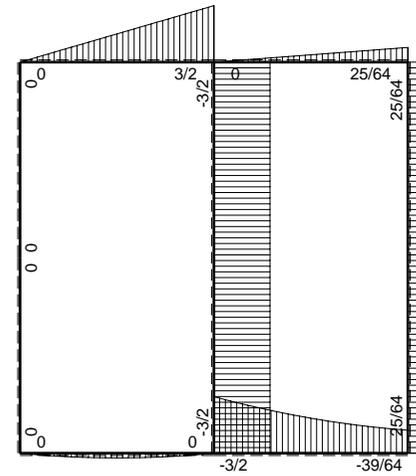
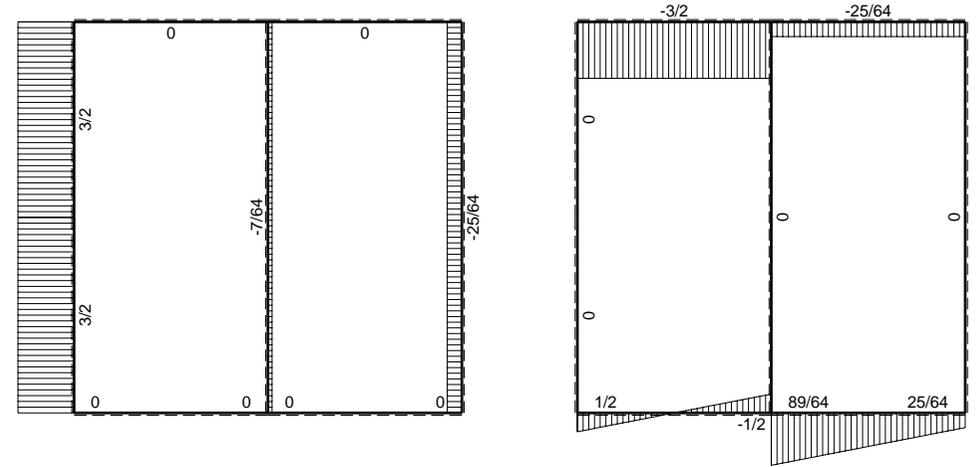
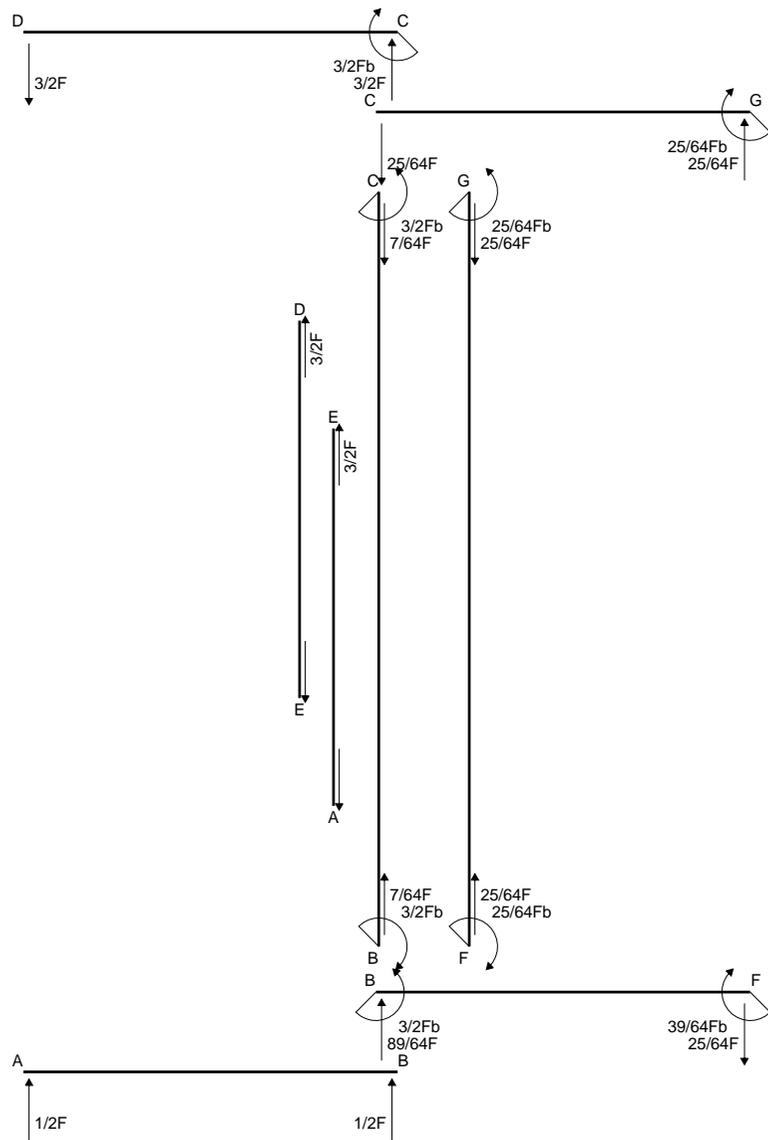
$$\sigma_c = -Mv/J_u = -136. \text{ N/mm}^2$$

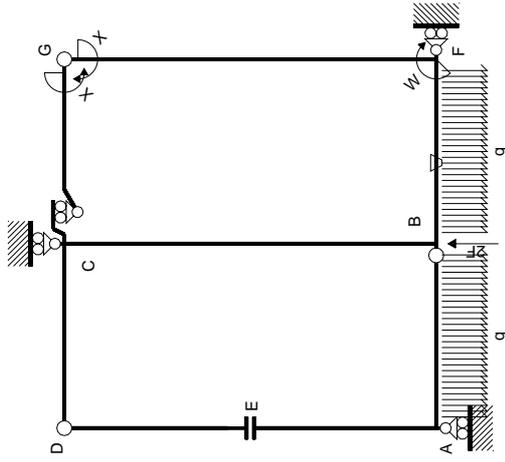
$$\tau_c = 4.531 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 136.2 \text{ N/mm}^2$$

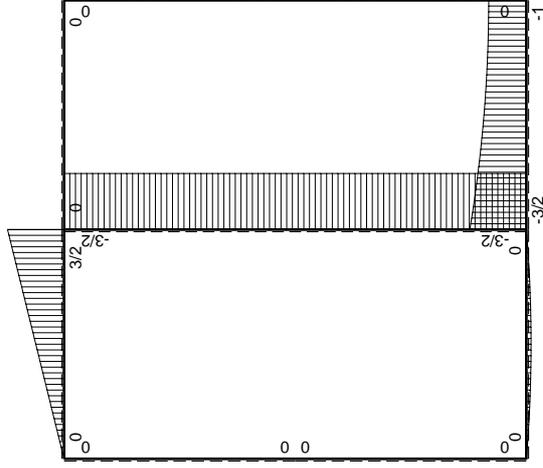
$$S = 4266. \text{ mm}^3$$



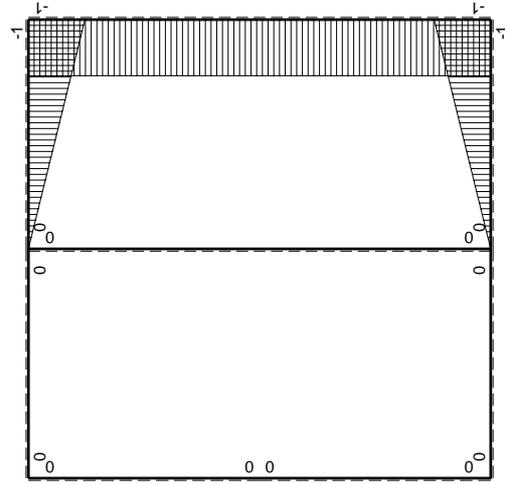




Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M_x(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	$1/2Fx-1/2qx^2$	$0$	$0$	$0$	$0$	$0$	$0+0$	$0$
BA b	$-1/2Fx+1/2qx^2$	$0$	$0$	$0$	$0$	$0$	$0+0$	$0$
CD b	$3/2Fb-3/2Fx$	$-3/2Fx$	$0$	$0$	$0$	$0$	$0+0$	$0$
DC b	$0$	$0$	$0$	$0$	$0$	$0$	$0+0$	$0$
DE b	$0$	$0$	$0$	$0$	$0$	$0$	$0+0$	$0$
ED b	$0$	$0$	$0$	$0$	$0$	$0$	$0+0$	$0$
EAB b	$0$	$0$	$0$	$0$	$0$	$0$	$0+0$	$0$
AE b	$0$	$0$	$0$	$0$	$0$	$0$	$0+0$	$0$
BF b	$-x/b$	$-3/2Fb+Fx-1/2qx^2$	$-Fb/EJ$	$3/2Fx-Fx^2/b+1/2qx^3/b$	$Fx/EJ$	$x^2/b^2$	$(13/24+1/2)Fb^2/EJ$	$1/3Xb/EJ$
FBB b	$1-x/b$	$Fb+1/2qx^2$	$Fb/EJ$	$Fb-Fx+1/2Fx^2/b-1/2qx^3/b$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$1/3Xb/EJ$	$1/3Xb/EJ$
GCB b	$-1+x/b$	$0$	$0$	$0$	$0$	$x^2/b^2$	$0+0$	$1/3Xb/EJ$
CG b	$x/b$	$0$	$0$	$0$	$0$	$1-2x/b+x^2/b^2$	$0+0$	$1/3Xb/EJ$
FG 2b	$-1$	$0$	$0$	$0$	$0$	$1$	$0+0$	$2Xb/EJ$
GF 2b	$1$	$0$	$0$	$0$	$0$	$1$	$0+0$	$2Xb/EJ$
CB 2b	$0$	$-3/2Fb$	$0$	$0$	$0$	$0$	$0+0$	$0$
BC 2b	$0$	$3/2Fb$	$0$	$0$	$0$	$0$	$0+0$	$0$
totali								
iperstatica $X=W_{gc}$								
							$25/24Fb^2/EJ$	$8/3Xb/EJ$
								$-25/64Fb$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x\theta} = \int_0^b (3/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

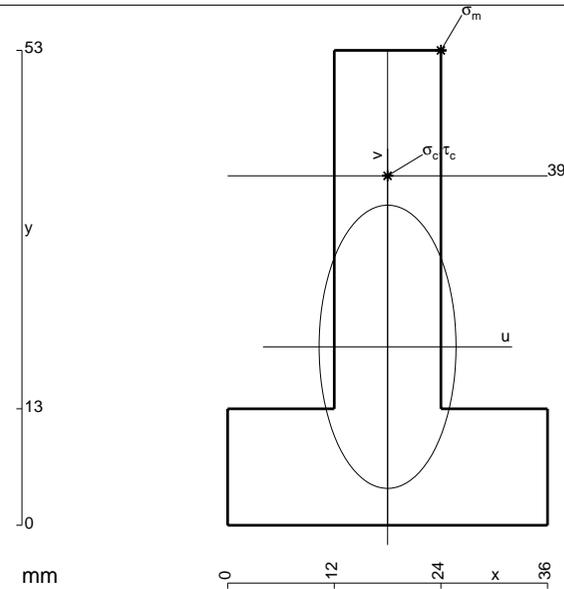
$$= [3/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (3/4 b - 1/3 b + 1/8 b) Fb 1/EJ + (1/2 b) \theta = 25/24 Fb^2/EJ$$

$$L_{FB}^{x\theta} = \int_0^b (1 - x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [x - 1/2 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b + 1/6 b - 1/8 b) Fb 1/EJ + (-b + 1/2 b) \theta = 25/24 Fb^2/EJ$$



$$A = 948. \text{ mm}^2$$

$$J_u = 236998. \text{ mm}^4$$

$$J_v = 56304. \text{ mm}^4$$

$$y_g = 19.92 \text{ mm}$$

$$T_y = -2265. \text{ N}$$

$$M_x = 1426950. \text{ Nmm}$$

$$x_m = 24. \text{ mm}$$

$$y_m = 53. \text{ mm}$$

$$u_m = 6. \text{ mm}$$

$$v_m = 33.08 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -199.2 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 39. \text{ mm}$$

$$v_c = 19.08 \text{ mm}$$

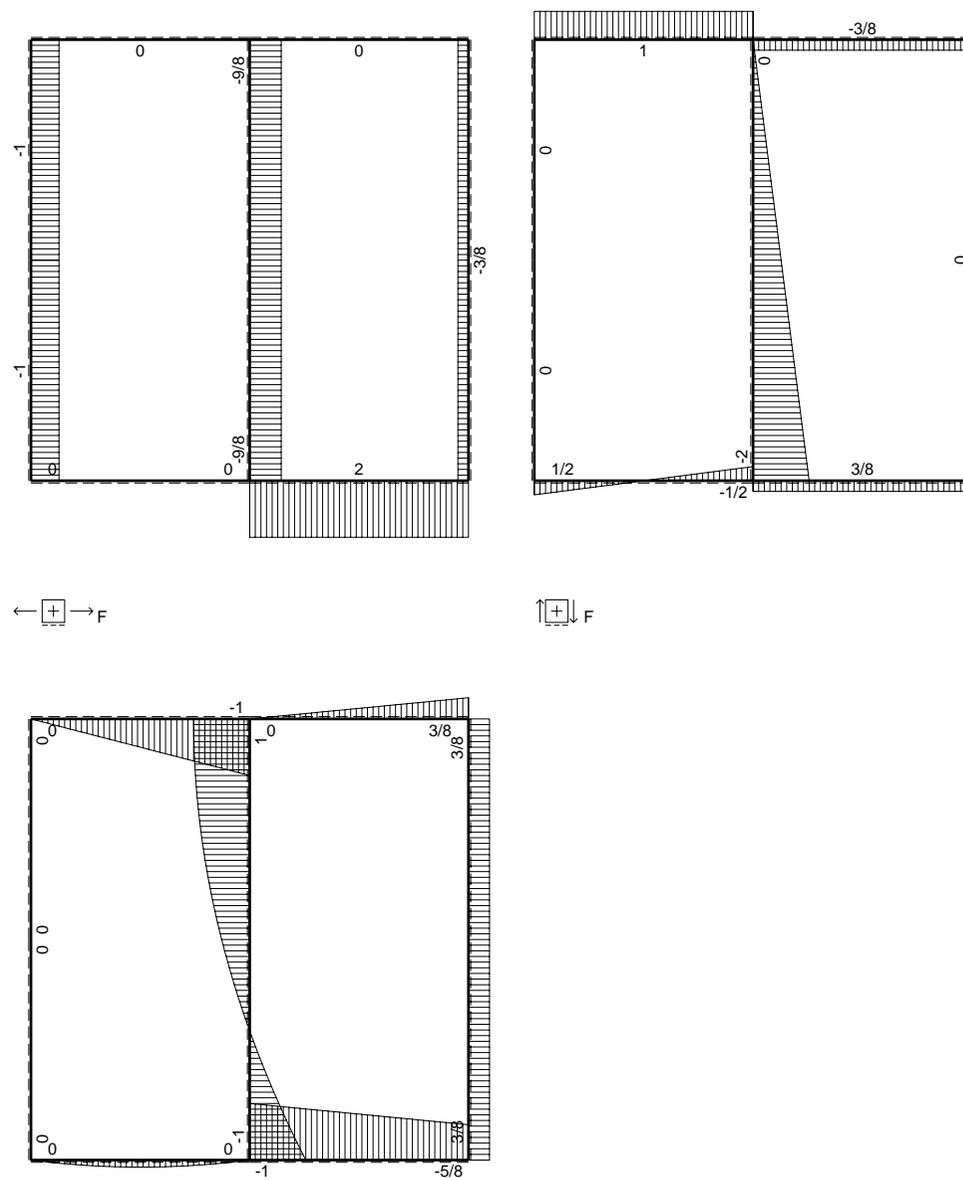
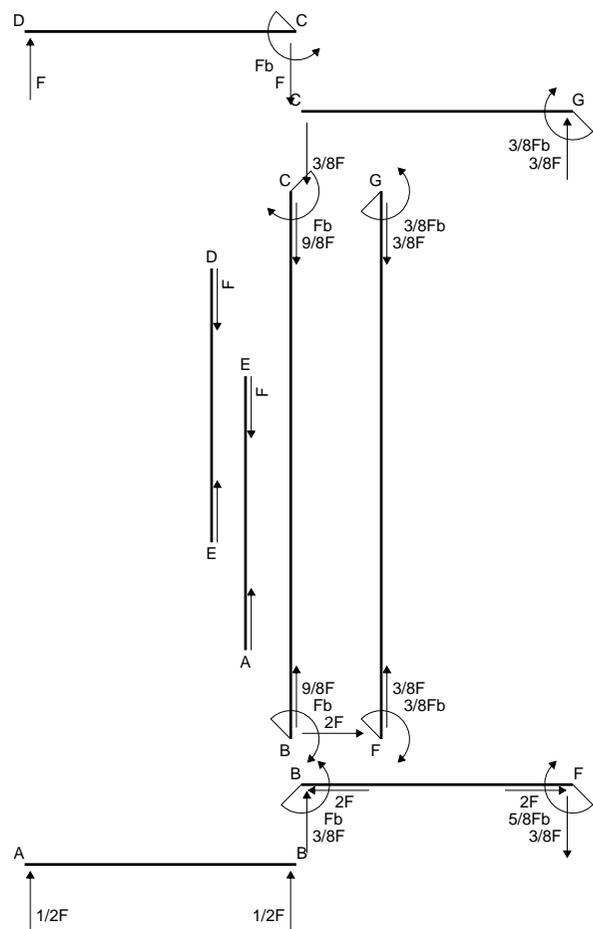
$$\sigma_c = -Mv/J_u = -114.9 \text{ N/mm}^2$$

$$\tau_c = 3.49 \text{ N/mm}^2$$

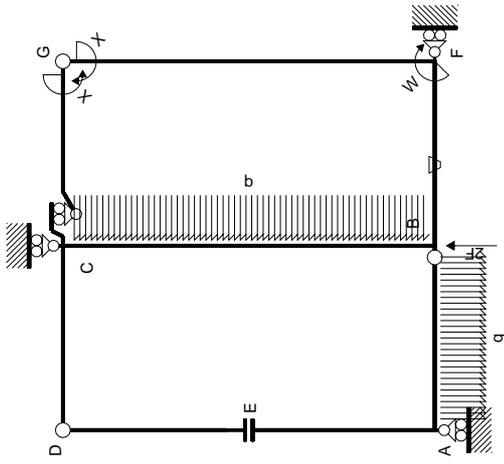
$$\sigma_\varrho = \sqrt{\sigma^2 + 3\tau^2} = 115.1 \text{ N/mm}^2$$

$$S = 4382. \text{ mm}^3$$



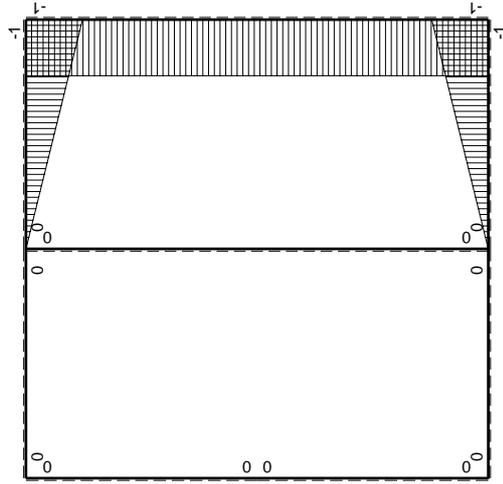


$\oplus$   $F_b$



Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\leftarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / EJ dx$
AB b	0	$1/2Fx - 1/2qx^2$	0	0	0	0	0+0	0
BA b	0	$-1/2Fx + 1/2qx^2$	0	0	0	0	0+0	0
CD b	0	$-Fb + Fx$	0	0	0	0	0+0	0
DC b	0	$Fx$	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
ED b	0	0	0	0	0	0	0+0	0
EA b	0	0	0	0	0	0	0+0	0
AE b	0	0	0	0	0	0	0+0	0
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb-Fx$	$Fb/EJ - Fx/EJ$	$1-2x/b+x^2/b^2$	$1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2xb/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2xb/EJ$
CB 2b	0	$Fb - 1/2qx^2$	0	0	0	0	0+0	0
BC 2b	0	$Fb - 2Fx + 1/2qx^2$	0	0	0	0	0+0	0
totali								$Fb^2/EJ$
								$8/3xb/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

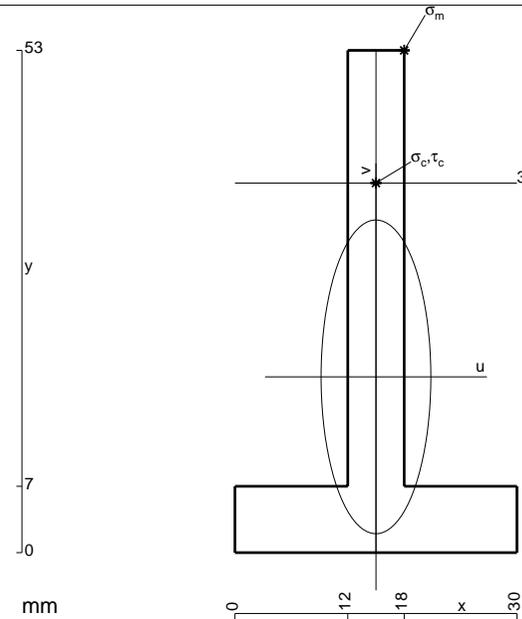
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



$$A = 486. \text{ mm}^2$$

$$J_u = 133275. \text{ mm}^4$$

$$J_v = 16578. \text{ mm}^4$$

$$y_g = 18.55 \text{ mm}$$

$$N = -1373. \text{ N}$$

$$T_y = -2440. \text{ N}$$

$$M_x = -817400. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$y_m = 53. \text{ mm}$$

$$u_m = 3. \text{ mm}$$

$$v_m = 34.45 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 208.5 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 39. \text{ mm}$$

$$v_c = 20.45 \text{ mm}$$

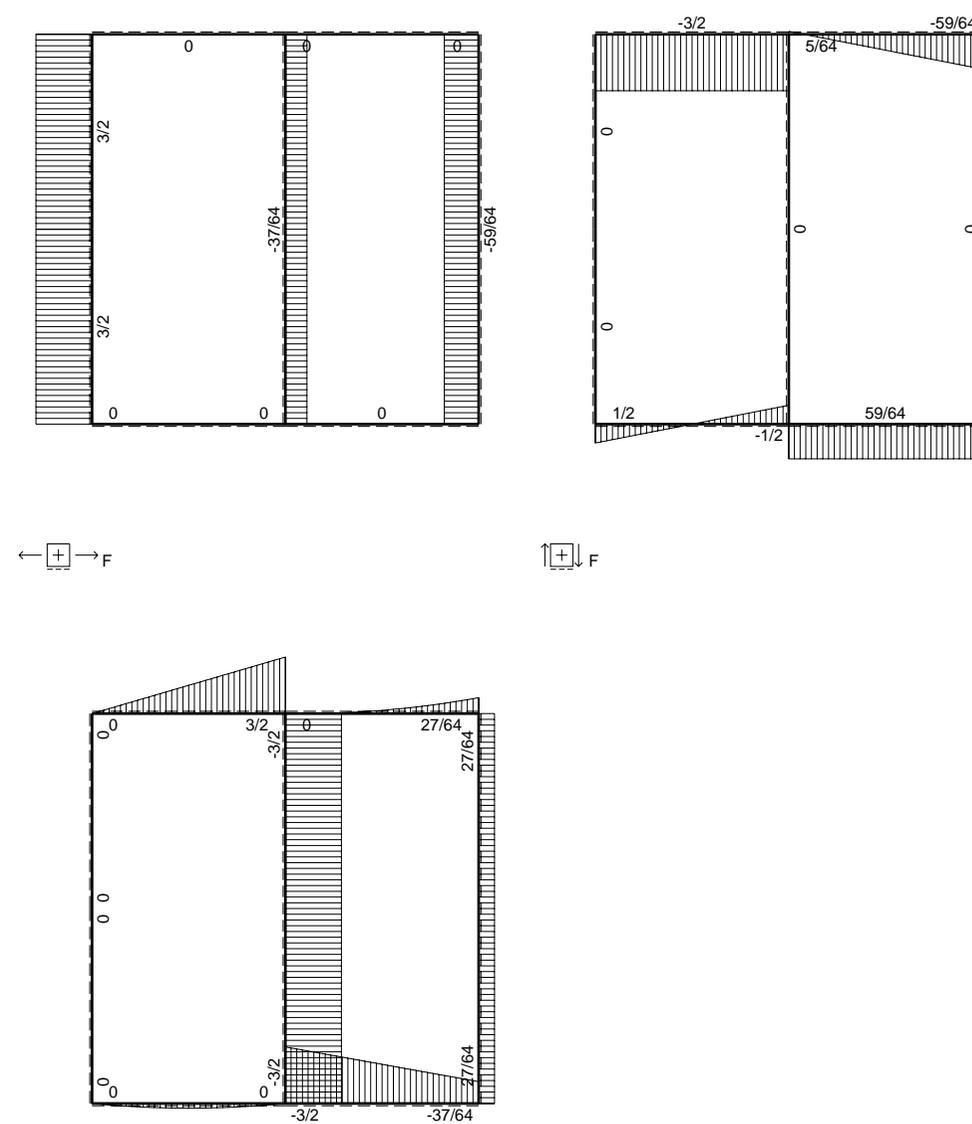
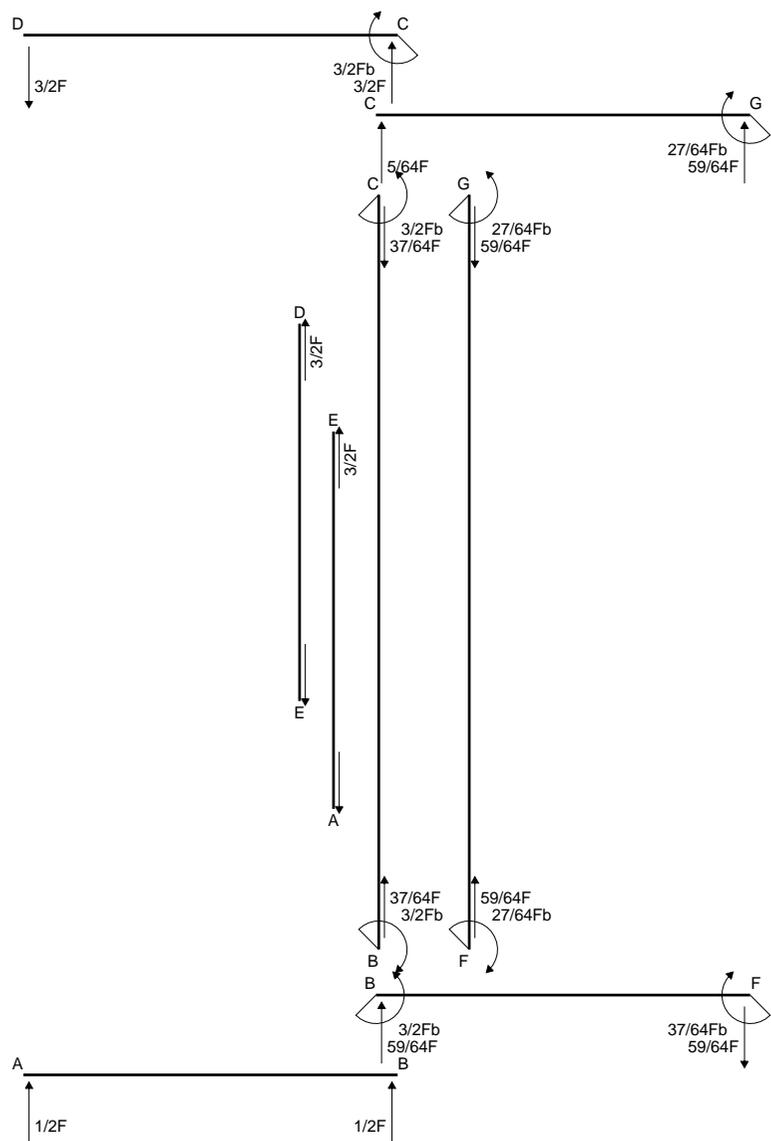
$$\sigma_c = N/A - Mv/J_u = 122.6 \text{ N/mm}^2$$

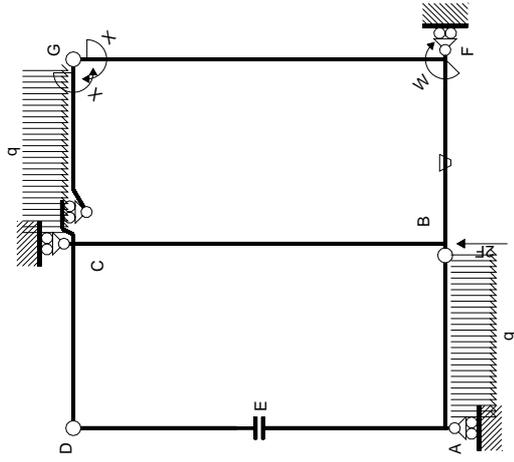
$$\tau_c = 7.036 \text{ N/mm}^2$$

$$\sigma_\varrho = \sqrt{\sigma^2 + 3\tau^2} = 123.2 \text{ N/mm}^2$$

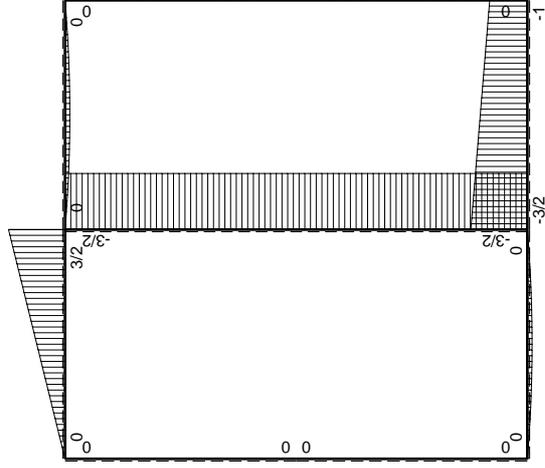
$$S = 2306. \text{ mm}^3$$



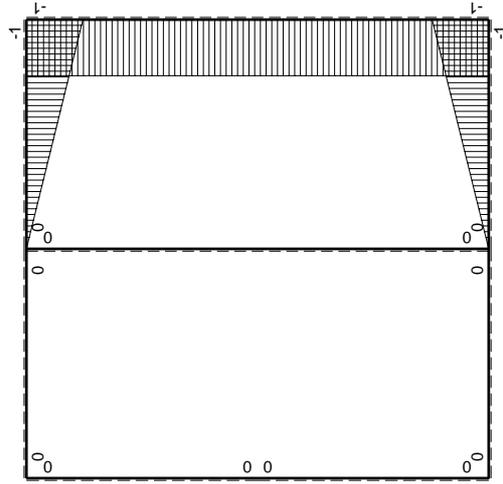




Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica X=W<sub>gc</sub>

←	M <sub>0</sub> (x)	θ	M <sub>0</sub>	M <sub>0</sub> θ	M <sub>0</sub> x	$\int M_0(M_0/EJ+\theta)dx$	$\int M_0 M_x/EJ dx$
AB B	0	0	0	0	0	0	0
BA B	0	0	0	0	0	0	0
CD B	0	0	0	0	0	0	0
DC B	0	0	0	0	0	0	0
DE B	0	0	0	0	0	0	0
ED B	0	0	0	0	0	0	0
EA B	0	0	0	0	0	0	0
AE B	0	0	0	0	0	0	0
BF B	-x/b	-3/2Fb+1/2Fx	-Fb/EJ	3/2Fx-1/2Fx <sup>2</sup> /b	Fx/EJ	x <sup>2</sup> /b <sup>2</sup>	(7/12+1/2)Fb <sup>2</sup> /EJ
FB B	1-x/b	Fb+1/2Fx	Fb/EJ	Fb-1/2Fx-1/2Fx <sup>2</sup> /b	Fb/EJ-Fx/EJ	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	(1/24+0)Fb <sup>2</sup> /EJ
GC B	-1+x/b	-1/2Fx+1/2qx <sup>2</sup>	0	1/2Fx-Fx <sup>2</sup> /b+1/2qx <sup>3</sup> /b	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	1/3xb/EJ
CG B	x/b	1/2Fx-1/2qx <sup>2</sup>	0	1/2Fx <sup>2</sup> /b-1/2qx <sup>3</sup> /b	0	x <sup>2</sup> /b <sup>2</sup>	1/3xb/EJ
FG 2b	-1	0	0	0	0	1	2xb/EJ
GF 2b	1	0	0	0	0	1	2xb/EJ
CB 2b	0	-3/2Fb	0	0	0	0	0
BC 2b	0	3/2Fb	0	0	0	0	0
totali							9/8Fb <sup>2</sup> /EJ
							-27/64Fb

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{xo} = \int_0^b (3/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

$$= [3/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (3/4 b - 1/6 b) Fb 1/EJ + (1/2 b) \theta = 13/12 Fb^2/EJ$$

$$L_{FB}^{xo} = \int_0^b (1 - 1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [x - 1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

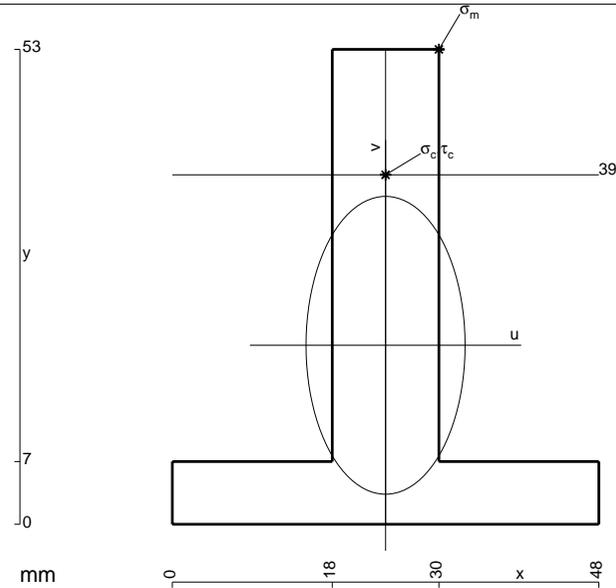
$$= (b - 1/4 b - 1/6 b) Fb 1/EJ + (-b + 1/2 b) \theta = 13/12 Fb^2/EJ$$

$$L_{GC}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

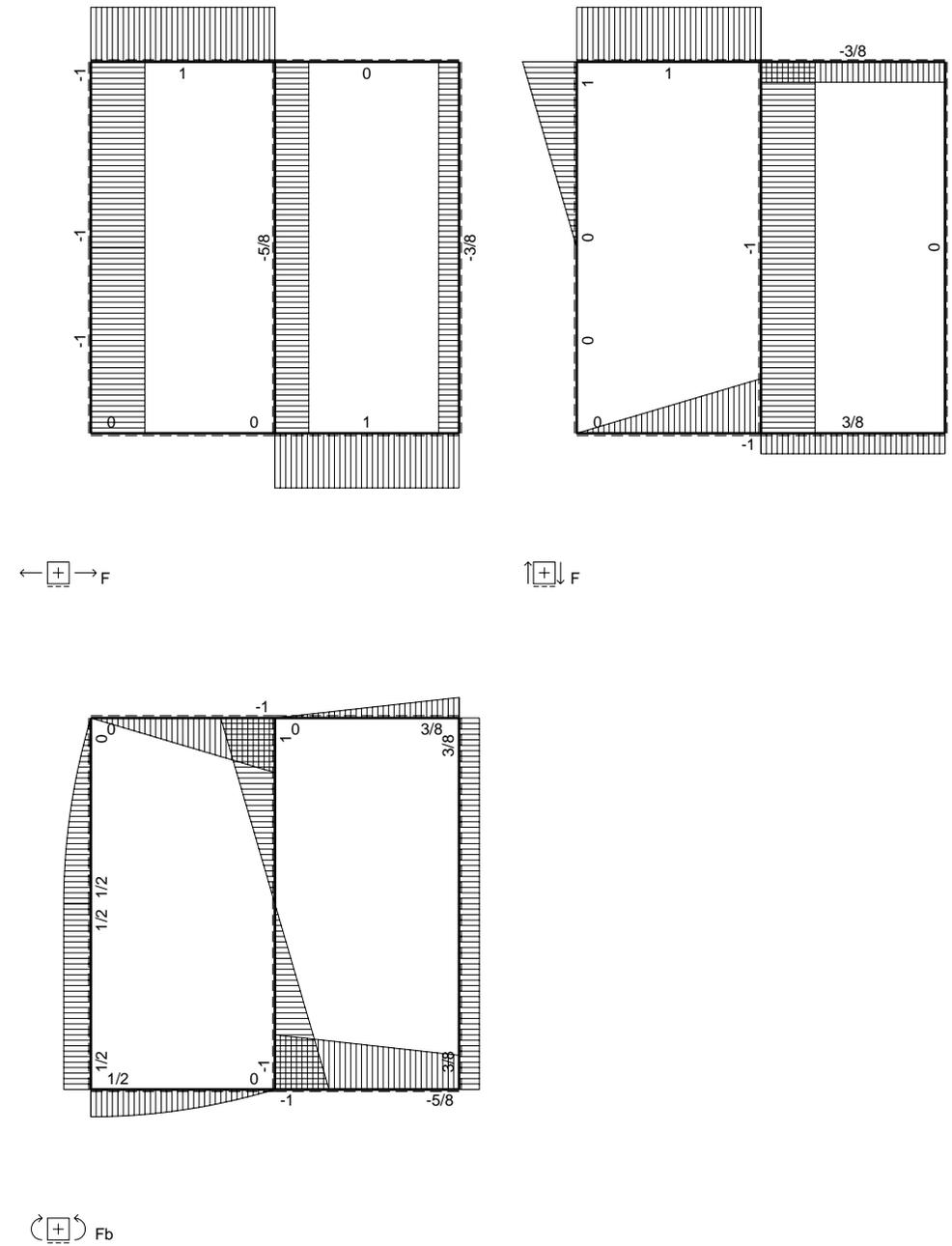
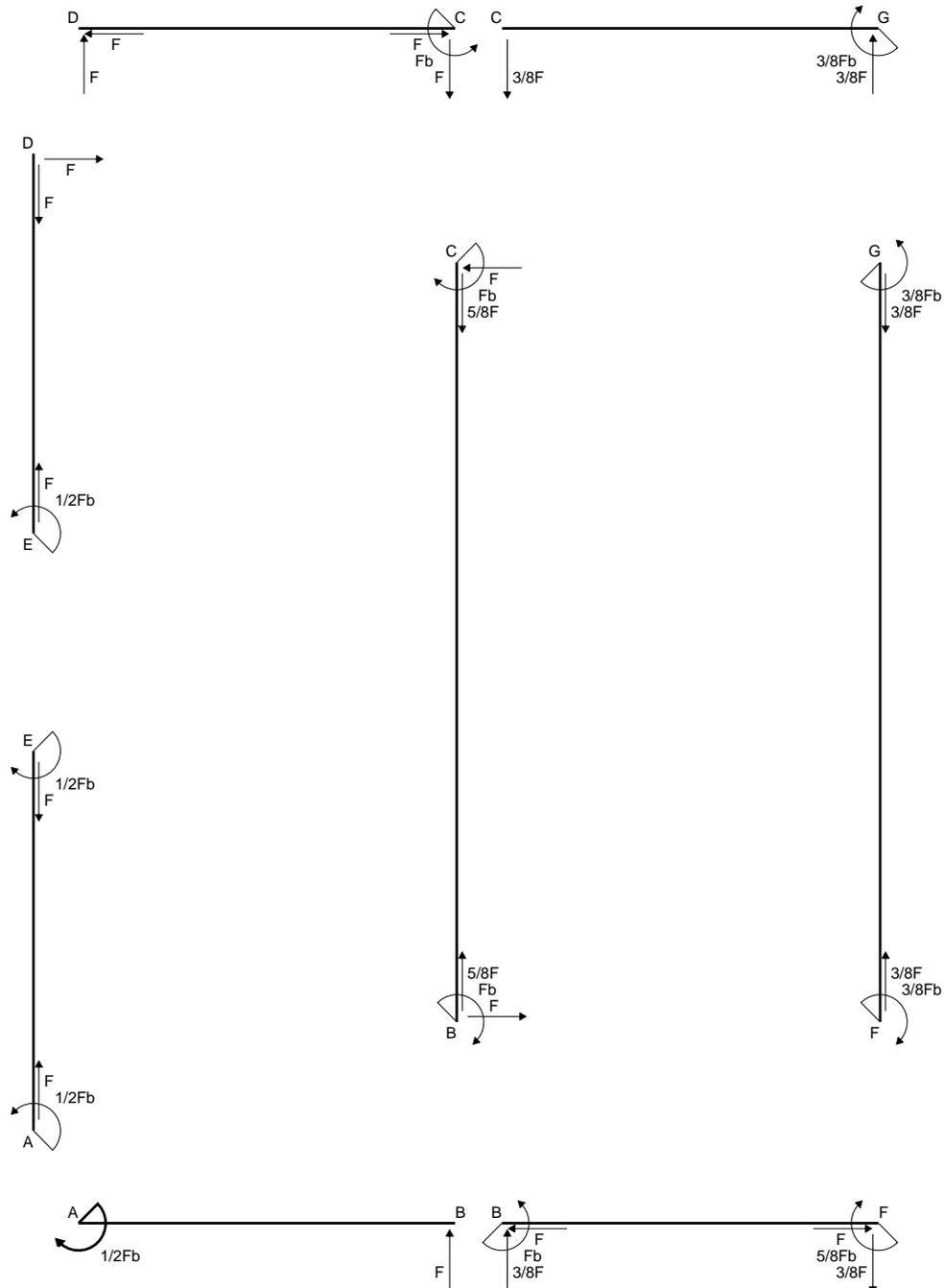
$$L_{CG}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

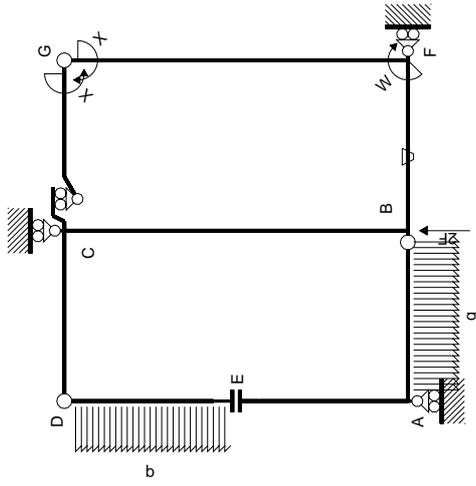
$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$



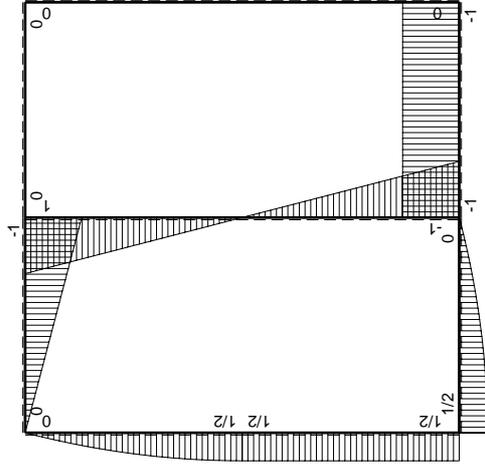
- A = 888. mm<sup>2</sup>
- J<sub>u</sub> = 245383. mm<sup>4</sup>
- J<sub>v</sub> = 71136. mm<sup>4</sup>
- y<sub>g</sub> = 19.97 mm
- T<sub>y</sub> = -2295. N
- M<sub>x</sub> = 1629450. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 53. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 33.03 mm
- σ<sub>m</sub> = -M<sub>v</sub>/J<sub>u</sub> = -219.3 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 39. mm
- v<sub>c</sub> = 19.03 mm
- σ<sub>c</sub> = -M<sub>v</sub>/J<sub>u</sub> = -126.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.408 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 126.5 N/mm<sup>2</sup>
- S = 4373. mm<sup>3</sup>



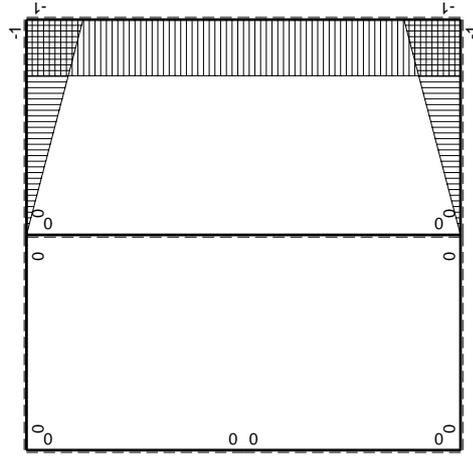




Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	$1/2Fb-1/2qx^2$	0	0	0	0	0	0+0	0
BA b	$-Fx+1/2qx^2$	0	0	0	0	0	0+0	0
CD b	$-Fb+Fx$	0	0	0	0	0	0+0	0
DC b	$Fx$	0	0	0	0	0	0+0	0
DE b	$Fx-1/2qx^2$	0	0	0	0	0	0+0	0
ED b	$-1/2Fb+1/2qx^2$	0	0	0	0	0	0+0	0
EA b	$1/2Fb$	0	0	0	0	0	0+0	0
AE b	$-1/2Fb$	0	0	0	0	0	0+0	0
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb-Fx$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$1/3xb/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2xb/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2xb/EJ$
CB 2b	0	$Fb-Fx$	0	0	0	0	0+0	0
BC 2b	0	$Fb-Fx$	0	0	0	0	0+0	0
totali								$Fb^2/EJ$
								$8/3xb/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

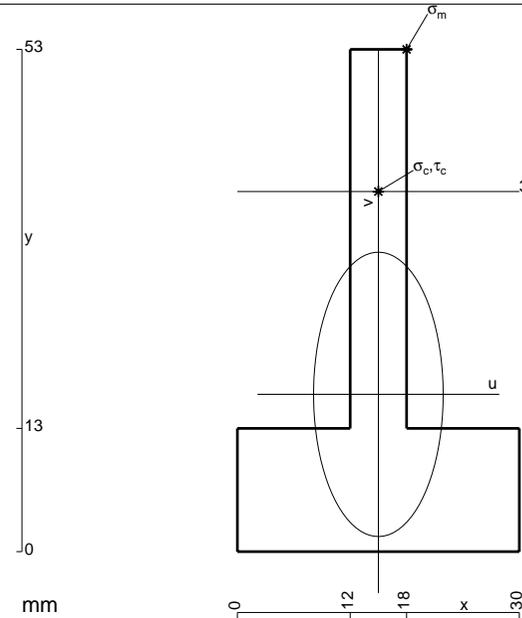
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

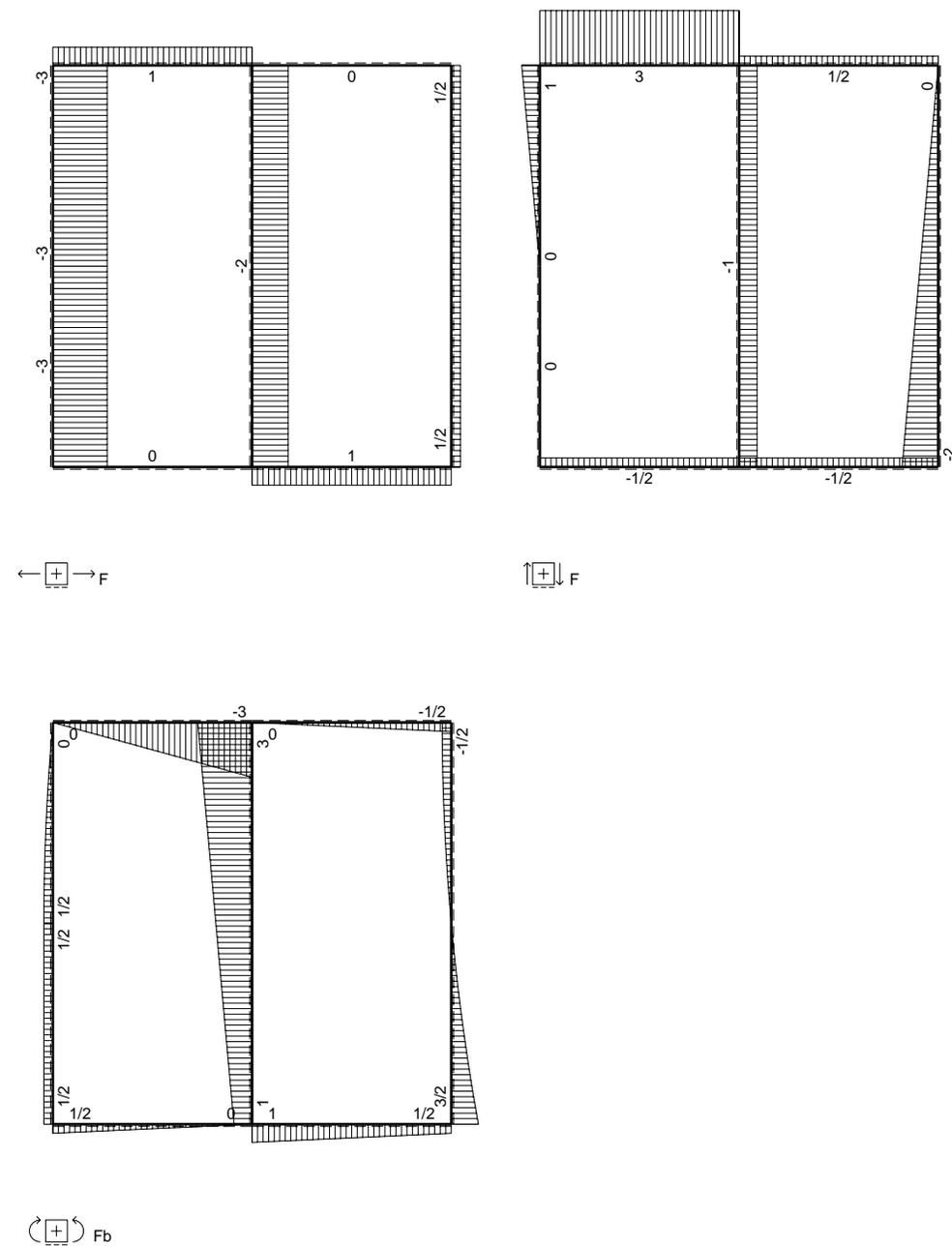
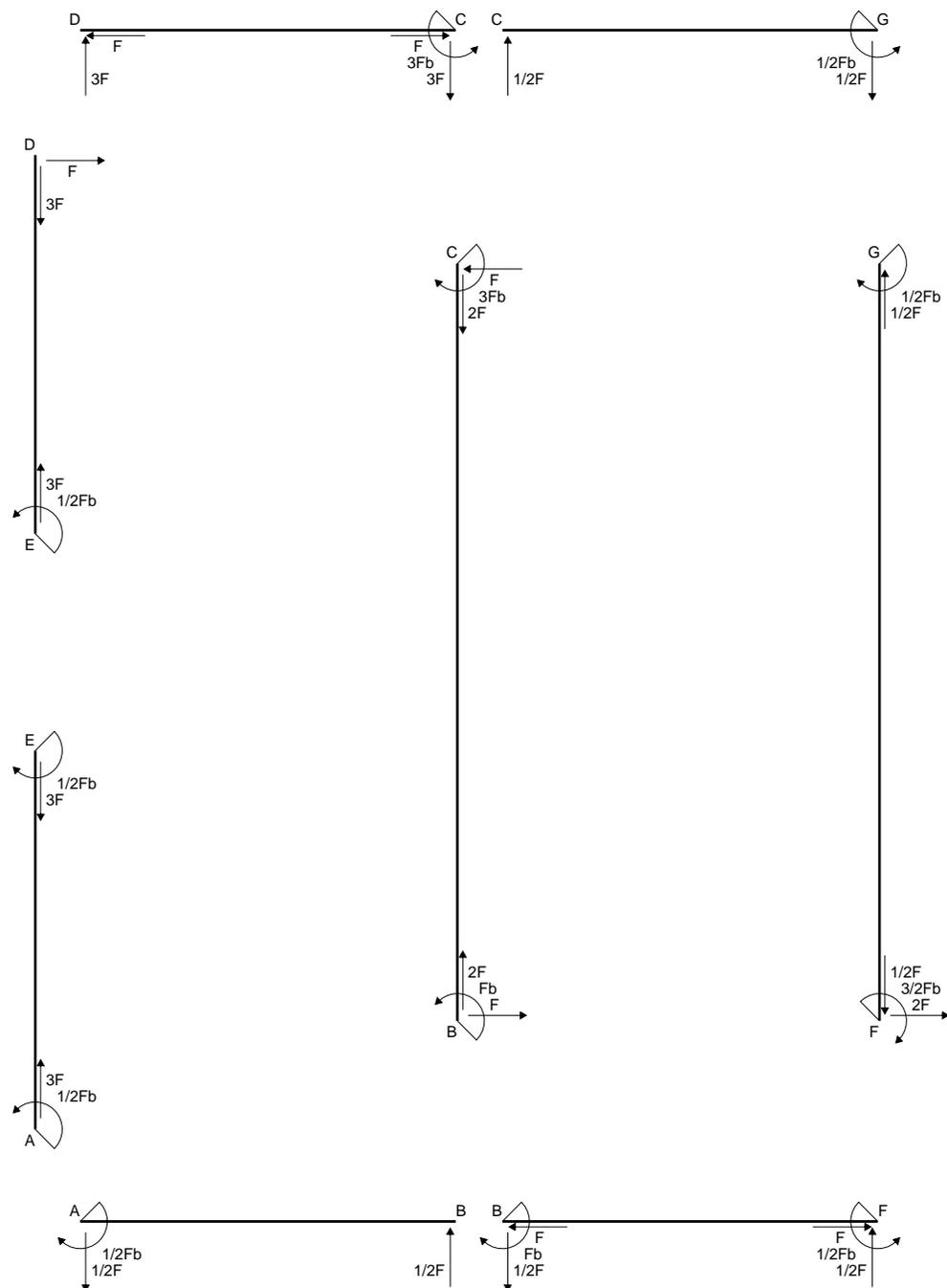
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

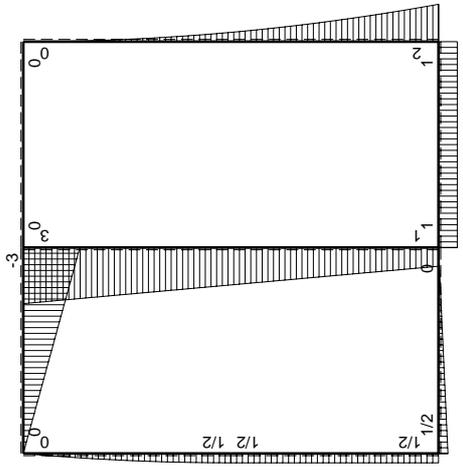
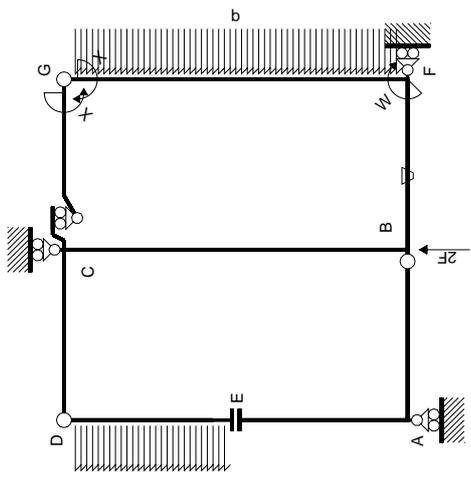
$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



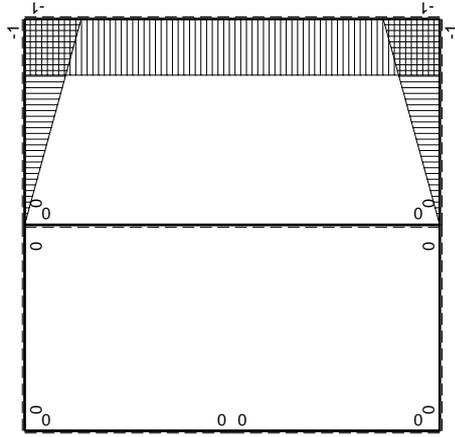
- A = 630. mm<sup>2</sup>
- J<sub>u</sub> = 141827. mm<sup>4</sup>
- J<sub>v</sub> = 29970. mm<sup>4</sup>
- y<sub>g</sub> = 16.6 mm
- N = 1180. N
- T<sub>y</sub> = 1180. N
- M<sub>x</sub> = -885000. Nmm
- x<sub>m</sub> = 18. mm
- y<sub>m</sub> = 53. mm
- u<sub>m</sub> = 3. mm
- v<sub>m</sub> = 36.4 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = 229. N/mm<sup>2</sup>
- x<sub>c</sub> = 15. mm
- y<sub>c</sub> = 38. mm
- v<sub>c</sub> = 21.4 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = 135.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.607 N/mm<sup>2</sup>
- σ<sub>0</sub> = √(σ<sup>2</sup>+3τ<sup>2</sup>) = 135.6 N/mm<sup>2</sup>
- S<sup>3</sup> = 2601. mm<sup>3</sup>







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica X=W <sub>gc</sub>		iperstatica X=W <sub>gc</sub>		totali	
←	M <sup>0</sup> (x)	M <sup>0</sup> (x)	M <sup>0</sup> (x)	M <sup>0</sup> (x)	M <sup>0</sup> (x)
AB b	0	1/2Fb-1/2Fx	0	0	0
BA b	0	-1/2Fx	0	0	0
CD b	0	-3Fb+3Fx	0	0	0
DC b	0	3Fx	0	0	0
DE b	0	Fx-1/2qx <sup>2</sup>	0	0	0
ED b	0	-1/2Fb+1/2qx <sup>2</sup>	0	0	0
EA b	0	1/2Fb	0	0	0
AE b	0	-1/2Fb	0	0	0
BF b	-x/b	Fb	-Fb/EJ	-Fx	Fx/EJ
FB b	1-x/b	-Fb	Fb/EJ	-Fb+Fx	Fb/EJ-Fx/EJ
GC b	-1+x/b	0	0	0	0
CG b	x/b	0	0	0	0
FG 2b	-1	2Fb-2Fx+1/2qx <sup>2</sup>	0	-2Fb+2Fx-1/2Fx <sup>2</sup> /b	0
GF 2b	1	-1/2qx <sup>2</sup>	0	-1/2Fx <sup>2</sup> /b	0
CB 2b	0	3Fb-Fx	0	0	0
BC 2b	0	-Fb-Fx	0	0	0
totali					
		-4/3Fb <sup>2</sup> /EJ		-4/3Fb <sup>2</sup> /EJ	
		8/3Xb/EJ		8/3Xb/EJ	

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x_0} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

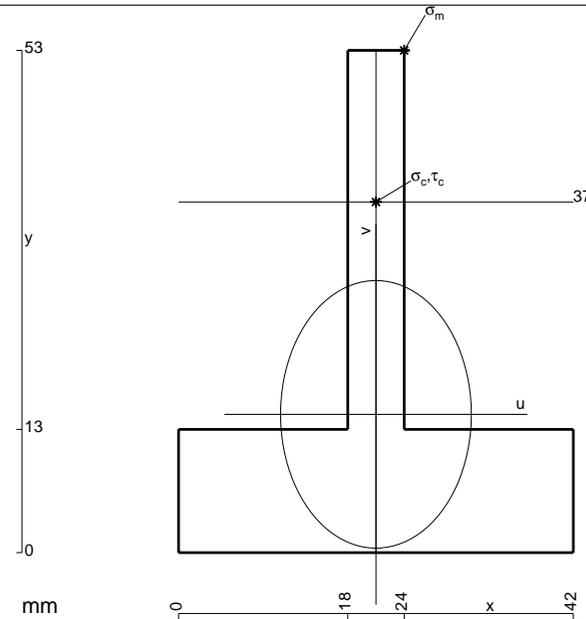
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x_0} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

$$L_{GF}^{x_0} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



$$A = 786. \text{ mm}^2$$

$$J_u = 156767. \text{ mm}^4$$

$$J_v = 80982. \text{ mm}^4$$

$$y_g = 14.59 \text{ mm}$$

$$N = 410. \text{ N}$$

$$T_y = 1230. \text{ N}$$

$$M_x = -971700. \text{ Nmm}$$

$$x_m = 24. \text{ mm}$$

$$y_m = 53. \text{ mm}$$

$$u_m = 3. \text{ mm}$$

$$v_m = 38.41 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 238.6 \text{ N/mm}^2$$

$$x_c = 21. \text{ mm}$$

$$y_c = 37. \text{ mm}$$

$$v_c = 22.41 \text{ mm}$$

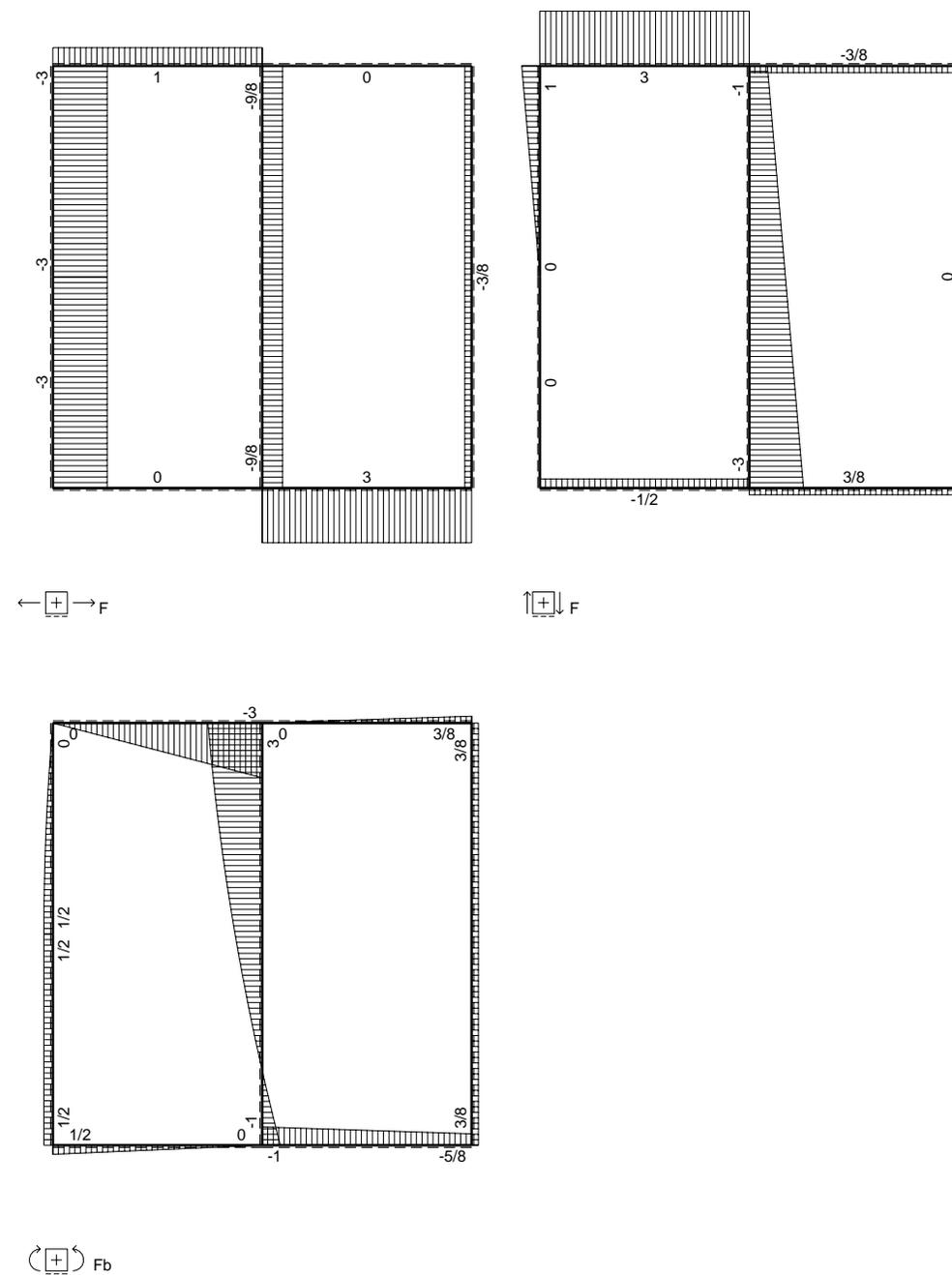
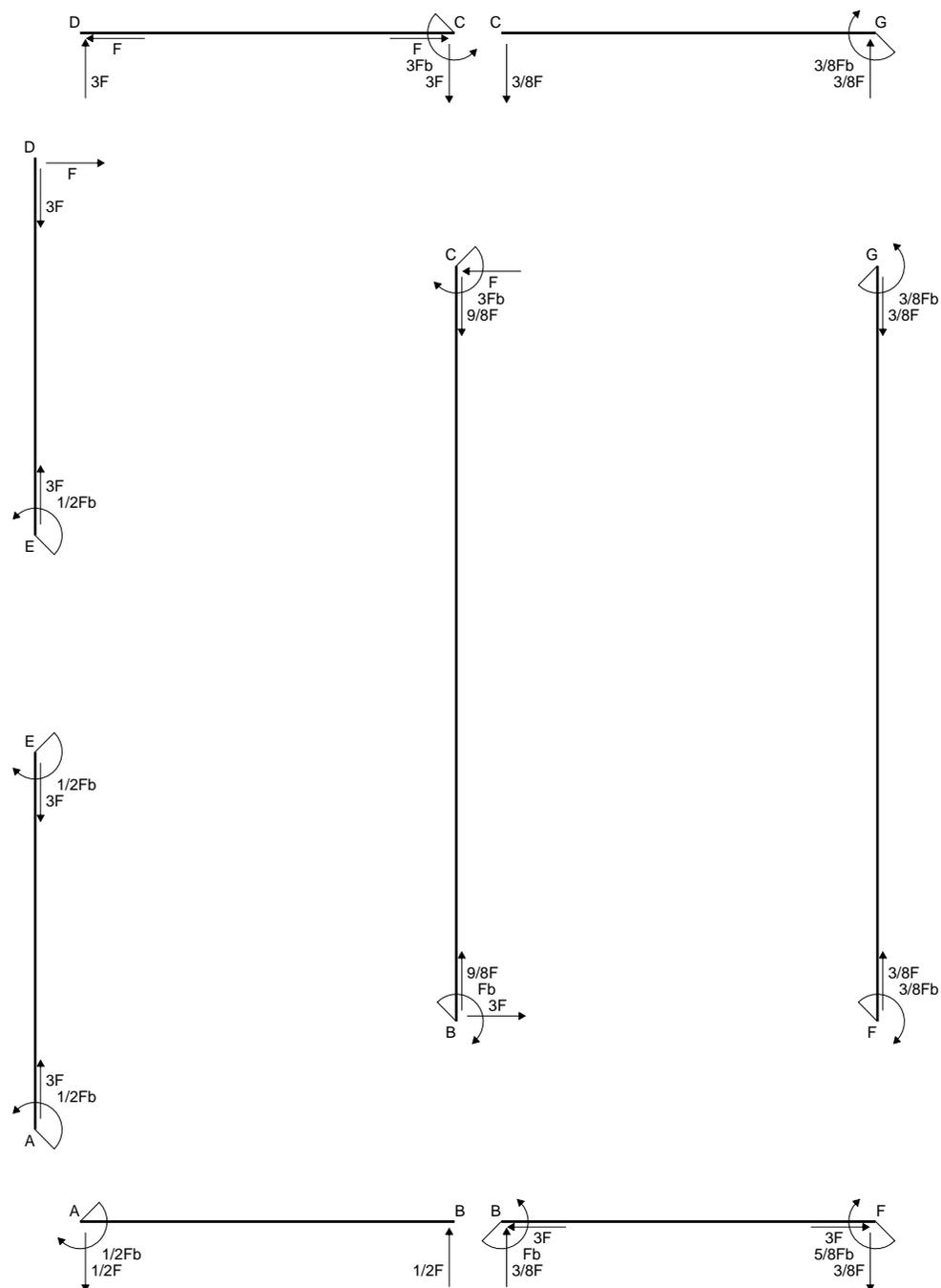
$$\sigma_c = N/A - Mv/J_u = 139.4 \text{ N/mm}^2$$

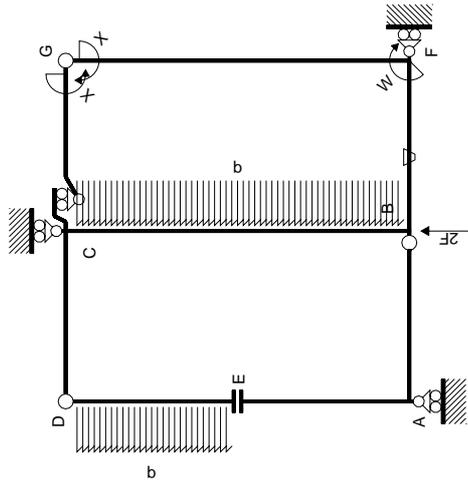
$$\tau_c = 3.817 \text{ N/mm}^2$$

$$\sigma_\varphi = \sqrt{\sigma^2 + 3\tau^2} = 139.6 \text{ N/mm}^2$$

$$S = 2919. \text{ mm}^3$$

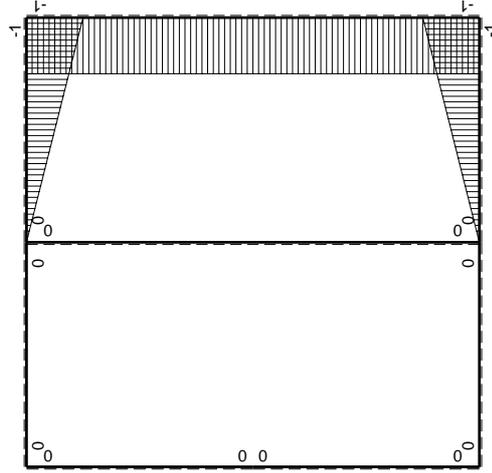
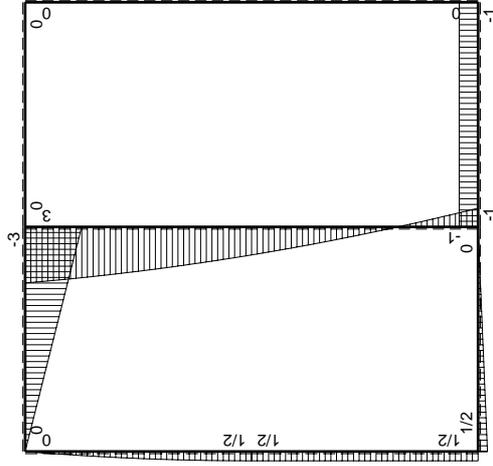






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / EJ dx$
AB b	0	$1/2Fb - 1/2Fx$	0	0	0	0	0+0	0
BA b	0	$-1/2Fx$	0	0	0	0	0+0	0
CD b	0	$-3Fb + 3Fx$	0	0	0	0	0+0	0
DC b	0	$3Fx$	0	0	0	0	0+0	0
DE b	0	$Fx - 1/2qx^2$	0	0	0	0	0+0	0
ED b	0	$-1/2Fb + 1/2qx^2$	0	0	0	0	0+0	0
EA b	0	$1/2Fb$	0	0	0	0	0+0	0
AE b	0	$-1/2Fb$	0	0	0	0	0+0	0
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2 + 1/2)Fb^2/EJ$	$1/3x^3/b^3/EJ$
FB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb - Fx$	$Fb/EJ - Fx/EJ$	$1 - 2x/b + x^2/b^2$	$1/2 + 1/2)Fb^2/EJ$	$1/3x^3/b^3/EJ$
GC b	$-1+x/b$	0	0	0	0	$-1 - 2x/b + x^2/b^2$	0+0	$1/3x^3/b^3/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3x^3/b^3/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2x^3/b^3/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2x^3/b^3/EJ$
CB 2b	0	$3Fb - Fx - 1/2qx^2$	0	0	0	0	0+0	0
BC 2b	0	$Fb - 3Fx + 1/2qx^2$	0	0	0	0	0+0	0
totali								$8/3x^3/b^3/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

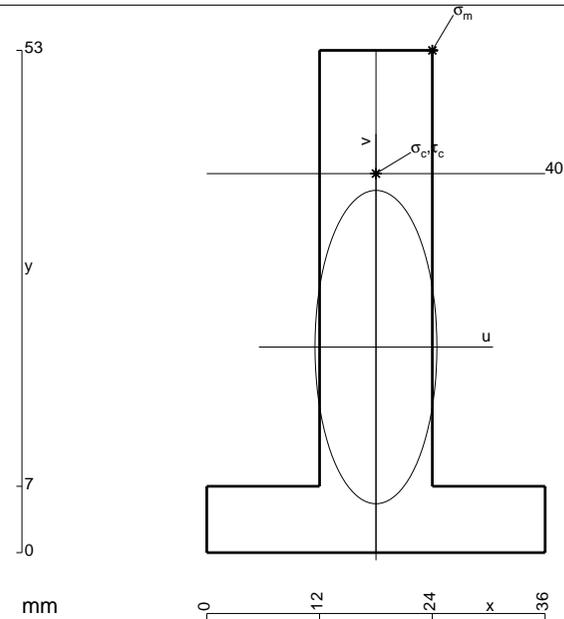
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



$$A = 804. \text{ mm}^2$$

$$J_u = 219865. \text{ mm}^4$$

$$J_v = 33840. \text{ mm}^4$$

$$y_g = 21.69 \text{ mm}$$

$$N = 1100. \text{ N}$$

$$T_y = 3300. \text{ N}$$

$$M_x = -1386000. \text{ Nmm}$$

$$x_m = 24. \text{ mm}$$

$$y_m = 53. \text{ mm}$$

$$u_m = 6. \text{ mm}$$

$$v_m = 31.31 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 198.7 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 40. \text{ mm}$$

$$v_c = 18.31 \text{ mm}$$

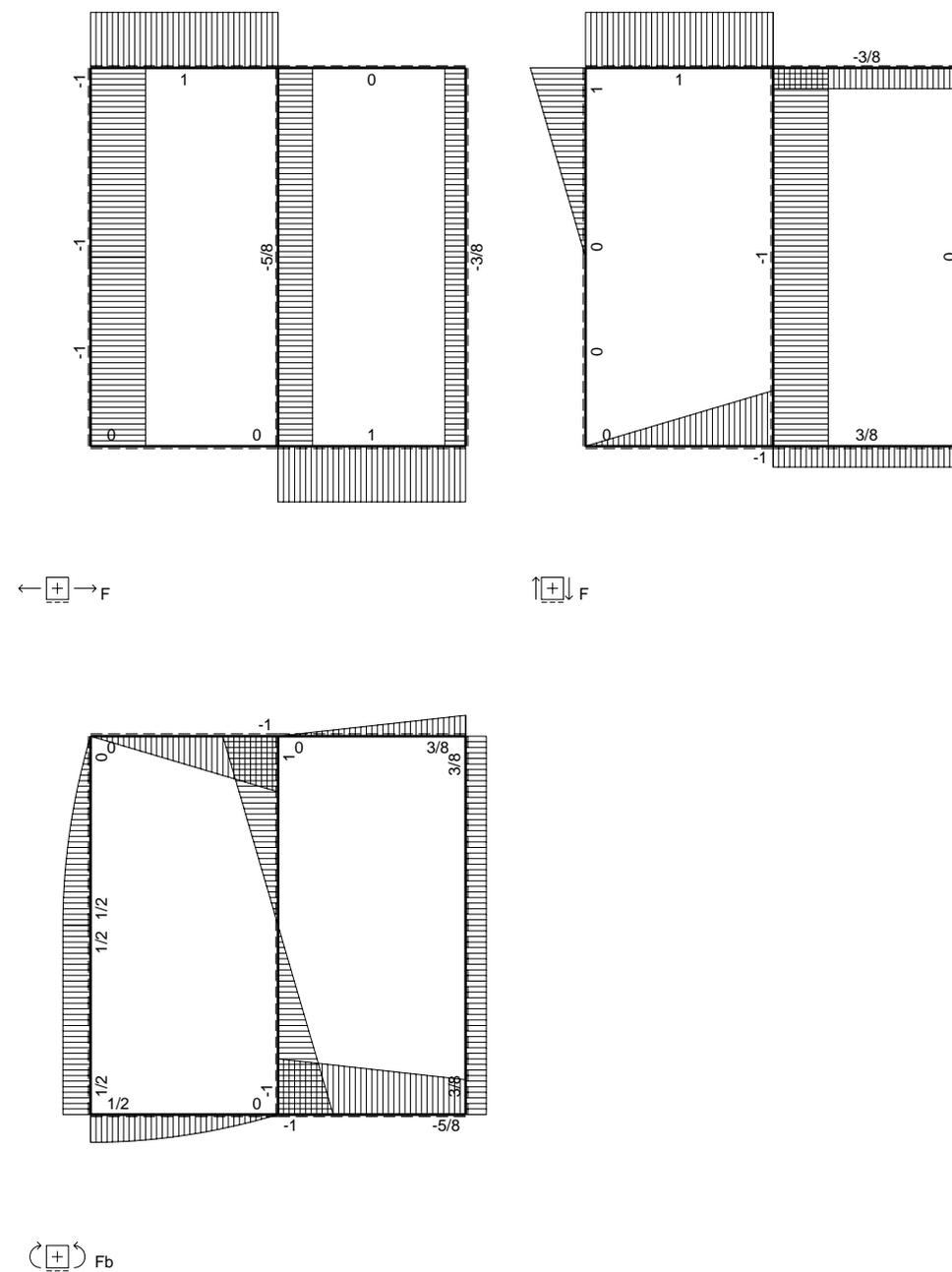
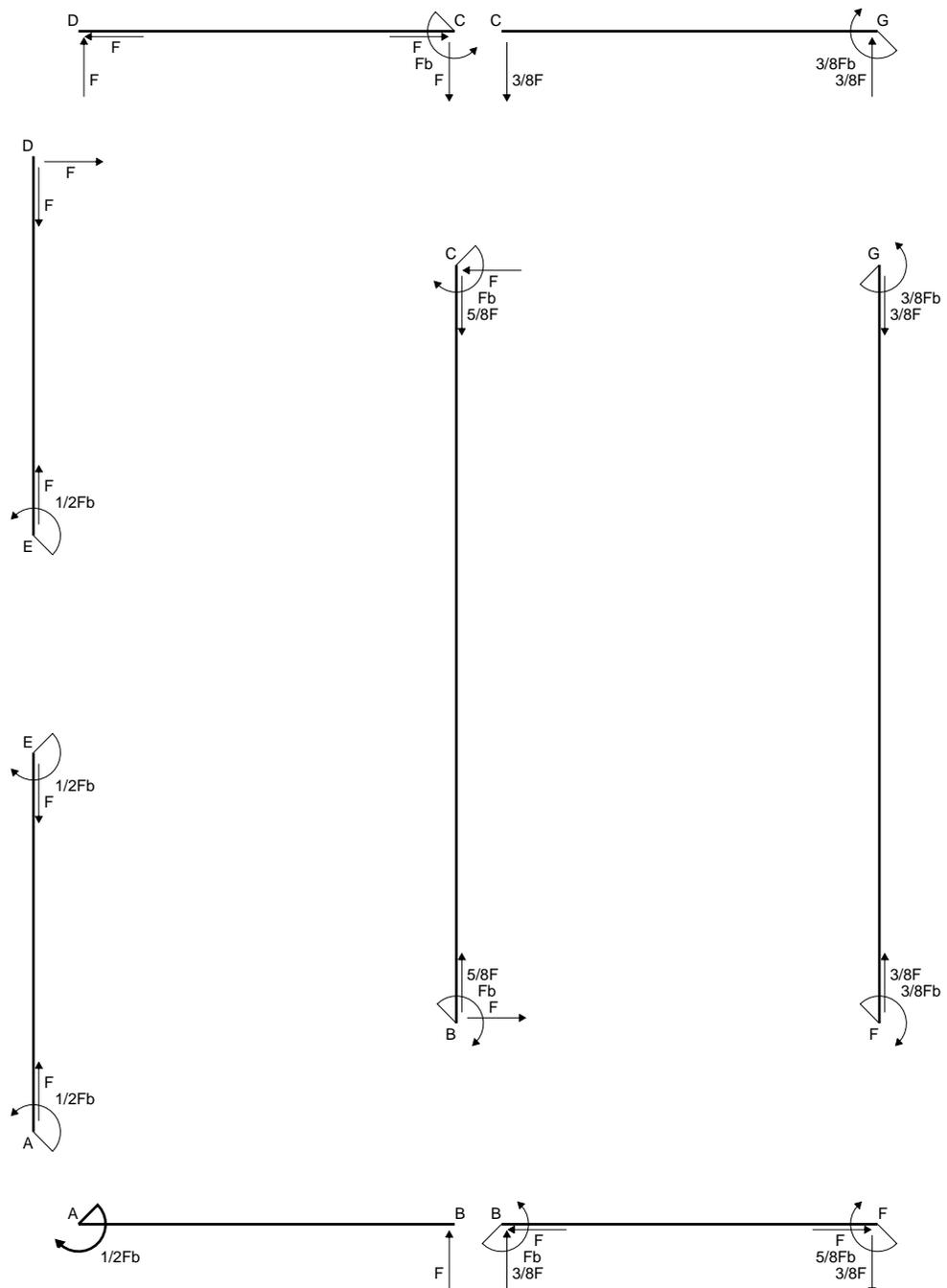
$$\sigma_c = N/A - Mv/J_u = 116.8 \text{ N/mm}^2$$

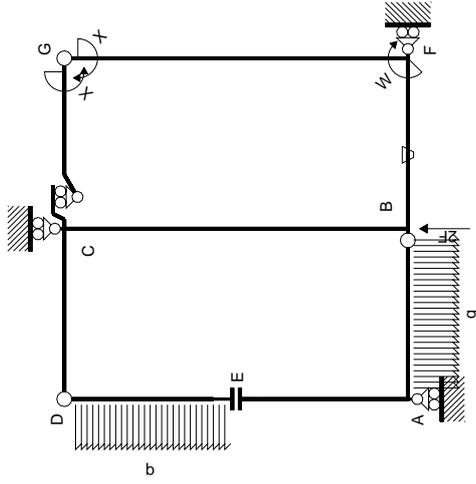
$$\tau_c = 4.84 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 117.1 \text{ N/mm}^2$$

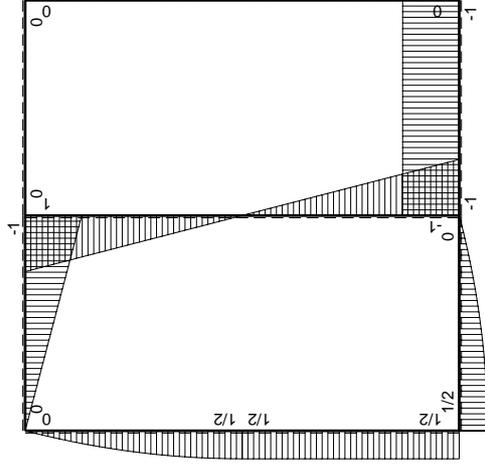
$$S = 3870. \text{ mm}^3$$



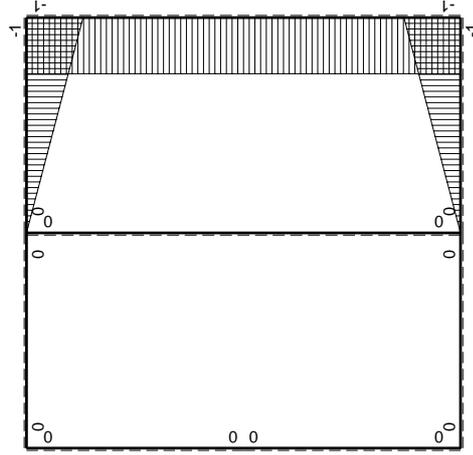




Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	$1/2Fb-1/2qx^2$	0	0	0	0	0	0+0	0
BA b	$-Fx+1/2qx^2$	0	0	0	0	0	0+0	0
CD b	$-Fb+Fx$	0	0	0	0	0	0+0	0
DC b	$Fx$	0	0	0	0	0	0+0	0
DE b	$Fx-1/2qx^2$	0	0	0	0	0	0+0	0
ED b	$-1/2Fb+1/2qx^2$	0	0	0	0	0	0+0	0
EA b	$1/2Fb$	0	0	0	0	0	0+0	0
AE b	$-1/2Fb$	0	0	0	0	0	0+0	0
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb-Fx$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$1/3xb/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2xb/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2xb/EJ$
CB 2b	0	$Fb-Fx$	0	0	0	0	0+0	0
BC 2b	0	$Fb-Fx$	0	0	0	0	0+0	0
totali								$Fb^2/EJ$
								$8/3xb/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

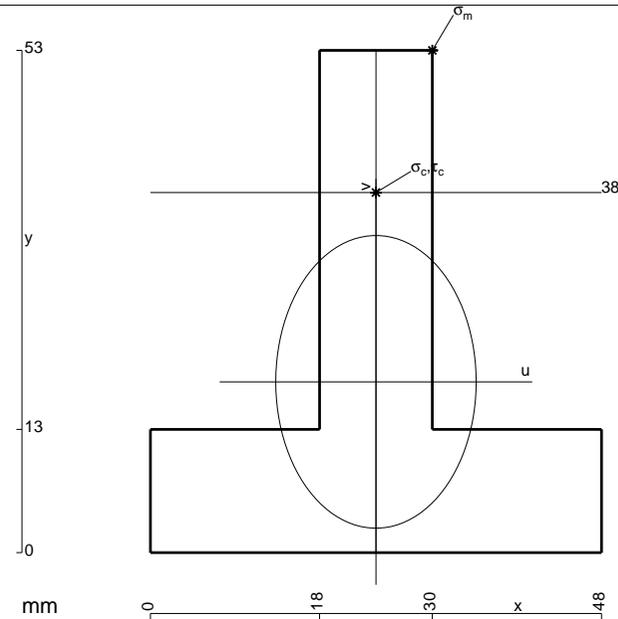
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



$$A = 1104. \text{ mm}^2$$

$$J_u = 263311. \text{ mm}^4$$

$$J_v = 125568. \text{ mm}^4$$

$$y_g = 18.02 \text{ mm}$$

$$N = 3380. \text{ N}$$

$$T_y = 3380. \text{ N}$$

$$M_x = -1554800. \text{ Nmm}$$

$$x_m = 30. \text{ mm}$$

$$y_m = 53. \text{ mm}$$

$$u_m = 6. \text{ mm}$$

$$v_m = 34.98 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 209.6 \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 38. \text{ mm}$$

$$v_c = 19.98 \text{ mm}$$

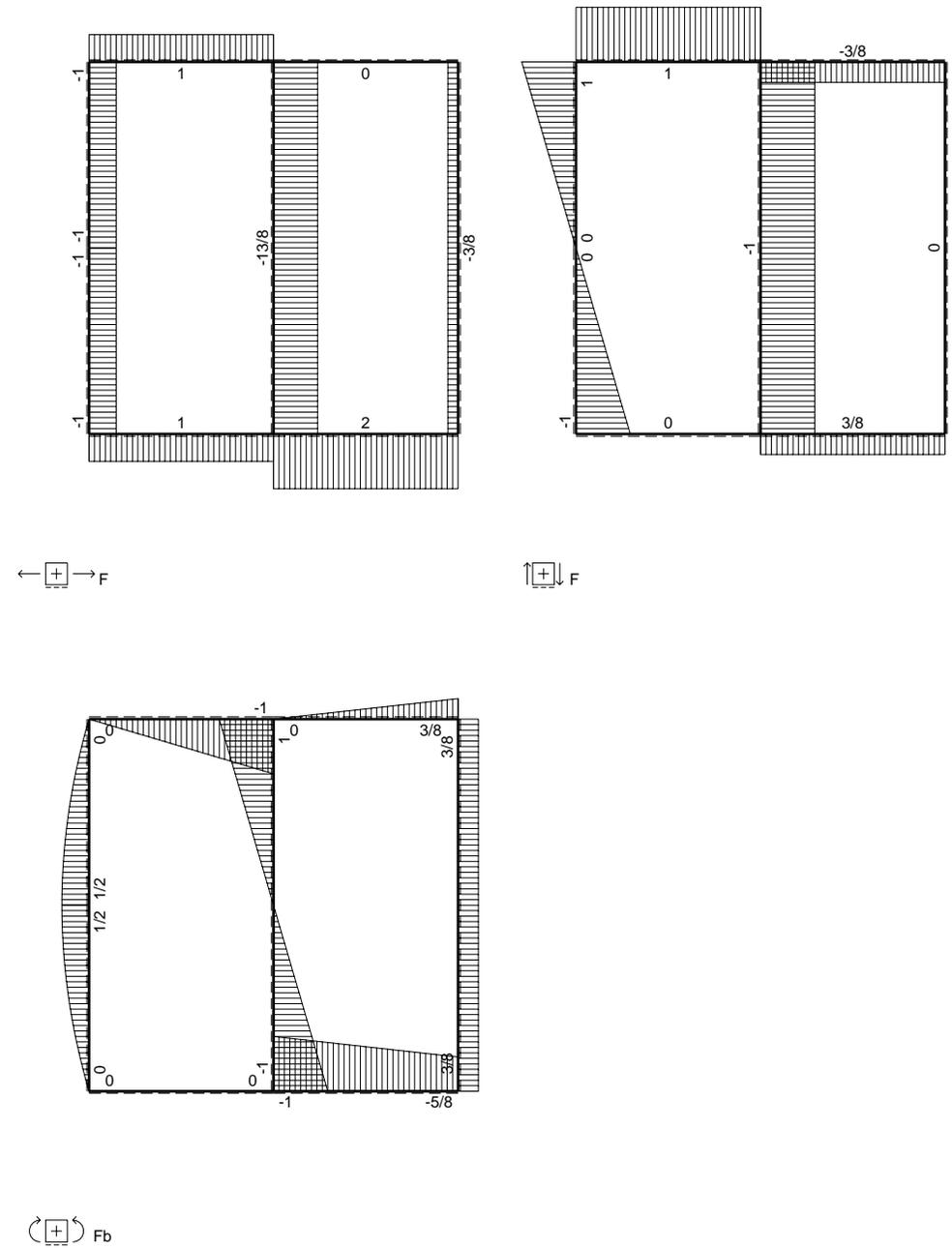
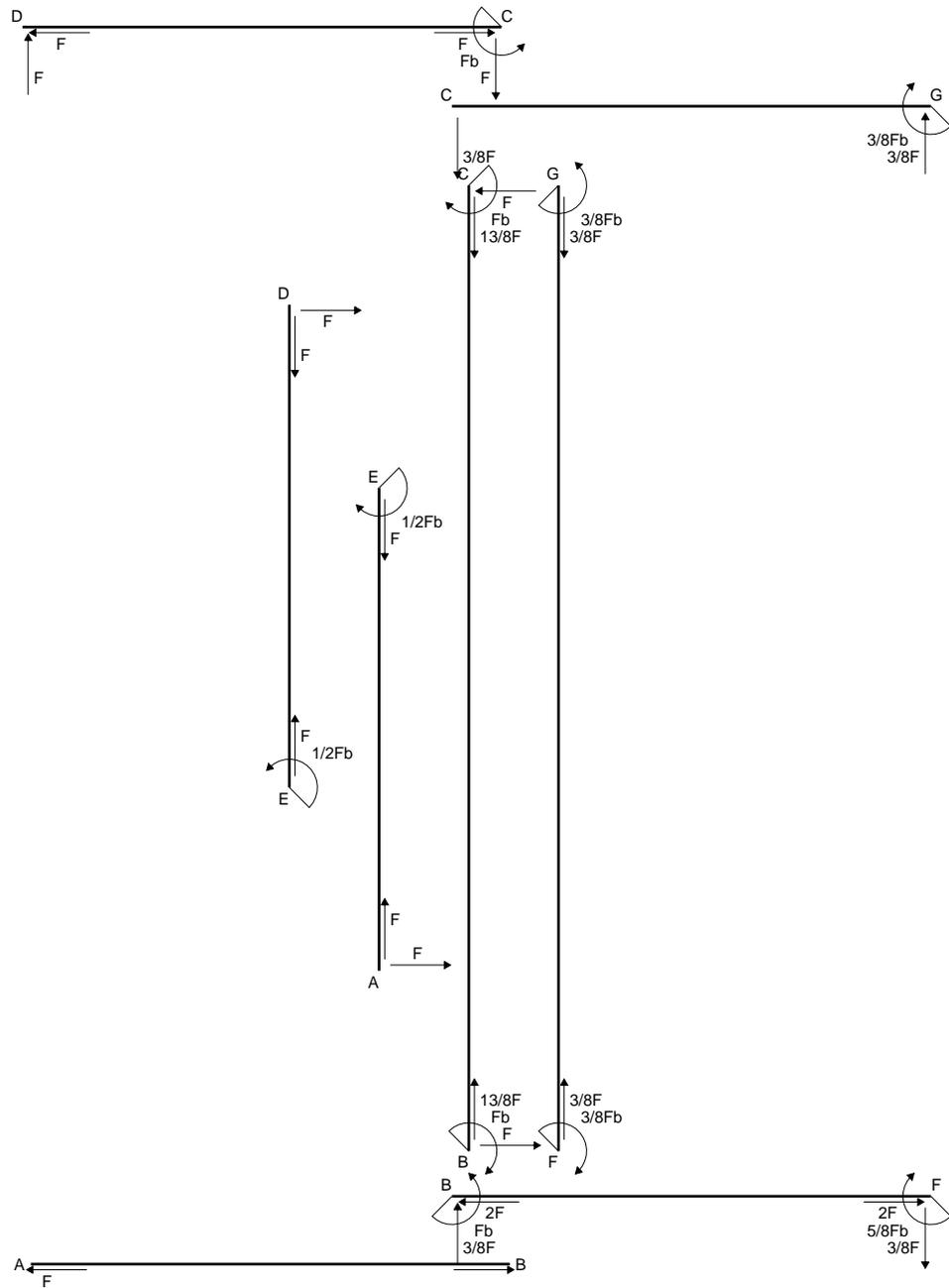
$$\sigma_c = N/A - Mv/J_u = 121. \text{ N/mm}^2$$

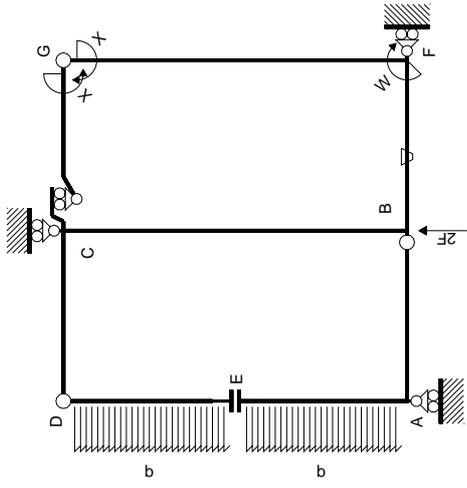
$$\tau_c = 5.291 \text{ N/mm}^2$$

$$\sigma_\varphi = \sqrt{\sigma^2 + 3\tau^2} = 121.4 \text{ N/mm}^2$$

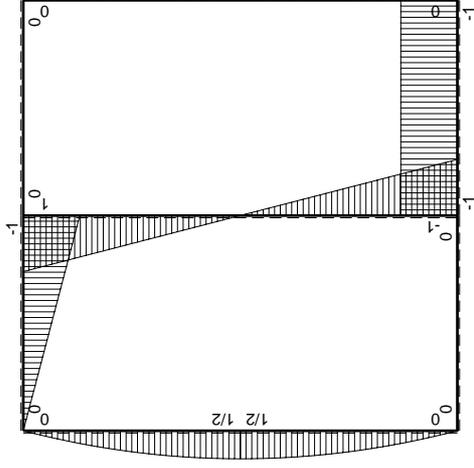
$$S = 4946. \text{ mm}^3$$



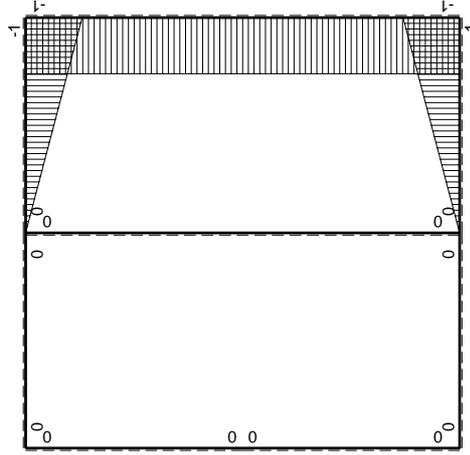




Schema di calcolo iperstatico



$M_x$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica X=W<sub>gc</sub>

→	M <sub>0</sub> (x)	M <sub>0</sub> (x)	θ	M <sub>0</sub> M <sub>0</sub>	M <sub>0</sub> θ	M <sub>0</sub> M <sub>0</sub>	∫M <sub>0</sub> (M <sub>0</sub> /EJ+θ)dx	∫M <sub>0</sub> M <sub>0</sub> /EJdx
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0+0	0
CD b	0	-Fb+Fx	0	0	0	0	0+0	0
DC b	0	Fx	0	0	0	0	0+0	0
DE b	0	Fx-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
ED b	0	-1/2Fb+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
EA b	0	1/2Fb-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
AE b	0	-Fx+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
BF b	-x/b	-Fb	-Fb/EJ	Fx	Fx/EJ	x <sup>2</sup> /b <sup>2</sup>	(1/2+1/2)Fb <sup>2</sup> /EJ	1/3xb/EJ
FB b	1-x/b	Fb	Fb/EJ	Fb-Fx	Fb/EJ-Fx/EJ	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	1/3xb/EJ	1/3xb/EJ
GC b	-1+x/b	0	0	0	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	0+0	1/3xb/EJ
CG b	x/b	0	0	0	0	x <sup>2</sup> /b <sup>2</sup>	0+0	2xb/EJ
FG 2b	-1	0	0	0	0	1	0+0	0
GF 2b	1	0	0	0	0	1	0+0	0
CB 2b	0	Fb-Fx	0	0	0	0	0+0	8/3xb/EJ
BC 2b	0	Fb-Fx	0	0	0	0	0+0	0
totali								

iperstatica X=W<sub>gc</sub>

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

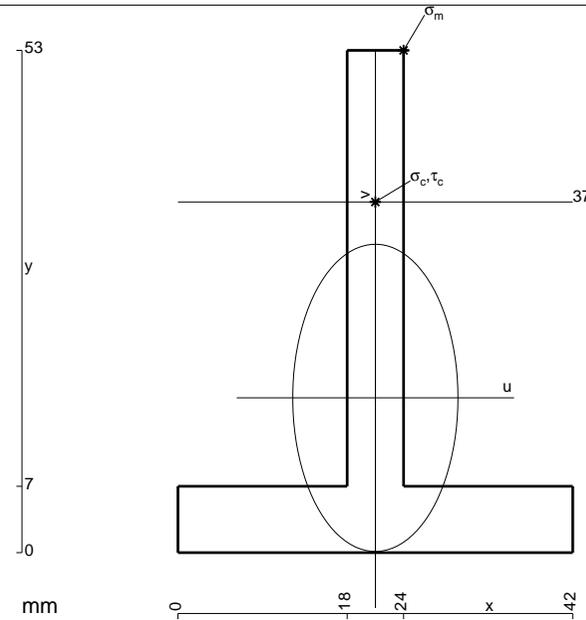
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



$$A = 570. \text{ mm}^2$$

$$J_u = 149839. \text{ mm}^4$$

$$J_v = 44046. \text{ mm}^4$$

$$y_g = 16.33 \text{ mm}$$

$$N = -2844. \text{ N}$$

$$T_y = -1750. \text{ N}$$

$$M_x = 875000. \text{ Nmm}$$

$$x_m = 24. \text{ mm}$$

$$y_m = 53. \text{ mm}$$

$$u_m = 3. \text{ mm}$$

$$v_m = 36.67 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -219.1 \text{ N/mm}^2$$

$$x_c = 21. \text{ mm}$$

$$y_c = 37. \text{ mm}$$

$$v_c = 20.67 \text{ mm}$$

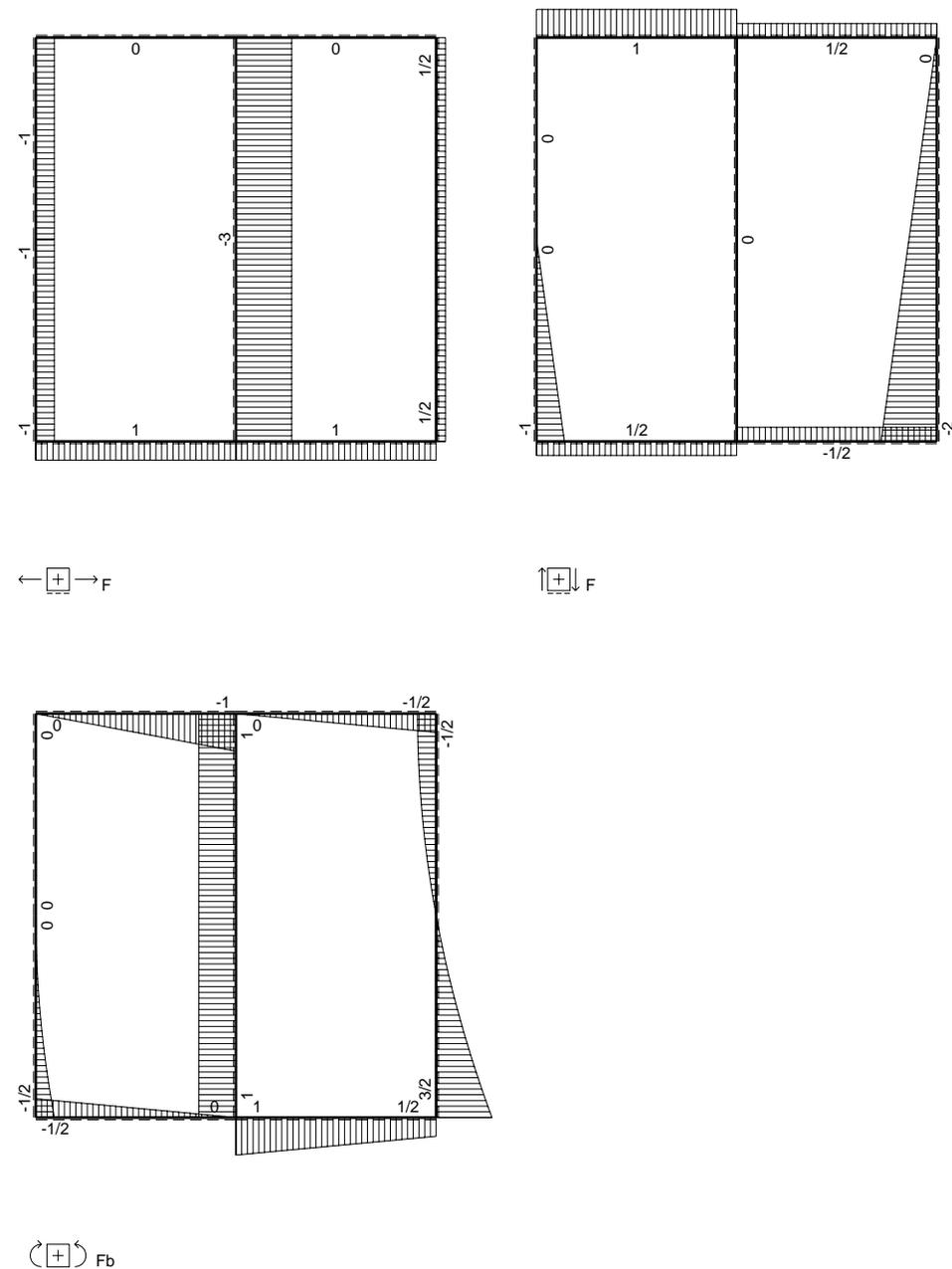
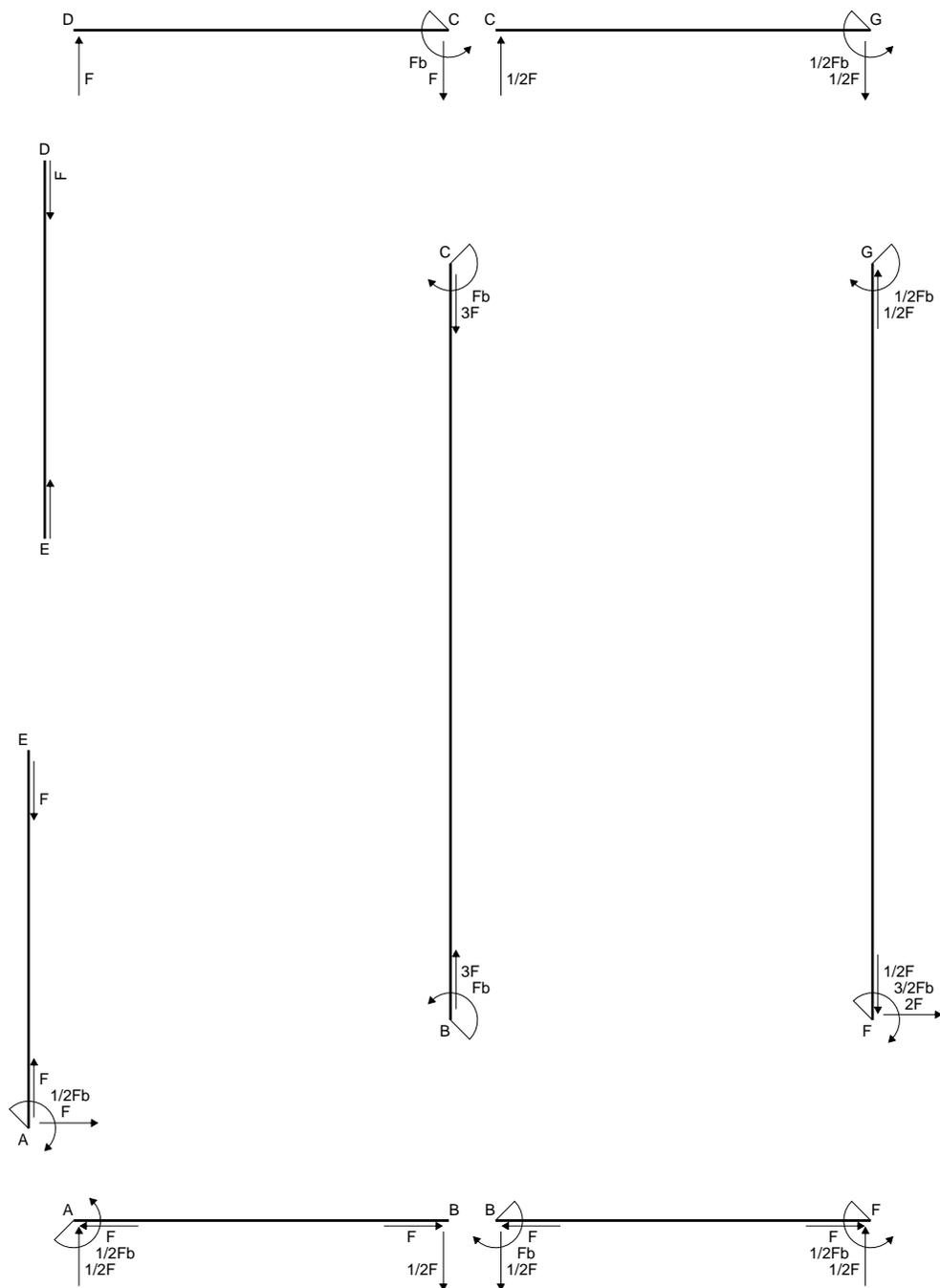
$$\sigma_c = N/A - Mv/J_u = -125.7 \text{ N/mm}^2$$

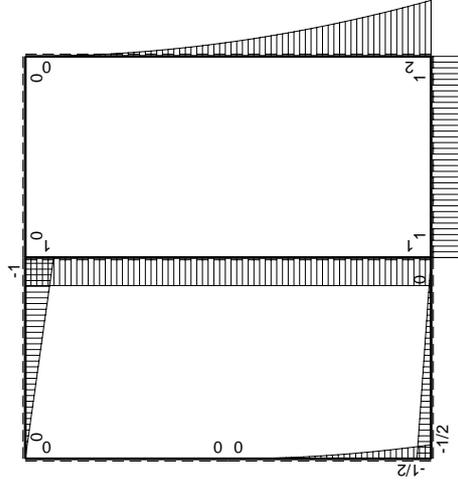
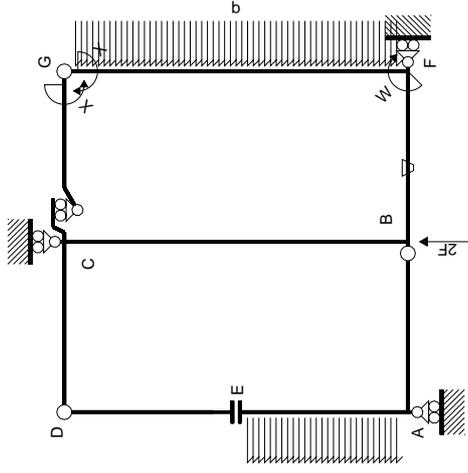
$$\tau_c = 5.357 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 126. \text{ N/mm}^2$$

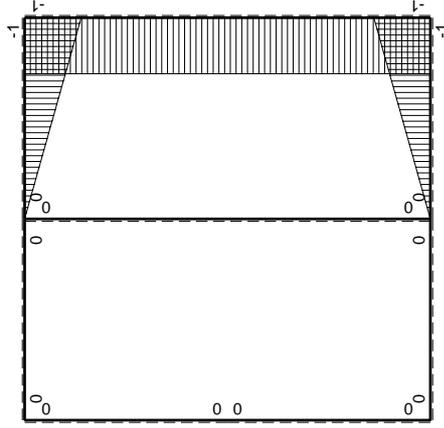
$$S = 2752. \text{ mm}^3$$







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\leftarrow$	$M(x)$	$M^0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / E dx$
AB b	0	$-1/2Fb + 1/2Fx$	0	0	0	0	0+0	0
BA b	0	$1/2Fx$	0	0	0	0	0+0	0
CD b	0	$-Fb + Fx$	0	0	0	0	0+0	0
DC b	0	$Fx$	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
EA b	0	$-1/2qx^2$	0	0	0	0	0+0	0
AE b	0	$1/2Fb - Fx + 1/2qx^2$	0	0	0	0	0+0	0
BF b	$-x/b$	$Fb$	$-Fb/EJ$	$-Fx$	$Fx/EJ$	$x^2/b^2$	$(-1/2 + 1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$-Fb$	$Fb/EJ$	$-Fb + Fx$	$Fb/EJ - Fx/EJ$	$1-2x/b + x^2/b^2$	$(-1/2 + 1/2)Fb^2/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b + x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	$2Fb - 2Fx + 1/2qx^2$	0	$-2Fb + 2Fx - 1/2Fx^2/b$	0	1	$(-4/3 + 0)Fb^2/EJ$	$2xb/EJ$
GF 2b	1	$-1/2qx^2$	0	$-1/2Fx^2/b$	0	1	$(-4/3 + 0)Fb^2/EJ$	$2xb/EJ$
CB 2b	0	$Fb$	0	0	0	0	0+0	0
BC 2b	0	$-Fb$	0	0	0	0	0+0	0
totali							$-4/3Fb^2/EJ$	$8/3xb/EJ$
		iperstatica $X=W_{gc}$						

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x\theta} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x\theta} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

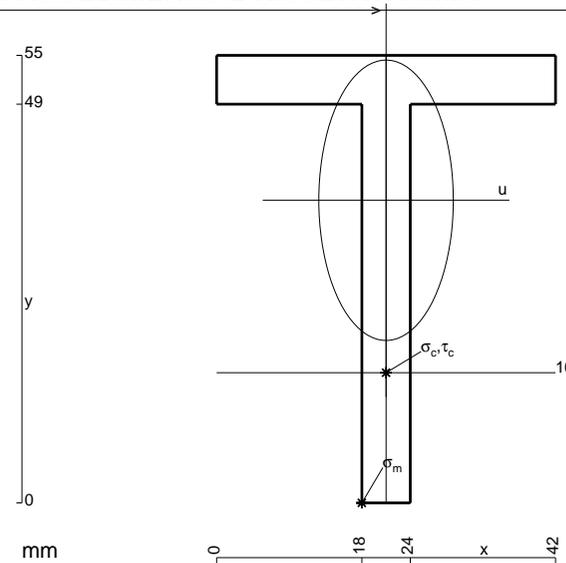
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x\theta} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

$$L_{GF}^{x\theta} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



$$A = 546. \text{ mm}^2$$

$$J_u = 162198. \text{ mm}^4$$

$$J_v = 37926. \text{ mm}^4$$

$$y_g = 37.19 \text{ mm}$$

$$T_y = 1750. \text{ N}$$

$$M_x = -997500. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -37.19 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -228.7 \text{ N/mm}^2$$

$$x_c = 21. \text{ mm}$$

$$y_c = 16. \text{ mm}$$

$$v_c = -21.19 \text{ mm}$$

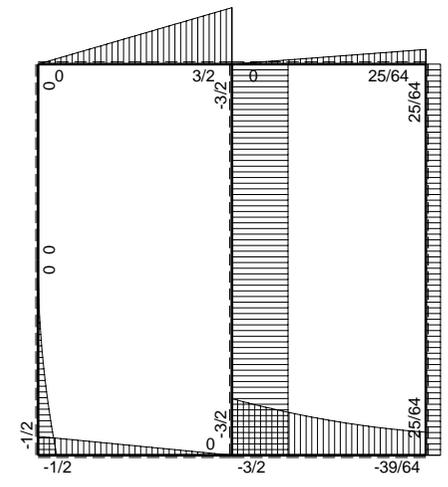
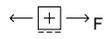
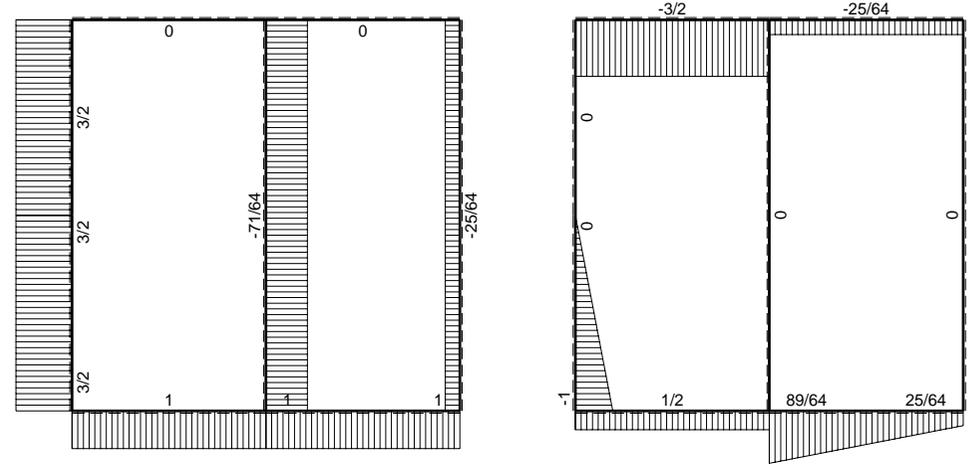
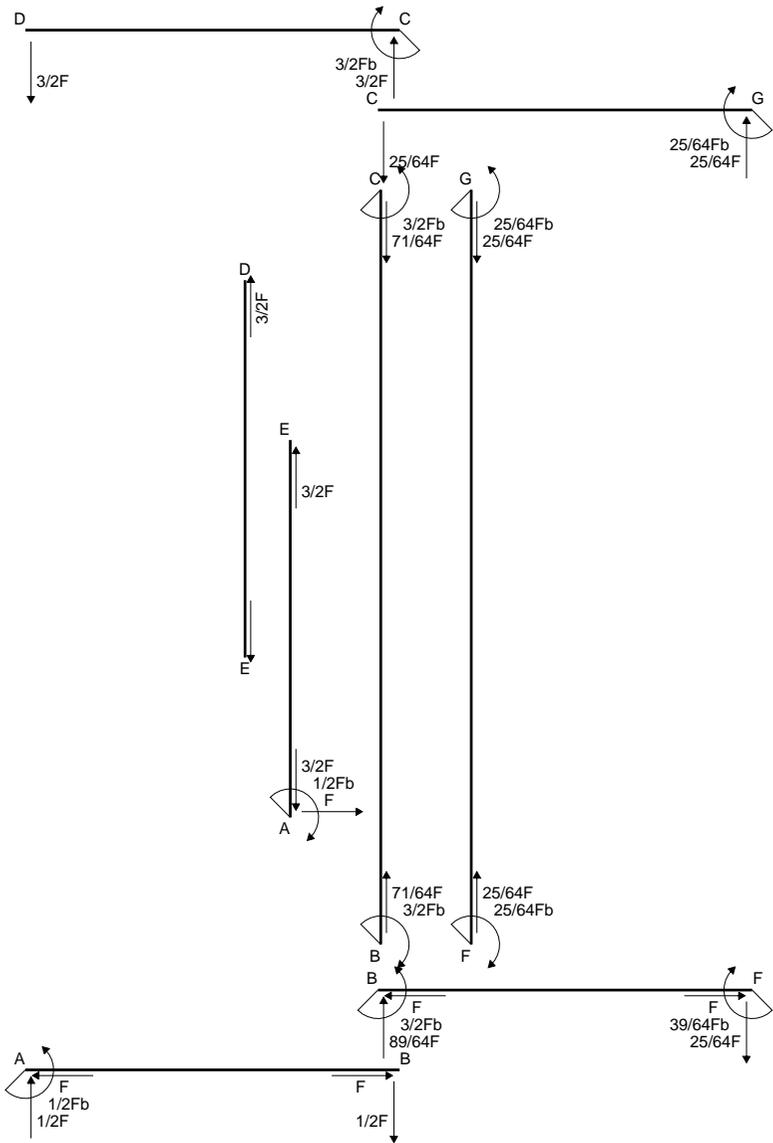
$$\sigma_c = -Mv/J_u = -130.3 \text{ N/mm}^2$$

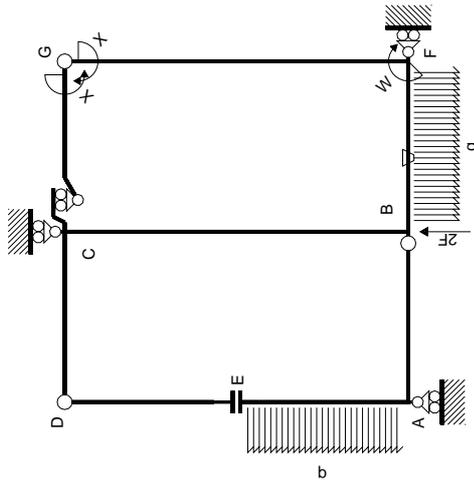
$$\tau_c = 5.039 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 130.6 \text{ N/mm}^2$$

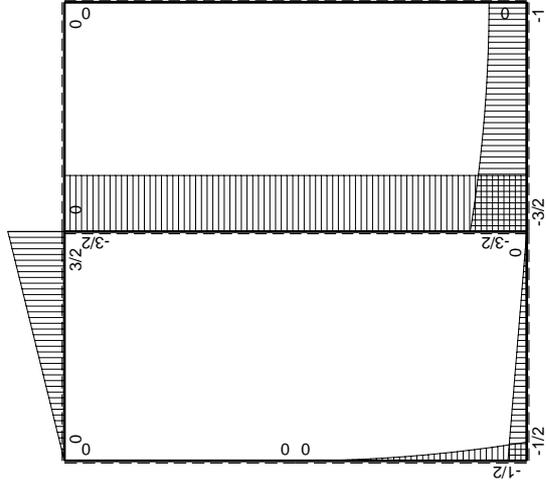
$$S = 2802. \text{ mm}^3$$



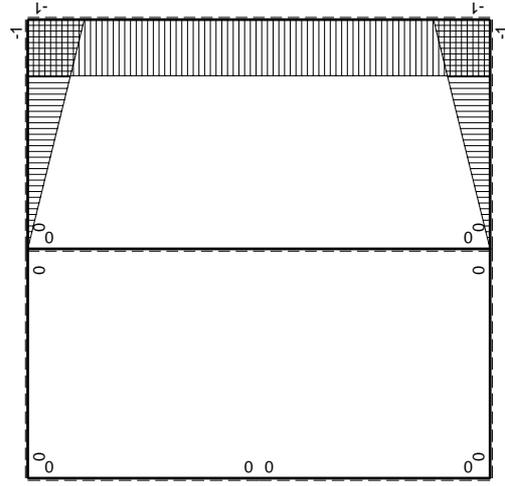




Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica X=W<sub>gc</sub>

←	M <sup>x</sup> (x)	M <sup>o</sup> (x)	θ	M <sup>x</sup> M <sub>o</sub>	M <sup>x</sup> θ	M <sup>x</sup> M <sub>x</sub>	$\int M^x(M^o/EJ+\theta)dx$	$\int M^x M^x/EJ dx$
AB b	0	-1/2Fb+1/2Fx	0	0	0	0	0+0	0
BA b	0	1/2Fx	0	0	0	0	0+0	0
CD b	0	3/2Fb-3/2Fx	0	0	0	0	0+0	0
DC b	0	-3/2Fx	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
ED b	0	0	0	0	0	0	0+0	0
EAB b	0	-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
AE b	0	1/2Fb-Fx+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
BF b	-x/b	-3/2Fb+Fx-1/2qx <sup>2</sup>	-Fb/EJ	3/2Fx-Fx <sup>2</sup> /b+1/2qx <sup>3</sup> /b	Fx/EJ	x <sup>2</sup> /b <sup>2</sup>	(1/3/24+1/2)Fb <sup>2</sup> /EJ	1/3xb/EJ
FBB b	1-x/b	Fb+1/2qx <sup>2</sup>	Fb/EJ	Fb-Fx+1/2Fx <sup>2</sup> /b-1/2qx <sup>3</sup> /b	Fb/EJ-Fx/EJ	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	1/3xb/EJ	1/3xb/EJ
GCB b	-1+x/b	0	0	0	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	0+0	1/3xb/EJ
CG b	x/b	0	0	0	0	x <sup>2</sup> /b <sup>2</sup>	0+0	2xb/EJ
FG 2b	-1	0	0	0	0	1	0+0	0
GF 2b	1	0	0	0	0	1	0+0	0
CB 2b	0	-3/2Fb	0	0	0	0	0+0	0
BC 2b	0	3/2Fb	0	0	0	0	0+0	8/3xb/EJ
totali								
iperstatica X=W <sub>gc</sub>								

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x\theta} = \int_0^b (3/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

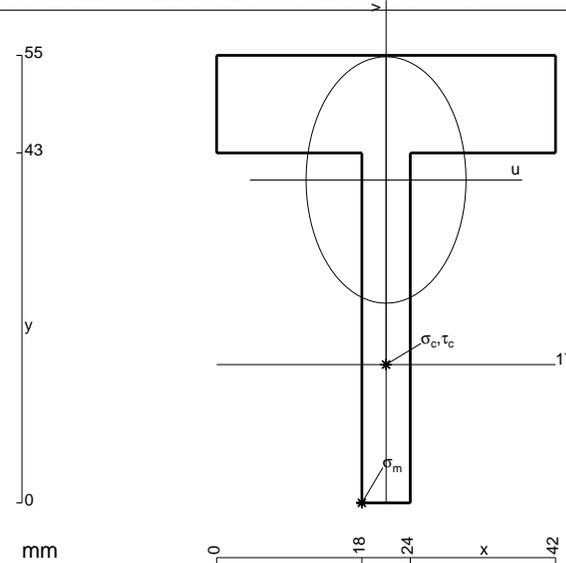
$$= [3/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (3/4 b - 1/3 b + 1/8 b) Fb 1/EJ + (1/2 b) \theta = 25/24 Fb^2/EJ$$

$$L_{FB}^{x\theta} = \int_0^b (1 - x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [x - 1/2 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b + 1/6 b - 1/8 b) Fb 1/EJ + (-b + 1/2 b) \theta = 25/24 Fb^2/EJ$$



$$A = 762. \text{ mm}^2$$

$$J_u = 174852. \text{ mm}^4$$

$$J_v = 74862. \text{ mm}^4$$

$$y_g = 39.69 \text{ mm}$$

$$T_y = -1725. \text{ N}$$

$$M_x = 1052250. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -39.69 \text{ mm}$$

$$\sigma_m = -Mv/J_u = 238.8 \text{ N/mm}^2$$

$$x_c = 21. \text{ mm}$$

$$y_c = 17. \text{ mm}$$

$$v_c = -22.69 \text{ mm}$$

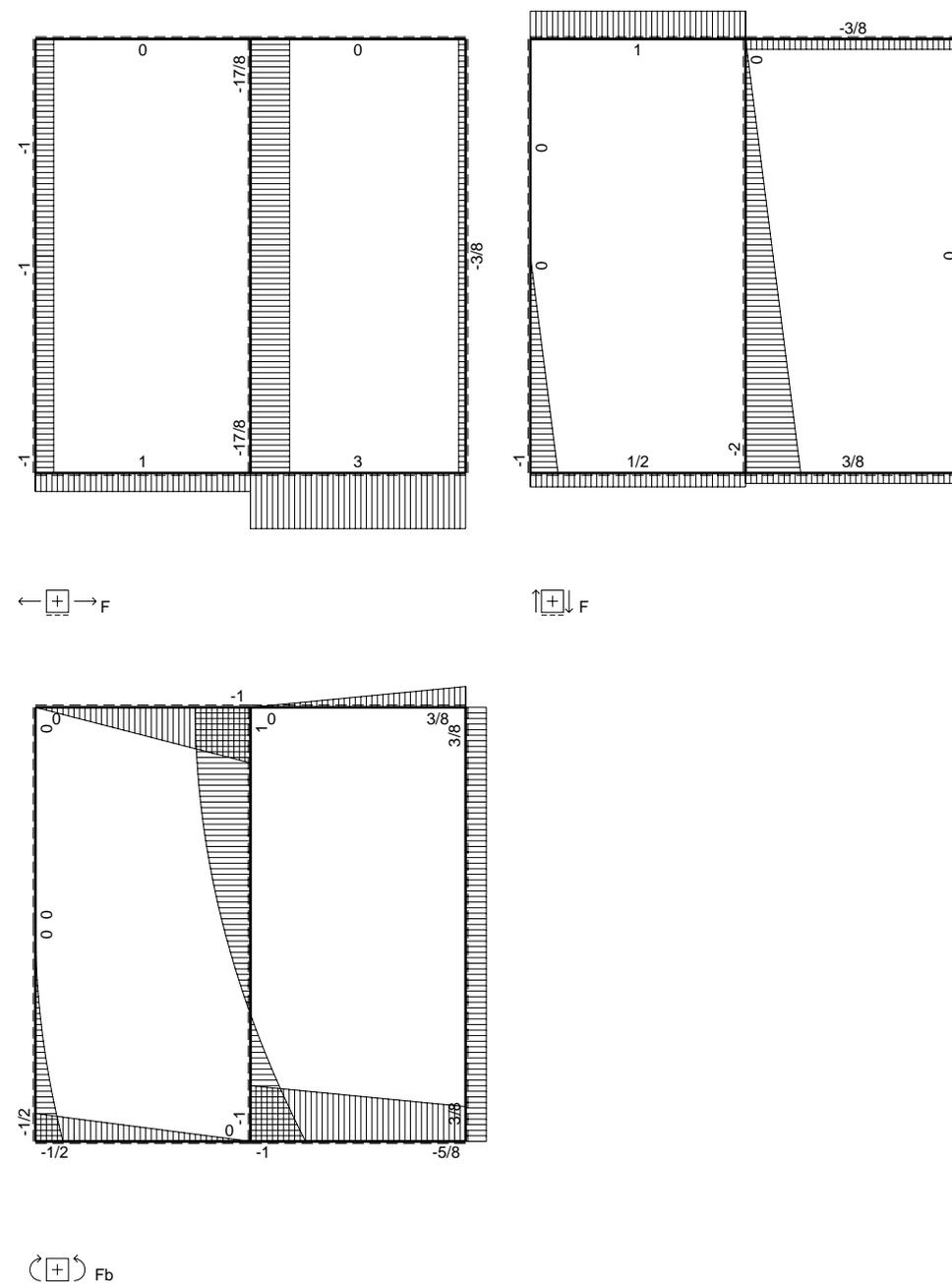
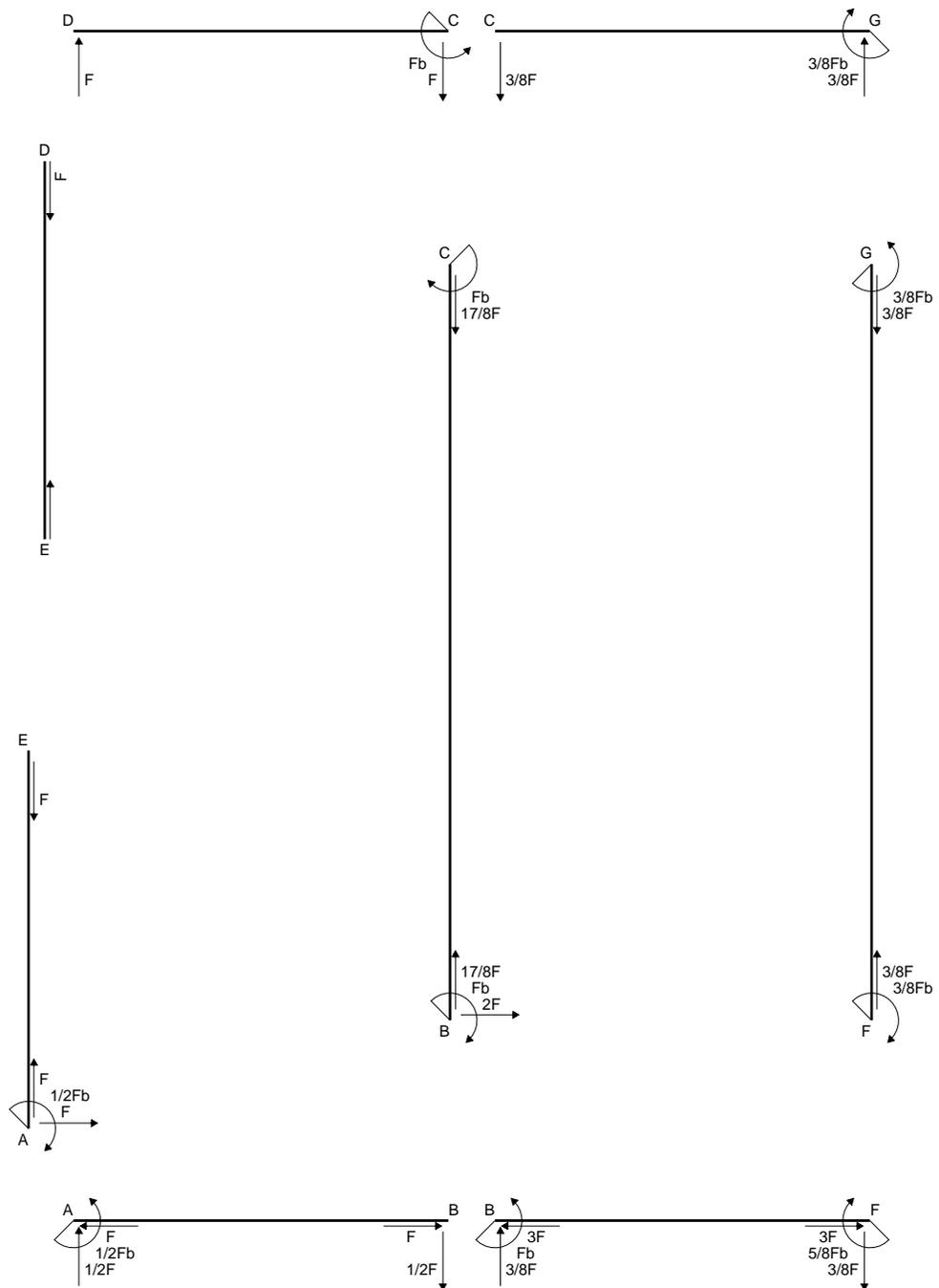
$$\sigma_c = -Mv/J_u = 136.5 \text{ N/mm}^2$$

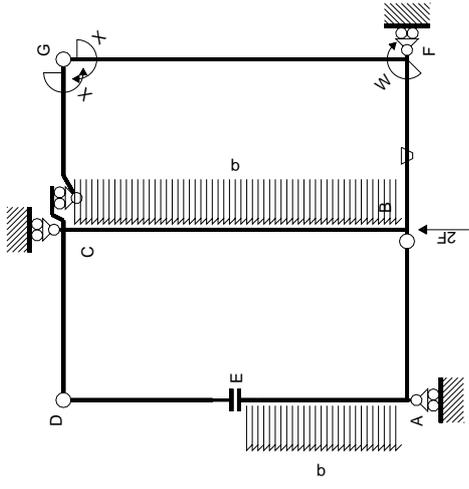
$$\tau_c = 5.231 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 136.8 \text{ N/mm}^2$$

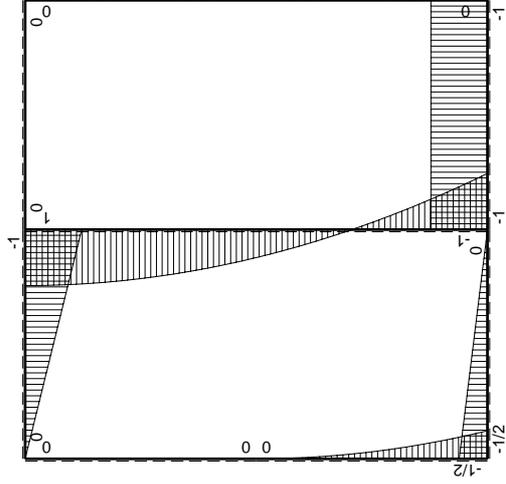
$$S = 3181. \text{ mm}^3$$



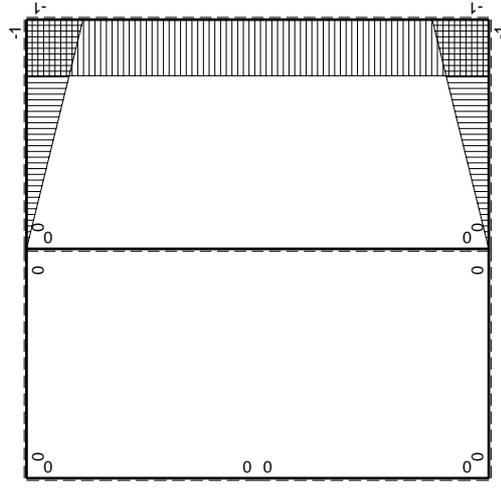




Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Sviluppi di calcolo iperstatica

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\leftarrow$	$M(x)$	$M(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB B	0	$-1/2Fb+1/2Fx$	0	0	0	0	0+0	0
BA B	0	$1/2Fx$	0	0	0	0	0+0	0
CD B	0	$-Fb+Fx$	0	0	0	0	0+0	0
DC B	0	$Fx$	0	0	0	0	0+0	0
DE B	0	0	0	0	0	0	0+0	0
ED B	0	0	0	0	0	0	0+0	0
EA B	0	$-1/2qx^2$	0	0	0	0	0+0	0
AE B	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0+0	0
BF B	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB B	$1-x/b$	$Fb$	$Fb/EJ$	$Fb-Fx$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$1/3xb/EJ$	$1/3xb/EJ$
GC B	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG B	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2xb/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2xb/EJ$
CB 2b	0	$Fb-1/2qx^2$	0	0	0	0	0+0	0
BC 2b	0	$Fb-2Fx+1/2qx^2$	0	0	0	0	0+0	0
totali								$Fb^2/EJ$
								$8/3xb/EJ$

iperstatica  $X=W_{gc}$

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

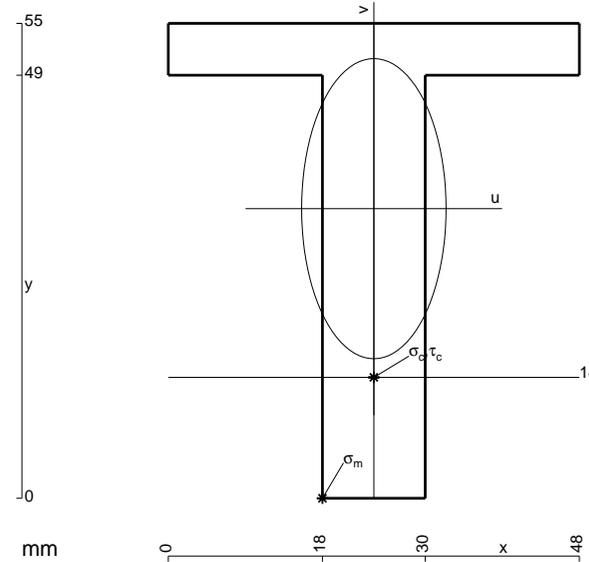
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

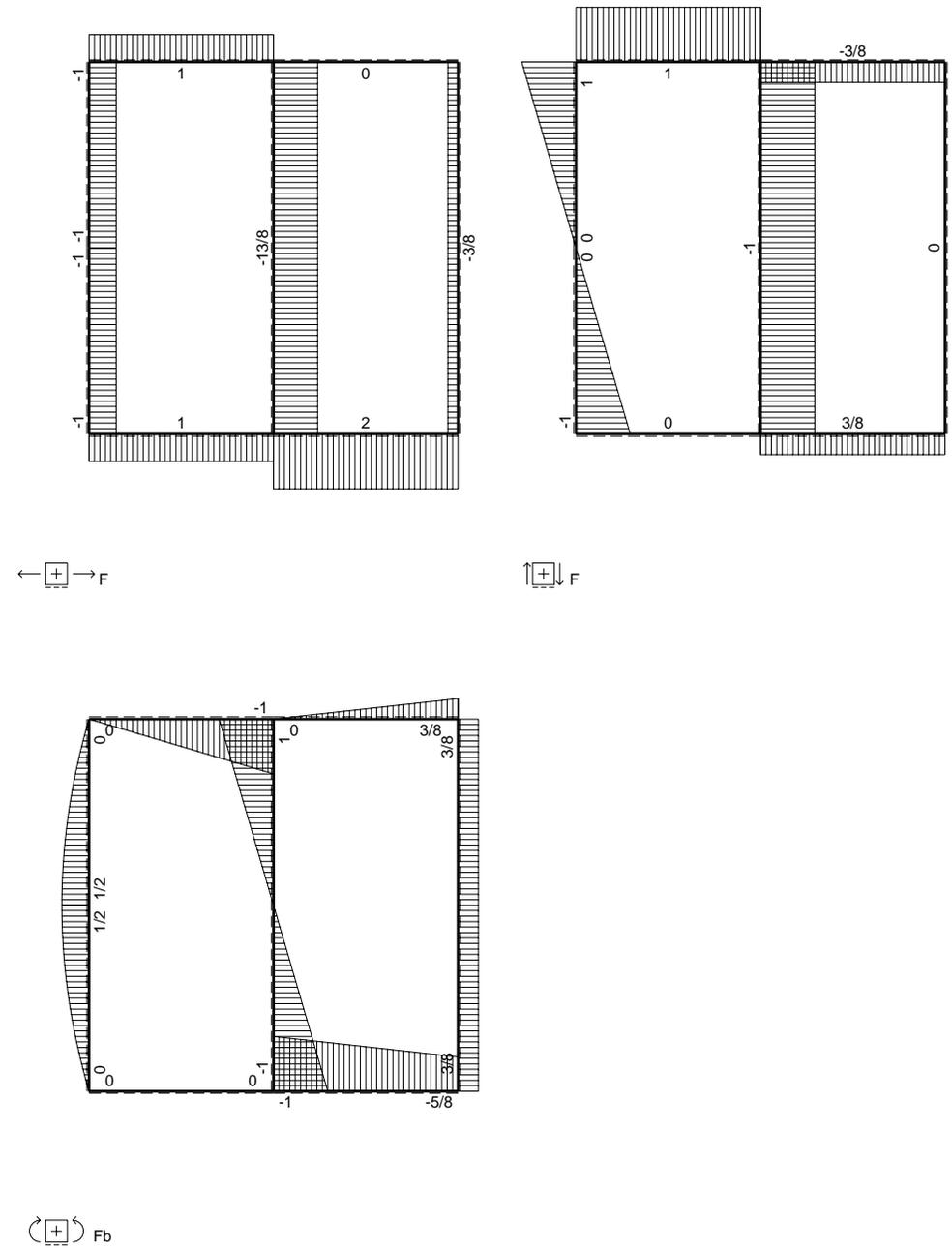
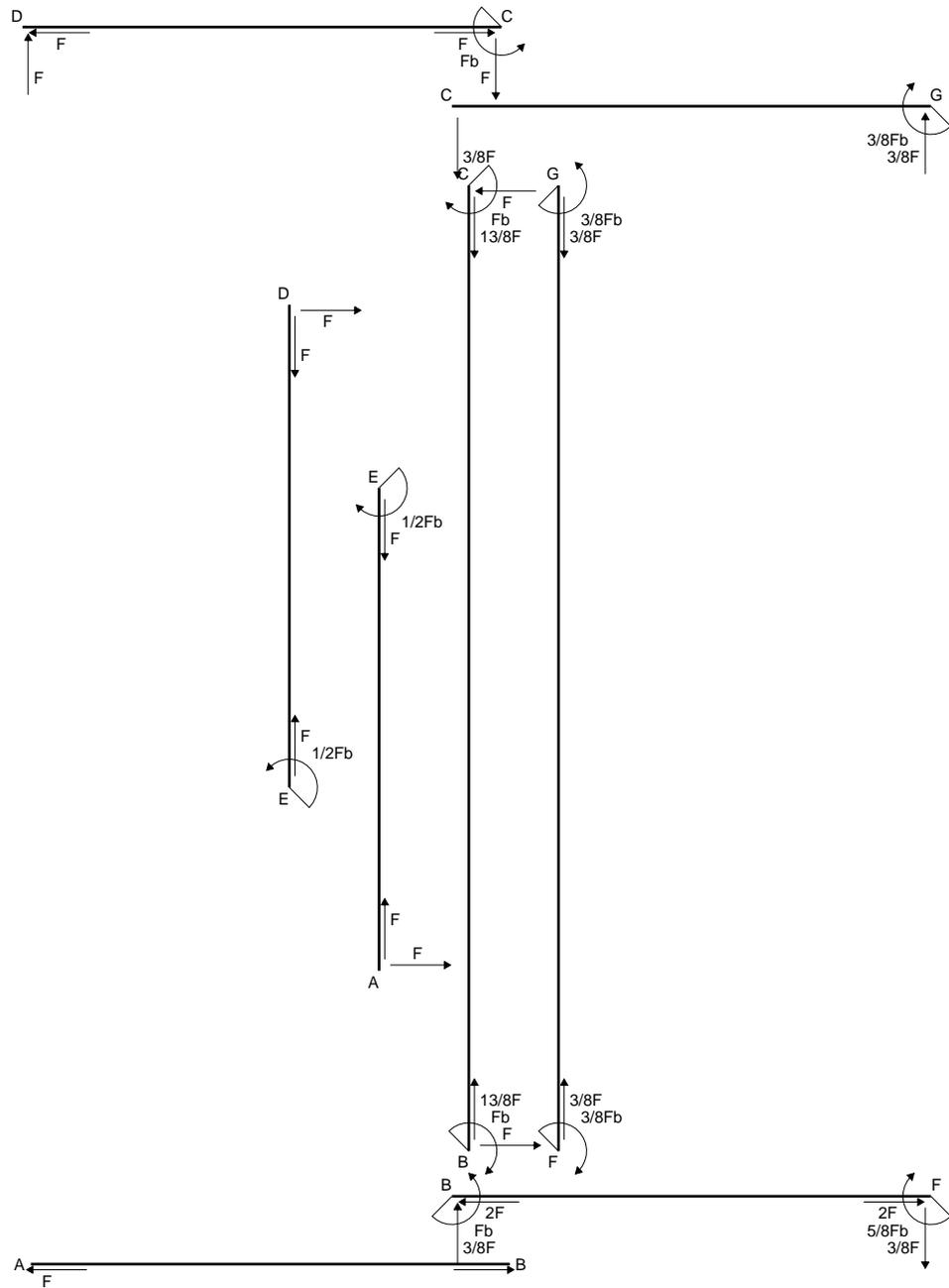
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

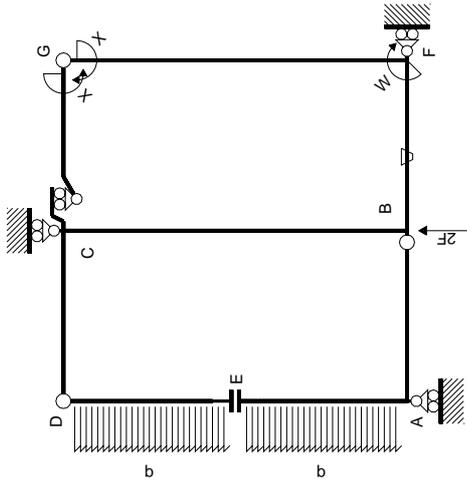
$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



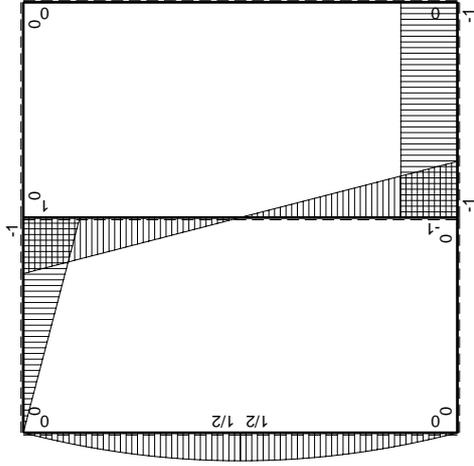
- A = 876. mm<sup>2</sup>
- J<sub>u</sub> = 264708. mm<sup>4</sup>
- J<sub>v</sub> = 62352. mm<sup>4</sup>
- y<sub>g</sub> = 33.54 mm
- N = -4930. N
- T<sub>y</sub> = -4640. N
- M<sub>x</sub> = -1531200. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -33.54 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = -199.6 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 14. mm
- v<sub>c</sub> = -19.54 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = -118.7 N/mm<sup>2</sup>
- τ<sub>c</sub> = 6.513 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 119.2 N/mm<sup>2</sup>
- S = 4459. mm<sup>3</sup>



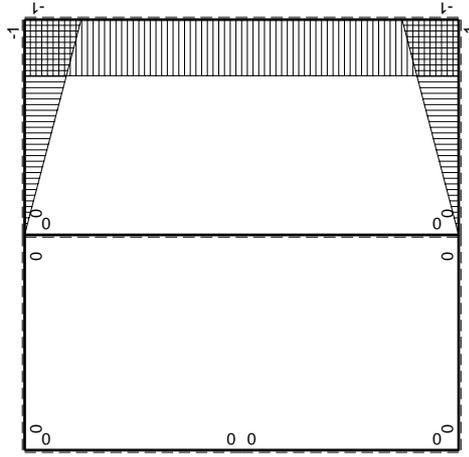




Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica X=W<sub>gc</sub>

→	M <sub>0</sub> (x)	M <sub>0</sub> (x)	θ	M <sub>0</sub> M <sub>0</sub>	M <sub>0</sub> θ	M <sub>0</sub> M <sub>x</sub>	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0+0	0
CD b	0	-Fb+Fx	0	0	0	0	0+0	0
DC b	0	Fx	0	0	0	0	0+0	0
DE b	0	Fx-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
ED b	0	-1/2Fb+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
EA b	0	1/2Fb-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
AE b	0	-Fx+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
BF b	-x/b	-Fb	-Fb/EJ	Fx	Fx/EJ	x <sup>2</sup> /b <sup>2</sup>	(1/2+1/2)Fb <sup>2</sup> /EJ	1/3xb/EJ
FB b	1-x/b	Fb	Fb/EJ	Fb-Fx	Fb/EJ-Fx/EJ	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	1/3xb/EJ	1/3xb/EJ
GC b	-1+x/b	0	0	0	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	0+0	1/3xb/EJ
CG b	x/b	0	0	0	0	x <sup>2</sup> /b <sup>2</sup>	0+0	2xb/EJ
FG 2b	-1	0	0	0	0	1	0+0	0
GF 2b	1	0	0	0	0	1	0+0	0
CB 2b	0	Fb-Fx	0	0	0	0	0+0	8/3xb/EJ
BC 2b	0	Fb-Fx	0	0	0	0	0+0	0
totali								

iperstatica X=W<sub>gc</sub>

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

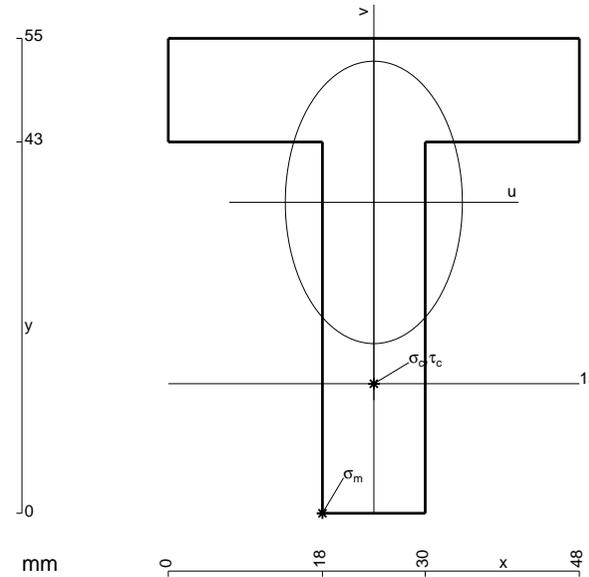
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

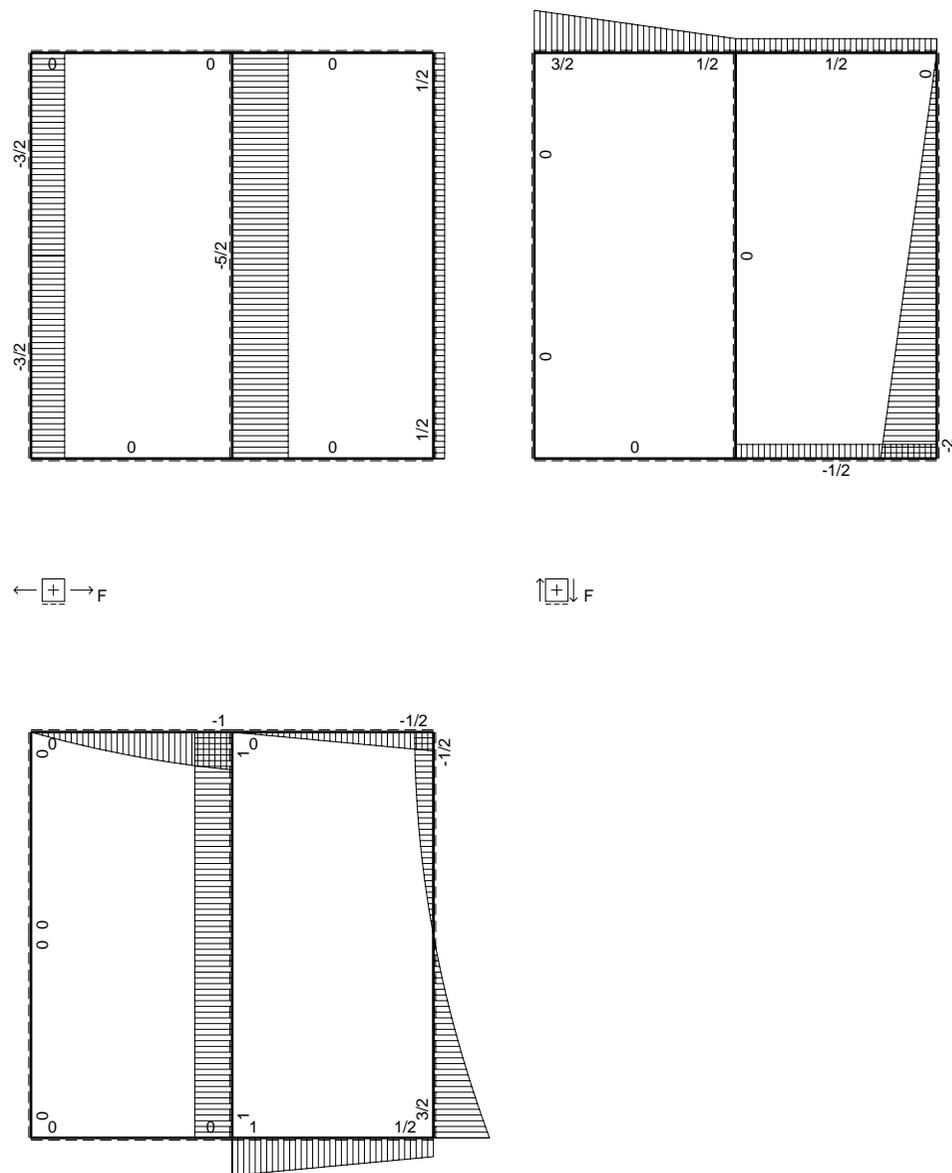
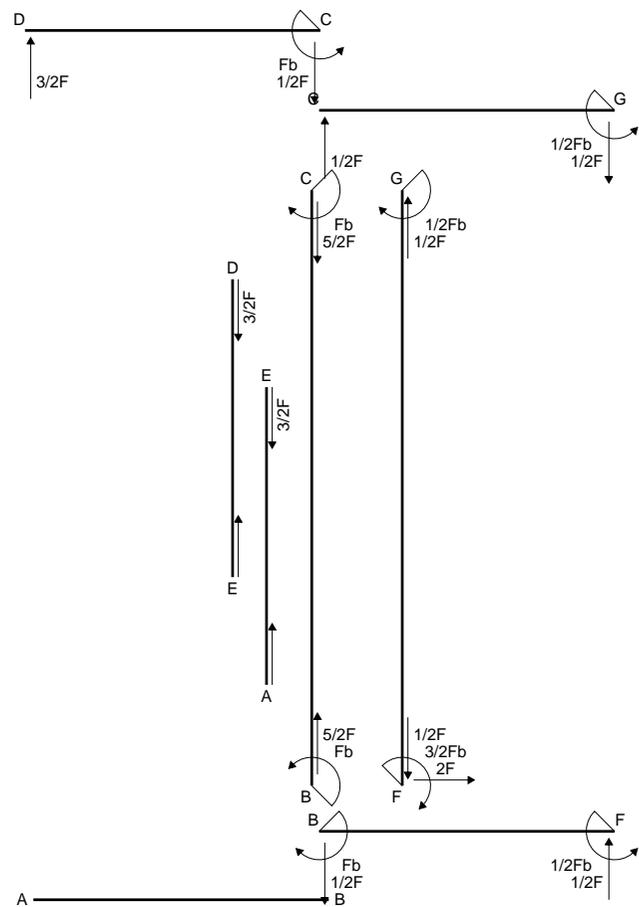
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

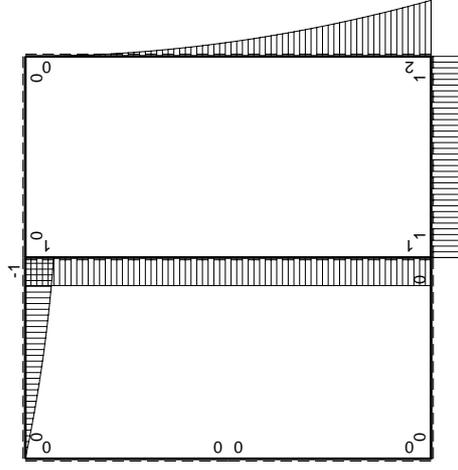
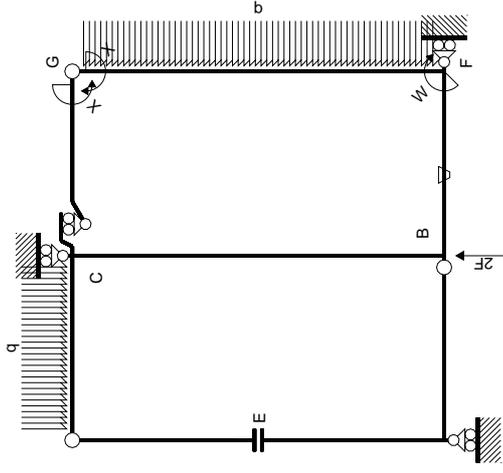
$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



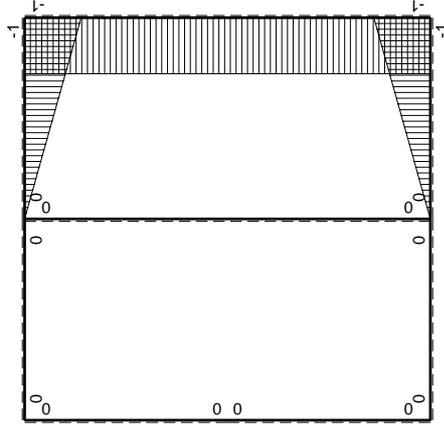
- A = 1092. mm<sup>2</sup>
- J<sub>u</sub> = 292252. mm<sup>4</sup>
- J<sub>v</sub> = 116784. mm<sup>4</sup>
- y<sub>g</sub> = 36.01 mm
- N = -3884. N
- T<sub>y</sub> = -2390. N
- M<sub>x</sub> = -1673000. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -36.01 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = -209.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 15. mm
- v<sub>c</sub> = -21.01 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = -123.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.497 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 124. N/mm<sup>2</sup>
- S = 5131. mm<sup>3</sup>







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\leftarrow$	$M_x(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / EJ dx$
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0+0	0
CD b	0	$-Fb + 1/2Fx + 1/2qx^2$	0	0	0	0	0+0	0
DC b	0	$3/2Fx - 1/2qx^2$	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
ED b	0	0	0	0	0	0	0+0	0
EA b	0	0	0	0	0	0	0+0	0
AE b	0	0	0	0	0	0	0+0	0
BF b	$-x/b$	Fb	$-Fb/EJ$	$-Fx$	$Fx/EJ$	$x^2/b^2$	$(-1/2 + 1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$-Fb$	Fb/EJ	$-Fb + Fx$	$Fb/EJ - Fx/EJ$	$1-2x/b + x^2/b^2$	$(-1/2 + 1/2)Fb^2/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b + x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	$2Fb - 2Fx + 1/2qx^2$	0	$-2Fb + 2Fx - 1/2Fx^2/b$	0	1	$(-4/3 + 0)Fb^2/EJ$	$2xb/EJ$
GF 2b	1	$-1/2qx^2$	0	$-1/2Fx^2/b$	0	1	$(-4/3 + 0)Fb^2/EJ$	$2xb/EJ$
CB 2b	0	Fb	0	0	0	0	0+0	0
BC 2b	0	$-Fb$	0	0	0	0	0+0	0
totali								$8/3xb/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x\theta} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x\theta} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

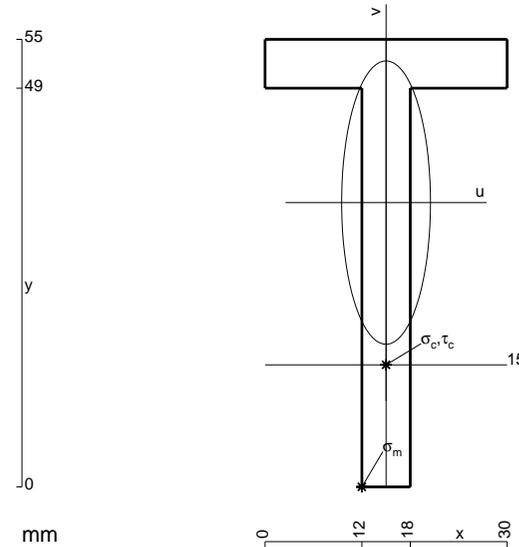
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x\theta} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

$$L_{GF}^{x\theta} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



$$A = 474. \text{ mm}^2$$

$$J_u = 143796. \text{ mm}^4$$

$$J_v = 14382. \text{ mm}^4$$

$$y_g = 34.94 \text{ mm}$$

$$T_y = 1950. \text{ N}$$

$$M_x = -901875. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -34.94 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -219.2 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 15. \text{ mm}$$

$$v_c = -19.94 \text{ mm}$$

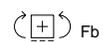
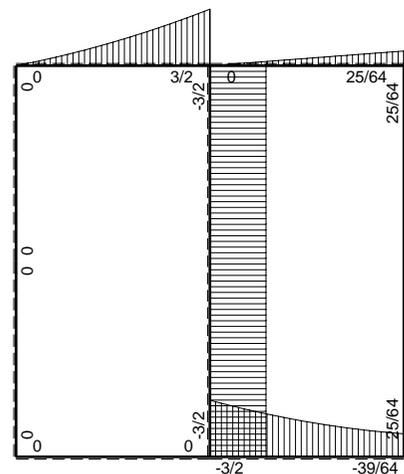
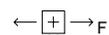
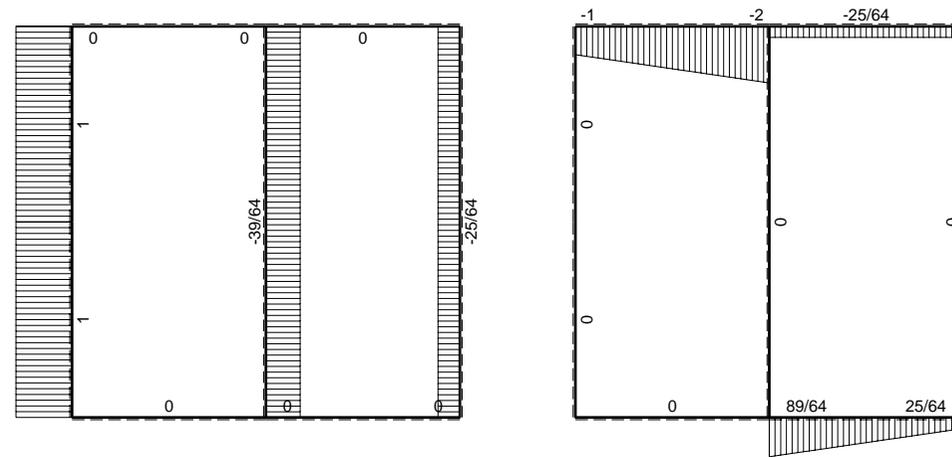
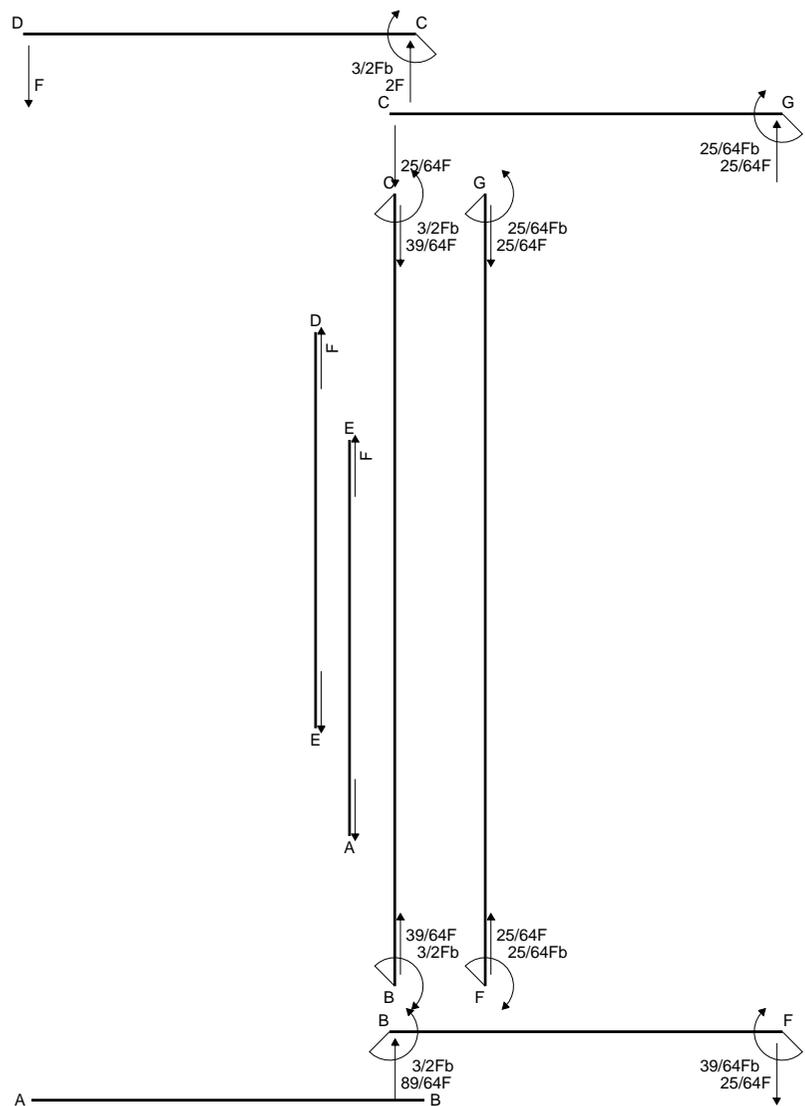
$$\sigma_c = -Mv/J_u = -125.1 \text{ N/mm}^2$$

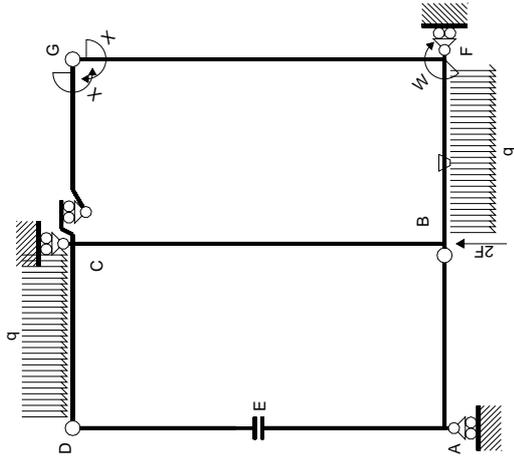
$$\tau_c = 5.582 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 125.5 \text{ N/mm}^2$$

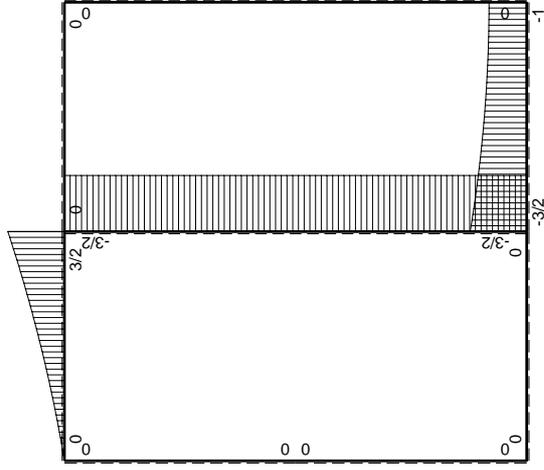
$$S = 2470. \text{ mm}^3$$



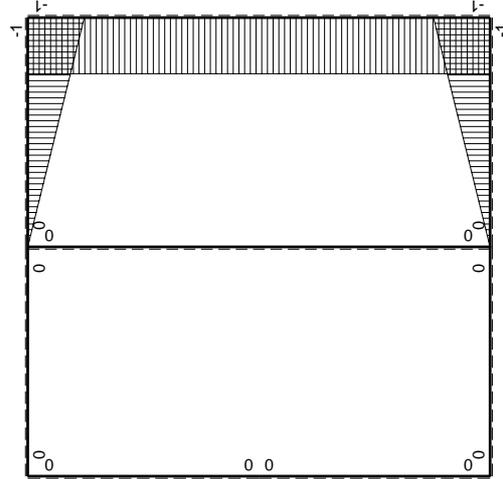




Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica X=W<sub>gc</sub>

$\rightarrow$	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x(M^0/EJ+\theta)dx$	$\int M^x M_x/EJdx$
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0+0	0
CD b	0	$3/2Fb-2Fx+1/2qx^2$	0	0	0	0	0+0	0
DC b	0	$-Fx-1/2qx^2$	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
ED b	0	0	0	0	0	0	0+0	0
EA b	0	0	0	0	0	0	0+0	0
AE b	0	0	0	0	0	0	0+0	0
BF b	$-x/b$	$-3/2Fb+Fx-1/2qx^2$	$-Fb/EJ$	$3/2Fx-Fx^2/b+1/2qx^3/b$	$Fx/EJ$	$x^2/b^2$	$(13/24+1/2)Fb^2/EJ$	$1/3Xb/EJ$
FB b	$1-x/b$	$Fb+1/2qx^2$	$Fb/EJ$	$Fb-Fx+1/2Fx^2/b-1/2qx^3/b$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$1/3Xb/EJ$	$1/3Xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3Xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3Xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2Xb/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2Xb/EJ$
CB 2b	0	$-3/2Fb$	0	0	0	0	0+0	0
BC 2b	0	$3/2Fb$	0	0	0	0	0+0	0
totali							$25/24Fb^2/EJ$	$8/3Xb/EJ$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (3/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

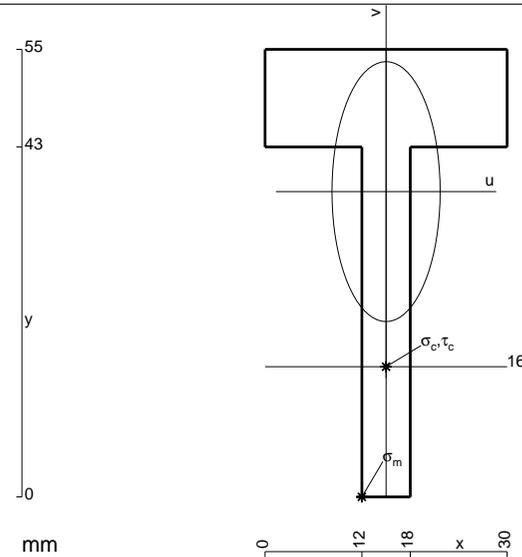
$$= [3/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (3/4 b - 1/3 b + 1/8 b) Fb 1/EJ + (1/2 b) \theta = 25/24 Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [x - 1/2 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b + 1/6 b - 1/8 b) Fb 1/EJ + (-b + 1/2 b) \theta = 25/24 Fb^2/EJ$$



$$A = 618. \text{ mm}^2$$

$$J_u = 157731. \text{ mm}^4$$

$$J_v = 27774. \text{ mm}^4$$

$$y_g = 37.52 \text{ mm}$$

$$T_y = -1620. \text{ N}$$

$$M_x = 959850. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -37.52 \text{ mm}$$

$$\sigma_m = -Mv/J_u = 228.3 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 16. \text{ mm}$$

$$v_c = -21.52 \text{ mm}$$

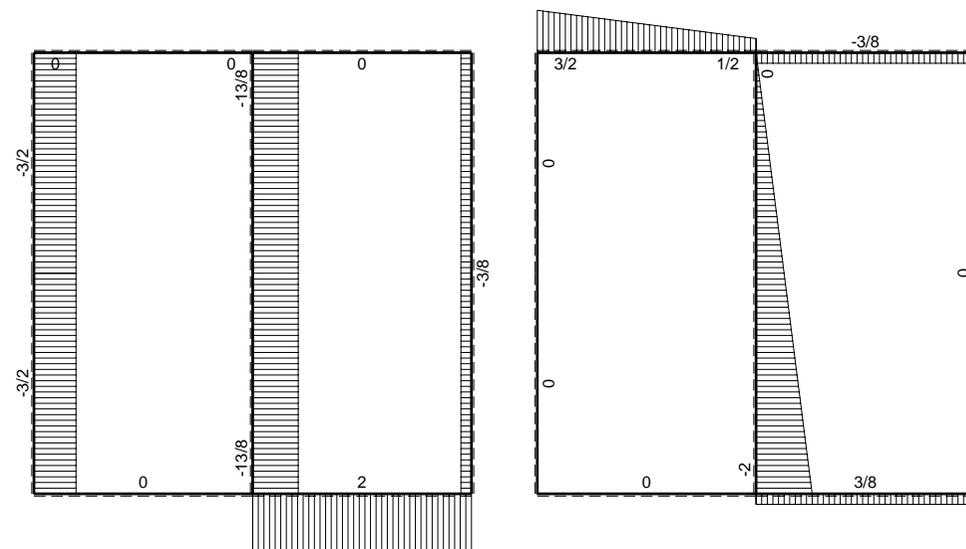
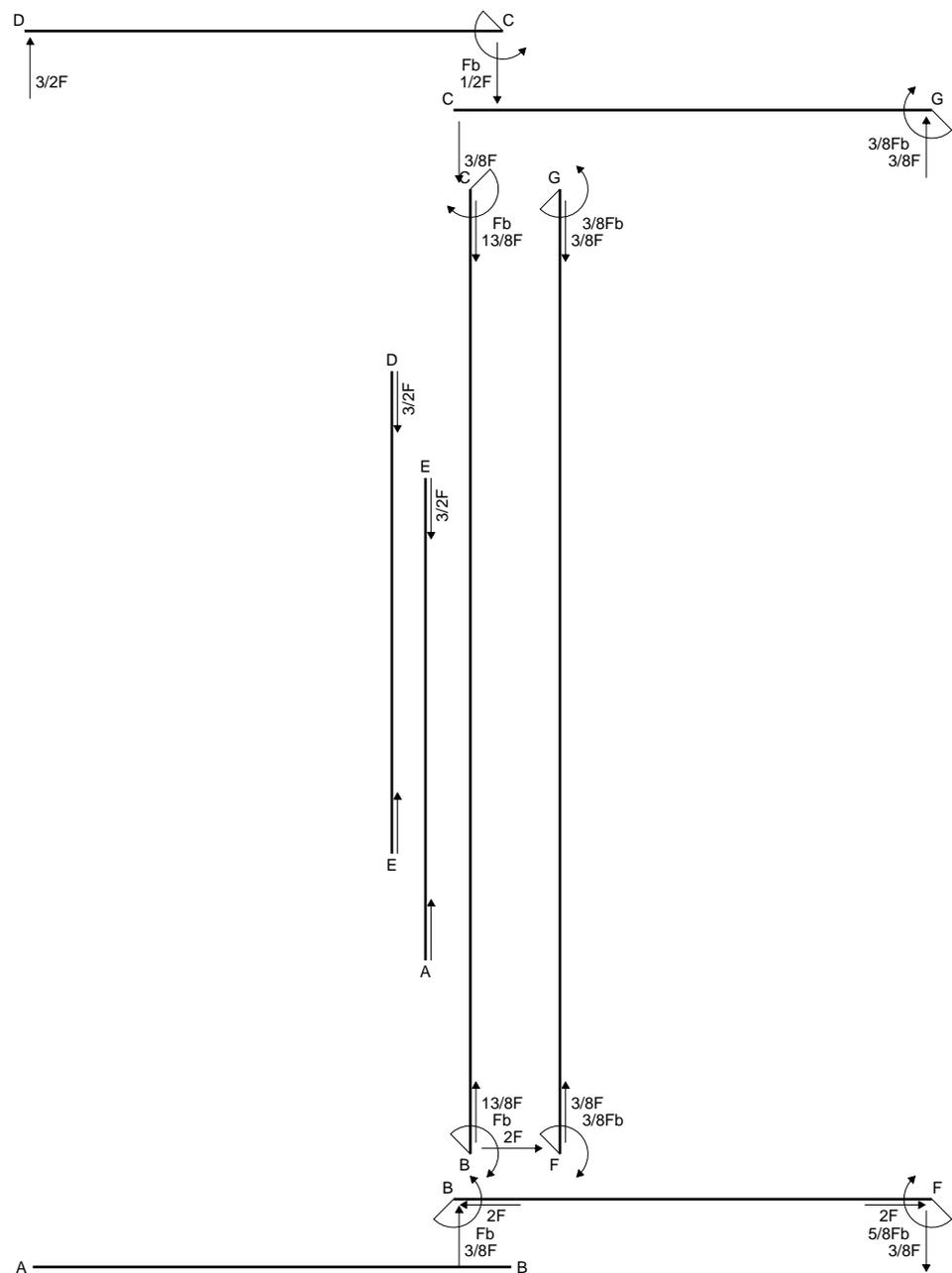
$$\sigma_c = -Mv/J_u = 131. \text{ N/mm}^2$$

$$\tau_c = 4.851 \text{ N/mm}^2$$

$$\sigma_0 = \sqrt{\sigma^2 + 3\tau^2} = 131.2 \text{ N/mm}^2$$

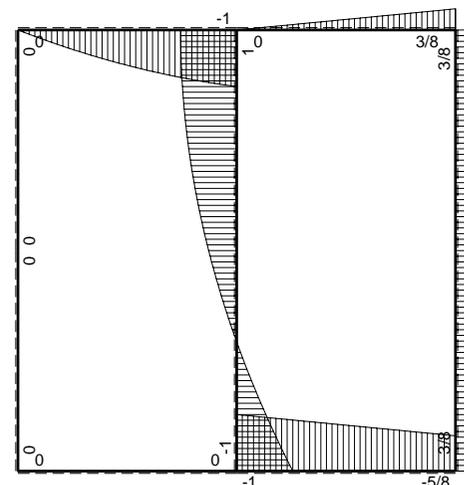
$$S = 2834. \text{ mm}^3$$





← ⊕ → F

↑ ⊕ ↓ F



⊕ ⊖ F<sub>b</sub>



$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

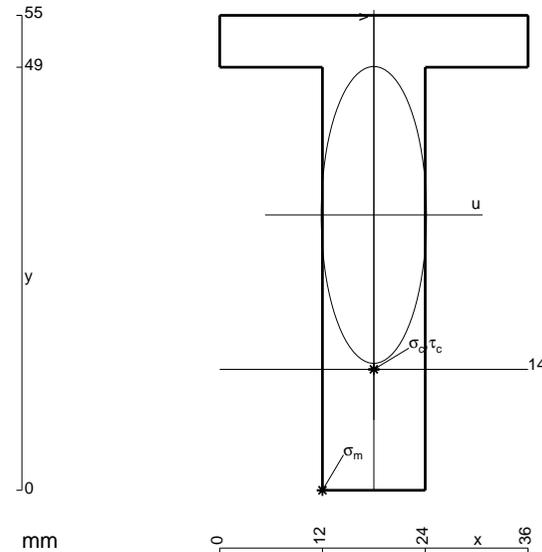
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



$$A = 804. \text{ mm}^2$$

$$J_u = 237762. \text{ mm}^4$$

$$J_v = 30384. \text{ mm}^4$$

$$y_g = 31.89 \text{ mm}$$

$$N = -3429. \text{ N}$$

$$T_y = -4220. \text{ N}$$

$$M_x = -1751300. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -6. \text{ mm}$$

$$v_m = -31.89 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -239.1 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 14. \text{ mm}$$

$$v_c = -17.89 \text{ mm}$$

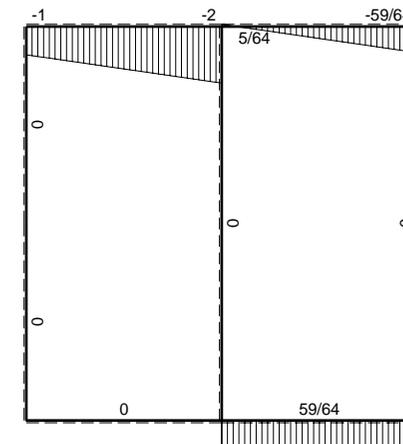
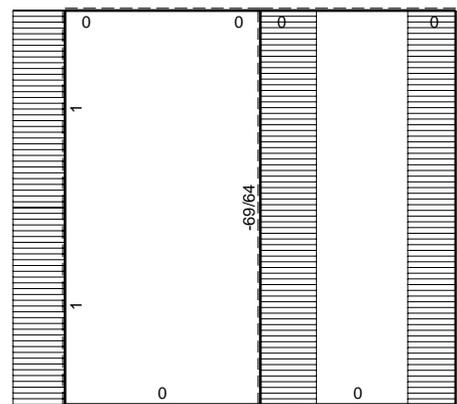
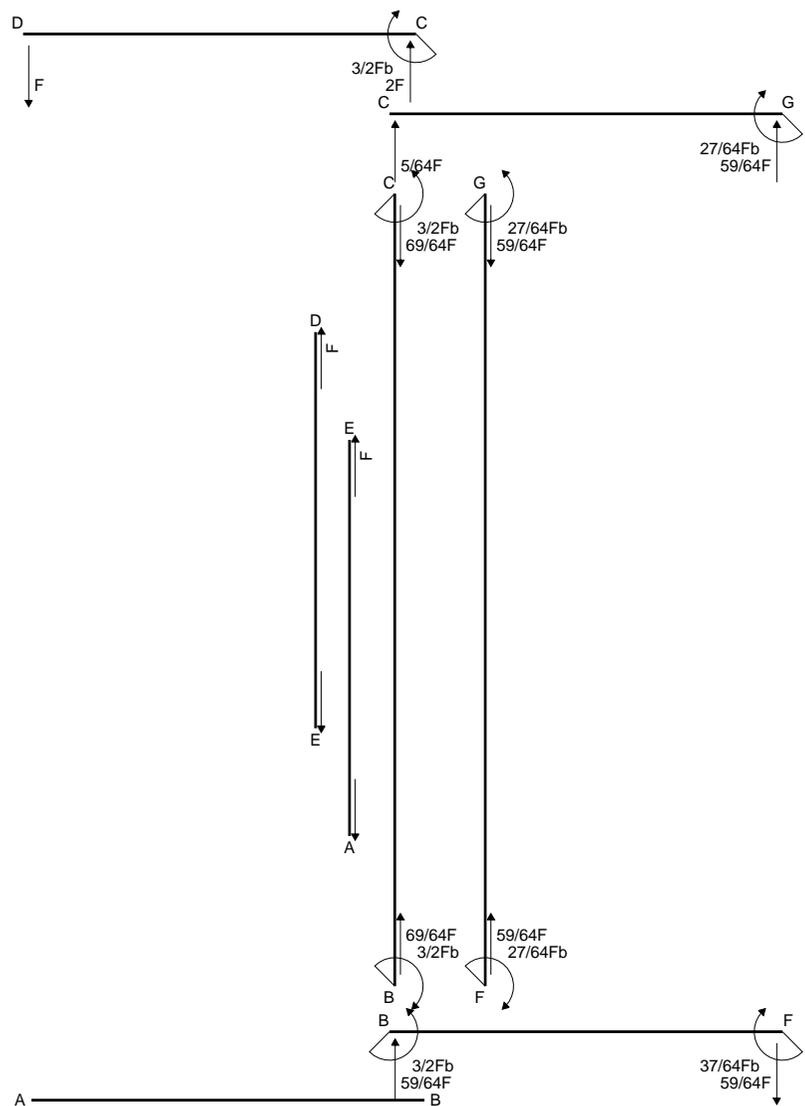
$$\sigma_c = N/A - Mv/J_u = -136. \text{ N/mm}^2$$

$$\tau_c = 6.184 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 136.4 \text{ N/mm}^2$$

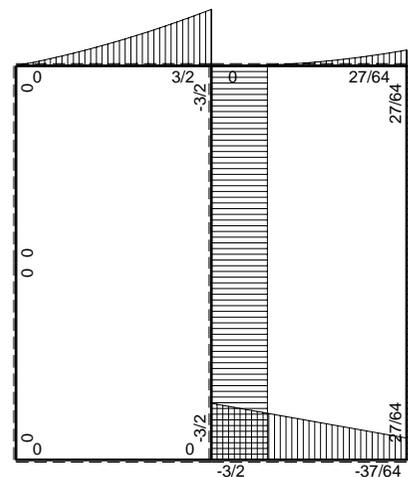
$$S = 4181. \text{ mm}^3$$





← ⊕ → F

↑ ⊕ ↓ F



⊕ F<sub>b</sub>



$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{xo} = \int_0^b (3/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

$$= [3/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (3/4 b - 1/6 b) Fb 1/EJ + (1/2 b) \theta = 13/12 Fb^2/EJ$$

$$L_{FB}^{xo} = \int_0^b (1 - 1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [x - 1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

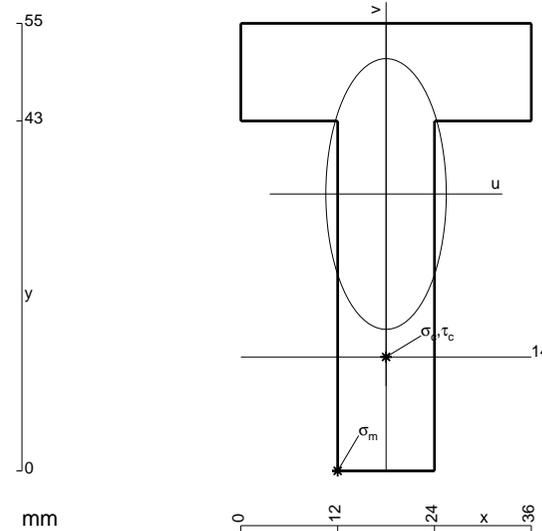
$$= (b - 1/4 b - 1/6 b) Fb 1/EJ + (-b + 1/2 b) \theta = 13/12 Fb^2/EJ$$

$$L_{GC}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{CG}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$



$$A = 948. \text{ mm}^2$$

$$J_u = 262515. \text{ mm}^4$$

$$J_v = 52848. \text{ mm}^4$$

$$y_g = 34.03 \text{ mm}$$

$$T_y = -4660. \text{ N}$$

$$M_x = 1537800. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -6. \text{ mm}$$

$$v_m = -34.03 \text{ mm}$$

$$\sigma_m = -Mv/J_u = 199.4 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 14. \text{ mm}$$

$$v_c = -20.03 \text{ mm}$$

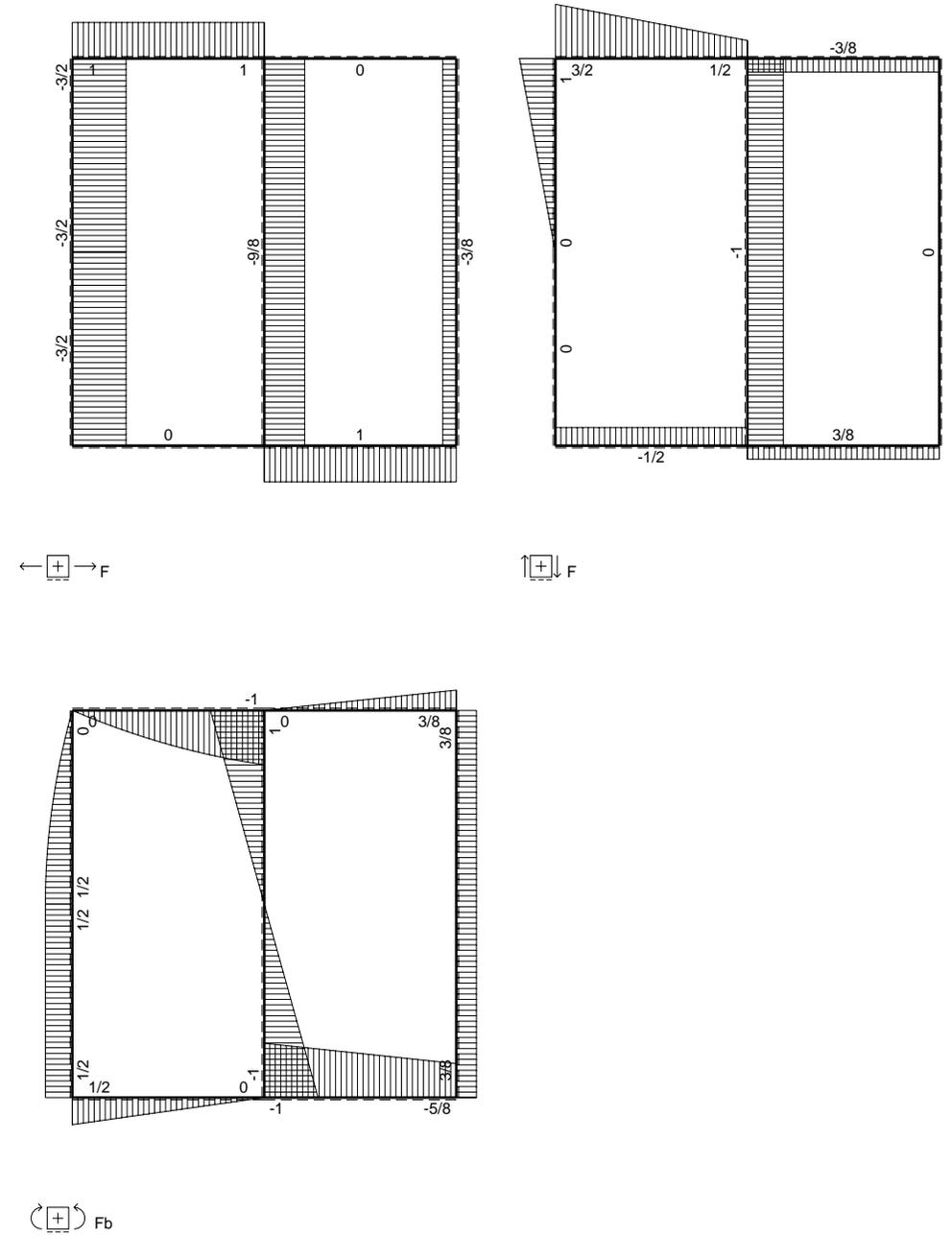
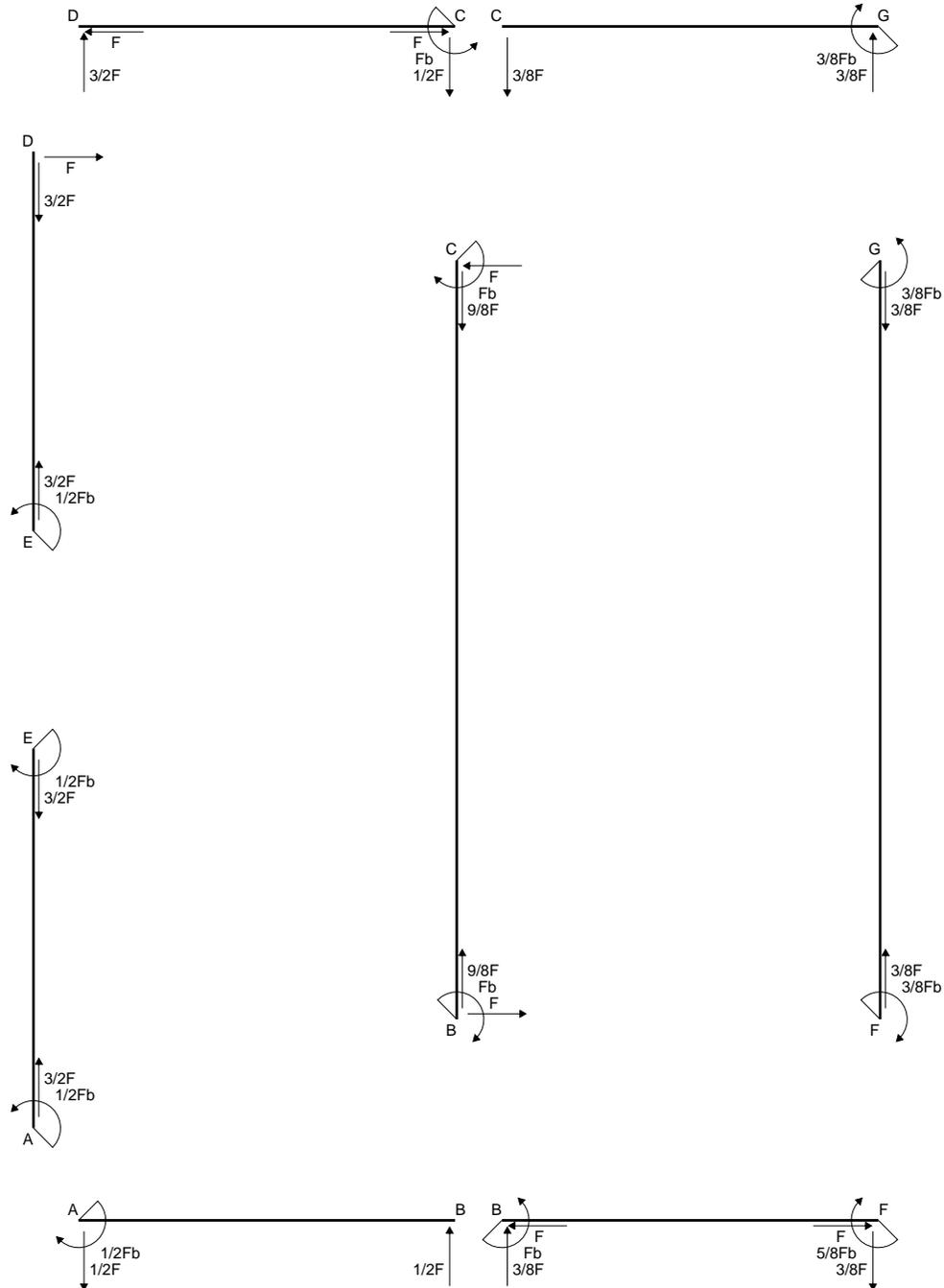
$$\sigma_c = -Mv/J_u = 117.3 \text{ N/mm}^2$$

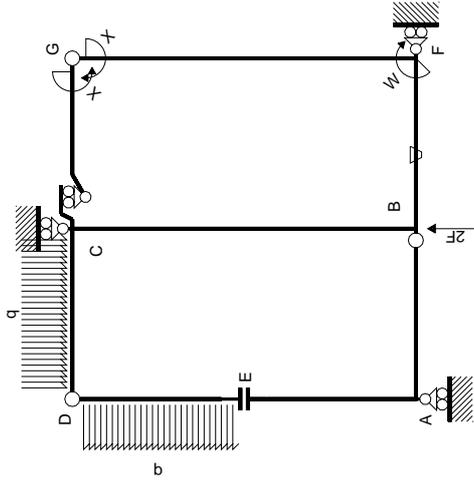
$$\tau_c = 6.718 \text{ N/mm}^2$$

$$\sigma_o = \sqrt{\sigma^2 + 3\tau^2} = 117.9 \text{ N/mm}^2$$

$$S = 4541. \text{ mm}^3$$

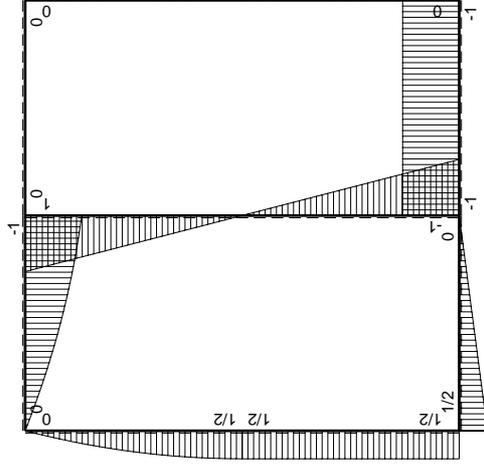






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati

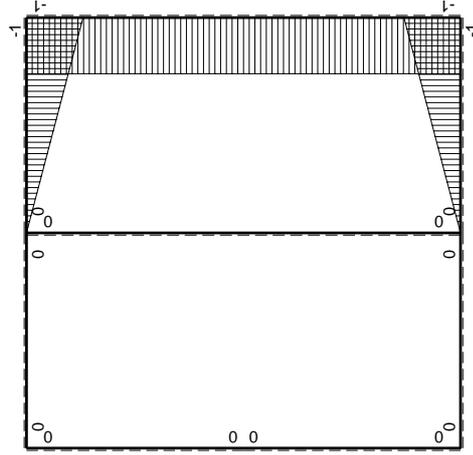


Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\leftarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	0	$1/2Fb-1/2Fx$	0	0	0	0	0+0	0
BA b	0	$-1/2Fx$	0	0	0	0	0+0	0
CD b	0	$-b+1/2Fx+1/2qx^2$	0	0	0	0	0+0	0
DC b	0	$3/2Fx-1/2qx^2$	0	0	0	0	0+0	0
DE b	0	$Fx-1/2qx^2$	0	0	0	0	0+0	0
ED b	0	$-1/2Fb+1/2qx^2$	0	0	0	0	0+0	0
EA b	0	$1/2Fb$	0	0	0	0	0+0	0
AE b	0	$-1/2Fb$	0	0	0	0	0+0	0
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FBB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb-Fx$	$Fb/EJ-Fx/EJ$	$1-2x/b+x^2/b^2$	$1/3xb/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2xb/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2xb/EJ$
CB 2b	0	$Fb-Fx$	0	0	0	0	0+0	0
BC 2b	0	$Fb-Fx$	0	0	0	0	0+0	0
totali								$Fb^2/EJ$
								$8/3xb/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica



$M_x$  flessione da iperstatica  $X=1$

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

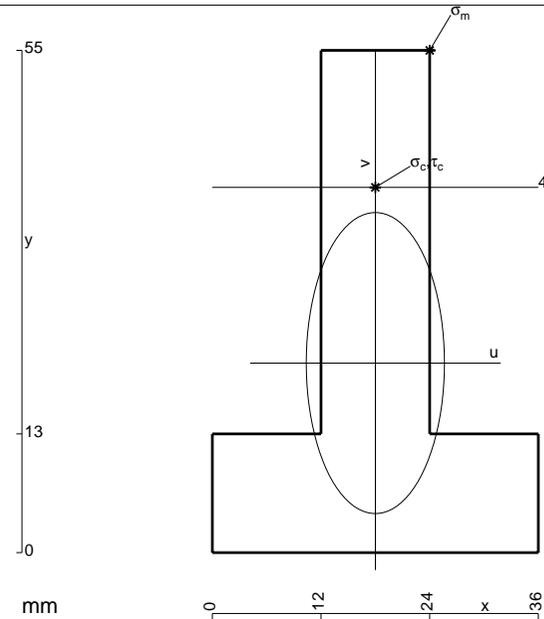
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

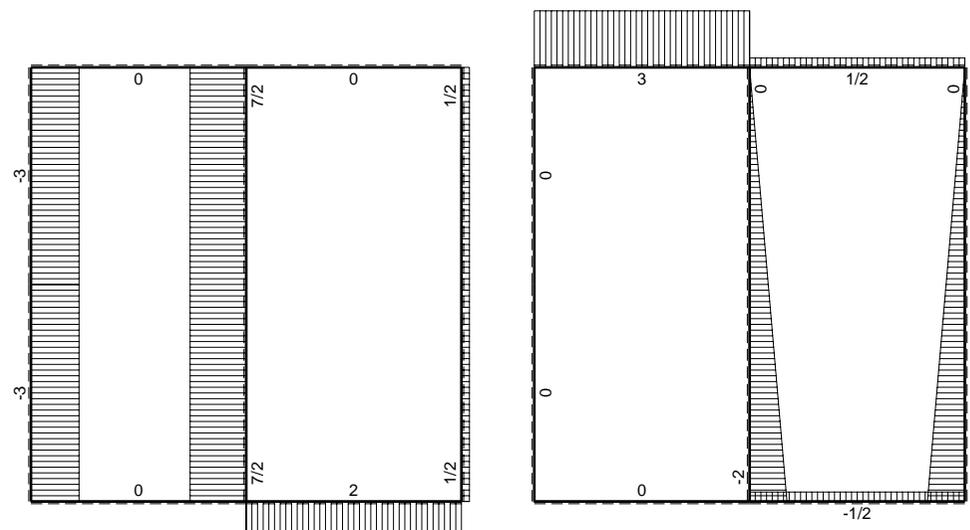
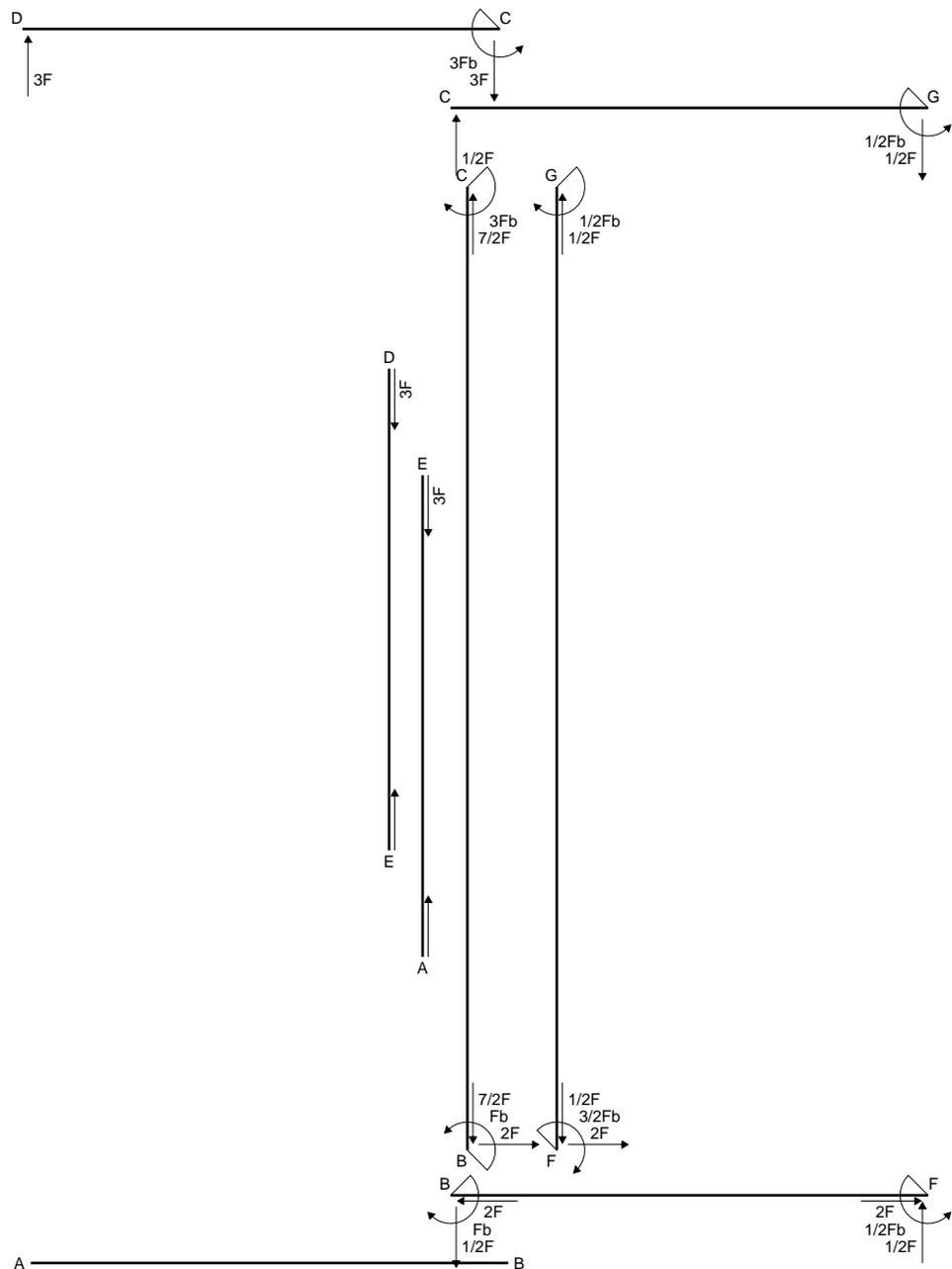
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



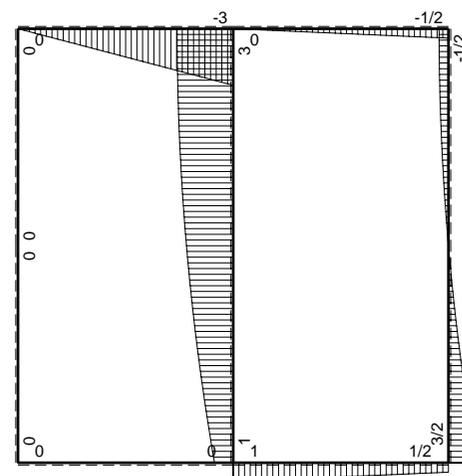
- A = 972. mm<sup>2</sup>
- J<sub>u</sub> = 264196. mm<sup>4</sup>
- J<sub>v</sub> = 56592. mm<sup>4</sup>
- y<sub>g</sub> = 20.76 mm
- N = -3724. N
- T<sub>y</sub> = -3310. N
- M<sub>x</sub> = 1588800. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 55. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 34.24 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = -209.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 40. mm
- v<sub>c</sub> = 19.24 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = -119.5 N/mm<sup>2</sup>
- τ<sub>c</sub> = 5.025 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 119.9 N/mm<sup>2</sup>
- S = 4813. mm<sup>3</sup>





← ⊕ → F

↑ ⊕ ↓ F



⊕ ⊕ F<sub>b</sub>



$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x\theta} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x\theta} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

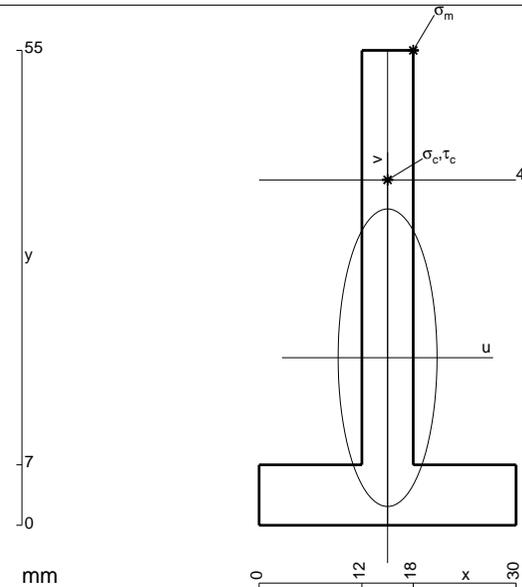
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x\theta} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

$$L_{GF}^{x\theta} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



$$A = 498. \text{ mm}^2$$

$$J_u = 147997. \text{ mm}^4$$

$$J_v = 16614. \text{ mm}^4$$

$$y_g = 19.4 \text{ mm}$$

$$T_y = 1740. \text{ N}$$

$$M_x = -904800. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$y_m = 55. \text{ mm}$$

$$u_m = 3. \text{ mm}$$

$$v_m = 35.6 \text{ mm}$$

$$\sigma_m = -Mv/J_u = 217.6 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 40. \text{ mm}$$

$$v_c = 20.6 \text{ mm}$$

$$\sigma_c = -Mv/J_u = 125.9 \text{ N/mm}^2$$

$$\tau_c = 4.955 \text{ N/mm}^2$$

$$\sigma_\varrho = \sqrt{\sigma^2 + 3\tau^2} = 126.2 \text{ N/mm}^2$$

$$S = 2529. \text{ mm}^3$$







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x\theta} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x\theta} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

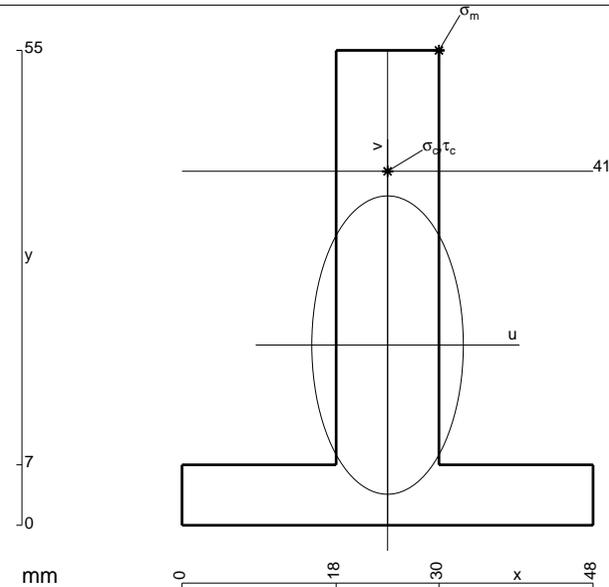
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x\theta} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

$$L_{GF}^{x\theta} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

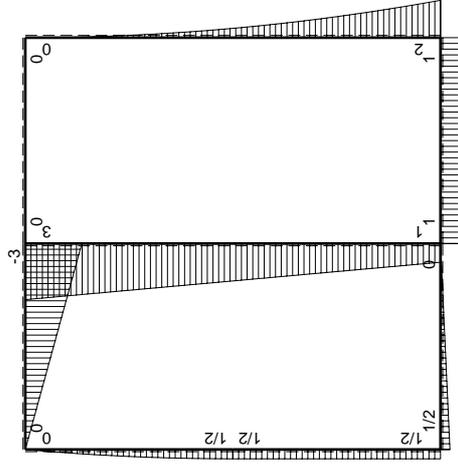
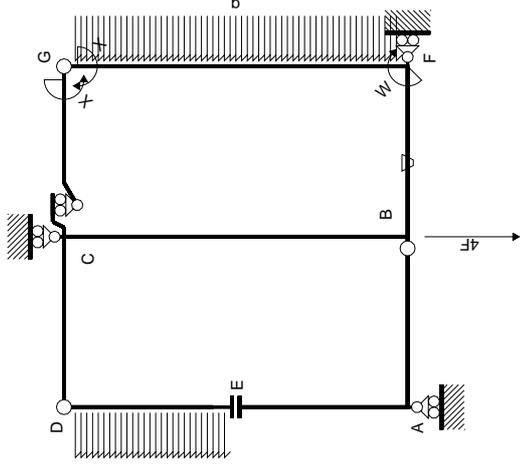
$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



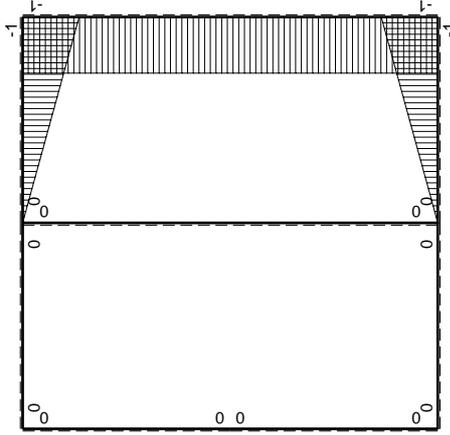
$A = 912. \text{ mm}^2$   
 $J_u = 272448. \text{ mm}^4$   
 $J_v = 71424. \text{ mm}^4$   
 $y_g = 20.87 \text{ mm}$   
 $T_y = 3220. \text{ N}$   
 $M_x = -1835400. \text{ Nmm}$   
 $x_m = 30. \text{ mm}$   
 $y_m = 55. \text{ mm}$   
 $u_m = 6. \text{ mm}$   
 $v_m = 34.13 \text{ mm}$   
 $\sigma_m = -Mv/J_u = 229.9 \text{ N/mm}^2$   
 $x_c = 24. \text{ mm}$   
 $y_c = 41. \text{ mm}$   
 $v_c = 20.13 \text{ mm}$   
 $\sigma_c = -Mv/J_u = 135.6 \text{ N/mm}^2$   
 $\tau_c = 4.489 \text{ N/mm}^2$   
 $\sigma_\varphi = \sqrt{\sigma^2 + 3\tau^2} = 135.8 \text{ N/mm}^2$   
 $S = 4558. \text{ mm}^3$







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica X=W <sub>gc</sub>		M <sup>0</sup> (x)		M <sup>x</sup> (x)		θ		M <sup>x</sup> M <sub>0</sub>		M <sup>x</sup> θ		M <sup>x</sup> M <sub>x</sub>		∫M <sup>x</sup> (M <sub>0</sub> /EJ+θ)dx		∫M <sup>x</sup> M <sub>x</sub> /EJdx	
AB b	0	1/2Fb-1/2Fx	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BA b	0	-1/2Fx	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CD b	0	-3Fb+3Fx	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DC b	0	3Fx	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DE b	0	Fx-1/2qx <sup>2</sup>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ED b	0	-1/2Fb+1/2qx <sup>2</sup>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EA b	0	1/2Fb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AE b	0	-1/2Fb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BF b	-x/b	Fb	-Fb/EJ	-Fb/EJ	-Fx	Fx/EJ	x <sup>2</sup> /b <sup>2</sup>	-1/2+1/2)Fb <sup>2</sup> /EJ	1/3xb/EJ	0+0	0	0	0	0	0	0	0
FB b	1-x/b	-Fb	Fb/EJ	-Fb+Fx	Fb/EJ-Fx/EJ	Fb/EJ-Fx/EJ	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	(-1/2+1/2)Fb <sup>2</sup> /EJ	1/3xb/EJ	0+0	0	0	0	0	0	0	0
GC b	-1+x/b	0	0	0	0	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	0+0	1/3xb/EJ	0+0	0	0	0	0	0	0	0
CG b	x/b	0	0	0	0	0	x <sup>2</sup> /b <sup>2</sup>	0+0	1/3xb/EJ	0+0	0	0	0	0	0	0	0
FG 2b	-1	2Fb-2Fx+1/2qx <sup>2</sup>	0	-2Fb+2Fx-1/2Fx <sup>2</sup> /b	0	0	1	(-4/3+0)Fb <sup>2</sup> /EJ	2xb/EJ	0+0	0	0	0	0	0	0	0
GF 2b	1	-1/2qx <sup>2</sup>	0	-1/2Fx <sup>2</sup> /b	0	0	1	(-4/3+0)Fb <sup>2</sup> /EJ	2xb/EJ	0+0	0	0	0	0	0	0	0
CB 2b	0	3Fb-Fx	0	0	0	0	0	0+0	8/3xb/EJ	0+0	0	0	0	0	0	0	0
BC 2b	0	-Fb-Fx	0	0	0	0	0	0+0	8/3xb/EJ	0+0	0	0	0	0	0	0	0
totali																	
		iperstatica X=W <sub>gc</sub>															

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x_0} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

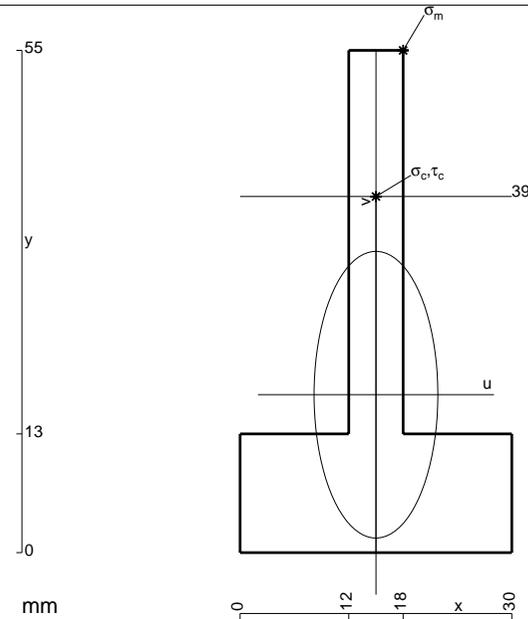
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x_0} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

$$L_{GF}^{x_0} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



$$A = 642. \text{ mm}^2$$

$$J_u = 158306. \text{ mm}^4$$

$$J_v = 30006. \text{ mm}^4$$

$$y_g = 17.29 \text{ mm}$$

$$N = 540. \text{ N}$$

$$T_y = 1620. \text{ N}$$

$$M_x = -988200. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$y_m = 55. \text{ mm}$$

$$u_m = 3. \text{ mm}$$

$$v_m = 37.71 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 236.2 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 39. \text{ mm}$$

$$v_c = 21.71 \text{ mm}$$

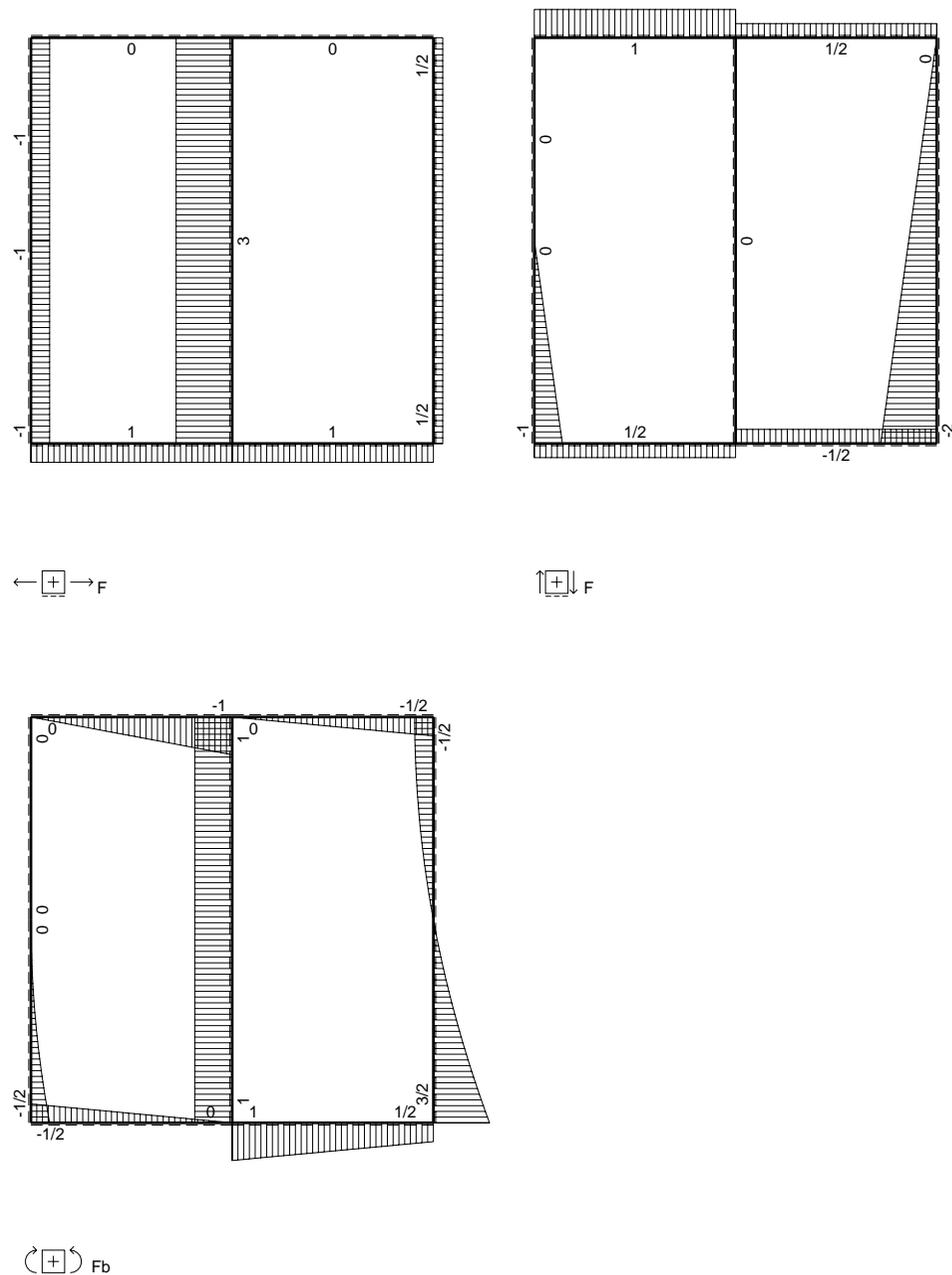
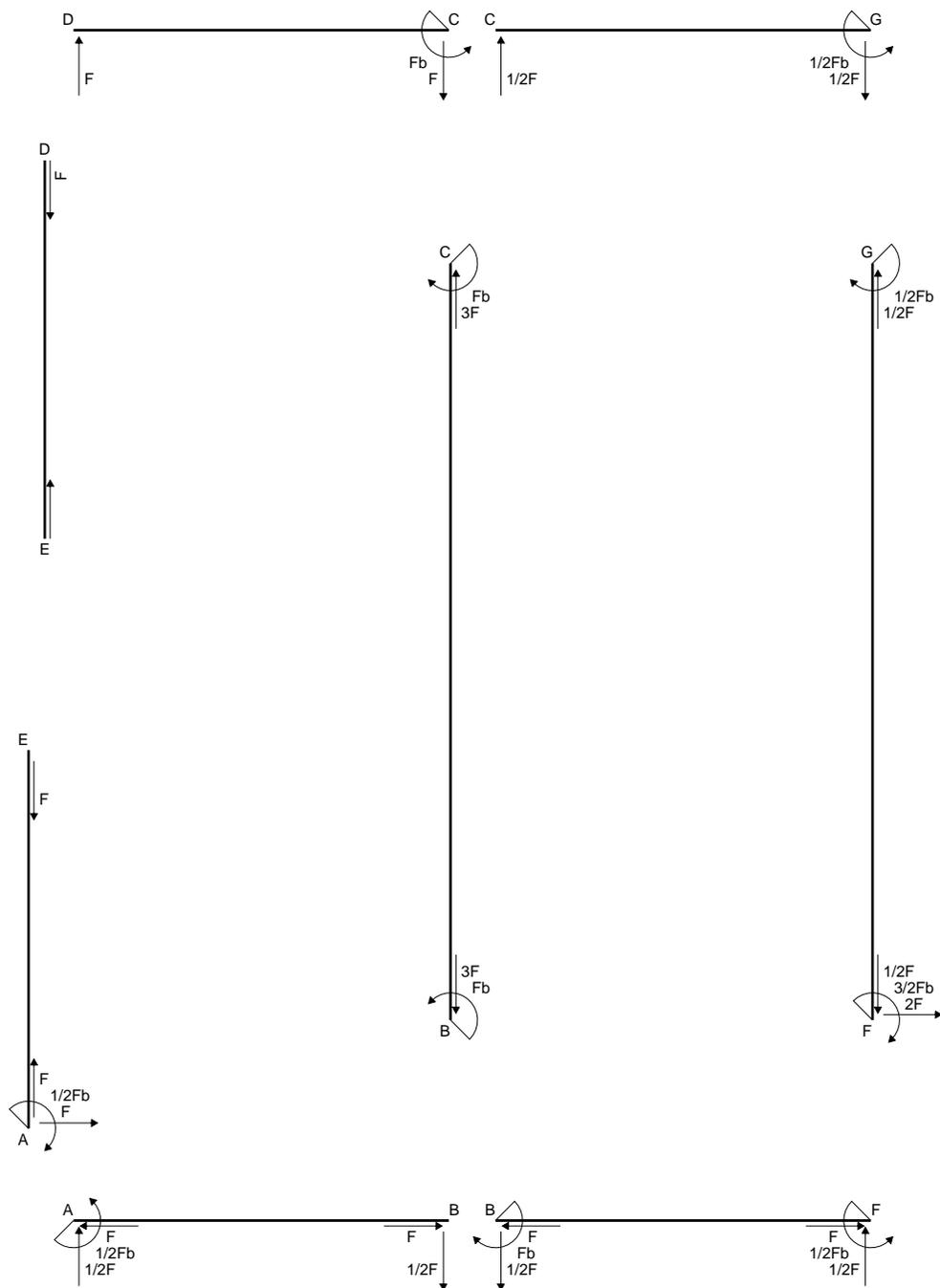
$$\sigma_c = N/A - Mv/J_u = 136.3 \text{ N/mm}^2$$

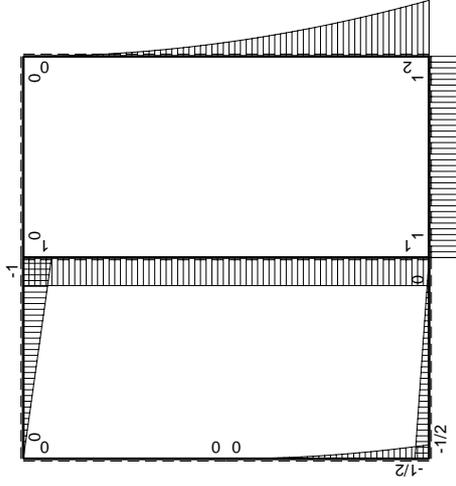
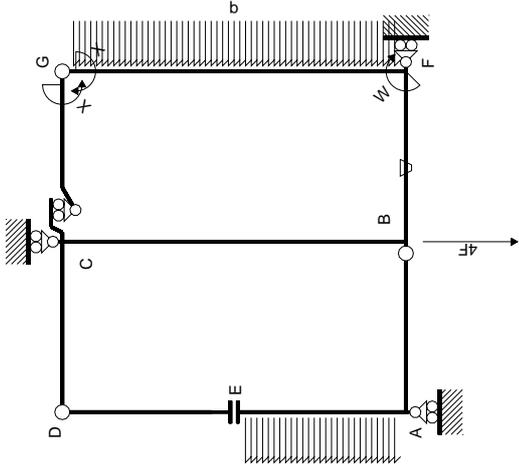
$$\tau_c = 4.864 \text{ N/mm}^2$$

$$\sigma_\varrho = \sqrt{\sigma^2 + 3\tau^2} = 136.6 \text{ N/mm}^2$$

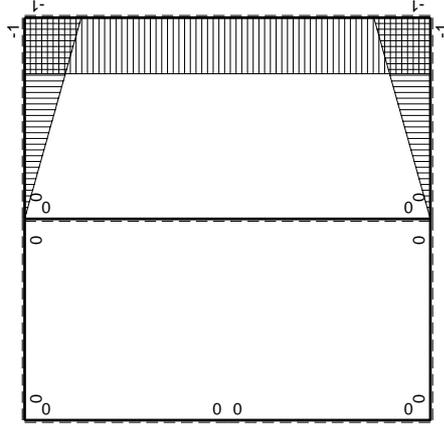
$$S = 2852. \text{ mm}^3$$







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\leftarrow$	$M(x)$	$M^0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / E dx$
AB b	0	$-1/2Fb + 1/2Fx$	0	0	0	0	0+0	0
BA b	0	$1/2Fx$	0	0	0	0	0+0	0
CD b	0	$-Fb + Fx$	0	0	0	0	0+0	0
DC b	0	$Fx$	0	0	0	0	0+0	0
ED b	0	0	0	0	0	0	0+0	0
EA b	0	$-1/2qx^2$	0	0	0	0	0+0	0
AE b	0	$1/2Fb - Fx + 1/2qx^2$	0	0	0	0	0+0	0
BF b	$-x/b$	$Fb$	$-Fb/EJ$	$-Fx$	$Fx/EJ$	$x^2/b^2$	$(-1/2 + 1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$-Fb$	$Fb/EJ$	$-Fb + Fx$	$Fb/EJ - Fx/EJ$	$1-2x/b + x^2/b^2$	$(-1/2 + 1/2)Fb^2/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b + x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	$2Fb - 2Fx + 1/2qx^2$	0	$-2Fb + 2Fx - 1/2Fx^2/b$	0	1	$(-4/3 + 0)Fb^2/EJ$	$2xb/EJ$
GF 2b	1	$-1/2qx^2$	0	$-1/2Fx^2/b$	0	1	$(-4/3 + 0)Fb^2/EJ$	$2xb/EJ$
CB 2b	0	$Fb$	0	0	0	0	0+0	0
BC 2b	0	$-Fb$	0	0	0	0	0+0	0
totali							$-4/3Fb^2/EJ$	$8/3xb/EJ$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x_0} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

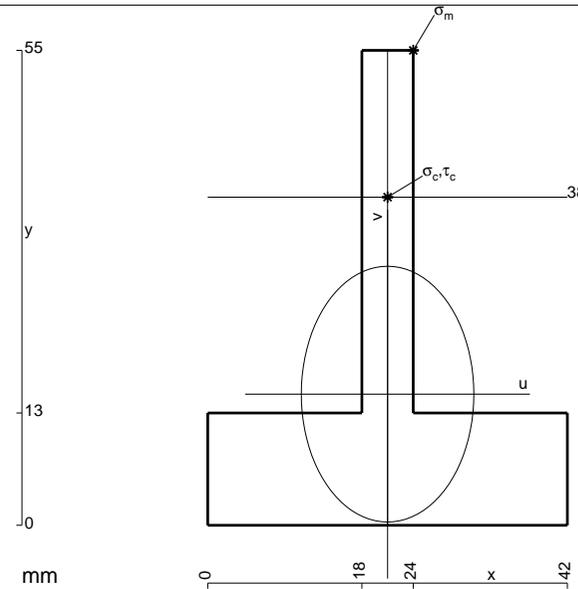
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x_0} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

$$L_{GF}^{x_0} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



$$A = 798. \text{ mm}^2$$

$$J_u = 175127. \text{ mm}^4$$

$$J_v = 81018. \text{ mm}^4$$

$$y_g = 15.18 \text{ mm}$$

$$T_y = 1330. \text{ N}$$

$$M_x = -877800. \text{ Nmm}$$

$$x_m = 24. \text{ mm}$$

$$y_m = 55. \text{ mm}$$

$$u_m = 3. \text{ mm}$$

$$v_m = 39.82 \text{ mm}$$

$$\sigma_m = -Mv/J_u = 199.6 \text{ N/mm}^2$$

$$x_c = 21. \text{ mm}$$

$$y_c = 38. \text{ mm}$$

$$v_c = 22.82 \text{ mm}$$

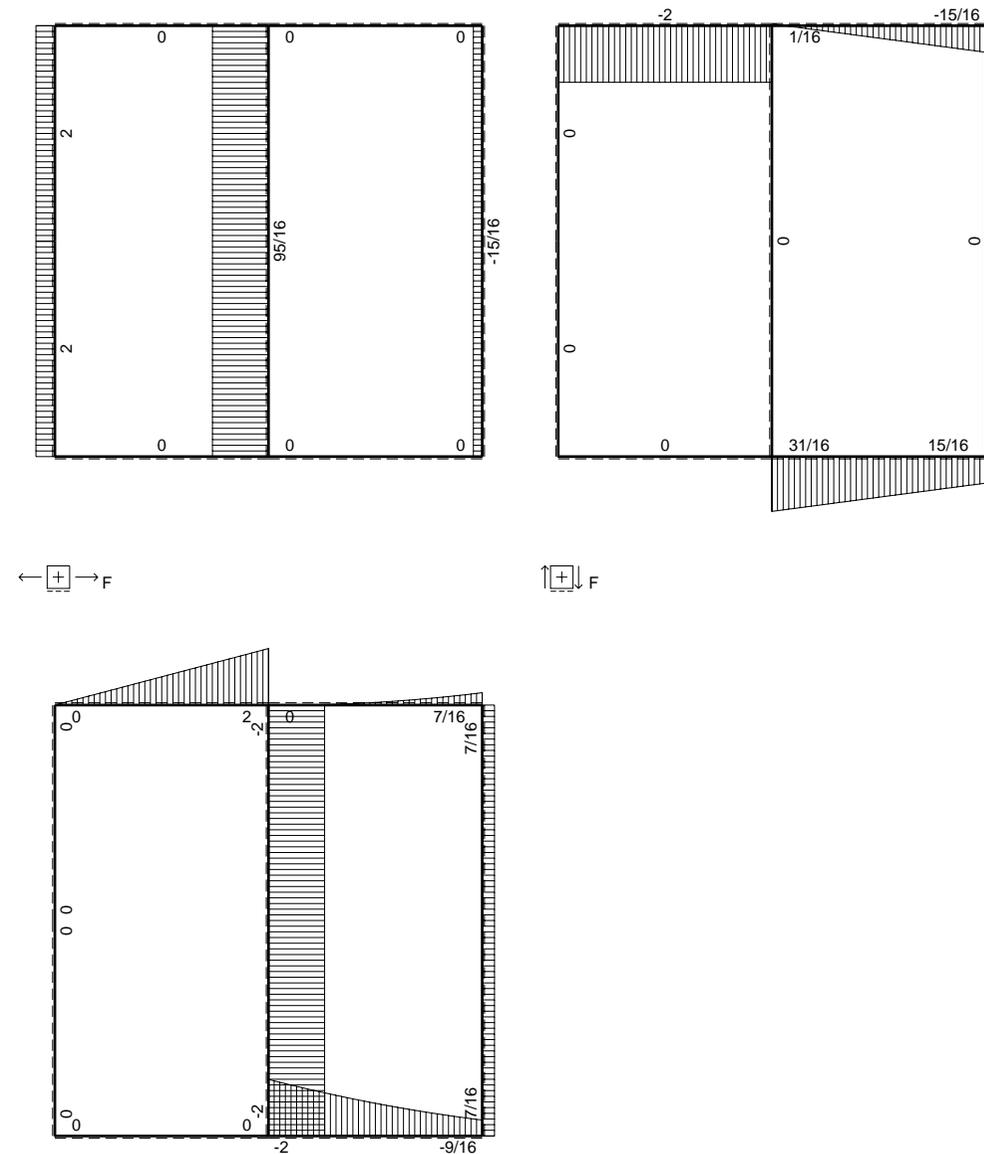
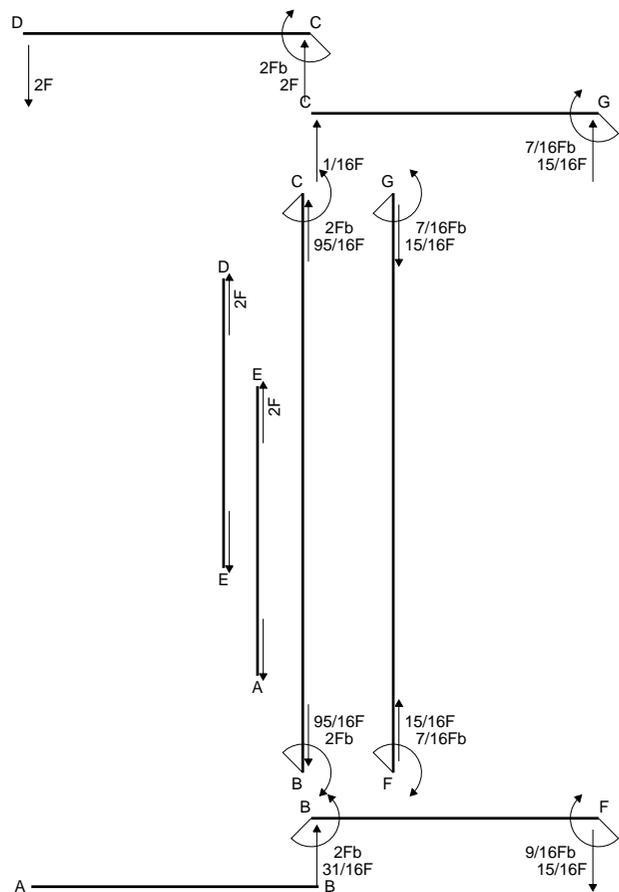
$$\sigma_c = -Mv/J_u = 114.4 \text{ N/mm}^2$$

$$\tau_c = 4.043 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 114.6 \text{ N/mm}^2$$

$$S = 3194. \text{ mm}^3$$







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{xo} = \int_0^b (2x/b - 3/2 x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

$$= [x^2/b - 1/2 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b + 1/8 b) Fb 1/EJ + (1/2 b) \theta = 9/8 Fb^2/EJ$$

$$L_{FB}^{xo} = \int_0^b (1 - 1/2 x/b - 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [x - 1/4 x^2/b - 1/8 x^4/b^3]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

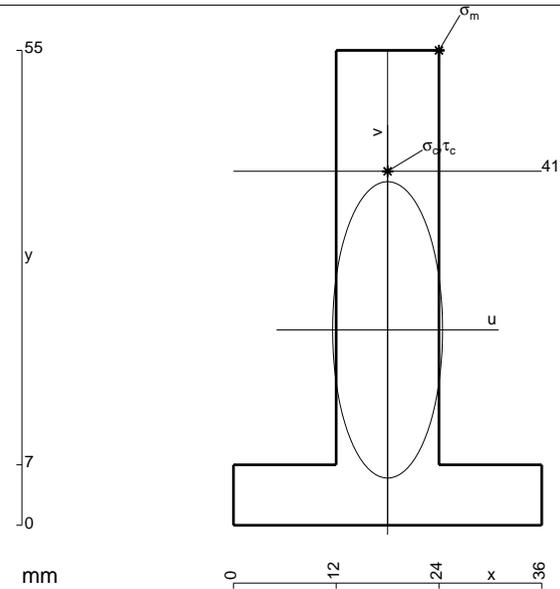
$$= (b - 1/4 b - 1/8 b) Fb 1/EJ + (-b + 1/2 b) \theta = 9/8 Fb^2/EJ$$

$$L_{GC}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{CG}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$



$$A = 828. \text{ mm}^2$$

$$J_u = 244195. \text{ mm}^4$$

$$J_v = 34128. \text{ mm}^4$$

$$y_g = 22.63 \text{ mm}$$

$$T_y = -2260. \text{ N}$$

$$M_x = 1582000. \text{ Nmm}$$

$$x_m = 24. \text{ mm}$$

$$y_m = 55. \text{ mm}$$

$$u_m = 6. \text{ mm}$$

$$v_m = 32.37 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -209.7 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 41. \text{ mm}$$

$$v_c = 18.37 \text{ mm}$$

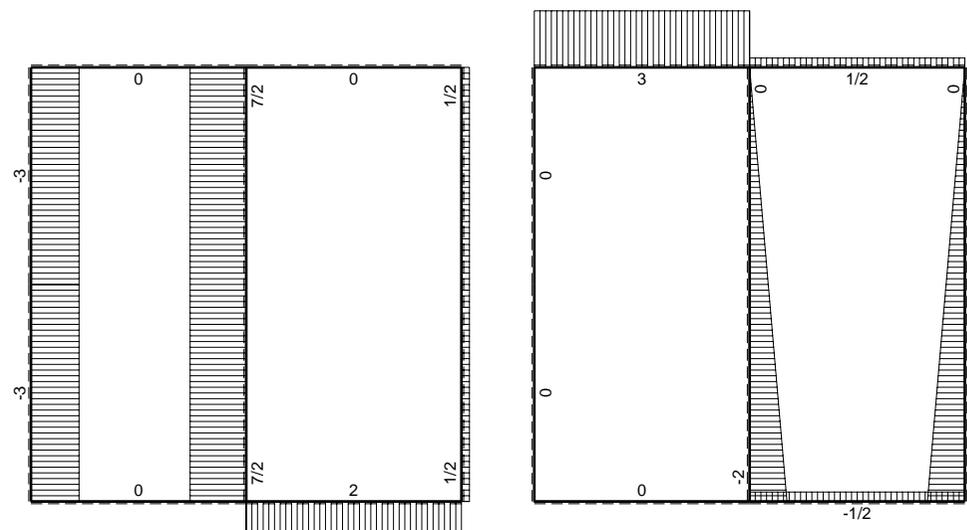
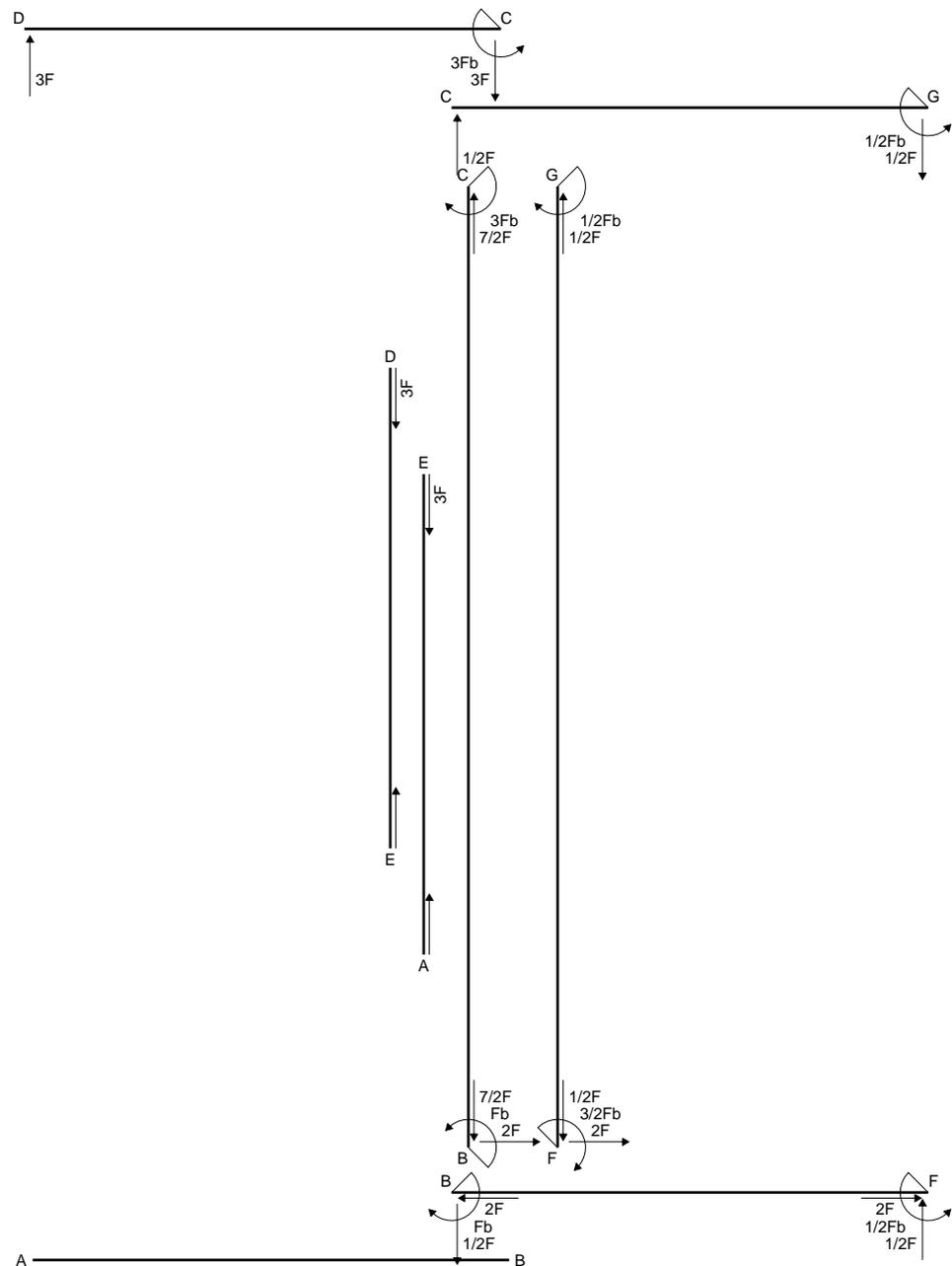
$$\sigma_c = -Mv/J_u = -119. \text{ N/mm}^2$$

$$\tau_c = 3.287 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 119.1 \text{ N/mm}^2$$

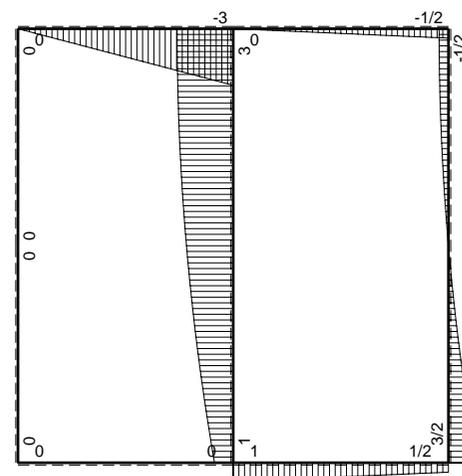
$$S = 4262. \text{ mm}^3$$





← ⊕ → F

↑ ⊕ ↓ F



⊕ ⊖ F<sub>b</sub>



$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x\theta} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x\theta} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

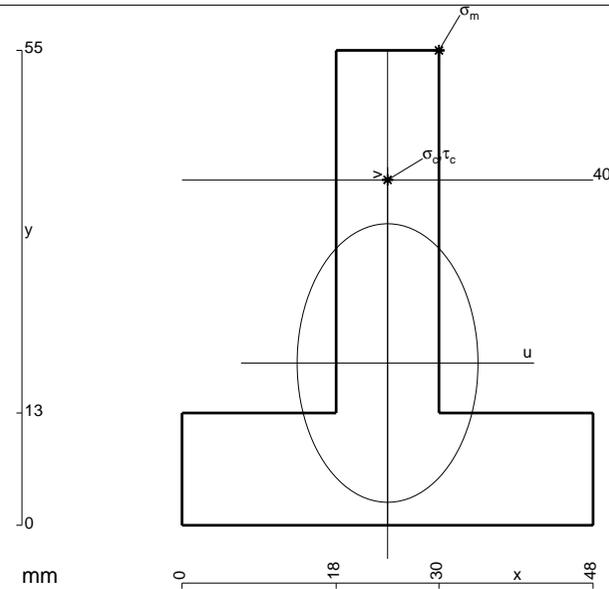
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x\theta} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

$$L_{GF}^{x\theta} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



$$A = 1128. \text{ mm}^2$$

$$J_u = 293725. \text{ mm}^4$$

$$J_v = 125856. \text{ mm}^4$$

$$y_g = 18.79 \text{ mm}$$

$$T_y = 2400. \text{ N}$$

$$M_x = -1776000. \text{ Nmm}$$

$$x_m = 30. \text{ mm}$$

$$y_m = 55. \text{ mm}$$

$$u_m = 6. \text{ mm}$$

$$v_m = 36.21 \text{ mm}$$

$$\sigma_m = -Mv/J_u = 219. \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 40. \text{ mm}$$

$$v_c = 21.21 \text{ mm}$$

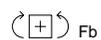
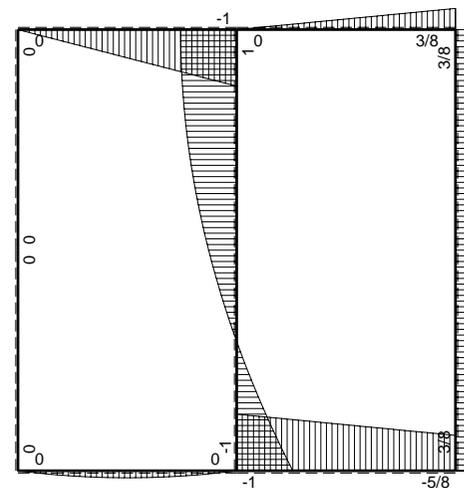
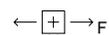
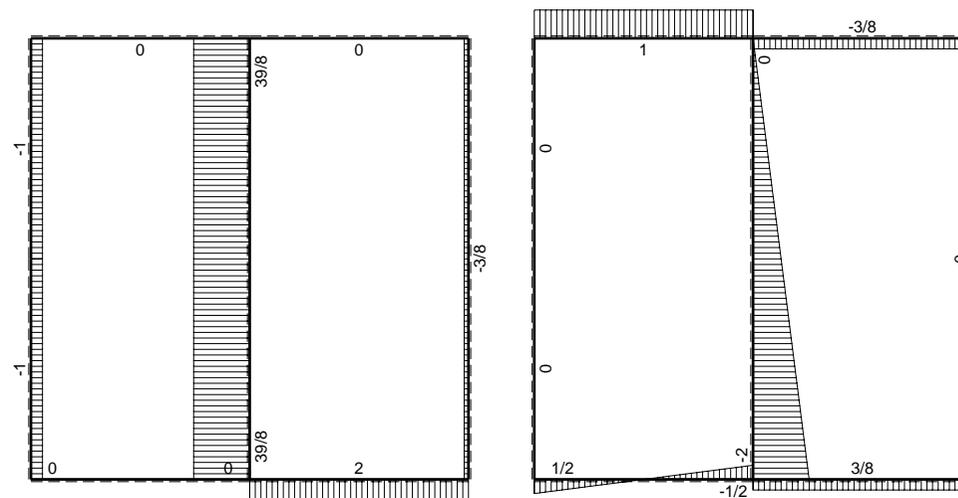
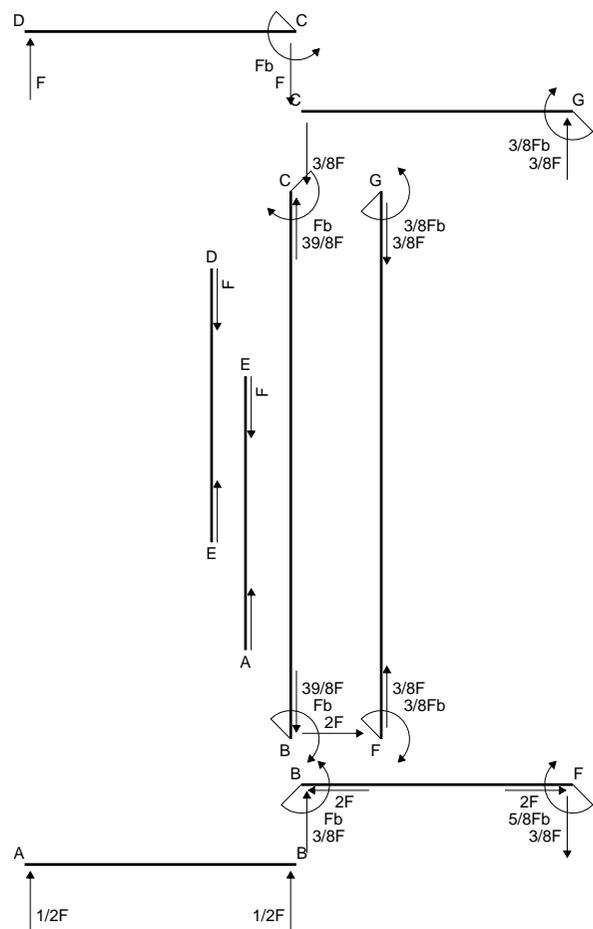
$$\sigma_c = -Mv/J_u = 128.3 \text{ N/mm}^2$$

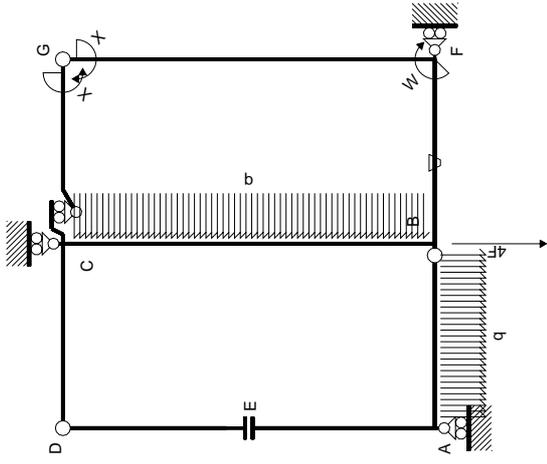
$$\tau_c = 3.519 \text{ N/mm}^2$$

$$\sigma_\varphi = \sqrt{\sigma^2 + 3\tau^2} = 128.4 \text{ N/mm}^2$$

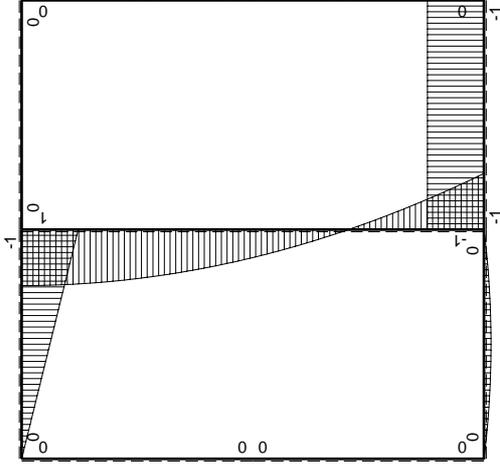
$$S = 5168. \text{ mm}^3$$



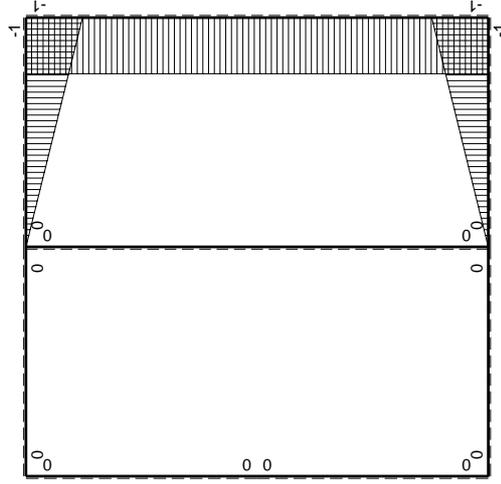




Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / EJ dx$
AB b	0	$1/2Fx - 1/2qx^2$	0	0	0	0	0+0	0
BA b	0	$-1/2Fx + 1/2qx^2$	0	0	0	0	0+0	0
CD b	0	$-Fb + Fx$	0	0	0	0	0+0	0
DC b	0	$Fx$	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
EA b	0	0	0	0	0	0	0+0	0
AF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb-Fx$	$Fb/EJ - Fx/EJ$	$1-2x/b+x^2/b^2$	$1/3xb/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2xb/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2xb/EJ$
CB 2b	0	$Fb - 1/2qx^2$	0	0	0	0	0+0	0
BC 2b	0	$Fb - 2Fx + 1/2qx^2$	0	0	0	0	0+0	0
totali								$8/3xb/EJ$
								$-3/8Fb$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

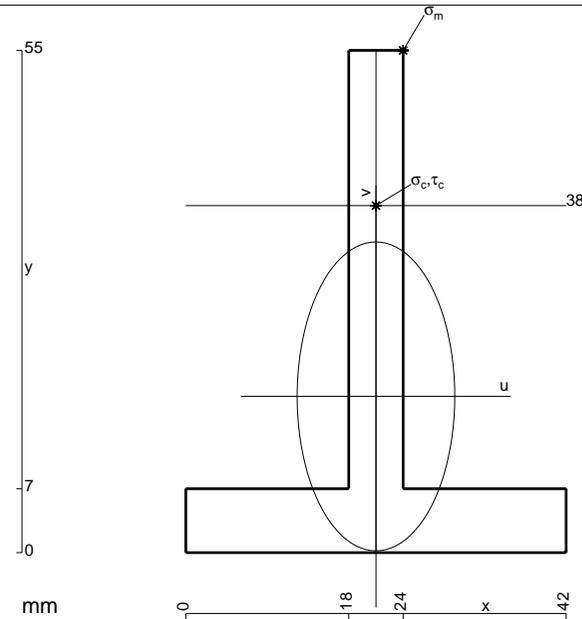
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



$$A = 582. \text{ mm}^2$$

$$J_u = 166519. \text{ mm}^4$$

$$J_v = 44082. \text{ mm}^4$$

$$y_g = 17.11 \text{ mm}$$

$$N = 5948. \text{ N}$$

$$T_y = -2440. \text{ N}$$

$$M_x = -963800. \text{ Nmm}$$

$$x_m = 24. \text{ mm}$$

$$y_m = 55. \text{ mm}$$

$$u_m = 3. \text{ mm}$$

$$v_m = 37.89 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 229.5 \text{ N/mm}^2$$

$$x_c = 21. \text{ mm}$$

$$y_c = 38. \text{ mm}$$

$$v_c = 20.89 \text{ mm}$$

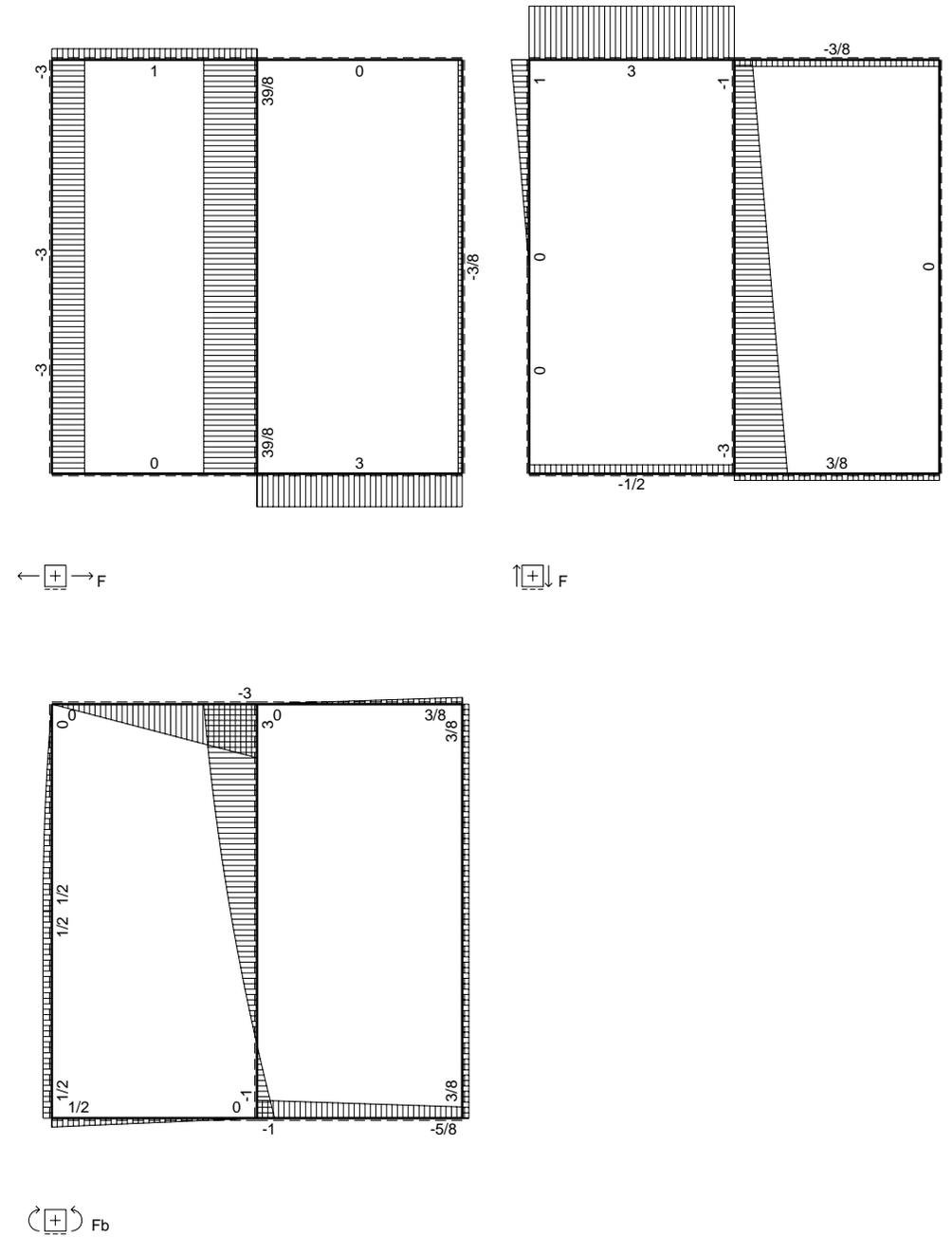
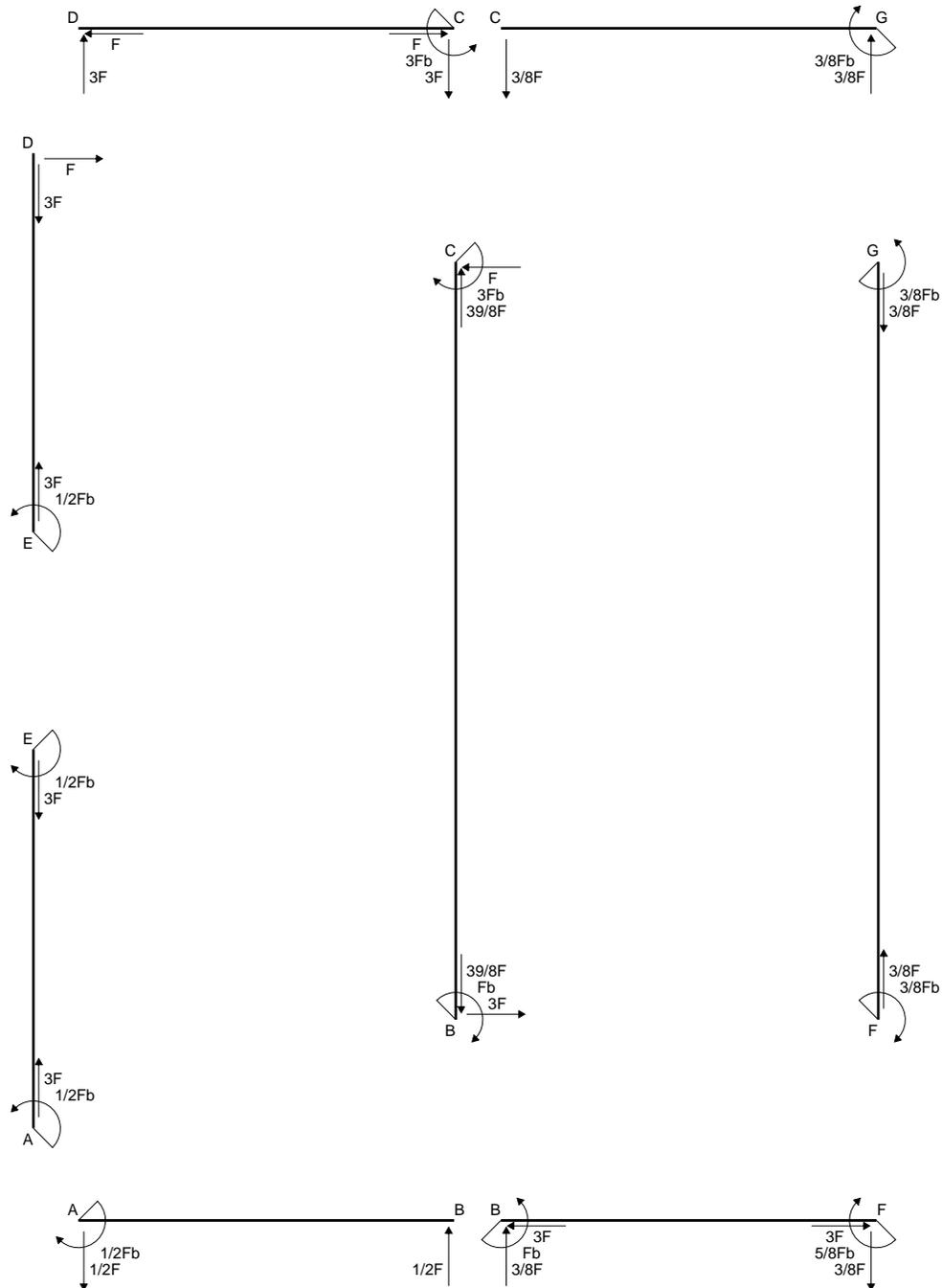
$$\sigma_c = N/A - Mv/J_u = 131.1 \text{ N/mm}^2$$

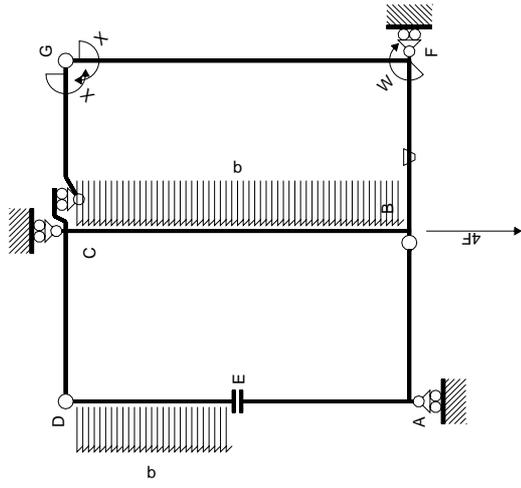
$$\tau_c = 7.321 \text{ N/mm}^2$$

$$\sigma_\varphi = \sqrt{\sigma^2 + 3\tau^2} = 131.8 \text{ N/mm}^2$$

$$S = 2998. \text{ mm}^3$$

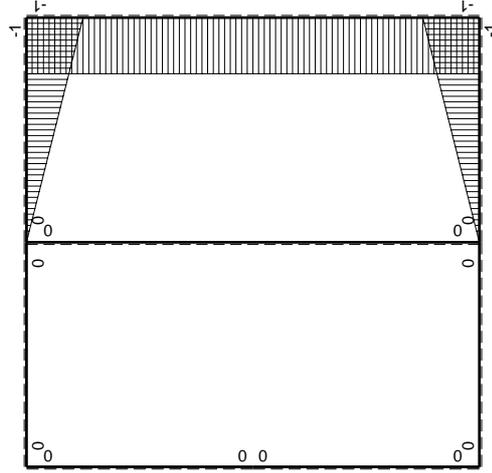
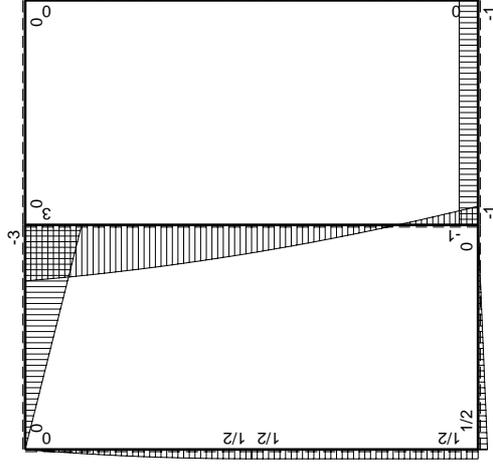






Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / EJ dx$
AB b	0	$1/2Fb - 1/2Fx$	0	0	0	0	0+0	0
BA b	0	$-1/2Fx$	0	0	0	0	0+0	0
CD b	0	$-3Fb + 3Fx$	0	0	0	0	0+0	0
DC b	0	$3Fx$	0	0	0	0	0+0	0
DE b	0	$Fx - 1/2qx^2$	0	0	0	0	0+0	0
ED b	0	$-1/2Fb + 1/2qx^2$	0	0	0	0	0+0	0
EA b	0	$1/2Fb$	0	0	0	0	0+0	0
AE b	0	$-1/2Fb$	0	0	0	0	0+0	0
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2 + 1/2)Fb^2/EJ$	$1/3x^3/EJ$
FB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb - Fx$	$Fb/EJ - Fx/EJ$	$1 - 2x/b + x^2/b^2$	$1/3x^3/EJ$	$1/3x^3/EJ$
GC b	$-1+x/b$	0	0	0	0	$1 - 2x/b + x^2/b^2$	0+0	$1/3x^3/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3x^3/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2x^2/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2x^2/EJ$
CB 2b	0	$3Fb - Fx - 1/2qx^2$	0	0	0	0	0+0	0
BC 2b	0	$Fb - 3Fx + 1/2qx^2$	0	0	0	0	0+0	0
totali								$8/3x^3/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

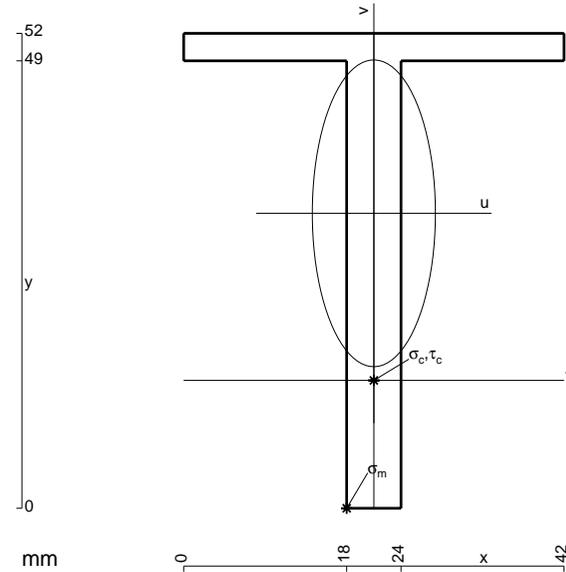
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

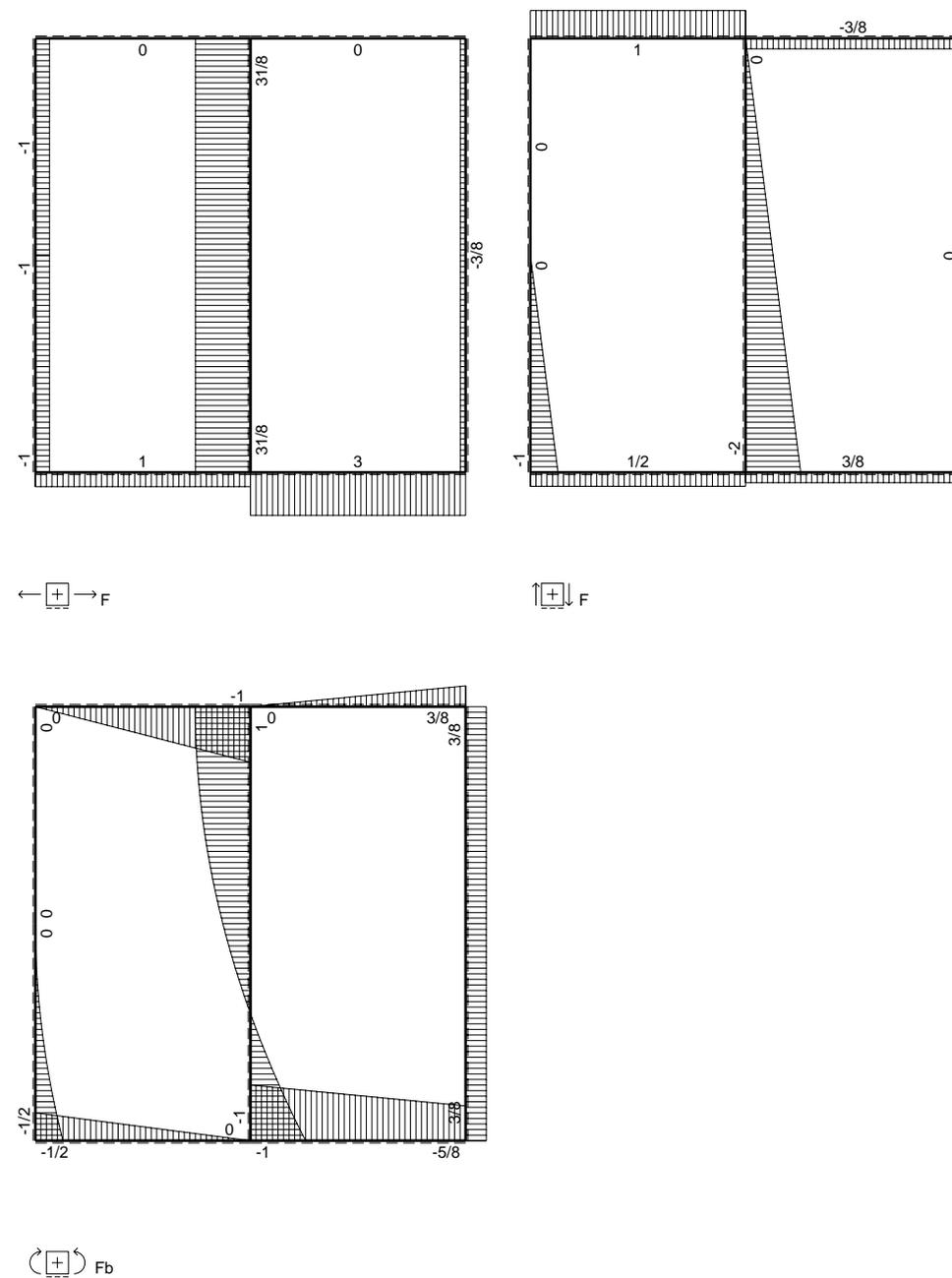
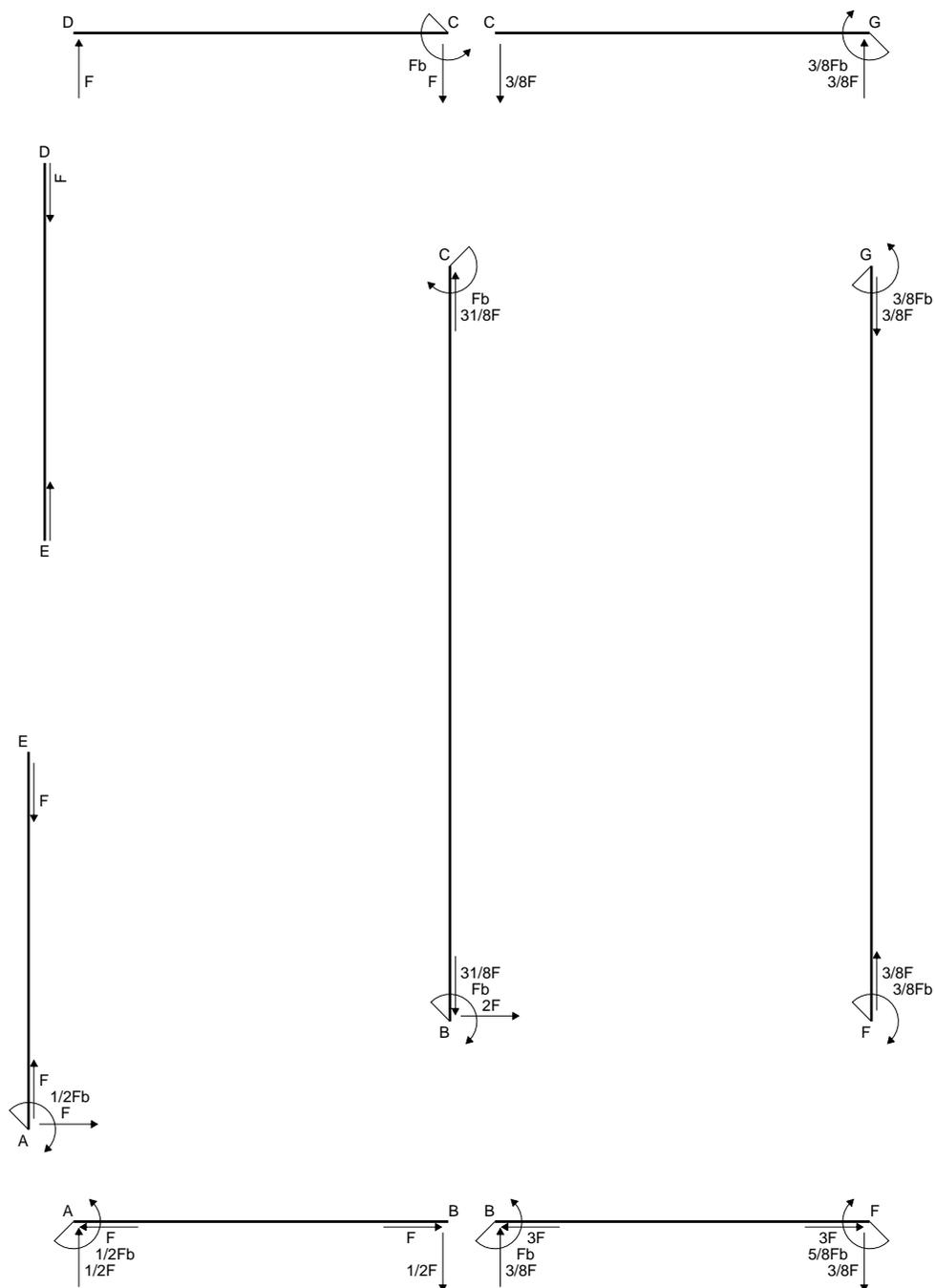
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



- A = 420. mm<sup>2</sup>
- J<sub>u</sub> = 118542. mm<sup>4</sup>
- J<sub>v</sub> = 19404. mm<sup>4</sup>
- y<sub>g</sub> = 32.3 mm
- N = 380. N
- T<sub>y</sub> = 1140. N
- M<sub>x</sub> = -877800. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -32.3 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = -238.3 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 14. mm
- v<sub>c</sub> = -18.3 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = -134.6 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.406 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 134.7 N/mm<sup>2</sup>
- S = 2125. mm<sup>3</sup>







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

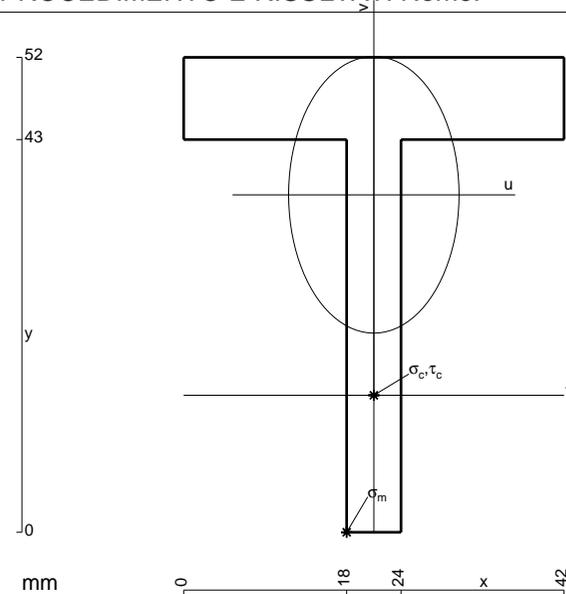
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

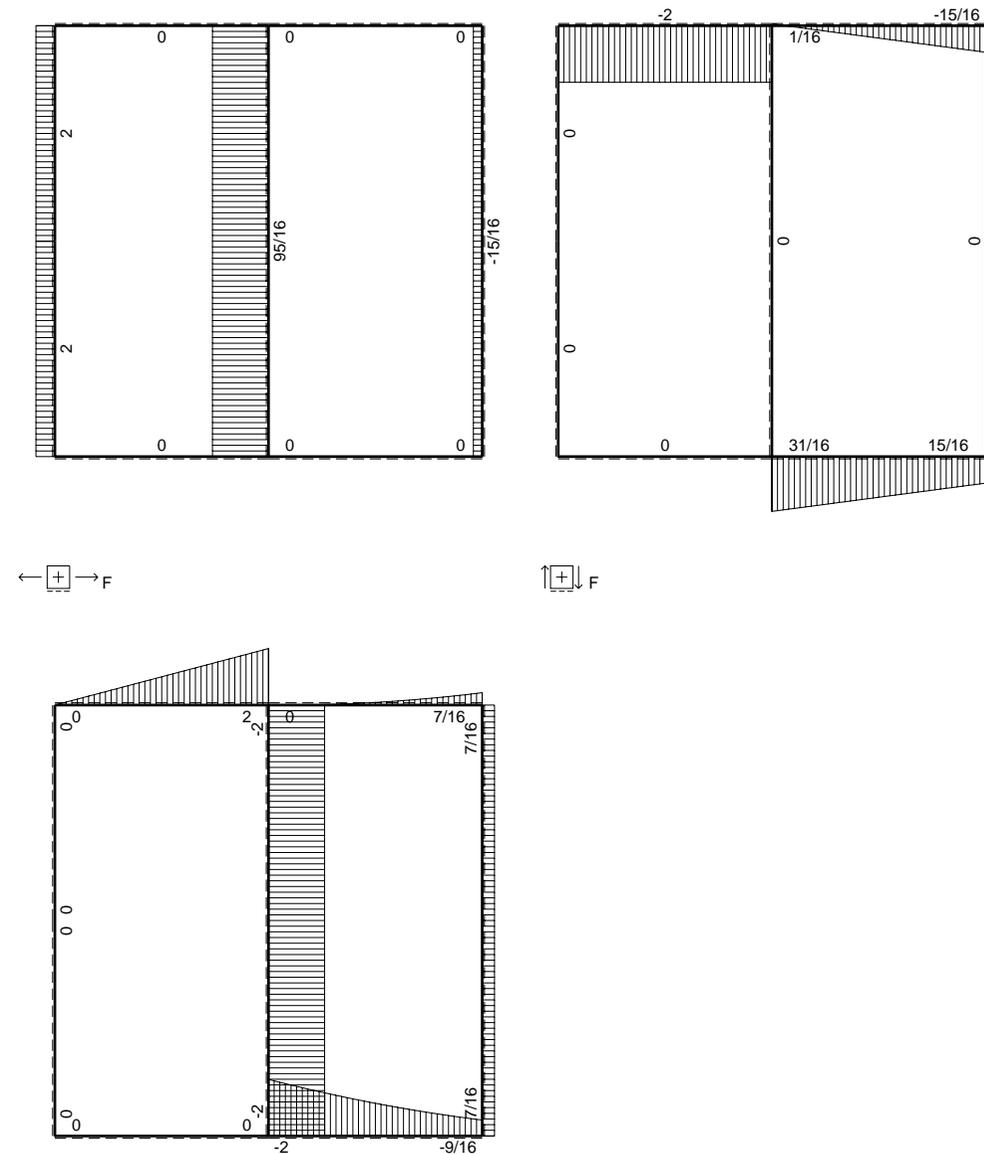
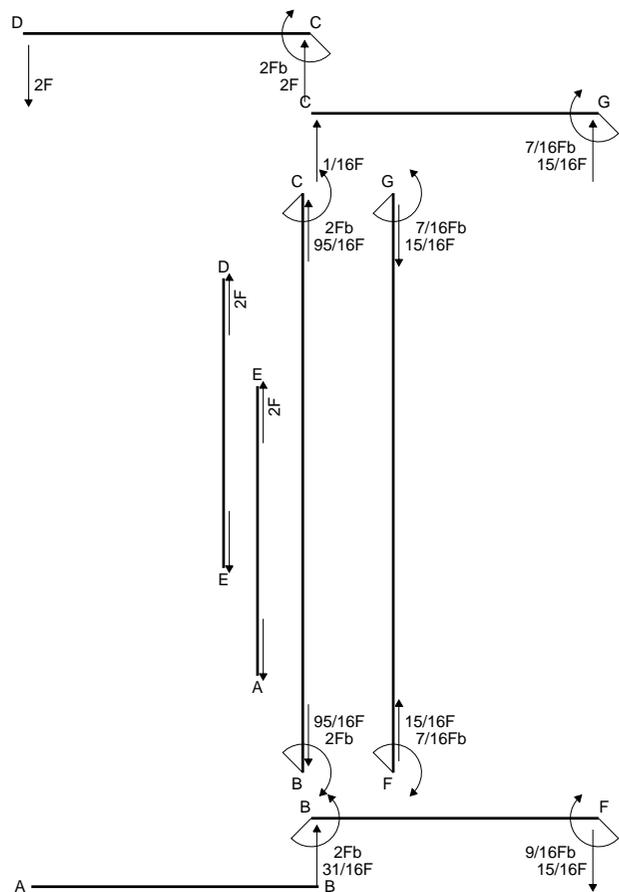
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



$A = 636. \text{ mm}^2$   
 $J_u = 145963. \text{ mm}^4$   
 $J_v = 56340. \text{ mm}^4$   
 $y_g = 36.95 \text{ mm}$   
 $N = 7905. \text{ N}$   
 $T_y = -4080. \text{ N}$   
 $M_x = -836400. \text{ Nmm}$   
 $x_m = 18. \text{ mm}$   
 $u_m = -3. \text{ mm}$   
 $v_m = -36.95 \text{ mm}$   
 $\sigma_m = N/A - Mv/J_u = -199.3 \text{ N/mm}^2$   
 $x_c = 21. \text{ mm}$   
 $y_c = 15. \text{ mm}$   
 $v_c = -21.95 \text{ mm}$   
 $\sigma_c = N/A - Mv/J_u = -113.4 \text{ N/mm}^2$   
 $\tau_c = 12.35 \text{ N/mm}^2$   
 $\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 115.4 \text{ N/mm}^2$   
 $S = 2651. \text{ mm}^3$





$\curvearrowright (+)$   $F_b$



$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{xo} = \int_0^b (2x/b - 3/2 x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (x/b) \theta dx$$

$$= [x^2/b - 1/2 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b + 1/8 b) Fb 1/EJ + (1/2 b) \theta = 9/8 Fb^2/EJ$$

$$L_{FB}^{xo} = \int_0^b (1 - 1/2 x/b - 1/2 x^3/b^3) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [x - 1/4 x^2/b - 1/8 x^4/b^3]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

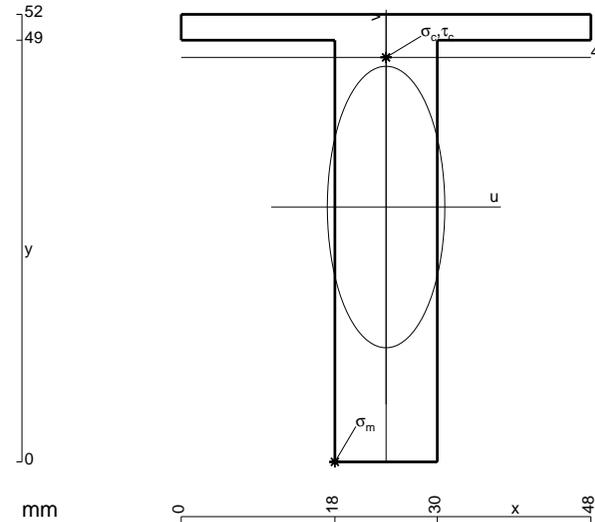
$$= (b - 1/4 b - 1/8 b) Fb 1/EJ + (-b + 1/2 b) \theta = 9/8 Fb^2/EJ$$

$$L_{GC}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{CG}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$



$$A = 732. \text{ mm}^2$$

$$J_u = 195951. \text{ mm}^4$$

$$J_v = 34704. \text{ mm}^4$$

$$y_g = 29.61 \text{ mm}$$

$$T_y = -3080. \text{ N}$$

$$M_x = 1386000. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$u_m = -6. \text{ mm}$$

$$v_m = -29.61 \text{ mm}$$

$$\sigma_m = -Mv/J_u = 209.5 \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 47. \text{ mm}$$

$$v_c = 17.39 \text{ mm}$$

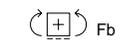
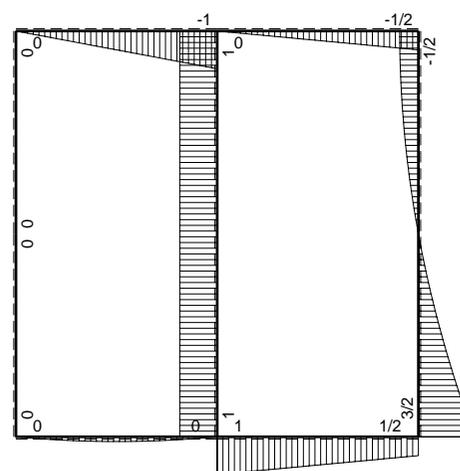
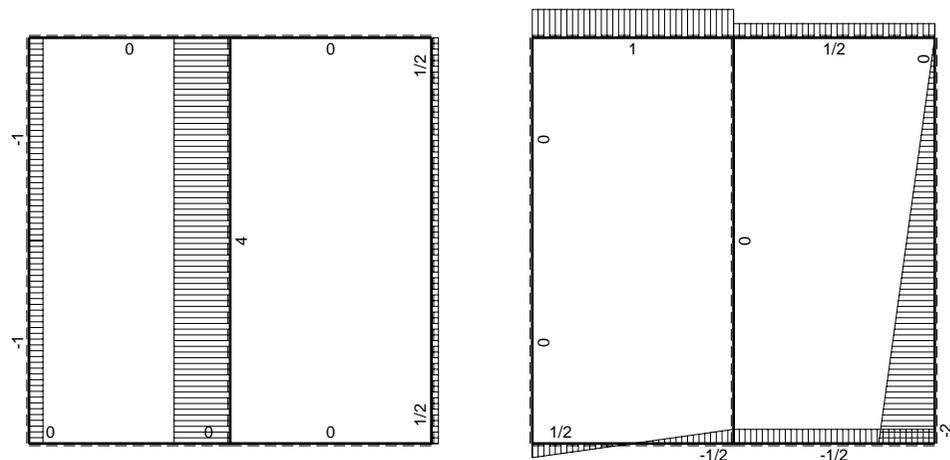
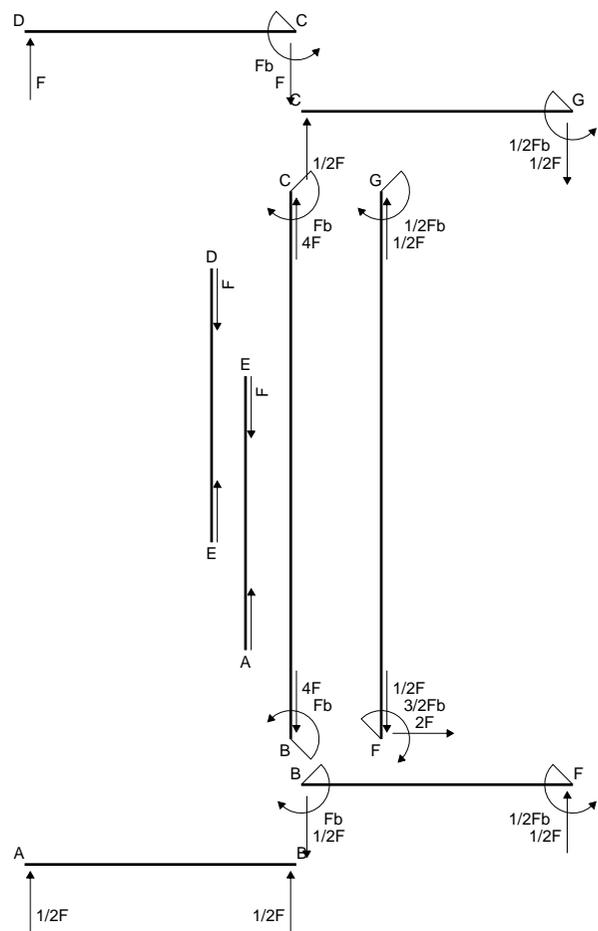
$$\sigma_c = -Mv/J_u = -123. \text{ N/mm}^2$$

$$\tau_c = 4.517 \text{ N/mm}^2$$

$$\sigma_o = \sqrt{\sigma^2 + 3\tau^2} = 123.2 \text{ N/mm}^2$$

$$S = 3449. \text{ mm}^3$$







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x\theta} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x\theta} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

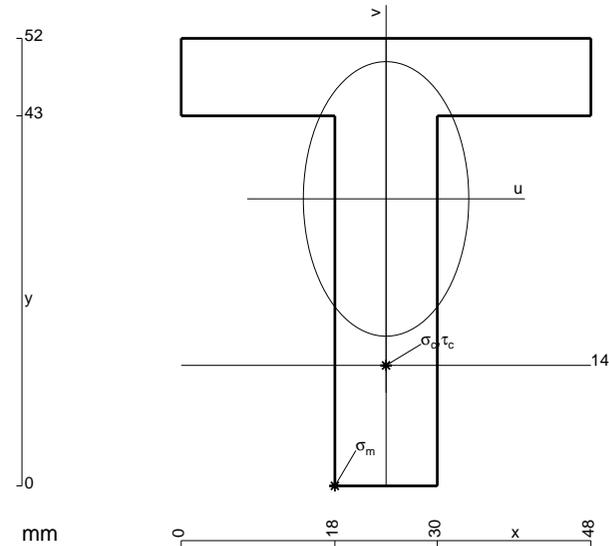
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x\theta} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

$$L_{GF}^{x\theta} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



$$A = 948. \text{ mm}^2$$

$$J_u = 241377. \text{ mm}^4$$

$$J_v = 89136. \text{ mm}^4$$

$$y_g = 33.35 \text{ mm}$$

$$T_y = 3240. \text{ N}$$

$$M_x = -1587600. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$u_m = -6. \text{ mm}$$

$$v_m = -33.35 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -219.3 \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 14. \text{ mm}$$

$$v_c = -19.35 \text{ mm}$$

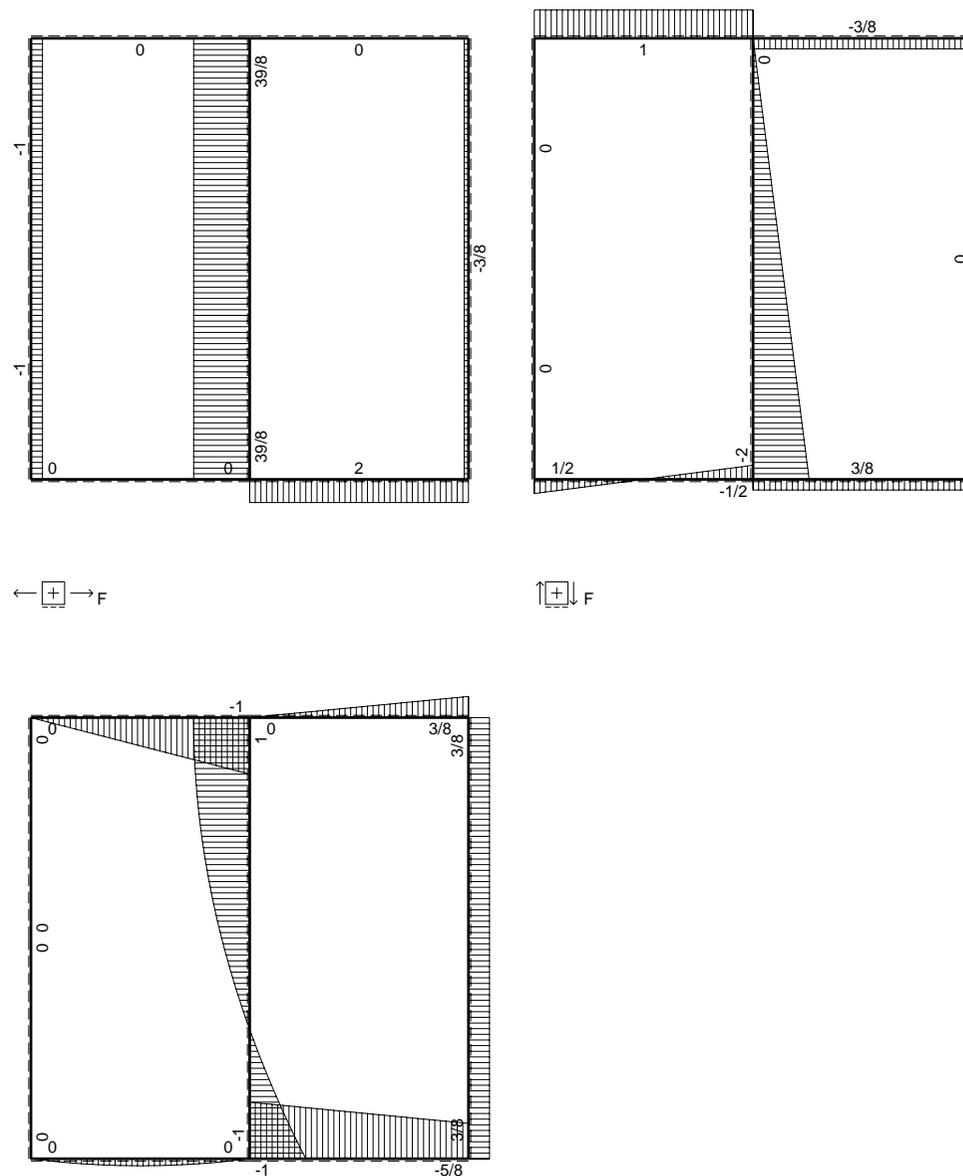
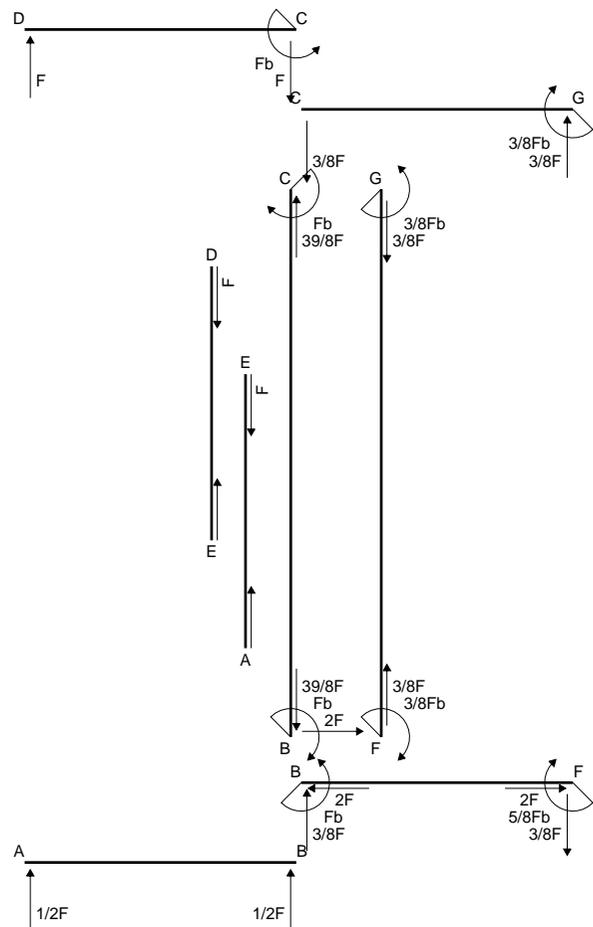
$$\sigma_c = -Mv/J_u = -127.3 \text{ N/mm}^2$$

$$\tau_c = 4.951 \text{ N/mm}^2$$

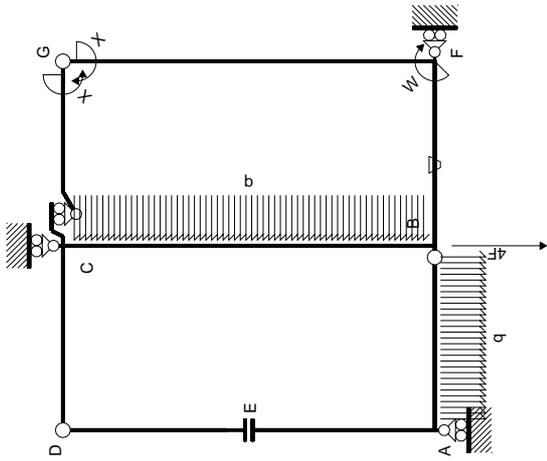
$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 127.5 \text{ N/mm}^2$$

$$S = 4426. \text{ mm}^3$$

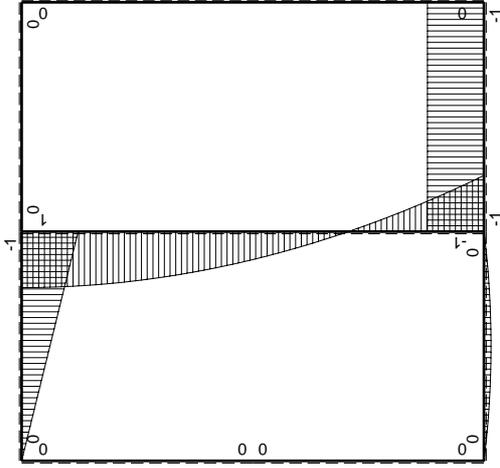




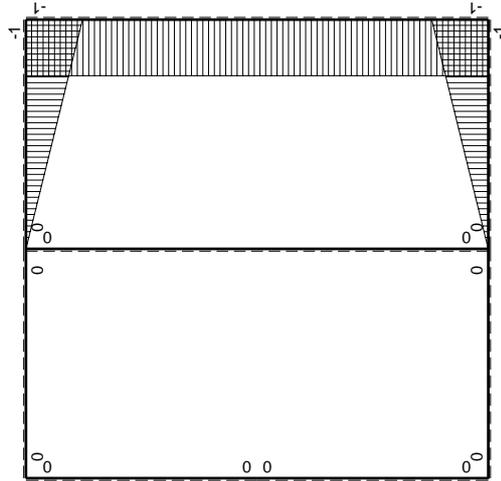
$\curvearrowright \boxed{+} \curvearrowleft F_b$



Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{gc}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / EJ dx$
AB b	0	$1/2Fx - 1/2qx^2$	0	0	0	0	0+0	0
BA b	0	$-1/2Fx + 1/2qx^2$	0	0	0	0	0+0	0
CD b	0	$-Fb + Fx$	0	0	0	0	0+0	0
DC b	0	$Fx$	0	0	0	0	0+0	0
DE b	0	0	0	0	0	0	0+0	0
EA b	0	0	0	0	0	0	0+0	0
AE b	0	0	0	0	0	0	0+0	0
BF b	$-x/b$	$-Fb$	$-Fb/EJ$	$Fx$	$Fx/EJ$	$x^2/b^2$	$(1/2+1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$Fb$	$Fb/EJ$	$Fb-Fx$	$Fb/EJ - Fx/EJ$	$1-2x/b+x^2/b^2$	$1/3xb/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	0	0	0	0	1	0+0	$2xb/EJ$
GF 2b	1	0	0	0	0	1	0+0	$2xb/EJ$
CB 2b	0	$Fb - 1/2qx^2$	0	0	0	0	0+0	0
BC 2b	0	$Fb - 2Fx + 1/2qx^2$	0	0	0	0	0+0	0
totali								$Fb^2/EJ$
								$8/3xb/EJ$

iperstatica  $X=W_{gc}$

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

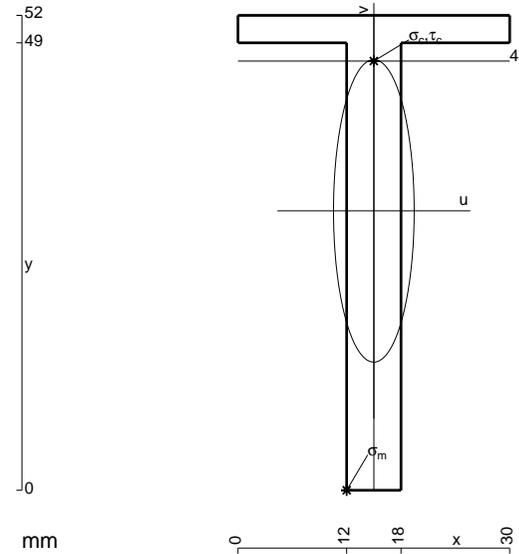
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



$$A = 384. \text{ mm}^2$$

$$J_u = 105473. \text{ mm}^4$$

$$J_v = 7632. \text{ mm}^4$$

$$y_g = 30.59 \text{ mm}$$

$$N = 7946. \text{ N}$$

$$T_y = -3260. \text{ N}$$

$$M_x = -863900. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -30.59 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -229.9 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 47. \text{ mm}$$

$$v_c = 16.41 \text{ mm}$$

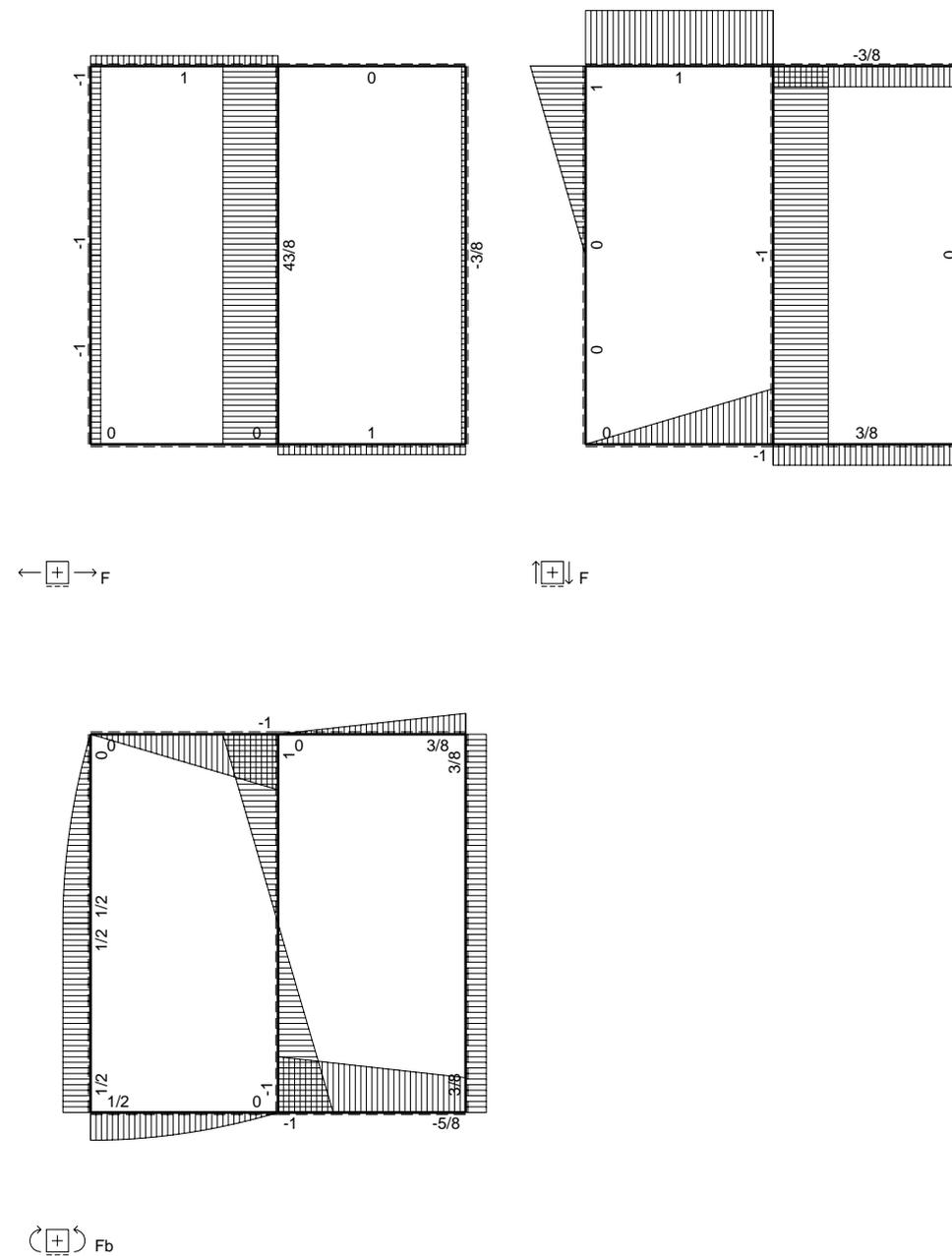
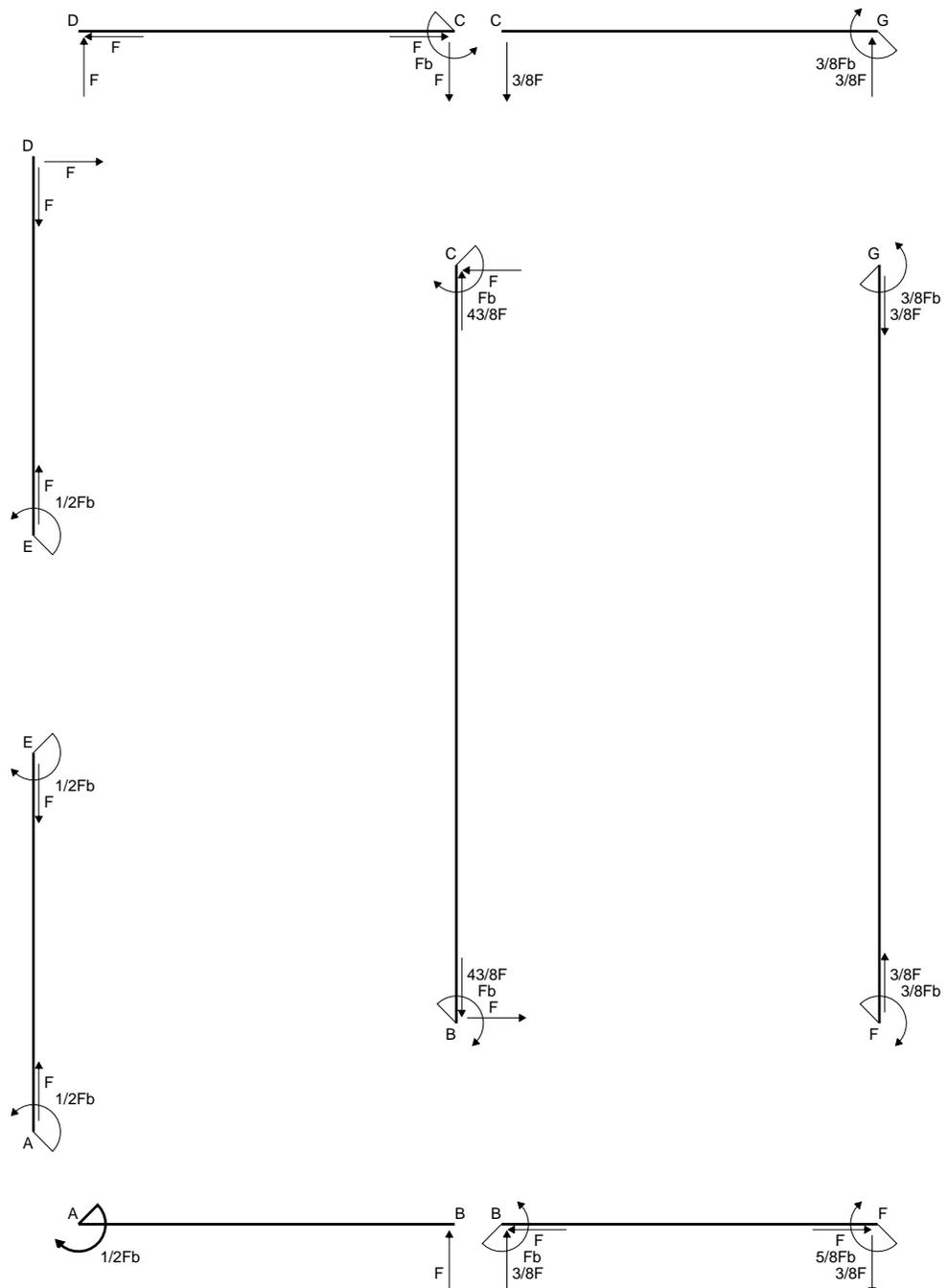
$$\sigma_c = N/A - Mv/J_u = 155.1 \text{ N/mm}^2$$

$$\tau_c = 10.31 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 156.1 \text{ N/mm}^2$$

$$S = 2000. \text{ mm}^3$$







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

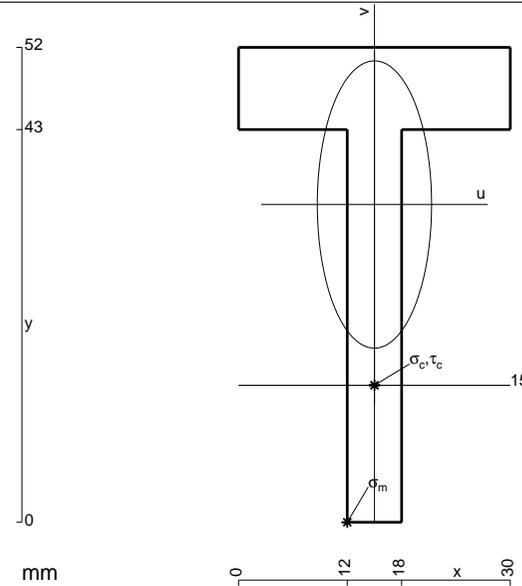
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



$$A = 528. \text{ mm}^2$$

$$J_u = 130762. \text{ mm}^4$$

$$J_v = 21024. \text{ mm}^4$$

$$y_g = 34.8 \text{ mm}$$

$$N = 7955. \text{ N}$$

$$T_y = -1480. \text{ N}$$

$$M_x = 843600. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -34.8 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 239.5 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 15. \text{ mm}$$

$$v_c = -19.8 \text{ mm}$$

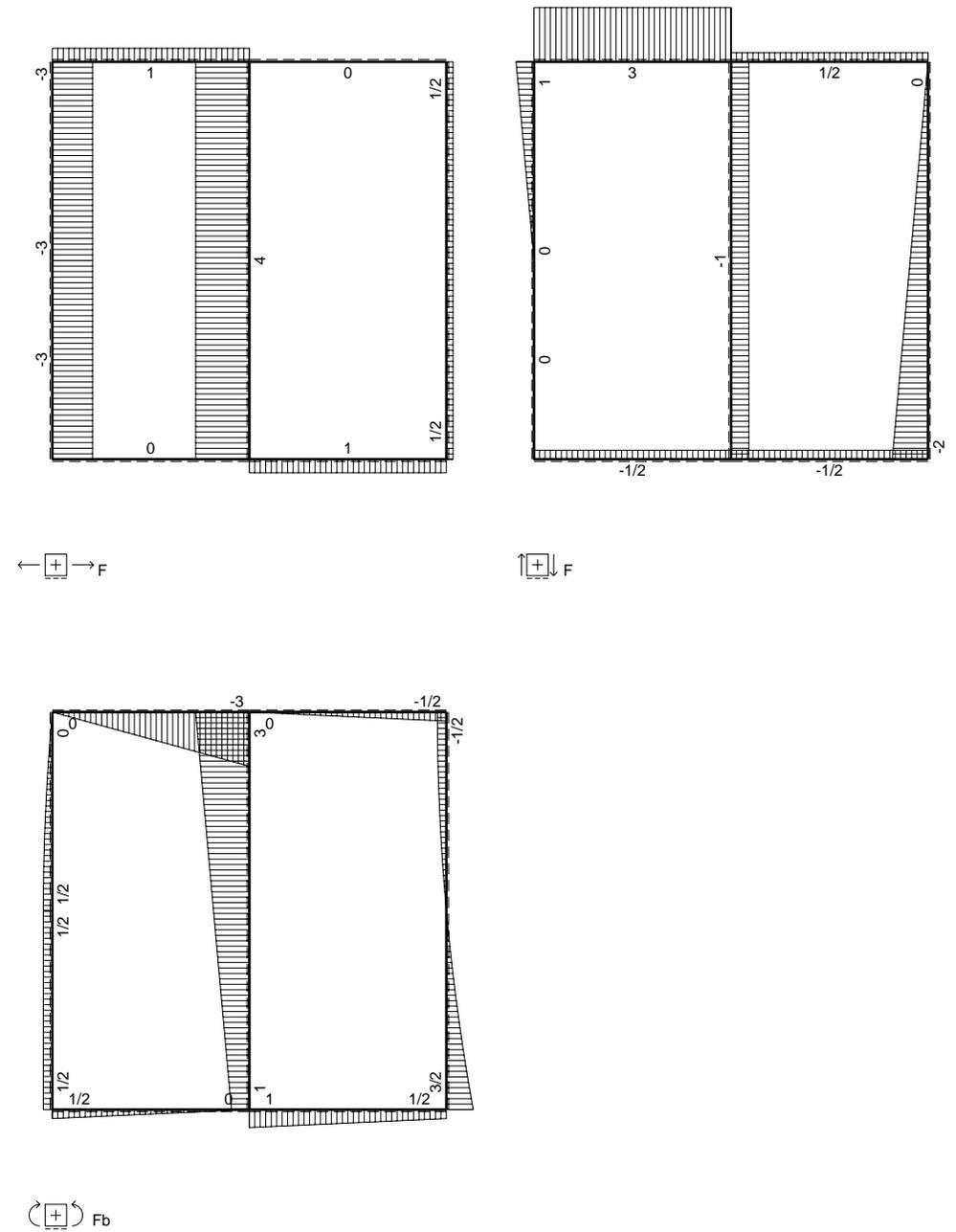
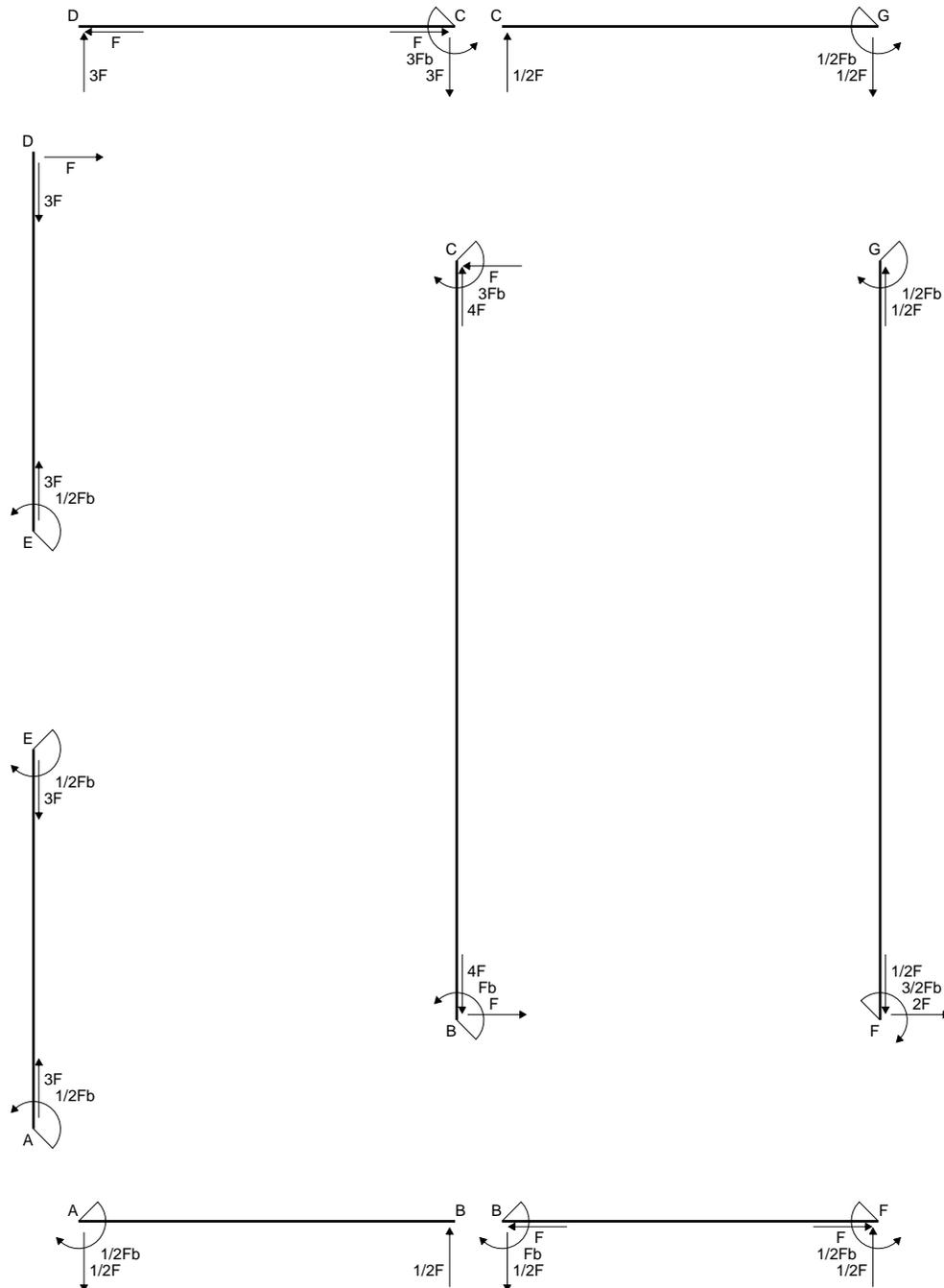
$$\sigma_c = N/A - Mv/J_u = 142.8 \text{ N/mm}^2$$

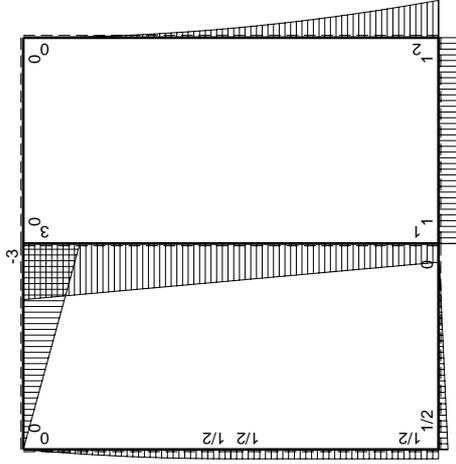
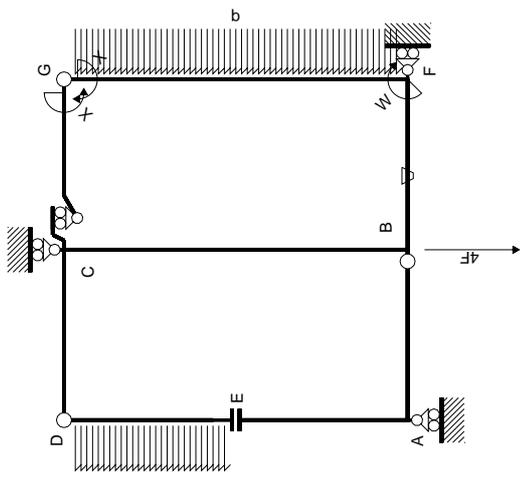
$$\tau_c = 4.634 \text{ N/mm}^2$$

$$\sigma_\varphi = \sqrt{\sigma^2 + 3\tau^2} = 143. \text{ N/mm}^2$$

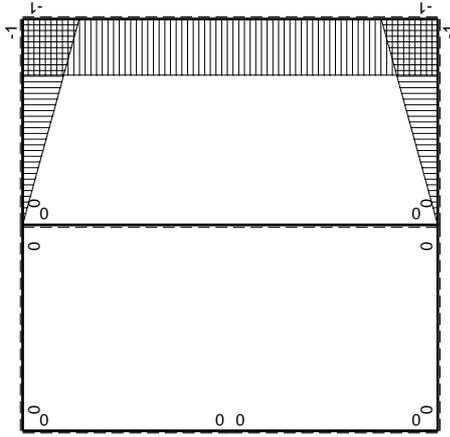
$$S = 2457. \text{ mm}^3$$







$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

←	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / E dx$
AB b	0	$1/2Fb - 1/2Fx$	0	0	0	0	0+0	0
BA b	0	$-1/2Fx$	0	0	0	0	0+0	0
CD b	0	$-3Fb + 3Fx$	0	0	0	0	0+0	0
DC b	0	$3Fx$	0	0	0	0	0+0	0
DE b	0	$Fx - 1/2qx^2$	0	0	0	0	0+0	0
ED b	0	$-1/2Fb + 1/2qx^2$	0	0	0	0	0+0	0
EA b	0	$1/2Fb$	0	0	0	0	0+0	0
AE b	0	$-1/2Fb$	0	0	0	0	0+0	0
BF b	$-x/b$	$Fb$	$-Fb/EJ$	$-Fx$	$Fx/EJ$	$x^2/b^2$	$(-1/2 + 1/2)Fb^2/EJ$	$1/3xb/EJ$
FB b	$1-x/b$	$-Fb$	$Fb/EJ$	$-Fb + Fx$	$Fb/EJ - Fx/EJ$	$1 - 2x/b + x^2/b^2$	$(-1/2 + 1/2)Fb^2/EJ$	$1/3xb/EJ$
GC b	$-1+x/b$	0	0	0	0	$1 - 2x/b + x^2/b^2$	0+0	$1/3xb/EJ$
CG b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3xb/EJ$
FG 2b	-1	$2Fb - 2Fx + 1/2qx^2$	0	$-2Fb + 2Fx - 1/2Fx^2/b$	0	1	$(-4/3 + 0)Fb^2/EJ$	$2xb/EJ$
GF 2b	1	$-1/2qx^2$	0	$-1/2Fx^2/b$	0	1	$(-4/3 + 0)Fb^2/EJ$	$2xb/EJ$
CB 2b	0	$3Fb - Fx$	0	0	0	0	0+0	0
BC 2b	0	$-Fb - Fx$	0	0	0	0	0+0	0
totali							$-4/3Fb^2/EJ$	$8/3xb/EJ$

Quadro contributi PLV per iperstatica X=W<sub>gc</sub>

iperstatica X=W<sub>gc</sub>

Sviluppi di calcolo iperstatica

$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (1/2 b) \theta = 0$$

$$L_{FB}^{x_0} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx$$

$$= [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

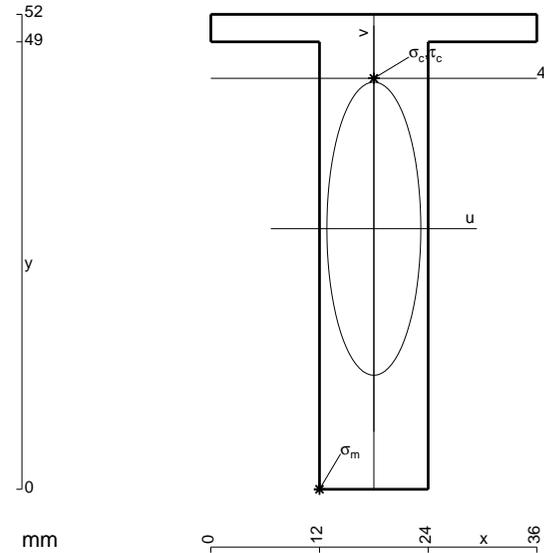
$$= (-b + 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = 0$$

$$L_{FG}^{x_0} = \int_0^{2b} (-2 + 2x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-2x + x^2/b - 1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4b + 4b - 4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$

$$L_{GF}^{x_0} = \int_0^{2b} (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^{2b} Fb 1/EJ$$

$$= (-4/3 b) Fb 1/EJ = -4/3 Fb^2/EJ$$



$$A = 696. \text{ mm}^2$$

$$J_u = 179409. \text{ mm}^4$$

$$J_v = 18720. \text{ mm}^4$$

$$y_g = 28.53 \text{ mm}$$

$$N = 690. \text{ N}$$

$$T_y = 2070. \text{ N}$$

$$M_x = -1262700. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -6. \text{ mm}$$

$$v_m = -28.53 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -199.8 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 45. \text{ mm}$$

$$v_c = 16.47 \text{ mm}$$

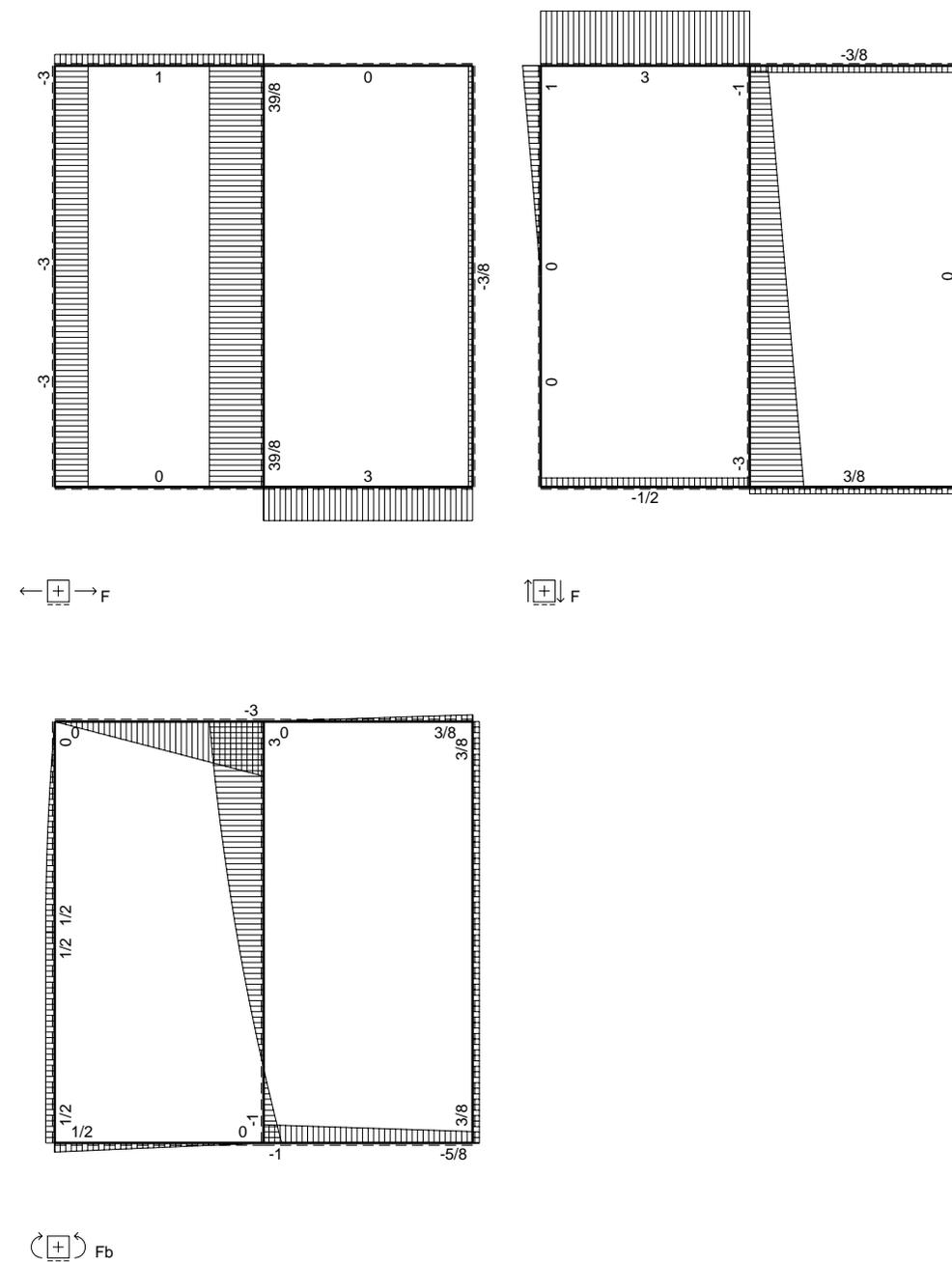
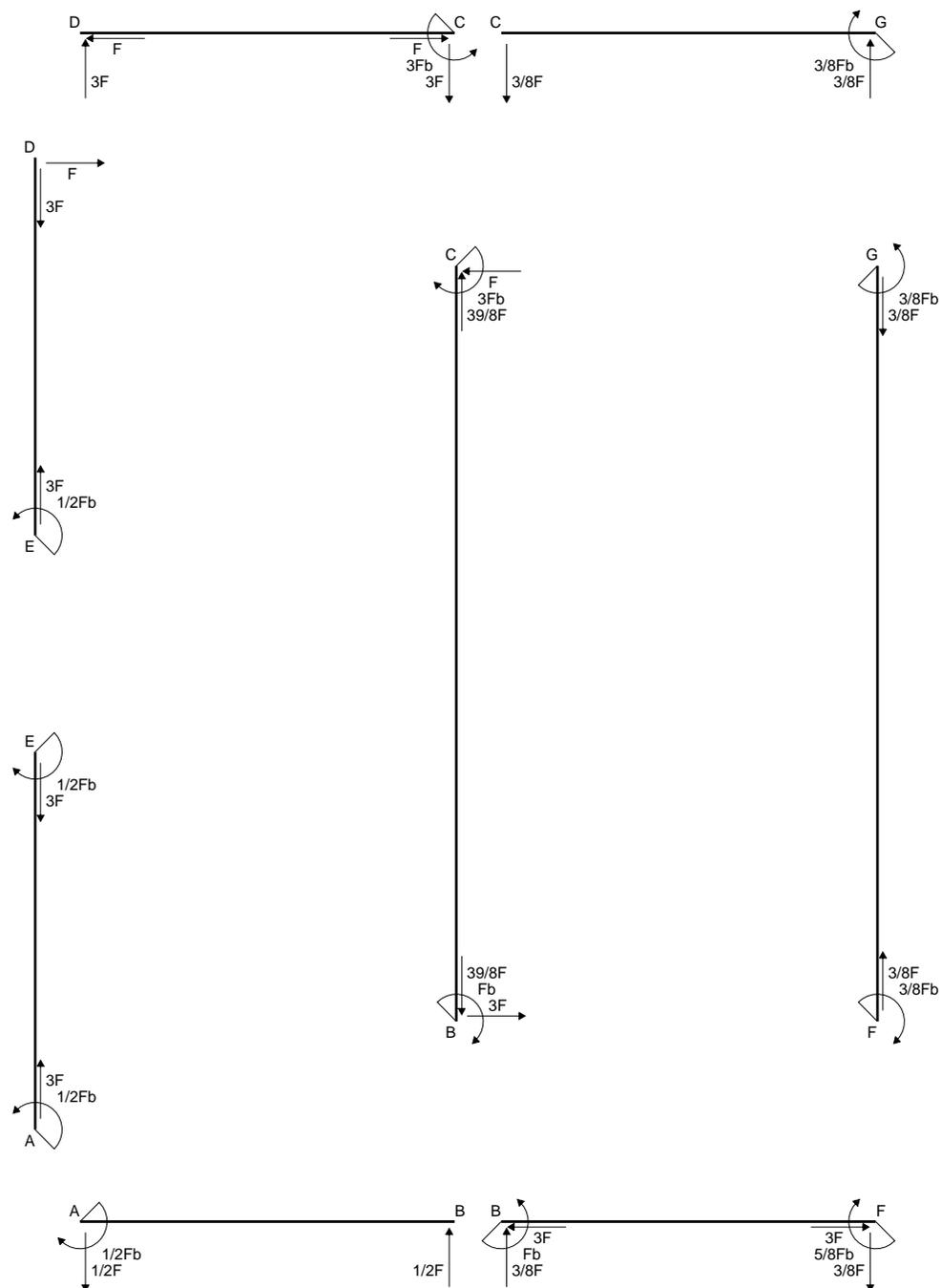
$$\sigma_c = N/A - Mv/J_u = 116.9 \text{ N/mm}^2$$

$$\tau_c = 3.133 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 117. \text{ N/mm}^2$$

$$S = 3259. \text{ mm}^3$$







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

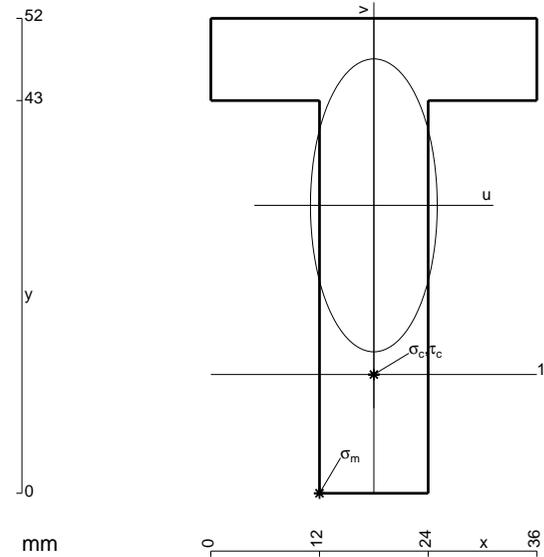
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

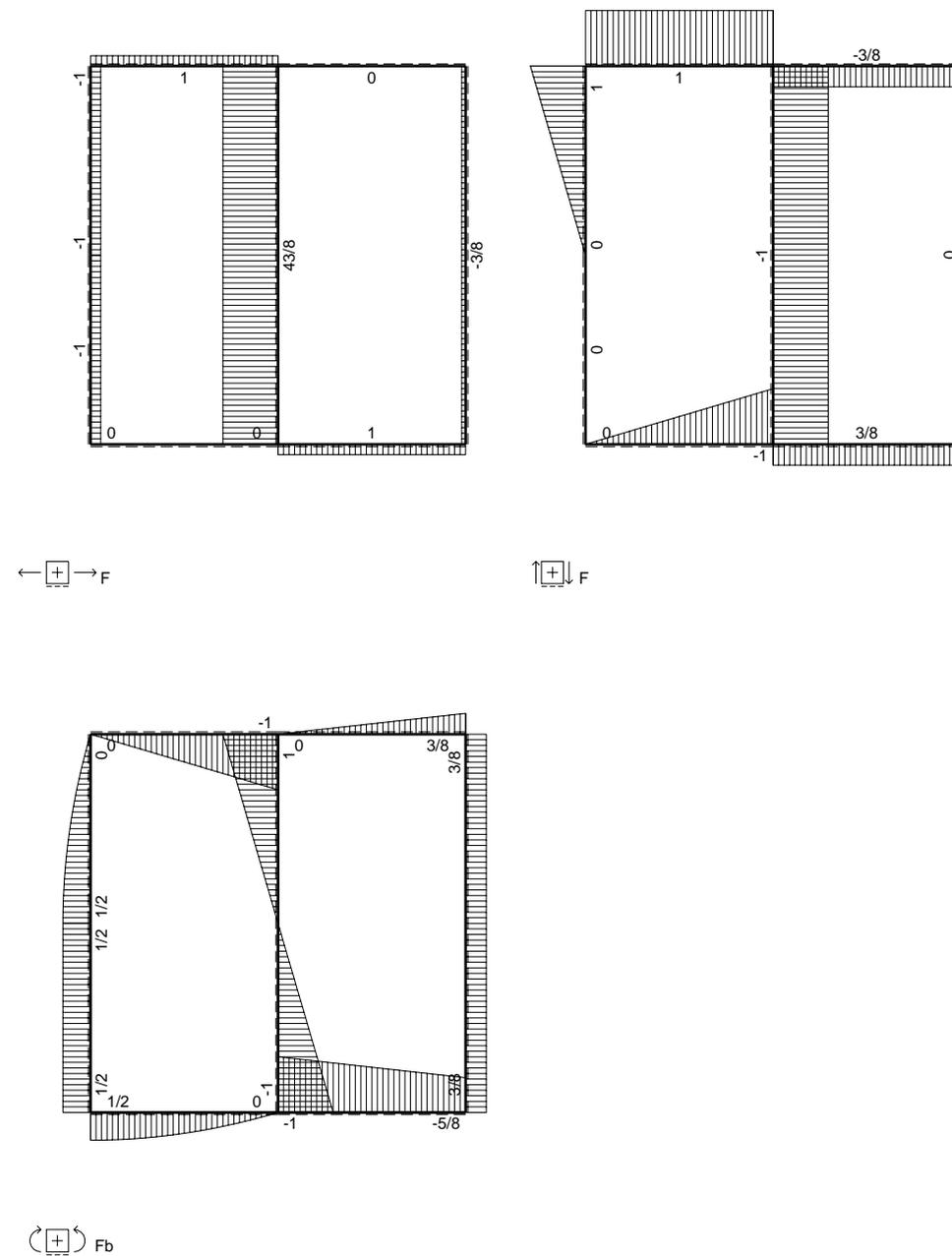
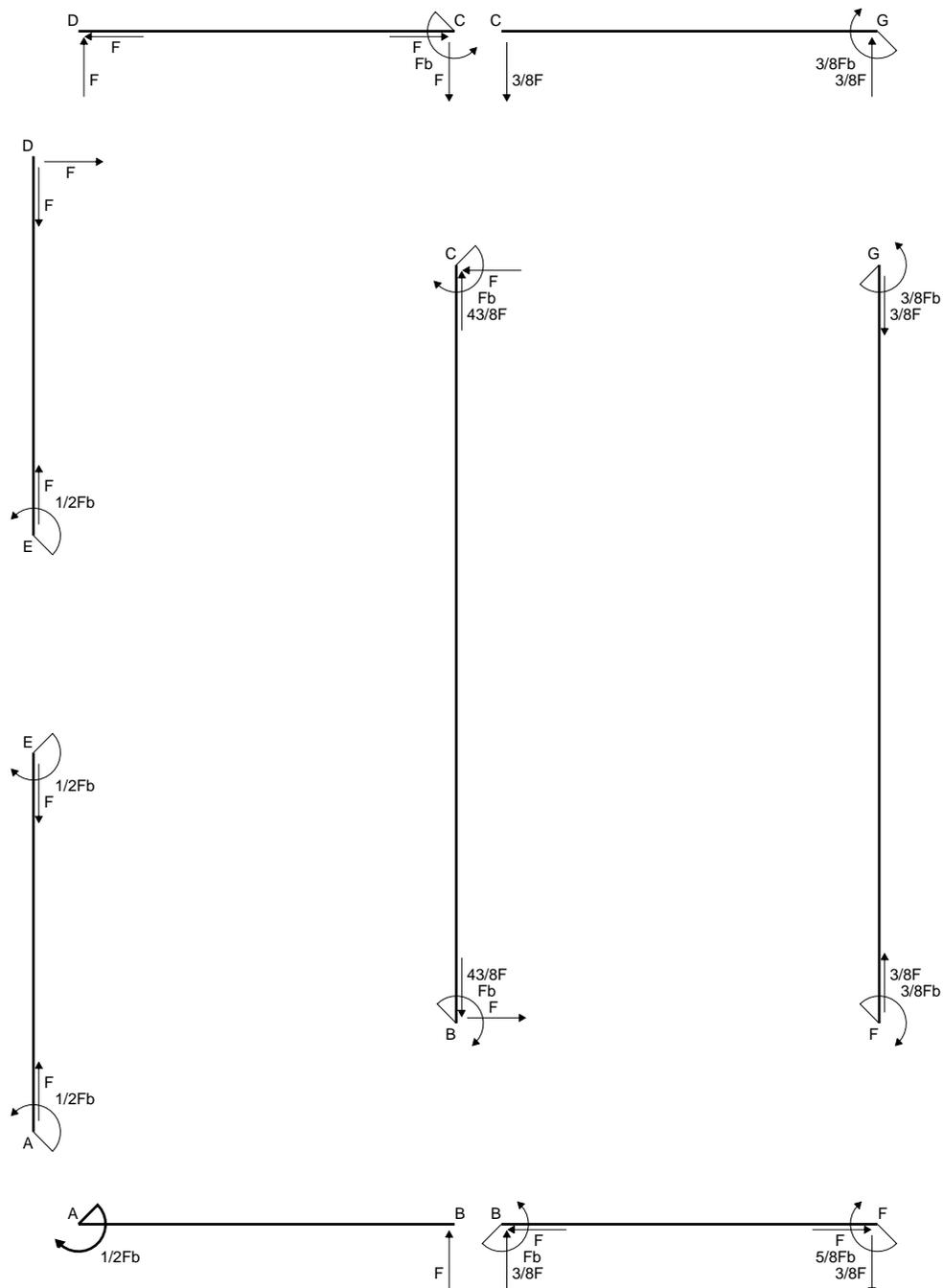
$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



- A = 840. mm<sup>2</sup>
- J<sub>u</sub> = 216237. mm<sup>4</sup>
- J<sub>v</sub> = 41184. mm<sup>4</sup>
- y<sub>g</sub> = 31.53 mm
- N = 740. N
- T<sub>y</sub> = 2220. N
- M<sub>x</sub> = -1443000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -31.53 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = -209.5 N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 13. mm
- v<sub>c</sub> = -18.53 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = -122.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 3.34 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 122.9 N/mm<sup>2</sup>
- S = 3904. mm<sup>3</sup>







$$L_{BF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FB}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{GC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CG}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{FG}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{GF}^{xx} = \int_0^{2b} (1) 1/EJ dx = [x]_0^{2b} 1/EJ$$

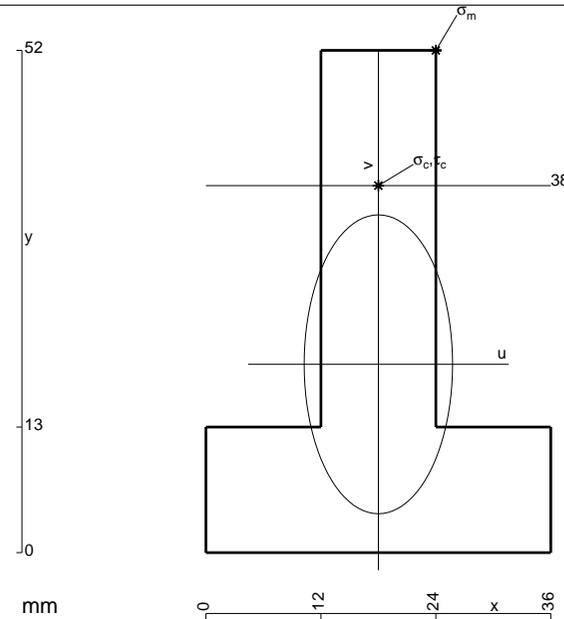
$$= (2b) 1/EJ = 2 b/EJ$$

$$L_{BF}^{x_0} = \int_0^b (x/b) Fb 1/EJ dx + \int_0^b (x/b) \theta dx = [1/2 x^2/b]_0^b Fb 1/EJ + [1/2 x^2/b]_0^b \theta$$

$$= (1/2 b) Fb 1/EJ + (1/2 b) \theta = Fb^2/EJ$$

$$L_{FB}^{x_0} = \int_0^b (1 - x/b) Fb 1/EJ dx + \int_0^b (-1 + x/b) \theta dx = [x - 1/2 x^2/b]_0^b Fb 1/EJ + [-x + 1/2 x^2/b]_0^b \theta$$

$$= (b - 1/2 b) Fb 1/EJ + (-b + 1/2 b) \theta = Fb^2/EJ$$



$$A = 936. \text{ mm}^2$$

$$J_u = 224094. \text{ mm}^4$$

$$J_v = 56160. \text{ mm}^4$$

$$y_g = 19.5 \text{ mm}$$

$$N = 11126. \text{ N}$$

$$T_y = -2070. \text{ N}$$

$$M_x = -1428300. \text{ Nmm}$$

$$x_m = 24. \text{ mm}$$

$$y_m = 52. \text{ mm}$$

$$u_m = 6. \text{ mm}$$

$$v_m = 32.5 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 219. \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 38. \text{ mm}$$

$$v_c = 18.5 \text{ mm}$$

$$\sigma_c = N/A - Mv/J_u = 129.8 \text{ N/mm}^2$$

$$\tau_c = 3.298 \text{ N/mm}^2$$

$$\sigma_0 = \sqrt{\sigma^2 + 3\tau^2} = 129.9 \text{ N/mm}^2$$

$$S = 4284. \text{ mm}^3$$

