

$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica X=W<sup>EF</sup>

←	M <sub>x</sub> (x)	M <sub>0</sub> (x)	θ	M <sub>x</sub> θ	M <sub>x</sub> M <sub>0</sub>	∫M <sub>x</sub> (M <sub>0</sub> /EJ+θ)dx	∫M <sub>x</sub> M <sub>0</sub> /EJdx
AB	0	0	0	0	0	0	0
BA	0	0	0	0	0	0	0
BC	0	Fb-√5/5Fx	0	0	0	0	0
AC	0	0	0	0	0	0	0
CA	0	0	0	0	0	0	0
DB	0	0	0	0	0	0	0
BD	0	0	0	0	0	0	0
DE	-x/b	0	0	0	0	x <sup>2</sup> /b <sup>2</sup>	1/3Xb/EJ
ED	1-x/b	0	0	0	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	1/3Xb/EJ
CD	0	0	0	0	0	0	0
DC	0	0	0	0	0	0	0
EF	-1	1/2qx <sup>2</sup>	-Fb/EJ	-1/2Fx <sup>2</sup> /b	Fb/EJ	1	Xb/EJ
FE	1	-1/2Fb+Fx-1/2qx <sup>2</sup>	Fb/EJ	-1/2Fb+Fx-1/2Fx <sup>2</sup> /b	Fb/EJ	1	(-1/6+1)Fb <sup>2</sup> /EJ
FC	-1+x/b	1/2Fb-1/2qx <sup>2</sup>	0	-1/2Fb+1/2Fx+1/2Fx <sup>2</sup> /b-1/2qx <sup>3</sup> /b	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	(-5/24+0)Fb <sup>2</sup> /EJ
CF	x/b	-Fx+1/2qx <sup>2</sup>	0	-Fx <sup>2</sup> /b+1/2qx <sup>3</sup> /b	0	x <sup>2</sup> /b <sup>2</sup>	1/3Xb/EJ
totali							5/3Xb/EJ
							-3/8Fb

Sviluppi di calcolo iperstatica

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

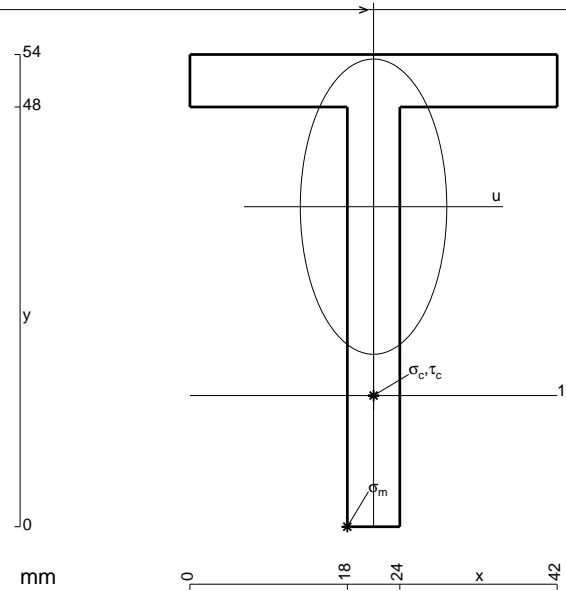
$$L_{FC}^{xo} = \int_0^b (-1/2 + 1/2 x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx$$

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

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

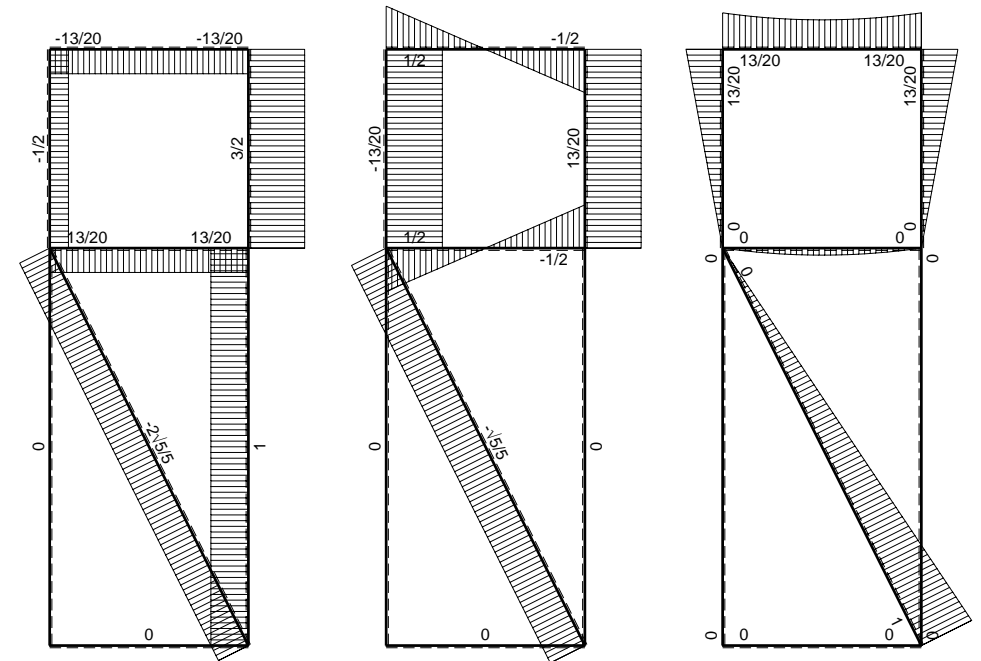
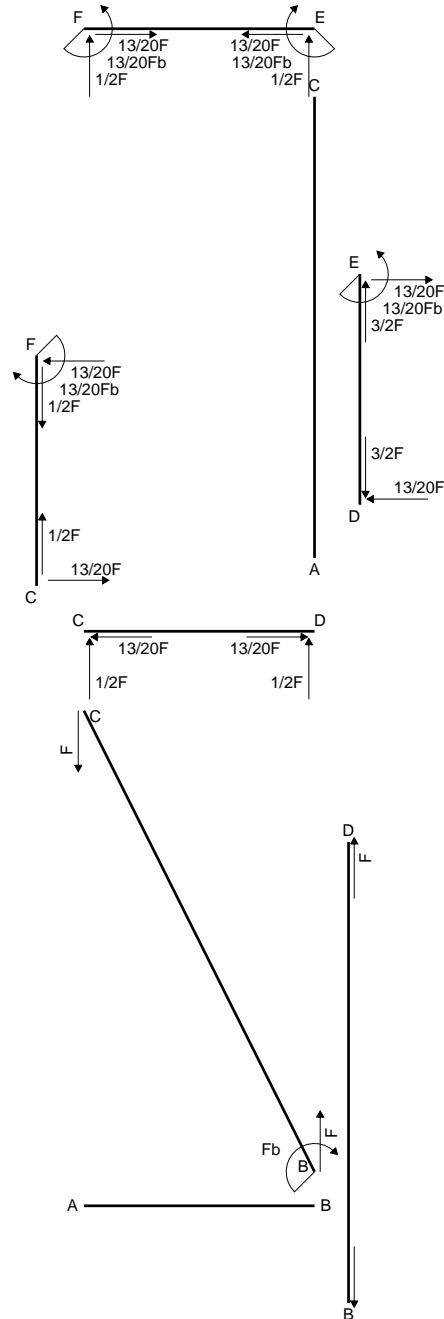
$$L_{CF}^{xo} = \int_0^b (-x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

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



- 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
- N = -1959. N
- T<sub>y</sub> = -979.4 N
- M<sub>x</sub> = 897900. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -36.6 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = 209.7 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> = N/A-Mv/J<sub>u</sub> = 122.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.775 N/mm<sup>2</sup>
- σ<sub>φ</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 122.4 N/mm<sup>2</sup>
- S = 2619. mm<sup>3</sup>





← ⊕ → F

↑ ⊕ ↓ F

⊕ ⊖ F<sub>b</sub>



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

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

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

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

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

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

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

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

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

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

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

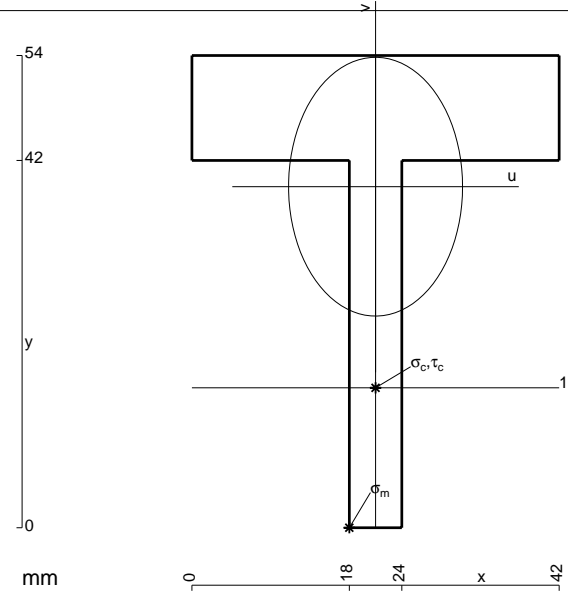
$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

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

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

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

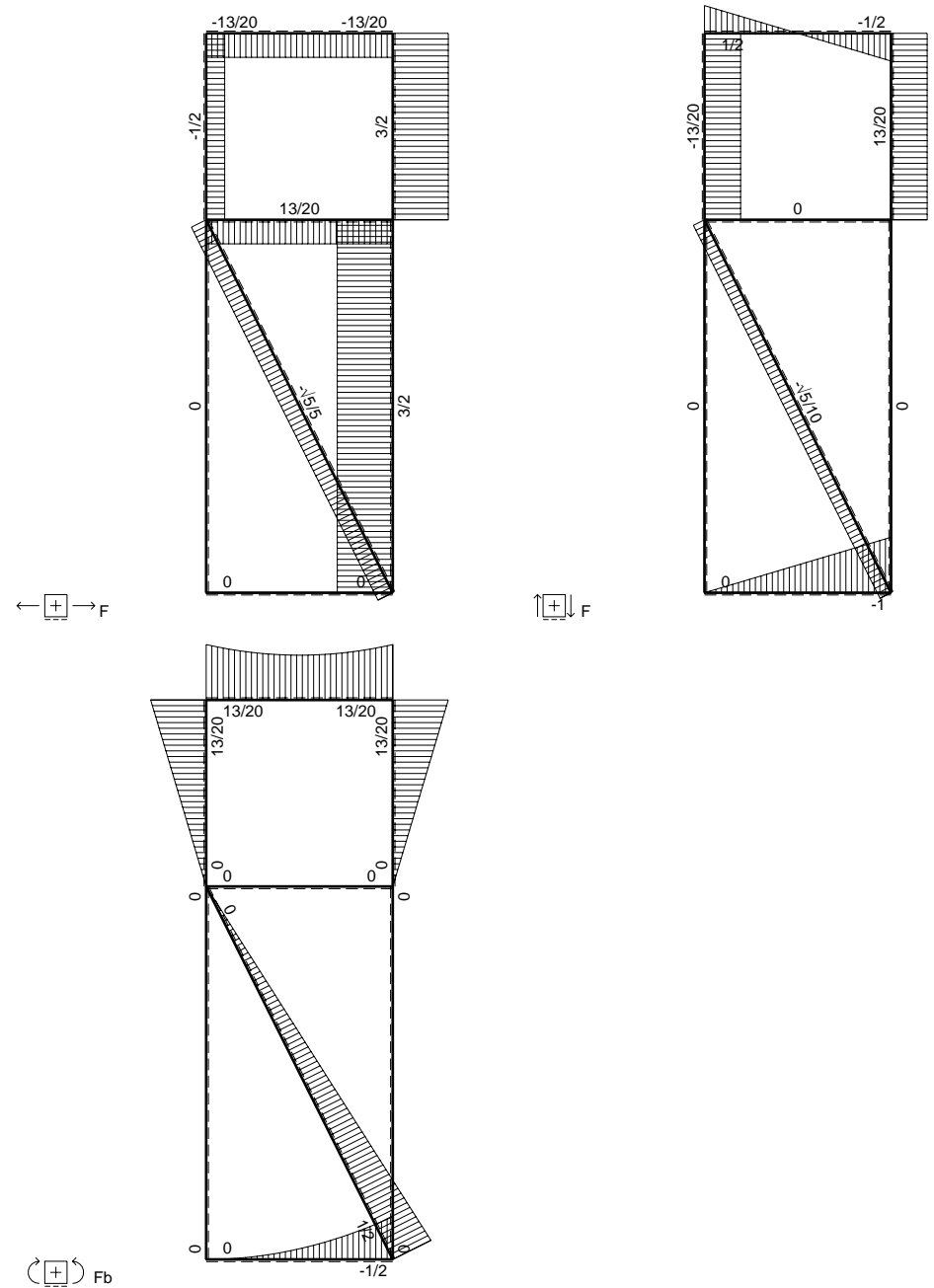
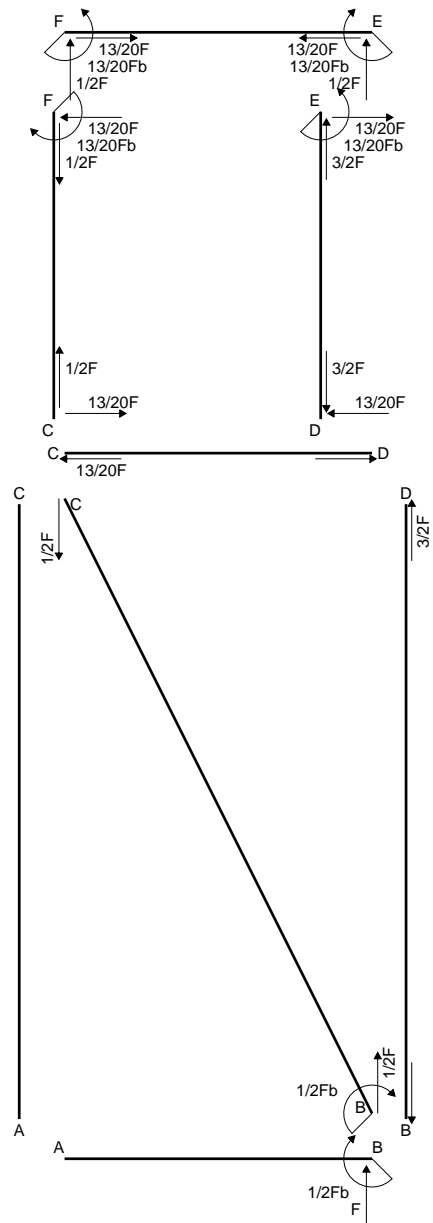
$$= (1/4 b - 1/6 b) Fb 1/EJ + (-b) \theta = 13/12 Fb^2/EJ$$



- 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> = 39. mm
- N = -1869. N
- T<sub>y</sub> = -934.7 N
- M<sub>x</sub> = 940500. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -39. mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = 219.1 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 16. mm
- v<sub>c</sub> = -23. mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = 128.2 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.8 N/mm<sup>2</sup>
- σ<sub>φ</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 128.3 N/mm<sup>2</sup>
- S = 2976. mm<sup>3</sup>







⊕ F<sub>b</sub>



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

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

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

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

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

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

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

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

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

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

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

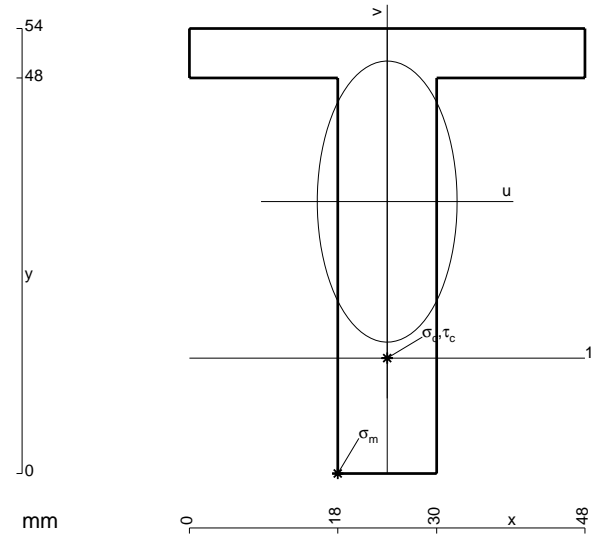
$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

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

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

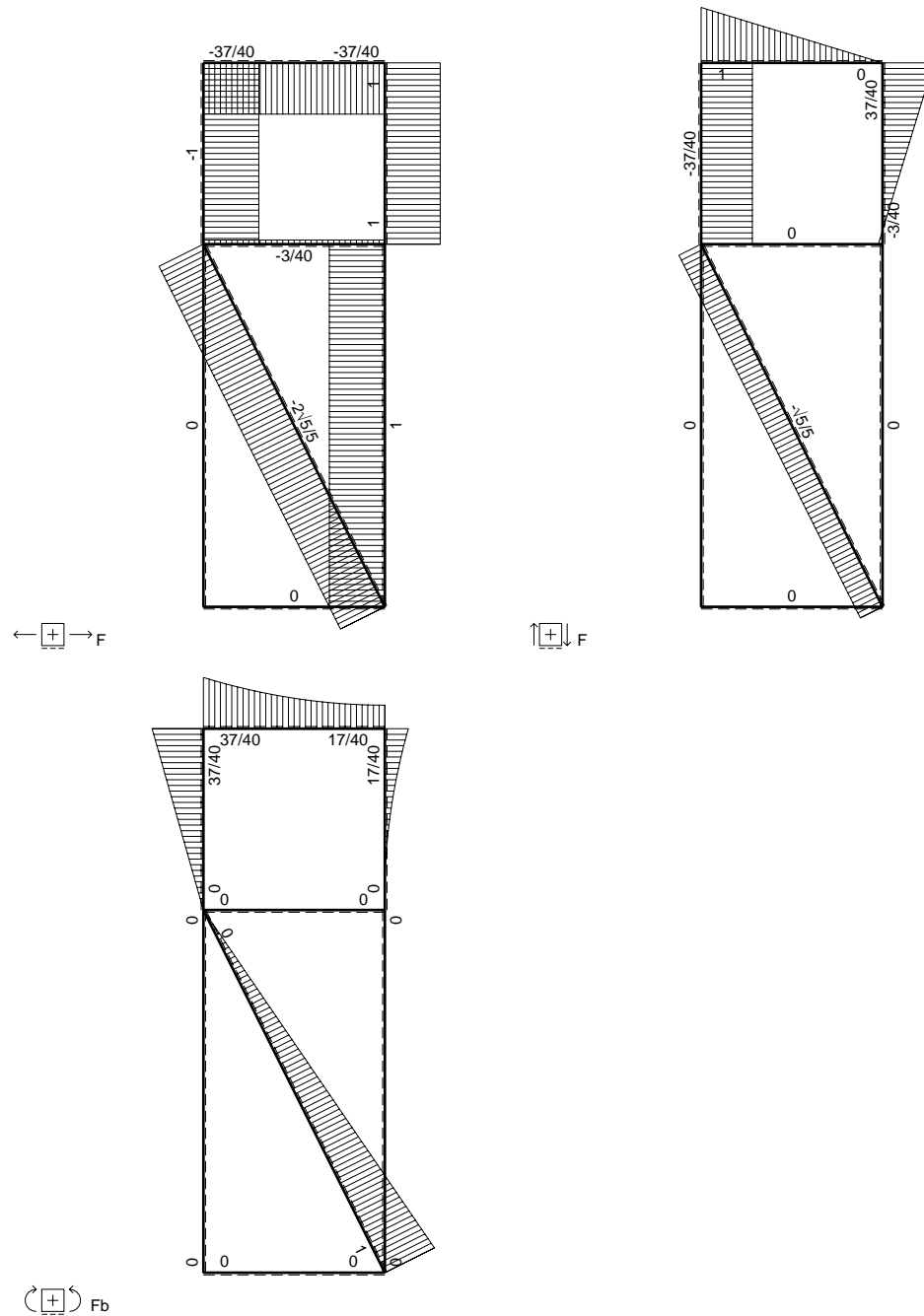
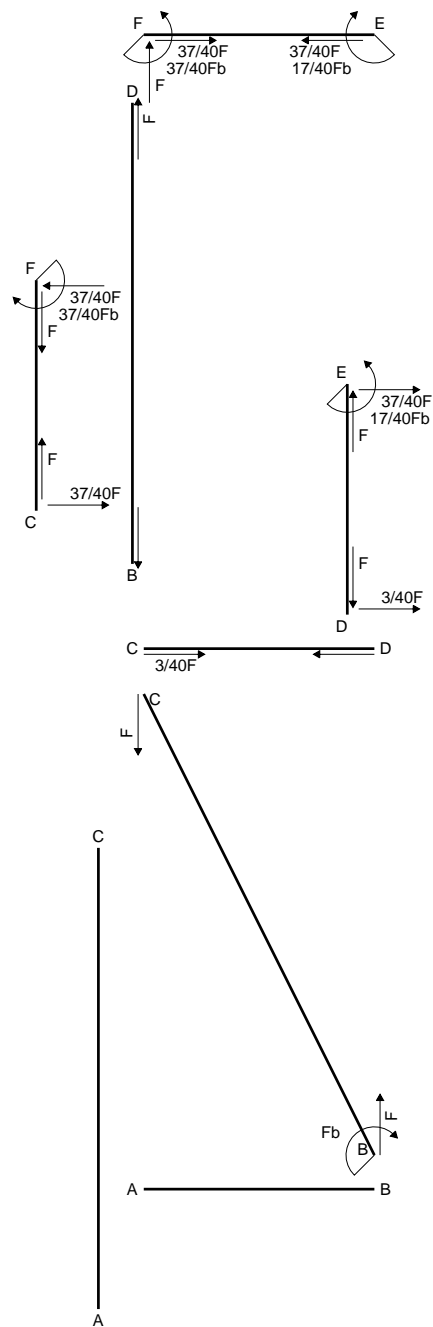
$$L_{FE}^{xo} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

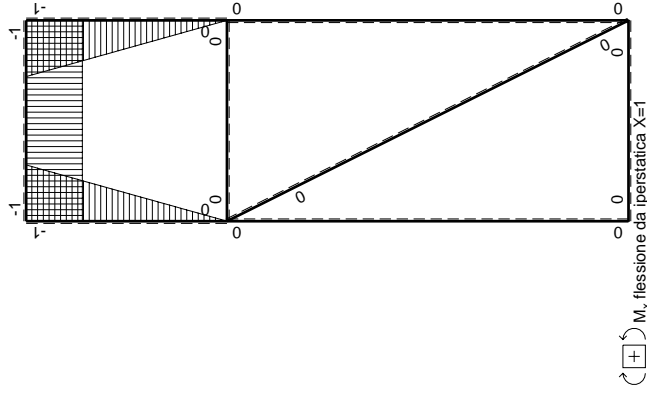
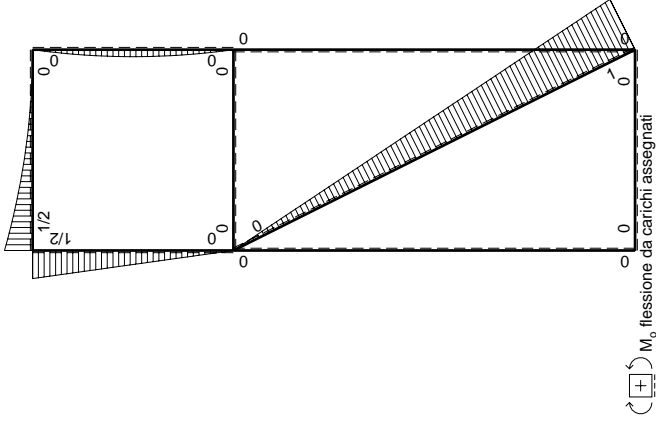
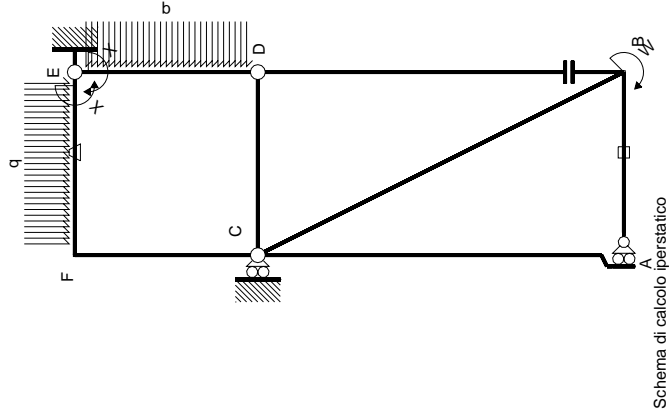
$$= (1/4 b - 1/6 b) Fb 1/EJ + (-b) \theta = 13/12 Fb^2/EJ$$



- 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> = 33. mm
- T<sub>y</sub> = -7150. N
- M<sub>x</sub> = -1751750. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -33. mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -229.9 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 14. mm
- v<sub>c</sub> = -19. mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -132.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 10.35 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 133.6 N/mm<sup>2</sup>
- S = 4368. mm<sup>3</sup>







Quadro contributi PLV per iperstatica X=W<sub>EF</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	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0	0
BC √5b	0	Fb-√5/5Fx	0	0	0	0	0+0	0
CA 2b	0	0	0	0	0	0	0+0	0
DB 2b	0	0	0	0	0	0	0+0	0
BD 2b	0	0	0	0	0	0	0+0	0
DE 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>	(1/2+0)Fb <sup>2</sup> /EJ	1/3Xb/EJ
ED 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>	(1/2+0)Fb <sup>2</sup> /EJ	1/3Xb/EJ
CD b	0	0	0	0	0	0	0+0	0
DC b	0	0	0	0	0	0	0+0	0
EF b	-1	1/2qx <sup>2</sup>	-Fb/EJ	-1/2Fx <sup>2</sup> /b	Fb/EJ	1	(-1/6+1)Fb <sup>2</sup> /EJ	Xb/EJ
FE b	1	-1/2Fb+Fx-1/2qx <sup>2</sup>	Fb/EJ	-1/2Fb+Fx-1/2Fx <sup>2</sup> /b	Fb/EJ	1	(-1/6+1)Fb <sup>2</sup> /EJ	Xb/EJ
FC b	-1+x/b	1/2Fb-1/2Fx	0	-1/2Fb+Fx-1/2Fx <sup>2</sup> /b	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	(-1/6+0)Fb <sup>2</sup> /EJ	1/3Xb/EJ
CF b	x/b	-1/2Fx	0	-1/2Fx <sup>2</sup> /b	0	x <sup>2</sup> /b <sup>2</sup>	(-1/6+0)Fb <sup>2</sup> /EJ	1/3Xb/EJ
totali							17/24Fb <sup>2</sup> /EJ	5/3Xb/EJ
								-17/40Fb

Sviluppi di calcolo iperstatica

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

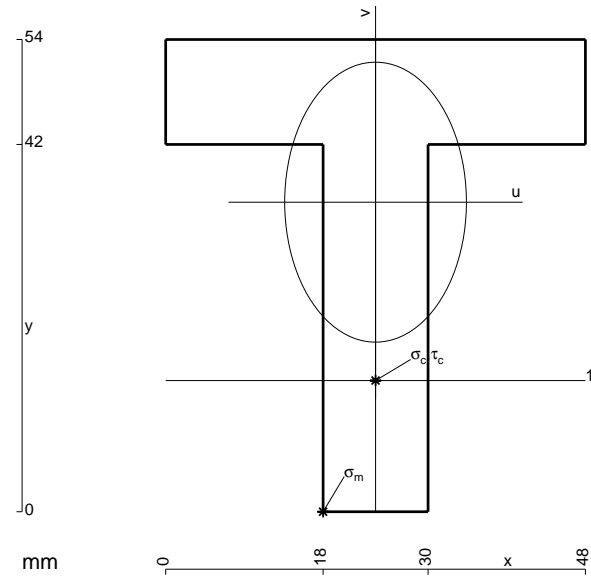
$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ + (-b) \theta = 5/6 Fb^2/EJ$$

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

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

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

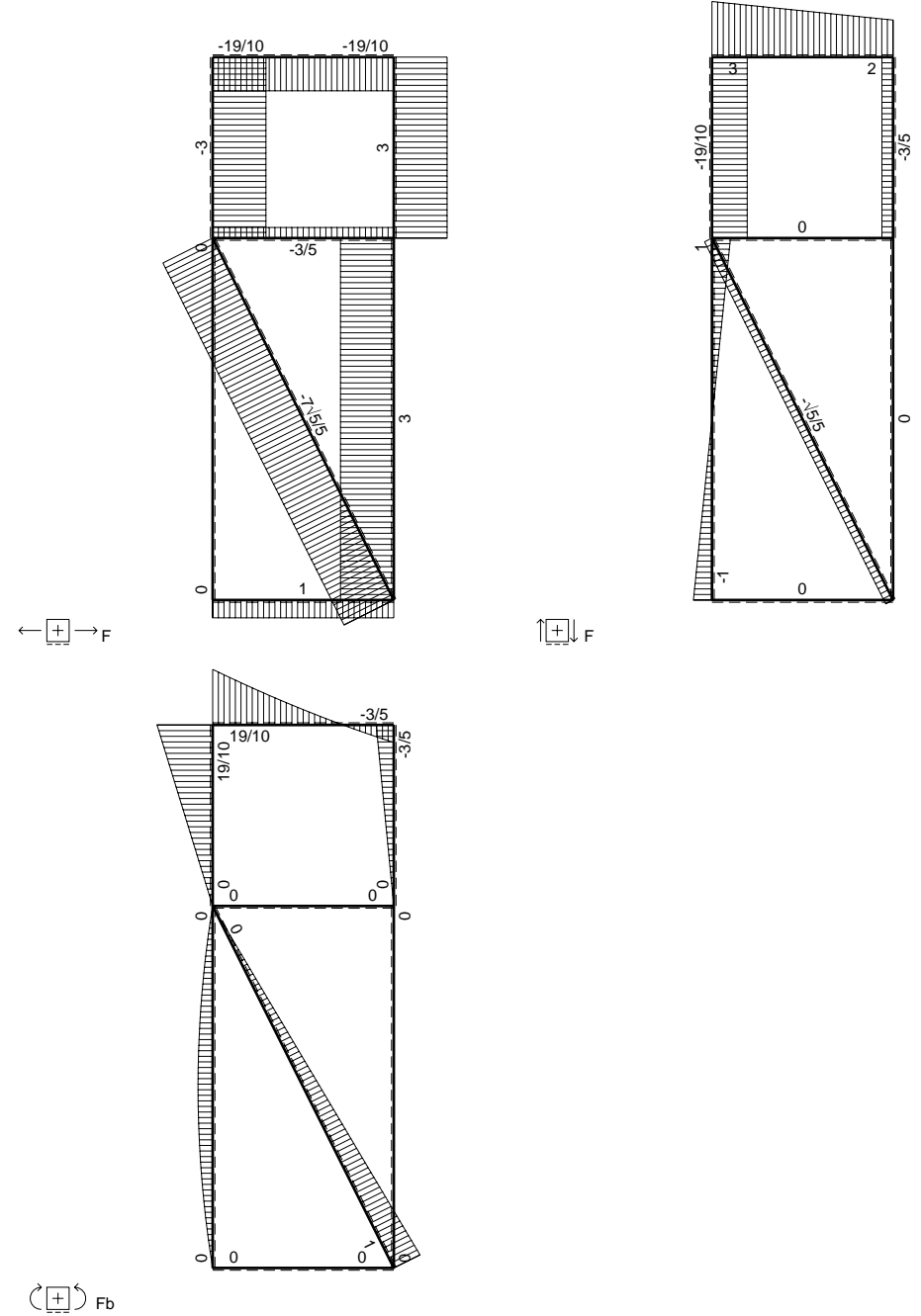
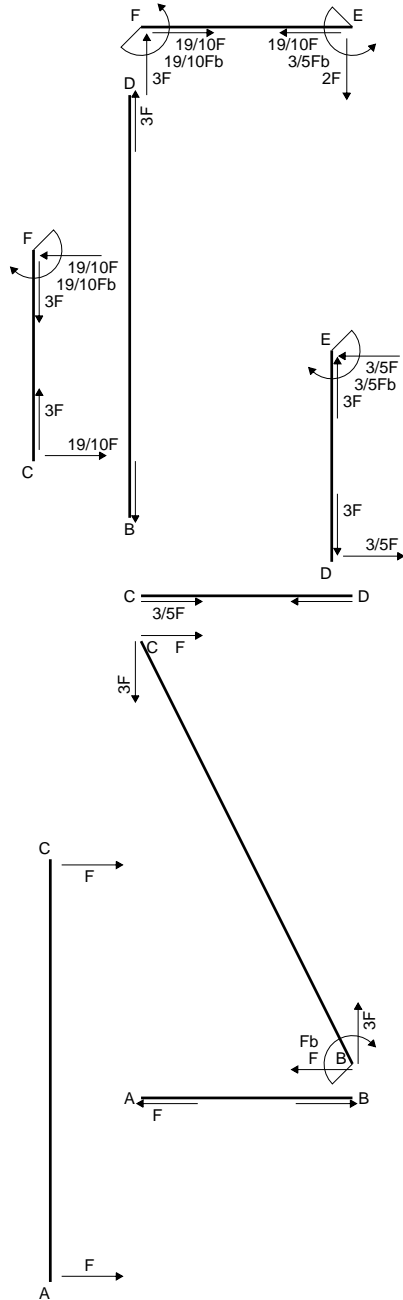
$$= (-1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$



- A = 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
- N = -3202. N
- T<sub>y</sub> = -1601. N
- M<sub>x</sub> = 1897400. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -35.4 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> = -20.4 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = 136.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.419 N/mm<sup>2</sup>
- σ<sub>ρ</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 136.9 N/mm<sup>2</sup>
- S = 5022. mm<sup>3</sup>









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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

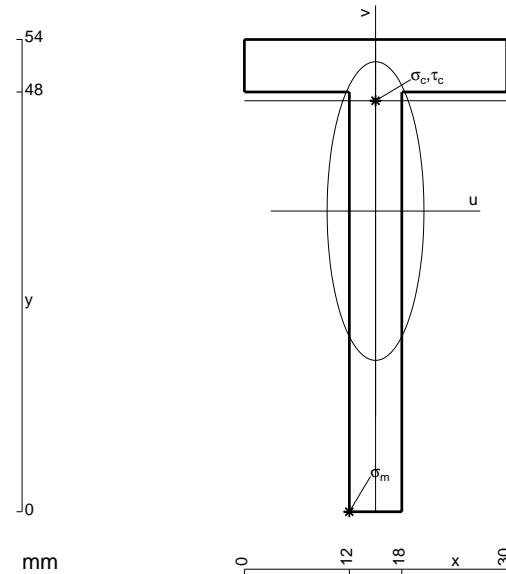
$$= (-5/2 b + 3/2 b - 1/6 b) Fb 1/EJ + (-b) \theta = -1/6 Fb^2/EJ$$

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

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

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

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



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

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

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

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

$$N = -4571. \text{ N}$$

$$T_y = -652.9 \text{ N}$$

$$M_x = 832200. \text{ Nmm}$$

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

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

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

$$\sigma_m = N/A - Mv/J_u = 199.7 \text{ N/mm}^2$$

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

$$y_c = 47. \text{ mm}$$

$$v_c = 12.62 \text{ mm}$$

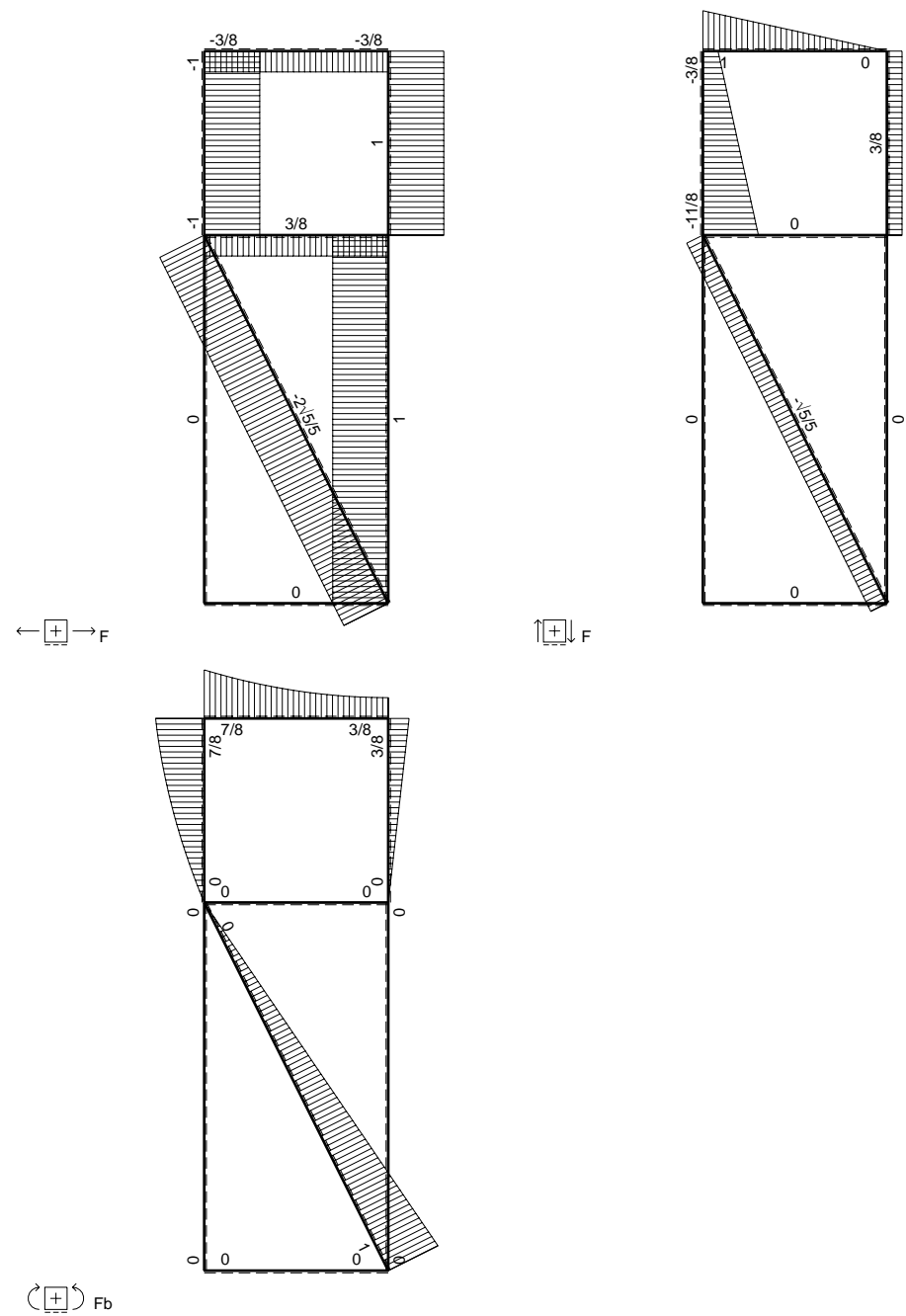
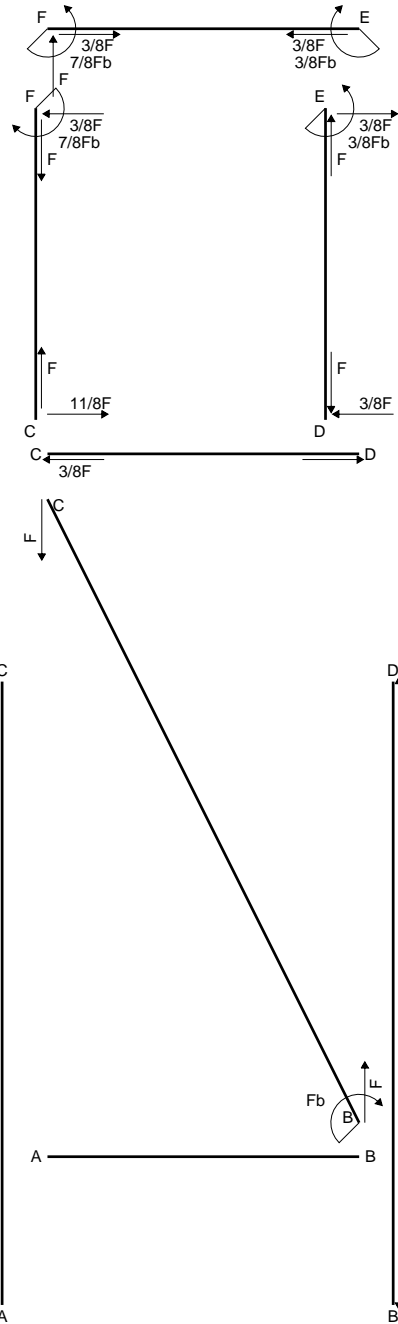
$$\sigma_c = N/A - Mv/J_u = -86.63 \text{ N/mm}^2$$

$$\tau_c = 2.446 \text{ N/mm}^2$$

$$\sigma_\varphi = \sqrt{\sigma^2 + 3\tau^2} = 86.73 \text{ N/mm}^2$$

$$S = 3069. \text{ mm}^3$$







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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

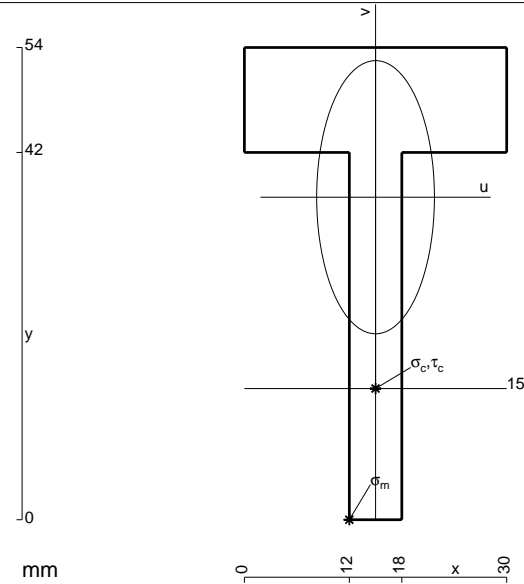
$$L_{FC}^{xo} = \int_0^b (-1/2 + 1/2 x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx$$

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

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

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

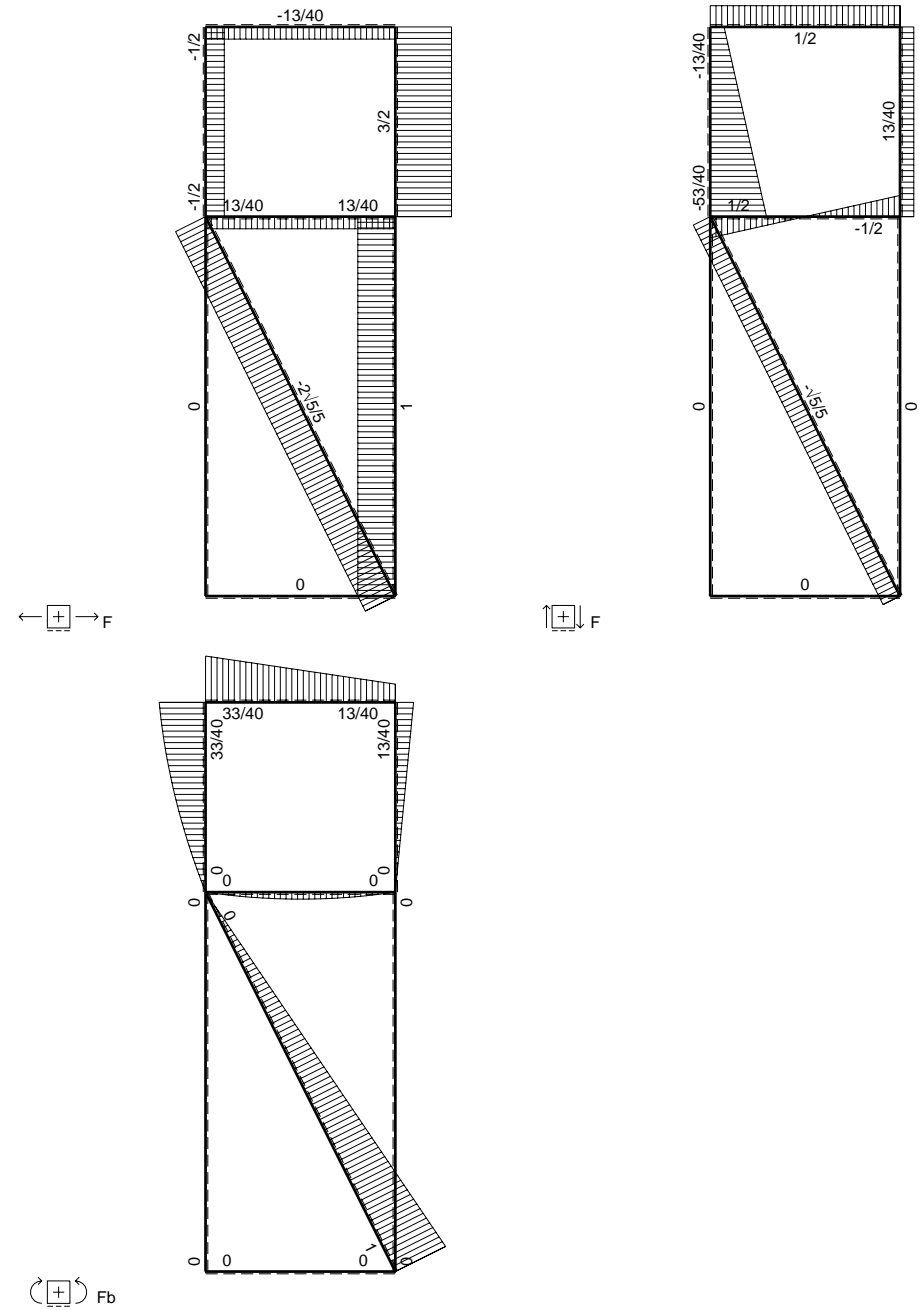
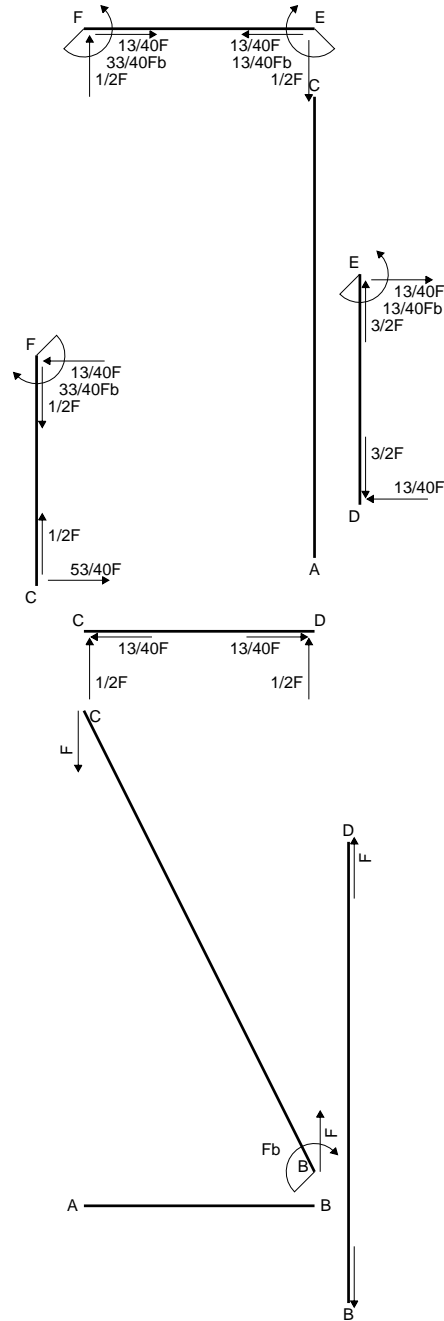
$$= (-1/3 b + 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$



- A = 612. mm<sup>2</sup>
- J<sub>u</sub> = 149427. mm<sup>4</sup>
- J<sub>v</sub> = 27756. mm<sup>4</sup>
- y<sub>g</sub> = 36.88 mm
- N = -1279. N
- T<sub>y</sub> = -639.5 N
- M<sub>x</sub> = 858000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -36.88 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = 209.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 15. mm
- y<sub>c</sub> = 15. mm
- v<sub>c</sub> = -21.88 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = 123.6 N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.886 N/mm<sup>2</sup>
- σ<sub>φ</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 123.6 N/mm<sup>2</sup>
- S = 2644. mm<sup>3</sup>









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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

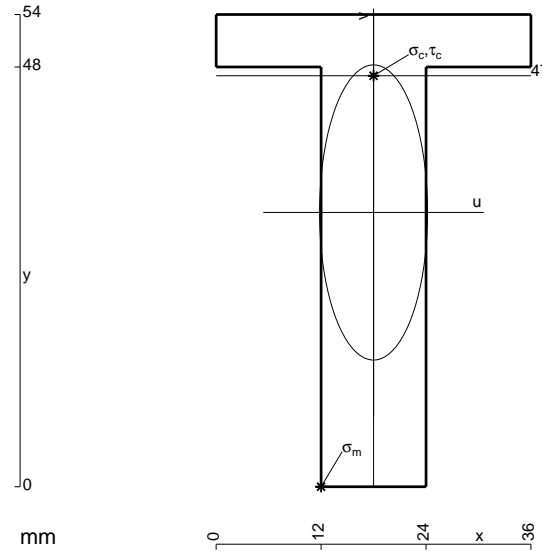
$$L_{FC}^{xo} = \int_0^b (-1/2 + 1/2 x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx$$

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

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

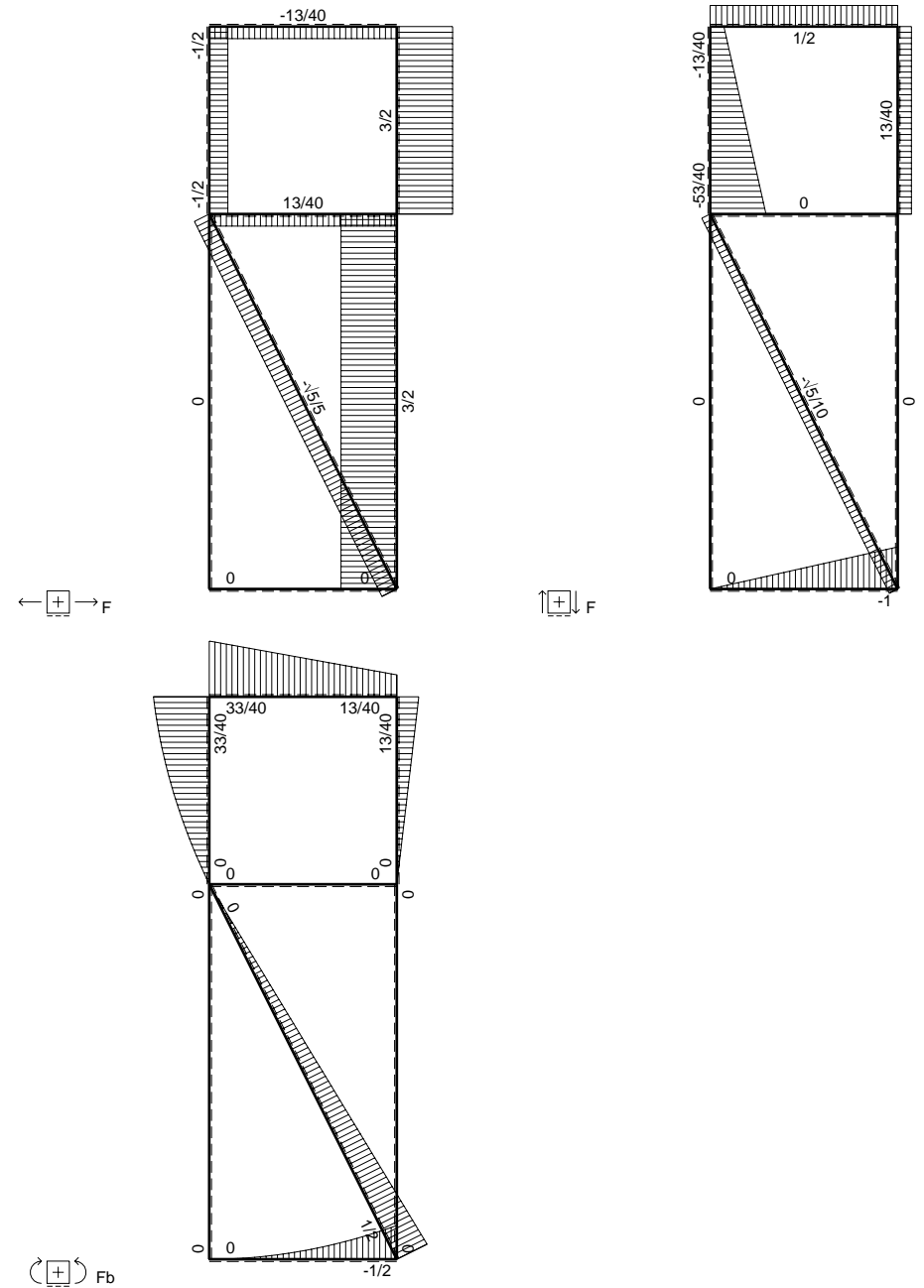
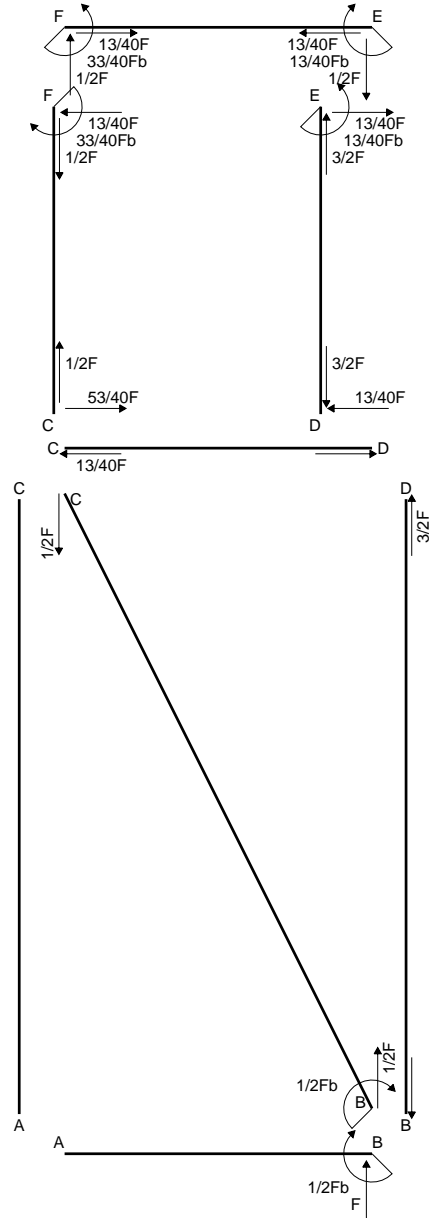
$$L_{CF}^{xo} = \int_0^b (-x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

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

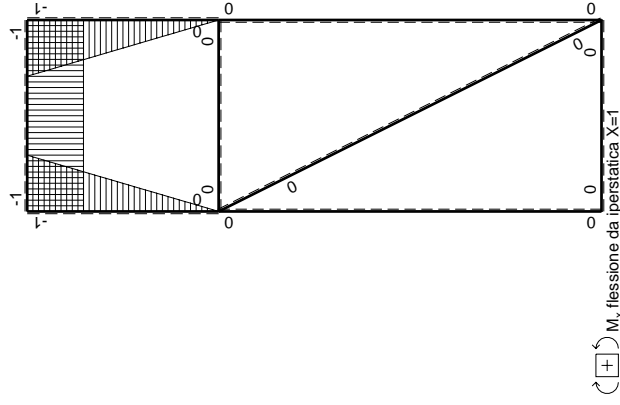
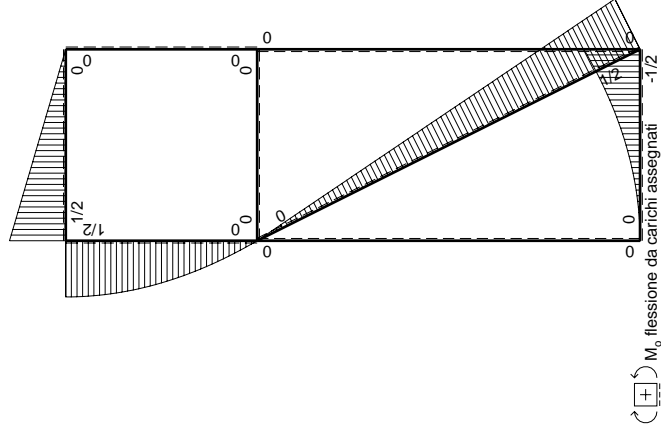
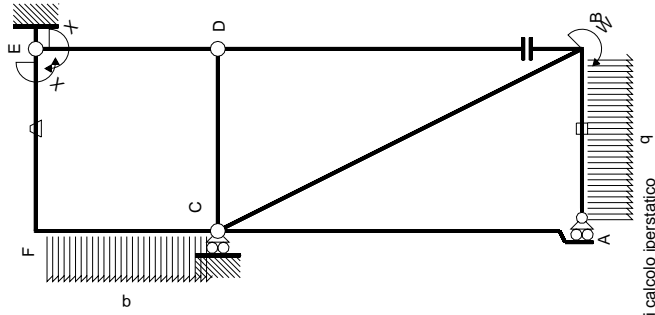


- A = 792. mm<sup>2</sup>
- J<sub>u</sub> = 225759. mm<sup>4</sup>
- J<sub>v</sub> = 30240. mm<sup>4</sup>
- y<sub>g</sub> = 31.36 mm
- N = -2236. N
- T<sub>y</sub> = -1118. N
- M<sub>x</sub> = 1600000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -31.36 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = 219.5 N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 47. mm
- v<sub>c</sub> = 15.64 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = -113.6 N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.83 N/mm<sup>2</sup>
- σ<sub>ρ</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 113.7 N/mm<sup>2</sup>
- S = 4435. mm<sup>3</sup>





⊕ F<sub>b</sub>



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

$\rightarrow$	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x (M_0/EJ + \theta) dx$	$\int M^x M_x / E dx$
AB b	0	$-1/2qx^2$	0	0	0	0	0	0
BA b	0	$1/2Fb - Fx + 1/2qx^2$	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$1/2Fb - \sqrt{5}/10Fx$	0	0	0	0	0	0
AC 2b	0	0	0	0	0	0	0	0
CA 2b	0	0	0	0	0	0	0	0
DB 2b	0	0	0	0	0	0	0	0
BD 2b	0	0	0	0	0	0	0	0
DE b	-x/b	0	0	0	0	0	0	0
ED b	1-x/b	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
EF b	-1	$1/2Fx$	-Fb/EJ	-1/2Fx	Fb/EJ	1	$(-1/4+1)Fb^2/EJ$	Xb/EJ
FE b	1	$-1/2Fb+1/2Fx$	Fb/EJ	-1/2Fb+1/2Fx	Fb/EJ	1	$(-1/4+1)Fb^2/EJ$	Xb/EJ
FC b	-1+x/b	$1/2Fb-1/2qx^2$	0	$-1/2Fb+1/2Fx+1/2Fx^2/b-1/2qx^3/b$	0	0	$(-5/24+0)Fb^2/EJ$	$1/3Xb/EJ$
CF b	x/b	$-Fx+1/2qx^2$	0	$-Fx^2/b+1/2qx^3/b$	0	0	$13/24Fb^2/EJ$	$5/3Xb/EJ$
totali								
iperstatica $X=W_{EF}$								

Sviluppi di calcolo iperstatica

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

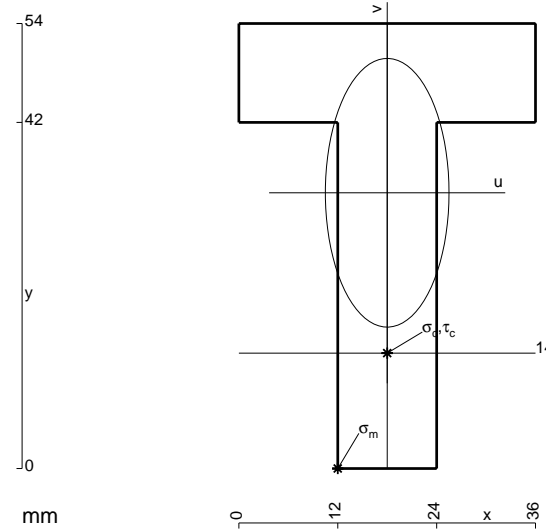
$$L_{FC}^{xo} = \int_0^b (-1/2 + 1/2 x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx$$

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

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

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

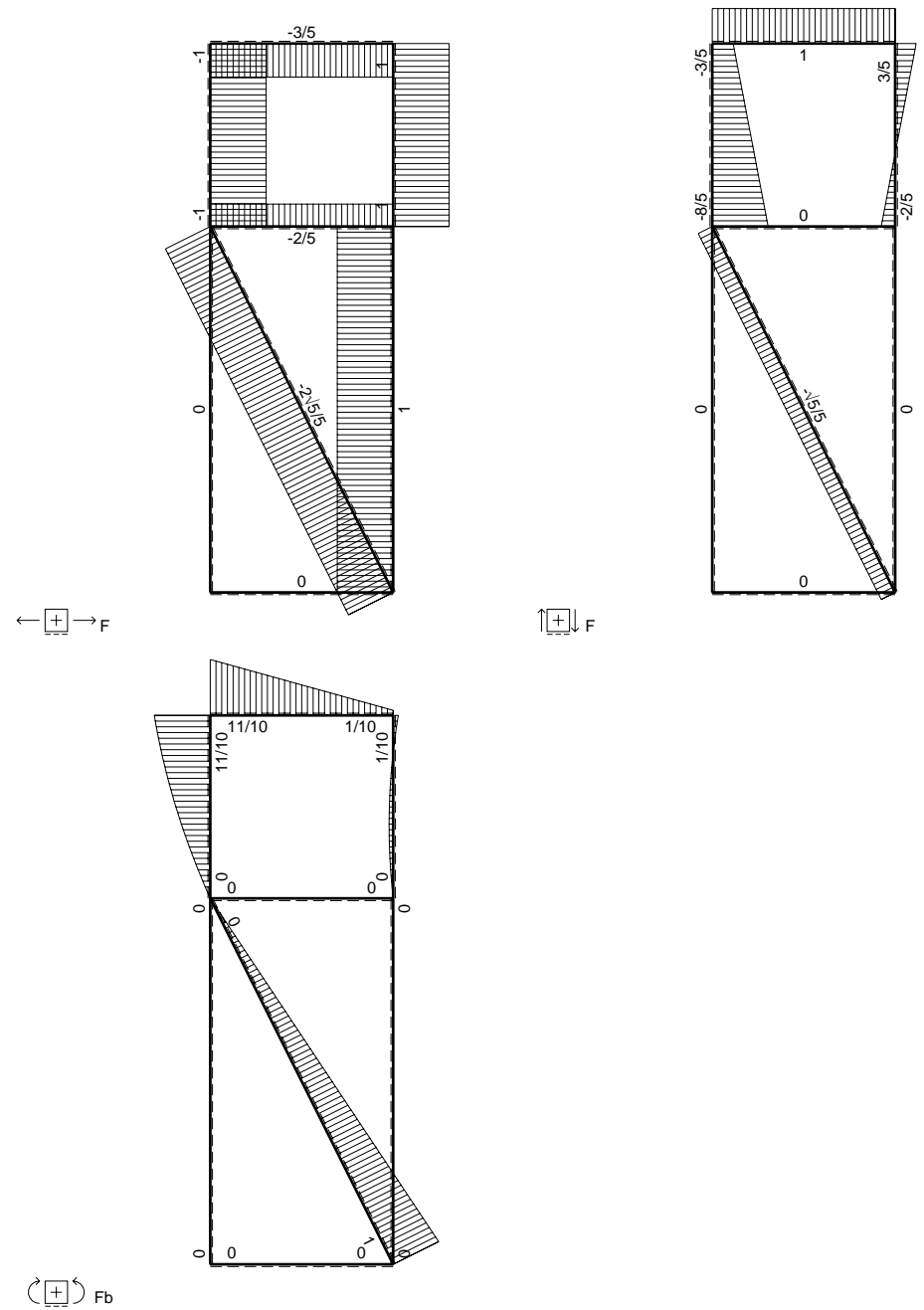
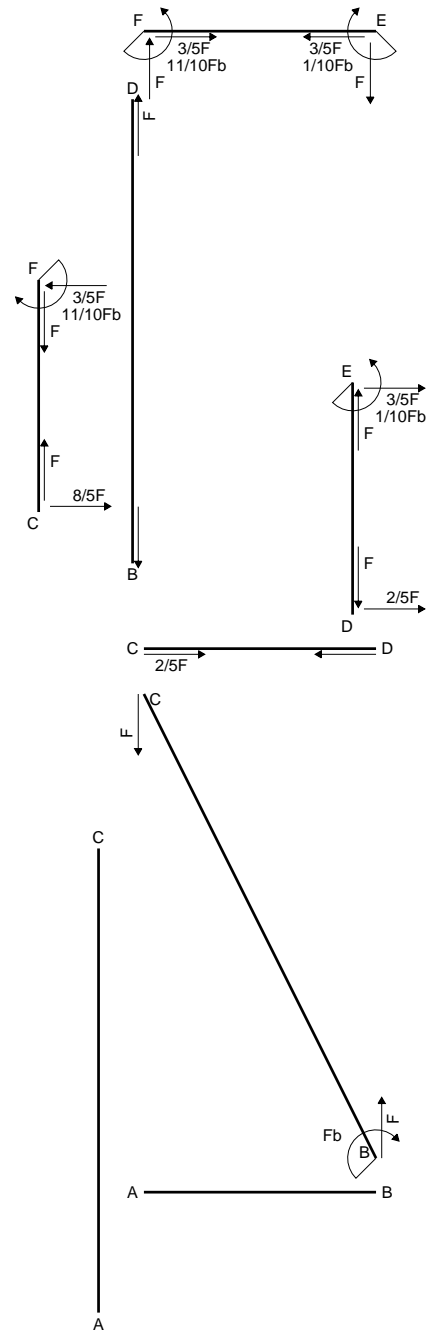
$$= (-1/3 b + 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$



- A = 936. mm<sup>2</sup>
- J<sub>u</sub> = 248849. mm<sup>4</sup>
- J<sub>v</sub> = 52704. mm<sup>4</sup>
- y<sub>g</sub> = 33.46 mm
- T<sub>y</sub> = -5030. N
- M<sub>x</sub> = -1710200. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -33.46 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -230. N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 14. mm
- v<sub>c</sub> = -19.46 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -133.7 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.488 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 = 4446. mm<sup>3</sup>









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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

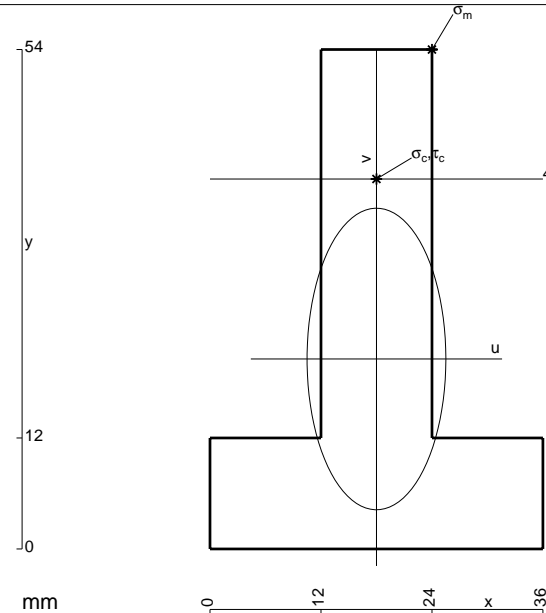
$$= (-b + 1/2 b) Fb 1/EJ + (-b) \theta = 1/2 Fb^2/EJ$$

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

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

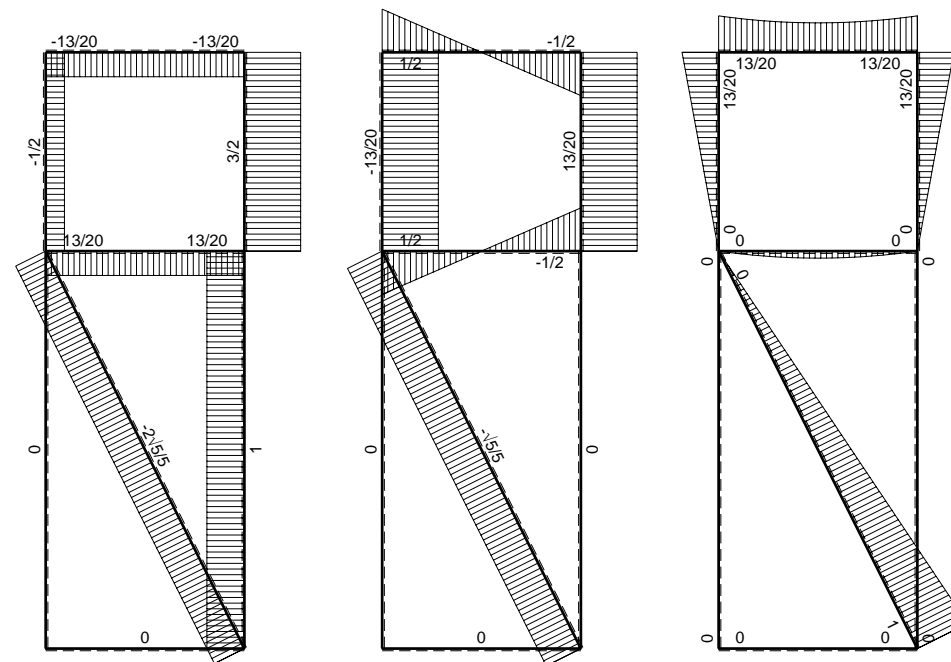
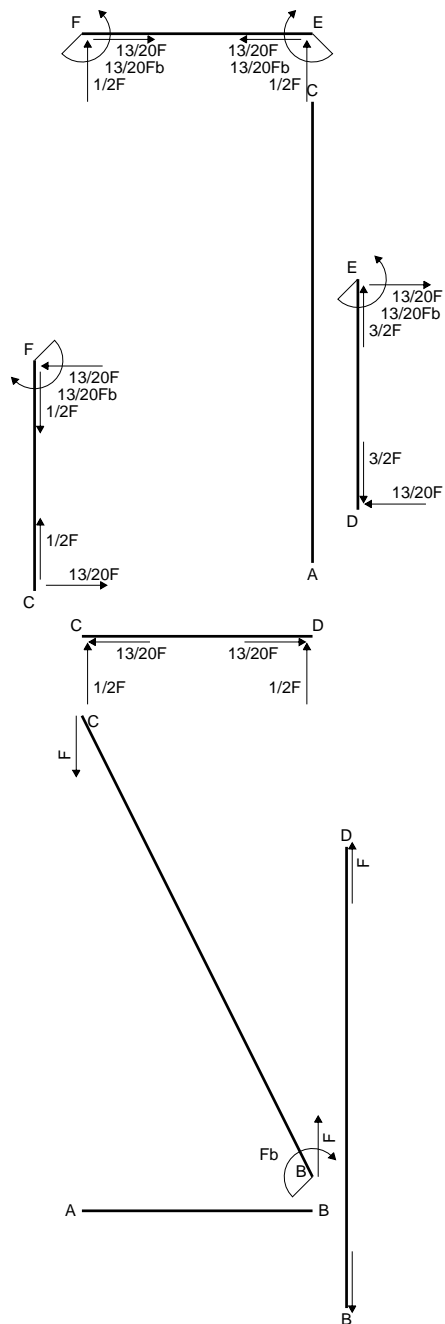
$$L_{CF}^{x_0} = \int_0^b (-3/2 x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/2 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

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



- A = 936. mm<sup>2</sup>
- J<sub>u</sub> = 248849. mm<sup>4</sup>
- J<sub>v</sub> = 52704. mm<sup>4</sup>
- y<sub>g</sub> = 20.54 mm
- N = -2191. N
- T<sub>y</sub> = -1096. N
- M<sub>x</sub> = 1764000. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 33.46 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = -239.5 N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 40. mm
- v<sub>c</sub> = 19.46 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>v</sub> = -140.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.631 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup>+3τ<sup>2</sup>) = 140.3 N/mm<sup>2</sup>
- S = 4446. mm<sup>3</sup>





← ⊕ → F

↑ ⊕ ↓ F

⊕ ⊖ F<sub>b</sub>



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

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

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

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

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

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

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

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

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

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

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

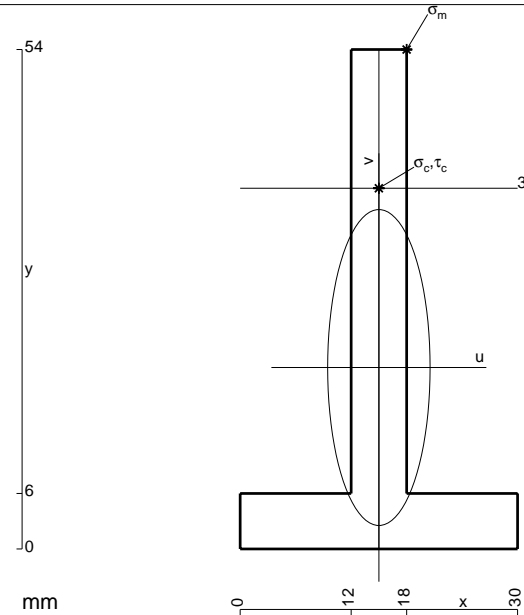
$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

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

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

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

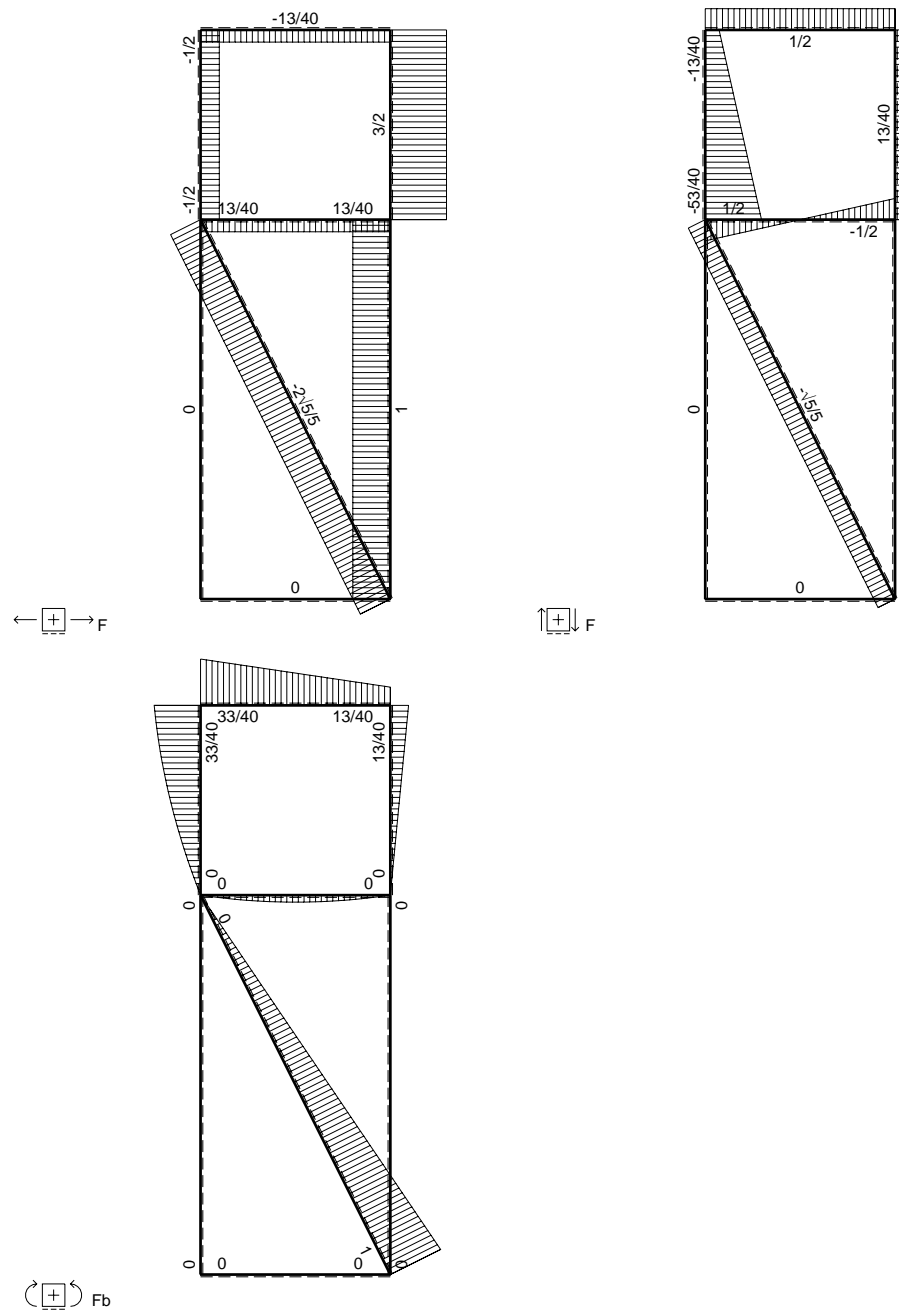
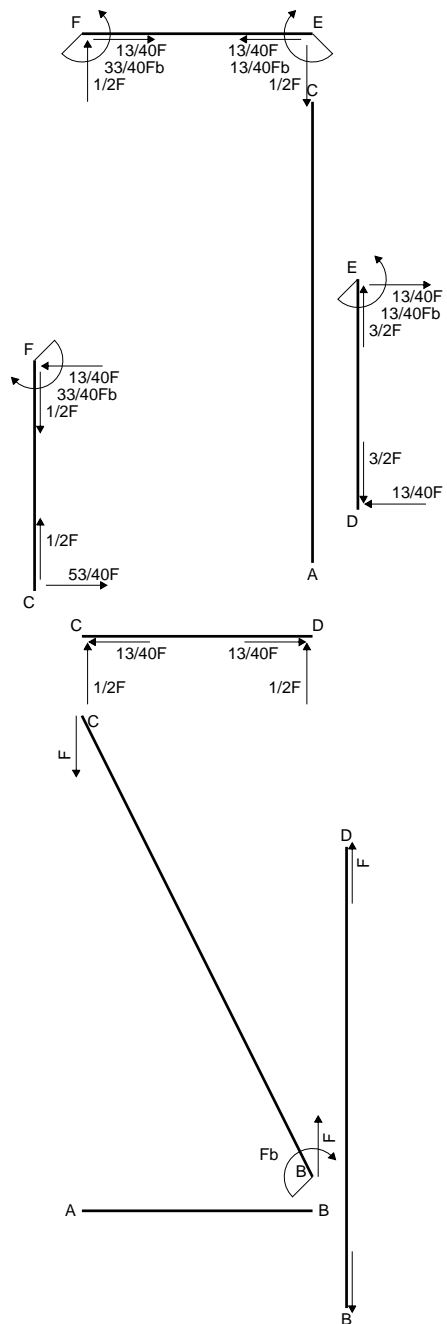
$$= (1/4 b - 1/6 b) Fb 1/EJ + (-b) \theta = 13/12 Fb^2/EJ$$

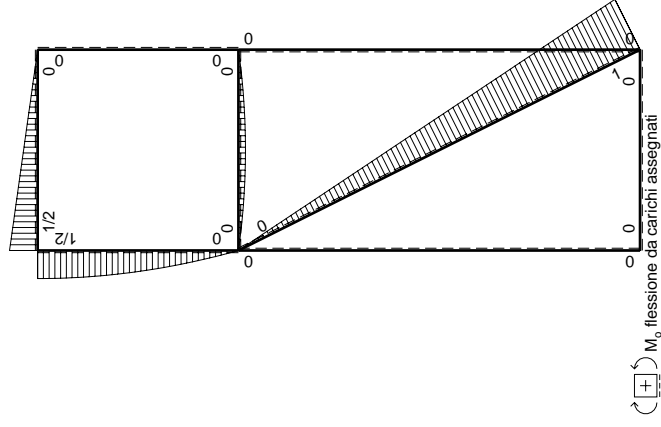
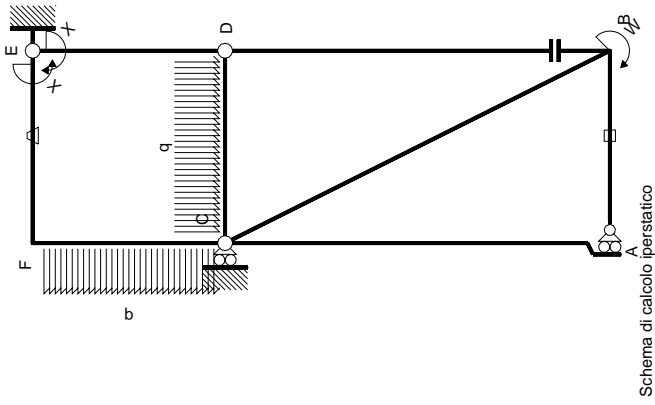


- A = 468. mm<sup>2</sup>
- J<sub>u</sub> = 136587. mm<sup>4</sup>
- J<sub>v</sub> = 14364. mm<sup>4</sup>
- y<sub>g</sub> = 19.62 mm
- N = -1825. N
- T<sub>y</sub> = -912.3 N
- M<sub>x</sub> = 775200. Nmm
- x<sub>m</sub> = 18. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 3. mm
- v<sub>m</sub> = 34.38 mm
- v<sub>c</sub> = 19.38 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = -199. 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> = -113.9 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.694 N/mm<sup>2</sup>
- σ<sub>g</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 114. N/mm<sup>2</sup>
- S<sup>3</sup> = 2420. mm<sup>3</sup>





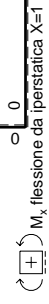




Quadro contributi PLV per iperstatica  $X=W_{EP}$

$\leftarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x$	$M_\theta$	$M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJdx$
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0	0
BC $\sqrt{5}b$	$Fb-\sqrt{5}Fx$	0	0	0	0	0	0+0	0
CA 2b	0	0	0	0	0	0	0+0	0
DB 2b	0	0	0	0	0	0	0+0	0
BD 2b	0	0	0	0	0	0	0+0	0
DE b	-x/b	0	0	0	0	$x^2/b^2$	0+0	1/3Xb/EJ
ED b	1-x/b	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	1/3Xb/EJ
CD b	$1/2Fx-1/2qx^2$	0	0	0	0	0	0+0	0
DC b	$-1/2Fx+1/2qx^2$	0	0	0	0	0	0+0	0
EF b	-1	$1/2Fx$	-Fb/EJ	$-1/2Fx$	Fb/EJ	1	$(-1/4+1)Fb^2/EJ$	Xb/EJ
FE b	1	$-1/2Fx+1/2Fx$	Fb/EJ	$-1/2Fb+1/2Fx$	Fb/EJ	1	$(-1/4+1)Fb^2/EJ$	Xb/EJ
FC b	$-1+x/b$	$1/2Fb-1/2qx^2$	0	$-1/2Fb+1/2Fx+1/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(-5/24+0)Fb^2/EJ$	1/3Xb/EJ
CF b	x/b	$-Fx+1/2qx^2$	0	$-Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$	$13/24Fb^2/EJ$	5/3Xb/EJ
totali								
iperstatica $X=W_{EP}$								

Sviluppi di calcolo iperstatica



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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

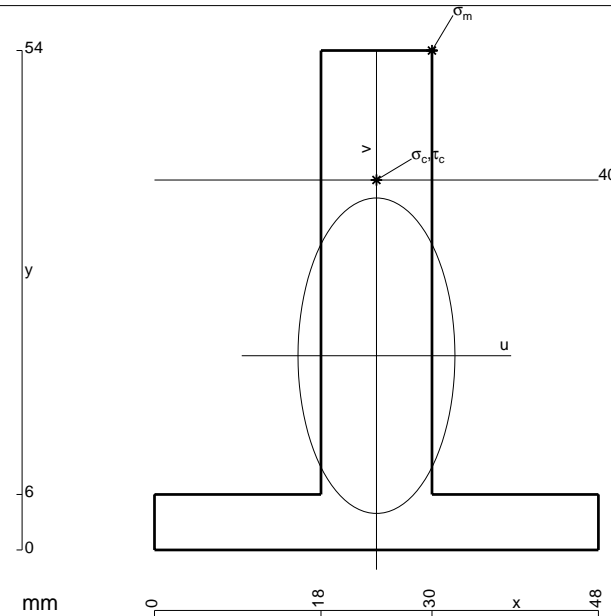
$$L_{FC}^{xo} = \int_0^b (-1/2 + 1/2 x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx$$

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

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

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

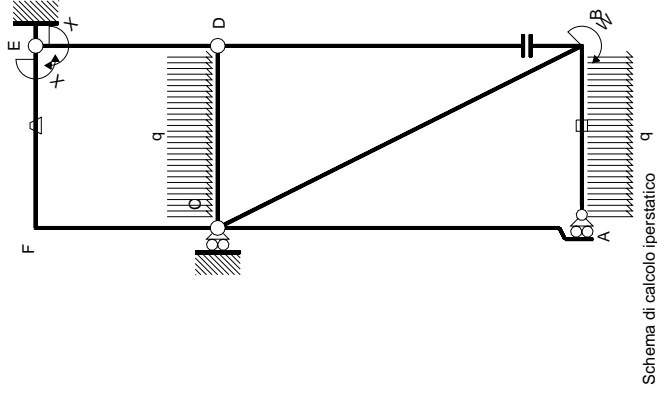
$$= (-1/3 b + 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$



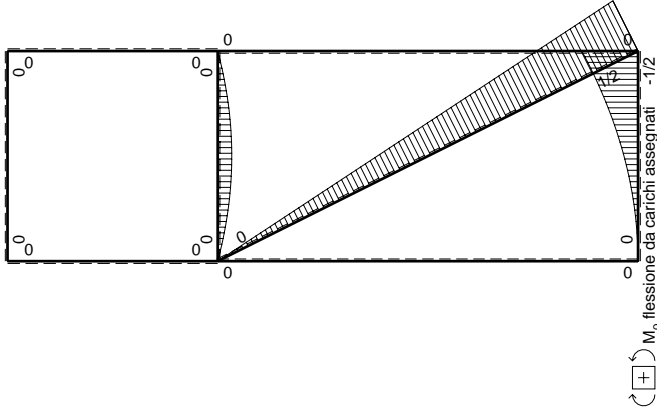
- A = 864. mm<sup>2</sup>
- J<sub>u</sub> = 251424. mm<sup>4</sup>
- J<sub>v</sub> = 62208. mm<sup>4</sup>
- y<sub>g</sub> = 21. mm
- N = -3417. N
- T<sub>y</sub> = -1708. N
- M<sub>x</sub> = 1566200. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 33. mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = -209.5 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> = -122.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.473 N/mm<sup>2</sup>
- σ<sub>o</sub> = √(σ<sup>2</sup>+3τ<sup>2</sup>) = 122.4 N/mm<sup>2</sup>
- S = 4368. mm<sup>3</sup>







Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati -1/2

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

→	$M_x(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int X M_x M_x / EJ dx$	
AB b	0	$-1/2qx^2$	0	0	0	0	0+0	0	
BA b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0+0	0	
BC $\sqrt{5}b$	0	$1/2Fb-\sqrt{5}/10Fx$	0	0	0	0	0	0	
AC 2b	0	0	0	0	0	0	0+0	0	
CA 2b	0	0	0	0	0	0	0+0	0	
DB 2b	0	0	0	0	0	0	0+0	0	
BD 2b	0	0	0	0	0	0	0+0	0	
DE b	$-x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	0	
CD b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
DC b	0	$-1/2Fx+1/2qx^2$	0	0	0	0	0+0	0	
EF b	-1	0	$-Fb/EJ$	0	$Fb/EJ$	1	$(0+1)Fb^2/EJ$	$Xb/EJ$	
FE b	1	0	$Fb/EJ$	0	$Fb/EJ$	1			
FC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
CF b	$x/b$	0	0	0	0	$x^2/b^2$	$Fb^2/EJ$	$5/3Xb/EJ$	
	totali								
	iperstatica $X=W_{EF}$								

Sviluppi di calcolo iperstatica

$M_x$  flessione da iperstatica  $X=1$

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

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

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

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

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

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

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

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

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

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

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

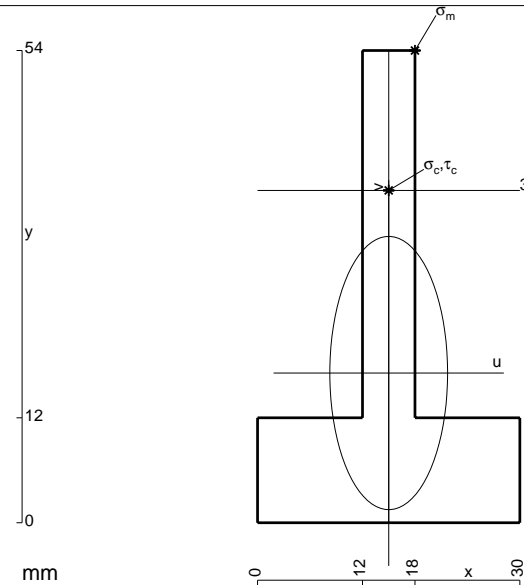
$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

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

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

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

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



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

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

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

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

$$T_y = -3960. \text{ N}$$

$$M_x = -891000. \text{ Nmm}$$

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

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

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

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

$$\sigma_m = -Mv/J_u = 219.9 \text{ N/mm}^2$$

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

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

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

$$\sigma_c = -Mv/J_u = 124.5 \text{ N/mm}^2$$

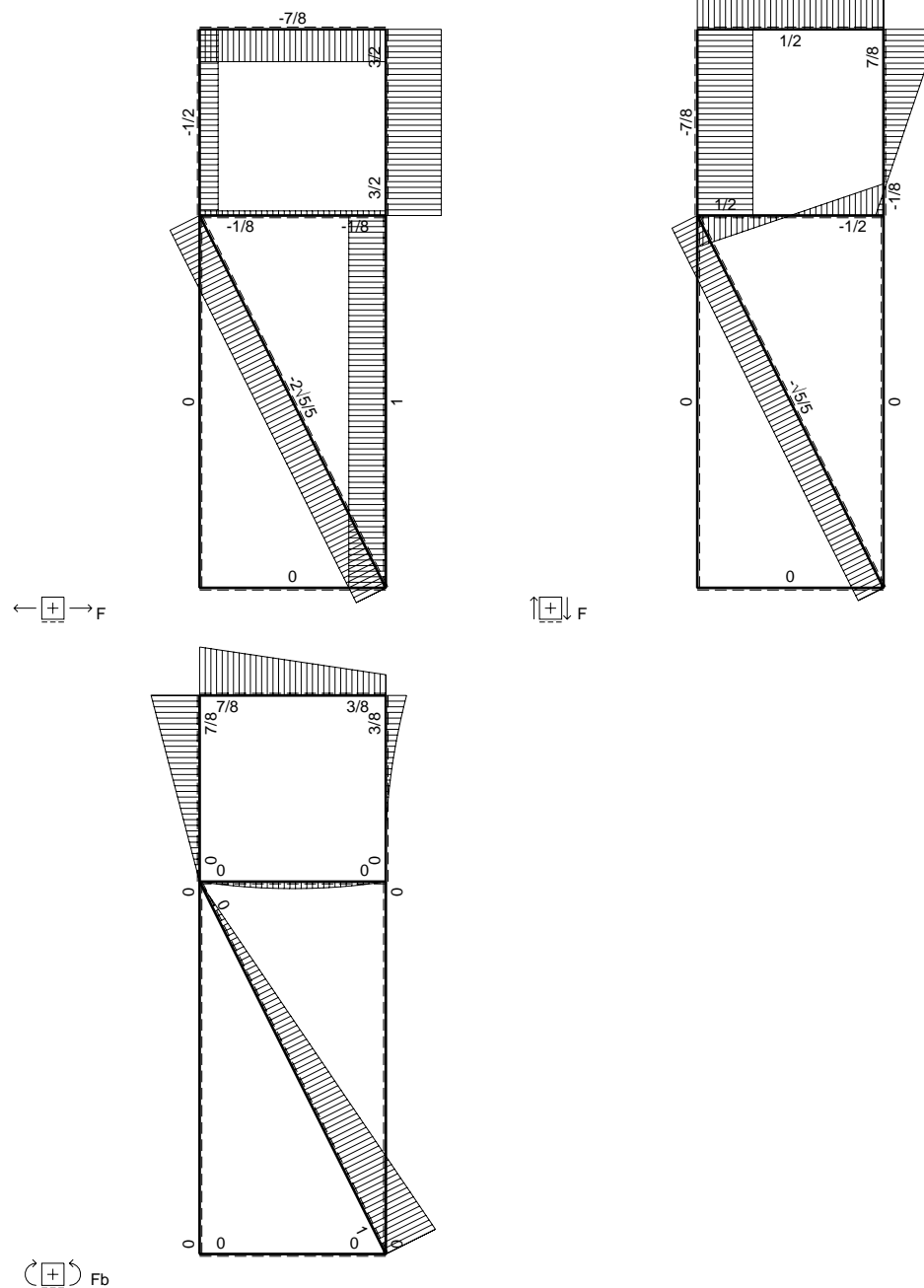
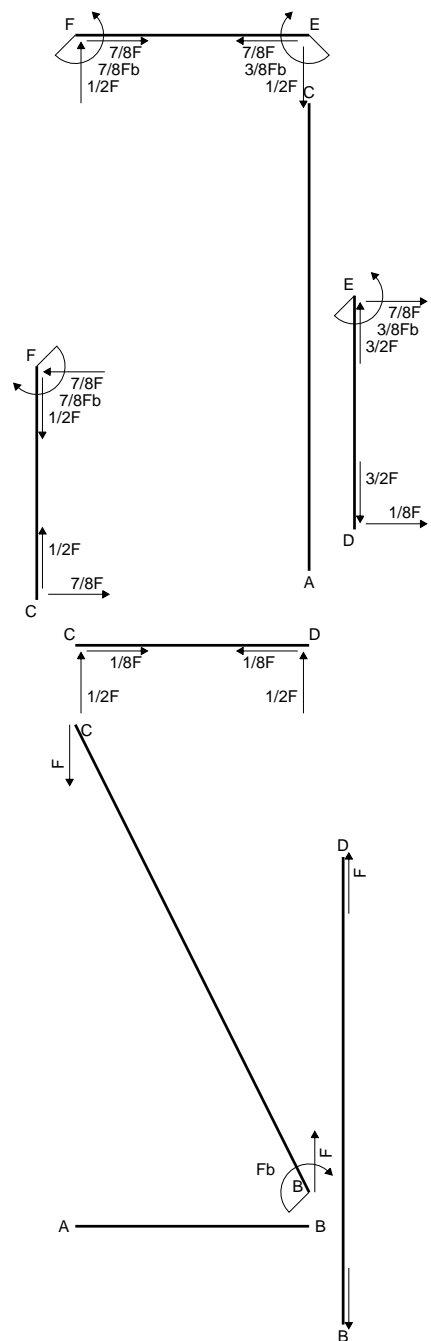
$$\tau_c = 12.25 \text{ N/mm}^2$$

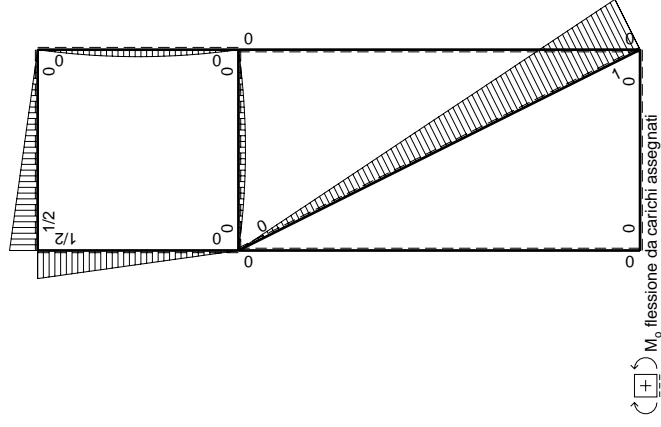
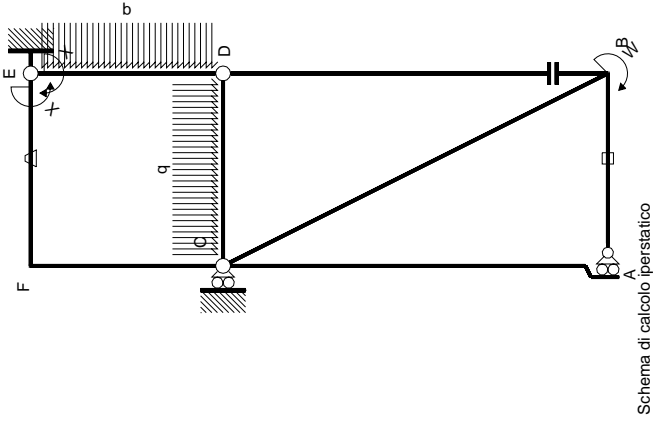
$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 126.3 \text{ N/mm}^2$$

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





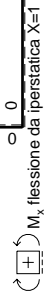




Quadro contributi PLV per iperstatica X=W<sup>EF</sup>

←	M <sup>x</sup> (x)	M <sup>0</sup> (x)	θ	M <sup>x</sup> M <sup>0</sup>	M <sup>x</sup> θ	M <sup>x</sup> M <sup>x</sup>	∫M <sup>x</sup> (M <sup>0</sup> /EJ+θ)dx	∫M <sup>x</sup> M <sup>x</sup> /EJdx
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0	0
BC √5b	0	Fb-√5/5Fx	0	0	0	0	0	0
CA 2b	0	0	0	0	0	0	0+0	0
DB 2b	0	0	0	0	0	0	0	0
BD 2b	0	0	0	0	0	0	0+0	0
DE 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>	0
ED 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>	1/3Xb/EJ
CD b	0	1/2Fx-1/2qx <sup>2</sup>	0	0	0	0	0	0
DC b	0	-1/2Fx+1/2qx <sup>2</sup>	0	0	0	0	0	0
EF b	-1	1/2Fx	-Fb/EJ	-1/2Fx	Fb/EJ	1	1	Xb/EJ
FE b	1	-1/2Fb+1/2Fx	Fb/EJ	-1/2Fb+1/2Fx	Fb/EJ	1	1	Xb/EJ
FC b	-1+x/b	1/2Fb-1/2Fx	0	-1/2Fb+Fx-1/2Fx <sup>2</sup> /b	0	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	1/3Xb/EJ
CF b	x/b	-1/2Fx	0	-1/2Fx <sup>2</sup> /b	0	0	x <sup>2</sup> /b <sup>2</sup>	1/3Xb/EJ
totali								5/8Fb <sup>2</sup> /EJ
								-3/8Fb

Sviluppi di calcolo iperstatica



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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

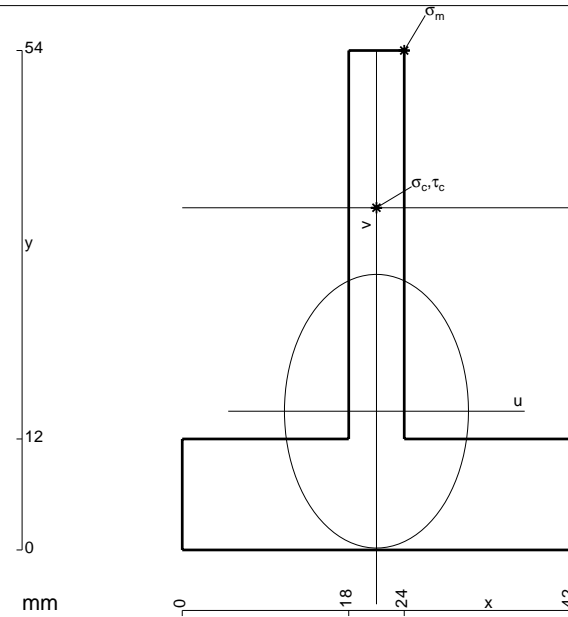
$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

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

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

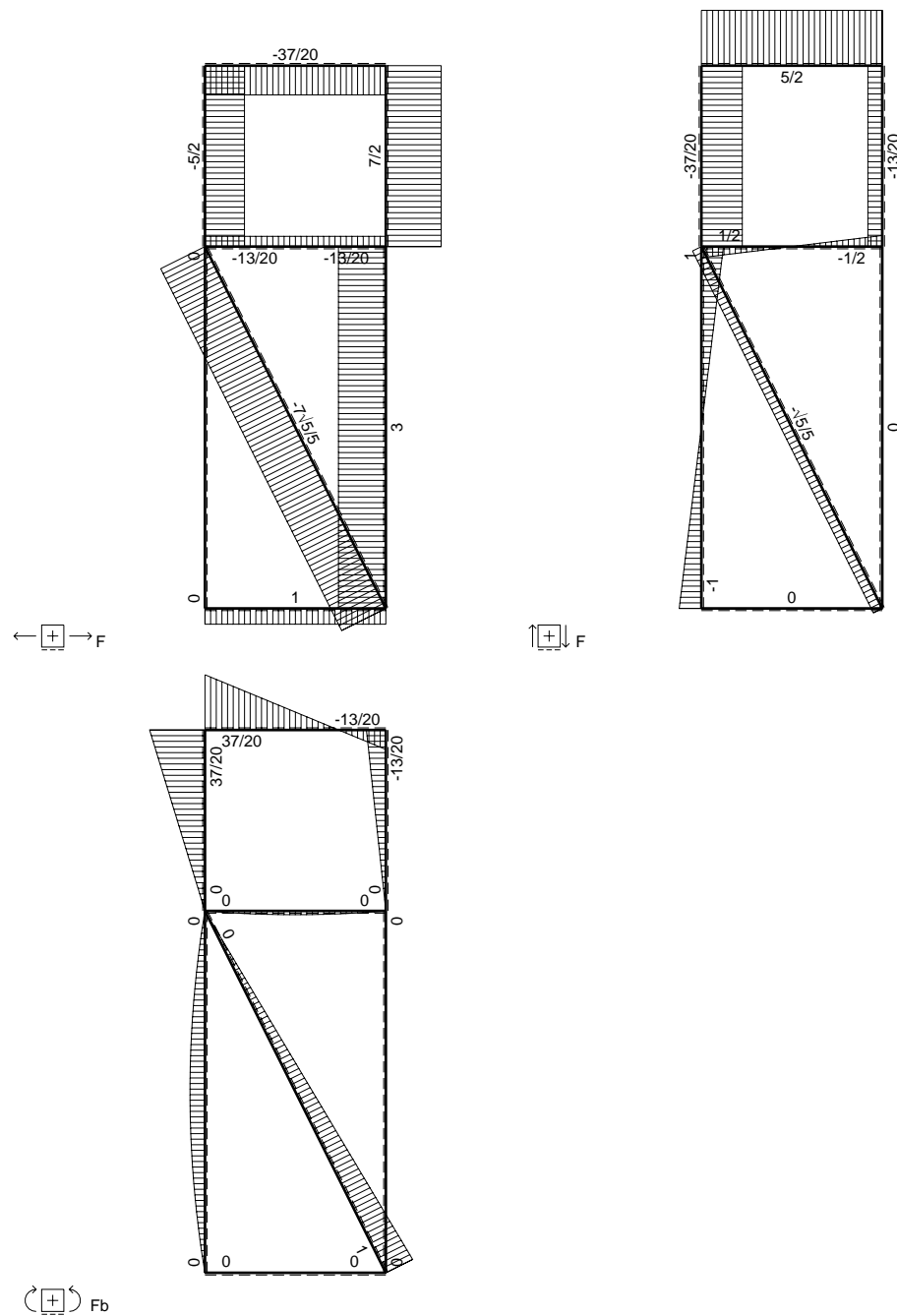
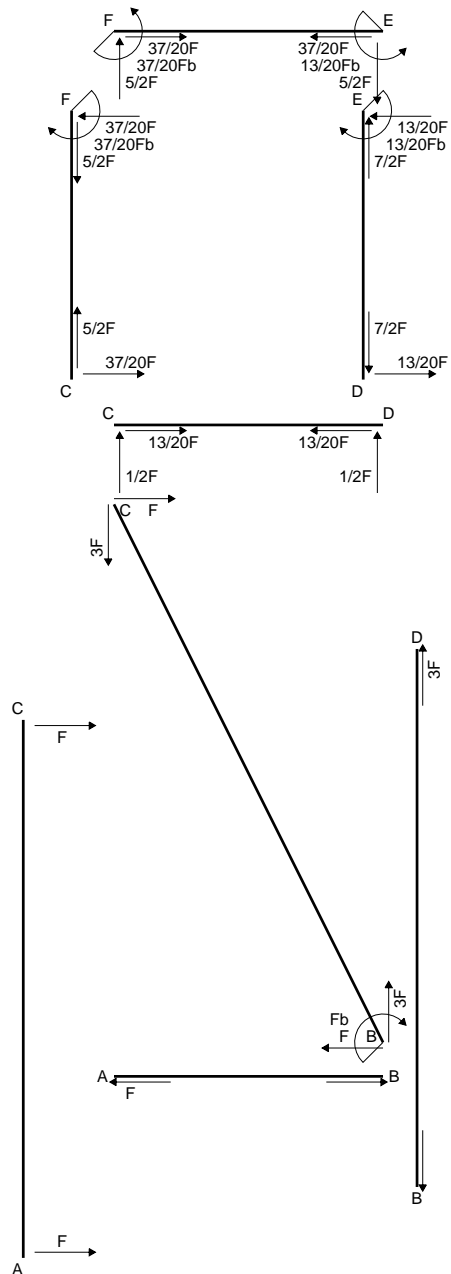
$$L_{CF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ$$

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



- A = 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
- N = -1762. N
- T<sub>y</sub> = -881. N
- M<sub>x</sub> = 965300. 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> = N/A-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. mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = -130.6 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.759 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup>+3τ<sup>2</sup>) = 130.7 N/mm<sup>2</sup>
- S = 3111. mm<sup>3</sup>







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

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

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

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

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

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

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

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

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

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

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

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

$$L_{EF}^{x_0} = \int_0^b (-5/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-5/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

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

$$L_{FE}^{x_0} = \int_0^b (-5/2 + 5/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-5/2 x + 5/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

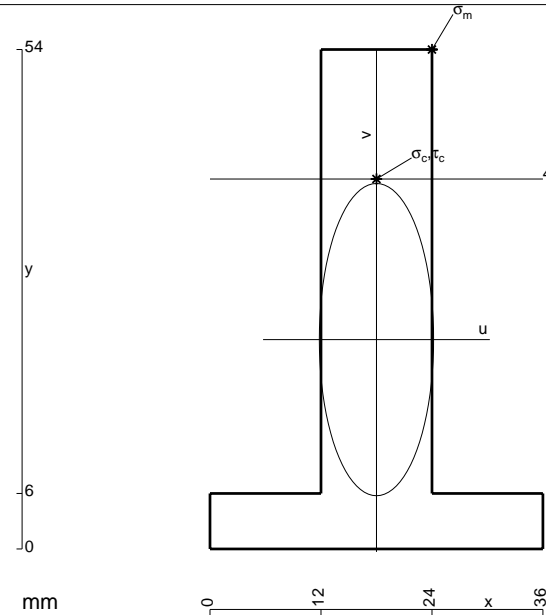
$$= (-5/2 b + 5/4 b) Fb 1/EJ + (-b) \theta = -1/4 Fb^2/EJ$$

$$L_{FC}^{x_0} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = [-5/2 x + 5/2 x^2/b - 5/6 x^3/b^2]_0^b Fb 1/EJ$$

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

$$L_{CF}^{x_0} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

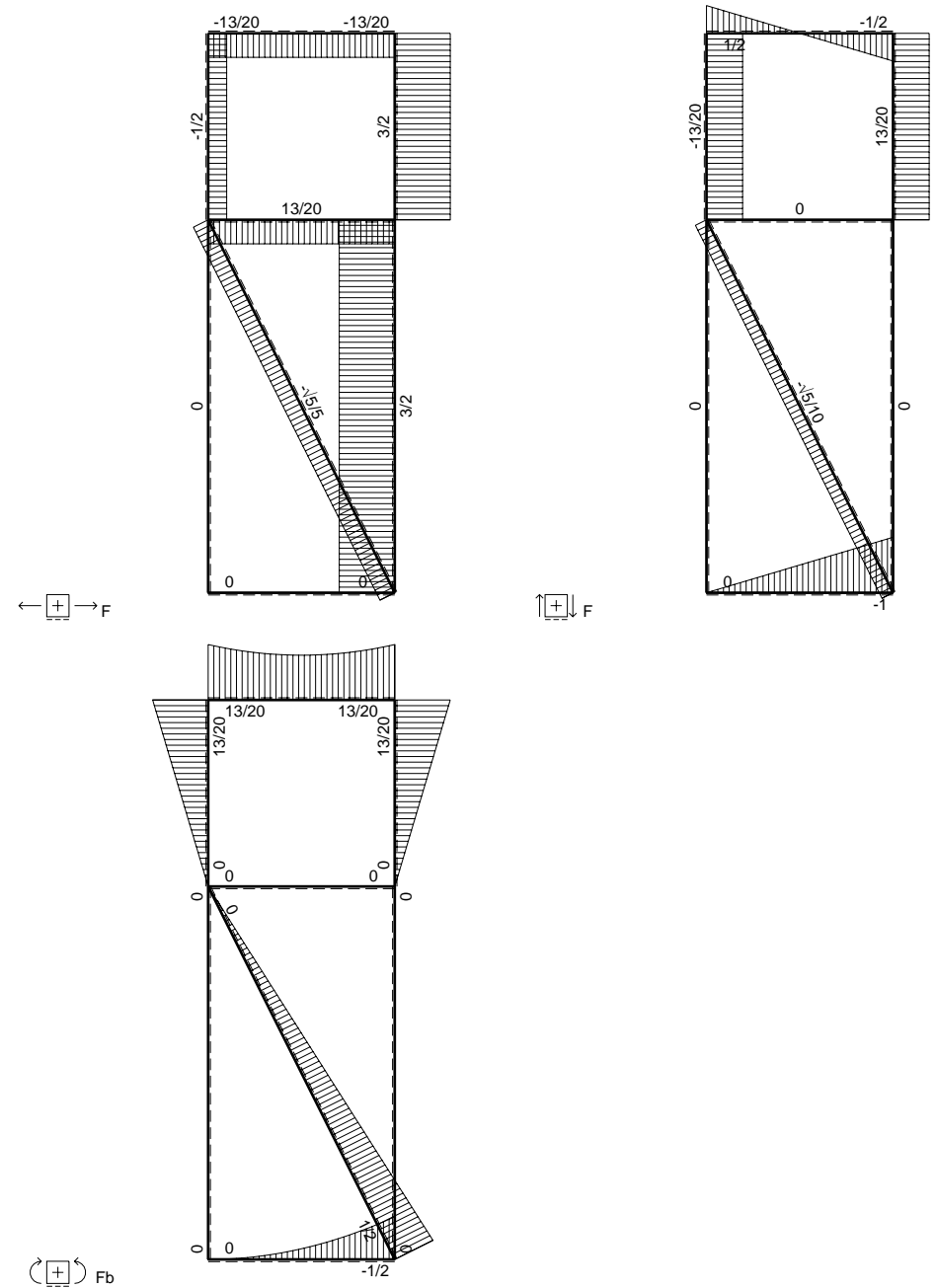
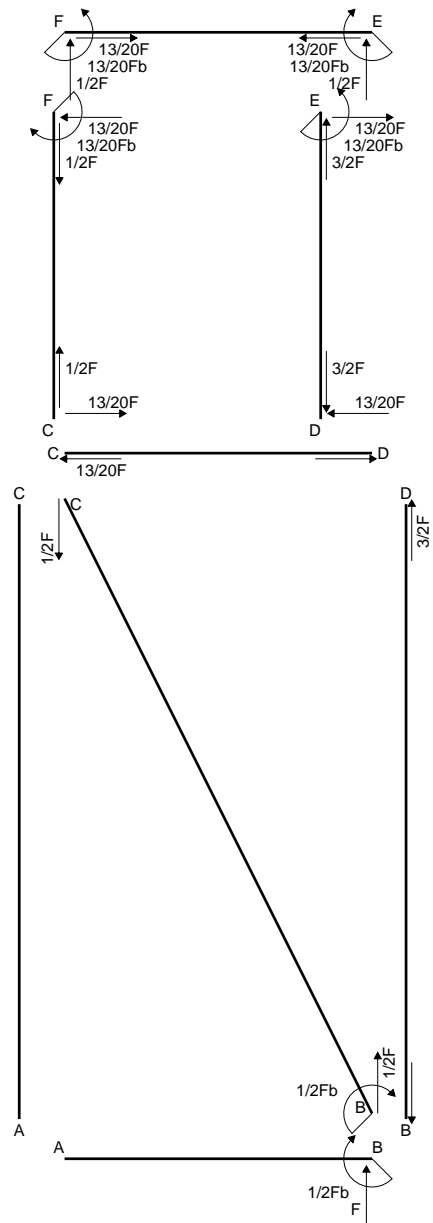
$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

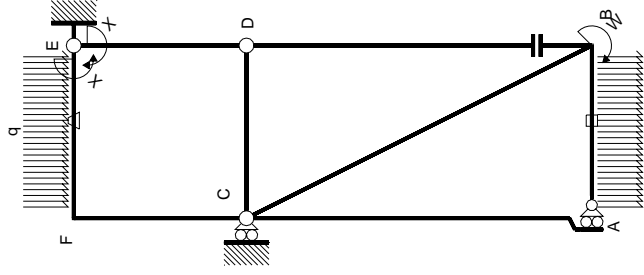


- A = 792. mm<sup>2</sup>
- J<sub>u</sub> = 225759. mm<sup>4</sup>
- J<sub>v</sub> = 30240. mm<sup>4</sup>
- y<sub>g</sub> = 22.64 mm
- N = -9673. N
- T<sub>y</sub> = -1382. N
- M<sub>x</sub> = 1637700. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 31.36 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = -239.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 40. mm
- v<sub>c</sub> = 17.36 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = -138.2 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.088 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup>+3τ<sup>2</sup>) = 138.2 N/mm<sup>2</sup>
- S = 4093. mm<sup>3</sup>

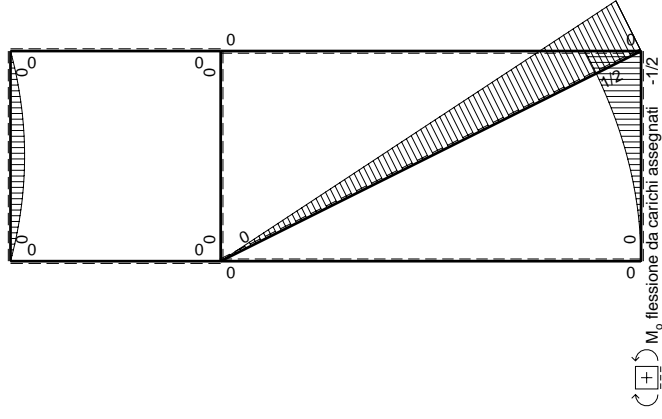








Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati -1/2

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

$\leftarrow$	$M_x(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	0	$-1/2qx^2$	0	0	0	0	0	0
BA b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$1/2Fb-\sqrt{5}/10Fx$	0	0	0	0	0	0
AC 2b	0	0	0	0	0	0	0	0
CA 2b	0	0	0	0	0	0	0	0
DB 2b	0	0	0	0	0	0	0	0
BD 2b	0	0	0	0	0	0	0	0
DE b	$-x/b$	0	0	0	0	0	0	0
ED b	$1-x/b$	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
EF b	-1	$-1/2Fx+1/2qx^2$	$-Fb/EJ$	$1/2Fx-1/2Fx^2/b$	$Fb/EJ$	1	$(1/12+1)Fb^2/EJ$	$Xb/EJ$
FE b	1	$1/2Fx-1/2qx^2$	$Fb/EJ$	$1/2Fx-1/2Fx^2/b$	$Fb/EJ$	1	$(1/12+1)Fb^2/EJ$	$Xb/EJ$
FC b	$-1+x/b$	0	0	0	0	0	0	0
CF b	$x/b$	0	0	0	0	0	0	0
totali							$13/12Fb^2/EJ$	$5/3Xb/EJ$
								$-13/20Fb$

Sviluppi di calcolo iperstatica

$M_x$  flessione da iperstatica  $X=1$



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

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

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

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

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

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

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

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

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

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

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

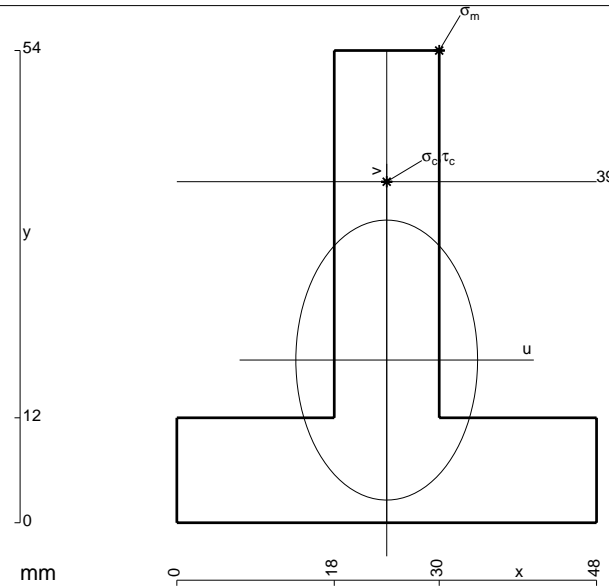
$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

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

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

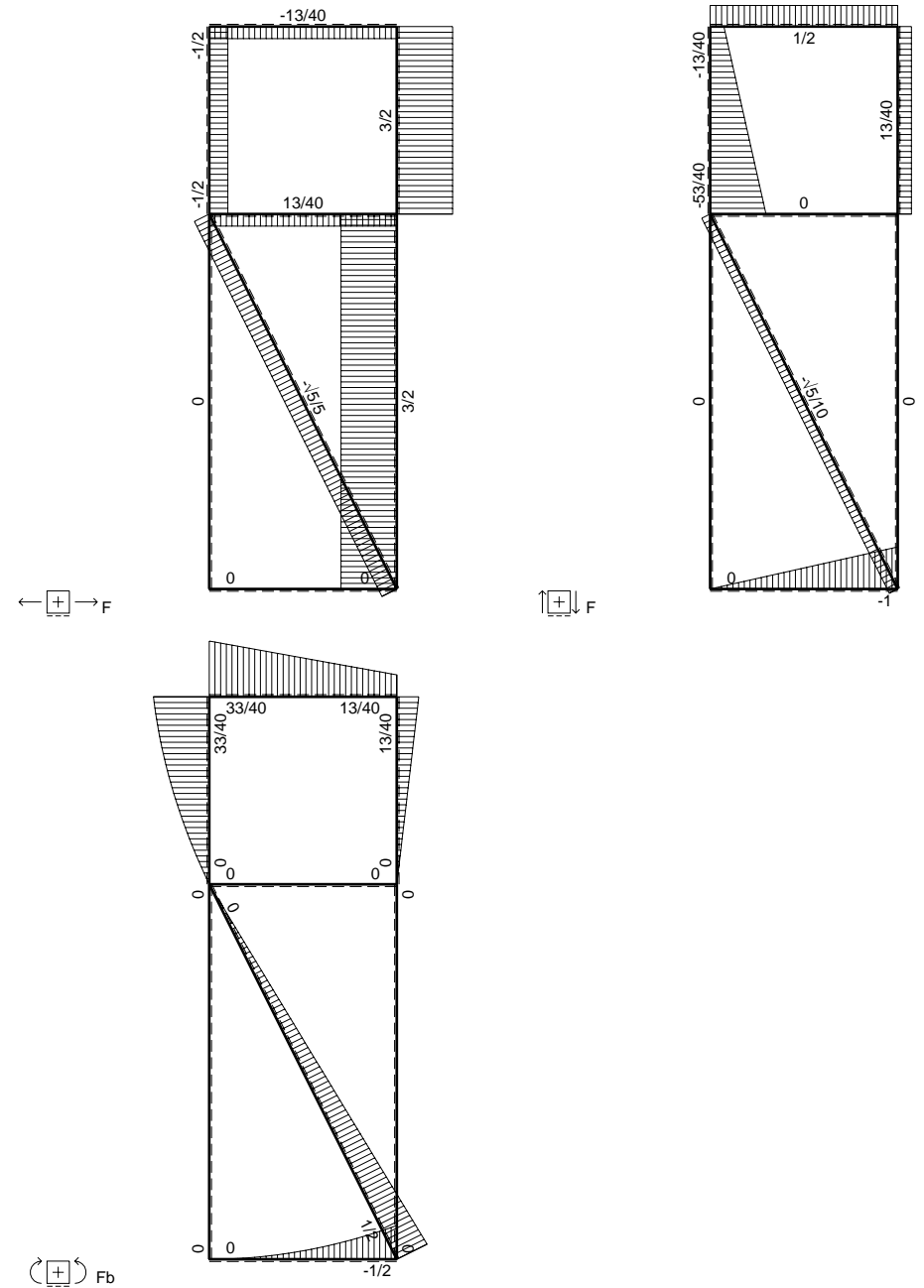
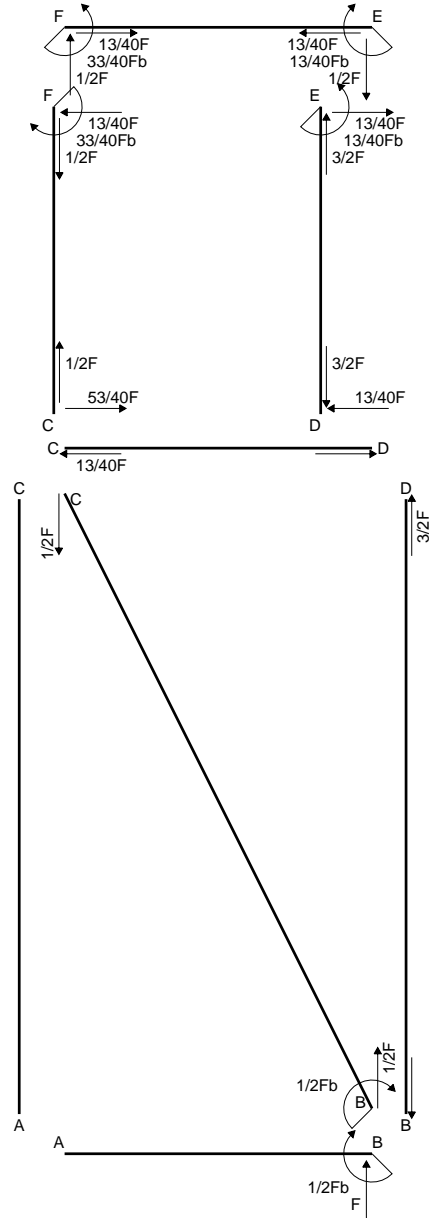
$$L_{FE}^{xo} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

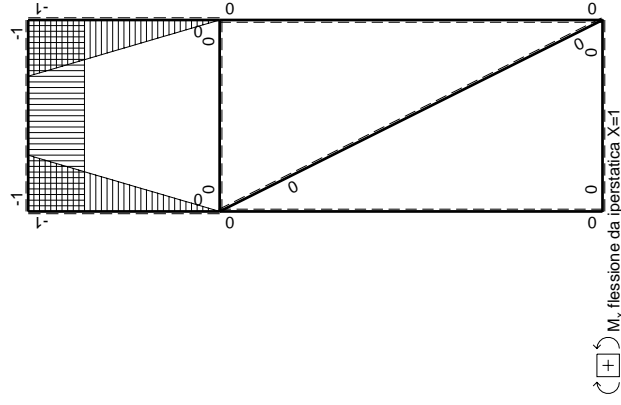
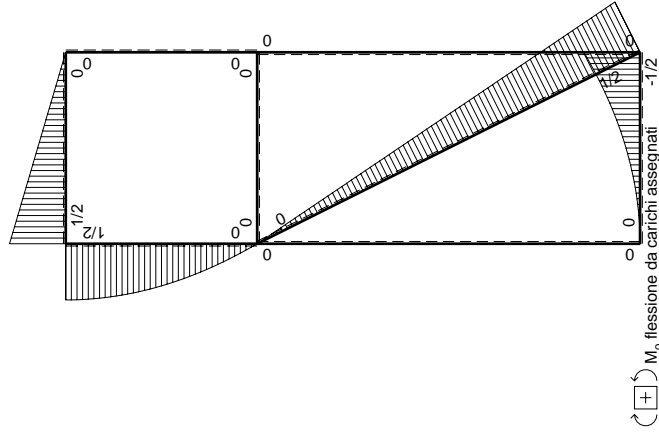
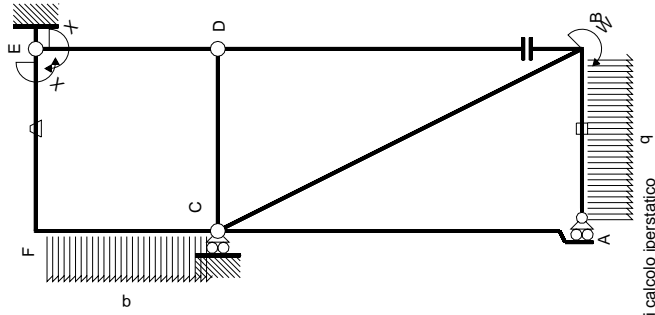
$$= (1/4 b - 1/6 b) Fb 1/EJ + (-b) \theta = 13/12 Fb^2/EJ$$



- 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> = 18.6 mm
- T<sub>y</sub> = -5490. N
- M<sub>x</sub> = -1564650. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 35.4 mm
- σ<sub>m</sub> = -M<sub>v</sub>/J<sub>u</sub> = 200. N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 39. mm
- v<sub>c</sub> = 20.4 mm
- σ<sub>c</sub> = -M<sub>v</sub>/J<sub>u</sub> = 115.2 N/mm<sup>2</sup>
- τ<sub>c</sub> = 8.296 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 = 5022. mm<sup>3</sup>







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

$\rightarrow$	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x (M_0/EJ + \theta) dx$	$\int M^x M_x / E dx$
AB b	0	$-1/2qx^2$	0	0	0	0	0	0
BA b	0	$1/2Fb - Fx + 1/2qx^2$	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$1/2Fb - \sqrt{5}/10Fx$	0	0	0	0	0	0
AC 2b	0	0	0	0	0	0	0	0
CA 2b	0	0	0	0	0	0	0	0
DB 2b	0	0	0	0	0	0	0	0
BD 2b	0	0	0	0	0	0	0	0
DE b	-x/b	0	0	0	0	$x^2/b^2$	0	0
ED b	1-x/b	0	0	0	0	$1-2x/b+x^2/b^2$	0	0
CD b	0	0	0	0	0	0	0	0
DC b	0	0	0	0	0	0	0	0
EF b	-1	$1/2Fx$	-Fb/EJ	-1/2Fx	Fb/EJ	1	$(-1/4+1)Fb^2/EJ$	Xb/EJ
FE b	1	$-1/2Fb+1/2Fx$	Fb/EJ	$-1/2Fb+1/2Fx$	Fb/EJ	1	$(-1/4+1)Fb^2/EJ$	Xb/EJ
FC b	-1+x/b	$1/2Fb-1/2qx^2$	0	$-1/2Fb+1/2Fx+1/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(-5/24+0)Fb^2/EJ$	$1/3Xb/EJ$
CF b	x/b	$-Fx+1/2qx^2$	0	$-Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$	$13/24Fb^2/EJ$	$5/3Xb/EJ$
totali								
iperstatica $X=W_{EF}$								

Sviluppi di calcolo iperstatica

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

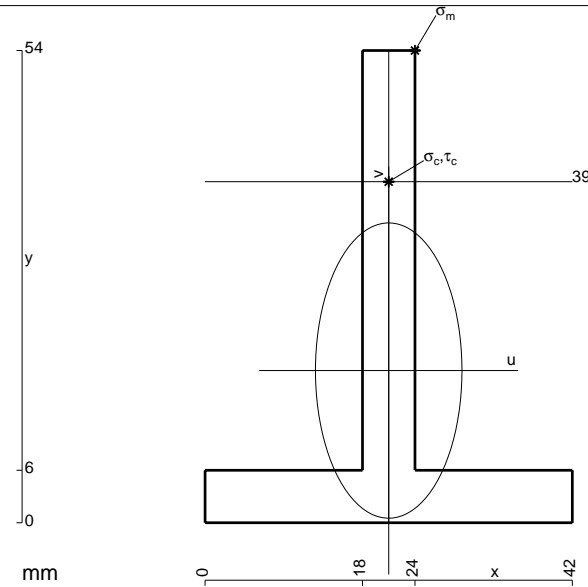
$$L_{FC}^{xo} = \int_0^b (-1/2 + 1/2 x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx$$

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

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

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

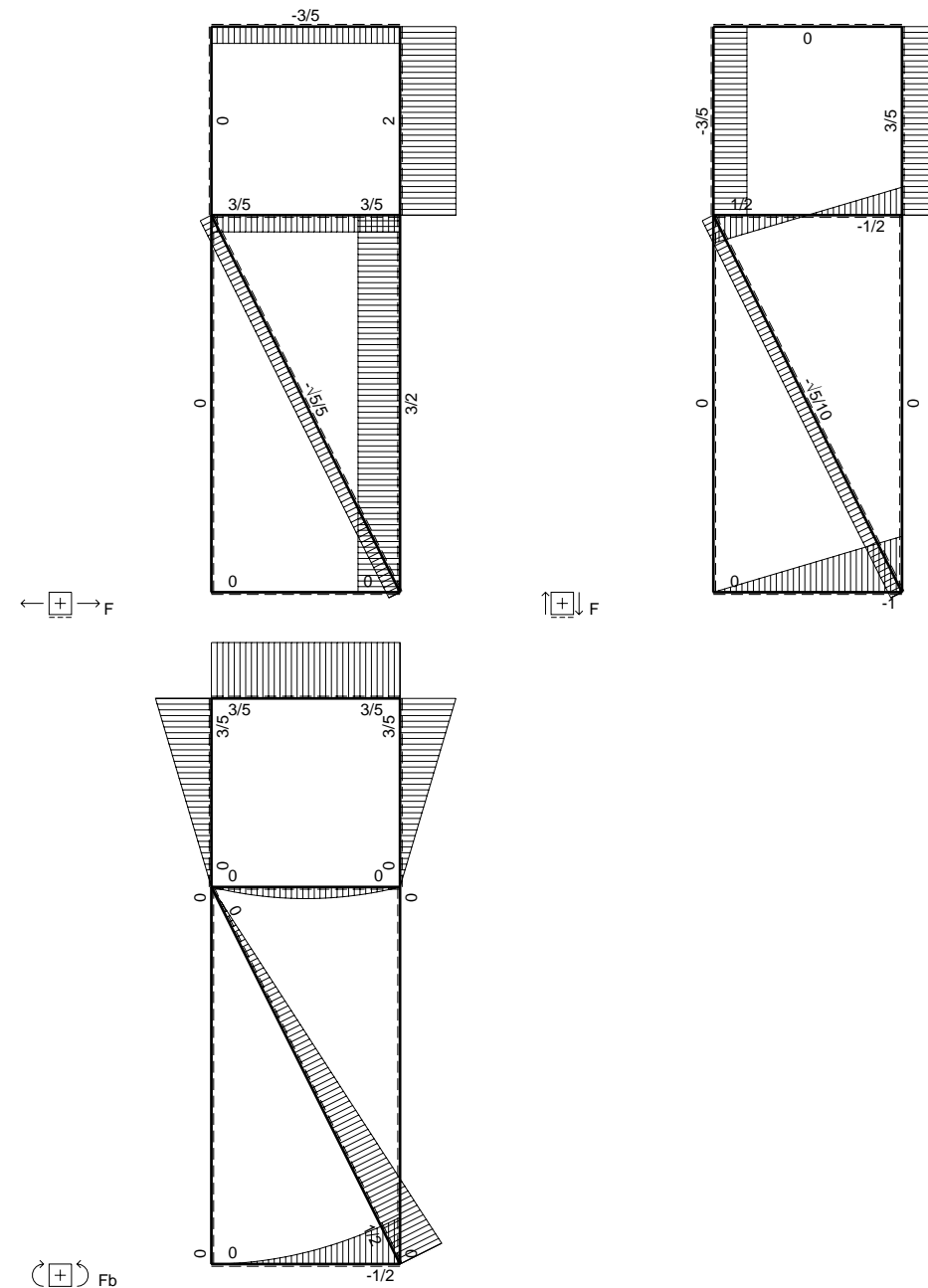
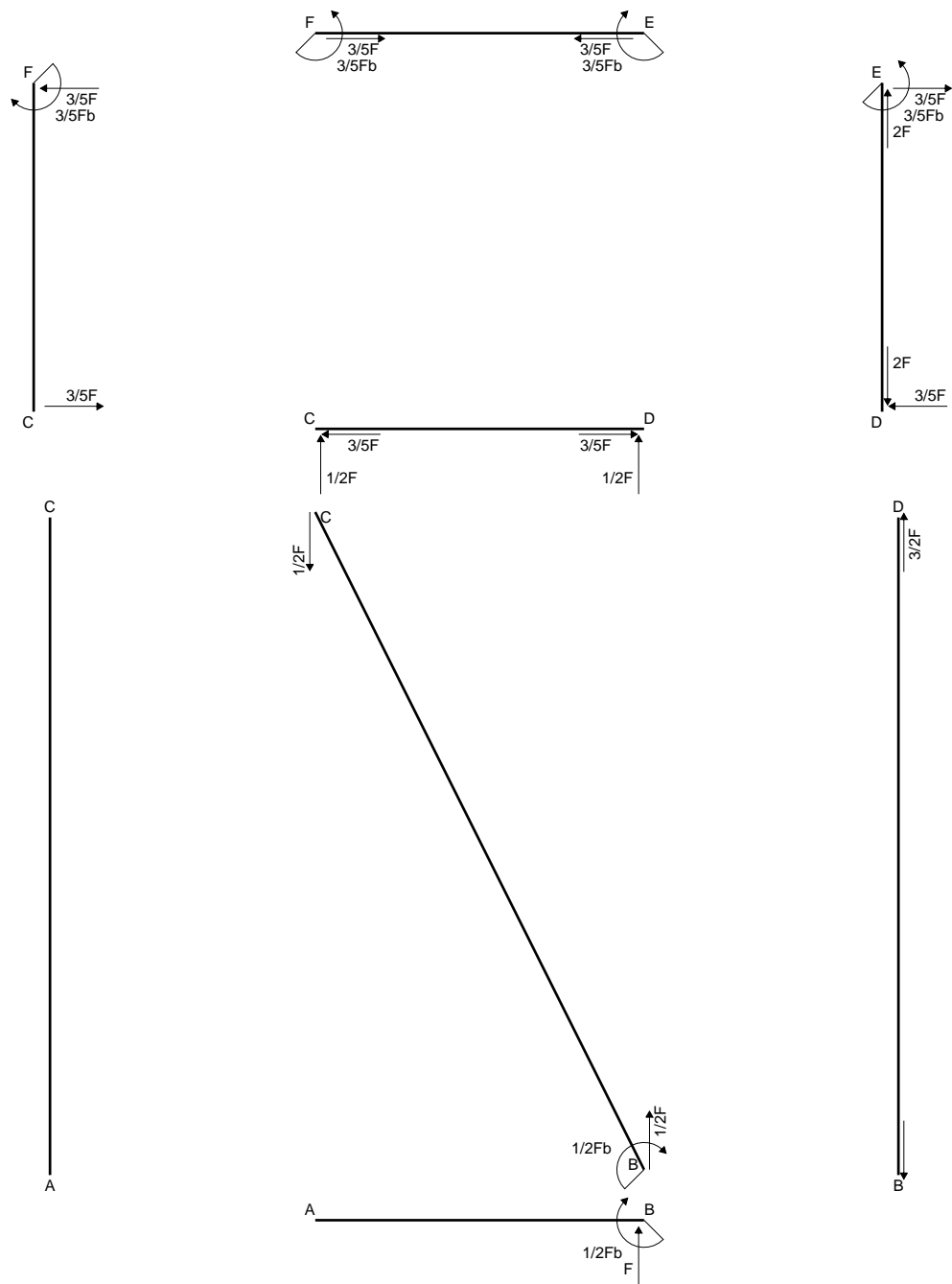
$$= (-1/3 b + 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$

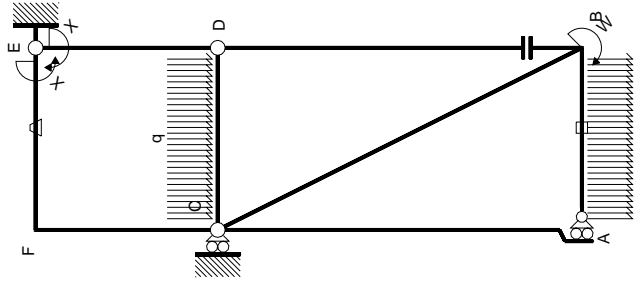


- A = 540. mm<sup>2</sup>
- J<sub>u</sub> = 154030. mm<sup>4</sup>
- J<sub>v</sub> = 37908. mm<sup>4</sup>
- y<sub>g</sub> = 17.4 mm
- T<sub>y</sub> = -2940. N
- M<sub>x</sub> = -882000. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 3. mm
- v<sub>m</sub> = 36.6 mm
- σ<sub>m</sub> = -M<sub>v</sub>/J<sub>u</sub> = 209.6 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 39. mm
- v<sub>c</sub> = 21.6 mm
- σ<sub>c</sub> = -M<sub>v</sub>/J<sub>u</sub> = 123.7 N/mm<sup>2</sup>
- τ<sub>c</sub> = 8.332 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 124.5 N/mm<sup>2</sup>
- S = 2619. mm<sup>3</sup>

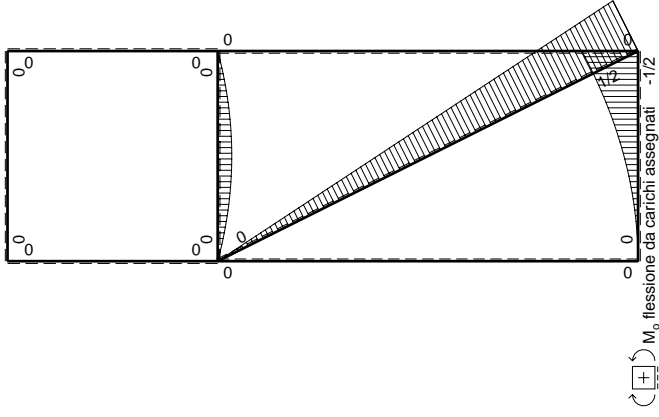








Schema di calcolo iperstatico

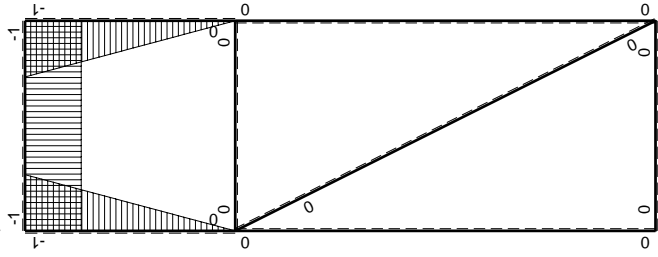


Quadro contributi PLV per iperstatica  $X=W_{EF}$

→	$M_x(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$
AB b	0	$-1/2qx^2$	0	0	0	0	0+0	0
BA b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$1/2Fb-\sqrt{5}/10Fx$	0	0	0	0	0	0
AC 2b	0	0	0	0	0	0	0+0	0
CA 2b	0	0	0	0	0	0	0+0	0
DB 2b	0	0	0	0	0	0	0+0	0
BD 2b	0	0	0	0	0	0	0+0	0
DE b	$-x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3Xb/EJ$
ED b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	0
CD b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0
DC b	0	$-1/2Fx+1/2qx^2$	0	0	0	0	0+0	0
EF b	-1	0	$-Fb/EJ$	0	$Fb/EJ$	1	$(0+1)Fb^2/EJ$	$Xb/EJ$
FE b	1	0	$Fb/EJ$	0	$Fb/EJ$	1		
FC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$
CF b	$x/b$	0	0	0	0	$x^2/b^2$	$Fb^2/EJ$	$5/3Xb/EJ$
totali								
iperstatica $X=W_{EF}$								
$-3/5Fb$								

Sviluppi di calcolo iperstatica

$M_x$  flessione da iperstatica  $X=1$



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

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

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

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

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

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

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

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

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

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

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

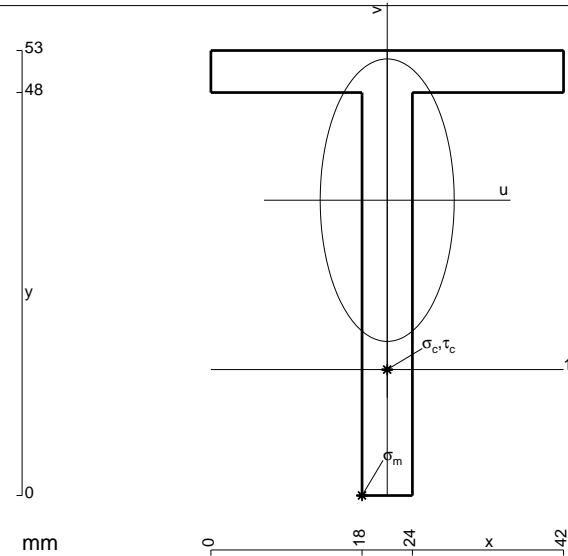
$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

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

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

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

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



$$A = 498. \text{ mm}^2$$

$$J_u = 141019. \text{ mm}^4$$

$$J_v = 31734. \text{ mm}^4$$

$$y_g = 35.17 \text{ mm}$$

$$T_y = -2840. \text{ N}$$

$$M_x = -880400. \text{ Nmm}$$

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

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

$$v_m = -35.17 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -219.6 \text{ N/mm}^2$$

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

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

$$v_c = -20.17 \text{ mm}$$

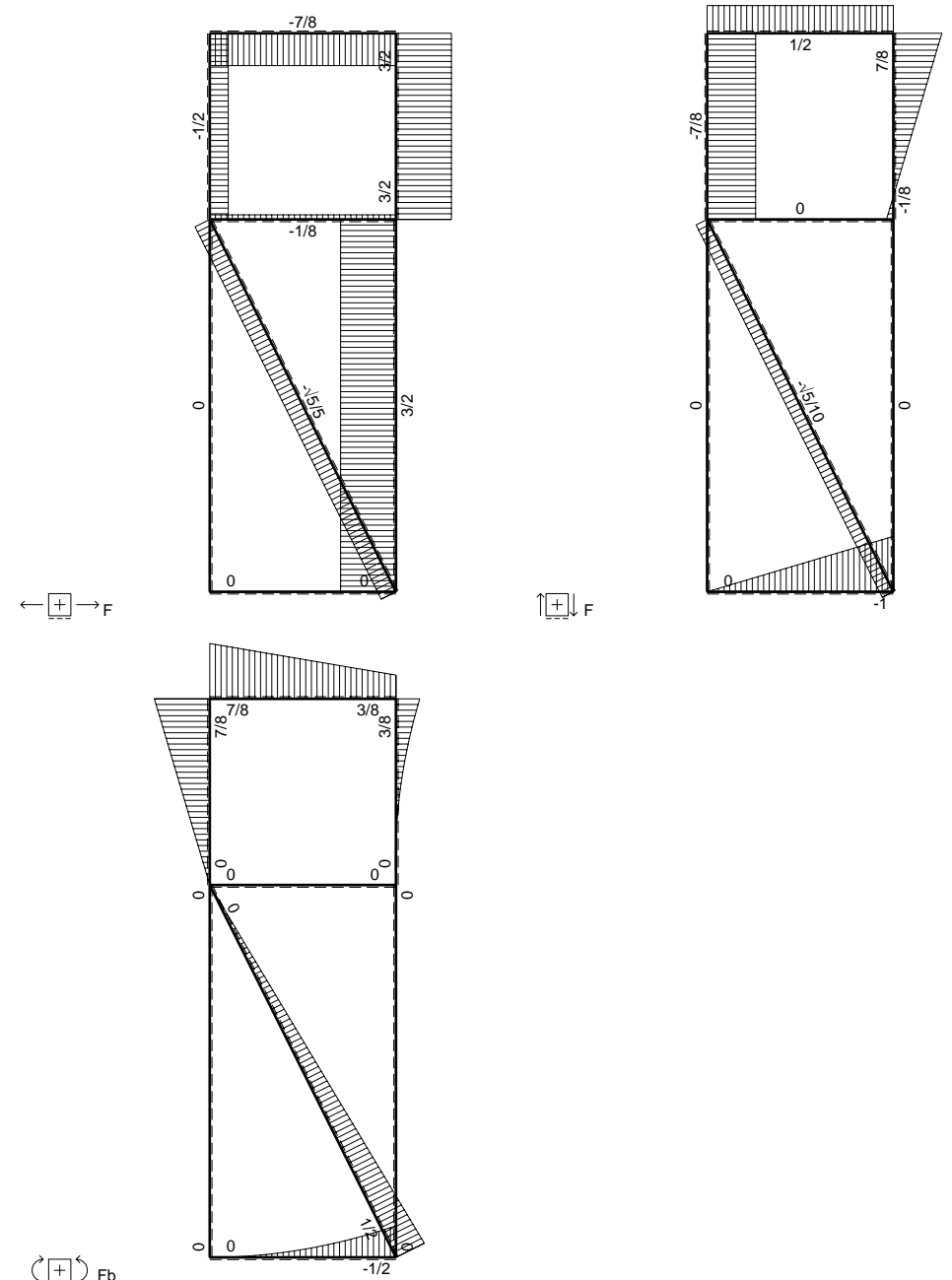
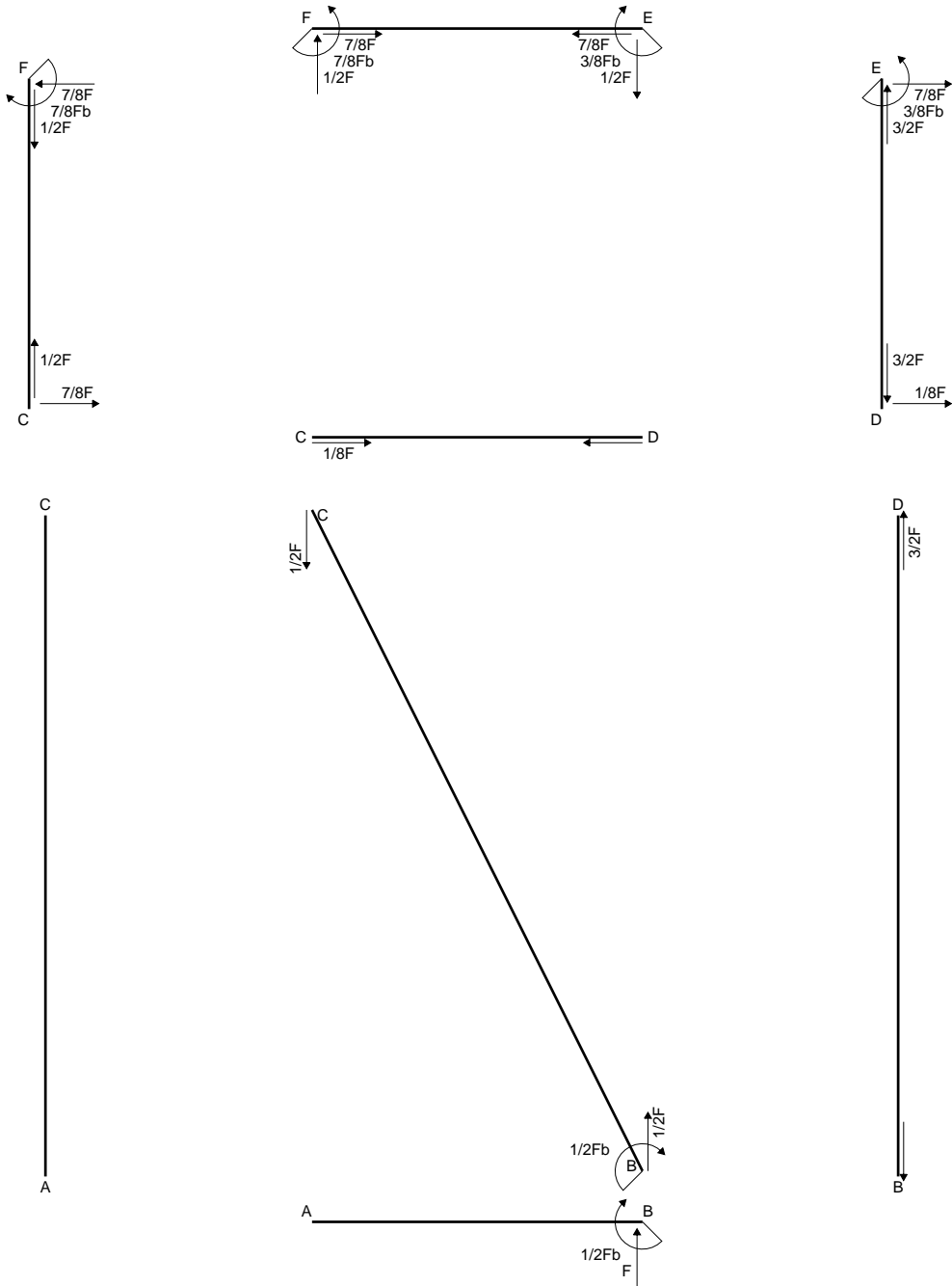
$$\sigma_c = -Mv/J_u = -126. \text{ N/mm}^2$$

$$\tau_c = 8.36 \text{ N/mm}^2$$

$$\sigma_o = \sqrt{\sigma^2 + 3\tau^2} = 126.8 \text{ N/mm}^2$$

$$S = 2491. \text{ mm}^3$$







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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

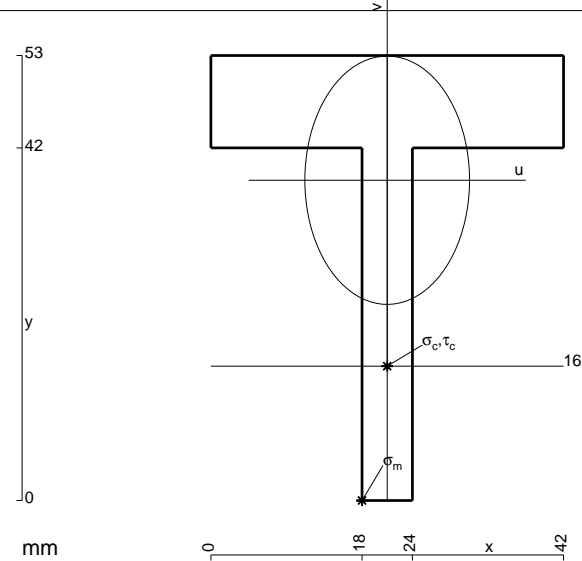
$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

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

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

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

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



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

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

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

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

$$T_y = -2850. \text{ N}$$

$$M_x = -940500. \text{ Nmm}$$

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

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

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

$$\sigma_m = -Mv/J_u = -229.7 \text{ N/mm}^2$$

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

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

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

$$\sigma_c = -Mv/J_u = -133.3 \text{ N/mm}^2$$

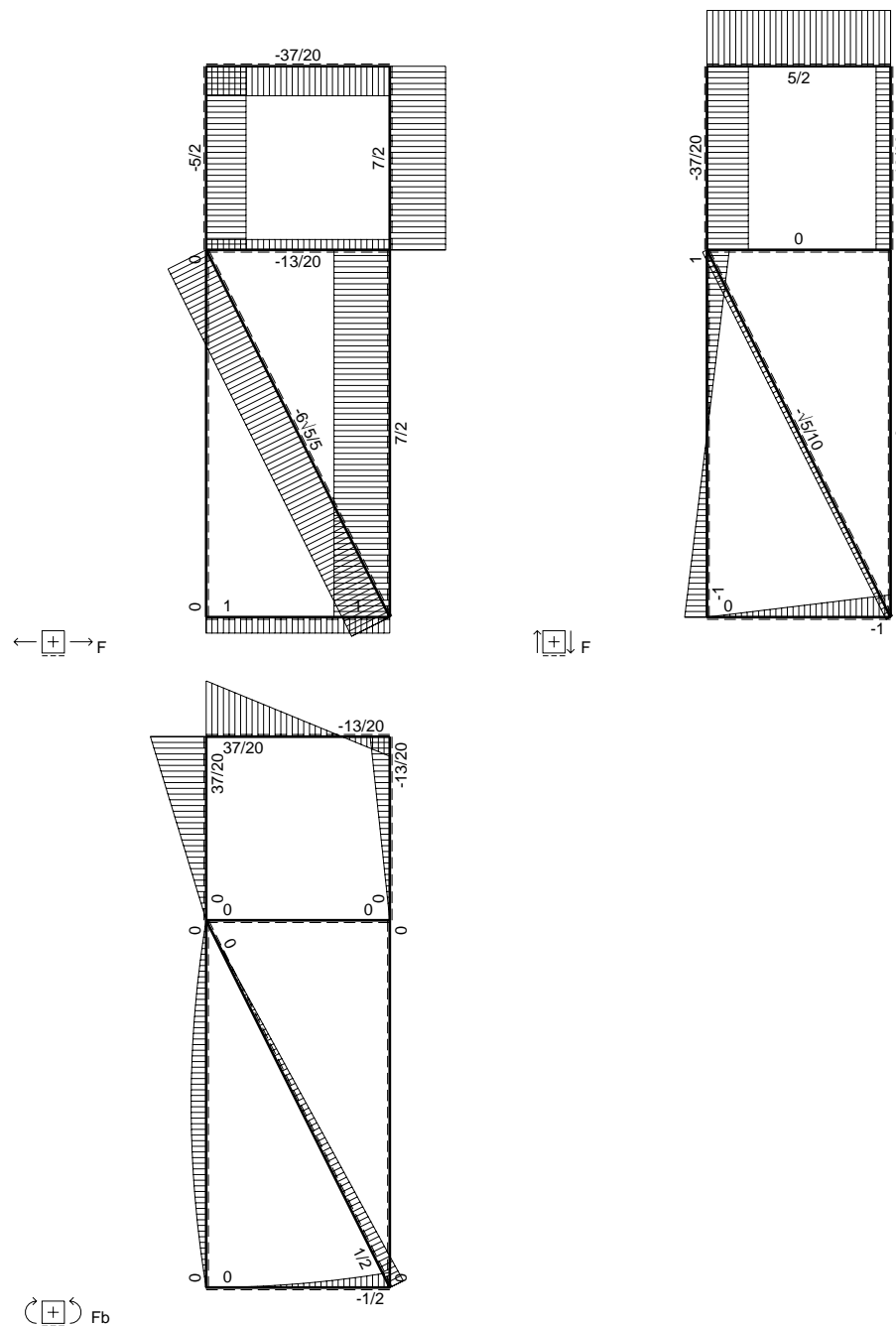
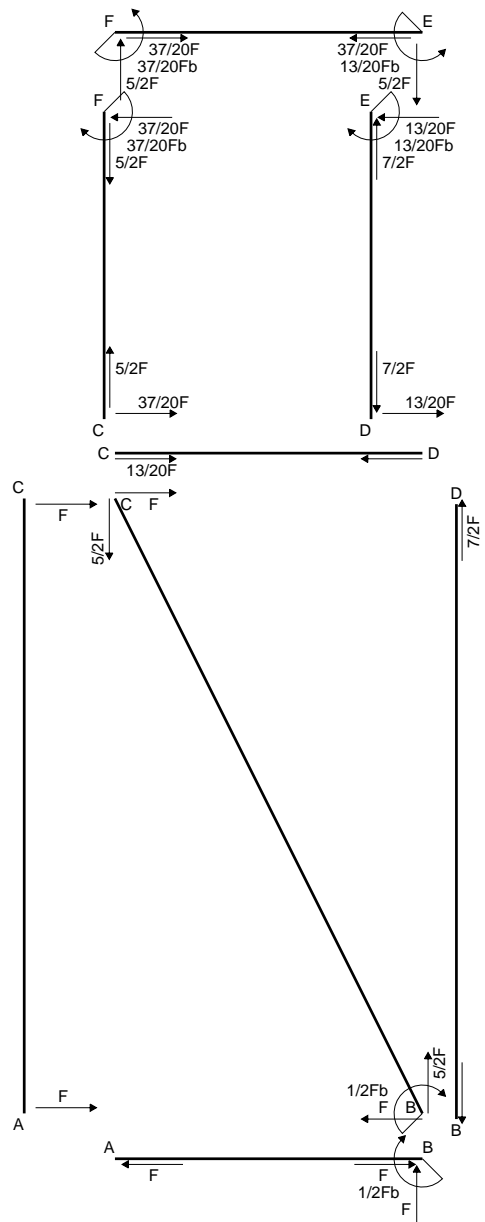
$$\tau_c = 8.8 \text{ N/mm}^2$$

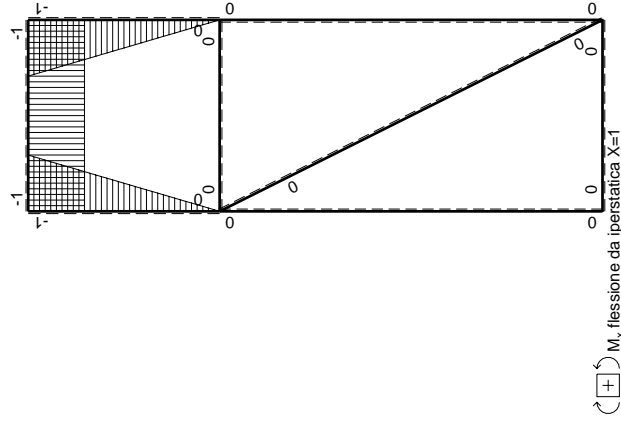
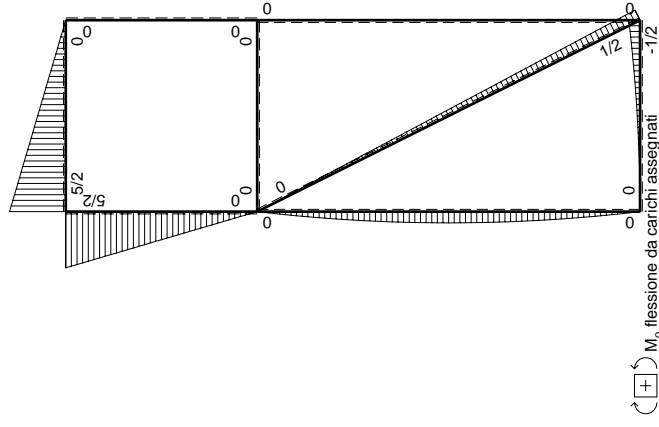
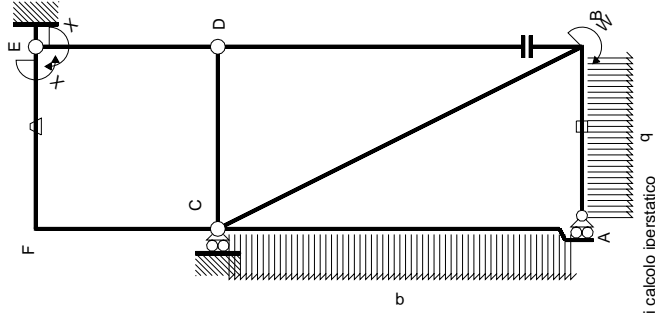
$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 134.2 \text{ N/mm}^2$$

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









Quadro contributi PLV per iperstatica X=V<sup>EF</sup>

→	M <sup>x</sup> (x)	M <sup>0</sup> (x)	θ	M <sup>x</sup> M <sup>0</sup>	M <sup>x</sup> θ	M <sup>x</sup> M <sup>x</sup>	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	0	-1/2qx <sup>2</sup>	0	0	0	0	0	0
BA b	0	1/2Fb-Fx+1/2qx <sup>2</sup>	0	0	0	0	0	0
BC √5b	0	1/2Fb-√5/10Fx	0	0	0	0	0	0
AC 2b	0	-Fx+1/2qx <sup>2</sup>	0	0	0	0	0	0
CA 2b	0	Fx-1/2qx <sup>2</sup>	0	0	0	0	0	0
DB 2b	0	0	0	0	0	0	0	0
BD 2b	0	0	0	0	0	0	0	0
DE b	-x/b	0	0	0	0	0	0	0
ED b	1-x/b	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
EF b	-1	5/2Fx	-Fb/EJ	-5/2Fx	Fb/EJ	1	(-5/4+1)Fb <sup>2</sup> /EJ	Xb/EJ
FE b	1	-5/2Fb+5/2Fx	Fb/EJ	-5/2Fb+5/2Fx	Fb/EJ	1	(-5/4+1)Fb <sup>2</sup> /EJ	Xb/EJ
FC b	-1+x/b	5/2Fb-5/2Fx	0	-5/2Fb+5Fx-5/2Fx <sup>2</sup> /b	0	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	1/3Xb/EJ
CF b	x/b	-5/2Fx	0	-5/2Fx <sup>2</sup> /b	0	0	x <sup>2</sup> /b <sup>2</sup>	1/3Xb/EJ
totali								
iperstatica X=V <sup>EF</sup>								

Sviluppi di calcolo iperstatica

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

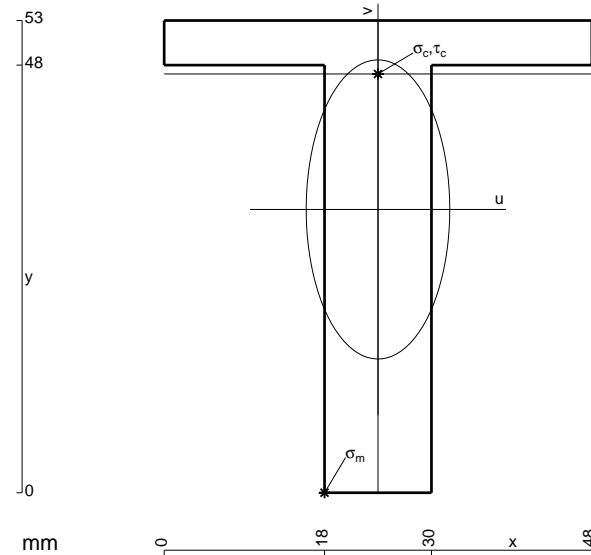
$$= (-5/2 b + 5/4 b) Fb 1/EJ + (-b) \theta = -1/4 Fb^2/EJ$$

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

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

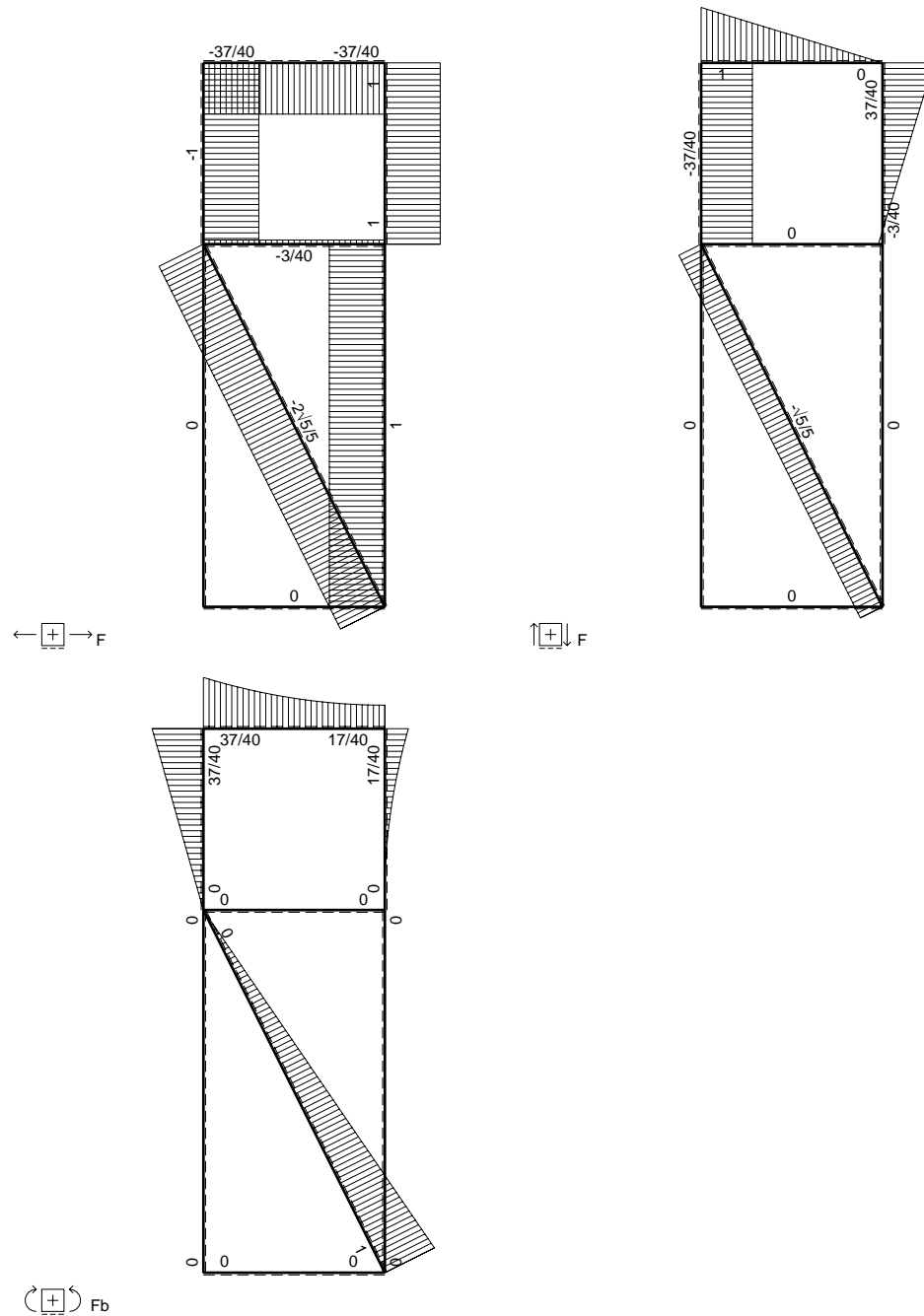
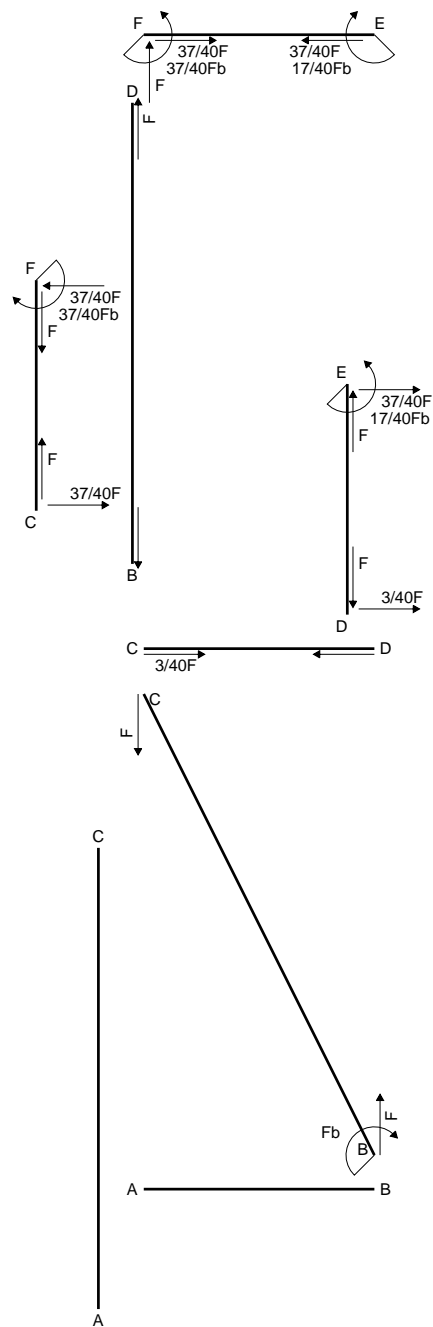
$$L_{CF}^{xo} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

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



- 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 = 5090. N
- T<sub>y</sub> = -5090. N
- M<sub>x</sub> = -1781500. 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> = -240. N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 47. mm
- v<sub>c</sub> = 15.21 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = 124. N/mm<sup>2</sup>
- τ<sub>c</sub> = 8.625 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 124.9 N/mm<sup>2</sup>
- S = 4678. mm<sup>3</sup>







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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

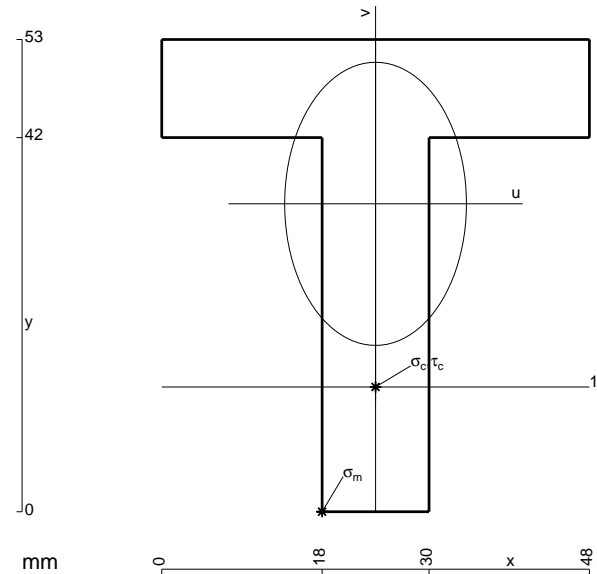
$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ + (-b) \theta = 5/6 Fb^2/EJ$$

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

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

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

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



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

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

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

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

$$N = -3703. \text{ N}$$

$$T_y = -1851. \text{ N}$$

$$M_x = 1531800. \text{ Nmm}$$

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

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

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

$$\sigma_m = N/A - Mv/J_u = 199.6 \text{ N/mm}^2$$

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

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

$$v_c = -20.56 \text{ mm}$$

$$\sigma_c = N/A - Mv/J_u = 117.3 \text{ N/mm}^2$$

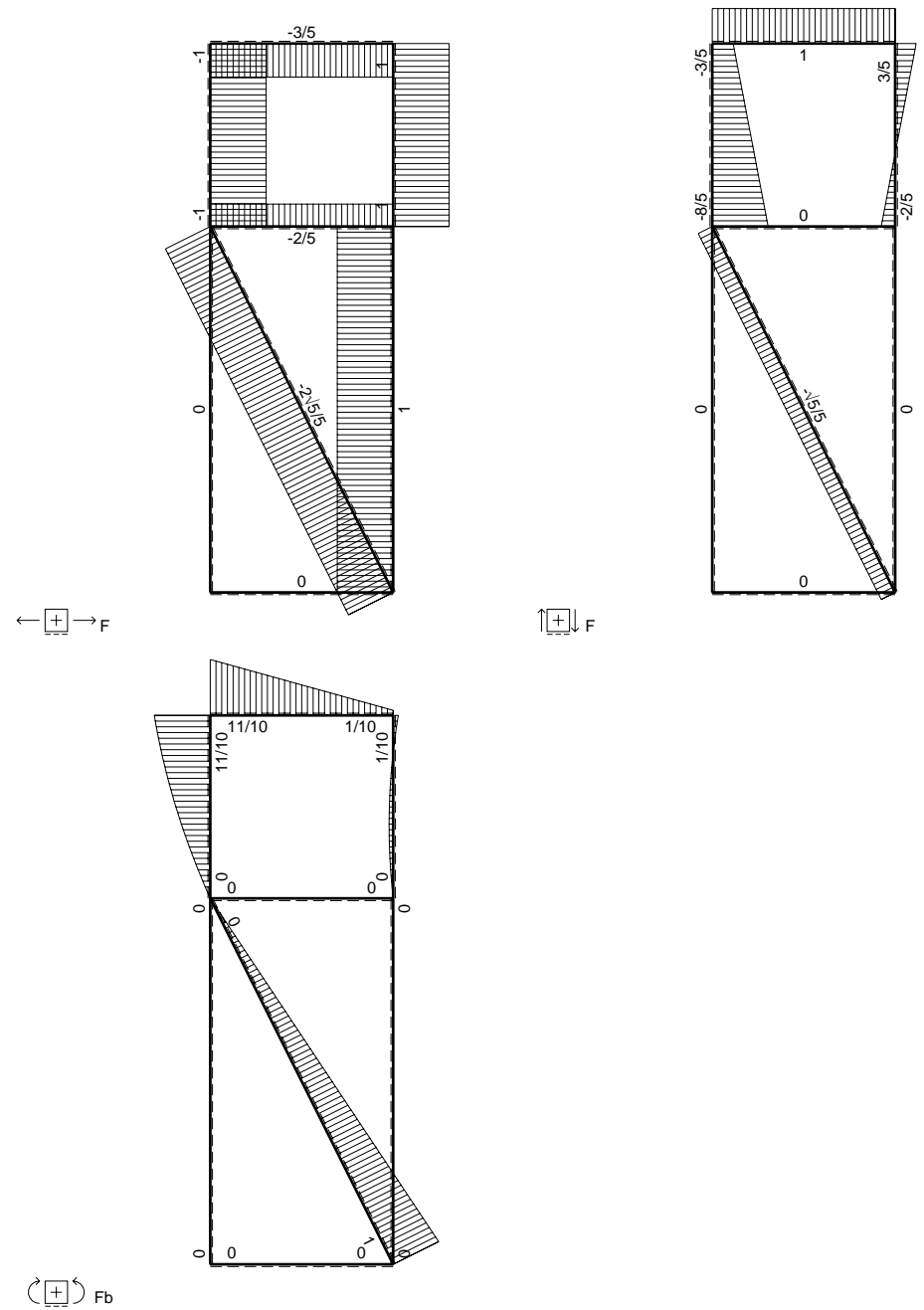
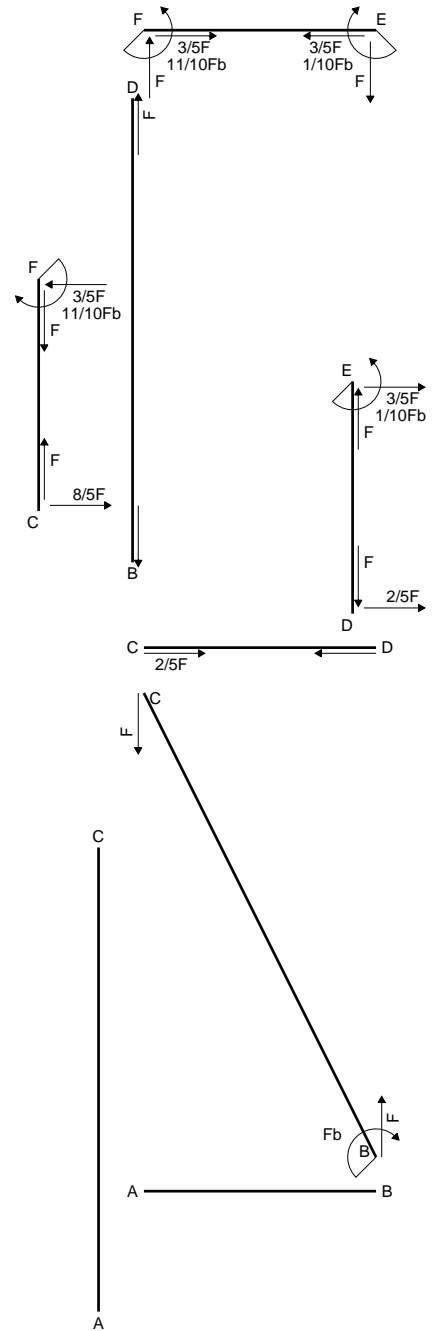
$$\tau_c = 2.742 \text{ N/mm}^2$$

$$\sigma_\varphi = \sqrt{\sigma^2 + 3\tau^2} = 117.4 \text{ N/mm}^2$$

$$S = 4630. \text{ mm}^3$$







Legend for internal force diagrams:  $\left[ \begin{matrix} + \\ + \end{matrix} \right] F$  and  $\left[ \begin{matrix} + \\ + \end{matrix} \right] F_b$



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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

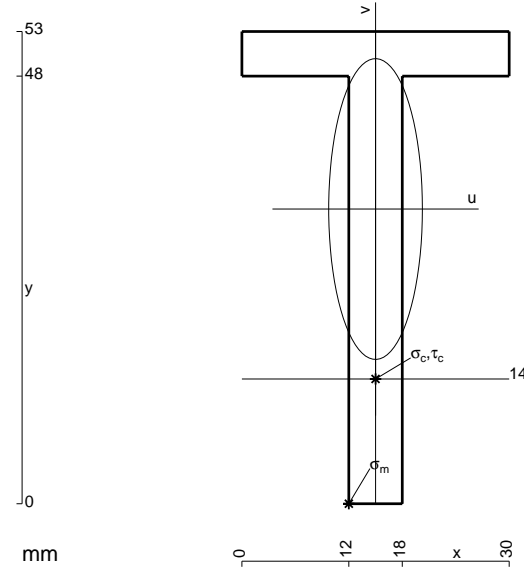
$$= (-b + 1/2 b) Fb 1/EJ + (-b) \theta = 1/2 Fb^2/EJ$$

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

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

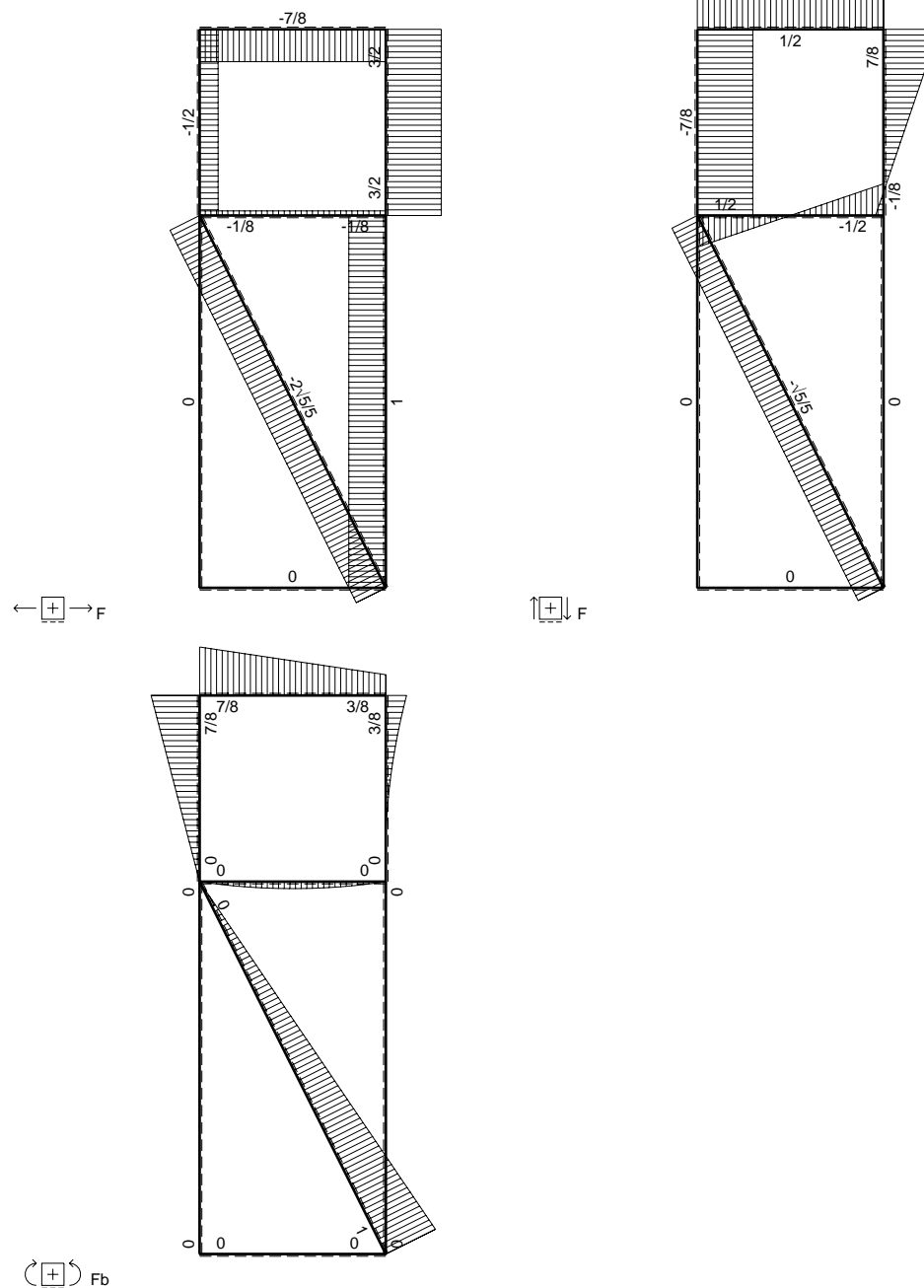
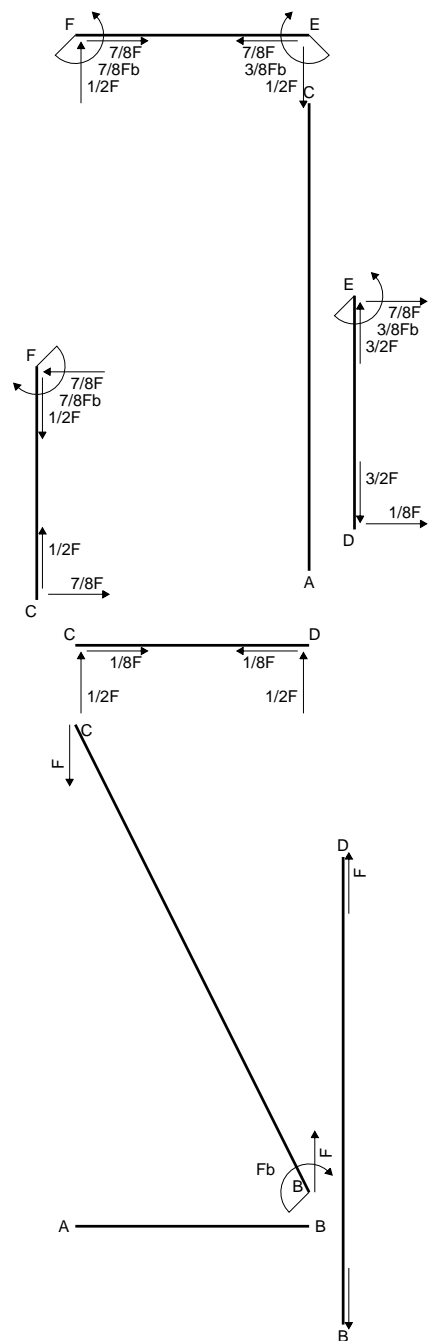
$$L_{CF}^{xo} = \int_0^b (-3/2 x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/2 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

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



- 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 = -1807. N
- T<sub>y</sub> = -903.4 N
- M<sub>x</sub> = 808000. 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> = 209.9 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> = 119.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.641 N/mm<sup>2</sup>
- σ<sub>φ</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 119.4 N/mm<sup>2</sup>
- S = 2190. mm<sup>3</sup>







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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

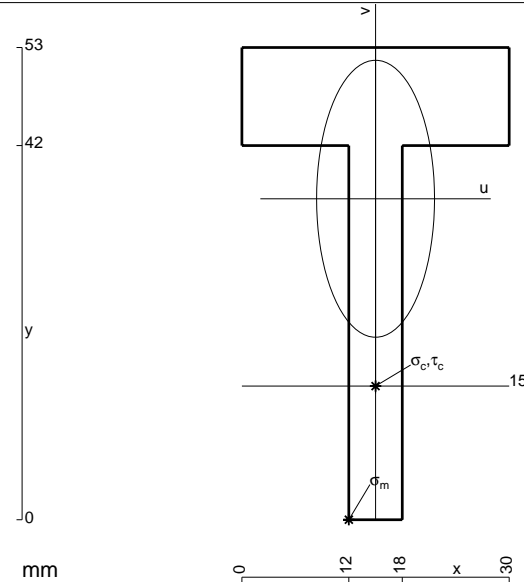
$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

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

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

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

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



$$A = 582. \text{ mm}^2$$

$$J_u = 140714. \text{ mm}^4$$

$$J_v = 25506. \text{ mm}^4$$

$$y_g = 36.03 \text{ mm}$$

$$N = -1762. \text{ N}$$

$$T_y = -881. \text{ N}$$

$$M_x = 866800. \text{ Nmm}$$

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

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

$$v_m = -36.03 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 218.9 \text{ N/mm}^2$$

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

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

$$v_c = -21.03 \text{ mm}$$

$$\sigma_c = N/A - Mv/J_u = 126.5 \text{ N/mm}^2$$

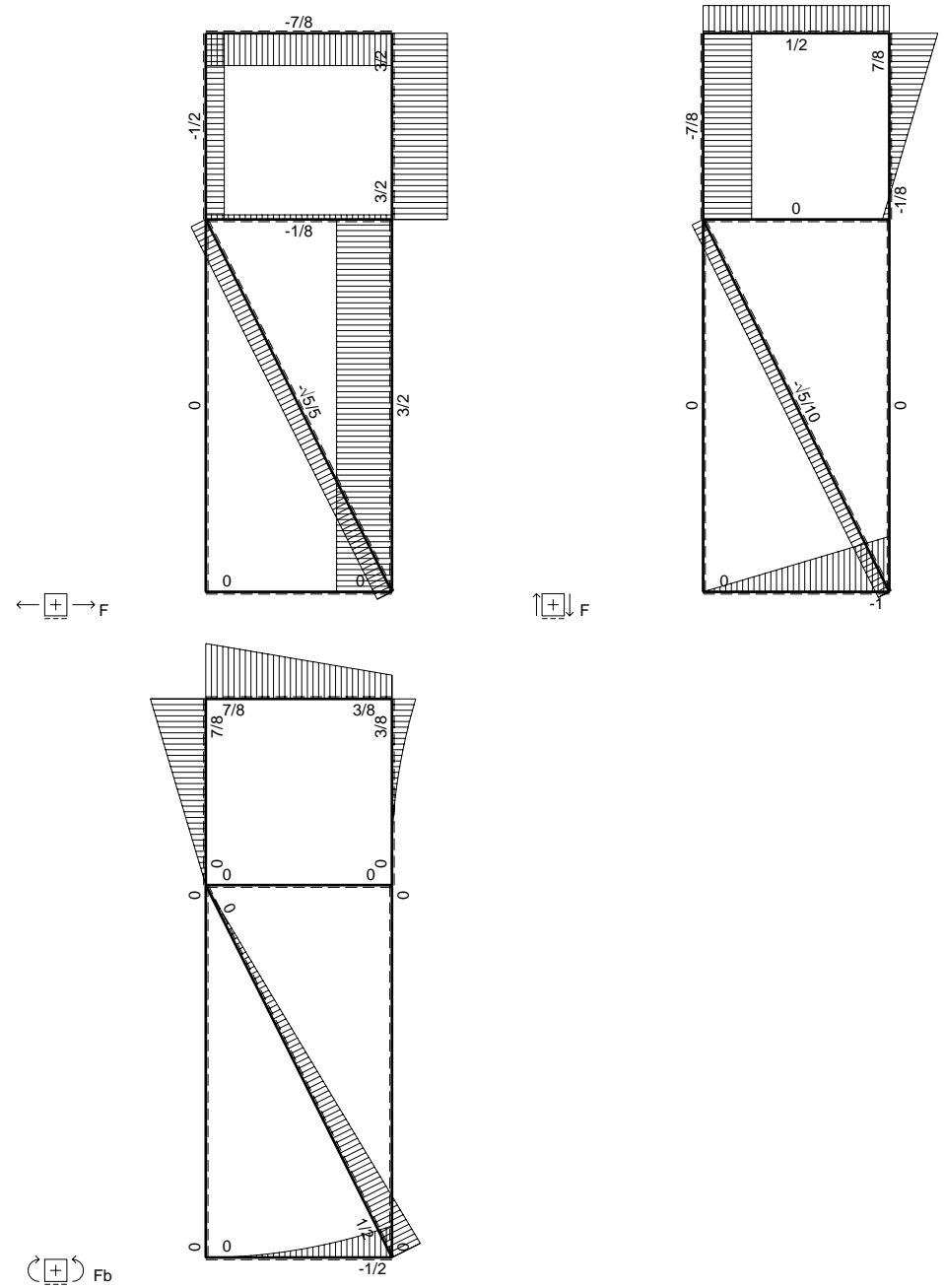
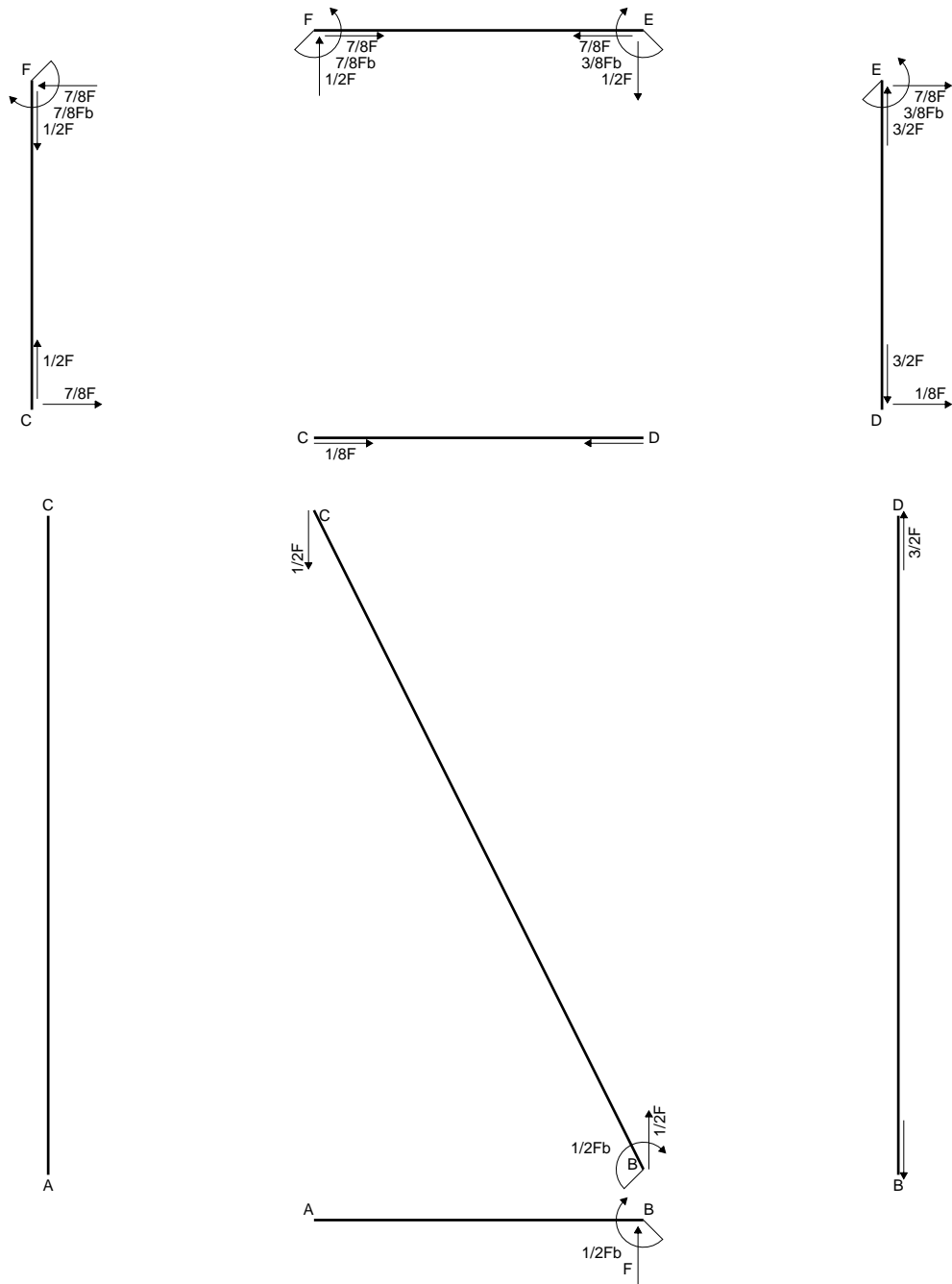
$$\tau_c = 2.679 \text{ N/mm}^2$$

$$\sigma_\varphi = \sqrt{\sigma^2 + 3\tau^2} = 126.6 \text{ N/mm}^2$$

$$S = 2567. \text{ mm}^3$$









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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

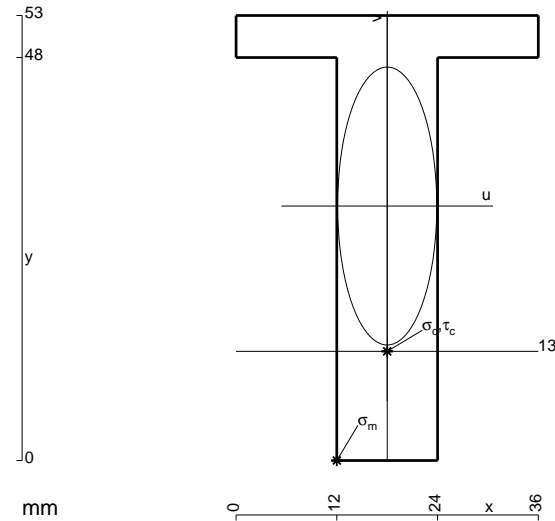
$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

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

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

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

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



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

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

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

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

$$T_y = -6550. \text{ N}$$

$$M_x = -1572000. \text{ Nmm}$$

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

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

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

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

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

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

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

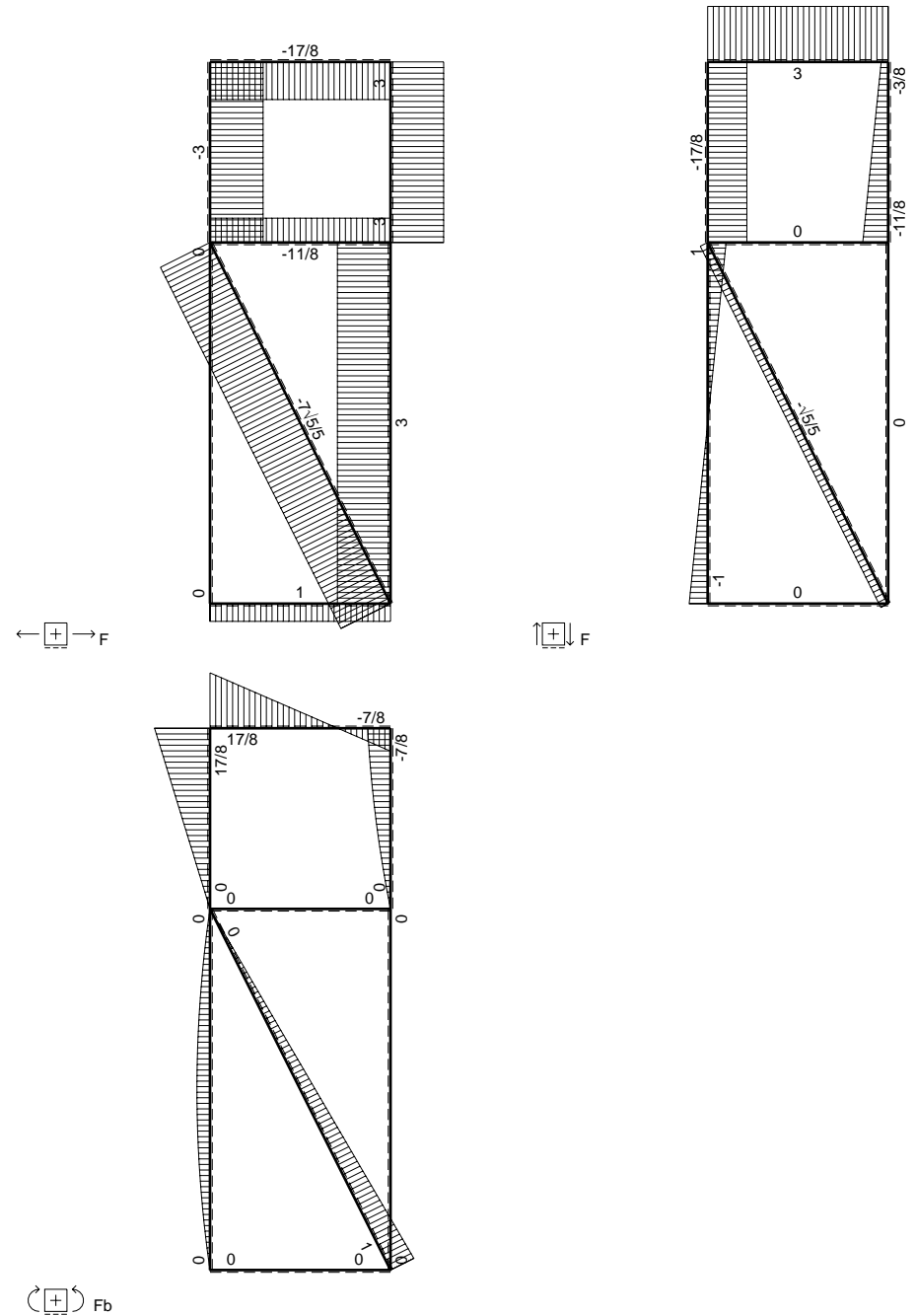
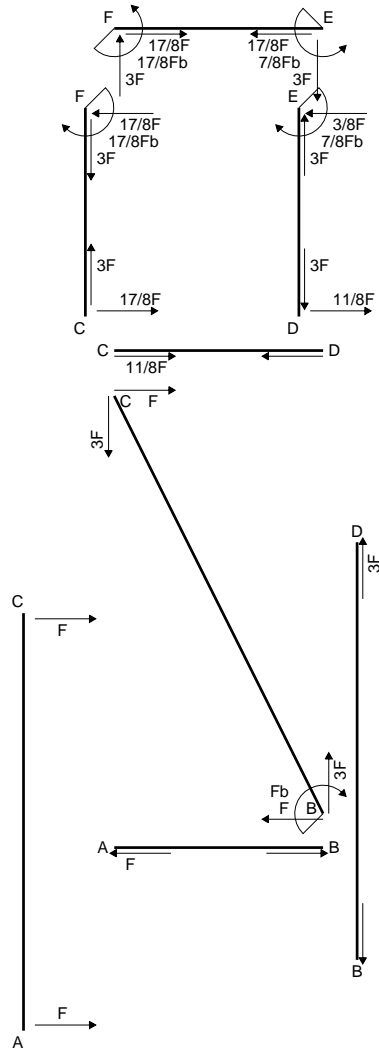
$$\sigma_c = -Mv/J_u = -131.3 \text{ N/mm}^2$$

$$\tau_c = 9.781 \text{ N/mm}^2$$

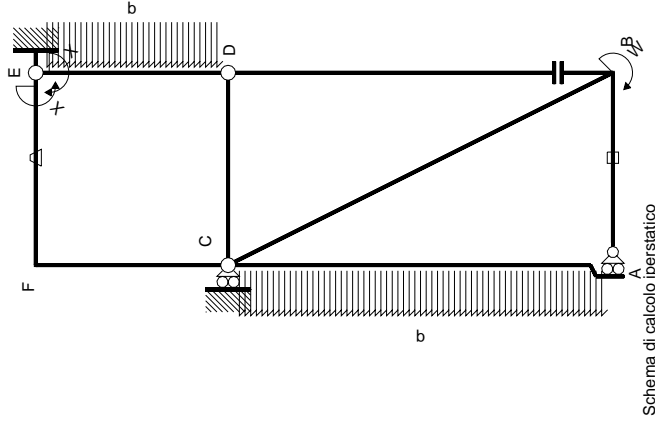
$$\sigma_o = \sqrt{\sigma^2 + 3\tau^2} = 132.4 \text{ N/mm}^2$$

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

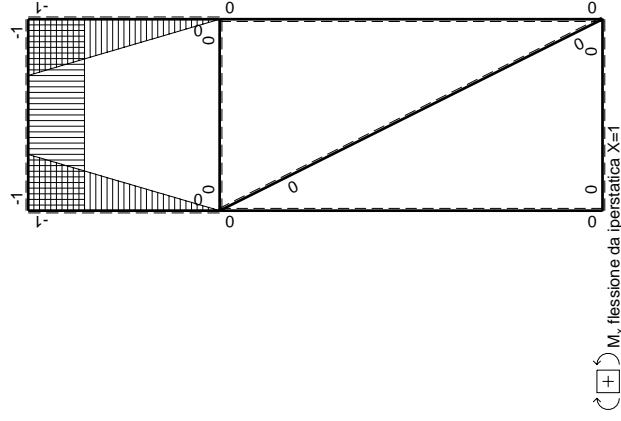




⊕ F<sub>b</sub>



$M_0$  flessione da carichi assegnati



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

$\leftarrow$	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x (M_0/EJ + \theta) dx$	$\int M^x M_x / EJ dx$
AB b	0	0	0	0	0	0	0	0
BA b	0	0	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$Fb - \sqrt{5}/5Fx$	0	0	0	0	0	0
CA 2b	0	$-Fx + 1/2qx^2$	0	0	0	0	0	0
CA 2b	0	$Fx - 1/2qx^2$	0	0	0	0	0	0
DB 2b	0	0	0	0	0	0	0	0
BD 2b	0	0	0	0	0	0	0	0
DE b	$-x/b$	$-1/2Fx + 1/2qx^2$	0	$1/2Fx^2/b - 1/2qx^3/b$	0	$x^2/b^2$	$(1/24+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$1-x/b$	$1/2Fx - 1/2qx^2$	0	$1/2Fx - Fx^2/b + 1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(1/24+0)Fb^2/EJ$	$1/3Xb/EJ$
CD b	0	0	0	0	0	0	0	0
DC b	0	0	0	0	0	0	0	0
EF b	-1	$3Fx$	$-Fb/EJ$	$-3Fx$	$Fb/EJ$	1	$(-3/2+1)Fb^2/EJ$	$Xb/EJ$
FE b	1	$-3Fb+3Fx$	$Fb/EJ$	$-3Fb+3Fx$	$Fb/EJ$	1	$(-3/2+1)Fb^2/EJ$	$Xb/EJ$
FC b	$-1+x/b$	$3Fb-3Fx$	0	$-3Fb+6Fx-3Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-1+0)Fb^2/EJ$	$1/3Xb/EJ$
CF b	$x/b$	$-3Fx$	0	$-3Fx^2/b$	0	$x^2/b^2$	$(-1+0)Fb^2/EJ$	$1/3Xb/EJ$
totali							$-35/24Fb^2/EJ$	$5/3Xb/EJ$
								$7/8Fb$

Sviluppi di calcolo iperstatica

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

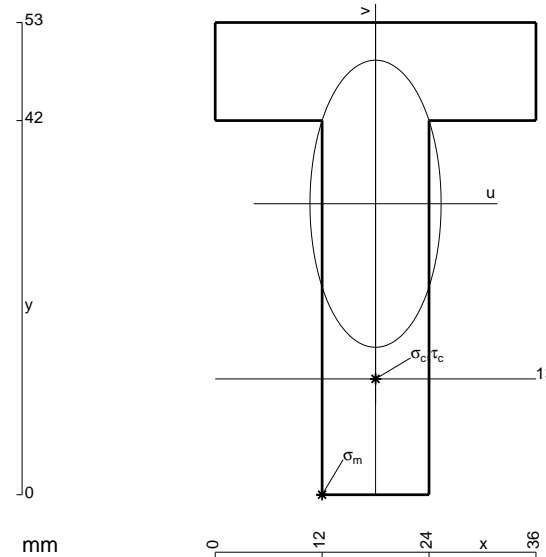
$$= (-3b + 3/2 b) Fb 1/EJ + (-b) \theta = -1/2 Fb^2/EJ$$

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

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

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

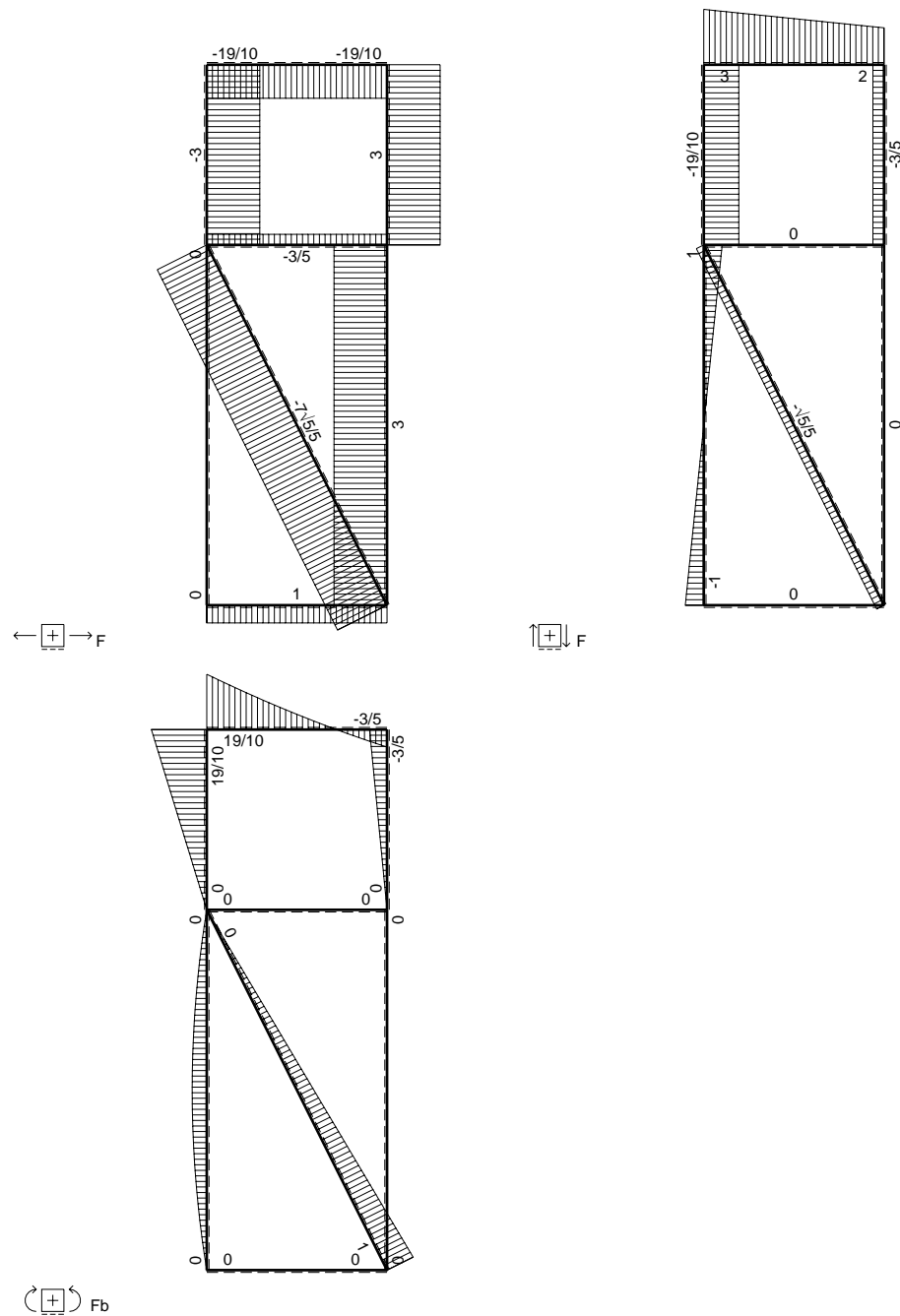
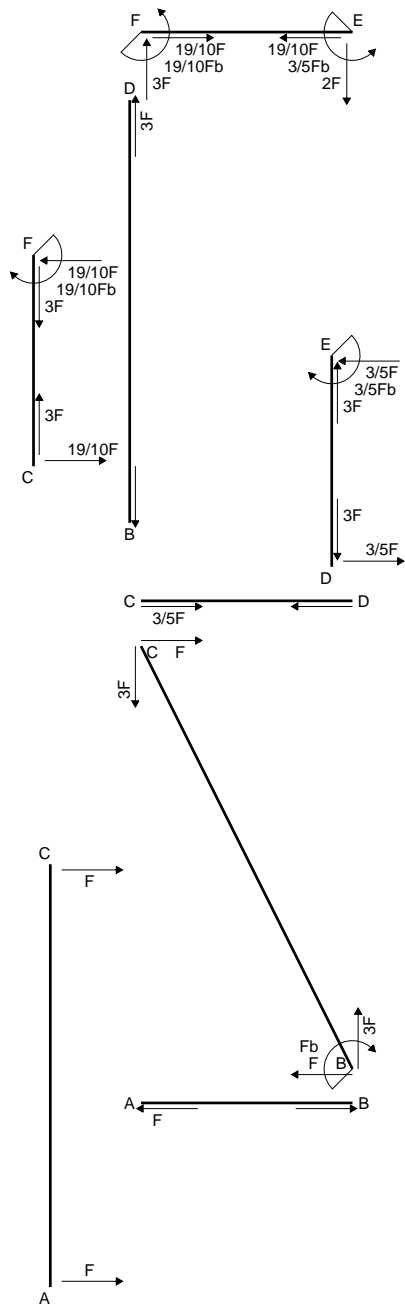
$$= (-b) Fb 1/EJ = - Fb^2/EJ$$



- A = 900. mm<sup>2</sup>
- J<sub>u</sub> = 233812. mm<sup>4</sup>
- J<sub>v</sub> = 48816. mm<sup>4</sup>
- y<sub>g</sub> = 32.66 mm
- N = -11082. N
- T<sub>y</sub> = -1583. N
- M<sub>x</sub> = 1805400. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -32.66 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> = 13. mm
- v<sub>c</sub> = -19.66 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = 139.5 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.303 N/mm<sup>2</sup>
- σ<sub>φ</sub> = √(σ<sup>2</sup>+3τ<sup>2</sup>) = 139.6 N/mm<sup>2</sup>
- S = 4081. mm<sup>3</sup>









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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

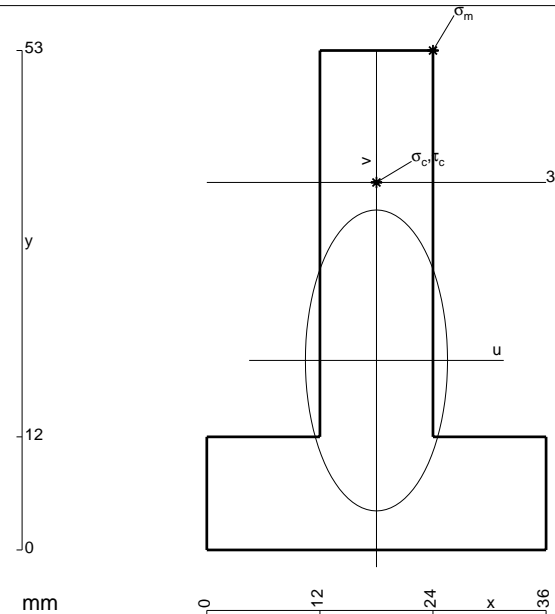
$$= (-5/2 b + 3/2 b - 1/6 b) Fb 1/EJ + (-b) \theta = -1/6 Fb^2/EJ$$

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

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

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

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



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

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

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

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

$$N = -7795. \text{ N}$$

$$T_y = -1114. \text{ N}$$

$$M_x = 1369500. \text{ Nmm}$$

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

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

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

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

$$\sigma_m = N/A - Mv/J_u = -199.6 \text{ N/mm}^2$$

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

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

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

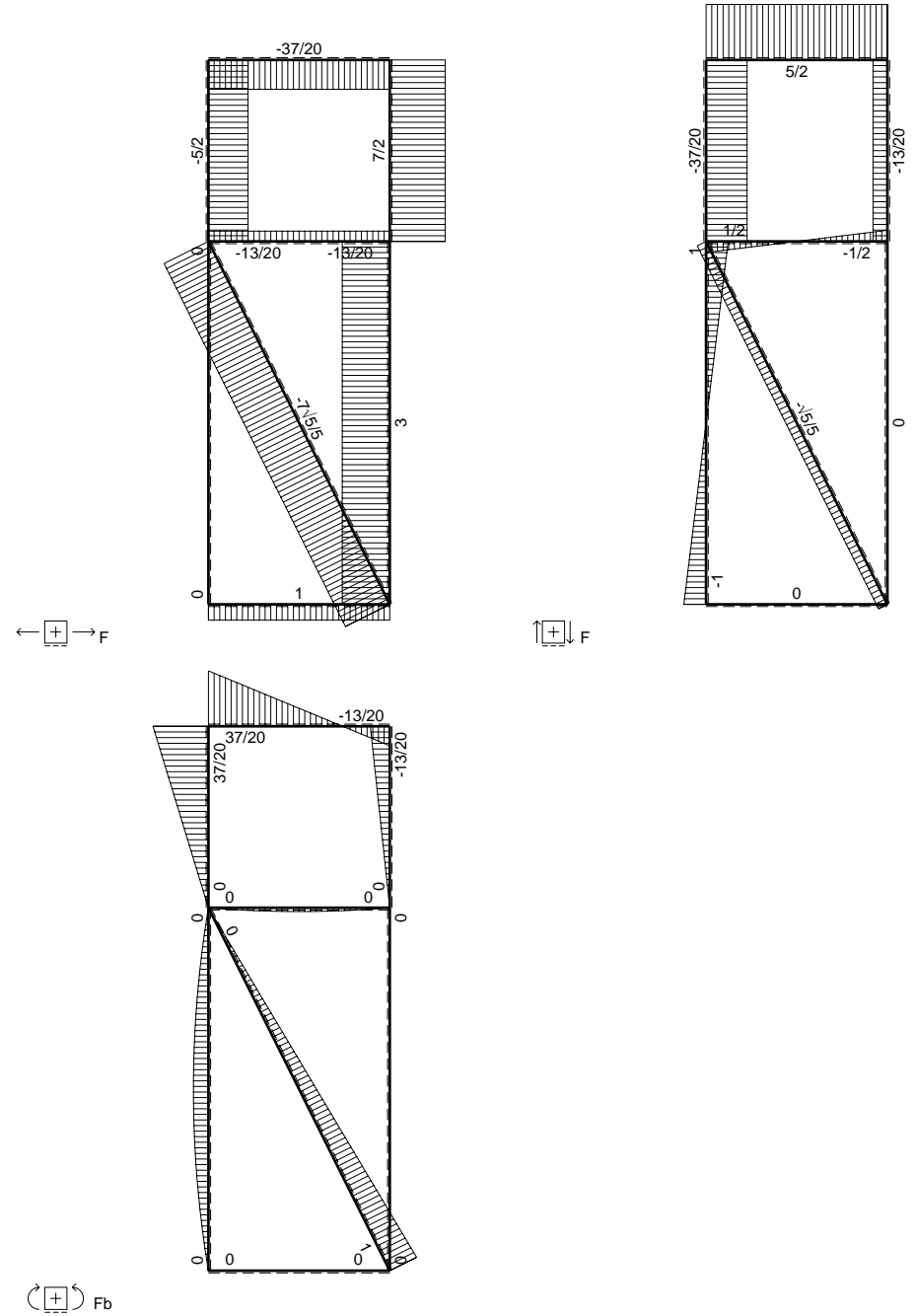
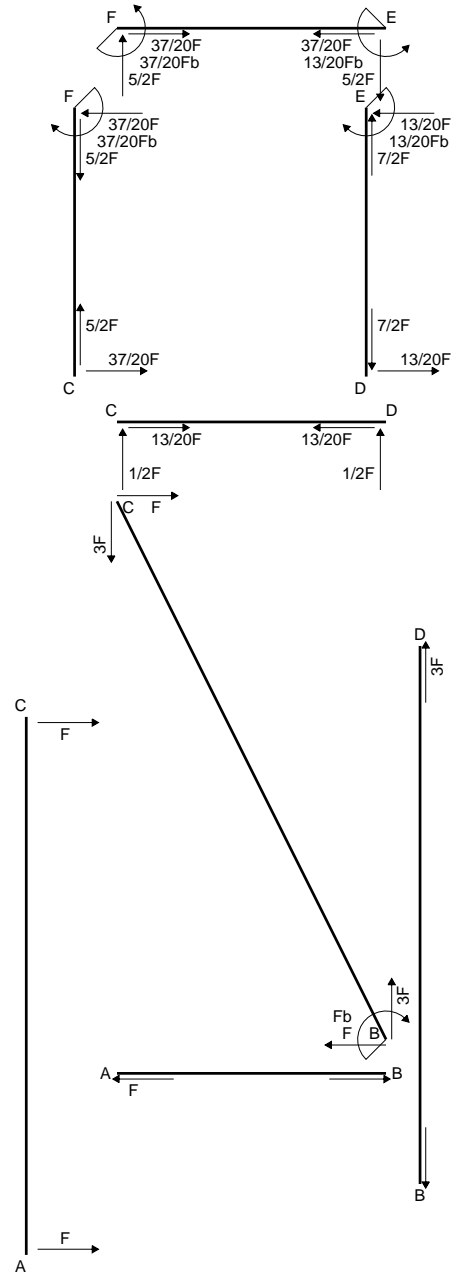
$$\sigma_c = N/A - Mv/J_u = -118.2 \text{ N/mm}^2$$

$$\tau_c = 1.713 \text{ N/mm}^2$$

$$\sigma_o = \sqrt{\sigma^2 + 3\tau^2} = 118.3 \text{ N/mm}^2$$

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







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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

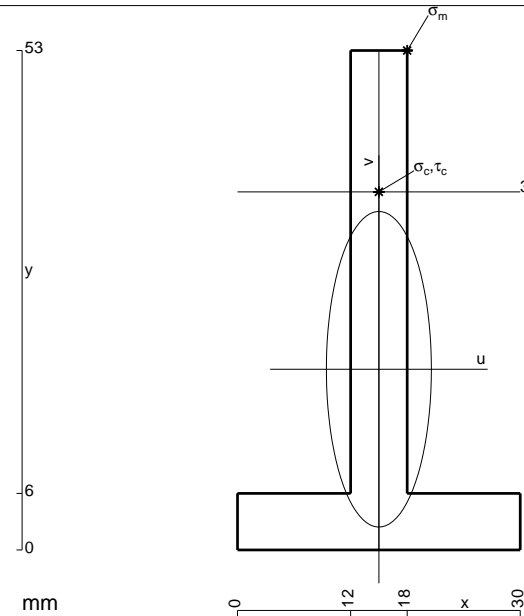
$$= (-5/2 b + 5/4 b) Fb 1/EJ + (-b) \theta = -1/4 Fb^2/EJ$$

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

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

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

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



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

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

$$J_v = 14346. \text{ mm}^4$$

$$y_g = 19.18 \text{ mm}$$

$$N = -4070. \text{ N}$$

$$T_y = -581.4 \text{ N}$$

$$M_x = 767000. \text{ Nmm}$$

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

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

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

$$v_m = 33.82 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -209. \text{ N/mm}^2$$

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

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

$$v_c = 18.82 \text{ mm}$$

$$\sigma_c = N/A - Mv/J_u = -120.2 \text{ N/mm}^2$$

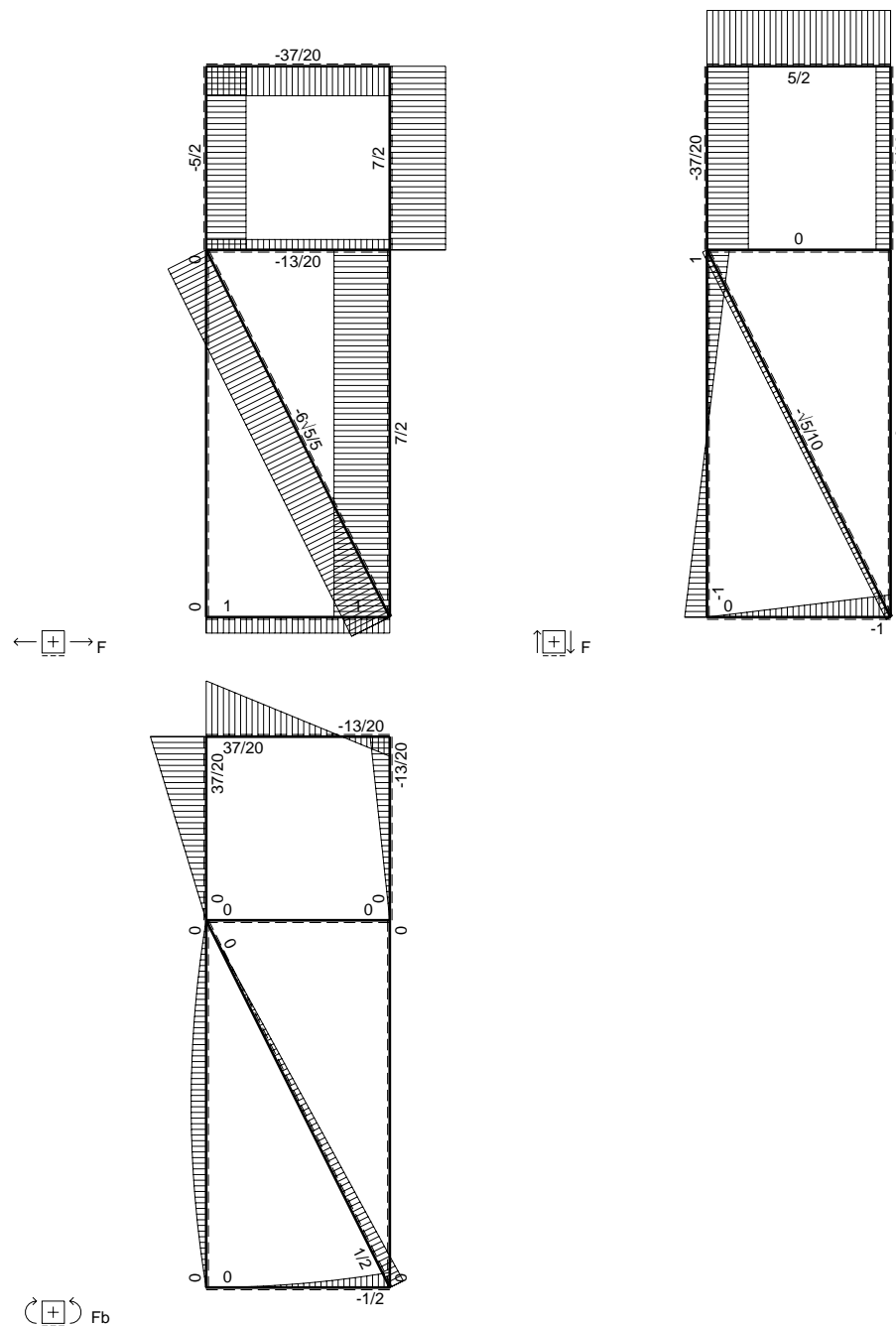
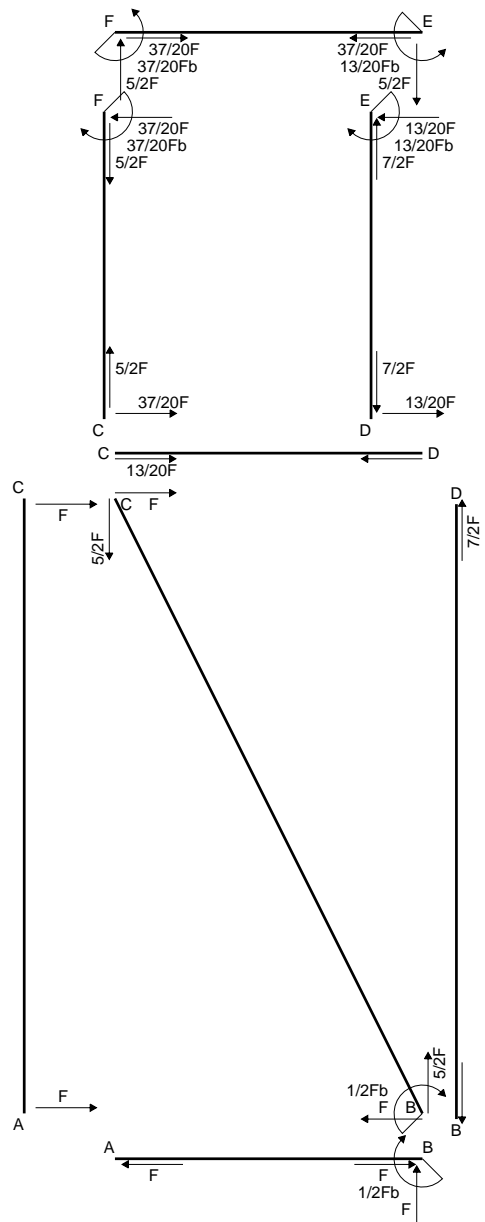
$$\tau_c = 1.771 \text{ N/mm}^2$$

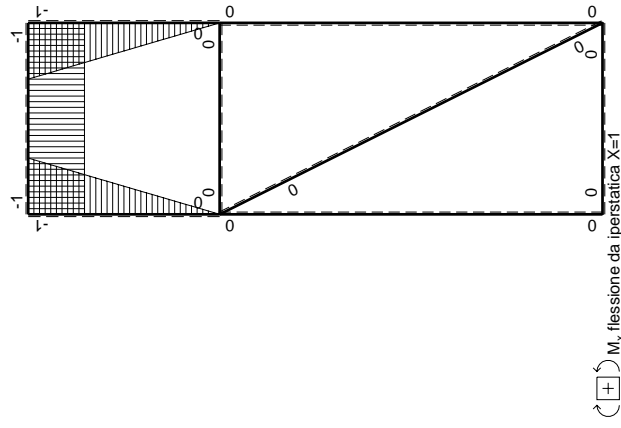
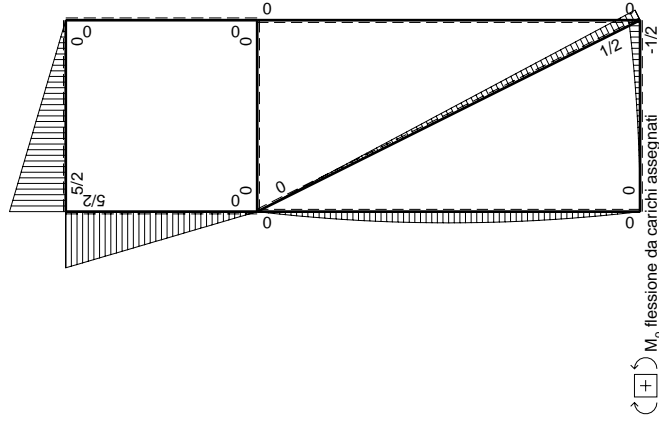
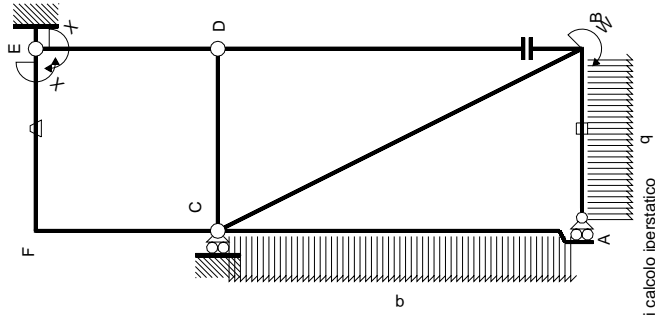
$$\sigma_g = \sqrt{\sigma^2 + 3\tau^2} = 120.3 \text{ N/mm}^2$$

$$S = 2369. \text{ mm}^3$$









Quadro contributi PLV per iperstatica  $X=W^{EP}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M M_0$	$M \theta$	$M M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	0	$-1/2qx^2$	0	0	0	0	0	0
BA b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$1/2Fb-\sqrt{5}/10Fx$	0	0	0	0	0	0
AC 2b	0	$-Fx+1/2qx^2$	0	0	0	0	0	0
CA 2b	0	$Fx-1/2qx^2$	0	0	0	0	0	0
DB 2b	0	0	0	0	0	0	0	0
BD 2b	0	0	0	0	0	0	0	0
DE b	$-x/b$	0	0	0	0	0	0	0
ED b	$1-x/b$	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
EF b	-1	$5/2Fx$	$-Fb/EJ$	$-5/2Fx$	$Fb/EJ$	1	$(-5/4+1)Fb^2/EJ$	$Xb/EJ$
FE b	1	$-5/2Fb+5/2Fx$	$Fb/EJ$	$-5/2Fb+5/2Fx$	$Fb/EJ$	1	$(-5/4+1)Fb^2/EJ$	$Xb/EJ$
FC b	$-1+x/b$	$5/2Fb-5/2Fx$	0	$-5/2Fb+5Fx-5/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-5/6+0)Fb^2/EJ$	$1/3Xb/EJ$
CF b	$x/b$	$-5/2Fx$	0	$-5/2Fx^2/b$	0	$x^2/b^2$	$-13/12Fb^2/EJ$	$5/3Xb/EJ$
totali								
iperstatica $X=W^{EP}$								

Sviluppi di calcolo iperstatica

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

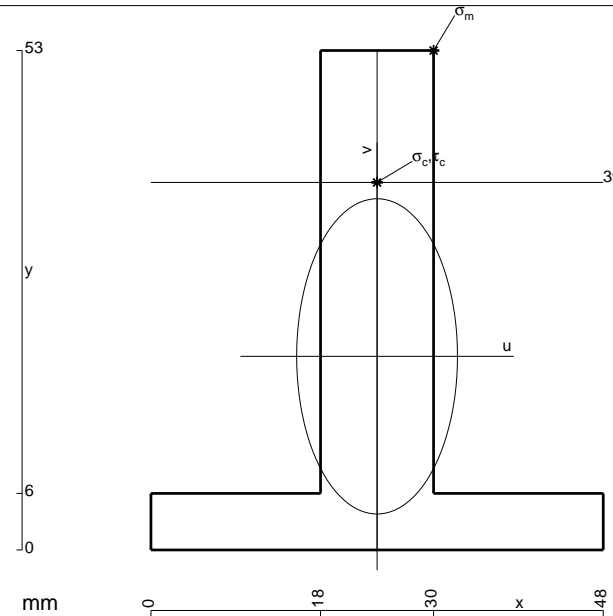
$$= (-5/2 b + 5/4 b) Fb 1/EJ + (-b) \theta = -1/4 Fb^2/EJ$$

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

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

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

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



$$A = 852. \text{ mm}^2$$

$$J_u = 238569. \text{ mm}^4$$

$$J_v = 62064. \text{ mm}^4$$

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

$$N = 5070. \text{ N}$$

$$T_y = -5070. \text{ N}$$

$$M_x = -1571700. \text{ Nmm}$$

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

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

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

$$v_m = 32.46 \text{ mm}$$

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

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

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

$$v_c = 18.46 \text{ mm}$$

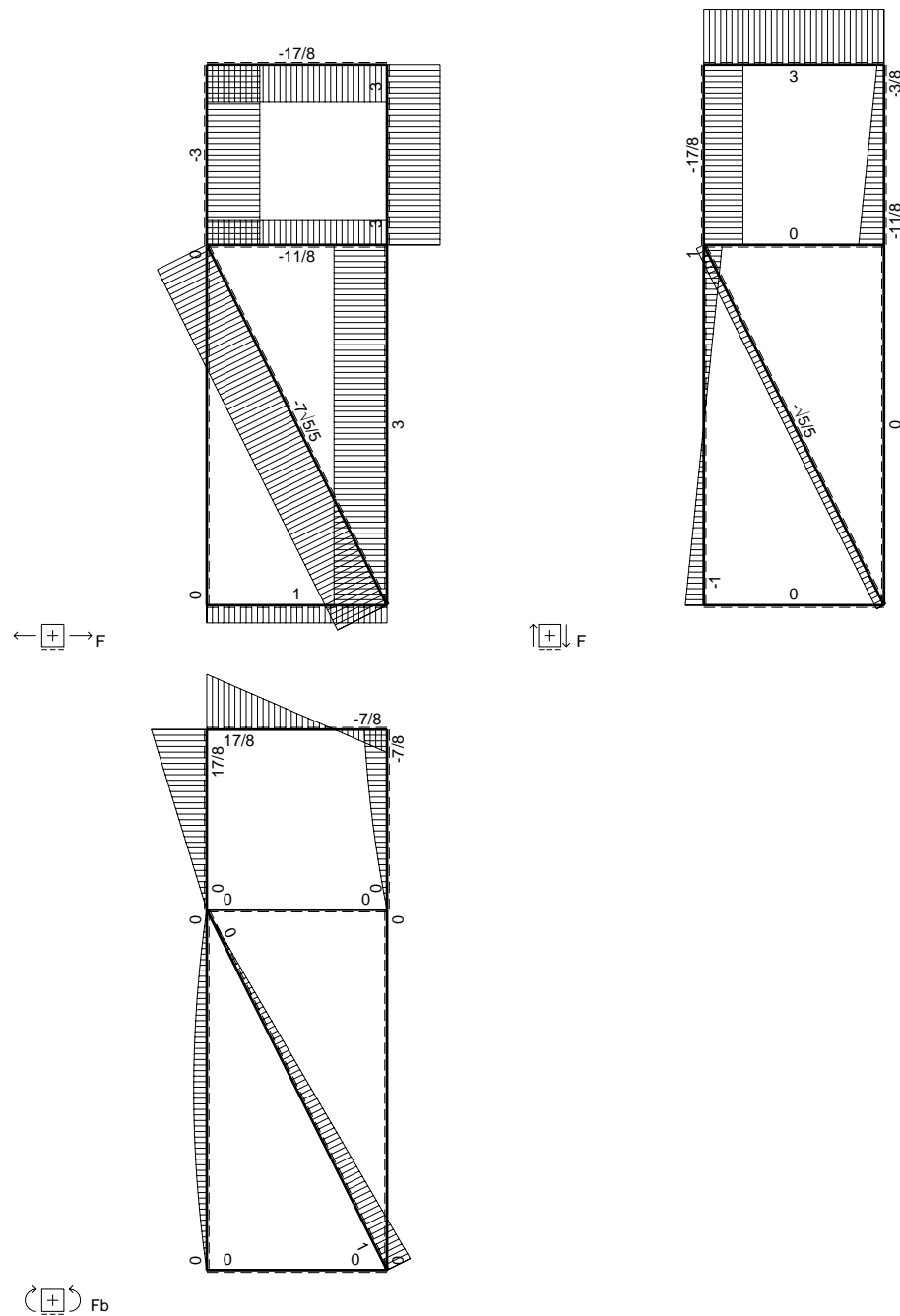
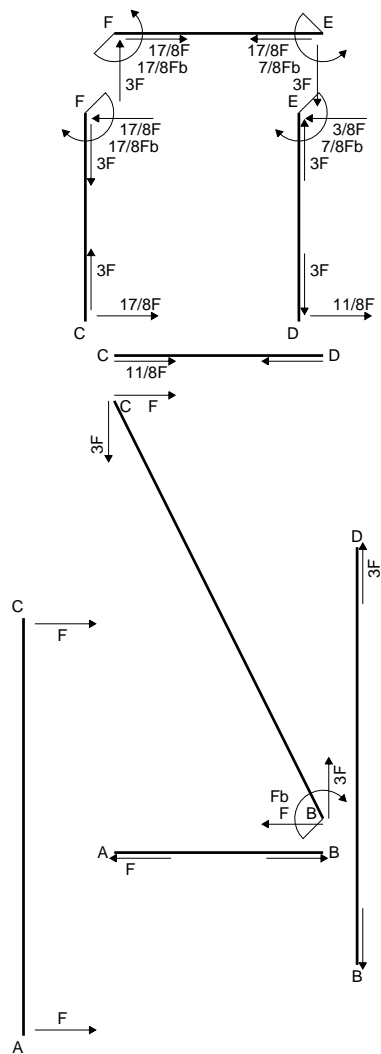
$$\sigma_c = N/A - Mv/J_u = 127.6 \text{ N/mm}^2$$

$$\tau_c = 7.574 \text{ N/mm}^2$$

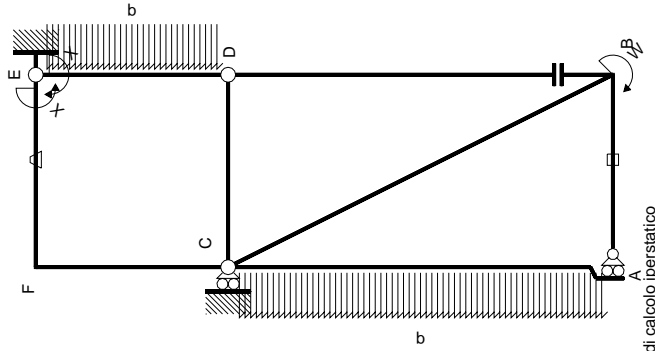
$$\sigma_o = \sqrt{\sigma^2 + 3\tau^2} = 128.2 \text{ N/mm}^2$$

$$S = 4277. \text{ mm}^3$$

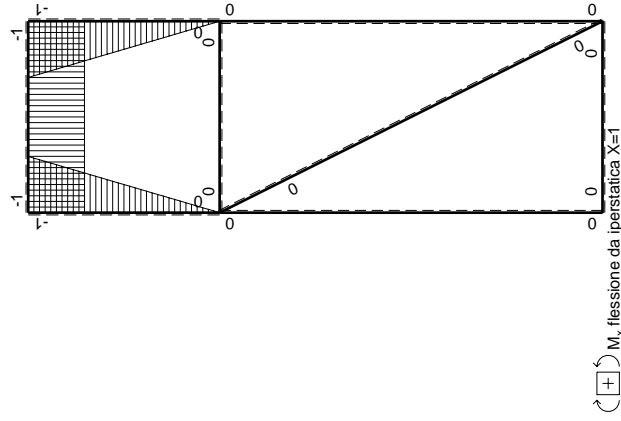




$\circlearrowleft (+) F_b$



$M_0$  flessione da carichi assegnati



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

$\leftarrow$	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x (M_0/EJ + \theta) dx$	$\int M^x M_x / EJ dx$
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0+0	0
BC $\sqrt{5}b$	0	$Fb - \sqrt{5}/5Fx$	0	0	0	0	0	0
AC 2b	0	$-Fx + 1/2qx^2$	0	0	0	0	0+0	0
CA 2b	0	$Fx - 1/2qx^2$	0	0	0	0	0+0	0
DB 2b	0	0	0	0	0	0	0+0	0
BD 2b	0	0	0	0	0	0	0+0	0
DE b	$-x/b$	$-1/2Fx + 1/2qx^2$	0	$1/2Fx^2/b - 1/2qx^3/b$	0	0	$x^2/b^2$	$1/3xb/EJ$
ED b	$1-x/b$	$1/2Fx - 1/2qx^2$	0	$1/2Fx - Fx^2/b + 1/2qx^3/b$	0	0	$1-2x/b+x^2/b^2$	$1/3xb/EJ$
CD b	0	0	0	0	0	0	0+0	0
DC b	0	0	0	0	0	0	0+0	0
EF b	-1	$3Fx$	$-Fb/EJ$	$-3Fx$	$Fb/EJ$	1	$(-3/2+1)Fb^2/EJ$	$xb/EJ$
FE b	1	$-3Fb+3Fx$	$Fb/EJ$	$-3Fb+3Fx$	$Fb/EJ$	1	$(-3/2+1)Fb^2/EJ$	$xb/EJ$
FC b	$-1+x/b$	$3Fb-3Fx$	0	$-3Fb+6Fx-3Fx^2/b$	0	0	$1-2x/b+x^2/b^2$	$1/3xb/EJ$
CF b	$x/b$	$-3Fx$	0	$-3Fx^2/b$	0	0	$x^2/b^2$	$1/3xb/EJ$
totali								$5/3xb/EJ$
								$7/8Fb$

Sviluppi di calcolo iperstatica

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

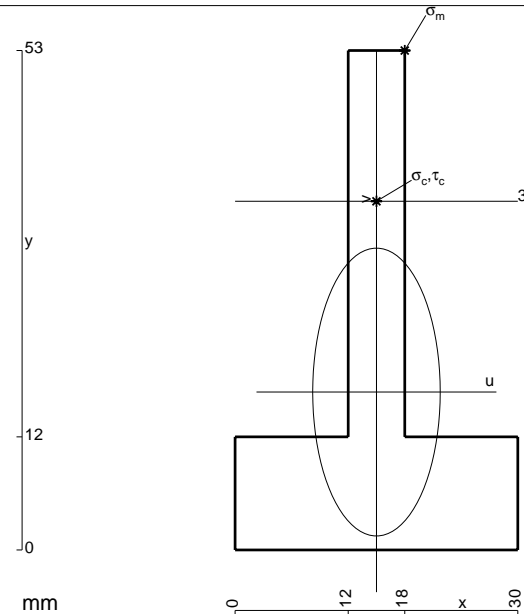
$$= (-3b + 3/2 b) Fb 1/EJ + (-b) \theta = -1/2 Fb^2/EJ$$

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

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

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

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



$$A = 606. \text{ mm}^2$$

$$J_u = 141406. \text{ mm}^4$$

$$J_v = 27738. \text{ mm}^4$$

$$y_g = 16.76 \text{ mm}$$

$$N = -4101. \text{ N}$$

$$T_y = -585.8 \text{ N}$$

$$M_x = 864600. \text{ Nmm}$$

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

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

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

$$v_m = 36.24 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -228.4 \text{ N/mm}^2$$

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

$$y_c = 37. \text{ mm}$$

$$v_c = 20.24 \text{ mm}$$

$$\sigma_c = N/A - Mv/J_u = -130.5 \text{ N/mm}^2$$

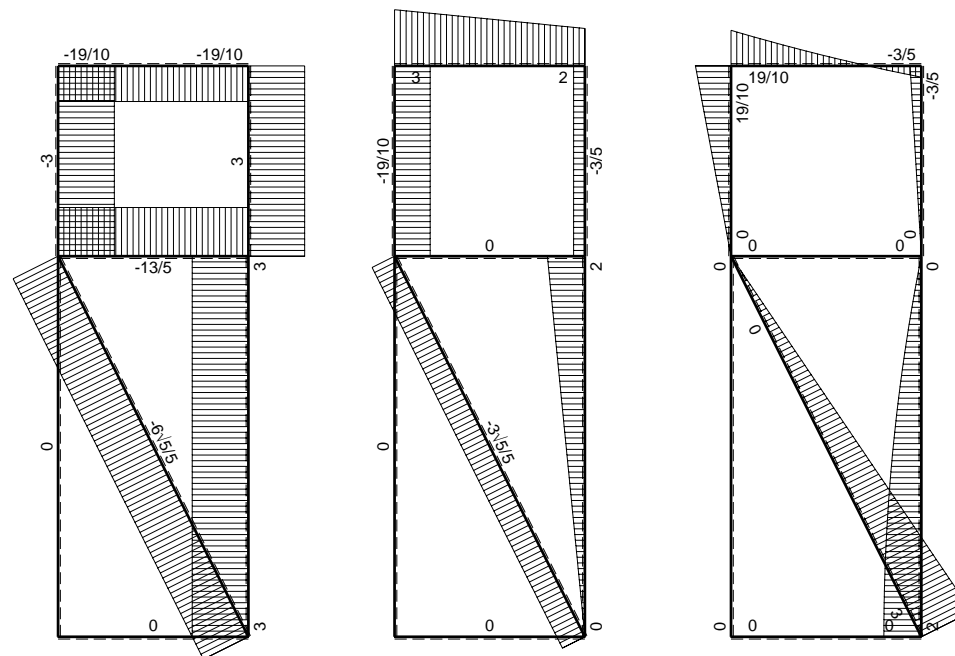
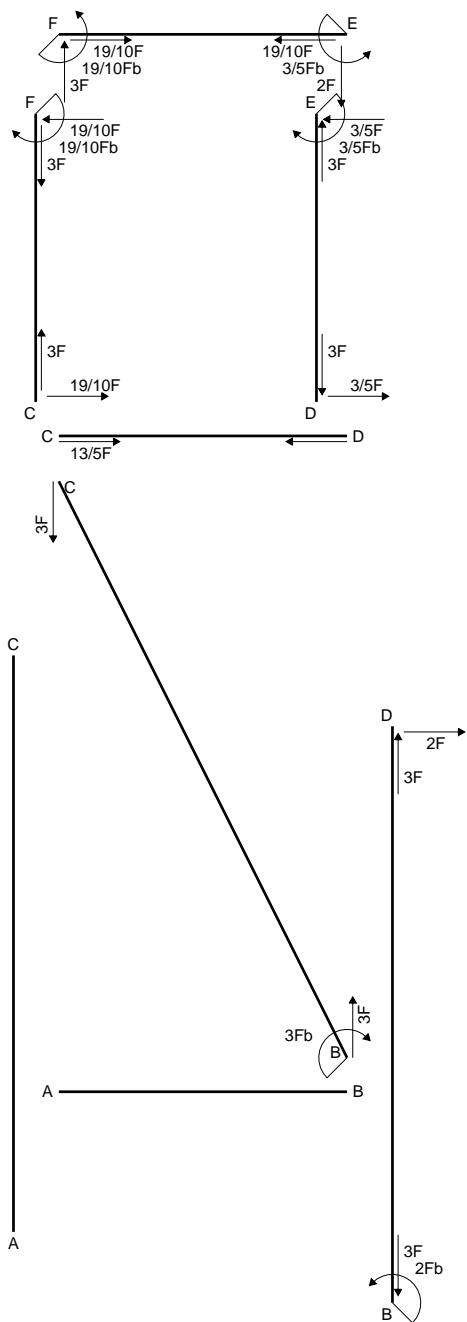
$$\tau_c = 1.872 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 130.6 \text{ N/mm}^2$$

$$S = 2711. \text{ mm}^3$$







← ⊕ → F

↑ ⊕ ↓ F

⊕ F<sub>b</sub>



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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

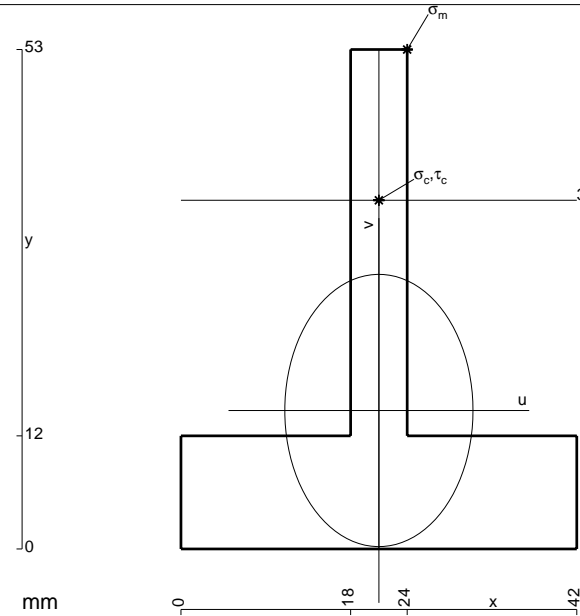
$$= (-5/2 b + 3/2 b - 1/6 b) Fb 1/EJ + (-b) \theta = -1/6 Fb^2/EJ$$

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

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

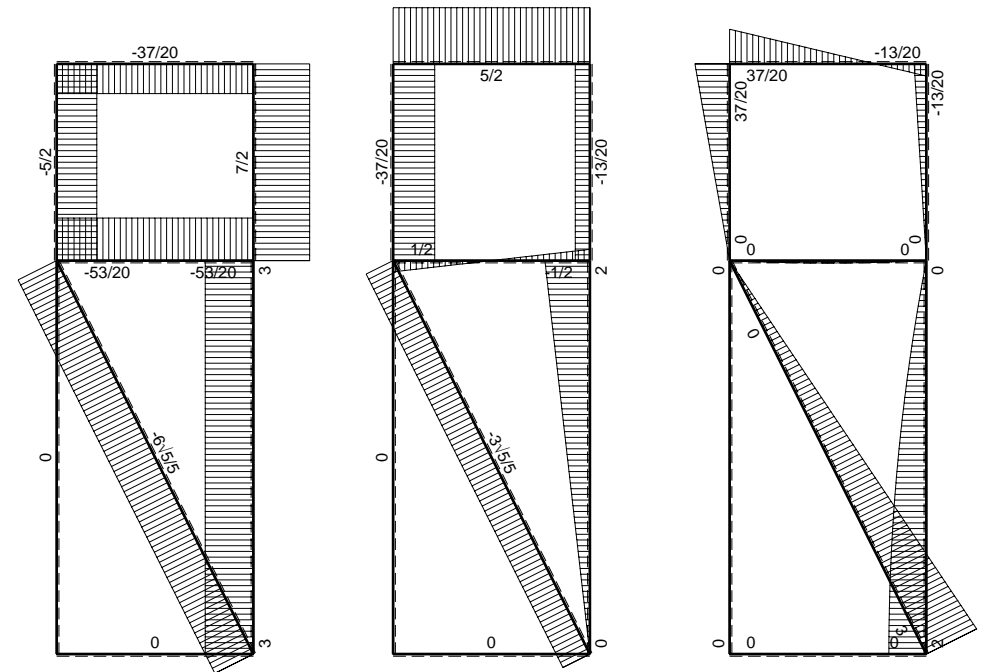
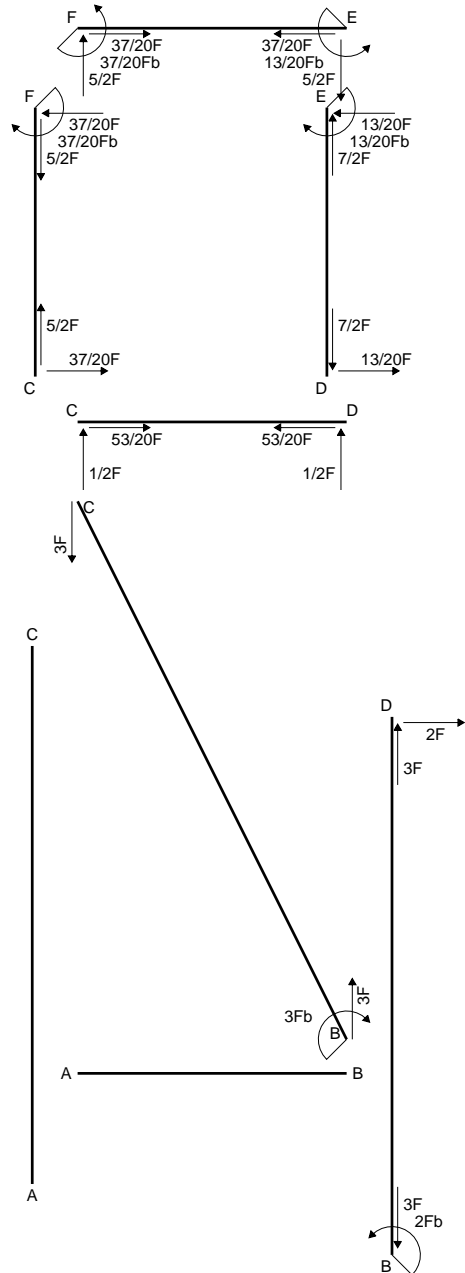
$$L_{CF}^{xo} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

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



- 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 = -1234. N
- T<sub>y</sub> = -617.2 N
- M<sub>x</sub> = 966000. 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 - M<sub>v</sub>/J<sub>u</sub> = -238. 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 - M<sub>v</sub>/J<sub>u</sub> = -139.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.911 N/mm<sup>2</sup>
- σ<sub>g</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 139.3 N/mm<sup>2</sup>
- S = 2910. mm<sup>3</sup>

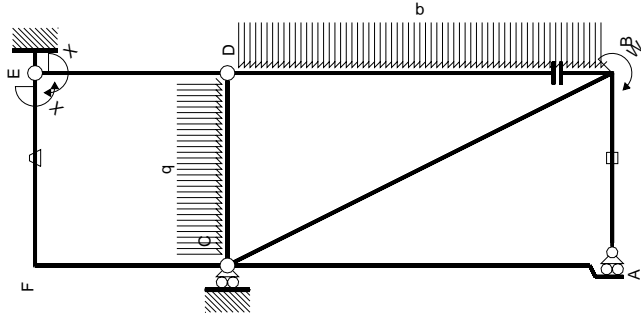




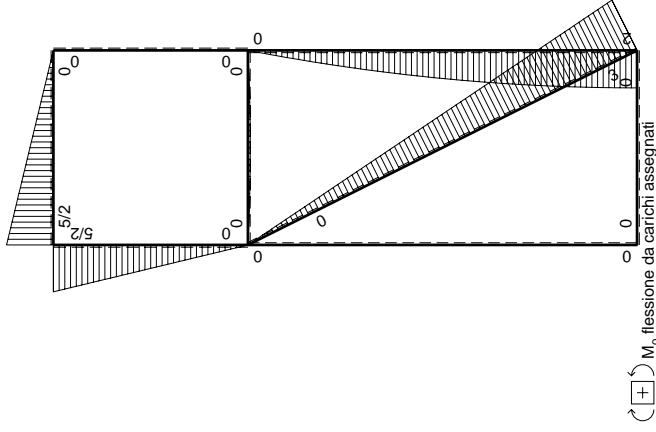
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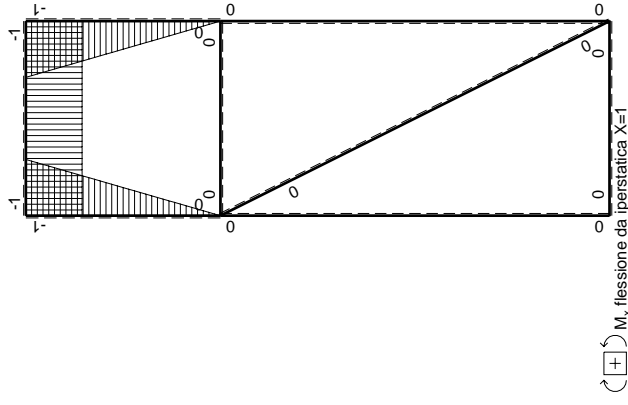
⊕ ⊖ F<sub>b</sub>



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>EP</sup>

←	M <sup>x</sup> (x)	M <sup>0</sup> (x)	θ	M <sup>x</sup> M <sup>0</sup>	M <sup>x</sup> θ	M <sup>x</sup> M <sup>x</sup>	∫M <sup>x</sup> (M <sup>0</sup> /EJ+θ)dx	∫M <sup>x</sup> M <sup>x</sup> /EJdx
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0	0
BC √5b	0	3Fb-3√5/5Fx	0	0	0	0	0	0
AC 2b	0	0	0	0	0	0	0+0	0
CA 2b	0	0	0	0	0	0	0	0
DB 2b	0	2Fx-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
BD 2b	0	-2Fb+1/2qx <sup>2</sup>	0	0	0	0	0	0
DE b	-x/b	0	0	0	0	x <sup>2</sup> /b <sup>2</sup>	0+0	1/3xb/EJ
ED b	1-x/b	0	0	0	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	0+0	1/3xb/EJ
CD b	0	1/2Fx-1/2qx <sup>2</sup>	0	0	0	0	0	0
DC b	0	-1/2Fx+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
EF b	-1	5/2Fx	-Fb/EJ	-5/2Fx	Fb/EJ	1	(-5/4+1)Fb <sup>2</sup> /EJ	Xb/EJ
FE b	1	-5/2Fb+5/2Fx	Fb/EJ	-5/2Fb+5/2Fx	Fb/EJ	1	(-5/4+1)Fb <sup>2</sup> /EJ	Xb/EJ
FC b	-1+x/b	5/2Fb-5/2Fx	0	-5/2Fb+5Fx-5/2Fx <sup>2</sup> /b	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	(-5/6+0)Fb <sup>2</sup> /EJ	1/3xb/EJ
CF b	x/b	-5/2Fx	0	-5/2Fx <sup>2</sup> /b	0	x <sup>2</sup> /b <sup>2</sup>	-13/12Fb <sup>2</sup> /EJ	5/3xb/EJ
totali								
iperstatica X=W <sup>EP</sup>		13/20Fb						

Sviluppi di calcolo iperstatica

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

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

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

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

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

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

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

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

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

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

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

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

$$L_{EF}^{x_0} = \int_0^b (-5/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-5/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

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

$$L_{FE}^{x_0} = \int_0^b (-5/2 + 5/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-5/2 x + 5/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

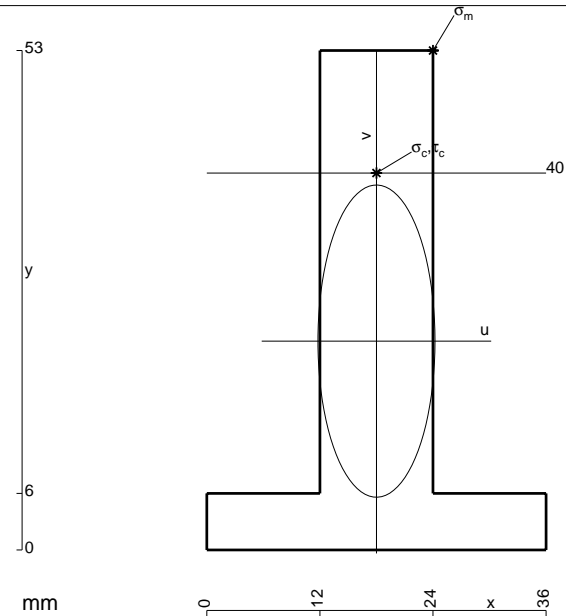
$$= (-5/2 b + 5/4 b) Fb 1/EJ + (-b) \theta = -1/4 Fb^2/EJ$$

$$L_{FC}^{x_0} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = [-5/2 x + 5/2 x^2/b - 5/6 x^3/b^2]_0^b Fb 1/EJ$$

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

$$L_{CF}^{x_0} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

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



$$A = 780. \text{ mm}^2$$

$$J_u = 214152. \text{ mm}^4$$

$$J_v = 30096. \text{ mm}^4$$

$$y_g = 22.16 \text{ mm}$$

$$N = -3274. \text{ N}$$

$$T_y = -1637. \text{ N}$$

$$M_x = 1354200. \text{ Nmm}$$

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

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

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

$$v_m = 30.84 \text{ mm}$$

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

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

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

$$v_c = 17.84 \text{ mm}$$

$$\sigma_c = N/A - Mv/J_u = -117. \text{ N/mm}^2$$

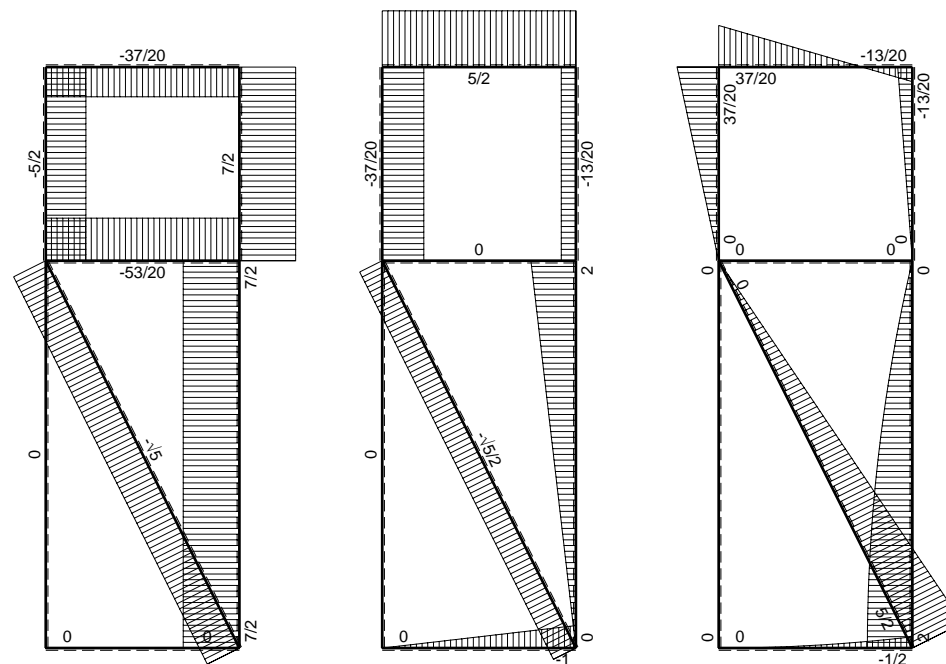
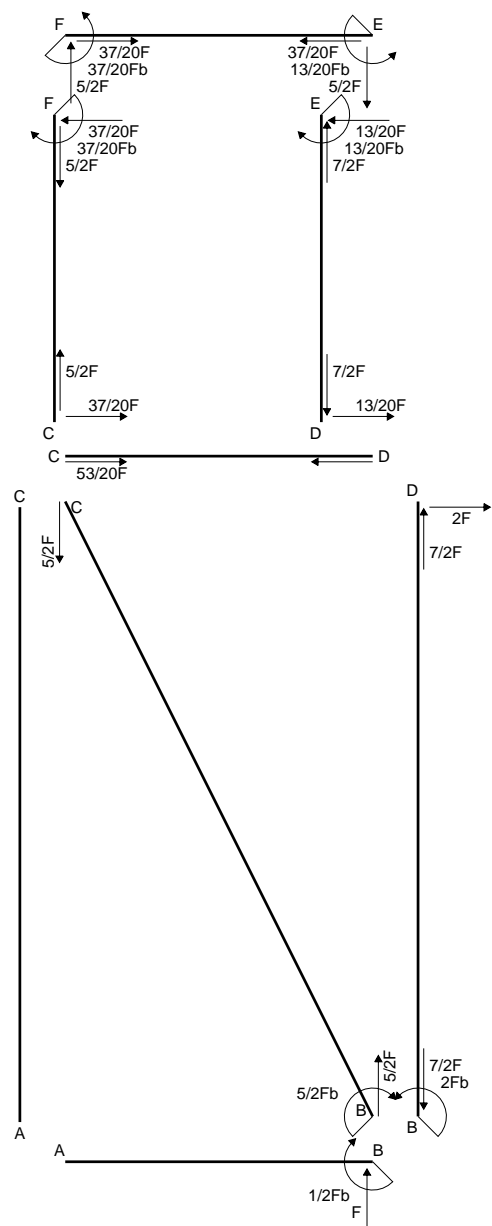
$$\tau_c = 2.418 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 117.1 \text{ N/mm}^2$$

$$S = 3797. \text{ mm}^3$$



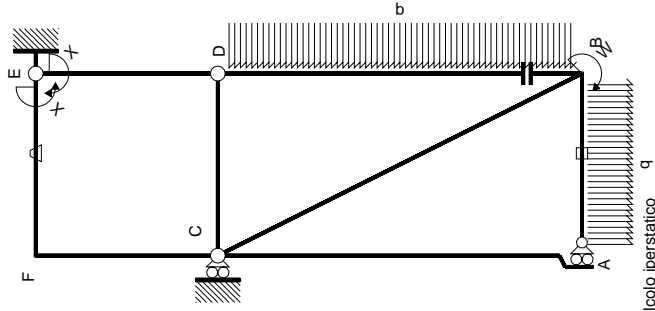




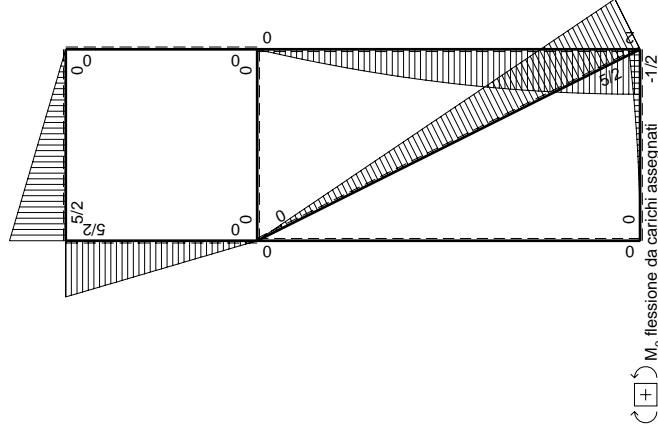
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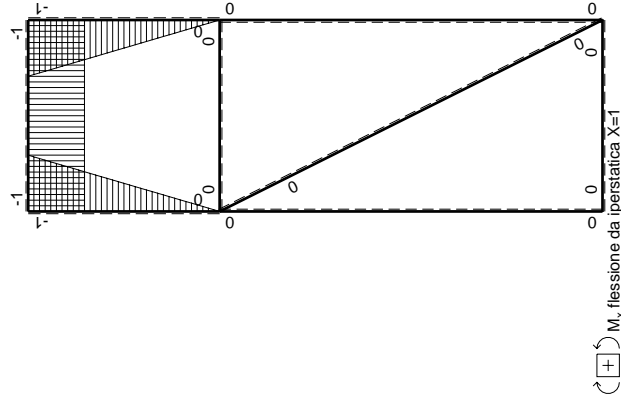
⊕ ⊖ F<sub>b</sub>



Schema di calcolo iperstatico q



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>EP</sup>

→	M <sub>x</sub> (x)	M <sub>0</sub> (x)	θ	M <sub>M<sub>0</sub></sub>	M <sub>θ</sub>	M <sub>M<sub>x</sub></sub>	∫M <sub>x</sub> (M <sub>0</sub> /EJ+θ)dx	∫M <sub>x</sub> M <sub>0</sub> /EJdx
AB b	0	-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
BA b	0	1/2Fb-Fx+1/2qx <sup>2</sup>	0	0	0	0	0	0
BC √5b	0	5/2Fb-√5/2Fx	0	0	0	0	0+0	0
CA 2b	0	0	0	0	0	0	0+0	0
DB 2b	0	2Fx-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
BD 2b	0	-2Fb+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
DE b	-x/b	0	0	0	0	x <sup>2</sup> /b <sup>2</sup>	0+0	1/3Xb/EJ
ED b	1-x/b	0	0	0	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	0+0	1/3Xb/EJ
CD b	0	0	0	0	0	0	0+0	0
DC b	0	0	0	0	0	0	0+0	0
EF b	-1	5/2Fx	-Fb/EJ	-5/2Fx	Fb/EJ	1	(-5/4+1)Fb <sup>2</sup> /EJ	Xb/EJ
FE b	1	-5/2Fb+5/2Fx	Fb/EJ	-5/2Fb+5/2Fx	Fb/EJ	1	(-5/4+1)Fb <sup>2</sup> /EJ	Xb/EJ
FC b	-1+x/b	5/2Fb-5/2Fx	0	-5/2Fb+5Fx-5/2Fx <sup>2</sup> /b	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	(-5/6+0)Fb <sup>2</sup> /EJ	1/3Xb/EJ
CF b	x/b	-5/2Fx	0	-5/2Fx <sup>2</sup> /b	0	x <sup>2</sup> /b <sup>2</sup>	-13/12Fb <sup>2</sup> /EJ	5/3Xb/EJ
totali								
iperstatica X=W <sup>EP</sup>								

Sviluppi di calcolo iperstatica

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

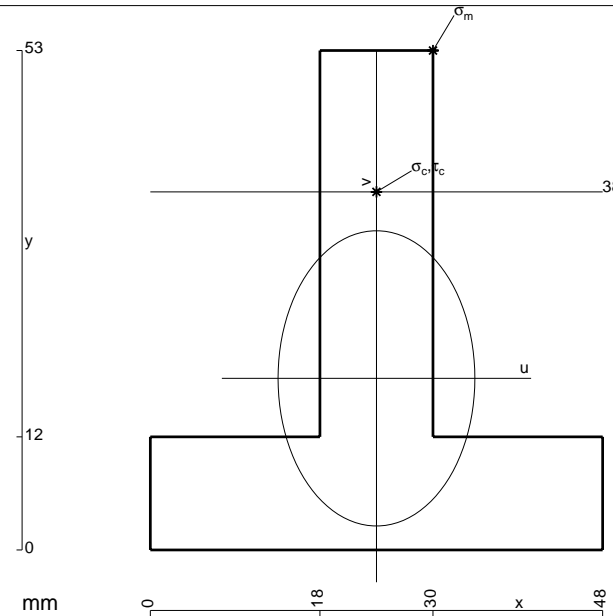
$$= (-5/2 b + 5/4 b) Fb 1/EJ + (-b) \theta = -1/4 Fb^2/EJ$$

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

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

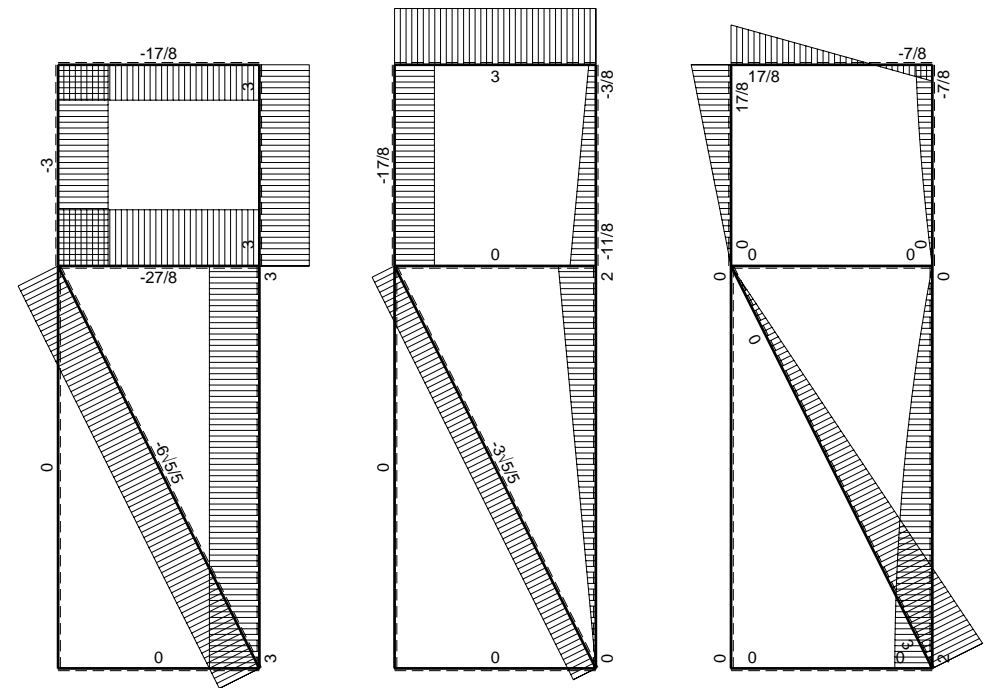
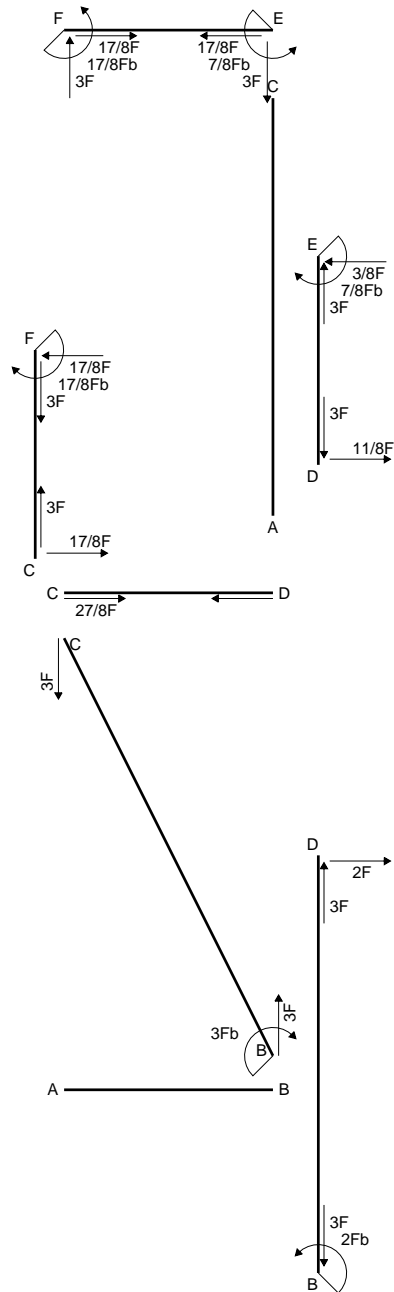
$$L_{CF}^{xo} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

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



- A = 1068. mm<sup>2</sup>
- J<sub>u</sub> = 262174. mm<sup>4</sup>
- J<sub>v</sub> = 116496. mm<sup>4</sup>
- y<sub>g</sub> = 18.21 mm
- N = -3466. N
- T<sub>y</sub> = -1733. N
- M<sub>x</sub> = 1550000. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 53. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 34.79 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = -208.9 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 38. mm
- v<sub>c</sub> = 19.79 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = -120.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.706 N/mm<sup>2</sup>
- σ<sub>o</sub> = √(σ<sup>2</sup>+3τ<sup>2</sup>) = 120.3 N/mm<sup>2</sup>
- S = 4913. mm<sup>3</sup>





← ⊕ → F

↑ ⊕ ↓ F

⊕ ⊖ F<sub>b</sub>



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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

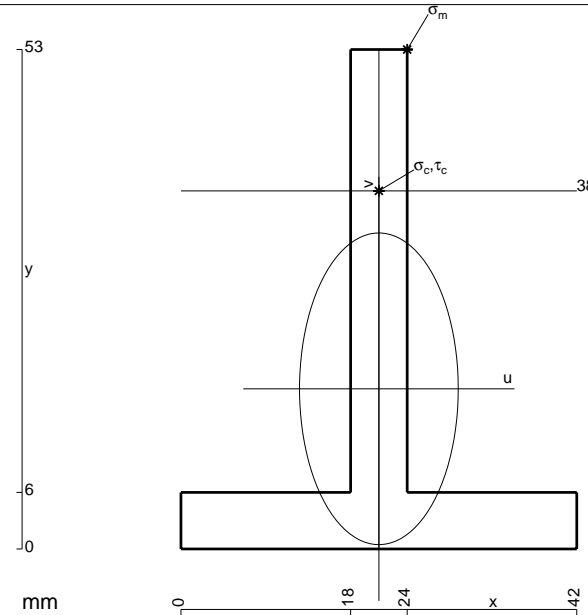
$$= (-3b + 3/2 b) Fb 1/EJ + (-b) \theta = -1/2 Fb^2/EJ$$

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

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

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

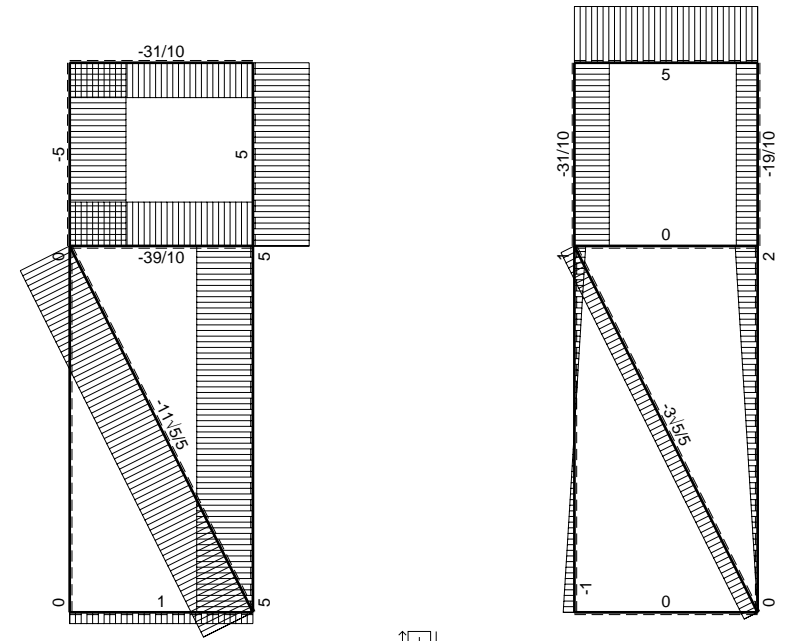
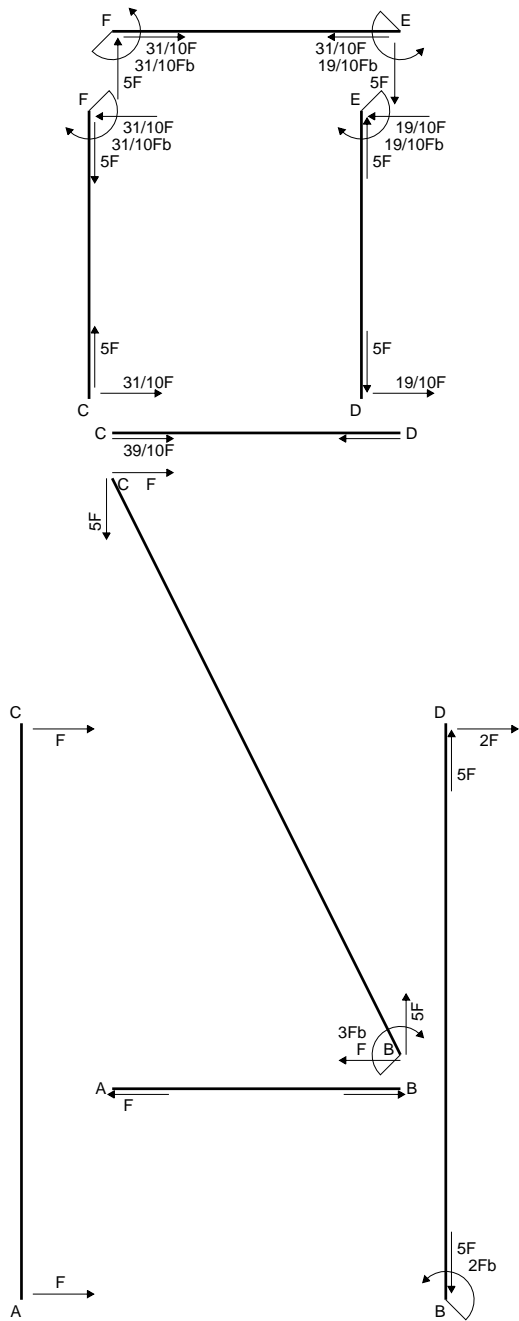
$$= (-b) Fb 1/EJ = - Fb^2/EJ$$



- 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
- N = -1771. N
- T<sub>y</sub> = -885.5 N
- M<sub>x</sub> = 871200. 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> = N/A-Mv/J<sub>u</sub> = -218. 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> = N/A-Mv/J<sub>v</sub> = -128.6 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.591 N/mm<sup>2</sup>
- σ<sub>g</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 128.6 N/mm<sup>2</sup>
- S<sup>3</sup> = 2566. mm<sup>3</sup>

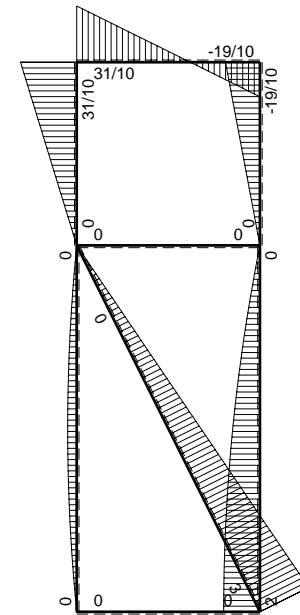




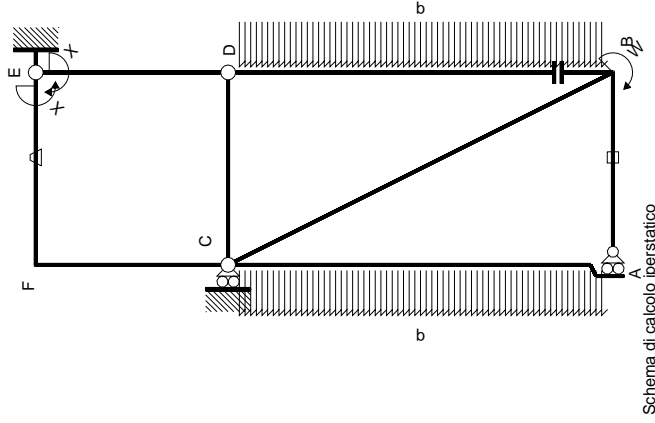


← ⊕ → F

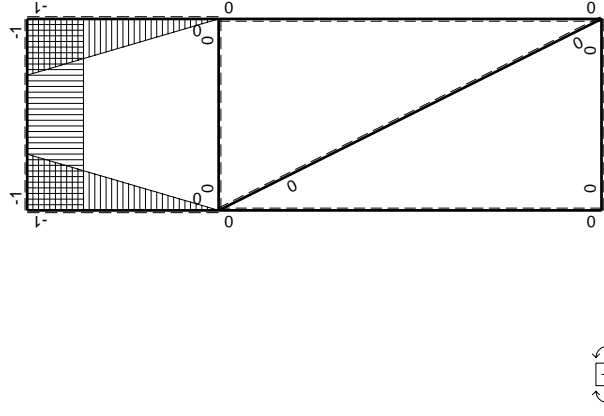
↑ ⊕ ↓ F



⊕ ⊖ F<sub>b</sub>



$M_0$  flessione da carichi assegnati



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

$\rightarrow$	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x (M_0/EJ + \theta) dx$	$\int M^x M_x / EIdx$
AB b	0	0	0	0	0	0	0	0
BA b	0	0	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$3Fb-3\sqrt{5}/5Fx$	0	0	0	0	0	0
CA 2b	0	$-Fx+1/2qx^2$	0	0	0	0	0	0
DB 2b	0	$2Fx-1/2qx^2$	0	0	0	0	0	0
BD 2b	0	$-2Fb+1/2qx^2$	0	0	0	0	0	0
DE b	$-x/b$	0	0	0	0	$x^2/b^2$	0	0
ED b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0	0
CD b	0	0	0	0	0	0	0	0
DC b	0	0	0	0	0	0	0	0
EF b	-1	$5Fx$	$-Fb/EJ$	$-5Fx$	$Fb/EJ$	1	$(-5/2+1)Fb^2/EJ$	$Xb/EJ$
FE b	1	$-5Fb+5Fx$	$Fb/EJ$	$-5Fb+5Fx$	$Fb/EJ$	1	$(-5/2+1)Fb^2/EJ$	$Xb/EJ$
FC b	$-1+x/b$	$5Fb-5Fx$	0	$-5Fb+10Fx-5Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-5/3+0)Fb^2/EJ$	$1/3Xb/EJ$
CF b	$x/b$	$-5Fx$	0	$-5Fx^2/b$	0	$x^2/b^2$	$-19/6Fb^2/EJ$	$5/3Xb/EJ$
totali								
								$19/10Fb$

Sviluppi di calcolo iperstatica

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

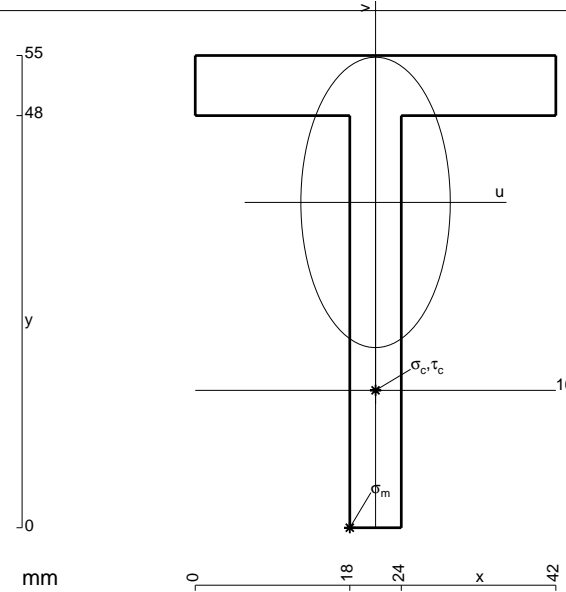
$$= (-5b + 5/2 b) Fb 1/EJ + (-b) \theta = -3/2 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-5 + 10x/b - 5x^2/b^2) Fb 1/EJ dx = [-5x + 5x^2/b - 5/3 x^3/b^2]_0^b Fb 1/EJ$$

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

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

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



$$A = 582. \text{ mm}^2$$

$$J_u = 166519. \text{ mm}^4$$

$$J_v = 44082. \text{ mm}^4$$

$$y_g = 37.89 \text{ mm}$$

$$N = -3394. \text{ N}$$

$$T_y = -925.7 \text{ N}$$

$$M_x = 1035000. \text{ Nmm}$$

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

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

$$v_m = -37.89 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 229.7 \text{ N/mm}^2$$

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

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

$$v_c = -21.89 \text{ mm}$$

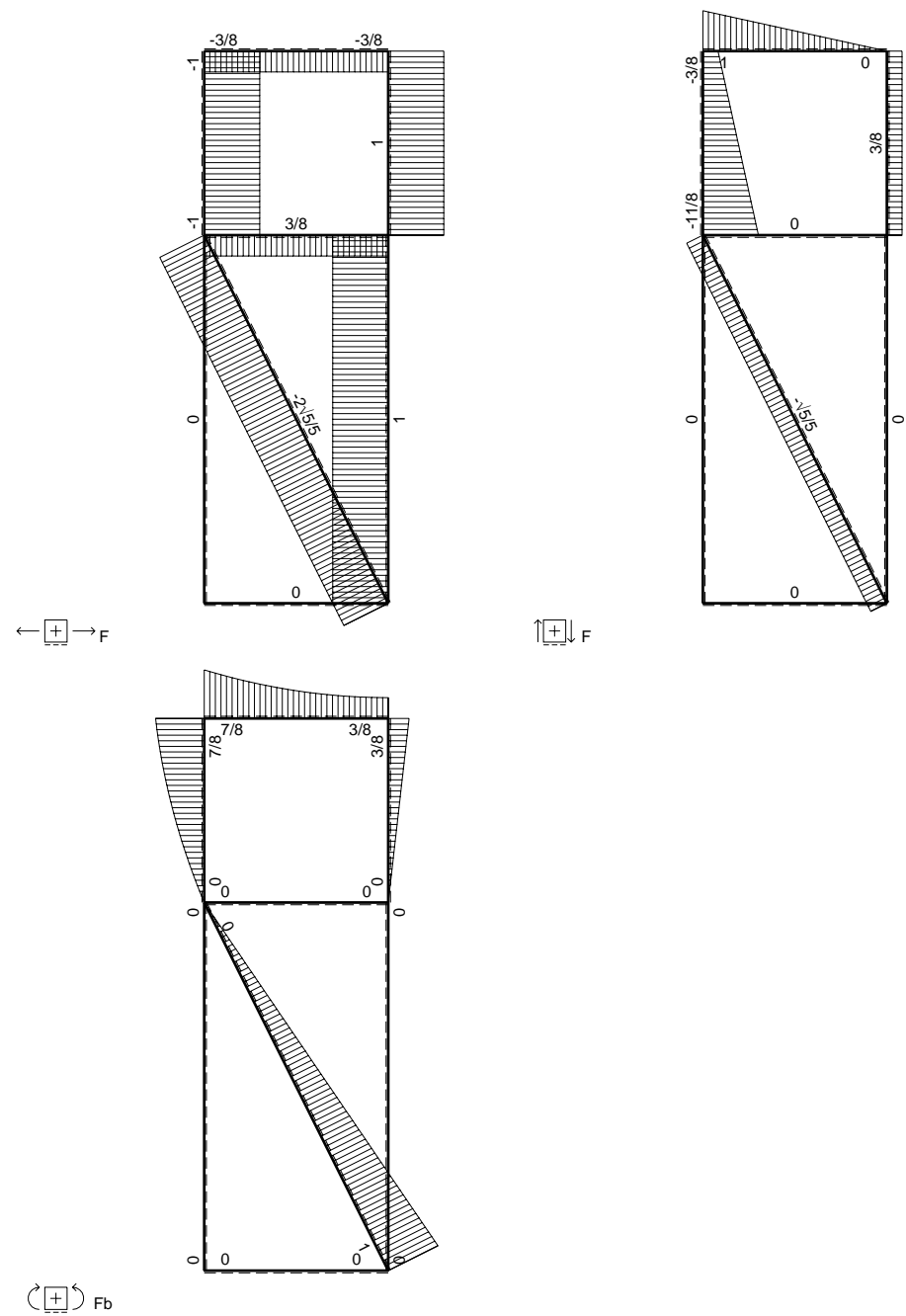
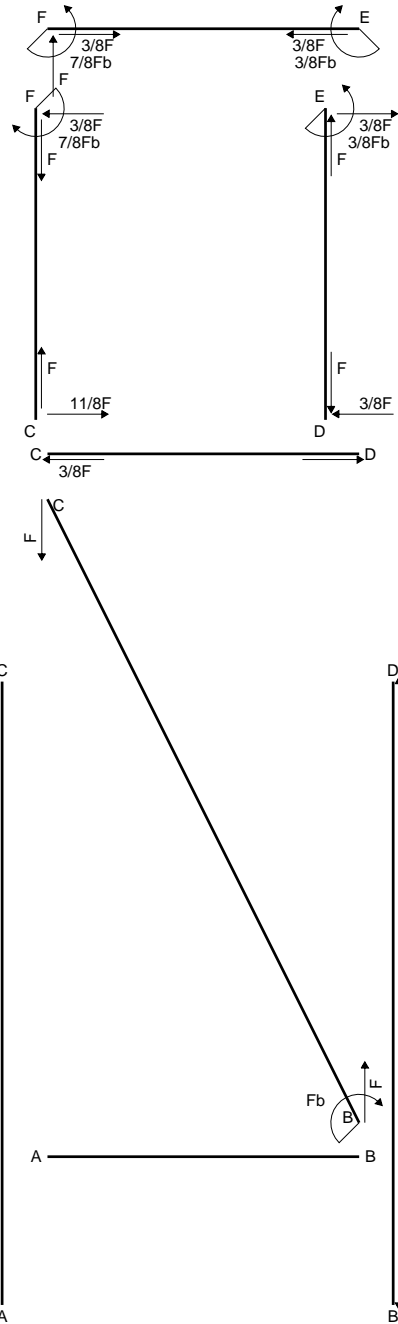
$$\sigma_c = N/A - Mv/J_u = 130.2 \text{ N/mm}^2$$

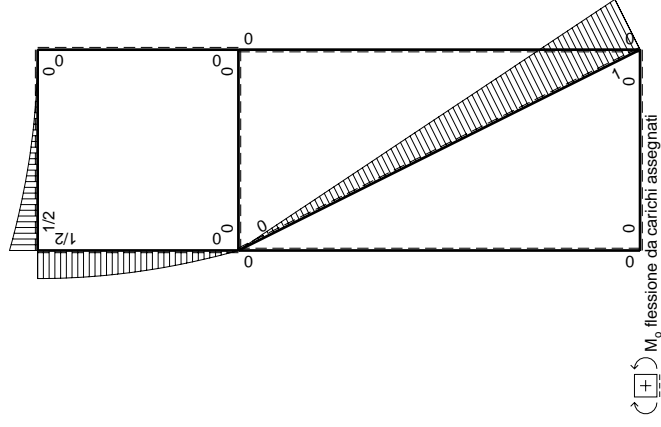
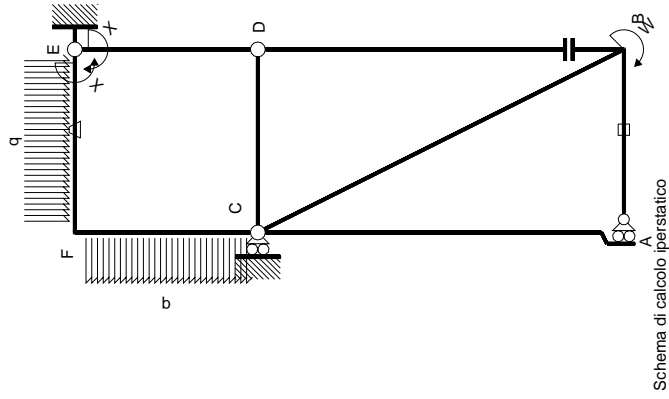
$$\tau_c = 2.659 \text{ N/mm}^2$$

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

$$S = 2870. \text{ mm}^3$$



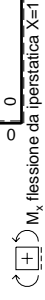




Quadro contributi PLV per iperstatica X=W<sup>EF</sup>

←	M <sup>x</sup> (x)	M <sub>0</sub> (x)	θ	M <sup>x</sup> θ	M <sup>x</sup> M <sub>0</sub>	∫M <sup>x</sup> (M <sub>0</sub> /EJ+θ)dx	∫M <sup>x</sup> M <sub>0</sub> /EJdx
AB	0	0	0	0	0	0	0
BA	0	0	0	0	0	0	0
BC	0	Fb-√5/5Fx	0	0	0	0	0
AC	0	0	0	0	0	0	0
CA	0	0	0	0	0	0	0
DB	0	0	0	0	0	0	0
BD	0	0	0	0	0	0	0
DE	-x/b	0	0	0	0	x <sup>2</sup> /b <sup>2</sup>	1/3Xb/EJ
ED	1-x/b	0	0	0	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	1/3Xb/EJ
CD	0	0	0	0	0	0	0
DC	0	0	0	0	0	0	0
EF	-1	1/2qx <sup>2</sup>	-Fb/EJ	-1/2Fx <sup>2</sup> /b	Fb/EJ	1	Xb/EJ
FE	1	-1/2Fb+Fx-1/2qx <sup>2</sup>	Fb/EJ	-1/2Fx <sup>2</sup> /b	Fb/EJ	1	(-1/6+1)Fb <sup>2</sup> /EJ
FC	-1+x/b	1/2Fb-1/2qx <sup>2</sup>	0	-1/2Fb+1/2Fx+1/2Fx <sup>2</sup> /b-1/2qx <sup>3</sup> /b	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	(-5/24+0)Fb <sup>2</sup> /EJ
CF	x/b	-Fx+1/2qx <sup>2</sup>	0	-Fx <sup>2</sup> /b+1/2qx <sup>3</sup> /b	0	x <sup>2</sup> /b <sup>2</sup>	1/3Xb/EJ
totali							5/3Xb/EJ
							-3/8Fb

Sviluppi di calcolo iperstatica



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

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

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

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

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

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/6 b) Fb 1/EJ + (b) \theta = 5/6 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx$$

$$= [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ + (-b) \theta = 5/6 Fb^2/EJ$$

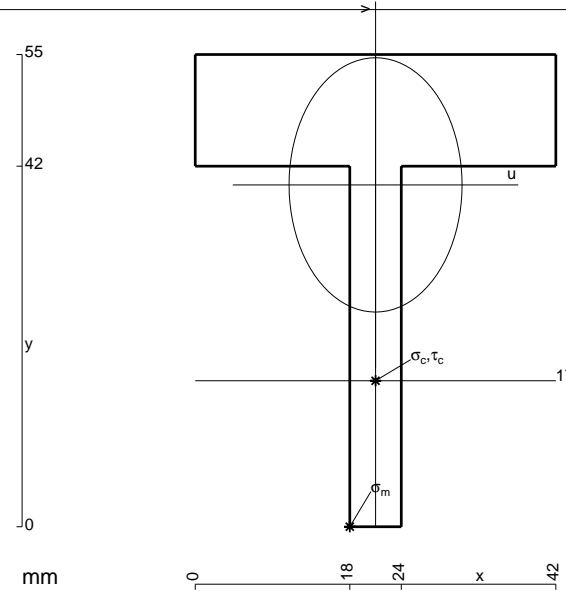
$$L_{FC}^{xo} = \int_0^b (-1/2 + 1/2 x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx$$

$$= [-1/2 x + 1/4 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/4 b + 1/6 b - 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

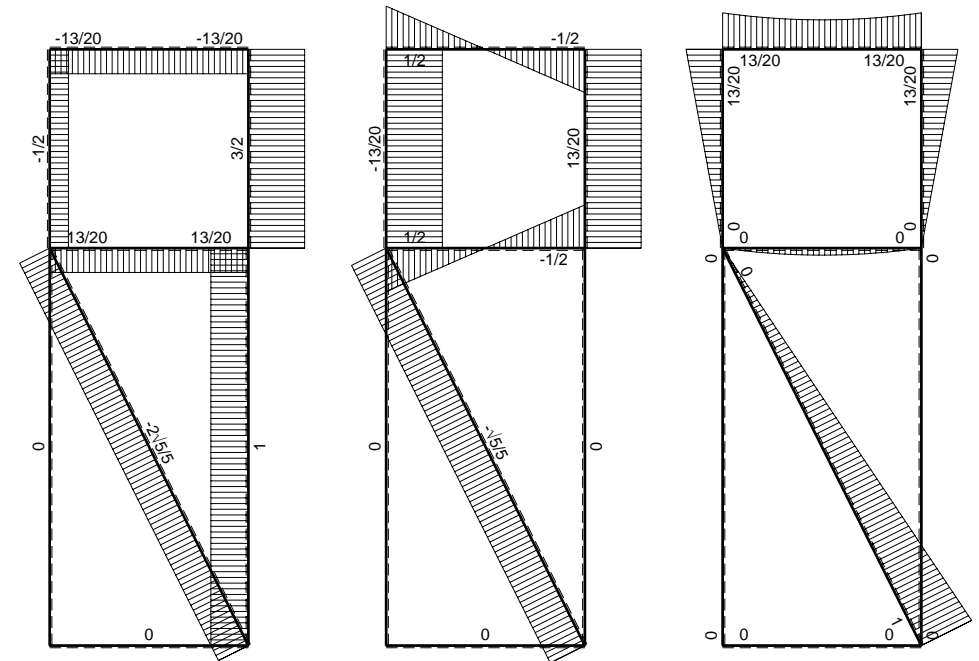
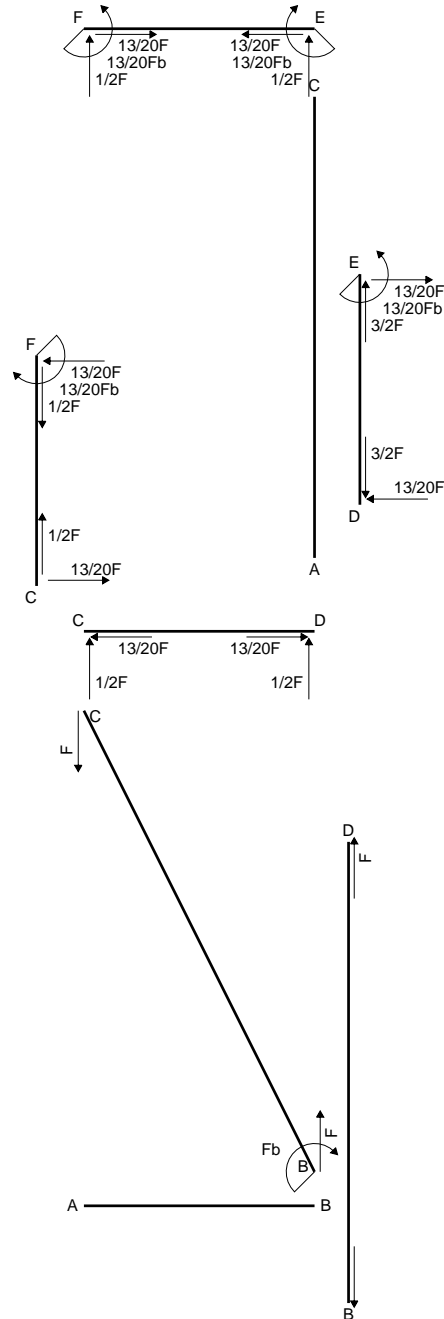
$$= (-1/3 b + 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$



- A = 798. mm<sup>2</sup>
- J<sub>u</sub> = 175127. mm<sup>4</sup>
- J<sub>v</sub> = 81018. mm<sup>4</sup>
- y<sub>g</sub> = 39.82 mm
- N = -1762. N
- T<sub>y</sub> = -881. N
- M<sub>x</sub> = 1063800. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -39.82 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> = 17. mm
- v<sub>c</sub> = -22.82 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = 136.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.678 N/mm<sup>2</sup>
- σ<sub>φ</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 136.5 N/mm<sup>2</sup>
- S = 3194. mm<sup>3</sup>







← ⊕ → F

↑ ⊕ ↓ F

⊕ ⊖ F<sub>b</sub>



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

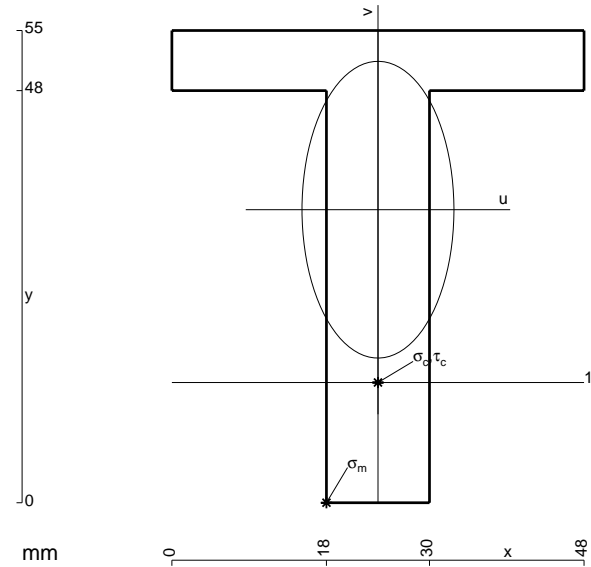
$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (1/4 b - 1/6 b) Fb 1/EJ + (b) \theta = 13/12 Fb^2/EJ$$

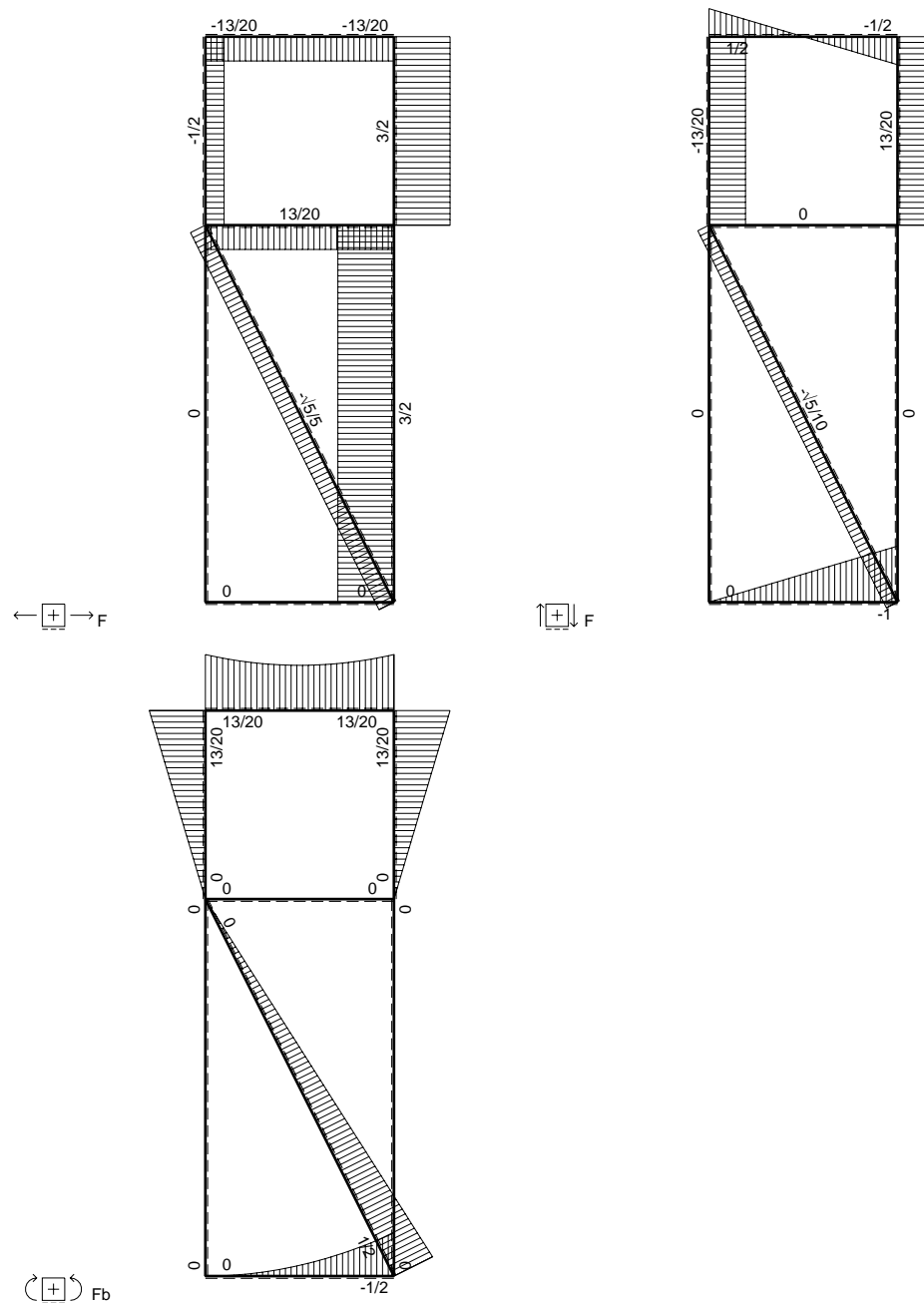
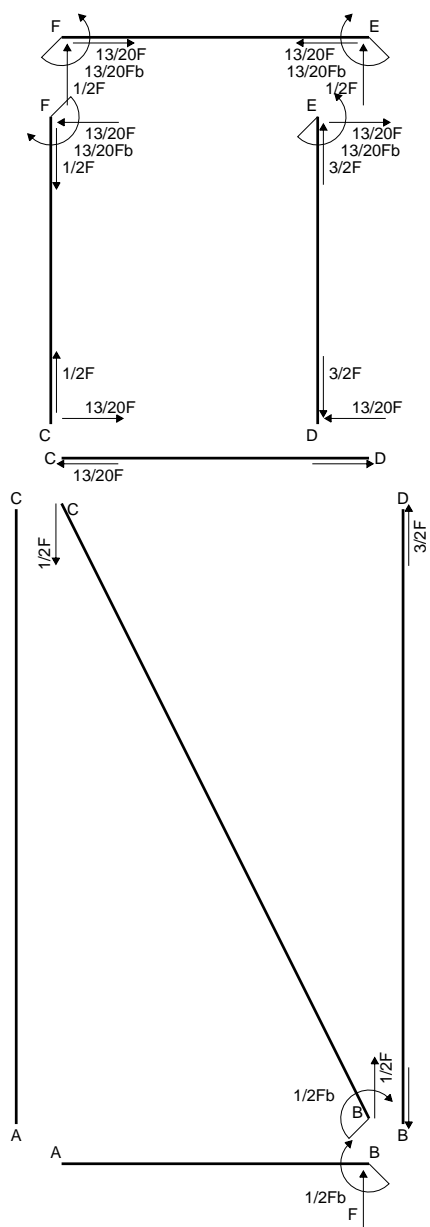
$$L_{FE}^{xo} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (1/4 b - 1/6 b) Fb 1/EJ + (-b) \theta = 13/12 Fb^2/EJ$$



- 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
- N = -2495. N
- T<sub>y</sub> = -1248. N
- M<sub>x</sub> = 1618200. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -34.13 mm
- σ<sub>m</sub> = N/A - M<sub>v</sub>/J<sub>u</sub> = 200. 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> = N/A - M<sub>v</sub>/J<sub>u</sub> = 116.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.74 N/mm<sup>2</sup>
- σ<sub>g</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 116.9 N/mm<sup>2</sup>
- S = 4558. mm<sup>3</sup>







$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

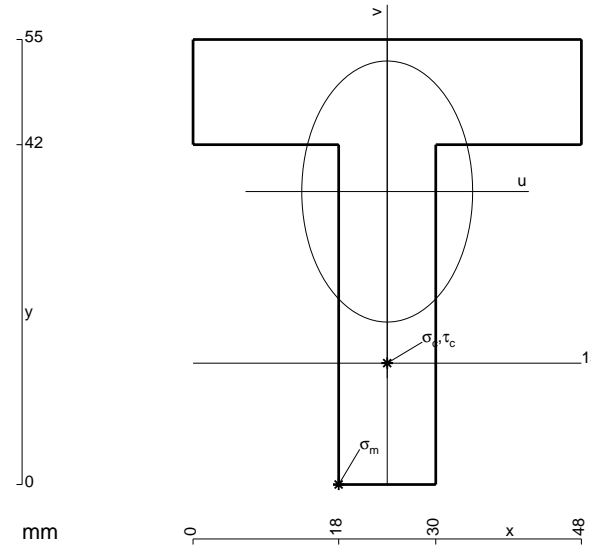
$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (1/4 b - 1/6 b) Fb 1/EJ + (b) \theta = 13/12 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

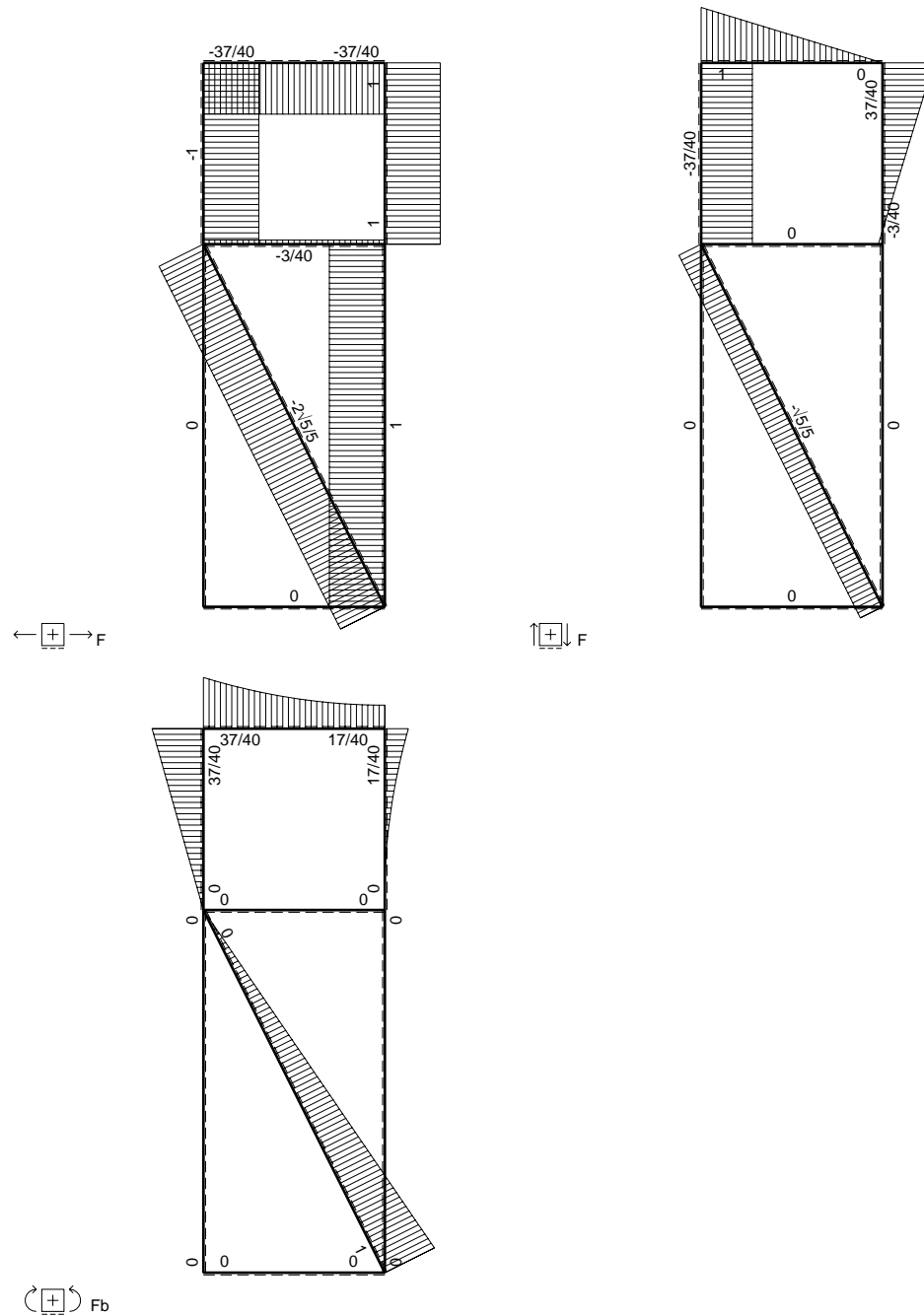
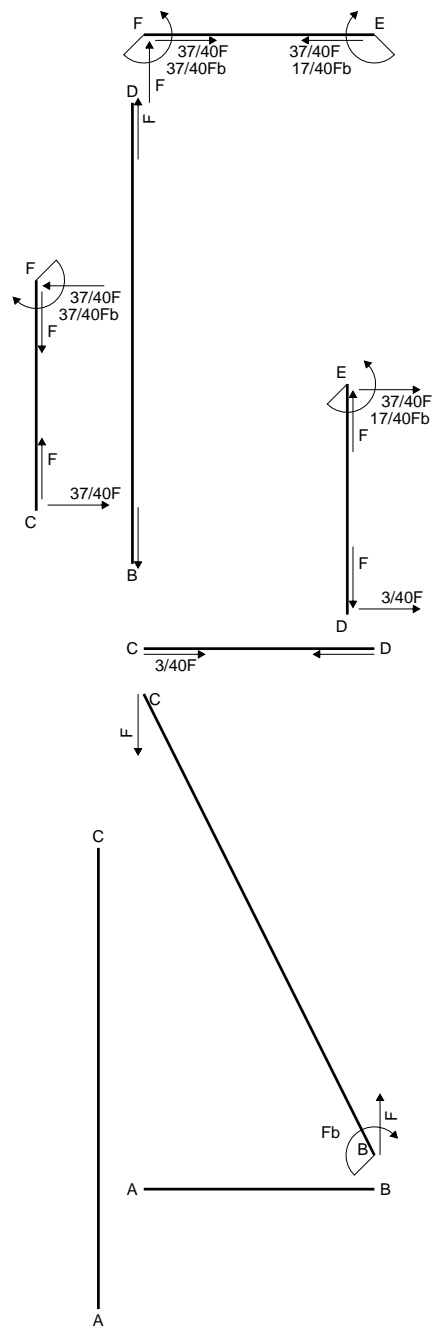
$$= (1/4 b - 1/6 b) Fb 1/EJ + (-b) \theta = 13/12 Fb^2/EJ$$



- 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> = -5490. N
- M<sub>x</sub> = -1701900. 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> = -209.8 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> = -122.9 N/mm<sup>2</sup>
- τ<sub>c</sub> = 8.05 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 123.7 N/mm<sup>2</sup>
- S = 5168. mm<sup>3</sup>









$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{x_0} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{x_0} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{x_0} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/6 b) Fb 1/EJ + (b) \theta = 5/6 Fb^2/EJ$$

$$L_{FE}^{x_0} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx$$

$$= [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

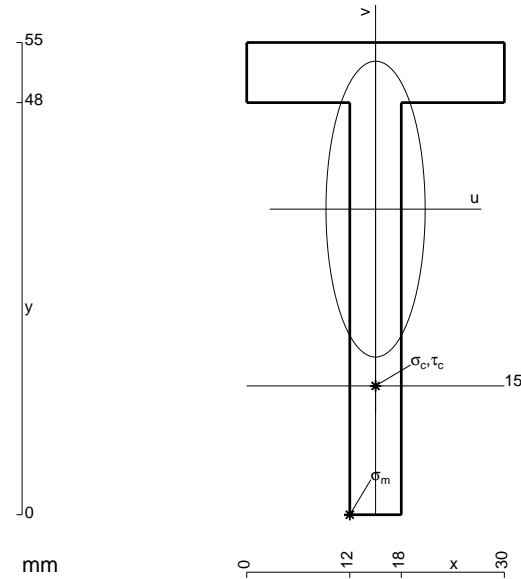
$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ + (-b) \theta = 5/6 Fb^2/EJ$$

$$L_{FC}^{x_0} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

$$L_{CF}^{x_0} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$



$$A = 498. \text{ mm}^2$$

$$J_u = 147997. \text{ mm}^4$$

$$J_v = 16614. \text{ mm}^4$$

$$y_g = 35.6 \text{ mm}$$

$$N = -1252. \text{ N}$$

$$T_y = -626.1 \text{ N}$$

$$M_x = 924000. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -35.6 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 219.7 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 15. \text{ mm}$$

$$v_c = -20.6 \text{ mm}$$

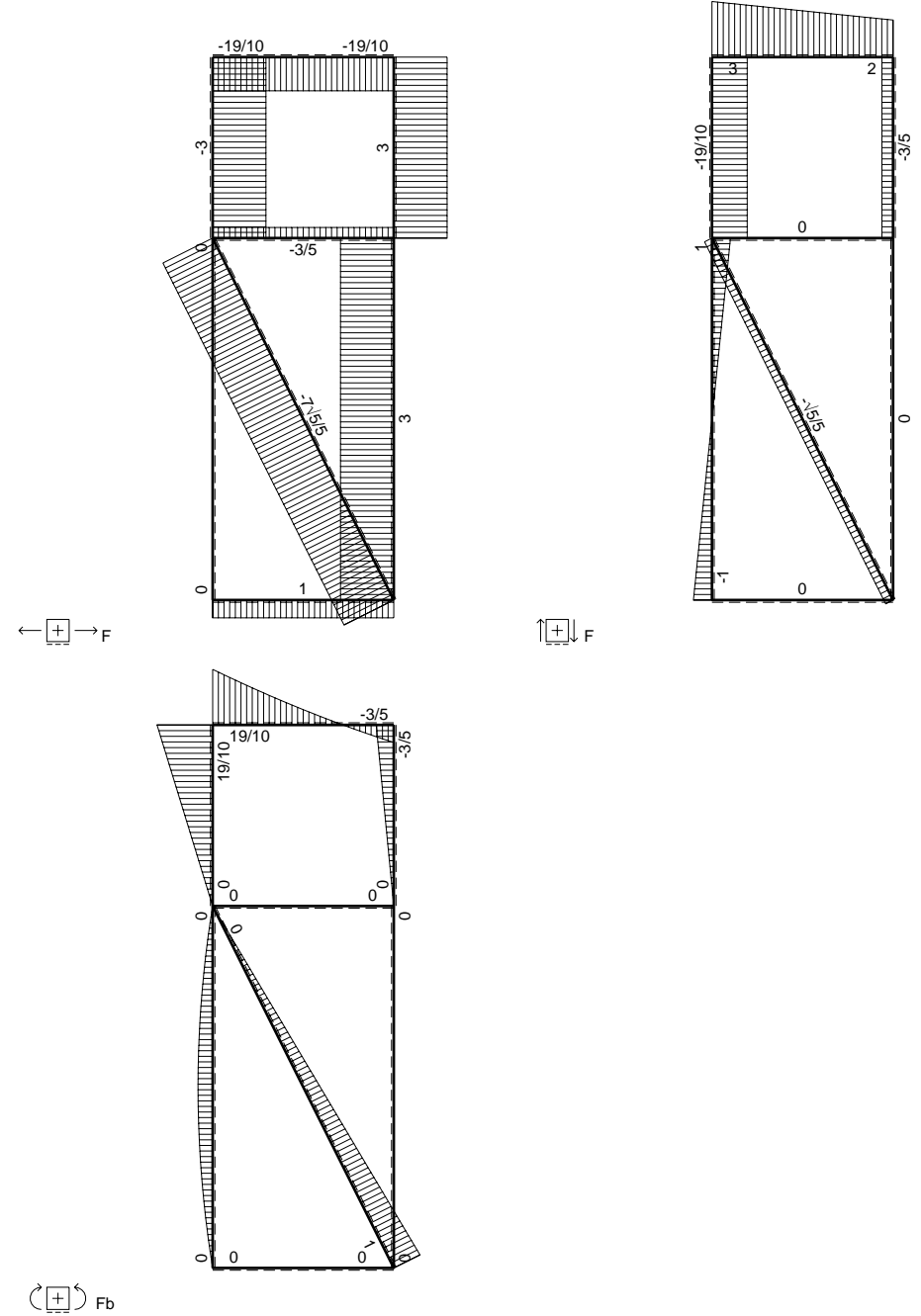
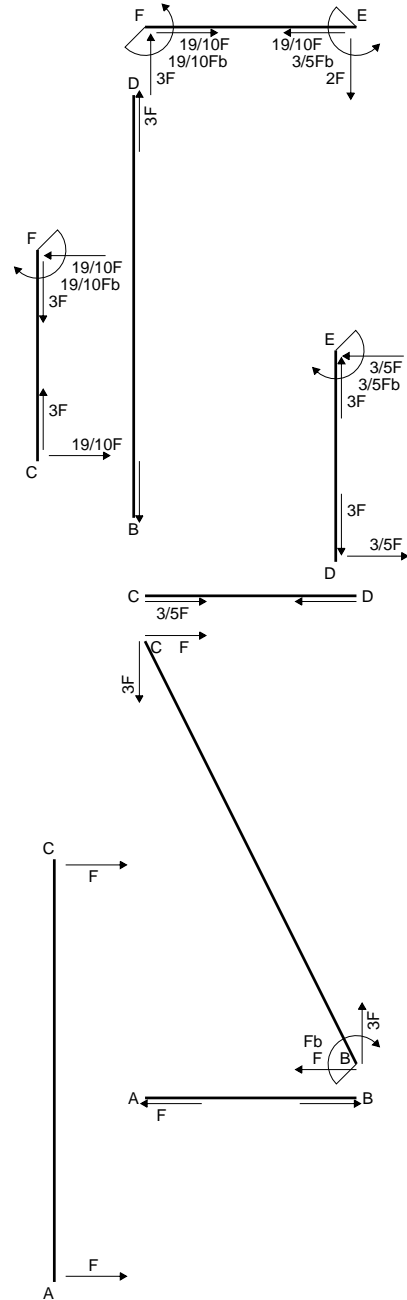
$$\sigma_c = N/A - Mv/J_u = 126.1 \text{ N/mm}^2$$

$$\tau_c = 1.783 \text{ N/mm}^2$$

$$\sigma_\varphi = \sqrt{\sigma^2 + 3\tau^2} = 126.1 \text{ N/mm}^2$$

$$S = 2529. \text{ mm}^3$$





⊕ F<sub>b</sub>



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-2x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-b - 1/6 b) Fb 1/EJ + (b) \theta = -1/6 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-5/2 + 3x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx$$

$$= [-5/2 x + 3/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

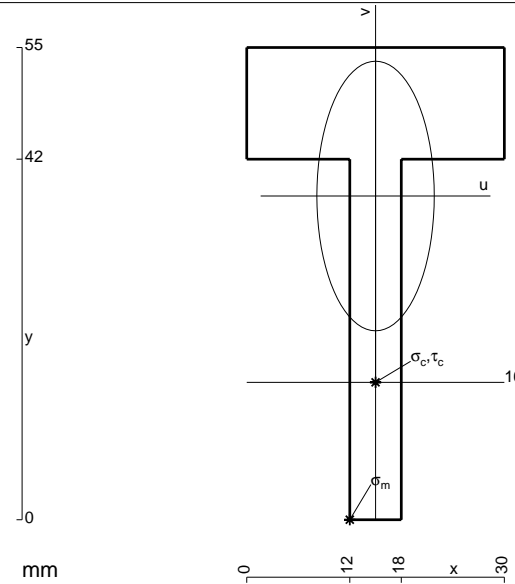
$$= (-5/2 b + 3/2 b - 1/6 b) Fb 1/EJ + (-b) \theta = -1/6 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = [-5/2 x + 5/2 x^2/b - 5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$



$$A = 642. \text{ mm}^2$$

$$J_u = 158306. \text{ mm}^4$$

$$J_v = 30006. \text{ mm}^4$$

$$y_g = 37.71 \text{ mm}$$

$$N = -4445. \text{ N}$$

$$T_y = -635. \text{ N}$$

$$M_x = 994000. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -37.71 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 229.8 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 16. \text{ mm}$$

$$v_c = -21.71 \text{ mm}$$

$$\sigma_c = N/A - Mv/J_u = 129.4 \text{ N/mm}^2$$

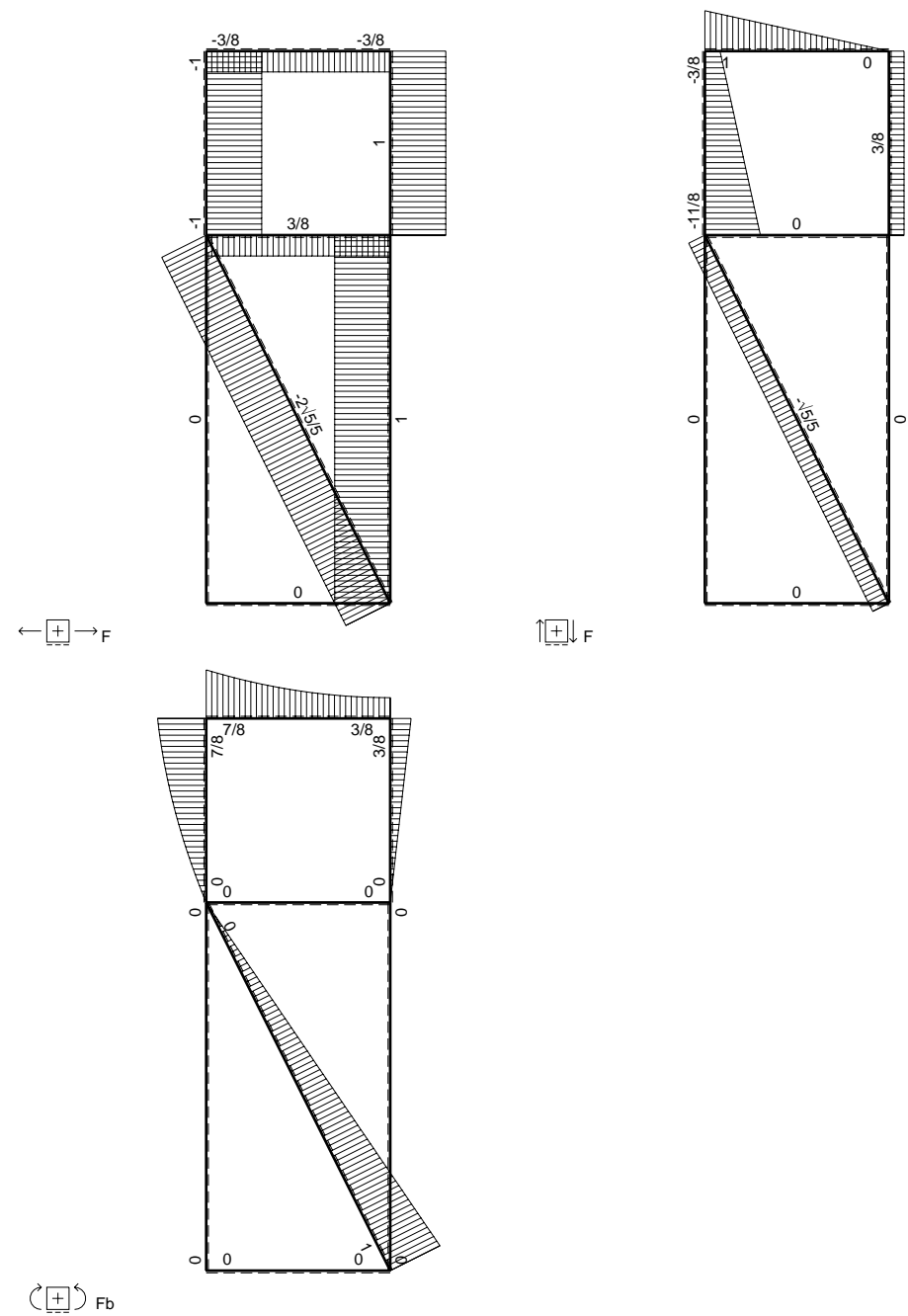
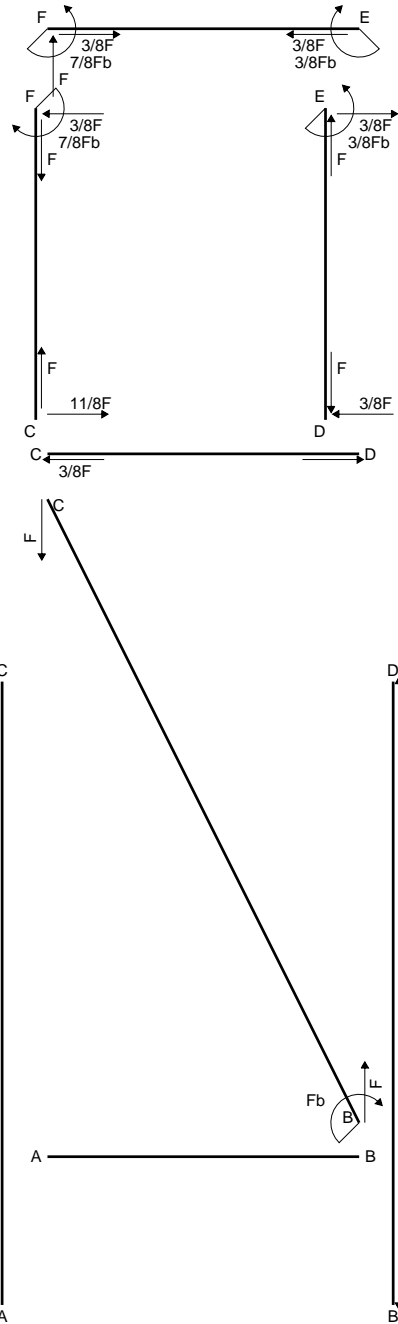
$$\tau_c = 1.907 \text{ N/mm}^2$$

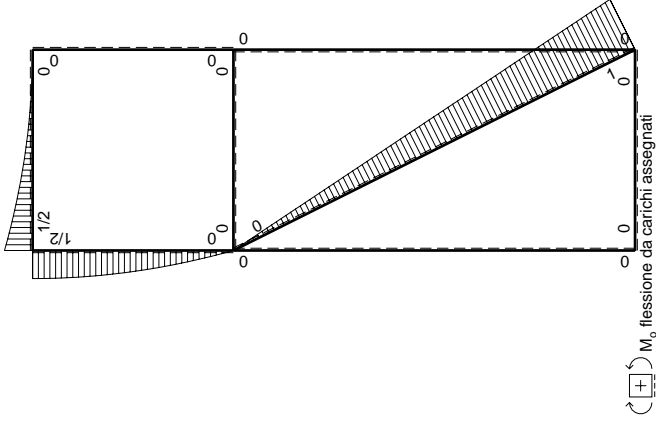
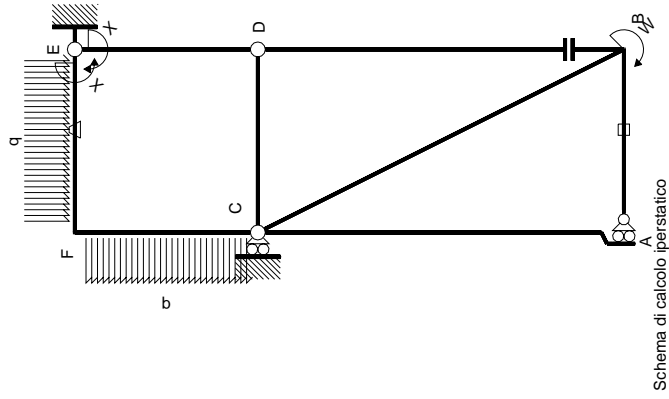
$$\sigma_\varphi = \sqrt{\sigma^2 + 3\tau^2} = 129.4 \text{ N/mm}^2$$

$$S = 2852. \text{ mm}^3$$









Quadro contributi PLV per iperstatica  $X=W_{EF}$

$\leftarrow$	$M(x)$	$M_0(x)$	$M_x$	$M_\theta$	$M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJdx$
AB	0	0	0	0	0	0+0	0
BA	0	0	0	0	0	0	0
BC	$Fb-\sqrt{5}/5Fx$	0	0	0	0	0+0	0
AC	0	0	0	0	0	0+0	0
CA	0	0	0	0	0	0	0
DB	0	0	0	0	0	0+0	0
BD	0	0	0	0	0	0	0
DE	$-x/b$	0	0	0	$x^2/b^2$	0+0	0
ED	$1-x/b$	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$
CD	0	0	0	0	0	0	0
DC	0	0	0	0	0	0+0	0
EF	-1	$1/2qx^2$	$-Fb/EJ$	$-1/2Fx^2/b$	$Fb/EJ$	1	$Xb/EJ$
FE	1	$-1/2Fb+Fx-1/2qx^2$	$Fb/EJ$	$-1/2Fx^2/b$	$Fb/EJ$	1	$(-1/6+1)Fb^2/EJ$
FC	$-1+x/b$	$1/2Fb-1/2qx^2$	0	$-1/2Fb+1/2Fx+1/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$1/3Xb/EJ$
CF	$x/b$	$-Fx+1/2qx^2$	0	$-Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$	$1/3Xb/EJ$
totali							$5/3Xb/EJ$
							$5/8Fb^2/EJ$
							$-3/8Fb$

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/6 b) Fb 1/EJ + (b) \theta = 5/6 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx$$

$$= [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ + (-b) \theta = 5/6 Fb^2/EJ$$

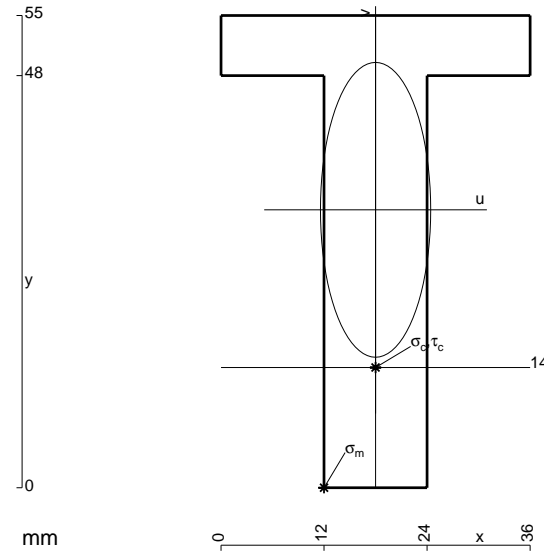
$$L_{FC}^{xo} = \int_0^b (-1/2 + 1/2 x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx$$

$$= [-1/2 x + 1/4 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/4 b + 1/6 b - 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$

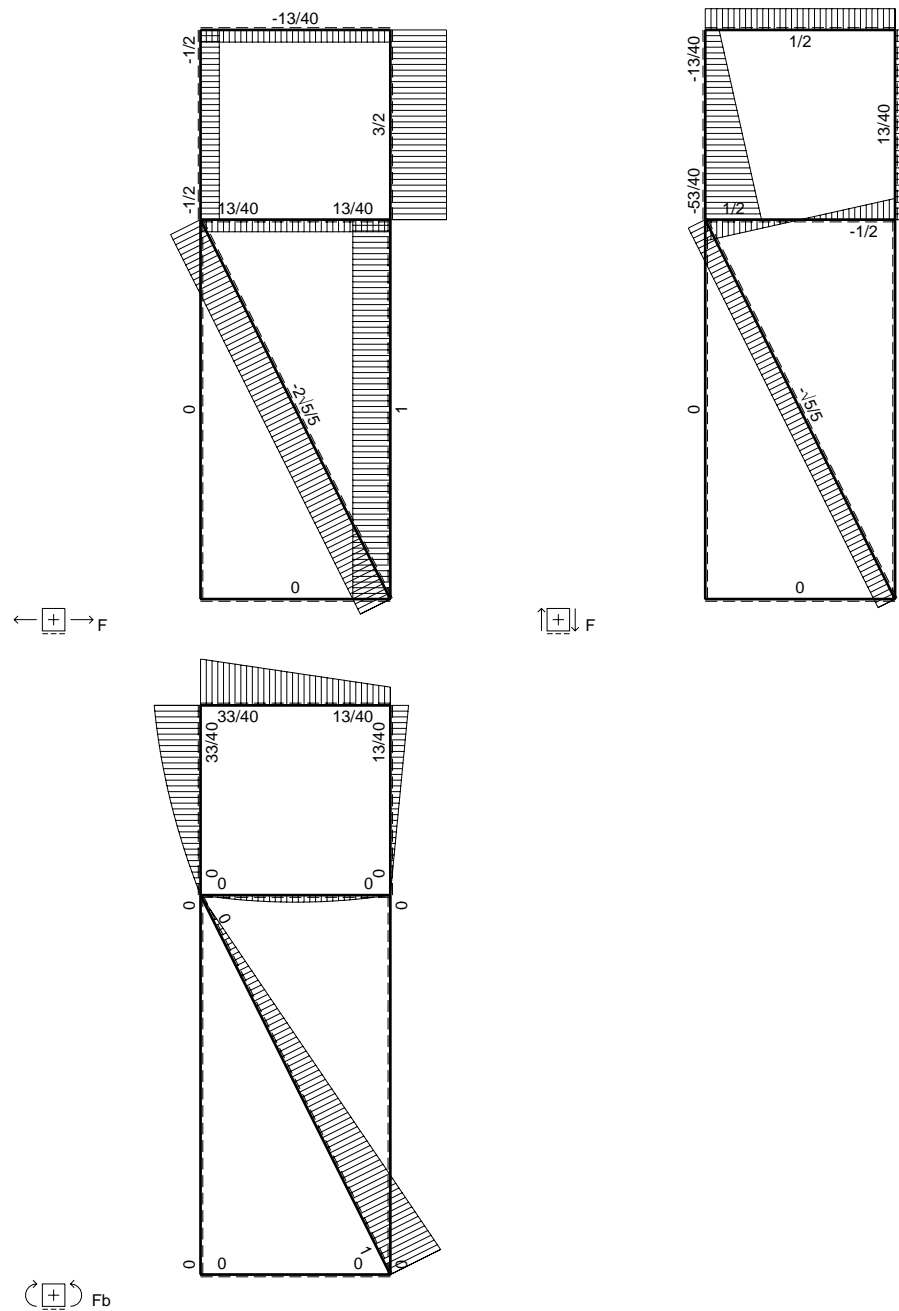
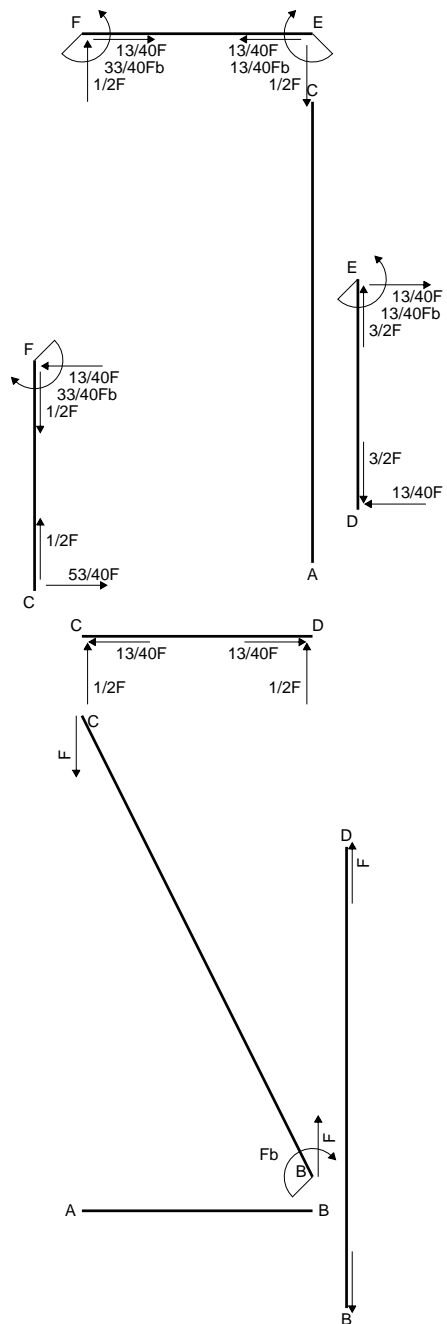
$$L_{CF}^{xo} = \int_0^b (-x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/3 b + 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$



- 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 = -2209. N
- T<sub>y</sub> = -1105. N
- M<sub>x</sub> = 1827800. 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> = 239.6 N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 14. mm
- v<sub>c</sub> = -18.37 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = 134.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.607 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 = 4262. mm<sup>3</sup>







$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (-2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/4 b) Fb 1/EJ + (b) \theta = 3/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + 1/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-1/2 x + 1/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

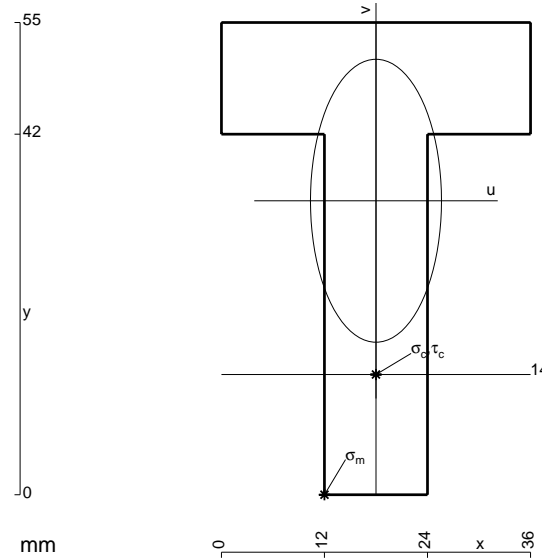
$$L_{FC}^{xo} = \int_0^b (-1/2 + 1/2 x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx$$

$$= [-1/2 x + 1/4 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/4 b + 1/6 b - 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

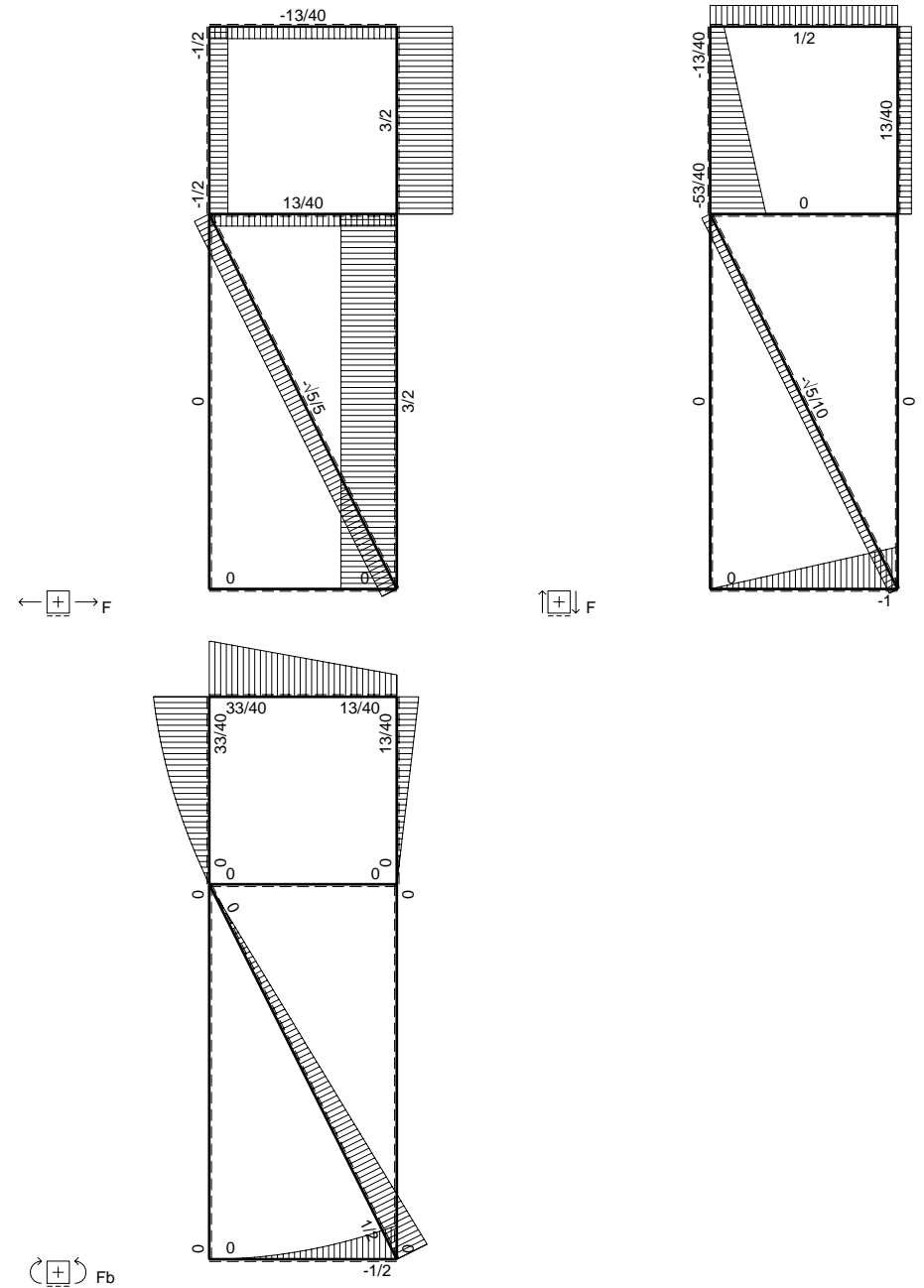
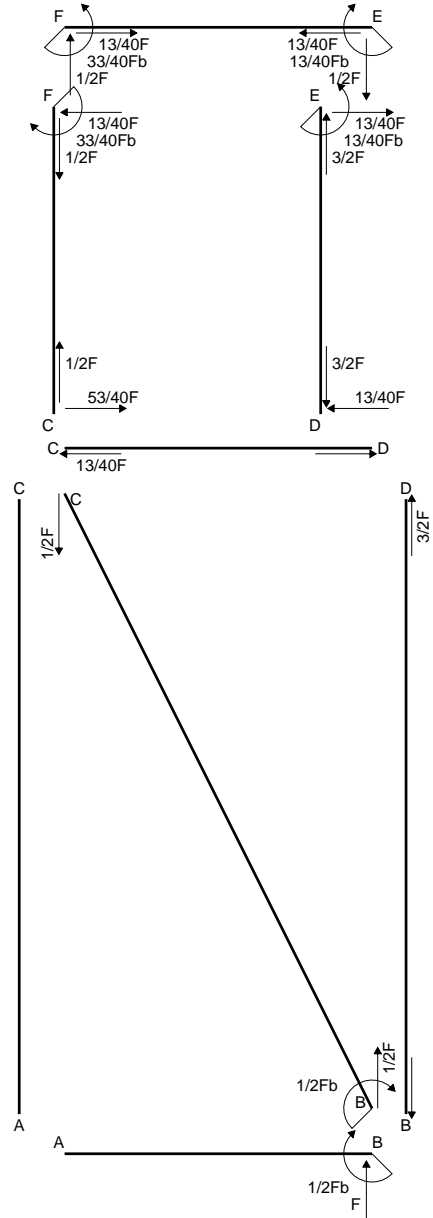
$$= (-1/3 b + 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$

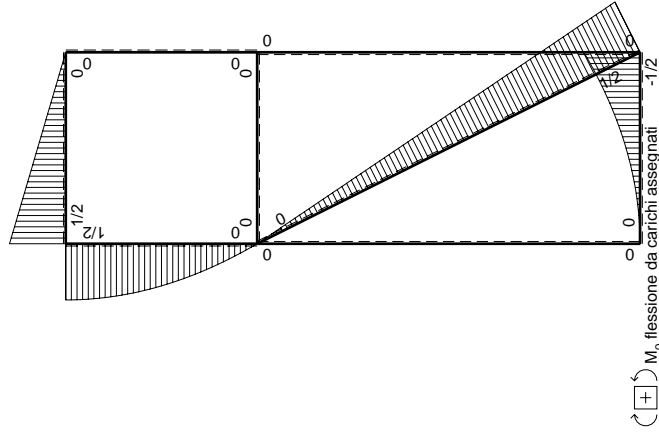
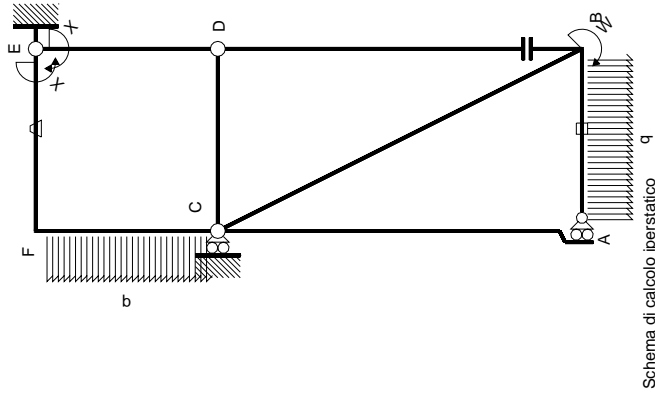


- A = 972. mm<sup>2</sup>
- J<sub>u</sub> = 264196. mm<sup>4</sup>
- J<sub>v</sub> = 56592. mm<sup>4</sup>
- y<sub>g</sub> = 34.24 mm
- N = -3605. N
- T<sub>y</sub> = -1802. N
- M<sub>x</sub> = 1571700. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -34.24 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = 200. N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 14. mm
- v<sub>c</sub> = -20.24 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = 116.7 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.602 N/mm<sup>2</sup>
- σ<sub>g</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 116.8 N/mm<sup>2</sup>
- S = 4576. mm<sup>3</sup>









Quadro contributi PLV per iperstatica  $X=W_{EF}$

$\rightarrow$	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x (M_0/EJ + \theta) dx$	$\int M^x M_x / E dx$	
AB b	0	$-1/2qx^2$	0	0	0	0	0	0	
BA b	0	$1/2Fb - Fx + 1/2qx^2$	0	0	0	0	0	0	
BC $\sqrt{5}b$	0	$1/2Fb - \sqrt{5}/10Fx$	0	0	0	0	0	0	
AC 2b	0	0	0	0	0	0	0	0	
CA 2b	0	0	0	0	0	0	0	0	
DB 2b	0	0	0	0	0	0	0	0	
BD 2b	0	0	0	0	0	0	0	0	
DE b	-x/b	0	0	0	0	$x^2/b^2$	0	0	
ED b	1-x/b	0	0	0	0	$1-2x/b+x^2/b^2$	0	0	
CD b	0	0	0	0	0	0	0	0	
DC b	0	0	0	0	0	0	0	0	
EF b	-1	$1/2Fx$	-Fb/EJ	-1/2Fx	Fb/EJ	1	$(-1/4+1)Fb^2/EJ$	Xb/EJ	
FE b	1	$-1/2Fb+1/2Fx$	Fb/EJ	$-1/2Fb+1/2Fx$	Fb/EJ	1	$(-1/4+1)Fb^2/EJ$	Xb/EJ	
FC b	-1+x/b	$1/2Fb-1/2qx^2$	0	$-1/2Fb+1/2Fx+1/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(-5/24+0)Fb^2/EJ$	$1/3Xb/EJ$	
CF b	x/b	$-Fx+1/2qx^2$	0	$-Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$	$13/24Fb^2/EJ$	$5/3Xb/EJ$	
totali									
		iperstatica $X=W_{EF}$							

Sviluppi di calcolo iperstatica



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/4 b) Fb 1/EJ + (b) \theta = 3/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + 1/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-1/2 x + 1/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

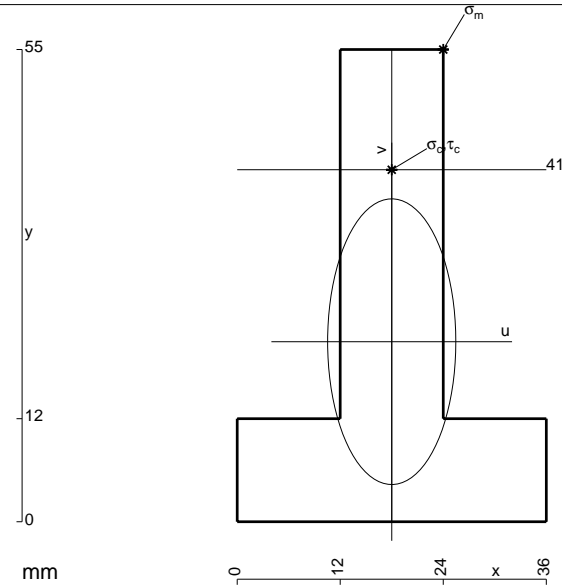
$$L_{FC}^{xo} = \int_0^b (-1/2 + 1/2 x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx$$

$$= [-1/2 x + 1/4 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/4 b + 1/6 b - 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$

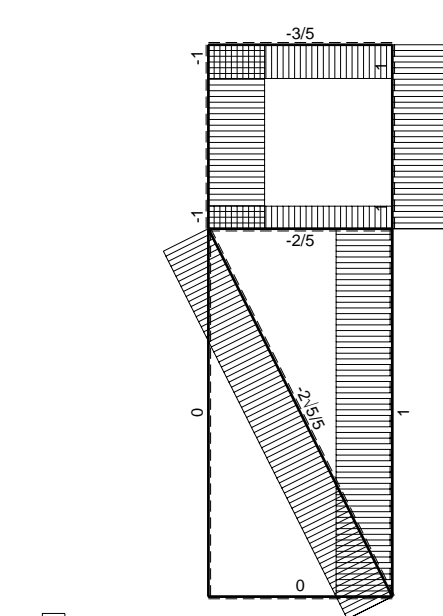
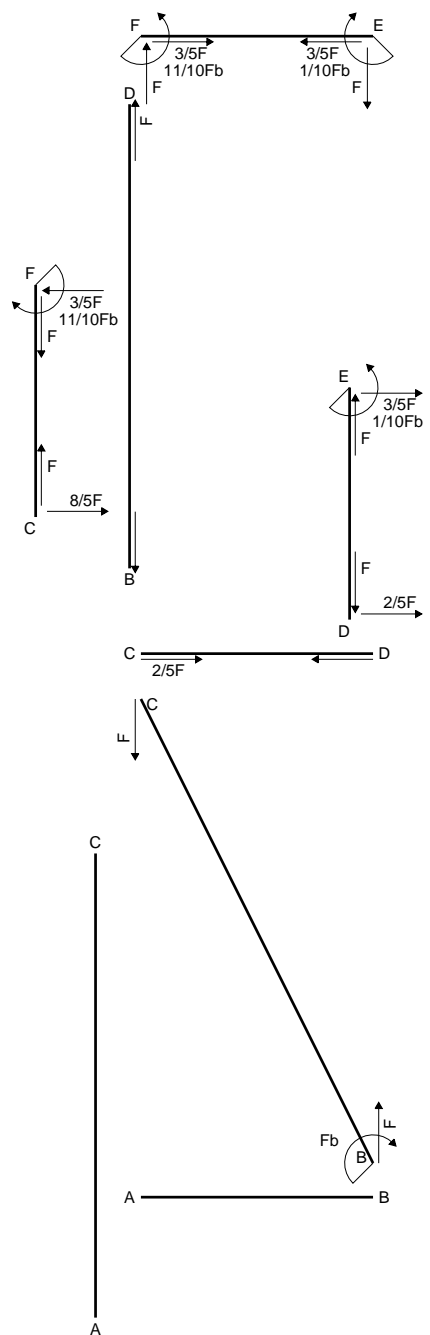
$$L_{CF}^{xo} = \int_0^b (-x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/3 b + 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$

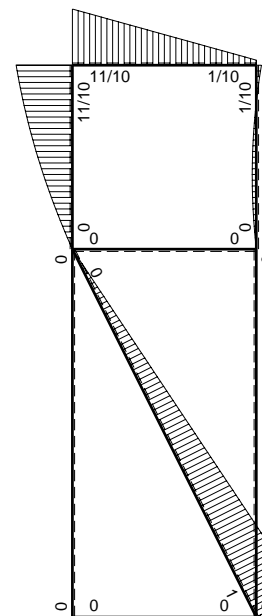


- A = 948. mm<sup>2</sup>
- J<sub>u</sub> = 262515. mm<sup>4</sup>
- J<sub>v</sub> = 52848. mm<sup>4</sup>
- y<sub>g</sub> = 20.97 mm
- T<sub>y</sub> = -7710. N
- M<sub>x</sub> = -1619100. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 55. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 34.03 mm
- σ<sub>m</sub> = -M<sub>v</sub>/J<sub>u</sub> = 209.9 N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 41. mm
- v<sub>c</sub> = 20.03 mm
- σ<sub>c</sub> = -M<sub>v</sub>/J<sub>u</sub> = 123.5 N/mm<sup>2</sup>
- τ<sub>c</sub> = 11.11 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 125. N/mm<sup>2</sup>
- S = 4541. mm<sup>3</sup>





← ⊕ → F



⊕ ↺ F<sub>b</sub>



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (b) \theta = 1/2 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

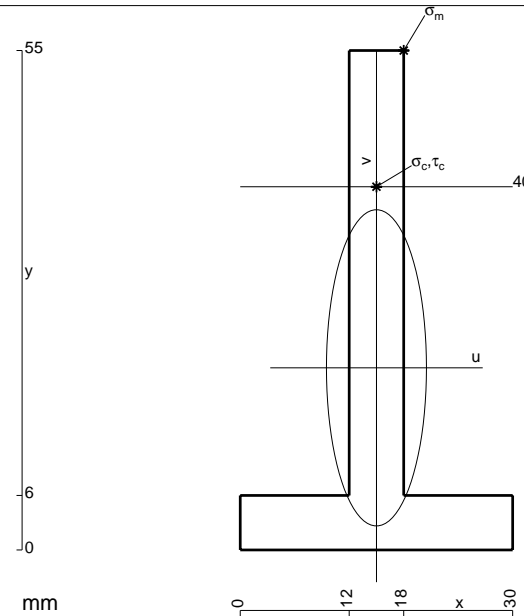
$$= (-b + 1/2 b) Fb 1/EJ + (-b) \theta = 1/2 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-1 + 3/2 x/b - 1/2 x^3/b^3) Fb 1/EJ dx = [-x + 3/4 x^2/b - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-b + 3/4 b - 1/8 b) Fb 1/EJ = -3/8 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-3/2 x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/2 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

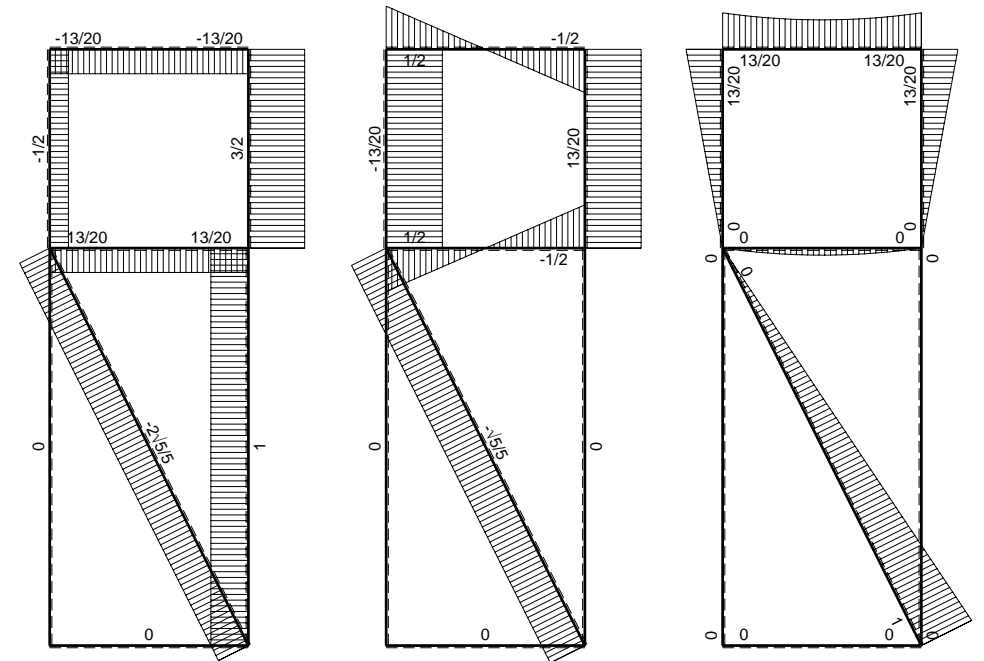
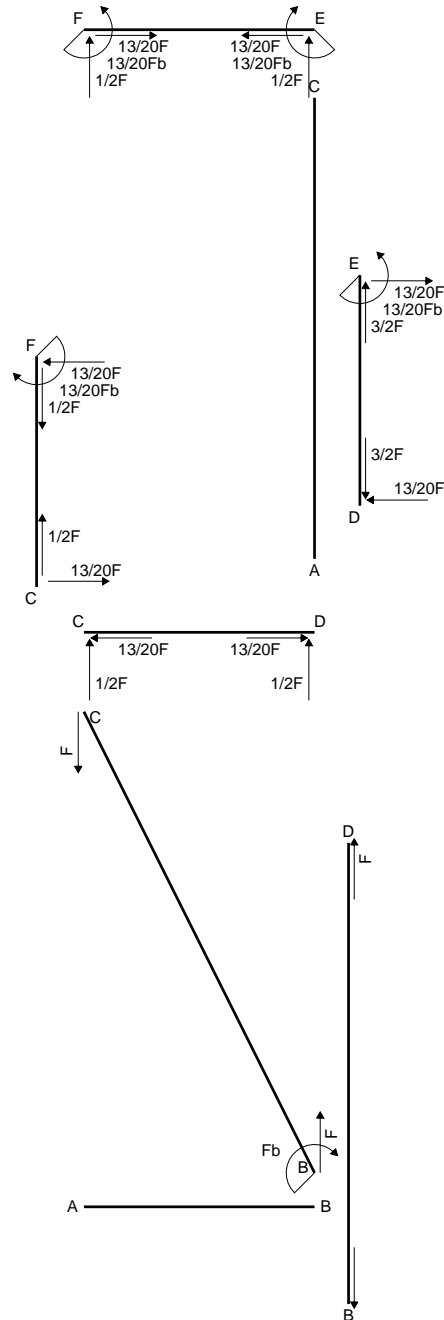
$$= (-1/2 b + 1/8 b) Fb 1/EJ = -3/8 Fb^2/EJ$$



- 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
- N = -1726. N
- T<sub>y</sub> = -863.1 N
- M<sub>x</sub> = 887800. 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> = N/A-Mv/J<sub>u</sub> = -219.4 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> = N/A-Mv/J<sub>u</sub> = -126.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.471 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 126.8 N/mm<sup>2</sup>
- S = 2470. mm<sup>3</sup>



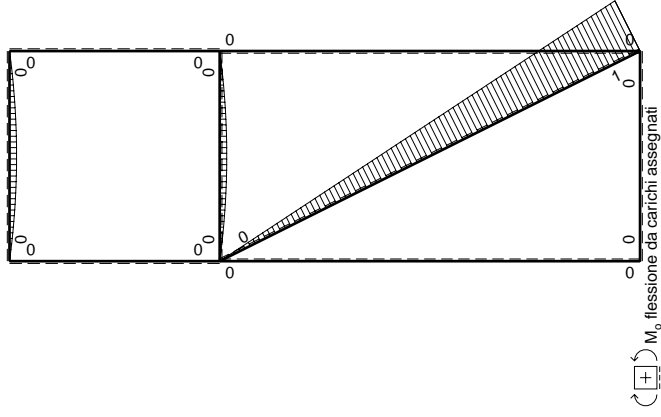
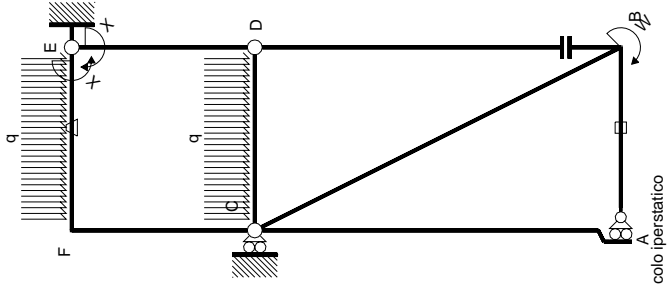




← ⊕ → F

↑ ⊕ ↓ F

⊕ ⊖ F<sub>b</sub>



Schema di calcolo iperstatico

$M_0$  flessione da carichi assegnati

Sviluppi di calcolo iperstatica

Quadro contributi PLV per iperstatica  $X=W_{EF}$

$\leftarrow$	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x(M_0/EJ+\theta)dx$	$\int M^x M_x/EJdx$
AB b	0	0	0	0	0	0	0	0
BA b	0	0	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$Fb-\sqrt{5}/5Fx$	0	0	0	0	0	0
AC 2b	0	0	0	0	0	0	0	0
CA 2b	0	0	0	0	0	0	0	0
DB 2b	0	0	0	0	0	0	0	0
BD 2b	0	0	0	0	0	0	0	0
DE b	-x/b	0	0	0	0	$x^2/b^2$	0	0
ED b	1-x/b	0	0	0	0	$1-2x/b+x^2/b^2$	0	0
CD b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0	0
DC b	0	$-1/2Fx+1/2qx^2$	0	0	0	0	0	0
EF b	-1	$-1/2Fx+1/2qx^2$	$-Fb/EJ$	$1/2Fx-1/2Fx^2/b$	$Fb/EJ$	1	$(1/12+1)Fb^2/EJ$	$Xb/EJ$
FE b	1	$1/2Fx-1/2qx^2$	$Fb/EJ$	$1/2Fx-1/2Fx^2/b$	$Fb/EJ$	1	$(1/12+1)Fb^2/EJ$	$Xb/EJ$
FC b	-1+x/b	0	0	0	0	$1-2x/b+x^2/b^2$	0	0
CF b	x/b	0	0	0	0	$x^2/b^2$	0	0
totali							$13/12Fb^2/EJ$	$5/3Xb/EJ$
								$-13/20Fb$

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

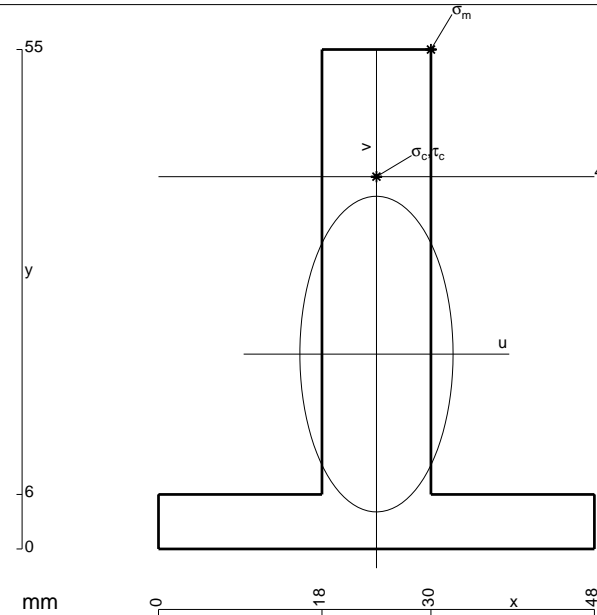
$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (1/4 b - 1/6 b) Fb 1/EJ + (b) \theta = 13/12 Fb^2/EJ$$

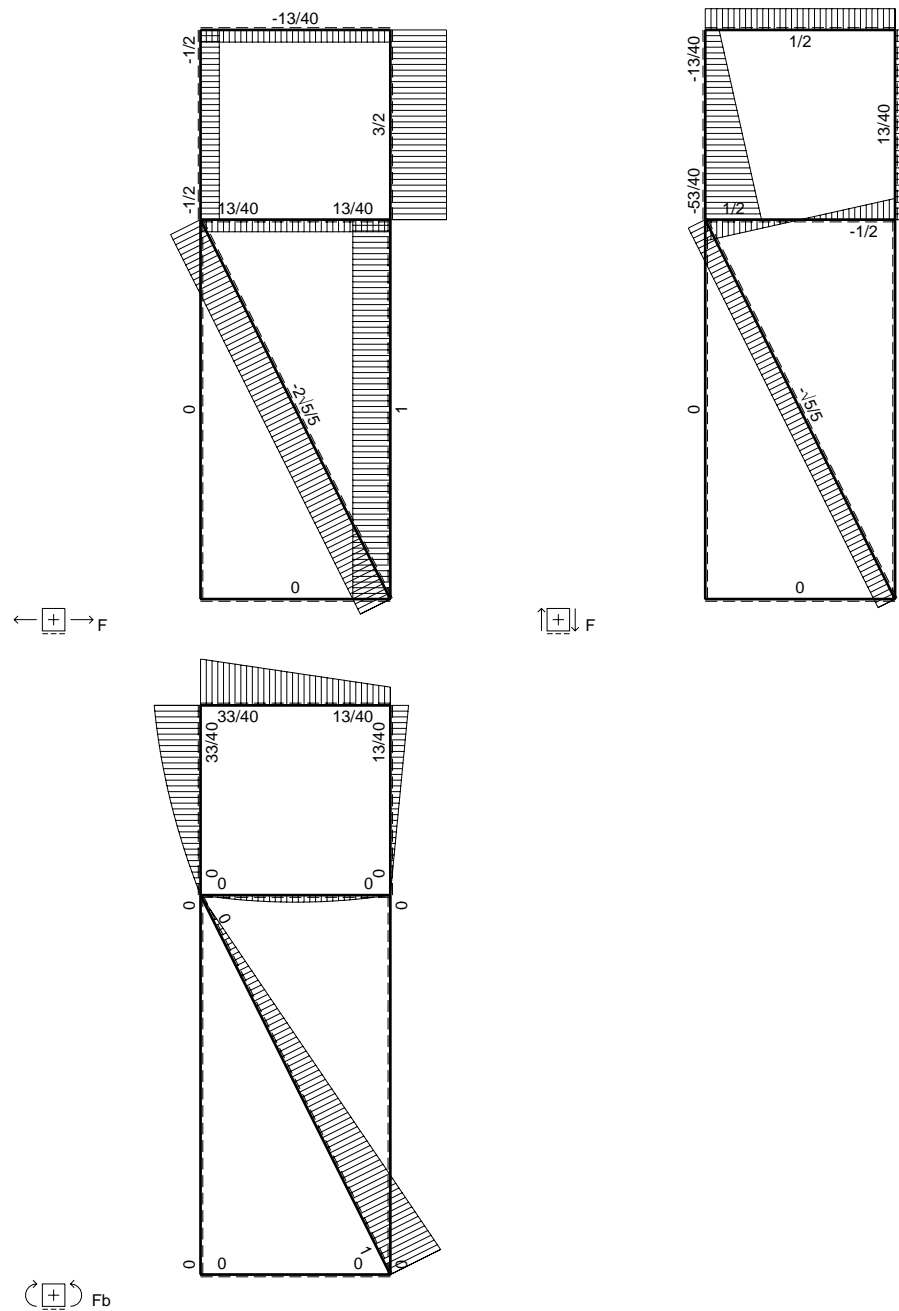
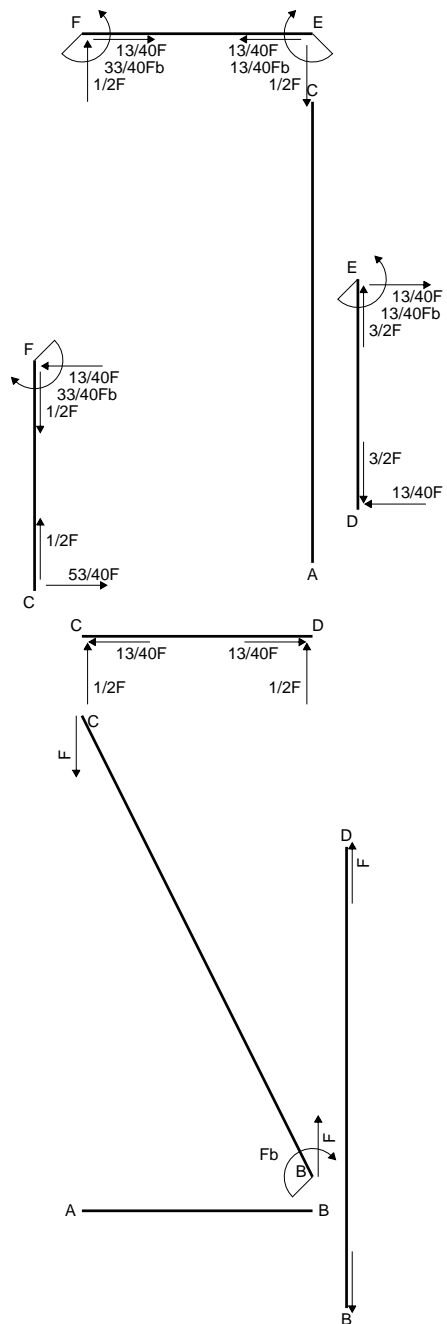
$$L_{FE}^{xo} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (1/4 b - 1/6 b) Fb 1/EJ + (-b) \theta = 13/12 Fb^2/EJ$$



- 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
- N = -3193. N
- T<sub>y</sub> = -1597. N
- M<sub>x</sub> = 1785000. 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> = N/A-Mv/J<sub>u</sub> = -229.8 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> = N/A-Mv/J<sub>u</sub> = -135.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.241 N/mm<sup>2</sup>
- σ<sub>o</sub> = √(σ<sup>2</sup>+3τ<sup>2</sup>) = 135.5 N/mm<sup>2</sup>
- S = 4459. mm<sup>3</sup>







$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/4 b) Fb 1/EJ + (b) \theta = 3/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + 1/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-1/2 x + 1/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

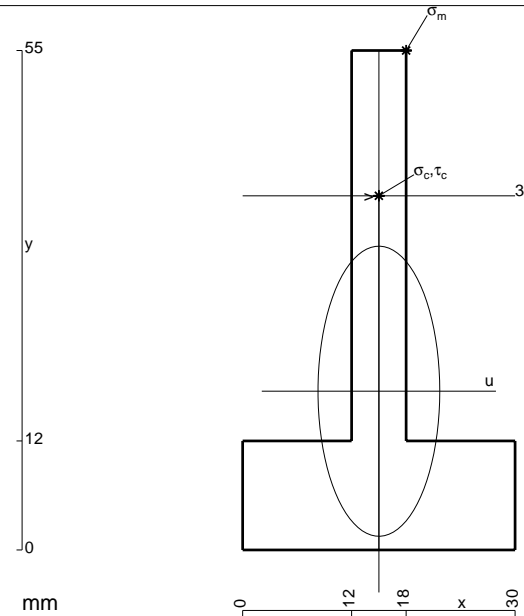
$$L_{FC}^{xo} = \int_0^b (-1/2 + 1/2 x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx$$

$$= [-1/2 x + 1/4 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/4 b + 1/6 b - 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/3 b + 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$



$$A = 618. \text{ mm}^2$$

$$J_u = 157731. \text{ mm}^4$$

$$J_v = 27774. \text{ mm}^4$$

$$y_g = 17.48 \text{ mm}$$

$$N = -1646. \text{ N}$$

$$T_y = -822.9 \text{ N}$$

$$M_x = 993600. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$y_m = 55. \text{ mm}$$

$$u_m = 3. \text{ mm}$$

$$v_m = 37.52 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -239. \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 39. \text{ mm}$$

$$v_c = 21.52 \text{ mm}$$

$$\sigma_c = N/A - Mv/J_u = -138.2 \text{ N/mm}^2$$

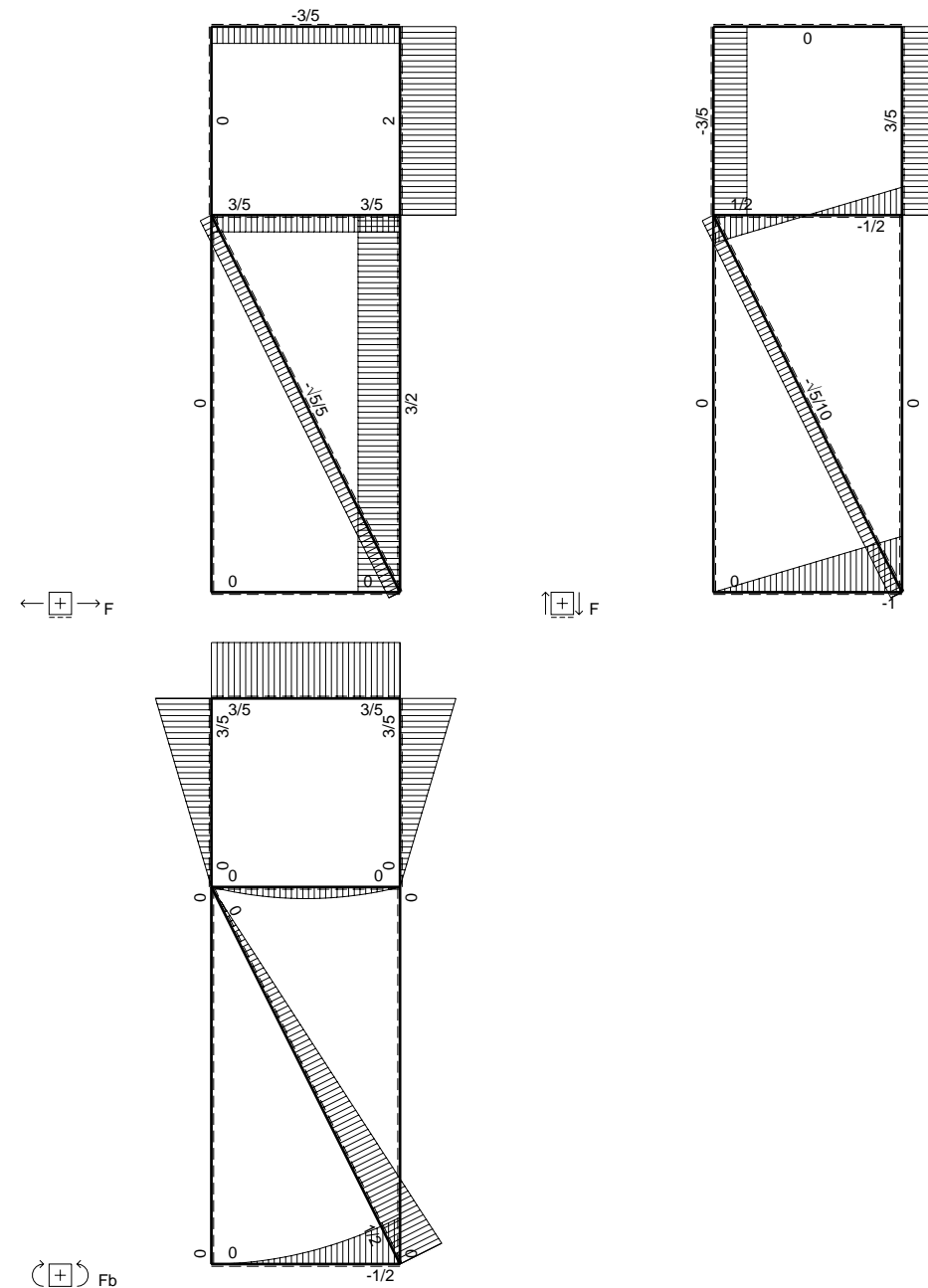
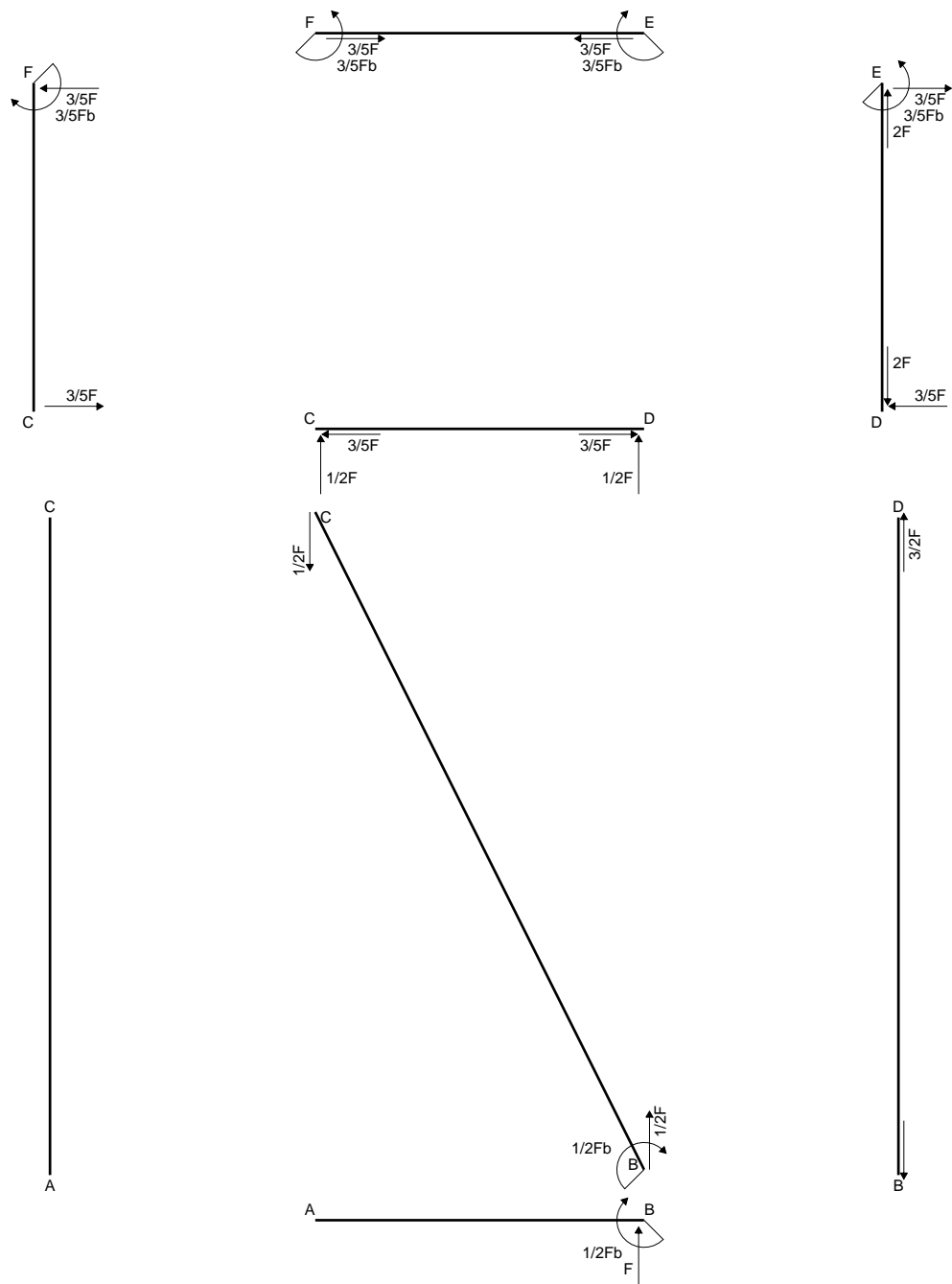
$$\tau_c = 2.464 \text{ N/mm}^2$$

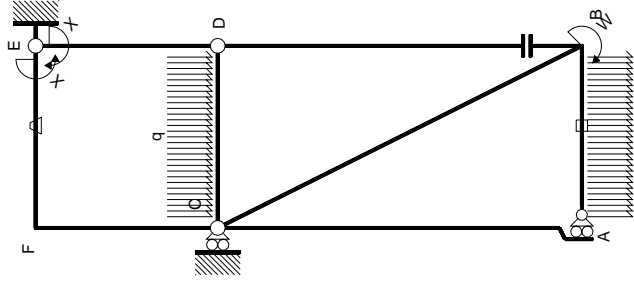
$$\sigma_g = \sqrt{\sigma^2 + 3\tau^2} = 138.3 \text{ N/mm}^2$$

$$S = 2834. \text{ mm}^3$$

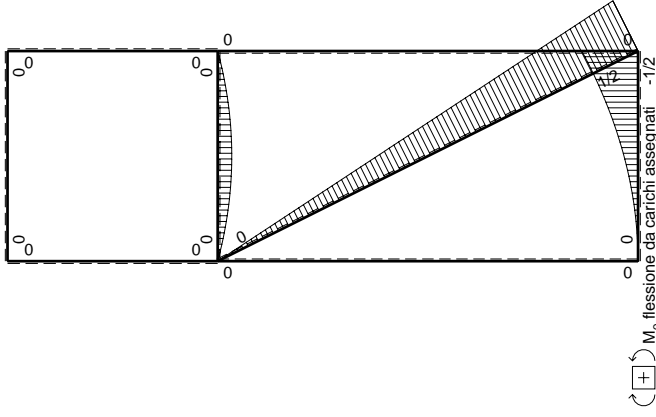








Schema di calcolo iperstatico



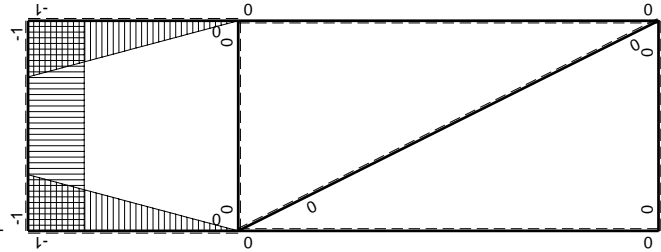
$M_0$  flessione da carichi assegnati -1/2

Quadro contributi PLV per iperstatica  $X=W_{EF}$

$\rightarrow$	$M_x(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int X M_x M_x / EJ dx$	
AB b	0	$-1/2qx^2$	0	0	0	0	0+0	0	
BA b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0+0	0	
BC $\sqrt{5}b$	0	$1/2Fb-\sqrt{5}/10Fx$	0	0	0	0	0	0	
AC 2b	0	0	0	0	0	0	0+0	0	
CA 2b	0	0	0	0	0	0	0+0	0	
DB 2b	0	0	0	0	0	0	0+0	0	
BD 2b	0	0	0	0	0	0	0+0	0	
DE b	$-x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3Xb/EJ$	
ED b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
CD b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0	
DC b	0	$-1/2Fx+1/2qx^2$	0	0	0	0	0+0	0	
EF b	-1	0	$-Fb/EJ$	0	$Fb/EJ$	1	$(0+1)Fb^2/EJ$	$Xb/EJ$	
FE b	1	0	$Fb/EJ$	0	$Fb/EJ$	1			
FC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$	
CF b	$x/b$	0	0	0	0	$x^2/b^2$	$Fb^2/EJ$	$5/3Xb/EJ$	
	totali								
	iperstatica $X=W_{EF}$								

Sviluppi di calcolo iperstatica

$M_x$  flessione da iperstatica  $X=1$



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

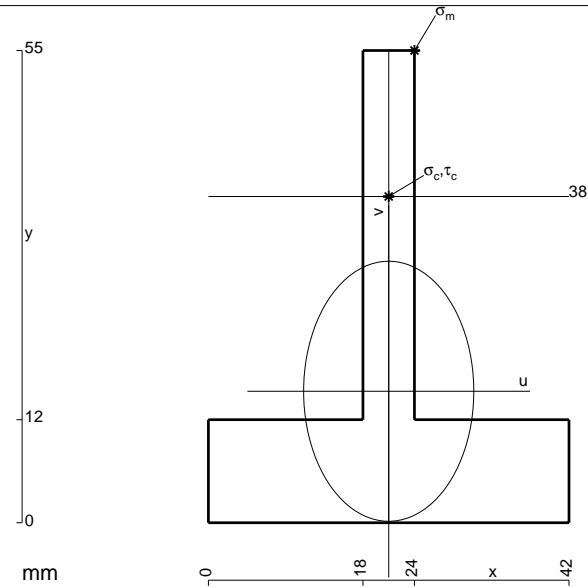
$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (1) \theta dx = [x]_0^b \theta$$

$$= (b) \theta = Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1) \theta dx = [-x]_0^b \theta$$

$$= (-b) \theta = Fb^2/EJ$$



$$A = 762. \text{ mm}^2$$

$$J_u = 174852. \text{ mm}^4$$

$$J_v = 74862. \text{ mm}^4$$

$$y_g = 15.31 \text{ mm}$$

$$T_y = -3030. \text{ N}$$

$$M_x = -878700. \text{ Nmm}$$

$$x_m = 24. \text{ mm}$$

$$y_m = 55. \text{ mm}$$

$$u_m = 3. \text{ mm}$$

$$v_m = 39.69 \text{ mm}$$

$$\sigma_m = -Mv/J_u = 199.5 \text{ N/mm}^2$$

$$x_c = 21. \text{ mm}$$

$$y_c = 38. \text{ mm}$$

$$v_c = 22.69 \text{ mm}$$

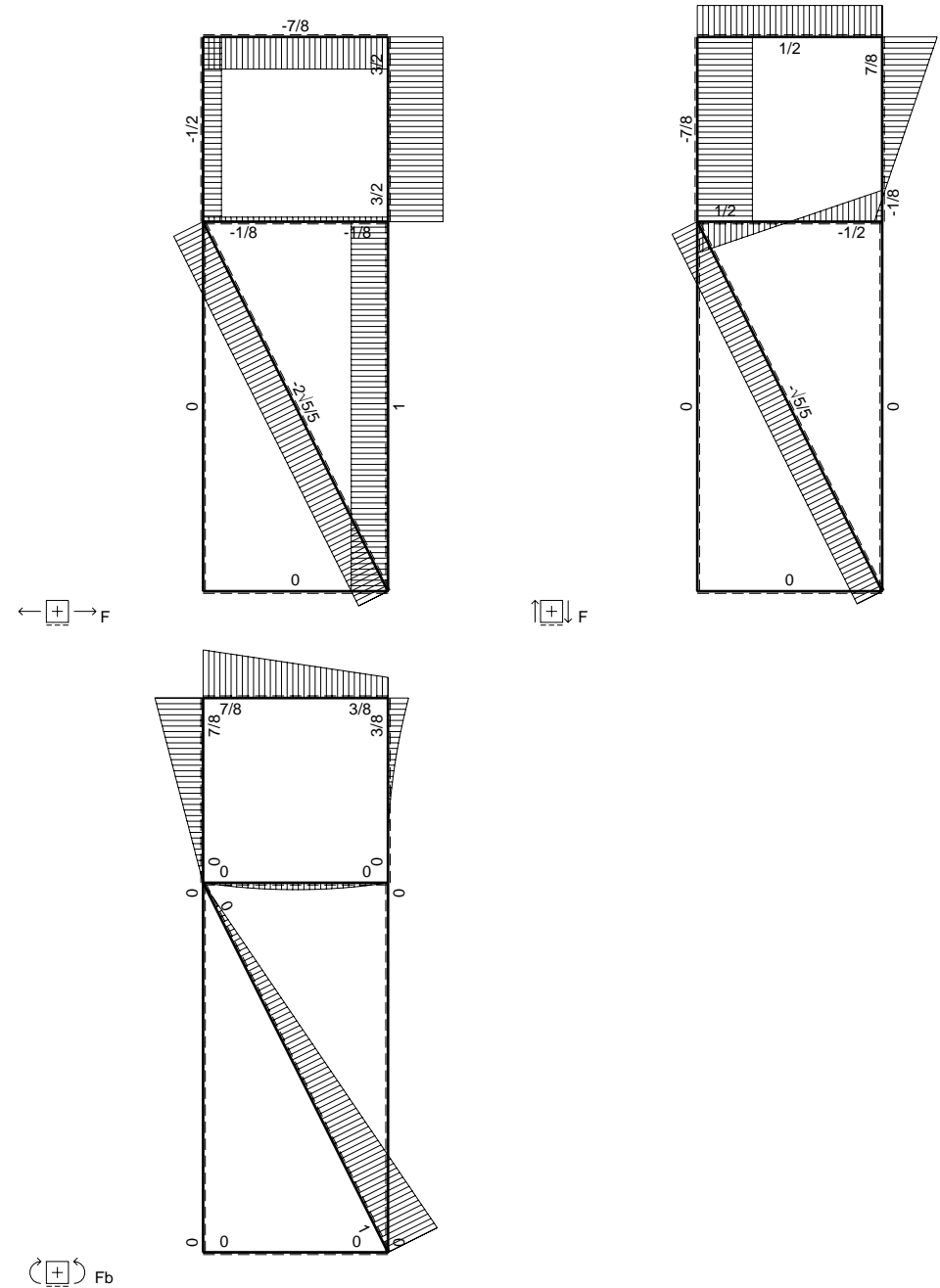
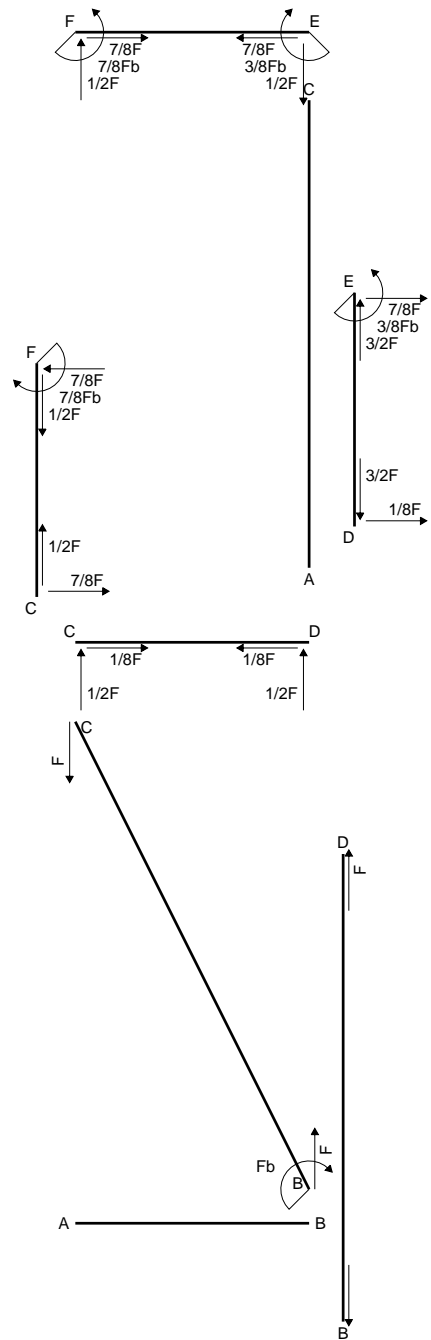
$$\sigma_c = -Mv/J_u = 114. \text{ N/mm}^2$$

$$\tau_c = 9.188 \text{ N/mm}^2$$

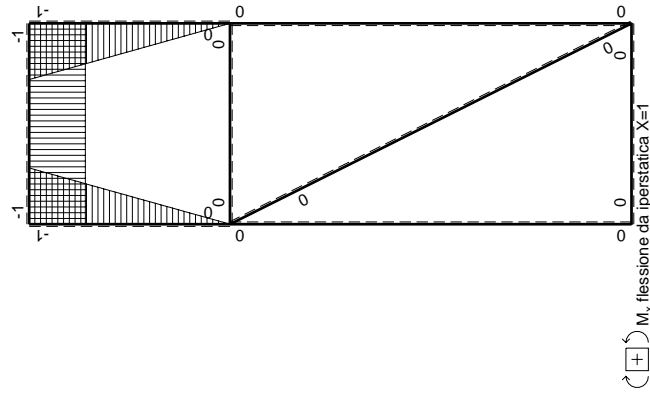
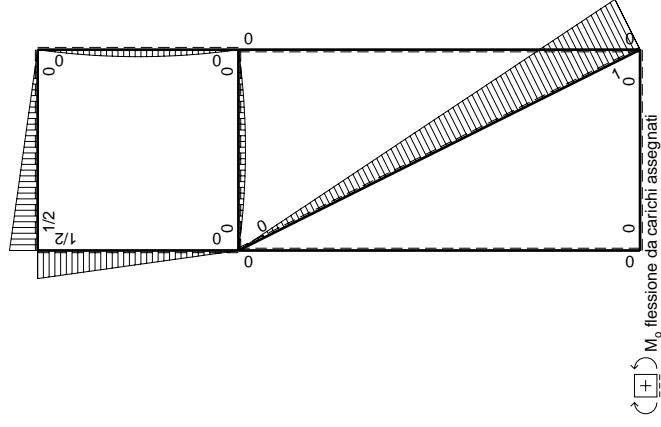
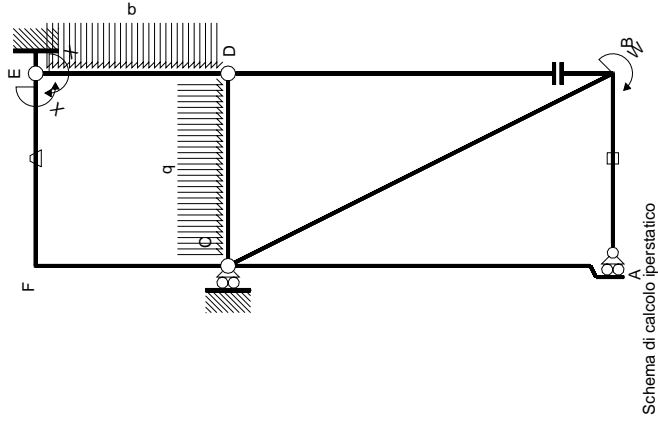
$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 115.1 \text{ N/mm}^2$$

$$S = 3181. \text{ mm}^3$$





← ⊕ →  $F$



Quadro contributi PLV per iperstatica X=W<sub>EF</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>	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJdx$
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0	0
BC √5b	0	Fb-√5/5Fx	0	0	0	0	0+0	0
CA 2b	0	0	0	0	0	0	0+0	0
DB 2b	0	0	0	0	0	0	0+0	0
BD 2b	0	0	0	0	0	0	0+0	0
DE 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>	0
ED 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>	1/3Xb/EJ
CD b	0	1/2Fx-1/2qx <sup>2</sup>	0	0	0	0	0	0
DC b	0	-1/2Fx+1/2qx <sup>2</sup>	0	0	0	0	0	0
EF b	-1	1/2Fx	-Fb/EJ	-1/2Fx	Fb/EJ	1	1	Xb/EJ
FE b	1	-1/2Fb+1/2Fx	Fb/EJ	-1/2Fb+1/2Fx	Fb/EJ	1	1	(-1/4+1)Fb <sup>2</sup> /EJ
FC b	-1+x/b	1/2Fb-1/2Fx	0	-1/2Fb+Fx-1/2Fx <sup>2</sup> /b	0	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	(-1/6+0)Fb <sup>2</sup> /EJ
CF b	x/b	-1/2Fx	0	-1/2Fx <sup>2</sup> /b	0	0	x <sup>2</sup> /b <sup>2</sup>	1/3Xb/EJ
totali								5/8Fb <sup>2</sup> /EJ
								-3/8Fb

iperstatica X=W<sub>EF</sub>

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/4 b) Fb 1/EJ + (b) \theta = 3/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + 1/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-1/2 x + 1/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

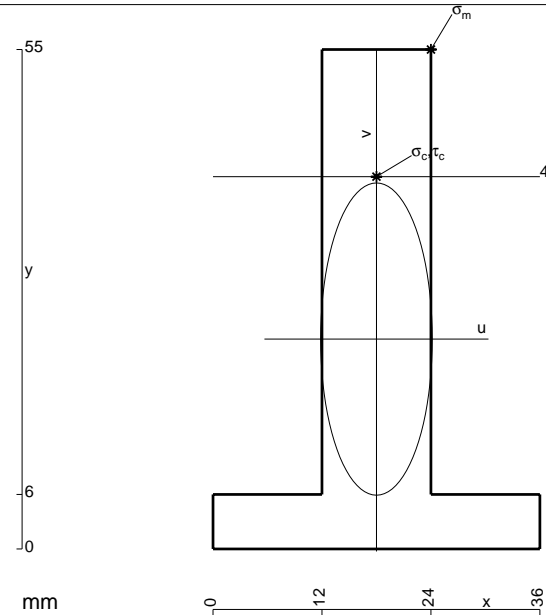
$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ$$

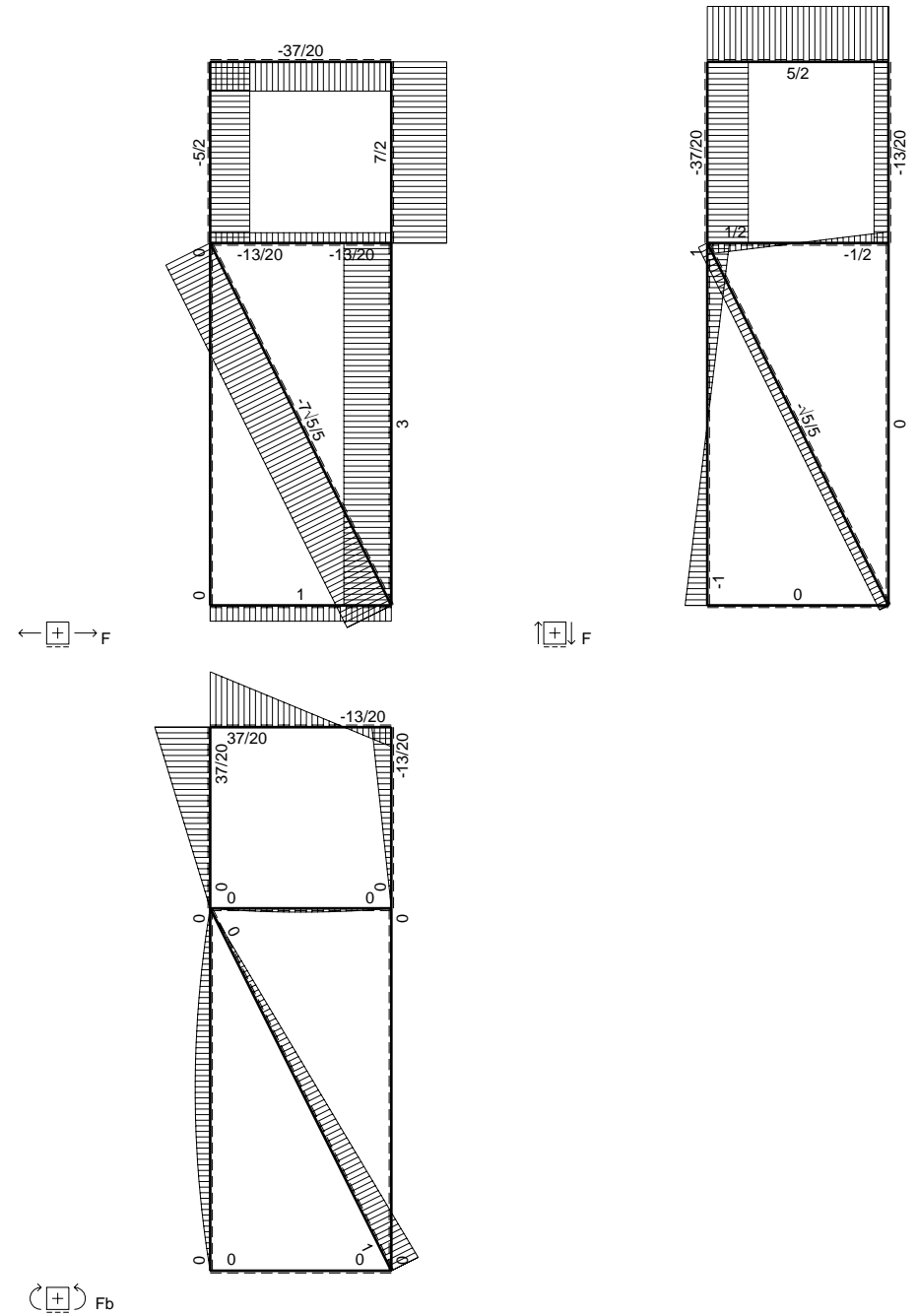
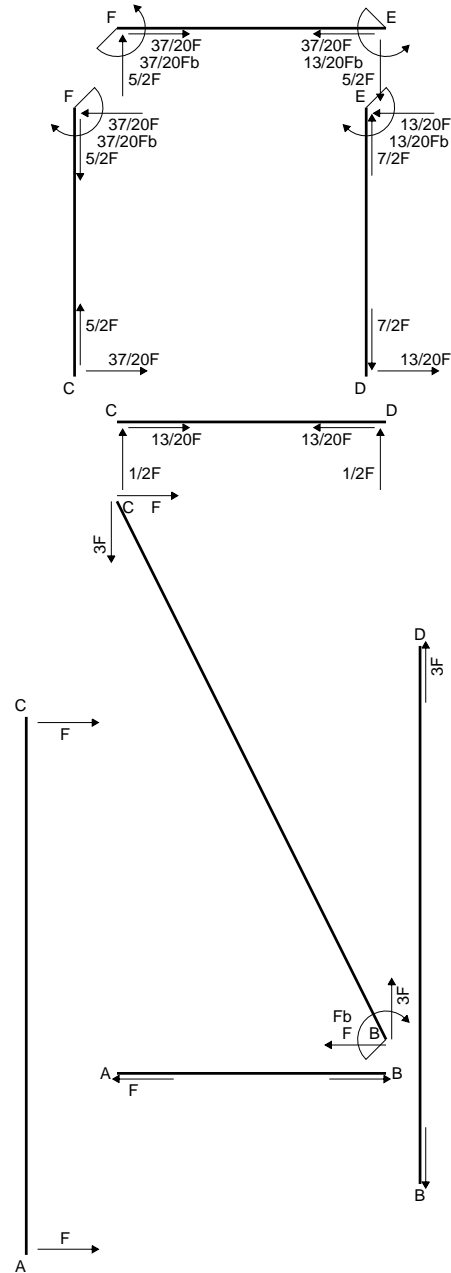
$$= (-1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$



- A = 804. mm<sup>2</sup>
- J<sub>u</sub> = 237762. mm<sup>4</sup>
- J<sub>v</sub> = 30384. mm<sup>4</sup>
- y<sub>g</sub> = 23.11 mm
- N = -2227. N
- T<sub>y</sub> = -1114. N
- M<sub>x</sub> = 1543800. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 55. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 31.89 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = -209.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 41. mm
- v<sub>c</sub> = 17.89 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = -118.9 N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.632 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup>+3τ<sup>2</sup>) = 119. N/mm<sup>2</sup>
- S = 4181. mm<sup>3</sup>









$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-5/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-5/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-5/4 b) Fb 1/EJ + (b) \theta = -1/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-5/2 + 5/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-5/2 x + 5/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

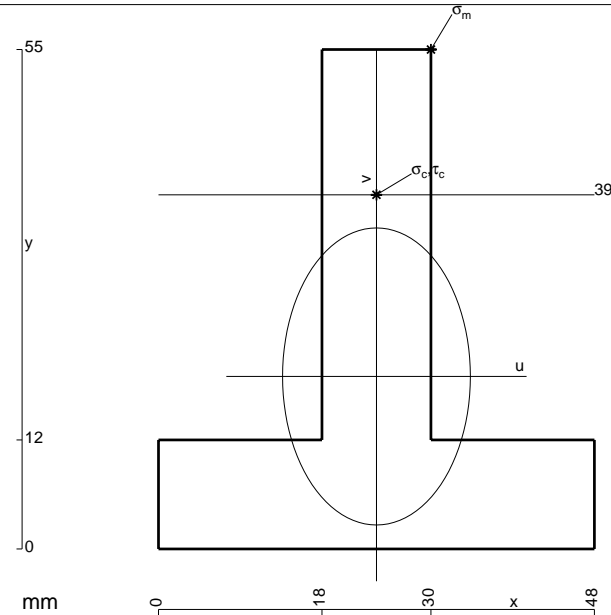
$$= (-5/2 b + 5/4 b) Fb 1/EJ + (-b) \theta = -1/4 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = [-5/2 x + 5/2 x^2/b - 5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$



- 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> = 18.99 mm
- N = -8171. N
- T<sub>y</sub> = -1167. N
- M<sub>x</sub> = 1722600. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 55. 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> = -219.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 39. mm
- v<sub>c</sub> = 20.01 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = -125.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.79 N/mm<sup>2</sup>
- σ<sub>o</sub> = √(σ<sup>2</sup>+3τ<sup>2</sup>) = 125.4 N/mm<sup>2</sup>
- S = 5377. mm<sup>3</sup>







$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

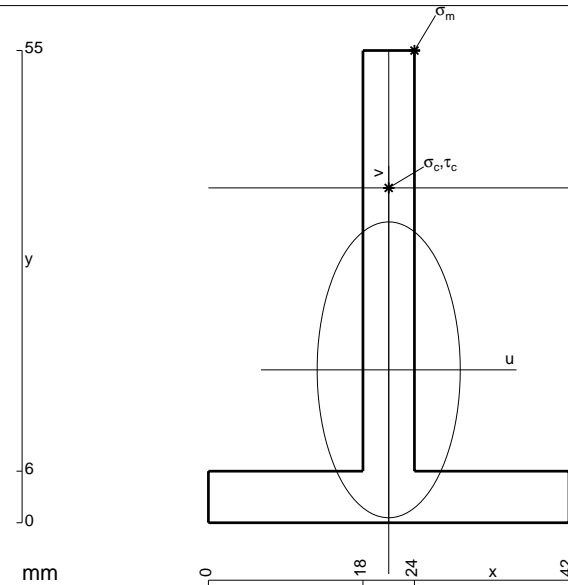
$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (1/4 b - 1/6 b) Fb 1/EJ + (b) \theta = 13/12 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (1/4 b - 1/6 b) Fb 1/EJ + (-b) \theta = 13/12 Fb^2/EJ$$



$$A = 546. \text{ mm}^2$$

$$J_u = 162198. \text{ mm}^4$$

$$J_v = 37926. \text{ mm}^4$$

$$y_g = 17.81 \text{ mm}$$

$$T_y = -2860. \text{ N}$$

$$M_x = -1001000. \text{ Nmm}$$

$$x_m = 24. \text{ mm}$$

$$y_m = 55. \text{ mm}$$

$$u_m = 3. \text{ mm}$$

$$v_m = 37.19 \text{ mm}$$

$$\sigma_m = -Mv/J_u = 229.5 \text{ N/mm}^2$$

$$x_c = 21. \text{ mm}$$

$$y_c = 39. \text{ mm}$$

$$v_c = 21.19 \text{ mm}$$

$$\sigma_c = -Mv/J_u = 130.8 \text{ N/mm}^2$$

$$\tau_c = 8.236 \text{ N/mm}^2$$

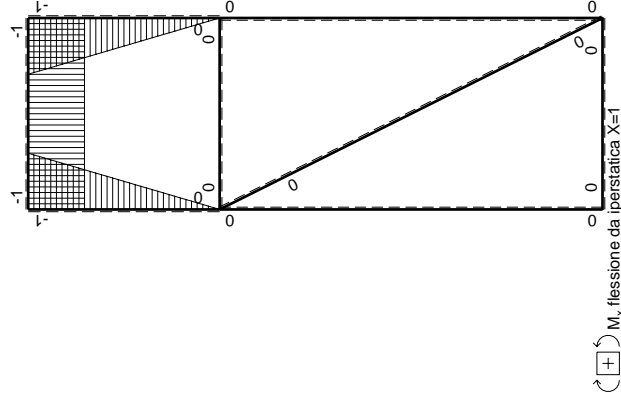
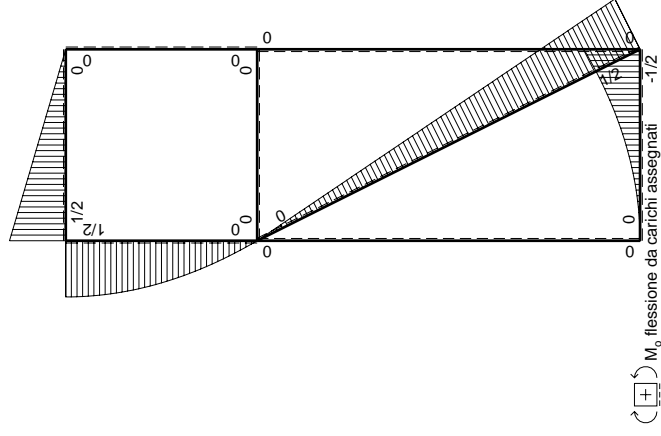
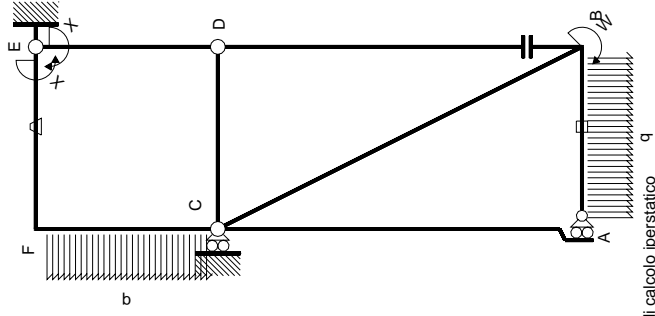
$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 131.6 \text{ N/mm}^2$$

$$S = 2802. \text{ mm}^3$$









Quadro contributi PLV per iperstatica  $X=W_{EF}$

$\rightarrow$	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x (M_0/EJ + \theta) dx$	$\int M^x M_x / E dx$
AB b	0	$-1/2qx^2$	0	0	0	0	0	0
BA b	0	$1/2Fb - Fx + 1/2qx^2$	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$1/2Fb - \sqrt{5}/10Fx$	0	0	0	0	0	0
AC 2b	0	0	0	0	0	0	0	0
CA 2b	0	0	0	0	0	0	0	0
DB 2b	0	0	0	0	0	0	0	0
BD 2b	0	0	0	0	0	0	0	0
DE b	-x/b	0	0	0	0	$x^2/b^2$	0	0
ED b	1-x/b	0	0	0	0	$1-2x/b+x^2/b^2$	0	0
CD b	0	0	0	0	0	0	0	0
DC b	0	0	0	0	0	0	0	0
EF b	-1	$1/2Fx$	-Fb/EJ	-1/2Fx	Fb/EJ	1	$(-1/4+1)Fb^2/EJ$	Xb/EJ
FE b	1	$-1/2Fb+1/2Fx$	Fb/EJ	$-1/2Fb+1/2Fx$	Fb/EJ	1	$(-1/4+1)Fb^2/EJ$	Xb/EJ
FC b	-1+x/b	$1/2Fb-1/2qx^2$	0	$-1/2Fb+1/2Fx+1/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(-5/24+0)Fb^2/EJ$	$1/3Xb/EJ$
CF b	x/b	$-Fx+1/2qx^2$	0	$-Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$	$13/24Fb^2/EJ$	$5/3Xb/EJ$
totali								
iperstatica $X=W_{EF}$								

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/4 b) Fb 1/EJ + (b) \theta = 3/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + 1/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-1/2 x + 1/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

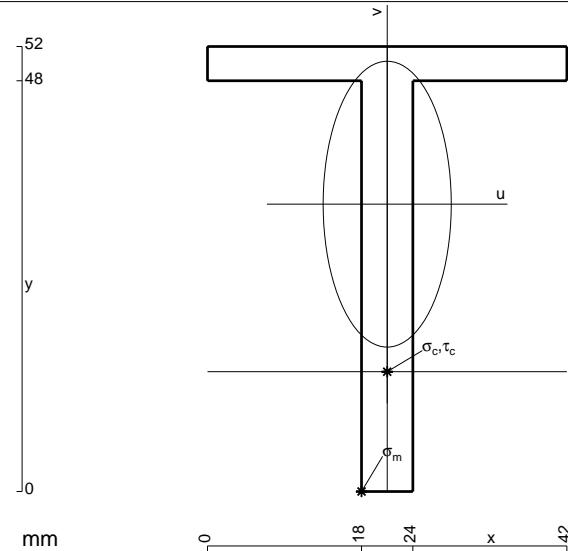
$$L_{FC}^{xo} = \int_0^b (-1/2 + 1/2 x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx$$

$$= [-1/2 x + 1/4 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/4 b + 1/6 b - 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$

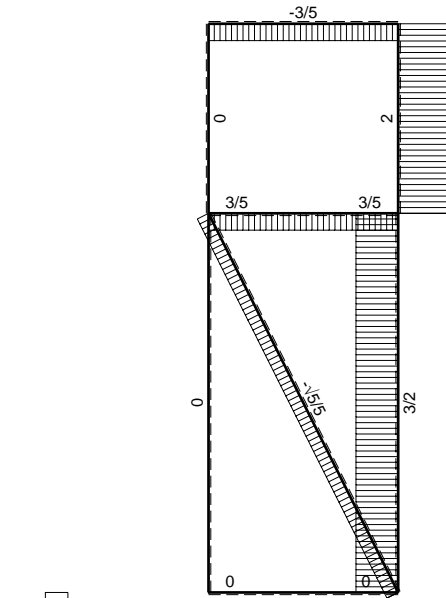
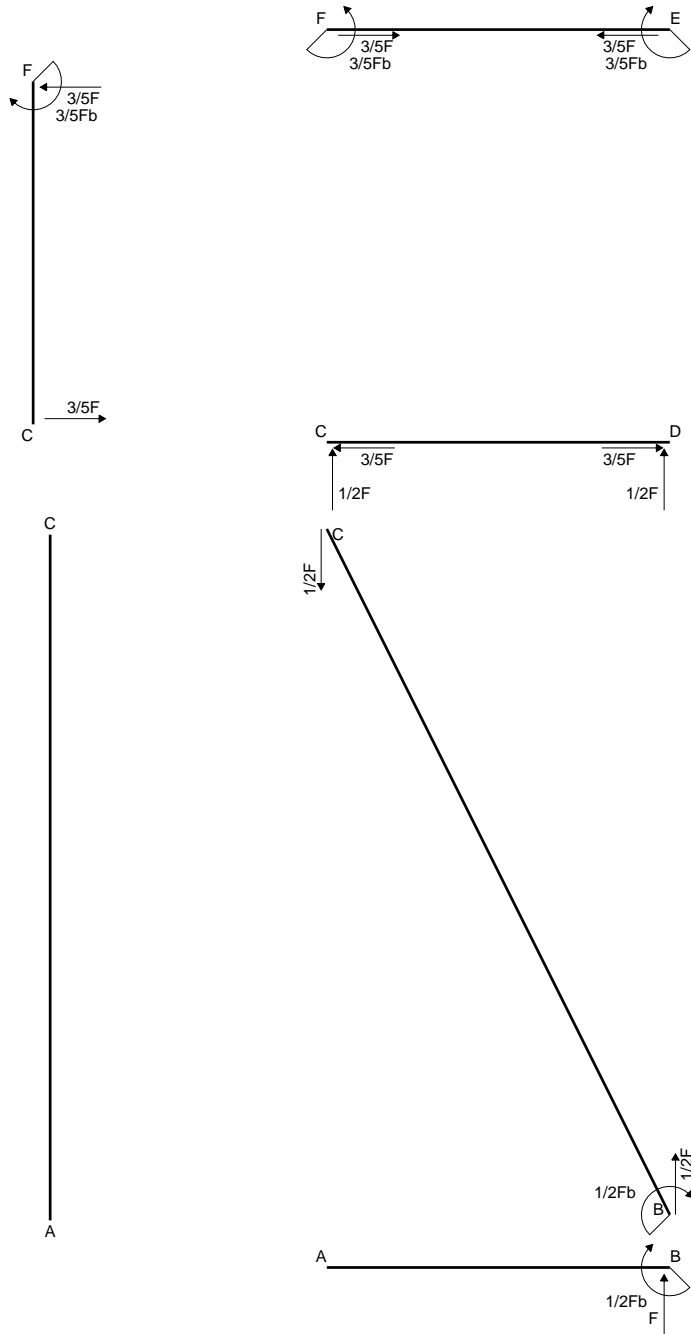
$$L_{CF}^{xo} = \int_0^b (-x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/3 b + 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$

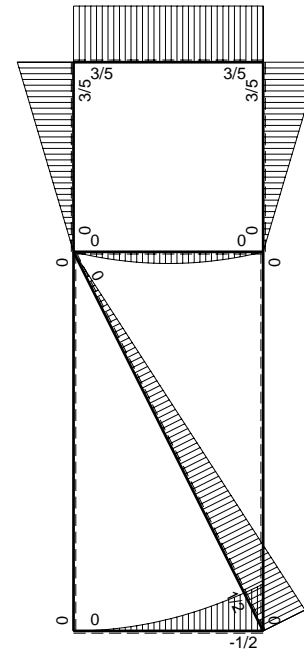


- A = 456. mm<sup>2</sup>
- J<sub>u</sub> = 127247. mm<sup>4</sup>
- J<sub>v</sub> = 25560. mm<sup>4</sup>
- y<sub>g</sub> = 33.58 mm
- T<sub>y</sub> = -2590. N
- M<sub>x</sub> = -906500. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -33.58 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -239.2 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> = -Mv/J<sub>u</sub> = -139.5 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.574 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 140.1 N/mm<sup>2</sup>
- S = 2233. mm<sup>3</sup>

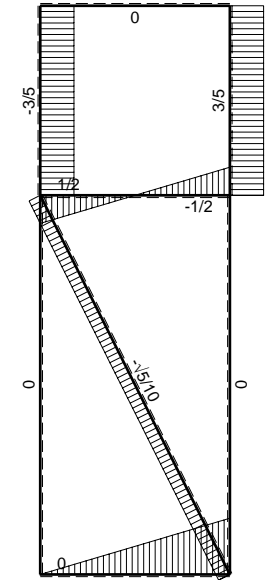




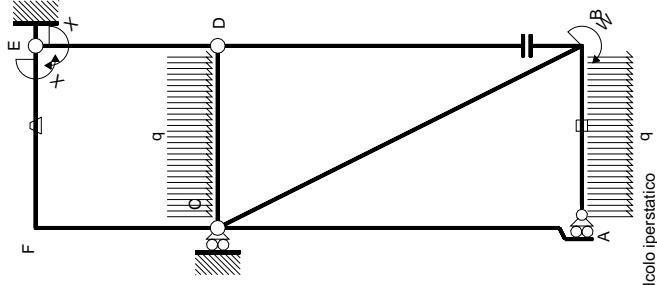
← ⊕ → F



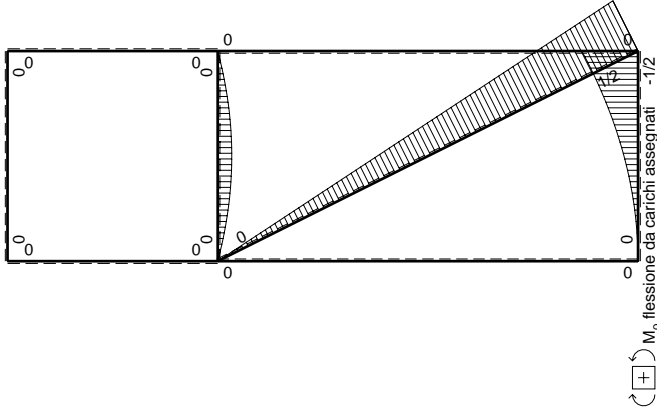
⊕ ⊖ Fb



↑ ⊕ ↓ F



Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati -1/2

Quadro contributi PLV per iperstatica  $X=W_{EF}$

→	$M_x(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int X M_x M_x / EJ dx$
AB b	0	$-1/2qx^2$	0	0	0	0	0+0	0
BA b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0+0	0
BC $\sqrt{5}b$	0	$1/2Fb-\sqrt{5}/10Fx$	0	0	0	0	0	0
AC 2b	0	0	0	0	0	0	0+0	0
CA 2b	0	0	0	0	0	0	0+0	0
DB 2b	0	0	0	0	0	0	0+0	0
BD 2b	0	0	0	0	0	0	0+0	0
DE b	$-x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3Xb/EJ$
ED b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$
CD b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0
DC b	0	$-1/2Fx+1/2qx^2$	0	0	0	0	0+0	0
EF b	-1	0	$-Fb/EJ$	0	$Fb/EJ$	1	$(0+1)Fb^2/EJ$	$Xb/EJ$
FE b	1	0	$Fb/EJ$	0	$Fb/EJ$	1	$(0+1)Fb^2/EJ$	$Xb/EJ$
FC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$
CF b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3Xb/EJ$
totali								
iperstatica $X=W_{EF}$								
							$Fb^2/EJ$	$5/3Xb/EJ$
							$-3/5Fb$	

Sviluppi di calcolo iperstatica

$M_x$  flessione da iperstatica  $X=1$



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

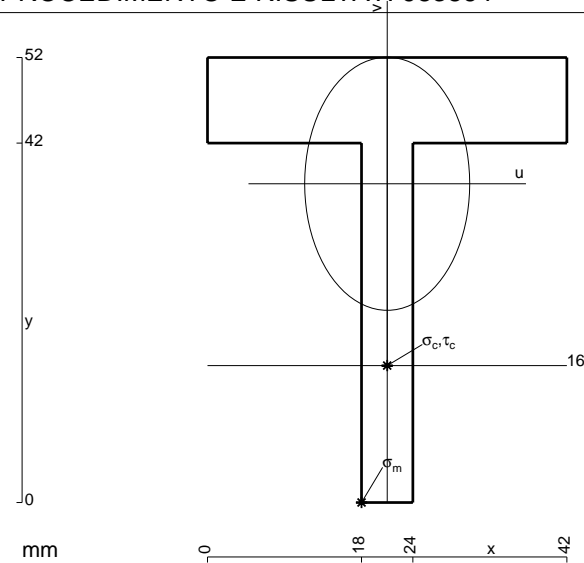
$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (1) \theta dx = [x]_0^b \theta$$

$$= (b) \theta = Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1) \theta dx = [-x]_0^b \theta$$

$$= (-b) \theta = Fb^2/EJ$$



$$A = 672. \text{ mm}^2$$

$$J_u = 147014. \text{ mm}^4$$

$$J_v = 62496. \text{ mm}^4$$

$$y_g = 37.25 \text{ mm}$$

$$T_y = -4260. \text{ N}$$

$$M_x = -788100. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -37.25 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -199.7 \text{ N/mm}^2$$

$$x_c = 21. \text{ mm}$$

$$y_c = 16. \text{ mm}$$

$$v_c = -21.25 \text{ mm}$$

$$\sigma_c = -Mv/J_u = -113.9 \text{ N/mm}^2$$

$$\tau_c = 13.56 \text{ N/mm}^2$$

$$\sigma_o = \sqrt{\sigma^2 + 3\tau^2} = 116.3 \text{ N/mm}^2$$

$$S = 2808. \text{ mm}^3$$









$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/4 b) Fb 1/EJ + (b) \theta = 3/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + 1/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-1/2 x + 1/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

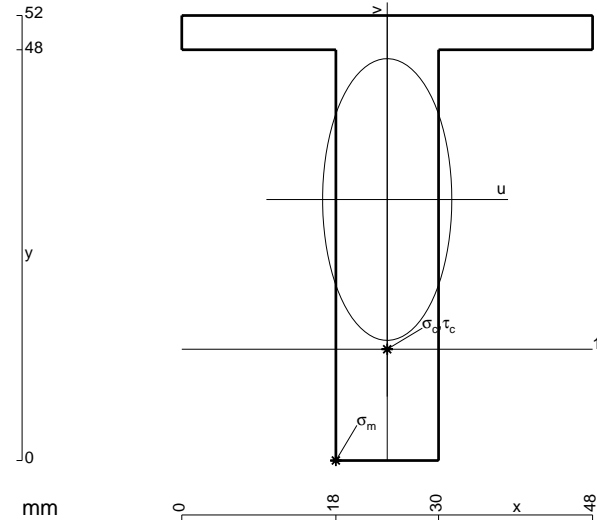
$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

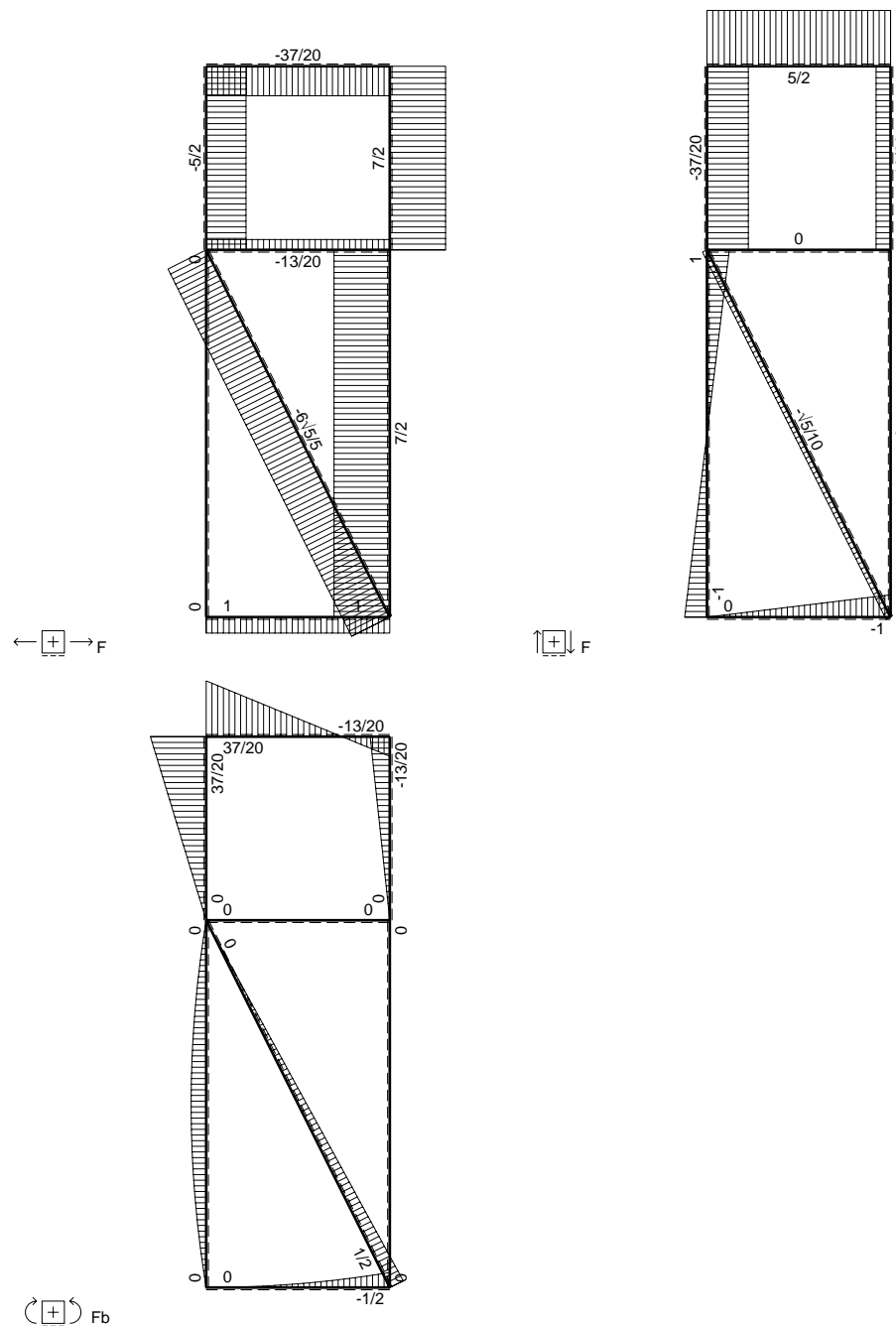
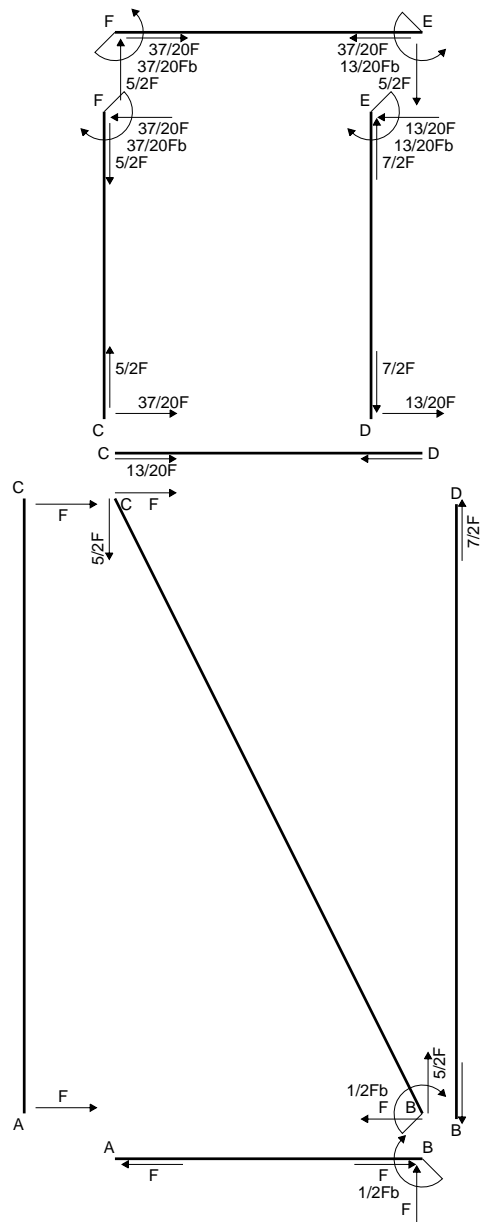
$$L_{CF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ$$

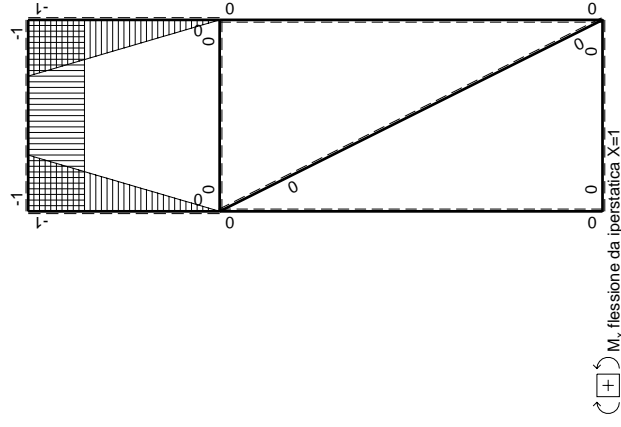
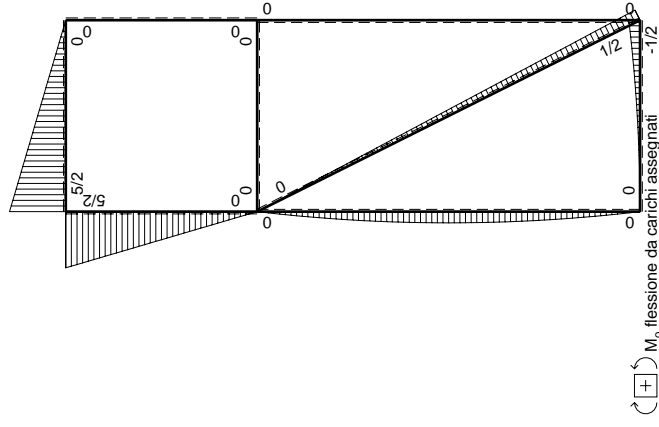
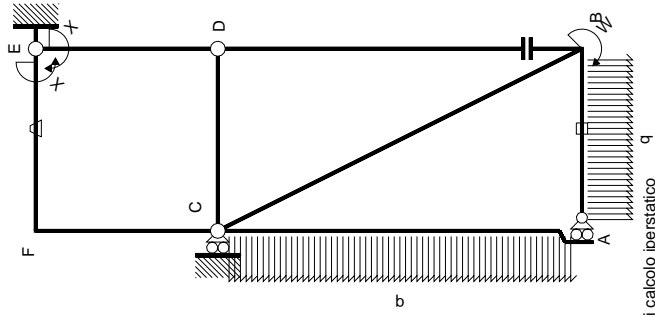
$$= (-1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$



- A = 768. mm<sup>2</sup>
- J<sub>u</sub> = 208192. mm<sup>4</sup>
- J<sub>v</sub> = 43776. mm<sup>4</sup>
- y<sub>g</sub> = 30.5 mm
- T<sub>y</sub> = -7160. N
- M<sub>x</sub> = -1432000. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -30.5 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -209.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 13. mm
- v<sub>c</sub> = -17.5 mm
- σ<sub>c</sub> = -Mv/J<sub>v</sub> = -120.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 10.73 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 = 3744. mm<sup>3</sup>







Quadro contributi PLV per iperstatica X=V<sup>EP</sup>

→	$M(x)$	$M_0(x)$	$\theta$	$M M_0$	$M \theta$	$M M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJdx$
AB b	0	$-1/2qx^2$	0	0	0	0	0	0
BA b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0	0
BC √5b	0	$1/2Fb-\sqrt{5}/10Fx$	0	0	0	0	0	0
AC 2b	0	$-Fx+1/2qx^2$	0	0	0	0	0	0
CA 2b	0	$Fx-1/2qx^2$	0	0	0	0	0	0
DB 2b	0	0	0	0	0	0	0	0
BD 2b	0	0	0	0	0	0	0	0
DE b	-x/b	0	0	0	0	0	0	0
ED b	1-x/b	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
EF b	-1	$5/2Fx$	$-Fb/EJ$	$-5/2Fx$	$Fb/EJ$	1	$(-5/4+1)Fb^2/EJ$	$Xb/EJ$
FE b	1	$-5/2Fb+5/2Fx$	$Fb/EJ$	$-5/2Fb+5/2Fx$	$Fb/EJ$	1	$(-5/4+1)Fb^2/EJ$	$Xb/EJ$
FC b	-1+x/b	$5/2Fb-5/2Fx$	0	$-5/2Fb+5Fx-5/2Fx^2/b$	0	0	$(-5/6+0)Fb^2/EJ$	$1/3Xb/EJ$
CF b	x/b	$-5/2Fx$	0	$-5/2Fx^2/b$	0	0	$(-5/6+0)Fb^2/EJ$	$1/3Xb/EJ$
totali								
iperstatica X=V <sup>EP</sup>								

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{x\theta} = \int_0^b (-5/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-5/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-5/4 b) Fb 1/EJ + (b) \theta = -1/4 Fb^2/EJ$$

$$L_{FE}^{x\theta} = \int_0^b (-5/2 + 5/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-5/2 x + 5/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

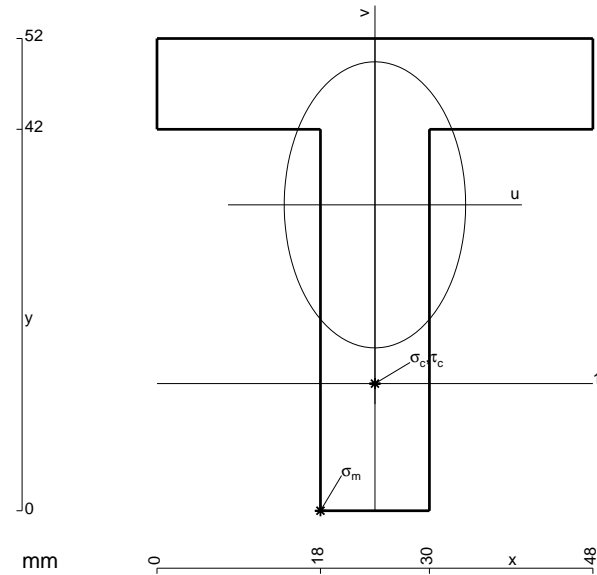
$$= (-5/2 b + 5/4 b) Fb 1/EJ + (-b) \theta = -1/4 Fb^2/EJ$$

$$L_{FC}^{x\theta} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = [-5/2 x + 5/2 x^2/b - 5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

$$L_{CF}^{x\theta} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

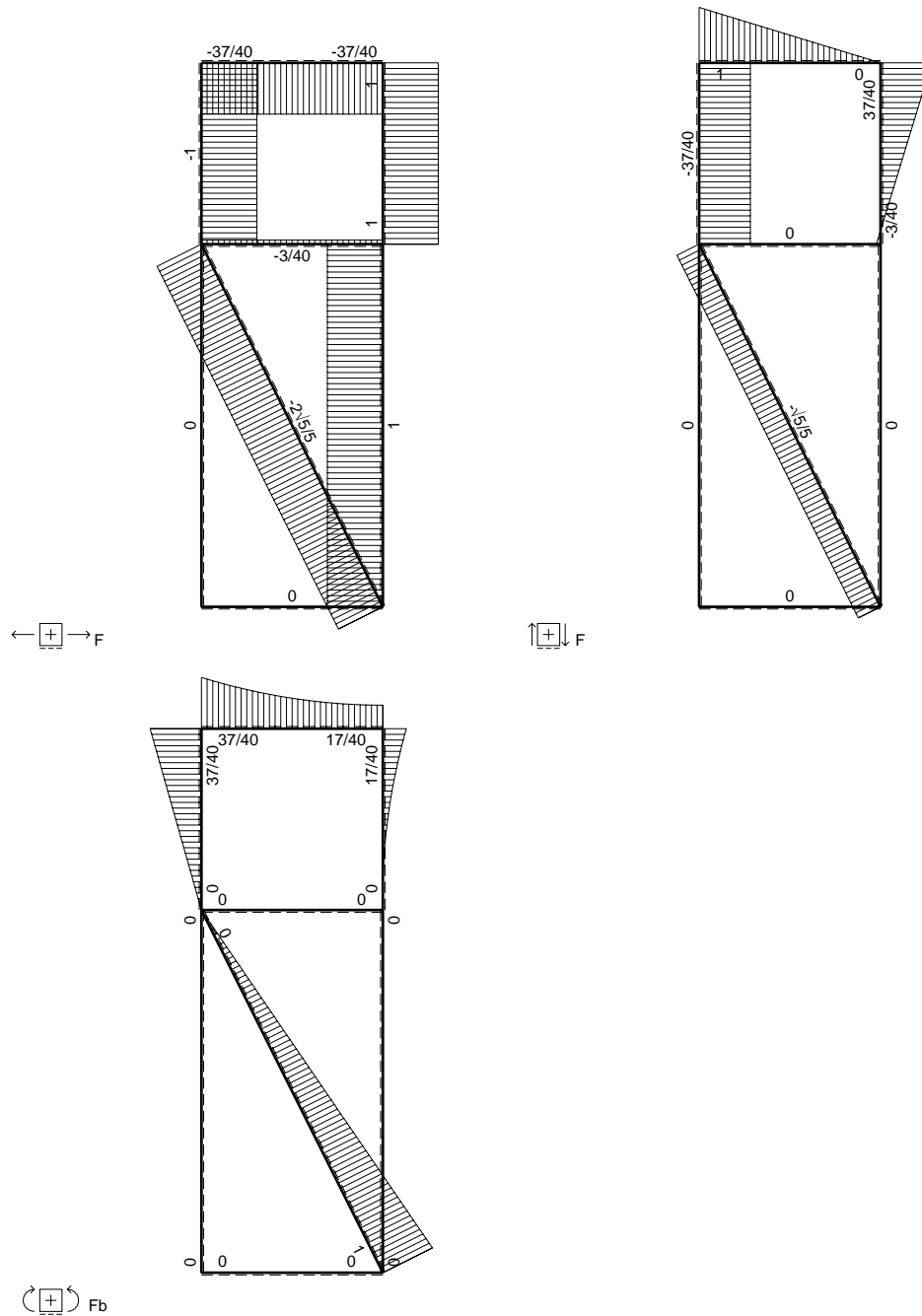
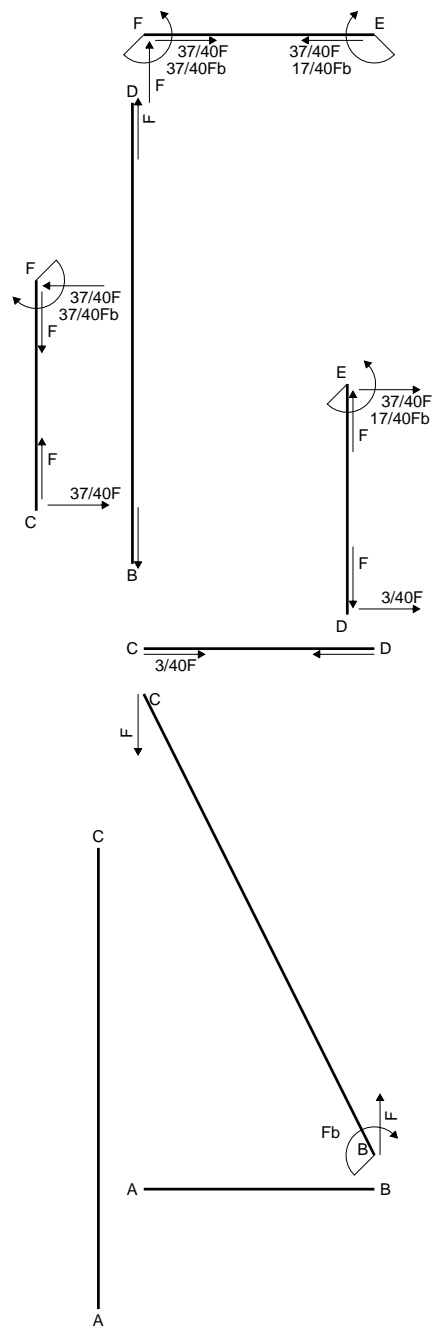
$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$



- 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
- N = 7500. N
- T<sub>y</sub> = -7500. N
- M<sub>x</sub> = -1650000. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -33.68 mm
- σ<sub>m</sub> = N/A - M<sub>v</sub>/J<sub>u</sub> = -219.9 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> = N/A - M<sub>v</sub>/J<sub>u</sub> = -125.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 11.47 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 126.9 N/mm<sup>2</sup>
- S = 4483. mm<sup>3</sup>









$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/6 b) Fb 1/EJ + (b) \theta = 5/6 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx$$

$$= [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

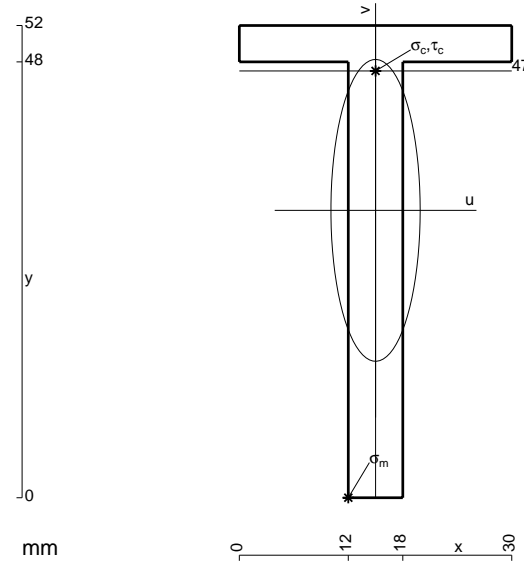
$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ + (-b) \theta = 5/6 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

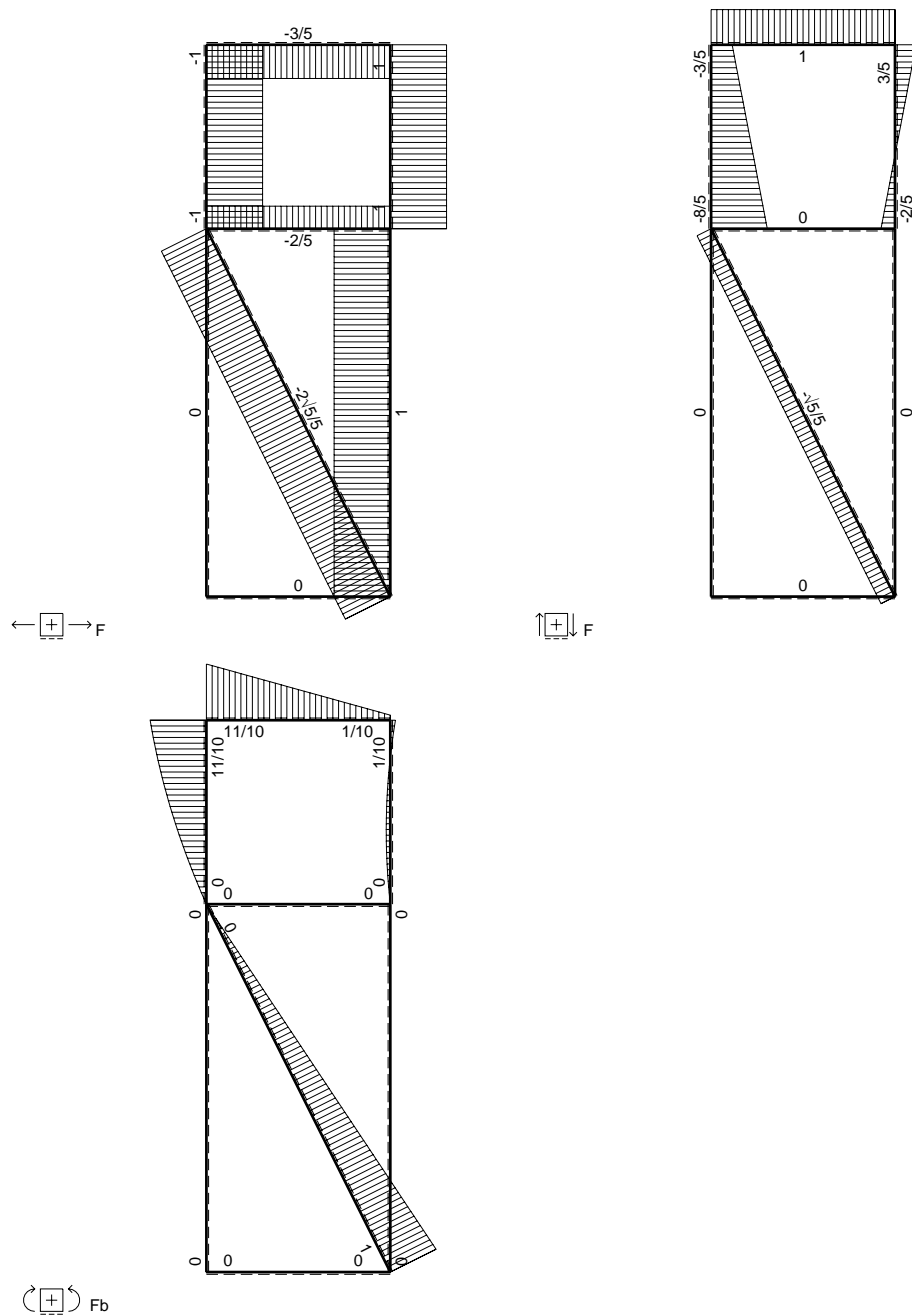
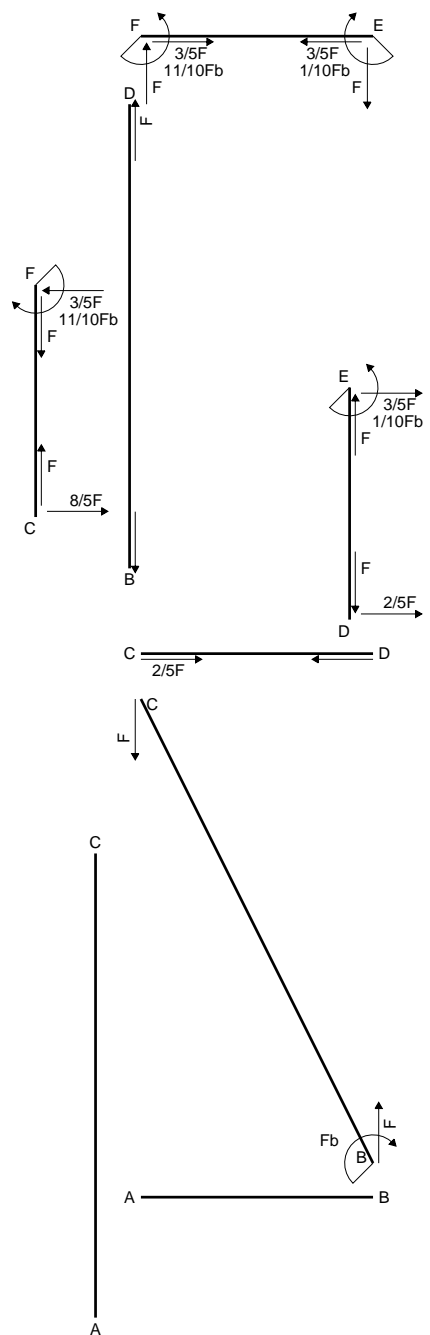
$$L_{CF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$



- A = 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 = -1547. N
- T<sub>y</sub> = -773.7 N
- M<sub>x</sub> = 830400. 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> = 229.4 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> = -116.9 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.628 N/mm<sup>2</sup>
- σ<sub>φ</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 117. N/mm<sup>2</sup>
- S = 2297. mm<sup>3</sup>



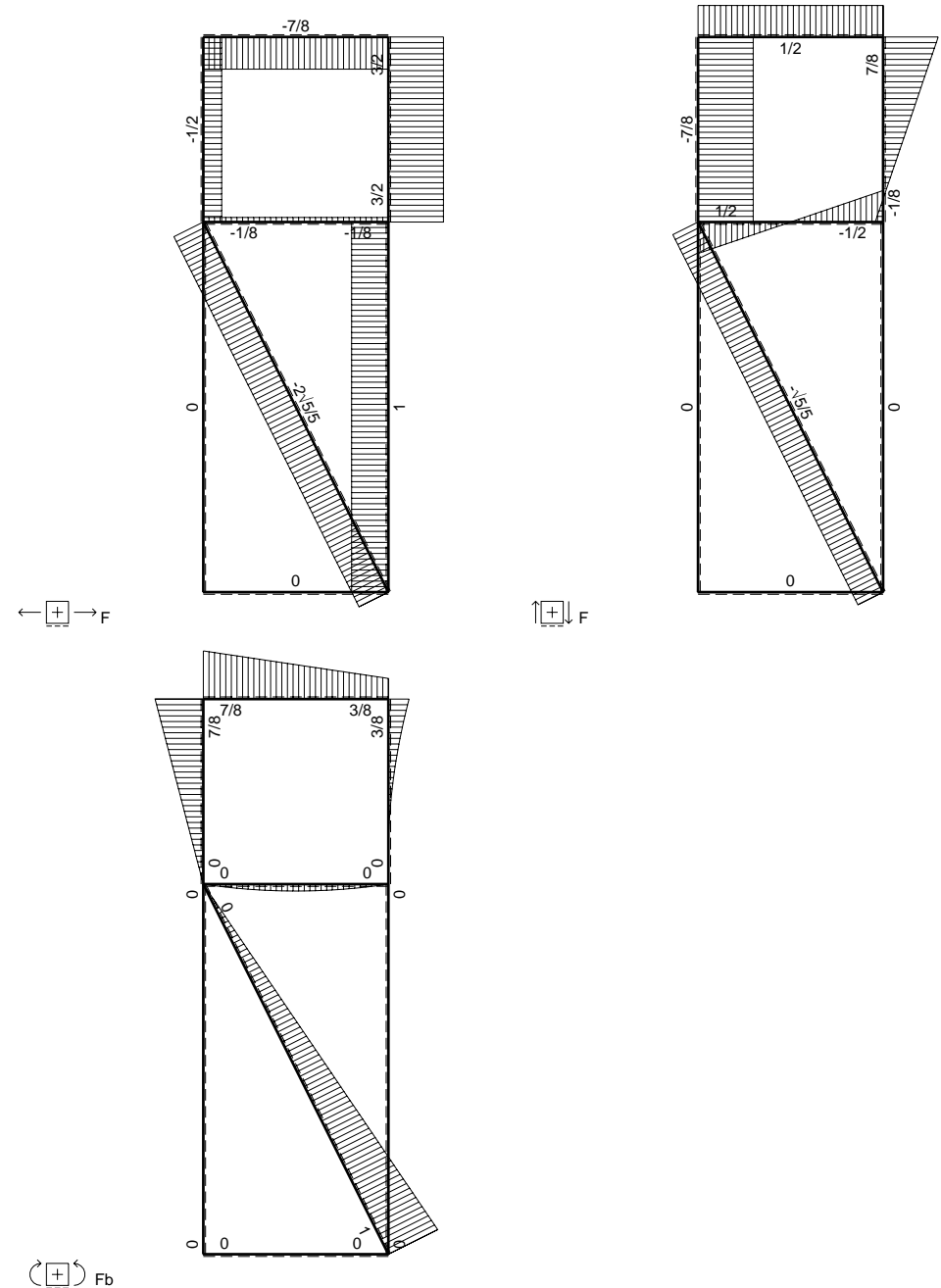
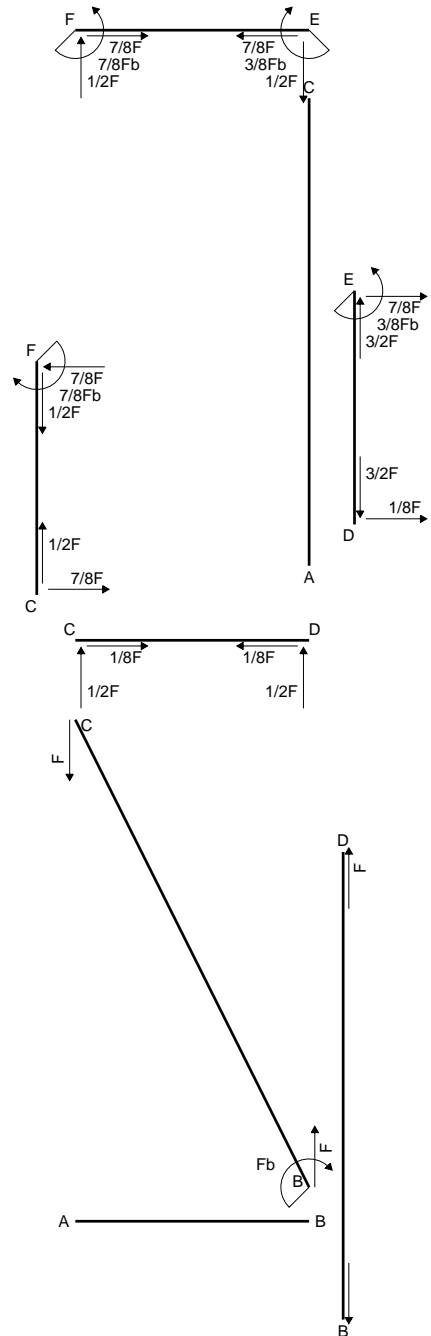














$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/4 b) Fb 1/EJ + (b) \theta = 3/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + 1/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-1/2 x + 1/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

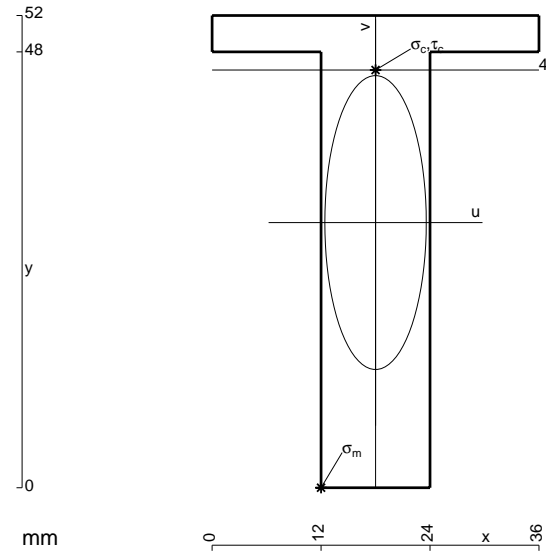
$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

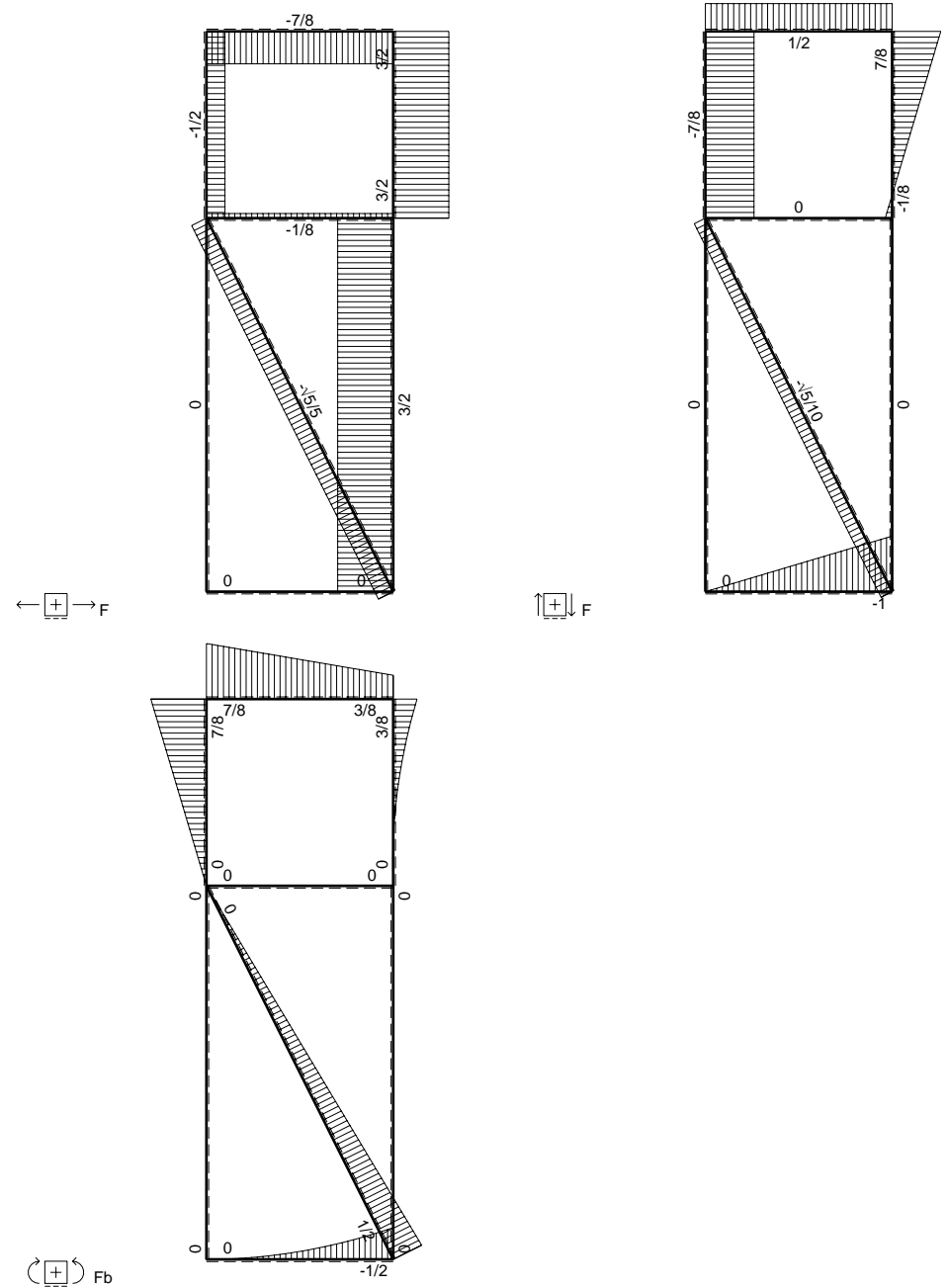
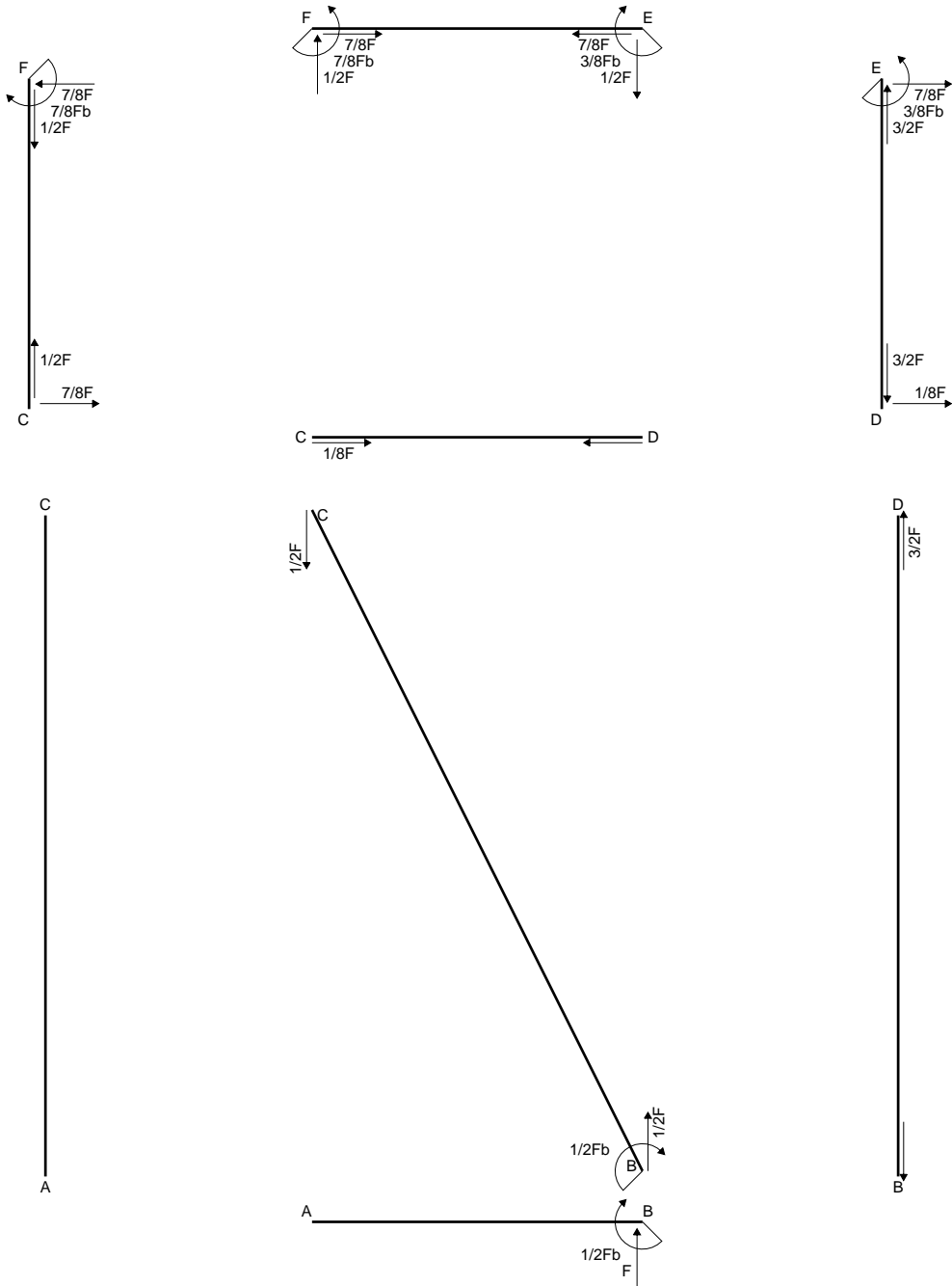
$$L_{CF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ$$

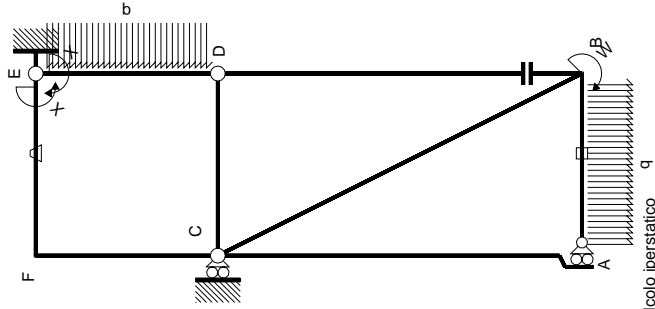
$$= (-1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$



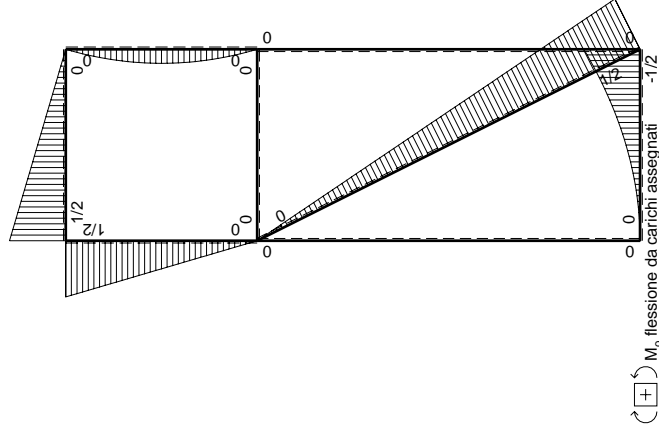
- A = 720. mm<sup>2</sup>
- J<sub>u</sub> = 188659. mm<sup>4</sup>
- J<sub>v</sub> = 22464. mm<sup>4</sup>
- y<sub>g</sub> = 29.2 mm
- N = -2129. N
- T<sub>y</sub> = -1064. N
- M<sub>x</sub> = 1309000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -29.2 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = 199.6 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> = -119.5 N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.609 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 119.6 N/mm<sup>2</sup>
- S = 3422. mm<sup>3</sup>







Schema di calcolo iperstatico



$M_x$ , flessione da iperstatica  $X=1$

Quadro contribuiti PLV per iperstatica  $X=W_{EF}$

$\rightarrow$	$M^k(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x (M_0/EJ + \theta) dx$	$\int M^x M_x / E J dx$
AB b	0	$-1/2qx^2$	0	0	0	0	0+0	0
BA b	0	$1/2Fb - Fx + 1/2qx^2$	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$1/2Fb - \sqrt{5}/10Fx$	0	0	0	0	0+0	0
CA 2b	0	0	0	0	0	0	0+0	0
DB 2b	0	0	0	0	0	0	0+0	0
BD 2b	0	0	0	0	0	0	0+0	0
DE b	$-x/b$	$-1/2Fx + 1/2qx^2$	0	$1/2F^2x^2/b - 1/2qx^3/b$	0	0	$x^2/b^2$	0
ED b	$1-x/b$	$1/2Fx - 1/2qx^2$	0	$1/2Fx - Fx^2/b + 1/2qx^3/b$	0	0	$1-2x/b + x^2/b^2$	$1/3xb/EJ$
CD b	0	0	0	0	0	0	0+0	0
DC b	0	0	0	0	0	0	0+0	0
EF b	-1	$1/2Fx$	$-Fb/EJ$	$-1/2Fx$	$Fb/EJ$	1	$(-1/4+1)Fb^2/EJ$	$xb/EJ$
FE b	1	$-1/2Fb + 1/2Fx$	$Fb/EJ$	$-1/2Fb + 1/2Fx$	$Fb/EJ$	1	$(-1/4+1)Fb^2/EJ$	$xb/EJ$
FC b	$-1+x/b$	$1/2Fb - 1/2Fx$	0	$-1/2Fb + Fx - 1/2Fx^2/b$	0	0	$1-2x/b + x^2/b^2$	$1/3xb/EJ$
CF b	$x/b$	$-1/2Fx$	0	$-1/2Fx^2/b$	0	0	$x^2/b^2$	$1/3xb/EJ$
totali								$5/8Fb^2/EJ$
								$-3/8Fb$

iperstatica  $X=W_{EF}$

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/4 b) Fb 1/EJ + (b) \theta = 3/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + 1/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-1/2 x + 1/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

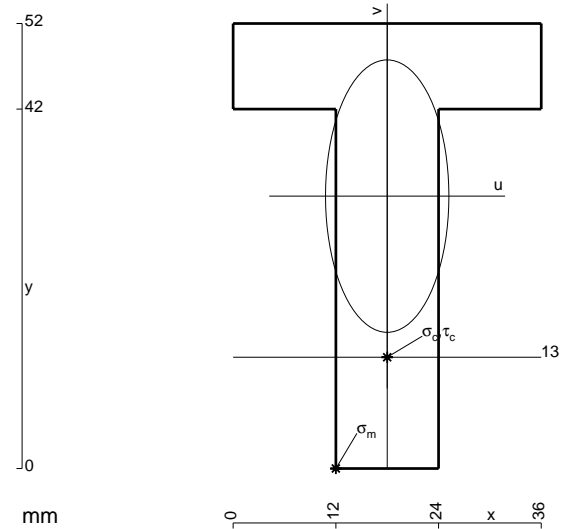
$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ$$

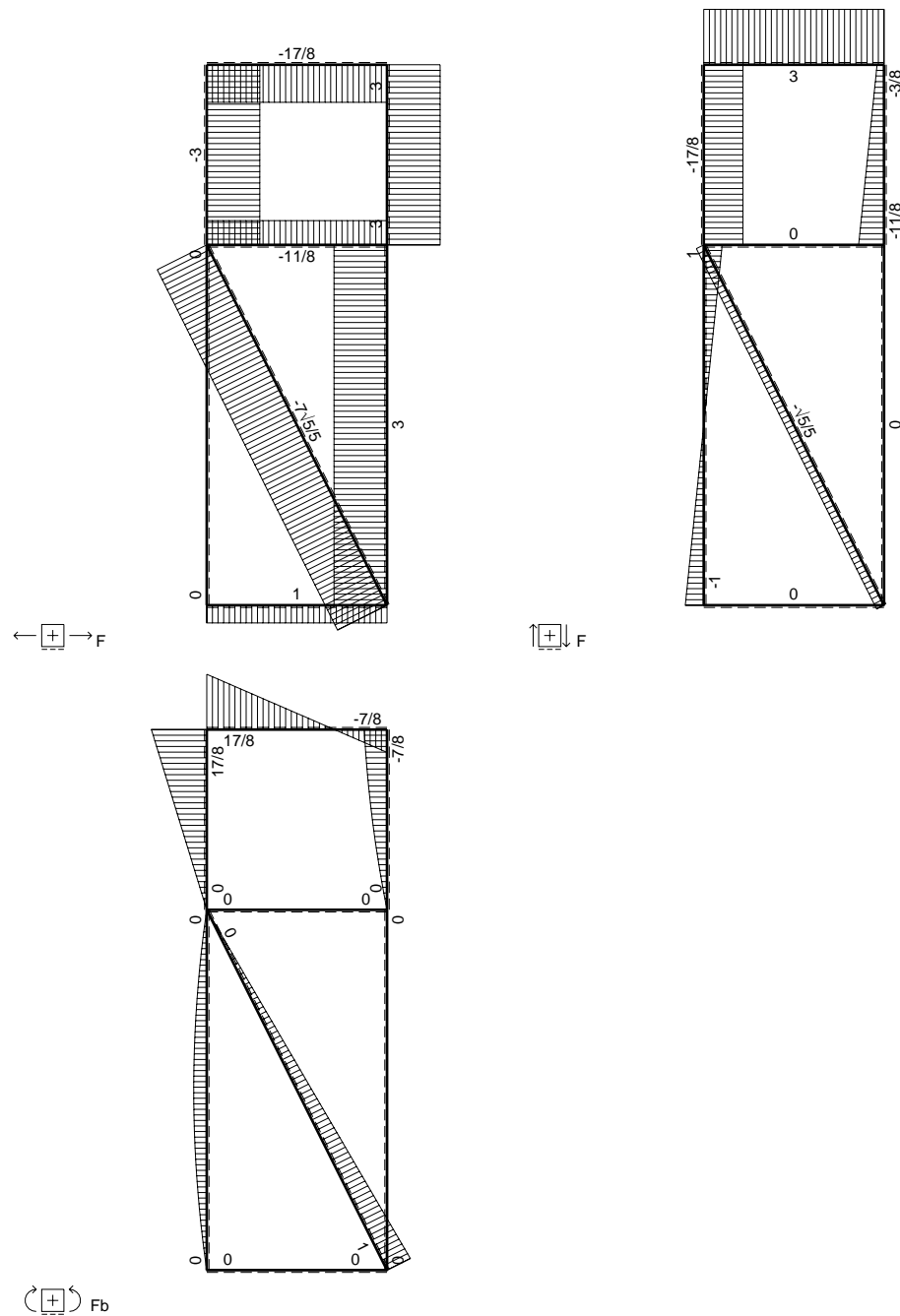
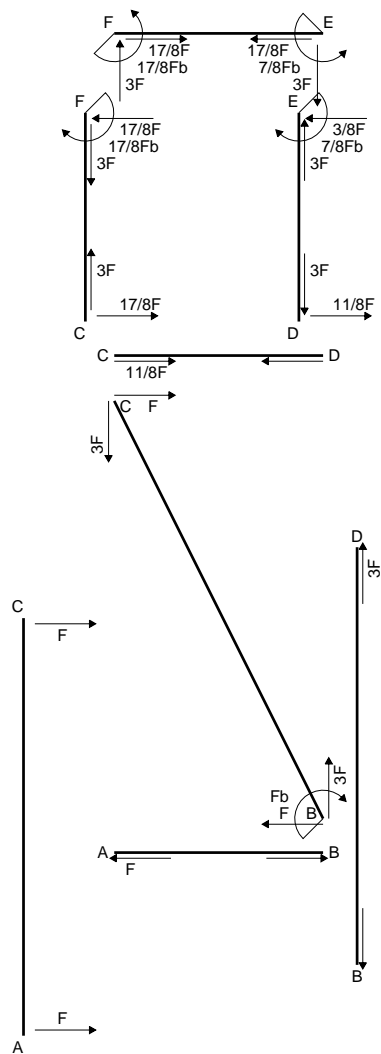
$$= (-1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

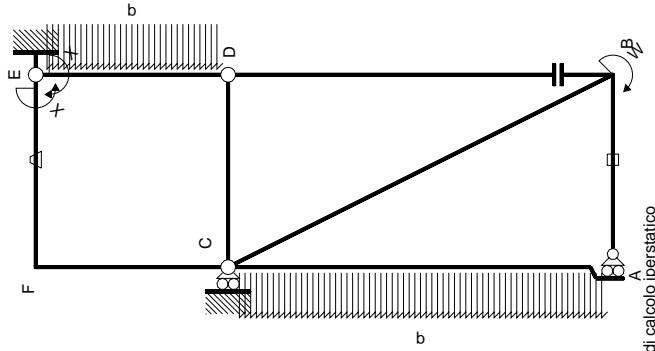


- A = 864. mm<sup>2</sup>
- J<sub>u</sub> = 219048. mm<sup>4</sup>
- J<sub>v</sub> = 44928. mm<sup>4</sup>
- y<sub>g</sub> = 31.83 mm
- T<sub>y</sub> = -4890. N
- M<sub>x</sub> = -1442550. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -31.83 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -209.6 N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 13. mm
- v<sub>c</sub> = -18.83 mm
- σ<sub>c</sub> = -Mv/J<sub>v</sub> = -124. N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.352 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 124.7 N/mm<sup>2</sup>
- S = 3952. mm<sup>3</sup>

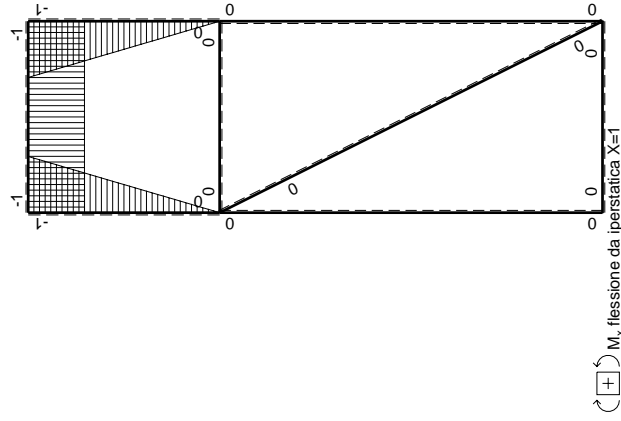








$M_0$  flessione da carichi assegnati



Quadro contributi PLV per iperstatica  $X=W_{EF}$

$\leftarrow$	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x (M_0/EJ + \theta) dx$	$\int M^x M_x / EJ dx$
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$Fb - \sqrt{5}/5Fx$	0	0	0	0	0	0
CA 2b	0	$-Fx + 1/2qx^2$	0	0	0	0	0+0	0
DB 2b	0	0	0	0	0	0	0+0	0
BD 2b	0	0	0	0	0	0	0+0	0
DE b	$-x/b$	$-1/2Fx + 1/2qx^2$	0	$1/2Fx^2/b - 1/2qx^3/b$	0	0	$x^2/b^2$	$1/3Xb/EJ$
ED b	$1-x/b$	$1/2Fx - 1/2qx^2$	0	$1/2Fx - Fx^2/b + 1/2qx^3/b$	0	0	$1-2x/b+x^2/b^2$	$1/3Xb/EJ$
CD b	0	0	0	0	0	0	0+0	0
DC b	0	0	0	0	0	0	0+0	0
EF b	-1	$3Fx$	$-Fb/EJ$	$-3Fx$	$Fb/EJ$	1	$(-3/2+1)Fb^2/EJ$	$Xb/EJ$
FE b	1	$-3Fb+3Fx$	$Fb/EJ$	$-3Fb+3Fx$	$Fb/EJ$	1	$(-3/2+1)Fb^2/EJ$	$Xb/EJ$
FC b	$-1+x/b$	$3Fb-3Fx$	0	$-3Fb+6Fx-3Fx^2/b$	0	0	$1-2x/b+x^2/b^2$	$(-1+0)Fb^2/EJ$
CF b	$x/b$	$-3Fx$	0	$-3Fx^2/b$	0	0	$x^2/b^2$	$1/3Xb/EJ$
totali								
iperstatica $X=W_{EF}$								$7/8Fb$

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-3x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-3/2 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-3/2 b) Fb 1/EJ + (b) \theta = -1/2 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-3 + 3x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-3x + 3/2 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

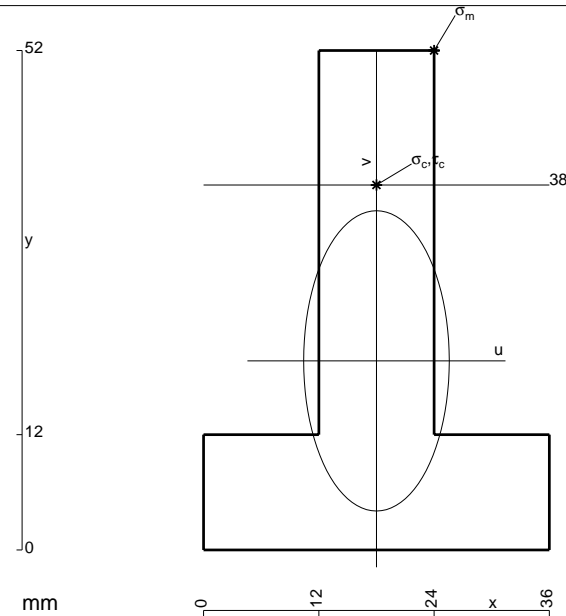
$$= (-3b + 3/2 b) Fb 1/EJ + (-b) \theta = -1/2 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-3 + 6x/b - 3x^2/b^2) Fb 1/EJ dx = [-3x + 3x^2/b - x^3/b^2]_0^b Fb 1/EJ$$

$$= (-3b + 3b - b) Fb 1/EJ = -Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-3x^2/b^2) Fb 1/EJ dx = [-x^3/b^2]_0^b Fb 1/EJ$$

$$= (-b) Fb 1/EJ = -Fb^2/EJ$$



$$A = 912. \text{ mm}^2$$

$$J_u = 222885. \text{ mm}^4$$

$$J_v = 52416. \text{ mm}^4$$

$$y_g = 19.68 \text{ mm}$$

$$N = -7357. \text{ N}$$

$$T_y = -1051. \text{ N}$$

$$M_x = 1457000. \text{ Nmm}$$

$$x_m = 24. \text{ mm}$$

$$y_m = 52. \text{ mm}$$

$$u_m = 6. \text{ mm}$$

$$v_m = 32.32 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -219.3 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 38. \text{ mm}$$

$$v_c = 18.32 \text{ mm}$$

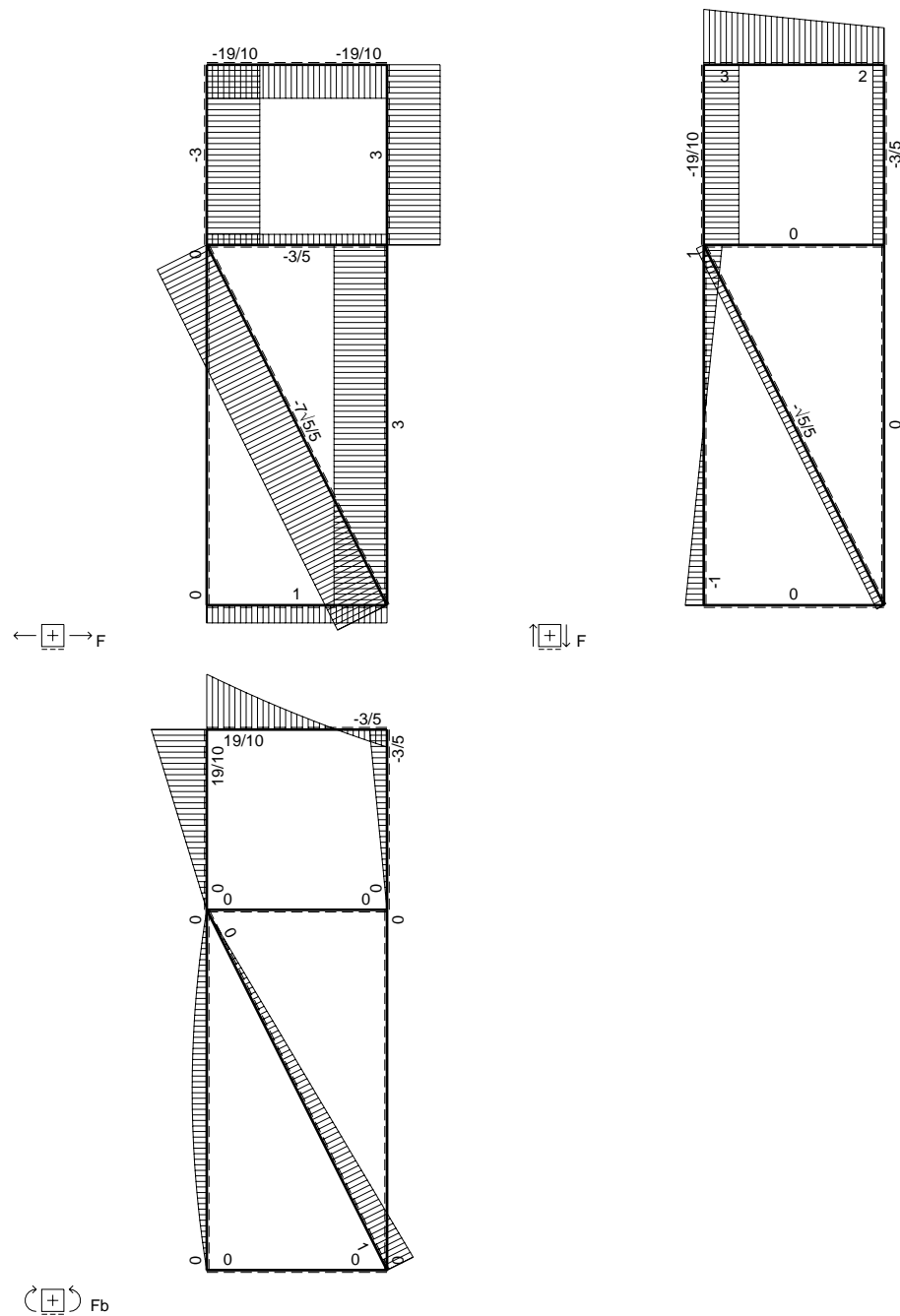
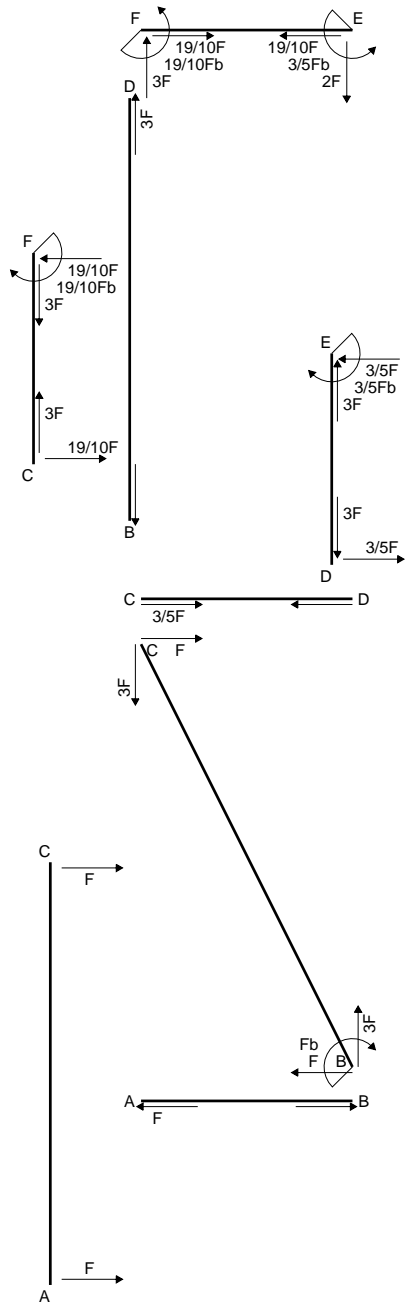
$$\sigma_c = N/A - Mv/J_u = -127.8 \text{ N/mm}^2$$

$$\tau_c = 1.671 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 127.8 \text{ N/mm}^2$$

$$S = 4253. \text{ mm}^3$$







$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-2x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-b - 1/6 b) Fb 1/EJ + (b) \theta = -1/6 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-5/2 + 3x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx$$

$$= [-5/2 x + 3/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

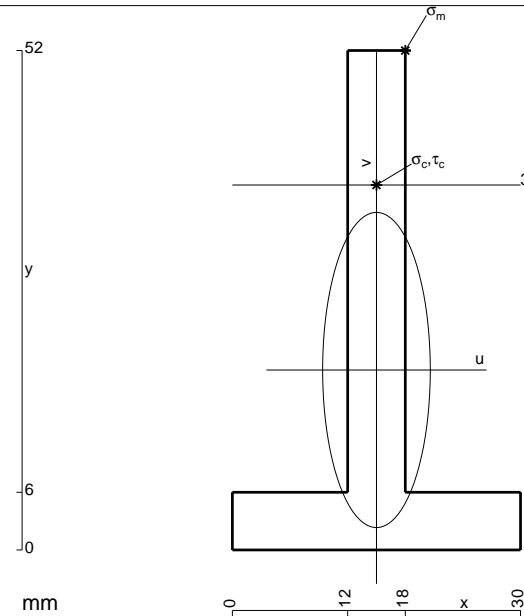
$$= (-5/2 b + 3/2 b - 1/6 b) Fb 1/EJ + (-b) \theta = -1/6 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = [-5/2 x + 5/2 x^2/b - 5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

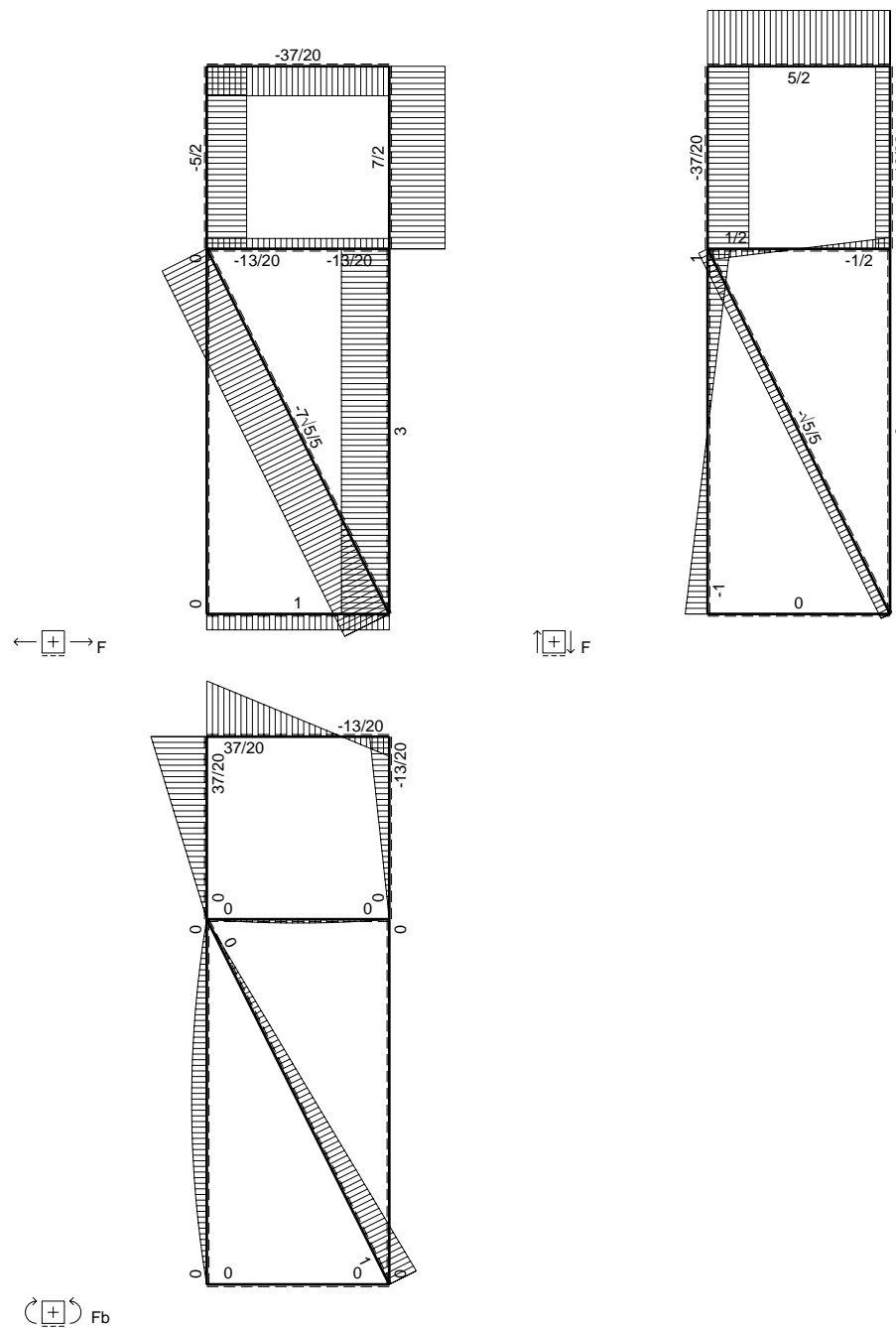
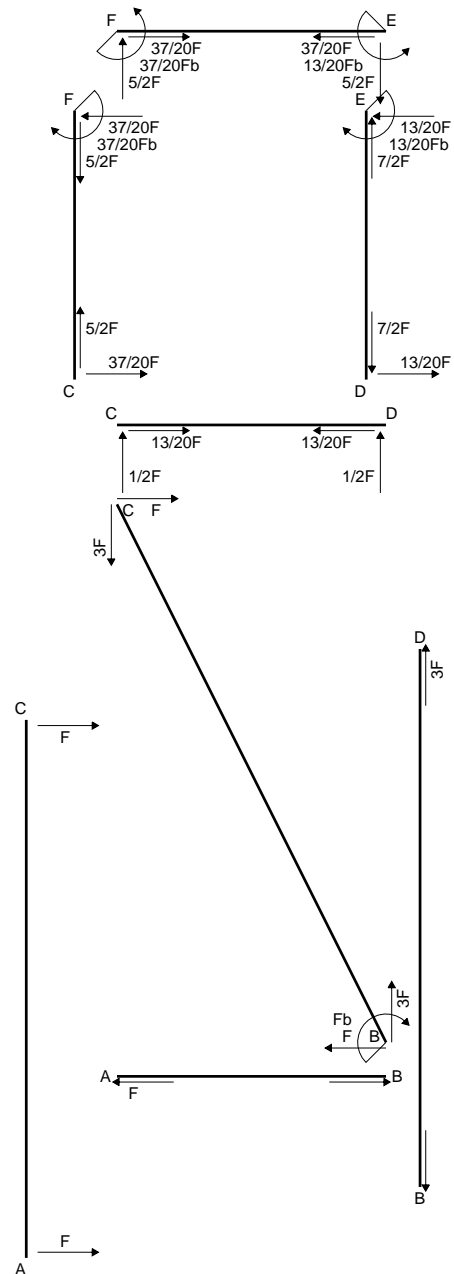
$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$



- 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 = -3851. N
- T<sub>y</sub> = -550.1 N
- M<sub>x</sub> = 811800. 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> = -228.2 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> = -135.7 N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.646 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup>+3τ<sup>2</sup>) = 135.8 N/mm<sup>2</sup>
- S = 2206. mm<sup>3</sup>









$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = \left[ \frac{1}{3} x^3/b^2 \right]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = \left[ x \right]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = \left[ x \right]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = \left[ \frac{1}{3} x^3/b^2 \right]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-5/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = \left[ -5/4 x^2/b \right]_0^b Fb 1/EJ + \left[ x \right]_0^b \theta$$

$$= (-5/4 b) Fb 1/EJ + (b) \theta = -1/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-5/2 + 5/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = \left[ -5/2 x + 5/4 x^2/b \right]_0^b Fb 1/EJ + \left[ -x \right]_0^b \theta$$

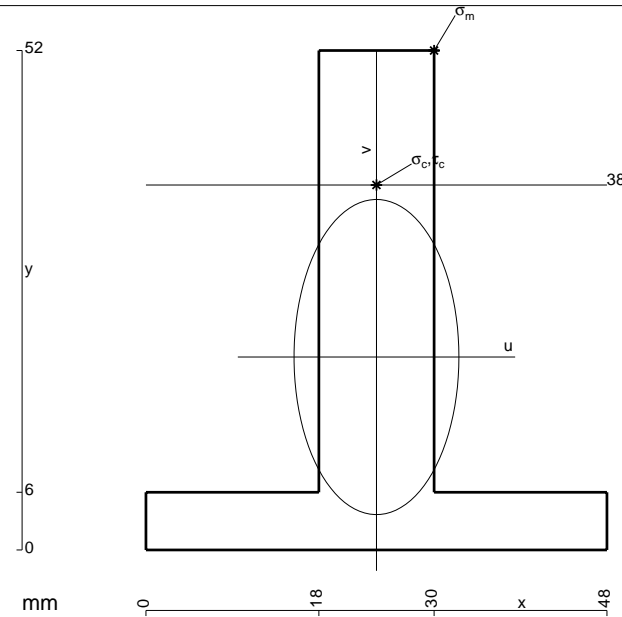
$$= (-5/2 b + 5/4 b) Fb 1/EJ + (-b) \theta = -1/4 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = \left[ -5/2 x + 5/2 x^2/b - 5/6 x^3/b^2 \right]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = \left[ -5/6 x^3/b^2 \right]_0^b Fb 1/EJ$$

$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$



$$A = 840. \text{ mm}^2$$

$$J_u = 226138. \text{ mm}^4$$

$$J_v = 61920. \text{ mm}^4$$

$$y_g = 20.09 \text{ mm}$$

$$N = -7325. \text{ N}$$

$$T_y = -1046. \text{ N}$$

$$M_x = 1638000. \text{ Nmm}$$

$$x_m = 30. \text{ mm}$$

$$y_m = 52. \text{ mm}$$

$$u_m = 6. \text{ mm}$$

$$v_m = 31.91 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -239.9 \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 38. \text{ mm}$$

$$v_c = 17.91 \text{ mm}$$

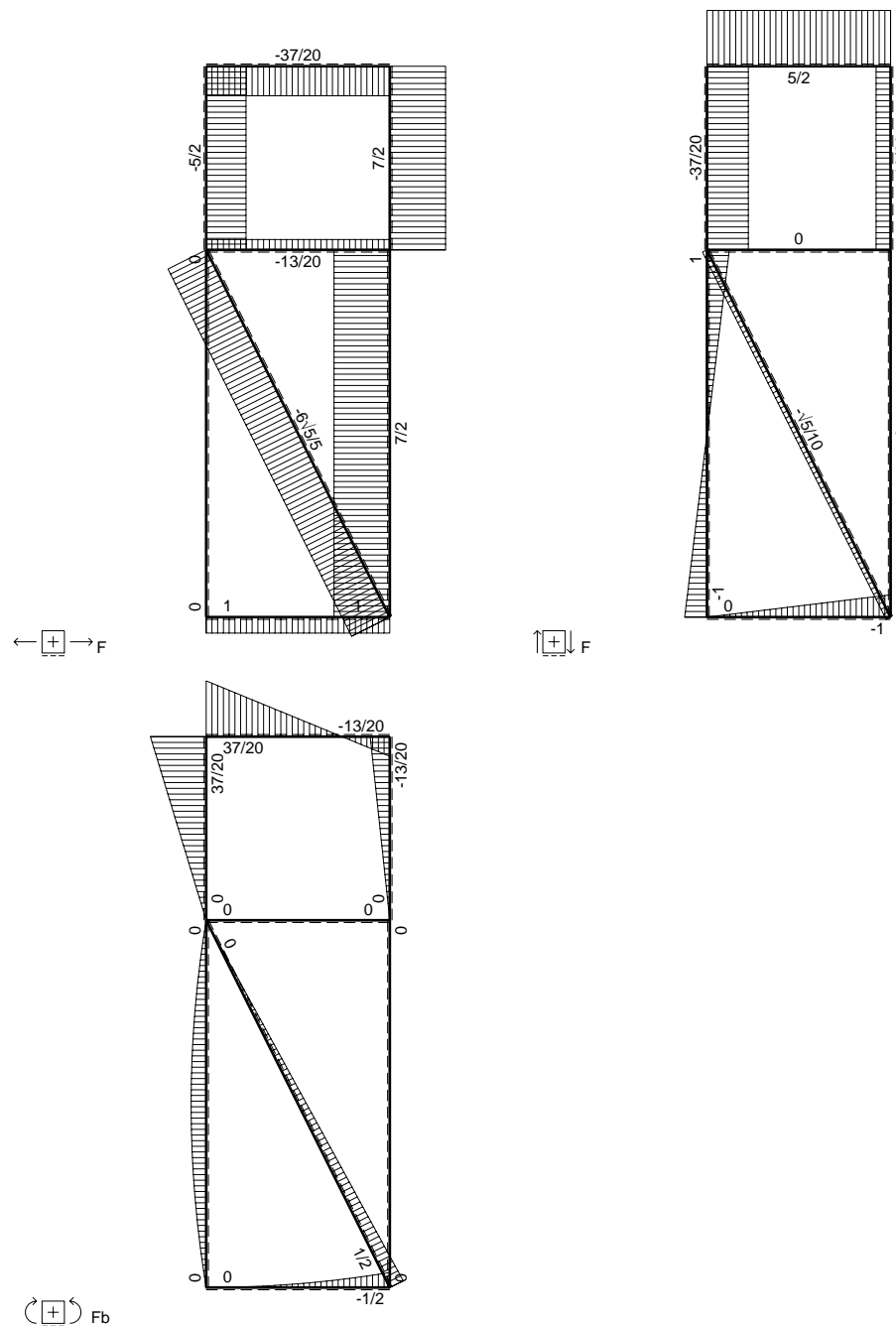
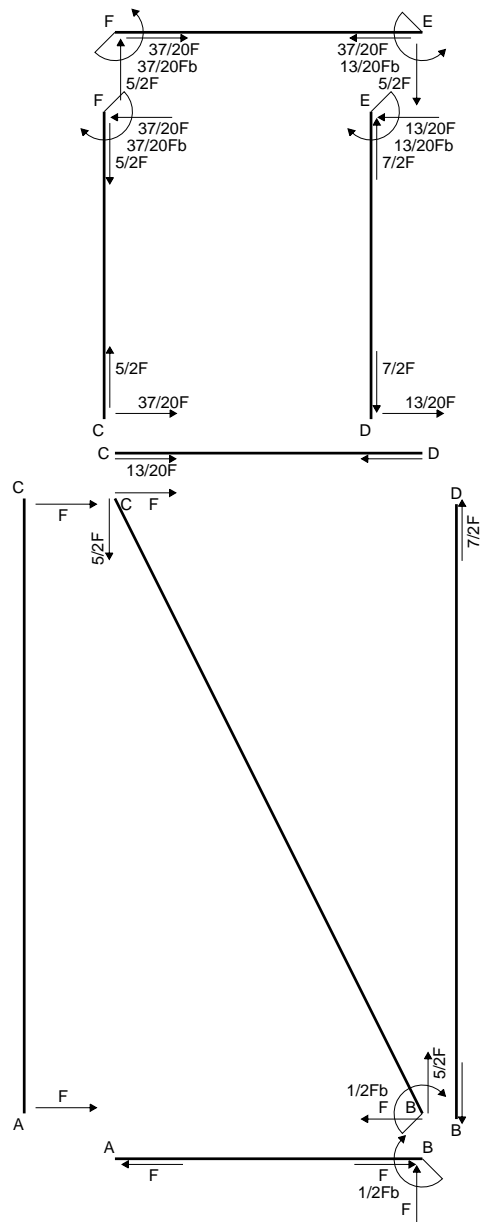
$$\sigma_c = N/A - Mv/J_u = -138.5 \text{ N/mm}^2$$

$$\tau_c = 1.614 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 138.5 \text{ N/mm}^2$$

$$S = 4186. \text{ mm}^3$$







$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{x_0} = \int_0^b (-5/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-5/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-5/4 b) Fb 1/EJ + (b) \theta = -1/4 Fb^2/EJ$$

$$L_{FE}^{x_0} = \int_0^b (-5/2 + 5/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-5/2 x + 5/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

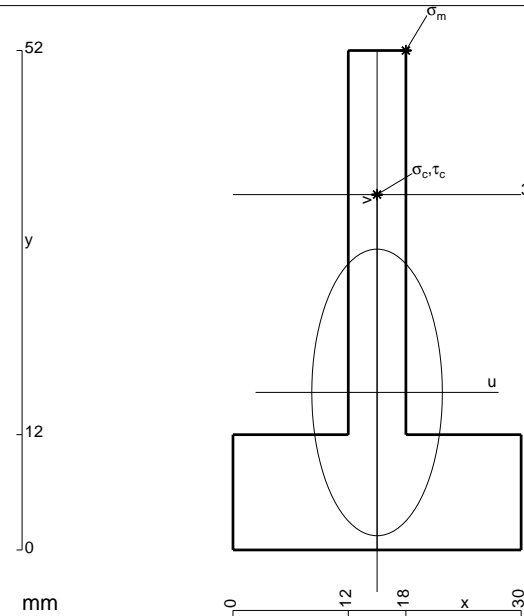
$$= (-5/2 b + 5/4 b) Fb 1/EJ + (-b) \theta = -1/4 Fb^2/EJ$$

$$L_{FC}^{x_0} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = [-5/2 x + 5/2 x^2/b - 5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

$$L_{CF}^{x_0} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$



$$A = 600. \text{ mm}^2$$

$$J_u = 133664. \text{ mm}^4$$

$$J_v = 27720. \text{ mm}^4$$

$$y_g = 16.4 \text{ mm}$$

$$N = 3920. \text{ N}$$

$$T_y = -3920. \text{ N}$$

$$M_x = -725200. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$y_m = 52. \text{ mm}$$

$$u_m = 3. \text{ mm}$$

$$v_m = 35.6 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 199.7 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 37. \text{ mm}$$

$$v_c = 20.6 \text{ mm}$$

$$\sigma_c = N/A - Mv/J_u = 118.3 \text{ N/mm}^2$$

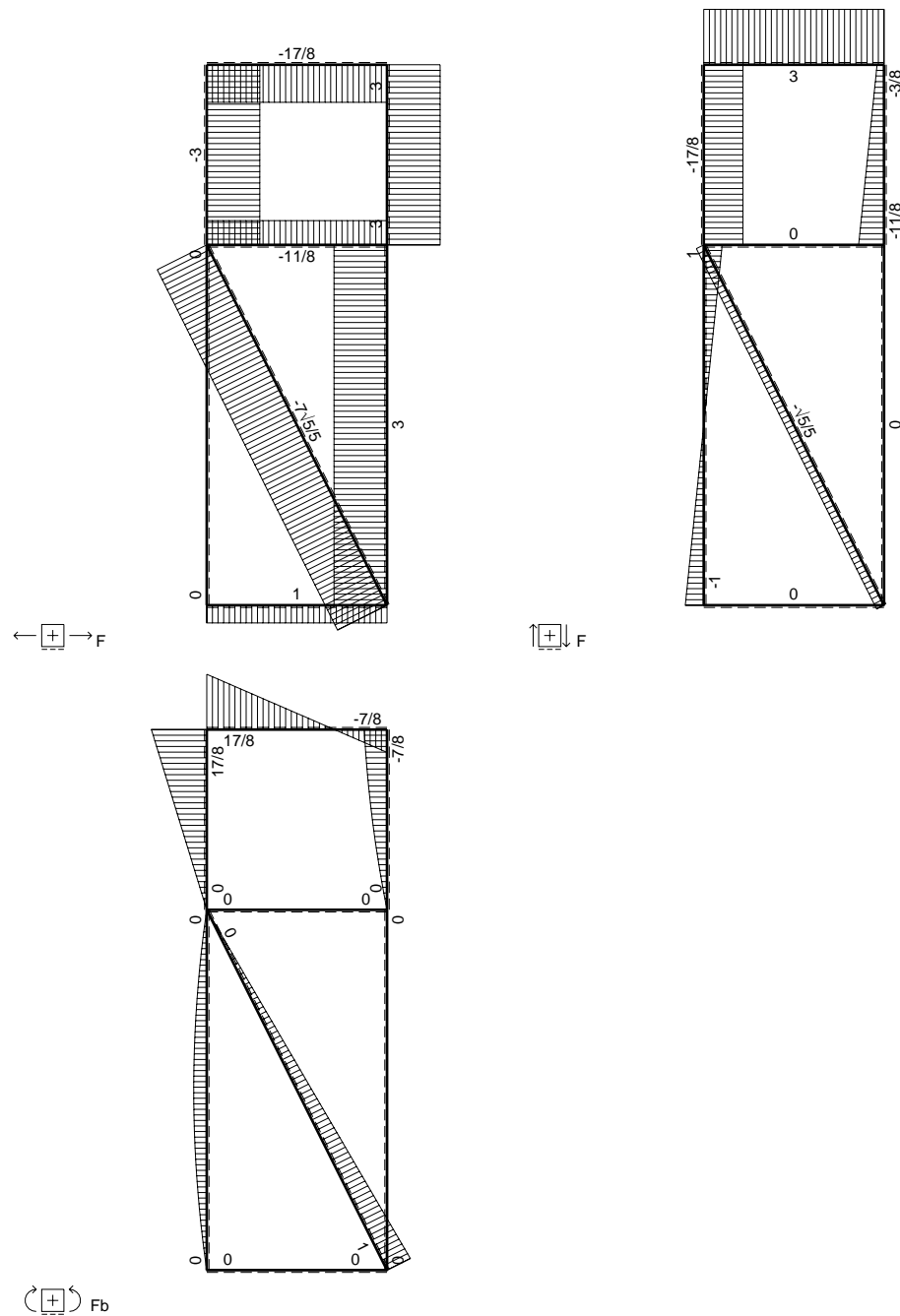
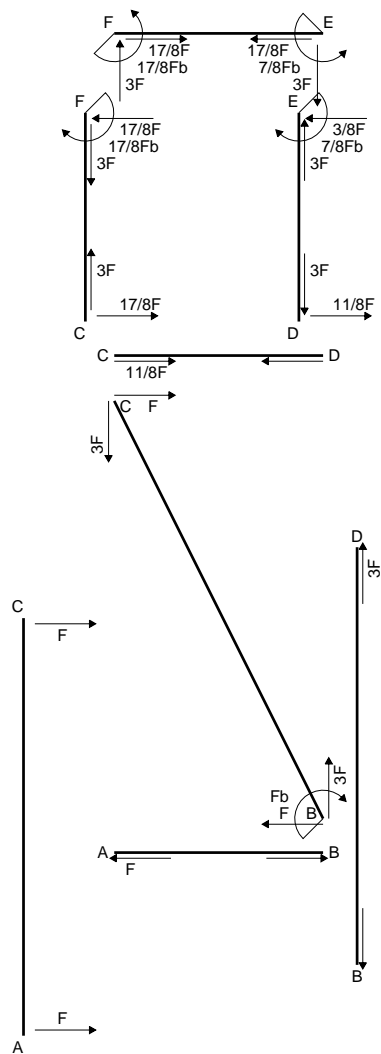
$$\tau_c = 12.36 \text{ N/mm}^2$$

$$\sigma_\varrho = \sqrt{\sigma^2 + 3\tau^2} = 120.2 \text{ N/mm}^2$$

$$S = 2529. \text{ mm}^3$$









$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-3x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-3/2 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-3/2 b) Fb 1/EJ + (b) \theta = -1/2 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-3 + 3x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-3x + 3/2 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

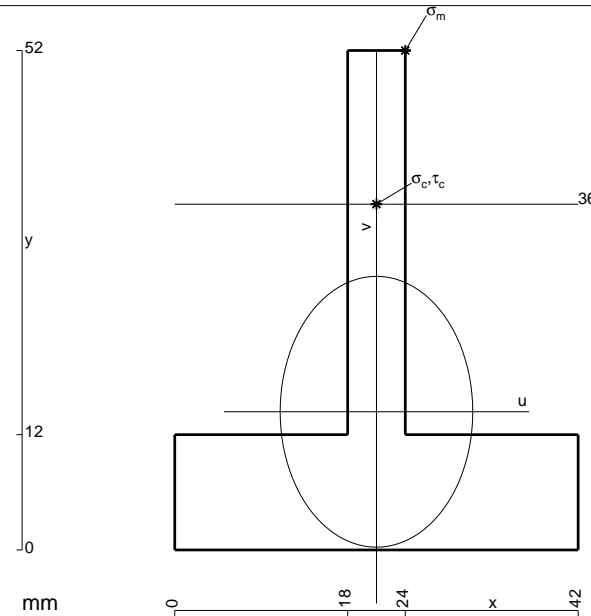
$$= (-3b + 3/2 b) Fb 1/EJ + (-b) \theta = -1/2 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-3 + 6x/b - 3x^2/b^2) Fb 1/EJ dx = [-3x + 3x^2/b - x^3/b^2]_0^b Fb 1/EJ$$

$$= (-3b + 3b - b) Fb 1/EJ = - Fb^2/EJ$$

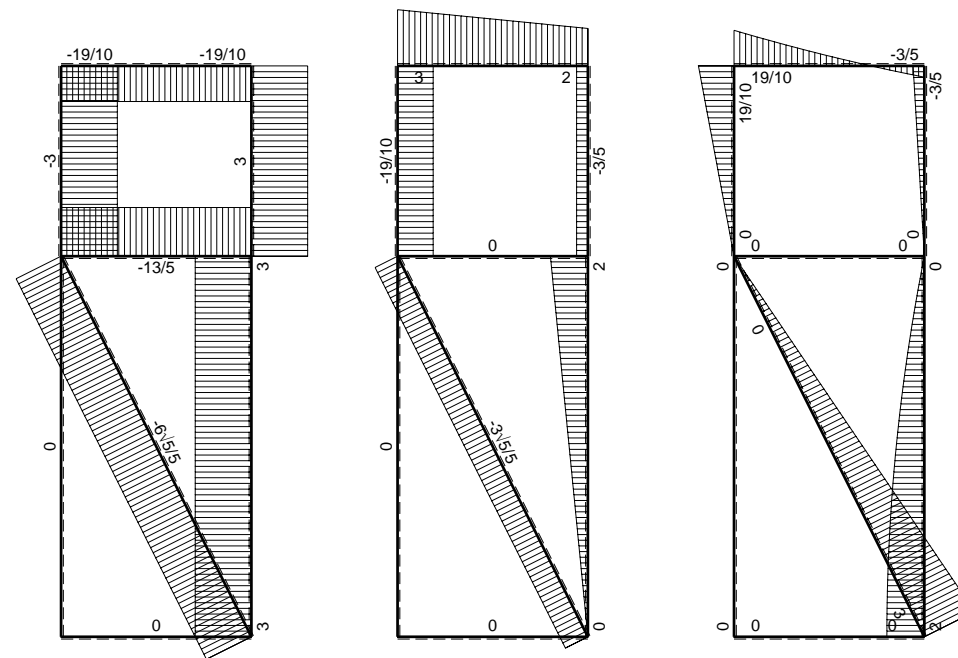
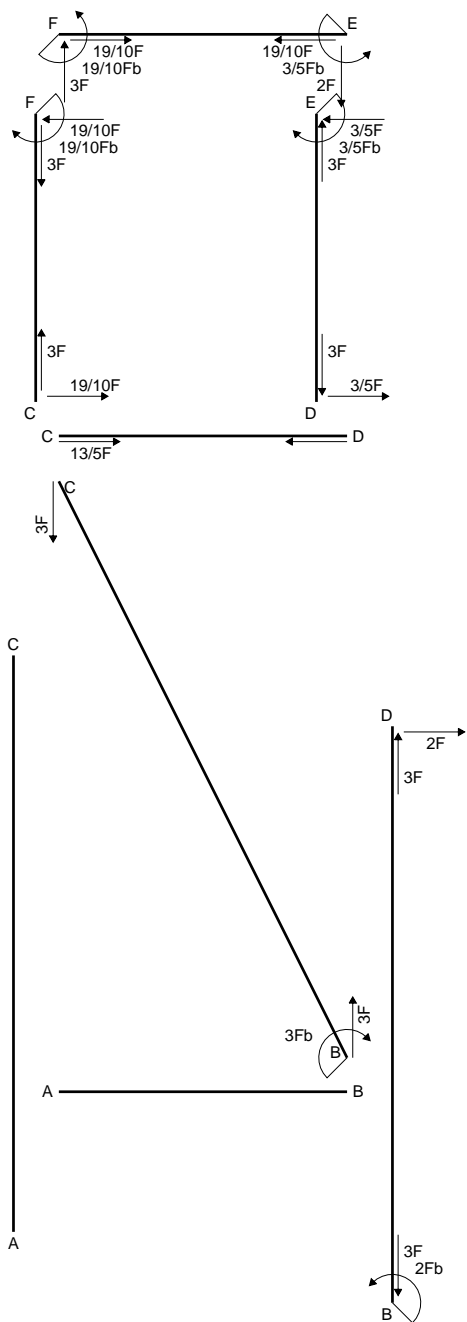
$$L_{CF}^{xo} = \int_0^b (-3x^2/b^2) Fb 1/EJ dx = [-x^3/b^2]_0^b Fb 1/EJ$$

$$= (-b) Fb 1/EJ = - Fb^2/EJ$$



- A = 744. mm<sup>2</sup>
- J<sub>u</sub> = 147953. mm<sup>4</sup>
- J<sub>v</sub> = 74808. mm<sup>4</sup>
- y<sub>g</sub> = 14.39 mm
- N = -6198. N
- T<sub>y</sub> = -885.5 N
- M<sub>x</sub> = 792000. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 52. mm
- u<sub>m</sub> = 3. mm
- v<sub>m</sub> = 37.61 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = -209.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 36. mm
- v<sub>c</sub> = 21.61 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = -124. N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.836 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup>+3τ<sup>2</sup>) = 124.1 N/mm<sup>2</sup>
- S = 2843. mm<sup>3</sup>





← ⊕ → F

↑ ⊕ ↓ F

⊕ ⊖ F<sub>b</sub>



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-2x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-b - 1/6 b) Fb 1/EJ + (b) \theta = -1/6 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-5/2 + 3x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx$$

$$= [-5/2 x + 3/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

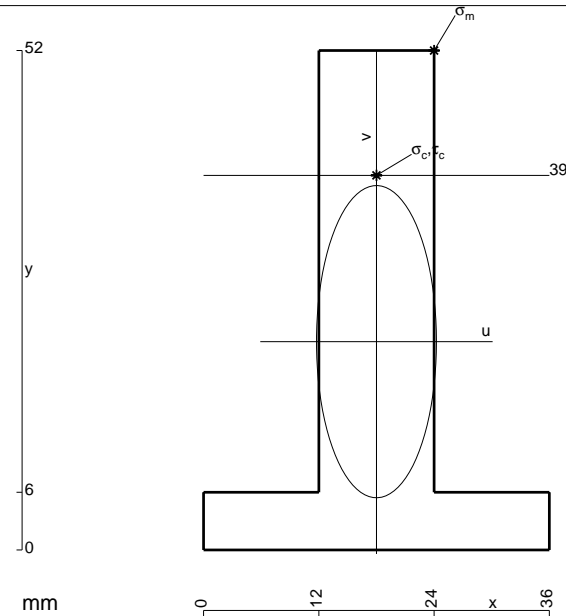
$$= (-5/2 b + 3/2 b - 1/6 b) Fb 1/EJ + (-b) \theta = -1/6 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = [-5/2 x + 5/2 x^2/b - 5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

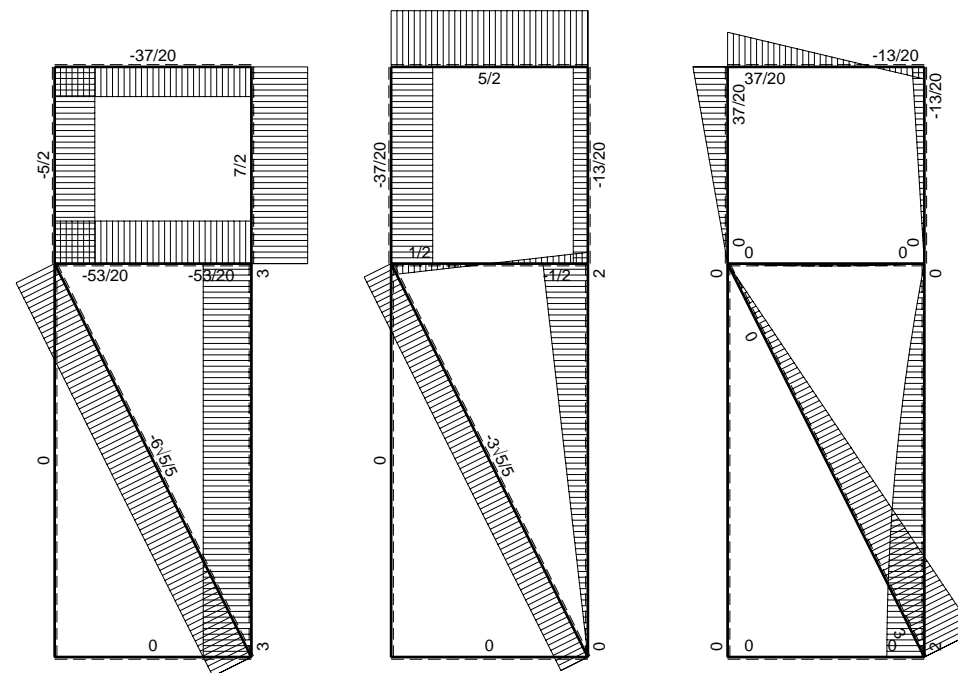
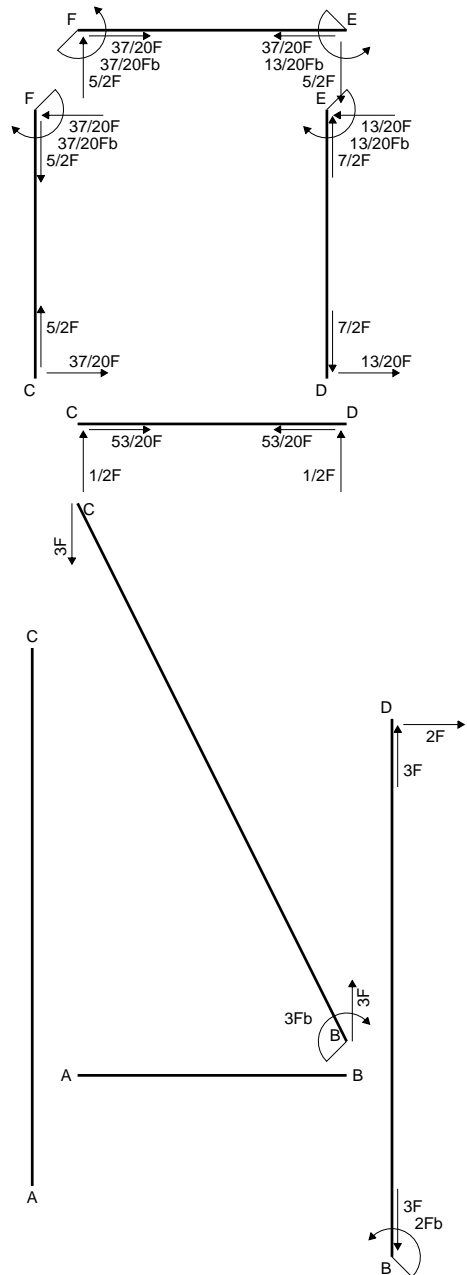
$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$



- A = 768. mm<sup>2</sup>
- J<sub>u</sub> = 202933. mm<sup>4</sup>
- J<sub>v</sub> = 29952. mm<sup>4</sup>
- y<sub>g</sub> = 21.69 mm
- N = -2925. N
- T<sub>y</sub> = -1462. N
- M<sub>x</sub> = 1438800. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 52. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 30.31 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = -218.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 39. mm
- v<sub>c</sub> = 17.31 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = -126.6 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.231 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 126.6 N/mm<sup>2</sup>
- S = 3715. mm<sup>3</sup>







← ⊕ → F

↑ ⊕ ↓ F

⊕ ⊖ F<sub>b</sub>



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = \left[ \frac{1}{3} x^3/b^2 \right]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = \left[ x \right]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = \left[ x \right]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = \left[ \frac{1}{3} x^3/b^2 \right]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{x\theta} = \int_0^b (-5/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = \left[ -5/4 x^2/b \right]_0^b Fb 1/EJ + \left[ x \right]_0^b \theta$$

$$= (-5/4 b) Fb 1/EJ + (b) \theta = -1/4 Fb^2/EJ$$

$$L_{FE}^{x\theta} = \int_0^b (-5/2 + 5/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = \left[ -5/2 x + 5/4 x^2/b \right]_0^b Fb 1/EJ + \left[ -x \right]_0^b \theta$$

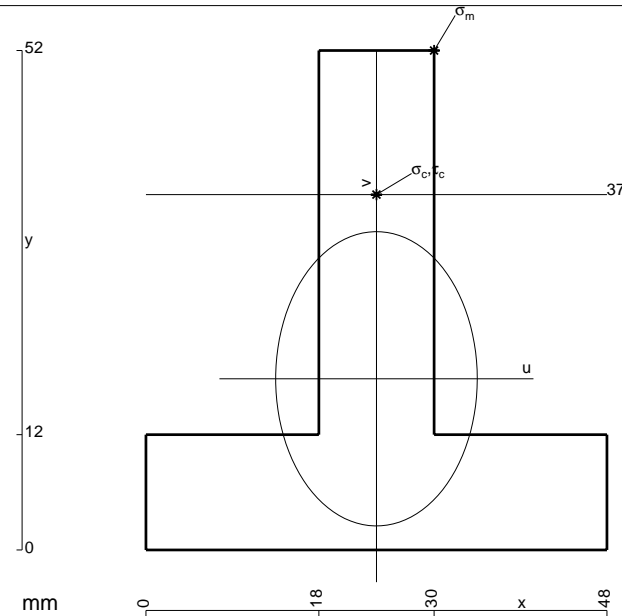
$$= (-5/2 b + 5/4 b) Fb 1/EJ + (-b) \theta = -1/4 Fb^2/EJ$$

$$L_{FC}^{x\theta} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = \left[ -5/2 x + 5/2 x^2/b - 5/6 x^3/b^2 \right]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

$$L_{CF}^{x\theta} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = \left[ -5/6 x^3/b^2 \right]_0^b Fb 1/EJ$$

$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$



$$A = 1056. \text{ mm}^2$$

$$J_u = 247901. \text{ mm}^4$$

$$J_v = 116352. \text{ mm}^4$$

$$y_g = 17.82 \text{ mm}$$

$$N = -3059. \text{ N}$$

$$T_y = -1529. \text{ N}$$

$$M_x = 1641600. \text{ Nmm}$$

$$x_m = 30. \text{ mm}$$

$$y_m = 52. \text{ mm}$$

$$u_m = 6. \text{ mm}$$

$$v_m = 34.18 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -229.2 \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 37. \text{ mm}$$

$$v_c = 19.18 \text{ mm}$$

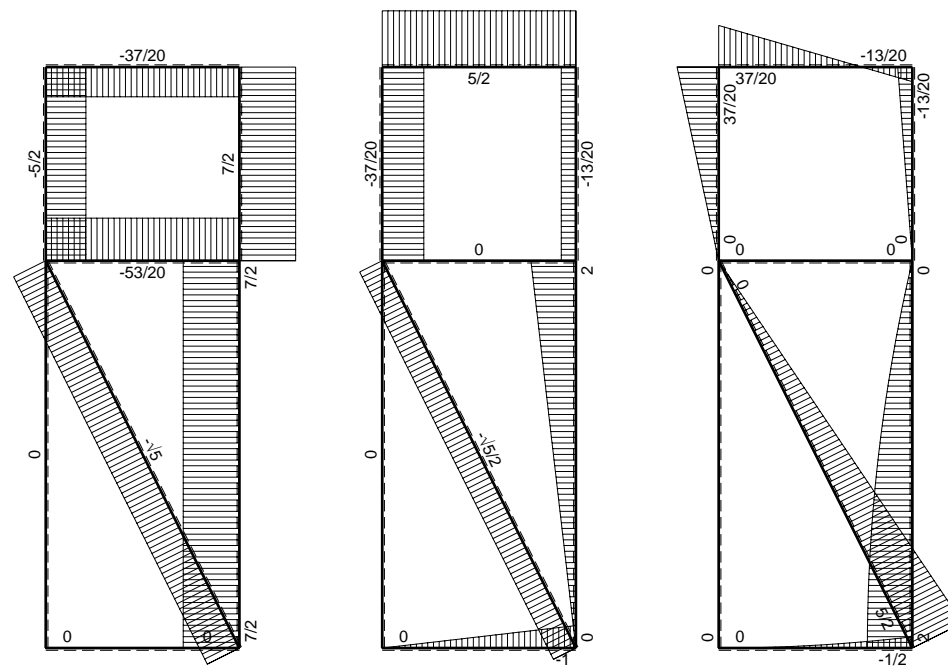
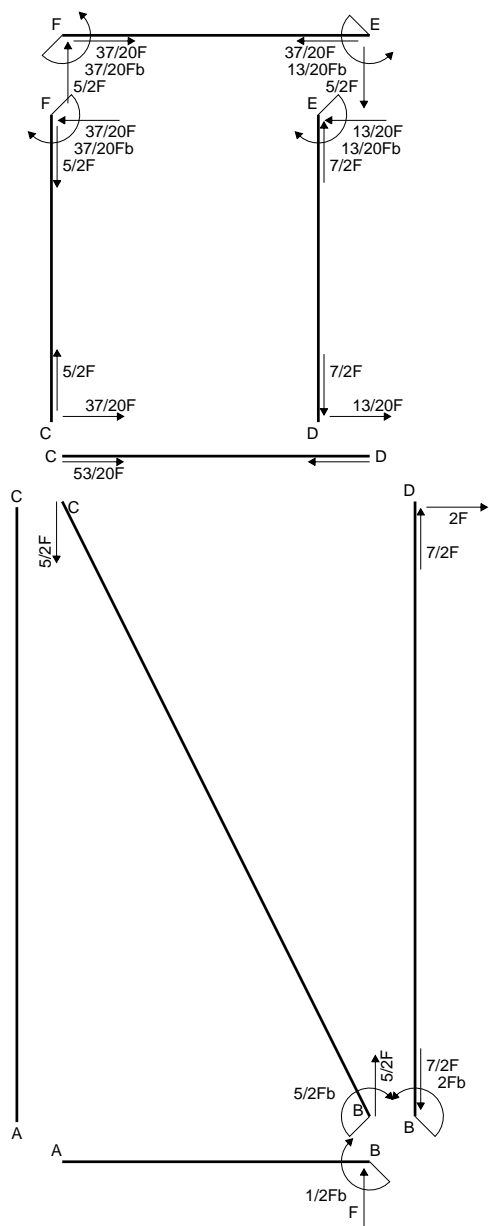
$$\sigma_c = N/A - Mv/J_u = -129.9 \text{ N/mm}^2$$

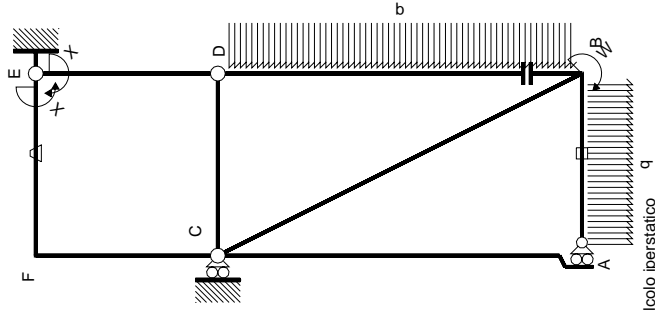
$$\tau_c = 2.469 \text{ N/mm}^2$$

$$\sigma_\varrho = \sqrt{\sigma^2 + 3\tau^2} = 130. \text{ N/mm}^2$$

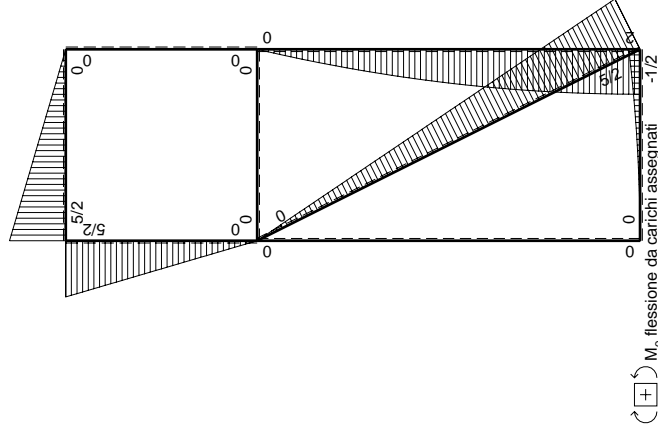
$$S = 4803. \text{ mm}^3$$





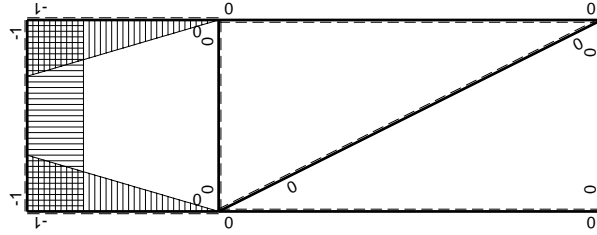


Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati

$M_x$  flessione da iperstatica  $X=1$



Quadro contributi PLV per iperstatica  $X=W_{EP}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	0	$-1/2qx^2$	0	0	0	0	0	0
BA b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$5/2Fb-\sqrt{5}2Fx$	0	0	0	0	0	0
CA 2b	0	0	0	0	0	0	0	0
DB 2b	0	$2Fx-1/2qx^2$	0	0	0	0	0	0
BD 2b	0	$-2Fb+1/2qx^2$	0	0	0	0	0	0
DE b	$-x/b$	0	0	0	0	$x^2/b^2$	0	0
ED b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0	$1/3xb/EJ$
CD b	0	0	0	0	0	0	0	0
DC b	0	0	0	0	0	0	0	0
EF b	-1	$5/2Fx$	$-Fb/EJ$	$-5/2Fx$	$Fb/EJ$	1	$(-5/4+1)Fb^2/EJ$	$xb/EJ$
FE b	1	$-5/2Fb+5/2Fx$	$Fb/EJ$	$-5/2Fb+5/2Fx$	$Fb/EJ$	1	$(-5/4+1)Fb^2/EJ$	$xb/EJ$
FC b	$-1+x/b$	$5/2Fb-5/2Fx$	0	$-5/2Fb+5Fx-5/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-5/6+0)Fb^2/EJ$	$1/3xb/EJ$
CF b	$x/b$	$-5/2Fx$	0	$-5/2Fx^2/b$	0	$x^2/b^2$	$-13/12Fb^2/EJ$	$5/3xb/EJ$
totali								
iperstatica $X=W_{EP}$								

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-5/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-5/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-5/4 b) Fb 1/EJ + (b) \theta = -1/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-5/2 + 5/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-5/2 x + 5/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

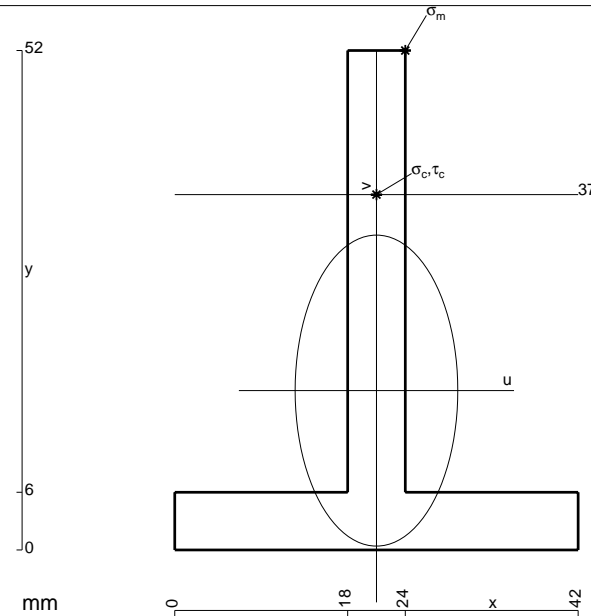
$$= (-5/2 b + 5/4 b) Fb 1/EJ + (-b) \theta = -1/4 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = [-5/2 x + 5/2 x^2/b - 5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

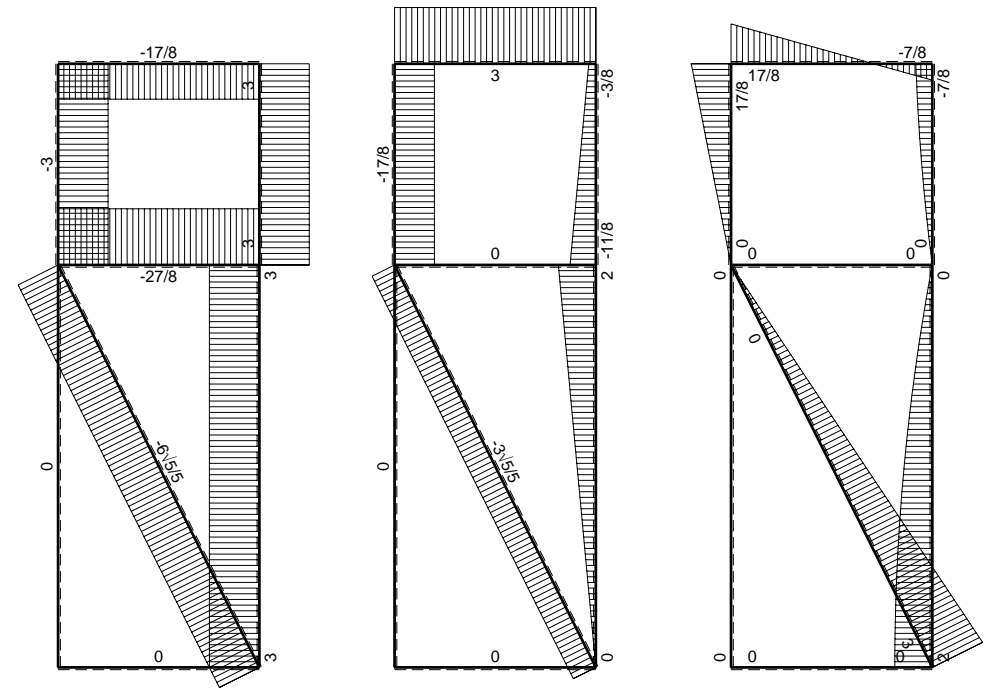
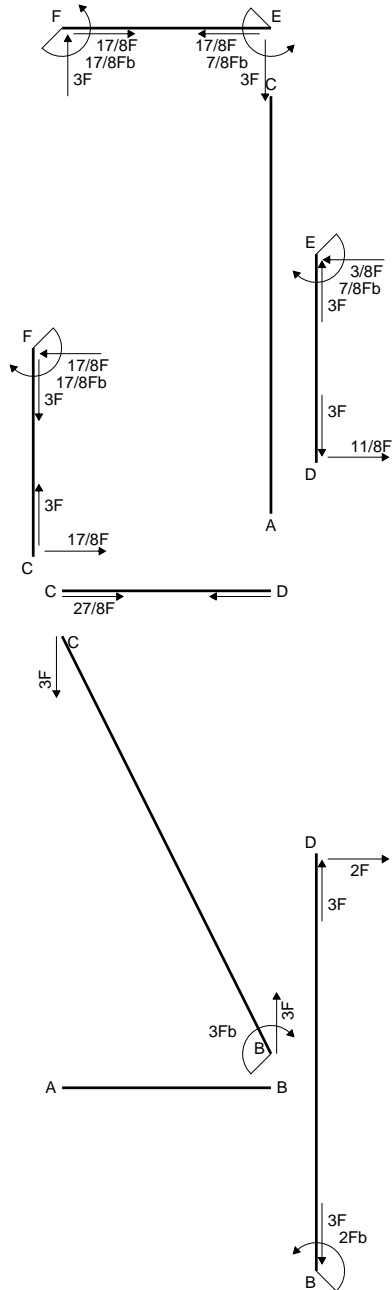
$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$



- 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
- N = -1610. N
- T<sub>y</sub> = -805. N
- M<sub>x</sub> = 918000. 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> = N/A-Mv/J<sub>u</sub> = -237.8 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> = N/A-Mv/J<sub>u</sub> = -138.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.434 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 138.4 N/mm<sup>2</sup>
- S = 2512. mm<sup>3</sup>



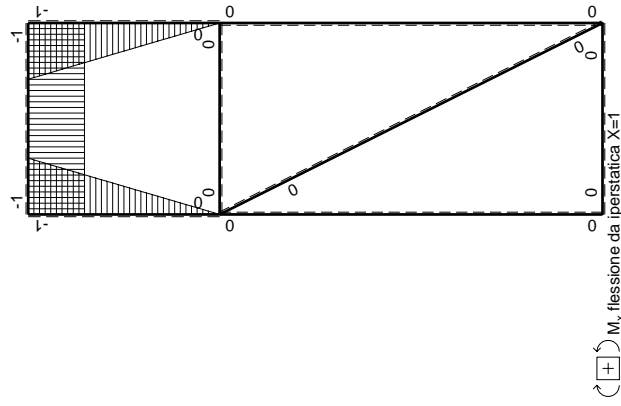
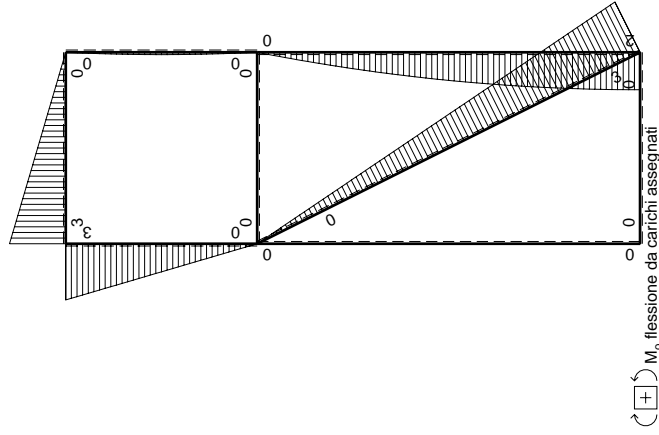
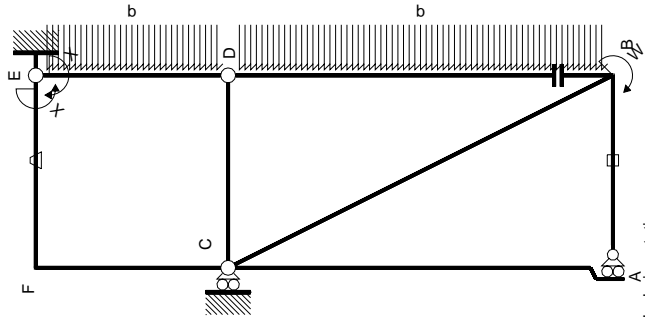




← ⊕ → F

↑ ⊕ ↓ F

⊕ ⊖ F<sub>b</sub>



Quadro contributi PLV per iperstatica  $X=W_{EF}$

$\leftarrow$	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x(M_0/EJ+\theta)dx$	$\int M^x M_x/EJdx$
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$3Fb-3\sqrt{5}/5Fx$	0	0	0	0	0+0	0
AC 2b	0	0	0	0	0	0	0+0	0
CA 2b	0	0	0	0	0	0	0+0	0
DB 2b	0	$2Fx-1/2qx^2$	0	0	0	0	0+0	0
BD 2b	0	$-2Fb+1/2qx^2$	0	0	0	0	0+0	0
DE b	$-x/b$	$-1/2Fx+1/2qx^2$	0	$1/2Fx^2/b-1/2qx^3/b$	0	0	$x^2/b^2$	$1/3xb/EJ$
ED b	$1-x/b$	$1/2Fx-1/2qx^2$	0	$1/2Fx-Fx^2/b+1/2qx^3/b$	0	0	$1-2x/b+x^2/b^2$	$1/3xb/EJ$
CD b	0	0	0	0	0	0	0+0	0
DC b	0	0	0	0	0	0	0+0	0
EF b	-1	$3Fx$	$-Fb/EJ$	$-3Fx$	$Fb/EJ$	1	$(-3/2+1)Fb^2/EJ$	$xb/EJ$
FE b	1	$-3Fb+3Fx$	$Fb/EJ$	$-3Fb+3Fx$	$Fb/EJ$	1	$(-3/2+1)Fb^2/EJ$	$xb/EJ$
FC b	$-1+x/b$	$3Fb-3Fx$	0	$-3Fb+6Fx-3Fx^2/b$	0	0	$1-2x/b+x^2/b^2$	$1/3xb/EJ$
CF b	$x/b$	$-3Fx$	0	$-3Fx^2/b$	0	0	$x^2/b^2$	$1/3xb/EJ$
totali							$-35/24Fb^2/EJ$	$5/3xb/EJ$
							$7/8Fb$	

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-3x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-3/2 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-3/2 b) Fb 1/EJ + (b) \theta = -1/2 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-3 + 3x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-3x + 3/2 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

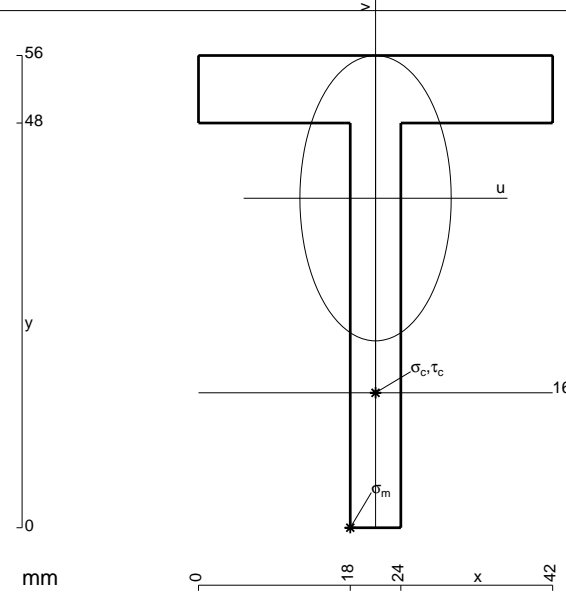
$$= (-3b + 3/2 b) Fb 1/EJ + (-b) \theta = -1/2 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-3 + 6x/b - 3x^2/b^2) Fb 1/EJ dx = [-3x + 3x^2/b - x^3/b^2]_0^b Fb 1/EJ$$

$$= (-3b + 3b - b) Fb 1/EJ = -Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-3x^2/b^2) Fb 1/EJ dx = [-x^3/b^2]_0^b Fb 1/EJ$$

$$= (-b) Fb 1/EJ = -Fb^2/EJ$$



$$A = 624. \text{ mm}^2$$

$$J_u = 178668. \text{ mm}^4$$

$$J_v = 50256. \text{ mm}^4$$

$$y_g = 39.08 \text{ mm}$$

$$N = -1422. \text{ N}$$

$$T_y = -711.1 \text{ N}$$

$$M_x = 922200. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -39.08 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 199.4 \text{ N/mm}^2$$

$$x_c = 21. \text{ mm}$$

$$y_c = 16. \text{ mm}$$

$$v_c = -23.08 \text{ mm}$$

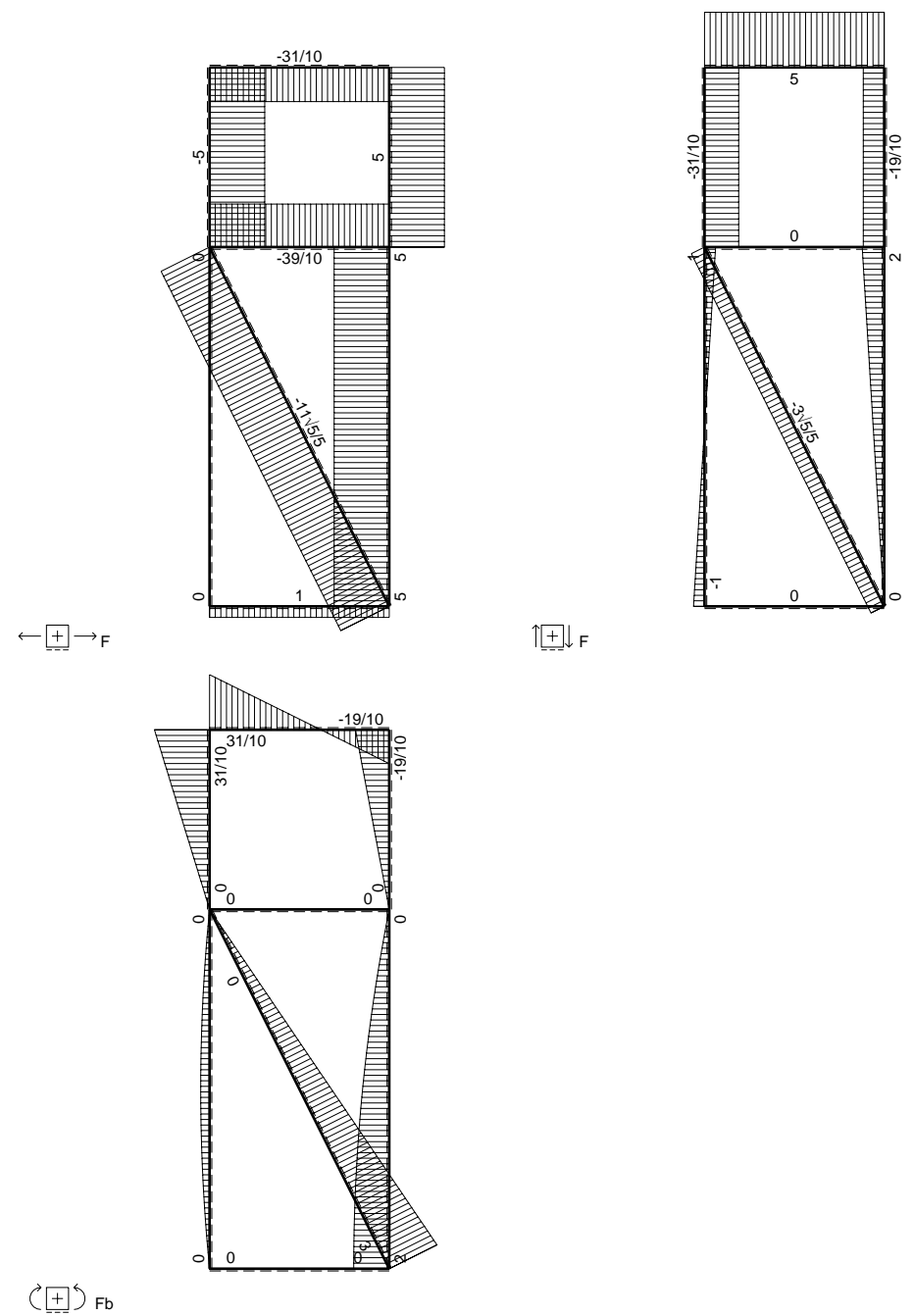
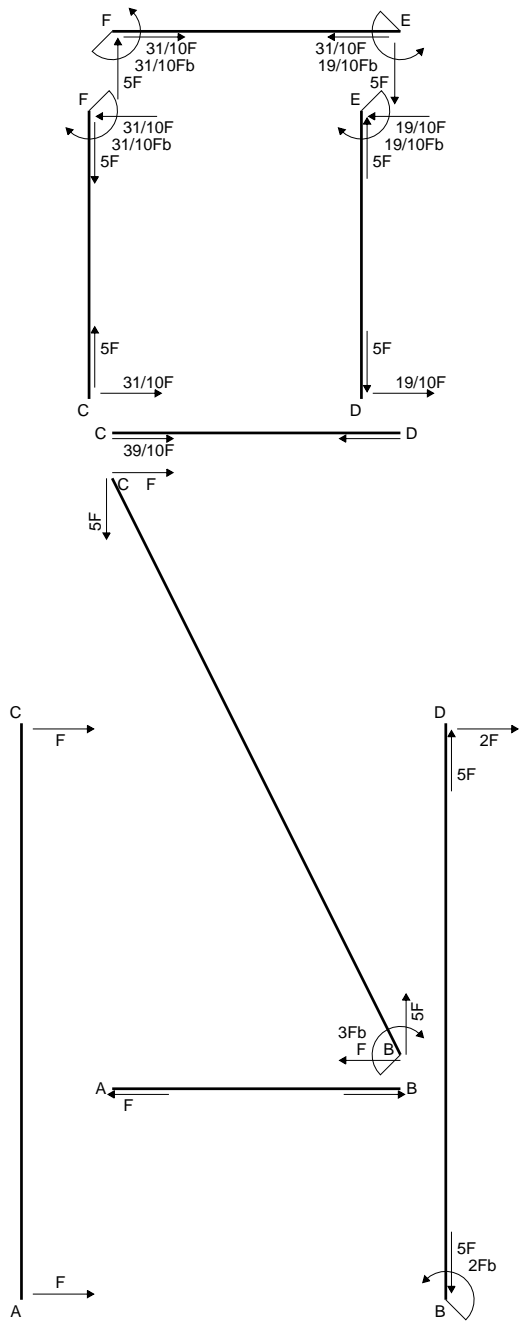
$$\sigma_c = N/A - Mv/J_u = 116.8 \text{ N/mm}^2$$

$$\tau_c = 1.979 \text{ N/mm}^2$$

$$\sigma_\varphi = \sqrt{\sigma^2 + 3\tau^2} = 116.9 \text{ N/mm}^2$$

$$S = 2983. \text{ mm}^3$$







$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-5x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-5/2 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-5/2 b) Fb 1/EJ + (b) \theta = -3/2 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-5 + 5x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-5x + 5/2 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

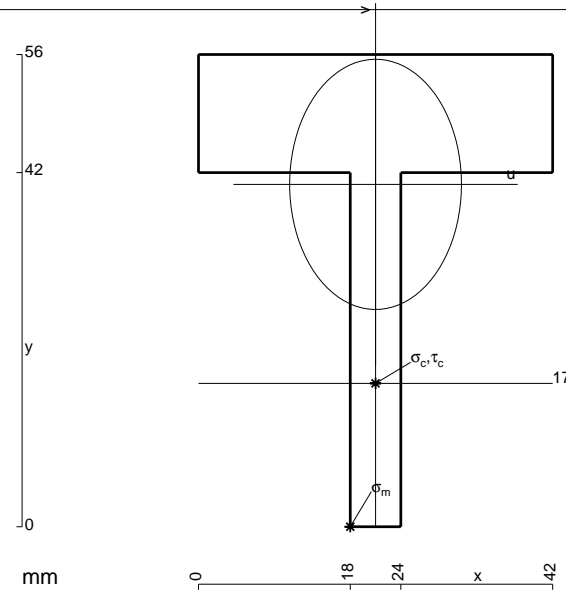
$$= (-5b + 5/2 b) Fb 1/EJ + (-b) \theta = -3/2 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-5 + 10x/b - 5x^2/b^2) Fb 1/EJ dx = [-5x + 5x^2/b - 5/3 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5b + 5b - 5/3 b) Fb 1/EJ = -5/3 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-5x^2/b^2) Fb 1/EJ dx = [-5/3 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/3 b) Fb 1/EJ = -5/3 Fb^2/EJ$$



$$A = 840. \text{ mm}^2$$

$$J_u = 184946. \text{ mm}^4$$

$$J_v = 87192. \text{ mm}^4$$

$$y_g = 40.6 \text{ mm}$$

$$N = -2558. \text{ N}$$

$$T_y = -697.7 \text{ N}$$

$$M_x = 967200. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -40.6 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 209.3 \text{ N/mm}^2$$

$$x_c = 21. \text{ mm}$$

$$y_c = 17. \text{ mm}$$

$$v_c = -23.6 \text{ mm}$$

$$\sigma_c = N/A - Mv/J_u = 120.4 \text{ N/mm}^2$$

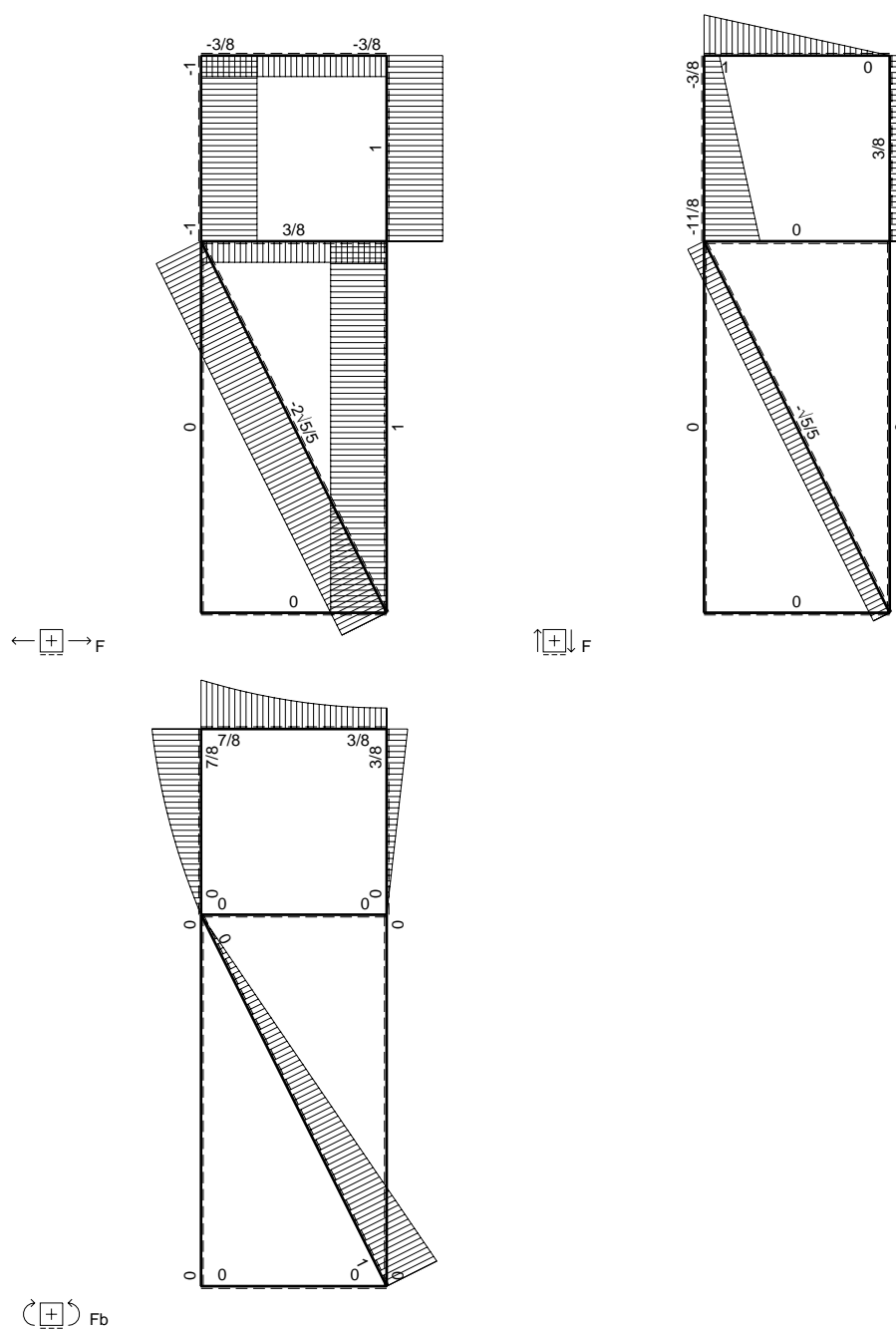
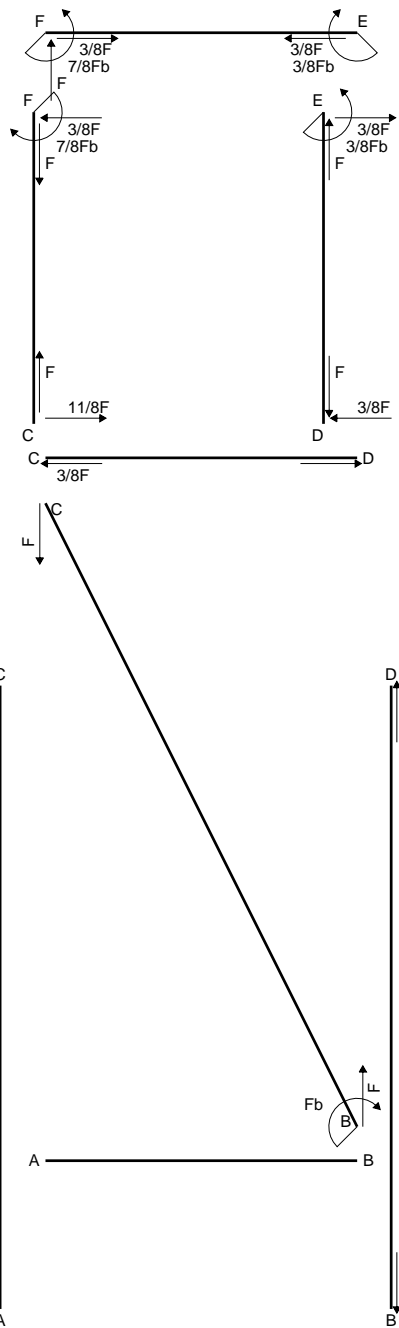
$$\tau_c = 2.058 \text{ N/mm}^2$$

$$\sigma_\varphi = \sqrt{\sigma^2 + 3\tau^2} = 120.4 \text{ N/mm}^2$$

$$S = 3274. \text{ mm}^3$$









$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/6 b) Fb 1/EJ + (b) \theta = 5/6 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx$$

$$= [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ + (-b) \theta = 5/6 Fb^2/EJ$$

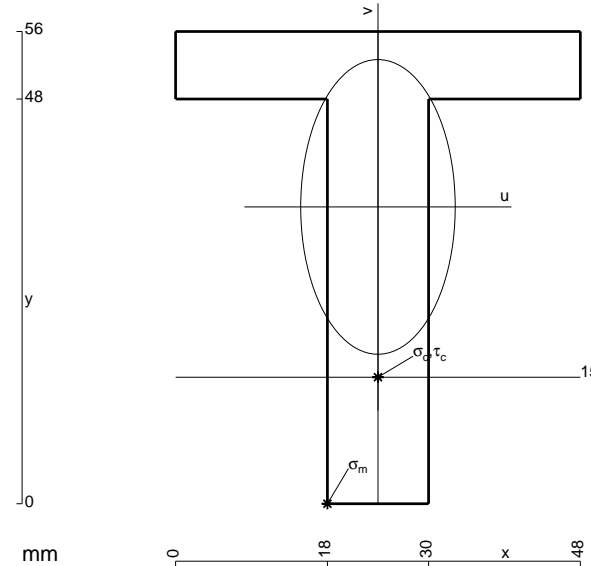
$$L_{FC}^{xo} = \int_0^b (-1/2 + 1/2 x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx$$

$$= [-1/2 x + 1/4 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/4 b + 1/6 b - 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$

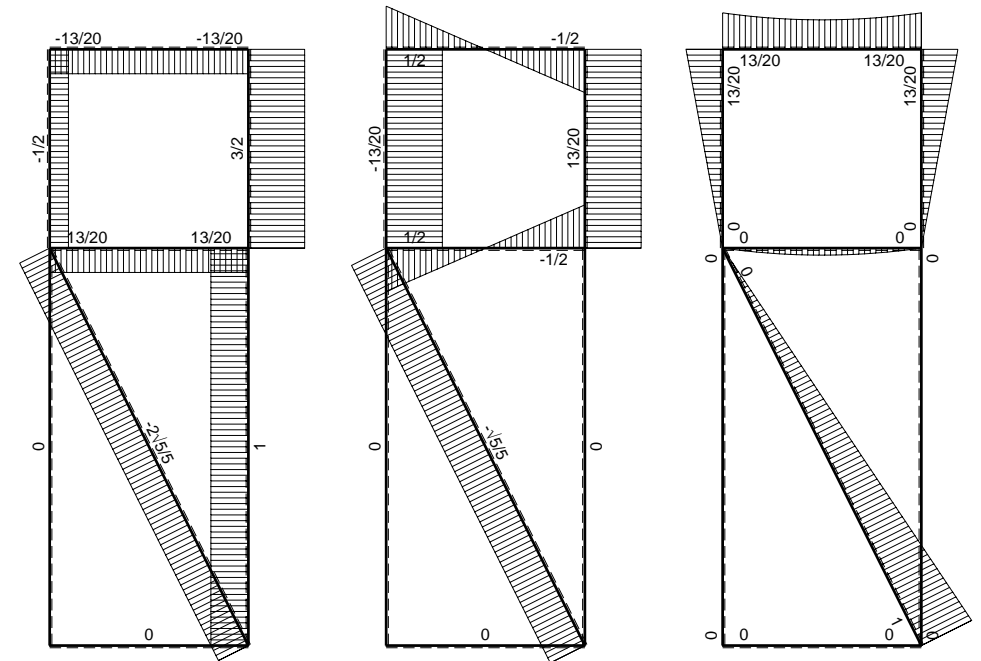
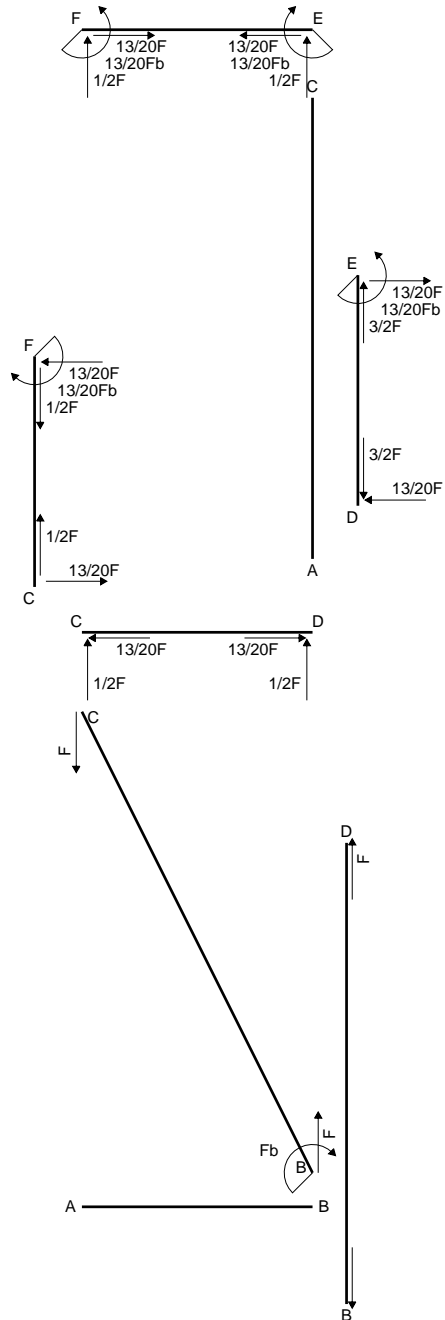
$$L_{CF}^{xo} = \int_0^b (-x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/3 b + 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$



- 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
- N = -2513. N
- T<sub>y</sub> = -1257. N
- M<sub>x</sub> = 1854600. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -35.2 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = 220. 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> = N/A - Mv/J<sub>u</sub> = 125.1 N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.78 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 = 4986. mm<sup>3</sup>





← ⊕ → F

↑ ⊕ ↓ F

⊕ ⊖ F<sub>b</sub>



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

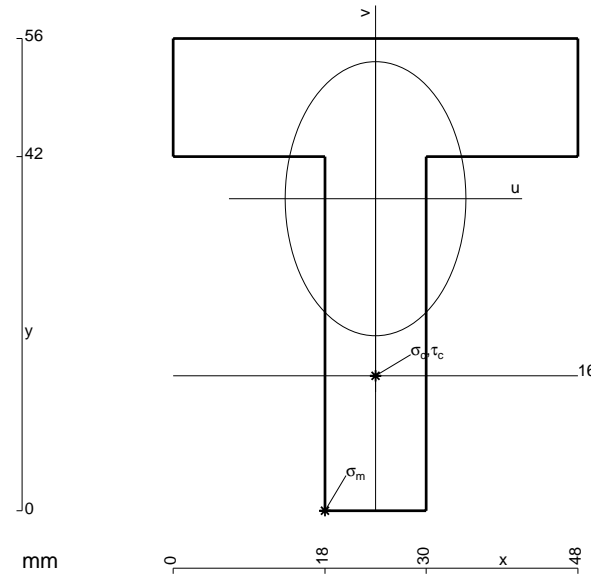
$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (1/4 b - 1/6 b) Fb 1/EJ + (b) \theta = 13/12 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

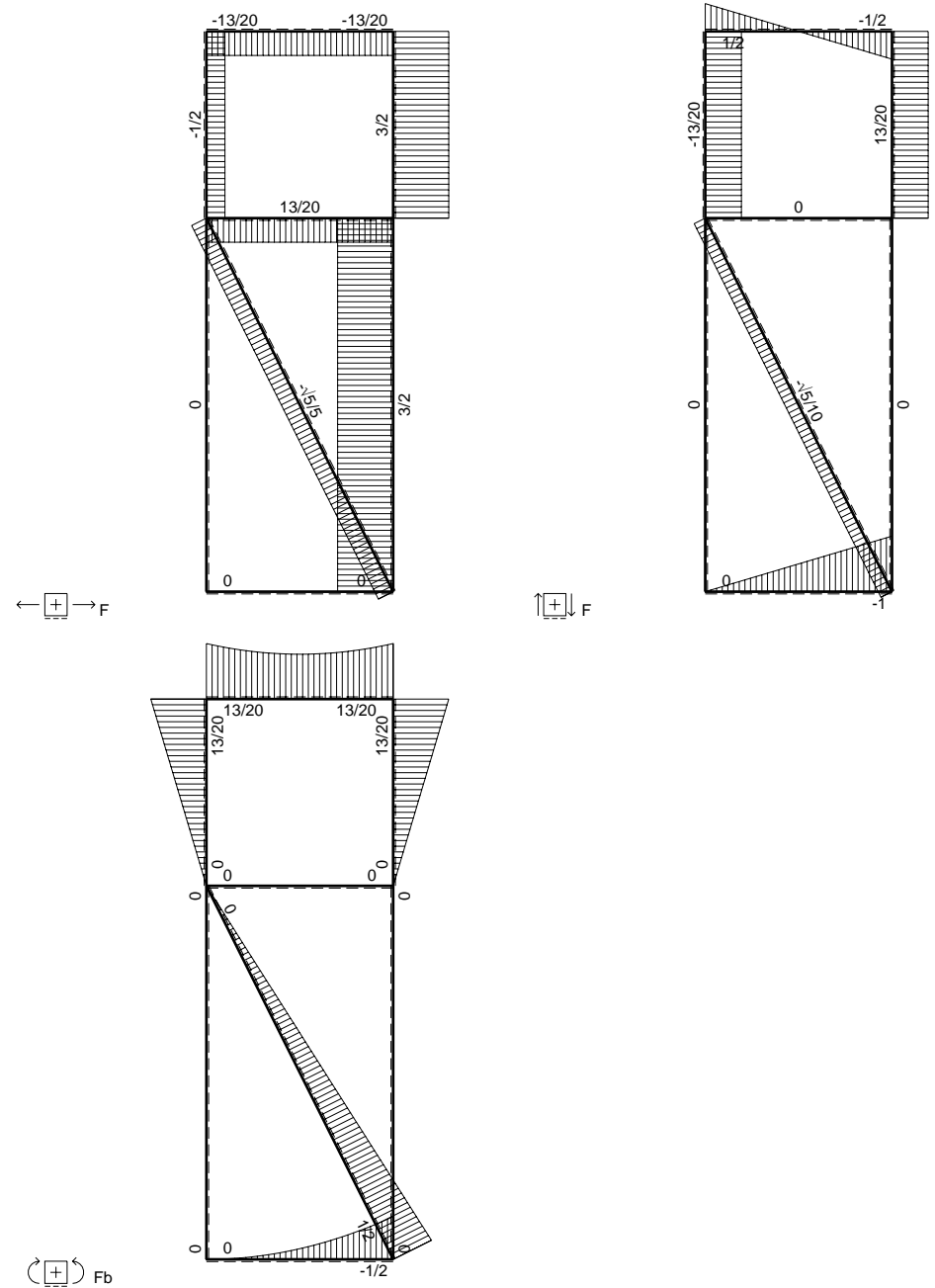
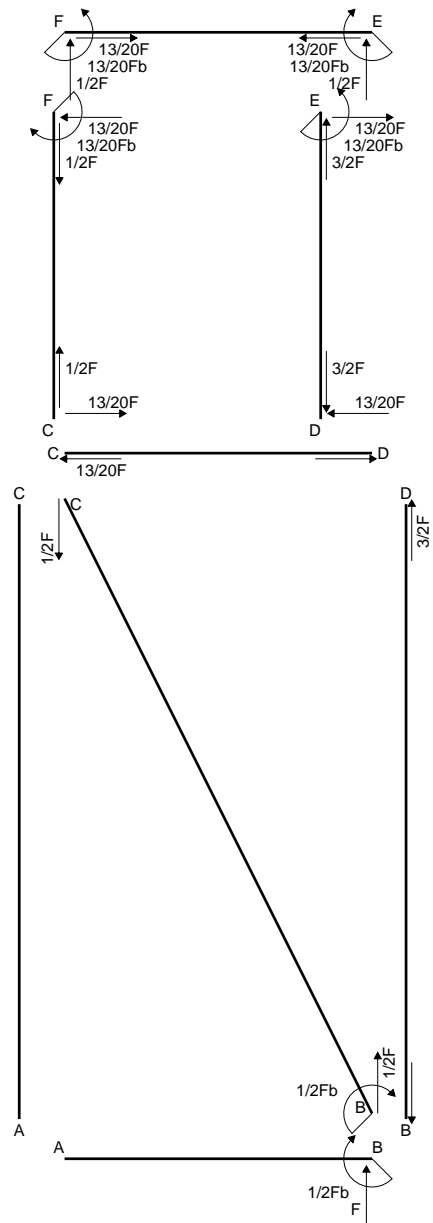
$$= (1/4 b - 1/6 b) Fb 1/EJ + (-b) \theta = 13/12 Fb^2/EJ$$



- A = 1176. mm<sup>2</sup>
- J<sub>u</sub> = 310856. mm<sup>4</sup>
- J<sub>v</sub> = 135072. mm<sup>4</sup>
- y<sub>g</sub> = 37. mm
- N = -2487. N
- T<sub>y</sub> = -1243. N
- M<sub>x</sub> = 1946000. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -37. mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = 229.5 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 16. mm
- v<sub>c</sub> = -21. mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = 129.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.856 N/mm<sup>2</sup>
- σ<sub>φ</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 129.4 N/mm<sup>2</sup>
- S = 5568. mm<sup>3</sup>







⊕ Fb



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

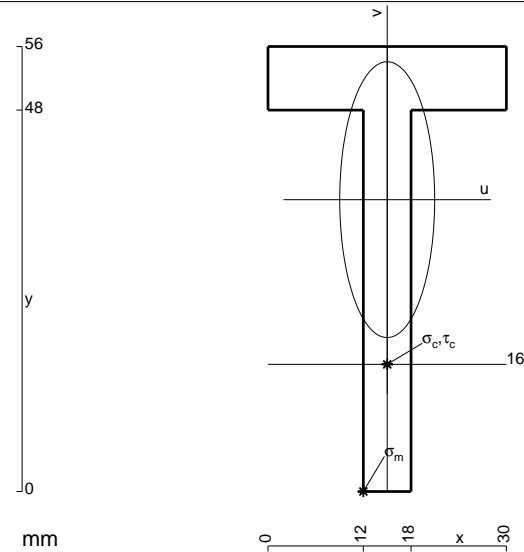
$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (1/4 b - 1/6 b) Fb 1/EJ + (b) \theta = 13/12 Fb^2/EJ$$

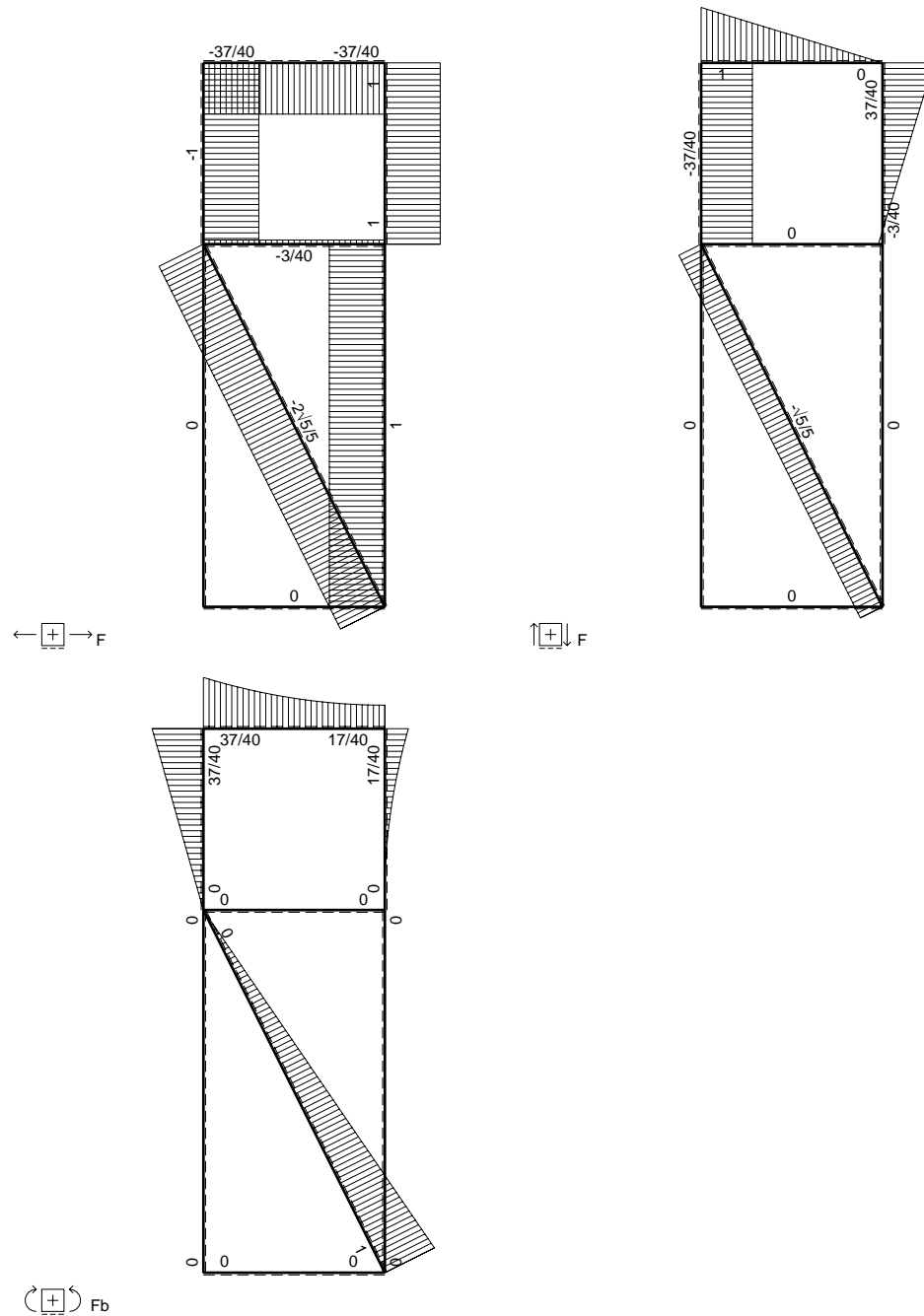
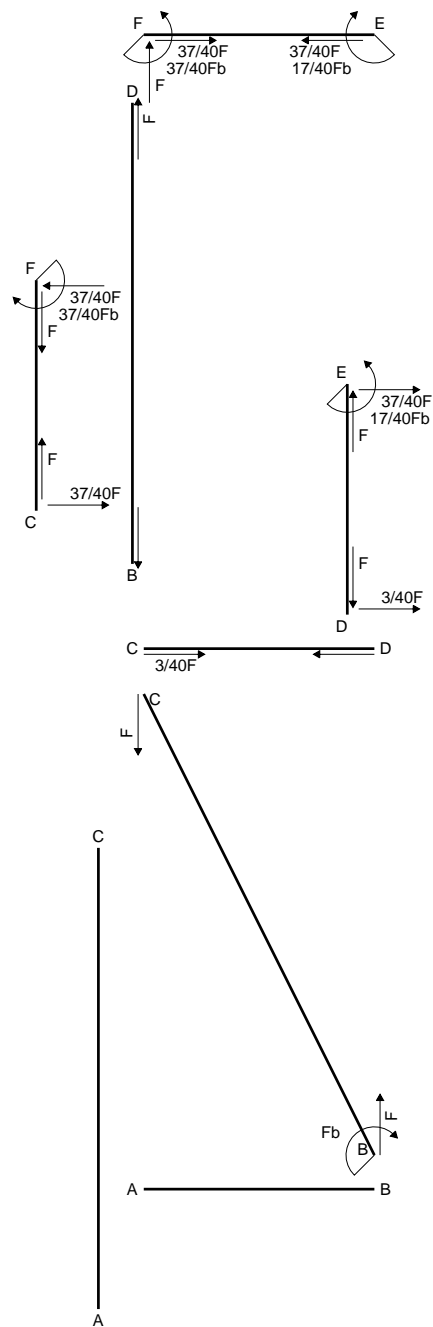
$$L_{FE}^{xo} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (1/4 b - 1/6 b) Fb 1/EJ + (-b) \theta = 13/12 Fb^2/EJ$$



- A = 528. mm<sup>2</sup>
- J<sub>u</sub> = 159209. mm<sup>4</sup>
- J<sub>v</sub> = 18864. mm<sup>4</sup>
- y<sub>g</sub> = 36.73 mm
- T<sub>y</sub> = -2810. N
- M<sub>x</sub> = -1039700. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -36.73 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -239.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 15. mm
- y<sub>c</sub> = 16. mm
- v<sub>c</sub> = -20.73 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -135.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 8.112 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 136.1 N/mm<sup>2</sup>
- S = 2758. mm<sup>3</sup>







$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/6 b) Fb 1/EJ + (b) \theta = 5/6 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx$$

$$= [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

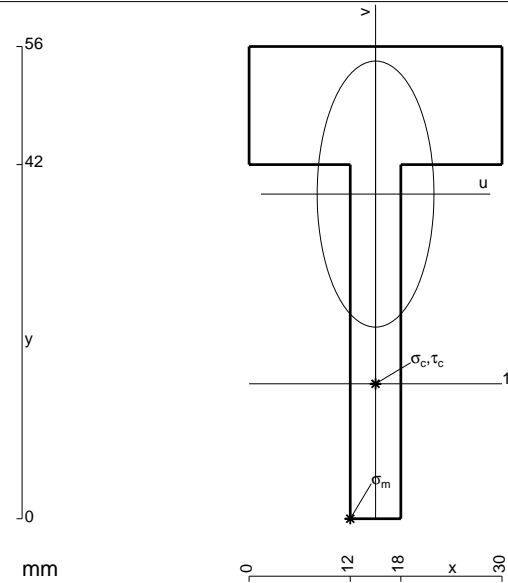
$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ + (-b) \theta = 5/6 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ$$

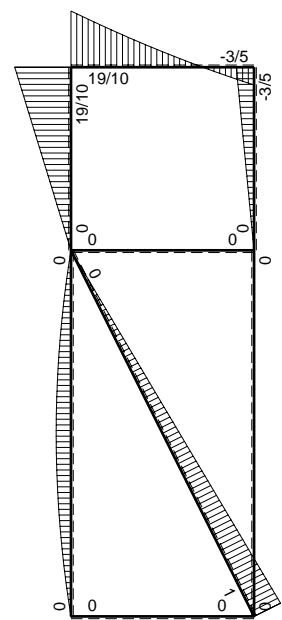
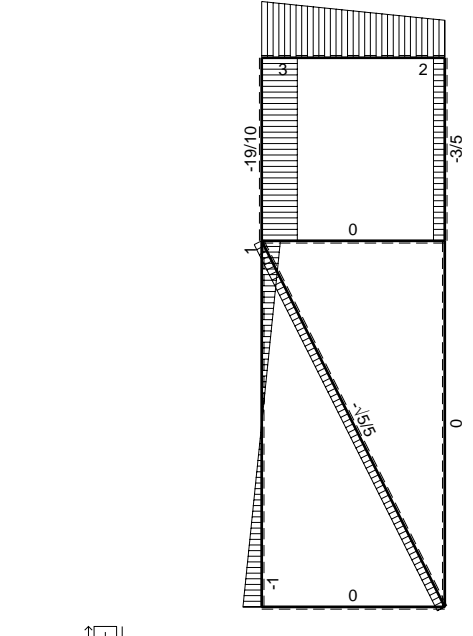
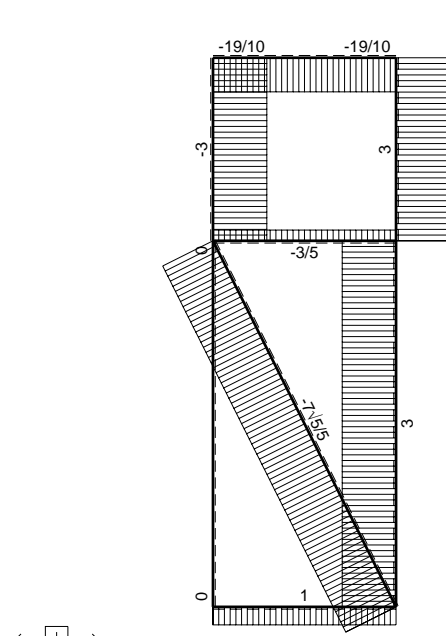
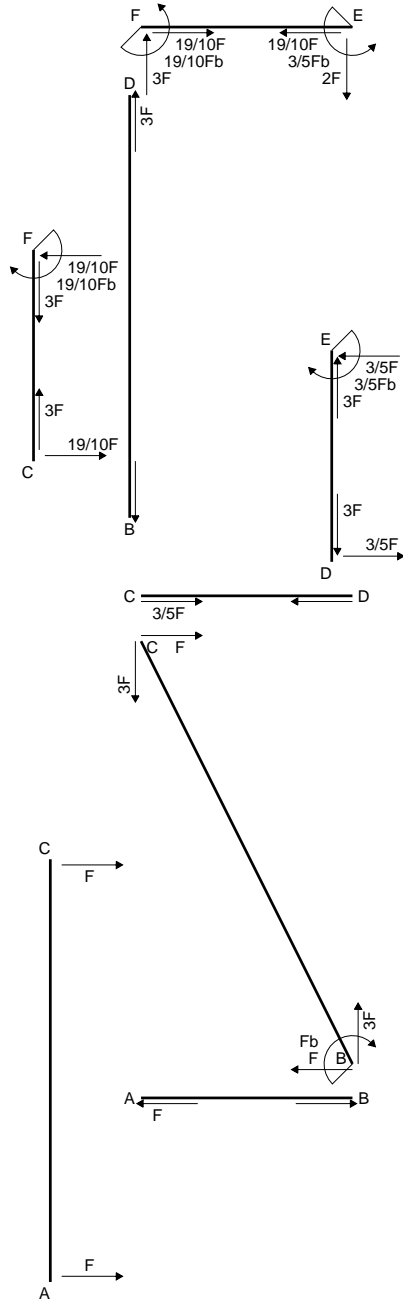
$$= (-1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$



- A = 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 = -2021. N
- T<sub>y</sub> = -1011. N
- M<sub>x</sub> = 881400. 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> = 199.7 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> = 115.5 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.947 N/mm<sup>2</sup>
- σ<sub>φ</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 115.6 N/mm<sup>2</sup>
- S = 2928. mm<sup>3</sup>









$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-2x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-b - 1/6 b) Fb 1/EJ + (b) \theta = -1/6 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-5/2 + 3x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx$$

$$= [-5/2 x + 3/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

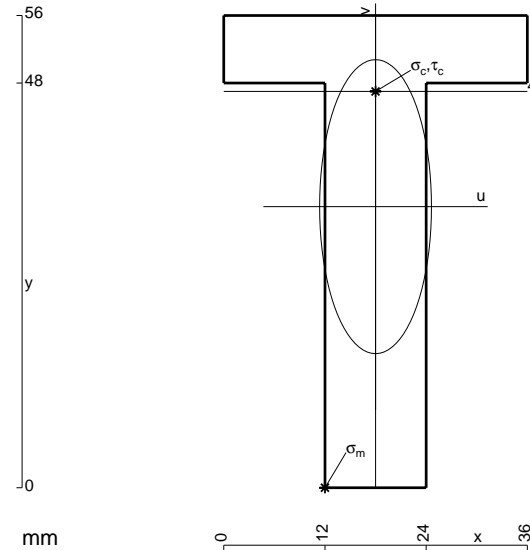
$$= (-5/2 b + 3/2 b - 1/6 b) Fb 1/EJ + (-b) \theta = -1/6 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = [-5/2 x + 5/2 x^2/b - 5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$



$$A = 864. \text{ mm}^2$$

$$J_u = 262656. \text{ mm}^4$$

$$J_v = 38016. \text{ mm}^4$$

$$y_g = 33.33 \text{ mm}$$

$$N = -13211. \text{ N}$$

$$T_y = -1887. \text{ N}$$

$$M_x = 1772400. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -6. \text{ mm}$$

$$v_m = -33.33 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 209.6 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 47. \text{ mm}$$

$$v_c = 13.67 \text{ mm}$$

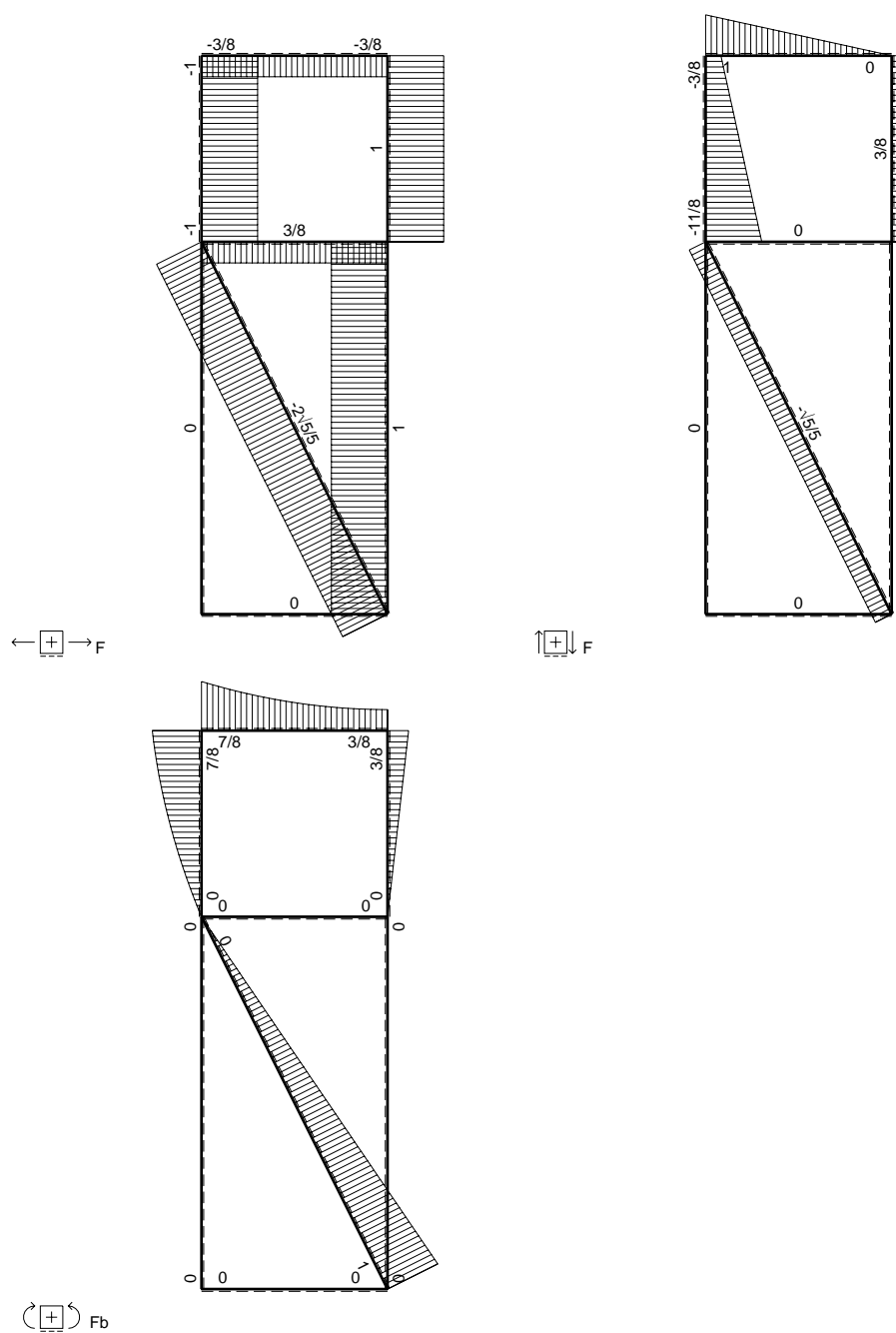
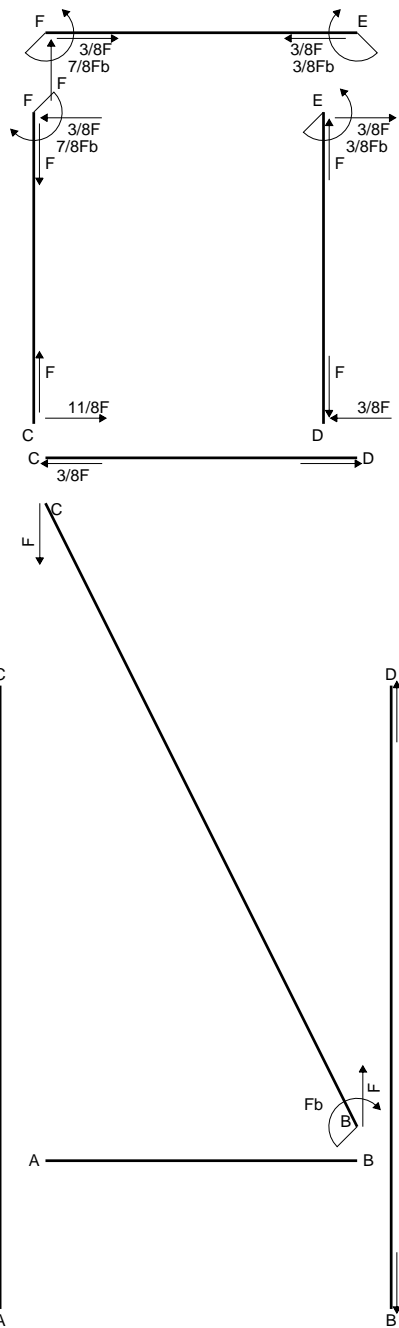
$$\sigma_c = N/A - Mv/J_u = -107.5 \text{ N/mm}^2$$

$$\tau_c = 3.321 \text{ N/mm}^2$$

$$\sigma_\varphi = \sqrt{\sigma^2 + 3\tau^2} = 107.7 \text{ N/mm}^2$$

$$S = 5546. \text{ mm}^3$$







$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/6 b) Fb 1/EJ + (b) \theta = 5/6 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx$$

$$= [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ + (-b) \theta = 5/6 Fb^2/EJ$$

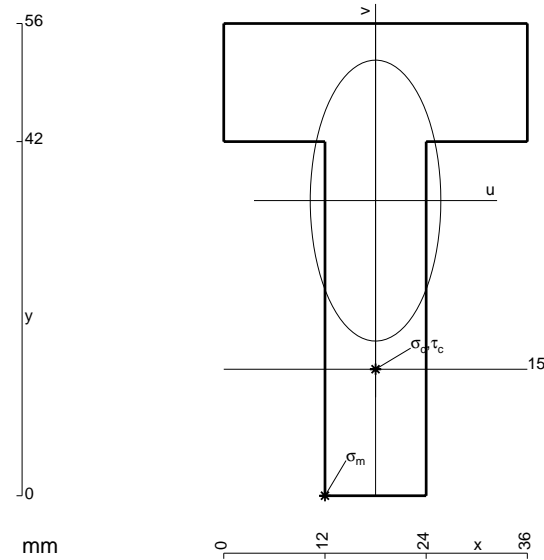
$$L_{FC}^{xo} = \int_0^b (-1/2 + 1/2 x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx$$

$$= [-1/2 x + 1/4 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/4 b + 1/6 b - 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

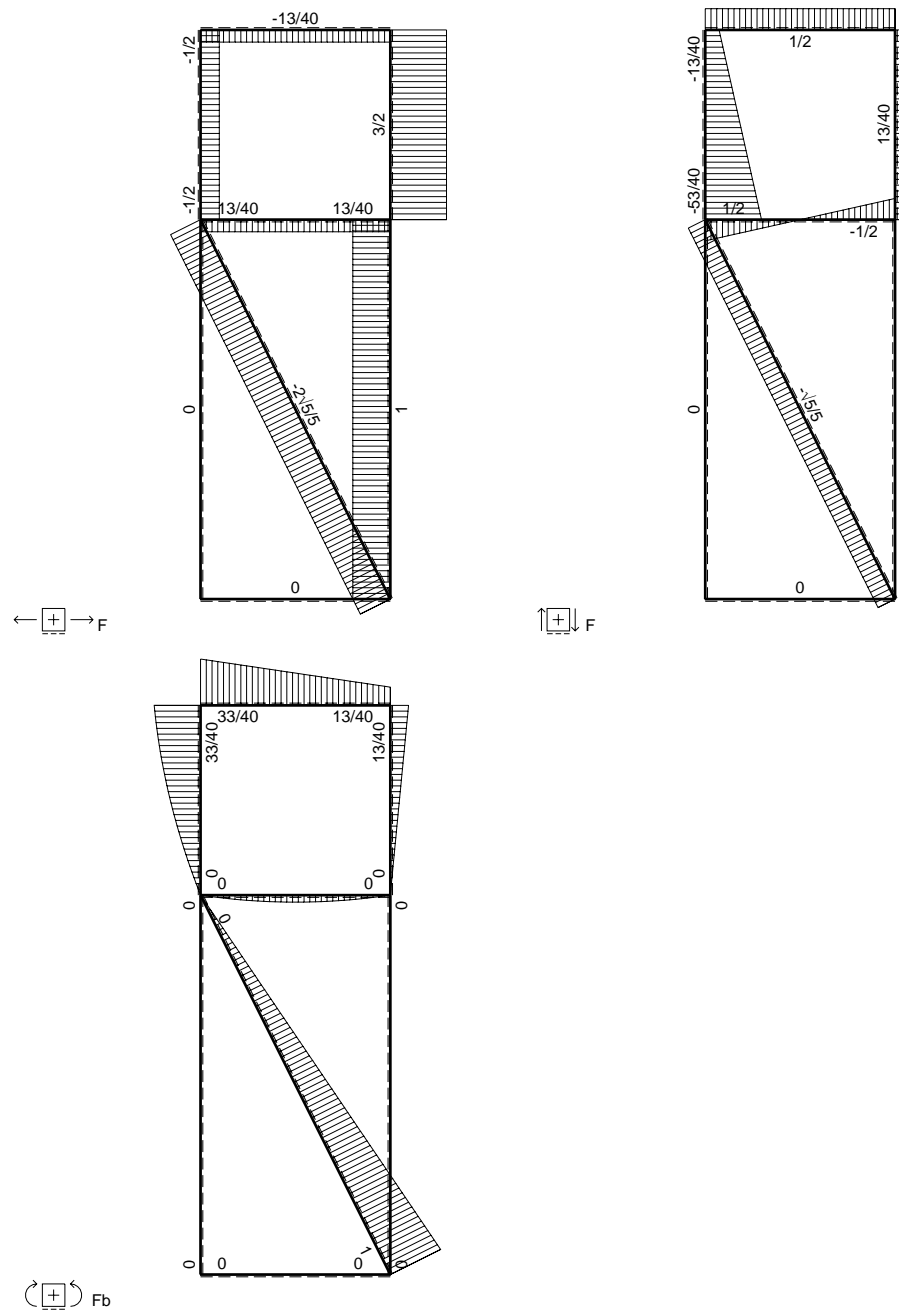
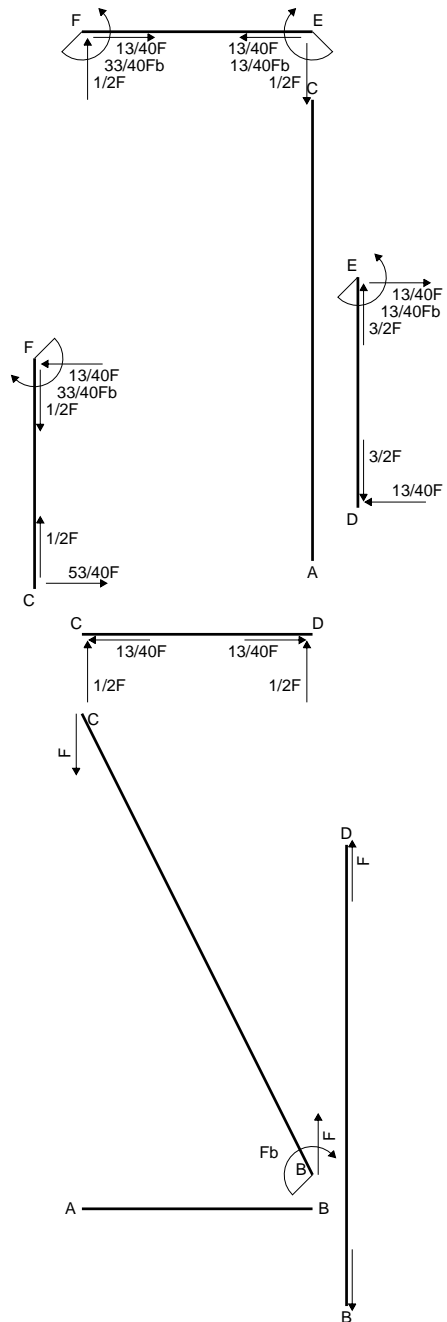
$$= (-1/3 b + 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$



- 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
- N = -3470. N
- T<sub>y</sub> = -1735. N
- M<sub>x</sub> = 1784800. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -35. mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = 219.7 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> = N/A - Mv/J<sub>u</sub> = 124.1 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.557 N/mm<sup>2</sup>
- σ<sub>φ</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 124.2 N/mm<sup>2</sup>
- S = 4950. mm<sup>3</sup>









$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/4 b) Fb 1/EJ + (b) \theta = 3/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + 1/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-1/2 x + 1/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

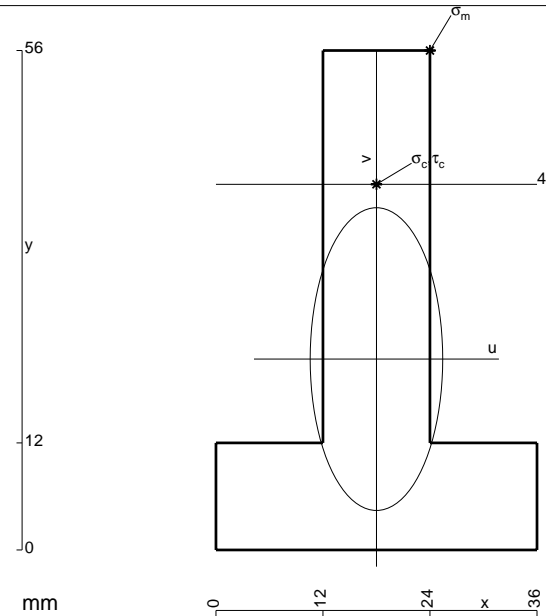
$$L_{FC}^{xo} = \int_0^b (-1/2 + 1/2 x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx$$

$$= [-1/2 x + 1/4 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/4 b + 1/6 b - 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$

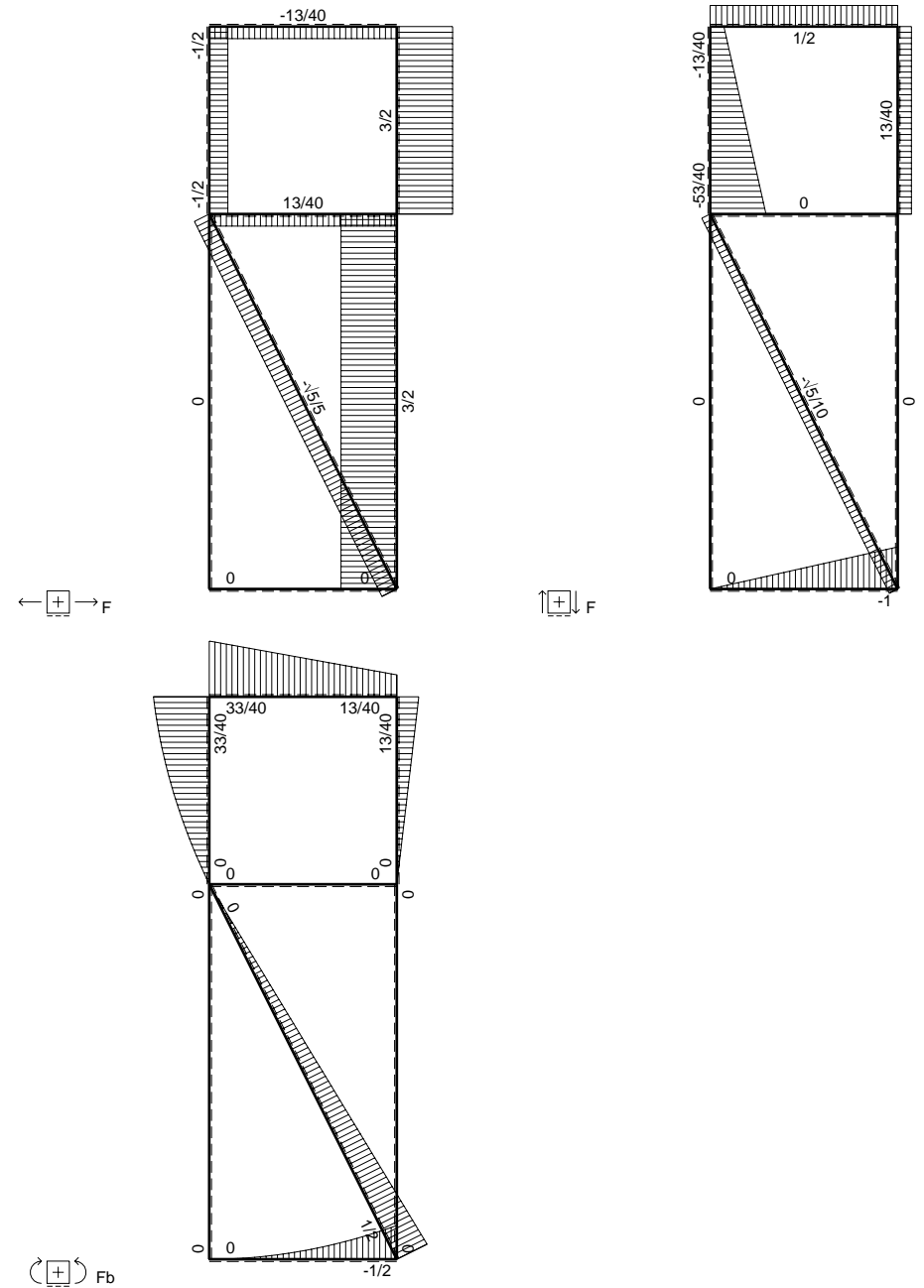
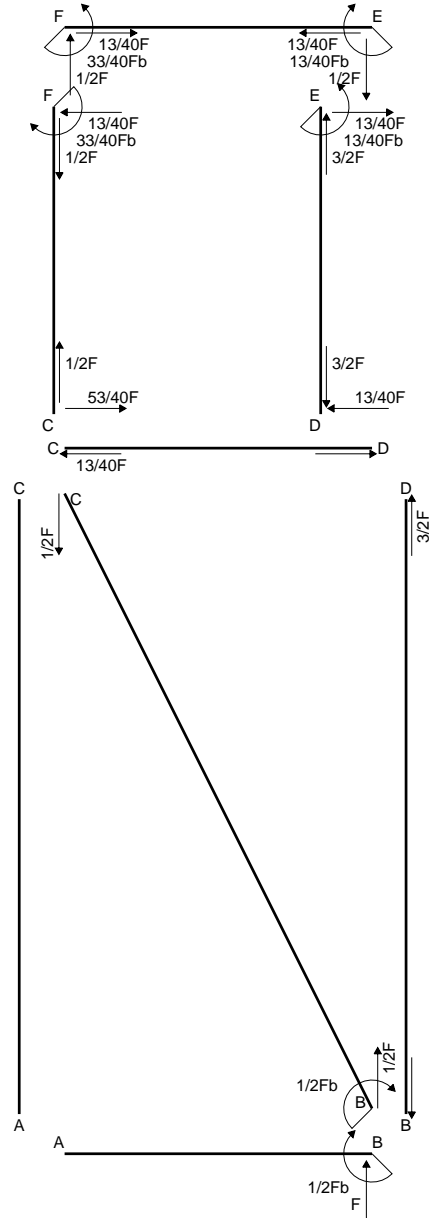
$$L_{CF}^{xo} = \int_0^b (-x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

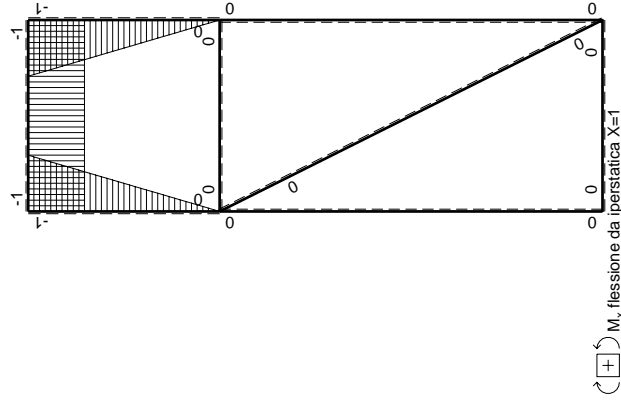
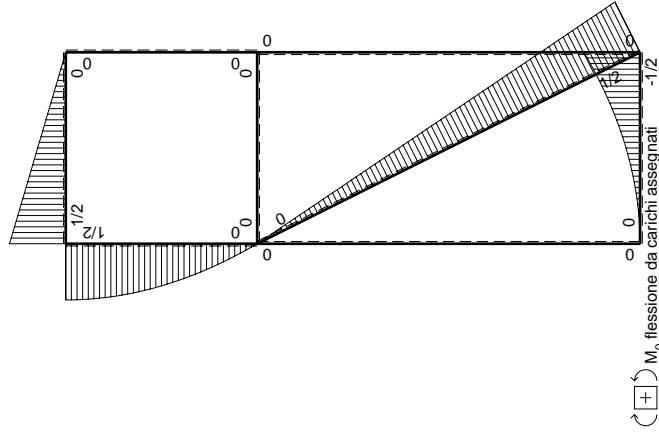
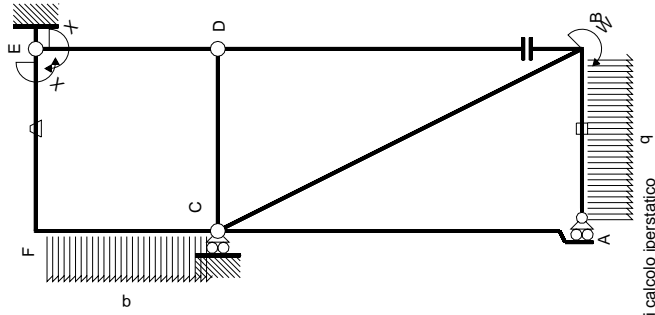
$$= (-1/3 b + 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$



- 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
- N = -3238. N
- T<sub>y</sub> = -1619. N
- M<sub>x</sub> = 1810000. 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> = N/A-Mv/J<sub>u</sub> = -229.7 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> = N/A-Mv/J<sub>u</sub> = -131.6 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.379 N/mm<sup>2</sup>
- σ<sub>o</sub> = √(σ<sup>2</sup>+3τ<sup>2</sup>) = 131.7 N/mm<sup>2</sup>
- S = 4878. mm<sup>3</sup>







Quadro contributi PLV per iperstatica  $X=W_{EF}$

$\rightarrow$	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x (M_0/EJ + \theta) dx$	$\int M^x M_x / E dx$
AB b	0	$-1/2qx^2$	0	0	0	0	0	0
BA b	0	$1/2Fb - Fx + 1/2qx^2$	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$1/2Fb - \sqrt{5}/10Fx$	0	0	0	0	0	0
AC 2b	0	0	0	0	0	0	0	0
CA 2b	0	0	0	0	0	0	0	0
DB 2b	0	0	0	0	0	0	0	0
BD 2b	0	0	0	0	0	0	0	0
DE b	-x/b	0	0	0	0	0	0	0
ED b	1-x/b	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
EF b	-1	$1/2Fx$	$-Fb/EJ$	$-1/2Fx$	$Fb/EJ$	1	$(-1/4+1)Fb^2/EJ$	$Xb/EJ$
FE b	1	$-1/2Fb+1/2Fx$	$Fb/EJ$	$-1/2Fb+1/2Fx$	$Fb/EJ$	1	$(-1/4+1)Fb^2/EJ$	$Xb/EJ$
FC b	$-1+x/b$	$1/2Fb-1/2qx^2$	0	$-1/2Fb+1/2Fx+1/2Fx^2/b-1/2qx^3/b$	0	0	$(-5/24+0)Fb^2/EJ$	$1/3Xb/EJ$
CF b	x/b	$-Fx+1/2qx^2$	0	$-Fx^2/b+1/2qx^3/b$	0	0	$13/24Fb^2/EJ$	$5/3Xb/EJ$
totali								
iperstatica $X=W_{EF}$								

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/4 b) Fb 1/EJ + (b) \theta = 3/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + 1/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-1/2 x + 1/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

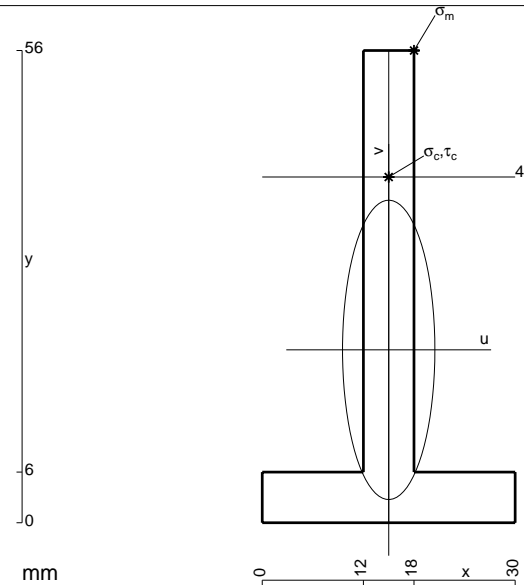
$$L_{FC}^{xo} = \int_0^b (-1/2 + 1/2 x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx$$

$$= [-1/2 x + 1/4 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/4 b + 1/6 b - 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/3 b + 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$



$$A = 480. \text{ mm}^2$$

$$J_u = 151240. \text{ mm}^4$$

$$J_v = 14400. \text{ mm}^4$$

$$y_g = 20.5 \text{ mm}$$

$$T_y = -3780. \text{ N}$$

$$M_x = -1020600. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$y_m = 56. \text{ mm}$$

$$u_m = 3. \text{ mm}$$

$$v_m = 35.5 \text{ mm}$$

$$\sigma_m = -Mv/J_u = 239.6 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 41. \text{ mm}$$

$$v_c = 20.5 \text{ mm}$$

$$\sigma_c = -Mv/J_u = 138.3 \text{ N/mm}^2$$

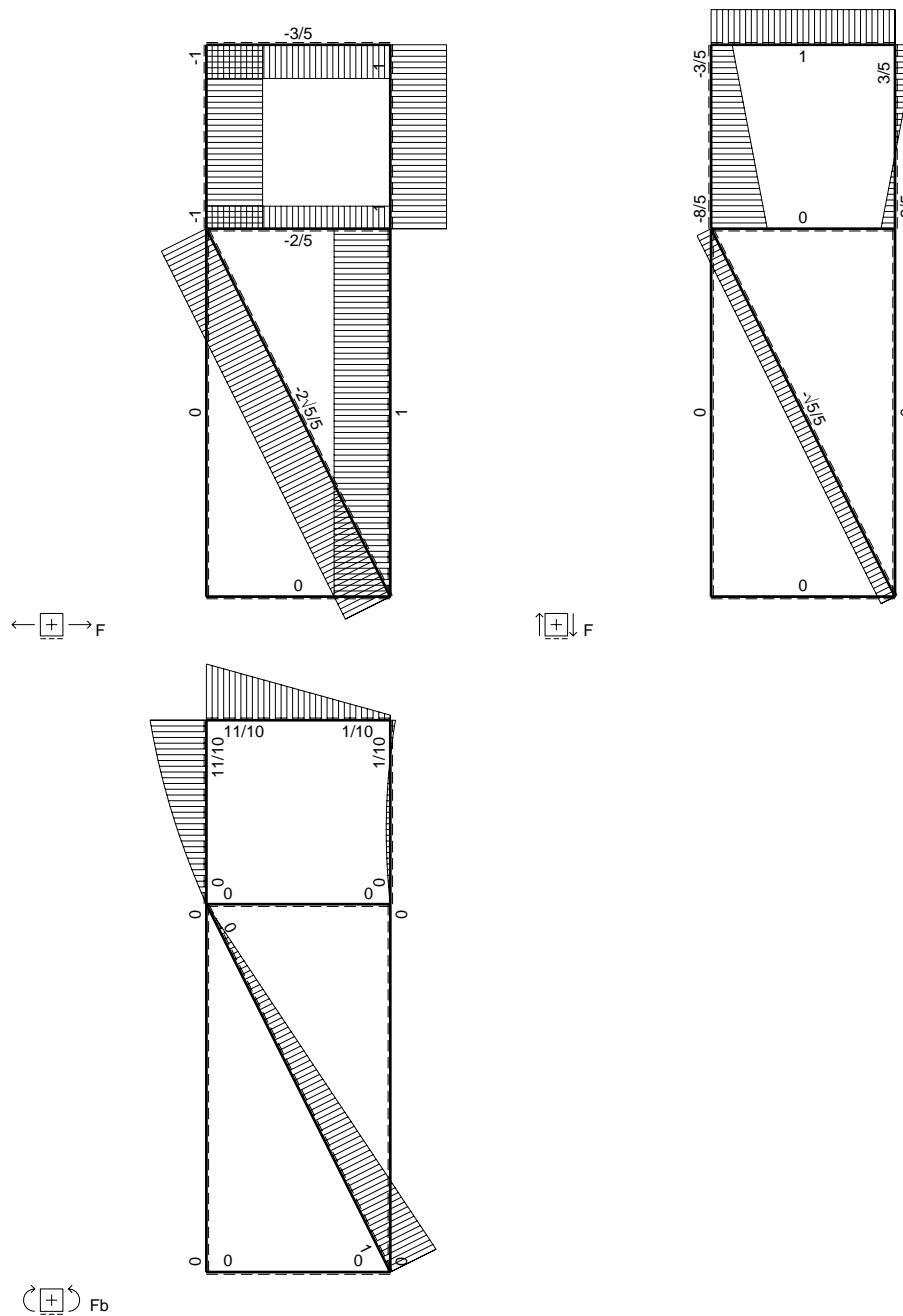
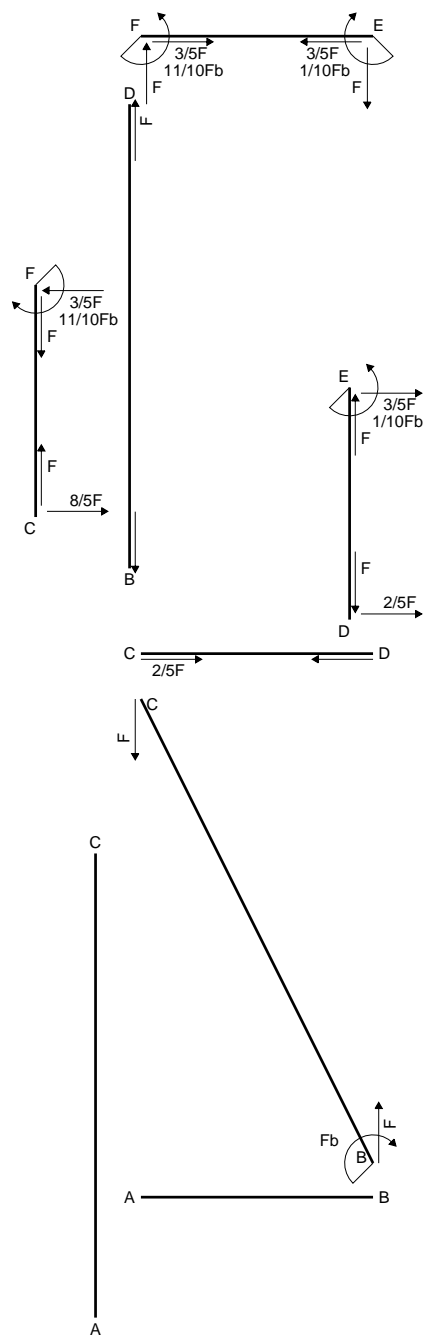
$$\tau_c = 10.5 \text{ N/mm}^2$$

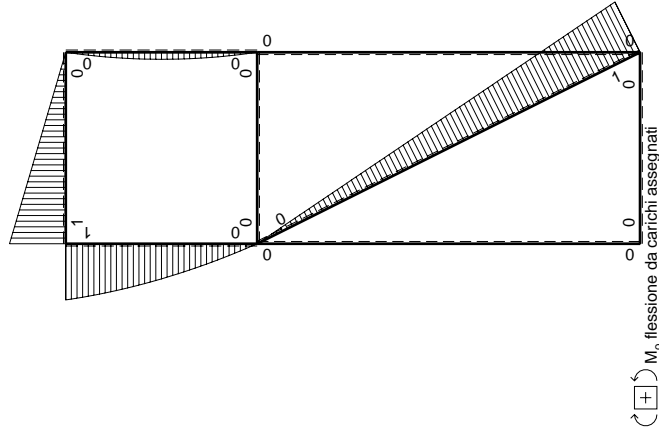
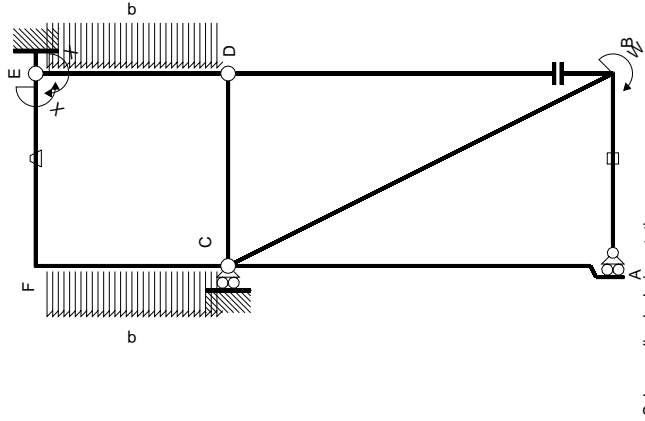
$$\sigma_o = \sqrt{\sigma^2 + 3\tau^2} = 139.5 \text{ N/mm}^2$$

$$S = 2520. \text{ mm}^3$$









Quadro contributi PLV per iperstatica  $X=W_{EF}$

$\rightarrow$	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x (M_0/EJ + \theta) dx$	$\int M^x M_x / E J dx$
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$Fb - \sqrt{5}/5 Fx$	0	0	0	0	0+0	0
CA 2b	0	0	0	0	0	0	0+0	0
DB 2b	0	0	0	0	0	0	0+0	0
BD 2b	0	0	0	0	0	0	0+0	0
DE b	$-x/b$	$-1/2Fx + 1/2qx^2$	0	$1/2Fx^2/b - 1/2qx^3/b$	0	0	$x^2/b^2$	0
ED b	$1-x/b$	$1/2Fx - 1/2qx^2$	0	$1/2Fx - Fx^2/b + 1/2qx^3/b$	0	0	$1-2x/b+x^2/b^2$	$1/3xb/EJ$
CD b	0	0	0	0	0	0	0+0	0
FE b	-1	Fx	$-Fb/EJ$	-Fx	$Fb/EJ$	1	$(-1/2+1)Fb^2/EJ$	$Xb/EJ$
FC b	$-1+x/b$	$-Fb + Fx$	$Fb/EJ$	$-Fb + Fx$	$Fb/EJ$	1	$(-1/2+1)Fb^2/EJ$	$Xb/EJ$
CF b	$x/b$	$-3/2Fx + 1/2qx^2$	0	$-Fb + 3/2Fx - 1/2qx^3/b$	0	0	$x^2/b^2$	$1/3xb/EJ$
totali								$5/3xb/EJ$
iperstatica $X=W_{EF}$								$-1/10Fb$

Sviluppi di calcolo iperstatica



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (b) \theta = 1/2 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

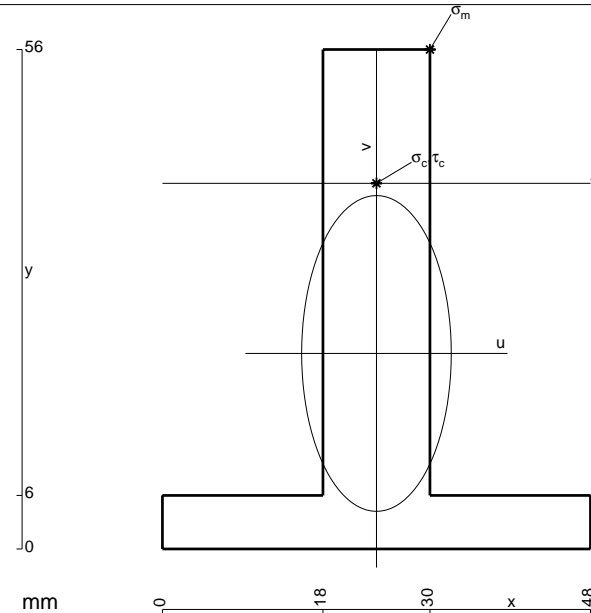
$$= (-b + 1/2 b) Fb 1/EJ + (-b) \theta = 1/2 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-1 + 3/2 x/b - 1/2 x^3/b^3) Fb 1/EJ dx = [-x + 3/4 x^2/b - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-b + 3/4 b - 1/8 b) Fb 1/EJ = -3/8 Fb^2/EJ$$

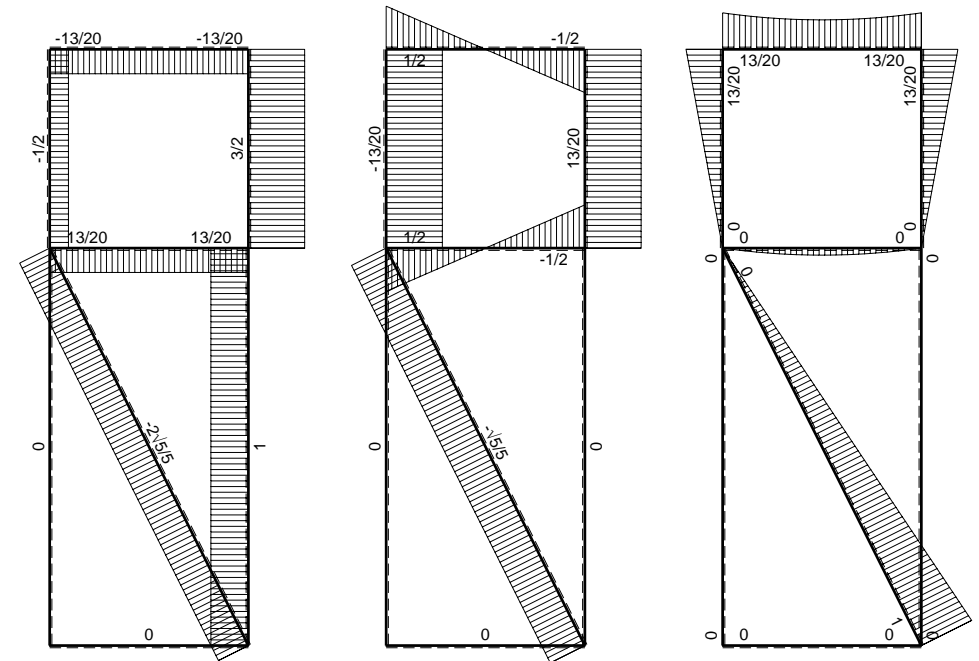
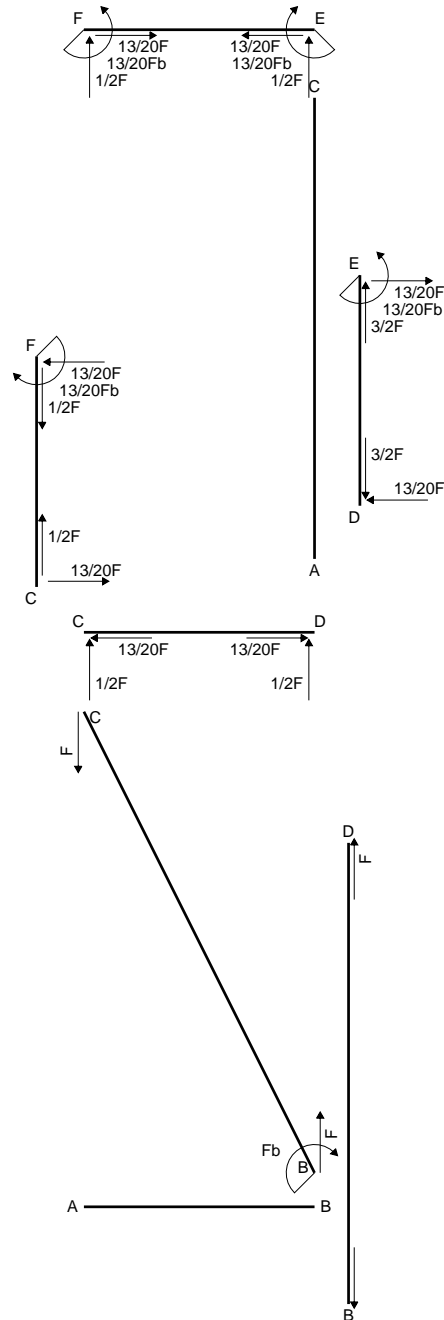
$$L_{CF}^{xo} = \int_0^b (-3/2 x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/2 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/8 b) Fb 1/EJ = -3/8 Fb^2/EJ$$



- A = 888. mm<sup>2</sup>
- J<sub>u</sub> = 278426. mm<sup>4</sup>
- J<sub>v</sub> = 62496. mm<sup>4</sup>
- y<sub>g</sub> = 21.92 mm
- N = -2478. N
- T<sub>y</sub> = -1239. N
- M<sub>x</sub> = 1606600. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 56. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 34.08 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = -199.4 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 41. mm
- v<sub>c</sub> = 19.08 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = -112.9 N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.774 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup>+3τ<sup>2</sup>) = 112.9 N/mm<sup>2</sup>
- S = 4785. mm<sup>3</sup>

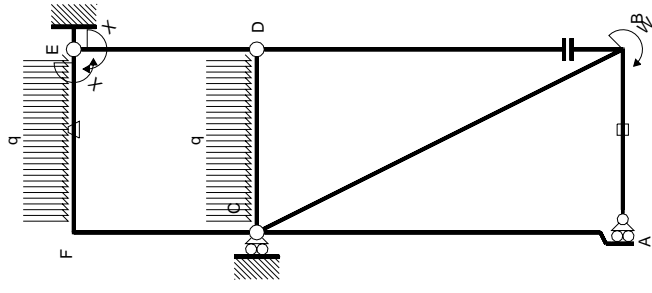




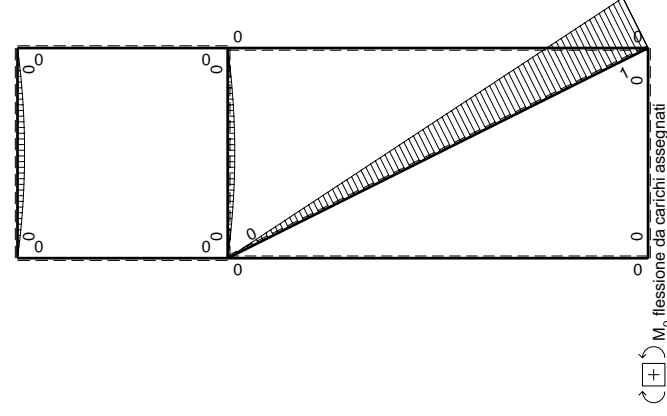
← ⊕ → F

↑ ⊕ ↓ F

⊕ ⊖ F<sub>b</sub>



Schema di calcolo iperstatico



M<sub>0</sub> flessione da carichi assegnati

←	M <sup>x</sup> (x)	M <sup>o</sup> (x)	θ	M <sup>x</sup> <sub>o</sub>	M <sup>x</sup> <sub>θ</sub>	M <sup>x</sup> <sub>x</sub>	∫M <sup>x</sup> <sub>o</sub> /EJ+θ)dx	∫M <sup>x</sup> <sub>x</sub> /EJdx	iperstatica X=W <sup>EF</sup>	
									totali	-13/20Fb
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
BC √5b	0	Fb-√5/5Fx	0	0	0	0	0	0	0	0
AC 2b	0	0	0	0	0	0	0+0	0	0	0
DB 2b	0	0	0	0	0	0	0+0	0	0	0
BD 2b	0	0	0	0	0	0	0+0	0	0	0
DE b	-x/b	0	0	0	0	0	0+0	1/3Xb/EJ	0	0
ED b	1-x/b	0	0	0	0	0	0+0	1/3Xb/EJ	0	0
CD b	0	1/2Fx-1/2qx <sup>2</sup>	0	0	0	0	0+0	0	0	0
DC b	0	-1/2Fx+1/2qx <sup>2</sup>	0	0	0	0	0+0	0	0	0
EF b	-1	-1/2Fx+1/2qx <sup>2</sup>	-Fb/EJ	1/2Fx-1/2Fx <sup>2</sup> /b	Fb/EJ	1	(1/12+1)Fb <sup>2</sup> /EJ	Xb/EJ	1/3Xb/EJ	0
FE b	1	1/2Fx-1/2qx <sup>2</sup>	Fb/EJ	1/2Fx-1/2Fx <sup>2</sup> /b	Fb/EJ	1	(1/12+1)Fb <sup>2</sup> /EJ	Xb/EJ	1/3Xb/EJ	0
FC b	-1+x/b	0	0	0	0	0	0+0	0	0	0
CF b	x/b	0	0	0	0	0	0+0	0	0	0
totali										

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = \left[ \frac{1}{3} x^3/b^2 \right]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = \left[ x \right]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = \left[ x \right]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = \left[ \frac{1}{3} x^3/b^2 \right]_0^b 1/EJ$$

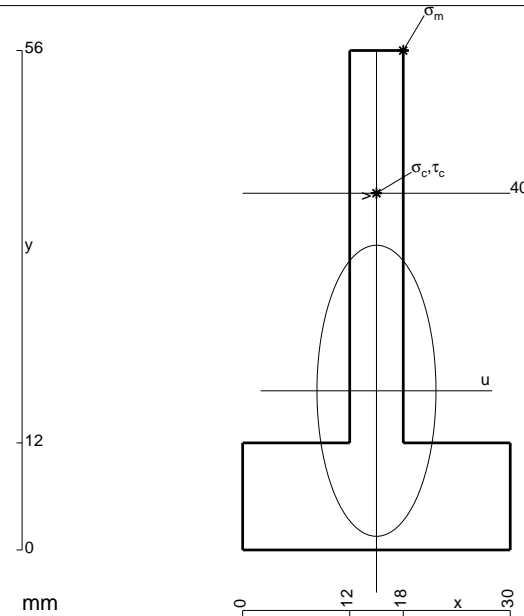
$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = \left[ \frac{1}{4} x^2/b - 1/6 x^3/b^2 \right]_0^b Fb 1/EJ + \left[ x \right]_0^b \theta$$

$$= (1/4 b - 1/6 b) Fb 1/EJ + (b) \theta = 13/12 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx = \left[ \frac{1}{4} x^2/b - 1/6 x^3/b^2 \right]_0^b Fb 1/EJ + \left[ -x \right]_0^b \theta$$

$$= (1/4 b - 1/6 b) Fb 1/EJ + (-b) \theta = 13/12 Fb^2/EJ$$



$$A = 624. \text{ mm}^2$$

$$J_u = 166321. \text{ mm}^4$$

$$J_v = 27792. \text{ mm}^4$$

$$y_g = 17.85 \text{ mm}$$

$$N = -1306. \text{ N}$$

$$T_y = -652.9 \text{ N}$$

$$M_x = 905200. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$u_m = 56. \text{ mm}$$

$$v_m = 3. \text{ mm}$$

$$v_m = 38.15 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -209.7 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 40. \text{ mm}$$

$$v_c = 22.15 \text{ mm}$$

$$\sigma_c = N/A - Mv/J_u = -122.7 \text{ N/mm}^2$$

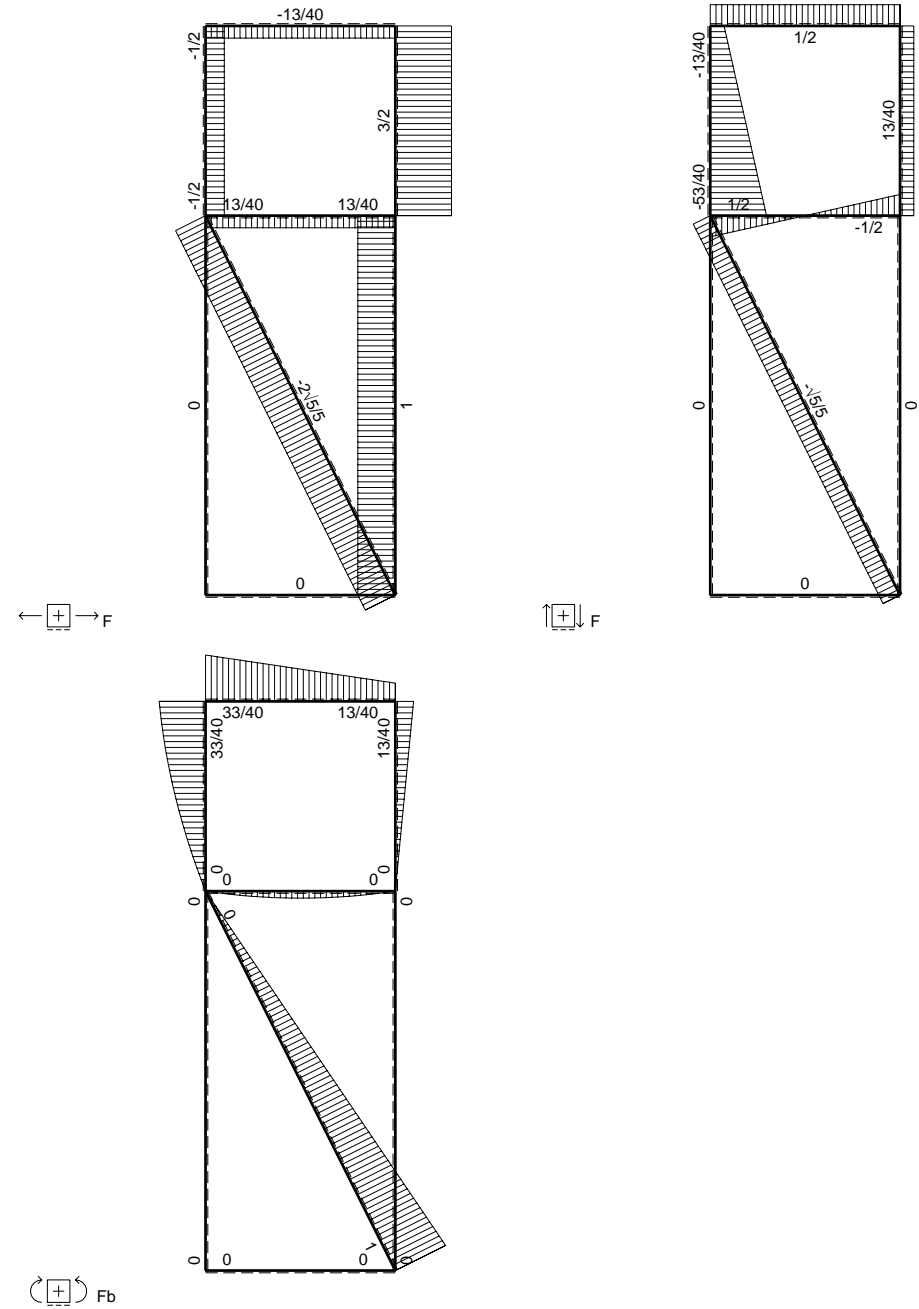
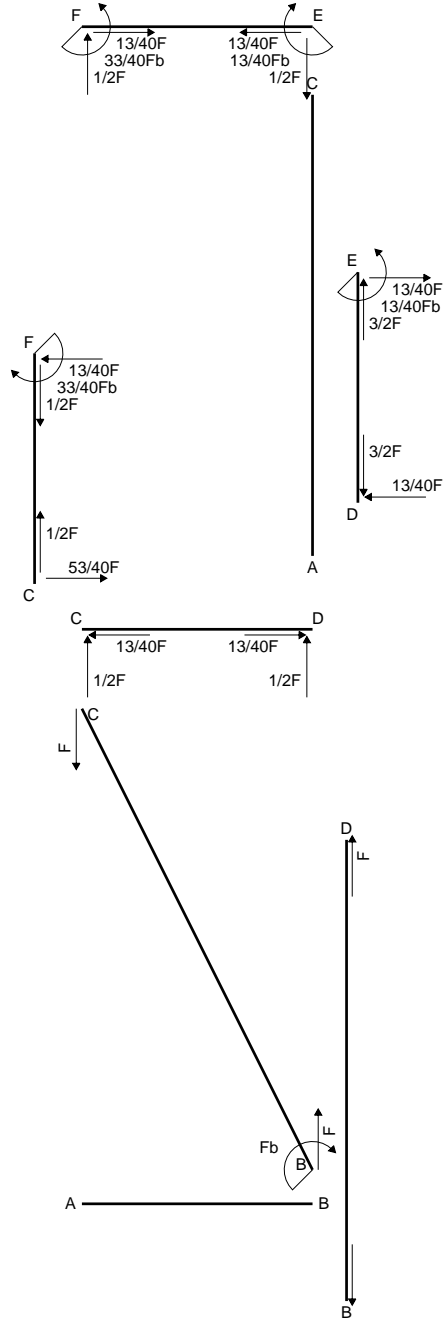
$$\tau_c = 1.894 \text{ N/mm}^2$$

$$\sigma_o = \sqrt{\sigma^2 + 3\tau^2} = 122.7 \text{ N/mm}^2$$

$$S = 2895. \text{ mm}^3$$









$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/4 b) Fb 1/EJ + (b) \theta = 3/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + 1/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-1/2 x + 1/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

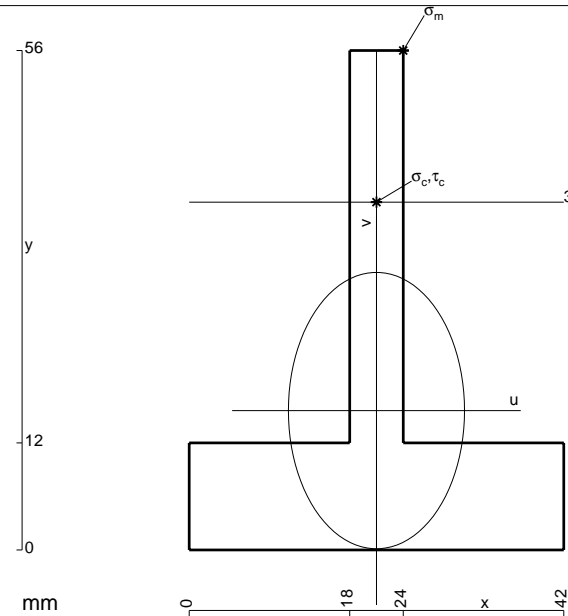
$$L_{FC}^{xo} = \int_0^b (-1/2 + 1/2 x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx$$

$$= [-1/2 x + 1/4 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/4 b + 1/6 b - 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$

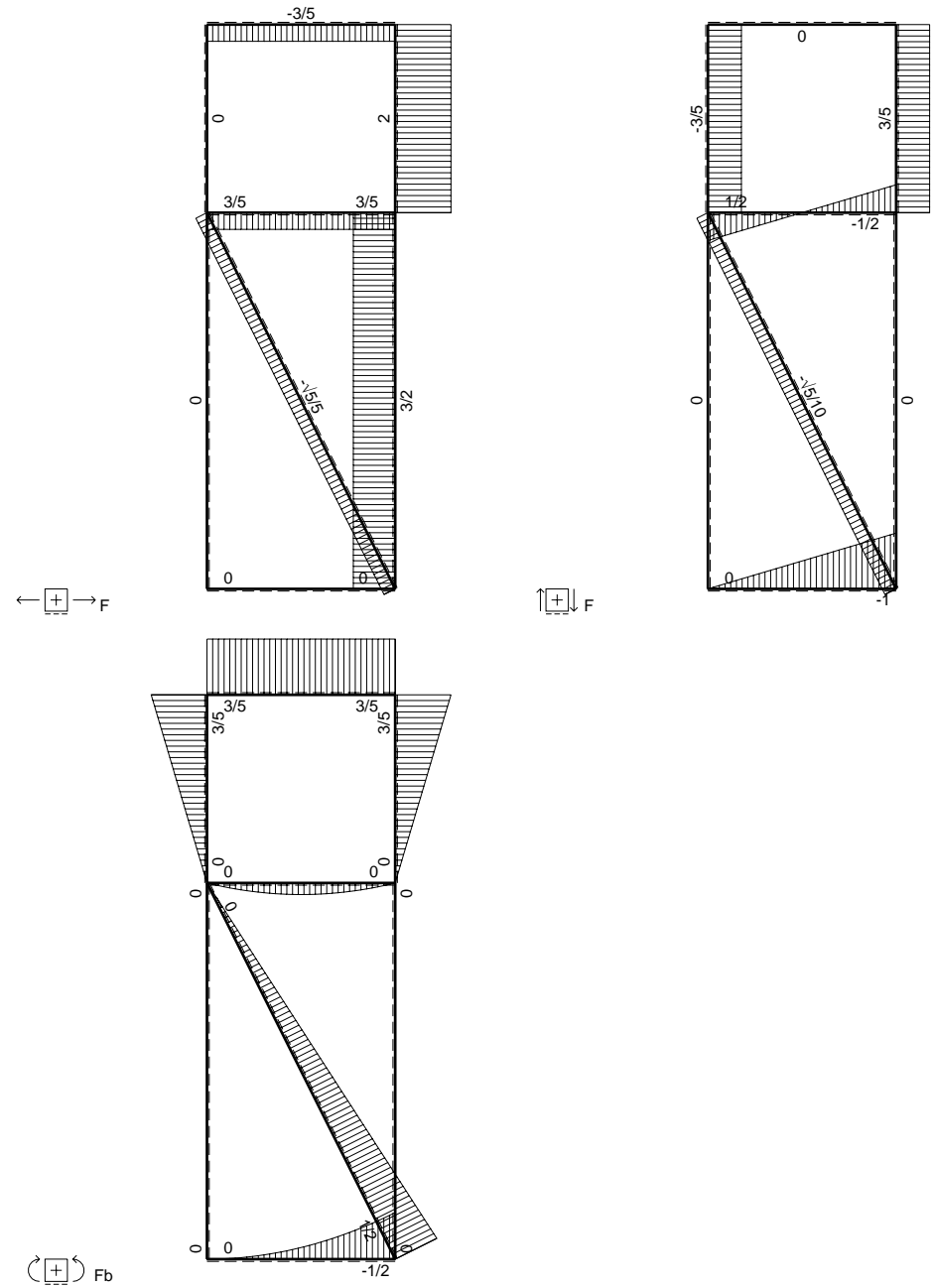
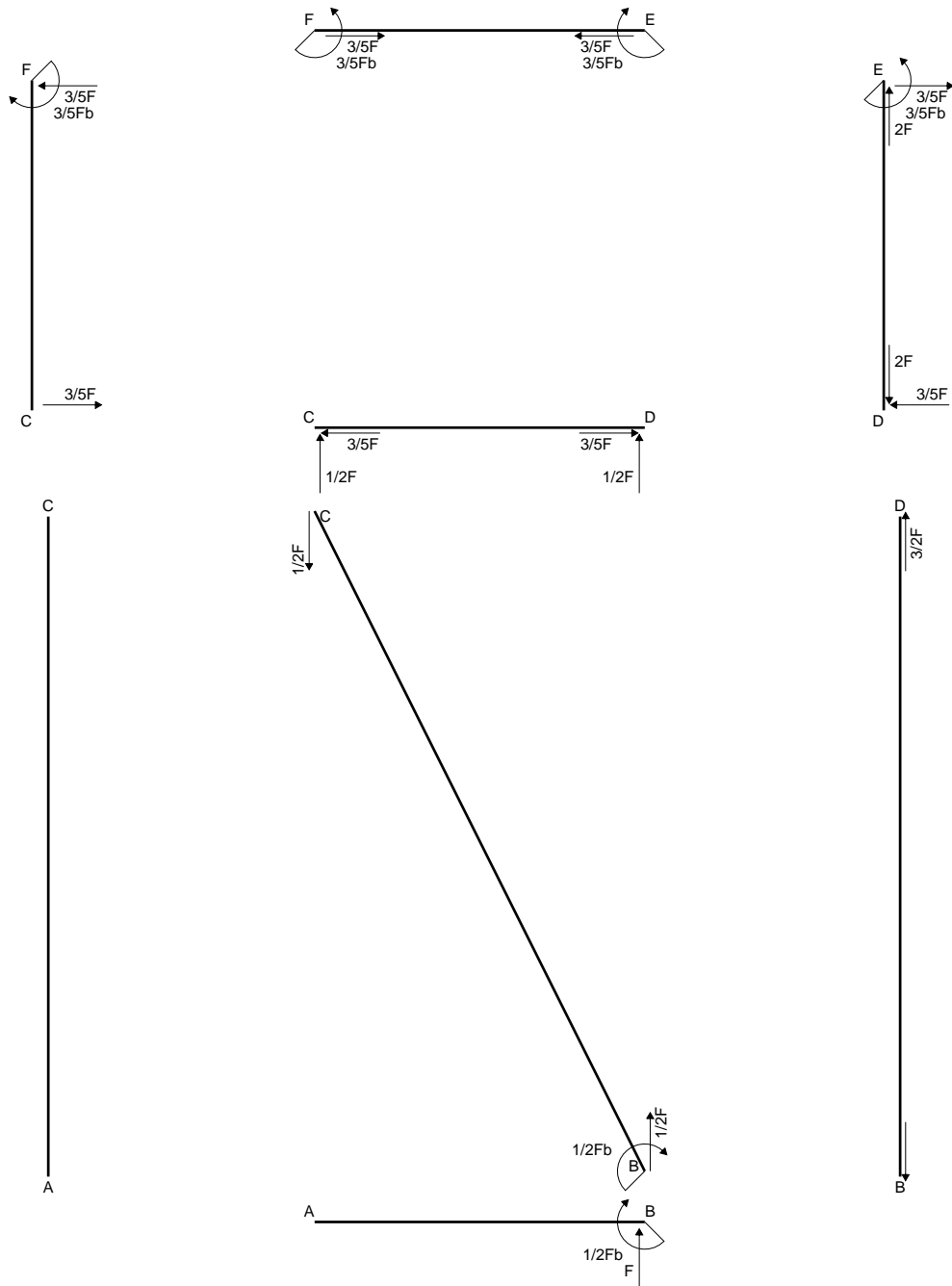
$$L_{CF}^{xo} = \int_0^b (-x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

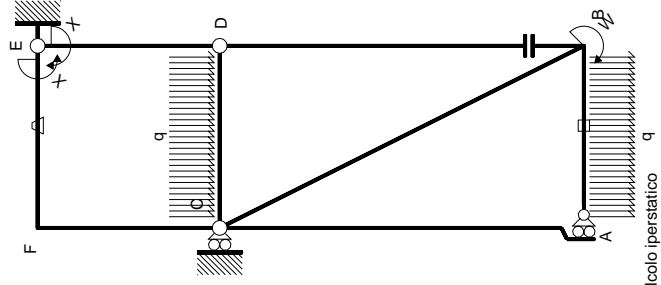
$$= (-1/3 b + 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$



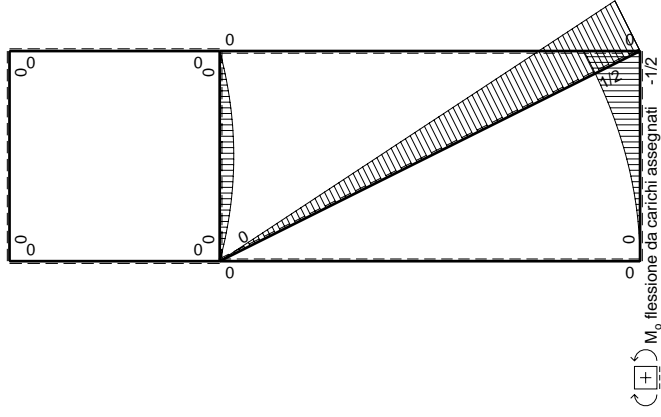
- A = 768. mm<sup>2</sup>
- J<sub>u</sub> = 184468. mm<sup>4</sup>
- J<sub>v</sub> = 74880. mm<sup>4</sup>
- y<sub>g</sub> = 15.63 mm
- N = -1351. N
- T<sub>y</sub> = -675.3 N
- M<sub>x</sub> = 996600. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 56. mm
- u<sub>m</sub> = 3. mm
- v<sub>m</sub> = 40.38 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = -219.9 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 39. mm
- v<sub>c</sub> = 23.38 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = -128. N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.984 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 128.1 N/mm<sup>2</sup>
- S = 3251. mm<sup>3</sup>







Schema di calcolo iperstatico



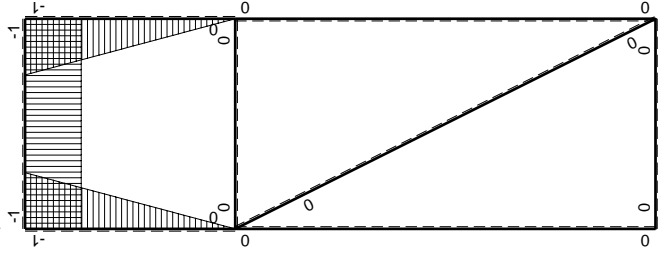
$M_0$  flessione da carichi assegnati  $-1/2$

Quadro contributi PLV per iperstatica  $X=W_{EF}$

$\rightarrow$	$M_x(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int X M_x M_x / EJ dx$
AB b	0	$-1/2qx^2$	0	0	0	0	0+0	0
BA b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0+0	0
BC $\sqrt{5}b$	0	$1/2Fb-\sqrt{5}/10Fx$	0	0	0	0	0	0
AC 2b	0	0	0	0	0	0	0+0	0
CA 2b	0	0	0	0	0	0	0+0	0
DB 2b	0	0	0	0	0	0	0+0	0
BD 2b	0	0	0	0	0	0	0+0	0
DE b	$-x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3Xb/EJ$
ED b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	0
CD b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0
DC b	0	$-1/2Fx+1/2qx^2$	0	0	0	0	0+0	0
EF b	-1	0	$-Fb/EJ$	0	$Fb/EJ$	1	$(0+1)Fb^2/EJ$	$Xb/EJ$
FE b	1	0	$Fb/EJ$	0	$Fb/EJ$	1		
FC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$
CF b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3Xb/EJ$
	totali						$Fb^2/EJ$	$5/3Xb/EJ$
	iperstatica $X=W_{EF}$						$-3/5Fb$	

Sviluppi di calcolo iperstatica

$M_x$  flessione da iperstatica  $X=1$



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

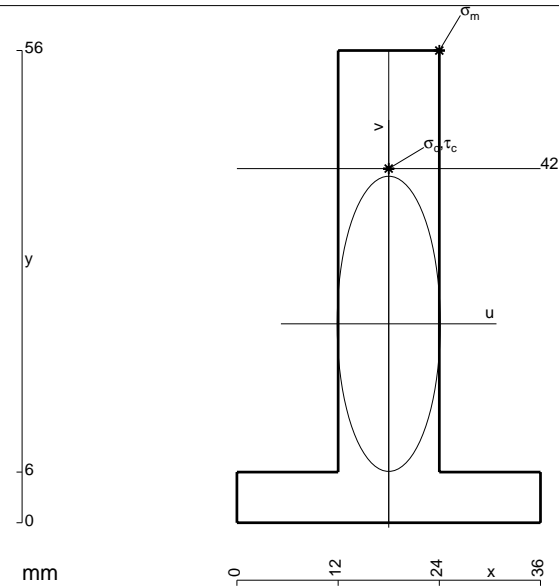
$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (1) \theta dx = [x]_0^b \theta$$

$$= (b) \theta = Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1) \theta dx = [-x]_0^b \theta$$

$$= (-b) \theta = Fb^2/EJ$$



$$A = 816. \text{ mm}^2$$

$$J_u = 250166. \text{ mm}^4$$

$$J_v = 30528. \text{ mm}^4$$

$$y_g = 23.59 \text{ mm}$$

$$T_y = -5070. \text{ N}$$

$$M_x = -1774500. \text{ Nmm}$$

$$x_m = 24. \text{ mm}$$

$$y_m = 56. \text{ mm}$$

$$u_m = 6. \text{ mm}$$

$$v_m = 32.41 \text{ mm}$$

$$\sigma_m = -Mv/J_u = 229.9 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 42. \text{ mm}$$

$$v_c = 18.41 \text{ mm}$$

$$\sigma_c = -Mv/J_u = 130.6 \text{ N/mm}^2$$

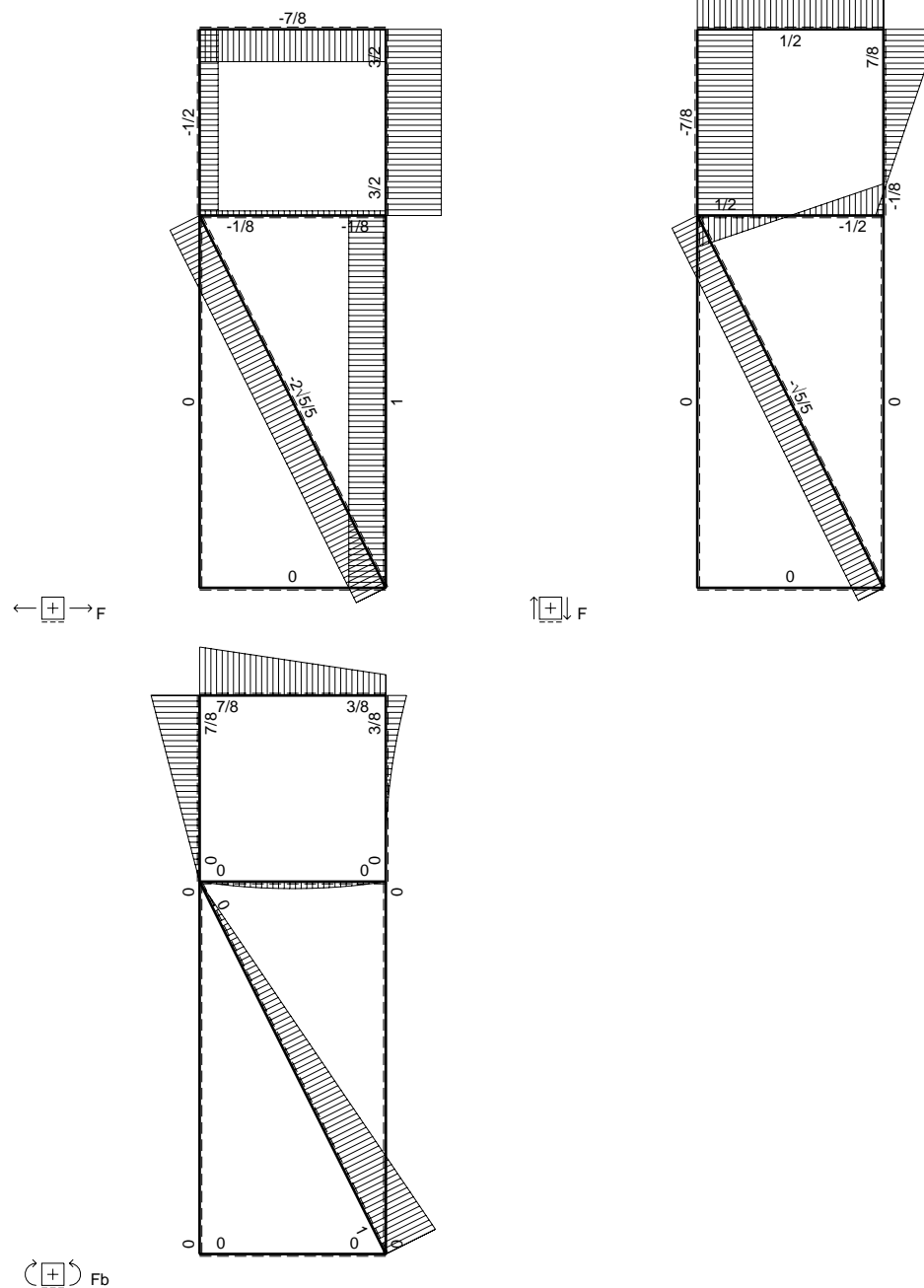
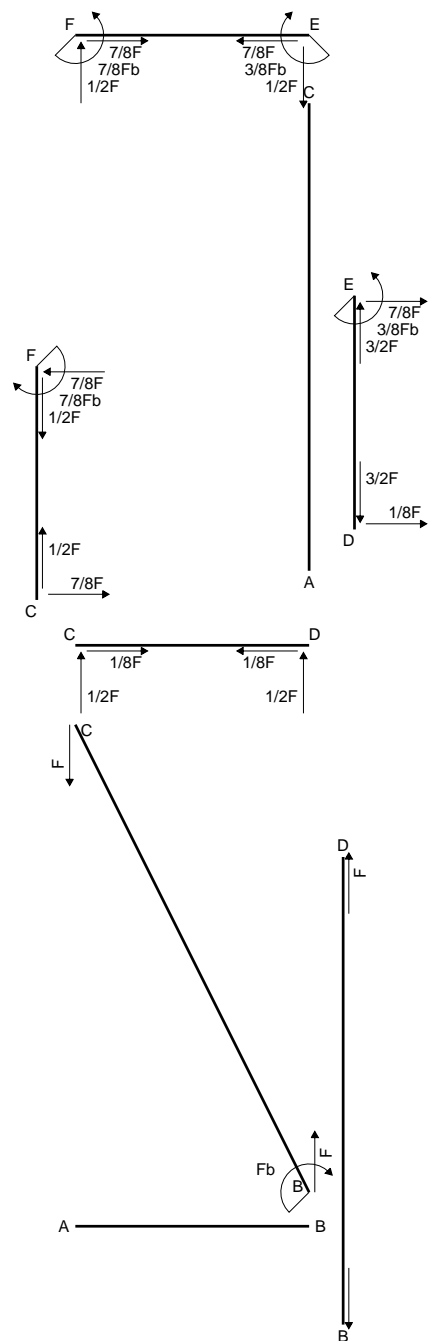
$$\tau_c = 7.21 \text{ N/mm}^2$$

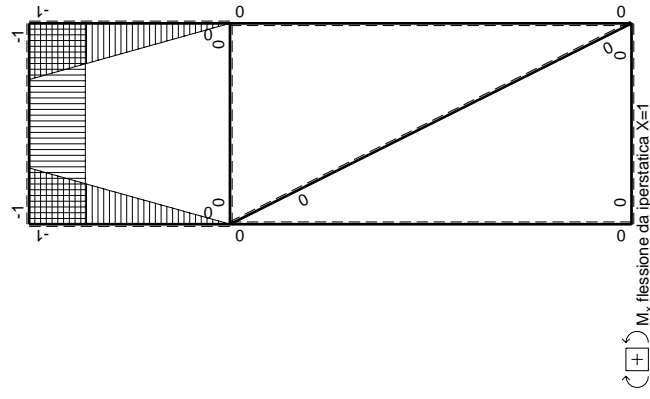
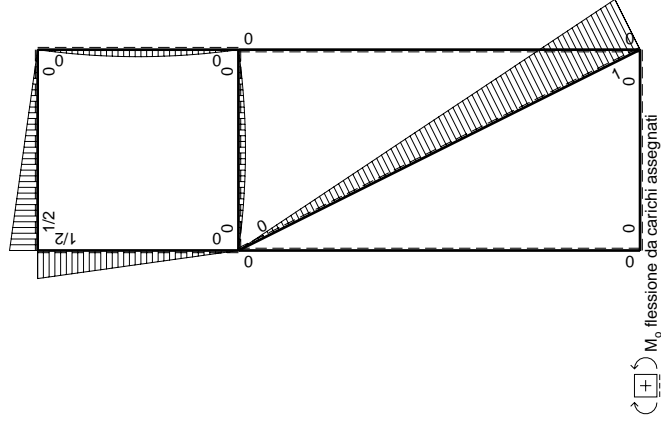
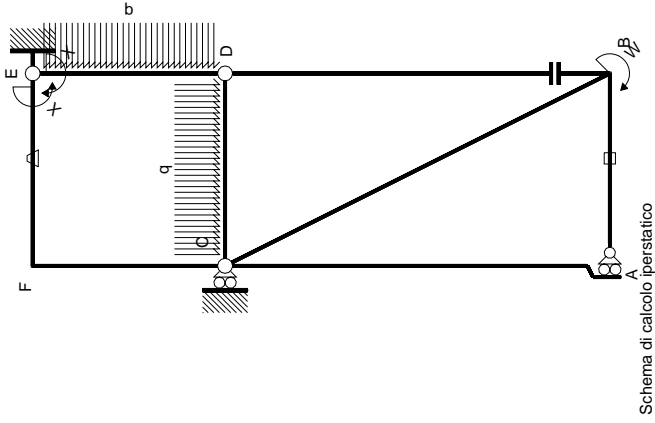
$$\sigma_o = \sqrt{\sigma^2 + 3\tau^2} = 131.2 \text{ N/mm}^2$$

$$S = 4269. \text{ mm}^3$$









Quadro contributi PLV per iperstatica X=W<sup>EF</sup>

←	M <sup>x</sup> (x)	M <sup>o</sup> (x)	θ	M <sup>x</sup> M <sup>o</sup>	M <sup>x</sup> θ	M <sup>x</sup> M <sup>x</sup>	∫M <sup>x</sup> (M <sup>o</sup> /EJ+θ)dx	∫M <sup>x</sup> M <sup>x</sup> /EJdx
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0	0
BC √5b	0	Fb-√5/5Fx	0	0	0	0	0	0
CA 2b	0	0	0	0	0	0	0+0	0
DB 2b	0	0	0	0	0	0	0+0	0
BD 2b	0	0	0	0	0	0	0	0
DE 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>	0
ED 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>	1/3Xb/EJ
CD b	0	1/2Fx-1/2qx <sup>2</sup>	0	0	0	0	0	0
DC b	0	-1/2Fx+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
EF b	-1	1/2Fx	-Fb/EJ	-1/2Fx	Fb/EJ	1	(-1/4+1)Fb <sup>2</sup> /EJ	Xb/EJ
FE b	1	-1/2Fb+1/2Fx	Fb/EJ	-1/2Fb+1/2Fx	Fb/EJ	1	(-1/4+1)Fb <sup>2</sup> /EJ	Xb/EJ
FC b	-1+x/b	1/2Fb-1/2Fx	0	-1/2Fb+Fx-1/2Fx <sup>2</sup> /b	0	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	1/3Xb/EJ
CF b	x/b	-1/2Fx	0	-1/2Fx <sup>2</sup> /b	0	0	x <sup>2</sup> /b <sup>2</sup>	1/3Xb/EJ
totali								5/8Fb <sup>2</sup> /EJ
								-3/8Fb

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{x_0} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{x_0} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{x_0} = \int_0^b (-1/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/4 b) Fb 1/EJ + (b) \theta = 3/4 Fb^2/EJ$$

$$L_{FE}^{x_0} = \int_0^b (-1/2 + 1/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-1/2 x + 1/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

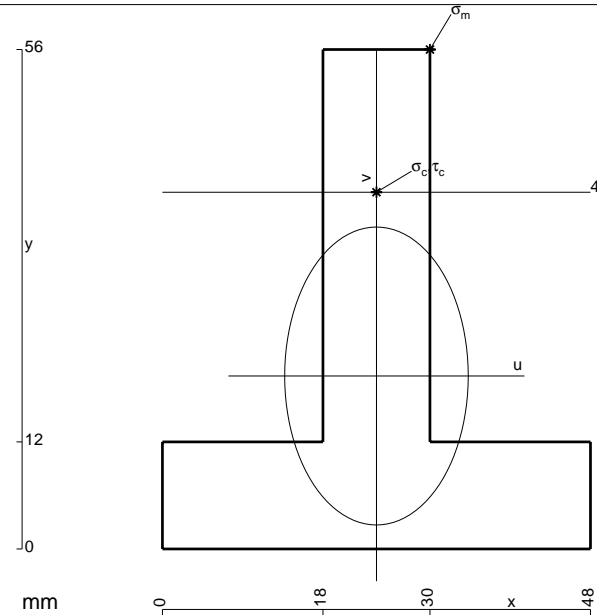
$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

$$L_{FC}^{x_0} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

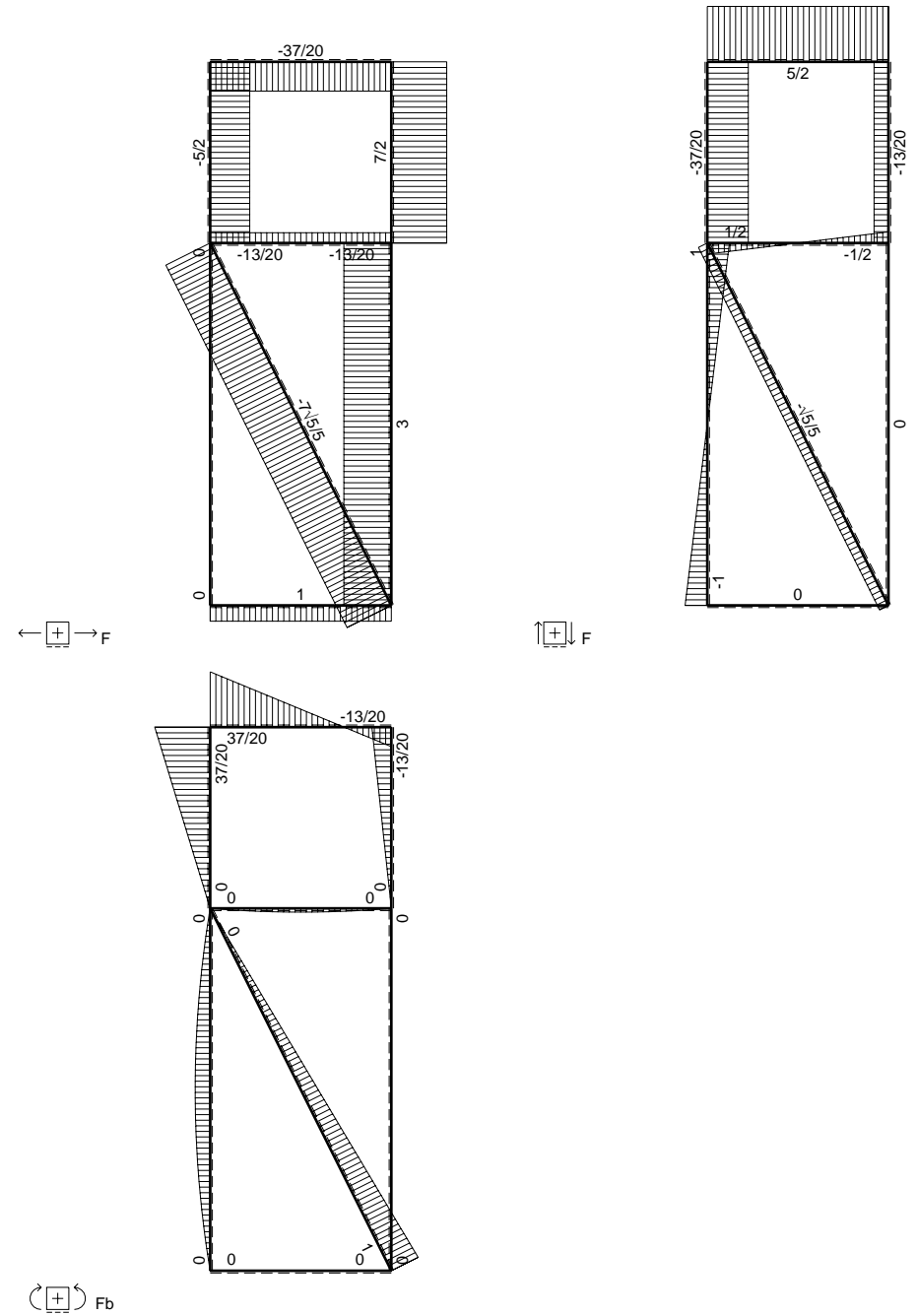
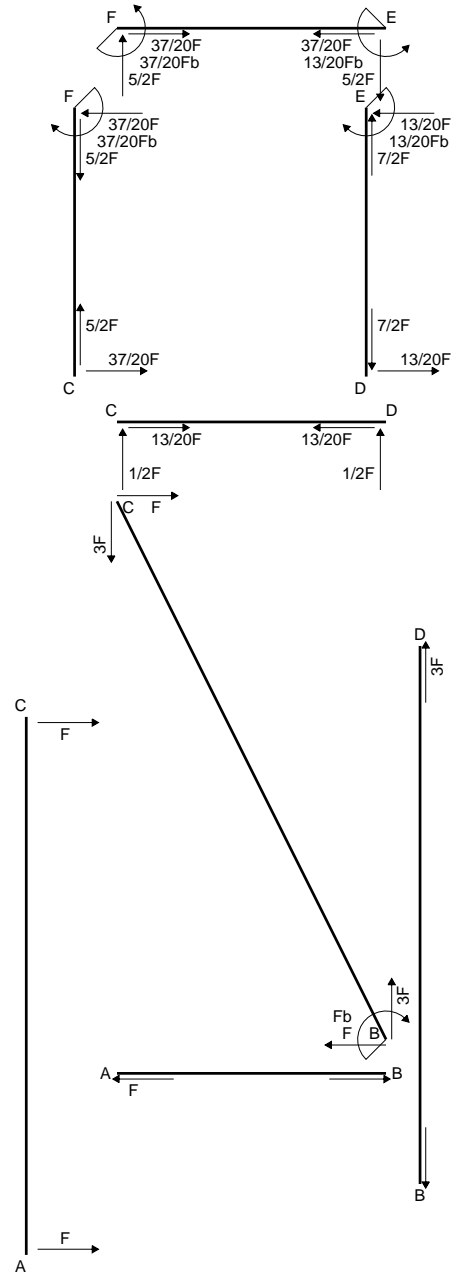
$$L_{CF}^{x_0} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ$$

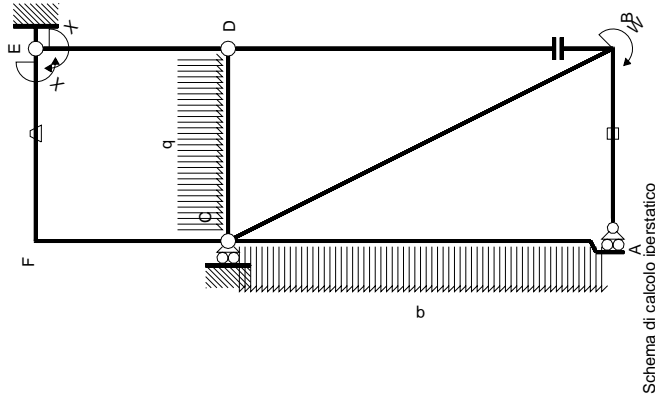
$$= (-1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$



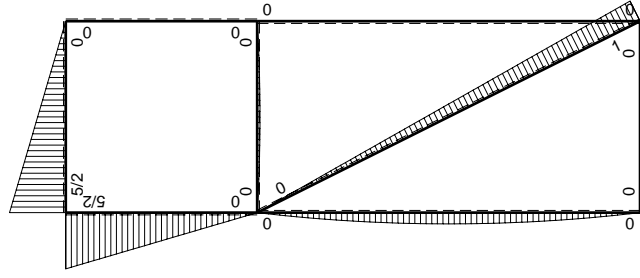
- A = 1104. mm<sup>2</sup>
- J<sub>u</sub> = 308071. mm<sup>4</sup>
- J<sub>v</sub> = 116928. mm<sup>4</sup>
- y<sub>g</sub> = 19.39 mm
- N = -2415. N
- T<sub>y</sub> = -1207. N
- M<sub>x</sub> = 1998000. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 56. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 36.61 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = -239.6 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> = -135.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.794 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup>+3τ<sup>2</sup>) = 135.9 N/mm<sup>2</sup>
- S = 5493. mm<sup>3</sup>







$M_0$  flessione da carichi assegnati

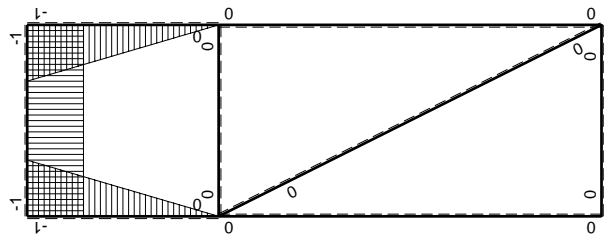


Quadro contributi PLV per iperstatica  $X=W_{EP}$

$\leftarrow$	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M^0$	$M^x \theta$	$M^x M^x$	$\int M^x(M^0/EJ+\theta)dx$	$\int M^x M^x/EJ dx$
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$Fb-\sqrt{5}/5Fx$	0	0	0	0	0	0
AC 2b	0	$-Fx+1/2qx^2$	0	0	0	0	0+0	0
CA 2b	0	$Fx-1/2qx^2$	0	0	0	0	0	0
DB 2b	0	0	0	0	0	0	0+0	0
BD 2b	0	0	0	0	0	0	0	0
DE b	$-x/b$	0	0	0	0	0	0+0	0
ED b	$1-x/b$	0	0	0	0	0	0	0
CD b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0	0
DC b	0	$-1/2Fx+1/2qx^2$	0	0	0	0	0+0	0
EF b	-1	$5/2Fx$	$-Fb/EJ$	$-5/2Fx$	$Fb/EJ$	1	$(-5/4+1)Fb^2/EJ$	$Xb/EJ$
FE b	1	$-5/2Fb+5/2Fx$	$Fb/EJ$	$-5/2Fb+5/2Fx$	$Fb/EJ$	1	$(-5/6+0)Fb^2/EJ$	$1/3Xb/EJ$
FC b	$-1+x/b$	$5/2Fb-5/2Fx$	0	$-5/2Fb+5Fx-5/2Fx^2/b$	0	0	$1-2x/b+x^2/b^2$	$1/3Xb/EJ$
CF b	$x/b$	$-5/2Fx$	0	$-5/2Fx^2/b$	0	0	$x^2/b^2$	$5/3Xb/EJ$
totali								$13/20Fb$

Sviluppi di calcolo iperstatica

$M_x$  flessione da iperstatica  $X=1$



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-5/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-5/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-5/4 b) Fb 1/EJ + (b) \theta = -1/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-5/2 + 5/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-5/2 x + 5/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

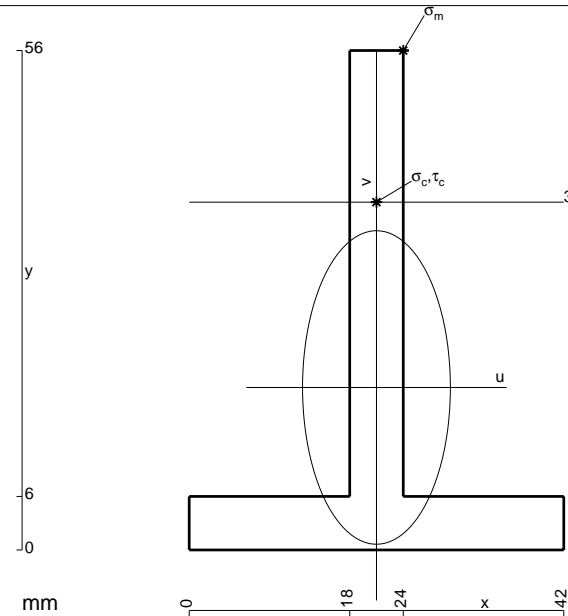
$$= (-5/2 b + 5/4 b) Fb 1/EJ + (-b) \theta = -1/4 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = [-5/2 x + 5/2 x^2/b - 5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

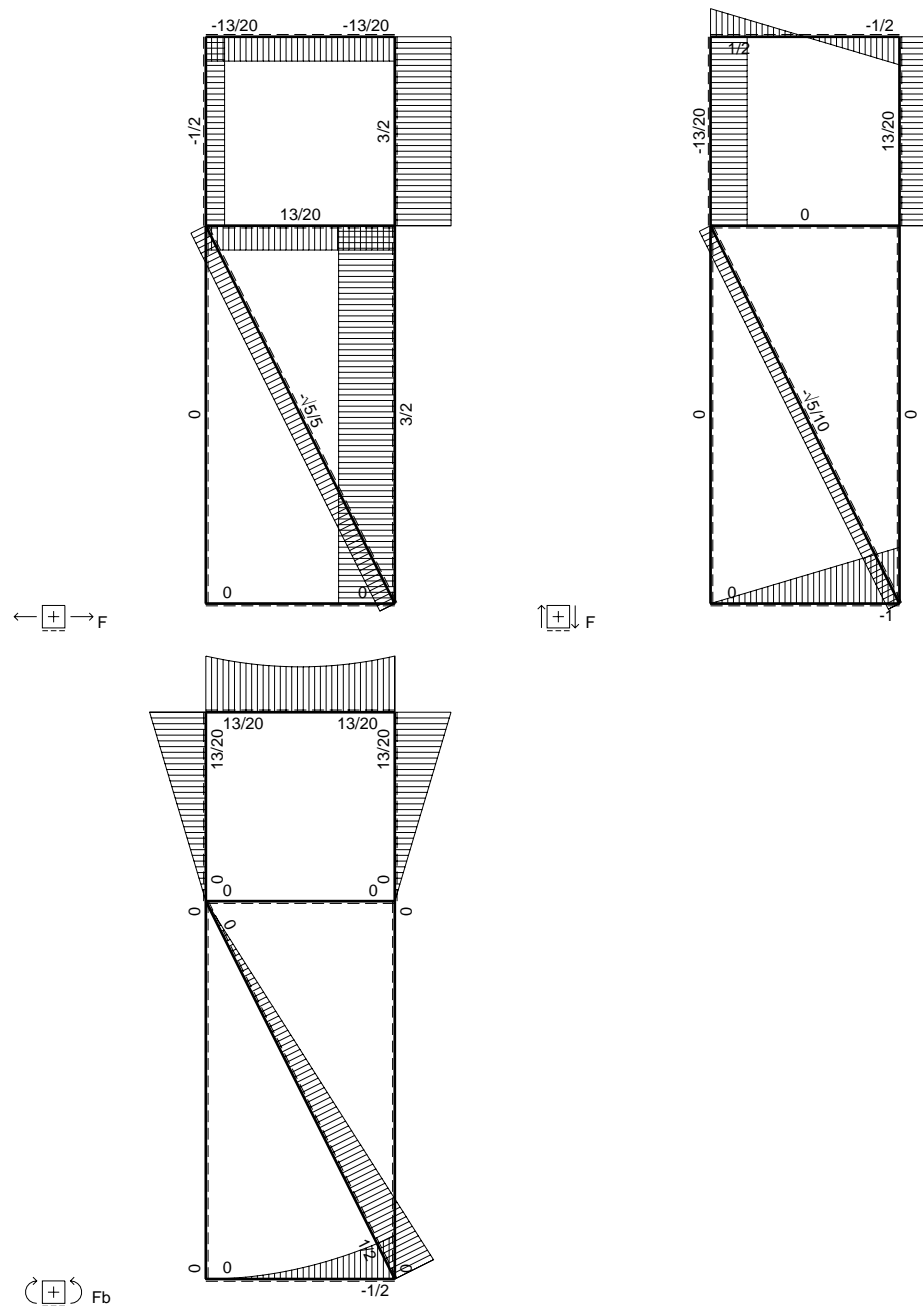
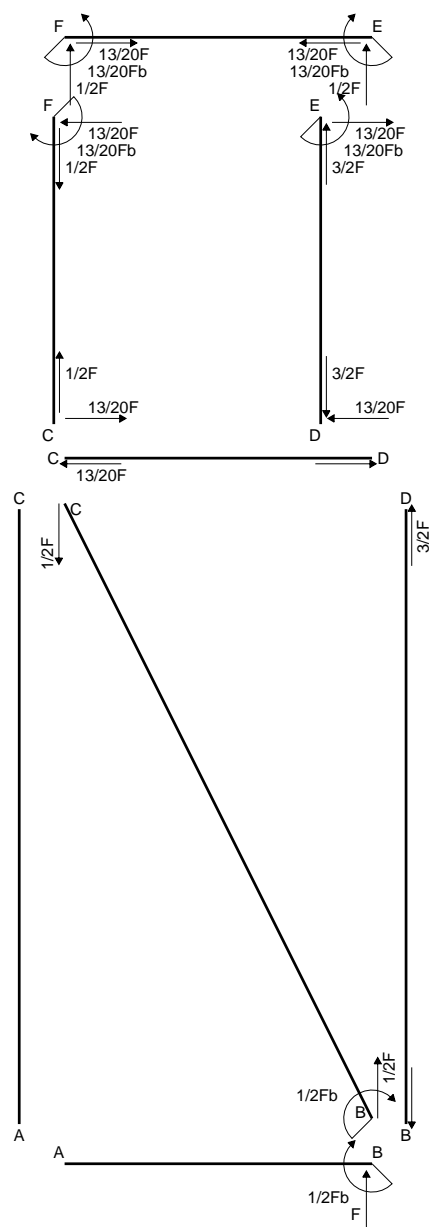
$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$



- 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 = -6793. N
- T<sub>y</sub> = -970.5 N
- M<sub>x</sub> = 846300. 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> = -199.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 39. mm
- v<sub>c</sub> = 20.78 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = -115.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.831 N/mm<sup>2</sup>
- σ<sub>o</sub> = √(σ<sup>2</sup>+3τ<sup>2</sup>) = 115.5 N/mm<sup>2</sup>
- S = 2987. mm<sup>3</sup>









$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

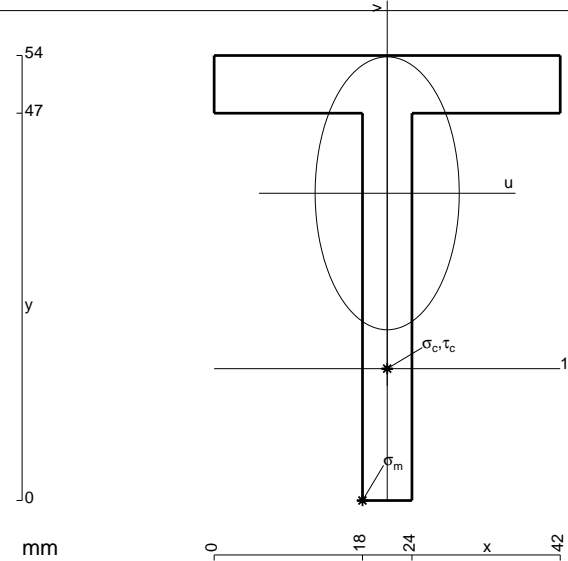
$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (1/4 b - 1/6 b) Fb 1/EJ + (b) \theta = 13/12 Fb^2/EJ$$

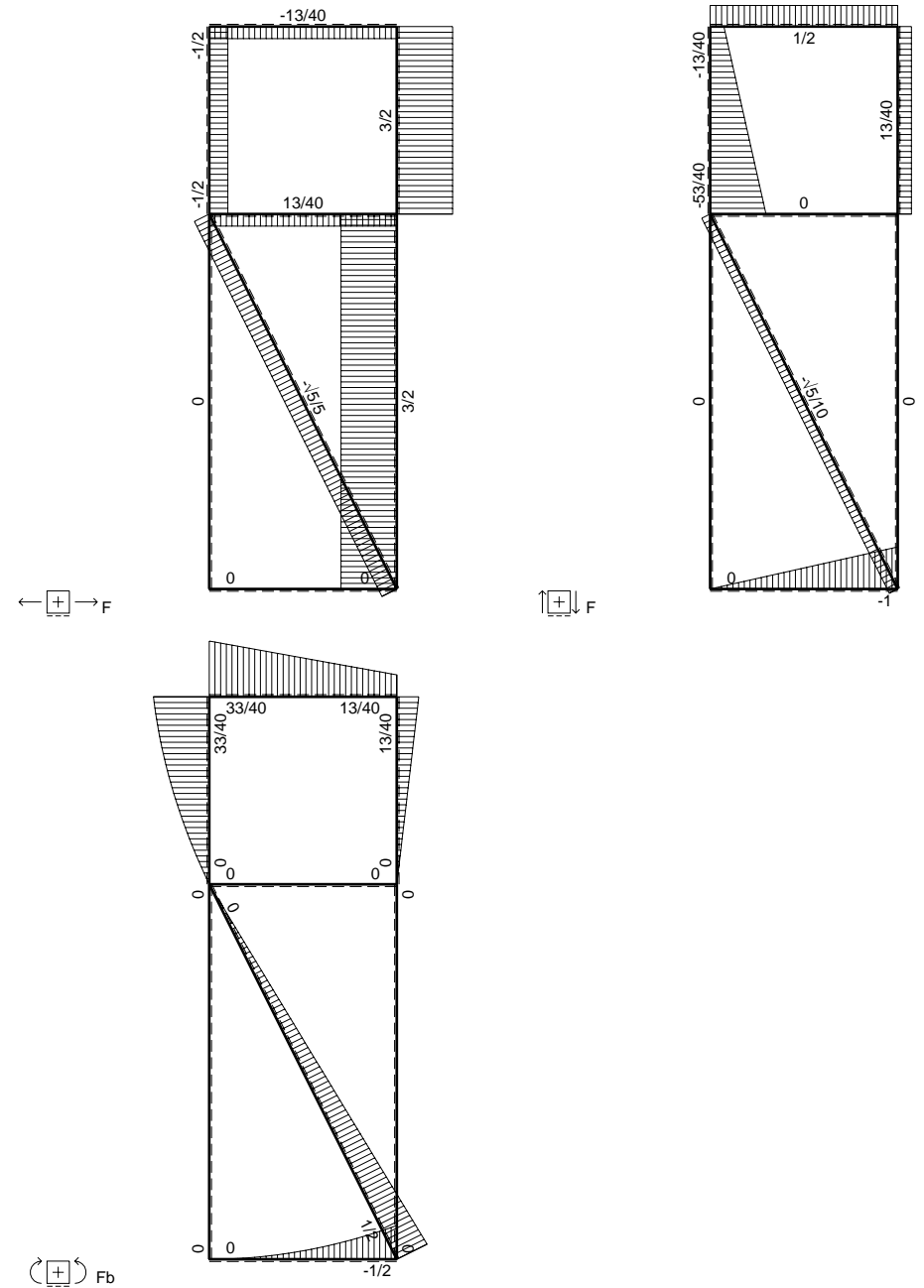
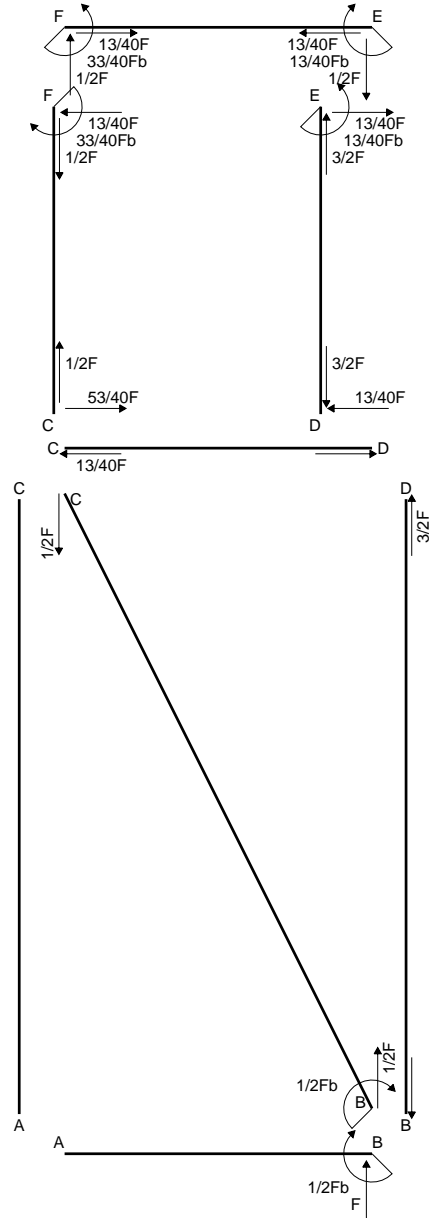
$$L_{FE}^{xo} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

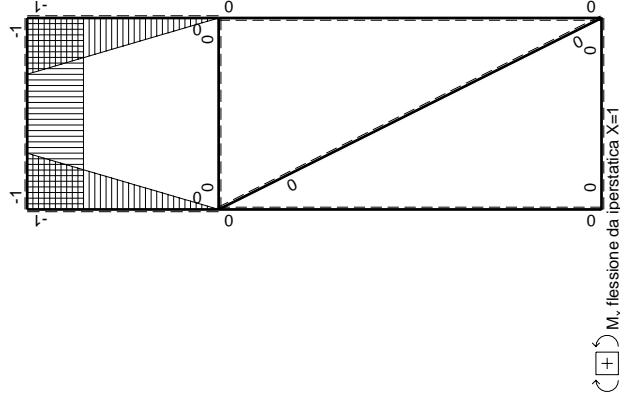
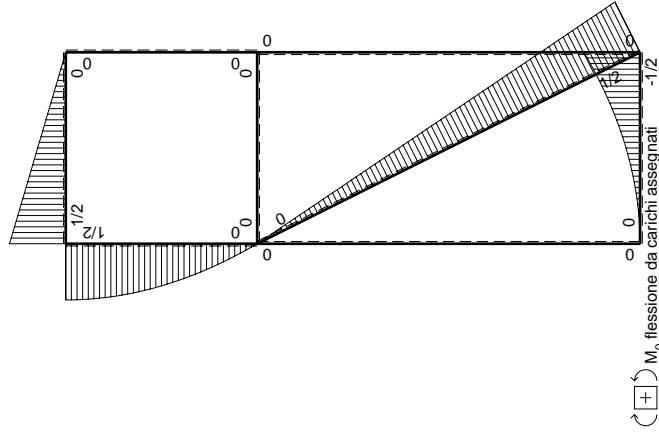
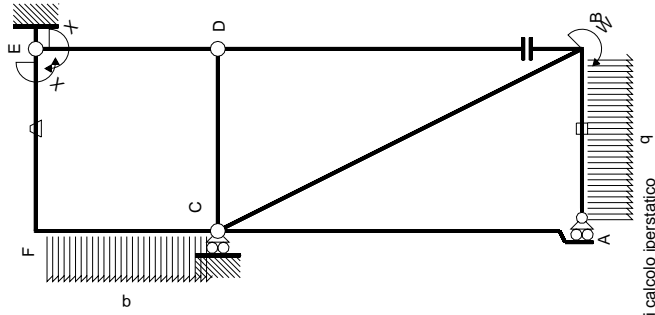
$$= (1/4 b - 1/6 b) Fb 1/EJ + (-b) \theta = 13/12 Fb^2/EJ$$



- A = 576. mm<sup>2</sup>
- J<sub>u</sub> = 158042. mm<sup>4</sup>
- J<sub>v</sub> = 44064. mm<sup>4</sup>
- y<sub>g</sub> = 37.28 mm
- T<sub>y</sub> = -4340. N
- M<sub>x</sub> = -889700. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -37.28 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -209.9 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 16. mm
- v<sub>c</sub> = -21.28 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -119.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 12.87 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 121.9 N/mm<sup>2</sup>
- S = 2811. mm<sup>3</sup>







Quadro contributi PLV per iperstatica  $X=W_{EF}$

$\rightarrow$	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x (M_0/EJ + \theta) dx$	$\int M^x M_x / E dx$
AB b	0	$-1/2qx^2$	0	0	0	0	0	0
BA b	0	$1/2Fb - Fx + 1/2qx^2$	0	0	0	0	0	0
BC √5b	0	$1/2Fb - \sqrt{5}/10Fx$	0	0	0	0	0	0
AC 2b	0	0	0	0	0	0	0	0
CA 2b	0	0	0	0	0	0	0	0
DB 2b	0	0	0	0	0	0	0	0
BD 2b	0	0	0	0	0	0	0	0
DE b	-x/b	0	0	0	0	$x^2/b^2$	0	0
ED b	1-x/b	0	0	0	0	$1-2x/b+x^2/b^2$	0	$1/3xb/EJ$
CD b	0	0	0	0	0	0	0	0
DC b	0	0	0	0	0	0	0	0
EF b	-1	$1/2Fx$	-Fb/EJ	-1/2Fx	Fb/EJ	1	$(-1/4+1)Fb^2/EJ$	$xb/EJ$
FE b	1	$-1/2Fb+1/2Fx$	Fb/EJ	$-1/2Fb+1/2Fx$	Fb/EJ	1	$(-1/4+1)Fb^2/EJ$	$xb/EJ$
FC b	-1+x/b	$1/2Fb-1/2qx^2$	0	$-1/2Fb+1/2Fx+1/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(-5/24+0)Fb^2/EJ$	$1/3xb/EJ$
CF b	x/b	$-Fx+1/2qx^2$	0	$-Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$	$13/24Fb^2/EJ$	$5/3xb/EJ$
totali								
iperstatica $X=W_{EF}$								

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/4 b) Fb 1/EJ + (b) \theta = 3/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + 1/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-1/2 x + 1/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

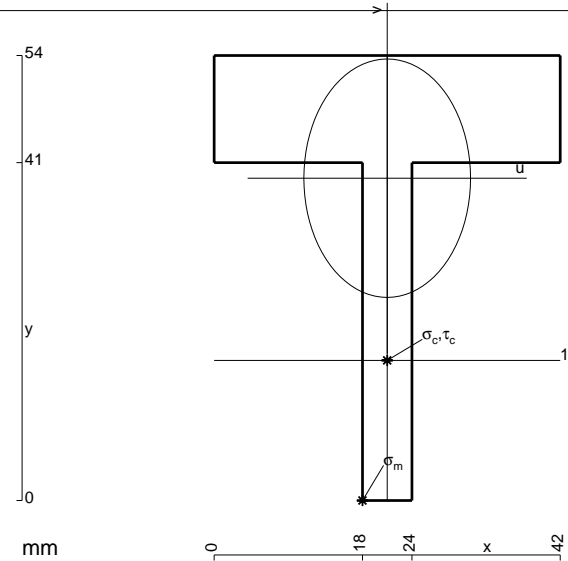
$$L_{FC}^{xo} = \int_0^b (-1/2 + 1/2 x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx$$

$$= [-1/2 x + 1/4 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/4 b + 1/6 b - 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/3 b + 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$



$$A = 792. \text{ mm}^2$$

$$J_u = 165782. \text{ mm}^4$$

$$J_v = 81000. \text{ mm}^4$$

$$y_g = 39.11 \text{ mm}$$

$$T_y = -4140. \text{ N}$$

$$M_x = -931500. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -39.11 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -219.8 \text{ N/mm}^2$$

$$x_c = 21. \text{ mm}$$

$$y_c = 17. \text{ mm}$$

$$v_c = -22.11 \text{ mm}$$

$$\sigma_c = -Mv/J_u = -124.3 \text{ N/mm}^2$$

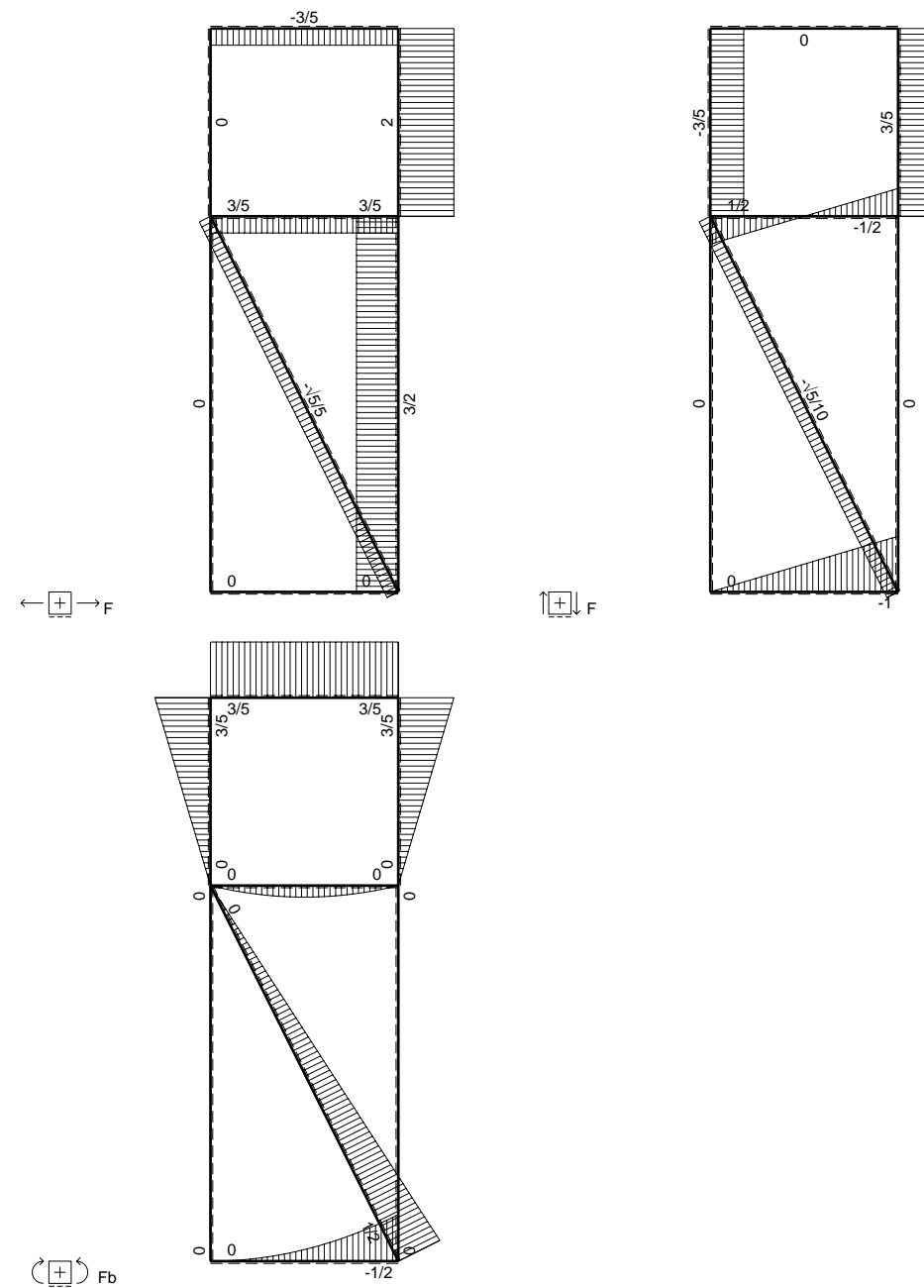
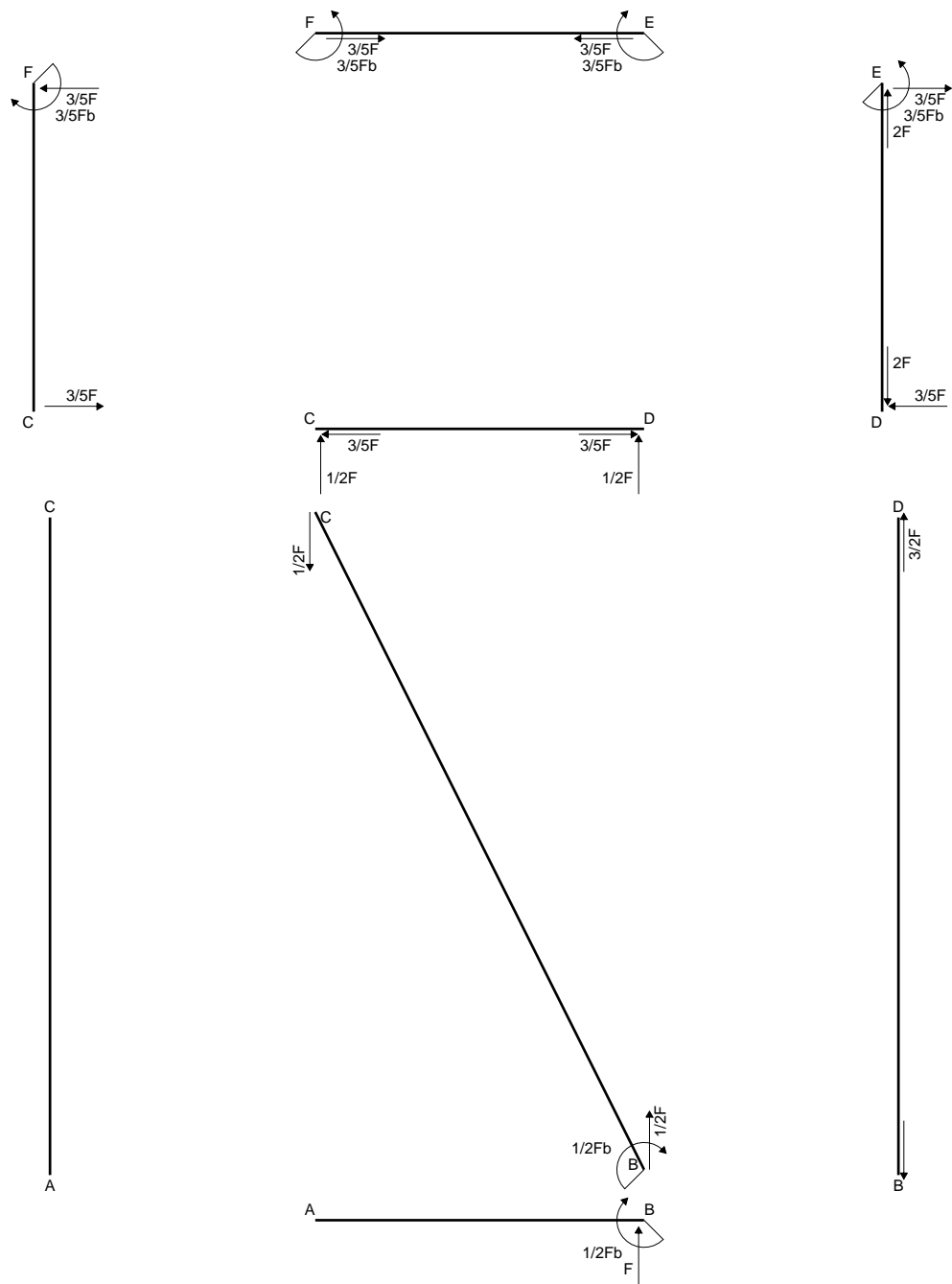
$$\tau_c = 13. \text{ N/mm}^2$$

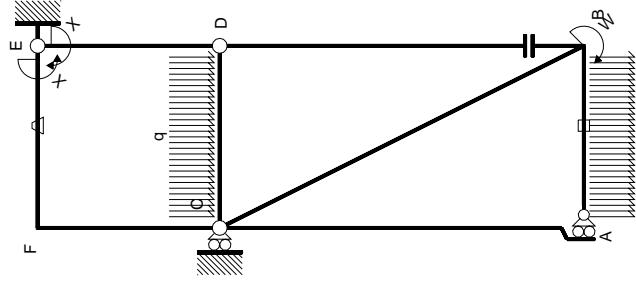
$$\sigma_o = \sqrt{\sigma^2 + 3\tau^2} = 126.3 \text{ N/mm}^2$$

$$S = 3123. \text{ mm}^3$$

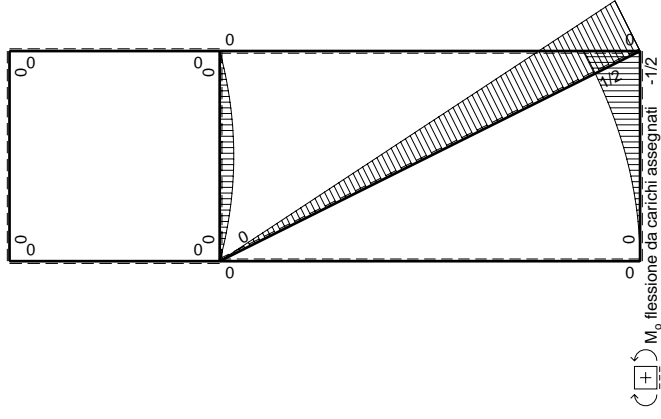








Schema di calcolo iperstatico



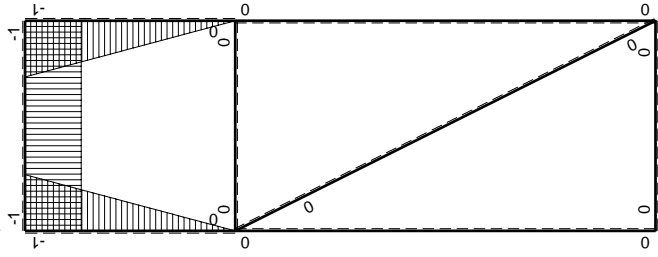
$M_0$  flessione da carichi assegnati -1/2

Quadro contributi PLV per iperstatica  $X=W_{EF}$

$\rightarrow$	$M_x(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int X M_x M_x / EJ dx$
AB b	0	$-1/2qx^2$	0	0	0	0	0+0	0
BA b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0+0	0
BC $\sqrt{5}b$	0	$1/2Fb-\sqrt{5}/10Fx$	0	0	0	0	0	0
AC 2b	0	0	0	0	0	0	0+0	0
CA 2b	0	0	0	0	0	0	0+0	0
DB 2b	0	0	0	0	0	0	0+0	0
BD 2b	0	0	0	0	0	0	0+0	0
DE b	$-x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3Xb/EJ$
ED b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$
CD b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0
DC b	0	$-1/2Fx+1/2qx^2$	0	0	0	0	0+0	0
EF b	-1	0	$-Fb/EJ$	0	$Fb/EJ$	1	$(0+1)Fb^2/EJ$	$Xb/EJ$
FE b	1	0	$Fb/EJ$	0	$Fb/EJ$	1	$(0+1)Fb^2/EJ$	$Xb/EJ$
FC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$
CF b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3Xb/EJ$
	totali						$Fb^2/EJ$	$5/3Xb/EJ$
	iperstatica $X=W_{EF}$						$-3/5Fb$	

Sviluppi di calcolo iperstatica

$M_x$  flessione da iperstatica  $X=1$



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

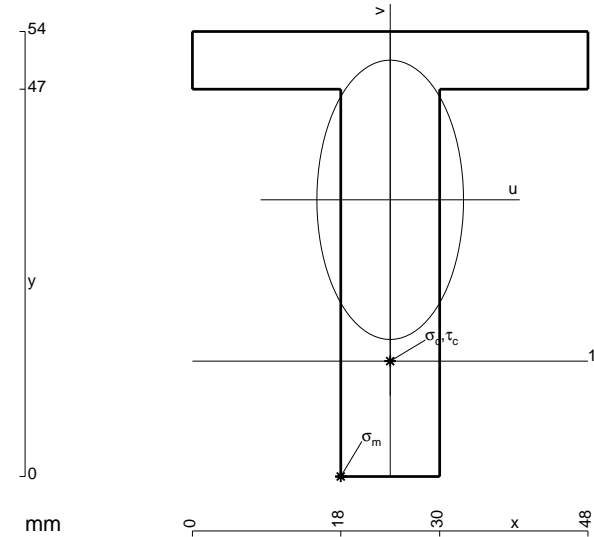
$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (1) \theta dx = [x]_0^b \theta$$

$$= (b) \theta = Fb^2/EJ$$

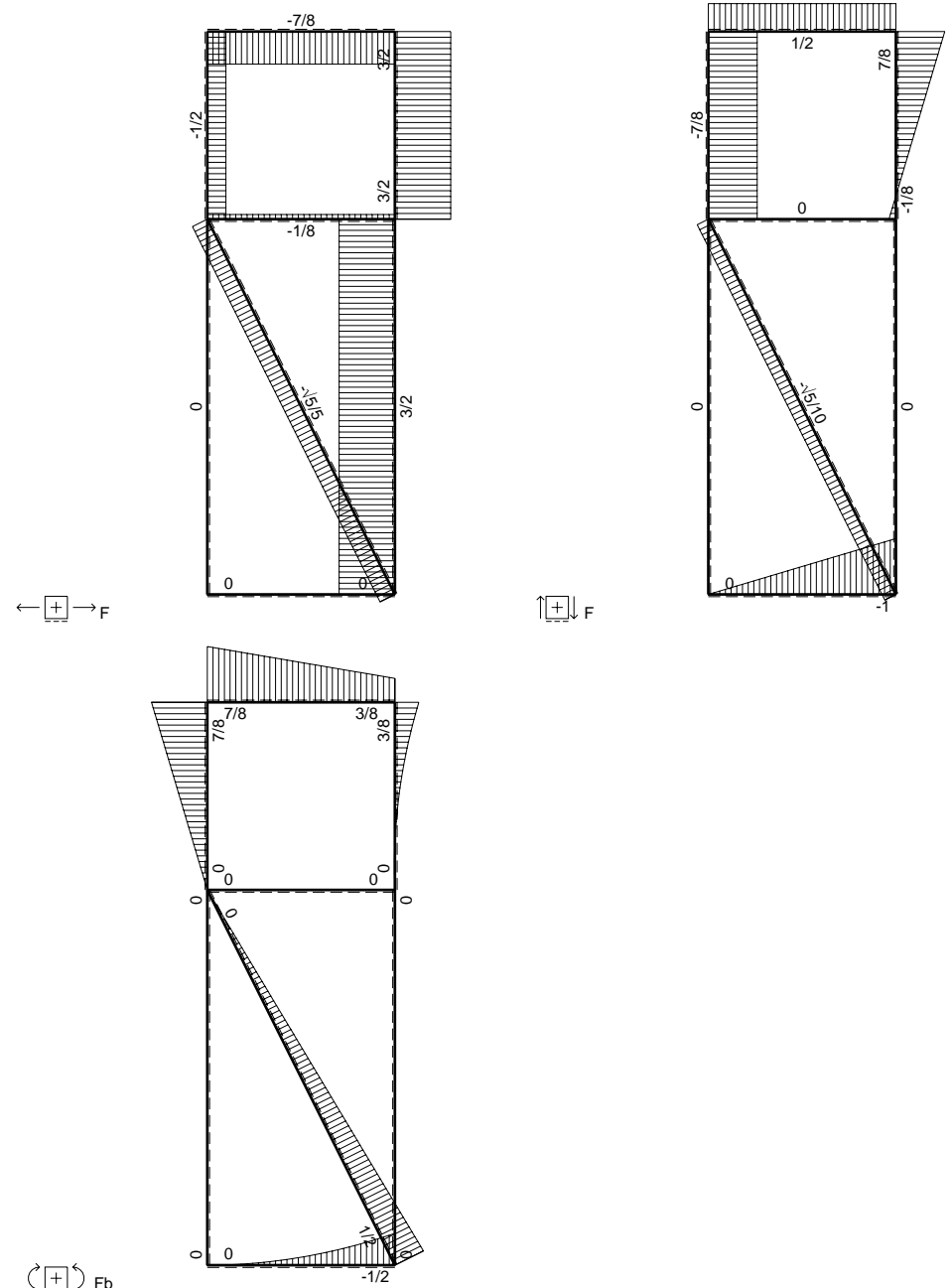
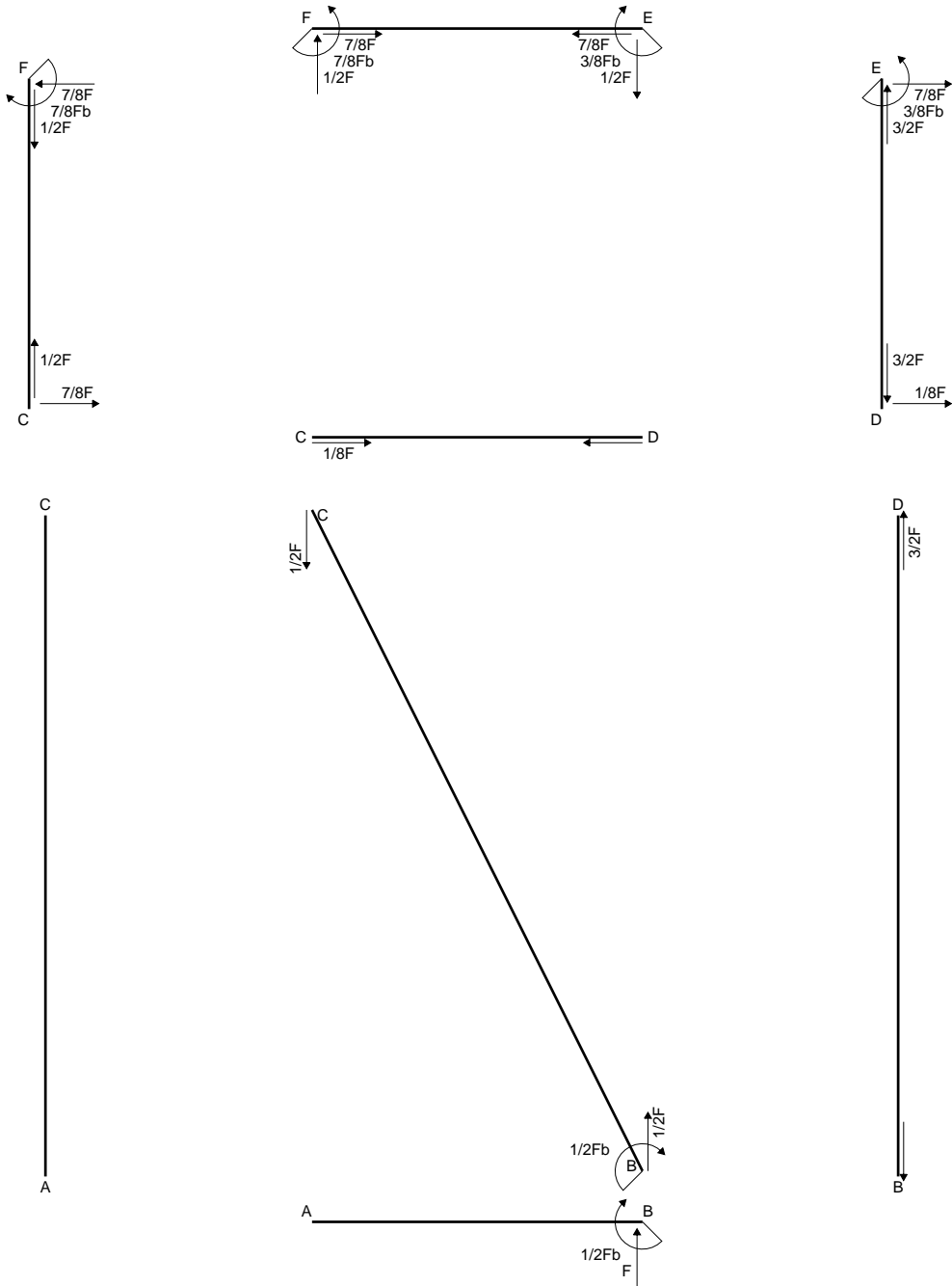
$$L_{FE}^{xo} = \int_0^b (-1) \theta dx = [-x]_0^b \theta$$

$$= (-b) \theta = Fb^2/EJ$$



$A = 900. \text{ mm}^2$   
 $J_u = 258693. \text{ mm}^4$   
 $J_v = 71280. \text{ mm}^4$   
 $y_g = 33.58 \text{ mm}$   
 $T_y = -7230. \text{ N}$   
 $M_x = -1771350. \text{ Nmm}$   
 $x_m = 18. \text{ mm}$   
 $u_m = -6. \text{ mm}$   
 $v_m = -33.58 \text{ mm}$   
 $\sigma_m = -Mv/J_u = -229.9 \text{ N/mm}^2$   
 $x_c = 24. \text{ mm}$   
 $y_c = 14. \text{ mm}$   
 $v_c = -19.58 \text{ mm}$   
 $\sigma_c = -Mv/J_u = -134.1 \text{ N/mm}^2$   
 $\tau_c = 10.4 \text{ N/mm}^2$   
 $\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 135.3 \text{ N/mm}^2$   
 $S = 4465. \text{ mm}^3$







$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/4 b) Fb 1/EJ + (b) \theta = 3/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + 1/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-1/2 x + 1/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

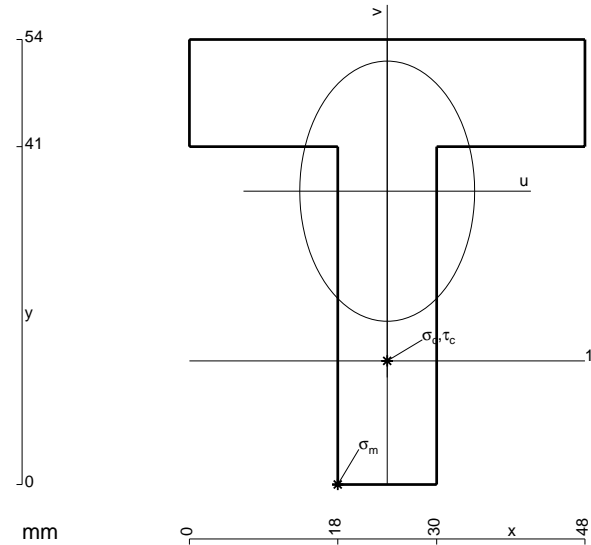
$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ$$

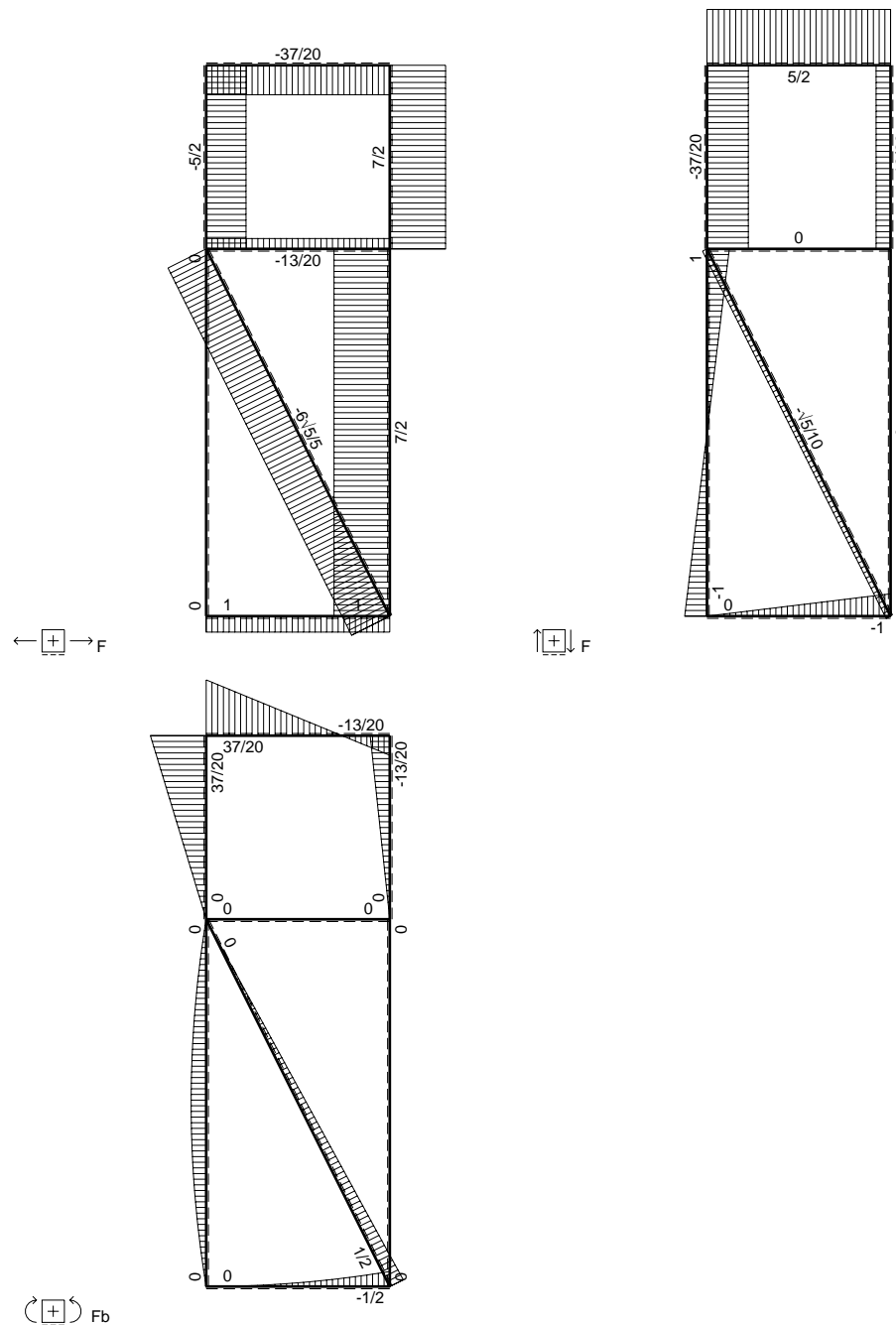
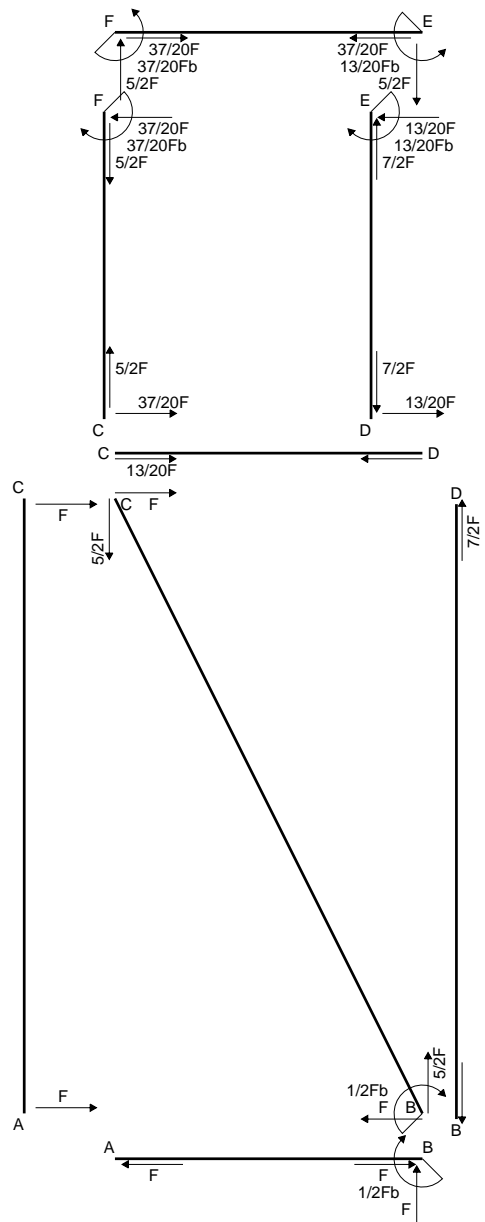
$$= (-1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

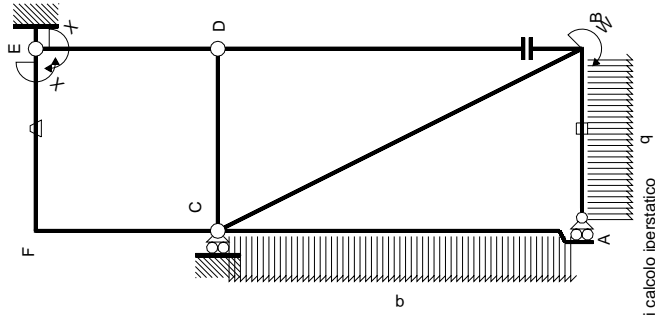


- A = 1116. mm<sup>2</sup>
- J<sub>u</sub> = 278254. mm<sup>4</sup>
- J<sub>v</sub> = 125712. mm<sup>4</sup>
- y<sub>g</sub> = 35.6 mm
- T<sub>y</sub> = -7070. N
- M<sub>x</sub> = -1873550. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -35.6 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -239.7 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> = -Mv/J<sub>u</sub> = -138.7 N/mm<sup>2</sup>
- τ<sub>c</sub> = 10.71 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 139.9 N/mm<sup>2</sup>
- S = 5057. mm<sup>3</sup>

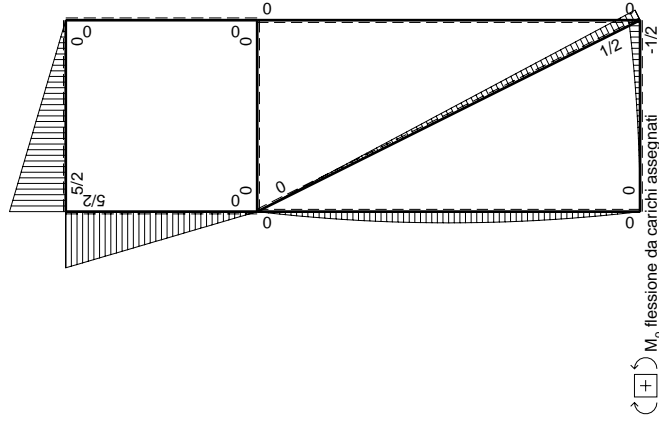




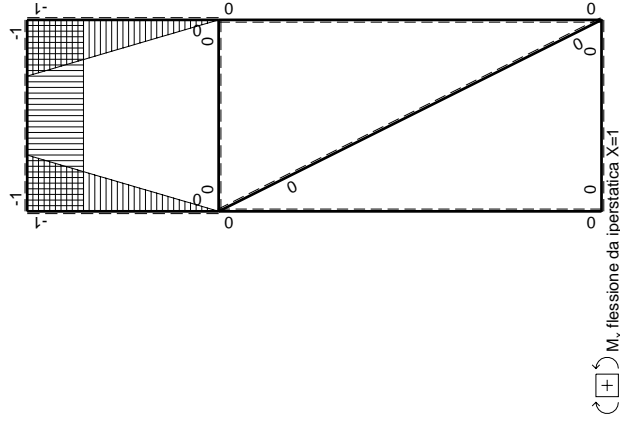




Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica X=W<sup>EP</sup>

→	M <sup>x</sup> (x)	M <sup>o</sup> (x)	θ	M <sup>x</sup> M <sup>o</sup>	M <sup>x</sup> θ	M <sup>x</sup> M <sup>x</sup>	∫M <sup>x</sup> (M <sup>o</sup> /EJ+θ)dx	∫M <sup>x</sup> M <sup>x</sup> /EJdx
AB b	0	-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
BA b	0	1/2Fb-Fx+1/2qx <sup>2</sup>	0	0	0	0	0	0
BC √5b	0	1/2Fb-√5/10Fx	0	0	0	0	0+0	0
AC 2b	0	-Fx+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
CA 2b	0	Fx-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
DB 2b	0	0	0	0	0	0	0+0	0
BD 2b	0	0	0	0	0	0	0+0	0
DE b	-x/b	0	0	0	0	0	0+0	1/3xb/EJ
ED b	1-x/b	0	0	0	0	0	0+0	1/3xb/EJ
CD b	0	0	0	0	0	0	0+0	0
DC b	0	0	0	0	0	0	0+0	0
EF b	-1	5/2Fx	-Fb/EJ	-5/2Fx	Fb/EJ	1	(-5/4+1)Fb <sup>2</sup> /EJ	Xb/EJ
FE b	1	-5/2Fb+5/2Fx	Fb/EJ	-5/2Fb+5/2Fx	Fb/EJ	1	(-5/4+1)Fb <sup>2</sup> /EJ	Xb/EJ
FC b	-1+x/b	5/2Fb-5/2Fx	0	-5/2Fb+5Fx-5/2Fx <sup>2</sup> /b	0	0	(-5/6+0)Fb <sup>2</sup> /EJ	1/3xb/EJ
CF b	x/b	-5/2Fx	0	-5/2Fx <sup>2</sup> /b	0	0	(-5/6+0)Fb <sup>2</sup> /EJ	1/3xb/EJ
totali								
iperstatica X=W <sup>EP</sup>								

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (-2x/b + x^2/b^2) 1/EJ dx = [-x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-5/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-5/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-5/4 b) Fb 1/EJ + (b) \theta = -1/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-5/2 + 5/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-5/2 x + 5/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

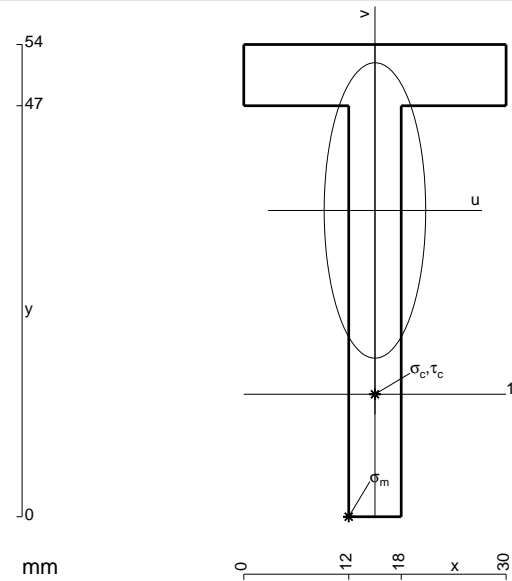
$$= (-5/2 b + 5/4 b) Fb 1/EJ + (-b) \theta = -1/4 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = [-5/2 x + 5/2 x^2/b - 5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

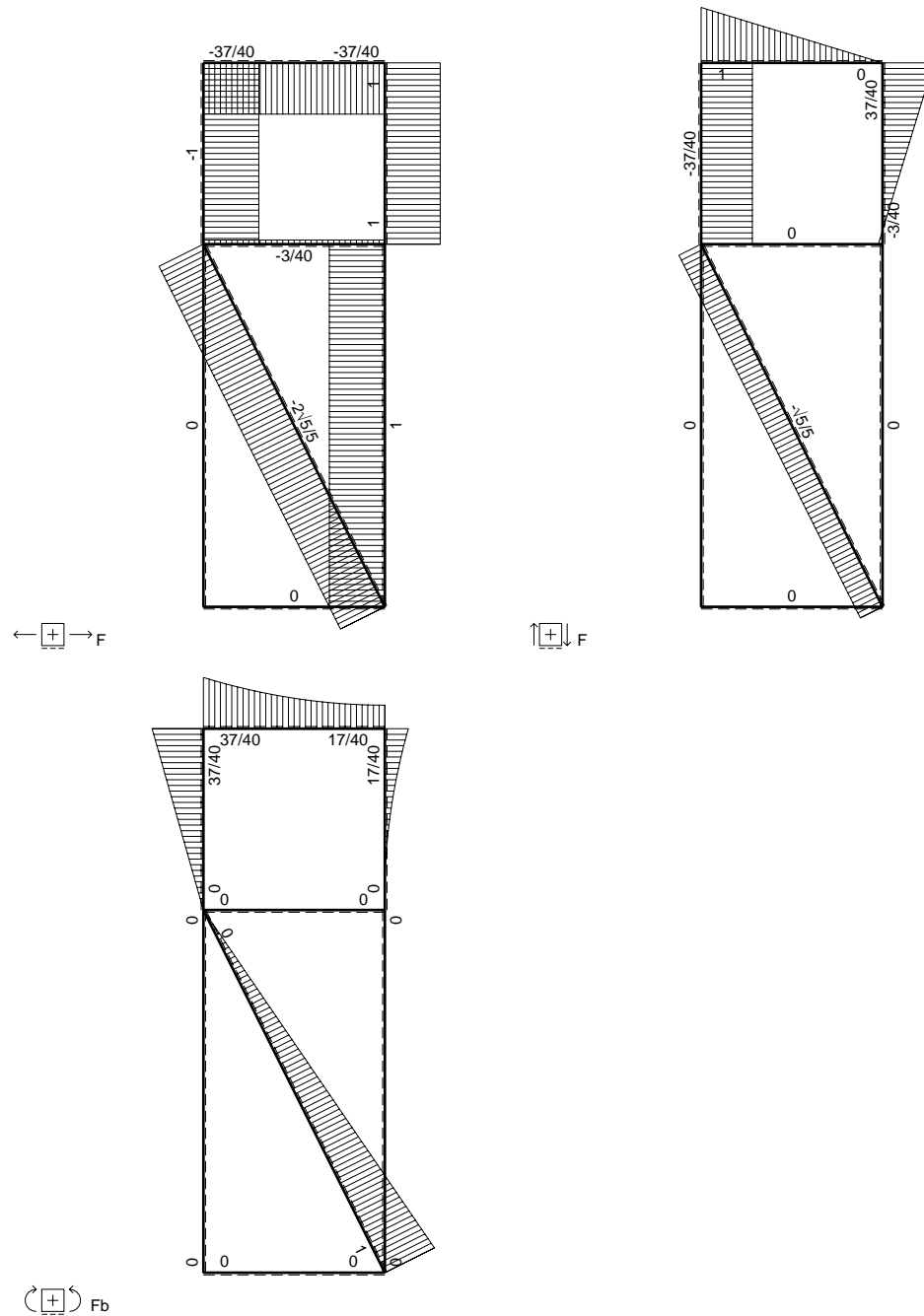
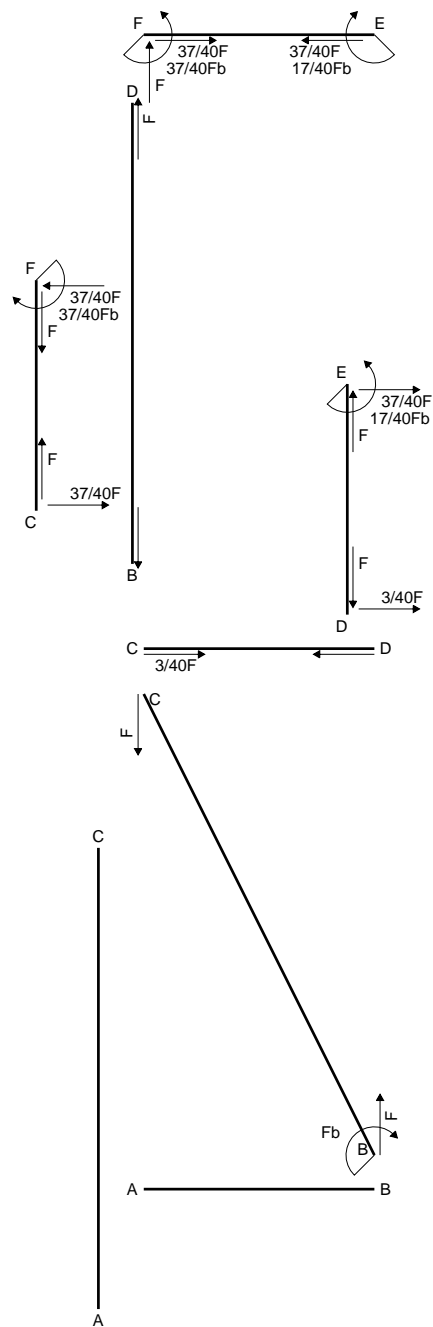
$$L_{CF}^{xo} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

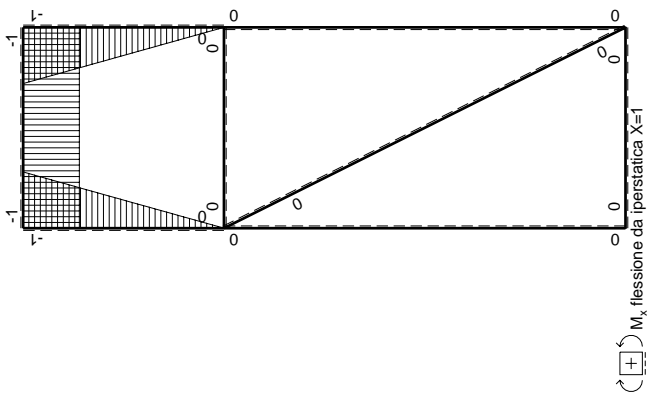
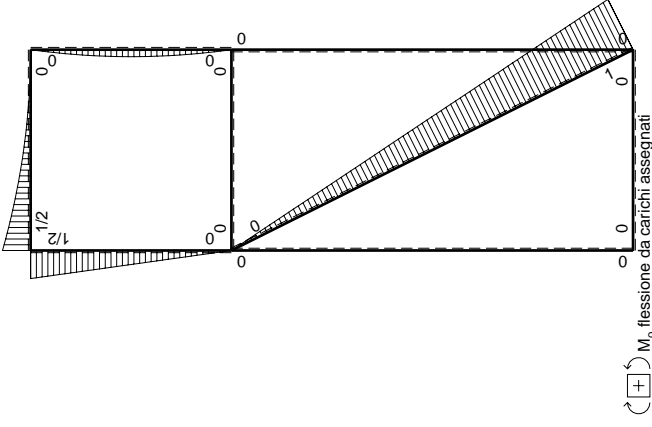
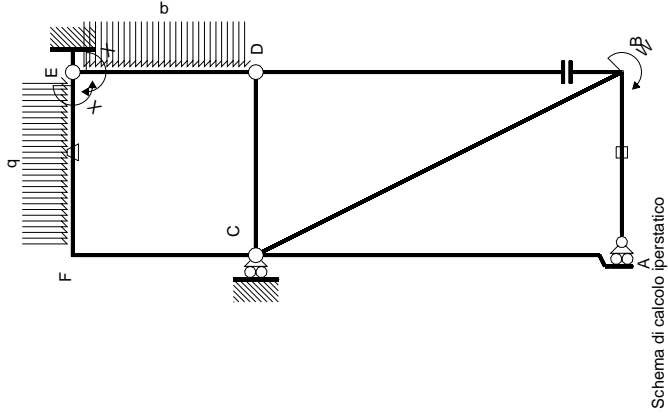
$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$



- 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
- N = 2890. N
- T<sub>y</sub> = -2890. N
- M<sub>x</sub> = -823650. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -35.02 mm
- σ<sub>m</sub> = N/A - M<sub>v</sub>/J<sub>u</sub> = -199.4 N/mm<sup>2</sup>
- x<sub>c</sub> = 15. mm
- y<sub>c</sub> = 14. mm
- v<sub>c</sub> = -21.02 mm
- σ<sub>c</sub> = N/A - M<sub>v</sub>/J<sub>u</sub> = -117.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 8.069 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 118.2 N/mm<sup>2</sup>
- S = 2354. mm<sup>3</sup>







Quadro contributi PLV per iperstatica X=W<sub>EF</sub>

←	M <sub>0</sub> (x)	M <sub>0</sub> (x)	θ	M <sub>0</sub>	M <sub>θ</sub>	M <sub>x</sub>	∫M <sub>0</sub> (M <sub>0</sub> /EJ+θ)dx	∫M <sub>x</sub> M <sub>0</sub> /EJdx
AB b	0	0	0	0	0	0	0	0
BA b	0	0	0	0	0	0	0	0
BC √5b	0	Fb√5/5Fx	0	0	0	0	0	0
CA 2b	0	0	0	0	0	0	0	0
DB 2b	0	0	0	0	0	0	0	0
BD 2b	0	0	0	0	0	0	0	0
DE 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>	(1/2+0)Fb <sup>2</sup> /EJ	1/3Xb/EJ
ED 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>	(1/2+0)Fb <sup>2</sup> /EJ	1/3Xb/EJ
CD b	0	0	0	0	0	0	0+0	0
DC b	0	0	0	0	0	0	0+0	0
EF b	-1	1/2qx <sup>2</sup>	-Fb/EJ	-1/2Fx <sup>2</sup> /b	Fb/EJ	1	(-1/6+1)Fb <sup>2</sup> /EJ	Xb/EJ
FE b	1	-1/2Fb+Fx-1/2qx <sup>2</sup>	Fb/EJ	-1/2Fb+Fx-1/2Fx <sup>2</sup> /b	Fb/EJ	1	(-1/6+1)Fb <sup>2</sup> /EJ	Xb/EJ
FC b	-1+x/b	1/2Fb-1/2Fx	0	-1/2Fb+Fx-1/2Fx <sup>2</sup> /b	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	(-1/6+0)Fb <sup>2</sup> /EJ	1/3Xb/EJ
CF b	x/b	-1/2Fx	0	-1/2Fx <sup>2</sup> /b	0	x <sup>2</sup> /b <sup>2</sup>	(-1/6+0)Fb <sup>2</sup> /EJ	1/3Xb/EJ
totali							17/24Fb <sup>2</sup> /EJ	5/3Xb/EJ
								-17/40Fb

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/6 b) Fb 1/EJ + (b) \theta = 5/6 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx$$

$$= [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

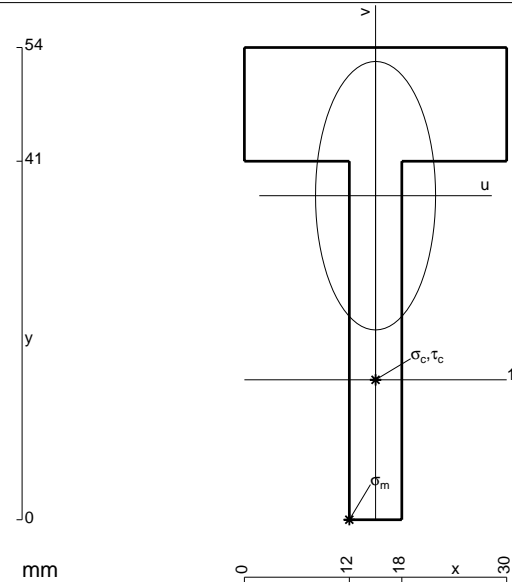
$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ + (-b) \theta = 5/6 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ$$

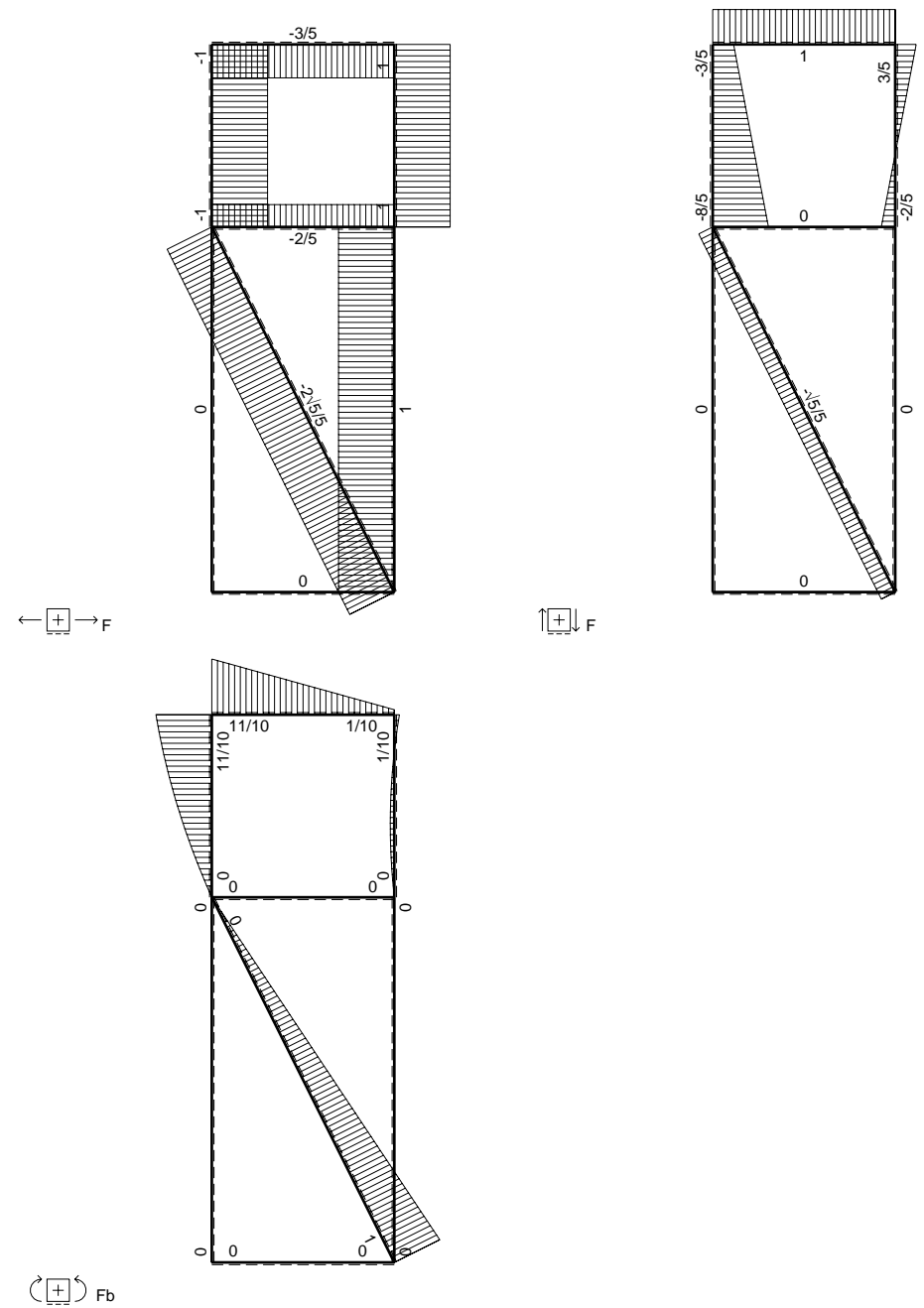
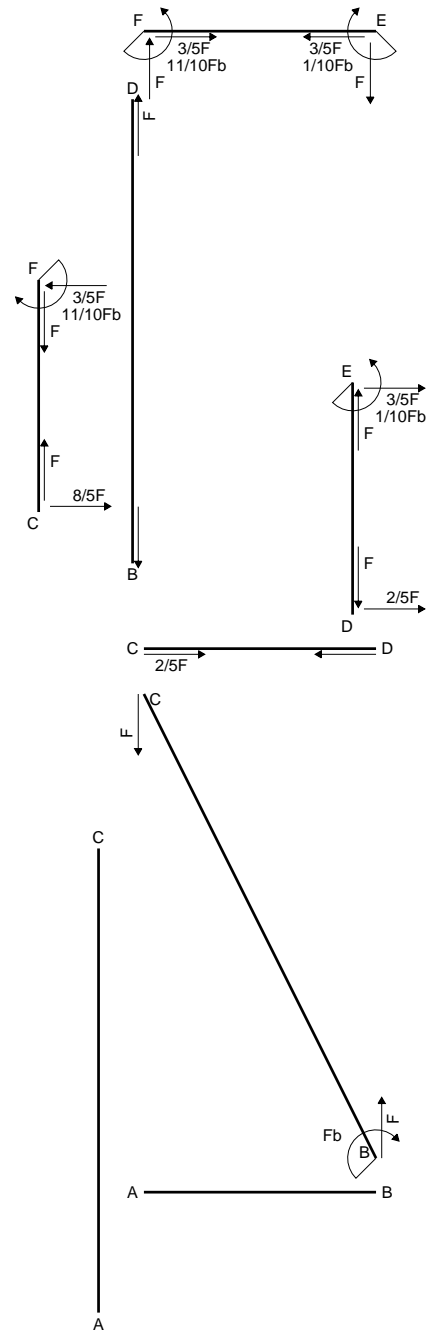
$$= (-1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

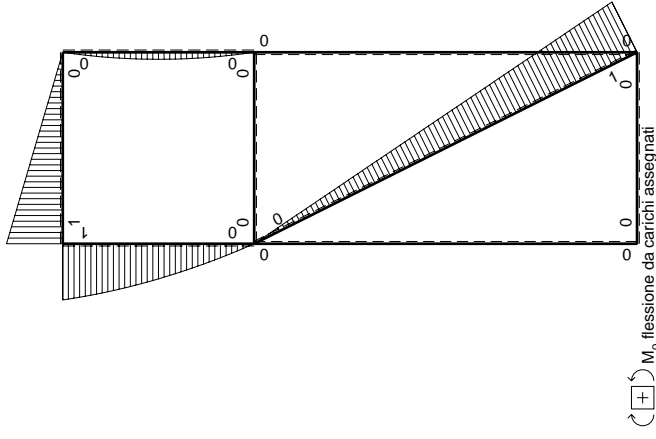
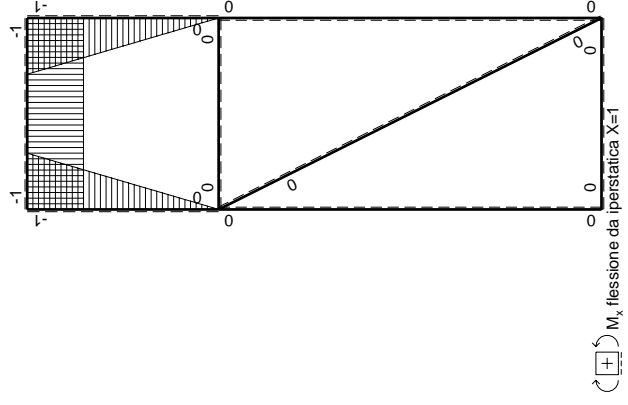
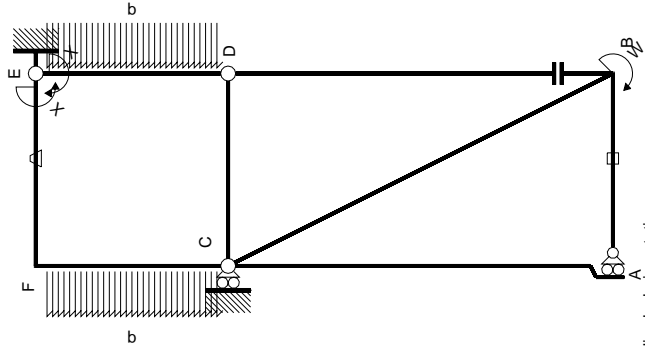


- A = 636. mm<sup>2</sup>
- J<sub>u</sub> = 149922. mm<sup>4</sup>
- J<sub>v</sub> = 29988. mm<sup>4</sup>
- y<sub>g</sub> = 37.06 mm
- N = -1270. N
- T<sub>y</sub> = -635. N
- M<sub>x</sub> = 852000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -37.06 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = 208.6 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> = 117.7 N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.969 N/mm<sup>2</sup>
- σ<sub>φ</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 117.7 N/mm<sup>2</sup>
- S = 2789. mm<sup>3</sup>









Quadro contributi PLV per iperstatica  $X=W_{EF}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$Fb-\sqrt{5}/5Fx$	0	0	0	0	0+0	0
CA 2b	0	0	0	0	0	0	0+0	0
DB 2b	0	0	0	0	0	0	0+0	0
BD 2b	0	0	0	0	0	0	0+0	0
DE b	$-x/b$	$-1/2Fx+1/2qx^2$	0	$1/2Fx^2/b-1/2qx^3/b$	0	0	$x^2/b^2$	0
ED b	$1-x/b$	$1/2Fx-1/2qx^2$	0	$1/2Fx-Fx^2/b+1/2qx^3/b$	0	0	$1-2x/b+x^2/b^2$	$1/3xb/EJ$
CD b	0	0	0	0	0	0	0+0	0
FE b	-1	Fx	$-Fb/EJ$	-Fx	$Fb/EJ$	1	$(-1/2+1)Fb^2/EJ$	$xb/EJ$
FE b	1	$-Fb+Fx$	$Fb/EJ$	$-Fb+Fx$	$Fb/EJ$	1	$(-1/2+1)Fb^2/EJ$	$xb/EJ$
FC b	$-1+x/b$	$Fb-1/2Fx-1/2qx^2$	0	$-Fb+3/2Fx-1/2qx^3/b$	0	0	$1-2x/b+x^2/b^2$	$1/3xb/EJ$
CF b	$x/b$	$-3/2Fx+1/2qx^2$	0	$-3/2Fx^2/b+1/2qx^3/b$	0	0	$x^2/b^2$	$1/3xb/EJ$
totali								$5/3xb/EJ$
iperstatica $X=W_{EF}$								$-1/10Fb$

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (b) \theta = 1/2 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

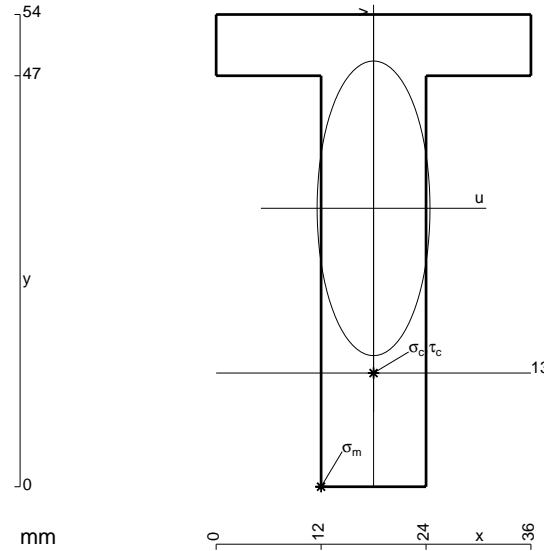
$$= (-b + 1/2 b) Fb 1/EJ + (-b) \theta = 1/2 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-1 + 3/2 x/b - 1/2 x^3/b^3) Fb 1/EJ dx = [-x + 3/4 x^2/b - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-b + 3/4 b - 1/8 b) Fb 1/EJ = -3/8 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-3/2 x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/2 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

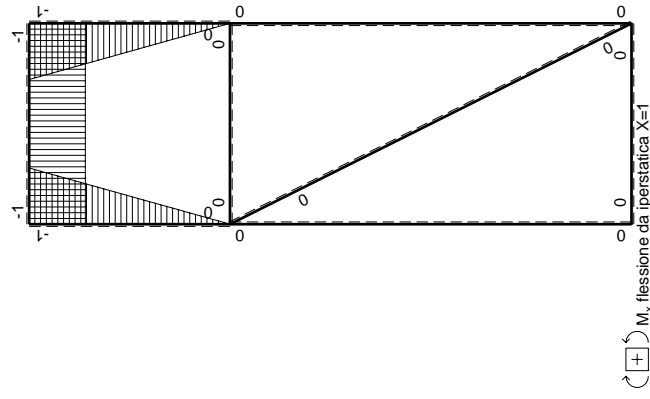
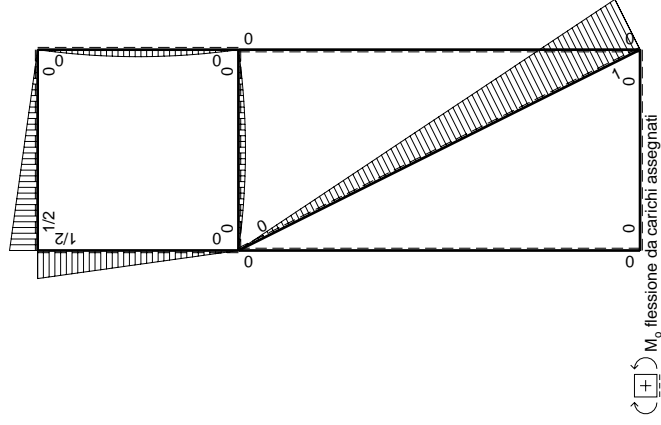
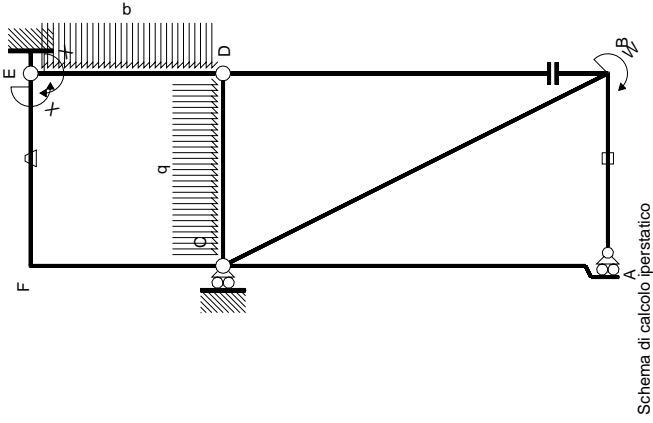
$$= (-1/2 b + 1/8 b) Fb 1/EJ = -3/8 Fb^2/EJ$$



- A = 816. mm<sup>2</sup>
- J<sub>u</sub> = 231827. mm<sup>4</sup>
- J<sub>v</sub> = 33984. mm<sup>4</sup>
- y<sub>g</sub> = 31.84 mm
- N = -2263. N
- T<sub>y</sub> = -1131. N
- M<sub>x</sub> = 1619200. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -31.84 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = 219.6 N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 13. mm
- v<sub>c</sub> = -18.84 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = 128.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.608 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 128.8 N/mm<sup>2</sup>
- S = 3953. mm<sup>3</sup>







Quadro contributi PLV per iperstatica  $X=W_{EF}$

←	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x (M_0/EJ + \theta) dx$	$\int M^x M_x / EJ dx$	iperstatica $X=W_{EF}$	
									totali	
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
BC $\sqrt{5}b$	0	$Fb\sqrt{5}/5Fx$	0	0	0	0	0+0	0	0	0
CA 2b	0	0	0	0	0	0	0+0	0	0	0
DB 2b	0	0	0	0	0	0	0+0	0	0	0
BD 2b	0	0	0	0	0	0	0+0	0	0	0
DE b	$-x/b$	$-1/2Fx + 1/2qx^2$	0	$1/2Fx^2/b - 1/2qx^3/b$	0	0	$x^2/b^2$	0	$(1/2+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$1-x/b$	$1/2Fx - 1/2qx^2$	0	$1/2Fx - Fx^2/b + 1/2qx^3/b$	0	0	$1-2x/b+x^2/b^2$	0	$(1/2+0)Fb^2/EJ$	$1/3Xb/EJ$
CD b	0	$1/2Fx - 1/2qx^2$	0	0	0	0	0	0	0+0	0
DC b	0	$-1/2Fx + 1/2qx^2$	0	0	0	0	0	0	0+0	0
EF b	-1	$1/2Fx$	$-Fb/EJ$	$-1/2Fx$	$Fb/EJ$	$Fb/EJ$	1	1	$(-1/4+1)Fb^2/EJ$	$Xb/EJ$
FE b	1	$-1/2Fb + 1/2Fx$	$Fb/EJ$	$-1/2Fb + 1/2Fx$	$Fb/EJ$	$Fb/EJ$	1	1	$(-1/4+1)Fb^2/EJ$	$Xb/EJ$
FC b	$-1+x/b$	$1/2Fb - 1/2Fx$	0	$-1/2Fb + Fx - 1/2Fx^2/b$	0	0	$1-2x/b+x^2/b^2$	0	$(-1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
CF b	$x/b$	$-1/2Fx$	0	$-1/2Fx^2/b$	0	0	$x^2/b^2$	0	$(-1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
totali									$5/8Fb^2/EJ$	$5/3Xb/EJ$
									$-3/8Fb$	

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/4 b) Fb 1/EJ + (b) \theta = 3/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + 1/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-1/2 x + 1/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

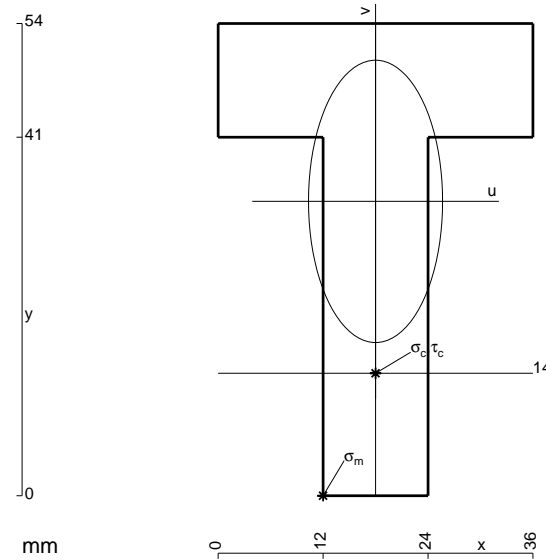
$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ$$

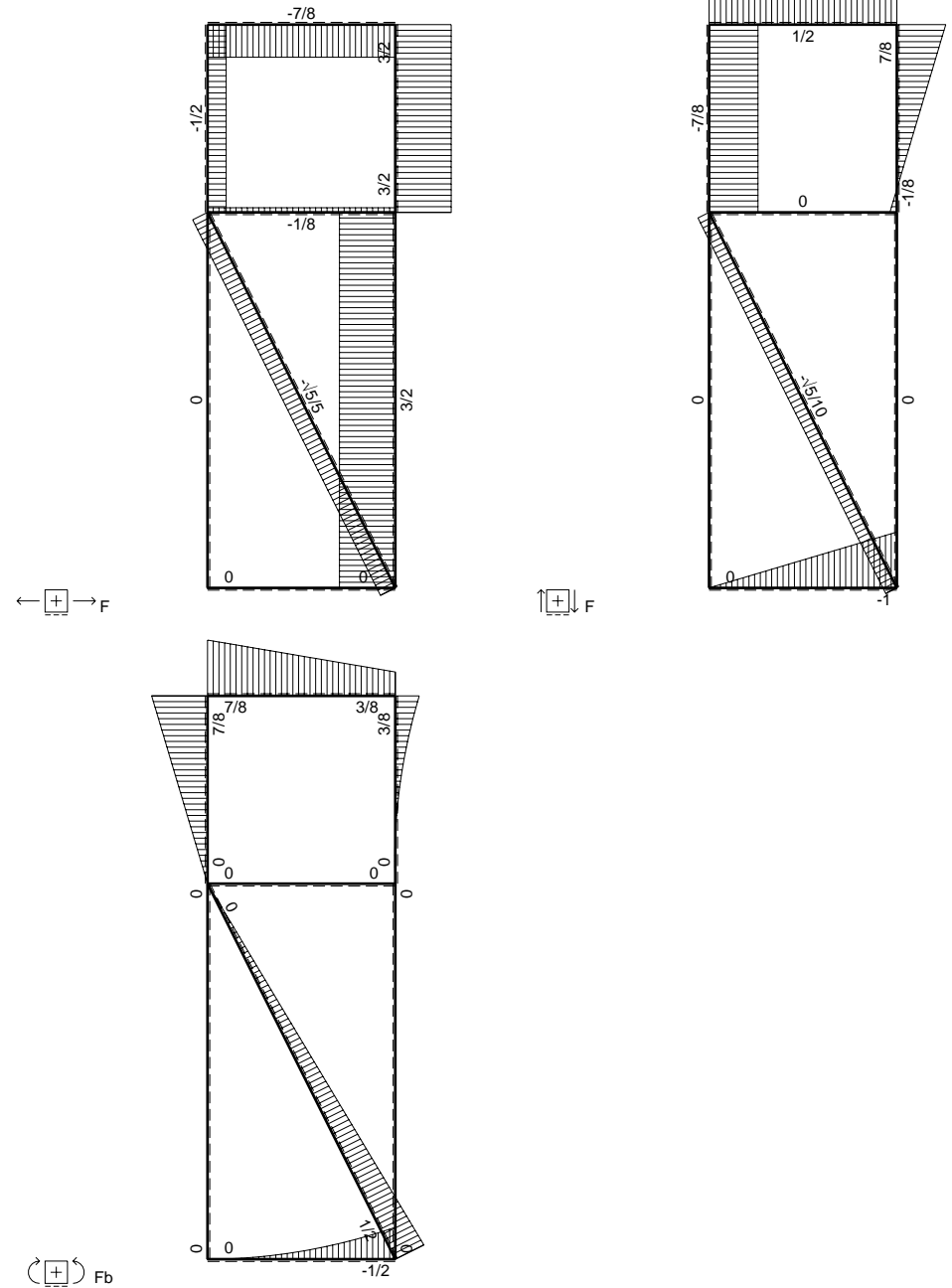
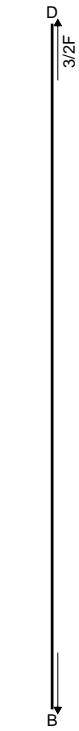
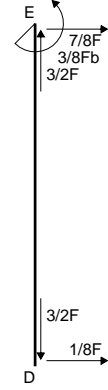
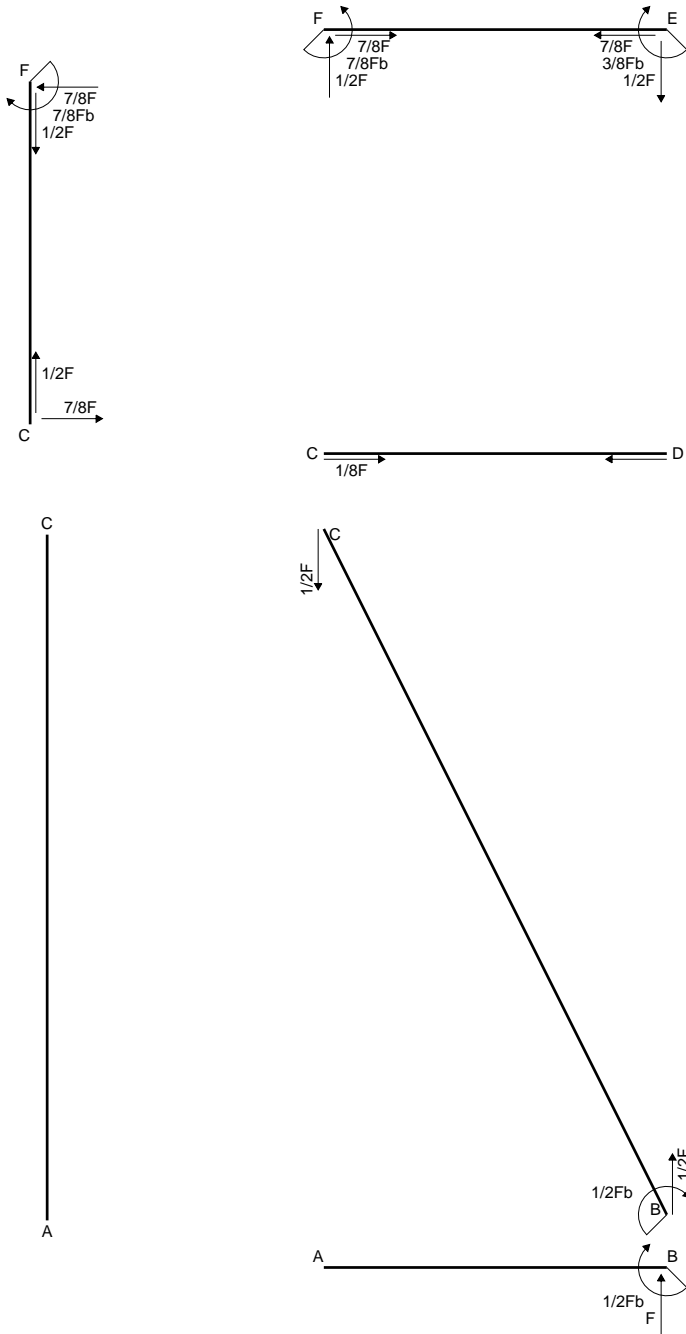
$$= (-1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$



- A = 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
- N = -2272. N
- T<sub>y</sub> = -1136. N
- M<sub>x</sub> = 1727200. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -33.66 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = 229.9 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> = N/A - Mv/J<sub>u</sub> = 133.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.694 N/mm<sup>2</sup>
- σ<sub>φ</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 133.3 N/mm<sup>2</sup>
- S = 4479. mm<sup>3</sup>









$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/4 b) Fb 1/EJ + (b) \theta = 3/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + 1/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-1/2 x + 1/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

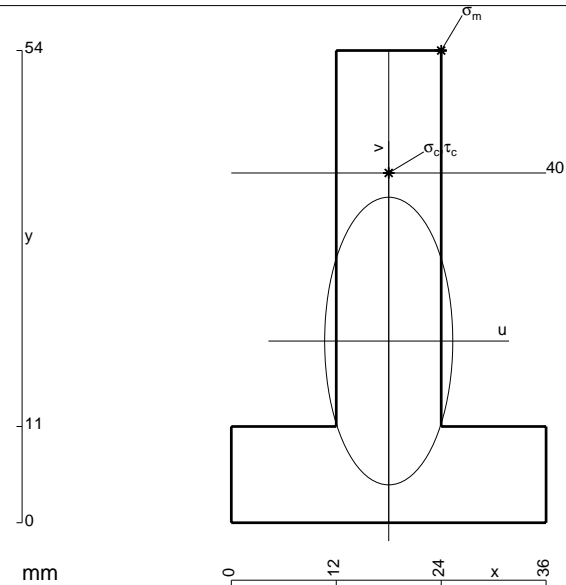
$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$



$$A = 912. \text{ mm}^2$$

$$J_u = 246834. \text{ mm}^4$$

$$J_v = 48960. \text{ mm}^4$$

$$y_g = 20.78 \text{ mm}$$

$$T_y = -4950. \text{ N}$$

$$M_x = -1782000. \text{ Nmm}$$

$$x_m = 24. \text{ mm}$$

$$y_m = 54. \text{ mm}$$

$$u_m = 6. \text{ mm}$$

$$v_m = 33.22 \text{ mm}$$

$$\sigma_m = -Mv/J_u = 239.9 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 40. \text{ mm}$$

$$v_c = 19.22 \text{ mm}$$

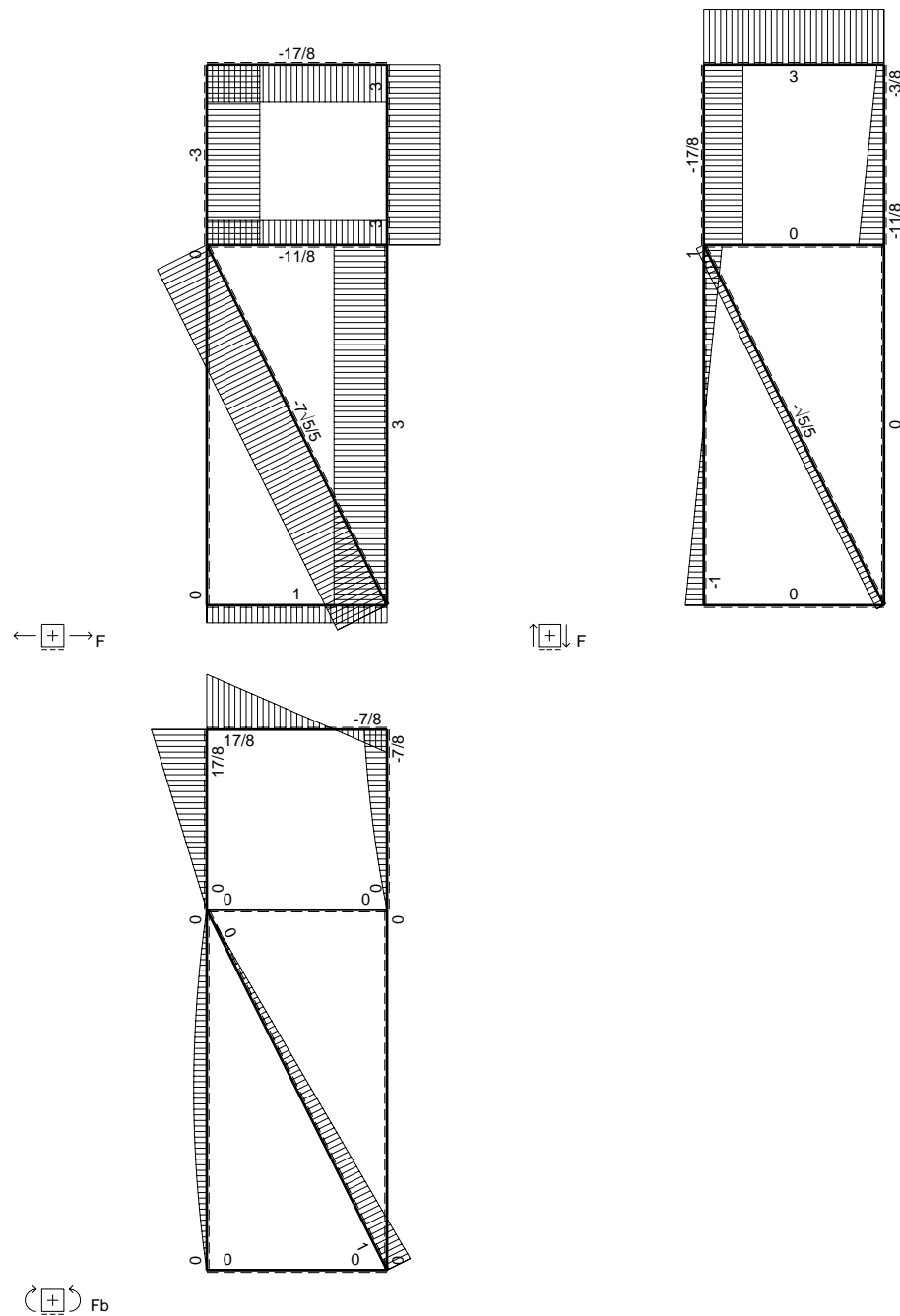
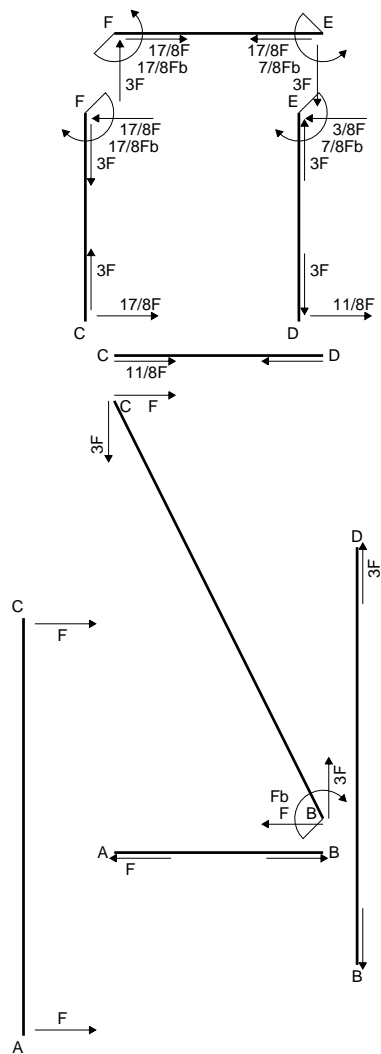
$$\sigma_c = -Mv/J_u = 138.8 \text{ N/mm}^2$$

$$\tau_c = 7.362 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 139.4 \text{ N/mm}^2$$

$$S = 4406. \text{ mm}^3$$





$\circlearrowleft (+) F_b$



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-3x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-3/2 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-3/2 b) Fb 1/EJ + (b) \theta = -1/2 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-3 + 3x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-3x + 3/2 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

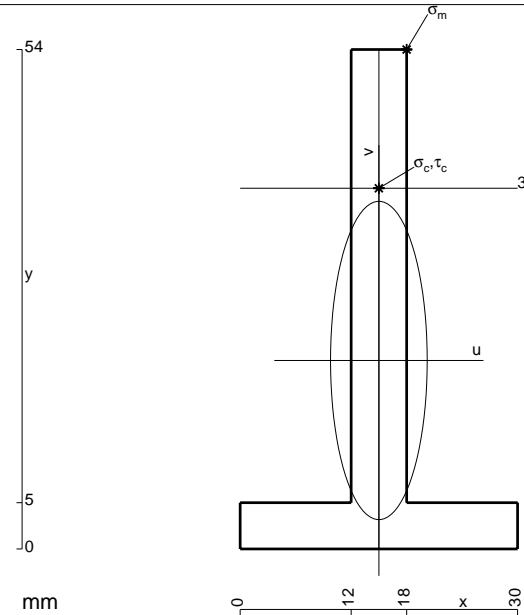
$$= (-3b + 3/2 b) Fb 1/EJ + (-b) \theta = -1/2 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-3 + 6x/b - 3x^2/b^2) Fb 1/EJ dx = [-3x + 3x^2/b - x^3/b^2]_0^b Fb 1/EJ$$

$$= (-3b + 3b - b) Fb 1/EJ = - Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-3x^2/b^2) Fb 1/EJ dx = [-x^3/b^2]_0^b Fb 1/EJ$$

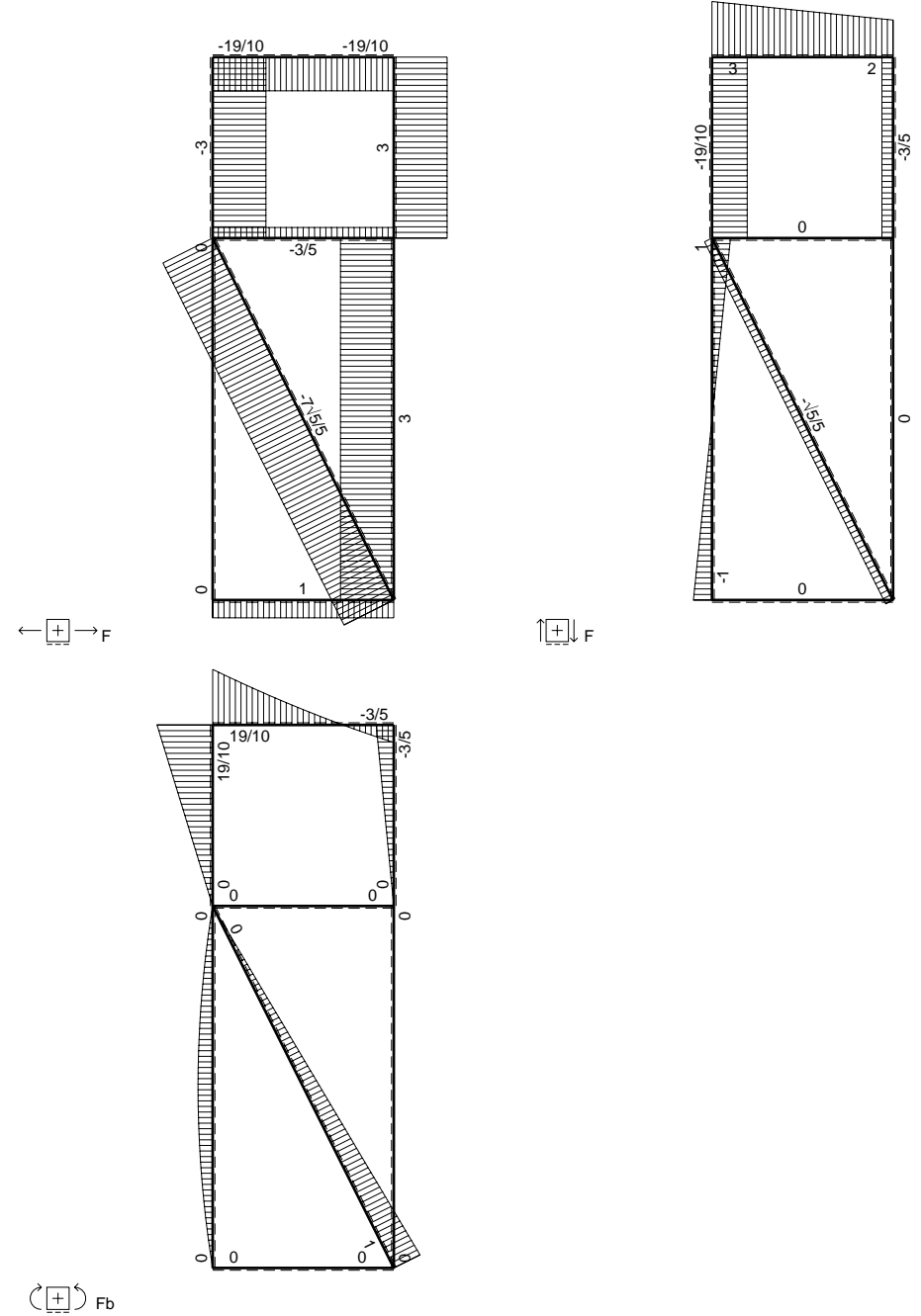
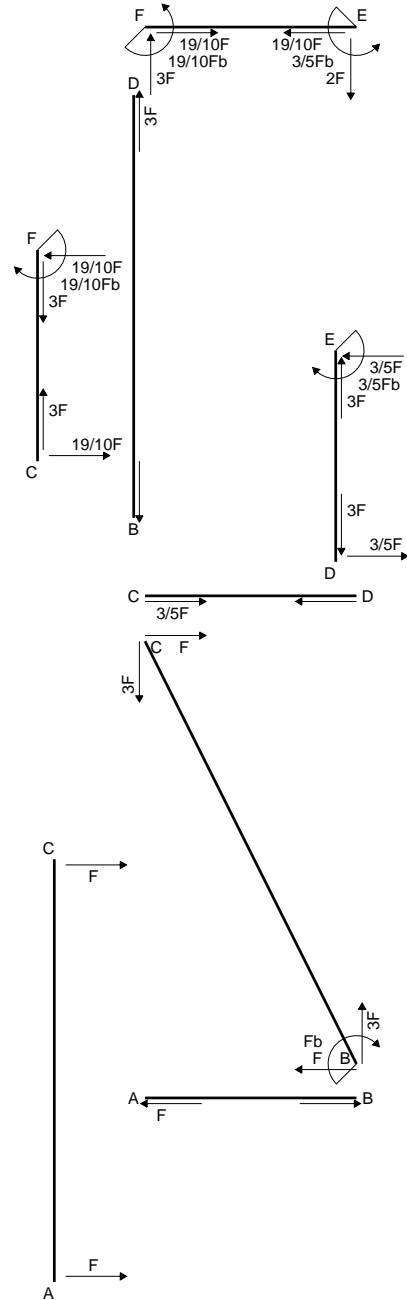
$$= (-b) Fb 1/EJ = - Fb^2/EJ$$



- 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
- N = -5979. N
- T<sub>y</sub> = -854.2 N
- M<sub>x</sub> = 725800. 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> = N/A-Mv/J<sub>u</sub> = -199. N/mm<sup>2</sup>
- x<sub>c</sub> = 15. mm
- y<sub>c</sub> = 39. mm
- v<sub>c</sub> = 18.62 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = -116.2 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.544 N/mm<sup>2</sup>
- σ<sub>g</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 116.3 N/mm<sup>2</sup>
- S<sup>2</sup> = 2351. mm<sup>3</sup>



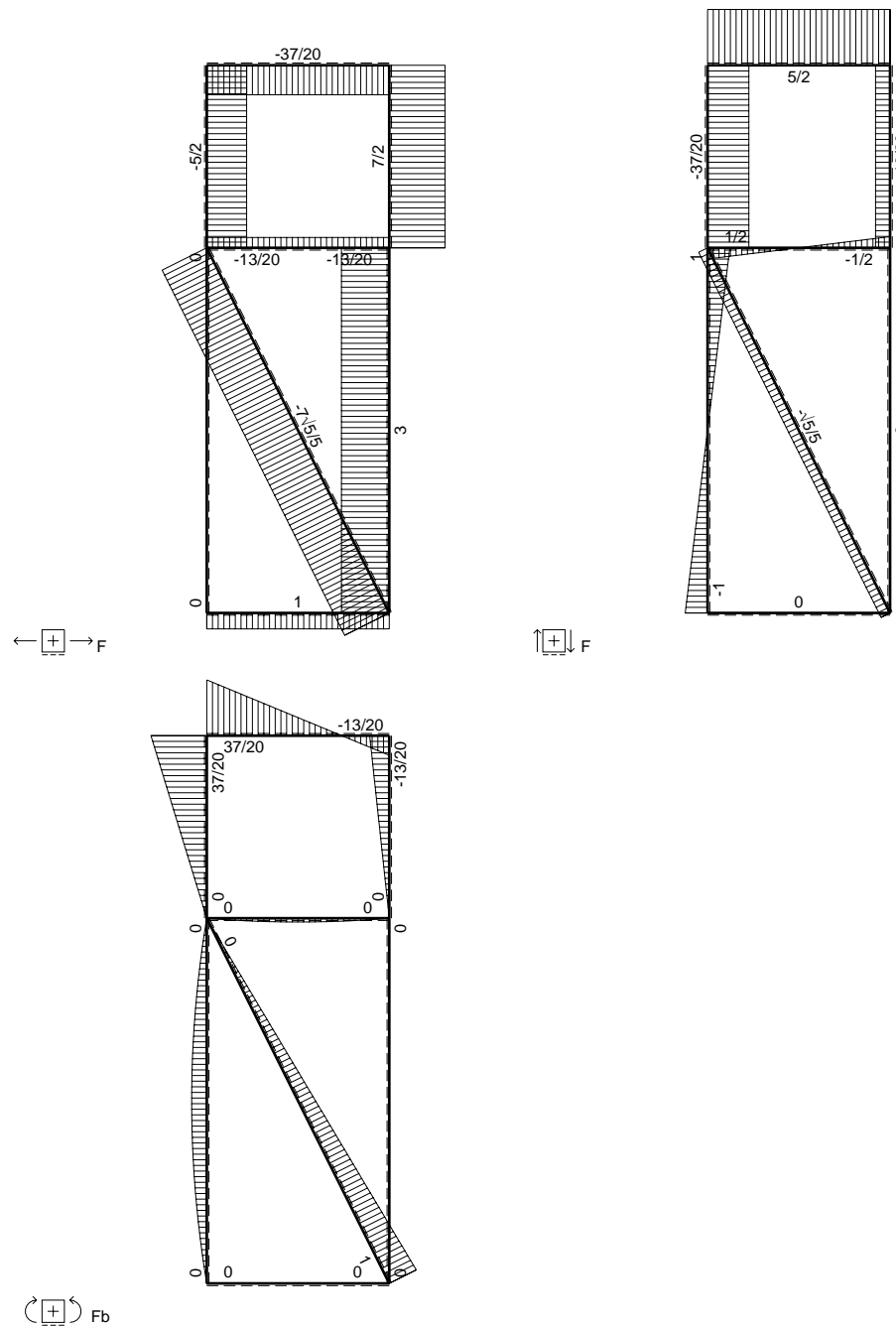
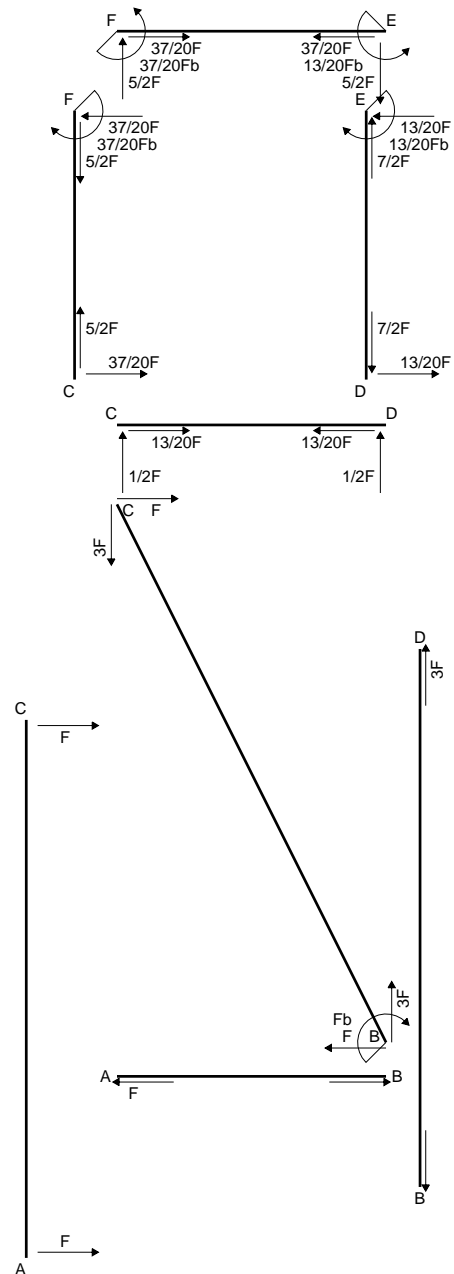














$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = \left[ \frac{1}{3} x^3/b^2 \right]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = \left[ x \right]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = \left[ x \right]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = \left[ \frac{1}{3} x^3/b^2 \right]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-5/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = \left[ -5/4 x^2/b \right]_0^b Fb 1/EJ + \left[ x \right]_0^b \theta$$

$$= (-5/4 b) Fb 1/EJ + (b) \theta = -1/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-5/2 + 5/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = \left[ -5/2 x + 5/4 x^2/b \right]_0^b Fb 1/EJ + \left[ -x \right]_0^b \theta$$

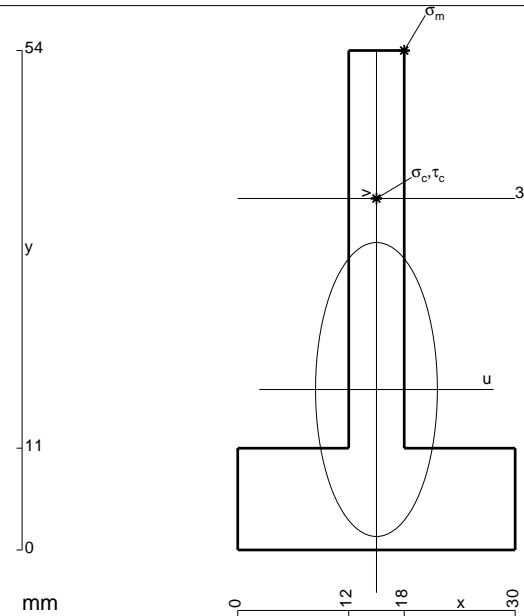
$$= (-5/2 b + 5/4 b) Fb 1/EJ + (-b) \theta = -1/4 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = \left[ -5/2 x + 5/2 x^2/b - 5/6 x^3/b^2 \right]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = \left[ -5/6 x^3/b^2 \right]_0^b Fb 1/EJ$$

$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$



$$A = 588. \text{ mm}^2$$

$$J_u = 148637. \text{ mm}^4$$

$$J_v = 25524. \text{ mm}^4$$

$$y_g = 17.35 \text{ mm}$$

$$N = -5917. \text{ N}$$

$$T_y = -845.2 \text{ N}$$

$$M_x = 850500. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$y_m = 54. \text{ mm}$$

$$u_m = 3. \text{ mm}$$

$$v_m = 36.65 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -219.8 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 38. \text{ mm}$$

$$v_c = 20.65 \text{ mm}$$

$$\sigma_c = N/A - Mv/J_u = -128.2 \text{ N/mm}^2$$

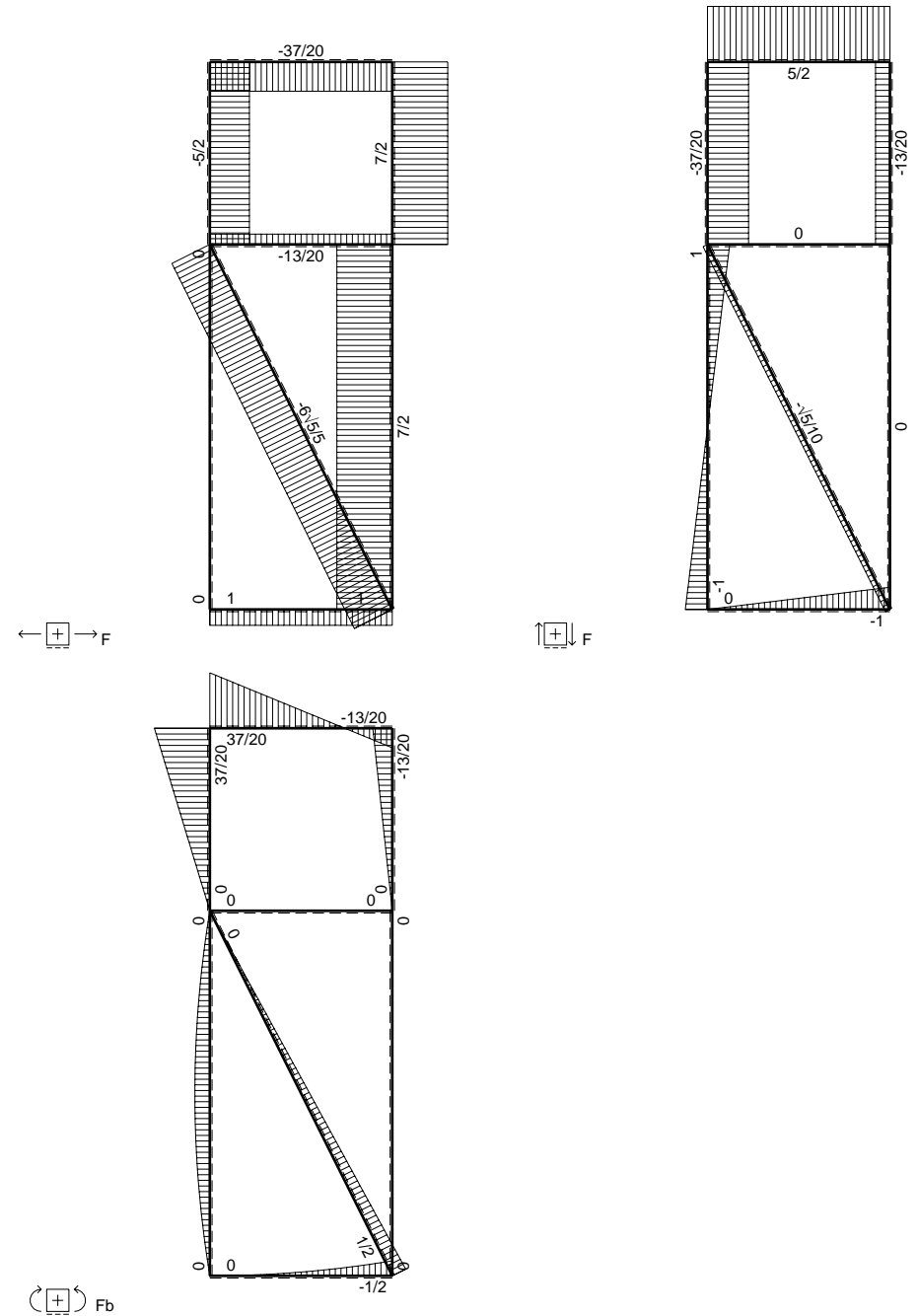
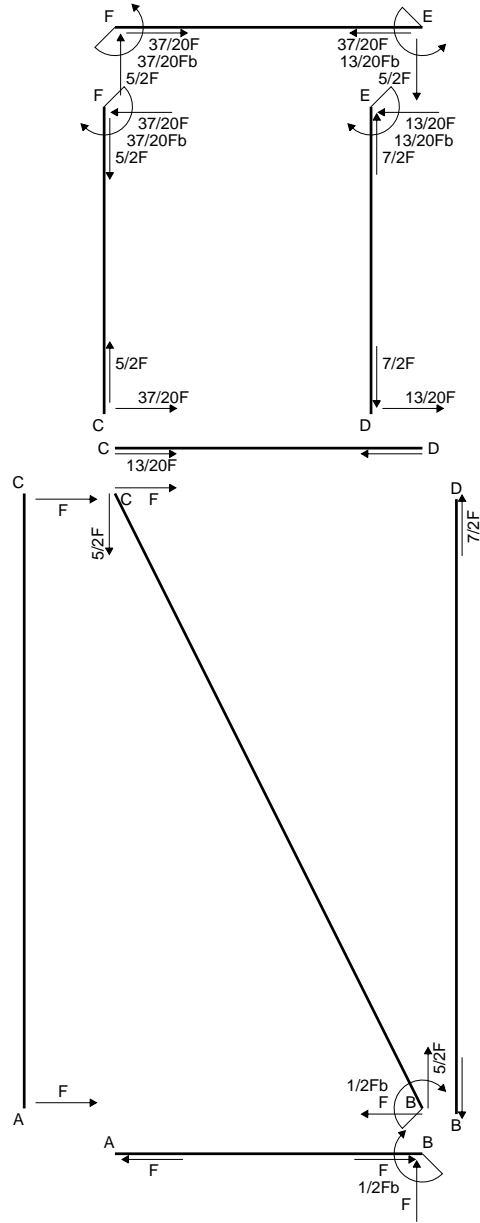
$$\tau_c = 2.607 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 128.3 \text{ N/mm}^2$$

$$S = 2751. \text{ mm}^3$$









$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = \left[ \frac{1}{3} x^3/b^2 \right]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = \left[ x \right]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = \left[ x \right]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = \left[ \frac{1}{3} x^3/b^2 \right]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-5/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = \left[ -5/4 x^2/b \right]_0^b Fb 1/EJ + \left[ x \right]_0^b \theta$$

$$= (-5/4 b) Fb 1/EJ + (b) \theta = -1/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-5/2 + 5/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = \left[ -5/2 x + 5/4 x^2/b \right]_0^b Fb 1/EJ + \left[ -x \right]_0^b \theta$$

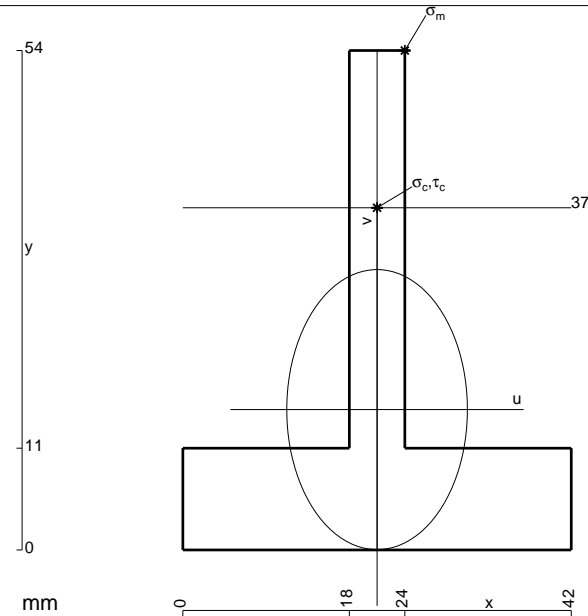
$$= (-5/2 b + 5/4 b) Fb 1/EJ + (-b) \theta = -1/4 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = \left[ -5/2 x + 5/2 x^2/b - 5/6 x^3/b^2 \right]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = \left[ -5/6 x^3/b^2 \right]_0^b Fb 1/EJ$$

$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$



$$A = 720. \text{ mm}^2$$

$$J_u = 165098. \text{ mm}^4$$

$$J_v = 68688. \text{ mm}^4$$

$$y_g = 15.18 \text{ mm}$$

$$N = 3890. \text{ N}$$

$$T_y = -3890. \text{ N}$$

$$M_x = -953050. \text{ Nmm}$$

$$x_m = 24. \text{ mm}$$

$$y_m = 54. \text{ mm}$$

$$u_m = 3. \text{ mm}$$

$$v_m = 38.83 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 229.5 \text{ N/mm}^2$$

$$x_c = 21. \text{ mm}$$

$$y_c = 37. \text{ mm}$$

$$v_c = 21.83 \text{ mm}$$

$$\sigma_c = N/A - Mv/J_u = 131.4 \text{ N/mm}^2$$

$$\tau_c = 12.15 \text{ N/mm}^2$$

$$\sigma_o = \sqrt{\sigma^2 + 3\tau^2} = 133.1 \text{ N/mm}^2$$

$$S = 3093. \text{ mm}^3$$







$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-3x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-3/2 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-3/2 b) Fb 1/EJ + (b) \theta = -1/2 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-3 + 3x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-3x + 3/2 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

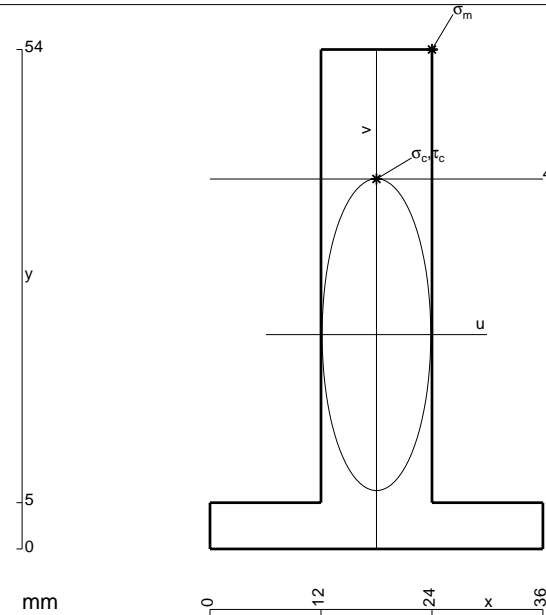
$$= (-3b + 3/2 b) Fb 1/EJ + (-b) \theta = -1/2 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-3 + 6x/b - 3x^2/b^2) Fb 1/EJ dx = [-3x + 3x^2/b - x^3/b^2]_0^b Fb 1/EJ$$

$$= (-3b + 3b - b) Fb 1/EJ = -Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-3x^2/b^2) Fb 1/EJ dx = [-x^3/b^2]_0^b Fb 1/EJ$$

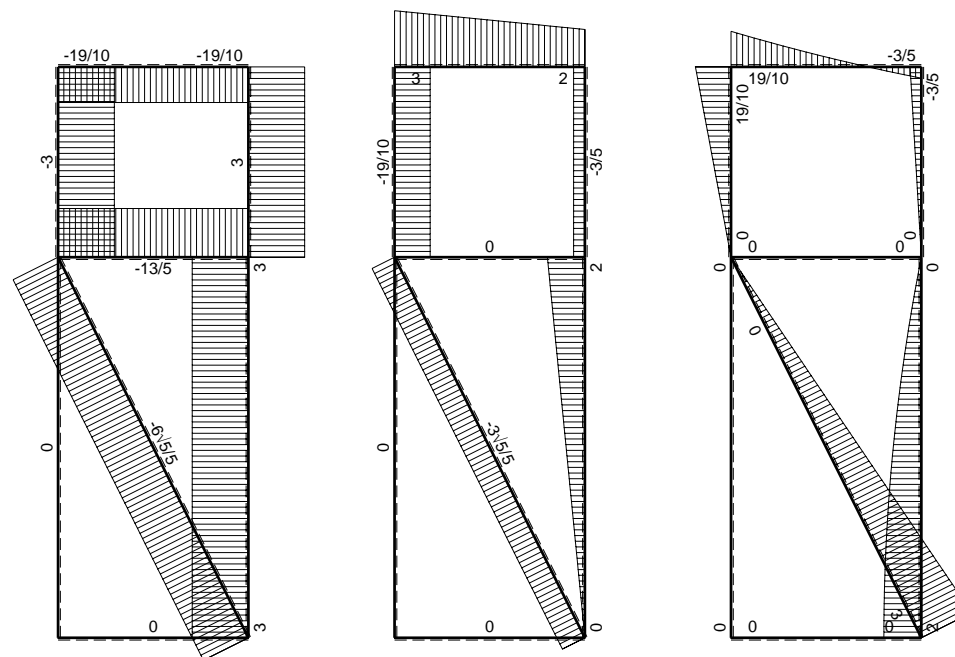
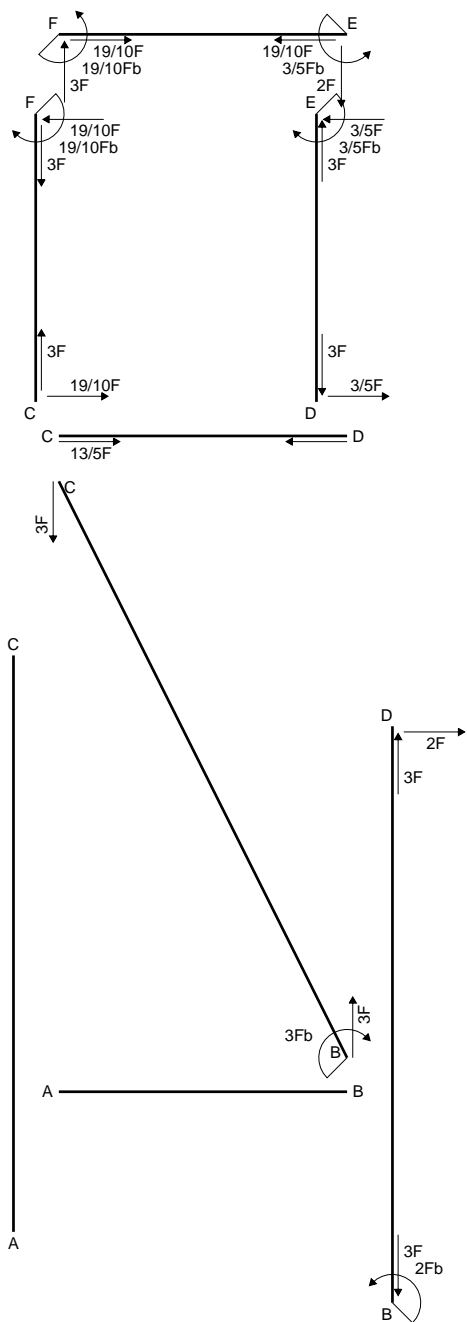
$$= (-b) Fb 1/EJ = -Fb^2/EJ$$



- 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
- N = -9517. N
- T<sub>y</sub> = -1360. N
- M<sub>x</sub> = 1611200. 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> = N/A-Mv/J<sub>u</sub> = -239.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 40. mm
- v<sub>c</sub> = 16.83 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = -136.5 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.076 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup>+3τ<sup>2</sup>) = 136.5 N/mm<sup>2</sup>
- S = 4003. mm<sup>3</sup>



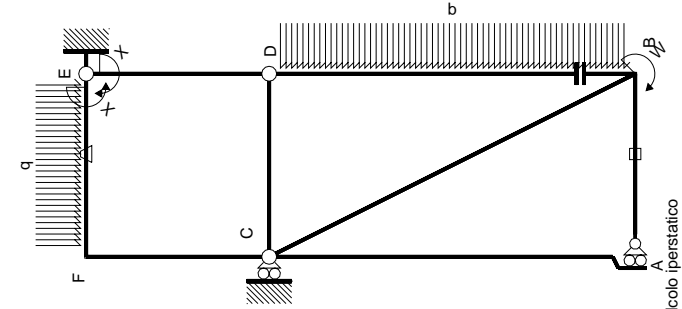




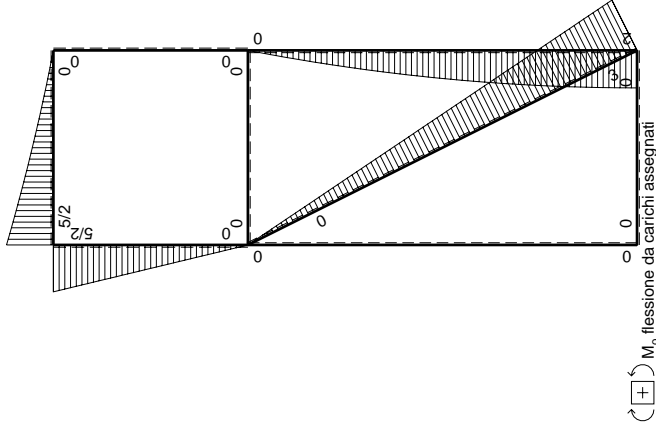
← ⊕ → F

↑ ⊕ ↓ F

⊕ ⊖ F<sub>b</sub>



Schema di calcolo iperstatico



$M_x$ , flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{EF}$

$\rightarrow$	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x (M_0/EJ + \theta) dx$	$\int M^x M_x / EIdx$
AB b	0	0	0	0	0	0	0	0
BA b	0	0	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$3Fb-3\sqrt{5}/5Fx$	0	0	0	0	0	0
AC 2b	0	0	0	0	0	0	0	0
CA 2b	0	0	0	0	0	0	0	0
DB 2b	0	$2Fx-1/2qx^2$	0	0	0	0	0	0
BD 2b	0	$-2Fb+1/2qx^2$	0	0	0	0	0	0
DE b	$-x/b$	0	0	0	0	$x^2/b^2$	0	0
ED b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0	$1/3Xb/EJ$
CD b	0	0	0	0	0	0	0	0
DC b	0	0	0	0	0	0	0	0
EF b	-1	$2Fx+1/2qx^2$	$-Fb/EJ$	$-2Fx-1/2Fx^2/b$	$Fb/EJ$	1	1	$Xb/EJ$
FE b	1	$-5/2Fb+3Fx-1/2qx^2$	$Fb/EJ$	$-5/2Fb+3Fx-1/2Fx^2/b$	$Fb/EJ$	1	1	$Xb/EJ$
FC b	$-1+x/b$	$5/2Fb-5/2Fx$	0	$-5/2Fb+5Fx-5/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	0	$1/3Xb/EJ$
CF b	$x/b$	$-5/2Fx$	0	$-5/2Fx^2/b$	0	$x^2/b^2$	0	$1/3Xb/EJ$
totali								$5/3Xb/EJ$
iperstatica $X=W_{EF}$								$3/5Fb$

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (-2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-2x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-b - 1/6 b) Fb 1/EJ + (b) \theta = -1/6 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-5/2 + 3x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx$$

$$= [-5/2 x + 3/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

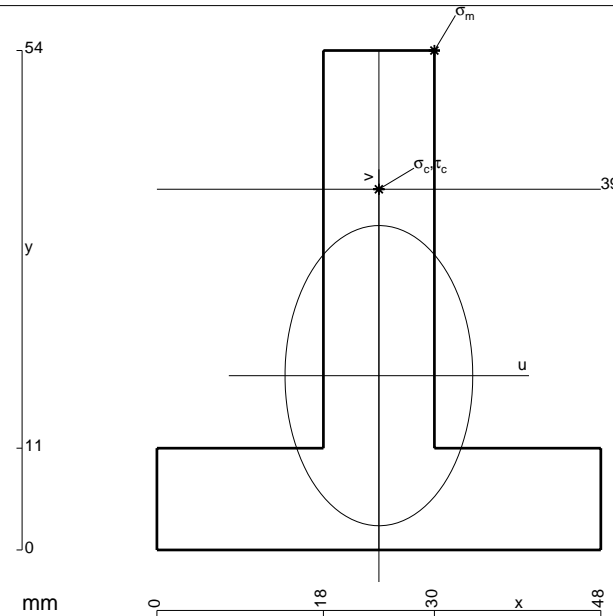
$$= (-5/2 b + 3/2 b - 1/6 b) Fb 1/EJ + (-b) \theta = -1/6 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = [-5/2 x + 5/2 x^2/b - 5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

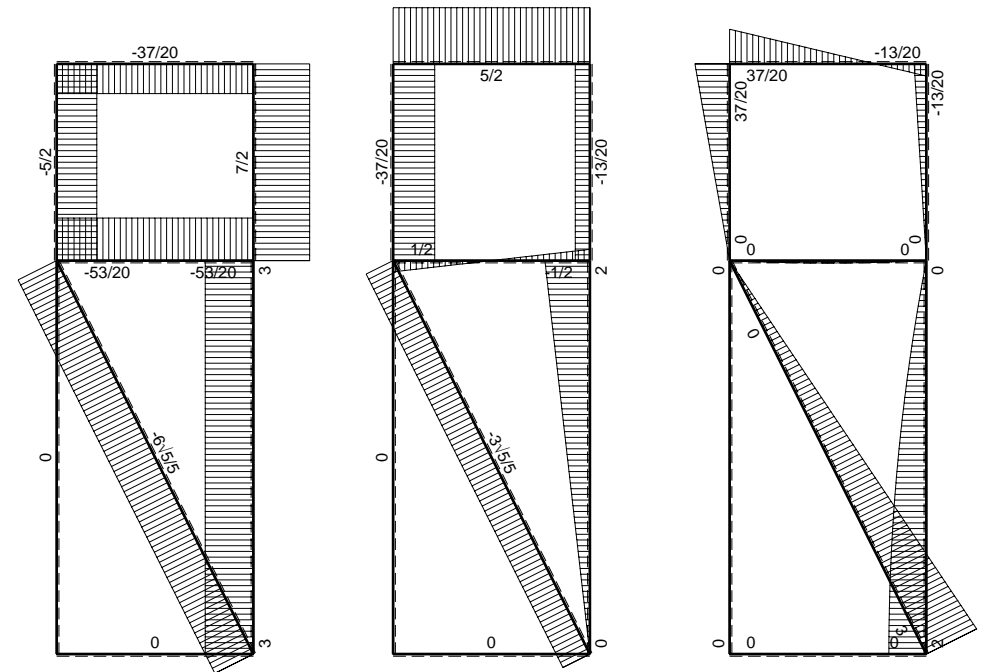
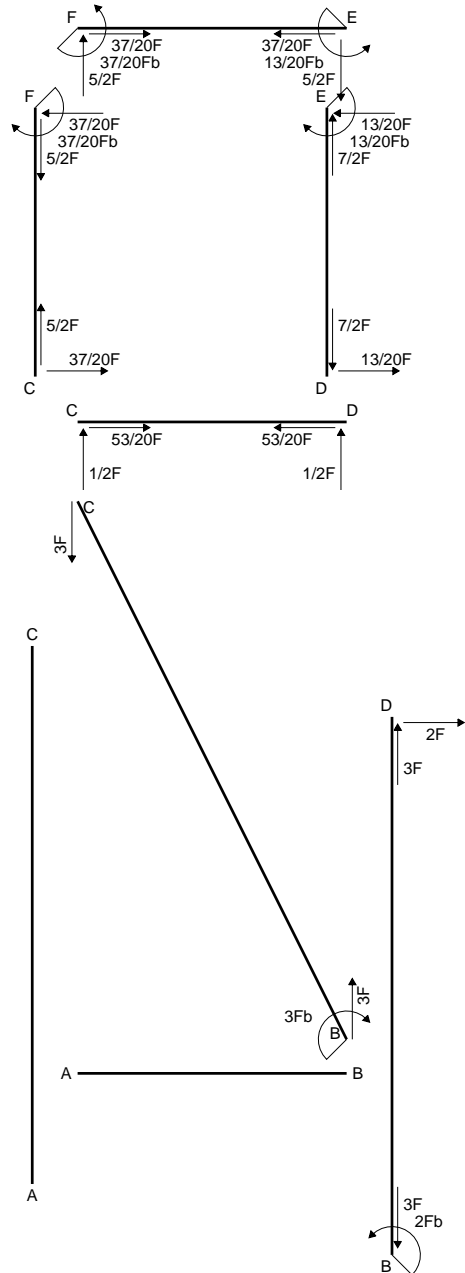
$$L_{CF}^{xo} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$



- 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> = 18.84 mm
- N = -2415. N
- T<sub>y</sub> = -1207. N
- M<sub>x</sub> = 1539000. Nmm
- x<sub>m</sub> = 30. mm
- y<sub>m</sub> = 54. 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> = -199. N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 39. mm
- v<sub>c</sub> = 20.16 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = -115.1 N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.821 N/mm<sup>2</sup>
- σ<sub>g</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 115.1 N/mm<sup>2</sup>
- S<sup>3</sup> = 4978. mm<sup>3</sup>







$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{x_0} = \int_0^b (-5/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-5/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-5/4 b) Fb 1/EJ + (b) \theta = -1/4 Fb^2/EJ$$

$$L_{FE}^{x_0} = \int_0^b (-5/2 + 5/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-5/2 x + 5/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

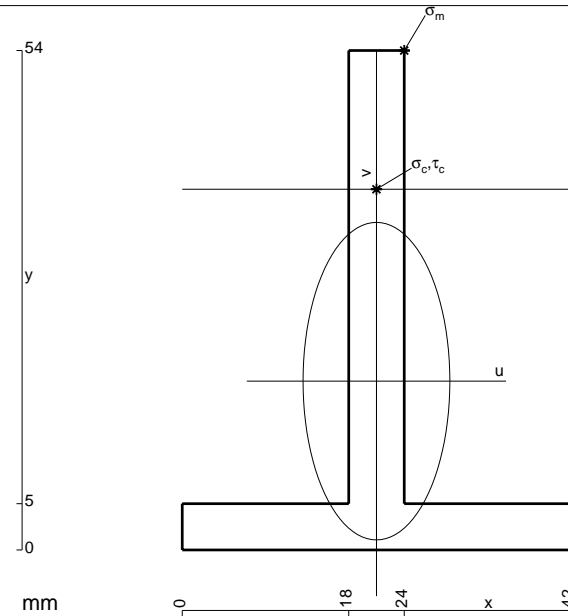
$$= (-5/2 b + 5/4 b) Fb 1/EJ + (-b) \theta = -1/4 Fb^2/EJ$$

$$L_{FC}^{x_0} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = [-5/2 x + 5/2 x^2/b - 5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

$$L_{CF}^{x_0} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

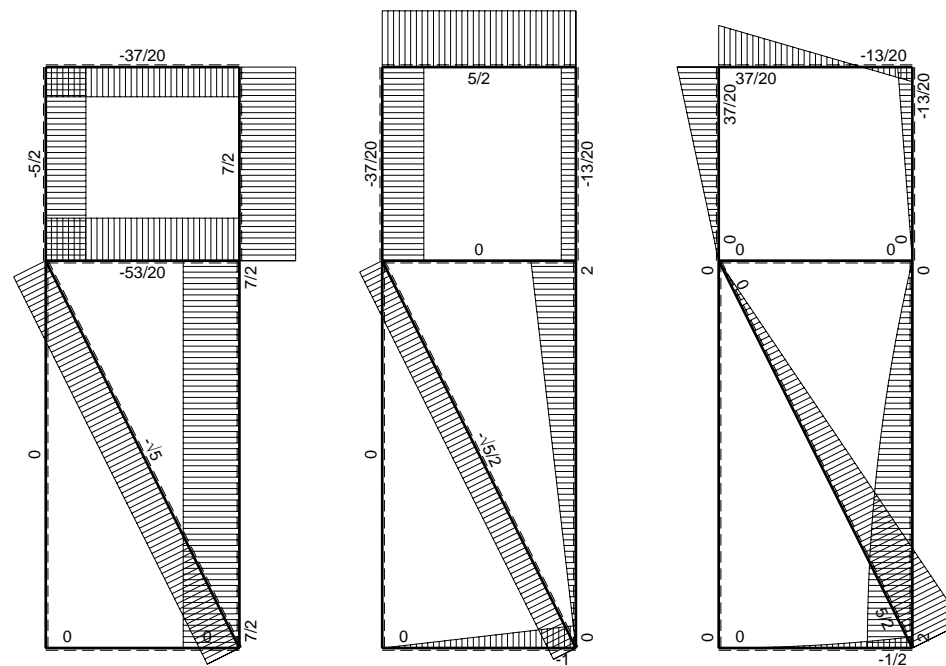
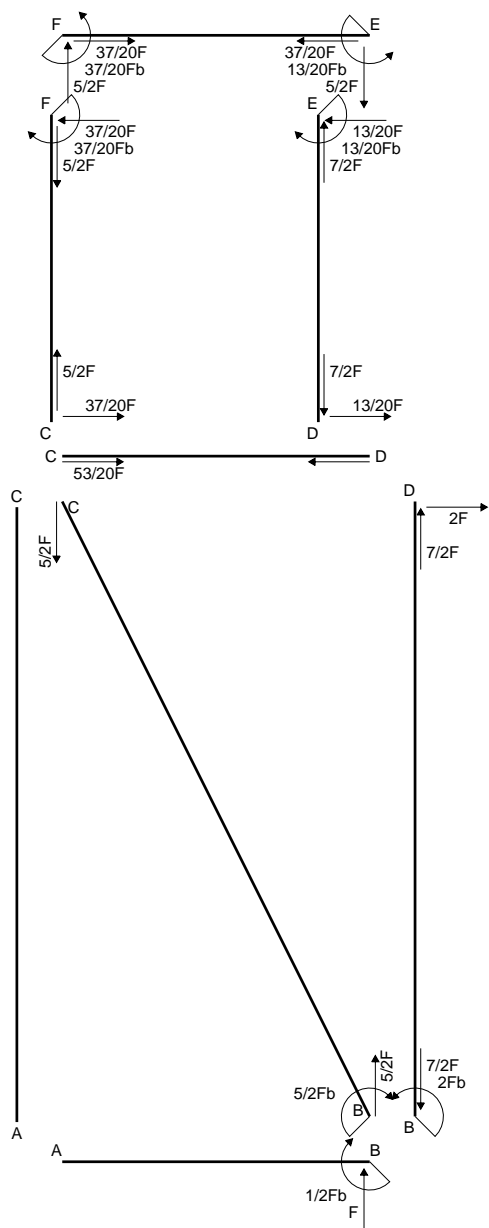
$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

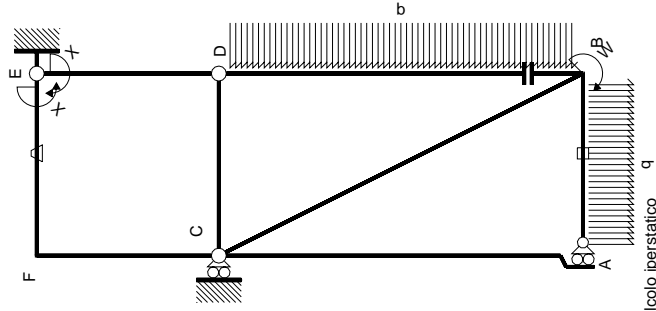


- A = 504. mm<sup>2</sup>
- J<sub>u</sub> = 148565. mm<sup>4</sup>
- J<sub>v</sub> = 31752. mm<sup>4</sup>
- y<sub>g</sub> = 18.25 mm
- N = -1261. N
- T<sub>y</sub> = -630.6 N
- M<sub>x</sub> = 846000. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 3. mm
- v<sub>m</sub> = 35.75 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = -206.1 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 39. mm
- v<sub>c</sub> = 20.75 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = -120.7 N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.799 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sub>c</sub><sup>2</sup>+3τ<sub>c</sub><sup>2</sup> = 120.7 N/mm<sup>2</sup>
- S = 2543. mm<sup>3</sup>

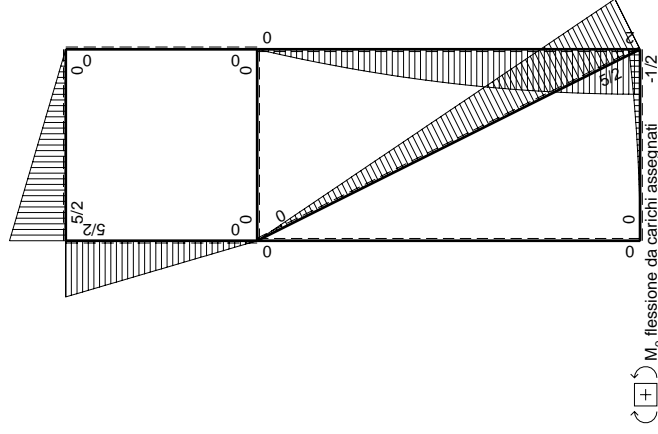




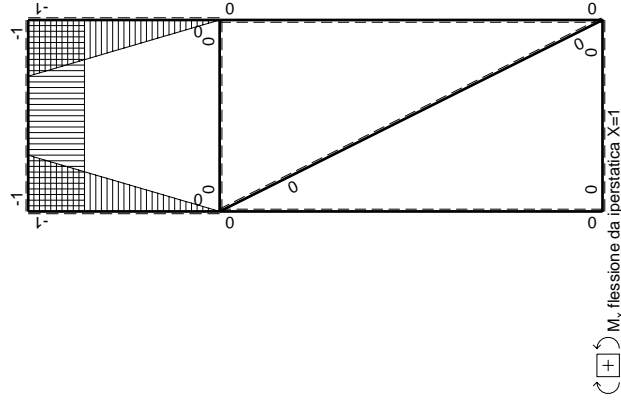




Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{EP}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	0	$-1/2qx^2$	0	0	0	0	0	0
BA b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$5/2Fb-\sqrt{5}2Fx$	0	0	0	0	0	0
CA 2b	0	0	0	0	0	0	0	0
DB 2b	0	$2Fx-1/2qx^2$	0	0	0	0	0	0
BD 2b	0	$-2Fb+1/2qx^2$	0	0	0	0	0	0
DE b	$-x/b$	0	0	0	0	$x^2/b^2$	0	0
ED b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0	$1/3xb/EJ$
CD b	0	0	0	0	0	0	0	0
DC b	0	0	0	0	0	0	0	0
EF b	-1	$5/2Fx$	$-Fb/EJ$	$-5/2Fx$	$Fb/EJ$	1	$(-5/4+1)Fb^2/EJ$	$xb/EJ$
FE b	1	$-5/2Fb+5/2Fx$	$Fb/EJ$	$-5/2Fb+5/2Fx$	$Fb/EJ$	1	$(-5/6+0)Fb^2/EJ$	$1/3xb/EJ$
FC b	$-1+x/b$	$5/2Fb-5/2Fx$	0	$-5/2Fb+5Fx-5/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-5/6+0)Fb^2/EJ$	$1/3xb/EJ$
CF b	$x/b$	$-5/2Fx$	0	$-5/2Fx^2/b$	0	$x^2/b^2$	$-13/12Fb^2/EJ$	$5/3xb/EJ$
totali								
iperstatica $X=W_{EP}$								

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = \left[ \frac{1}{3} x^3/b^2 \right]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = \left[ x \right]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = \left[ x \right]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = \left[ \frac{1}{3} x^3/b^2 \right]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-5/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = \left[ -5/4 x^2/b \right]_0^b Fb 1/EJ + \left[ x \right]_0^b \theta$$

$$= (-5/4 b) Fb 1/EJ + (b) \theta = -1/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-5/2 + 5/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = \left[ -5/2 x + 5/4 x^2/b \right]_0^b Fb 1/EJ + \left[ -x \right]_0^b \theta$$

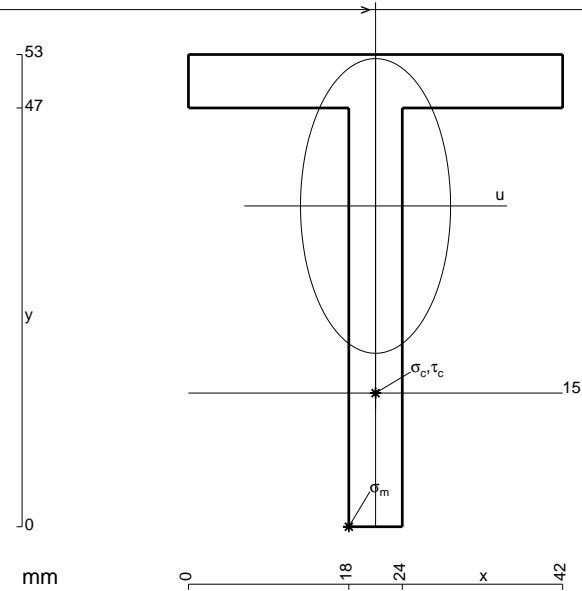
$$= (-5/2 b + 5/4 b) Fb 1/EJ + (-b) \theta = -1/4 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = \left[ -5/2 x + 5/2 x^2/b - 5/6 x^3/b^2 \right]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = \left[ -5/6 x^3/b^2 \right]_0^b Fb 1/EJ$$

$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$



$$A = 534. \text{ mm}^2$$

$$J_u = 146122. \text{ mm}^4$$

$$J_v = 37890. \text{ mm}^4$$

$$y_g = 36.01 \text{ mm}$$

$$N = -1297. \text{ N}$$

$$T_y = -648.5 \text{ N}$$

$$M_x = 899000. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -36.01 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 219.1 \text{ N/mm}^2$$

$$x_c = 21. \text{ mm}$$

$$y_c = 15. \text{ mm}$$

$$v_c = -21.01 \text{ mm}$$

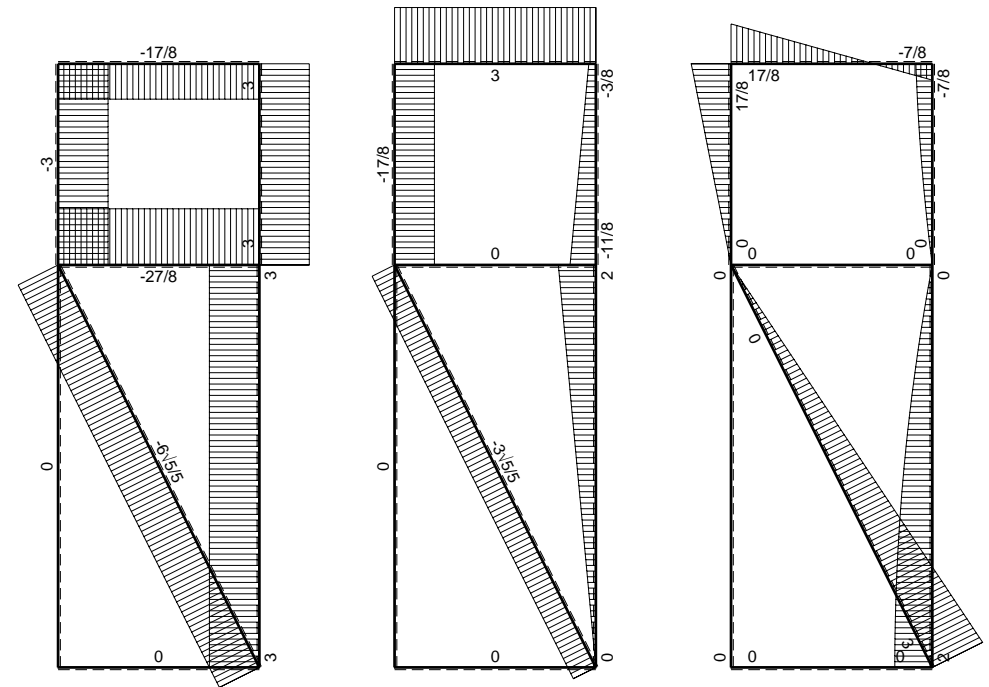
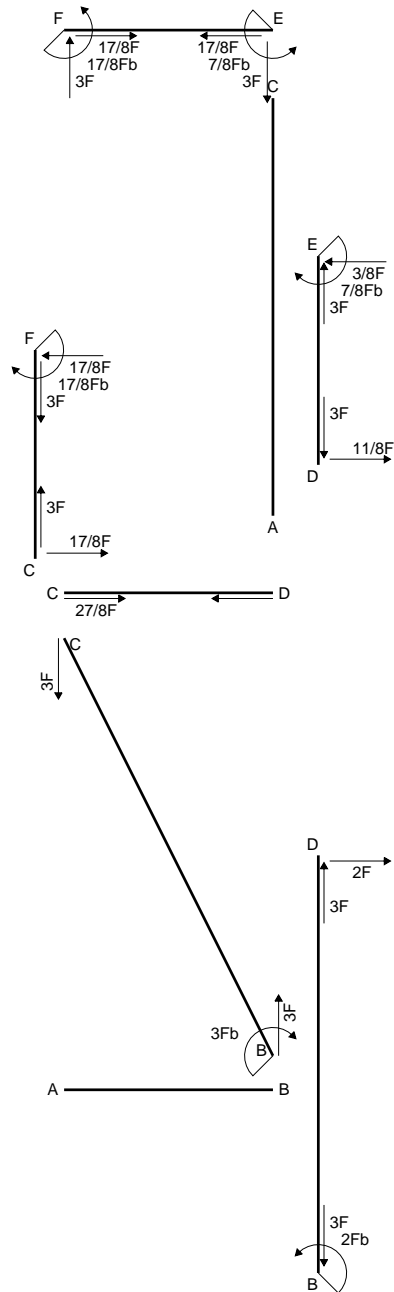
$$\sigma_c = N/A - Mv/J_u = 126.8 \text{ N/mm}^2$$

$$\tau_c = 1.898 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 126.8 \text{ N/mm}^2$$

$$S = 2566. \text{ mm}^3$$

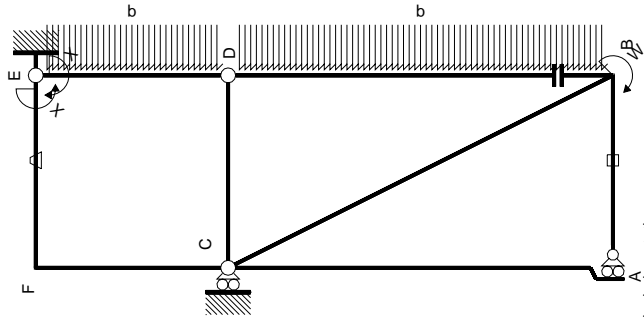




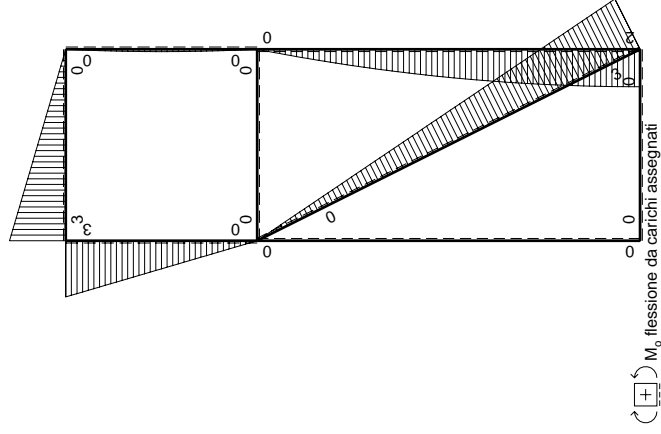
← ⊕ → F

↑ ⊕ ↓ F

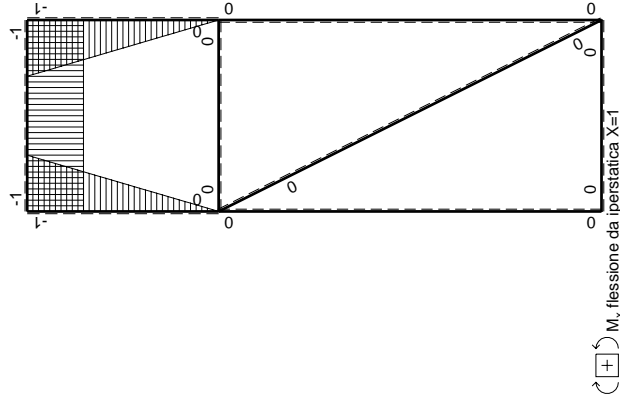
⊕ F<sub>b</sub>



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<sub>EF</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>	∫M <sub>x</sub> (M <sub>0</sub> /EJ+θ)dx	∫M <sub>x</sub> M <sub>x</sub> /EJdx
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0	0
BC √5b	0	3Fb-3√5/5Fx	0	0	0	0	0+0	0
AC 2b	0	0	0	0	0	0	0+0	0
CA 2b	0	0	0	0	0	0	0+0	0
DB 2b	0	2Fx-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
BD 2b	0	-2Fb+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
DE 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
ED 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
CD b	0	0	0	0	0	0	0+0	0
DC b	0	0	0	0	0	0	0+0	0
EF b	-1	3Fx	-Fb/EJ	-3Fx	Fb/EJ	1	(-3/2+1)Fb <sup>2</sup> /EJ	Xb/EJ
FE b	1	-3Fb+3Fx	Fb/EJ	-3Fb+3Fx	Fb/EJ	1	(-3/2+1)Fb <sup>2</sup> /EJ	Xb/EJ
FC b	-1+x/b	3Fb-3Fx	0	-3Fb+6Fx-3Fx <sup>2</sup> /b	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	(-1+0)Fb <sup>2</sup> /EJ	1/3Xb/EJ
CF b	x/b	-3Fx	0	-3Fx <sup>2</sup> /b	0	x <sup>2</sup> /b <sup>2</sup>	-35/24Fb <sup>2</sup> /EJ	5/3Xb/EJ
totali								
							7/8Fb	

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-3x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-3/2 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-3/2 b) Fb 1/EJ + (b) \theta = -1/2 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-3 + 3x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-3x + 3/2 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

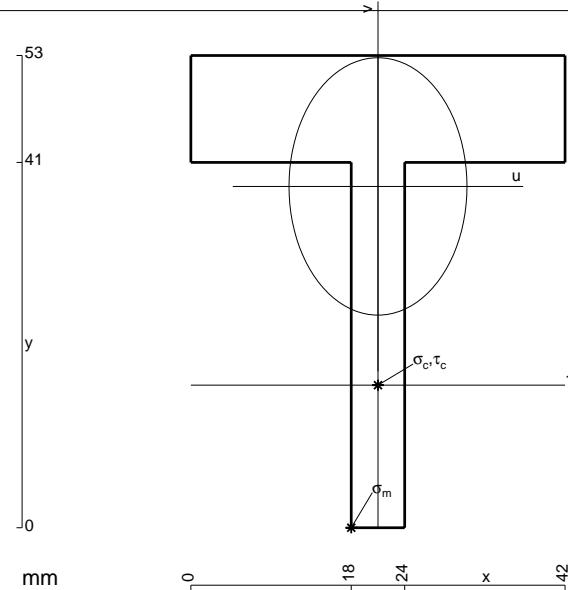
$$= (-3b + 3/2 b) Fb 1/EJ + (-b) \theta = -1/2 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-3 + 6x/b - 3x^2/b^2) Fb 1/EJ dx = [-3x + 3x^2/b - x^3/b^2]_0^b Fb 1/EJ$$

$$= (-3b + 3b - b) Fb 1/EJ = - Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-3x^2/b^2) Fb 1/EJ dx = [-x^3/b^2]_0^b Fb 1/EJ$$

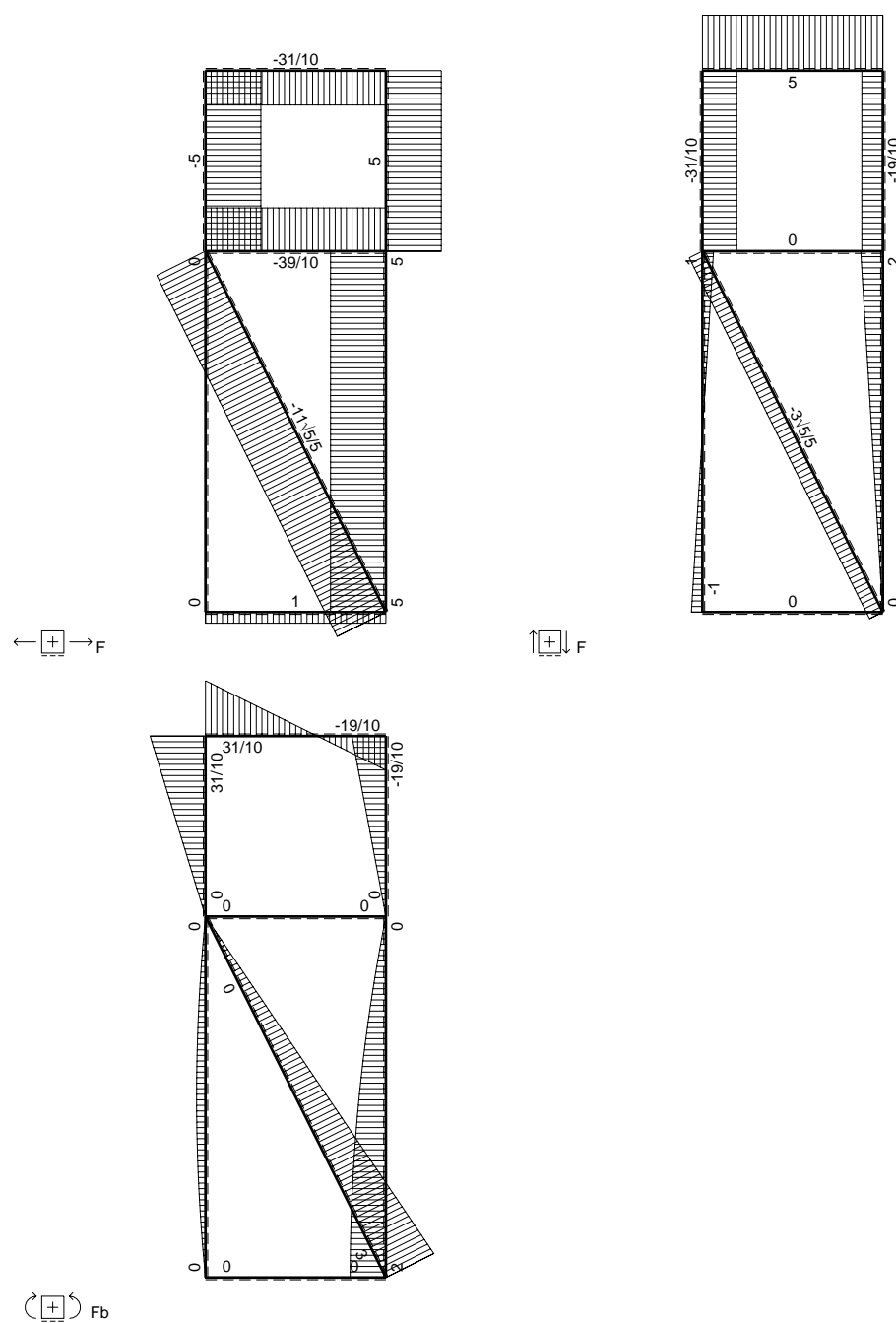
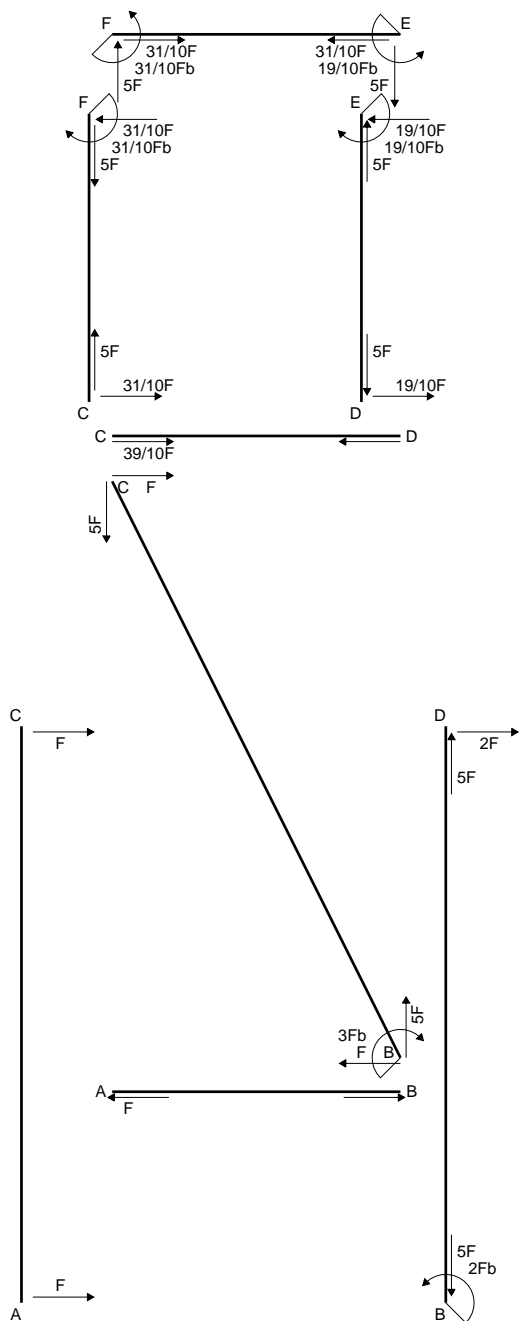
$$= (-b) Fb 1/EJ = - Fb^2/EJ$$

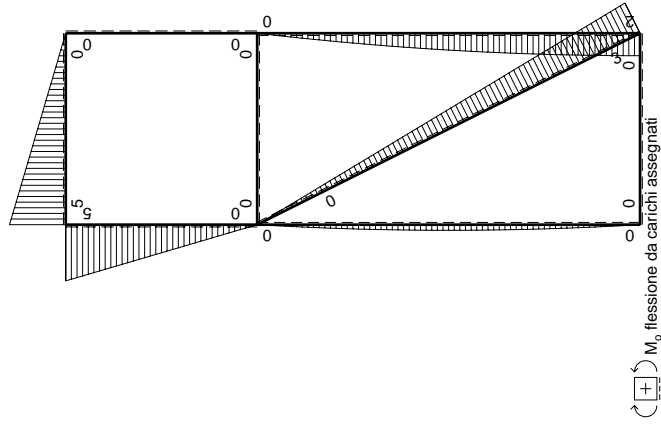
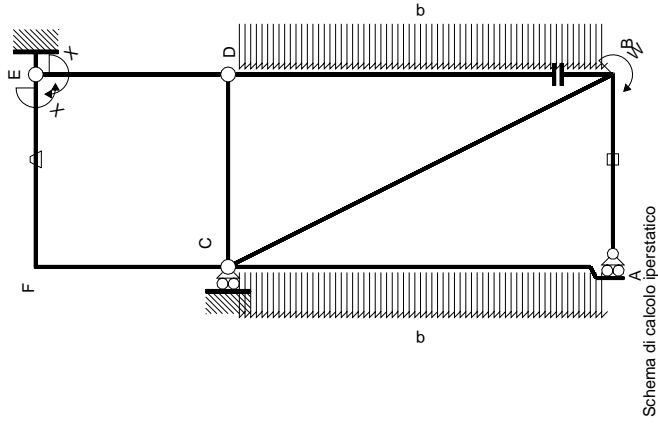


- A = 750. mm<sup>2</sup>
- J<sub>u</sub> = 156599. mm<sup>4</sup>
- J<sub>v</sub> = 74826. mm<sup>4</sup>
- y<sub>g</sub> = 38.31 mm
- N = -1261. N
- T<sub>y</sub> = -630.6 N
- M<sub>x</sub> = 930600. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -38.31 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = 226. 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> = 1.953 N/mm<sup>2</sup>
- σ<sub>g</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 130.9 N/mm<sup>2</sup>
- S = 2910. mm<sup>3</sup>





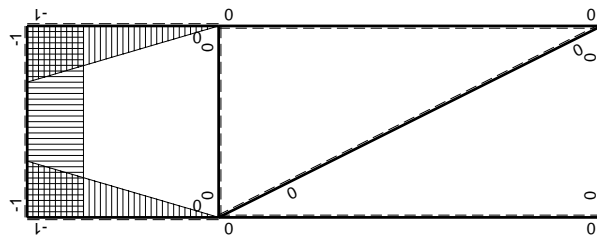




Quadro contributi PLV per iperstatica  $X=W_{E^f}$

$\rightarrow$	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M^0$	$M^x \theta$	$M^x M^x$	$\int M^x(M^0/EJ+\theta)dx$	$\int M^x M^x/EJ dx$
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$3Fb-3\sqrt{5}/5Fx$	0	0	0	0	0	0
AC 2b	0	$-Fx+1/2qx^2$	0	0	0	0	0+0	0
CA 2b	0	$Fx-1/2qx^2$	0	0	0	0	0	0
DB 2b	0	$2Fx-1/2qx^2$	0	0	0	0	0+0	0
BD 2b	0	$-2Fb+1/2qx^2$	0	0	0	0	0	0
DE b	$-x/b$	0	0	0	0	0	$x^2/b^2$	$1/3Xb/EJ$
ED b	$1-x/b$	0	0	0	0	0	$1-2x/b+x^2/b^2$	$1/3Xb/EJ$
CD b	0	0	0	0	0	0	0	0
DC b	0	0	0	0	0	0	0+0	0
EF b	-1	$5Fx$	$-Fb/EJ$	$-5Fx$	$Fb/EJ$	$Fb/EJ$	$(-5/2+1)Fb^2/EJ$	$Xb/EJ$
FE b	1	$-5Fb+5Fx$	$Fb/EJ$	$-5Fb+5Fx$	$Fb/EJ$	$Fb/EJ$	$(-5/2+1)Fb^2/EJ$	$Xb/EJ$
FC b	$-1+x/b$	$5Fb-5Fx$	0	$-5Fb+10Fx-5Fx^2/b$	0	0	$1-2x/b+x^2/b^2$	$1/3Xb/EJ$
CF b	$x/b$	$-5Fx$	0	$-5Fx^2/b$	0	0	$x^2/b^2$	$1/3Xb/EJ$
totali							$-19/6Fb^2/EJ$	$5/3Xb/EJ$
								$19/10Fb$

Sviluppi di calcolo iperstatica



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (-2x/b + x^2/b^2) 1/EJ dx = [-x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-5x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-5/2 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-5/2 b) Fb 1/EJ + (b) \theta = -3/2 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-5 + 5x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-5x + 5/2 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

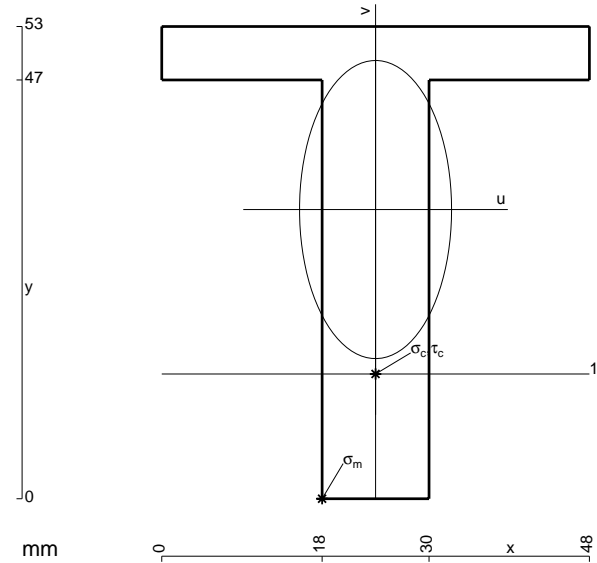
$$= (-5b + 5/2 b) Fb 1/EJ + (-b) \theta = -3/2 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-5 + 10x/b - 5x^2/b^2) Fb 1/EJ dx = [-5x + 5x^2/b - 5/3 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5b + 5b - 5/3 b) Fb 1/EJ = -5/3 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-5x^2/b^2) Fb 1/EJ dx = [-5/3 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/3 b) Fb 1/EJ = -5/3 Fb^2/EJ$$



$$A = 852. \text{ mm}^2$$

$$J_u = 238570. \text{ mm}^4$$

$$J_v = 62064. \text{ mm}^4$$

$$y_g = 32.46 \text{ mm}$$

$$N = -4181. \text{ N}$$

$$T_y = -1140. \text{ N}$$

$$M_x = 1785000. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$u_m = -6. \text{ mm}$$

$$v_m = -32.46 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 237.9 \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 14. \text{ mm}$$

$$v_c = -18.46 \text{ mm}$$

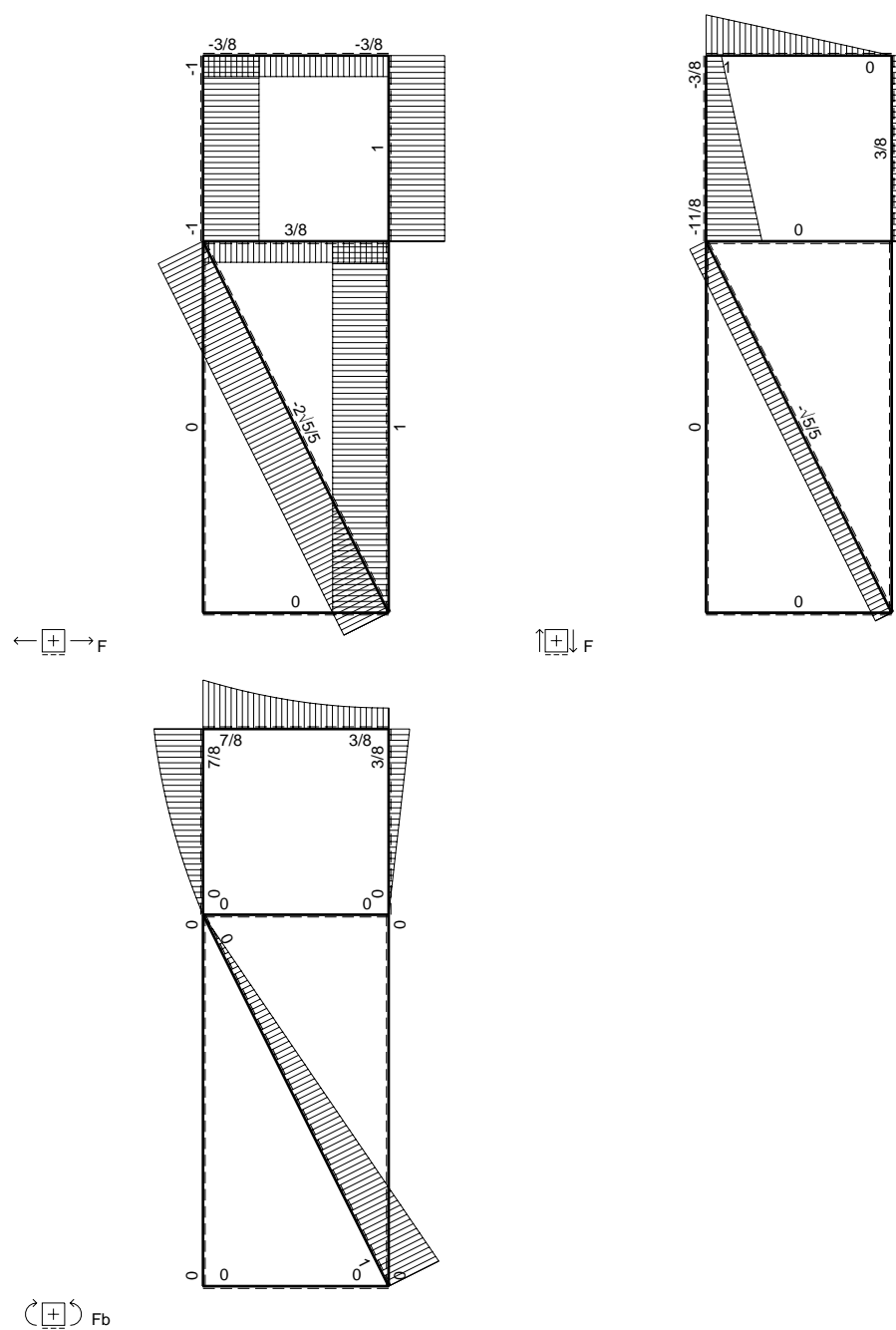
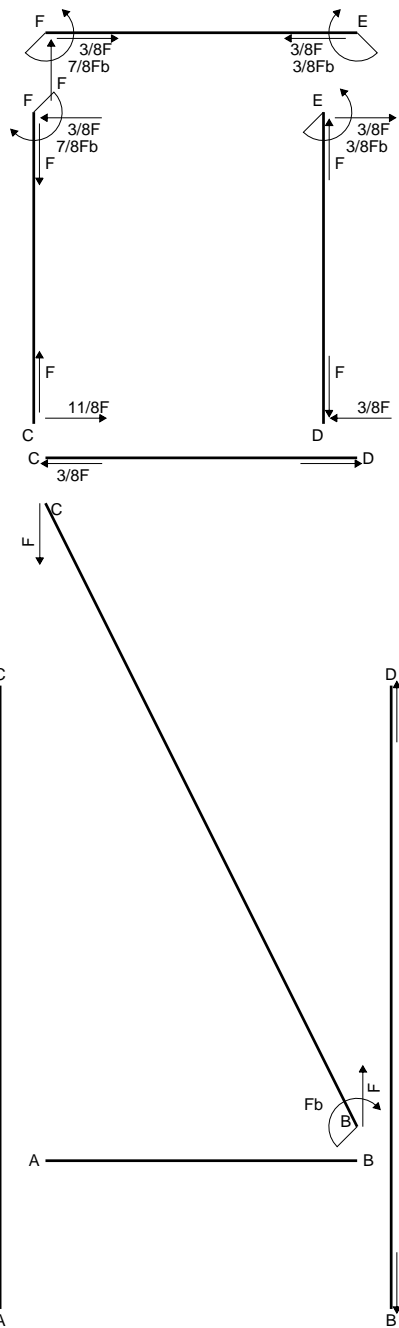
$$\sigma_c = N/A - Mv/J_u = 133.2 \text{ N/mm}^2$$

$$\tau_c = 1.704 \text{ N/mm}^2$$

$$\sigma_\varphi = \sqrt{\sigma^2 + 3\tau^2} = 133.2 \text{ N/mm}^2$$

$$S = 4277. \text{ mm}^3$$







$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/6 b) Fb 1/EJ + (b) \theta = 5/6 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx$$

$$= [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ + (-b) \theta = 5/6 Fb^2/EJ$$

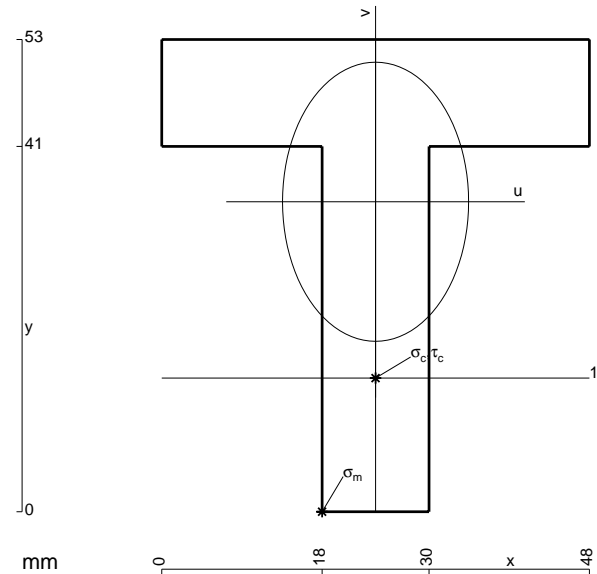
$$L_{FC}^{xo} = \int_0^b (-1/2 + 1/2 x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx$$

$$= [-1/2 x + 1/4 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/4 b + 1/6 b - 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

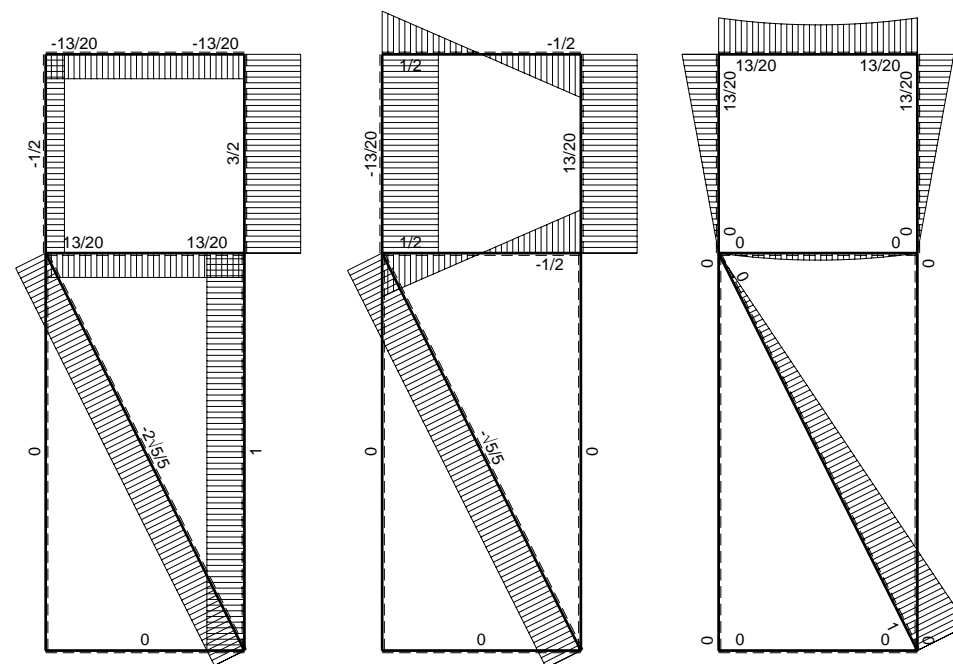
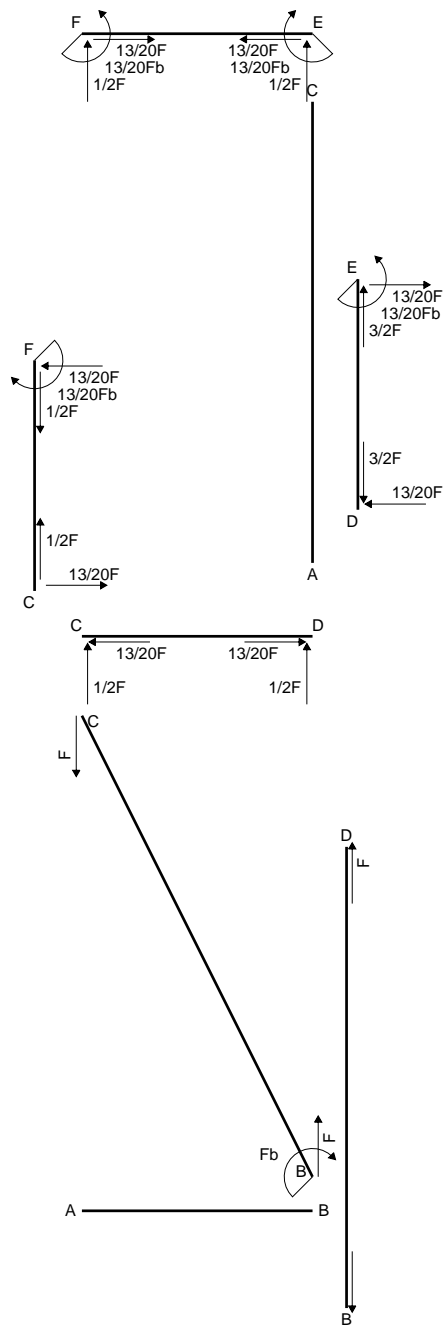
$$= (-1/3 b + 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$



- A = 1068. mm<sup>2</sup>
- J<sub>u</sub> = 262174. mm<sup>4</sup>
- J<sub>v</sub> = 116496. mm<sup>4</sup>
- y<sub>g</sub> = 34.79 mm
- N = -3703. N
- T<sub>y</sub> = -1851. N
- M<sub>x</sub> = 1531800. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -34.79 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = 199.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 15. mm
- v<sub>c</sub> = -19.79 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = 112.2 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.891 N/mm<sup>2</sup>
- σ<sub>φ</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 112.3 N/mm<sup>2</sup>
- S = 4913. mm<sup>3</sup>



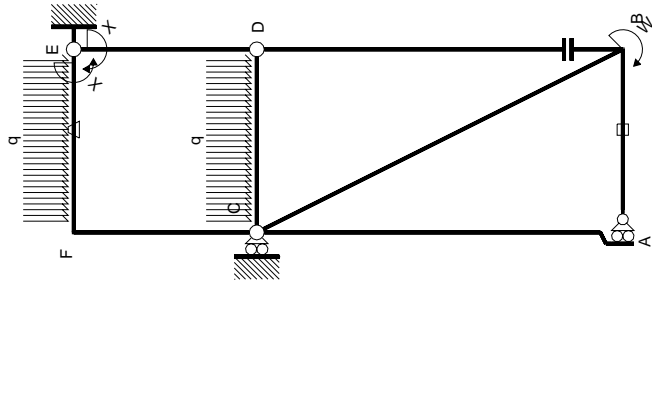




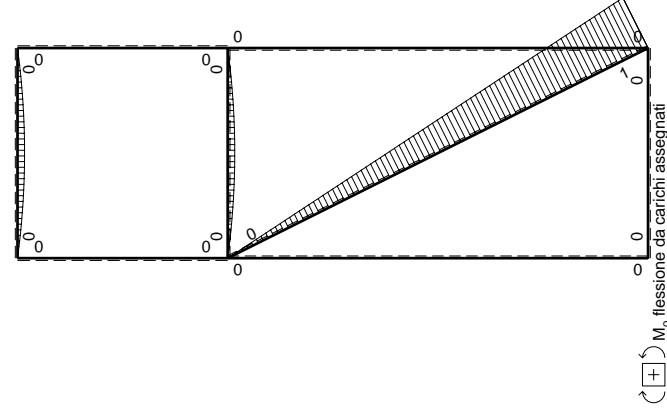
← ⊕ → F

↑ ⊕ ↓ F

⊕ ⊖ F<sub>b</sub>



Schema di calcolo iperstatico



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{EF}$

$\leftarrow$	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x (M_0/EJ + \theta) dx$	$\int M^x M_x / EJ dx$
AB b	0	0	0	0	0	0	0	0
BA b	0	0	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$Fb - \sqrt{5}/5Fx$	0	0	0	0	0	0
CA 2b	0	0	0	0	0	0	0	0
AC 2b	0	0	0	0	0	0	0	0
BD 2b	0	0	0	0	0	0	0	0
DB 2b	0	0	0	0	0	0	0	0
ED b	$1-x/b$	0	0	0	0	0	0	$1/3Xb/EJ$
CD b	0	$1/2Fx - 1/2qx^2$	0	0	0	0	0	0
DC b	0	$-1/2Fx + 1/2qx^2$	0	0	0	0	0	0
EF b	-1	$-1/2Fx + 1/2qx^2$	$-Fb/EJ$	$1/2Fx - 1/2Fx^2/b$	$Fb/EJ$	1	$(1/12+1)Fb^2/EJ$	$Xb/EJ$
FE b	1	$1/2Fx - 1/2qx^2$	$Fb/EJ$	$1/2Fx - 1/2Fx^2/b$	$Fb/EJ$	1	$(1/12+1)Fb^2/EJ$	$Xb/EJ$
FC b	$-1+x/b$	0	0	0	0	0	0	$1/3Xb/EJ$
CF b	$x/b$	0	0	0	0	0	0	$1/3Xb/EJ$
totali							$13/12Fb^2/EJ$	$5/3Xb/EJ$
								$-13/20Fb$

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

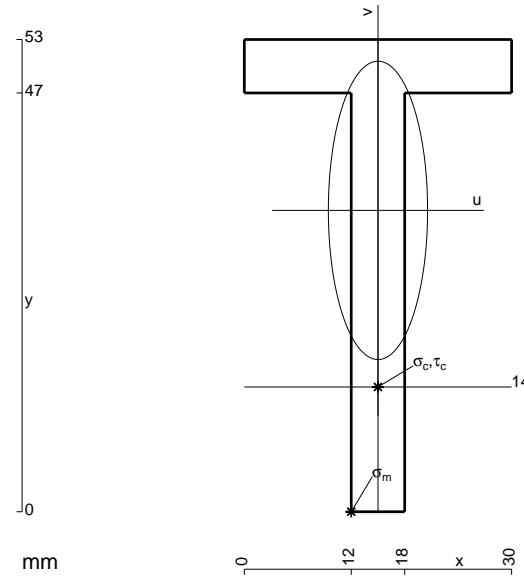
$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{x\theta} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (1/4 b - 1/6 b) Fb 1/EJ + (b) \theta = 13/12 Fb^2/EJ$$

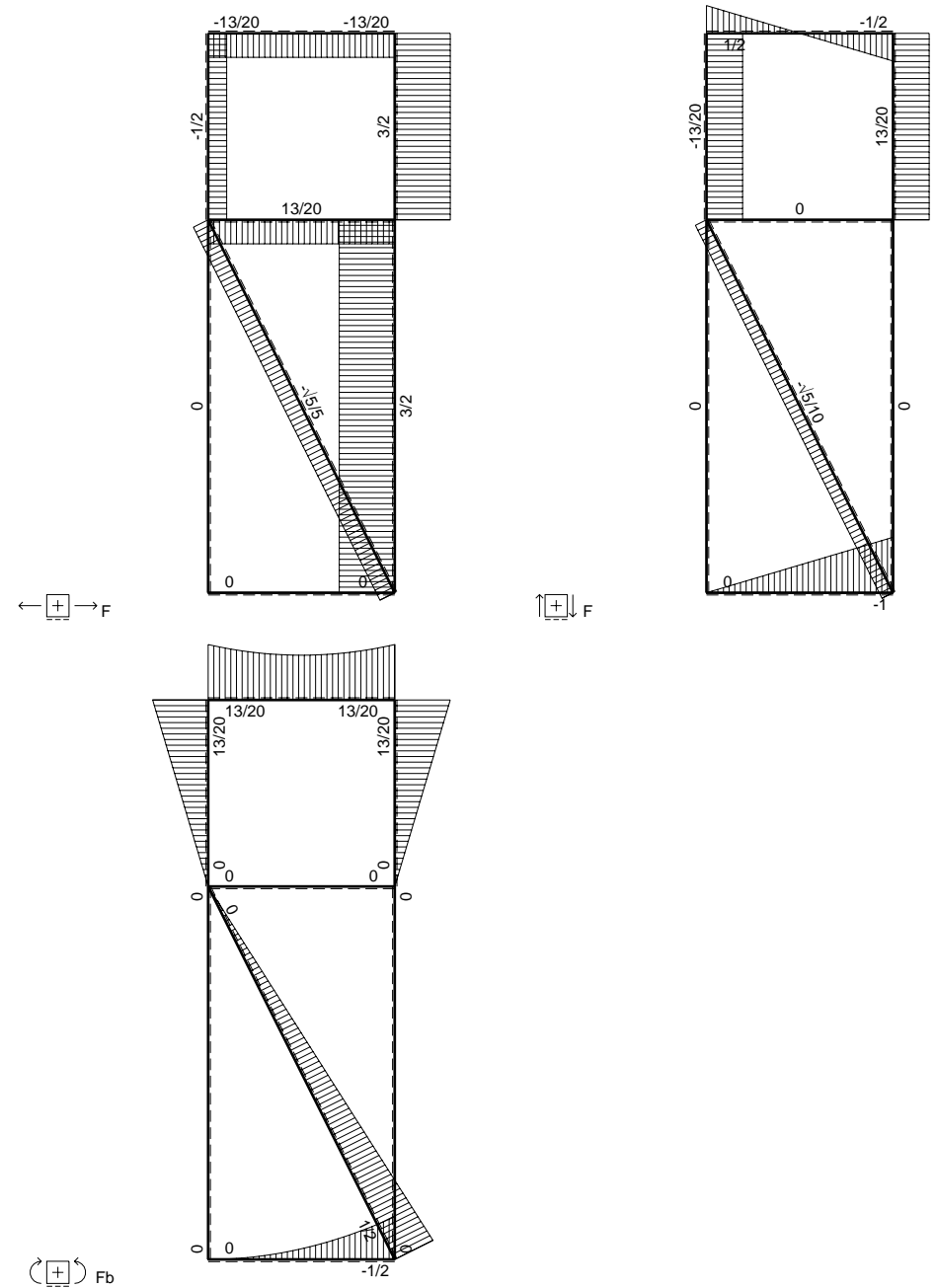
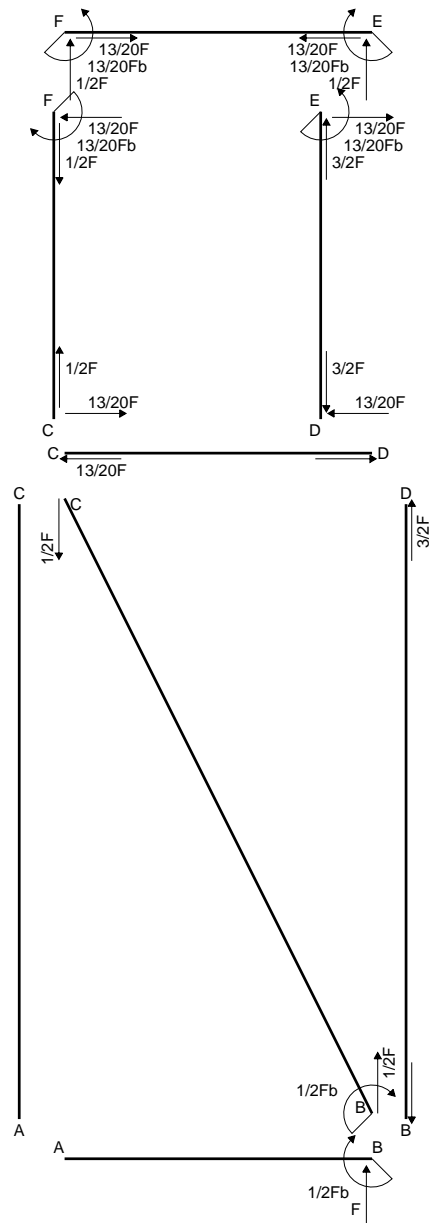
$$L_{FE}^{x\theta} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (1/4 b - 1/6 b) Fb 1/EJ + (-b) \theta = 13/12 Fb^2/EJ$$



- A = 462. mm<sup>2</sup>
- J<sub>u</sub> = 129608. mm<sup>4</sup>
- J<sub>v</sub> = 14346. mm<sup>4</sup>
- y<sub>g</sub> = 33.82 mm
- N = -1825. N
- T<sub>y</sub> = -912.3 N
- M<sub>x</sub> = 816000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -33.82 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = 209. N/mm<sup>2</sup>
- x<sub>c</sub> = 15. mm
- y<sub>c</sub> = 14. mm
- v<sub>c</sub> = -19.82 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = 120.9 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.643 N/mm<sup>2</sup>
- σ<sub>g</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 121. N/mm<sup>2</sup>
- S = 2253. mm<sup>3</sup>





⊕ F<sub>b</sub>



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

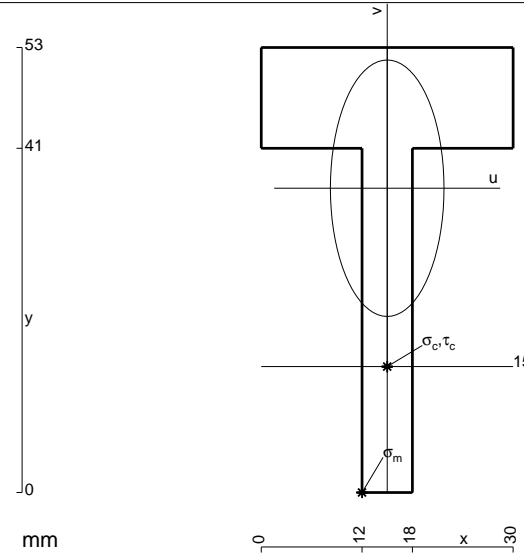
$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (1/4 b - 1/6 b) Fb 1/EJ + (b) \theta = 13/12 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

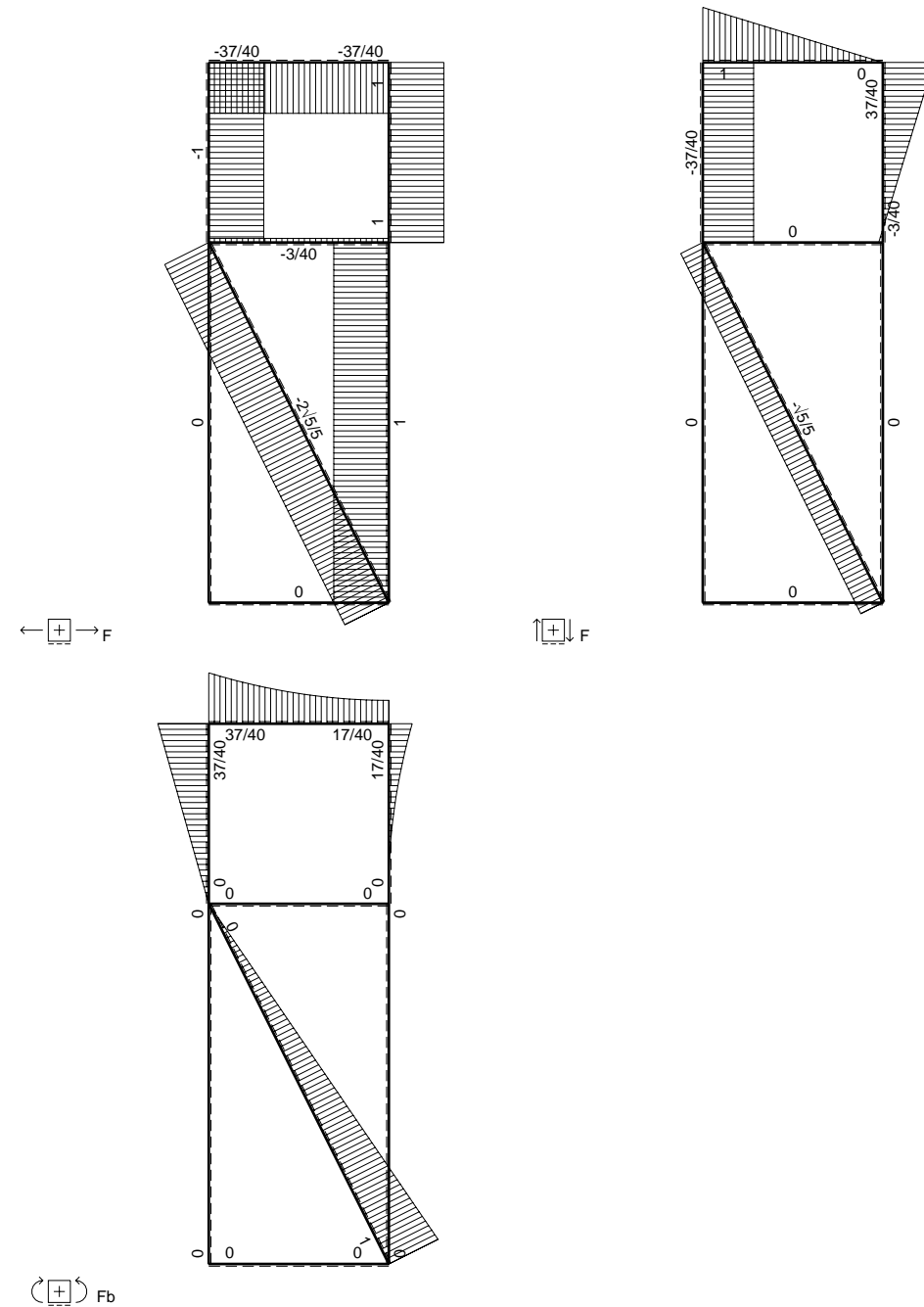
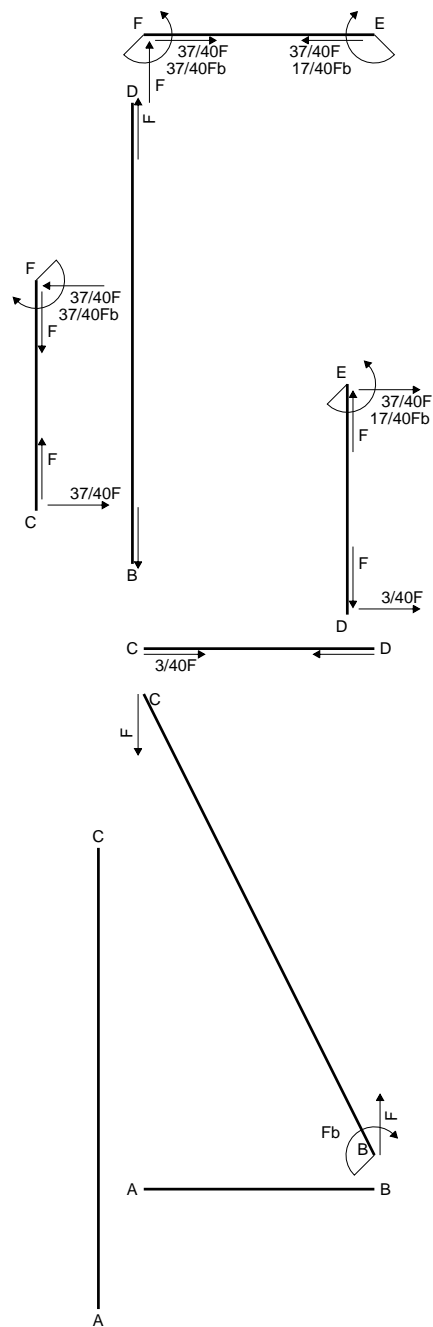
$$= (1/4 b - 1/6 b) Fb 1/EJ + (-b) \theta = 13/12 Fb^2/EJ$$

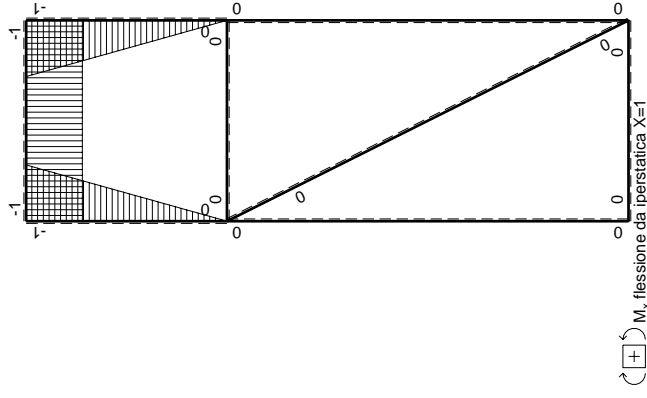
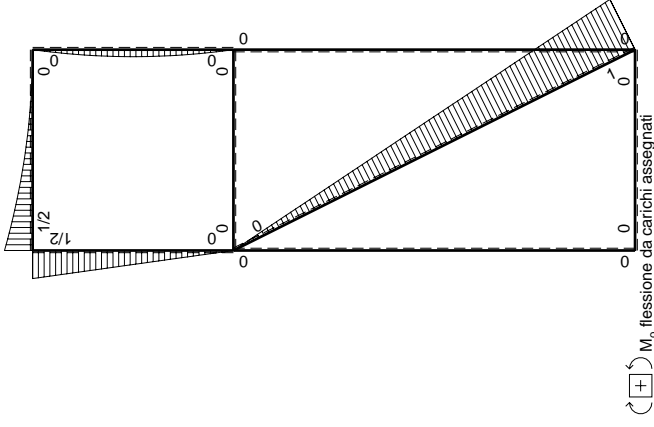
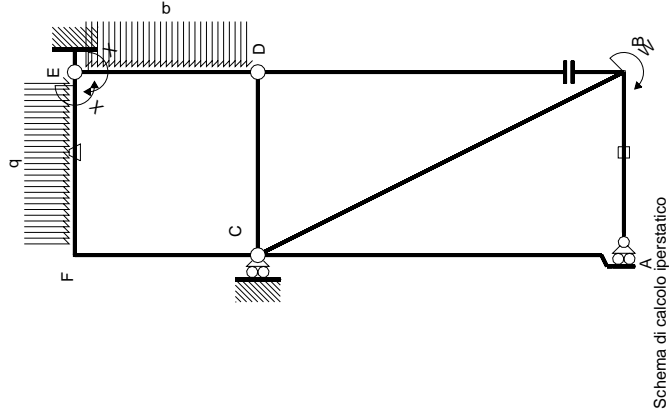


- A = 606. mm<sup>2</sup>
- J<sub>u</sub> = 141406. mm<sup>4</sup>
- J<sub>v</sub> = 27738. mm<sup>4</sup>
- y<sub>g</sub> = 36.24 mm
- T<sub>y</sub> = -3900. N
- M<sub>x</sub> = -858000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -36.24 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -219.9 N/mm<sup>2</sup>
- x<sub>c</sub> = 15. mm
- y<sub>c</sub> = 15. mm
- v<sub>c</sub> = -21.24 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -128.9 N/mm<sup>2</sup>
- τ<sub>c</sub> = 11.89 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 130.5 N/mm<sup>2</sup>
- S = 2587. mm<sup>3</sup>









Quadro contributi PLV per iperstatica X=W<sub>EF</sub>

←	M <sub>0</sub> (x)	M <sub>0</sub> (x)	θ	M <sub>0</sub>	M <sub>θ</sub>	M <sub>X</sub>	∫M <sub>0</sub> (M <sub>0</sub> /EJ+θ)dx	∫M <sub>X</sub> M <sub>0</sub> /EJdx
AB b	0	0	0	0	0	0	0	0
BA b	0	0	0	0	0	0	0	0
BC √5b	0	Fb-√5/5Fx	0	0	0	0	0	0
CA 2b	0	0	0	0	0	0	0	0
DB 2b	0	0	0	0	0	0	0	0
BD 2b	0	0	0	0	0	0	0	0
DE 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
ED 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
CD b	0	0	0	0	0	0	0+0	0
DC b	0	0	0	0	0	0	0+0	0
EF b	-1	1/2qx <sup>2</sup>	-Fb/EJ	-1/2Fx <sup>2</sup> /b	Fb/EJ	1	(-1/6+1)Fb <sup>2</sup> /EJ	Xb/EJ
FE b	1	-1/2Fb+Fx-1/2qx <sup>2</sup>	Fb/EJ	-1/2Fb+Fx-1/2Fx <sup>2</sup> /b	Fb/EJ	1	(-1/6+1)Fb <sup>2</sup> /EJ	Xb/EJ
FC b	-1+x/b	1/2Fb-1/2Fx	0	-1/2Fb+Fx-1/2Fx <sup>2</sup> /b	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	(-1/6+0)Fb <sup>2</sup> /EJ	1/3Xb/EJ
CF b	x/b	-1/2Fx	0	-1/2Fx <sup>2</sup> /b	0	x <sup>2</sup> /b <sup>2</sup>	(-1/6+0)Fb <sup>2</sup> /EJ	1/3Xb/EJ
totali							17/24Fb <sup>2</sup> /EJ	5/3Xb/EJ
								-17/40Fb

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{x\theta} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{x\theta} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{x\theta} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/6 b) Fb 1/EJ + (b) \theta = 5/6 Fb^2/EJ$$

$$L_{FE}^{x\theta} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx$$

$$= [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

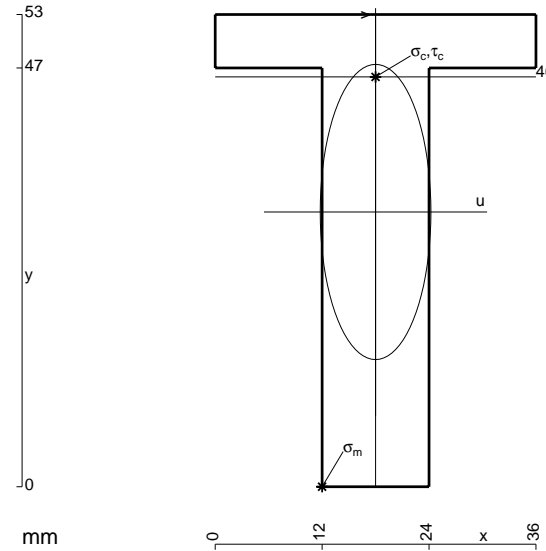
$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ + (-b) \theta = 5/6 Fb^2/EJ$$

$$L_{FC}^{x\theta} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

$$L_{CF}^{x\theta} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$



- A = 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> = 30.84 mm
- N = -3023. N
- T<sub>y</sub> = -1512. N
- M<sub>x</sub> = 1622400. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -30.84 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = 229.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 46. mm
- v<sub>c</sub> = 15.16 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = -118.7 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.545 N/mm<sup>2</sup>
- σ<sub>φ</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 118.8 N/mm<sup>2</sup>
- S = 4327. mm<sup>3</sup>







$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-2x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-b - 1/6 b) Fb 1/EJ + (b) \theta = -1/6 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-5/2 + 3x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx$$

$$= [-5/2 x + 3/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

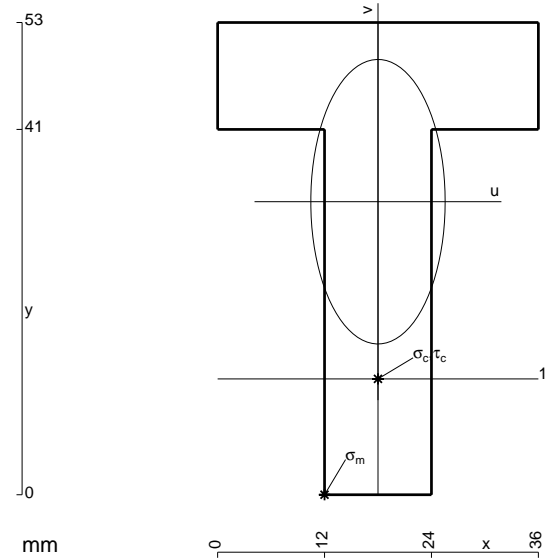
$$= (-5/2 b + 3/2 b - 1/6 b) Fb 1/EJ + (-b) \theta = -1/6 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = [-5/2 x + 5/2 x^2/b - 5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

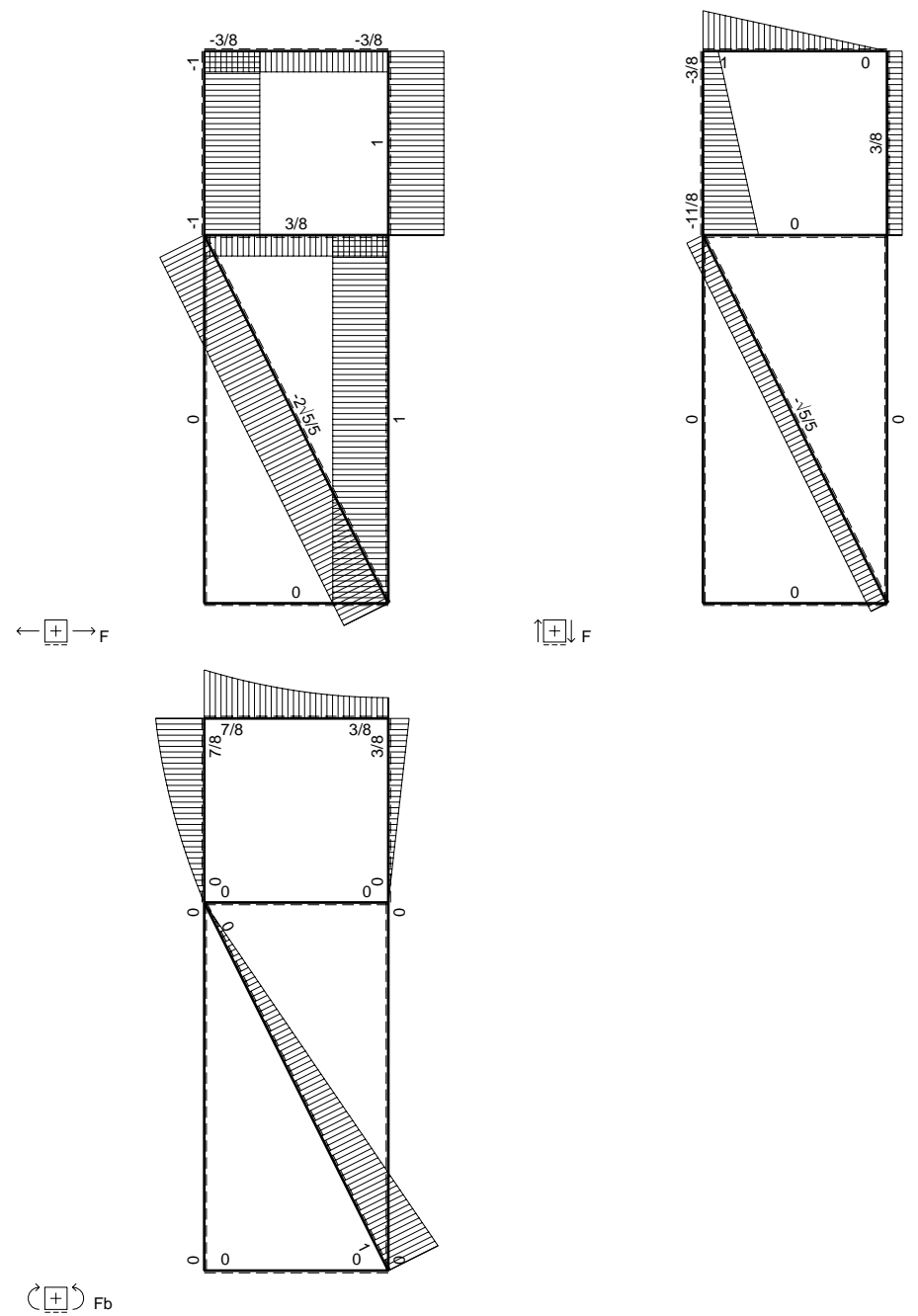
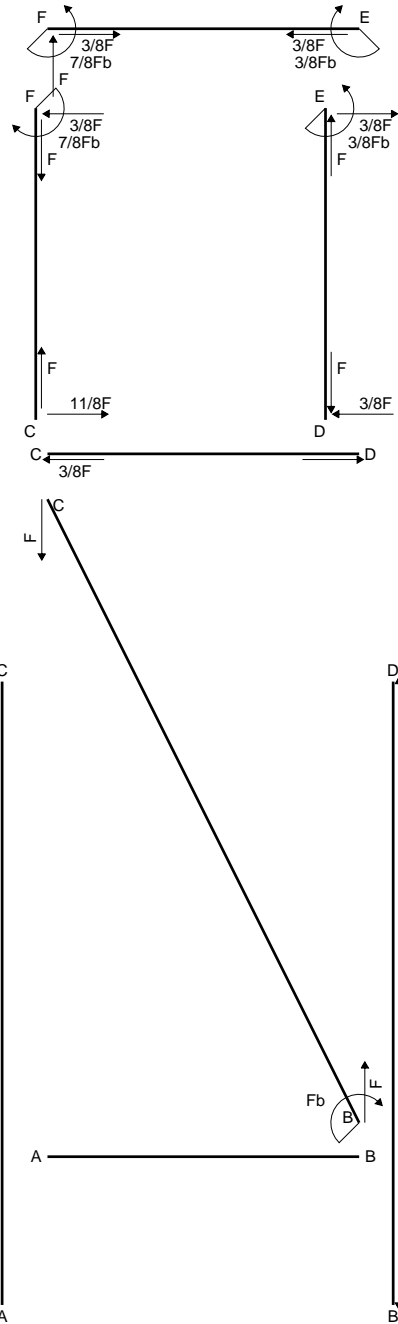
$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

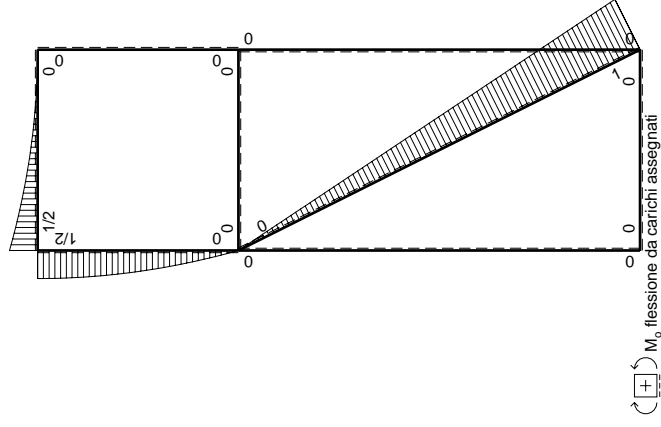
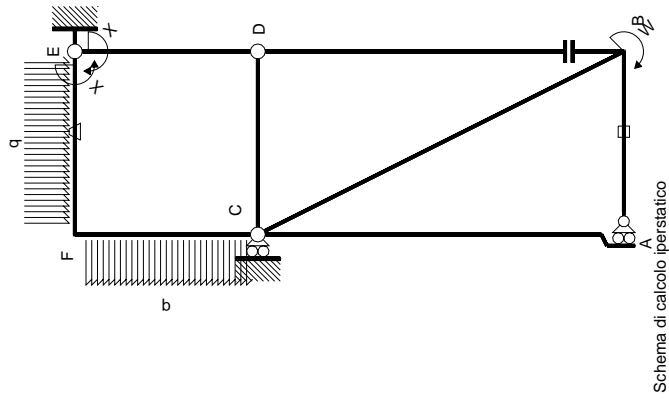


- A = 924. mm<sup>2</sup>
- J<sub>u</sub> = 235641. mm<sup>4</sup>
- J<sub>v</sub> = 52560. mm<sup>4</sup>
- y<sub>g</sub> = 32.89 mm
- N = -11082. N
- T<sub>y</sub> = -1583. N
- M<sub>x</sub> = 1805400. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -32.89 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = 240. N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 13. mm
- v<sub>c</sub> = -19.89 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = 140.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.305 N/mm<sup>2</sup>
- σ<sub>g</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 140.5 N/mm<sup>2</sup>
- S = 4117. mm<sup>3</sup>





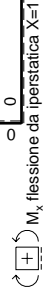




Quadro contributi PLV per iperstatica X=W<sup>EF</sup>

←	M <sub>x</sub> (x)	M <sub>0</sub> (x)	θ	M <sub>x</sub> θ	M <sub>x</sub> M <sub>0</sub>	∫M <sub>x</sub> (M <sub>0</sub> /EJ+θ)dx	∫M <sub>x</sub> M <sub>0</sub> /EJdx
AB	0	0	0	0	0	0	0
BA	0	0	0	0	0	0	0
BC	0	Fb-√5/5Fx	0	0	0	0	0
AC	0	0	0	0	0	0	0
CA	0	0	0	0	0	0	0
DB	0	0	0	0	0	0	0
BD	0	0	0	0	0	0	0
DE	-x/b	0	0	0	x <sup>2</sup> /b <sup>2</sup>	0	1/3Xb/EJ
ED	1-x/b	0	0	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	0	1/3Xb/EJ
CD	0	0	0	0	0	0	0
DC	0	0	0	0	0	0	0
EF	-1	1/2qx <sup>2</sup>	-Fb/EJ	-1/2Fx <sup>2</sup> /b	Fb/EJ	1	Xb/EJ
FE	1	-1/2Fb+Fx-1/2qx <sup>2</sup>	Fb/EJ	-1/2Fx <sup>2</sup> /b	Fb/EJ	1	Xb/EJ
FC	-1+x/b	1/2Fb-1/2qx <sup>2</sup>	0	-1/2Fb+1/2Fx+1/2Fx <sup>2</sup> /b-1/2qx <sup>3</sup> /b	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	(-5/24+0)Fb <sup>2</sup> /EJ
CF	x/b	-Fx+1/2qx <sup>2</sup>	0	-Fx <sup>2</sup> /b+1/2qx <sup>3</sup> /b	0	x <sup>2</sup> /b <sup>2</sup>	1/3Xb/EJ
totali							5/3Xb/EJ
							-3/8Fb

Sviluppi di calcolo iperstatica



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/6 b) Fb 1/EJ + (b) \theta = 5/6 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx$$

$$= [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ + (-b) \theta = 5/6 Fb^2/EJ$$

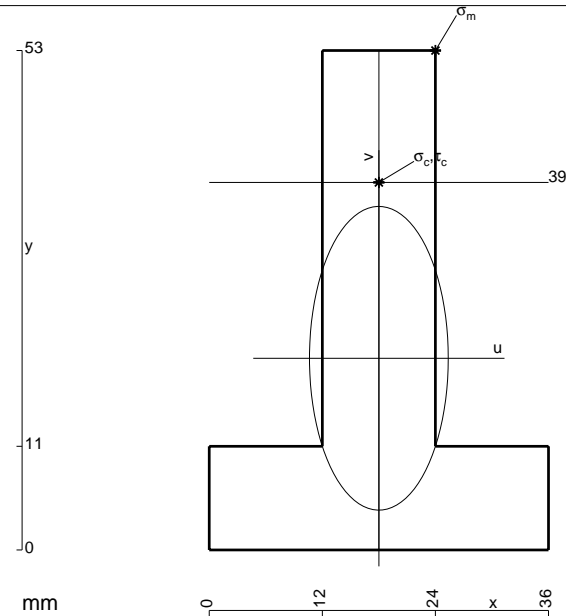
$$L_{FC}^{xo} = \int_0^b (-1/2 + 1/2 x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx$$

$$= [-1/2 x + 1/4 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/4 b + 1/6 b - 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/3 b + 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$



- A = 900. mm<sup>2</sup>
- J<sub>u</sub> = 233812. mm<sup>4</sup>
- J<sub>v</sub> = 48816. mm<sup>4</sup>
- y<sub>g</sub> = 20.34 mm
- N = -2299. N
- T<sub>y</sub> = -1149. N
- M<sub>x</sub> = 1413500. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 53. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 32.66 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = -200. N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 39. mm
- v<sub>c</sub> = 18.66 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = -115.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.766 N/mm<sup>2</sup>
- σ<sub>g</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 115.4 N/mm<sup>2</sup>
- S<sup>3</sup> = 4311. mm<sup>3</sup>







$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{x\theta} = \int_0^b (-1/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/4 b) Fb 1/EJ + (b) \theta = 3/4 Fb^2/EJ$$

$$L_{FE}^{x\theta} = \int_0^b (-1/2 + 1/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-1/2 x + 1/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

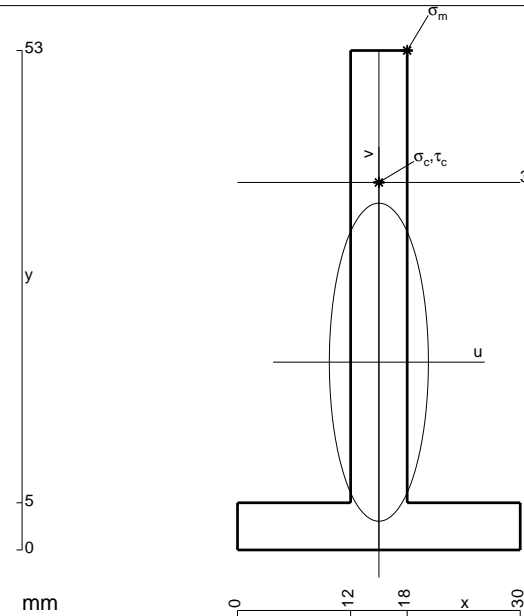
$$L_{FC}^{x\theta} = \int_0^b (-1/2 + 1/2 x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx$$

$$= [-1/2 x + 1/4 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/4 b + 1/6 b - 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$

$$L_{CF}^{x\theta} = \int_0^b (-x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/3 b + 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$



$$A = 438. \text{ mm}^2$$

$$J_u = 124872. \text{ mm}^4$$

$$J_v = 12114. \text{ mm}^4$$

$$y_g = 19.92 \text{ mm}$$

$$N = -1181. \text{ N}$$

$$T_y = -590.3 \text{ N}$$

$$M_x = 778800. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$y_m = 53. \text{ mm}$$

$$u_m = 3. \text{ mm}$$

$$v_m = 33.08 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -209. \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 39. \text{ mm}$$

$$v_c = 19.08 \text{ mm}$$

$$\sigma_c = N/A - Mv/J_u = -121.7 \text{ N/mm}^2$$

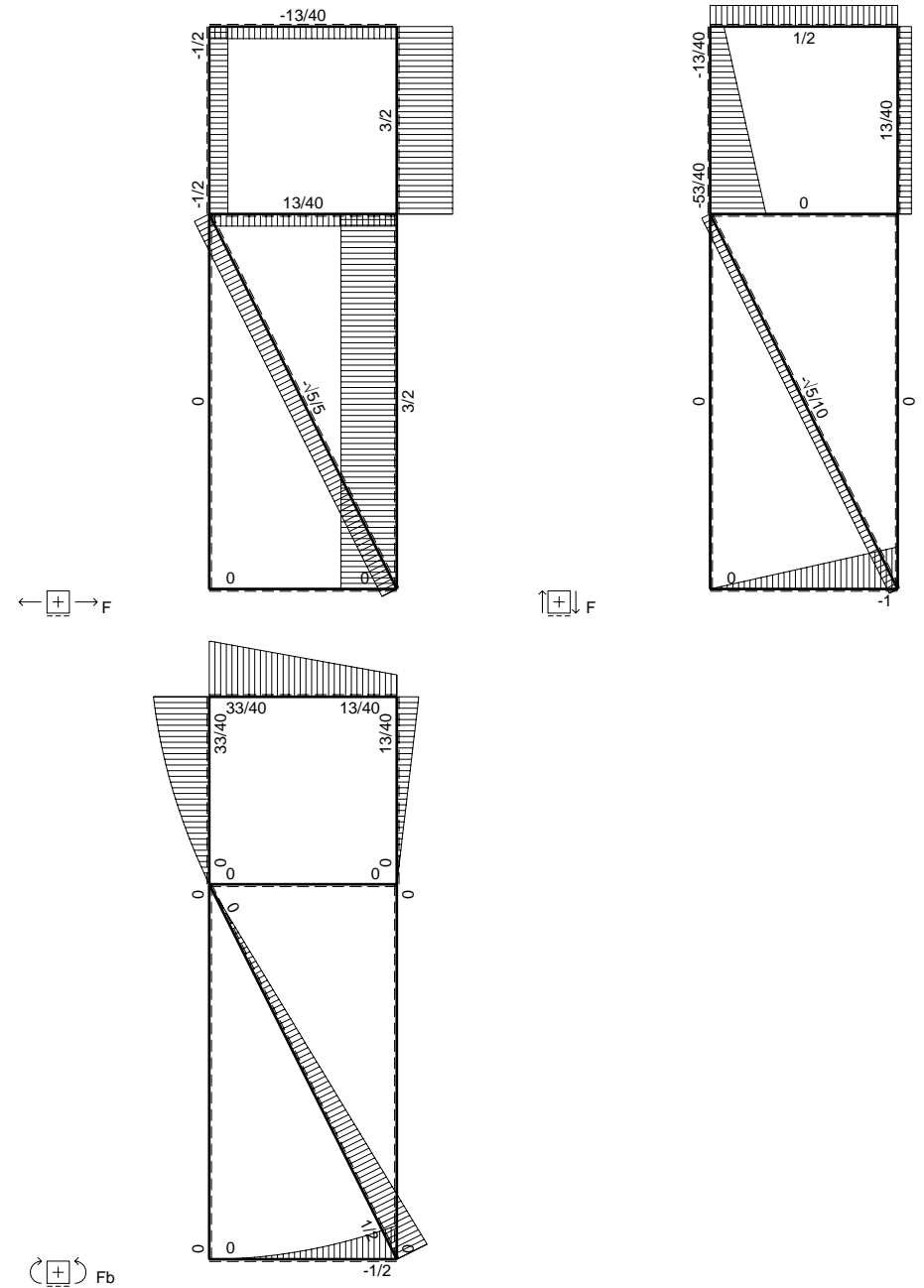
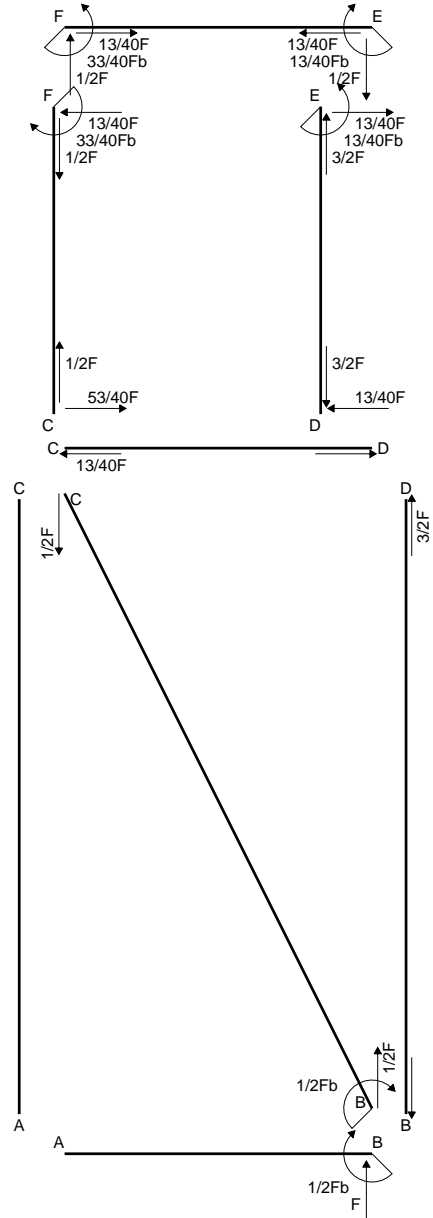
$$\tau_c = 1.726 \text{ N/mm}^2$$

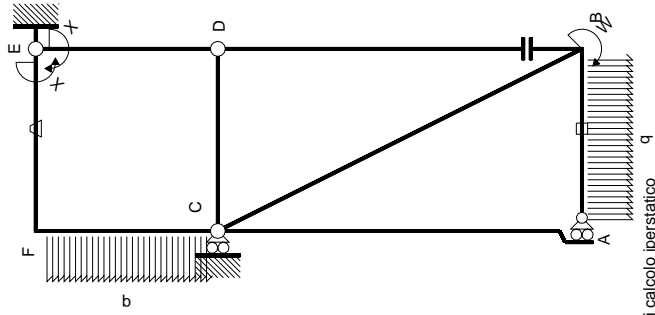
$$\sigma_g = \sqrt{\sigma^2 + 3\tau^2} = 121.7 \text{ N/mm}^2$$

$$S = 2190. \text{ mm}^3$$

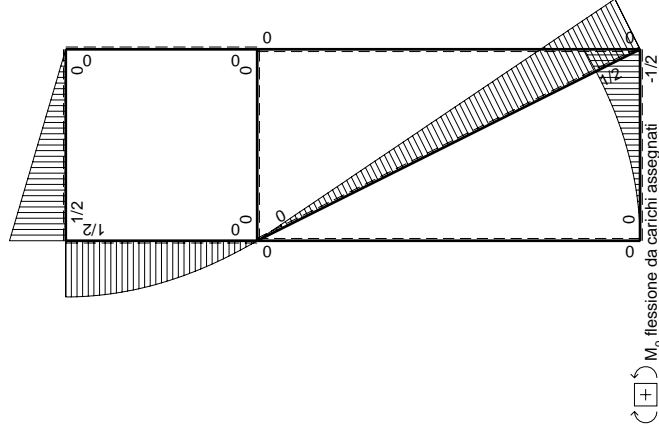




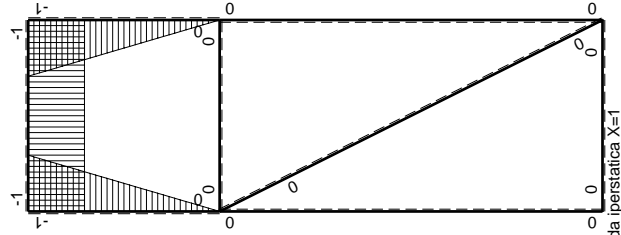




Schema di calcolo iperstatico



$M_x$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica $X=W_{EF}$		$M_x(x)$		$M_0(x)$		$M_x\theta$		$M_x M_x$		$\int M_x(M_0/EJ+\theta)dx$		$\int M_x M_x/EJ dx$	
AB b	0	$-1/2qx^2$	0	0	0	0	0	0	0	0+0	0	0	
BA b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0	0	0	0+0	0	0	
BC √5b	0	$1/2Fb-\sqrt{5}/10Fx$	0	0	0	0	0	0	0	0+0	0	0	
AC 2b	0	0	0	0	0	0	0	0	0	0+0	0	0	
CA 2b	0	0	0	0	0	0	0	0	0	0+0	0	0	
DB 2b	0	0	0	0	0	0	0	0	0	0+0	0	0	
BD 2b	0	0	0	0	0	0	0	0	0	0+0	0	0	
DE b	-x/b	0	0	0	0	0	0	$x^2/b^2$	0	0+0	0	0	
ED b	1-x/b	0	0	0	0	0	0	$1-2x/b+x^2/b^2$	0	0+0	0	0	
CD b	0	0	0	0	0	0	0	0	0	0+0	0	0	
DC b	0	0	0	0	0	0	0	0	0	0+0	0	0	
EF b	-1	$1/2Fx$	$-Fb/EJ$	$-1/2Fx$	$Fb/EJ$	$Fb/EJ$	$Fb/EJ$	1	1	$(-1/4+1)Fb^2/EJ$	$Xb/EJ$	0	
FE b	1	$-1/2Fb+1/2Fx$	$Fb/EJ$	$-1/2Fb+1/2Fx$	$Fb/EJ$	$Fb/EJ$	$Fb/EJ$	1	1	$(-5/24+0)Fb^2/EJ$	$1/3Xb/EJ$	0	
FC b	-1+x/b	$1/2Fb-1/2qx^2$	0	$-1/2Fb+1/2Fx+1/2Fx^2/b-1/2qx^3/b$	0	0	0	$1-2x/b+x^2/b^2$	0	$x^2/b^2$	$13/24Fb^2/EJ$	$5/3Xb/EJ$	
CF b	x/b	$-Fx+1/2qx^2$	0	$-Fx^2/b+1/2qx^3/b$	0	0	0	0	0	$13/24Fb^2/EJ$	$5/3Xb/EJ$	0	
totali													
		iperstatica $X=W_{EF}$											

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/4 b) Fb 1/EJ + (b) \theta = 3/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + 1/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-1/2 x + 1/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

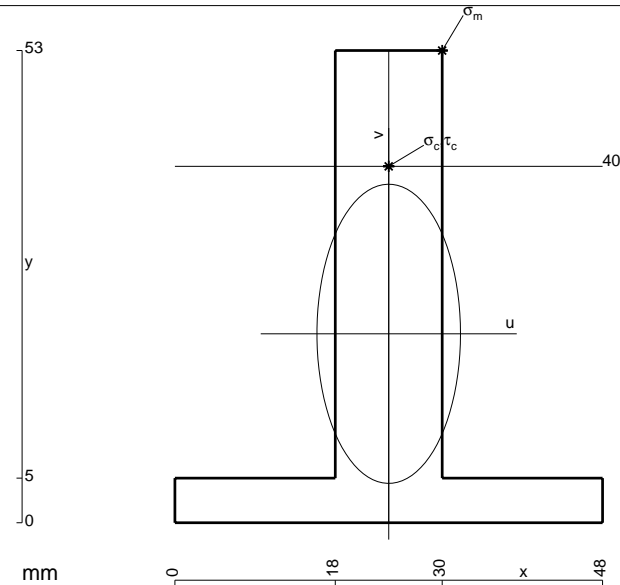
$$L_{FC}^{xo} = \int_0^b (-1/2 + 1/2 x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx$$

$$= [-1/2 x + 1/4 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/4 b + 1/6 b - 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/3 b + 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$



$$A = 816. \text{ mm}^2$$

$$J_u = 230061. \text{ mm}^4$$

$$J_v = 52992. \text{ mm}^4$$

$$y_g = 21.21 \text{ mm}$$

$$T_y = -1590300. \text{ N}$$

$$M_x = -1590300. \text{ Nmm}$$

$$x_m = 30. \text{ mm}$$

$$y_m = 53. \text{ mm}$$

$$u_m = 6. \text{ mm}$$

$$v_m = 31.79 \text{ mm}$$

$$\sigma_m = -Mv/J_u = 219.8 \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 40. \text{ mm}$$

$$v_c = 18.79 \text{ mm}$$

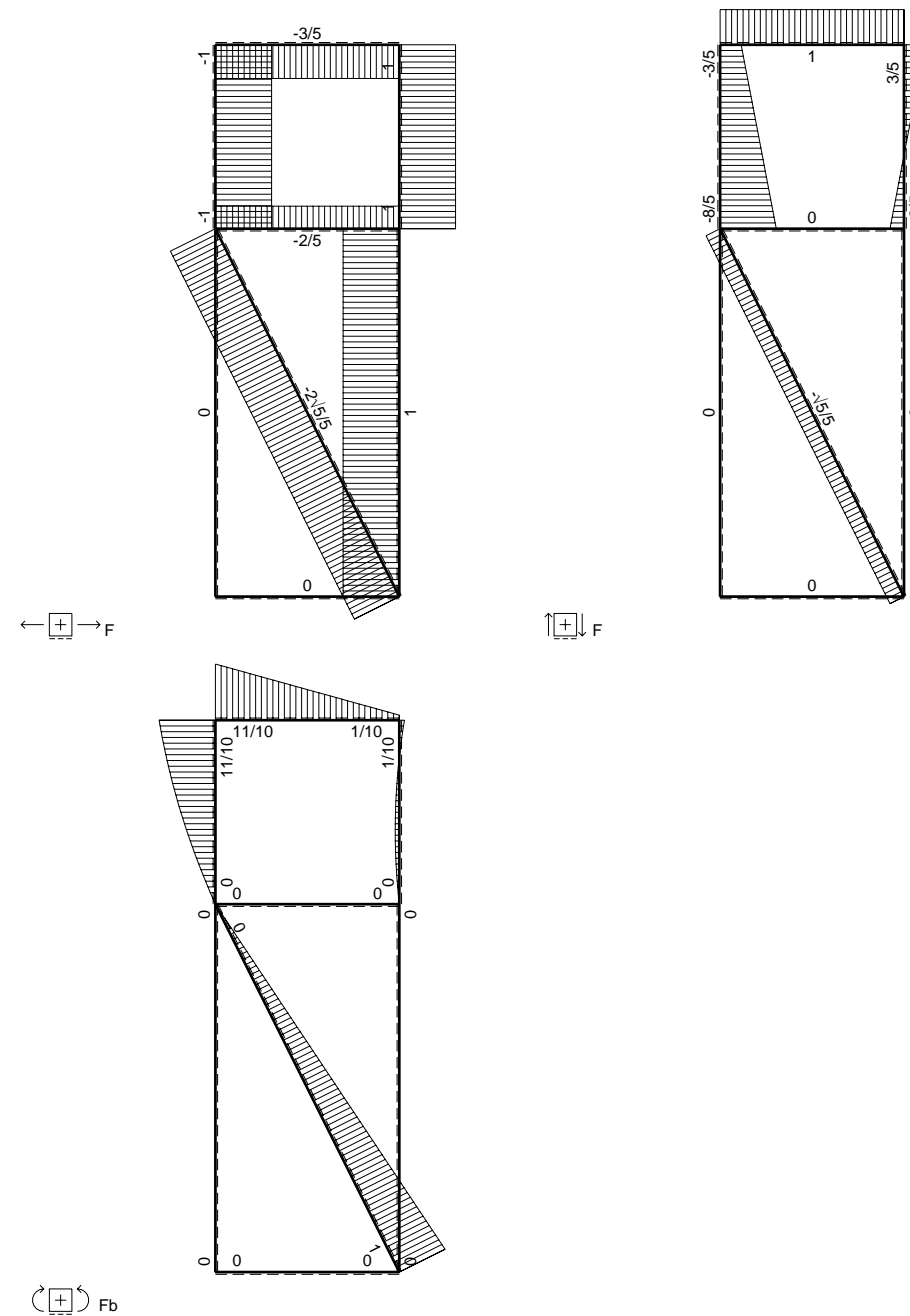
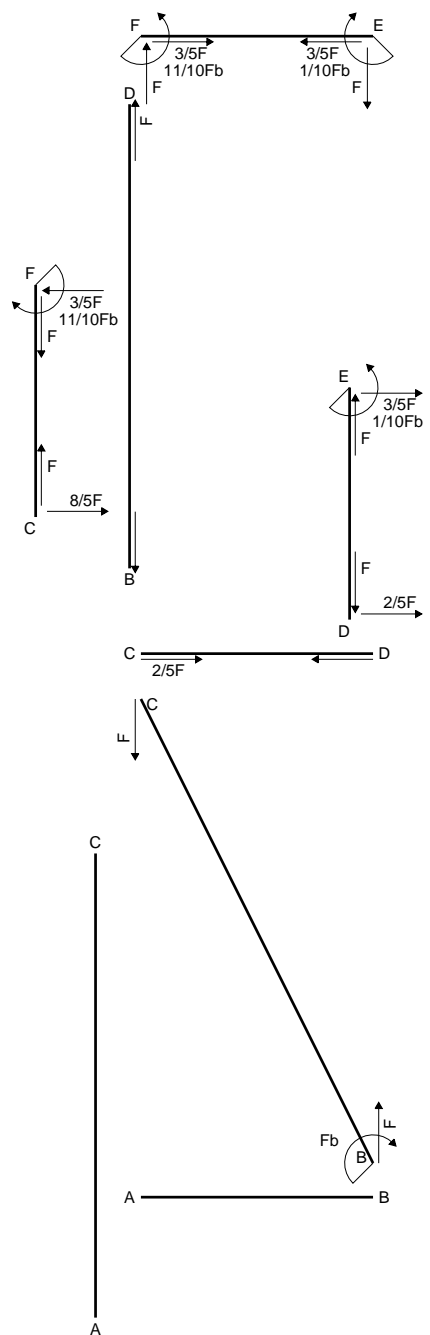
$$\sigma_c = -Mv/J_u = 129.9 \text{ N/mm}^2$$

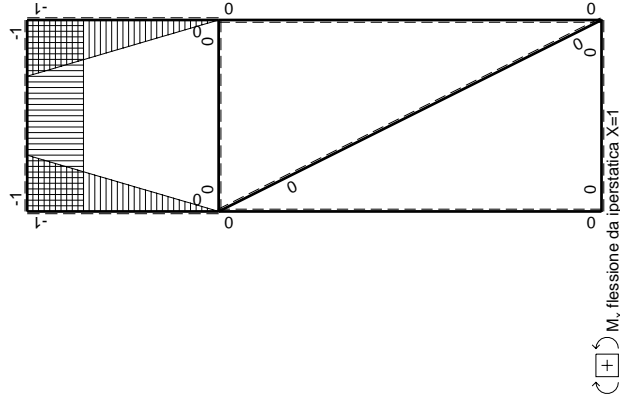
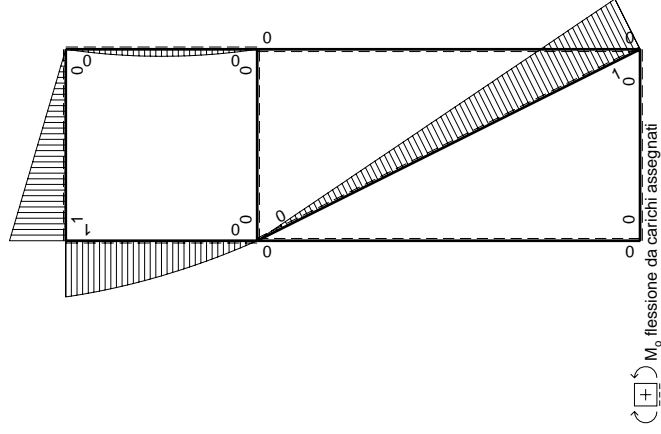
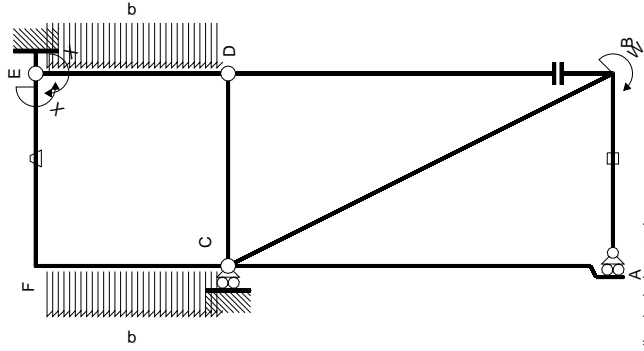
$$\tau_c = 7.332 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 130.5 \text{ N/mm}^2$$

$$S = 3946. \text{ mm}^3$$







Quadro contributi PLV per iperstatica  $X=W_{EF}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / EJ dx$
AB b	0	0	0	0	0	0	0	0
BA b	0	0	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$Fb - \sqrt{5}/5Fx$	0	0	0	0	0	0
CA 2b	0	0	0	0	0	0	0	0
AC 2b	0	0	0	0	0	0	0	0
DB 2b	0	0	0	0	0	0	0	0
BD 2b	0	0	0	0	0	0	0	0
DE b	$-x/b$	$-1/2Fx + 1/2qx^2$	0	$1/2Fx^2/b - 1/2qx^3/b$	0	$x^2/b^2$	$(1/24+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$1-x/b$	$1/2Fx - 1/2qx^2$	0	$1/2Fx - Fx^2/b + 1/2qx^3/b$	0	$1-2x/b + x^2/b^2$	$(1/24+0)Fb^2/EJ$	$1/3Xb/EJ$
CD b	0	0	0	0	0	0	0	0
DC b	0	0	0	0	0	0	0	0
EF b	-1	Fx	$-Fb/EJ$	-Fx	$Fb/EJ$	1	$(-1/2+1)Fb^2/EJ$	$Xb/EJ$
FE b	1	$-Fb+Fx$	$Fb/EJ$	$-Fb+Fx$	$Fb/EJ$	1	$(-1/2+1)Fb^2/EJ$	$Xb/EJ$
FC b	$-1+x/b$	$Fb - 1/2Fx - 1/2qx^2$	0	$-Fb + 3/2Fx - 1/2qx^3/b$	0	$1-2x/b + x^2/b^2$	$(-3/8+0)Fb^2/EJ$	$1/3Xb/EJ$
CF b	$x/b$	$-3/2Fx + 1/2qx^2$	0	$-3/2Fx^2/b + 1/2qx^3/b$	0	$x^2/b^2$	$(-3/8+0)Fb^2/EJ$	$1/3Xb/EJ$
totali							$1/6Fb^2/EJ$	$5/3Xb/EJ$
iperstatica $X=W_{EF}$							$-1/10Fb$	

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (b) \theta = 1/2 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

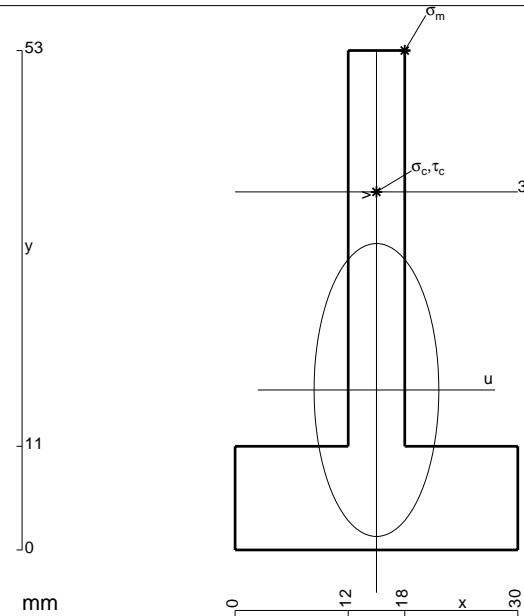
$$= (-b + 1/2 b) Fb 1/EJ + (-b) \theta = 1/2 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-1 + 3/2 x/b - 1/2 x^3/b^3) Fb 1/EJ dx = [-x + 3/4 x^2/b - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-b + 3/4 b - 1/8 b) Fb 1/EJ = -3/8 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-3/2 x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/2 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

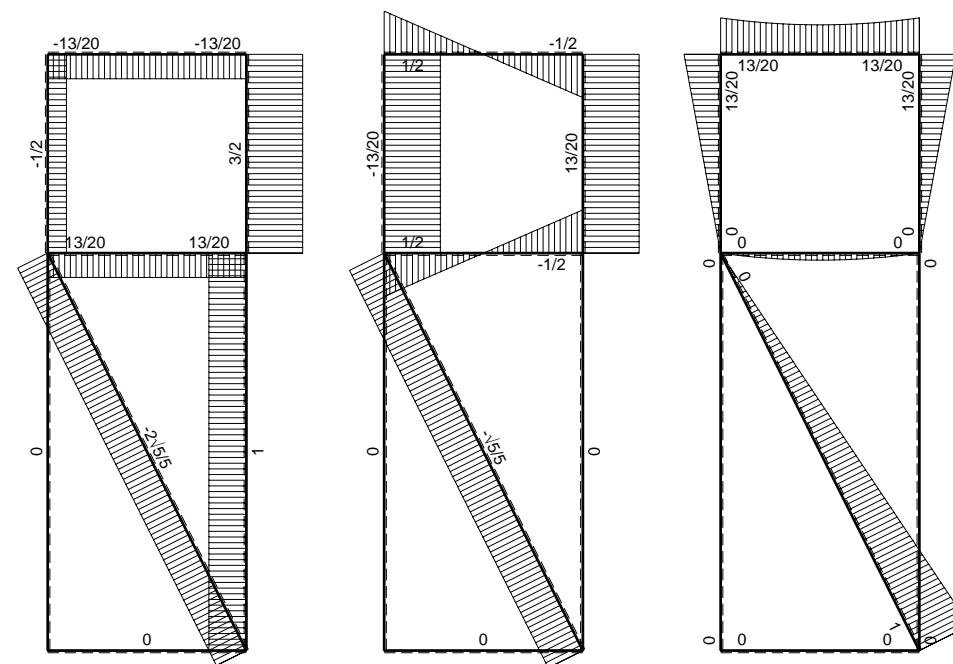
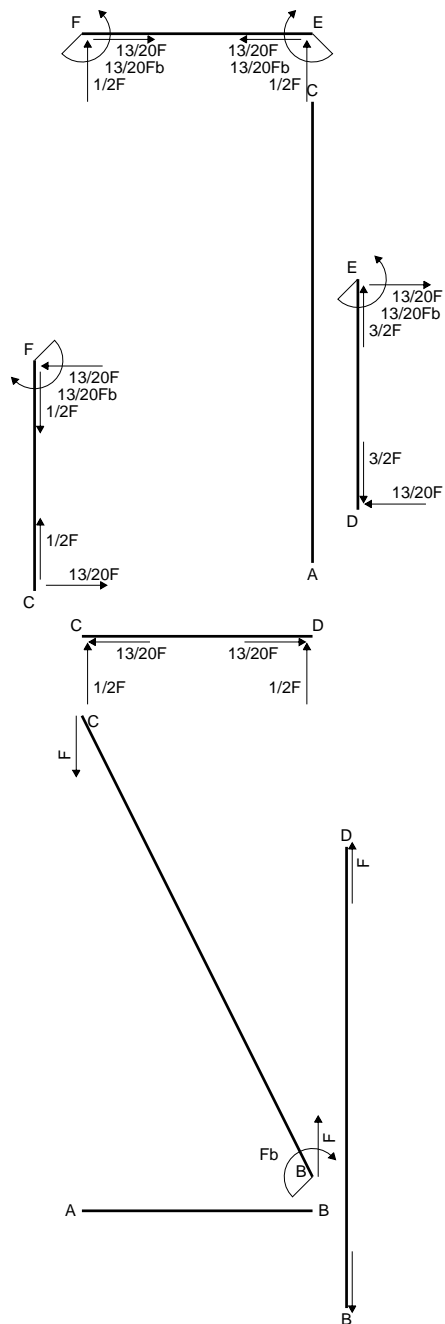
$$= (-1/2 b + 1/8 b) Fb 1/EJ = -3/8 Fb^2/EJ$$



- 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 = -1199. N
- T<sub>y</sub> = -599.3 N
- M<sub>x</sub> = 884400. 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> = -228.5 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> = -134.2 N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.822 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 134.2 N/mm<sup>2</sup>
- S = 2567. mm<sup>3</sup>



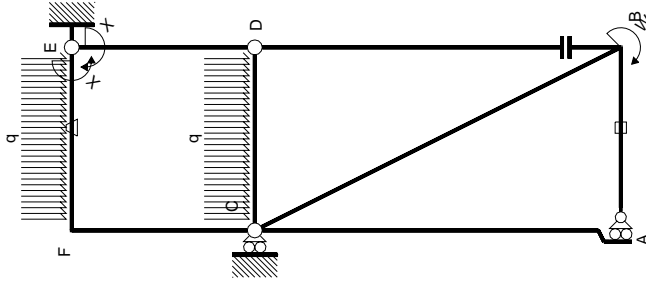




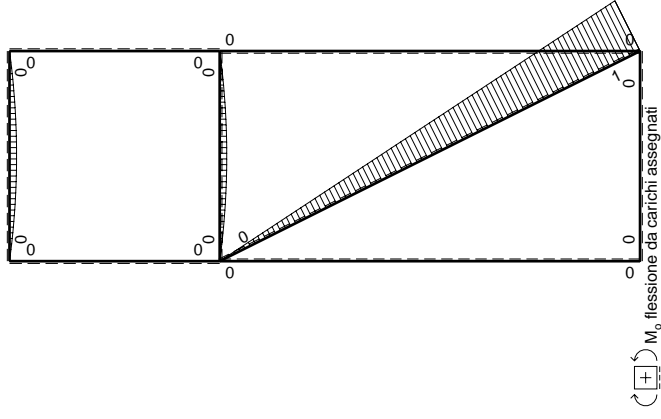
← ⊕ → F

↑ ⊕ ↓ F

⊕ ⊖ F<sub>b</sub>



Schema di calcolo iperstatico



Quadro contributi PLV per iperstatica  $X=W_{EF}$

$\leftarrow$	$M^x(x)$	$M^0(x)$	$\theta$	$M^x_0$	$M^x_\theta$	$M^x_x$	$\int M^x(M^0/EJ+\theta)dx$	$\int M^x M^x/EJ dx$
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$Fb-\sqrt{5}/5Fx$	0	0	0	0	0	0
AC 2b	0	0	0	0	0	0	0+0	0
CA 2b	0	0	0	0	0	0	0	0
DB 2b	0	0	0	0	0	0	0+0	0
BD 2b	0	0	0	0	0	0	0	0
DE b	-x/b	0	0	0	0	$x^2/b^2$	0+0	1/3Xb/EJ
ED b	1-x/b	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	1/3Xb/EJ
CD b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0
DC b	0	$-1/2Fx+1/2qx^2$	0	0	0	0	0+0	0
EF b	-1	$-1/2Fx+1/2qx^2$	$-Fb/EJ$	$1/2Fx-1/2Fx^2/b$	$Fb/EJ$	1	$(1/12+1)Fb^2/EJ$	Xb/EJ
FE b	1	$1/2Fx-1/2qx^2$	$Fb/EJ$	$1/2Fx-1/2Fx^2/b$	$Fb/EJ$	1	$(1/12+1)Fb^2/EJ$	Xb/EJ
FC b	-1+x/b	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	1/3Xb/EJ
CF b	x/b	0	0	0	0	$x^2/b^2$	0+0	1/3Xb/EJ
totali							$13/12Fb^2/EJ$	$5/3Xb/EJ$
								$-13/20Fb$

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = \left[ \frac{1}{3} x^3/b^2 \right]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = \left[ x \right]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = \left[ x \right]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = \left[ \frac{1}{3} x^3/b^2 \right]_0^b 1/EJ$$

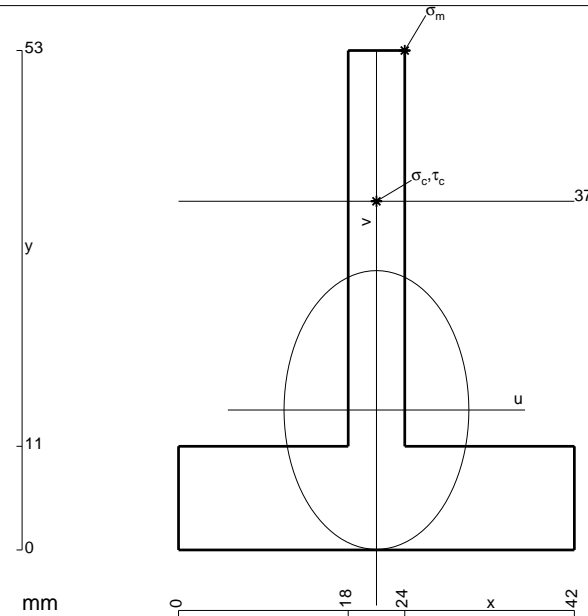
$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = \left[ \frac{1}{4} x^2/b - 1/6 x^3/b^2 \right]_0^b Fb 1/EJ + \left[ x \right]_0^b \theta$$

$$= (1/4 b - 1/6 b) Fb 1/EJ + (b) \theta = 13/12 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx = \left[ \frac{1}{4} x^2/b - 1/6 x^3/b^2 \right]_0^b Fb 1/EJ + \left[ -x \right]_0^b \theta$$

$$= (1/4 b - 1/6 b) Fb 1/EJ + (-b) \theta = 13/12 Fb^2/EJ$$



$$A = 714. \text{ mm}^2$$

$$J_u = 156211. \text{ mm}^4$$

$$J_v = 68670. \text{ mm}^4$$

$$y_g = 14.85 \text{ mm}$$

$$N = -1243. \text{ N}$$

$$T_y = -621.6 \text{ N}$$

$$M_x = 973000. \text{ Nmm}$$

$$x_m = 24. \text{ mm}$$

$$y_m = 53. \text{ mm}$$

$$u_m = 3. \text{ mm}$$

$$v_m = 38.15 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -239.4 \text{ N/mm}^2$$

$$x_c = 21. \text{ mm}$$

$$y_c = 37. \text{ mm}$$

$$v_c = 22.15 \text{ mm}$$

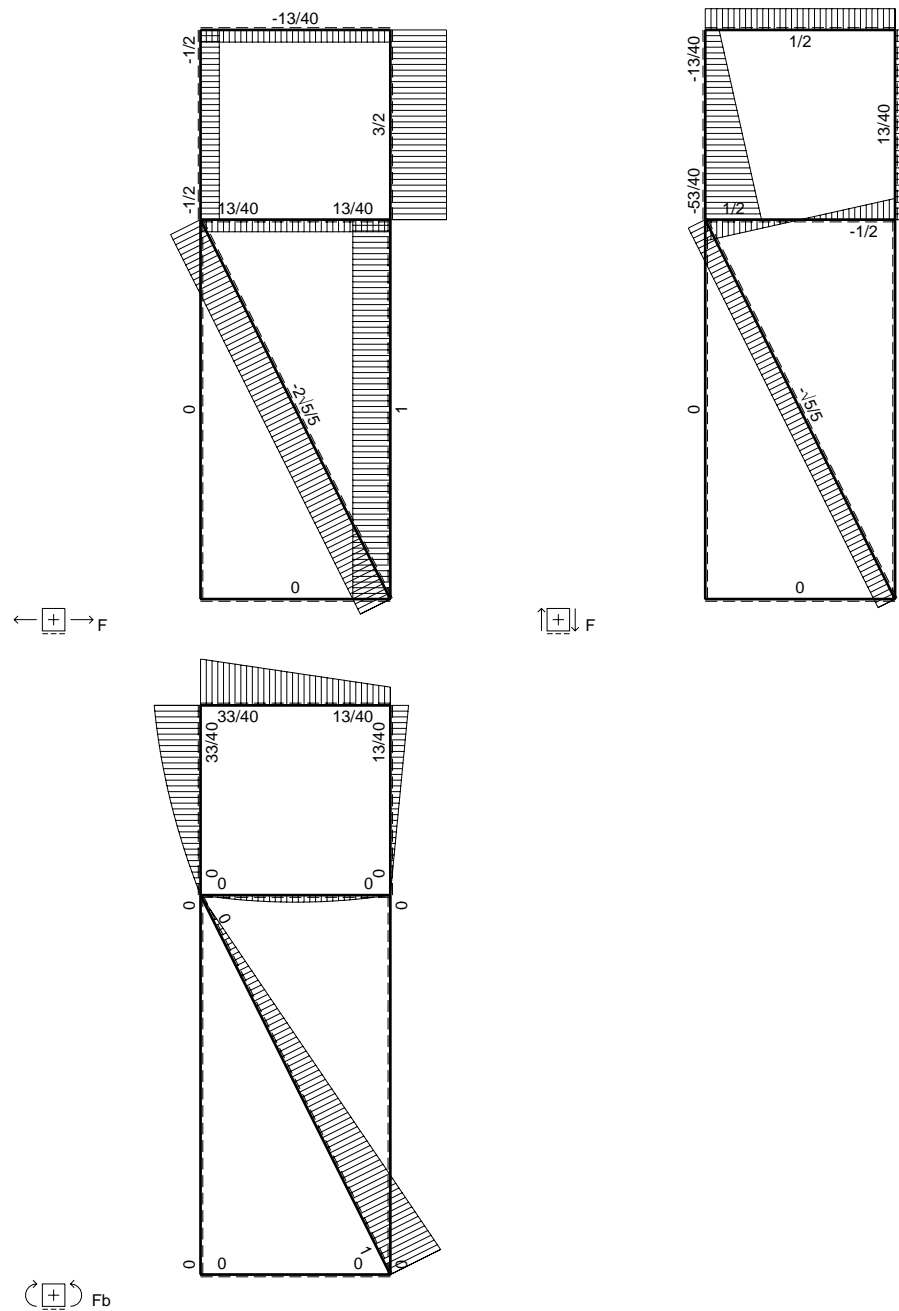
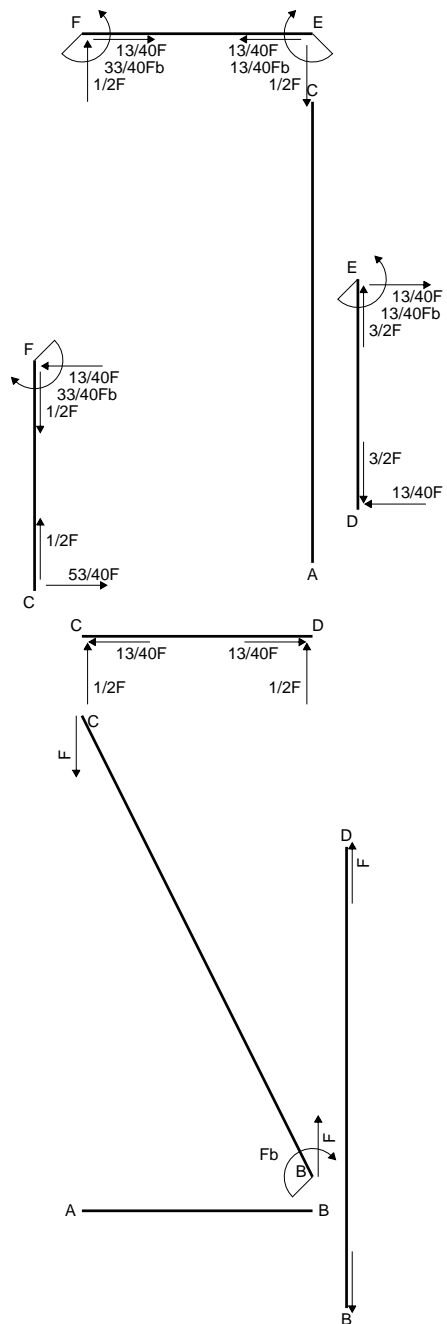
$$\sigma_c = N/A - Mv/J_u = -139.7 \text{ N/mm}^2$$

$$\tau_c = 1.919 \text{ N/mm}^2$$

$$\sigma_o = \sqrt{\sigma^2 + 3\tau^2} = 139.7 \text{ N/mm}^2$$

$$S = 2894. \text{ mm}^3$$







$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/4 b) Fb 1/EJ + (b) \theta = 3/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + 1/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-1/2 x + 1/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

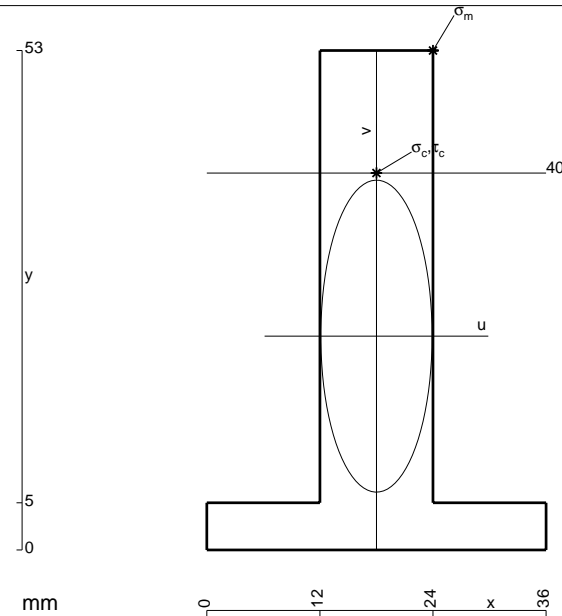
$$L_{FC}^{xo} = \int_0^b (-1/2 + 1/2 x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx$$

$$= [-1/2 x + 1/4 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/4 b + 1/6 b - 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/3 b + 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$



$$A = 756. \text{ mm}^2$$

$$J_u = 207276. \text{ mm}^4$$

$$J_v = 26352. \text{ mm}^4$$

$$y_g = 22.69 \text{ mm}$$

$$N = -3229. \text{ N}$$

$$T_y = -1614. \text{ N}$$

$$M_x = 1335700. \text{ Nmm}$$

$$x_m = 24. \text{ mm}$$

$$y_m = 53. \text{ mm}$$

$$u_m = 6. \text{ mm}$$

$$v_m = 30.31 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -199.6 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 40. \text{ mm}$$

$$v_c = 17.31 \text{ mm}$$

$$\sigma_c = N/A - Mv/J_u = -115.8 \text{ N/mm}^2$$

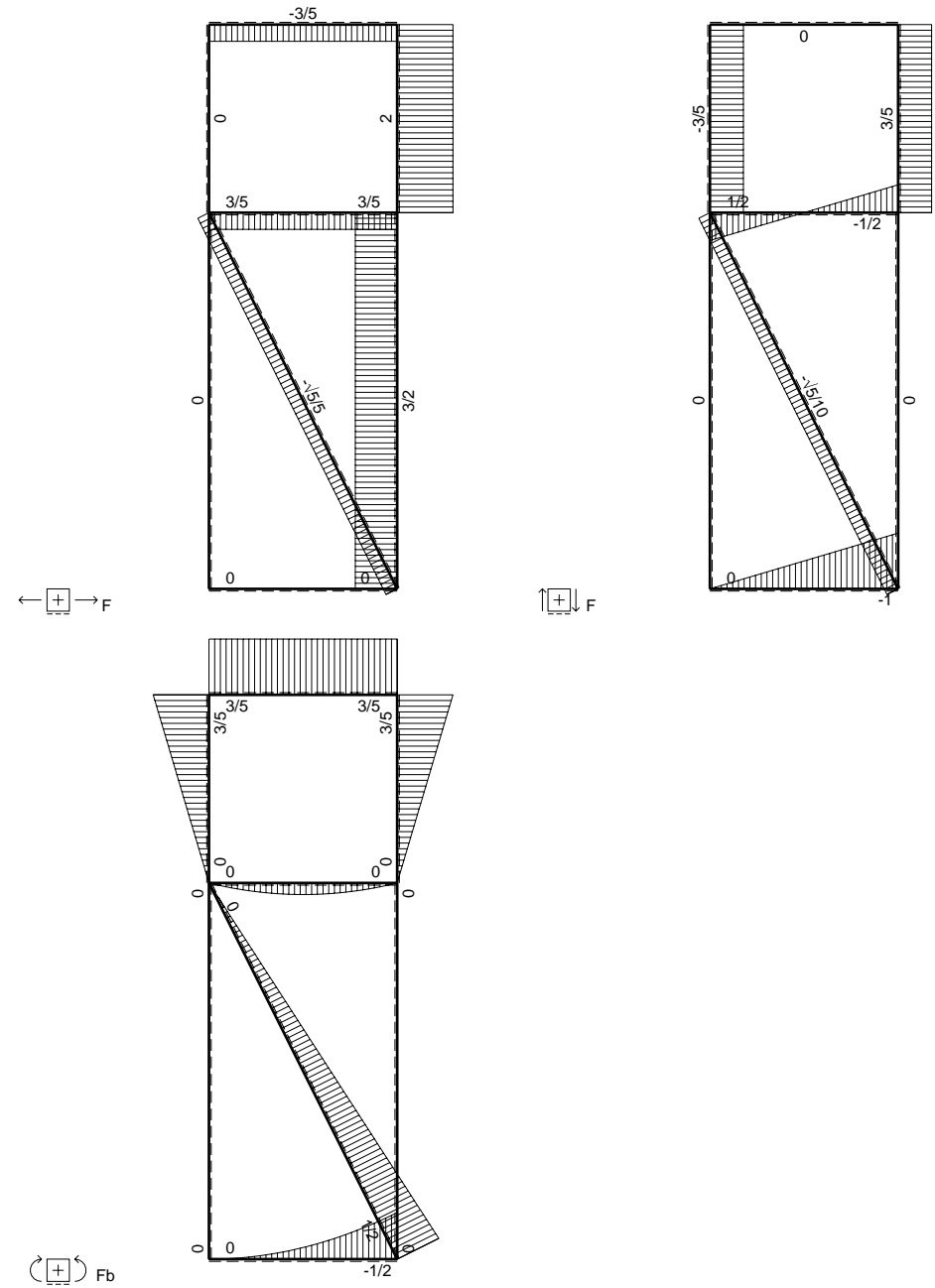
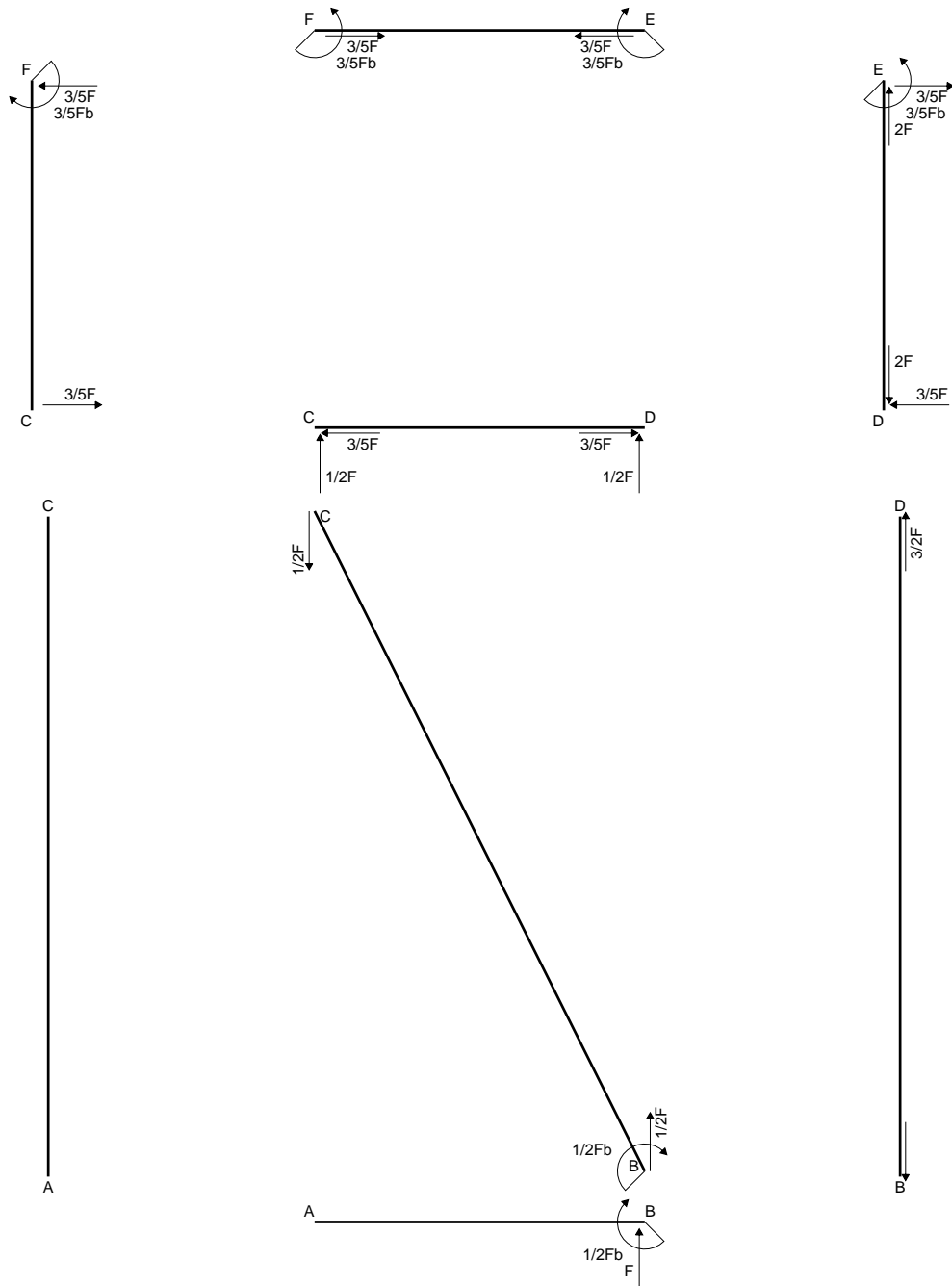
$$\tau_c = 2.411 \text{ N/mm}^2$$

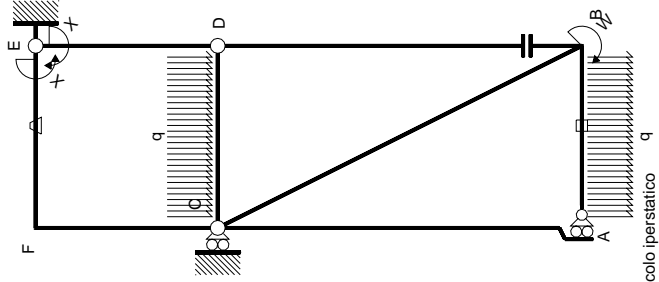
$$\sigma_o = \sqrt{\sigma^2 + 3\tau^2} = 115.9 \text{ N/mm}^2$$

$$S = 3714. \text{ mm}^3$$

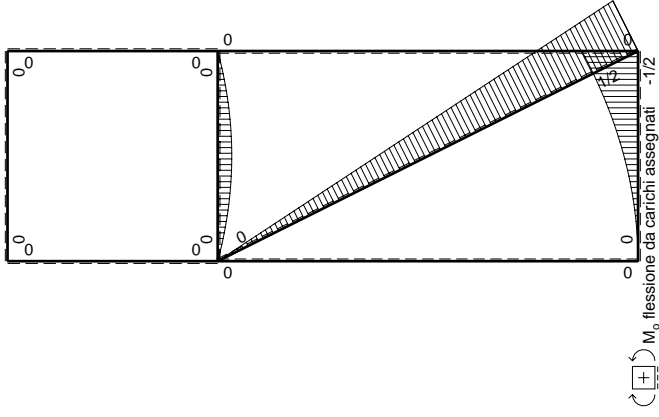








Schema di calcolo iperstatico



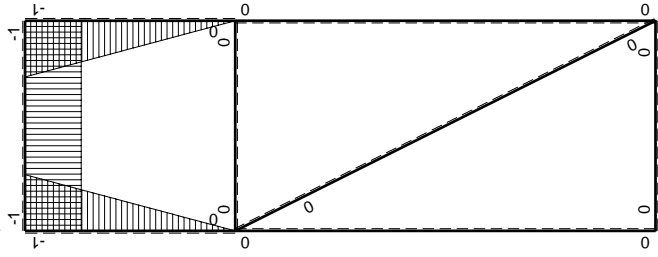
$M_0$  flessione da carichi assegnati -1/2

Quadro contributi PLV per iperstatica  $X=W_{EF}$

→	$M_x(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int X M_x M_x / EJ dx$
AB b	0	$-1/2qx^2$	0	0	0	0	0+0	0
BA b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0+0	0
BC $\sqrt{5}b$	0	$1/2Fb-\sqrt{5}/10Fx$	0	0	0	0	0	0
AC 2b	0	0	0	0	0	0	0+0	0
CA 2b	0	0	0	0	0	0	0+0	0
DB 2b	0	0	0	0	0	0	0+0	0
BD 2b	0	0	0	0	0	0	0+0	0
DE b	$-x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3Xb/EJ$
ED b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$
CD b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0
DC b	0	$-1/2Fx+1/2qx^2$	0	0	0	0	0+0	0
EF b	-1	0	$-Fb/EJ$	0	$Fb/EJ$	1	$(0+1)Fb^2/EJ$	$Xb/EJ$
FE b	1	0	$Fb/EJ$	0	$Fb/EJ$	1	$(0+1)Fb^2/EJ$	$Xb/EJ$
FC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$
CF b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3Xb/EJ$
totali								
iperstatica $X=W_{EF}$								
							$Fb^2/EJ$	$5/3Xb/EJ$
							$-3/5Fb$	

Sviluppi di calcolo iperstatica

$M_x$  flessione da iperstatica  $X=1$



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = \left[ \frac{1}{3} x^3/b^2 \right]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = \left[ x \right]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = \left[ x \right]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = \left[ \frac{1}{3} x^3/b^2 \right]_0^b 1/EJ$$

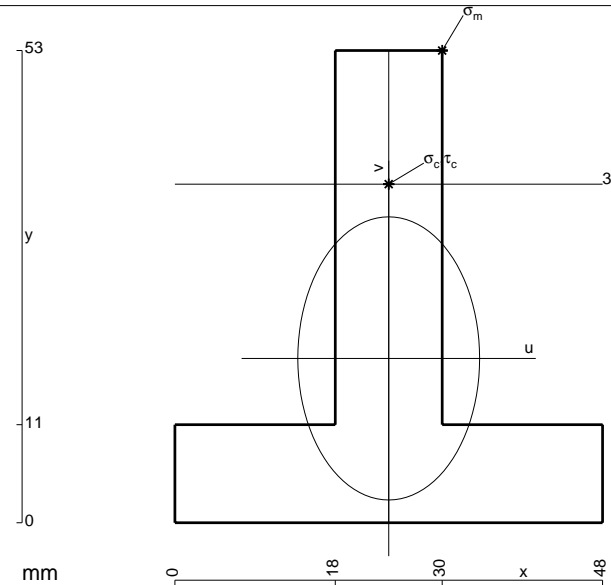
$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (1) \theta dx = \left[ x \right]_0^b \theta$$

$$= (b) \theta = Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1) \theta dx = \left[ -x \right]_0^b \theta$$

$$= (-b) \theta = Fb^2/EJ$$



$$A = 1032. \text{ mm}^2$$

$$J_u = 260495. \text{ mm}^4$$

$$J_v = 107424. \text{ mm}^4$$

$$y_g = 18.44 \text{ mm}$$

$$T_y = -7910. \text{ N}$$

$$M_x = -1582000. \text{ Nmm}$$

$$x_m = 30. \text{ mm}$$

$$y_m = 53. \text{ mm}$$

$$u_m = 6. \text{ mm}$$

$$v_m = 34.56 \text{ mm}$$

$$\sigma_m = -Mv/J_u = 209.9 \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 38. \text{ mm}$$

$$v_c = 19.56 \text{ mm}$$

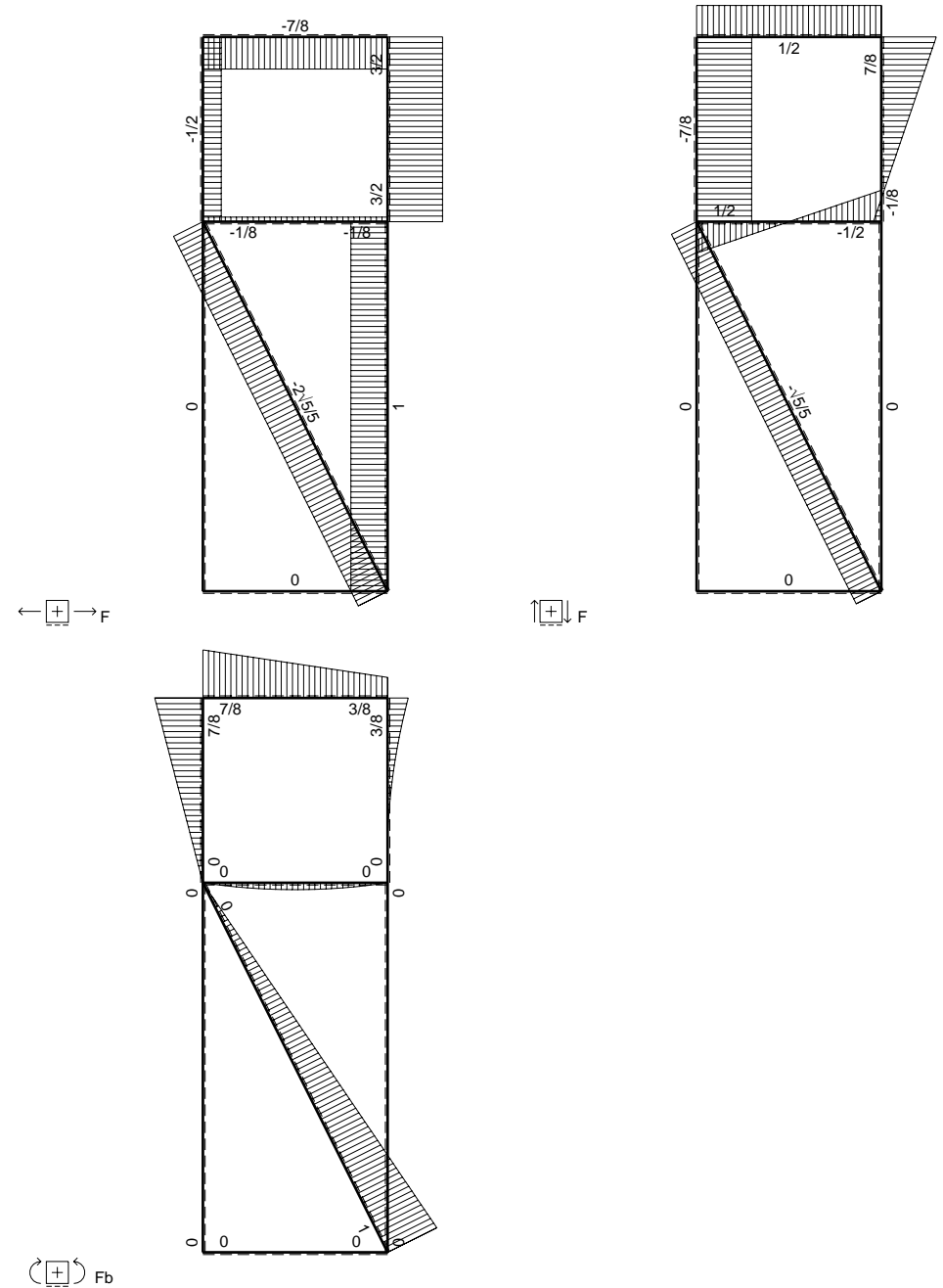
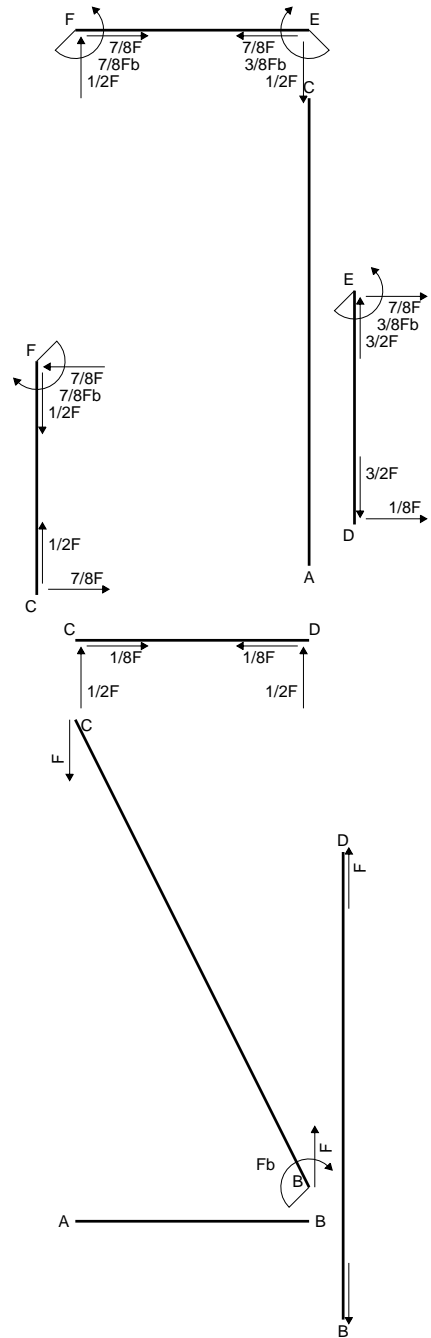
$$\sigma_c = -Mv/J_u = 118.8 \text{ N/mm}^2$$

$$\tau_c = 12.32 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 120.7 \text{ N/mm}^2$$

$$S = 4870. \text{ mm}^3$$







$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/4 b) Fb 1/EJ + (b) \theta = 3/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + 1/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-1/2 x + 1/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

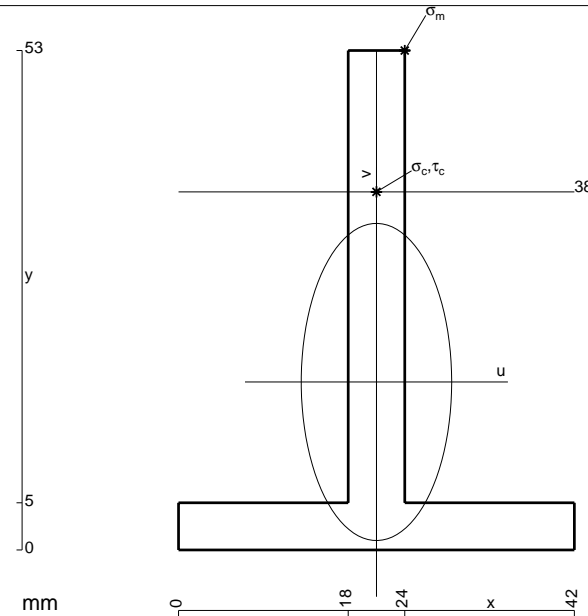
$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ$$

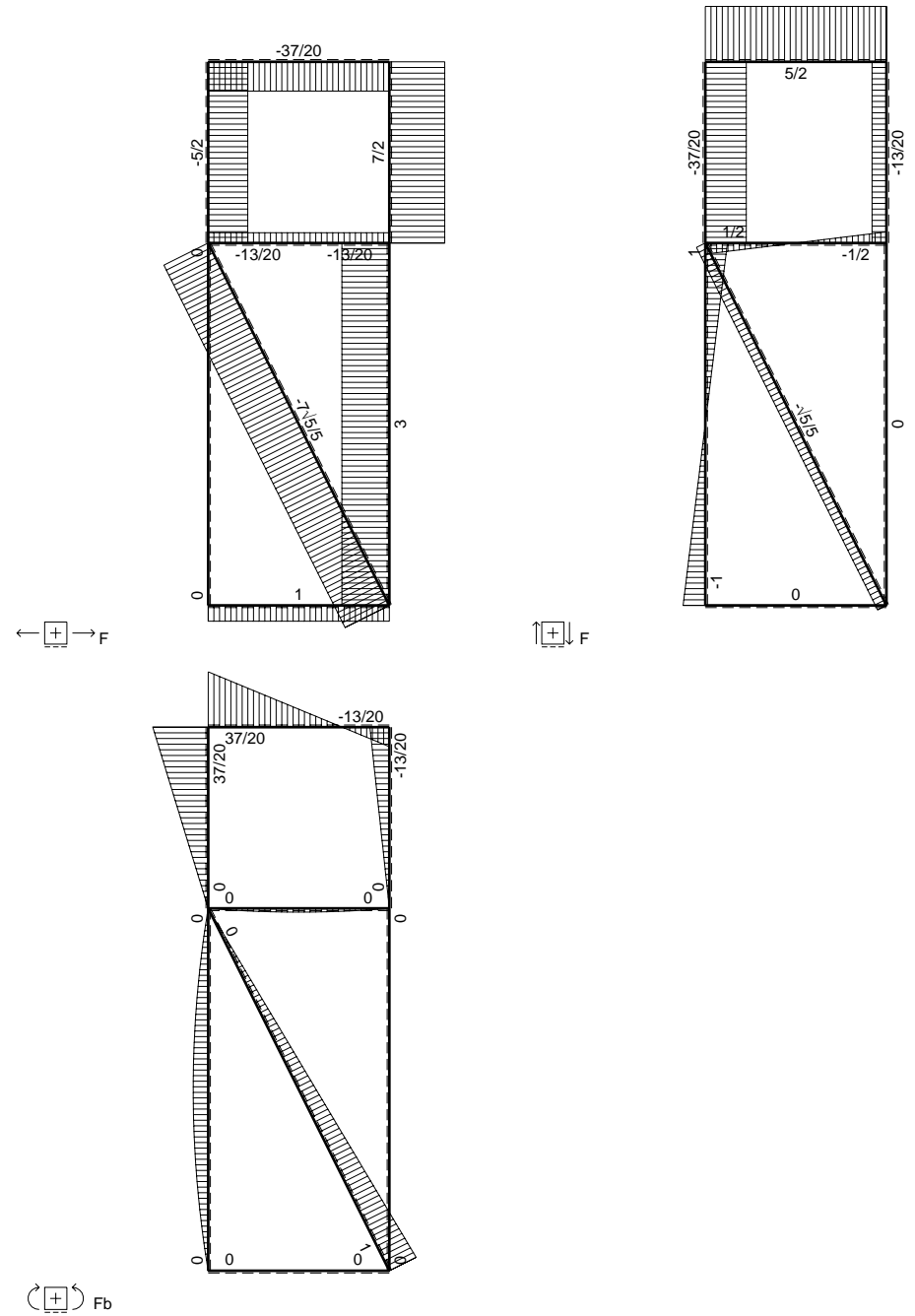
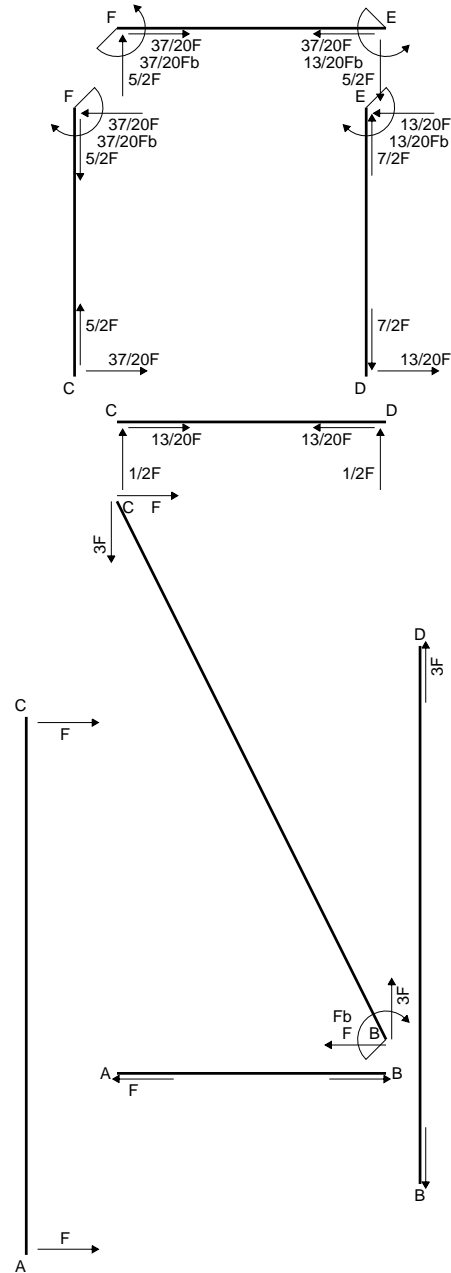
$$= (-1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$



- A = 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> = 17.83 mm
- N = -1762. N
- T<sub>y</sub> = -881. N
- M<sub>x</sub> = 866800. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 53. 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> = -219.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 38. mm
- v<sub>c</sub> = 20.17 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = -127.5 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.593 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup>+3τ<sup>2</sup>) = 127.6 N/mm<sup>2</sup>
- S = 2491. mm<sup>3</sup>







Legend for internal force diagrams:

- $\leftarrow \boxed{+} \rightarrow F$  (Axial force)
- $\uparrow \boxed{+} \downarrow F_b$  (Shear force)
- $\curvearrowright \boxed{+} \curvearrowleft F_b$  (Bending moment)



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-5/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-5/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-5/4 b) Fb 1/EJ + (b) \theta = -1/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-5/2 + 5/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-5/2 x + 5/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

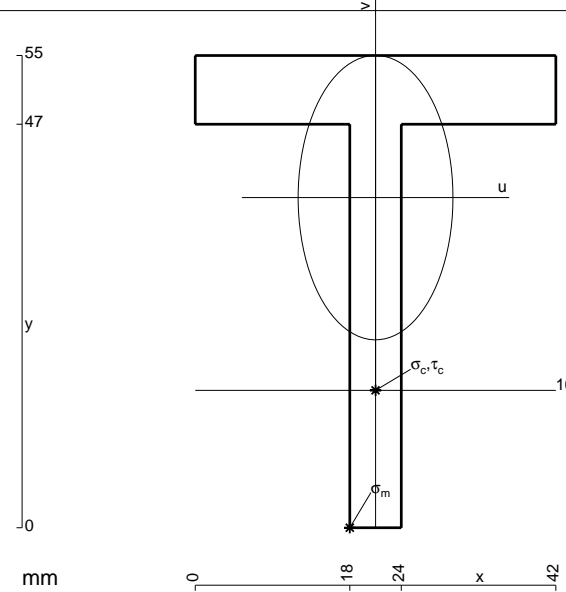
$$= (-5/2 b + 5/4 b) Fb 1/EJ + (-b) \theta = -1/4 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = [-5/2 x + 5/2 x^2/b - 5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

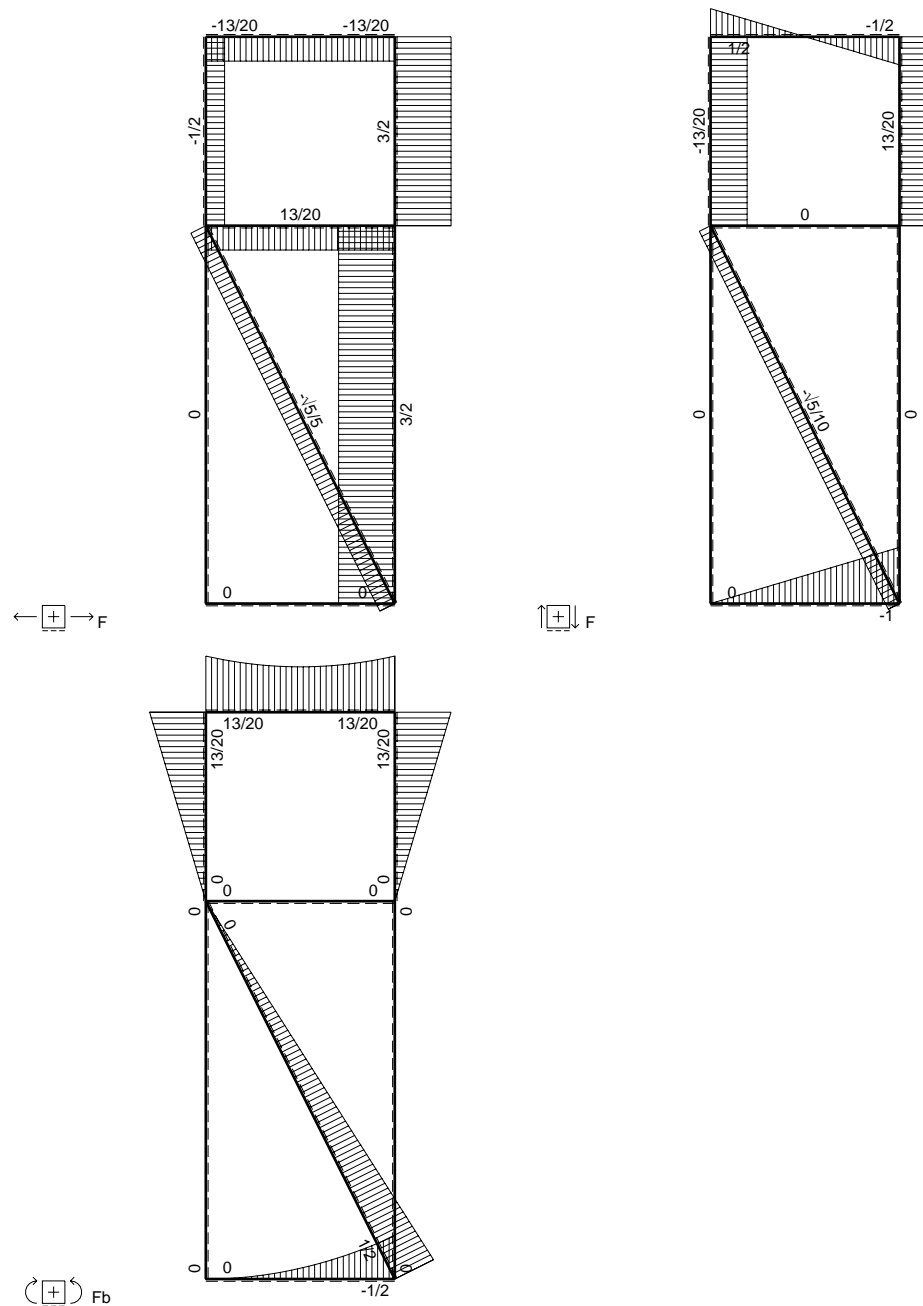
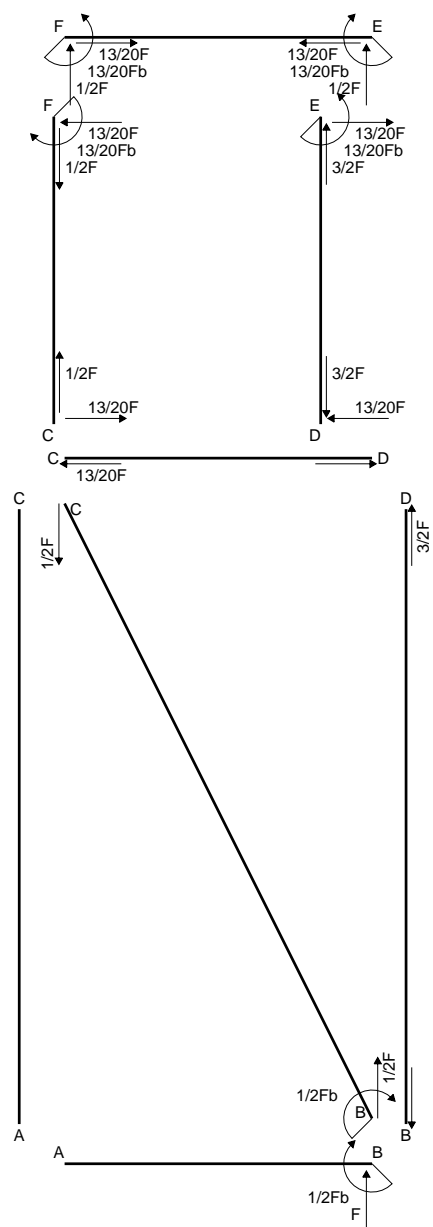
$$L_{CF}^{xo} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$



- A = 618. mm<sup>2</sup>
- J<sub>u</sub> = 169652. mm<sup>4</sup>
- J<sub>v</sub> = 50238. mm<sup>4</sup>
- y<sub>g</sub> = 38.45 mm
- N = -6637. N
- T<sub>y</sub> = -948.1 N
- M<sub>x</sub> = 1060000. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -38.45 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = 229.5 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 16. mm
- v<sub>c</sub> = -22.45 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = 129.5 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.723 N/mm<sup>2</sup>
- σ<sub>φ</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 129.6 N/mm<sup>2</sup>
- S = 2923. mm<sup>3</sup>







$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

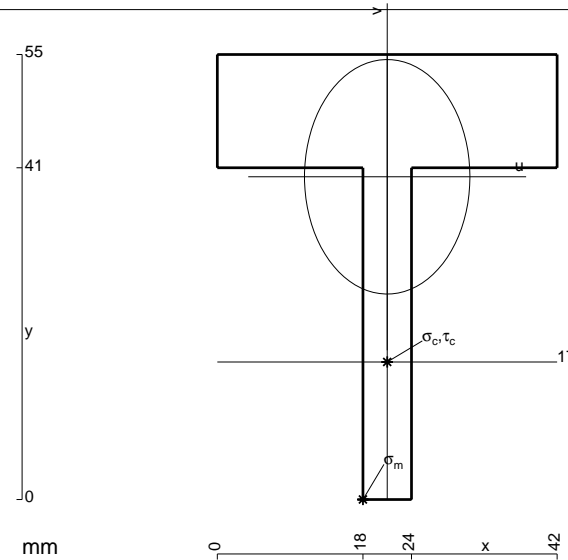
$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (1/4 b - 1/6 b) Fb 1/EJ + (b) \theta = 13/12 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

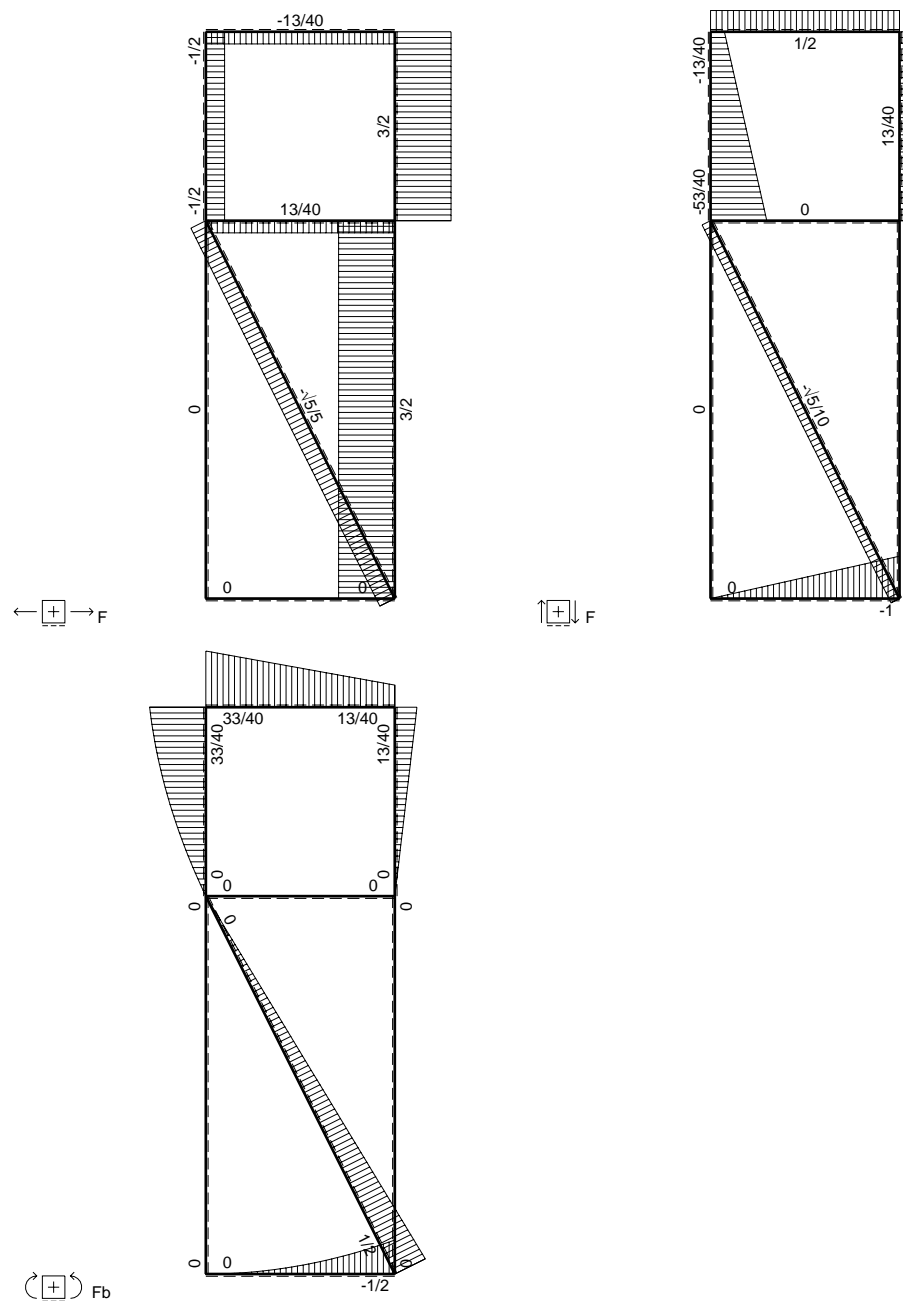
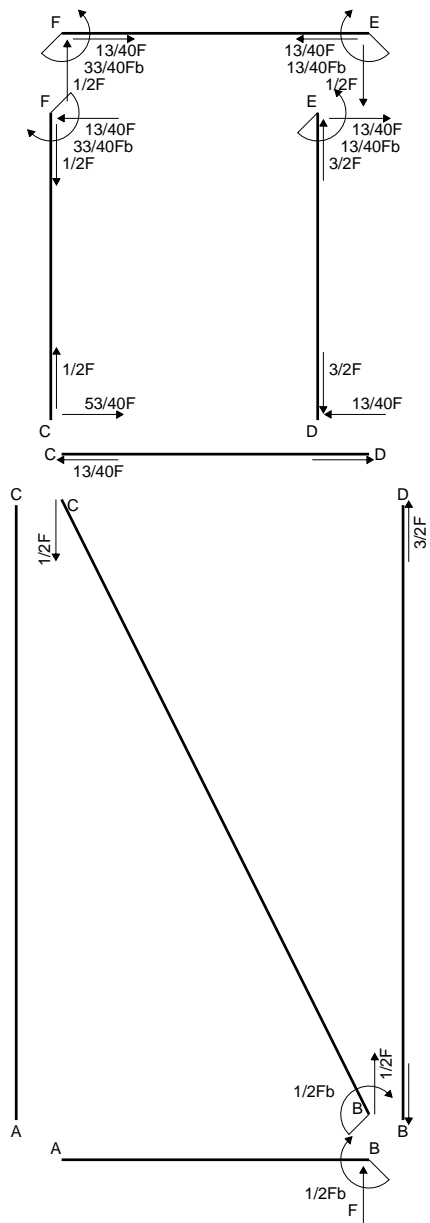
$$= (1/4 b - 1/6 b) Fb 1/EJ + (-b) \theta = 13/12 Fb^2/EJ$$



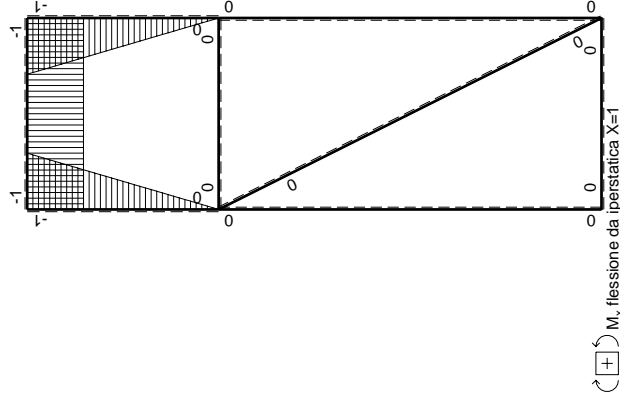
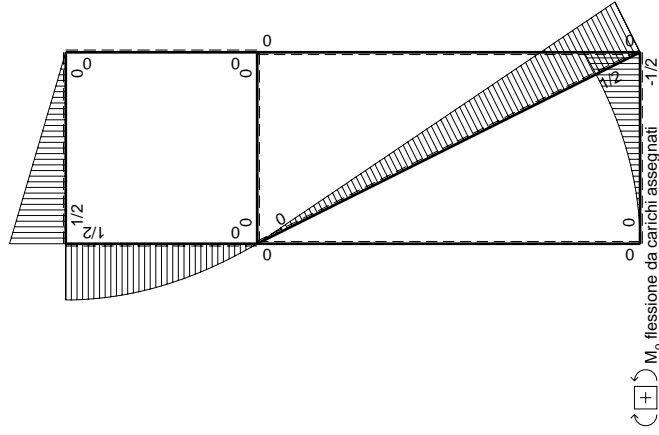
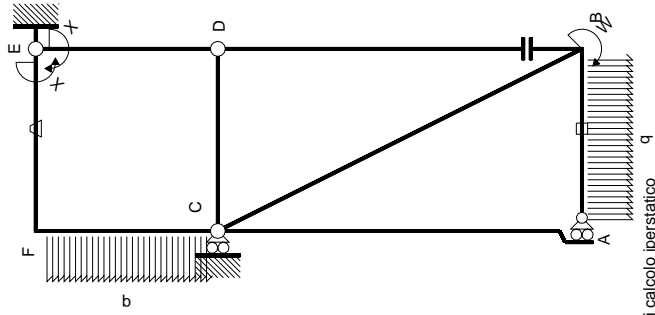
- A = 834. mm<sup>2</sup>
- J<sub>u</sub> = 175228. mm<sup>4</sup>
- J<sub>v</sub> = 87174. mm<sup>4</sup>
- y<sub>g</sub> = 39.89 mm
- T<sub>y</sub> = -3900. N
- M<sub>x</sub> = -1053000. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -39.89 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -239.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 17. mm
- v<sub>c</sub> = -22.89 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -137.5 N/mm<sup>2</sup>
- τ<sub>c</sub> = 11.88 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 139.1 N/mm<sup>2</sup>
- S = 3202. mm<sup>3</sup>







⊕ F<sub>b</sub>



Quadro contributi PLV per iperstatica  $X=W_{EF}$

$\rightarrow$	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x (M_0/EJ + \theta) dx$	$\int M^x M_x / E dx$
AB b	0	$-1/2qx^2$	0	0	0	0	0	0
BA b	0	$1/2Fb - Fx + 1/2qx^2$	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$1/2Fb - \sqrt{5}/10Fx$	0	0	0	0	0	0
AC 2b	0	0	0	0	0	0	0	0
CA 2b	0	0	0	0	0	0	0	0
DB 2b	0	0	0	0	0	0	0	0
BD 2b	0	0	0	0	0	0	0	0
DE b	-x/b	0	0	0	0	0	0	0
ED b	1-x/b	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
EF b	-1	$1/2Fx$	$-Fb/EJ$	$-1/2Fx$	$Fb/EJ$	1	$(-1/4+1)Fb^2/EJ$	$Xb/EJ$
FE b	1	$-1/2Fb+1/2Fx$	$Fb/EJ$	$-1/2Fb+1/2Fx$	$Fb/EJ$	1	$(-1/4+1)Fb^2/EJ$	$Xb/EJ$
FC b	$-1+x/b$	$1/2Fb-1/2qx^2$	0	$-1/2Fb+1/2Fx+1/2Fx^2/b-1/2qx^3/b$	0	0	$(-5/24+0)Fb^2/EJ$	$1/3Xb/EJ$
CF b	x/b	$-Fx+1/2qx^2$	0	$-Fx^2/b+1/2qx^3/b$	0	0	$13/24Fb^2/EJ$	$5/3Xb/EJ$
totali								
iperstatica $X=W_{EF}$								

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/4 b) Fb 1/EJ + (b) \theta = 3/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + 1/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-1/2 x + 1/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

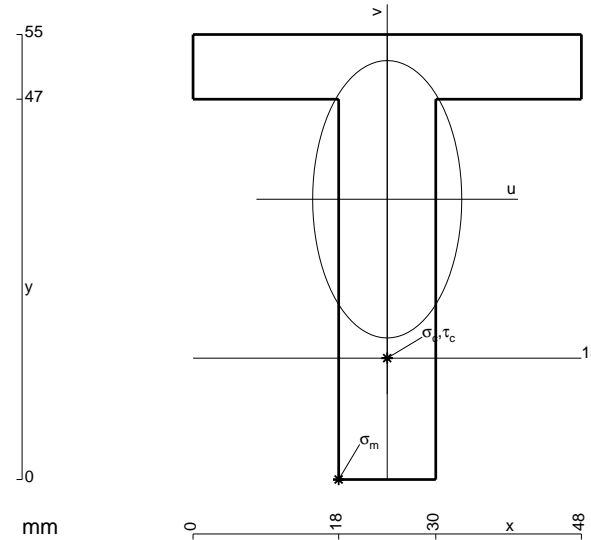
$$L_{FC}^{xo} = \int_0^b (-1/2 + 1/2 x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx$$

$$= [-1/2 x + 1/4 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/4 b + 1/6 b - 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$

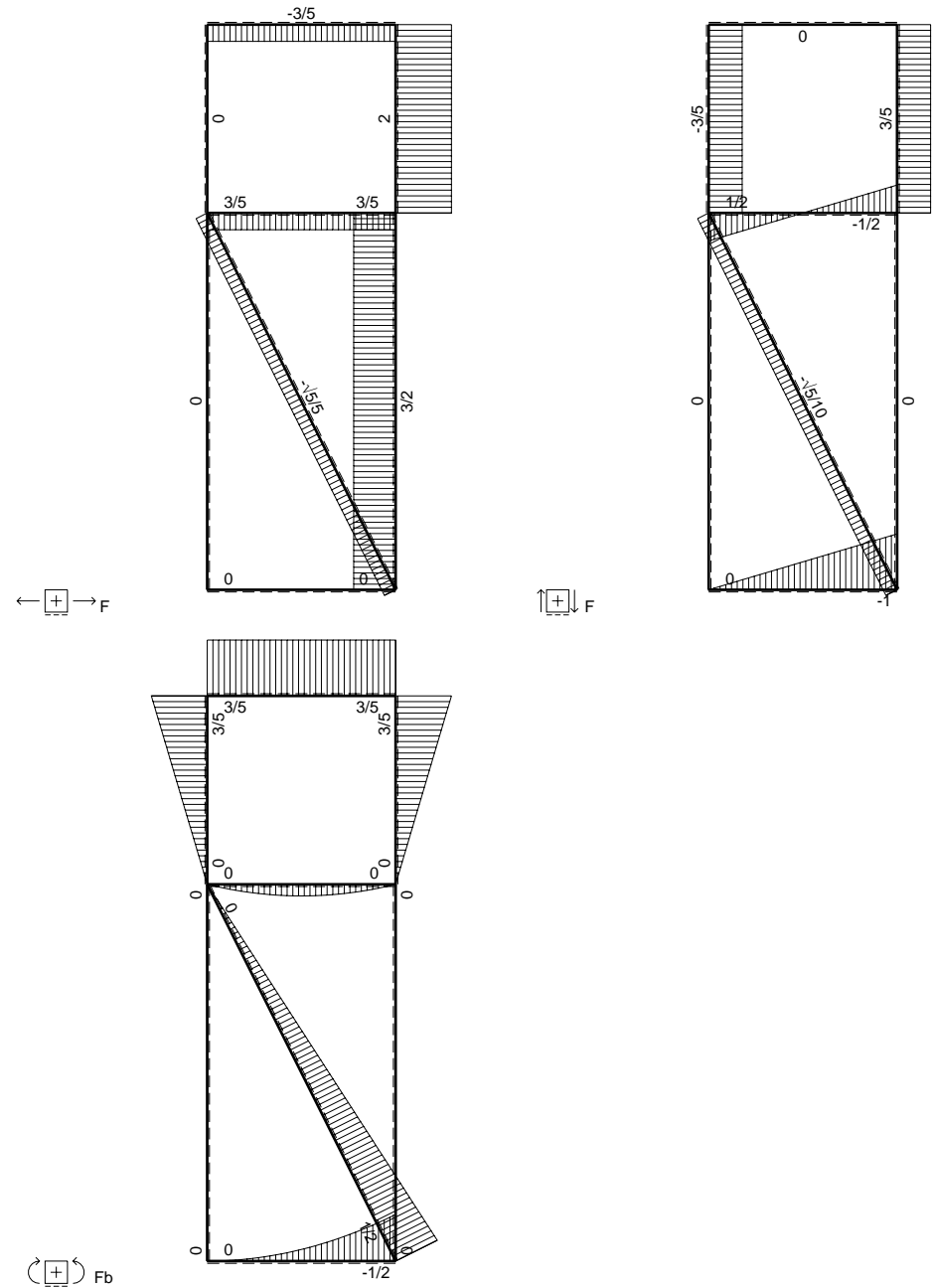
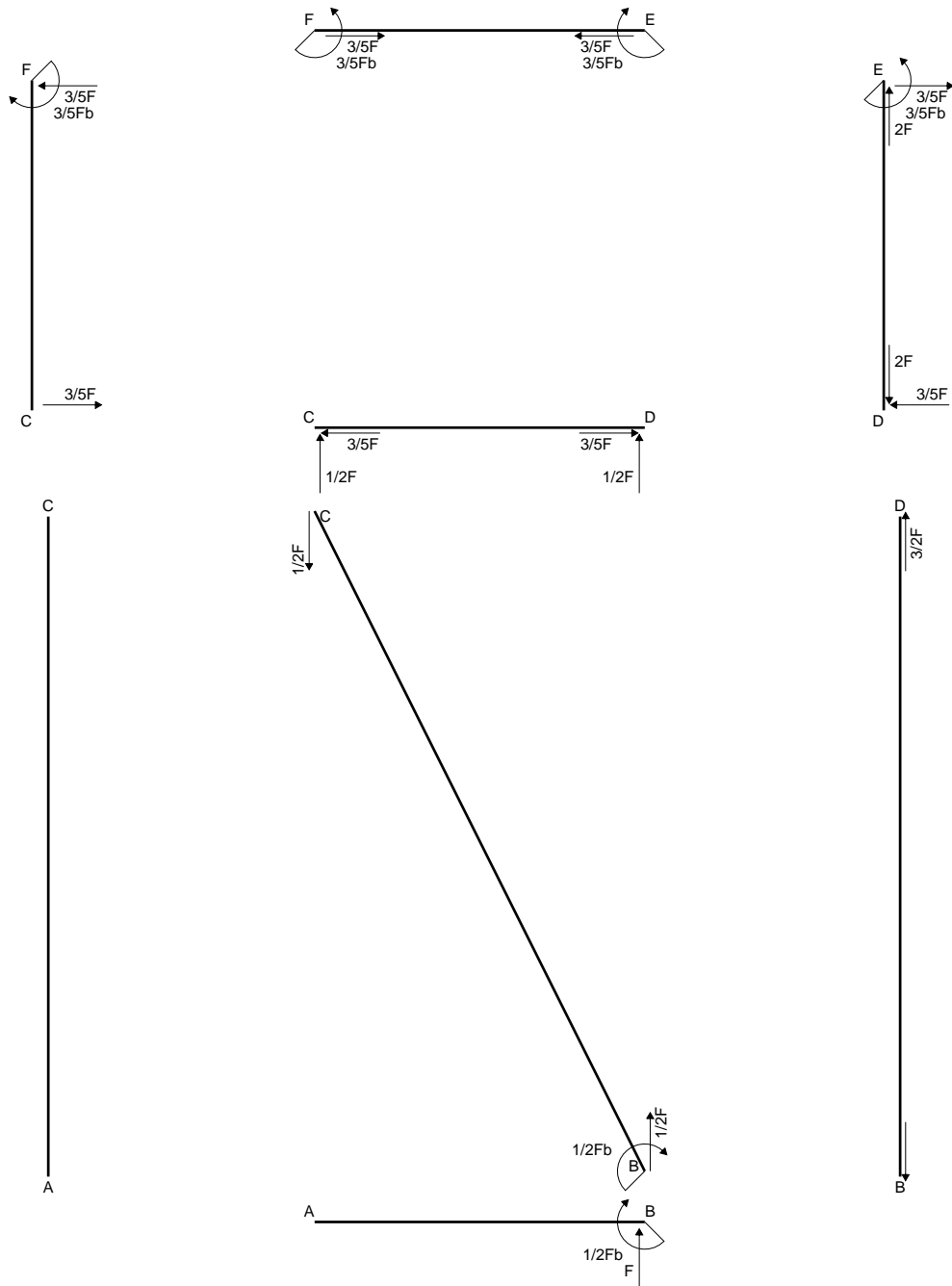
$$L_{CF}^{xo} = \int_0^b (-x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

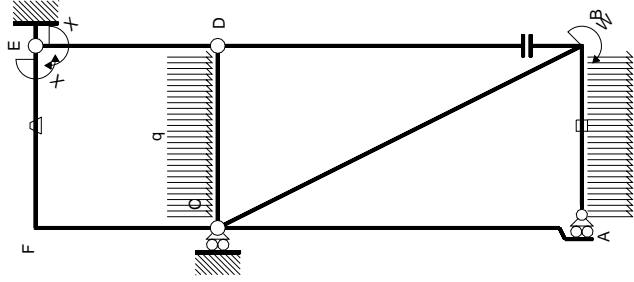
$$= (-1/3 b + 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$



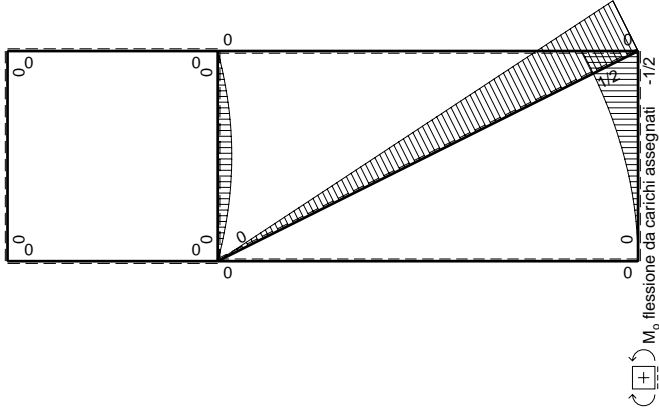
- A = 948. mm<sup>2</sup>
- J<sub>u</sub> = 278641. mm<sup>4</sup>
- J<sub>v</sub> = 80496. mm<sup>4</sup>
- y<sub>g</sub> = 34.64 mm
- T<sub>y</sub> = -5540. N
- M<sub>x</sub> = -1606600. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -34.64 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -199.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 15. mm
- v<sub>c</sub> = -19.64 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -113.2 N/mm<sup>2</sup>
- τ<sub>c</sub> = 8.094 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 114.1 N/mm<sup>2</sup>
- S = 4885. mm<sup>3</sup>







Schema di calcolo iperstatico



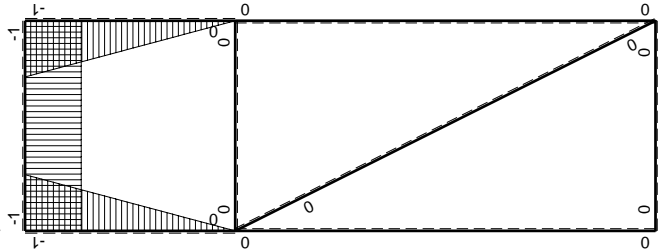
$M_0$  flessione da carichi assegnati -1/2

Quadro contributi PLV per iperstatica  $X=W_{EF}$

→	$M_x(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int X M_x M_x / EJ dx$
AB b	0	$-1/2qx^2$	0	0	0	0	0+0	0
BA b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0+0	0
BC $\sqrt{5}b$	0	$1/2Fb-\sqrt{5}/10Fx$	0	0	0	0	0	0
AC 2b	0	0	0	0	0	0	0+0	0
CA 2b	0	0	0	0	0	0	0+0	0
DB 2b	0	0	0	0	0	0	0+0	0
BD 2b	0	0	0	0	0	0	0+0	0
DE b	$-x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3Xb/EJ$
ED b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	0
CD b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0
DC b	0	$-1/2Fx+1/2qx^2$	0	0	0	0	0+0	0
EF b	-1	0	$-Fb/EJ$	0	$Fb/EJ$	1	$(0+1)Fb^2/EJ$	$Xb/EJ$
FE b	1	0	$Fb/EJ$	0	$Fb/EJ$	1		
FC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$
CF b	$x/b$	0	0	0	0	$x^2/b^2$	$Fb^2/EJ$	$5/3Xb/EJ$
	totali							
	iperstatica $X=W_{EF}$							

Sviluppi di calcolo iperstatica

$M_x$  flessione da iperstatica  $X=1$



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

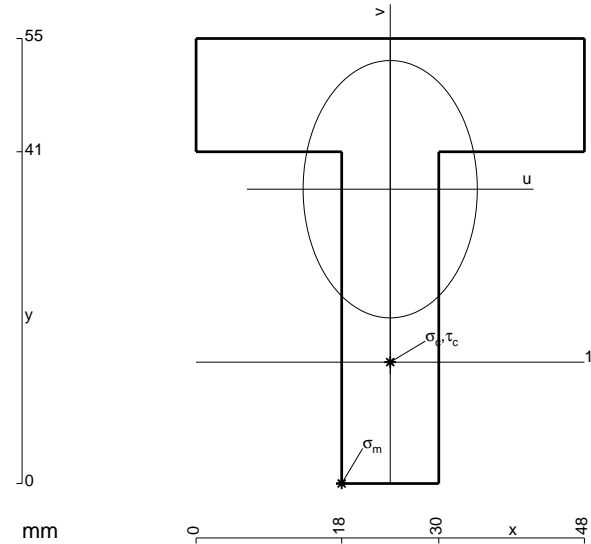
$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (1) \theta dx = [x]_0^b \theta$$

$$= (b) \theta = Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1) \theta dx = [-x]_0^b \theta$$

$$= (-b) \theta = Fb^2/EJ$$



$$A = 1164. \text{ mm}^2$$

$$J_u = 294703. \text{ mm}^4$$

$$J_v = 134928. \text{ mm}^4$$

$$y_g = 36.38 \text{ mm}$$

$$T_y = -5480. \text{ N}$$

$$M_x = -1698800. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$u_m = -6. \text{ mm}$$

$$v_m = -36.38 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -209.7 \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 15. \text{ mm}$$

$$v_c = -21.38 \text{ mm}$$

$$\sigma_c = -Mv/J_u = -123.2 \text{ N/mm}^2$$

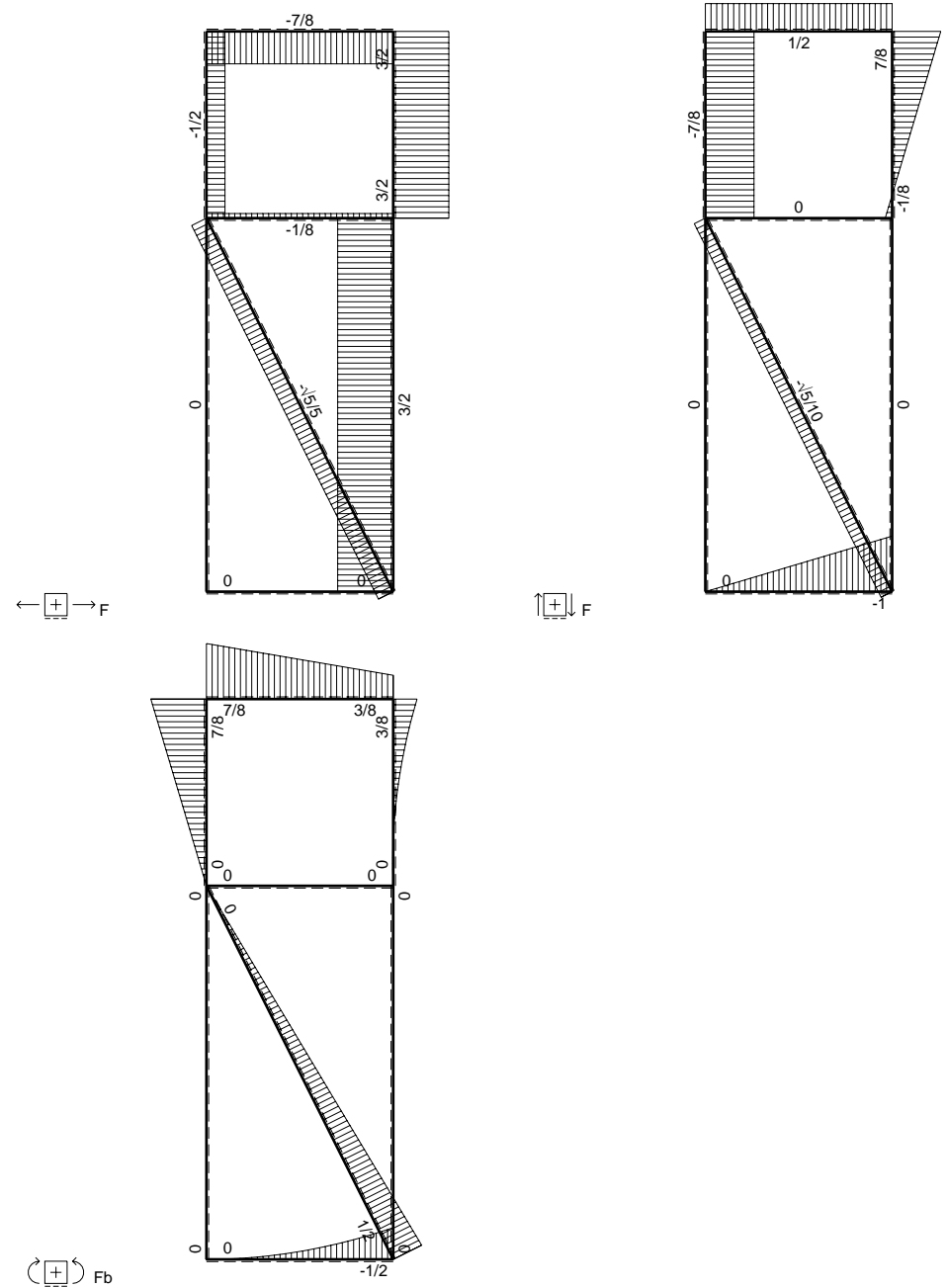
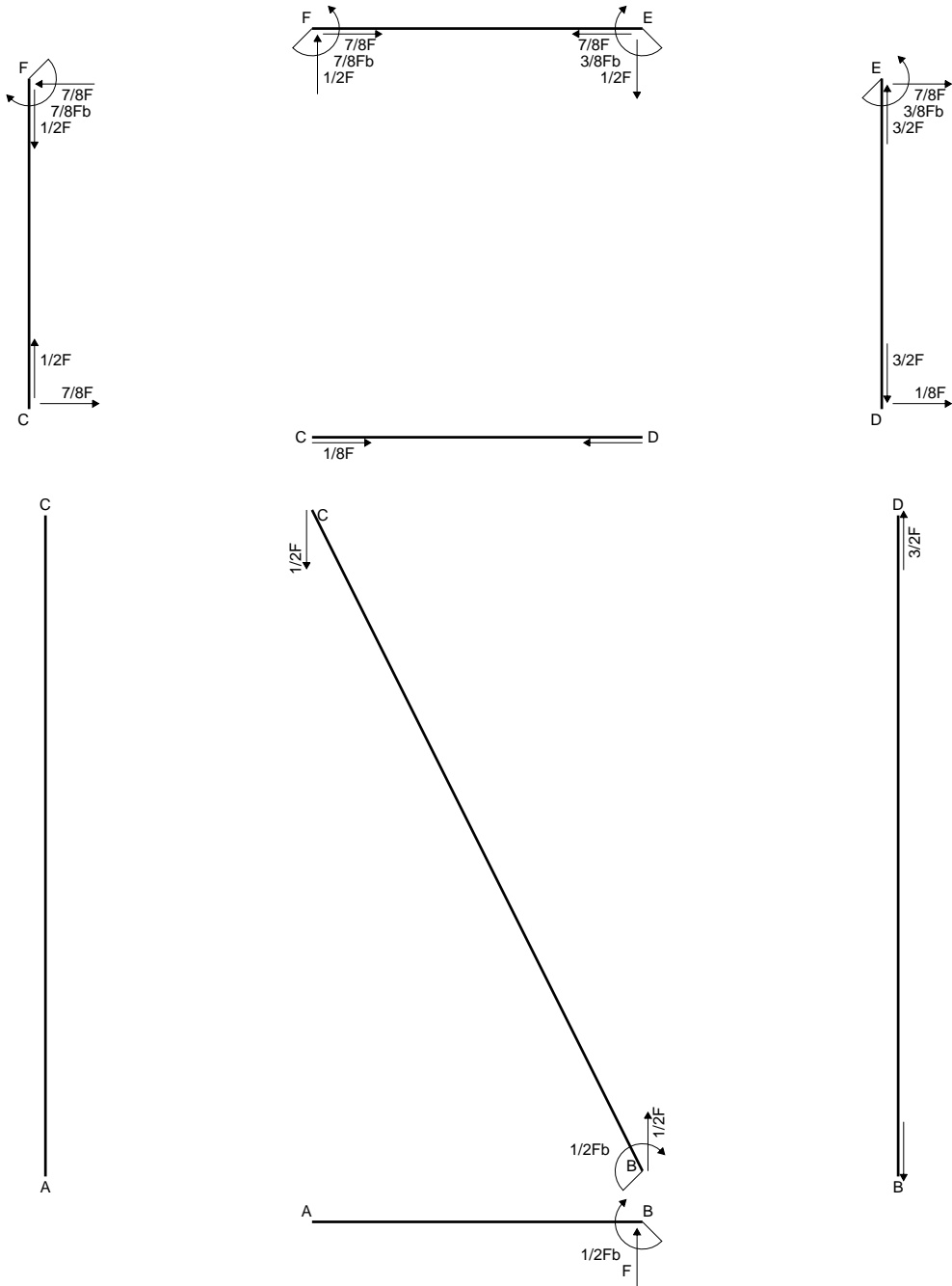
$$\tau_c = 8.054 \text{ N/mm}^2$$

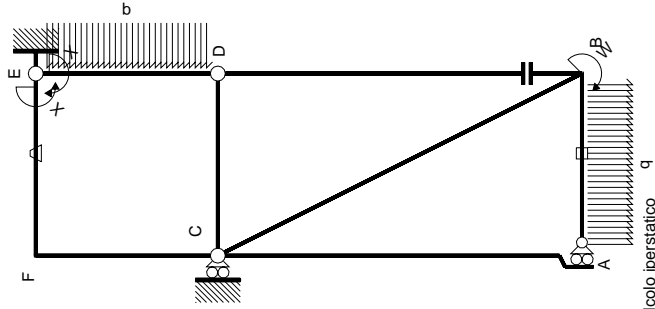
$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 124. \text{ N/mm}^2$$

$$S = 5198. \text{ mm}^3$$

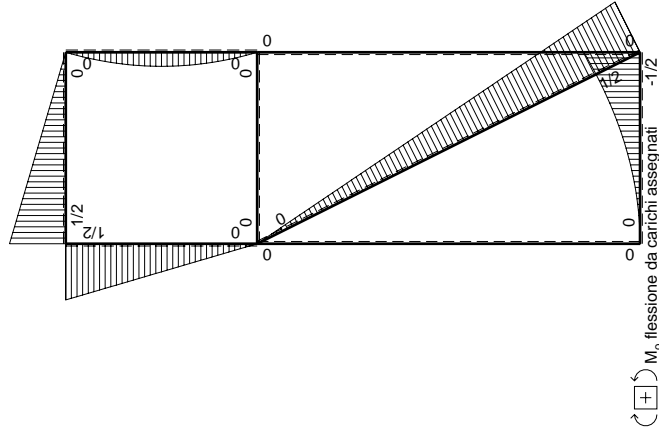




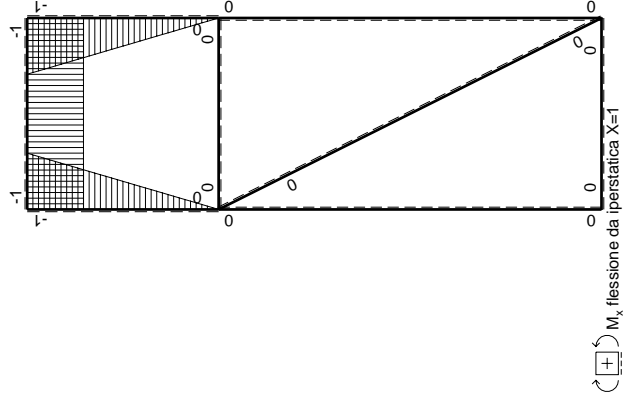




Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contribuiti PLV per iperstatica X=W<sup>EF</sup>

←	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	-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
BA B	0	1/2Fb-Fx+1/2qx <sup>2</sup>	0	0	0	0	0	0
BC √5b	0	1/2Fb-√5/10Fx	0	0	0	0	0+0	0
CA 2b	0	0	0	0	0	0	0+0	0
DB 2b	0	0	0	0	0	0	0+0	0
BD 2b	0	0	0	0	0	0	0+0	0
DE b	-x/b	-1/2Fx+1/2qx <sup>2</sup>	0	1/2F <sup>2</sup> x <sup>2</sup> /b-1/2qx <sup>3</sup> /b	0	0	x <sup>2</sup> /b <sup>2</sup>	0
ED 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>	1/3xb/EJ
CD b	0	0	0	0	0	0	0+0	0
DC b	0	0	0	0	0	0	0+0	0
EF b	-1	1/2Fx	-Fb/EJ	-1/2Fx	Fb/EJ	1	(-1/4+1)Fb <sup>2</sup> /EJ	Xb/EJ
FE b	1	-1/2Fb+1/2Fx	Fb/EJ	-1/2Fb+1/2Fx	Fb/EJ	1	(-1/4+1)Fb <sup>2</sup> /EJ	Xb/EJ
FC b	-1+x/b	1/2Fb-1/2Fx	0	-1/2Fb+Fx-1/2Fx <sup>2</sup> /b	0	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	(-1/6+0)Fb <sup>2</sup> /EJ
CF b	x/b	-1/2Fx	0	-1/2Fx <sup>2</sup> /b	0	0	x <sup>2</sup> /b <sup>2</sup>	1/3xb/EJ
totali								5/8Fb <sup>2</sup> /EJ
								-3/8Fb

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/4 b) Fb 1/EJ + (b) \theta = 3/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + 1/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-1/2 x + 1/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

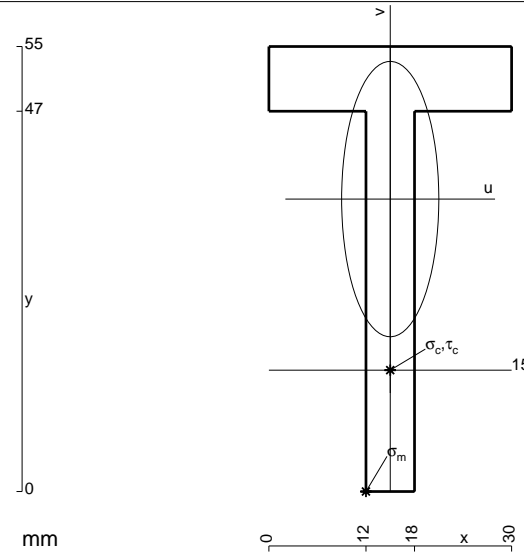
$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

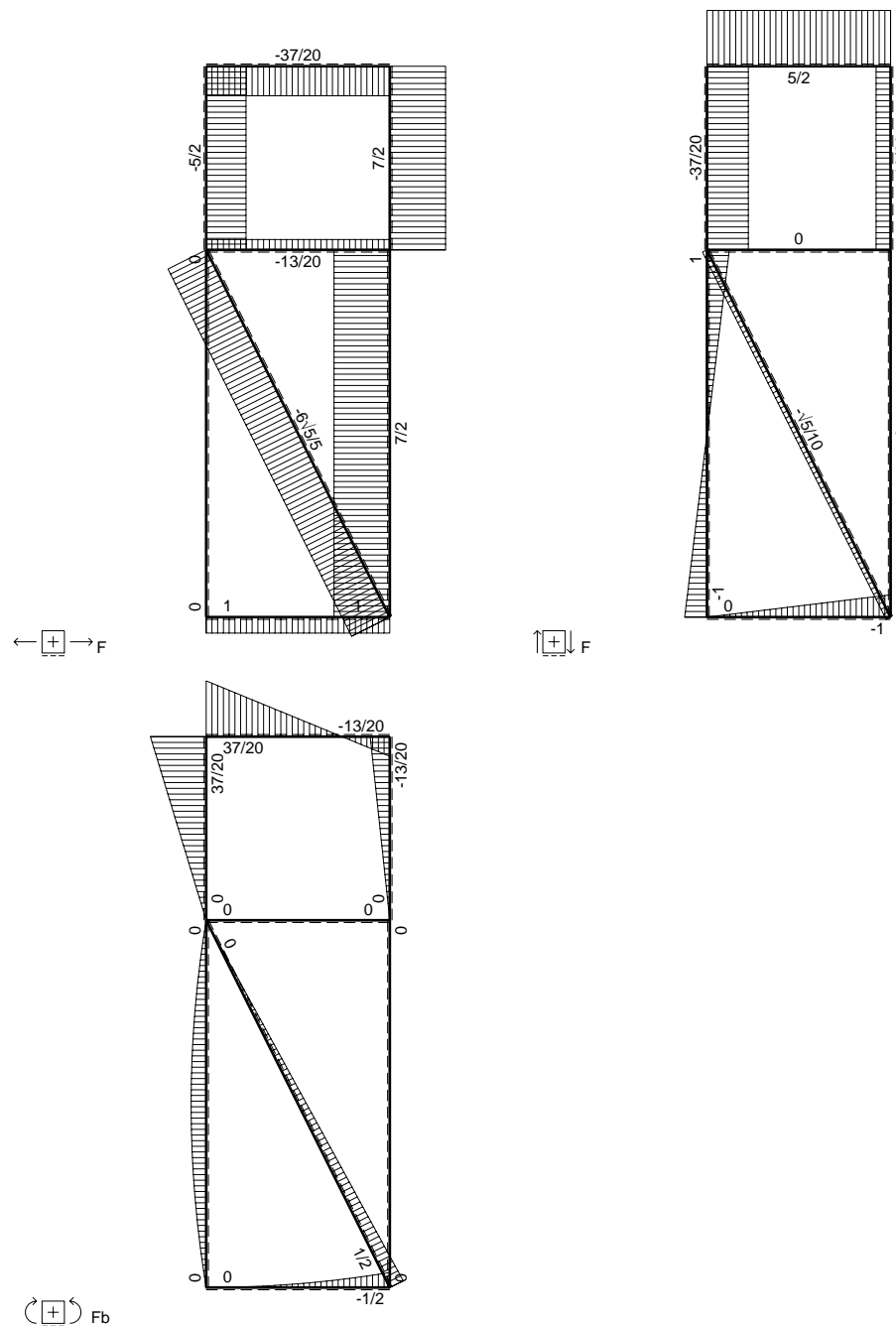
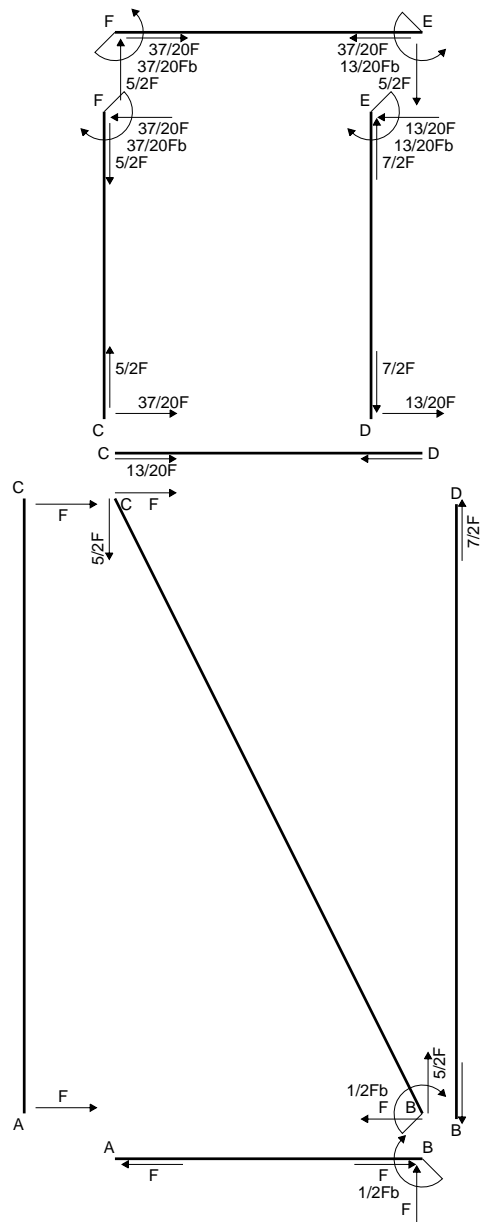
$$L_{CF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ$$

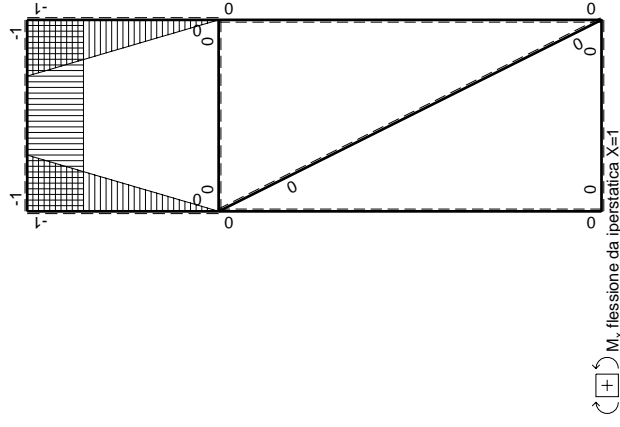
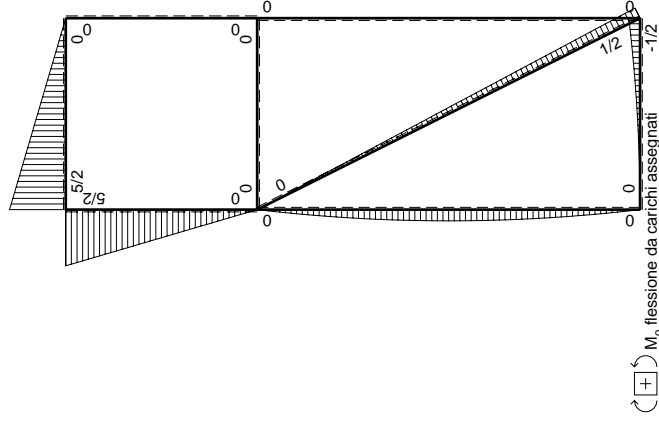
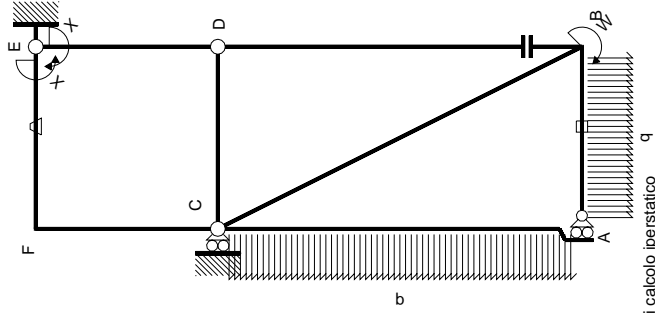
$$= (-1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$



- A = 522. mm<sup>2</sup>
- J<sub>u</sub> = 151243. mm<sup>4</sup>
- J<sub>v</sub> = 18846. mm<sup>4</sup>
- y<sub>g</sub> = 36.14 mm
- T<sub>y</sub> = -2780. N
- M<sub>x</sub> = -917400. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -36.14 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -219.2 N/mm<sup>2</sup>
- x<sub>c</sub> = 15. mm
- y<sub>c</sub> = 15. mm
- v<sub>c</sub> = -21.14 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -128.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.897 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 129. N/mm<sup>2</sup>
- S = 2578. mm<sup>3</sup>







Quadro contributi PLV per iperstatica X=W<sup>EP</sup>

→	M <sup>x</sup> (x)	M <sup>0</sup> (x)	θ	M <sup>x</sup> M <sup>0</sup>	M <sup>x</sup> θ	M <sup>x</sup> M <sup>x</sup>	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	0	-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
BA b	0	1/2Fb-Fx+1/2qx <sup>2</sup>	0	0	0	0	0	0
BC √5b	0	1/2Fb-√5/10Fx	0	0	0	0	0+0	0
AC 2b	0	-Fx+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
CA 2b	0	Fx-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
DB 2b	0	0	0	0	0	0	0+0	0
BD 2b	0	0	0	0	0	0	0+0	0
DE b	-x/b	0	0	0	0	0	0+0	1/3xb/EJ
ED b	1-x/b	0	0	0	0	0	0+0	1/3xb/EJ
CD b	0	0	0	0	0	0	0+0	0
DC b	0	0	0	0	0	0	0+0	0
EF b	-1	5/2Fx	-Fb/EJ	-5/2Fx	Fb/EJ	1	(-5/4+1)Fb <sup>2</sup> /EJ	Xb/EJ
FE b	1	-5/2Fb+5/2Fx	Fb/EJ	-5/2Fb+5/2Fx	Fb/EJ	1	(-5/4+1)Fb <sup>2</sup> /EJ	Xb/EJ
FC b	-1+x/b	5/2Fb-5/2Fx	0	-5/2Fb+5Fx-5/2Fx <sup>2</sup> /b	0	0	(-5/6+0)Fb <sup>2</sup> /EJ	1/3xb/EJ
CF b	x/b	-5/2Fx	0	-5/2Fx <sup>2</sup> /b	0	0	(-5/6+0)Fb <sup>2</sup> /EJ	1/3xb/EJ
totali								
iperstatica X=W <sup>EP</sup>								

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-5/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-5/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-5/4 b) Fb 1/EJ + (b) \theta = -1/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-5/2 + 5/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-5/2 x + 5/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

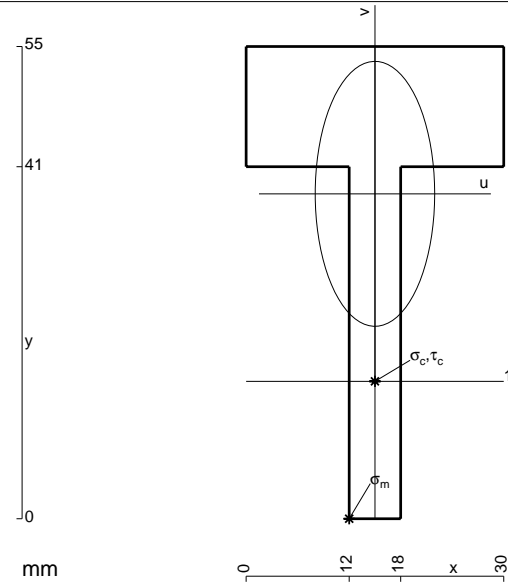
$$= (-5/2 b + 5/4 b) Fb 1/EJ + (-b) \theta = -1/4 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = [-5/2 x + 5/2 x^2/b - 5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

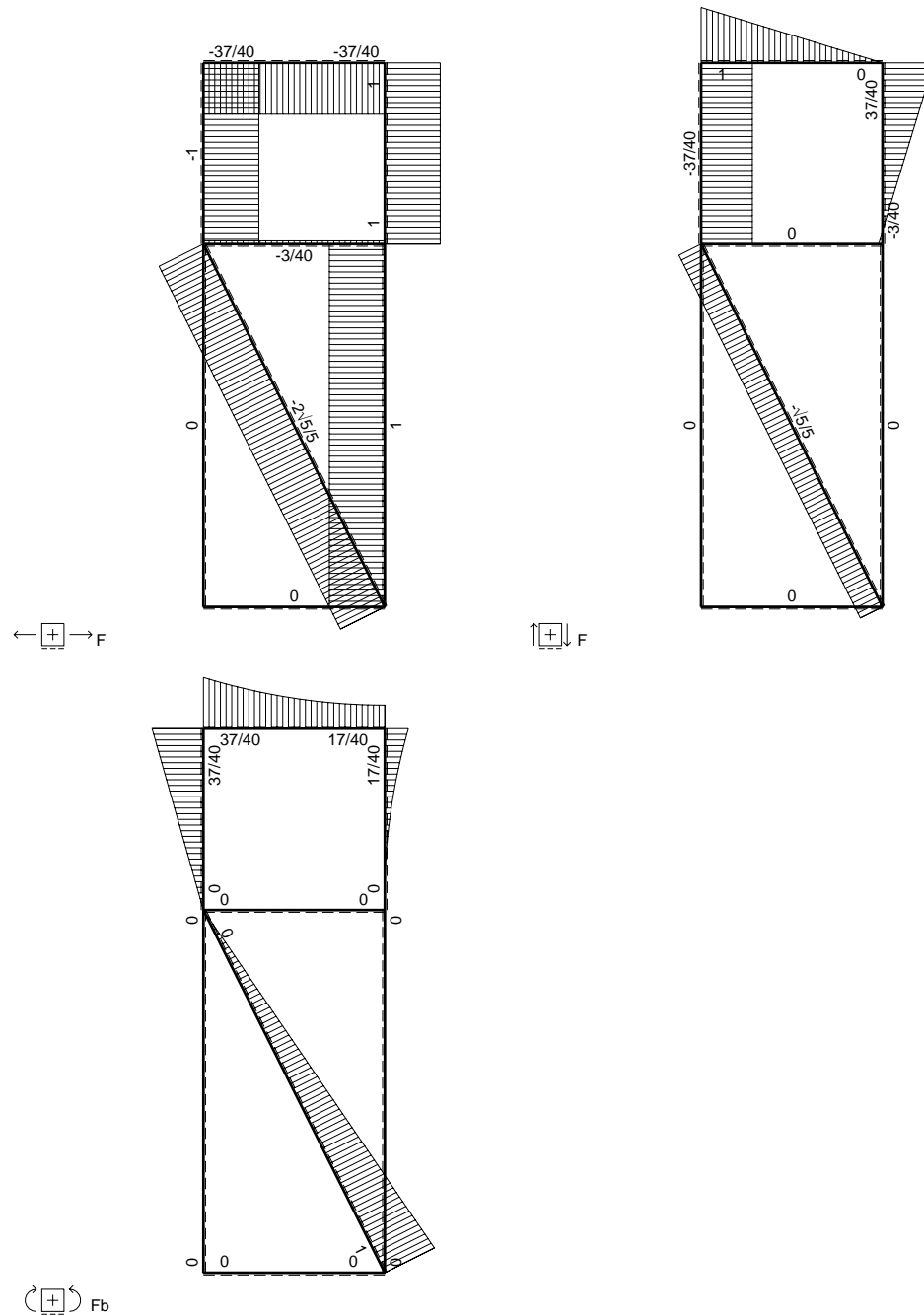
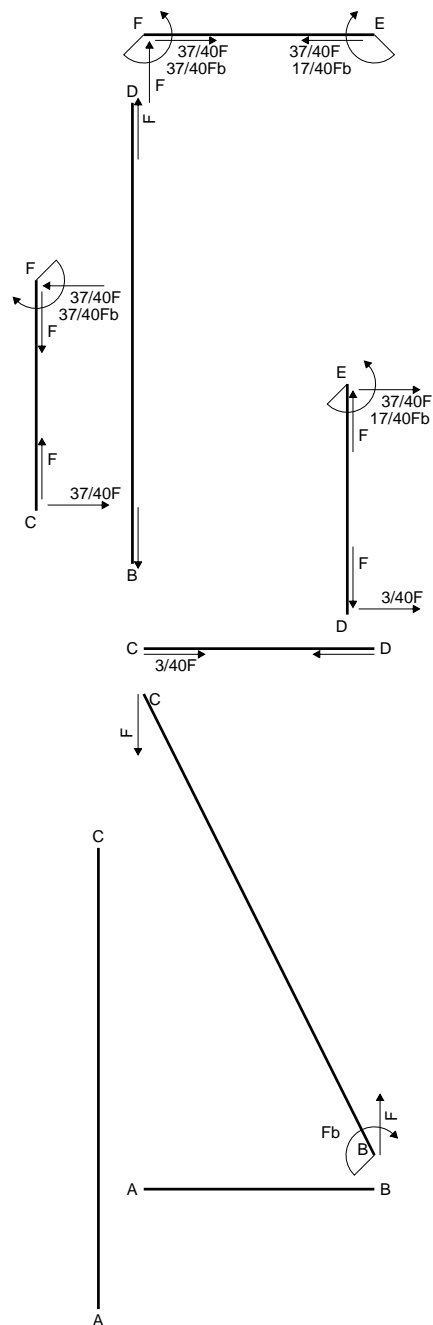
$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$



- A = 666. mm<sup>2</sup>
- J<sub>u</sub> = 158641. mm<sup>4</sup>
- J<sub>v</sub> = 32238. mm<sup>4</sup>
- y<sub>g</sub> = 37.84 mm
- N = 2800. N
- T<sub>y</sub> = -2800. N
- M<sub>x</sub> = -980000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -37.84 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = -229.6 N/mm<sup>2</sup>
- x<sub>c</sub> = 15. mm
- y<sub>c</sub> = 16. mm
- v<sub>c</sub> = -21.84 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = -130.7 N/mm<sup>2</sup>
- τ<sub>c</sub> = 8.427 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 131.5 N/mm<sup>2</sup>
- S = 2865. mm<sup>3</sup>









$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/6 b) Fb 1/EJ + (b) \theta = 5/6 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx$$

$$= [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

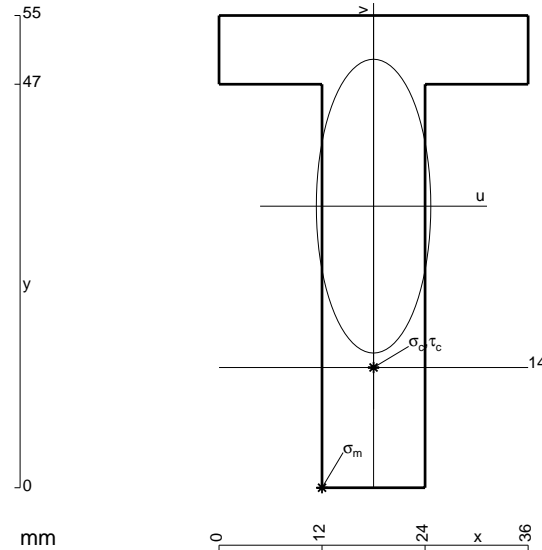
$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ + (-b) \theta = 5/6 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

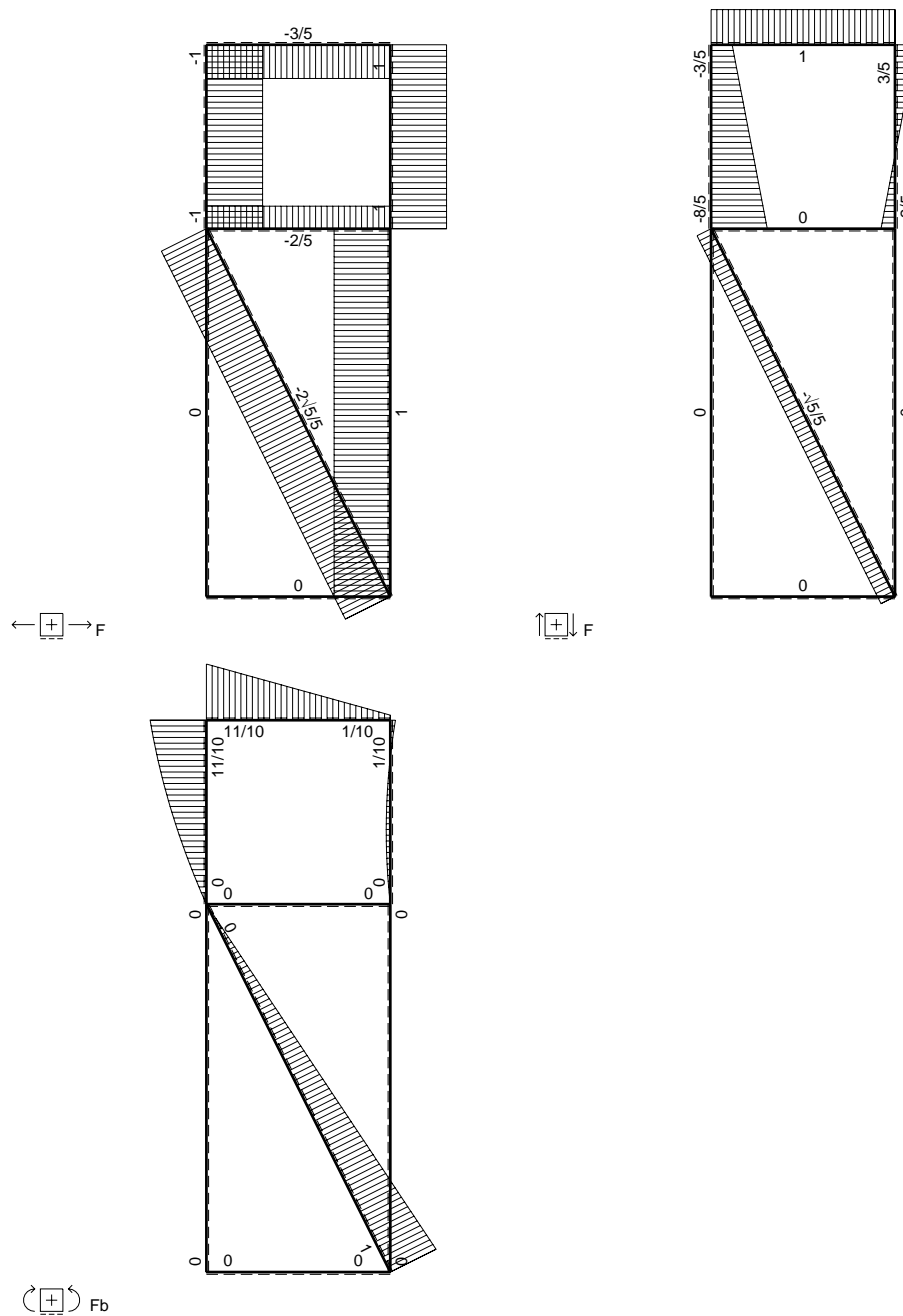
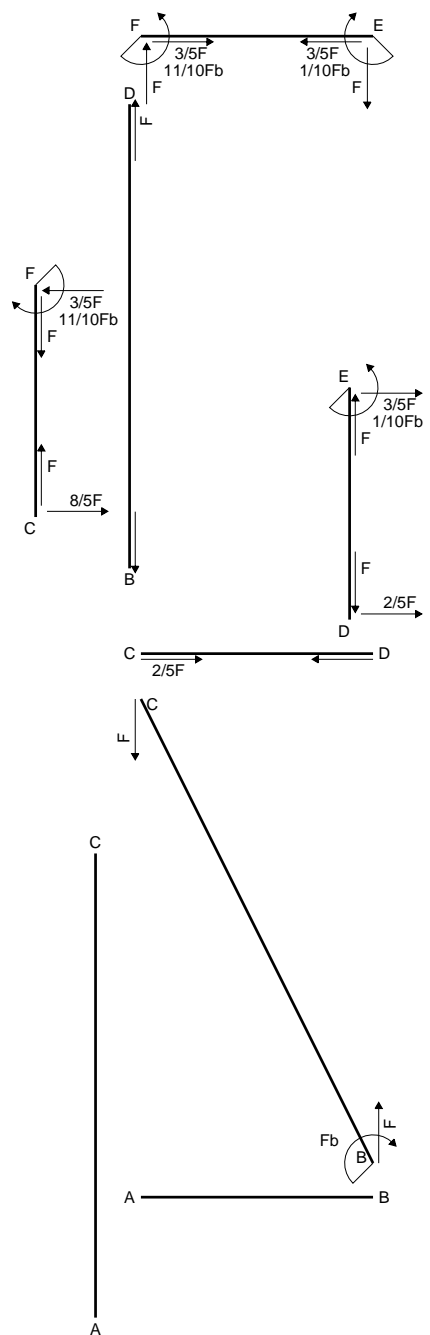
$$L_{CF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$



- A = 852. mm<sup>2</sup>
- J<sub>u</sub> = 249536. mm<sup>4</sup>
- J<sub>v</sub> = 37872. mm<sup>4</sup>
- y<sub>g</sub> = 32.8 mm
- N = -2227. N
- T<sub>y</sub> = -1114. N
- M<sub>x</sub> = 1842600. 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> = 239.6 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> = 136.2 N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.612 N/mm<sup>2</sup>
- σ<sub>φ</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 136.2 N/mm<sup>2</sup>
- S = 4334. mm<sup>3</sup>







$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (b) \theta = 1/2 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

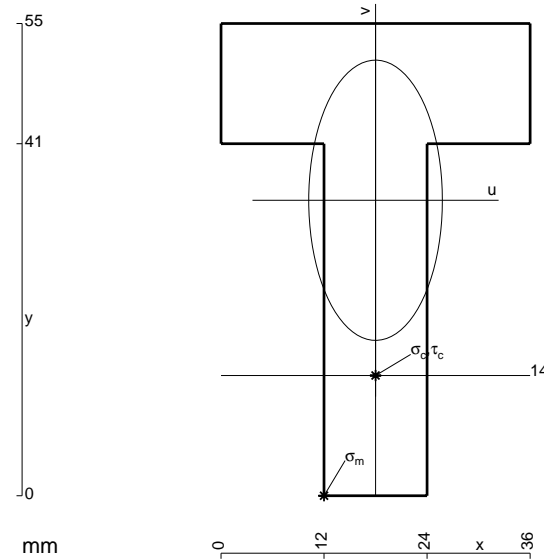
$$= (-b + 1/2 b) Fb 1/EJ + (-b) \theta = 1/2 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-1 + 3/2 x/b - 1/2 x^3/b^3) Fb 1/EJ dx = [-x + 3/4 x^2/b - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-b + 3/4 b - 1/8 b) Fb 1/EJ = -3/8 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-3/2 x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/2 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/8 b) Fb 1/EJ = -3/8 Fb^2/EJ$$

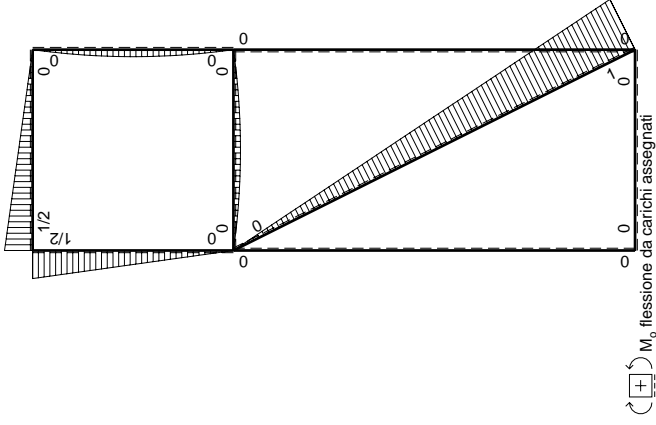
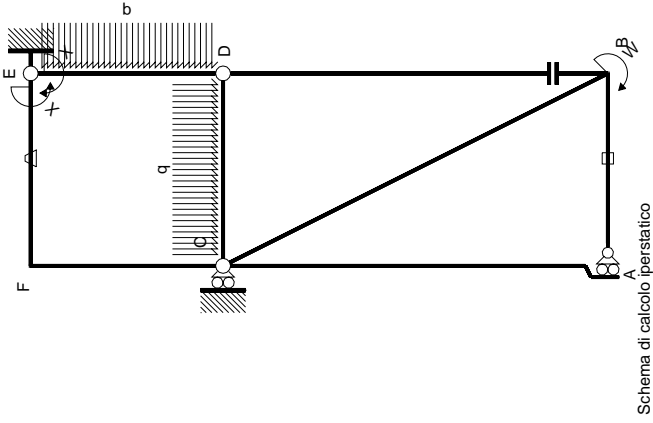


$A = 996. \text{ mm}^2$   
 $J_u = 265432. \text{ mm}^4$   
 $J_v = 60336. \text{ mm}^4$   
 $y_g = 34.42 \text{ mm}$   
 $N = -3596. \text{ N}$   
 $T_y = -1798. \text{ N}$   
 $M_x = 1567800. \text{ Nmm}$   
 $x_m = 12. \text{ mm}$   
 $u_m = -6. \text{ mm}$   
 $v_m = -34.42 \text{ mm}$   
 $\sigma_m = N/A - Mv/J_u = 199.7 \text{ N/mm}^2$   
 $x_c = 18. \text{ mm}$   
 $y_c = 14. \text{ mm}$   
 $v_c = -20.42 \text{ mm}$   
 $\sigma_c = N/A - Mv/J_u = 117. \text{ N/mm}^2$   
 $\tau_c = 2.6 \text{ N/mm}^2$   
 $\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 117.1 \text{ N/mm}^2$   
 $S = 4606. \text{ mm}^3$

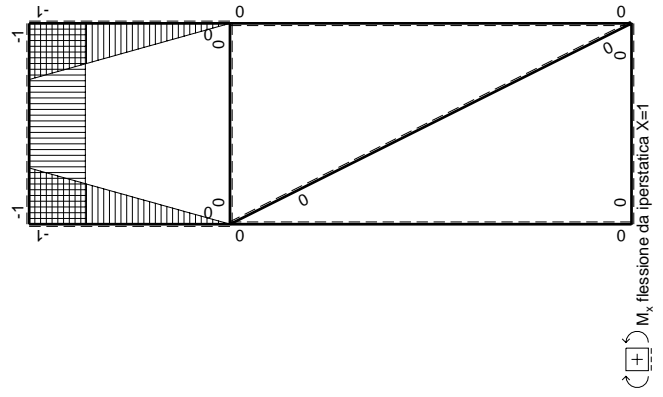








$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{EF}$

←	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x (M_0/EJ + \theta) dx$	$\int M^x M_x / EJ dx$	iperstatica $X=W_{EF}$	
									totali	
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
BC $\sqrt{5}b$	0	$Fb\sqrt{5}/5Fx$	0	0	0	0	0+0	0	0	0
CA 2b	0	0	0	0	0	0	0+0	0	0	0
DB 2b	0	0	0	0	0	0	0+0	0	0	0
BD 2b	0	0	0	0	0	0	0+0	0	0	0
DE b	$-x/b$	$-1/2Fx+1/2qx^2$	0	$1/2Fx^2/b-1/2qx^3/b$	0	0	$x^2/b^2$	0	$(1/2+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$1-x/b$	$1/2Fx-1/2qx^2$	0	$1/2Fx-Fx^2/b+1/2qx^3/b$	0	0	$1-2x/b+x^2/b^2$	0	$(1/2+0)Fb^2/EJ$	$1/3Xb/EJ$
CD b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0	0	0+0	0
DC b	0	$-1/2Fx+1/2qx^2$	0	0	0	0	0	0	0+0	0
EF b	-1	$1/2Fx$	$-Fb/EJ$	$-1/2Fx$	$Fb/EJ$	1	1	1	$(-1/4+1)Fb^2/EJ$	$Xb/EJ$
FE b	1	$-1/2Fb+1/2Fx$	$Fb/EJ$	$-1/2Fb+1/2Fx$	$Fb/EJ$	1	1	1	$(-1/4+1)Fb^2/EJ$	$Xb/EJ$
FC b	$-1+x/b$	$1/2Fb-1/2Fx$	0	$-1/2Fb+Fx-1/2Fx^2/b$	0	0	$1-2x/b+x^2/b^2$	0	$(-1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
CF b	$x/b$	$-1/2Fx$	0	$-1/2Fx^2/b$	0	0	$x^2/b^2$	0	$(-1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
totali									$5/8Fb^2/EJ$	$5/3Xb/EJ$
									$-3/8Fb$	

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{x_0} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{x_0} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{x_0} = \int_0^b (-1/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/4 b) Fb 1/EJ + (b) \theta = 3/4 Fb^2/EJ$$

$$L_{FE}^{x_0} = \int_0^b (-1/2 + 1/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-1/2 x + 1/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

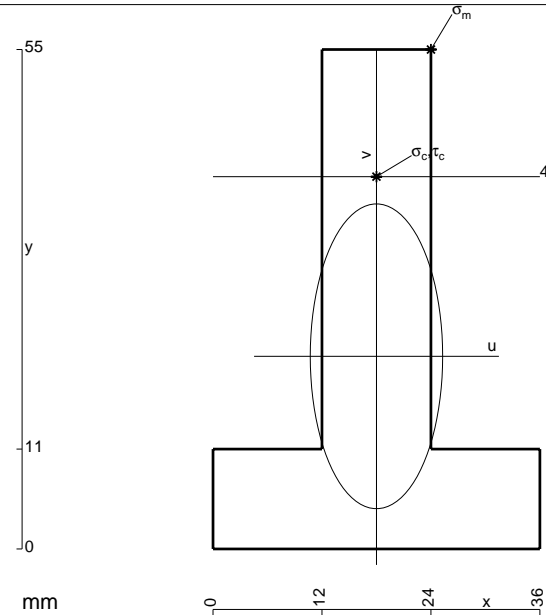
$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

$$L_{FC}^{x_0} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

$$L_{CF}^{x_0} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$



- A = 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
- N = -3381. N
- T<sub>y</sub> = -1690. N
- M<sub>x</sub> = 1587600. 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> = N/A-Mv/J<sub>u</sub> = -209.7 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> = N/A-Mv/J<sub>u</sub> = -124.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.435 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup>+3τ<sup>2</sup>) = 124.4 N/mm<sup>2</sup>
- S = 4500. mm<sup>3</sup>



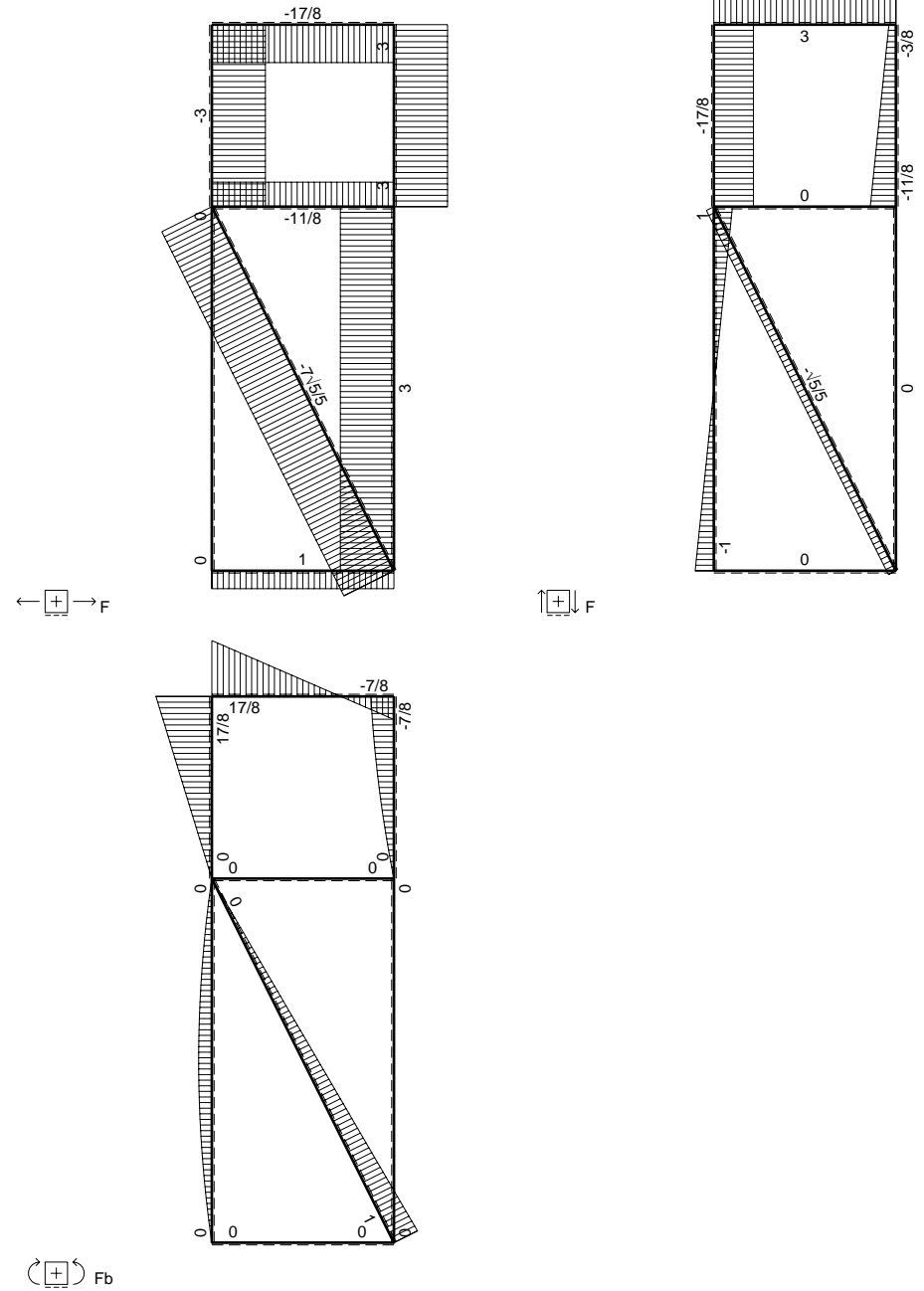
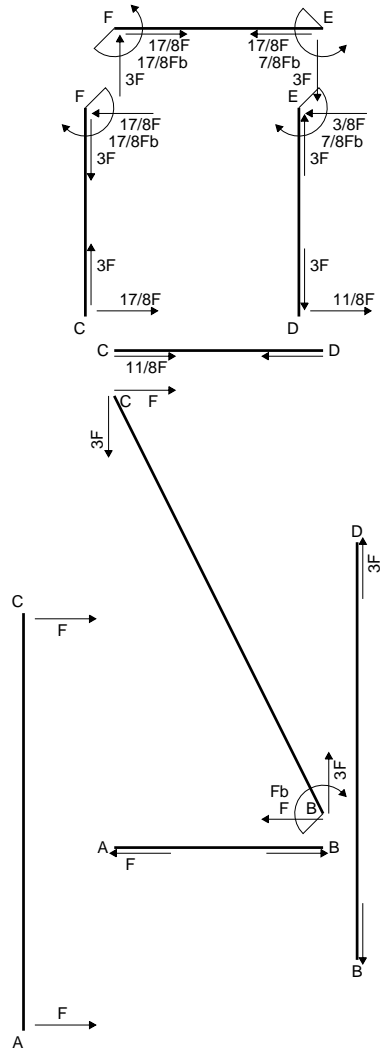












$\curvearrowright (+)$   $F_b$



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-3x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-3/2 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-3/2 b) Fb 1/EJ + (b) \theta = -1/2 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-3 + 3x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-3x + 3/2 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

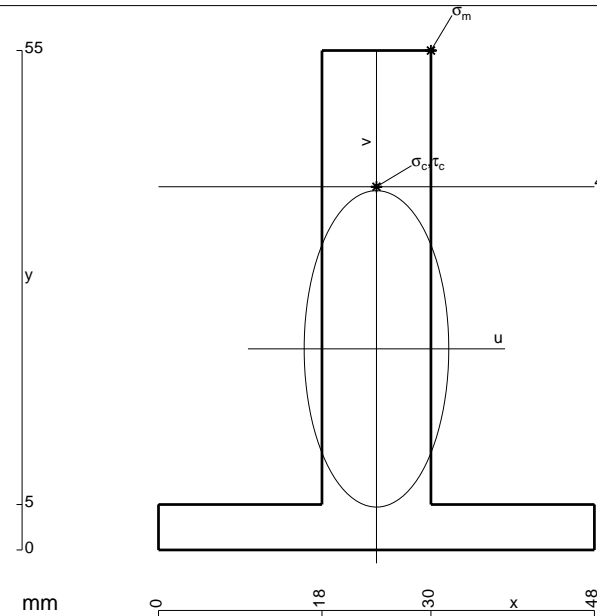
$$= (-3b + 3/2 b) Fb 1/EJ + (-b) \theta = -1/2 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-3 + 6x/b - 3x^2/b^2) Fb 1/EJ dx = [-3x + 3x^2/b - x^3/b^2]_0^b Fb 1/EJ$$

$$= (-3b + 3b - b) Fb 1/EJ = - Fb^2/EJ$$

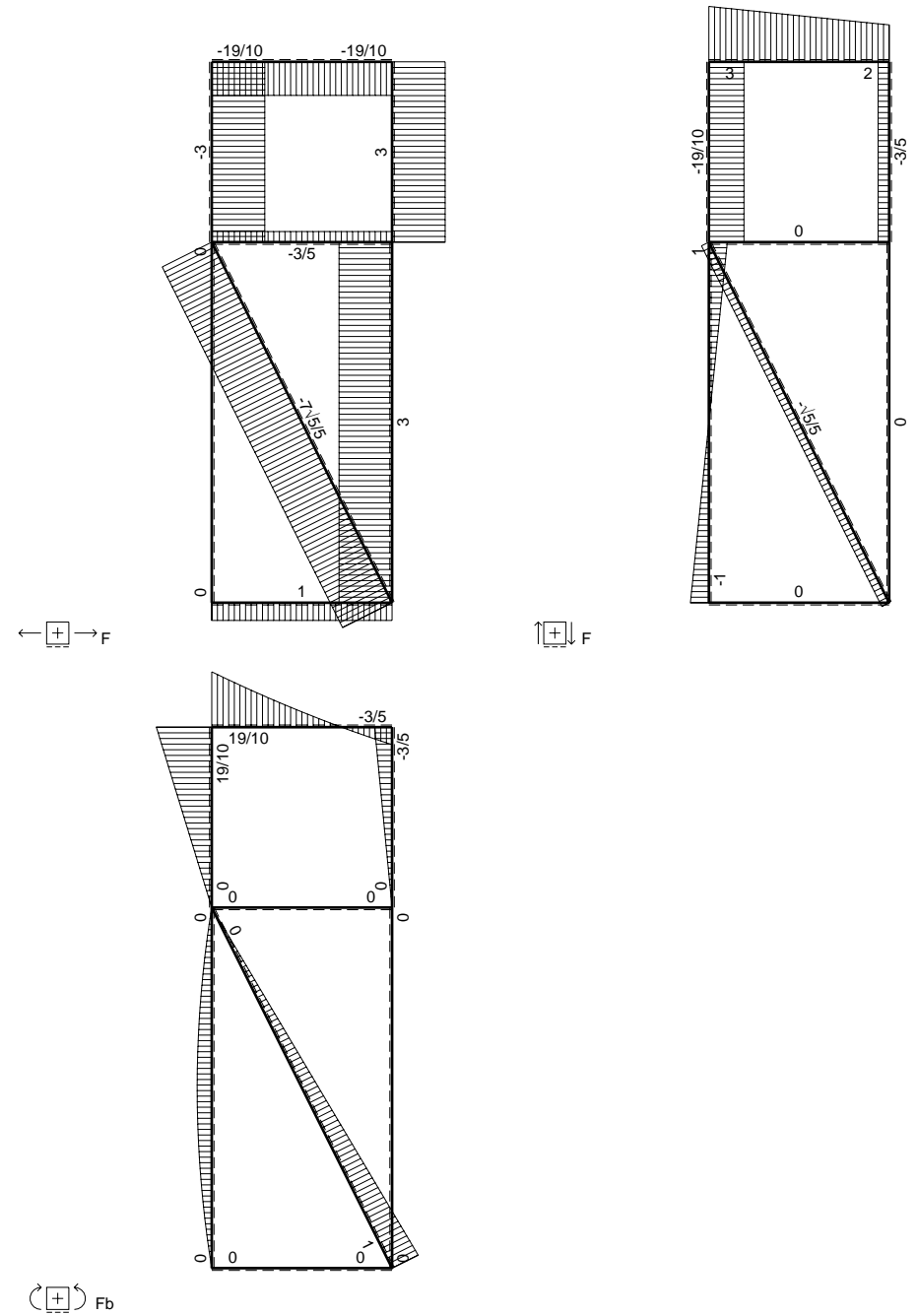
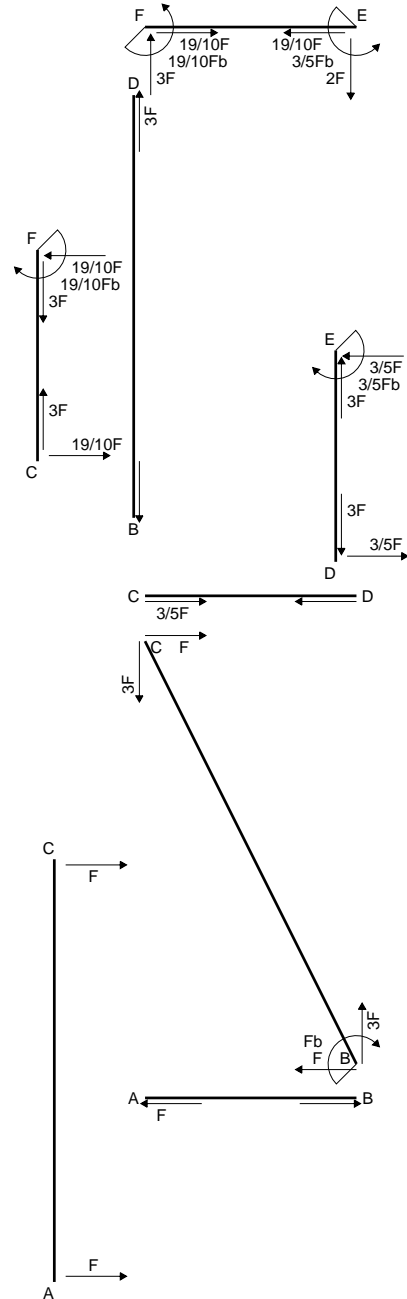
$$L_{CF}^{xo} = \int_0^b (-3x^2/b^2) Fb 1/EJ dx = [-x^3/b^2]_0^b Fb 1/EJ$$

$$= (-b) Fb 1/EJ = - Fb^2/EJ$$



- 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
- N = -10550. N
- T<sub>y</sub> = -1507. N
- M<sub>x</sub> = 1685000. 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> = N/A-Mv/J<sub>u</sub> = -229.6 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 40. mm
- v<sub>c</sub> = 17.86 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = -130.5 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.247 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 = 4564. mm<sup>3</sup>







$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-2x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-b - 1/6 b) Fb 1/EJ + (b) \theta = -1/6 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-5/2 + 3x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx$$

$$= [-5/2 x + 3/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

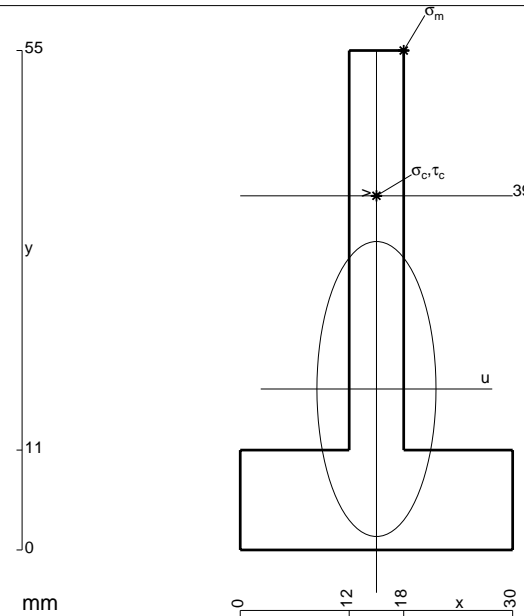
$$= (-5/2 b + 3/2 b - 1/6 b) Fb 1/EJ + (-b) \theta = -1/6 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = [-5/2 x + 5/2 x^2/b - 5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$



$$A = 594. \text{ mm}^2$$

$$J_u = 156836. \text{ mm}^4$$

$$J_v = 25542. \text{ mm}^4$$

$$y_g = 17.72 \text{ mm}$$

$$N = -5604. \text{ N}$$

$$T_y = -800.5 \text{ N}$$

$$M_x = 966600. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$y_m = 55. \text{ mm}$$

$$u_m = 3. \text{ mm}$$

$$v_m = 37.28 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -239.2 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 39. \text{ mm}$$

$$v_c = 21.28 \text{ mm}$$

$$\sigma_c = N/A - Mv/J_u = -140.6 \text{ N/mm}^2$$

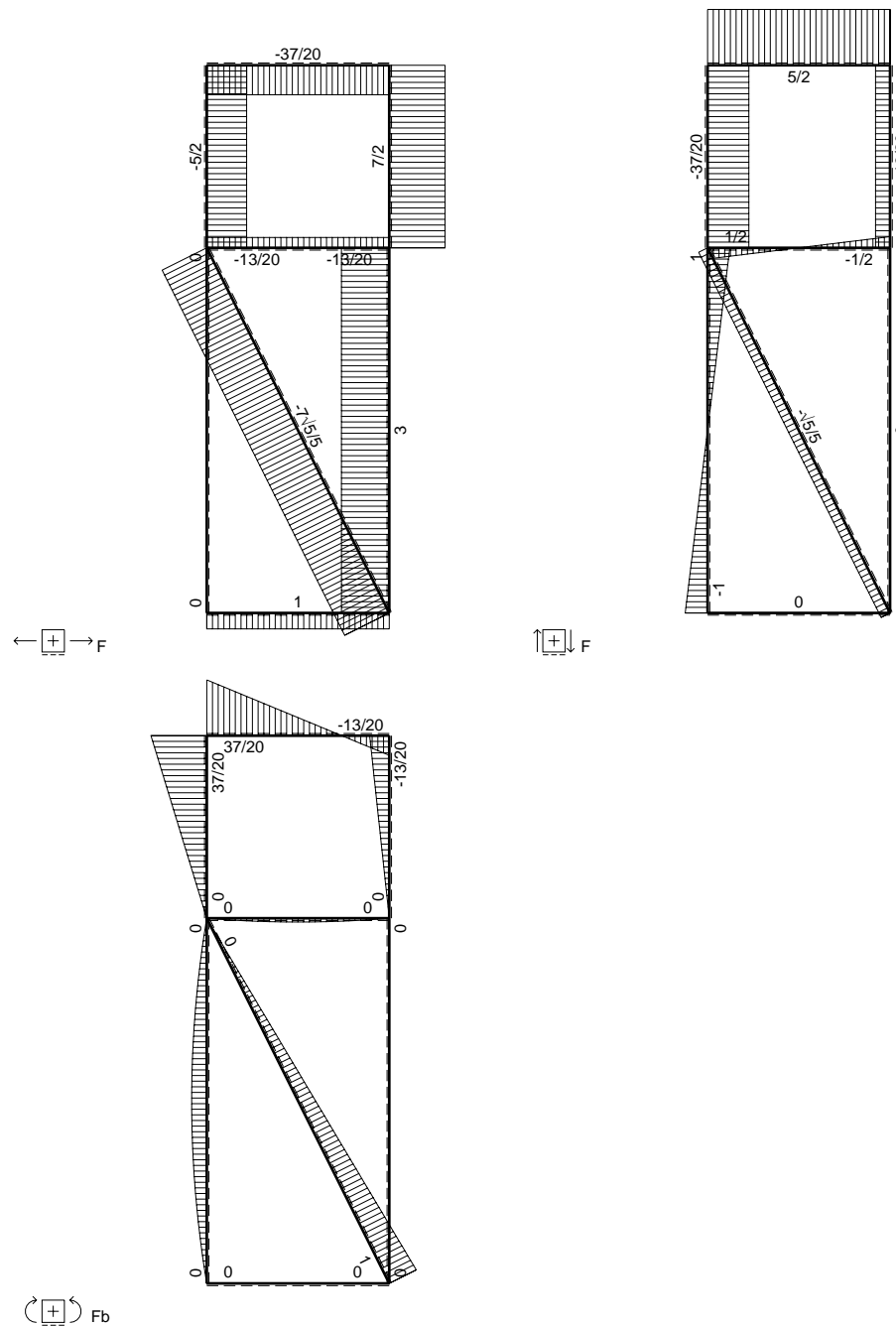
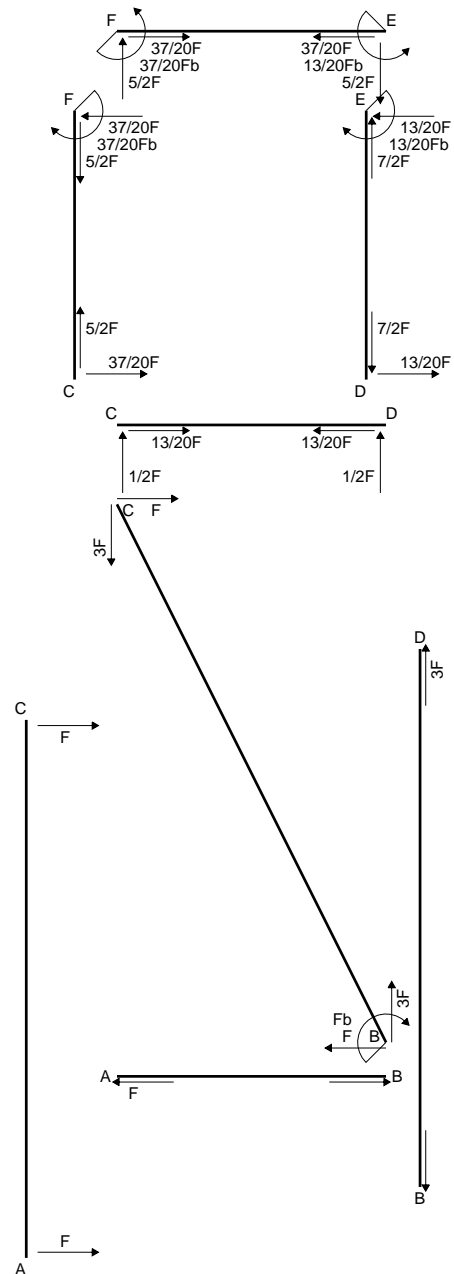
$$\tau_c = 2.391 \text{ N/mm}^2$$

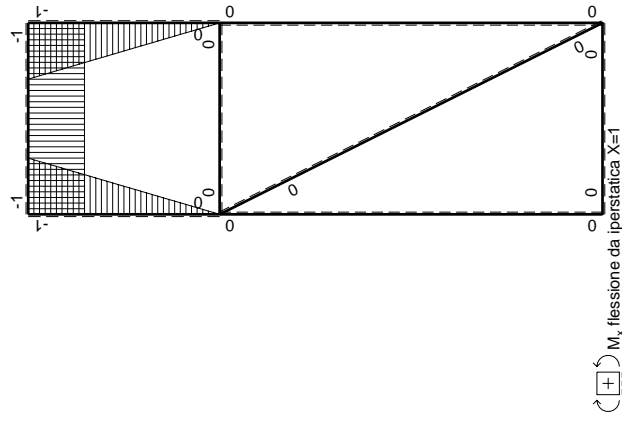
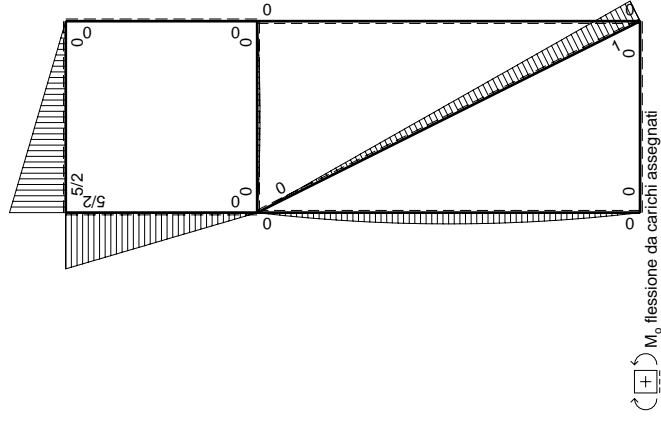
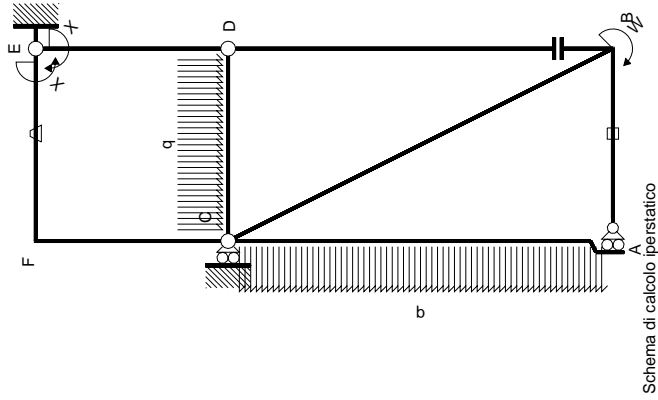
$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 140.6 \text{ N/mm}^2$$

$$S = 2811. \text{ mm}^3$$









Quadro contributi PLV per iperstatica X=W<sup>EP</sup>

←	M <sup>x</sup> (x)	M <sup>o</sup> (x)	θ	M <sup>x</sup> M <sup>o</sup>	M <sup>x</sup> θ	M <sup>x</sup> M <sup>x</sup>	∫M <sup>x</sup> (M <sup>o</sup> /EJ+θ)dx	∫M <sup>x</sup> M <sup>x</sup> /EJdx
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0	0
BC √5b	0	Fb-√5/5Fx	0	0	0	0	0	0
AC 2b	0	-Fx+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
CA 2b	0	Fx-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
DB 2b	0	0	0	0	0	0	0+0	0
BD 2b	0	0	0	0	0	0	0+0	0
DE b	-x/b	0	0	0	0	x <sup>2</sup> /b <sup>2</sup>	0+0	1/3Xb/EJ
ED b	1-x/b	0	0	0	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	0+0	1/3Xb/EJ
CD b	0	1/2Fx-1/2qx <sup>2</sup>	0	0	0	0	0	0
DC b	0	-1/2Fx+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
EF b	-1	5/2Fx	-Fb/EJ	-5/2Fx	Fb/EJ	1	(-5/4+1)Fb <sup>2</sup> /EJ	Xb/EJ
FE b	1	-5/2Fb+5/2Fx	Fb/EJ	-5/2Fb+5/2Fx	Fb/EJ	1	(-5/4+1)Fb <sup>2</sup> /EJ	Xb/EJ
FC b	-1+x/b	5/2Fb-5/2Fx	0	-5/2Fb+5Fx-5/2Fx <sup>2</sup> /b	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	(-5/6+0)Fb <sup>2</sup> /EJ	1/3Xb/EJ
CF b	x/b	-5/2Fx	0	-5/2Fx <sup>2</sup> /b	0	x <sup>2</sup> /b <sup>2</sup>	-13/12Fb <sup>2</sup> /EJ	5/3Xb/EJ
totali								
iperstatica X=W <sup>EP</sup>		13/20Fb						

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{x_0} = \int_0^b (-5/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-5/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-5/4 b) Fb 1/EJ + (b) \theta = -1/4 Fb^2/EJ$$

$$L_{FE}^{x_0} = \int_0^b (-5/2 + 5/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-5/2 x + 5/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

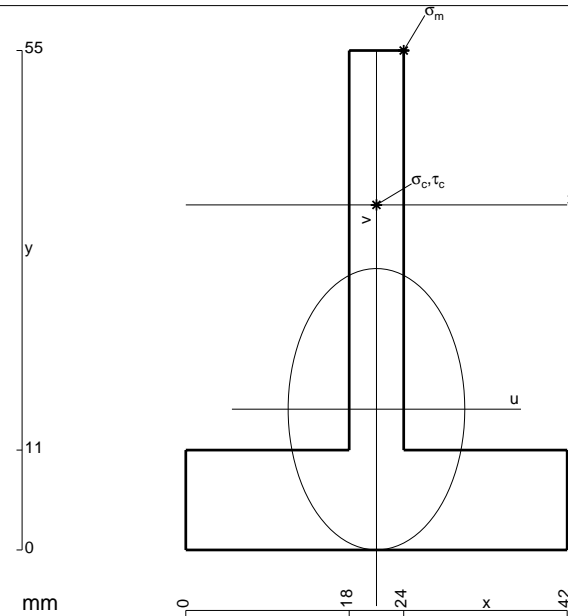
$$= (-5/2 b + 5/4 b) Fb 1/EJ + (-b) \theta = -1/4 Fb^2/EJ$$

$$L_{FC}^{x_0} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = [-5/2 x + 5/2 x^2/b - 5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

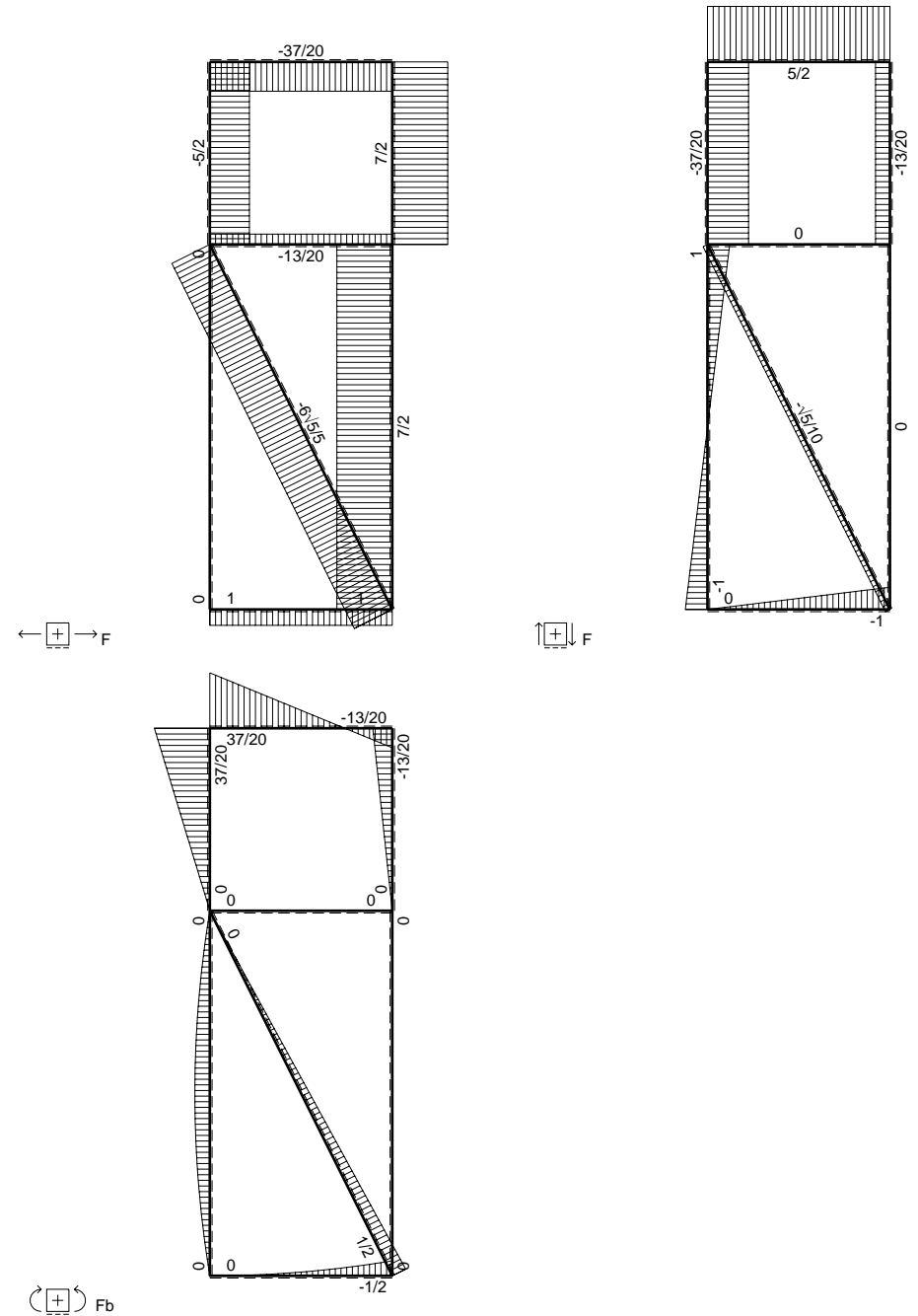
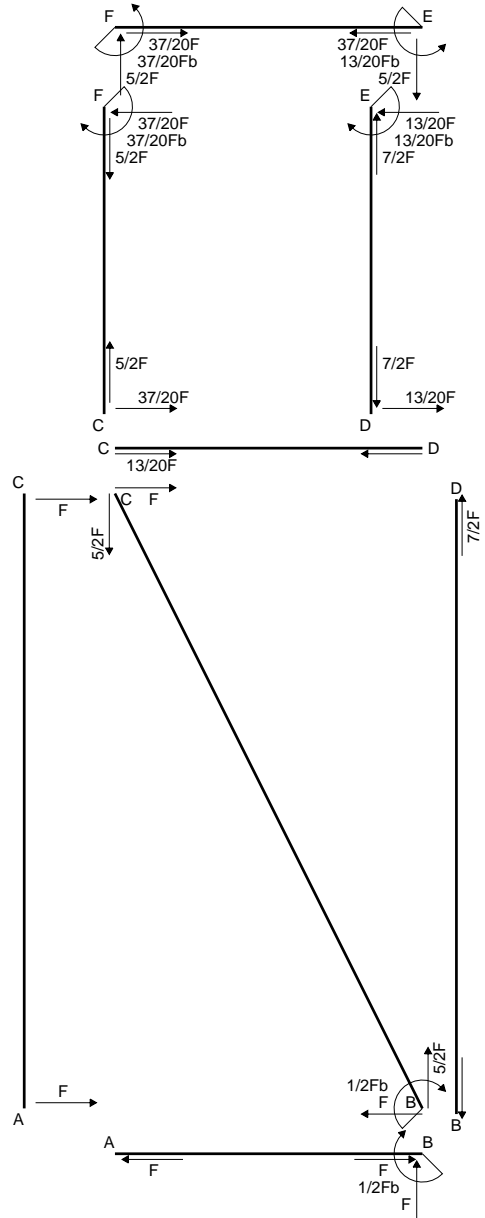
$$L_{CF}^{x_0} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

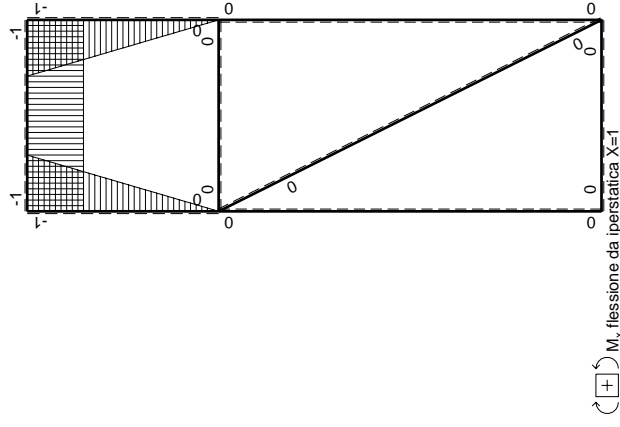
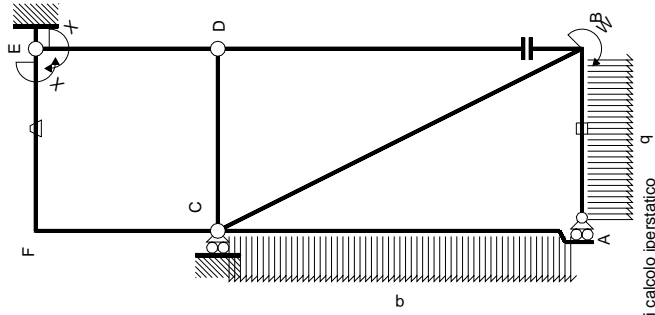
$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$



- A = 726. mm<sup>2</sup>
- J<sub>u</sub> = 174301. mm<sup>4</sup>
- J<sub>v</sub> = 68706. mm<sup>4</sup>
- y<sub>g</sub> = 15.5 mm
- N = -4602. N
- T<sub>y</sub> = -657.4 N
- M<sub>x</sub> = 852600. 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
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = -199.6 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>u</sub> = -116.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.988 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 116.4 N/mm<sup>2</sup>
- S = 3162. mm<sup>3</sup>







Quadro contributi PLV per iperstatica  $X=W^{EP}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M M_0$	$M \theta$	$M M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	0	$-1/2qx^2$	0	0	0	0	0	0
BA b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$1/2Fb-\sqrt{5}/10Fx$	0	0	0	0	0	0
AC 2b	0	$-Fx+1/2qx^2$	0	0	0	0	0	0
CA 2b	0	$Fx-1/2qx^2$	0	0	0	0	0	0
DB 2b	0	0	0	0	0	0	0	0
BD 2b	0	0	0	0	0	0	0	0
DE b	$-x/b$	0	0	0	0	$x^2/b^2$	0	0
ED b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0	0
CD b	0	0	0	0	0	0	0	0
DC b	0	0	0	0	0	0	0	0
EF b	-1	$5/2Fx$	$-Fb/EJ$	$-5/2Fx$	$Fb/EJ$	1	$(-5/4+1)Fb^2/EJ$	$Xb/EJ$
FE b	1	$-5/2Fb+5/2Fx$	$Fb/EJ$	$-5/2Fb+5/2Fx$	$Fb/EJ$	1	$(-5/4+1)Fb^2/EJ$	$Xb/EJ$
FC b	$-1+x/b$	$5/2Fb-5/2Fx$	0	$-5/2Fb+5Fx-5/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-5/6+0)Fb^2/EJ$	$1/3Xb/EJ$
CF b	$x/b$	$-5/2Fx$	0	$-5/2Fx^2/b$	0	$x^2/b^2$	$-13/12Fb^2/EJ$	$5/3Xb/EJ$
totali								
iperstatica $X=W^{EP}$								

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-5/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-5/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-5/4 b) Fb 1/EJ + (b) \theta = -1/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-5/2 + 5/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-5/2 x + 5/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

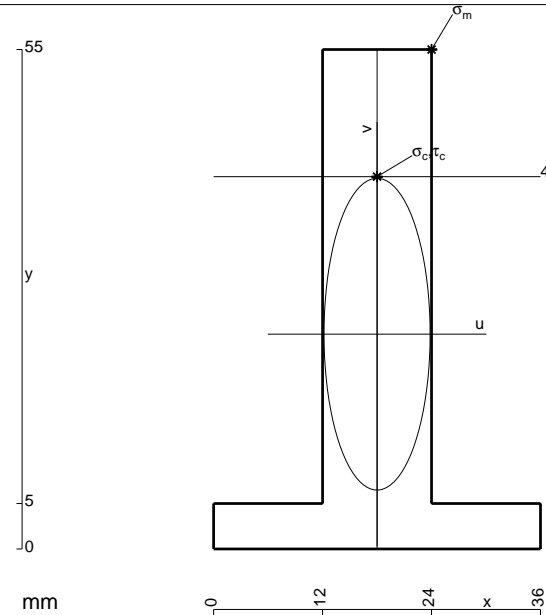
$$= (-5/2 b + 5/4 b) Fb 1/EJ + (-b) \theta = -1/4 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = [-5/2 x + 5/2 x^2/b - 5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

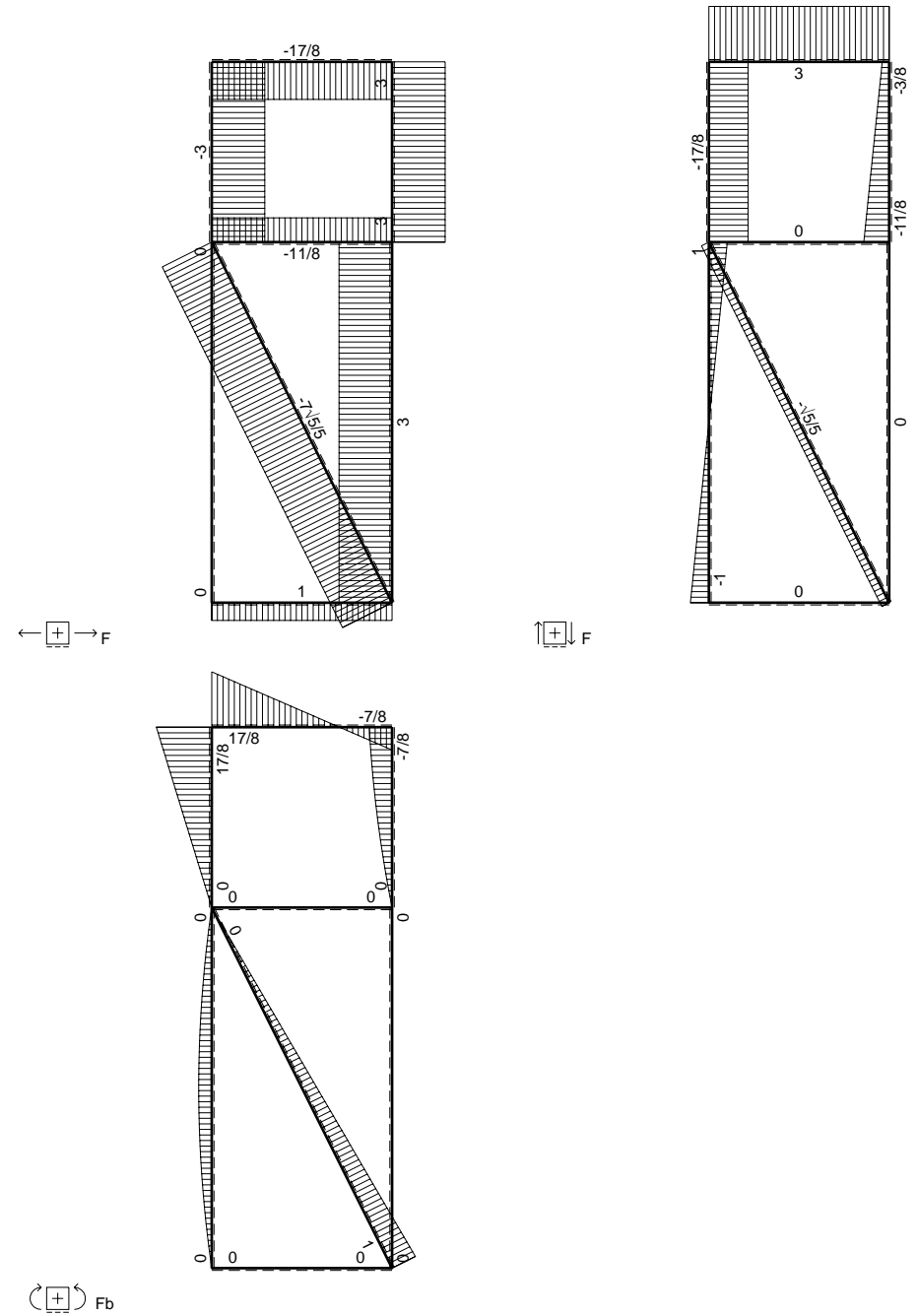
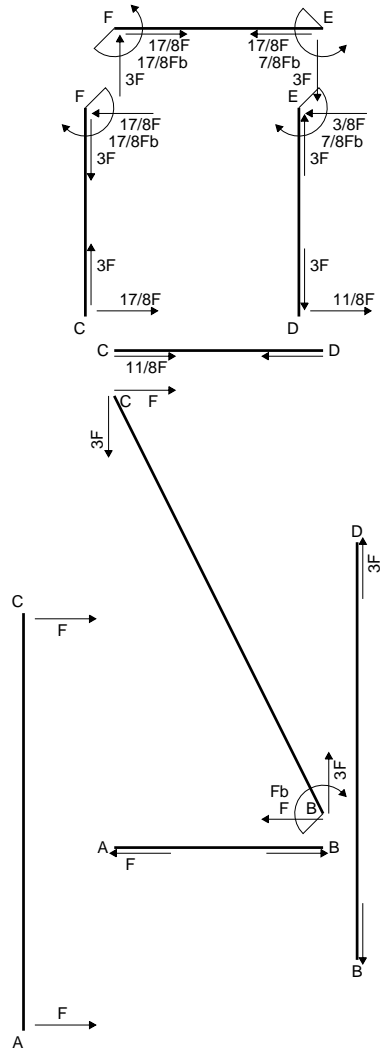
$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

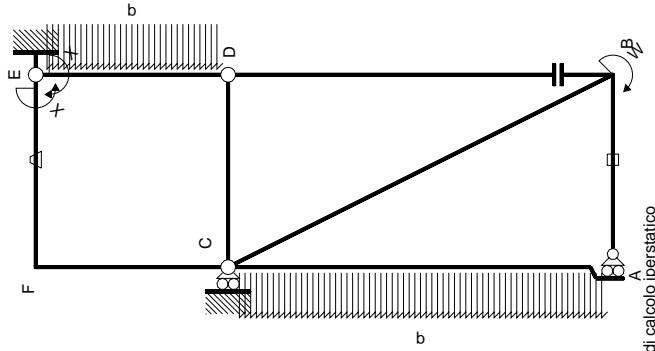


- A = 780. mm<sup>2</sup>
- J<sub>u</sub> = 230087. mm<sup>4</sup>
- J<sub>v</sub> = 26640. mm<sup>4</sup>
- y<sub>g</sub> = 23.65 mm
- N = 4820. N
- T<sub>y</sub> = -4820. N
- M<sub>x</sub> = -1494200. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 55. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 31.35 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = 209.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 41. mm
- v<sub>c</sub> = 17.35 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = 118.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.14 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 119.5 N/mm<sup>2</sup>
- S = 4090. mm<sup>3</sup>

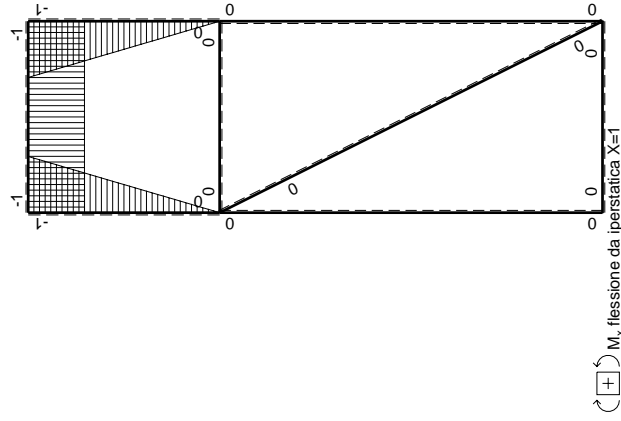








$M_0$  flessione da carichi assegnati



Quadro contributi PLV per iperstatica  $X=W_{EF}$

$\leftarrow$	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x (M_0/EJ + \theta) dx$	$\int M^x M_x / EJ dx$
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$Fb - \sqrt{5}/5Fx$	0	0	0	0	0+0	0
CA 2b	0	$-Fx + 1/2qx^2$	0	0	0	0	0+0	0
CA 2b	0	$Fx - 1/2qx^2$	0	0	0	0	0+0	0
DB 2b	0	0	0	0	0	0	0+0	0
BD 2b	0	0	0	0	0	0	0+0	0
DE b	$-x/b$	$-1/2Fx + 1/2qx^2$	0	$1/2Fx^2/b - 1/2qx^3/b$	0	0	$x^2/b^2$	$1/3Xb/EJ$
ED b	$1-x/b$	$1/2Fx - 1/2qx^2$	0	$1/2Fx - Fx^2/b + 1/2qx^3/b$	0	0	$1-2x/b+x^2/b^2$	$1/3Xb/EJ$
CD b	0	0	0	0	0	0	0+0	0
DC b	0	0	0	0	0	0	0+0	0
EF b	-1	$3Fx$	$-Fb/EJ$	$-3Fx$	$Fb/EJ$	1	$(-3/2+1)Fb^2/EJ$	$Xb/EJ$
FE b	1	$-3Fb+3Fx$	$Fb/EJ$	$-3Fb+3Fx$	$Fb/EJ$	1	$(-3/2+1)Fb^2/EJ$	$Xb/EJ$
FC b	$-1+x/b$	$3Fb-3Fx$	0	$-3Fb+6Fx-3Fx^2/b$	0	0	$1-2x/b+x^2/b^2$	$(-1+0)Fb^2/EJ$
CF b	$x/b$	$-3Fx$	0	$-3Fx^2/b$	0	0	$x^2/b^2$	$1/3Xb/EJ$
totali							$-35/24Fb^2/EJ$	$5/3Xb/EJ$
							$7/8Fb$	

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-3x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-3/2 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-3/2 b) Fb 1/EJ + (b) \theta = -1/2 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-3 + 3x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-3x + 3/2 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

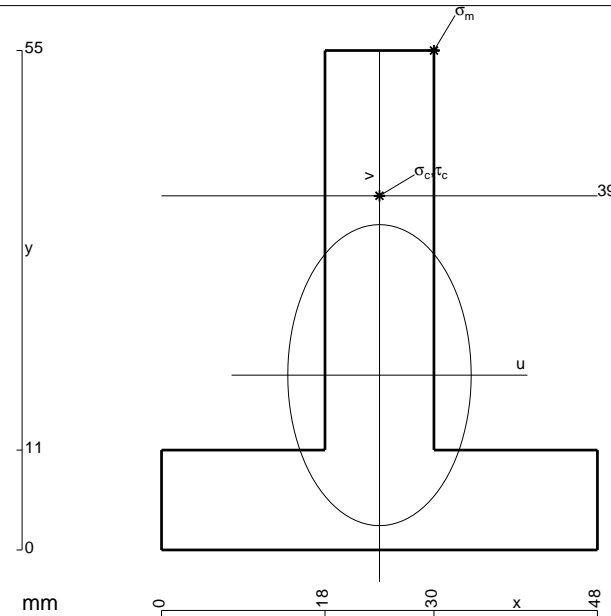
$$= (-3b + 3/2 b) Fb 1/EJ + (-b) \theta = -1/2 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-3 + 6x/b - 3x^2/b^2) Fb 1/EJ dx = [-3x + 3x^2/b - x^3/b^2]_0^b Fb 1/EJ$$

$$= (-3b + 3b - b) Fb 1/EJ = - Fb^2/EJ$$

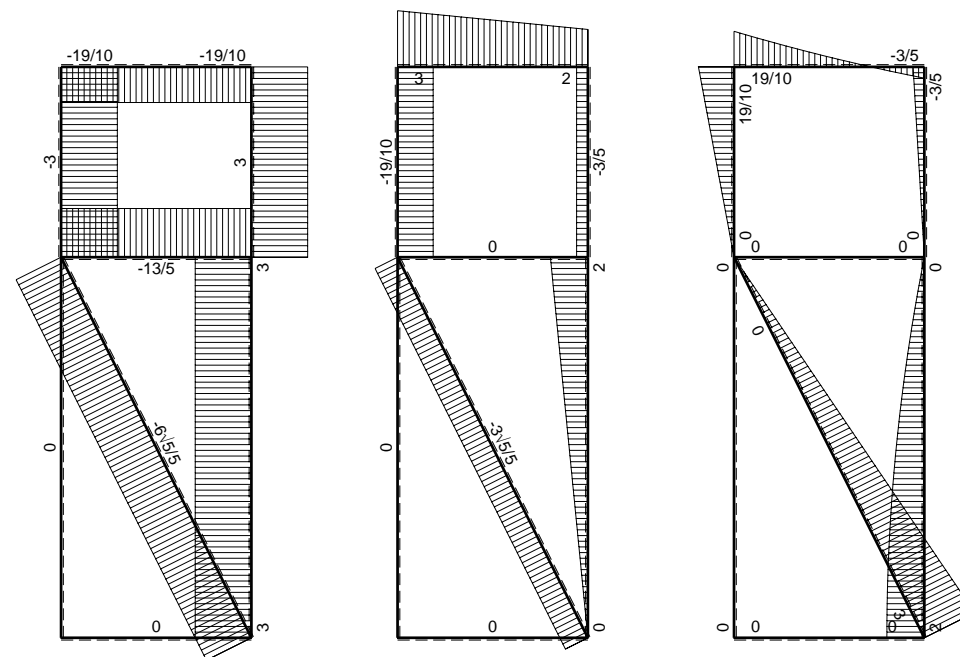
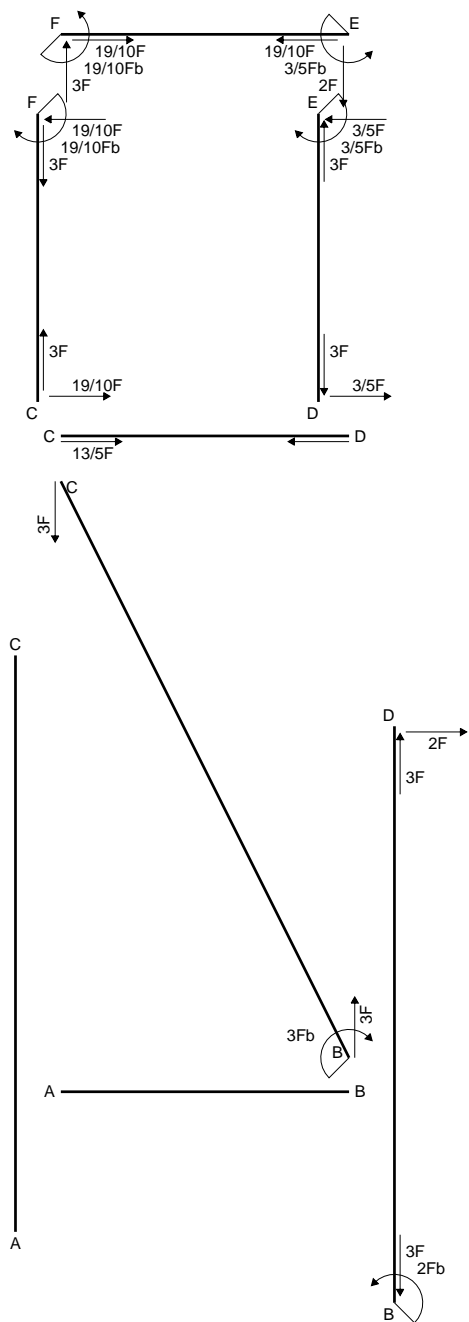
$$L_{CF}^{xo} = \int_0^b (-3x^2/b^2) Fb 1/EJ dx = [-x^3/b^2]_0^b Fb 1/EJ$$

$$= (-b) Fb 1/EJ = - Fb^2/EJ$$



- 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
- N = -8171. N
- T<sub>y</sub> = -1167. N
- M<sub>x</sub> = 1722600. 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> = N/A-Mv/J<sub>u</sub> = -220. N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 39. mm
- v<sub>c</sub> = 19.75 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>v</sub> = -125. N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.786 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 125. N/mm<sup>2</sup>
- S = 5328. mm<sup>3</sup>





← ⊕ → F

↑ ⊕ ↓ F

⊕ ⊖ F<sub>b</sub>



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-2x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-b - 1/6 b) Fb 1/EJ + (b) \theta = -1/6 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-5/2 + 3x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx$$

$$= [-5/2 x + 3/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

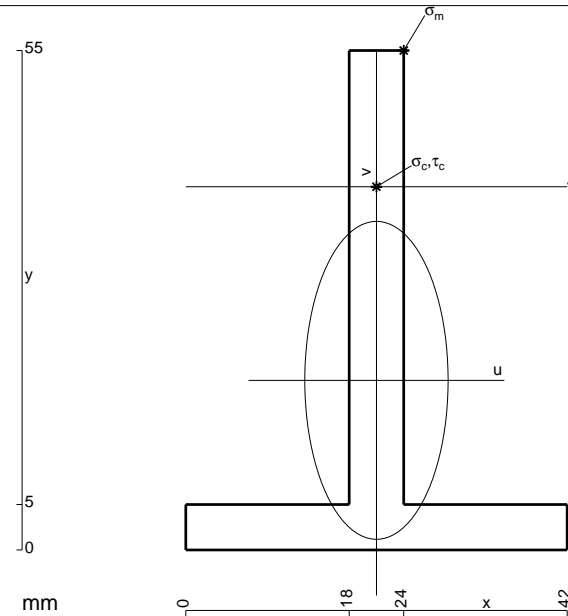
$$= (-5/2 b + 3/2 b - 1/6 b) Fb 1/EJ + (-b) \theta = -1/6 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = [-5/2 x + 5/2 x^2/b - 5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

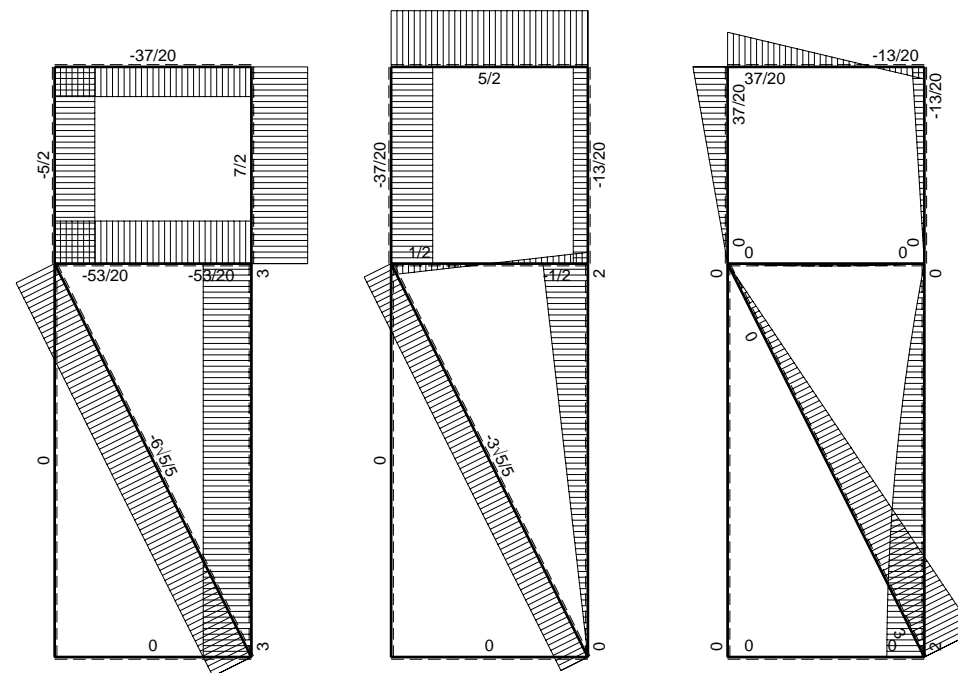
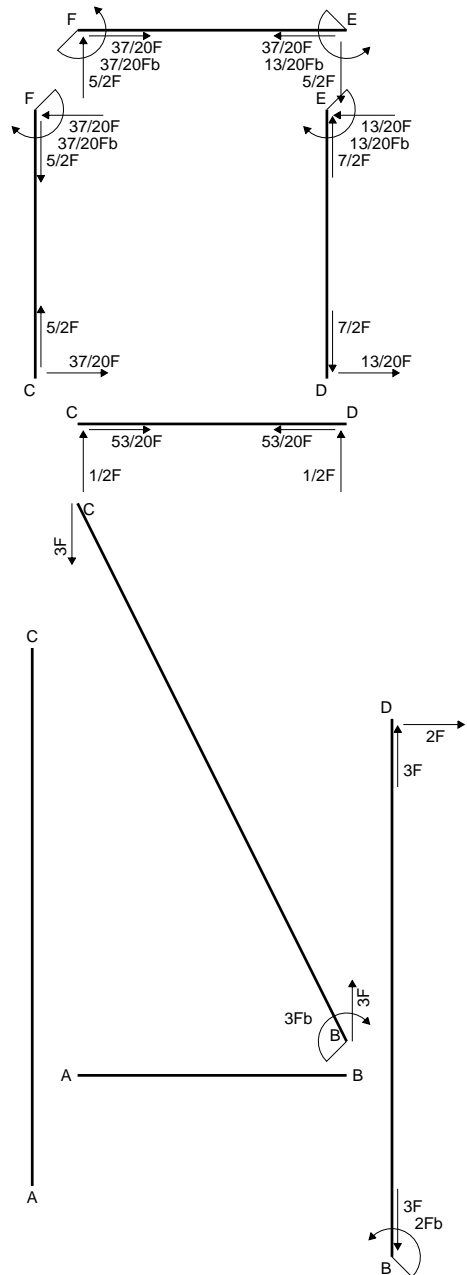
$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$



- A = 510. mm<sup>2</sup>
- J<sub>u</sub> = 156357. mm<sup>4</sup>
- J<sub>v</sub> = 31770. mm<sup>4</sup>
- y<sub>g</sub> = 18.68 mm
- N = -1234. N
- T<sub>y</sub> = -617.2 N
- M<sub>x</sub> = 966000. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 55. mm
- u<sub>m</sub> = 3. mm
- v<sub>m</sub> = 36.32 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = -226.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 40. mm
- v<sub>c</sub> = 21.32 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = -134.2 N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.707 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 = 2594. mm<sup>3</sup>



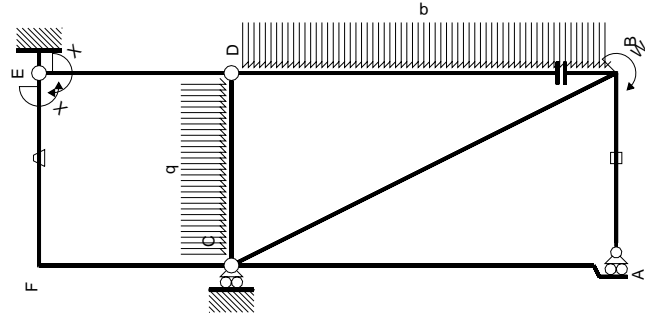




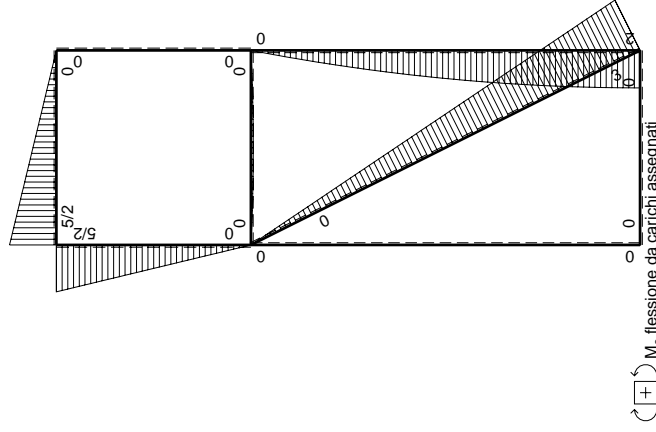
← ⊕ → F

⊕ F

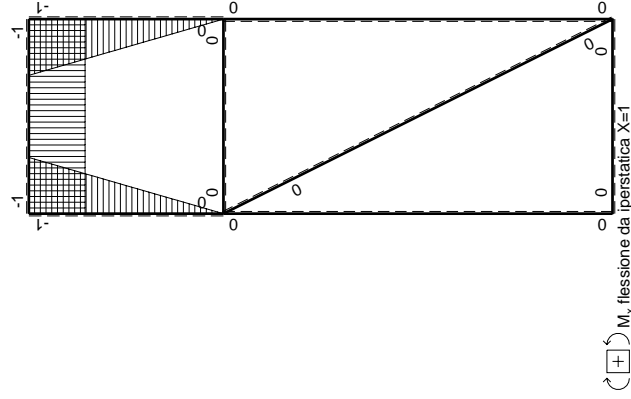
⊕ F<sub>b</sub>



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>EP</sup>

←	M <sup>x</sup> (x)	M <sup>0</sup> (x)	θ	M <sup>x</sup> M <sup>0</sup>	M <sup>x</sup> θ	M <sup>x</sup> M <sup>x</sup>	∫M <sup>x</sup> (M <sup>0</sup> /EJ+θ)dx	∫M <sup>x</sup> M <sup>x</sup> /EJdx
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0	0
BC √5b	0	3Fb-3√5/5Fx	0	0	0	0	0	0
AC 2b	0	0	0	0	0	0	0+0	0
CA 2b	0	0	0	0	0	0	0	0
DB 2b	0	2Fx-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
BD 2b	0	-2Fb+1/2qx <sup>2</sup>	0	0	0	0	0	0
DE b	-x/b	0	0	0	0	x <sup>2</sup> /b <sup>2</sup>	0+0	1/3xb/EJ
ED b	1-x/b	0	0	0	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	0+0	1/3xb/EJ
CD b	0	1/2Fx-1/2qx <sup>2</sup>	0	0	0	0	0	0
DC b	0	-1/2Fx+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
EF b	-1	5/2Fx	-Fb/EJ	-5/2Fx	Fb/EJ	1	(-5/4+1)Fb <sup>2</sup> /EJ	Xb/EJ
FE b	1	-5/2Fb+5/2Fx	Fb/EJ	-5/2Fb+5/2Fx	Fb/EJ	1	(-5/4+1)Fb <sup>2</sup> /EJ	Xb/EJ
FC b	-1+x/b	5/2Fb-5/2Fx	0	-5/2Fb+5Fx-5/2Fx <sup>2</sup> /b	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	(-5/6+0)Fb <sup>2</sup> /EJ	1/3xb/EJ
CF b	x/b	-5/2Fx	0	-5/2Fx <sup>2</sup> /b	0	x <sup>2</sup> /b <sup>2</sup>	-13/12Fb <sup>2</sup> /EJ	5/3xb/EJ
totali								
iperstatica X=W <sup>EP</sup>		13/20Fb						

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-5/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-5/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-5/4 b) Fb 1/EJ + (b) \theta = -1/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-5/2 + 5/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-5/2 x + 5/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

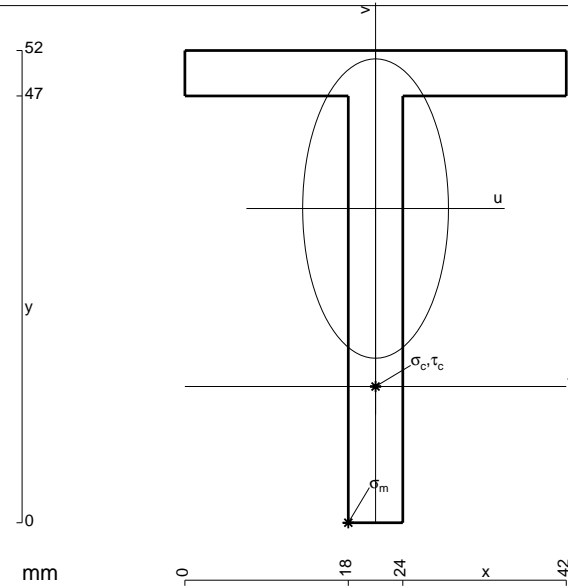
$$= (-5/2 b + 5/4 b) Fb 1/EJ + (-b) \theta = -1/4 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = [-5/2 x + 5/2 x^2/b - 5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

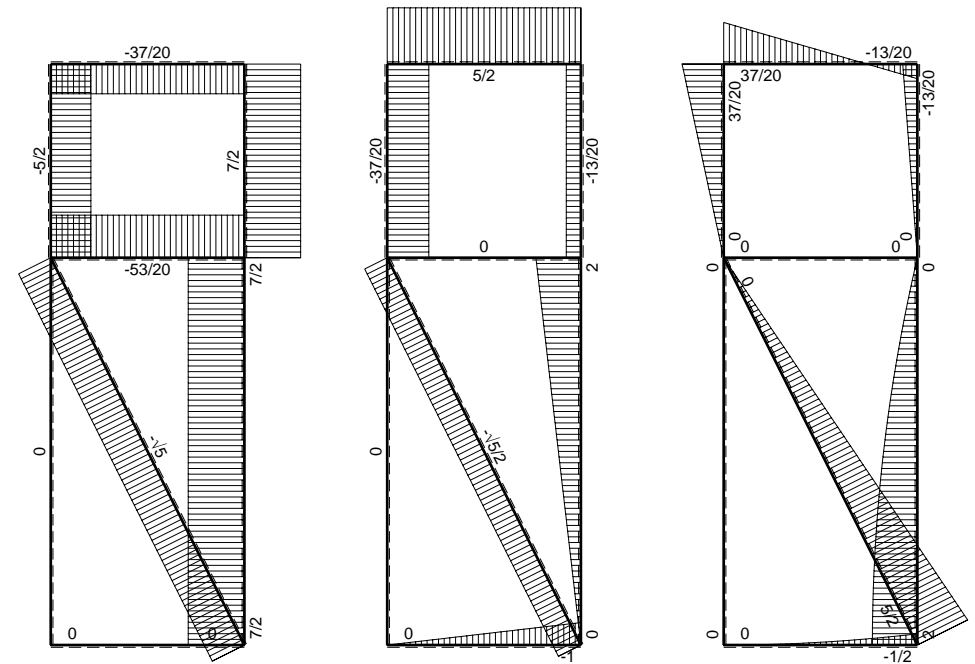
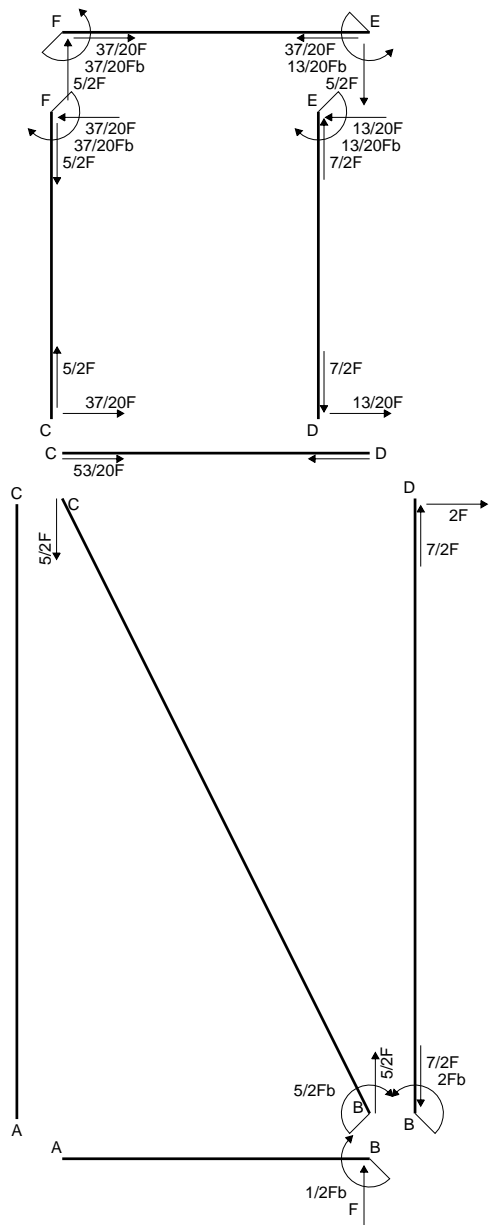
$$L_{CF}^{xo} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

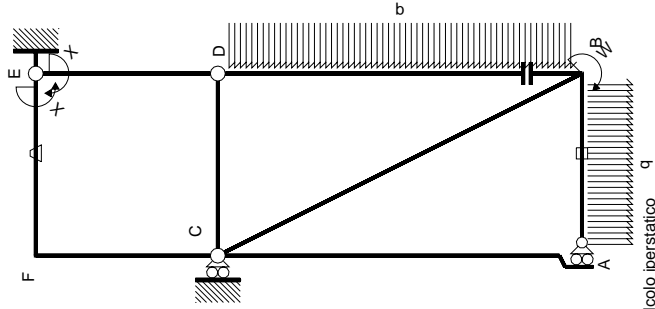
$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$



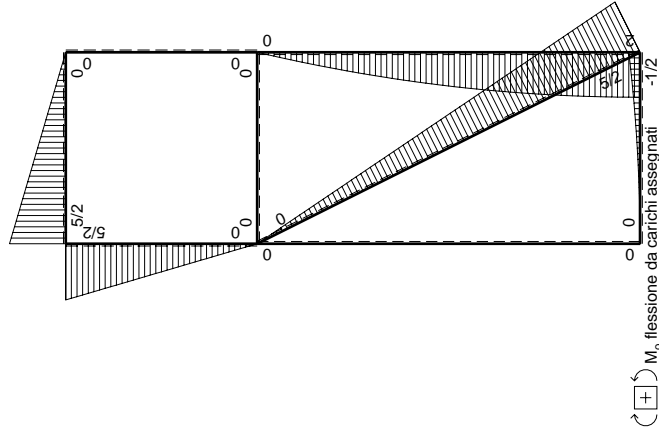
- A = 492. mm<sup>2</sup>
- J<sub>u</sub> = 133716. mm<sup>4</sup>
- J<sub>v</sub> = 31716. mm<sup>4</sup>
- y<sub>g</sub> = 34.6 mm
- N = -1181. N
- T<sub>y</sub> = -590.3 N
- M<sub>x</sub> = 924000. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -34.6 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = 236.7 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> = N/A - Mv/J<sub>u</sub> = 133. N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.794 N/mm<sup>2</sup>
- σ<sub>ρ</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 133.1 N/mm<sup>2</sup>
- S = 2439. mm<sup>3</sup>



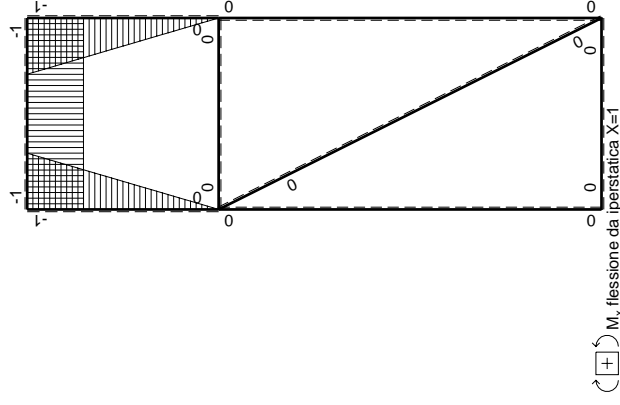




Schema di calcolo iperstatico q



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contributi PLV per iperstatica X=W<sup>EP</sup>

→	M <sup>x</sup> (x)	M <sup>0</sup> (x)	θ	M <sup>x</sup> M <sup>0</sup>	M <sup>x</sup> θ	M <sup>x</sup> M <sup>x</sup>	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJdx$
AB b	0	-1/2qx <sup>2</sup>	0	0	0	0	0	0
BA b	0	1/2Fb-Fx+1/2qx <sup>2</sup>	0	0	0	0	0	0
BC √5b	0	5/2Fb-√5/2Fx	0	0	0	0	0	0
CA 2b	0	0	0	0	0	0	0	0
AC 2b	0	0	0	0	0	0	0	0
DB 2b	0	2Fx-1/2qx <sup>2</sup>	0	0	0	0	0	0
BD 2b	0	-2Fb+1/2qx <sup>2</sup>	0	0	0	0	0	0
DE b	-x/b	0	0	0	0	x <sup>2</sup> /b <sup>2</sup>	0	1/3xb/EJ
ED b	1-x/b	0	0	0	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	0	1/3xb/EJ
CD b	0	0	0	0	0	0	0	0
DC b	0	0	0	0	0	0	0	0
EF b	-1	5/2Fx	-Fb/EJ	-5/2Fx	Fb/EJ	1	(-5/4+1)Fb <sup>2</sup> /EJ	Xb/EJ
FE b	1	-5/2Fb+5/2Fx	Fb/EJ	-5/2Fb+5/2Fx	Fb/EJ	1	(-5/4+1)Fb <sup>2</sup> /EJ	Xb/EJ
FC b	-1+x/b	5/2Fb-5/2Fx	0	-5/2Fb+5Fx-5/2Fx <sup>2</sup> /b	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	(-5/6+0)Fb <sup>2</sup> /EJ	1/3xb/EJ
CF b	x/b	-5/2Fx	0	-5/2Fx <sup>2</sup> /b	0	x <sup>2</sup> /b <sup>2</sup>	(-5/6+0)Fb <sup>2</sup> /EJ	1/3xb/EJ
totali							-13/12Fb <sup>2</sup> /EJ	5/3xb/EJ
								13/20Fb

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{x\theta} = \int_0^b (-5/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-5/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-5/4 b) Fb 1/EJ + (b) \theta = -1/4 Fb^2/EJ$$

$$L_{FE}^{x\theta} = \int_0^b (-5/2 + 5/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-5/2 x + 5/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

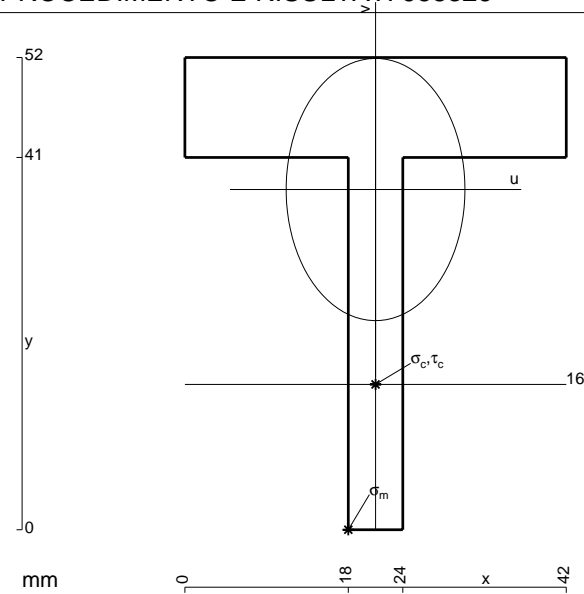
$$= (-5/2 b + 5/4 b) Fb 1/EJ + (-b) \theta = -1/4 Fb^2/EJ$$

$$L_{FC}^{x\theta} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = [-5/2 x + 5/2 x^2/b - 5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

$$L_{CF}^{x\theta} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$



$$A = 708. \text{ mm}^2$$

$$J_u = 147634. \text{ mm}^4$$

$$J_v = 68652. \text{ mm}^4$$

$$y_g = 37.47 \text{ mm}$$

$$N = -1923. \text{ N}$$

$$T_y = -961.5 \text{ N}$$

$$M_x = 795500. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -37.47 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 199.2 \text{ N/mm}^2$$

$$x_c = 21. \text{ mm}$$

$$y_c = 16. \text{ mm}$$

$$v_c = -21.47 \text{ mm}$$

$$\sigma_c = N/A - Mv/J_u = 112.9 \text{ N/mm}^2$$

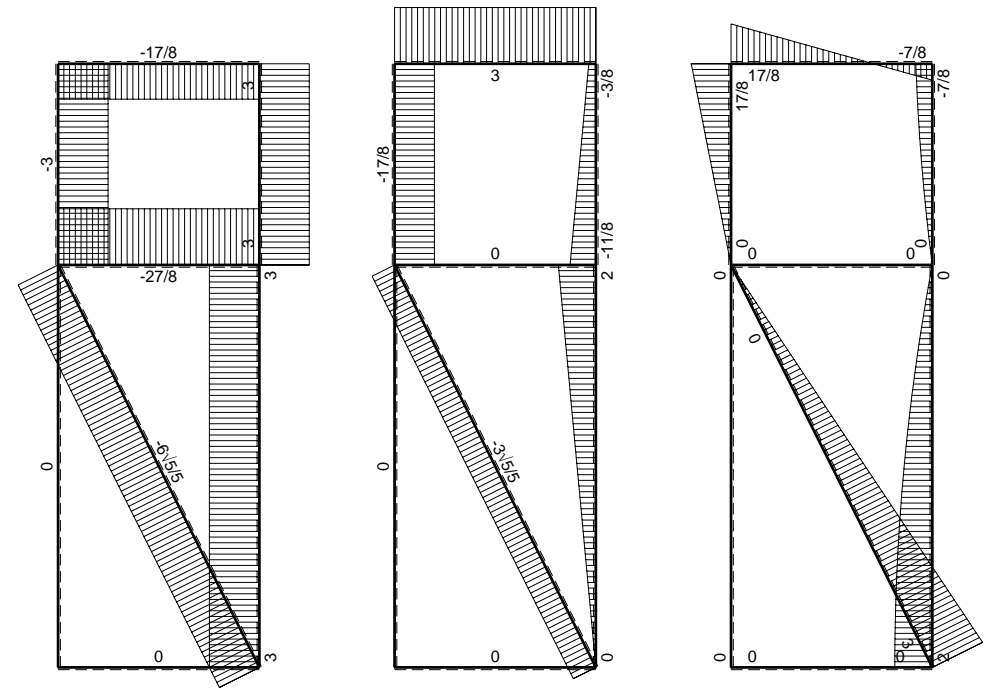
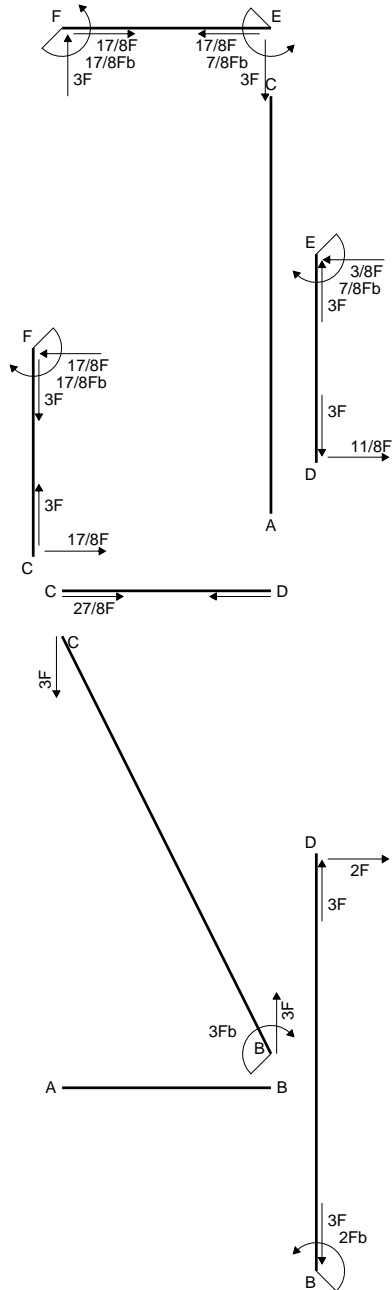
$$\tau_c = 3.07 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 113.1 \text{ N/mm}^2$$

$$S = 2829. \text{ mm}^3$$



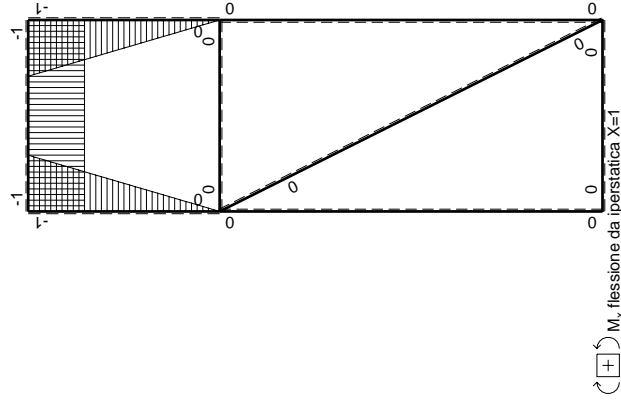
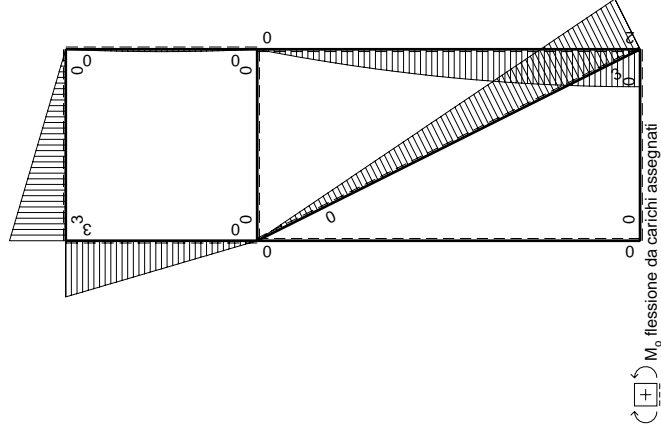
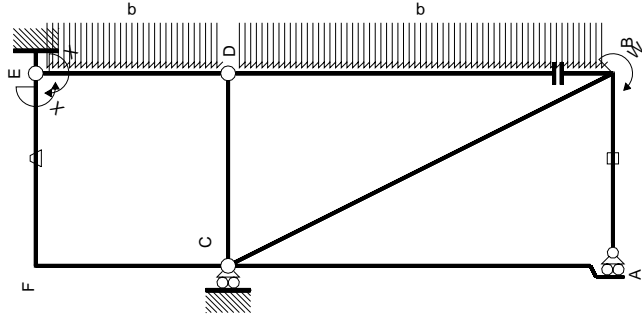




← ⊕ → F

↑ ⊕ ↓ F

⊕ ⊖ F<sub>b</sub>



Quadro contributi PLV per iperstatica  $X=W_{EF}$

$\leftarrow$	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x(M_0/EJ+\theta)dx$	$\int M^x M_x/EJdx$
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$3Fb-3\sqrt{5}/5Fx$	0	0	0	0	0+0	0
AC 2b	0	0	0	0	0	0	0+0	0
CA 2b	0	0	0	0	0	0	0+0	0
DB 2b	0	$2Fx-1/2qx^2$	0	0	0	0	0+0	0
BD 2b	0	$-2Fb+1/2qx^2$	0	0	0	0	0+0	0
DE b	$-x/b$	$-1/2Fx+1/2qx^2$	0	$1/2Fx^2/b-1/2qx^3/b$	0	0	$x^2/b^2$	$1/3Xb/EJ$
ED b	$1-x/b$	$1/2Fx-1/2qx^2$	0	$1/2Fx-Fx^2/b+1/2qx^3/b$	0	0	$1-2x/b+x^2/b^2$	$1/3Xb/EJ$
CD b	0	0	0	0	0	0	0+0	0
DC b	0	0	0	0	0	0	0+0	0
EF b	-1	$3Fx$	$-Fb/EJ$	$-3Fx$	$Fb/EJ$	1	$(-3/2+1)Fb^2/EJ$	$Xb/EJ$
FE b	1	$-3Fb+3Fx$	$Fb/EJ$	$-3Fb+3Fx$	$Fb/EJ$	1	$(-3/2+1)Fb^2/EJ$	$Xb/EJ$
FC b	$-1+x/b$	$3Fb-3Fx$	0	$-3Fb+6Fx-3Fx^2/b$	0	0	$1-2x/b+x^2/b^2$	$1/3Xb/EJ$
CF b	$x/b$	$-3Fx$	0	$-3Fx^2/b$	0	0	$x^2/b^2$	$1/3Xb/EJ$
totali							$-35/24Fb^2/EJ$	$5/3Xb/EJ$
							$7/8Fb$	

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-3x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-3/2 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-3/2 b) Fb 1/EJ + (b) \theta = -1/2 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-3 + 3x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-3x + 3/2 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

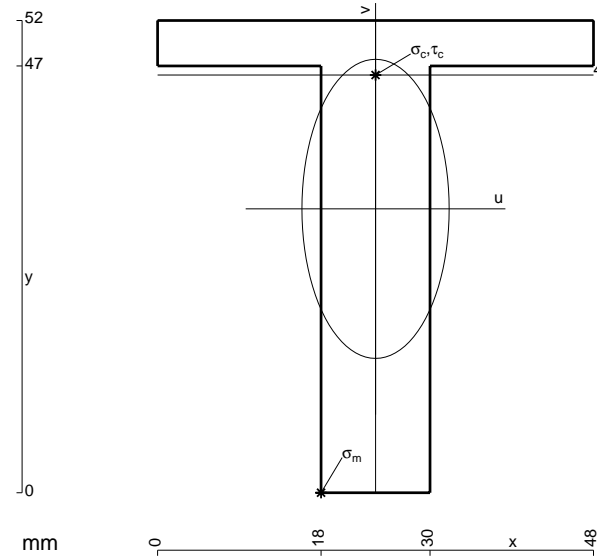
$$= (-3b + 3/2 b) Fb 1/EJ + (-b) \theta = -1/2 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-3 + 6x/b - 3x^2/b^2) Fb 1/EJ dx = [-3x + 3x^2/b - x^3/b^2]_0^b Fb 1/EJ$$

$$= (-3b + 3b - b) Fb 1/EJ = - Fb^2/EJ$$

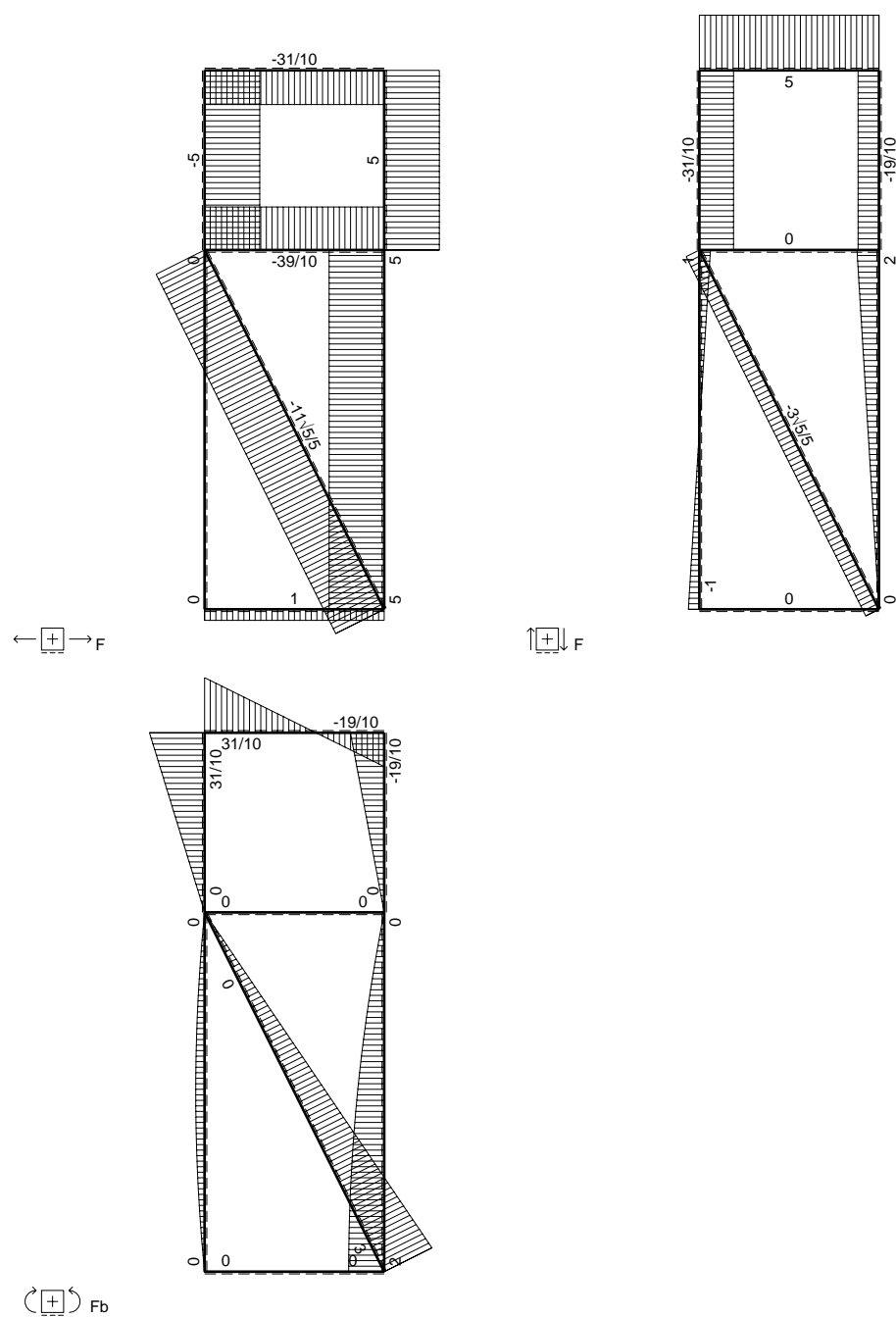
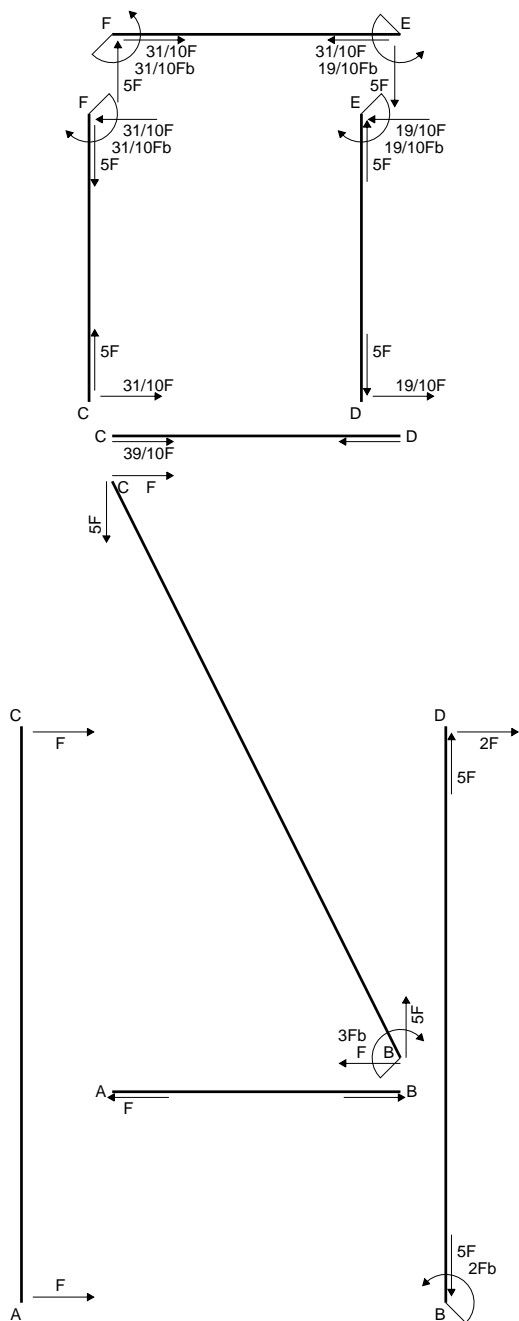
$$L_{CF}^{xo} = \int_0^b (-3x^2/b^2) Fb 1/EJ dx = [-x^3/b^2]_0^b Fb 1/EJ$$

$$= (-b) Fb 1/EJ = - Fb^2/EJ$$



- 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 = -3327. N
- T<sub>y</sub> = -1664. N
- M<sub>x</sub> = 1488000. 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> = 209.1 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 46. mm
- v<sub>c</sub> = 14.74 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = -104.7 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.898 N/mm<sup>2</sup>
- σ<sub>φ</sub> = √(σ<sup>2</sup>+3τ<sup>2</sup>) = 104.8 N/mm<sup>2</sup>
- S = 4560. mm<sup>3</sup>







$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-5x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-5/2 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-5/2 b) Fb 1/EJ + (b) \theta = -3/2 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-5 + 5x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-5x + 5/2 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

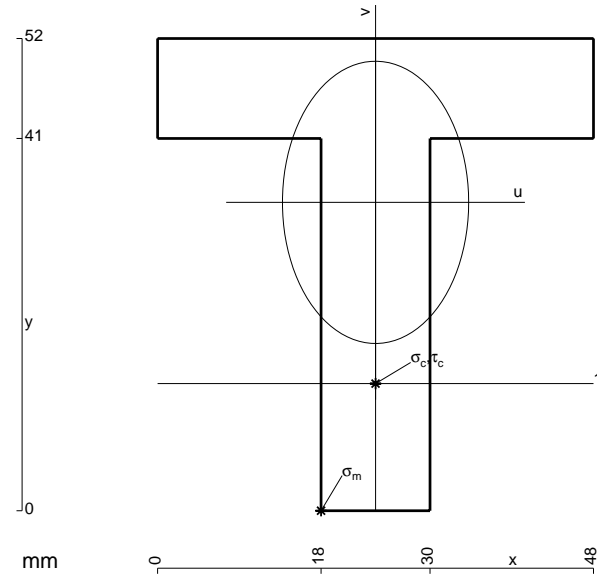
$$= (-5b + 5/2 b) Fb 1/EJ + (-b) \theta = -3/2 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-5 + 10x/b - 5x^2/b^2) Fb 1/EJ dx = [-5x + 5x^2/b - 5/3 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5b + 5b - 5/3 b) Fb 1/EJ = -5/3 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-5x^2/b^2) Fb 1/EJ dx = [-5/3 x^3/b^2]_0^b Fb 1/EJ$$

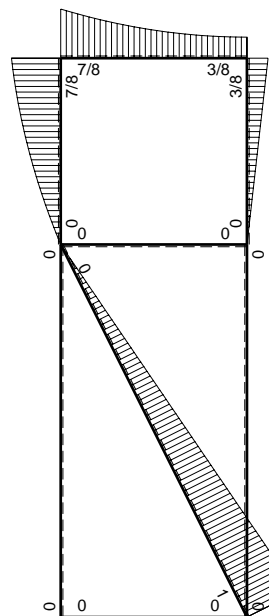
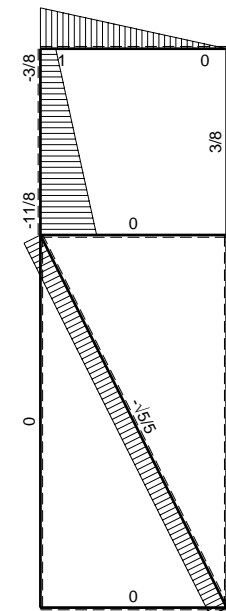
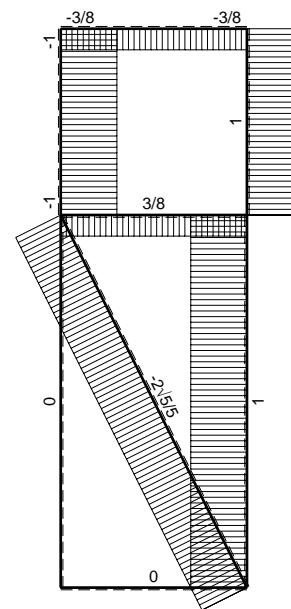
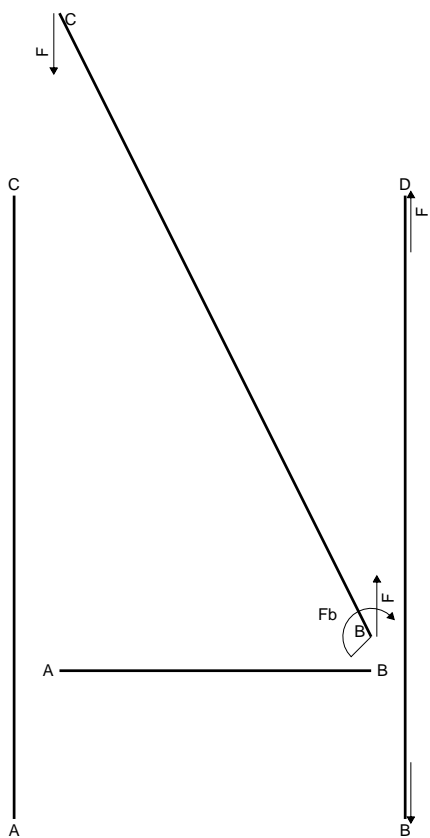
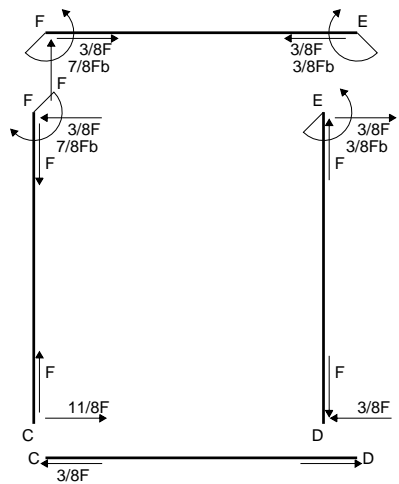
$$= (-5/3 b) Fb 1/EJ = -5/3 Fb^2/EJ$$



- 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 = -6100. N
- T<sub>y</sub> = -1664. N
- M<sub>x</sub> = 1636800. 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> = 219.6 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> = 126.6 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.548 N/mm<sup>2</sup>
- σ<sub>φ</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 126.7 N/mm<sup>2</sup>
- S = 4529. mm<sup>3</sup>







← ⊕ →  $F$

↑ ⊕ ↓  $F$

⊕  $F_b$



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (-2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/6 b) Fb 1/EJ + (b) \theta = 5/6 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx$$

$$= [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ + (-b) \theta = 5/6 Fb^2/EJ$$

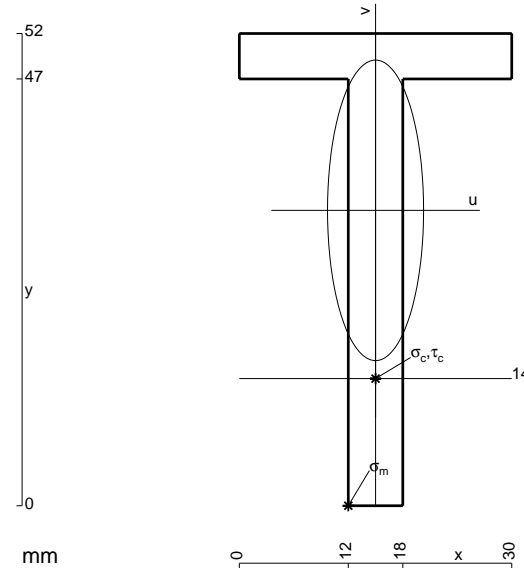
$$L_{FC}^{xo} = \int_0^b (-1/2 + 1/2 x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx$$

$$= [-1/2 x + 1/4 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/4 b + 1/6 b - 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$

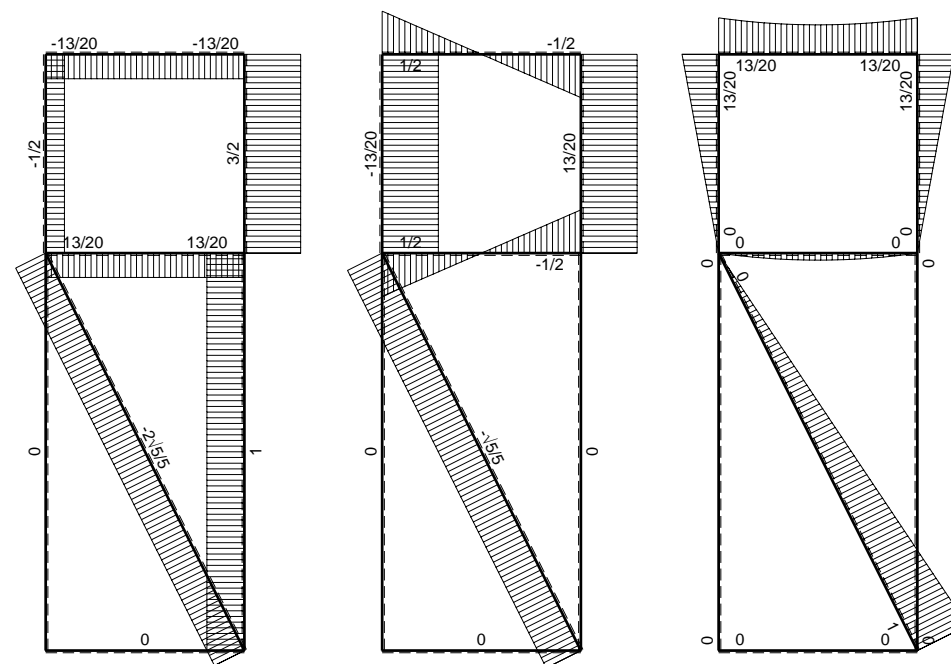
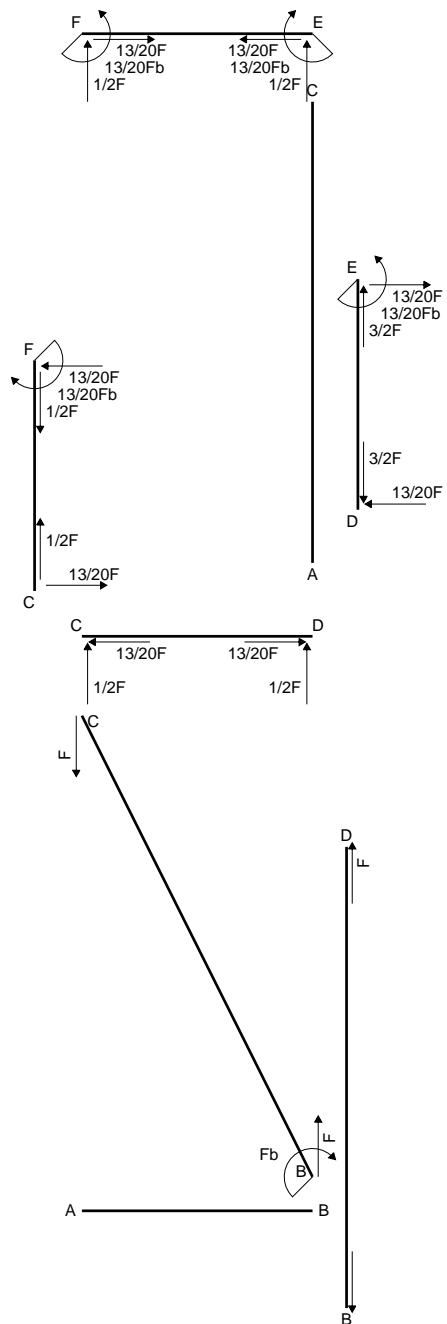
$$L_{CF}^{xo} = \int_0^b (-x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/3 b + 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$



- 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 = -1583. N
- T<sub>y</sub> = -791.6 N
- M<sub>x</sub> = 849600. 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> = 229.7 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> = 129.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.389 N/mm<sup>2</sup>
- σ<sub>φ</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 129.3 N/mm<sup>2</sup>
- S = 2144. mm<sup>3</sup>





← ⊕ → F

↑ ⊕ ↓ F

⊕ ⊖ F<sub>b</sub>



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

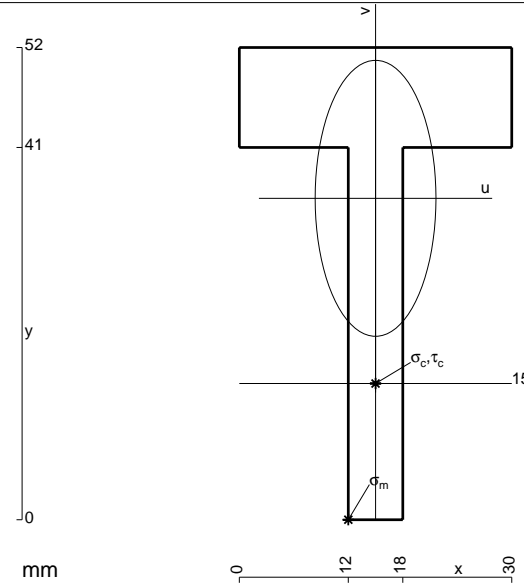
$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (1/4 b - 1/6 b) Fb 1/EJ + (b) \theta = 13/12 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

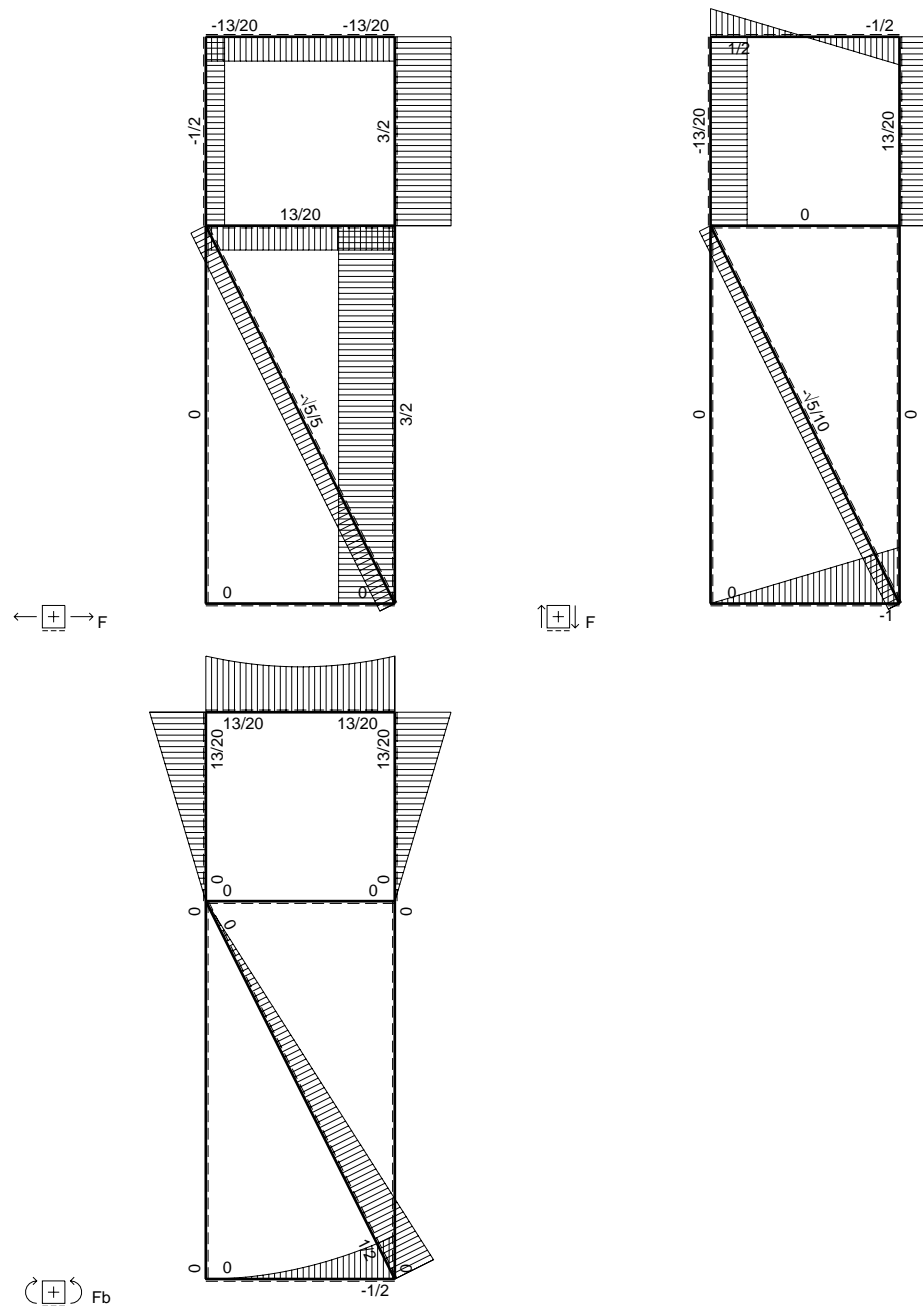
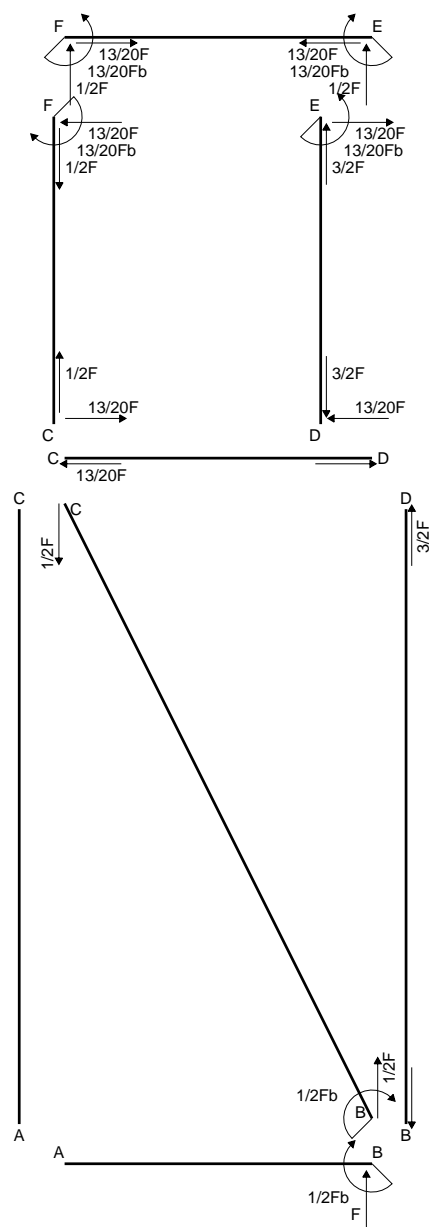
$$= (1/4 b - 1/6 b) Fb 1/EJ + (-b) \theta = 13/12 Fb^2/EJ$$



- 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 = -1592. N
- T<sub>y</sub> = -796. N
- M<sub>x</sub> = 907800. 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 - Mv/J<sub>u</sub> = 238.7 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 - Mv/J<sub>u</sub> = 136.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.503 N/mm<sup>2</sup>
- σ<sub>ρ</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 136.5 N/mm<sup>2</sup>
- S = 2511. mm<sup>3</sup>







⊕ F<sub>b</sub>



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

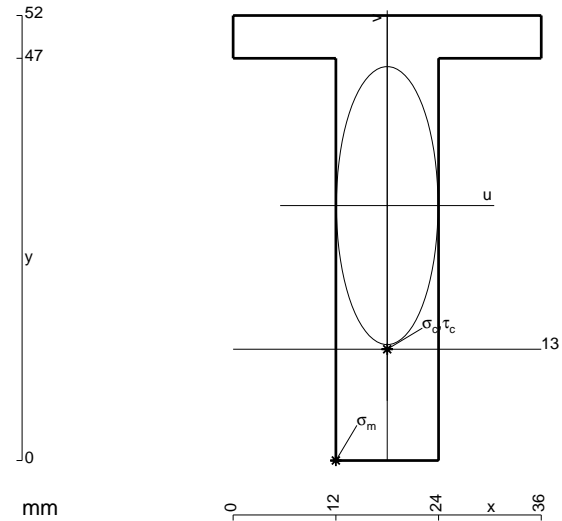
$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (1/4 b - 1/6 b) Fb 1/EJ + (b) \theta = 13/12 Fb^2/EJ$$

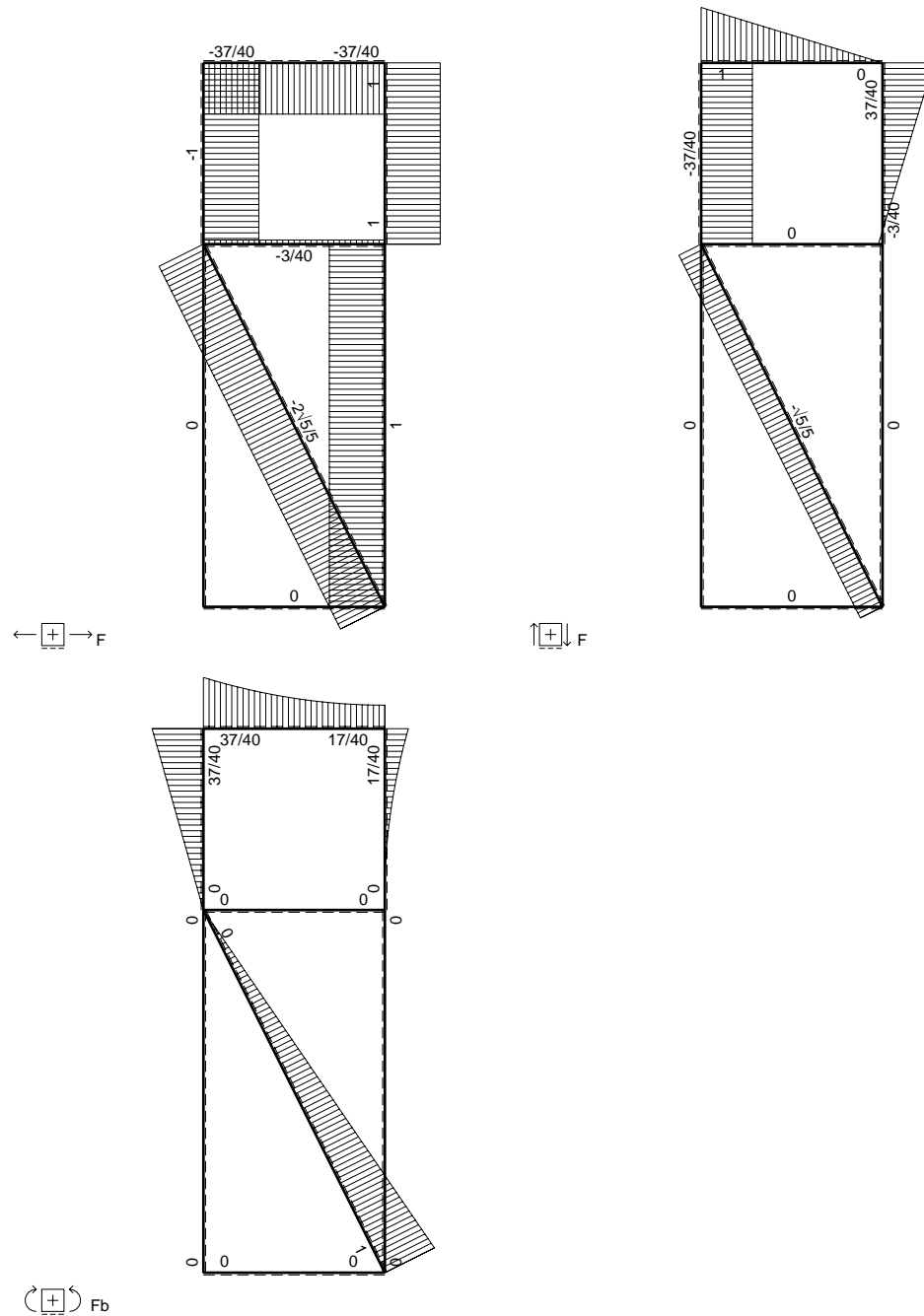
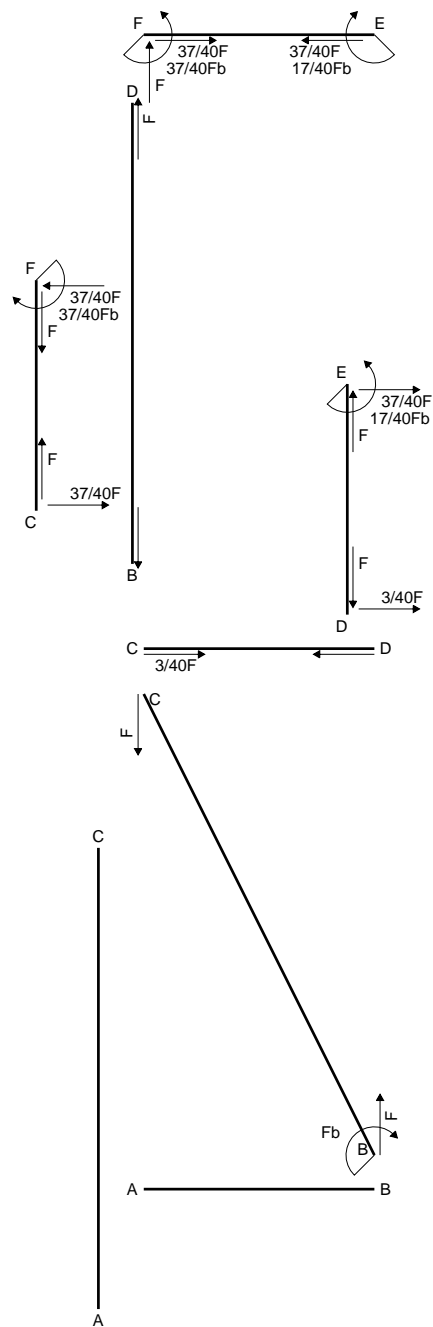
$$L_{FE}^{xo} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (1/4 b - 1/6 b) Fb 1/EJ + (-b) \theta = 13/12 Fb^2/EJ$$



- 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
- T<sub>y</sub> = -4790. N
- M<sub>x</sub> = -1317250. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -29.79 mm
- σ<sub>m</sub> = -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> = -Mv/J<sub>u</sub> = -112.6 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.383 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 113.3 N/mm<sup>2</sup>
- S = 3633. mm<sup>3</sup>







$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/6 b) Fb 1/EJ + (b) \theta = 5/6 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx$$

$$= [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

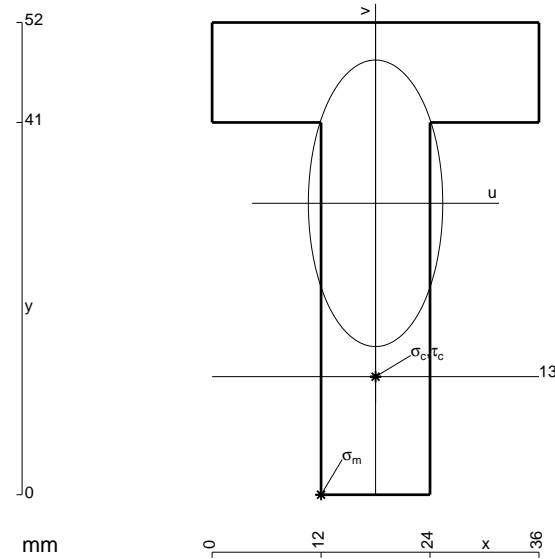
$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ + (-b) \theta = 5/6 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$



$$A = 888. \text{ mm}^2$$

$$J_u = 221232. \text{ mm}^4$$

$$J_v = 48672. \text{ mm}^4$$

$$y_g = 32.09 \text{ mm}$$

$$N = -2218. \text{ N}$$

$$T_y = -1109. \text{ N}$$

$$M_x = 1463200. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -6. \text{ mm}$$

$$v_m = -32.09 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 209.8 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 13. \text{ mm}$$

$$v_c = -19.09 \text{ mm}$$

$$\sigma_c = N/A - Mv/J_u = 123.8 \text{ N/mm}^2$$

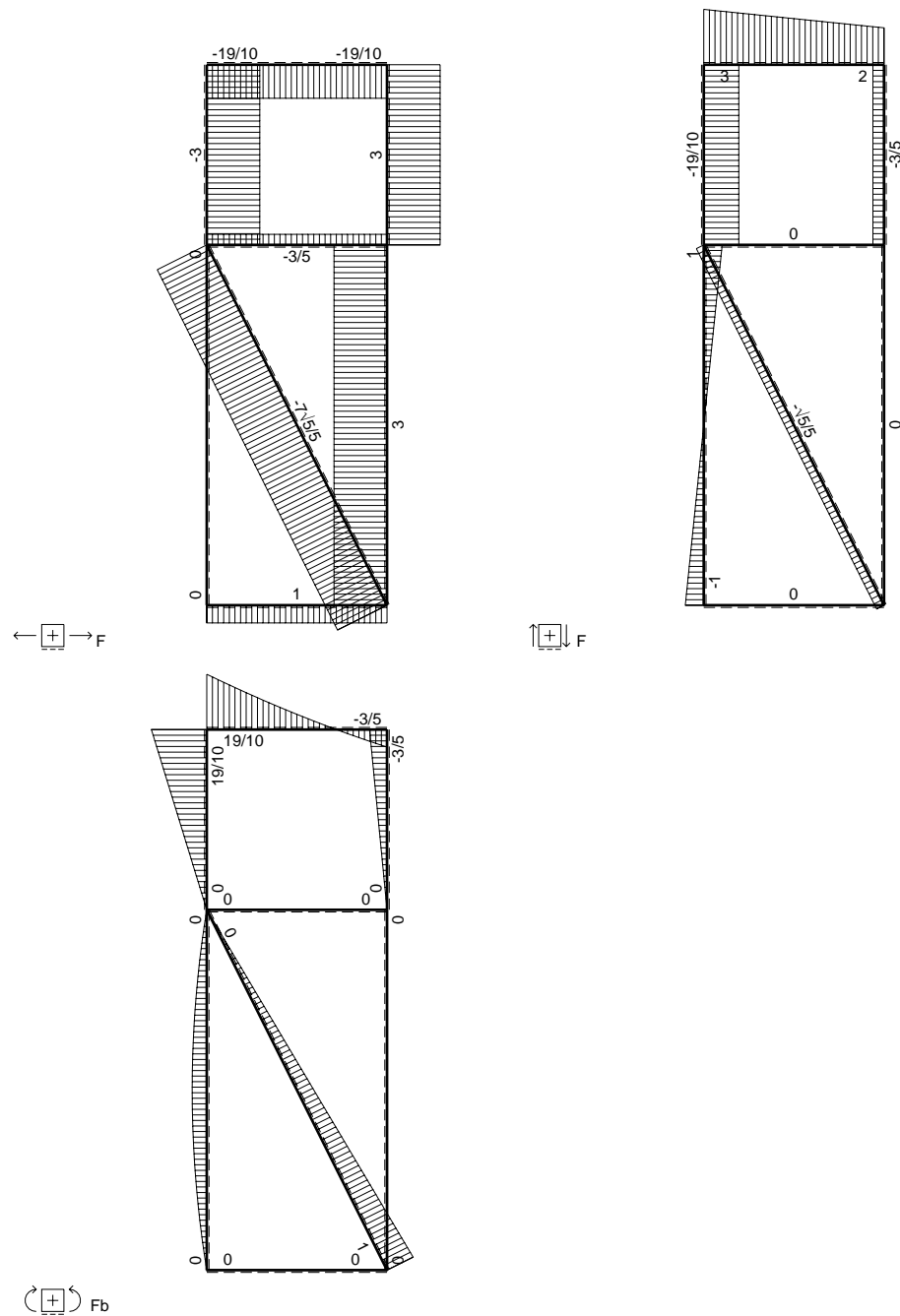
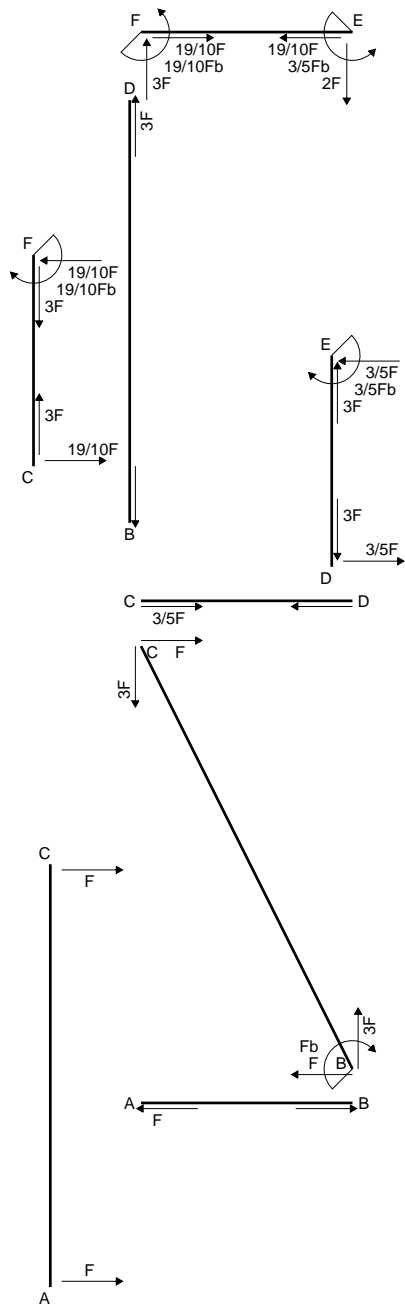
$$\tau_c = 1.668 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 123.8 \text{ N/mm}^2$$

$$S = 3993. \text{ mm}^3$$









$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-2x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-b - 1/6 b) Fb 1/EJ + (b) \theta = -1/6 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-5/2 + 3x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx$$

$$= [-5/2 x + 3/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

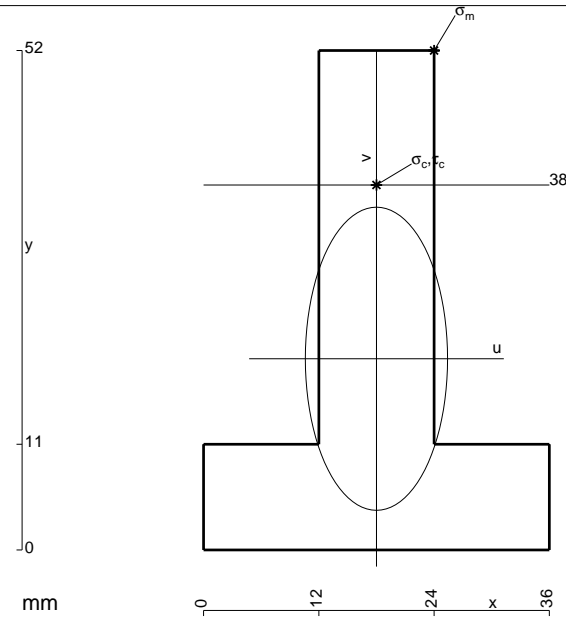
$$= (-5/2 b + 3/2 b - 1/6 b) Fb 1/EJ + (-b) \theta = -1/6 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = [-5/2 x + 5/2 x^2/b - 5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$



$$A = 888. \text{ mm}^2$$

$$J_u = 221232. \text{ mm}^4$$

$$J_v = 48672. \text{ mm}^4$$

$$y_g = 19.91 \text{ mm}$$

$$N = -7357. \text{ N}$$

$$T_y = -1051. \text{ N}$$

$$M_x = 1457000. \text{ Nmm}$$

$$x_m = 24. \text{ mm}$$

$$y_m = 52. \text{ mm}$$

$$u_m = 6. \text{ mm}$$

$$v_m = 32.09 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -219.7 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 38. \text{ mm}$$

$$v_c = 18.09 \text{ mm}$$

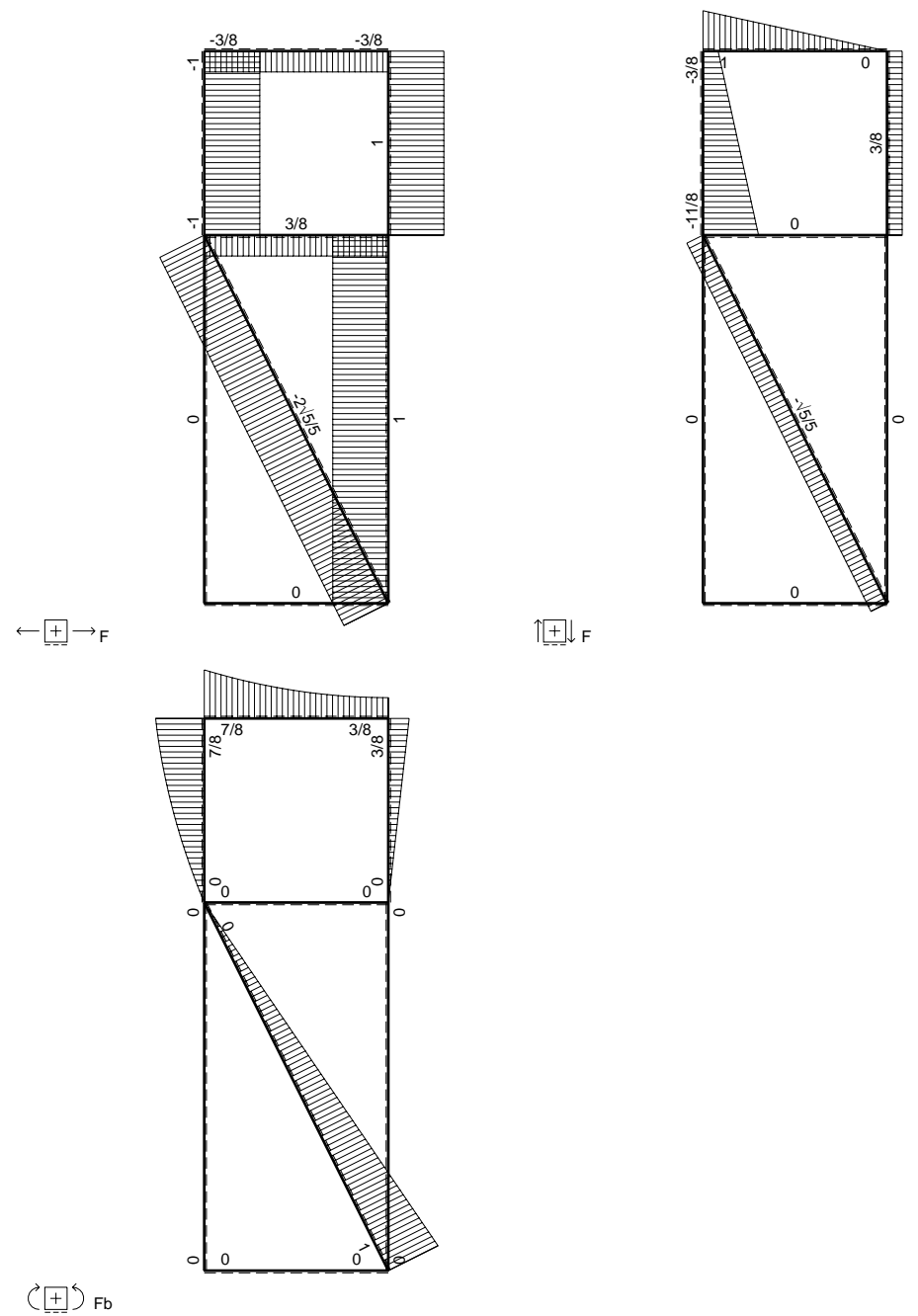
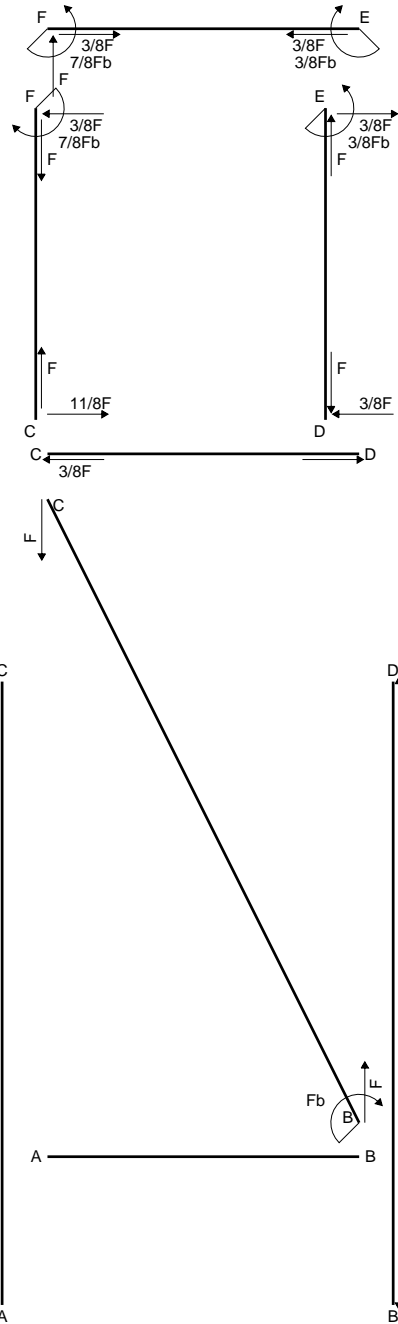
$$\sigma_c = N/A - Mv/J_u = -127.5 \text{ N/mm}^2$$

$$\tau_c = 1.669 \text{ N/mm}^2$$

$$\sigma_o = \sqrt{\sigma^2 + 3\tau^2} = 127.5 \text{ N/mm}^2$$

$$S = 4216. \text{ mm}^3$$







$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/6 b) Fb 1/EJ + (b) \theta = 5/6 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx$$

$$= [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ + (-b) \theta = 5/6 Fb^2/EJ$$

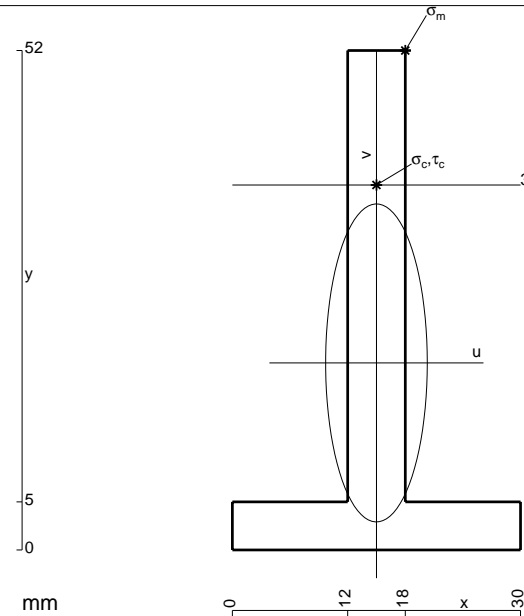
$$L_{FC}^{xo} = \int_0^b (-1/2 + 1/2 x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx$$

$$= [-1/2 x + 1/4 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/4 b + 1/6 b - 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

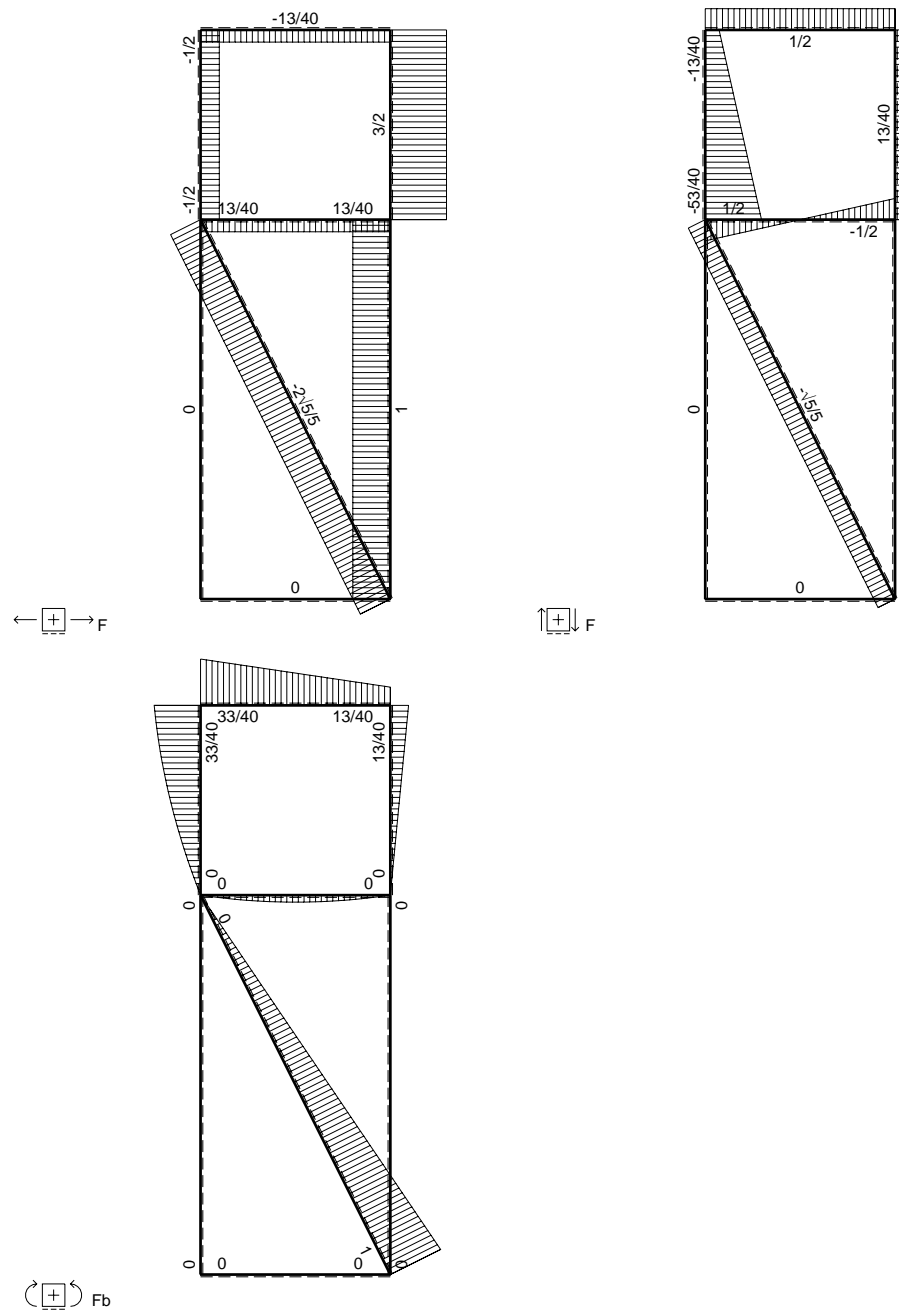
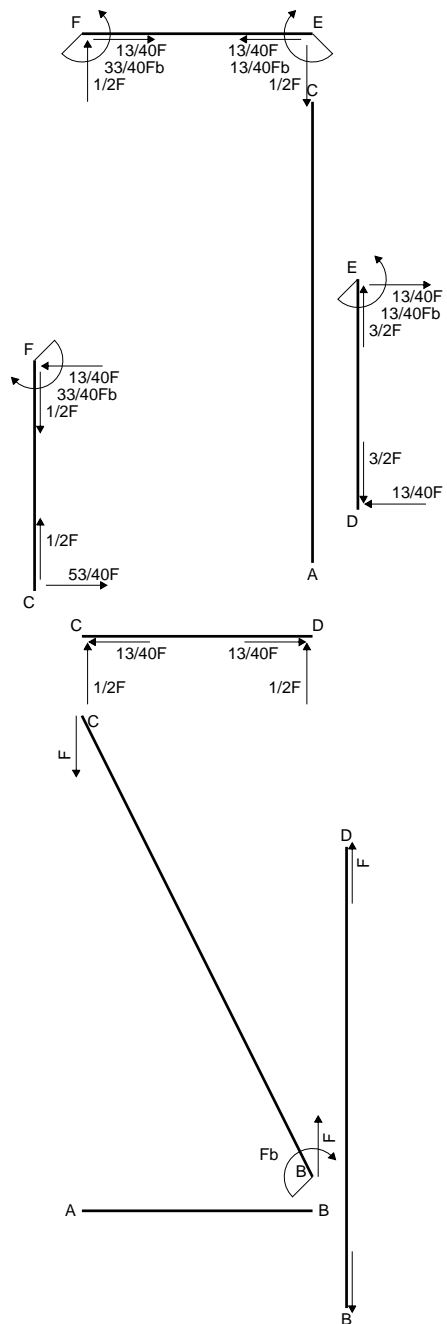
$$= (-1/3 b + 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$



- 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> = 19.47 mm
- N = -1118. N
- T<sub>y</sub> = -559. N
- M<sub>x</sub> = 825000. Nmm
- x<sub>m</sub> = 18. mm
- y<sub>m</sub> = 52. 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> = -229.2 N/mm<sup>2</sup>
- x<sub>c</sub> = 15. mm
- y<sub>c</sub> = 38. mm
- v<sub>c</sub> = 18.53 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = -131.7 N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.687 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 = 2144. mm<sup>3</sup>









$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/4 b) Fb 1/EJ + (b) \theta = 3/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + 1/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-1/2 x + 1/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

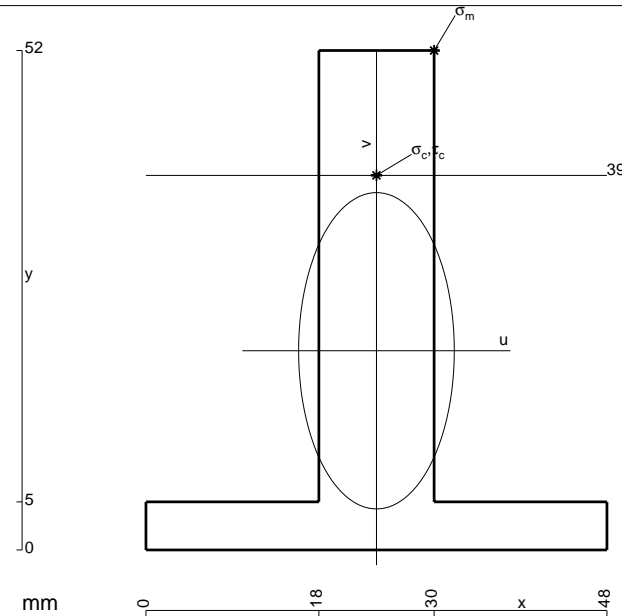
$$L_{FC}^{xo} = \int_0^b (-1/2 + 1/2 x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx$$

$$= [-1/2 x + 1/4 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/4 b + 1/6 b - 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/3 b + 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$



$$A = 804. \text{ mm}^2$$

$$J_u = 218133. \text{ mm}^4$$

$$J_v = 52848. \text{ mm}^4$$

$$y_g = 20.74 \text{ mm}$$

$$N = -2111. \text{ N}$$

$$T_y = -1055. \text{ N}$$

$$M_x = 1652000. \text{ Nmm}$$

$$x_m = 30. \text{ mm}$$

$$y_m = 52. \text{ mm}$$

$$u_m = 6. \text{ mm}$$

$$v_m = 31.26 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -239.4 \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 39. \text{ mm}$$

$$v_c = 18.26 \text{ mm}$$

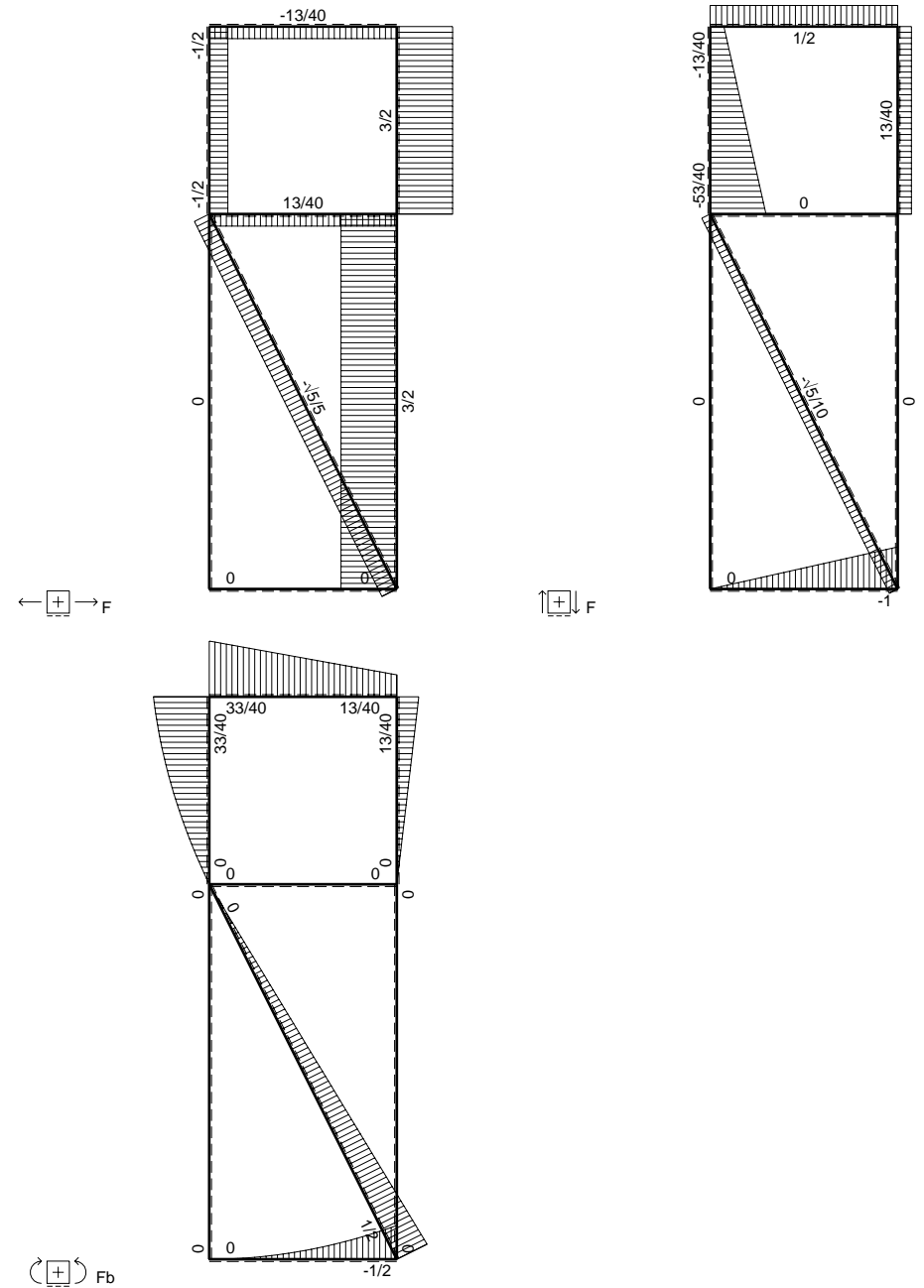
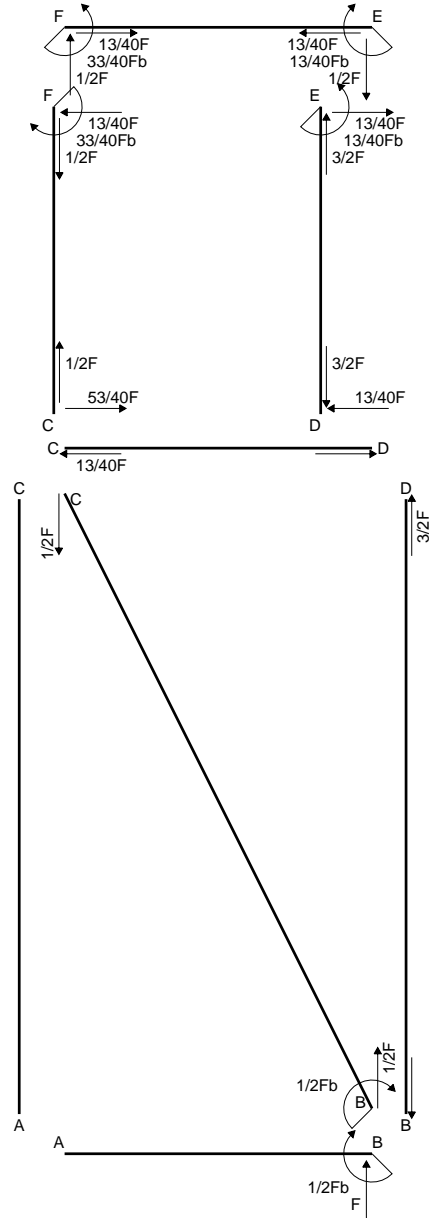
$$\sigma_c = N/A - Mv/J_u = -140.9 \text{ N/mm}^2$$

$$\tau_c = 1.557 \text{ N/mm}^2$$

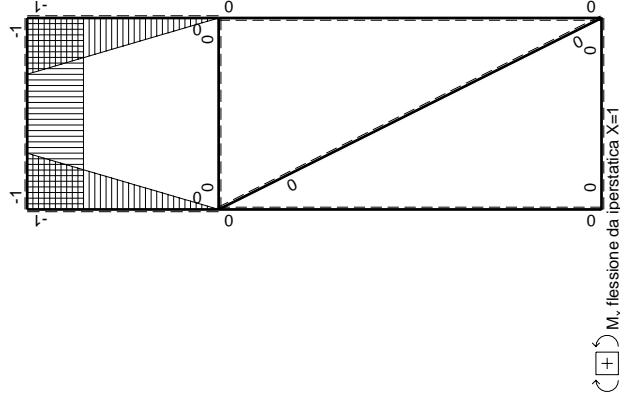
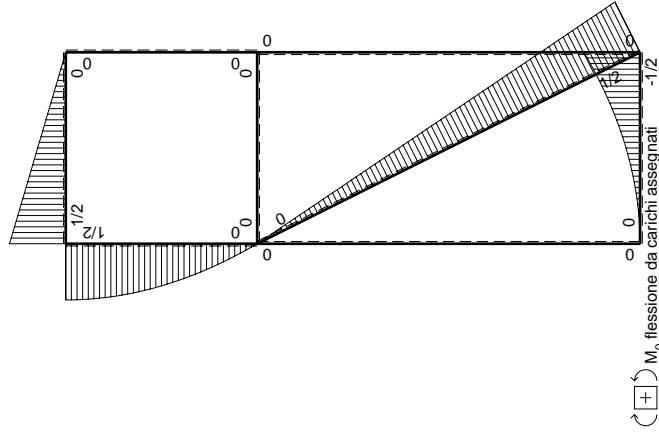
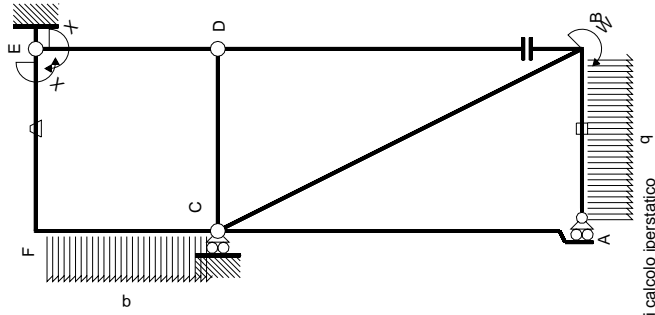
$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 140.9 \text{ N/mm}^2$$

$$S = 3863. \text{ mm}^3$$





⊕ F<sub>b</sub>



Quadro contributi PLV per iperstatica  $X=W_{EF}$

→	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x (M_0/EJ + \theta) dx$	$\int M^x M_x/EJ dx$
AB b	0	$-1/2qx^2$	0	0	0	0	0	0
BA b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0	0
BC √5b	0	$1/2Fb-\sqrt{5}/10Fx$	0	0	0	0	0	0
AC 2b	0	0	0	0	0	0	0	0
CA 2b	0	0	0	0	0	0	0	0
DB 2b	0	0	0	0	0	0	0	0
BD 2b	0	0	0	0	0	0	0	0
DE b	-x/b	0	0	0	0	0	0	0
ED b	1-x/b	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
EF b	-1	$1/2Fx$	-Fb/EJ	-1/2Fx	Fb/EJ	1	$(-1/4+1)Fb^2/EJ$	Xb/EJ
FE b	1	$-1/2Fb+1/2Fx$	Fb/EJ	$-1/2Fb+1/2Fx$	Fb/EJ	1	$(-1/4+1)Fb^2/EJ$	Xb/EJ
FC b	-1+x/b	$1/2Fb-1/2qx^2$	0	$-1/2Fb+1/2Fx+1/2Fx^2/b-1/2qx^3/b$	0	0	$(-5/24+0)Fb^2/EJ$	$1/3Xb/EJ$
CF b	x/b	$-Fx+1/2qx^2$	0	$-Fx^2/b+1/2qx^3/b$	0	0	$x^2/b^2$	$1/3Xb/EJ$
totali							$13/24Fb^2/EJ$	$5/3Xb/EJ$
		iperstatica $X=W_{EF}$						$-13/40Fb$

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/4 b) Fb 1/EJ + (b) \theta = 3/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + 1/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-1/2 x + 1/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

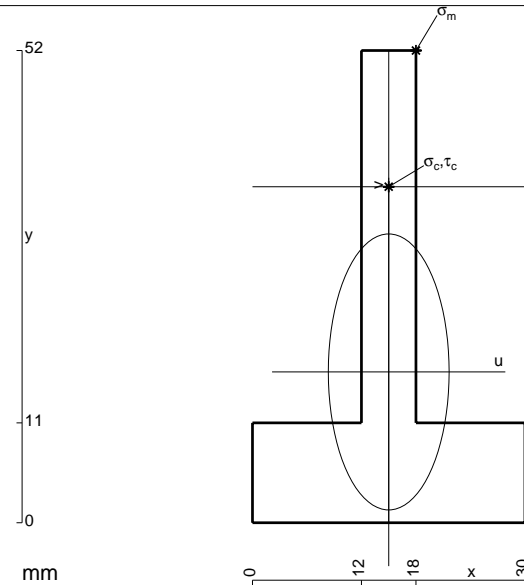
$$L_{FC}^{xo} = \int_0^b (-1/2 + 1/2 x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx$$

$$= [-1/2 x + 1/4 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/4 b + 1/6 b - 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/3 b + 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$



$$A = 576. \text{ mm}^2$$

$$J_u = 133062. \text{ mm}^4$$

$$J_v = 25488. \text{ mm}^4$$

$$y_g = 16.6 \text{ mm}$$

$$T_y = -4060. \text{ N}$$

$$M_x = -751100. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$y_m = 52. \text{ mm}$$

$$u_m = 3. \text{ mm}$$

$$v_m = 35.4 \text{ mm}$$

$$\sigma_m = -Mv/J_u = 199.8 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 37. \text{ mm}$$

$$v_c = 20.4 \text{ mm}$$

$$\sigma_c = -Mv/J_u = 115.1 \text{ N/mm}^2$$

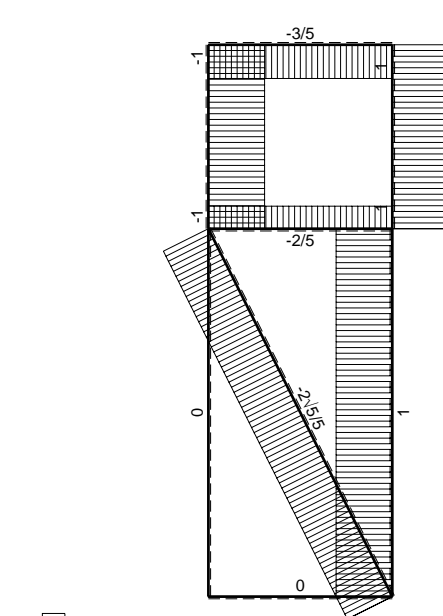
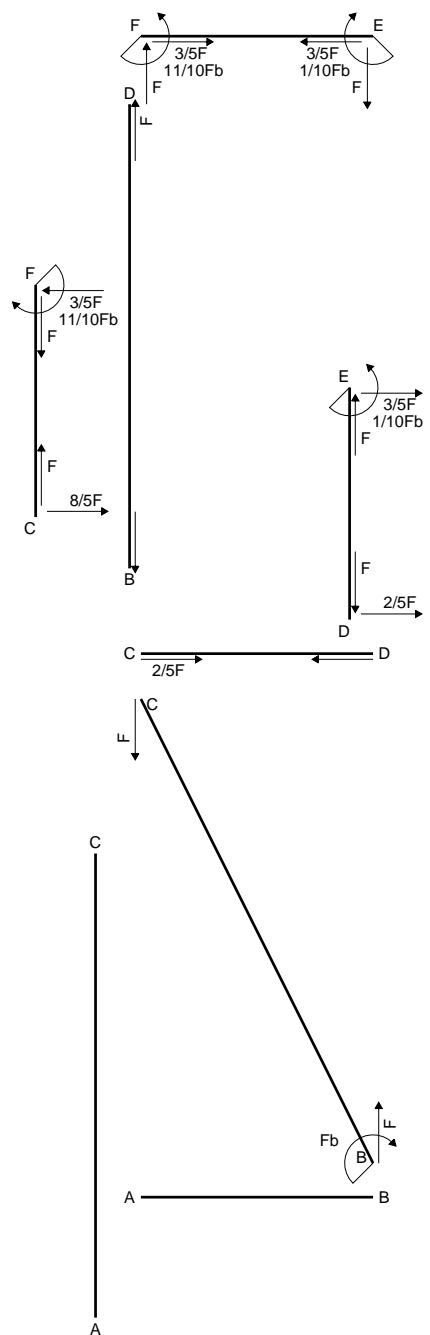
$$\tau_c = 12.77 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 117.2 \text{ N/mm}^2$$

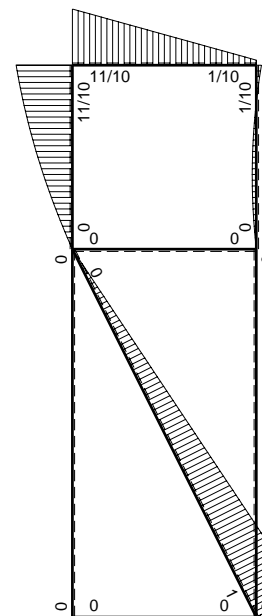
$$S = 2511. \text{ mm}^3$$



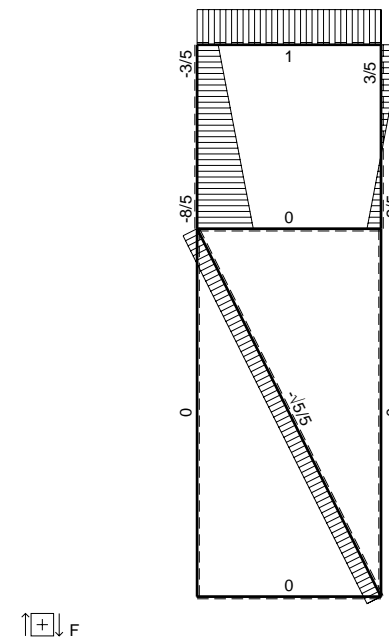




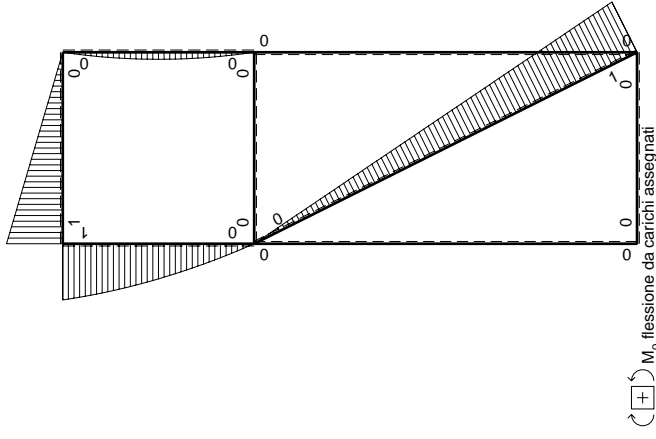
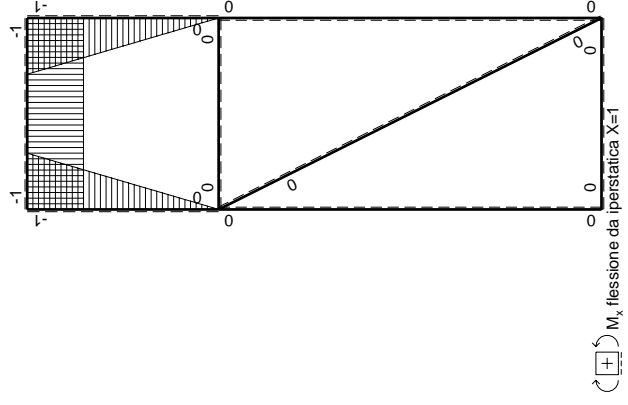
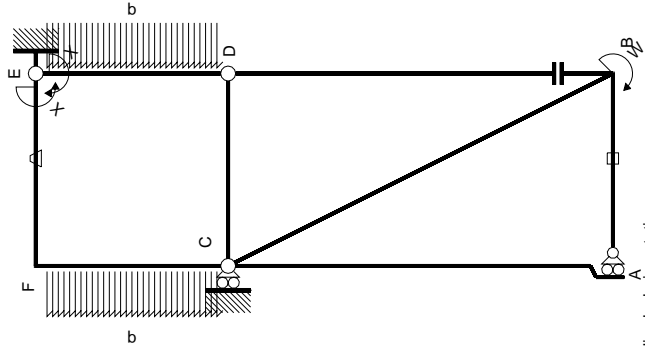
← (+) → F



⊕ Fb



↑ (+) ↓ F



Quadro contributi PLV per iperstatica  $X=W_{EF}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / EJ dx$
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$Fb - \sqrt{5}/5Fx$	0	0	0	0	0+0	0
CA 2b	0	0	0	0	0	0	0+0	0
DB 2b	0	0	0	0	0	0	0+0	0
BD 2b	0	0	0	0	0	0	0+0	0
DE b	$-x/b$	$-1/2Fx + 1/2qx^2$	0	$1/2Fx^2/b - 1/2qx^3/b$	0	0	$x^2/b^2$	0
ED b	$1-x/b$	$1/2Fx - 1/2qx^2$	0	$1/2Fx - Fx^2/b + 1/2qx^3/b$	0	0	$1-2x/b+x^2/b^2$	$1/3xb/EJ$
CD b	0	0	0	0	0	0	0+0	0
DC b	0	0	0	0	0	0	0+0	0
EF b	-1	Fx	$-Fb/EJ$	-Fx	$Fb/EJ$	1	$(-1/2+1)Fb^2/EJ$	$xb/EJ$
FE b	1	$-Fb+Fx$	$Fb/EJ$	$-Fb+Fx$	$Fb/EJ$	1	$(-1/2+1)Fb^2/EJ$	$xb/EJ$
FC b	$-1+x/b$	$Fb - 1/2Fx - 1/2qx^2$	0	$-Fb + 3/2Fx - 1/2qx^3/b$	0	0	$1-2x/b+x^2/b^2$	$1/3xb/EJ$
CF b	$x/b$	$-3/2Fx + 1/2qx^2$	0	$-3/2Fx^2/b + 1/2qx^3/b$	0	0	$x^2/b^2$	$1/3xb/EJ$
totali								$5/3xb/EJ$
iperstatica $X=W_{EF}$								$-1/10Fb$

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (b) \theta = 1/2 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

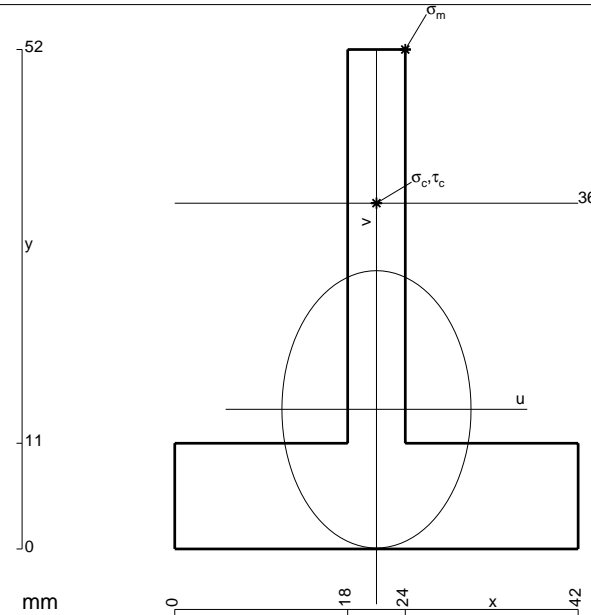
$$= (-b + 1/2 b) Fb 1/EJ + (-b) \theta = 1/2 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-1 + 3/2 x/b - 1/2 x^3/b^3) Fb 1/EJ dx = [-x + 3/4 x^2/b - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-b + 3/4 b - 1/8 b) Fb 1/EJ = -3/8 Fb^2/EJ$$

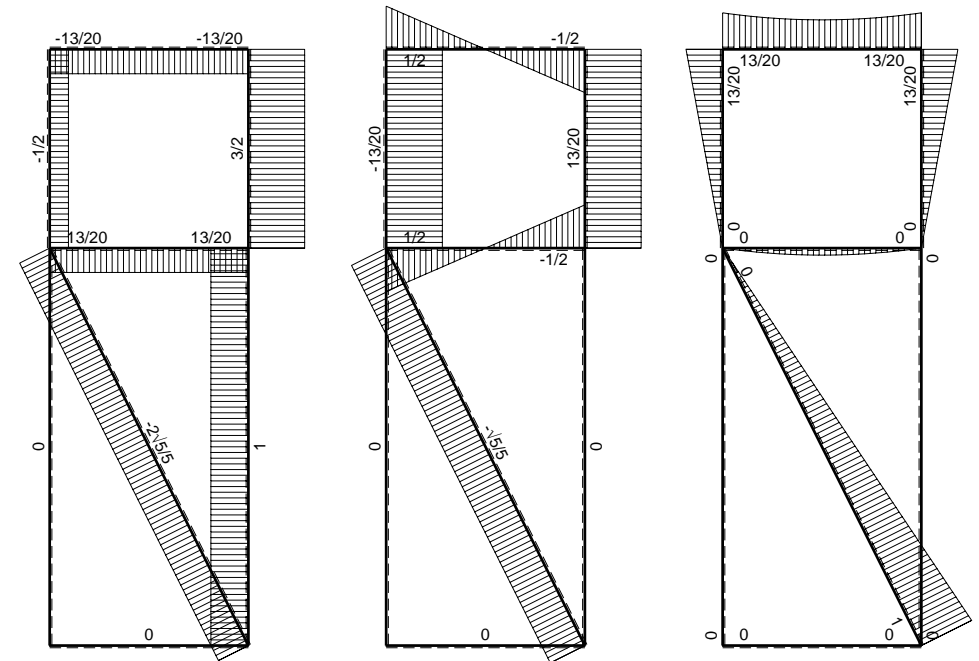
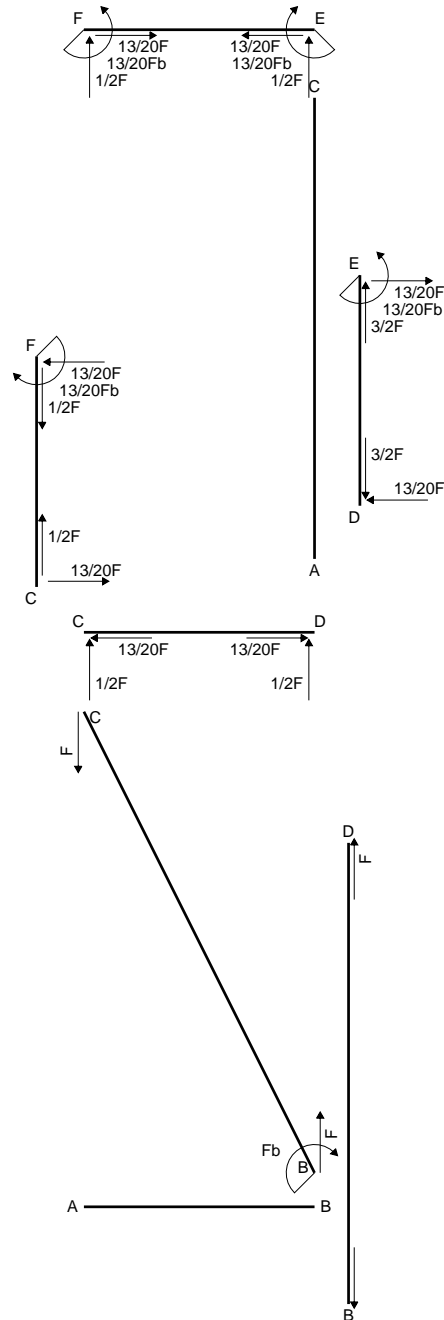
$$L_{CF}^{xo} = \int_0^b (-3/2 x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/2 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/8 b) Fb 1/EJ = -3/8 Fb^2/EJ$$



- 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 = -1825. N
- T<sub>y</sub> = -912.3 N
- M<sub>x</sub> = 816000. 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> = -209.7 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> = -121.2 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.913 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup>+3τ<sup>2</sup>) = 121.3 N/mm<sup>2</sup>
- S = 2829. mm<sup>3</sup>





← ⊕ → F

↑ ⊕ ↓ F

⊕ ⊖ F<sub>b</sub>



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

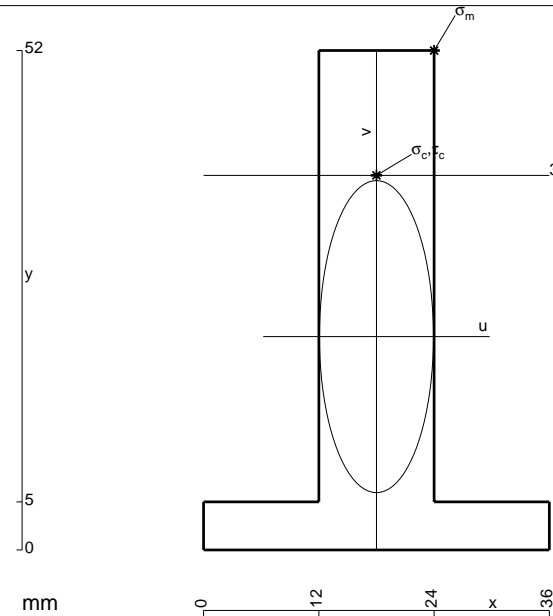
$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (1/4 b - 1/6 b) Fb 1/EJ + (b) \theta = 13/12 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

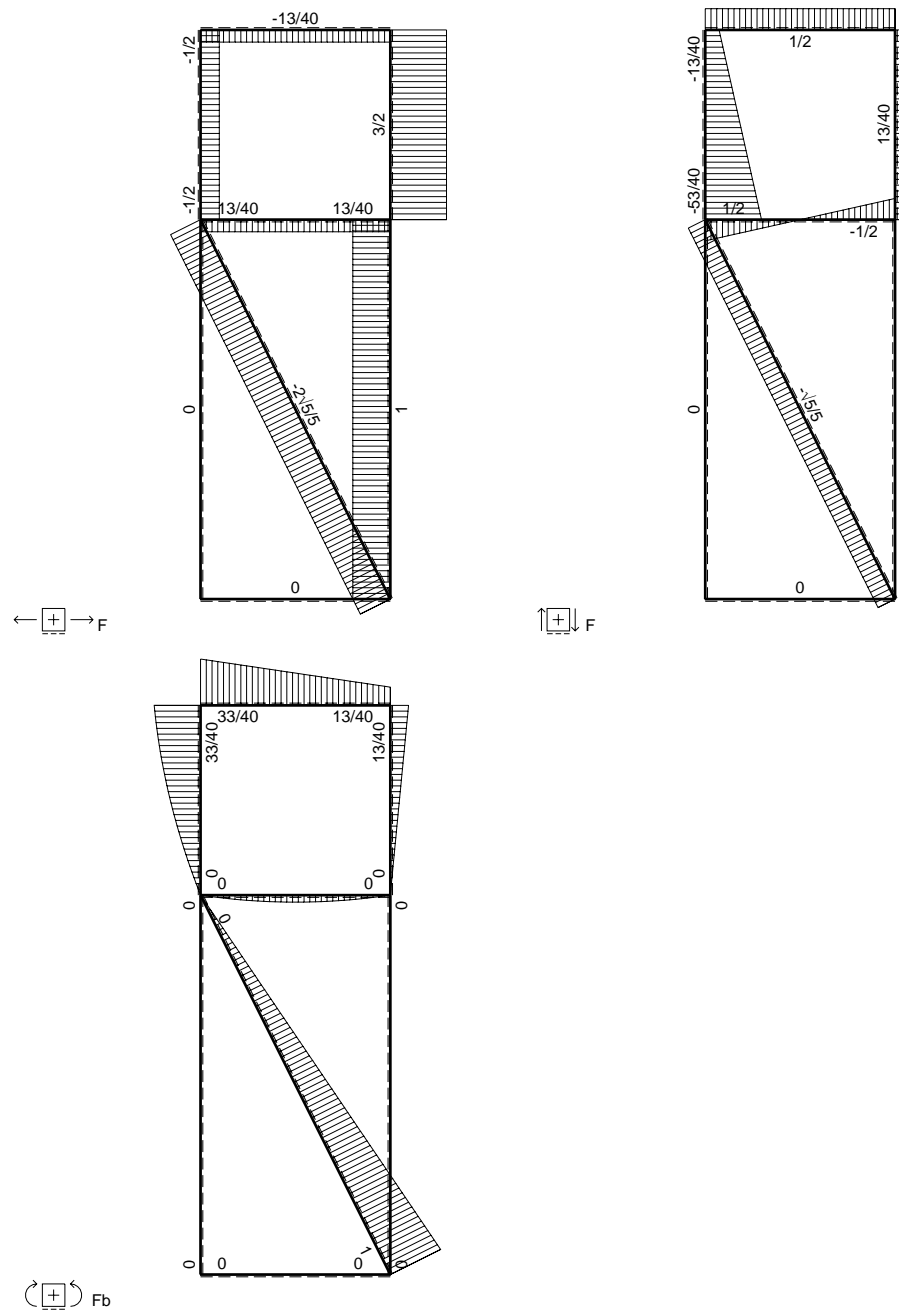
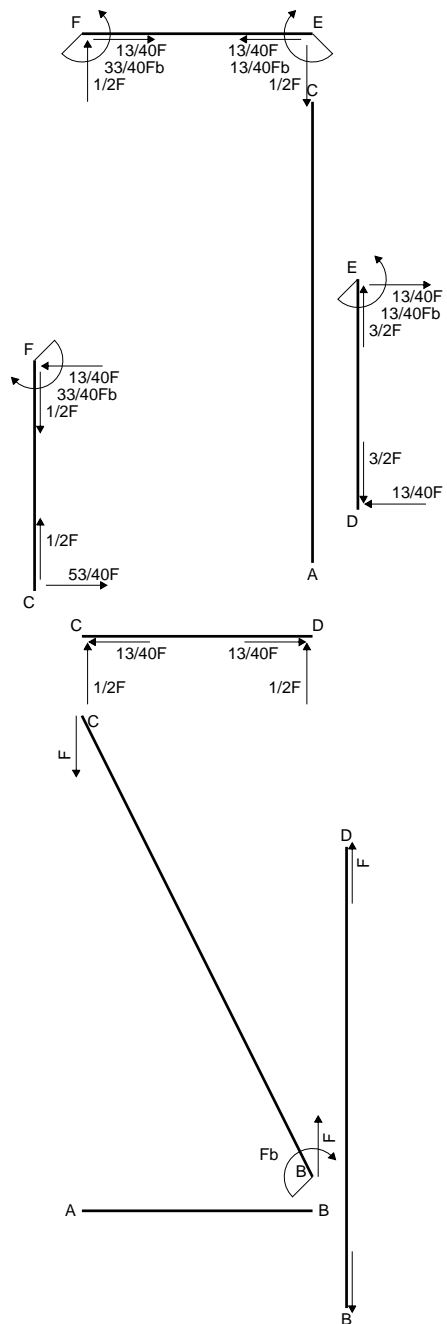
$$= (1/4 b - 1/6 b) Fb 1/EJ + (-b) \theta = 13/12 Fb^2/EJ$$

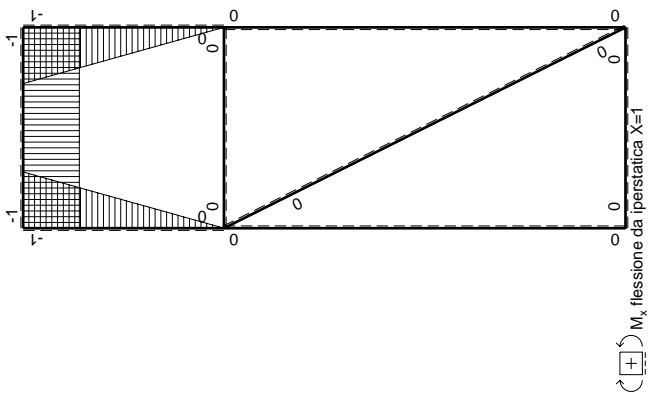
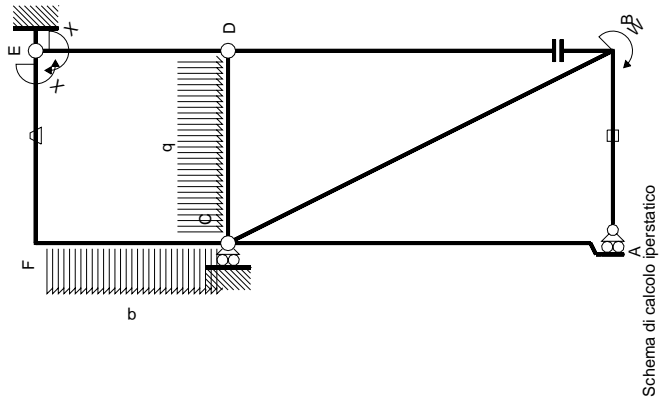


- A = 744. mm<sup>2</sup>
- J<sub>u</sub> = 196439. mm<sup>4</sup>
- J<sub>v</sub> = 26208. mm<sup>4</sup>
- y<sub>g</sub> = 22.21 mm
- N = -2889. N
- T<sub>y</sub> = -1445. N
- M<sub>x</sub> = 1421200. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 52. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 29.79 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = -219.4 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> = N/A-Mv/J<sub>u</sub> = -125.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.226 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 125.4 N/mm<sup>2</sup>
- S = 3633. mm<sup>3</sup>









←	$M(x)$	$M_0(x)$	$\theta$	$M_x^0$	$M_x^{\theta}$	$M_x^X$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x^0/EJdx$	iperstatica $X=W_{EP}$	
									totali	
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
BC $\sqrt{5}b$	0	$Fb-\sqrt{5}Fx$	0	0	0	0	0	0	0	0
CA 2b	0	0	0	0	0	0	0+0	0	0	0
CA 2b	0	0	0	0	0	0	0	0	0	0
DB 2b	0	0	0	0	0	0	0+0	0	0	0
DB 2b	0	0	0	0	0	0	0	0	0	0
DE b	-x/b	0	0	0	0	0	0+0	0	0	0
ED b	1-x/b	0	0	0	0	0	0+0	0	0	0
CD b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0	0	0	0
DC b	0	$-1/2Fx+1/2qx^2$	0	0	0	0	0+0	0	0	0
EF b	-1	$1/2Fx$	-Fb/EJ	$-1/2Fx$	Fb/EJ	1	$(-1/4+1)Fb^2/EJ$	Xb/EJ	1	$-13/40Fb$
FE b	1	$-1/2Fb+1/2Fx$	Fb/EJ	$-1/2Fb+1/2Fx$	Fb/EJ	1	$(-1/4+1)Fb^2/EJ$	Xb/EJ	1	$-13/40Fb$
FC b	-1+x/b	$1/2Fb-1/2qx^2$	0	$-1/2Fb+1/2Fx$	0	0	0	0	0	0
CF b	x/b	$-Fx+1/2qx^2$	0	$-Fx^2/b+1/2qx^3/b$	0	0	0	0	0	0
totali										

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/4 b) Fb 1/EJ + (b) \theta = 3/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + 1/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-1/2 x + 1/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

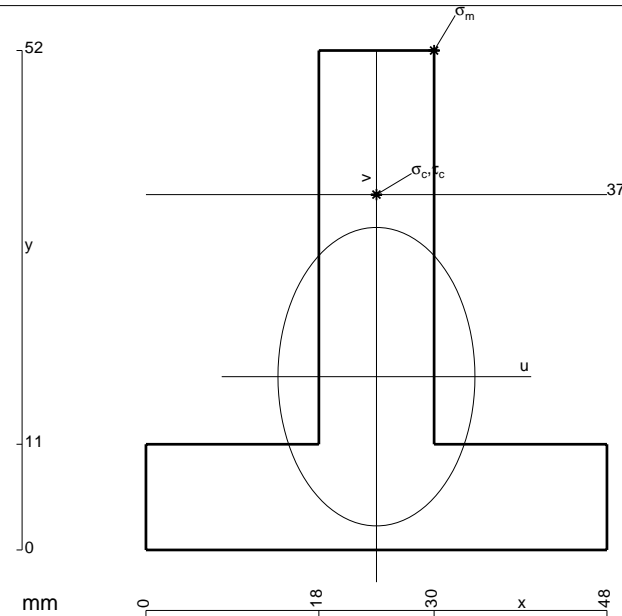
$$L_{FC}^{xo} = \int_0^b (-1/2 + 1/2 x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx$$

$$= [-1/2 x + 1/4 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/4 b + 1/6 b - 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/3 b + 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$



$$A = 1020. \text{ mm}^2$$

$$J_u = 246410. \text{ mm}^4$$

$$J_v = 107280. \text{ mm}^4$$

$$y_g = 18.04 \text{ mm}$$

$$N = -3068. \text{ N}$$

$$T_y = -1534. \text{ N}$$

$$M_x = 1646400. \text{ Nmm}$$

$$x_m = 30. \text{ mm}$$

$$y_m = 52. \text{ mm}$$

$$u_m = 6. \text{ mm}$$

$$v_m = 33.96 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -229.9 \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 37. \text{ mm}$$

$$v_c = 18.96 \text{ mm}$$

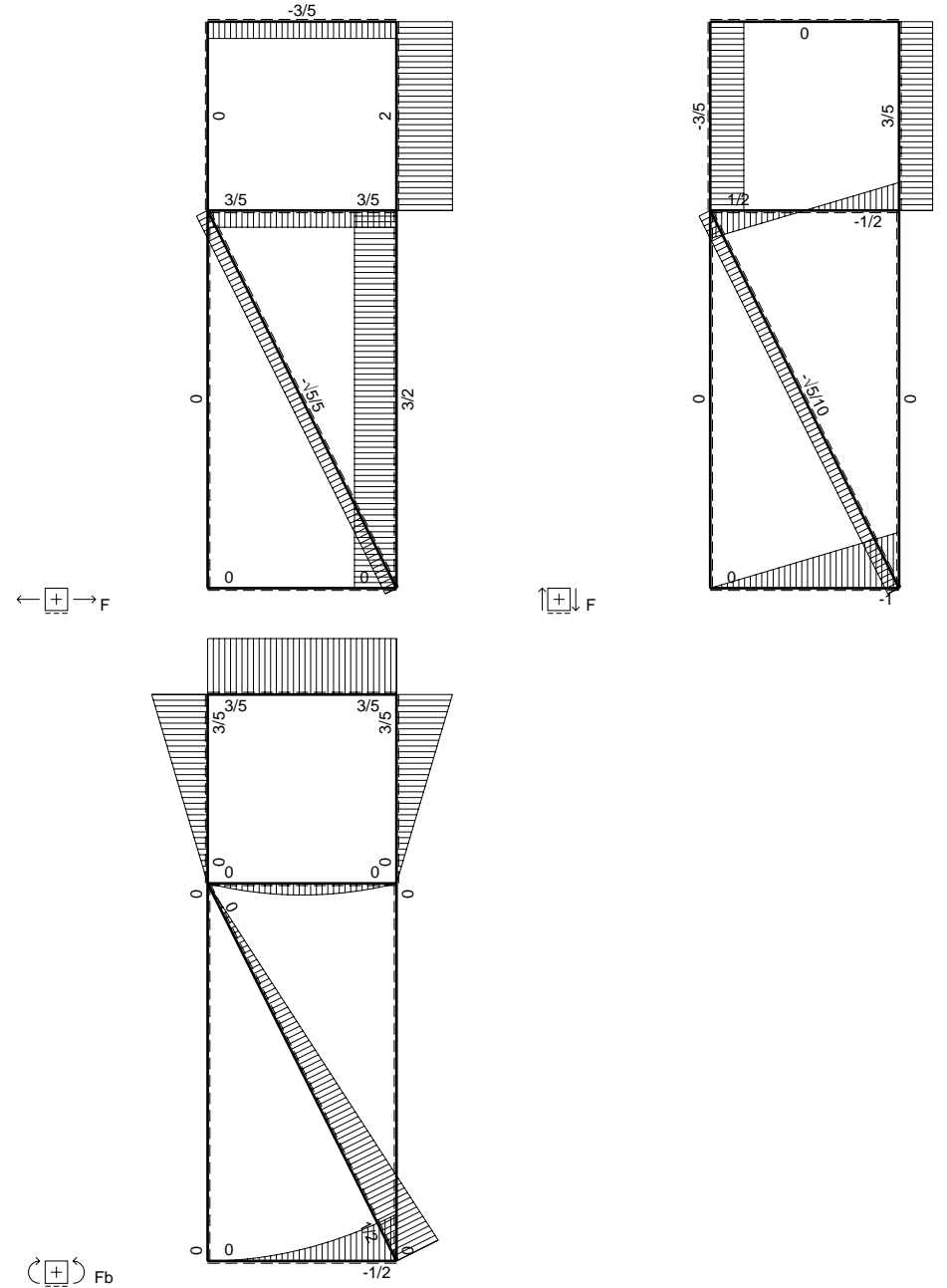
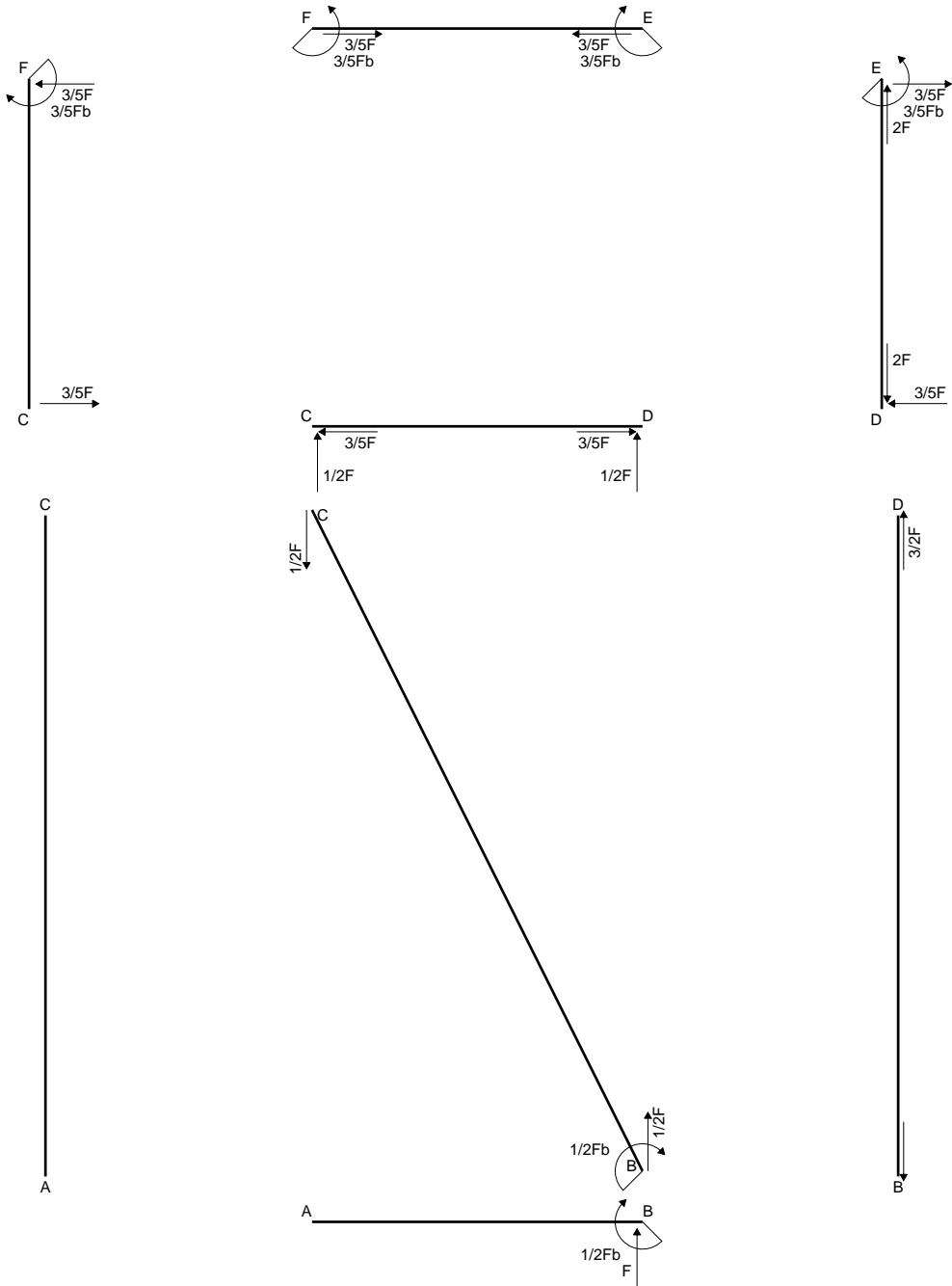
$$\sigma_c = N/A - Mv/J_u = -129.7 \text{ N/mm}^2$$

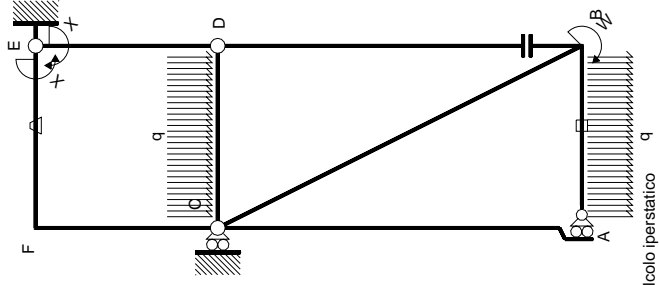
$$\tau_c = 2.471 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 129.8 \text{ N/mm}^2$$

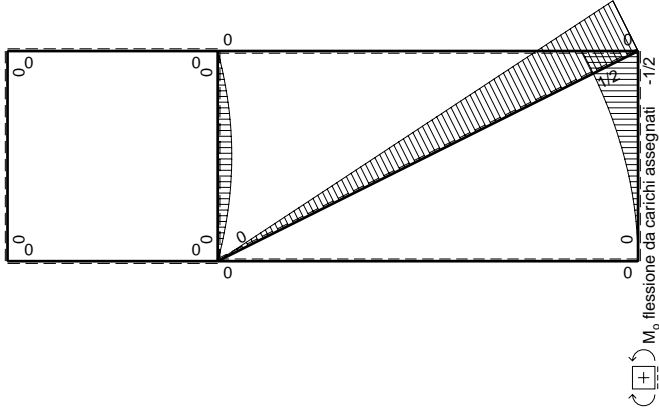
$$S = 4763. \text{ mm}^3$$







Schema di calcolo iperstatico



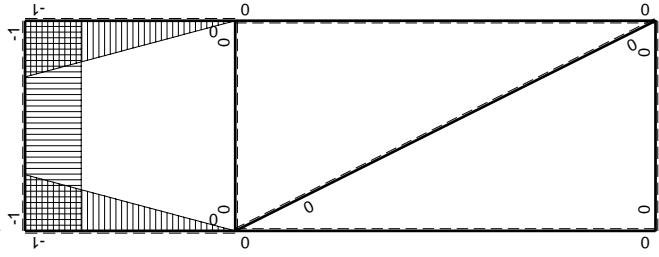
$M_0$  flessione da carichi assegnati -1/2

Quadro contributi PLV per iperstatica  $X=W_{EF}$

→	$M_x(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int X M_x M_x / EJ dx$
AB b	0	$-1/2qx^2$	0	0	0	0	0+0	0
BA b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0+0	0
BC $\sqrt{5}b$	0	$1/2Fb-\sqrt{5}/10Fx$	0	0	0	0	0	0
AC 2b	0	0	0	0	0	0	0+0	0
CA 2b	0	0	0	0	0	0	0+0	0
DB 2b	0	0	0	0	0	0	0+0	0
BD 2b	0	0	0	0	0	0	0+0	0
DE b	$-x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3Xb/EJ$
ED b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	0
CD b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0
DC b	0	$-1/2Fx+1/2qx^2$	0	0	0	0	0+0	0
EF b	-1	0	$-Fb/EJ$	0	$Fb/EJ$	1	$(0+1)Fb^2/EJ$	$Xb/EJ$
FE b	1	0	$Fb/EJ$	0	$Fb/EJ$	1		
FC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$
CF b	$x/b$	0	0	0	0	$x^2/b^2$	$Fb^2/EJ$	$5/3Xb/EJ$
totali								
iperstatica $X=W_{EF}$								
$-3/5Fb$								

Sviluppi di calcolo iperstatica

$M_x$  flessione da iperstatica  $X=1$



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

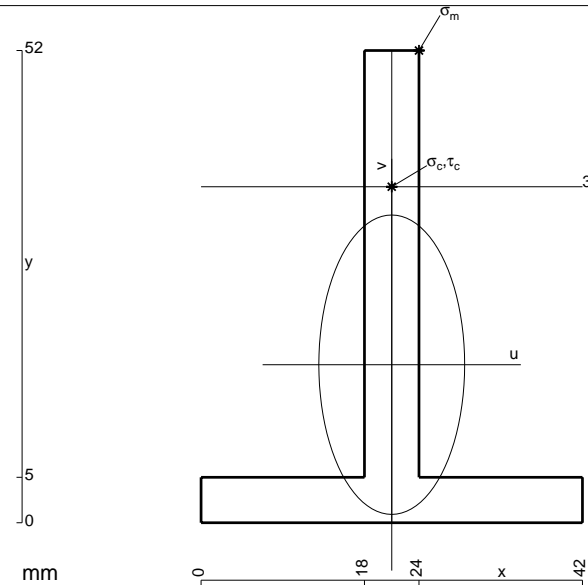
$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (1) \theta dx = [x]_0^b \theta$$

$$= (b) \theta = Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1) \theta dx = [-x]_0^b \theta$$

$$= (-b) \theta = Fb^2/EJ$$



$$A = 492. \text{ mm}^2$$

$$J_u = 133716. \text{ mm}^4$$

$$J_v = 31716. \text{ mm}^4$$

$$y_g = 17.4 \text{ mm}$$

$$T_y = -3630. \text{ N}$$

$$M_x = -925650. \text{ Nmm}$$

$$x_m = 24. \text{ mm}$$

$$y_m = 52. \text{ mm}$$

$$u_m = 3. \text{ mm}$$

$$v_m = 34.6 \text{ mm}$$

$$\sigma_m = -Mv/J_u = 239.5 \text{ N/mm}^2$$

$$x_c = 21. \text{ mm}$$

$$y_c = 37. \text{ mm}$$

$$v_c = 19.6 \text{ mm}$$

$$\sigma_c = -Mv/J_u = 135.7 \text{ N/mm}^2$$

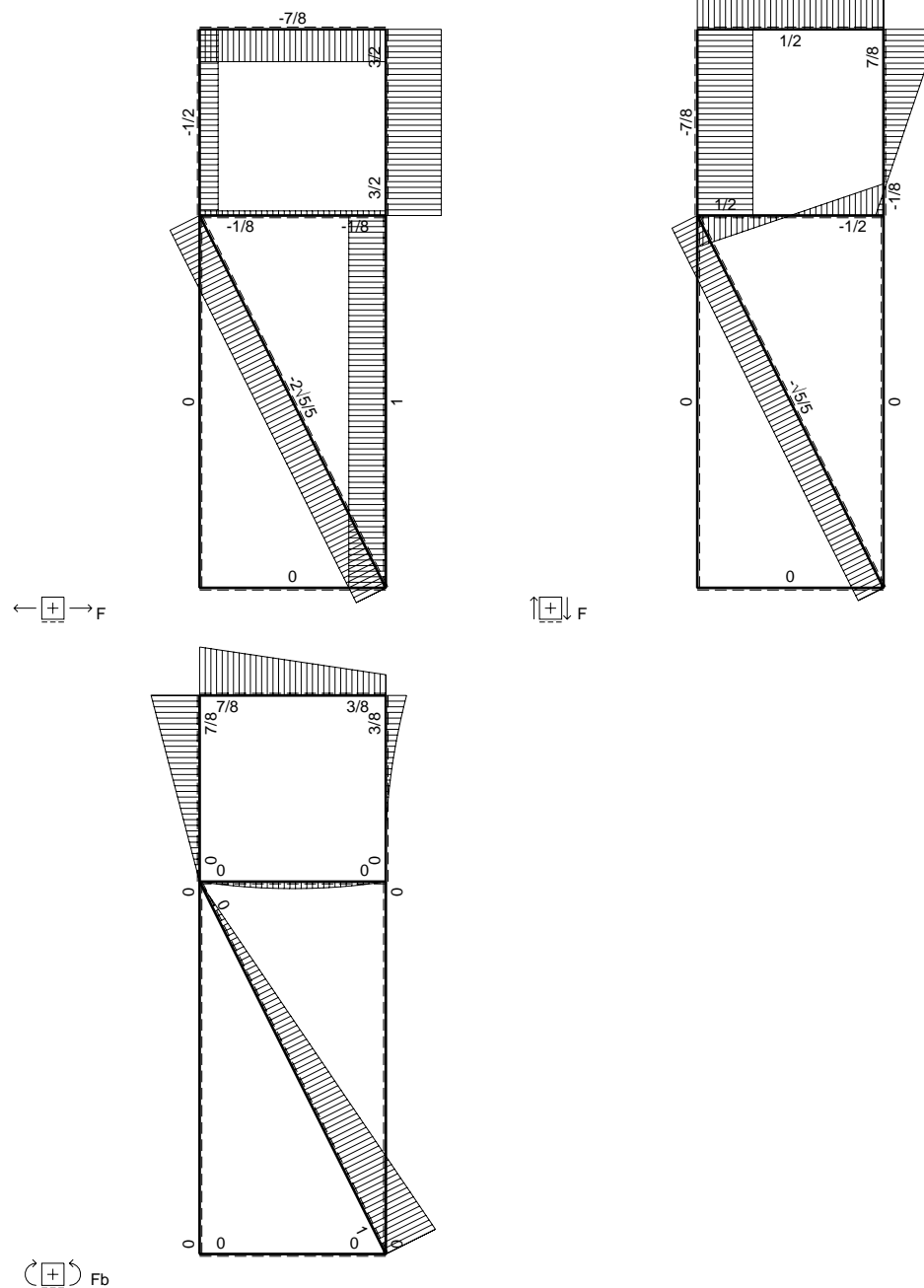
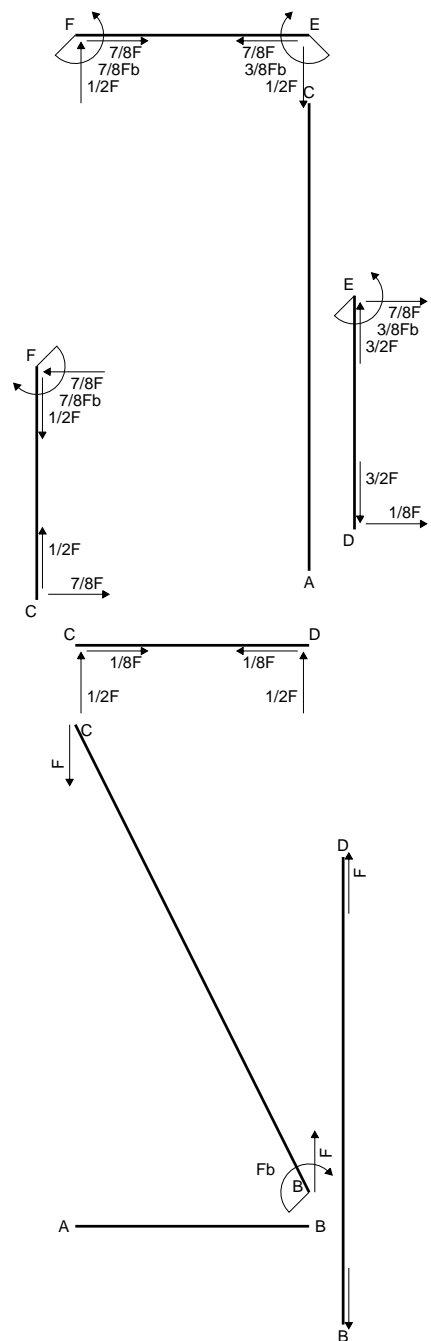
$$\tau_c = 11.03 \text{ N/mm}^2$$

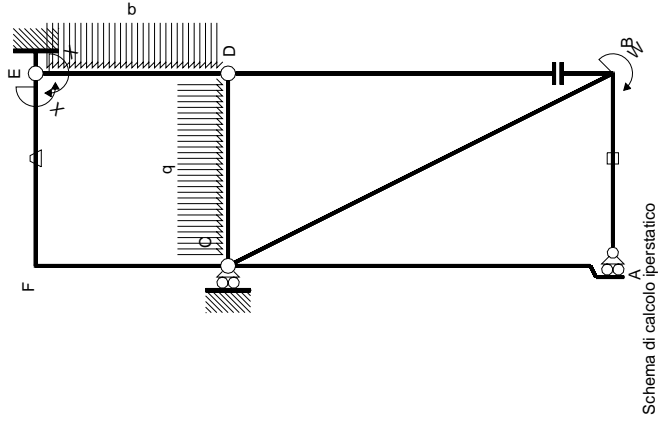
$$\sigma_o = \sqrt{\sigma^2 + 3\tau^2} = 137. \text{ N/mm}^2$$

$$S = 2439. \text{ mm}^3$$

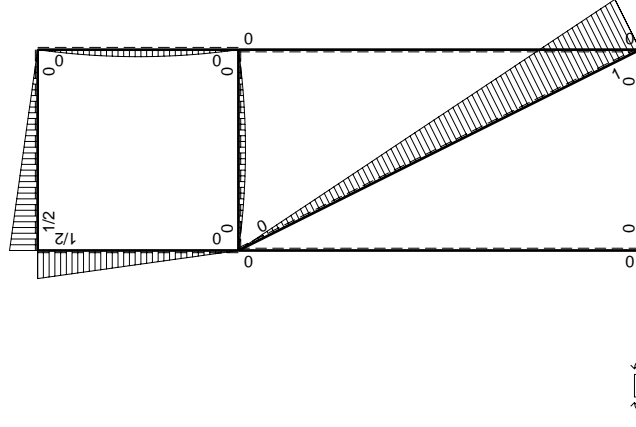




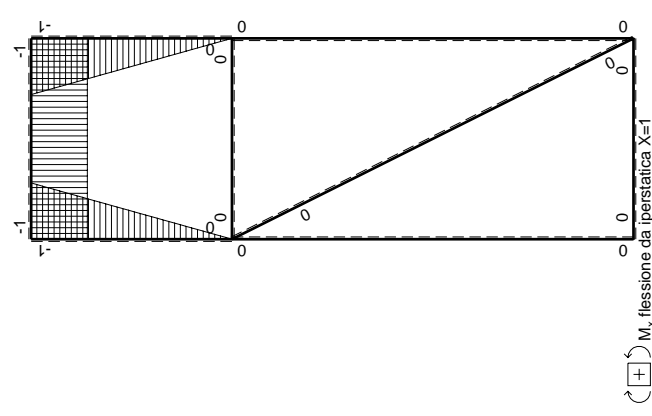




Schema di calcolo iperstatico



$M_0$  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 $X=W_{EF}$	
									totali	
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
BC $\sqrt{5}b$	0	$Fb\sqrt{5}/5Fx$	0	0	0	0	0+0	0	0	0
CA 2b	0	0	0	0	0	0	0+0	0	0	0
DB 2b	0	0	0	0	0	0	0+0	0	0	0
BD 2b	0	0	0	0	0	0	0+0	0	0	0
DE b	$-x/b$	$-1/2Fx + 1/2qx^2$	0	$1/2Fx^2/b - 1/2qx^3/b$	0	0	$x^2/b^2$	0	$(1/24+0)Fb^2/EJ$	$1/3Xb/EJ$
ED b	$1-x/b$	$1/2Fx - 1/2qx^2$	0	$1/2Fx - Fx^2/b + 1/2qx^3/b$	0	0	$1-2x/b+x^2/b^2$	0	$(1/24+0)Fb^2/EJ$	$1/3Xb/EJ$
CD b	0	$1/2Fx - 1/2qx^2$	0	0	0	0	0	0	0+0	0
DC b	0	$-1/2Fx + 1/2qx^2$	0	0	0	0	0	0	0+0	0
EF b	-1	$1/2Fx$	$-Fb/EJ$	$-1/2Fx$	$Fb/EJ$	$Fb/EJ$	1	1	$(-1/4+1)Fb^2/EJ$	$Xb/EJ$
FE b	1	$-1/2Fb + 1/2Fx$	$Fb/EJ$	$-1/2Fb + 1/2Fx$	$Fb/EJ$	$Fb/EJ$	1	1	$(-1/4+1)Fb^2/EJ$	$Xb/EJ$
FC b	$-1+x/b$	$1/2Fb - 1/2Fx$	0	$-1/2Fb + Fx - 1/2Fx^2/b$	0	0	$1-2x/b+x^2/b^2$	0	$(-1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
CF b	$x/b$	$-1/2Fx$	0	$-1/2Fx^2/b$	0	0	$x^2/b^2$	0	$(-1/6+0)Fb^2/EJ$	$1/3Xb/EJ$
totali									$5/8Fb^2/EJ$	$5/3Xb/EJ$
									$-3/8Fb$	

Sviluppi di calcolo iperstatica

Quadro contributi PLV per iperstatica  $X=W_{EF}$

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/4 b) Fb 1/EJ + (b) \theta = 3/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + 1/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-1/2 x + 1/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

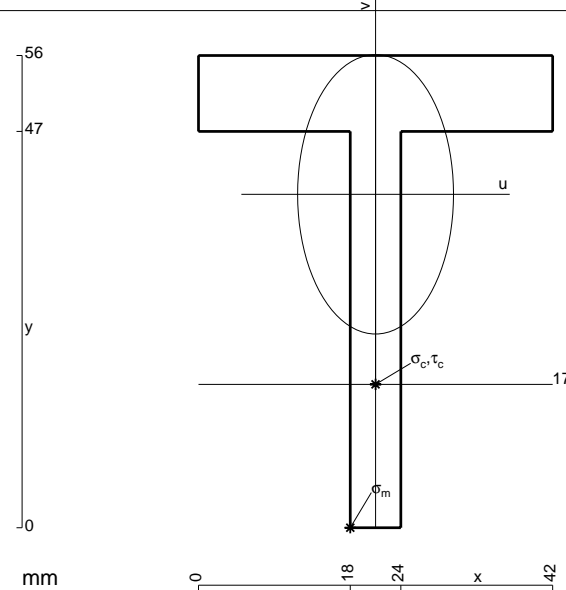
$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

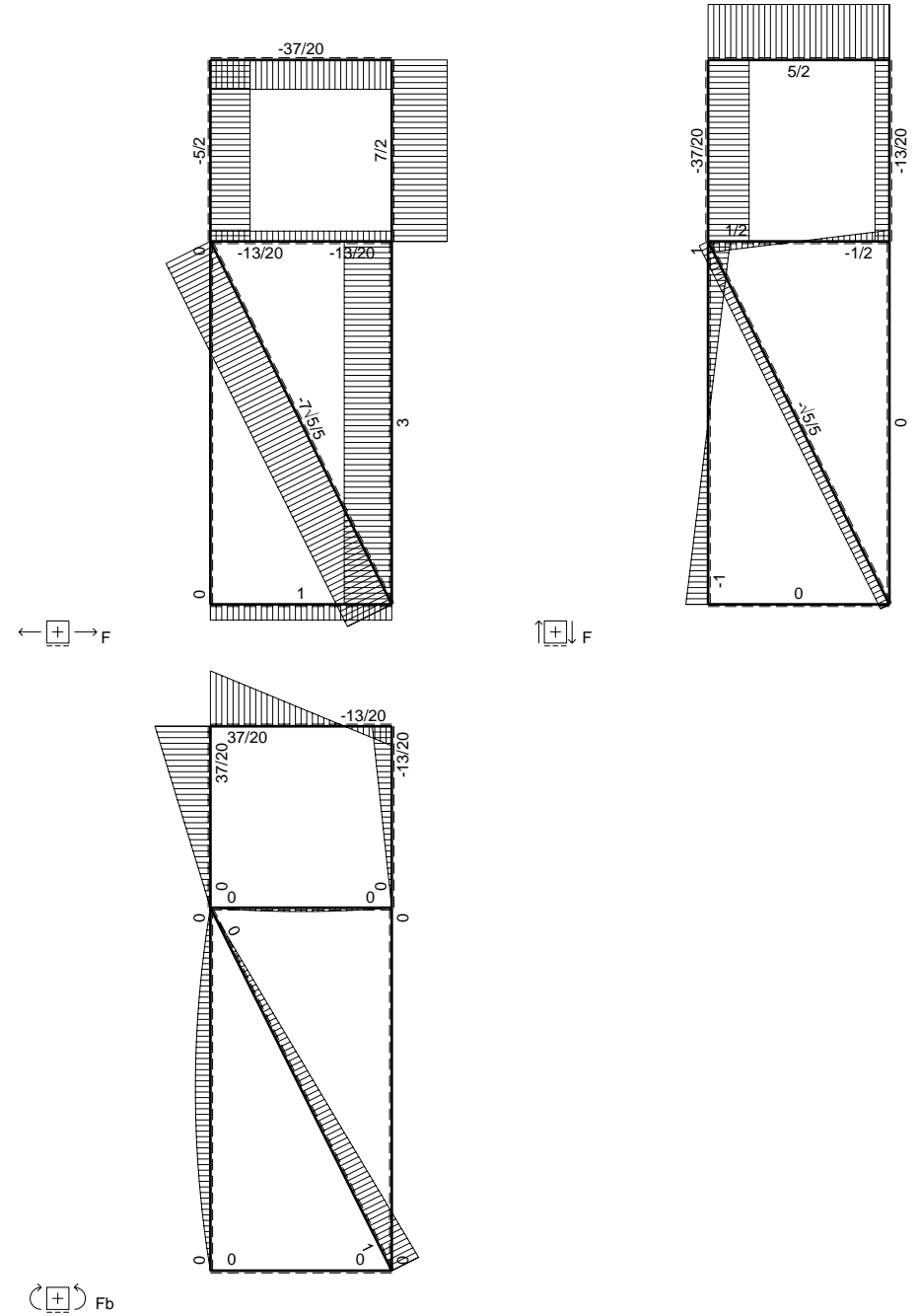
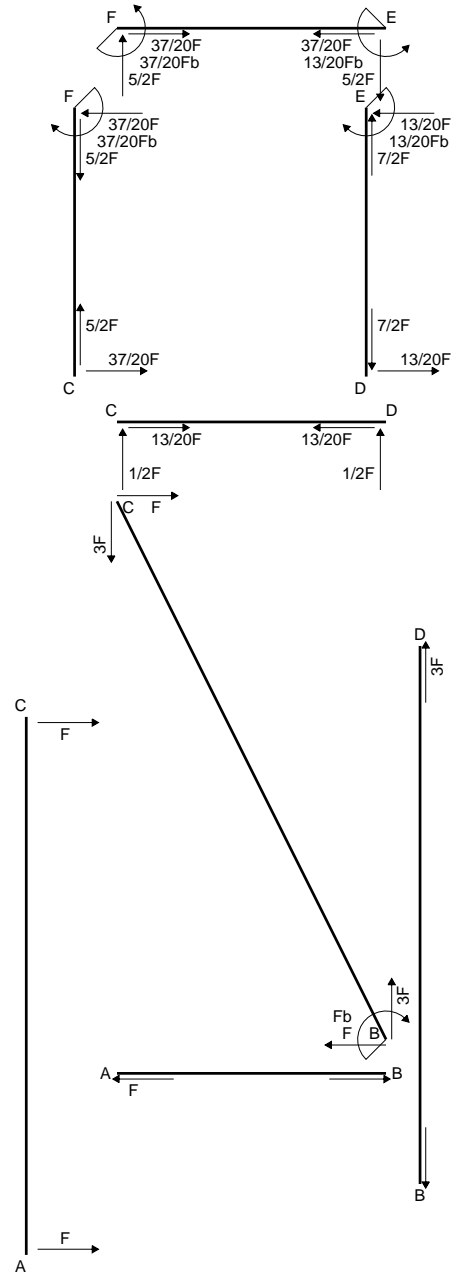
$$L_{CF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ$$

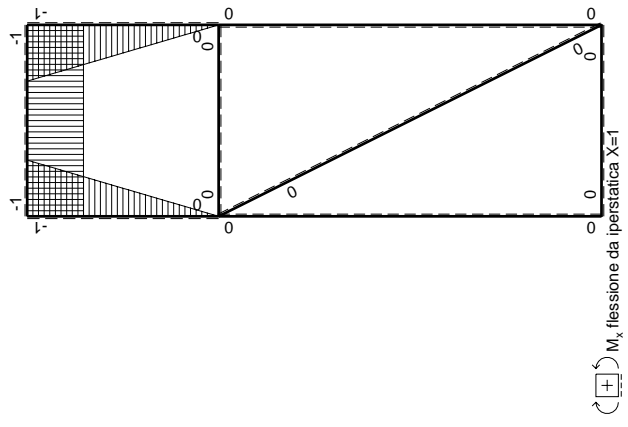
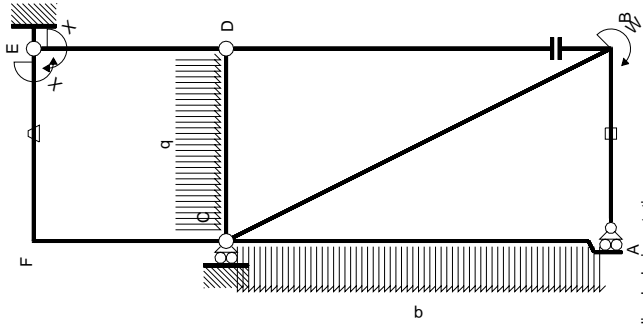
$$= (-1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$



- A = 660. mm<sup>2</sup>
- J<sub>u</sub> = 181086. mm<sup>4</sup>
- J<sub>v</sub> = 56412. mm<sup>4</sup>
- y<sub>g</sub> = 39.54 mm
- N = -1422. N
- T<sub>y</sub> = -711.1 N
- M<sub>x</sub> = 922200. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -39.54 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = 199.2 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 17. mm
- v<sub>c</sub> = -22.54 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = 112.6 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.072 N/mm<sup>2</sup>
- σ<sub>φ</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 112.7 N/mm<sup>2</sup>
- S = 3166. mm<sup>3</sup>







←	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M^0$	$M^x \theta$	$M^x M^x$	$\int M^x(M^0/EJ+\theta)dx$	$\int M^x M^x/EJdx$	iperstatica $X=W_{EP}$	
									totali	
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
BC $\sqrt{5}b$	0	$Fb-\sqrt{5}/5Fx$	0	0	0	0	0	0	0	0
AC 2b	0	$-Fx+1/2qx^2$	0	0	0	0	0+0	0	0	0
CA 2b	0	$Fx-1/2qx^2$	0	0	0	0	0	0	0	0
DB 2b	0	0	0	0	0	0	0+0	0	0	0
BD 2b	0	0	0	0	0	0	0	0	0	0
DE b	-x/b	0	0	0	0	0	0+0	0	0	0
ED b	1-x/b	0	0	0	0	0	0	0	0	0
CD b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0	0	0	0
DC b	0	$-1/2Fx+1/2qx^2$	0	0	0	0	0+0	0	0	0
EF b	-1	$5/2Fx$	$-Fb/EJ$	$-5/2Fx$	$Fb/EJ$	$Fb/EJ$	$(-5/4+1)Fb^2/EJ$	$Xb/EJ$	$1/3Xb/EJ$	$5/3Xb/EJ$
FE b	1	$-5/2Fb+5/2Fx$	$Fb/EJ$	$-5/2Fb+5/2Fx$	$Fb/EJ$	$Fb/EJ$	$(-5/6+0)Fb^2/EJ$	$1/3Xb/EJ$	$1/3Xb/EJ$	$5/3Xb/EJ$
FC b	-1+x/b	$5/2Fb-5/2Fx$	0	$-5/2Fb+5Fx-5/2Fx^2/b$	0	0	$x^2/b^2$	$1/3Xb/EJ$	$1/3Xb/EJ$	$5/3Xb/EJ$
CF b	x/b	$-5/2Fx$	0	$-5/2Fx^2/b$	0	0	0	$1/3Xb/EJ$	$1/3Xb/EJ$	$5/3Xb/EJ$
totali										

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-5/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-5/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-5/4 b) Fb 1/EJ + (b) \theta = -1/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-5/2 + 5/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-5/2 x + 5/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

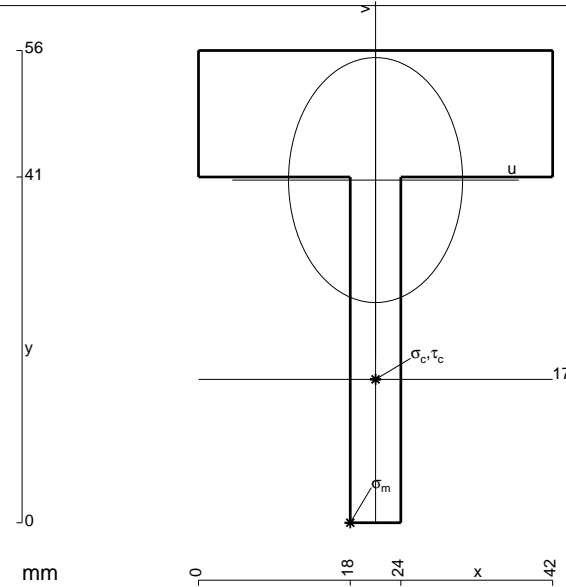
$$= (-5/2 b + 5/4 b) Fb 1/EJ + (-b) \theta = -1/4 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = [-5/2 x + 5/2 x^2/b - 5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

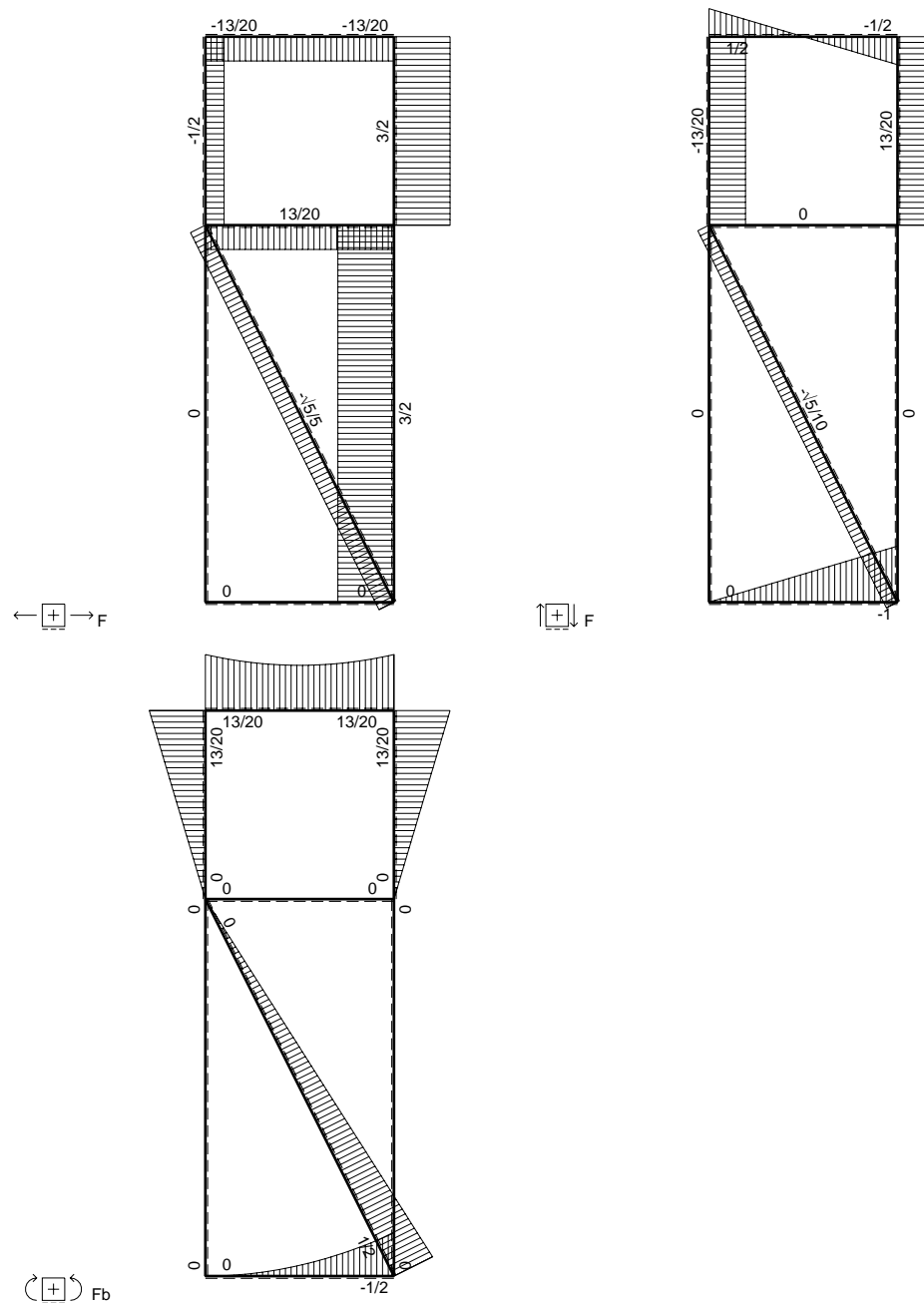
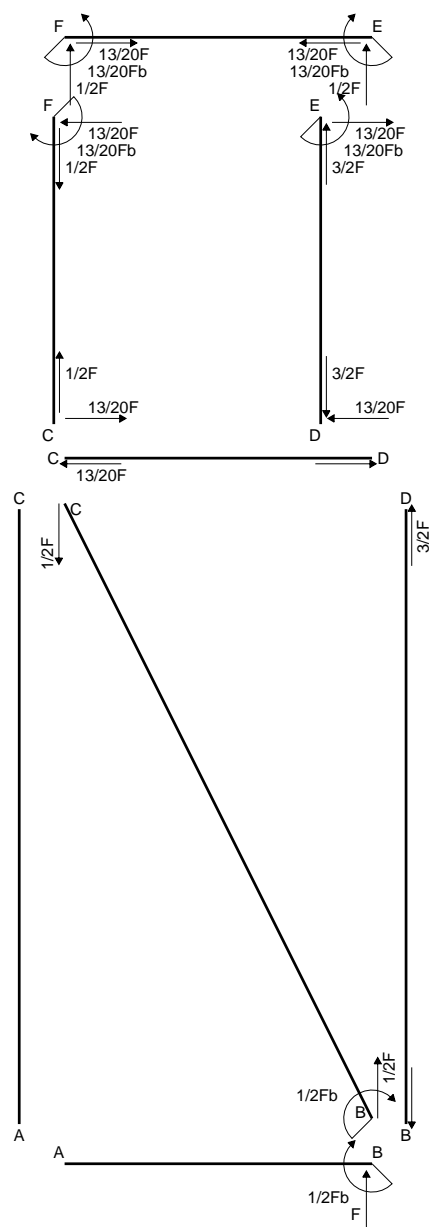
$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

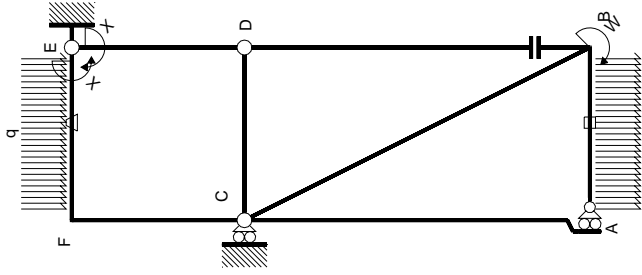


- A = 876. mm<sup>2</sup>
- J<sub>u</sub> = 184977. mm<sup>4</sup>
- J<sub>v</sub> = 93348. mm<sup>4</sup>
- y<sub>g</sub> = 40.64 mm
- N = -4946. N
- T<sub>y</sub> = -706.6 N
- M<sub>x</sub> = 979600. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -40.64 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = 209.6 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> = N/A - Mv/J<sub>u</sub> = 119.5 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.087 N/mm<sup>2</sup>
- σ<sub>φ</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 119.6 N/mm<sup>2</sup>
- S = 3278. mm<sup>3</sup>

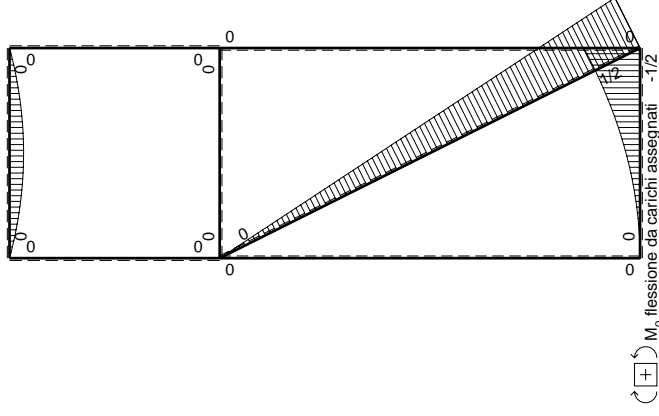








Schema di calcolo iperstatico

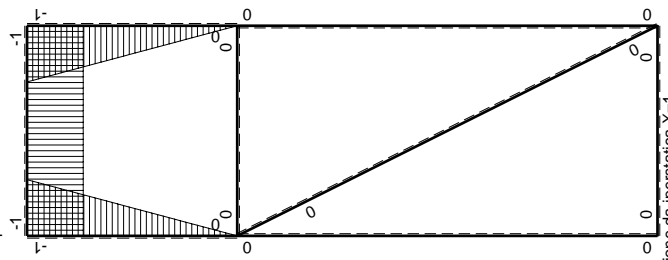


Quadro contributi PLV per iperstatica  $X=W_{EP}$

$\leftarrow$	$M_x(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	0	$-1/2qx^2$	0	0	0	0	0	0
BA b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$1/2Fb-\sqrt{5}/10Fx$	0	0	0	0	0	0
AC 2b	0	0	0	0	0	0	0	0
CA 2b	0	0	0	0	0	0	0	0
DB 2b	0	0	0	0	0	0	0	0
BD 2b	0	0	0	0	0	0	0	0
DE b	$-x/b$	0	0	0	0	0	0	0
ED b	$1-x/b$	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
EF b	-1	$-1/2Fx+1/2qx^2$	$-Fb/EJ$	$1/2Fx-1/2Fx^2/b$	$Fb/EJ$	1	$(1/12+1)Fb^2/EJ$	$Xb/EJ$
FE b	1	$1/2Fx-1/2qx^2$	$Fb/EJ$	$1/2Fx-1/2Fx^2/b$	$Fb/EJ$	1	$(1/12+1)Fb^2/EJ$	$Xb/EJ$
FC b	$-1+x/b$	0	0	0	0	0	0	0
CF b	$x/b$	0	0	0	0	0	0	0
totali							$13/12Fb^2/EJ$	$5/3Xb/EJ$
								$-13/20Fb$

Sviluppi di calcolo iperstatica

$M_x$  flessione da iperstatica  $X=1$



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

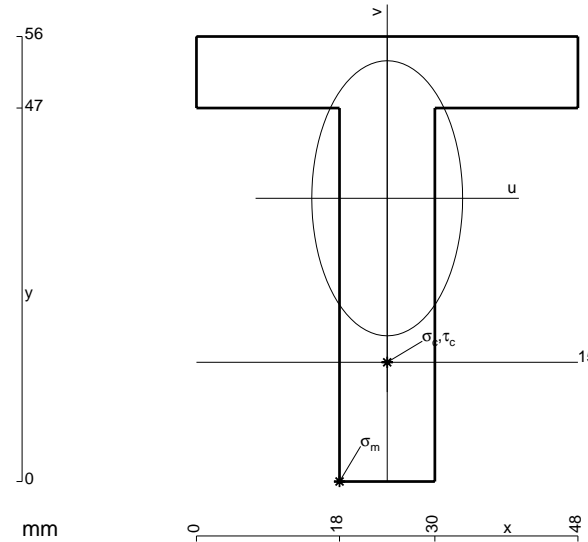
$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (1/4 b - 1/6 b) Fb 1/EJ + (b) \theta = 13/12 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (1/4 b - 1/6 b) Fb 1/EJ + (-b) \theta = 13/12 Fb^2/EJ$$



- A = 996. mm<sup>2</sup>
- J<sub>u</sub> = 298526. mm<sup>4</sup>
- J<sub>v</sub> = 89712. mm<sup>4</sup>
- y<sub>g</sub> = 35.64 mm
- T<sub>y</sub> = -5580. N
- M<sub>x</sub> = -1841400. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -35.64 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -219.9 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 15. mm
- v<sub>c</sub> = -20.64 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -127.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.891 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 128.1 N/mm<sup>2</sup>
- S = 5066. mm<sup>3</sup>







$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/4 b) Fb 1/EJ + (b) \theta = 3/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + 1/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-1/2 x + 1/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

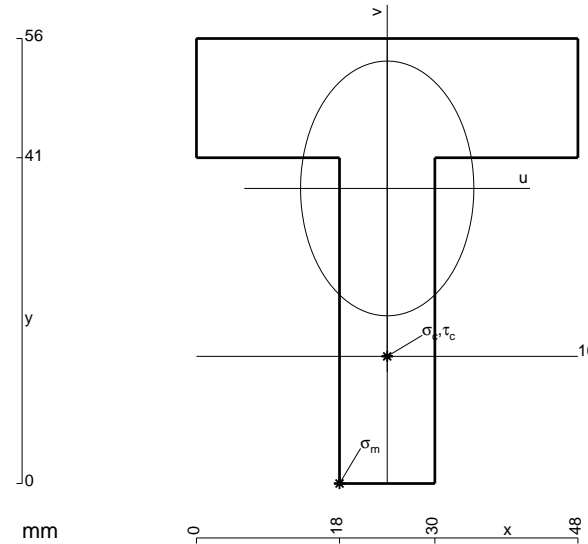
$$L_{FC}^{xo} = \int_0^b (-1/2 + 1/2 x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx$$

$$= [-1/2 x + 1/4 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/4 b + 1/6 b - 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

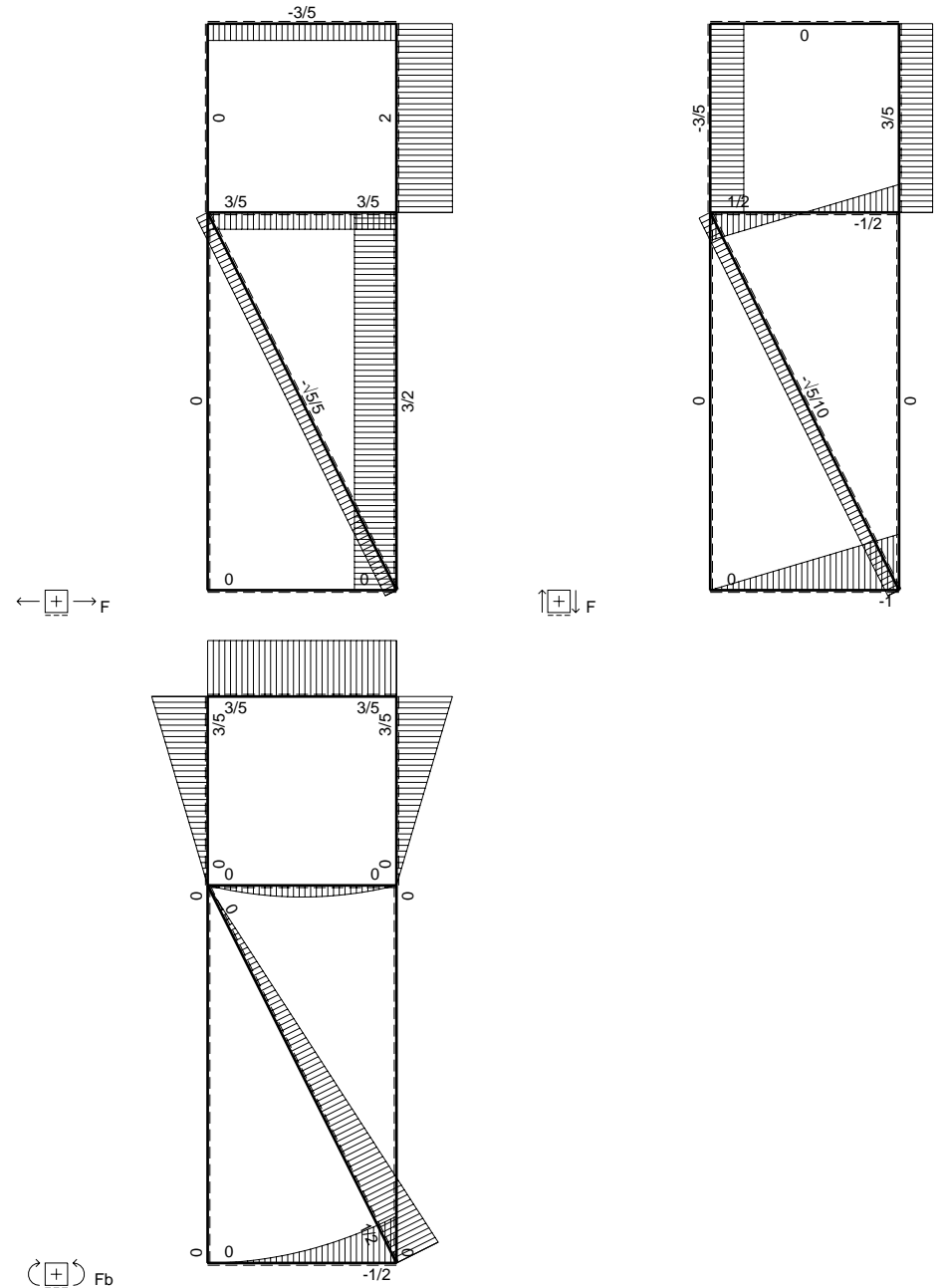
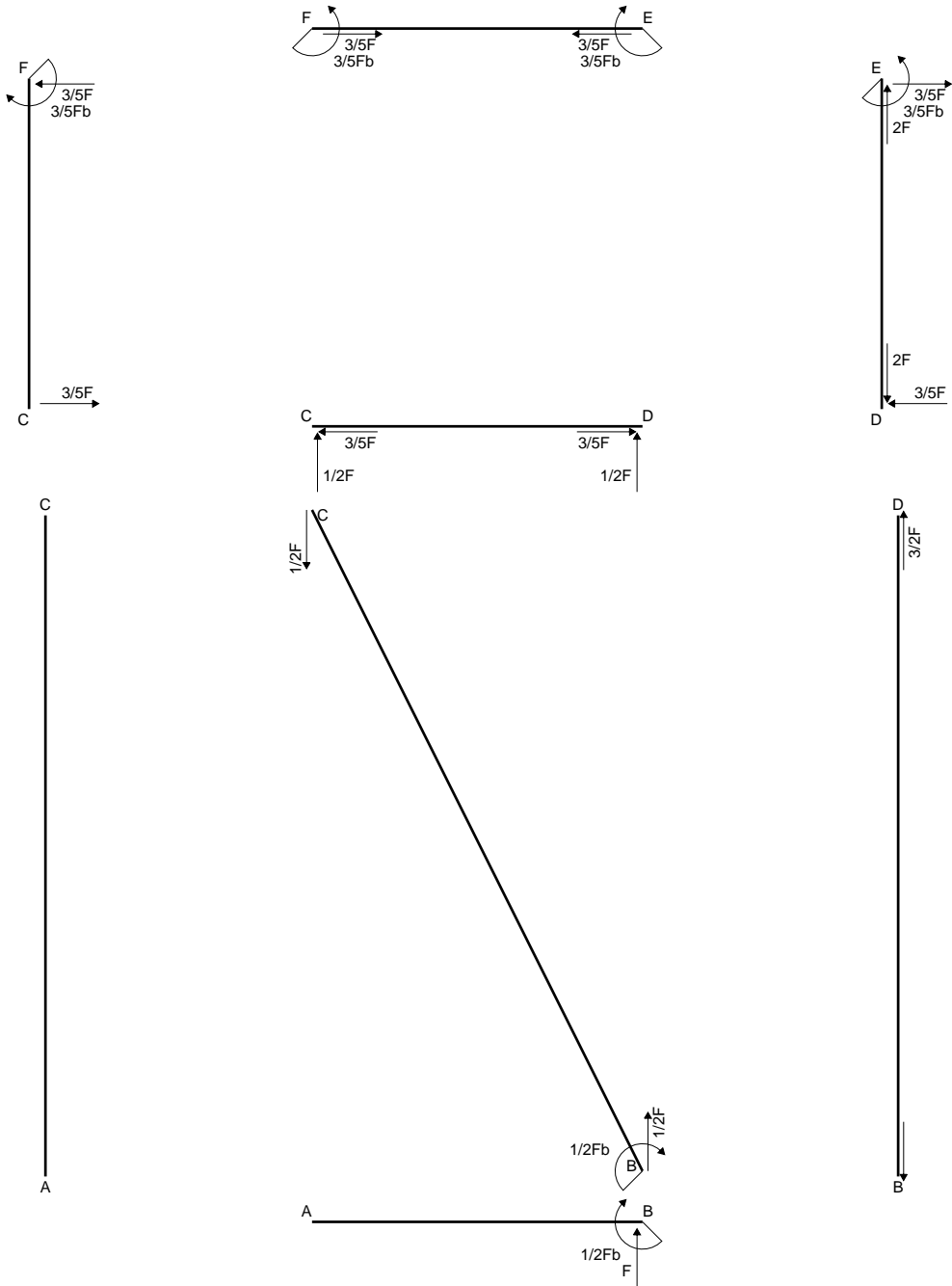
$$= (-1/3 b + 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$

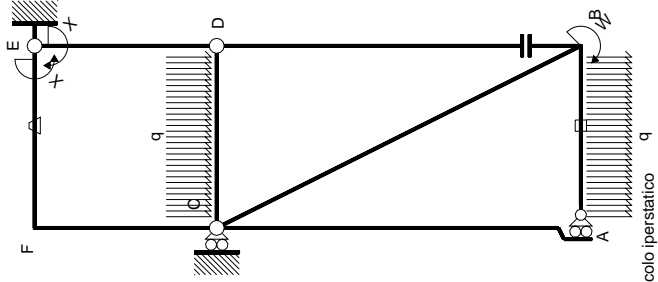


- A = 1212. mm<sup>2</sup>
- J<sub>u</sub> = 311566. mm<sup>4</sup>
- J<sub>v</sub> = 144144. mm<sup>4</sup>
- y<sub>g</sub> = 37.13 mm
- T<sub>y</sub> = -5510. N
- M<sub>x</sub> = -1928500. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -37.13 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -229.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 16. mm
- v<sub>c</sub> = -21.13 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -130.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 8.244 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 131.6 N/mm<sup>2</sup>
- S = 5594. mm<sup>3</sup>

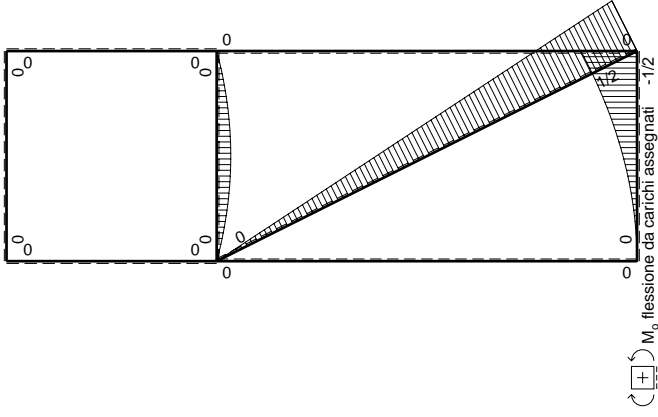








Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati  $-1/2$

Quadro contributi PLV per iperstatica  $X=W_{EF}$

→	$M_x(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$
AB b	0	$-1/2qx^2$	0	0	0	0	0+0	0
BA b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0+0	0
BC $\sqrt{5}b$	0	$1/2Fb-\sqrt{5}/10Fx$	0	0	0	0	0	0
AC 2b	0	0	0	0	0	0	0+0	0
CA 2b	0	0	0	0	0	0	0+0	0
DB 2b	0	0	0	0	0	0	0+0	0
BD 2b	0	0	0	0	0	0	0+0	0
DE b	$-x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3Xb/EJ$
ED b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$
CD b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0
DC b	0	$-1/2Fx+1/2qx^2$	0	0	0	0	0+0	0
EF b	-1	0	$-Fb/EJ$	0	$Fb/EJ$	1	$(0+1)Fb^2/EJ$	$Xb/EJ$
FE b	1	0	$Fb/EJ$	0	$Fb/EJ$	1	$(0+1)Fb^2/EJ$	$Xb/EJ$
FC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$
CF b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3Xb/EJ$
	totali						$Fb^2/EJ$	$5/3Xb/EJ$
	iperstatica $X=W_{EF}$						$-3/5Fb$	

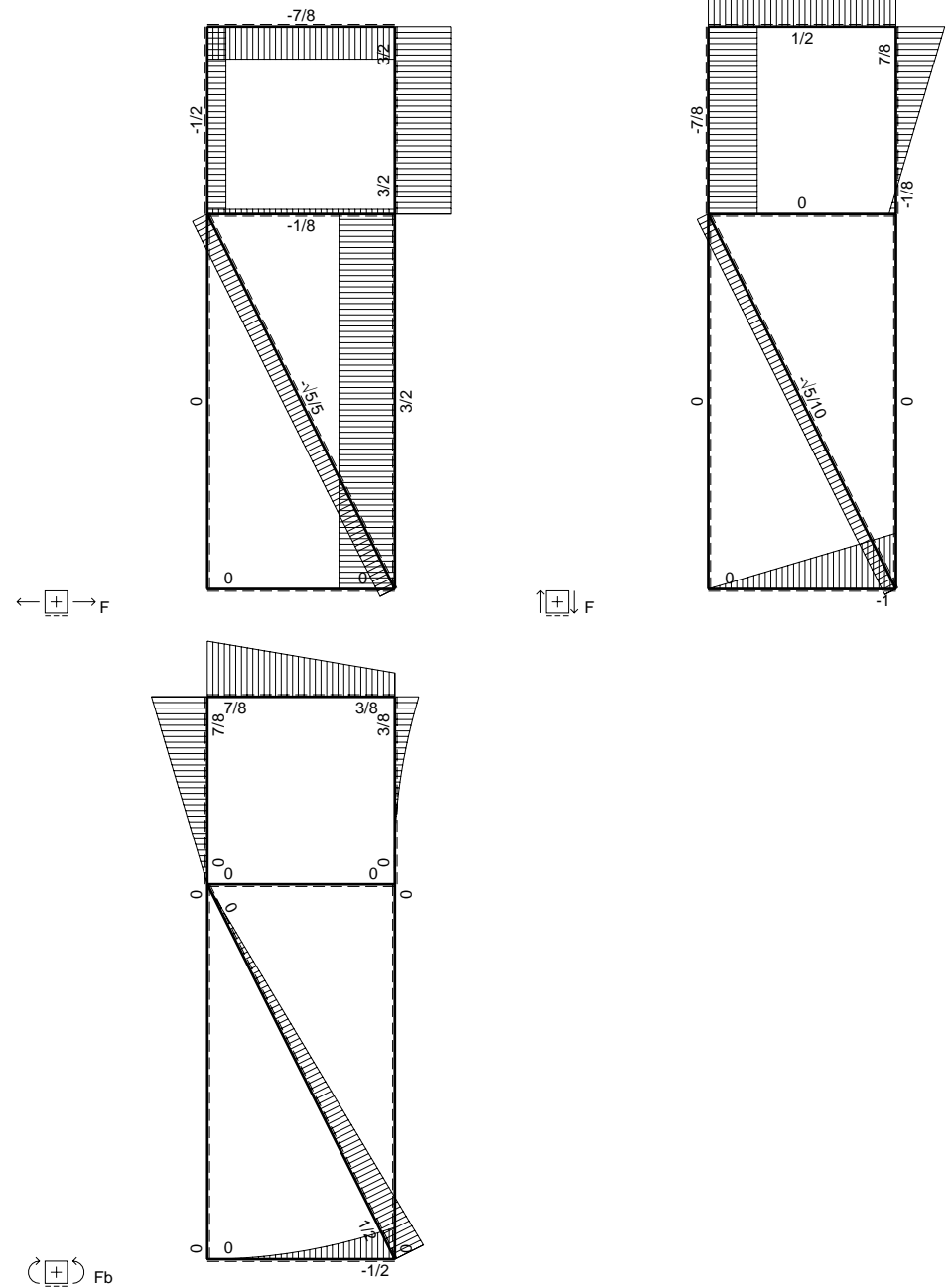
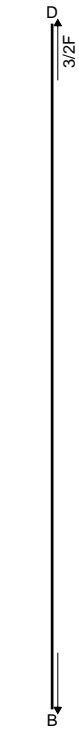
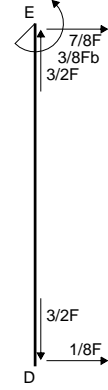
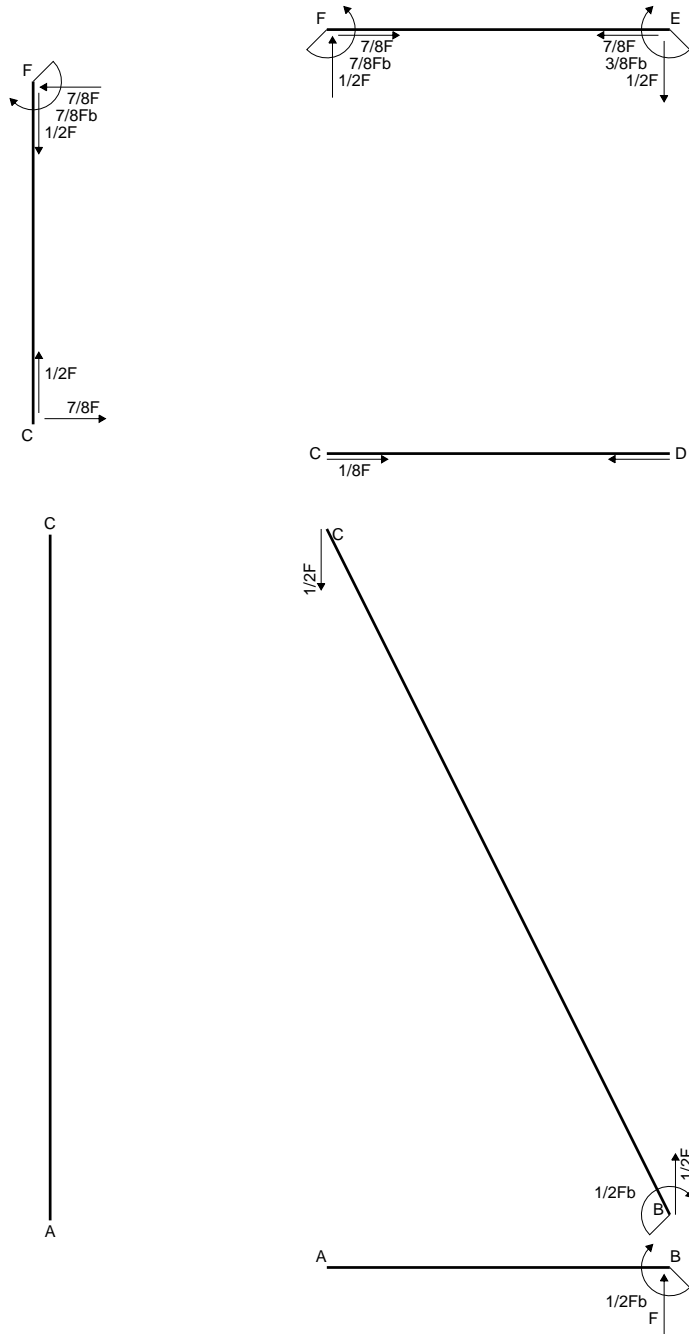
Sviluppi di calcolo iperstatica

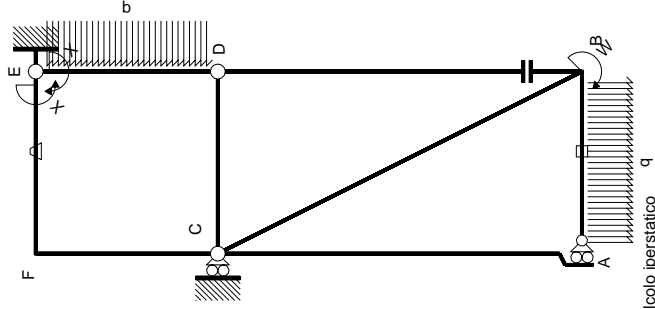
$M_x$  flessione da iperstatica  $X=1$



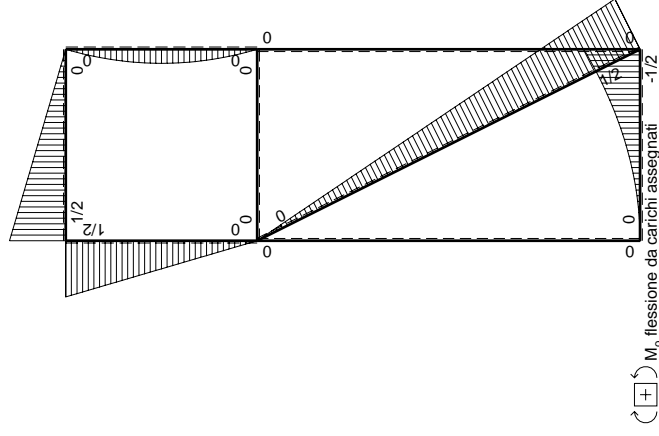




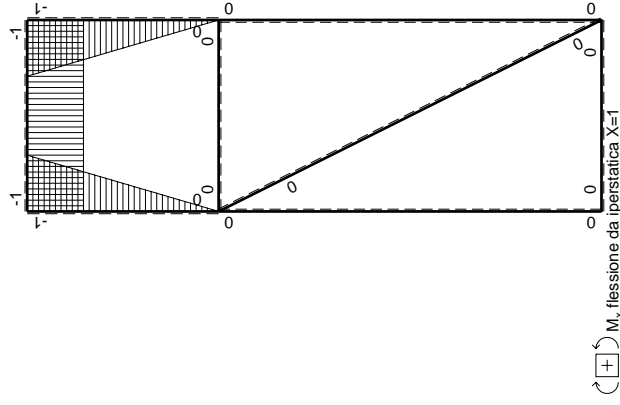




Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contribuiti PLV per iperstatica X=W<sup>EF</sup>

←	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	-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
BA B	0	1/2Fb-Fx+1/2qx <sup>2</sup>	0	0	0	0	0	0
BC √5b	0	1/2Fb-√5/10Fx	0	0	0	0	0+0	0
CA 2b	0	0	0	0	0	0	0+0	0
DB 2b	0	0	0	0	0	0	0+0	0
BD 2b	0	0	0	0	0	0	0+0	0
DE B	-x/b	-1/2Fx+1/2qx <sup>2</sup>	0	1/2F <sup>2</sup> x <sup>2</sup> /b-1/2qx <sup>3</sup> /b	0	0	x <sup>2</sup> /b <sup>2</sup>	0
ED 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>	1/3xb/EJ
CD b	0	0	0	0	0	0	0+0	0
DC b	0	0	0	0	0	0	0+0	0
EF B	-1	1/2Fx	-Fb/EJ	-1/2Fx	Fb/EJ	1	(-1/4+1)Fb <sup>2</sup> /EJ	Xb/EJ
FE B	1	-1/2Fb+1/2Fx	Fb/EJ	-1/2Fb+1/2Fx	Fb/EJ	1	(-1/4+1)Fb <sup>2</sup> /EJ	Xb/EJ
FC B	-1+x/b	1/2Fb-1/2Fx	0	-1/2Fb+Fx-1/2Fx <sup>2</sup> /b	0	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	(-1/6+0)Fb <sup>2</sup> /EJ
CF B	x/b	-1/2Fx	0	-1/2Fx <sup>2</sup> /b	0	0	x <sup>2</sup> /b <sup>2</sup>	1/3xb/EJ
totali								5/8Fb <sup>2</sup> /EJ
								-3/8Fb

iperstatica X=W<sup>EF</sup>

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/4 b) Fb 1/EJ + (b) \theta = 3/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + 1/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-1/2 x + 1/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

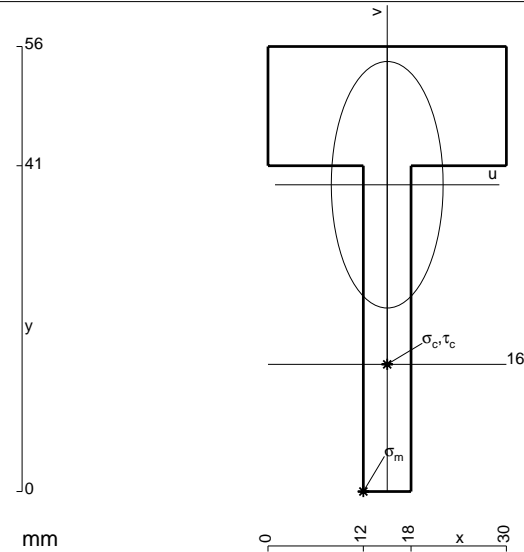
$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ$$

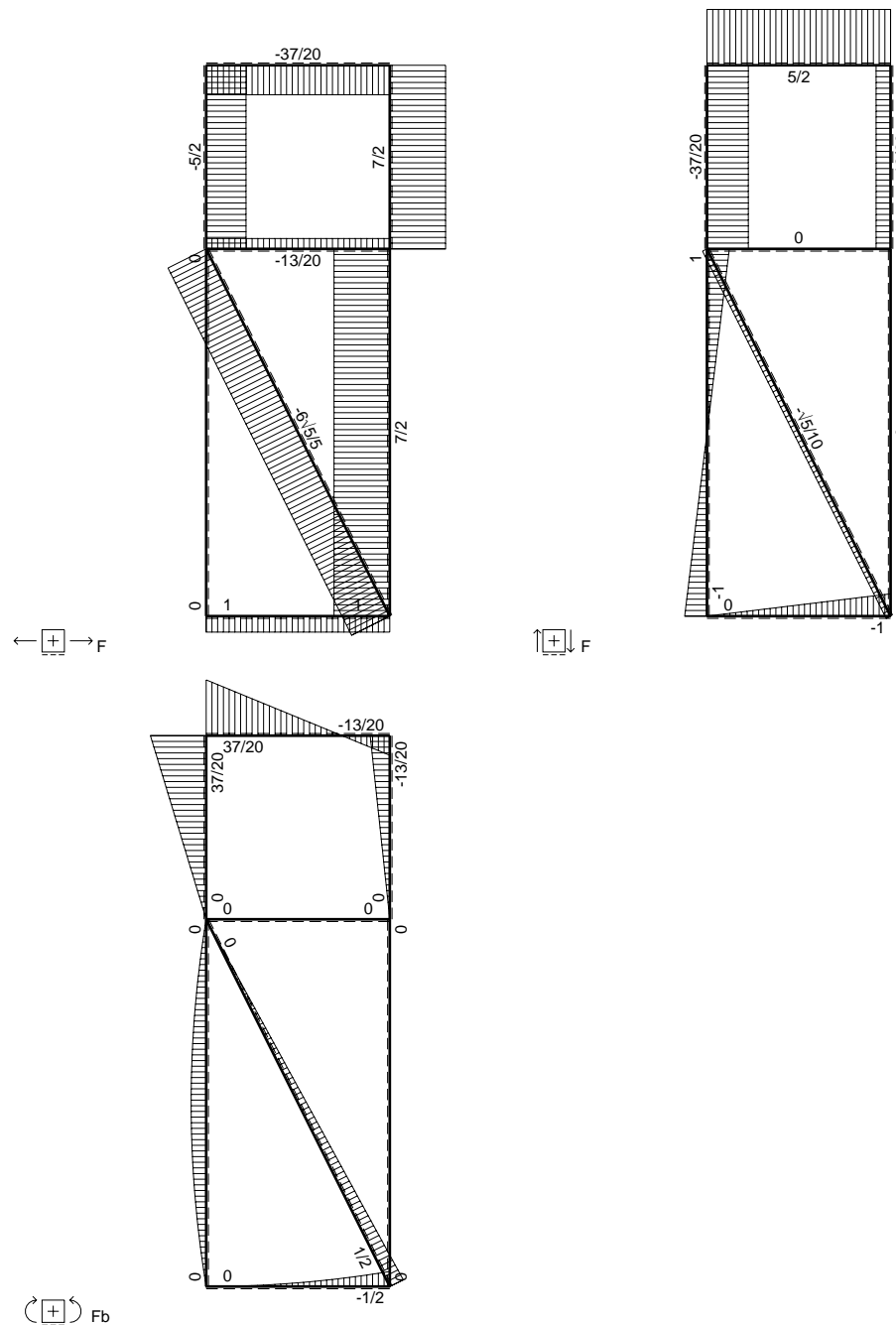
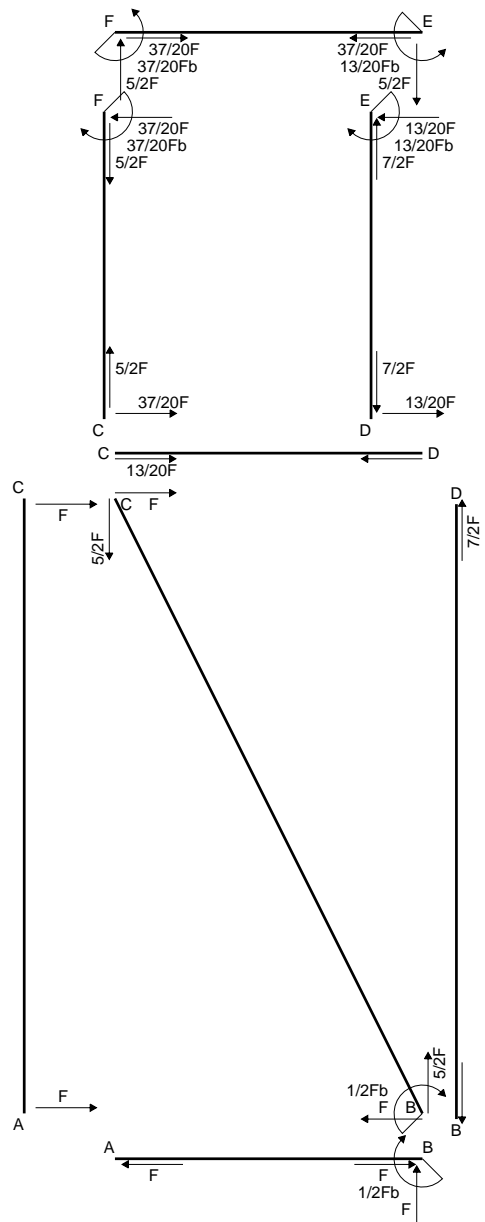
$$= (-1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$



- A = 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
- T<sub>y</sub> = -4450. N
- M<sub>x</sub> = -867750. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -38.6 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> = 16. mm
- v<sub>c</sub> = -22.6 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -117. N/mm<sup>2</sup>
- τ<sub>c</sub> = 13. N/mm<sup>2</sup>
- σ<sub>ρ</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 119.2 N/mm<sup>2</sup>
- S = 2938. mm<sup>3</sup>









$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-5/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-5/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-5/4 b) Fb 1/EJ + (b) \theta = -1/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-5/2 + 5/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-5/2 x + 5/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

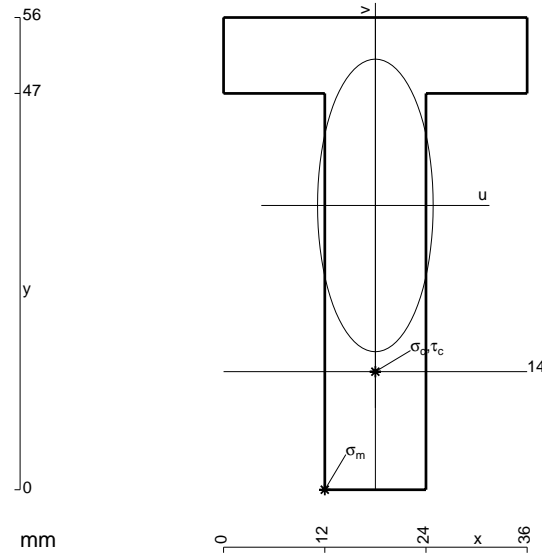
$$= (-5/2 b + 5/4 b) Fb 1/EJ + (-b) \theta = -1/4 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = [-5/2 x + 5/2 x^2/b - 5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

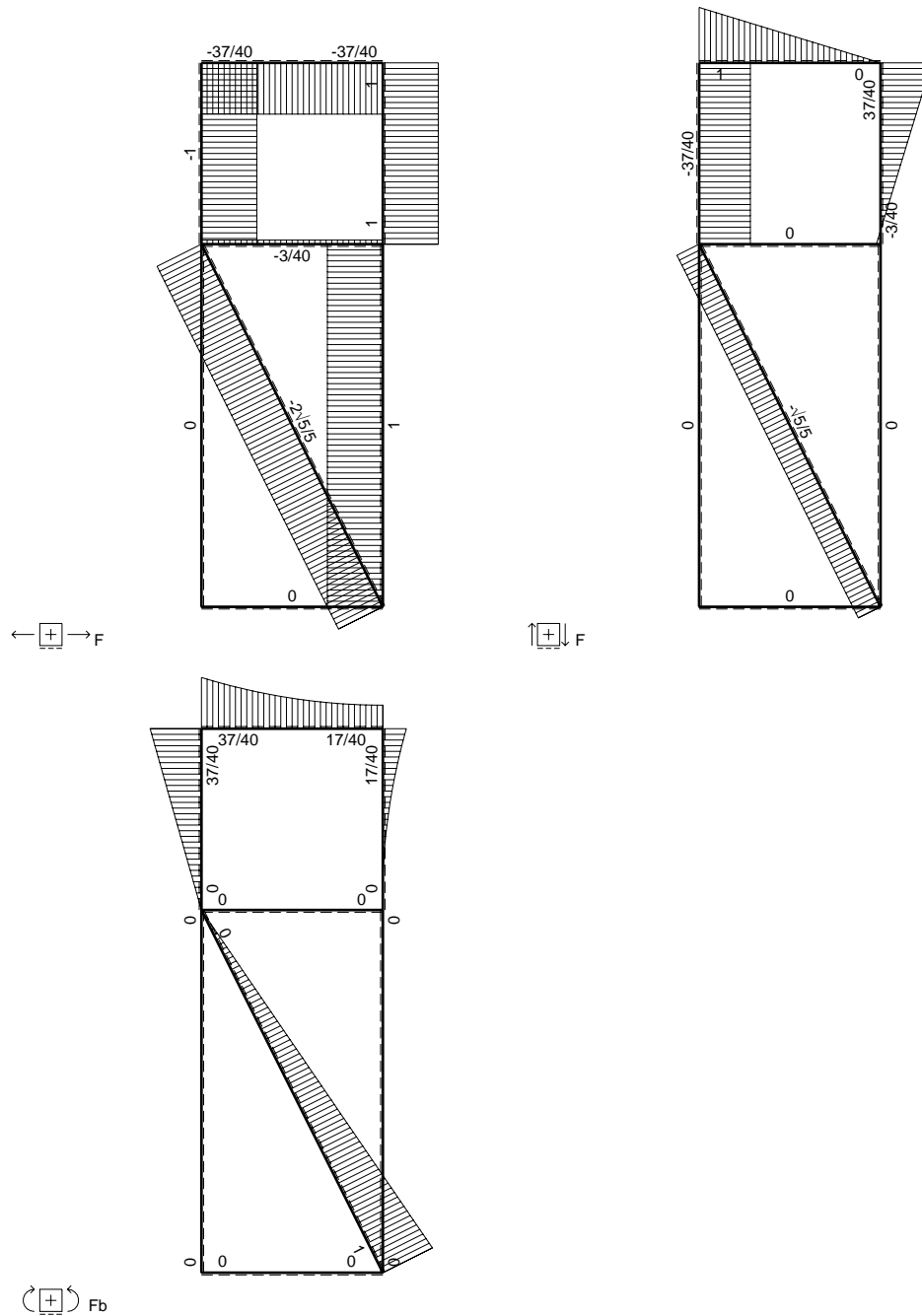
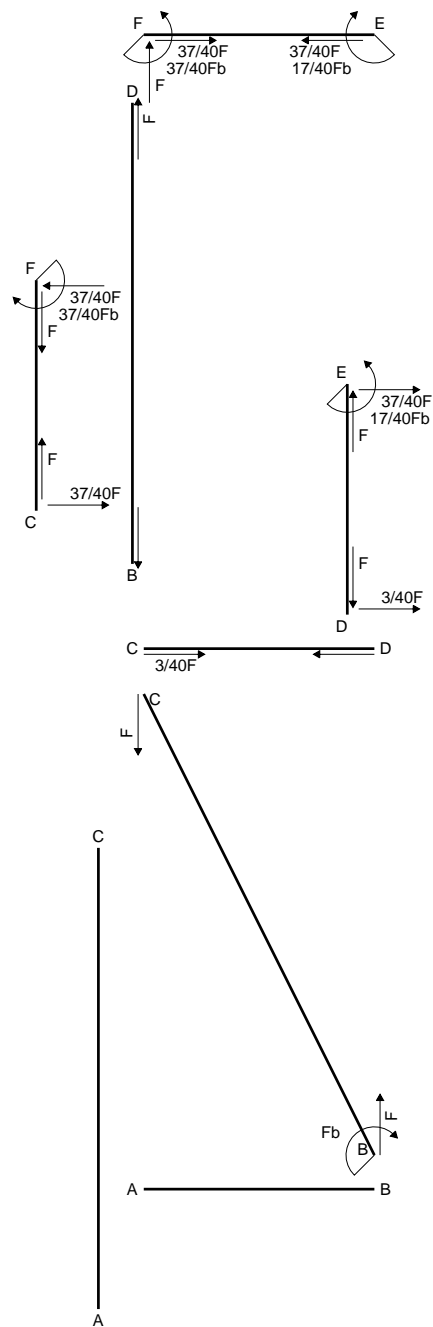
$$L_{CF}^{xo} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

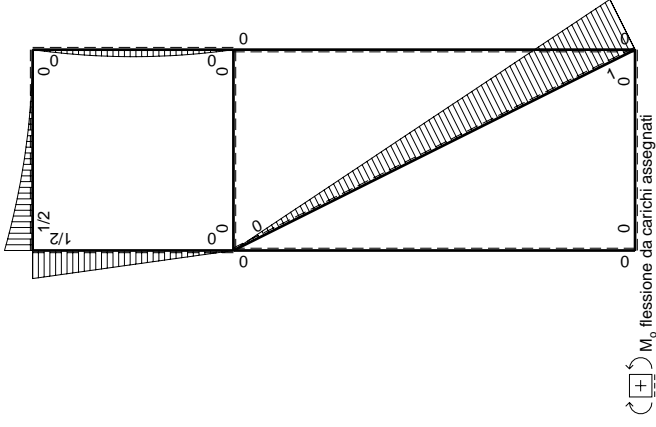
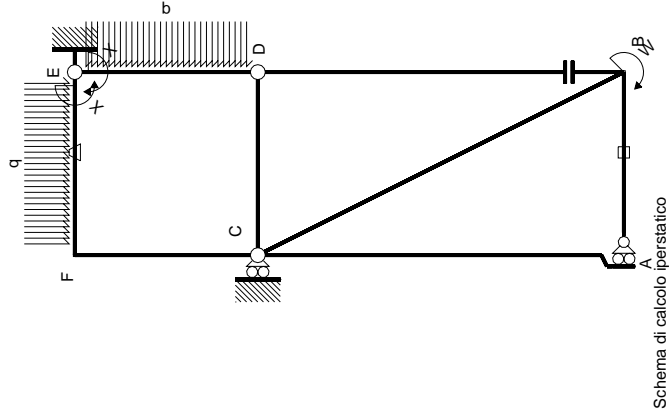
$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$



- A = 888. mm<sup>2</sup>
- J<sub>u</sub> = 267344. mm<sup>4</sup>
- J<sub>v</sub> = 41760. mm<sup>4</sup>
- y<sub>g</sub> = 33.72 mm
- N = 8280. N
- T<sub>y</sub> = -8280. N
- M<sub>x</sub> = -1738800. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -33.72 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = -210. N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 14. mm
- V<sub>c</sub> = -19.72 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = -118.9 N/mm<sup>2</sup>
- τ<sub>c</sub> = 11.58 N/mm<sup>2</sup>
- σ<sub>o</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 120.6 N/mm<sup>2</sup>
- S = 4488. mm<sup>3</sup>

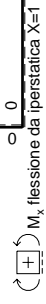






Quadro contributi PLV per iperstatica $X=W_{EF}$		$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x (M_0/EJ + \theta) dx$	$\int M^x M_x / E J dx$
AB b	0	0	0	0	0	0	0	0	0
BA b	0	0	0	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$Fb\sqrt{5}/5Fx$	0	0	0	0	0	0	0
AC 2b	0	0	0	0	0	0	0	0	0
CA 2b	0	0	0	0	0	0	0	0	0
DB 2b	0	0	0	0	0	0	0	0	0
BD 2b	0	0	0	0	0	0	0	0	0
DE b	-x/b	$-1/2Fx + 1/2qx^2$	0	0	$1/2Fx^2/b - 1/2qx^3/b$	0	0	$x^2/b^2$	$1/24+0)Fb^2/EJ$
ED b	1-x/b	$1/2Fx - 1/2qx^2$	0	0	$1/2Fx - Fx^2/b + 1/2qx^3/b$	0	0	$1-2x/b+x^2/b^2$	$(1/24+0)Fb^2/EJ$
CD b	0	0	0	0	0	0	0	0	0+0
DC b	0	0	0	0	0	0	0	0	0+0
EF b	-1	$1/2qx^2$	-Fb/EJ	-Fb/EJ	$-1/2Fx^2/b$	Fb/EJ	1	1	$(-1/6+1)Fb^2/EJ$
FE b	1	$-1/2Fb + Fx - 1/2qx^2$	Fb/EJ	-Fb/EJ	$-1/2Fb + Fx - 1/2Fx^2/b$	Fb/EJ	1	1	$(-1/6+0)Fb^2/EJ$
FC b	-1+x/b	$1/2Fb - 1/2Fx$	0	0	$-1/2Fb + Fx - 1/2Fx^2/b$	0	0	$x^2/b^2$	$(-1/6+0)Fb^2/EJ$
CF b	x/b	-1/2Fx	0	0	$-1/2Fx^2/b$	0	0	$x^2/b^2$	$1/3xb/EJ$
totali									$17/24Fb^2/EJ$
									$-17/40Fb$

Sviluppi di calcolo iperstatica



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/6 b) Fb 1/EJ + (b) \theta = 5/6 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx$$

$$= [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

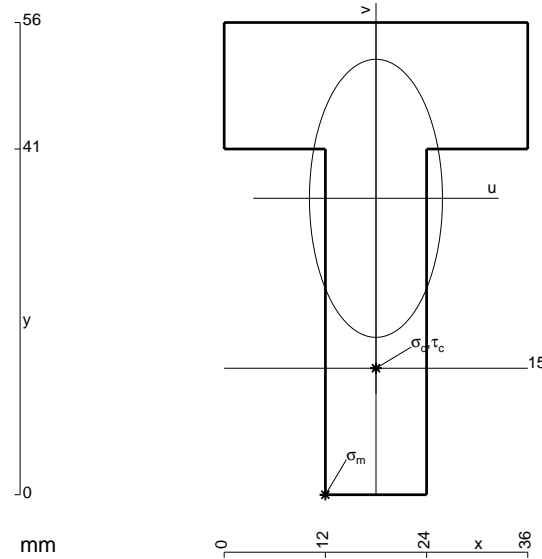
$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ + (-b) \theta = 5/6 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ$$

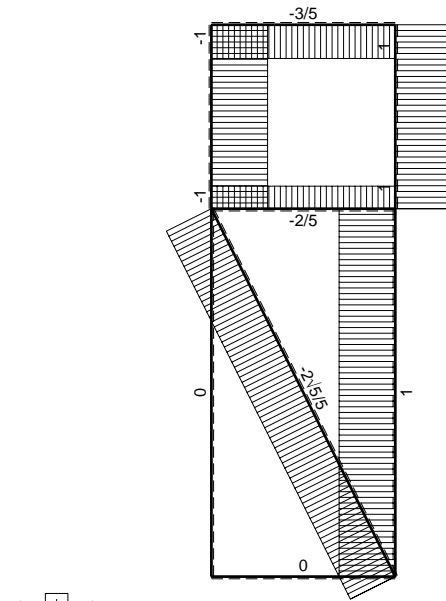
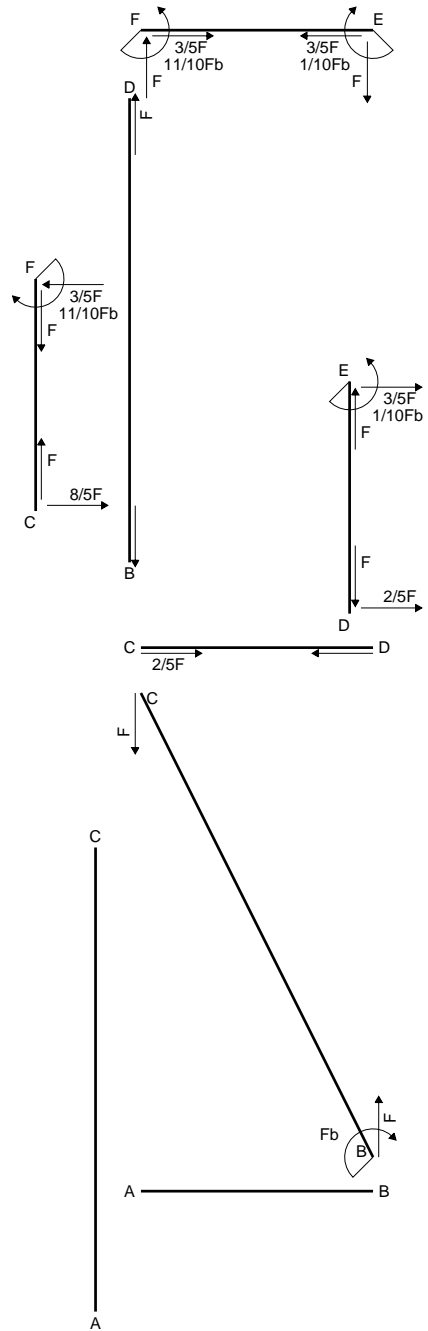
$$= (-1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$



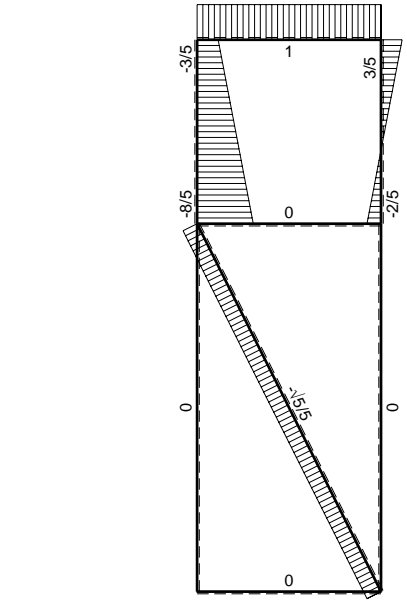
- A = 1032. mm<sup>2</sup>
- J<sub>u</sub> = 280881. mm<sup>4</sup>
- J<sub>v</sub> = 64224. mm<sup>4</sup>
- y<sub>g</sub> = 35.15 mm
- N = -3470. N
- T<sub>y</sub> = -1735. N
- M<sub>x</sub> = 1784800. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -35.15 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = 220. N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 15. mm
- v<sub>c</sub> = -20.15 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = 124.7 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.562 N/mm<sup>2</sup>
- σ<sub>g</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 124.8 N/mm<sup>2</sup>
- S = 4977. mm<sup>3</sup>



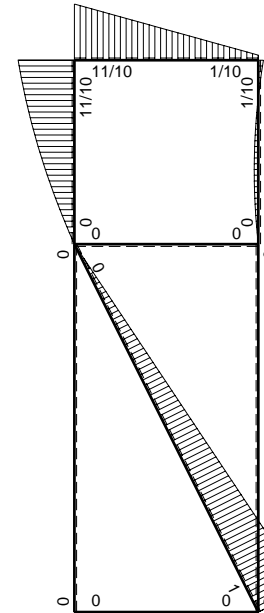




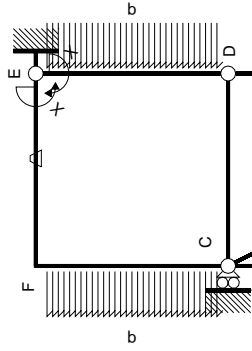
← ⊕ → F



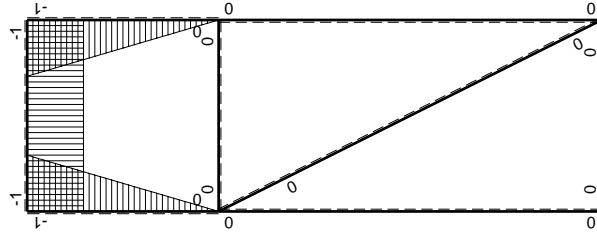
↑ ⊕ ↓ F



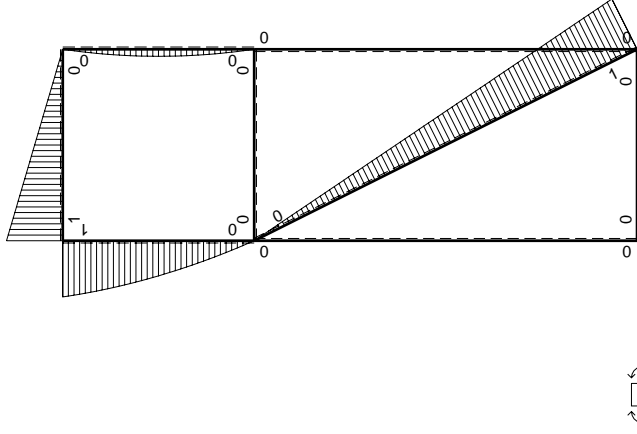
⊕ ⊕ F<sub>b</sub>



$M_x$  flessione da iperstatica  $X=1$



$M_0$  flessione da carichi assegnati



Quadro contributi PLV per iperstatica  $X=W_{EF}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$Fb-\sqrt{5}/5Fx$	0	0	0	0	0	0
CA 2b	0	0	0	0	0	0	0+0	0
DB 2b	0	0	0	0	0	0	0+0	0
BD 2b	0	0	0	0	0	0	0	0
DE b	$-x/b$	$-1/2Fx+1/2qx^2$	0	$1/2Fx^2/b-1/2qx^3/b$	0	0	$x^2/b^2$	0
ED b	$1-x/b$	$1/2Fx-1/2qx^2$	0	$1/2Fx-Fx^2/b+1/2qx^3/b$	0	0	$1-2x/b+x^2/b^2$	$1/3xb/EJ$
CD b	0	0	0	0	0	0	0+0	0
FE b	-1	Fx	$-Fb/EJ$	-Fx	$Fb/EJ$	1	$(-1/2+1)Fb^2/EJ$	$Xb/EJ$
FC b	$-1+x/b$	$Fb-1/2Fx-1/2qx^2$	0	$-Fb+3/2Fx-1/2qx^2/b$	0	0	$1-2x/b+x^2/b^2$	$1/3xb/EJ$
CF b	$x/b$	$-3/2Fx+1/2qx^2$	0	$-3/2Fx^2/b+1/2qx^3/b$	0	0	$x^2/b^2$	$1/6Fb^2/EJ$
totali								
iperstatica $X=W_{EF}$								

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{x_0} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{x_0} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{x_0} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (b) \theta = 1/2 Fb^2/EJ$$

$$L_{FE}^{x_0} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

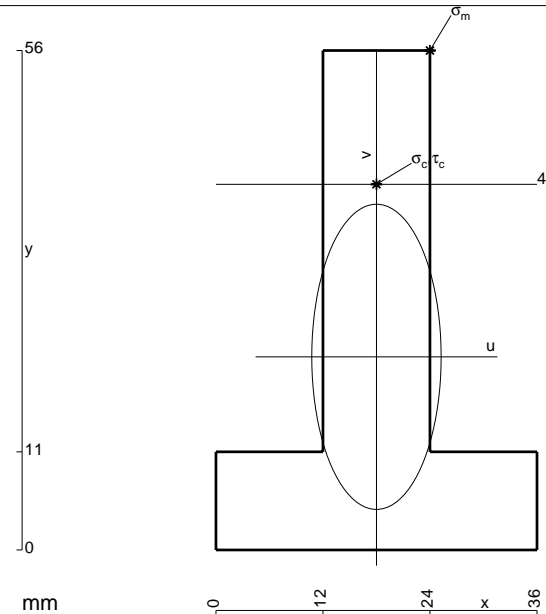
$$= (-b + 1/2 b) Fb 1/EJ + (-b) \theta = 1/2 Fb^2/EJ$$

$$L_{FC}^{x_0} = \int_0^b (-1 + 3/2 x/b - 1/2 x^3/b^3) Fb 1/EJ dx = [-x + 3/4 x^2/b - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-b + 3/4 b - 1/8 b) Fb 1/EJ = -3/8 Fb^2/EJ$$

$$L_{CF}^{x_0} = \int_0^b (-3/2 x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/2 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/8 b) Fb 1/EJ = -3/8 Fb^2/EJ$$



$$A = 936. \text{ mm}^2$$

$$J_u = 274232. \text{ mm}^4$$

$$J_v = 49248. \text{ mm}^4$$

$$y_g = 21.65 \text{ mm}$$

$$N = -3229. \text{ N}$$

$$T_y = -1614. \text{ N}$$

$$M_x = 1805000. \text{ Nmm}$$

$$x_m = 24. \text{ mm}$$

$$y_m = 56. \text{ mm}$$

$$u_m = 6. \text{ mm}$$

$$v_m = 34.35 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -229.5 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 41. \text{ mm}$$

$$v_c = 19.35 \text{ mm}$$

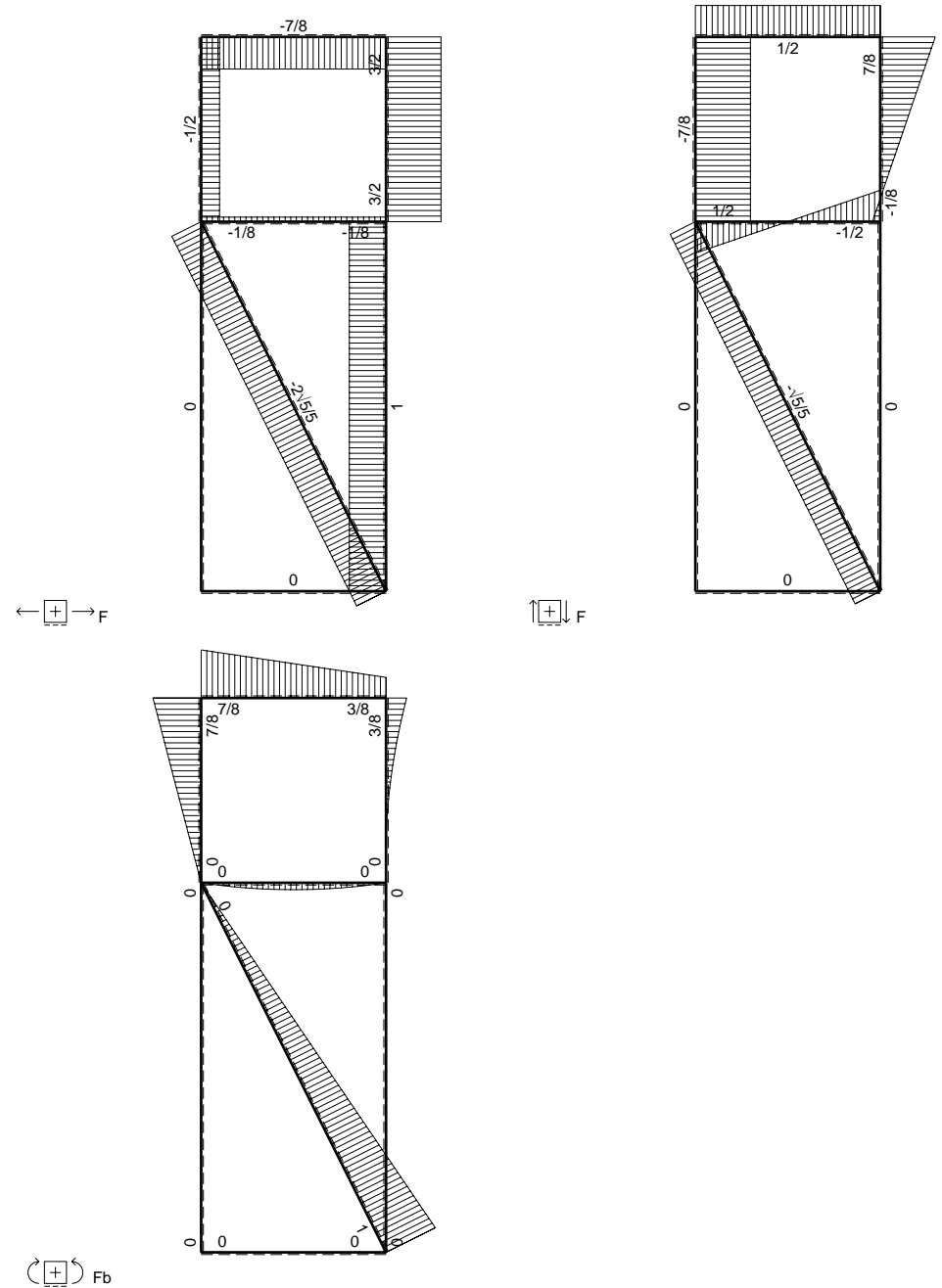
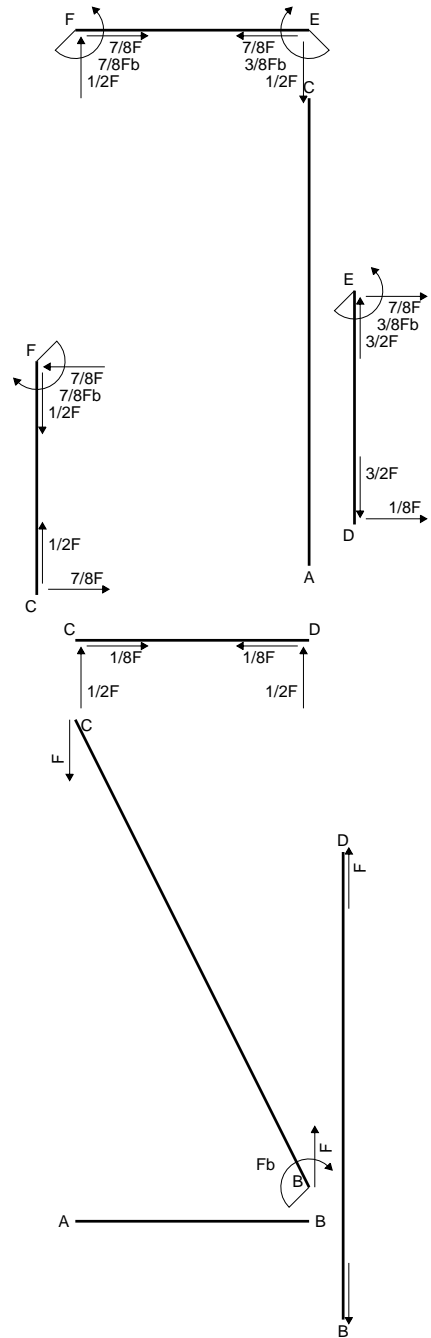
$$\sigma_c = N/A - Mv/J_u = -130.8 \text{ N/mm}^2$$

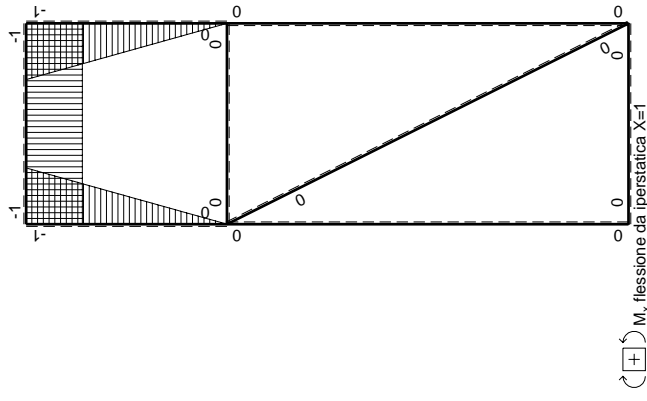
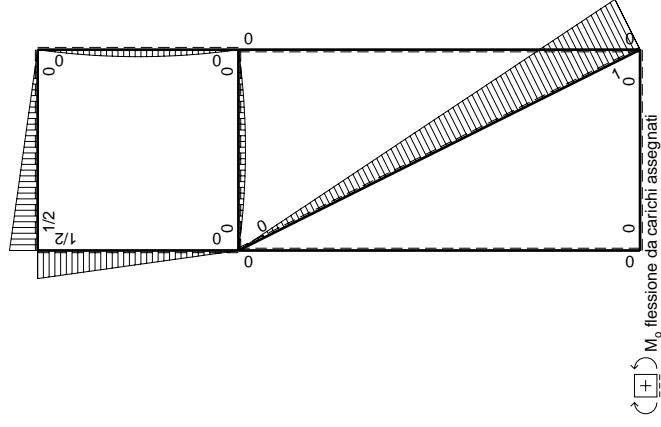
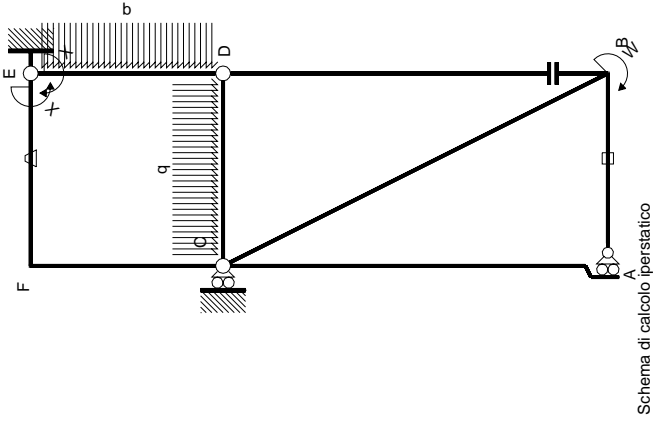
$$\tau_c = 2.371 \text{ N/mm}^2$$

$$\sigma_0 = \sqrt{\sigma^2 + 3\tau^2} = 130.9 \text{ N/mm}^2$$

$$S = 4832. \text{ mm}^3$$







Quadro contributi PLV per iperstatica X=W<sub>EF</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>	∫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	0
BA b	0	0	0	0	0	0	0	0
BC √5b	0	Fb-√5/5Fx	0	0	0	0	0+0	0
CA 2b	0	0	0	0	0	0	0+0	0
DB 2b	0	0	0	0	0	0	0+0	0
BD 2b	0	0	0	0	0	0	0+0	0
DE 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>	0
ED 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>	1/3Xb/EJ
CD b	0	1/2Fx-1/2qx <sup>2</sup>	0	0	0	0	0+0	0
DC b	0	-1/2Fx+1/2qx <sup>2</sup>	0	0	0	0	0+0	0
EF b	-1	1/2Fx	-Fb/EJ	-1/2Fx	Fb/EJ	1	(-1/4+1)Fb <sup>2</sup> /EJ	Xb/EJ
FE b	1	-1/2Fb+1/2Fx	Fb/EJ	-1/2Fb+1/2Fx	Fb/EJ	1	(-1/4+1)Fb <sup>2</sup> /EJ	Xb/EJ
FC b	-1+x/b	1/2Fb-1/2Fx	0	-1/2Fb+Fx-1/2Fx <sup>2</sup> /b	0	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	1/3Xb/EJ
CF b	x/b	-1/2Fx	0	-1/2Fx <sup>2</sup> /b	0	0	x <sup>2</sup> /b <sup>2</sup>	1/3Xb/EJ
totali								5/8Fb <sup>2</sup> /EJ
								-3/8Fb

iperstatica X=W<sub>EF</sub>

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{x_0} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{x_0} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{x_0} = \int_0^b (-1/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/4 b) Fb 1/EJ + (b) \theta = 3/4 Fb^2/EJ$$

$$L_{FE}^{x_0} = \int_0^b (-1/2 + 1/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-1/2 x + 1/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

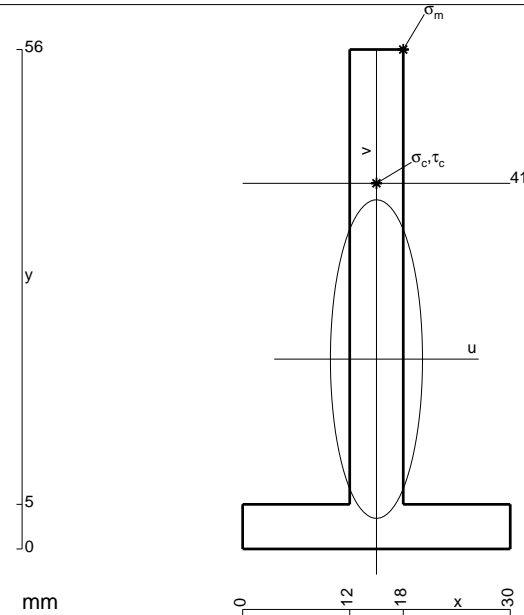
$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

$$L_{FC}^{x_0} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

$$L_{CF}^{x_0} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ$$

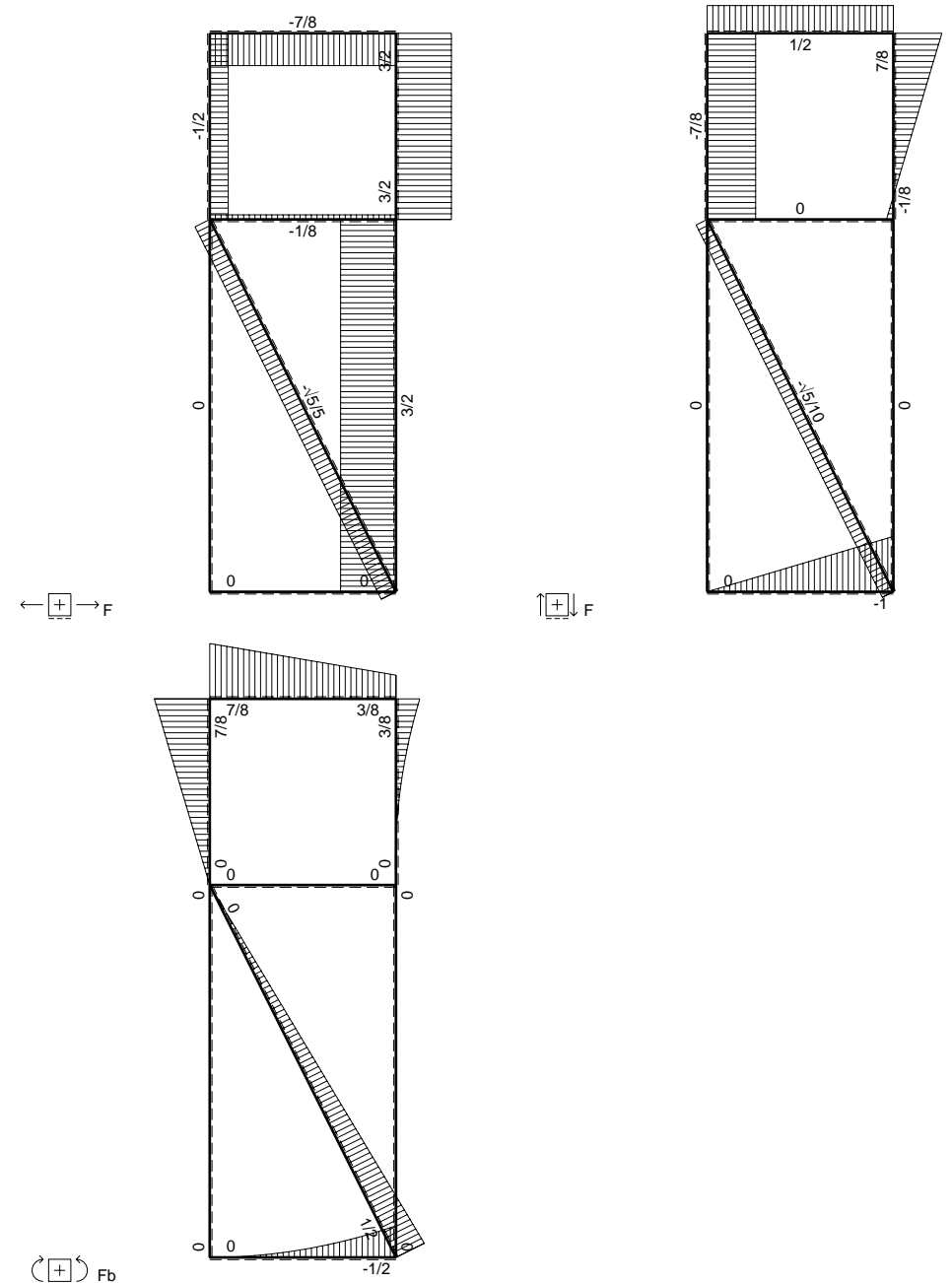
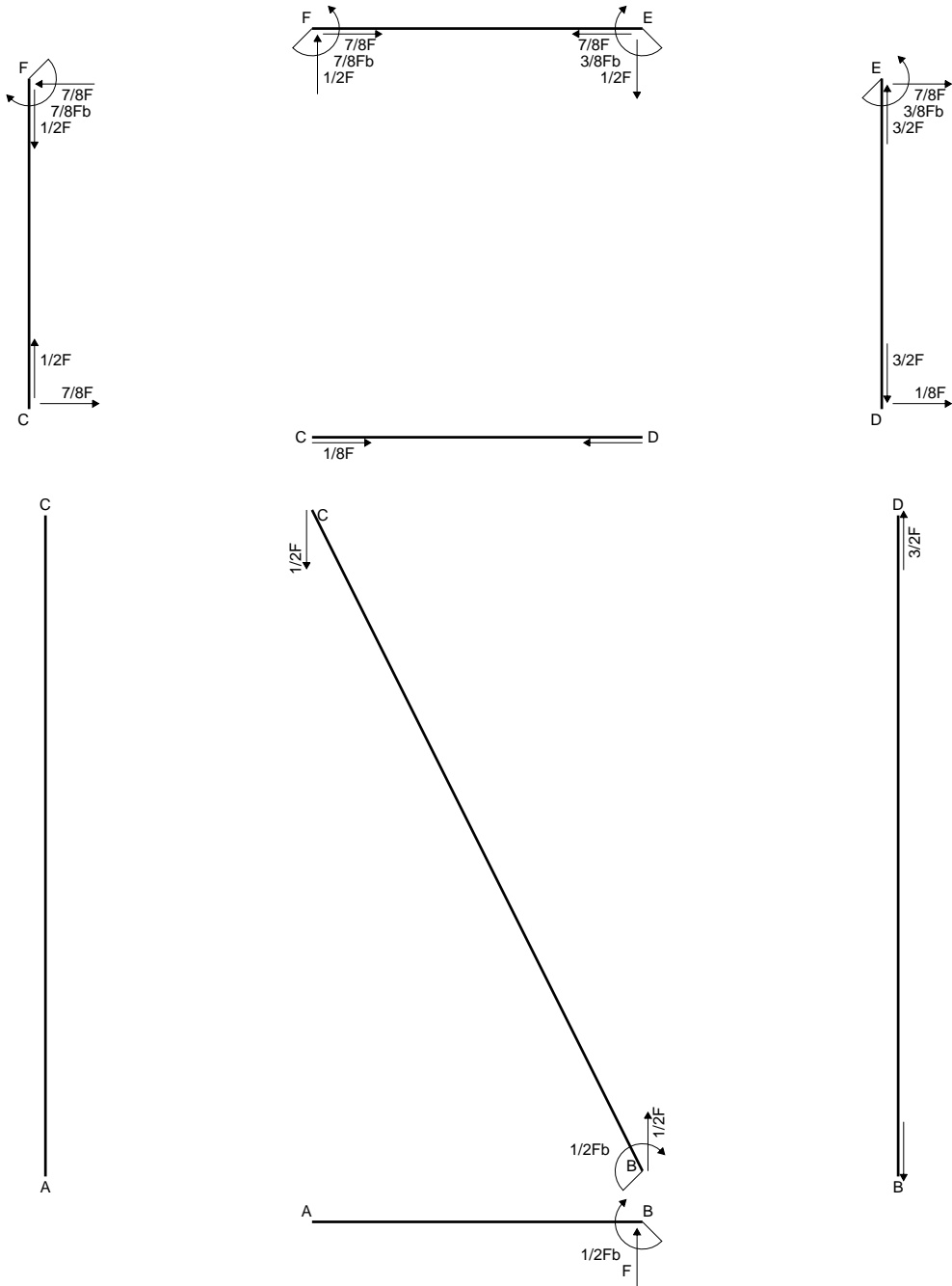
$$= (-1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$



- A = 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 = -1637. N
- T<sub>y</sub> = -818.4 N
- M<sub>x</sub> = 988200. 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-Mv/J<sub>u</sub> = -239.2 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-Mv/J<sub>u</sub> = -137.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.295 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup>+3τ<sup>2</sup>) = 137.5 N/mm<sup>2</sup>
- S = 2449. mm<sup>3</sup>









$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/4 b) Fb 1/EJ + (b) \theta = 3/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + 1/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-1/2 x + 1/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

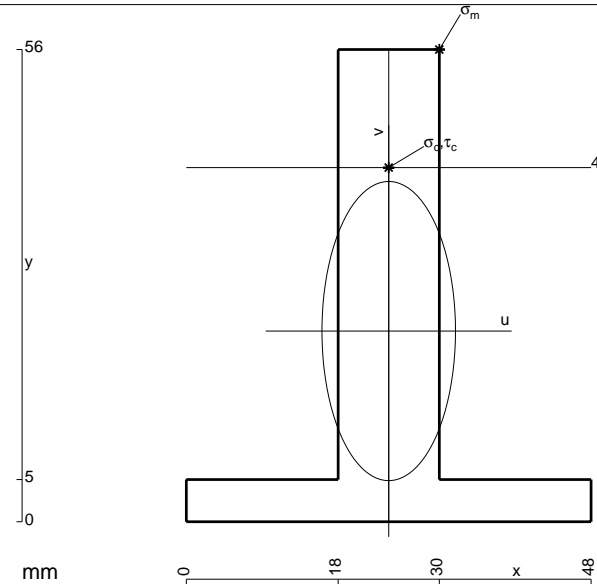
$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

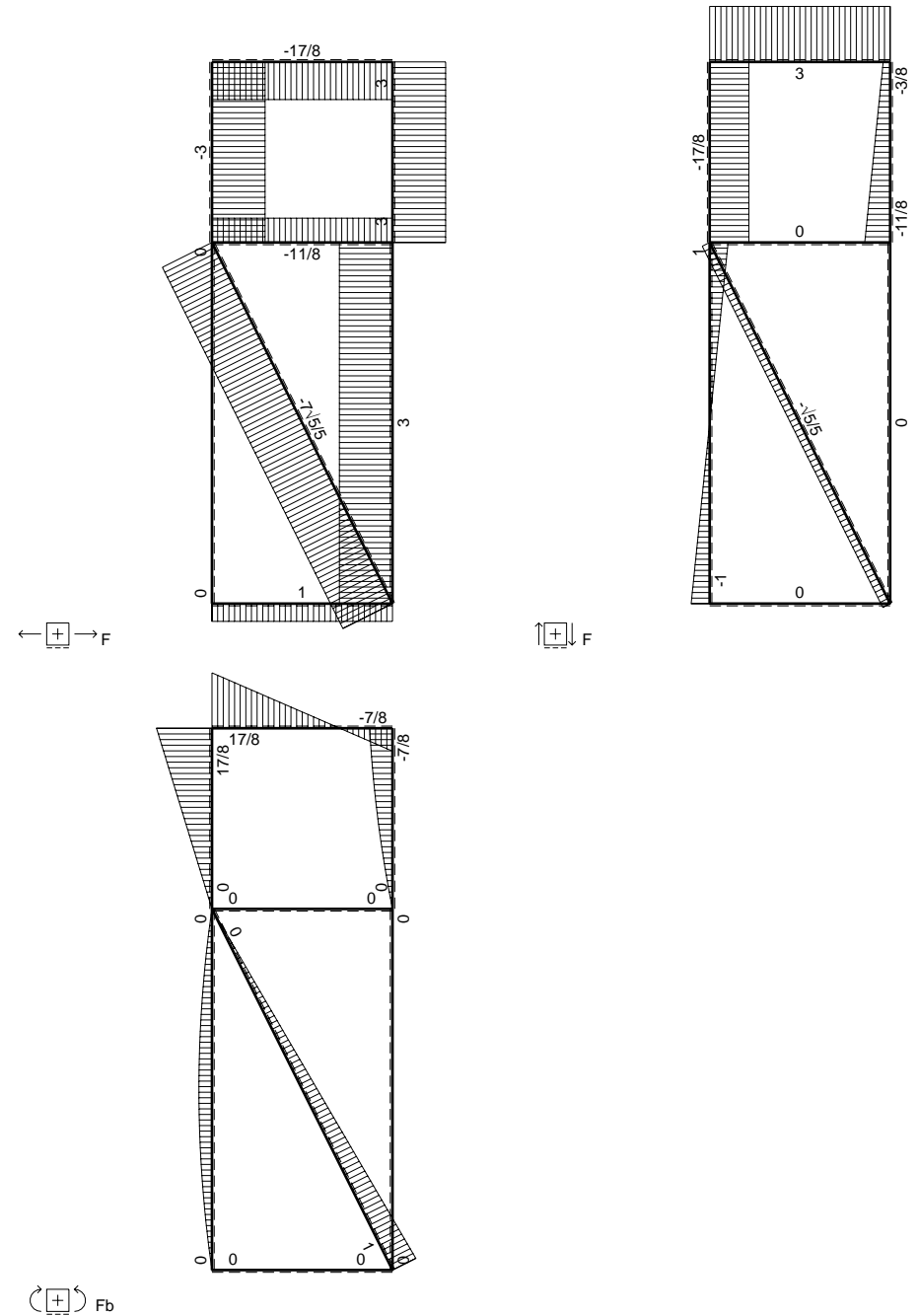
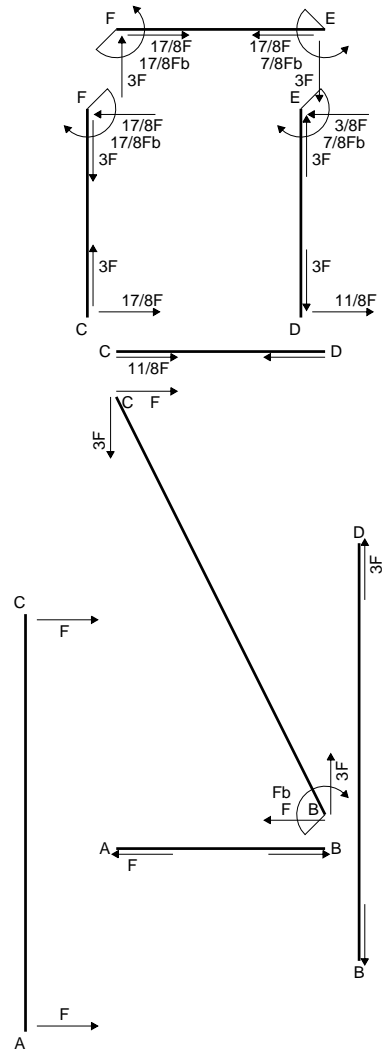
$$L_{CF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$



- A = 852. mm<sup>2</sup>
- J<sub>u</sub> = 268308. mm<sup>4</sup>
- J<sub>v</sub> = 53424. mm<sup>4</sup>
- y<sub>g</sub> = 22.61 mm
- T<sub>y</sub> = -5540. N
- M<sub>x</sub> = -1606600. 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> = -Mv/J<sub>u</sub> = 199.9 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> = -Mv/J<sub>u</sub> = 116.1 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.628 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 116.8 N/mm<sup>2</sup>
- S = 4433. mm<sup>3</sup>







$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-3x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-3/2 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-3/2 b) Fb 1/EJ + (b) \theta = -1/2 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-3 + 3x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-3x + 3/2 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

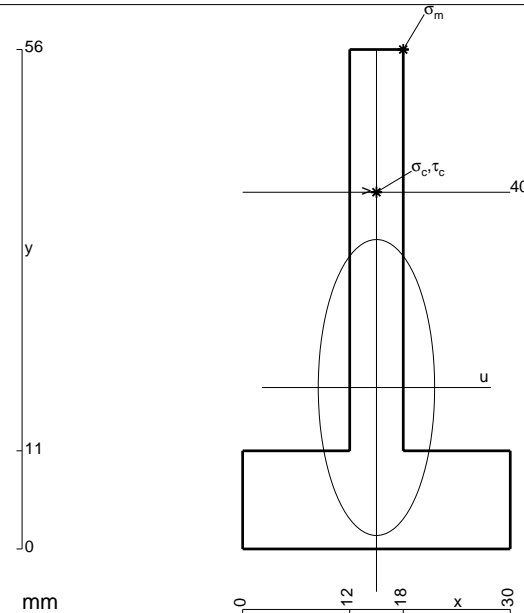
$$= (-3b + 3/2 b) Fb 1/EJ + (-b) \theta = -1/2 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-3 + 6x/b - 3x^2/b^2) Fb 1/EJ dx = [-3x + 3x^2/b - x^3/b^2]_0^b Fb 1/EJ$$

$$= (-3b + 3b - b) Fb 1/EJ = - Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-3x^2/b^2) Fb 1/EJ dx = [-x^3/b^2]_0^b Fb 1/EJ$$

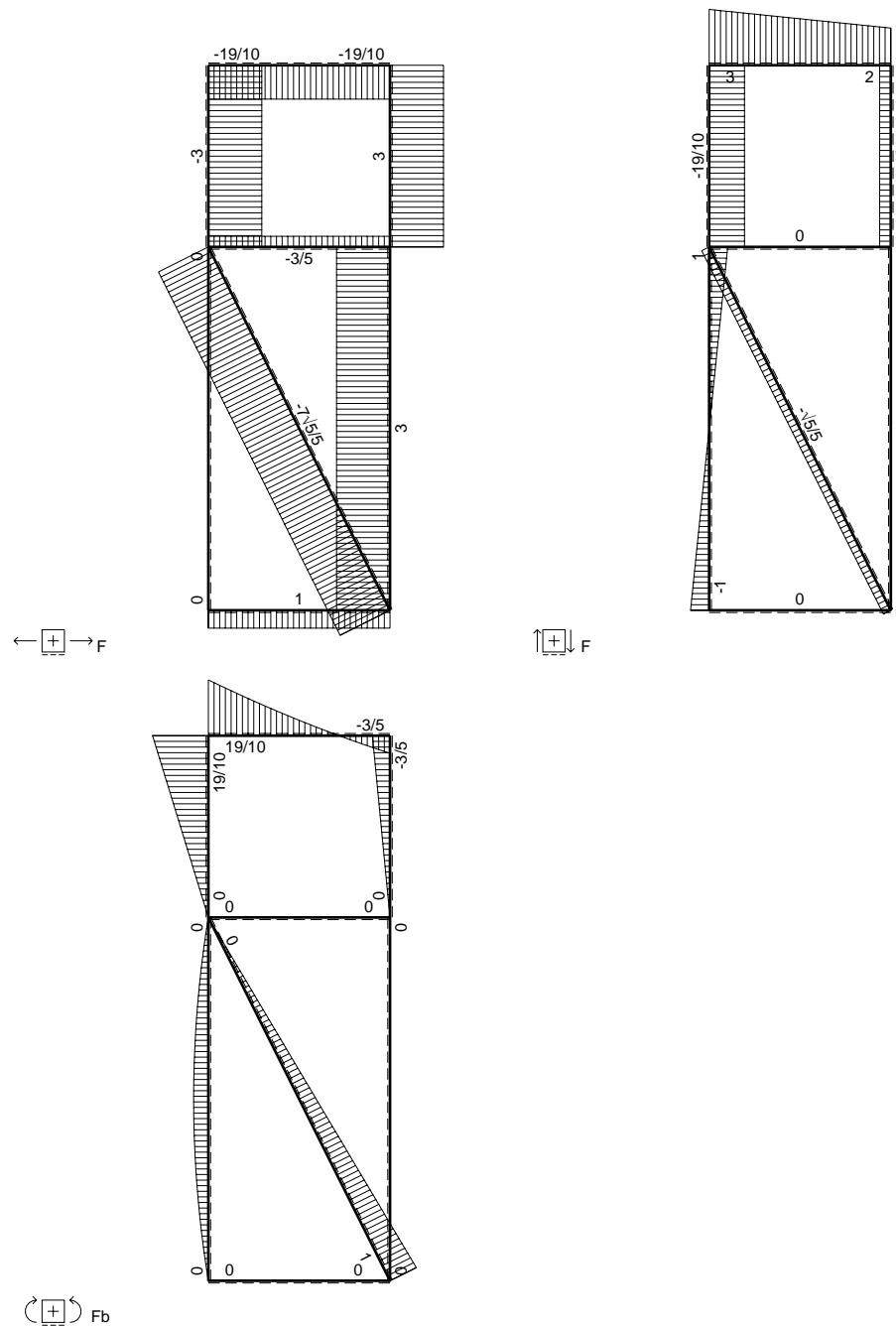
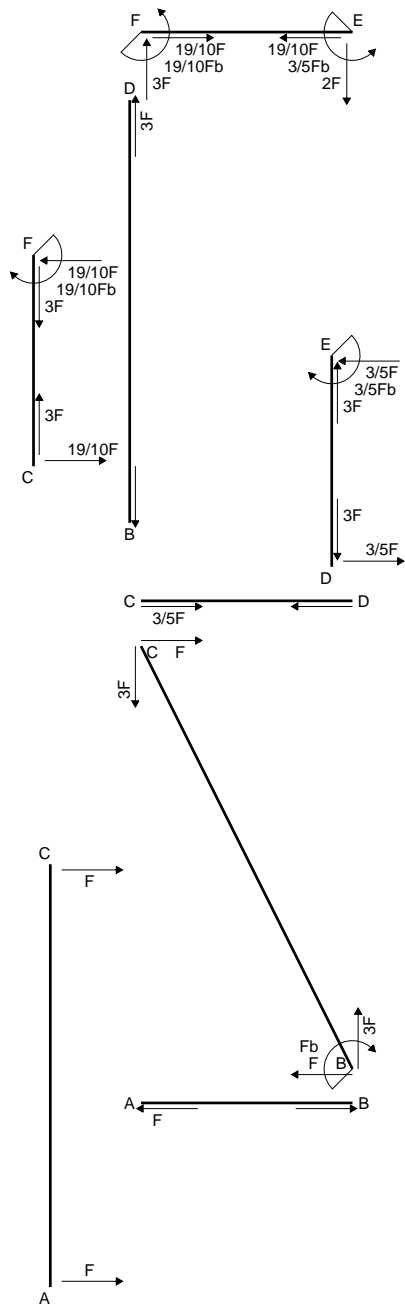
$$= (-b) Fb 1/EJ = - Fb^2/EJ$$



- 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 = -4445. N
- T<sub>y</sub> = -635. N
- M<sub>x</sub> = 880400. 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> = -209.3 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> = -124. N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.838 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup>+3τ<sup>2</sup>) = 124.1 N/mm<sup>2</sup>
- S = 2870. mm<sup>3</sup>



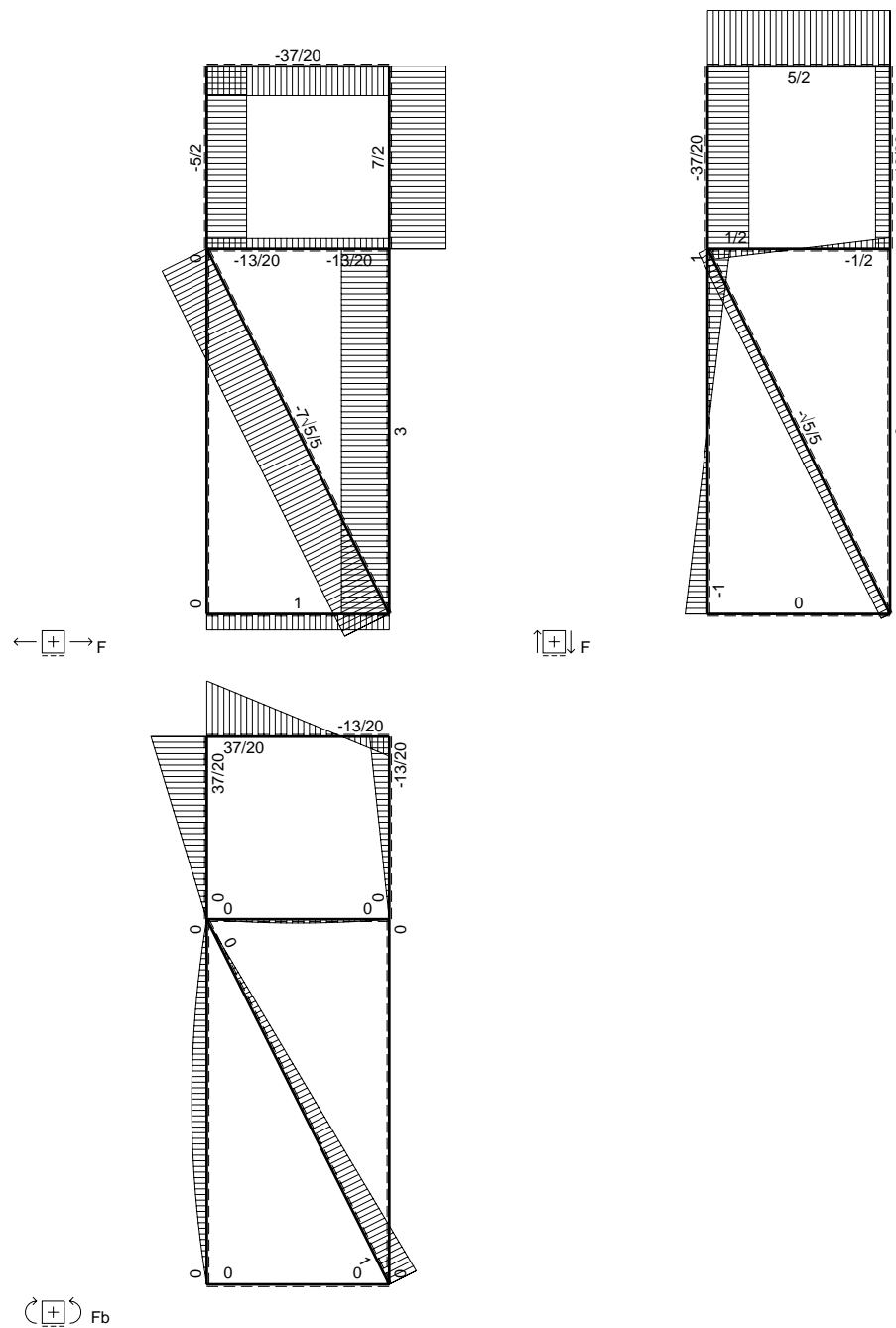
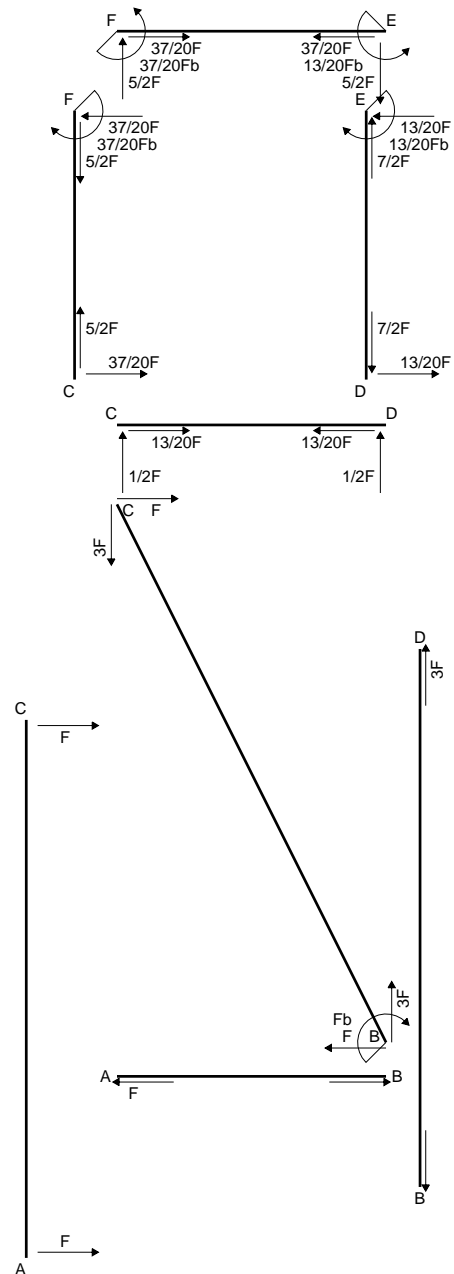














$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{x\theta} = \int_0^b (-5/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-5/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-5/4 b) Fb 1/EJ + (b) \theta = -1/4 Fb^2/EJ$$

$$L_{FE}^{x\theta} = \int_0^b (-5/2 + 5/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-5/2 x + 5/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

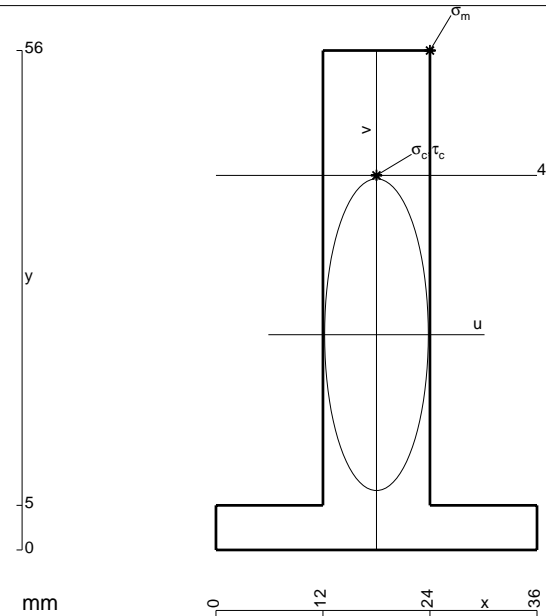
$$= (-5/2 b + 5/4 b) Fb 1/EJ + (-b) \theta = -1/4 Fb^2/EJ$$

$$L_{FC}^{x\theta} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = [-5/2 x + 5/2 x^2/b - 5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

$$L_{CF}^{x\theta} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

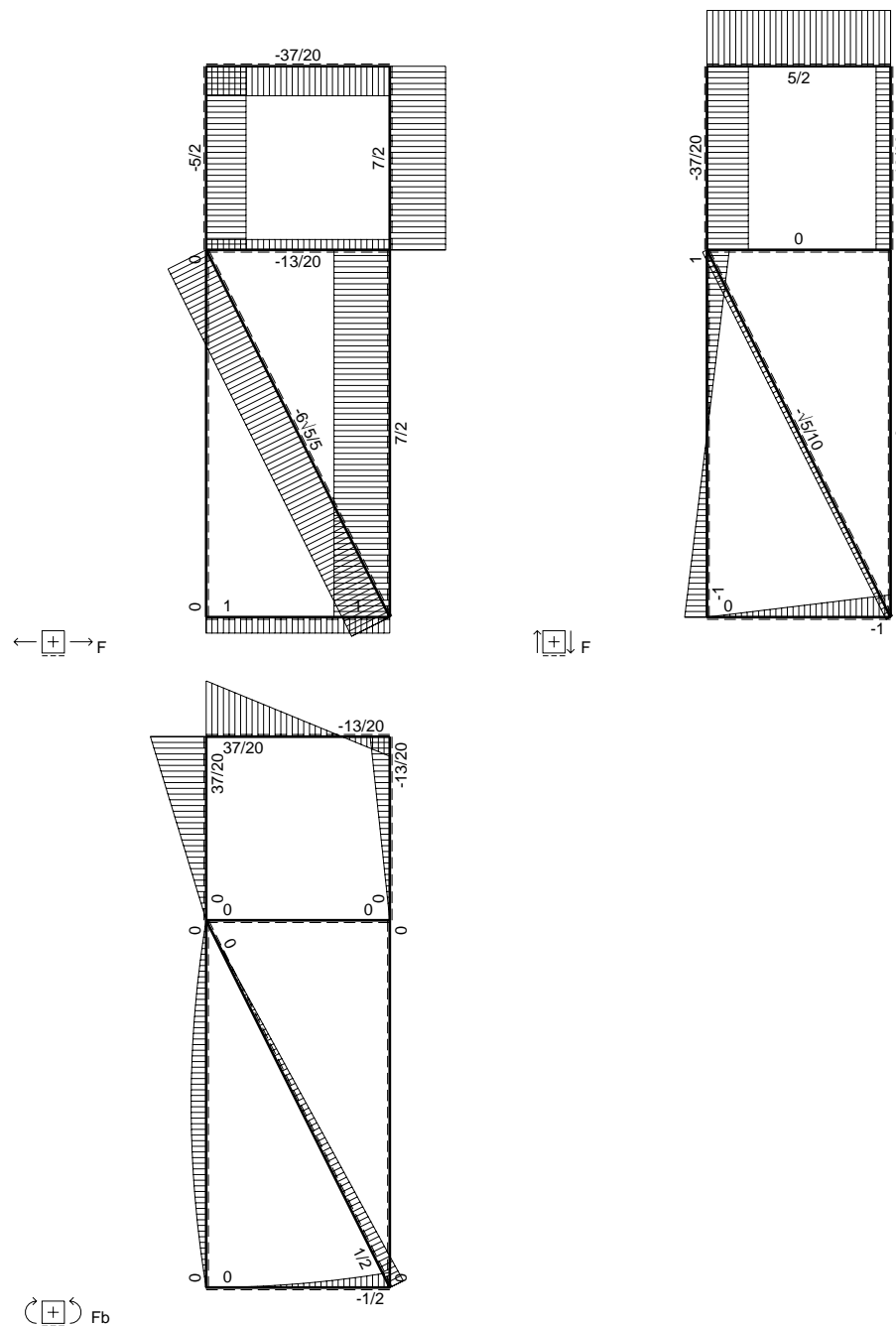
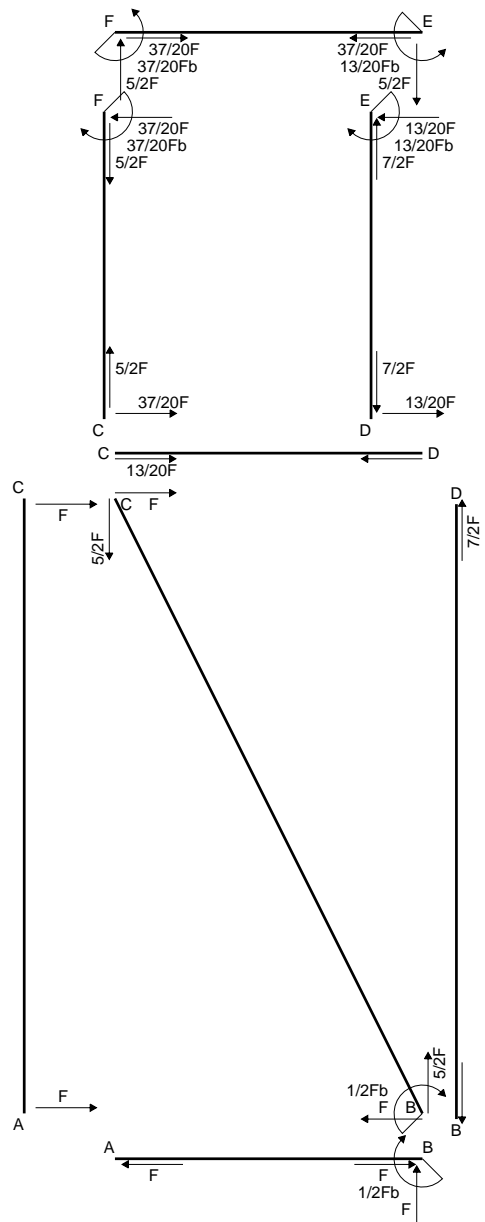
$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

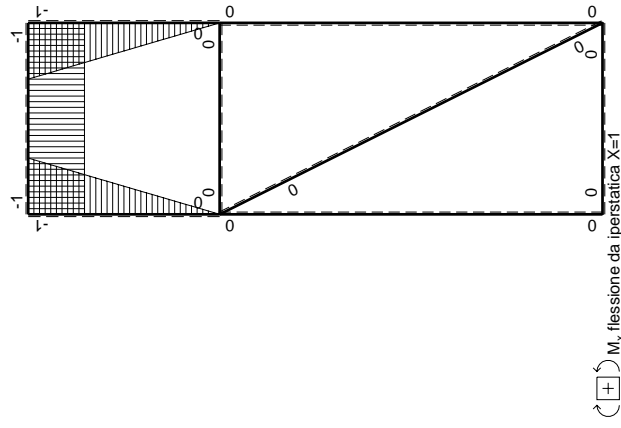
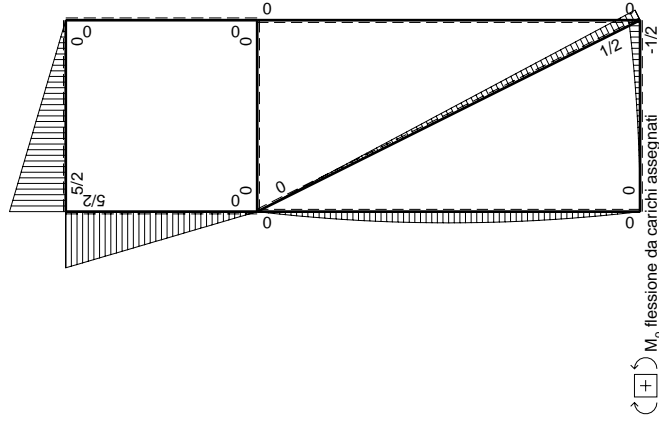
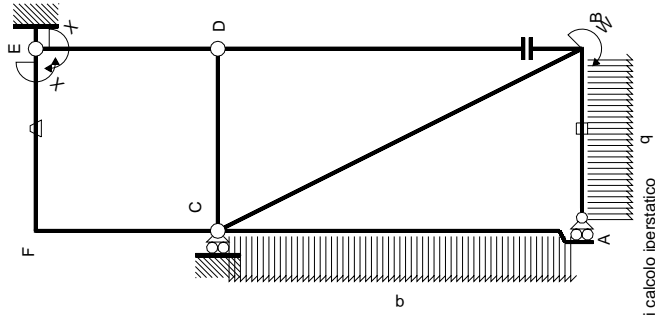


- A = 792. mm<sup>2</sup>
- J<sub>u</sub> = 242073. mm<sup>4</sup>
- J<sub>v</sub> = 26784. mm<sup>4</sup>
- y<sub>g</sub> = 24.14 mm
- N = -7482. N
- T<sub>y</sub> = -1069. N
- M<sub>x</sub> = 1673000. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 56. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 31.86 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = -229.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 42. mm
- v<sub>c</sub> = 17.86 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = -132.9 N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.537 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 132.9 N/mm<sup>2</sup>
- S = 4177. mm<sup>3</sup>









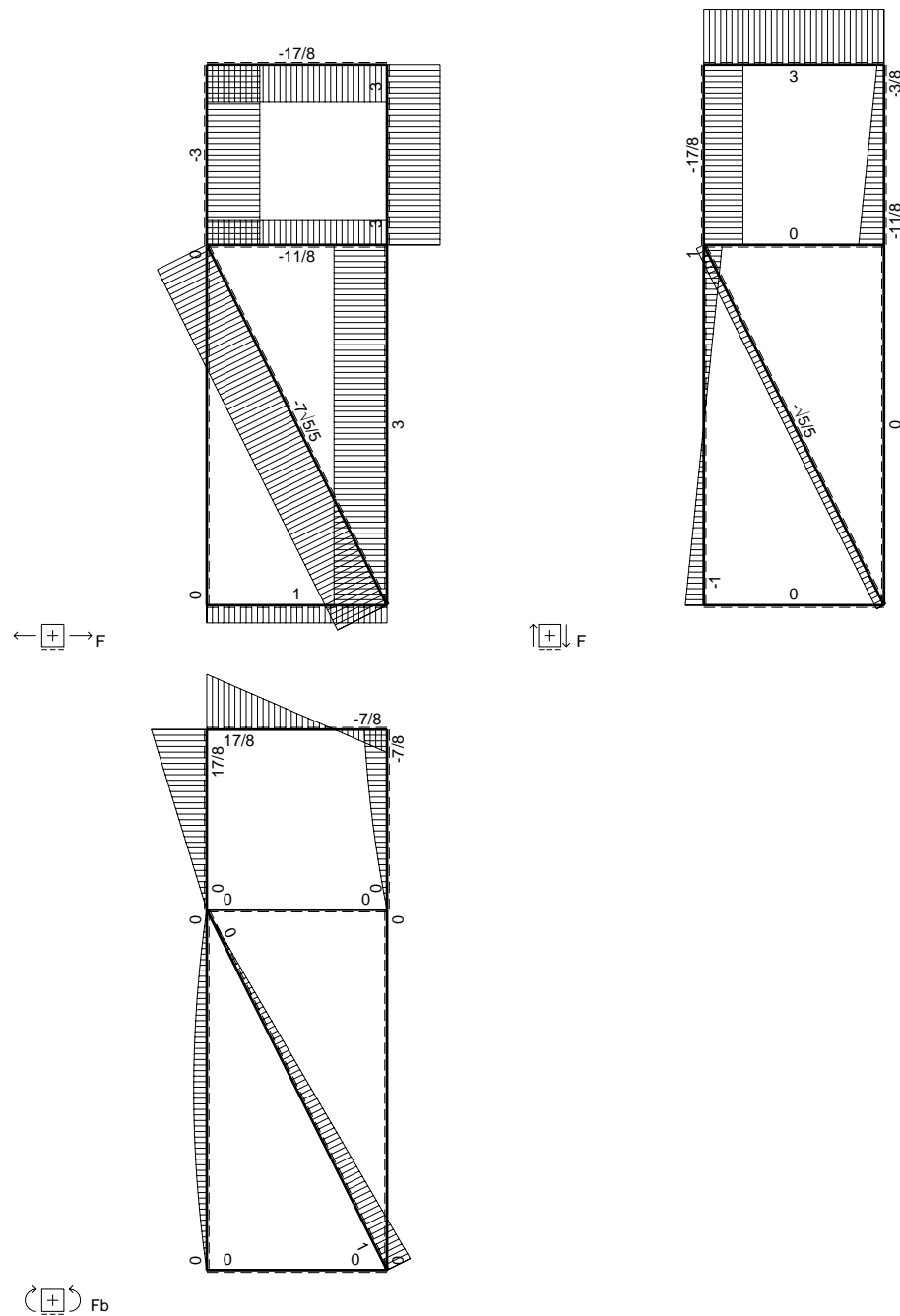
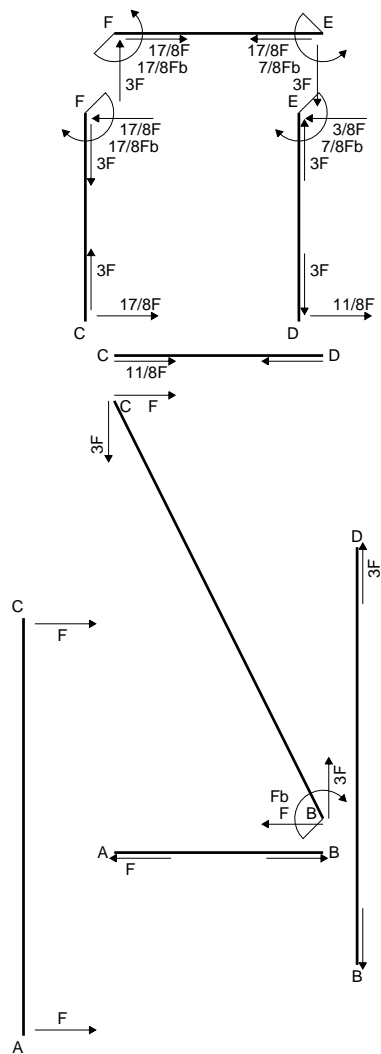
Quadro contributi PLV per iperstatica X=W<sup>EP</sup>

→	M <sup>x</sup> (x)	M <sup>0</sup> (x)	θ	M <sup>M<sub>0</sub></sup>	M <sup>θ</sup>	M <sup>M<sub>x</sub></sup>	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJdx$
AB b	0	-1/2qx <sup>2</sup>	0	0	0	0	0	0
BA b	0	1/2Fb-Fx+1/2qx <sup>2</sup>	0	0	0	0	0	0
BC √5b	0	1/2Fb-√5/10Fx	0	0	0	0	0	0
AC 2b	0	-Fx+1/2qx <sup>2</sup>	0	0	0	0	0	0
CA 2b	0	Fx-1/2qx <sup>2</sup>	0	0	0	0	0	0
DB 2b	0	0	0	0	0	0	0	0
BD 2b	0	0	0	0	0	0	0	0
DE b	-x/b	0	0	0	0	x <sup>2</sup> /b <sup>2</sup>	0	0
ED b	1-x/b	0	0	0	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	0	0
CD b	0	0	0	0	0	0	0	0
DC b	0	0	0	0	0	0	0	0
EF b	-1	5/2Fx	-Fb/EJ	-5/2Fx	Fb/EJ	1	(-5/4+1)Fb <sup>2</sup> /EJ	Xb/EJ
FE b	1	-5/2Fb+5/2Fx	Fb/EJ	-5/2Fb+5/2Fx	Fb/EJ	1	(-5/4+1)Fb <sup>2</sup> /EJ	Xb/EJ
FC b	-1+x/b	5/2Fb-5/2Fx	0	-5/2Fb+5Fx-5/2Fx <sup>2</sup> /b	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	(-5/6+0)Fb <sup>2</sup> /EJ	1/3Xb/EJ
CF b	x/b	-5/2Fx	0	-5/2Fx <sup>2</sup> /b	0	x <sup>2</sup> /b <sup>2</sup>	-13/12Fb <sup>2</sup> /EJ	5/3Xb/EJ
totali								
iperstatica X=W <sup>EP</sup>								

Sviluppi di calcolo iperstatica









$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-3x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-3/2 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-3/2 b) Fb 1/EJ + (b) \theta = -1/2 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-3 + 3x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-3x + 3/2 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

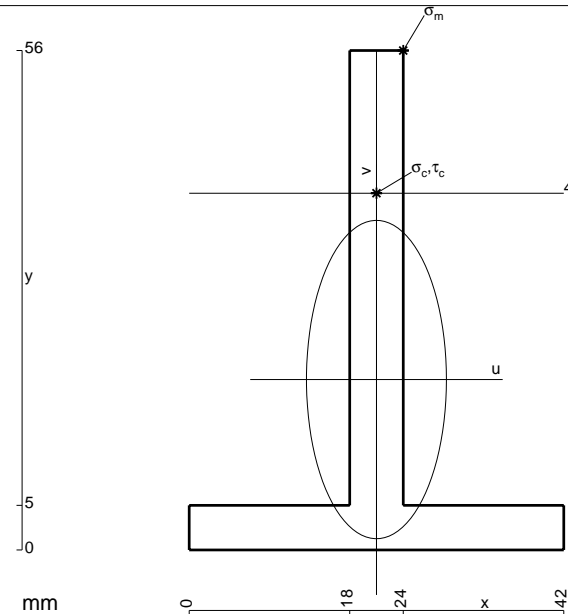
$$= (-3b + 3/2 b) Fb 1/EJ + (-b) \theta = -1/2 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-3 + 6x/b - 3x^2/b^2) Fb 1/EJ dx = [-3x + 3x^2/b - x^3/b^2]_0^b Fb 1/EJ$$

$$= (-3b + 3b - b) Fb 1/EJ = -Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-3x^2/b^2) Fb 1/EJ dx = [-x^3/b^2]_0^b Fb 1/EJ$$

$$= (-b) Fb 1/EJ = -Fb^2/EJ$$



$$A = 516. \text{ mm}^2$$

$$J_u = 164398. \text{ mm}^4$$

$$J_v = 31788. \text{ mm}^4$$

$$y_g = 19.1 \text{ mm}$$

$$N = -6668. \text{ N}$$

$$T_y = -952.6 \text{ N}$$

$$M_x = 830700. \text{ Nmm}$$

$$x_m = 24. \text{ mm}$$

$$y_m = 56. \text{ mm}$$

$$u_m = 3. \text{ mm}$$

$$v_m = 36.9 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -199.4 \text{ N/mm}^2$$

$$x_c = 21. \text{ mm}$$

$$y_c = 40. \text{ mm}$$

$$v_c = 20.9 \text{ mm}$$

$$\sigma_c = N/A - Mv/J_u = -118.5 \text{ N/mm}^2$$

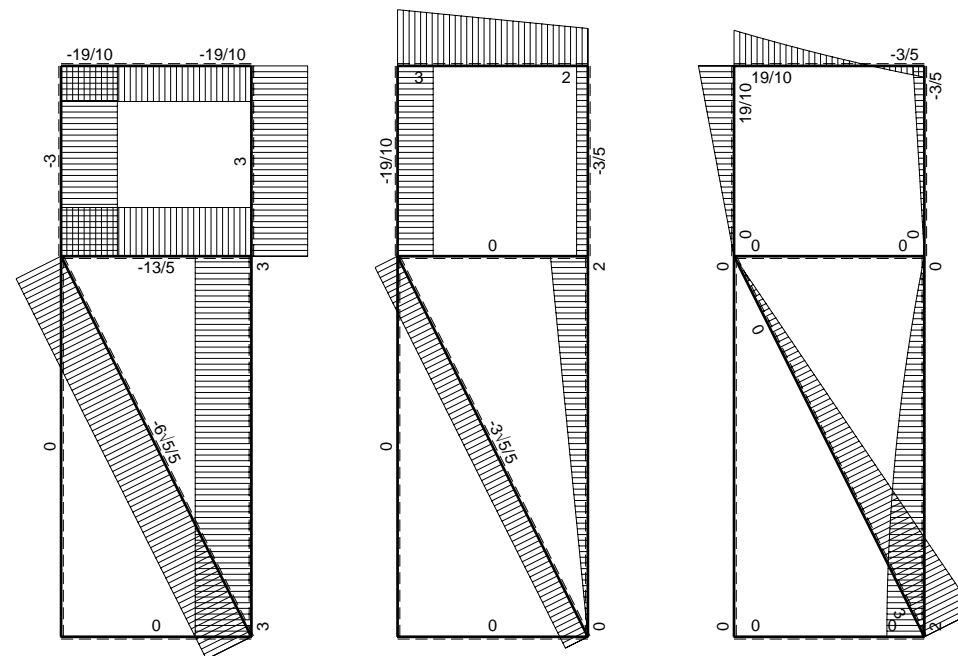
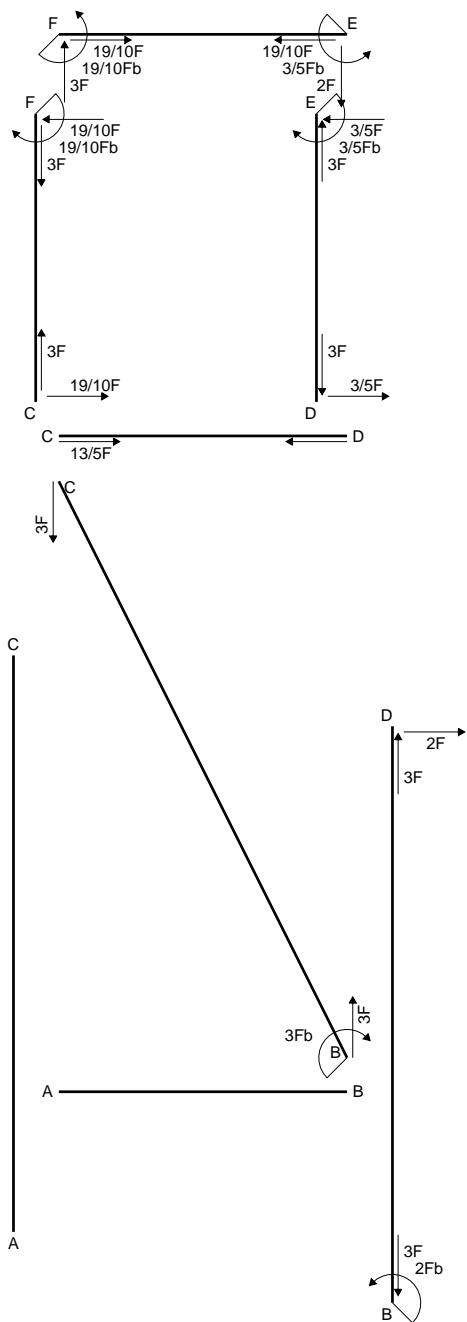
$$\tau_c = 2.679 \text{ N/mm}^2$$

$$\sigma_o = \sqrt{\sigma^2 + 3\tau^2} = 118.6 \text{ N/mm}^2$$

$$S = 2774. \text{ mm}^3$$







← ⊕ → F

↑ ⊕ ↓ F

⊕ ⊖ F<sub>b</sub>



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-2x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-b - 1/6 b) Fb 1/EJ + (b) \theta = -1/6 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-5/2 + 3x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx$$

$$= [-5/2 x + 3/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

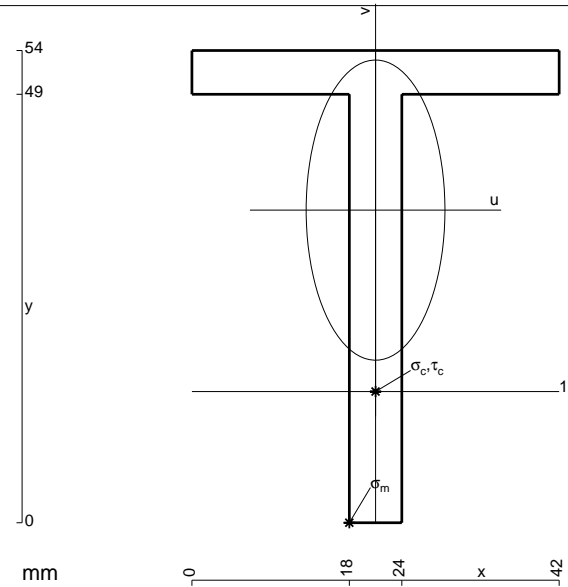
$$= (-5/2 b + 3/2 b - 1/6 b) Fb 1/EJ + (-b) \theta = -1/6 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = [-5/2 x + 5/2 x^2/b - 5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

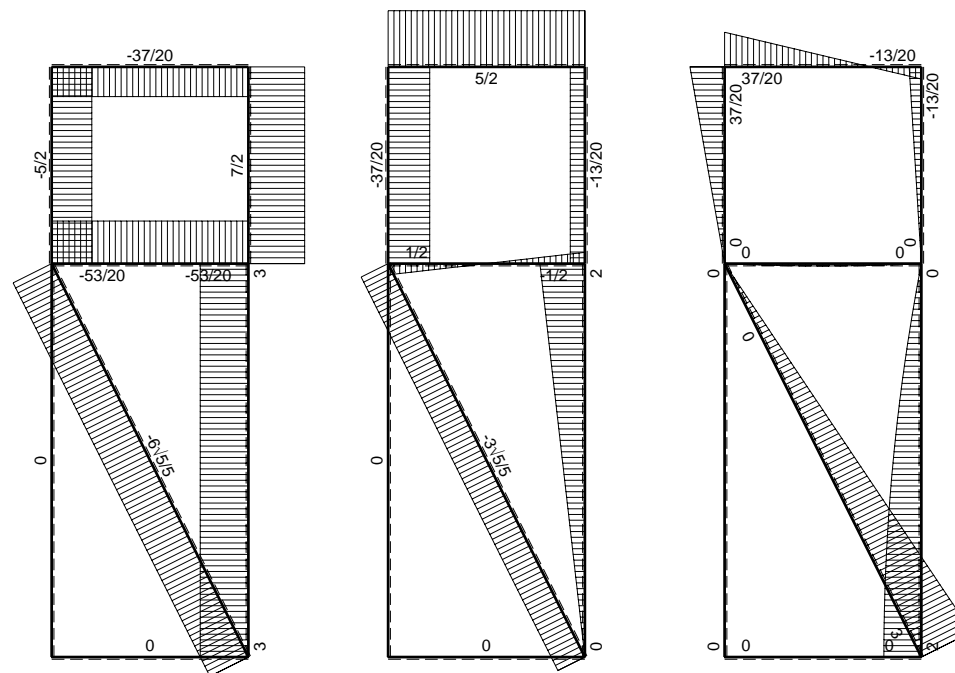
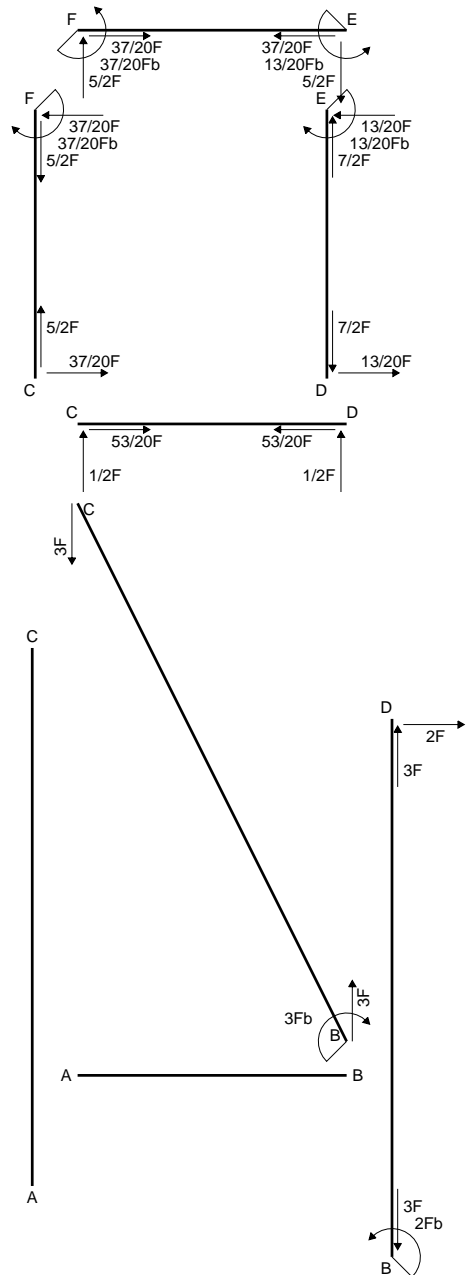
$$L_{CF}^{xo} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$



- A = 504. mm<sup>2</sup>
- J<sub>u</sub> = 148565. mm<sup>4</sup>
- J<sub>v</sub> = 31752. mm<sup>4</sup>
- y<sub>g</sub> = 35.75 mm
- N = -1932. N
- T<sub>y</sub> = -966. N
- M<sub>x</sub> = 885600. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -35.75 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = 209.3 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 15. mm
- v<sub>c</sub> = -20.75 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = 119.9 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.755 N/mm<sup>2</sup>
- σ<sub>φ</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 120. N/mm<sup>2</sup>
- S = 2543. mm<sup>3</sup>

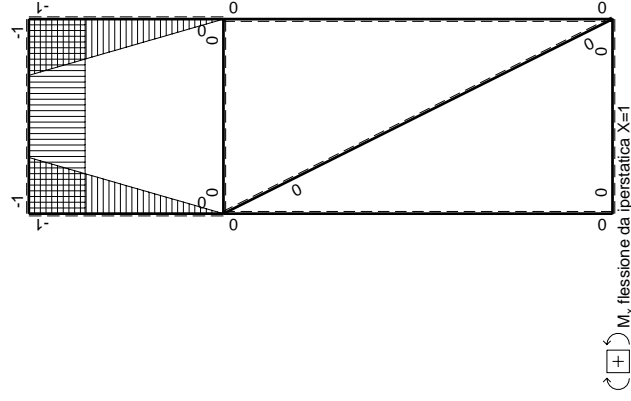
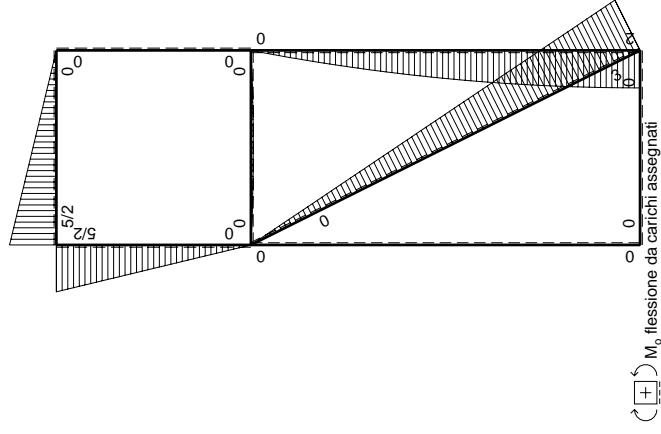
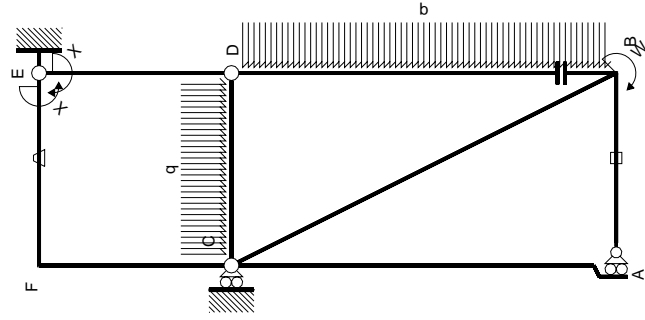




← ⊕ → F

⊕ F

⊕ F<sub>b</sub>



Quadro contributi PLV per iperstatica X=W<sub>EP</sub>

←	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M^0$	$M^x \theta$	$M^x M^x$	$\int M^x(M^0/EJ+\theta)dx$	$\int M^x M^x/EJ dx$	iperstatica X=W <sub>EP</sub>	
									$M^x(x)$	$M^0(x)$
AB b	0	0	0	0	0	0	0	0	0	0
BA b	0	0	0	0	0	0	0	0	0	0
BC √5b	0	3Fb-3√5/5Fx	0	0	0	0	0	0	0	0
AC 2b	0	0	0	0	0	0	0	0	0	0
CA 2b	0	0	0	0	0	0	0	0	0	0
DB 2b	0	2Fx-1/2qx <sup>2</sup>	0	0	0	0	0	0	0	0
BD 2b	0	-2Fb+1/2qx <sup>2</sup>	0	0	0	0	0	0	0	0
DE b	-x/b	0	0	0	0	0	0	0	0	0
ED b	1-x/b	0	0	0	0	0	0	0	0	0
CD b	0	1/2Fx-1/2qx <sup>2</sup>	0	0	0	0	0	0	0	0
DC b	0	-1/2Fx+1/2qx <sup>2</sup>	0	0	0	0	0	0	0	0
EF b	-1	5/2Fx	-Fb/EJ	-5/2Fx	Fb/EJ	1	(-5/4+1)Fb <sup>2</sup> /EJ	Xb/EJ	1	(-5/6+0)Fb <sup>2</sup> /EJ
FE b	1	-5/2Fb+5/2Fx	Fb/EJ	-5/2Fb+5/2Fx	Fb/EJ	1	(-5/4+1)Fb <sup>2</sup> /EJ	Xb/EJ	1	(-5/6+0)Fb <sup>2</sup> /EJ
FC b	-1+x/b	5/2Fb-5/2Fx	0	-5/2Fb+5Fx-5/2Fx <sup>2</sup> /b	0	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	1/3Xb/EJ	0	-13/12Fb <sup>2</sup> /EJ
CF b	x/b	-5/2Fx	0	-5/2Fx <sup>2</sup> /b	0	0	x <sup>2</sup> /b <sup>2</sup>	1/3Xb/EJ	0	13/20Fb
totali										

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = \left[ \frac{1}{3} x^3/b^2 \right]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = \left[ x - x^2/b + \frac{1}{3} x^3/b^2 \right]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = \left[ x \right]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = \left[ x \right]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = \left[ x - x^2/b + \frac{1}{3} x^3/b^2 \right]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = \left[ \frac{1}{3} x^3/b^2 \right]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-5/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = \left[ -5/4 x^2/b \right]_0^b Fb 1/EJ + \left[ x \right]_0^b \theta$$

$$= (-5/4 b) Fb 1/EJ + (b) \theta = -1/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-5/2 + 5/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = \left[ -5/2 x + 5/4 x^2/b \right]_0^b Fb 1/EJ + \left[ -x \right]_0^b \theta$$

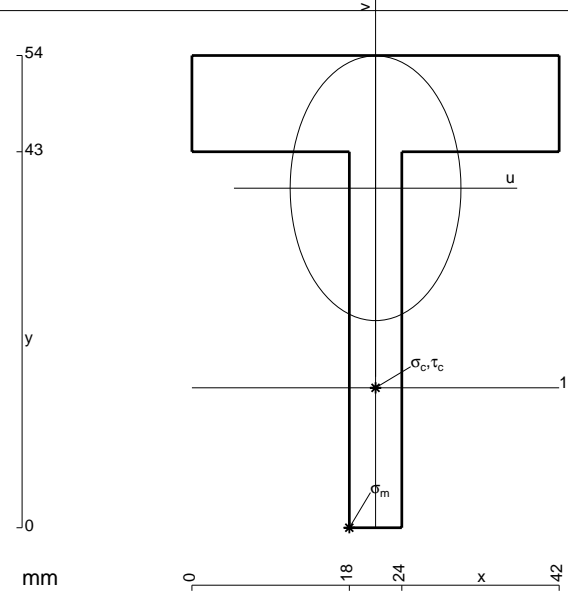
$$= (-5/2 b + 5/4 b) Fb 1/EJ + (-b) \theta = -1/4 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = \left[ -5/2 x + 5/2 x^2/b - 5/6 x^3/b^2 \right]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = \left[ -5/6 x^3/b^2 \right]_0^b Fb 1/EJ$$

$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$



$$A = 720. \text{ mm}^2$$

$$J_u = 165098. \text{ mm}^4$$

$$J_v = 68688. \text{ mm}^4$$

$$y_g = 38.83 \text{ mm}$$

$$N = -1878. \text{ N}$$

$$T_y = -939.1 \text{ N}$$

$$M_x = 945000. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -38.83 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 219.6 \text{ N/mm}^2$$

$$x_c = 21. \text{ mm}$$

$$y_c = 16. \text{ mm}$$

$$v_c = -22.83 \text{ mm}$$

$$\sigma_c = N/A - Mv/J_u = 128. \text{ N/mm}^2$$

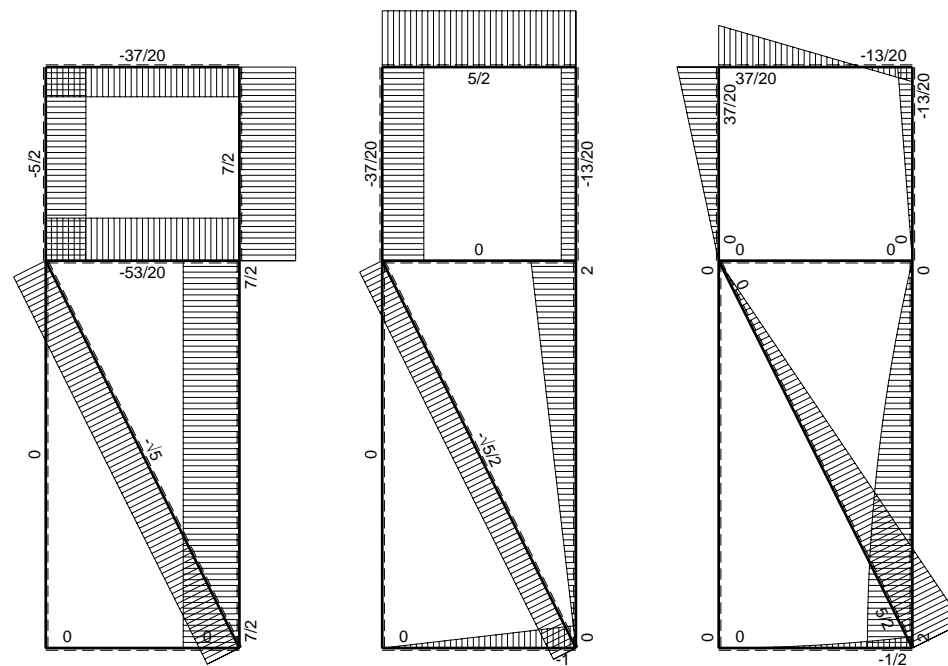
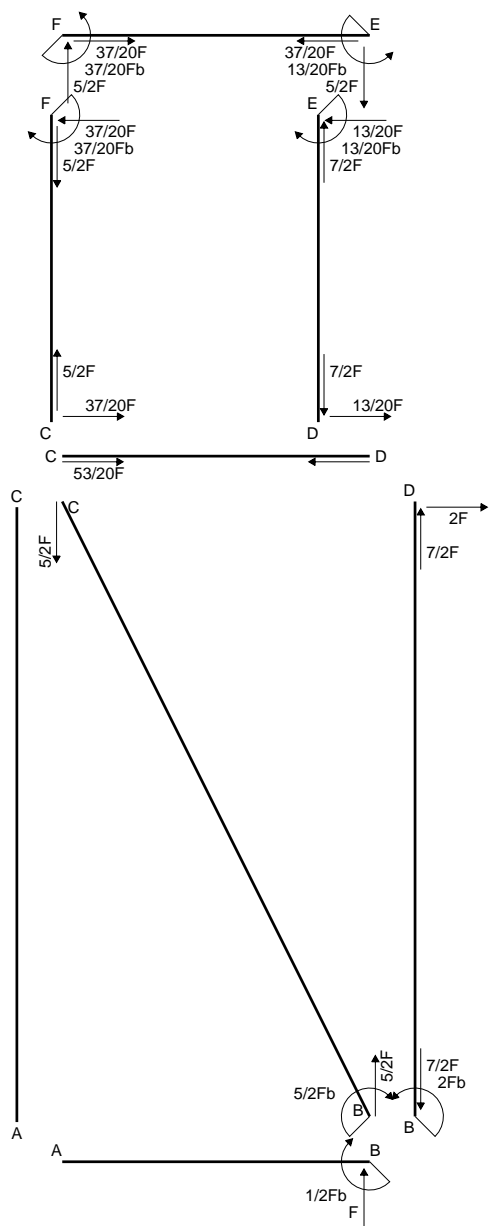
$$\tau_c = 2.806 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 128.1 \text{ N/mm}^2$$

$$S = 2959. \text{ mm}^3$$









$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-5/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-5/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-5/4 b) Fb 1/EJ + (b) \theta = -1/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-5/2 + 5/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-5/2 x + 5/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

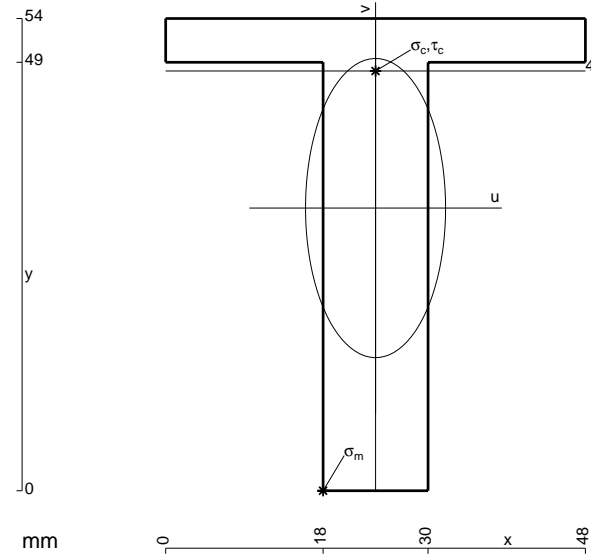
$$= (-5/2 b + 5/4 b) Fb 1/EJ + (-b) \theta = -1/4 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = [-5/2 x + 5/2 x^2/b - 5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

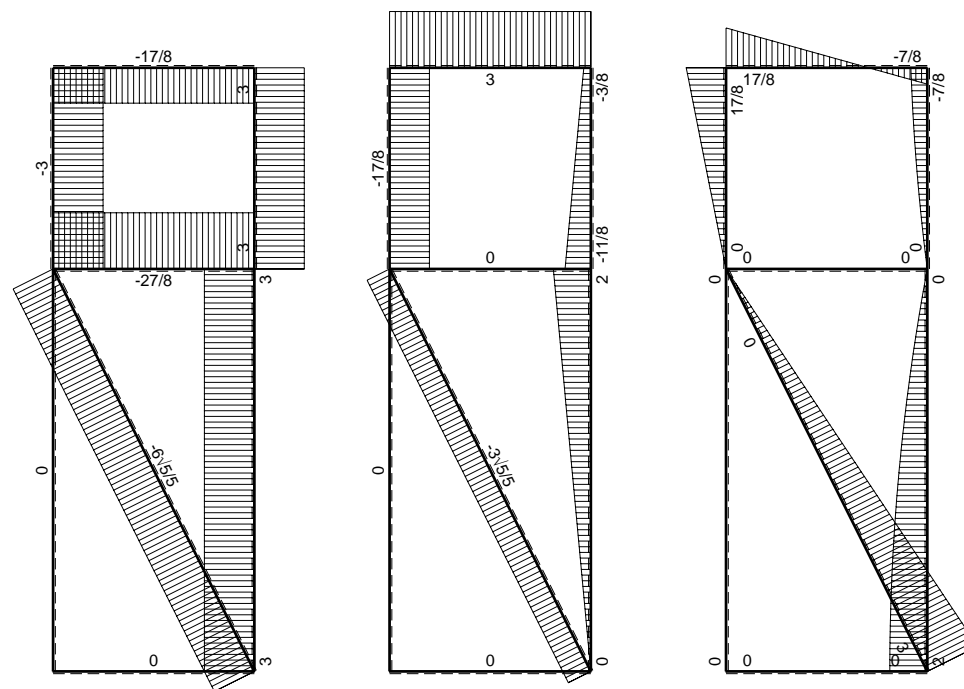
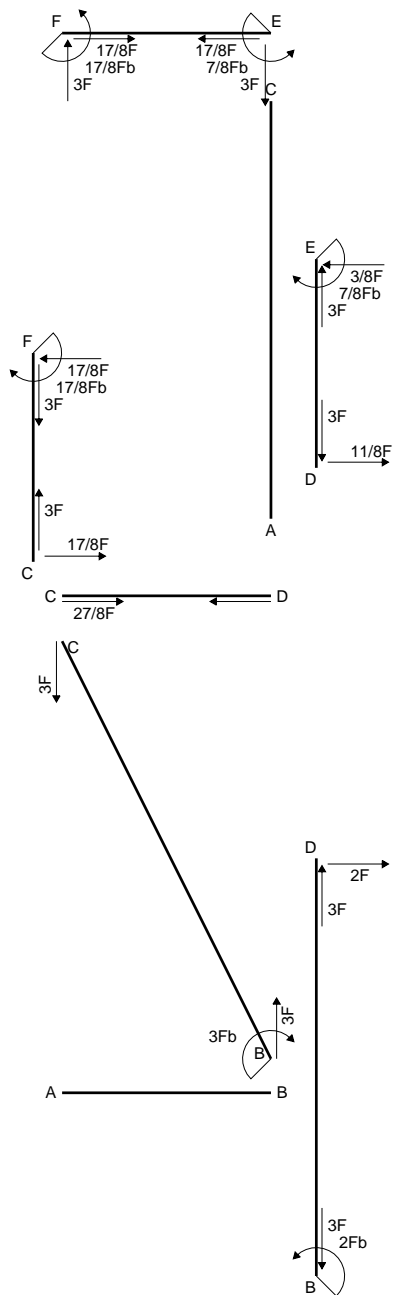
$$L_{CF}^{xo} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$



- 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> = 32.33 mm
- N = -3198. N
- T<sub>y</sub> = -1599. N
- M<sub>x</sub> = 1751750. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -32.33 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = 229.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 48. mm
- v<sub>c</sub> = 15.67 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = -117.1 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.636 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 = 4796. mm<sup>3</sup>





← ⊕ → F

↑ ⊕ ↓ F

⊕ ⊖ F<sub>b</sub>



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-3x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-3/2 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-3/2 b) Fb 1/EJ + (b) \theta = -1/2 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-3 + 3x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-3x + 3/2 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

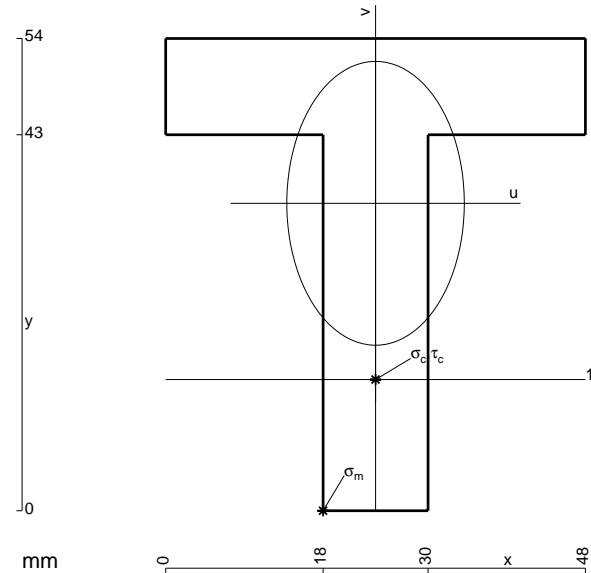
$$= (-3b + 3/2 b) Fb 1/EJ + (-b) \theta = -1/2 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-3 + 6x/b - 3x^2/b^2) Fb 1/EJ dx = [-3x + 3x^2/b - x^3/b^2]_0^b Fb 1/EJ$$

$$= (-3b + 3b - b) Fb 1/EJ = - Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-3x^2/b^2) Fb 1/EJ dx = [-x^3/b^2]_0^b Fb 1/EJ$$

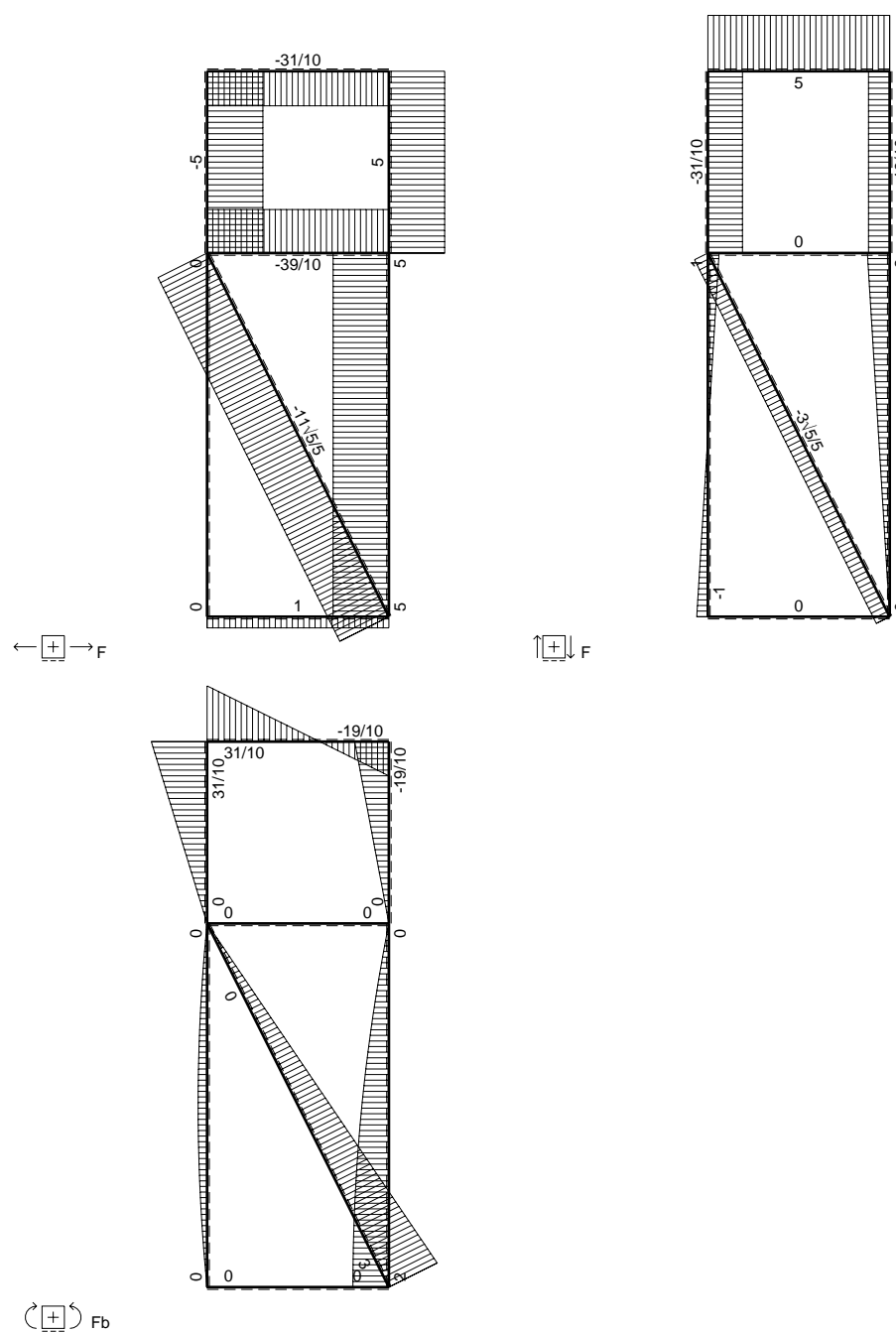
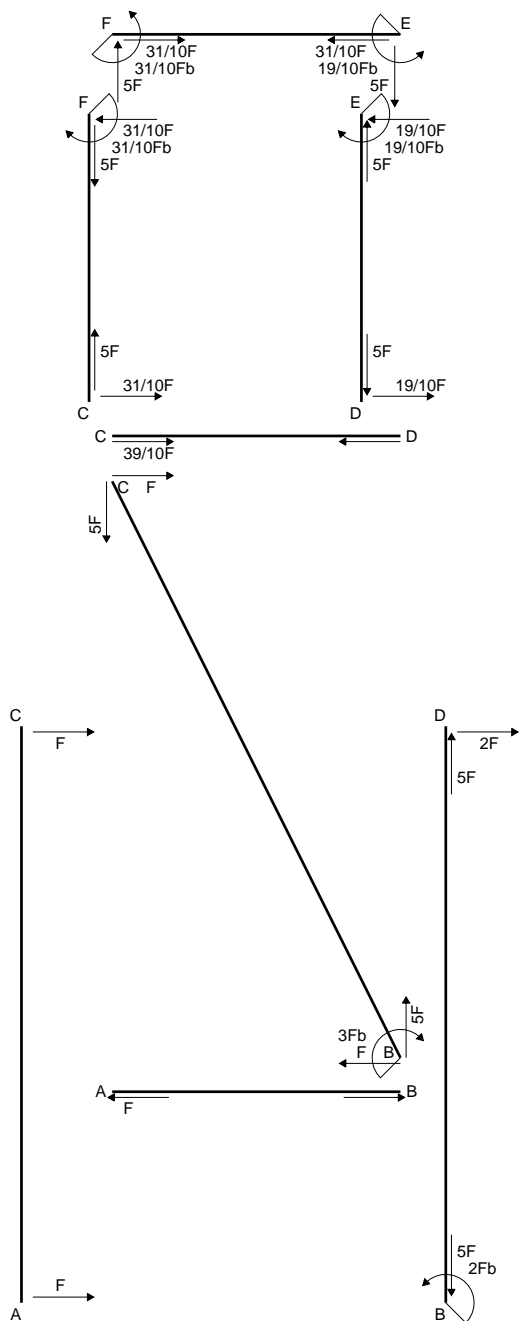
$$= (-b) Fb 1/EJ = - Fb^2/EJ$$



- 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 = -3193. N
- T<sub>y</sub> = -1597. N
- M<sub>x</sub> = 1892100. 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> = 238.8 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> = 135.6 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.408 N/mm<sup>2</sup>
- σ<sub>ρ</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 135.6 N/mm<sup>2</sup>
- S = 4978. mm<sup>3</sup>



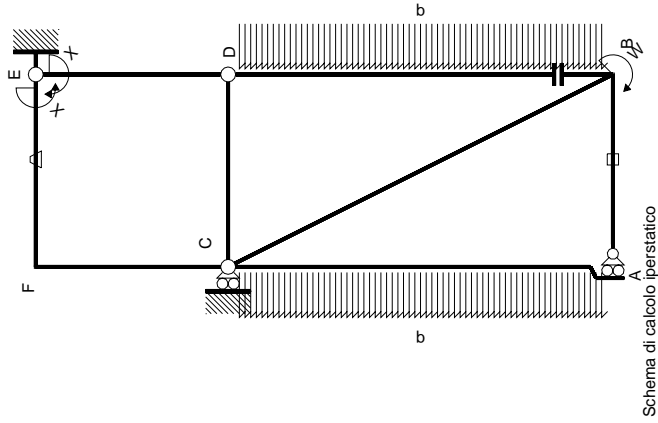




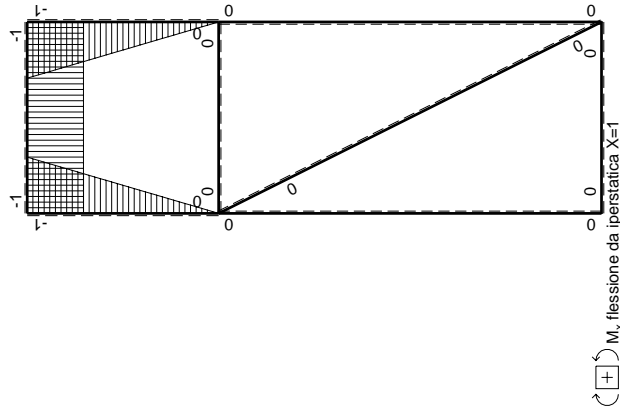
← (+) → F

↑ (+) ↓ F

⊙ (+) ⊙ F<sub>b</sub>



$M_0$  flessione da carichi assegnati



Quadro contributi PLV per iperstatica  $X=W_{Ef}$

$\rightarrow$	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x (M_0/EJ + \theta) dx$	$\int M^x M_x / EIdx$
AB b	0	0	0	0	0	0	0	0
BA b	0	0	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$3Fb-3\sqrt{5}/5Fx$	0	0	0	0	0	0
CA 2b	0	$-Fx+1/2qx^2$	0	0	0	0	0	0
DB 2b	0	$2Fx-1/2qx^2$	0	0	0	0	0	0
BD 2b	0	$-2Fb+1/2qx^2$	0	0	0	0	0	0
DE b	$-x/b$	0	0	0	0	$x^2/b^2$	0	0
ED b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0	$0+0$
CD b	0	0	0	0	0	0	0	0
DC b	0	0	0	0	0	0	0	$0+0$
EF b	-1	$5Fx$	$-Fb/EJ$	$-5Fx$	$Fb/EJ$	1	$(-5/2+1)Fb^2/EJ$	$Xb/EJ$
FE b	1	$-5Fb+5Fx$	$Fb/EJ$	$-5Fb+5Fx$	$Fb/EJ$	1	$(-5/2+1)Fb^2/EJ$	$Xb/EJ$
FC b	$-1+x/b$	$5Fb-5Fx$	0	$-5Fb+10Fx-5Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-5/3+0)Fb^2/EJ$	$1/3Xb/EJ$
CF b	$x/b$	$-5Fx$	0	$-5Fx^2/b$	0	$x^2/b^2$	$-19/6Fb^2/EJ$	$5/3Xb/EJ$
totali								
								$19/10Fb$

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-5x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-5/2 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-5/2 b) Fb 1/EJ + (b) \theta = -3/2 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-5 + 5x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-5x + 5/2 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

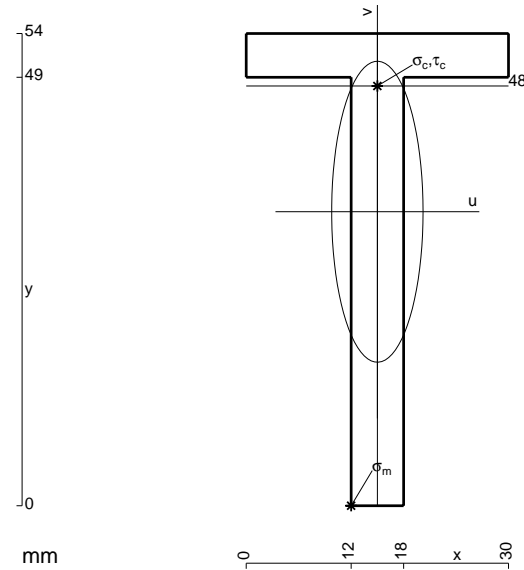
$$= (-5b + 5/2 b) Fb 1/EJ + (-b) \theta = -3/2 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-5 + 10x/b - 5x^2/b^2) Fb 1/EJ dx = [-5x + 5x^2/b - 5/3 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5b + 5b - 5/3 b) Fb 1/EJ = -5/3 Fb^2/EJ$$

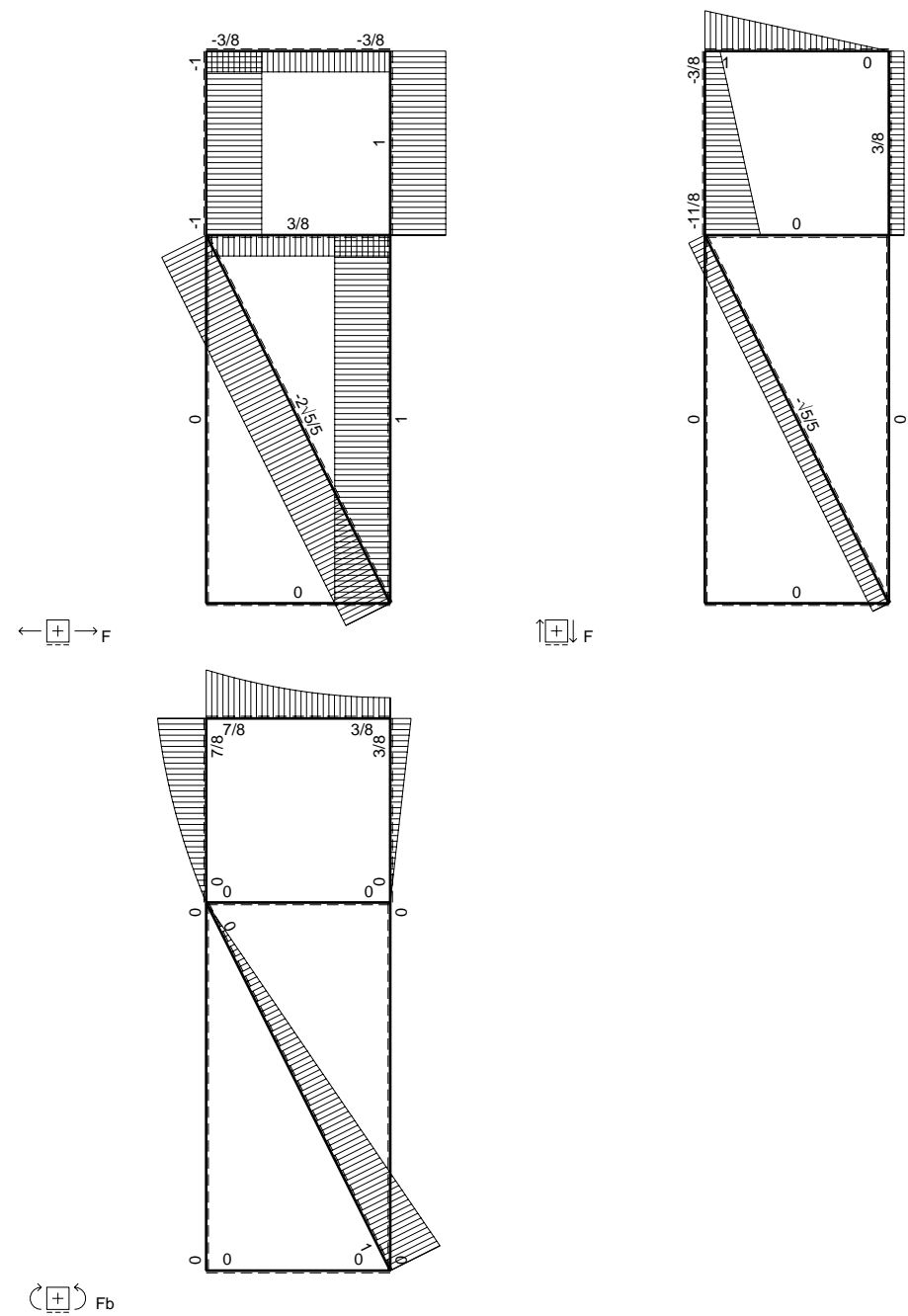
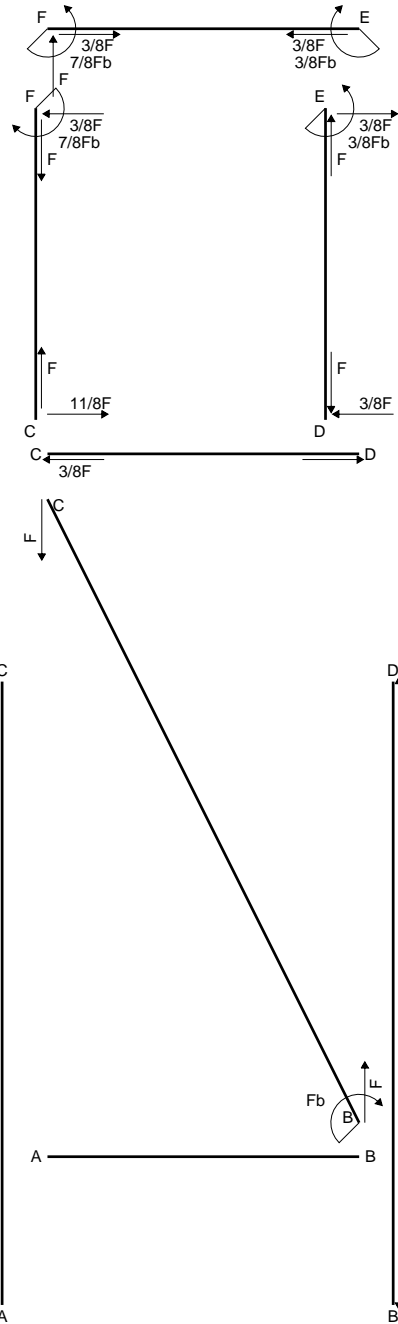
$$L_{CF}^{xo} = \int_0^b (-5x^2/b^2) Fb 1/EJ dx = [-5/3 x^3/b^2]_0^b Fb 1/EJ$$

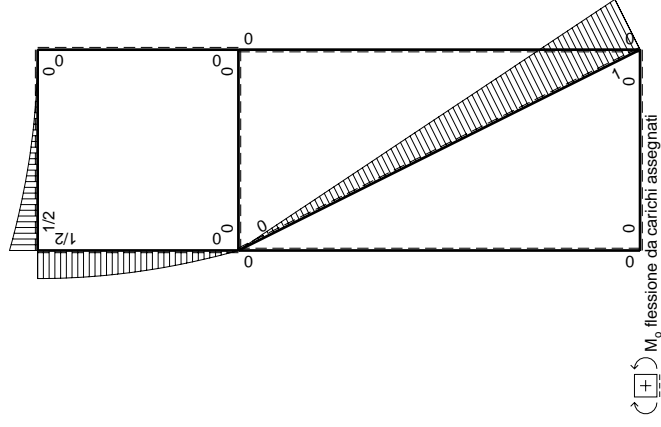
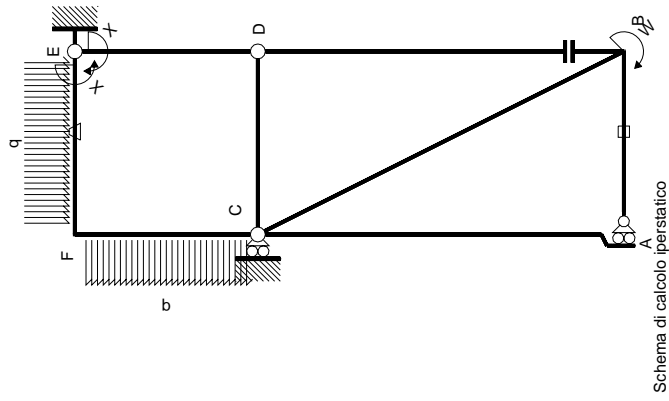
$$= (-5/3 b) Fb 1/EJ = -5/3 Fb^2/EJ$$



- 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> = 33.62 mm
- N = -2263. N
- T<sub>y</sub> = -617.2 N
- M<sub>x</sub> = 786600. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -33.62 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = 196. N/mm<sup>2</sup>
- x<sub>c</sub> = 15. mm
- y<sub>c</sub> = 48. mm
- V<sub>c</sub> = 14.38 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = -91.08 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.167 N/mm<sup>2</sup>
- σ<sub>o</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 91.15 N/mm<sup>2</sup>
- S<sup>i</sup> = 2771. mm<sup>3</sup>



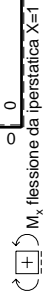




Quadro contributi PLV per iperstatica X=W<sup>EF</sup>

←	M <sub>x</sub> (x)	M <sub>0</sub> (x)	θ	M <sub>x</sub> θ	M <sub>x</sub> M <sub>0</sub>	∫M <sub>x</sub> (M <sub>0</sub> /EJ+θ)dx	∫M <sub>x</sub> M <sub>0</sub> /EJdx
AB	0	0	0	0	0	0	0
BA	0	0	0	0	0	0	0
BC	0	Fb-√5/5Fx	0	0	0	0	0
AC	0	0	0	0	0	0	0
CA	0	0	0	0	0	0	0
DB	0	0	0	0	0	0	0
BD	0	0	0	0	0	0	0
DE	-x/b	0	0	0	x <sup>2</sup> /b <sup>2</sup>	0	1/3Xb/EJ
ED	1-x/b	0	0	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	0	0+0
CD	0	0	0	0	0	0	0
DC	0	0	0	0	0	0	0+0
EF	-1	1/2qx <sup>2</sup>	-Fb/EJ	-1/2Fx <sup>2</sup> /b	Fb/EJ	1	Xb/EJ
FE	1	-1/2Fb+Fx-1/2qx <sup>2</sup>	Fb/EJ	-1/2Fx <sup>2</sup> /b	Fb/EJ	1	(-1/6+1)Fb <sup>2</sup> /EJ
FC	-1+x/b	1/2Fb-1/2qx <sup>2</sup>	0	-1/2Fb+1/2Fx+1/2Fx <sup>2</sup> /b-1/2qx <sup>3</sup> /b	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	(-5/24+0)Fb <sup>2</sup> /EJ
CF	x/b	-Fx+1/2qx <sup>2</sup>	0	-Fx <sup>2</sup> /b+1/2qx <sup>3</sup> /b	0	x <sup>2</sup> /b <sup>2</sup>	1/3Xb/EJ
totali							5/3Xb/EJ
							-3/8Fb

Sviluppi di calcolo iperstatica



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/6 b) Fb 1/EJ + (b) \theta = 5/6 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx$$

$$= [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ + (-b) \theta = 5/6 Fb^2/EJ$$

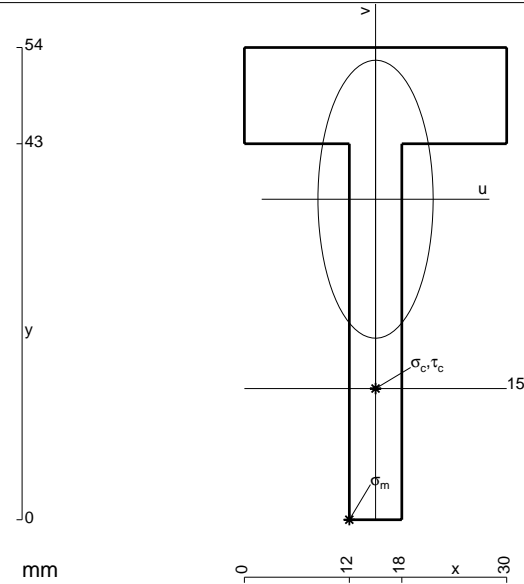
$$L_{FC}^{xo} = \int_0^b (-1/2 + 1/2 x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx$$

$$= [-1/2 x + 1/4 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/4 b + 1/6 b - 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

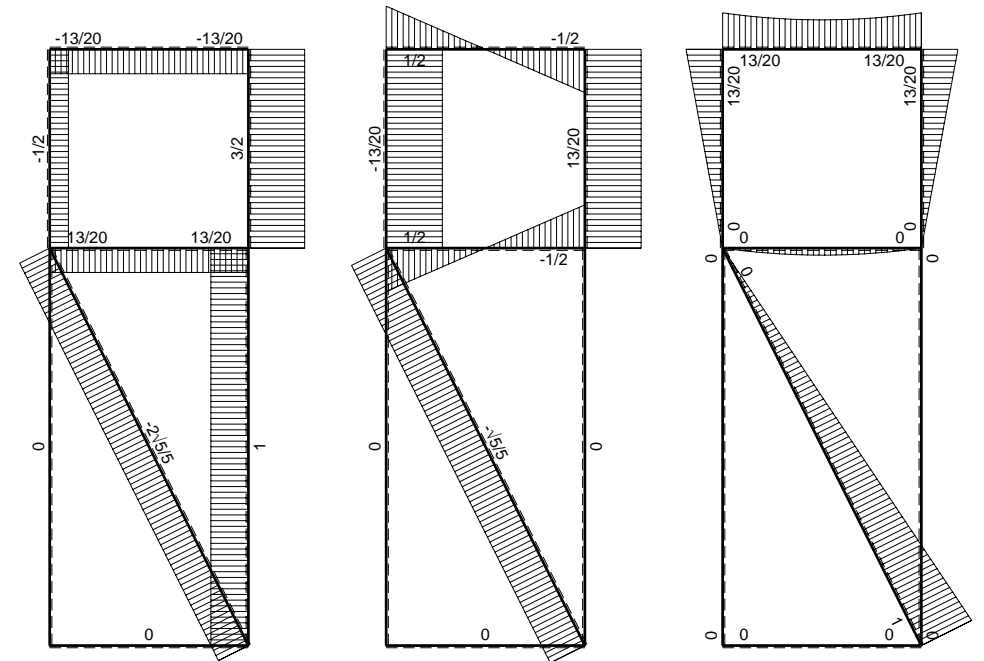
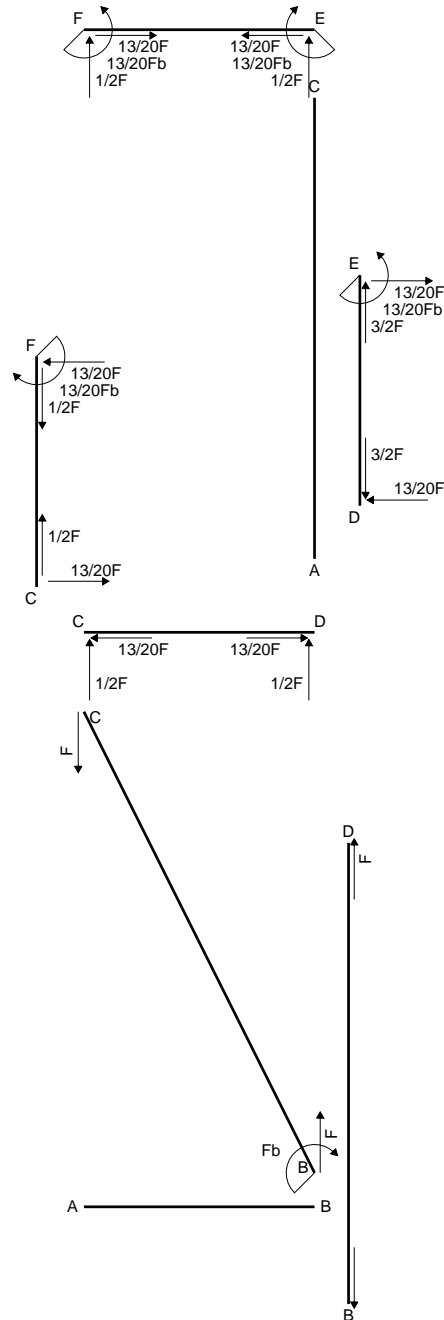
$$= (-1/3 b + 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$



- 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> = 36.65 mm
- N = -1279. N
- T<sub>y</sub> = -639.5 N
- M<sub>x</sub> = 858000. Nmm
- x<sub>m</sub> = 12. 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> = 209.4 N/mm<sup>2</sup>
- x<sub>c</sub> = 15. mm
- y<sub>c</sub> = 15. mm
- v<sub>c</sub> = -21.65 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = 122.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.881 N/mm<sup>2</sup>
- σ<sub>φ</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 122.9 N/mm<sup>2</sup>
- S = 2624. mm<sup>3</sup>







← ⊕ → F

↑ ⊕ ↓ F

⊕ ⊖ F<sub>b</sub>



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

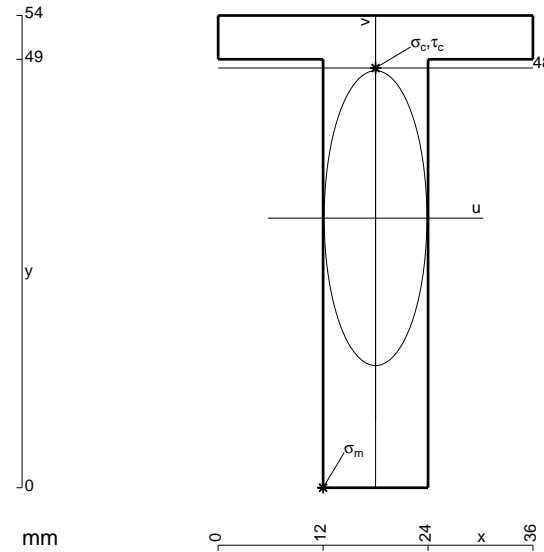
$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{x\theta} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (1/4 b - 1/6 b) Fb 1/EJ + (b) \theta = 13/12 Fb^2/EJ$$

$$L_{FE}^{x\theta} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (1/4 b - 1/6 b) Fb 1/EJ + (-b) \theta = 13/12 Fb^2/EJ$$



$$A = 768. \text{ mm}^2$$

$$J_u = 218489. \text{ mm}^4$$

$$J_v = 26496. \text{ mm}^4$$

$$y_g = 30.83 \text{ mm}$$

$$N = -2200. \text{ N}$$

$$T_y = -1100. \text{ N}$$

$$M_x = 1574400. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -6. \text{ mm}$$

$$v_m = -30.83 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 219.3 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 48. \text{ mm}$$

$$v_c = 17.17 \text{ mm}$$

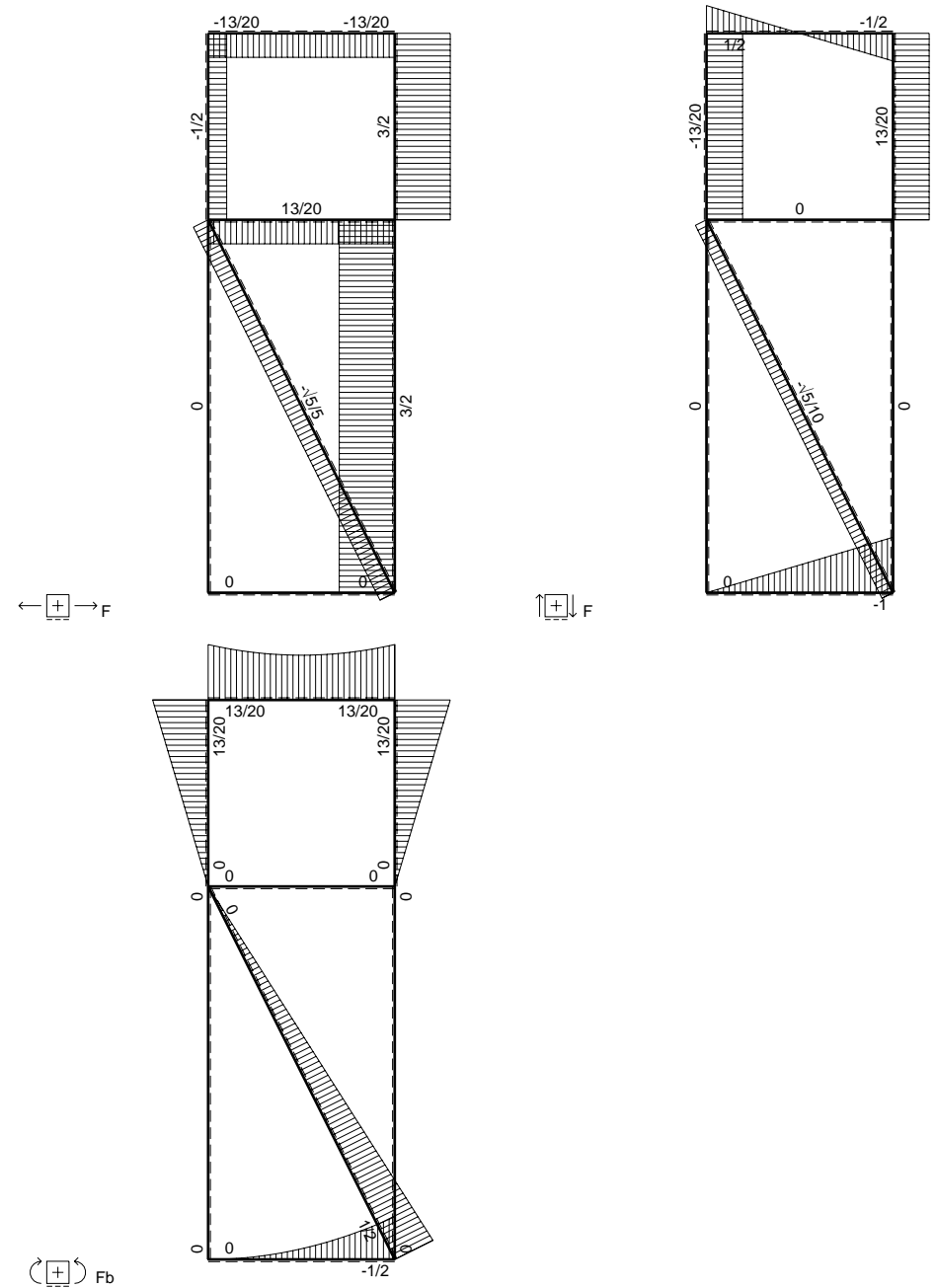
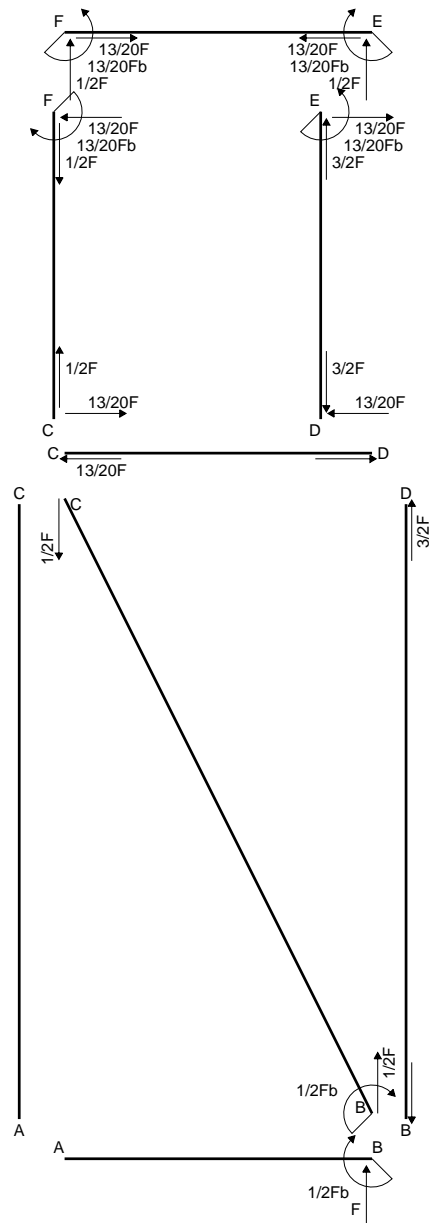
$$\sigma_c = N/A - Mv/J_u = -126.6 \text{ N/mm}^2$$

$$\tau_c = 1.65 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 126.6 \text{ N/mm}^2$$

$$S = 3933. \text{ mm}^3$$







$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

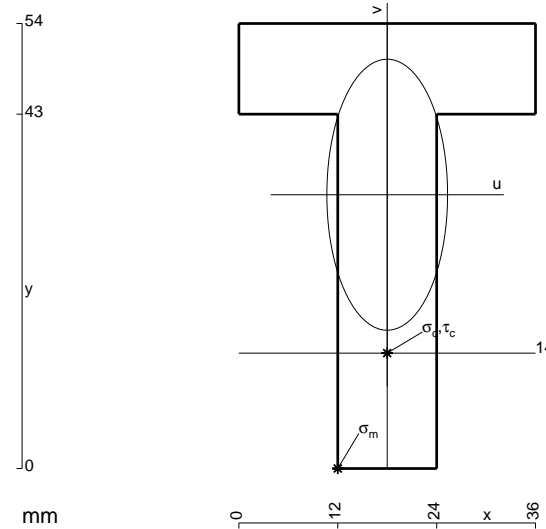
$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (1/4 b - 1/6 b) Fb 1/EJ + (b) \theta = 13/12 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

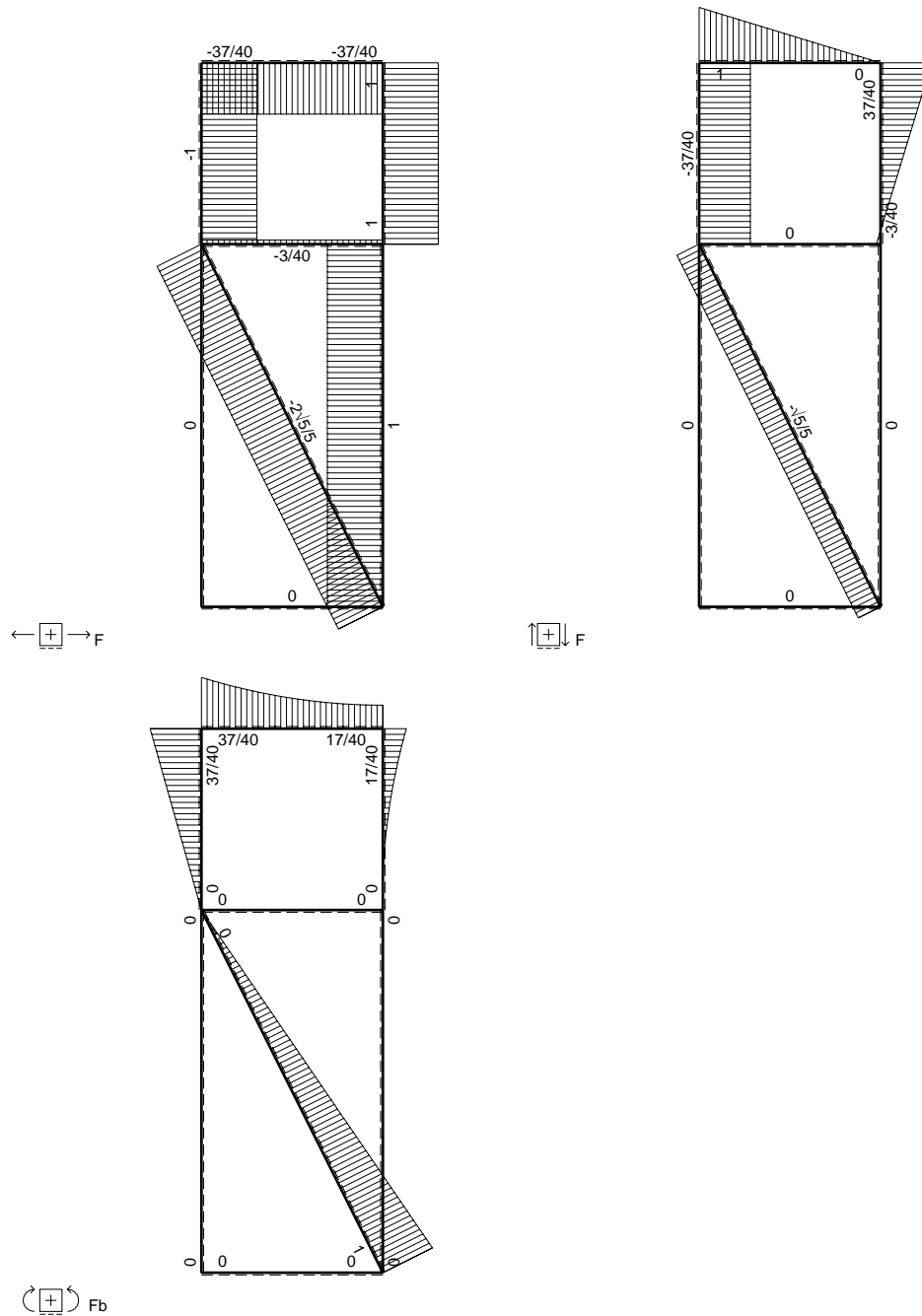
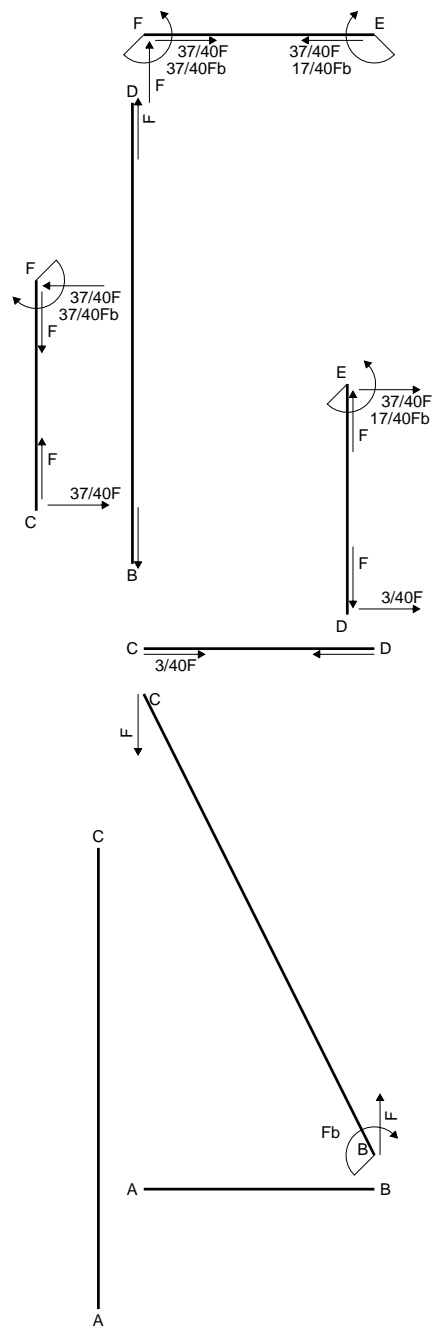
$$= (1/4 b - 1/6 b) Fb 1/EJ + (-b) \theta = 13/12 Fb^2/EJ$$



- 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
- T<sub>y</sub> = -5020. N
- M<sub>x</sub> = -1706800. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -33.22 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -229.7 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> = -Mv/J<sub>u</sub> = -132.9 N/mm<sup>2</sup>
- τ<sub>c</sub> = 7.467 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 133.6 N/mm<sup>2</sup>
- S = 4406. mm<sup>3</sup>









$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/6 b) Fb 1/EJ + (b) \theta = 5/6 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx$$

$$= [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

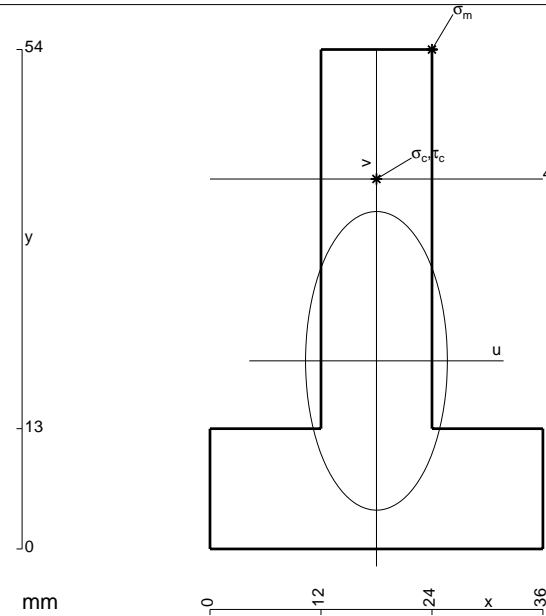
$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ + (-b) \theta = 5/6 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

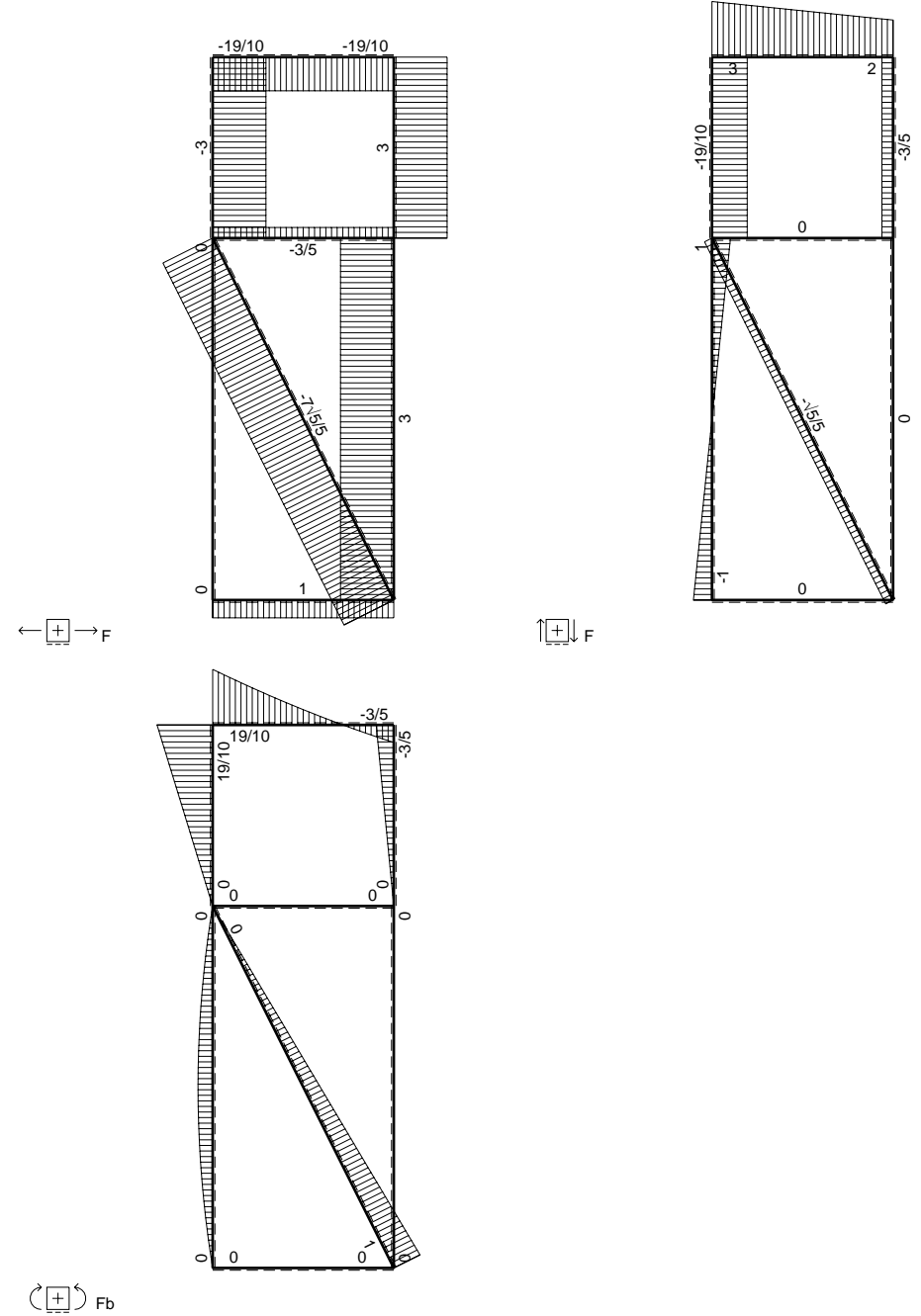
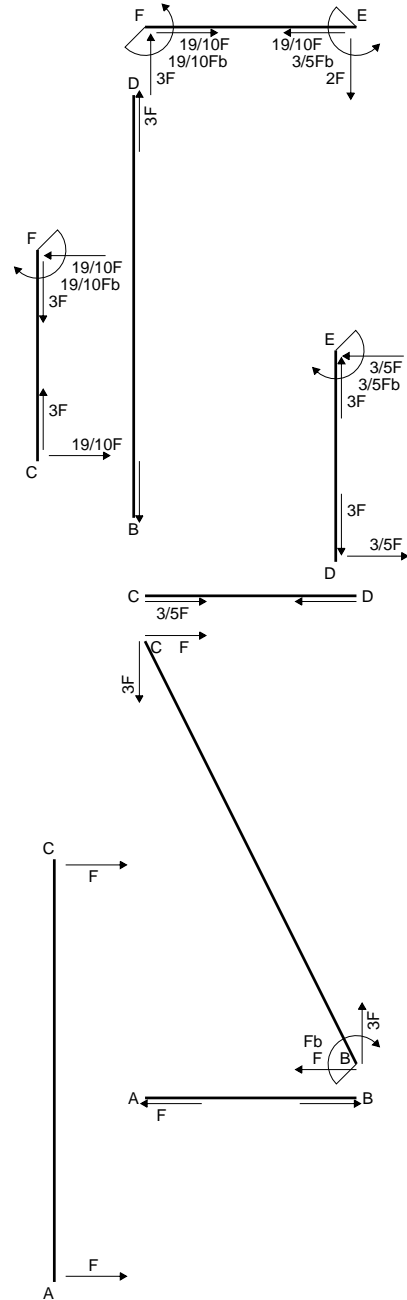
$$L_{CF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$



- A = 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> = 20.34 mm
- N = -2191. N
- T<sub>y</sub> = -1096. N
- M<sub>x</sub> = 1764000. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 33.66 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = -239.5 N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 40. mm
- v<sub>c</sub> = 19.66 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = -140.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.634 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup>+3τ<sup>2</sup>) = 140.8 N/mm<sup>2</sup>
- S = 4479. mm<sup>3</sup>







$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-2x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-b - 1/6 b) Fb 1/EJ + (b) \theta = -1/6 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-5/2 + 3x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx$$

$$= [-5/2 x + 3/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

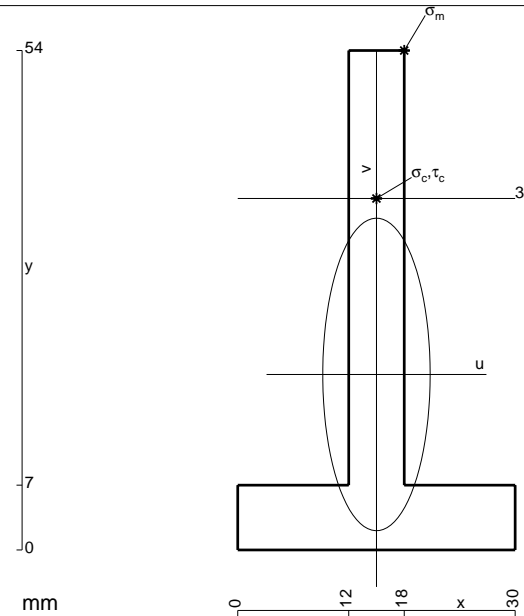
$$= (-5/2 b + 3/2 b - 1/6 b) Fb 1/EJ + (-b) \theta = -1/6 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = [-5/2 x + 5/2 x^2/b - 5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$



$$A = 492. \text{ mm}^2$$

$$J_u = 140516. \text{ mm}^4$$

$$J_v = 16596. \text{ mm}^4$$

$$y_g = 18.98 \text{ mm}$$

$$N = -6167. \text{ N}$$

$$T_y = -881. \text{ N}$$

$$M_x = 748600. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$y_m = 54. \text{ mm}$$

$$u_m = 3. \text{ mm}$$

$$v_m = 35.02 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -199.1 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 38. \text{ mm}$$

$$v_c = 19.02 \text{ mm}$$

$$\sigma_c = N/A - Mv/J_u = -113.9 \text{ N/mm}^2$$

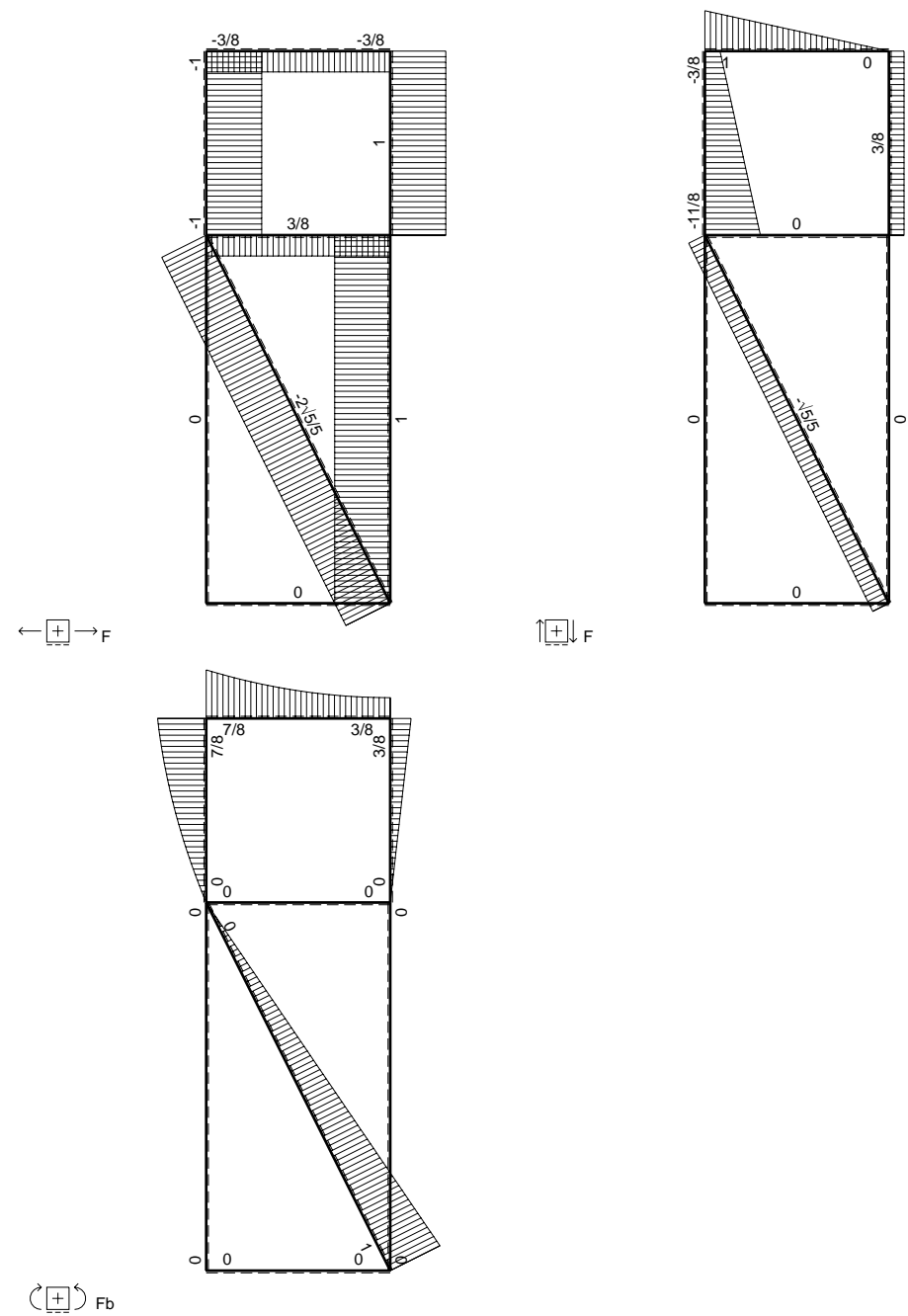
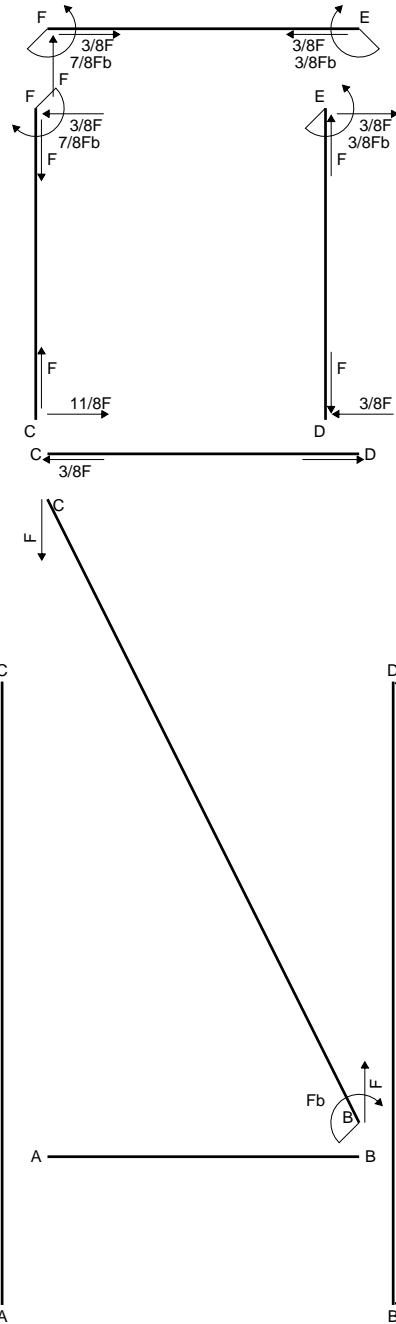
$$\tau_c = 2.711 \text{ N/mm}^2$$

$$\sigma_q = \sqrt{\sigma^2 + 3\tau^2} = 114. \text{ N/mm}^2$$

$$S = 2594. \text{ mm}^3$$









$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{x\theta} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/6 b) Fb 1/EJ + (b) \theta = 5/6 Fb^2/EJ$$

$$L_{FE}^{x\theta} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx$$

$$= [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ + (-b) \theta = 5/6 Fb^2/EJ$$

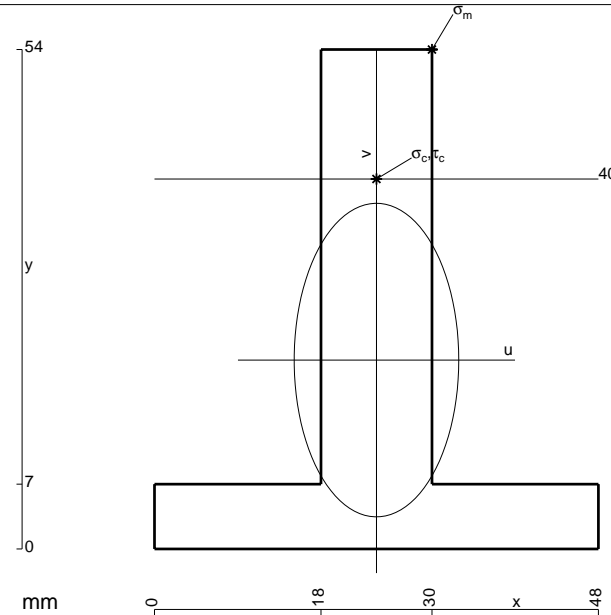
$$L_{FC}^{x\theta} = \int_0^b (-1/2 + 1/2 x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx$$

$$= [-1/2 x + 1/4 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/4 b + 1/6 b - 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$

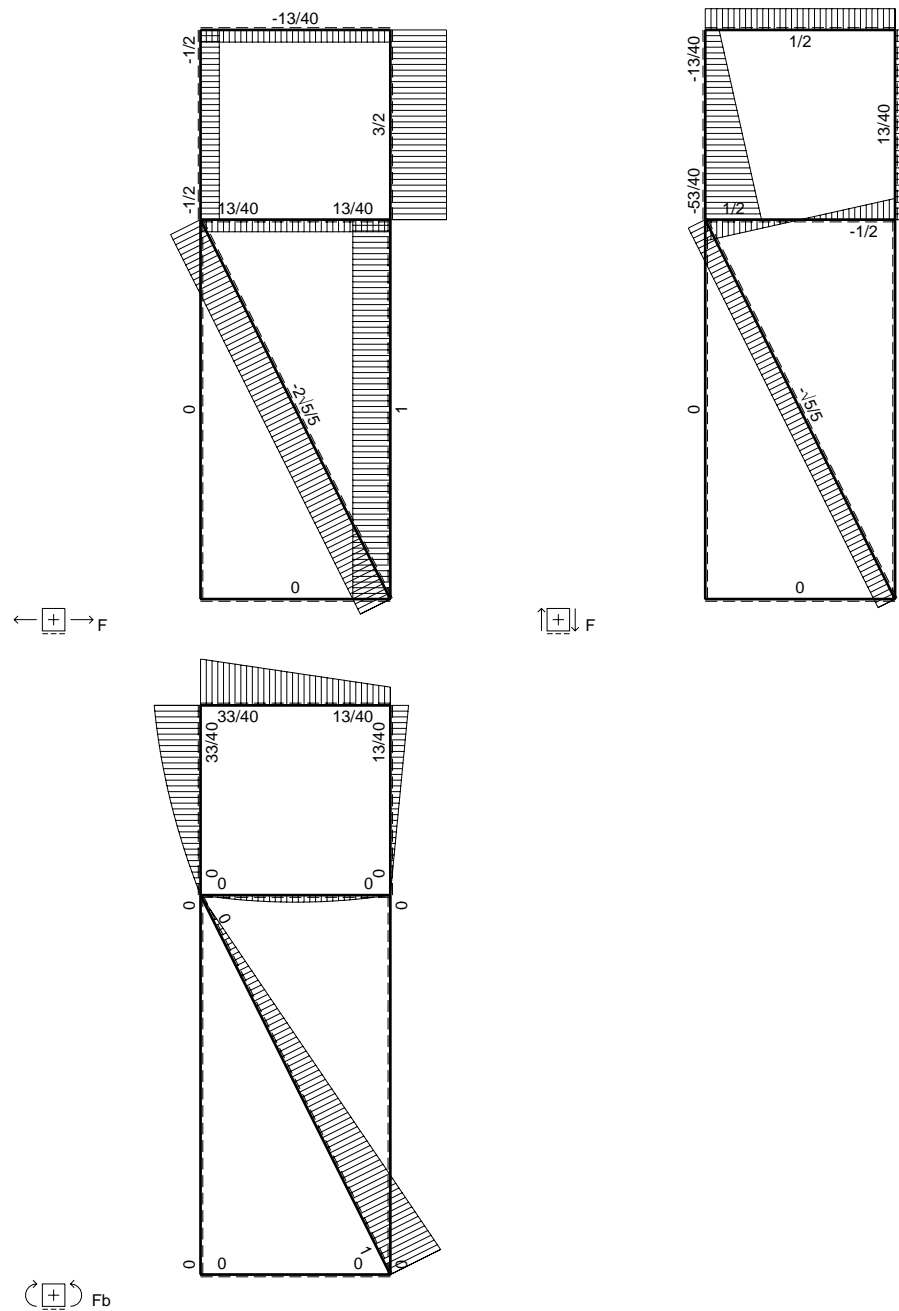
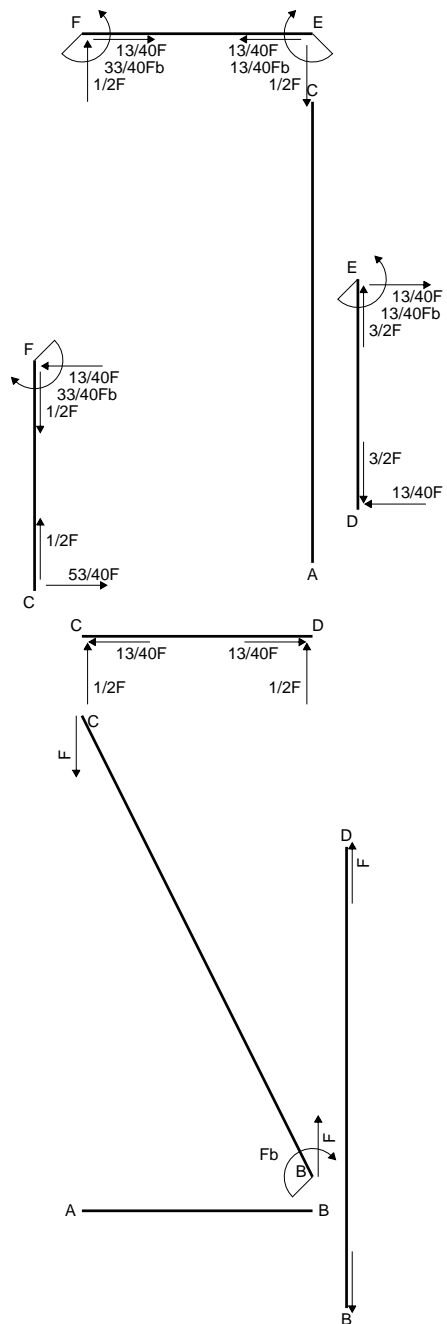
$$L_{CF}^{x\theta} = \int_0^b (-x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/3 b + 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$



- 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 = -3461. N
- T<sub>y</sub> = -1731. N
- M<sub>x</sub> = 1586700. 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> = -123.9 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.49 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup>+3τ<sup>2</sup>) = 124. N/mm<sup>2</sup>
- S = 4465. mm<sup>3</sup>







$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/4 b) Fb 1/EJ + (b) \theta = 3/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + 1/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-1/2 x + 1/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

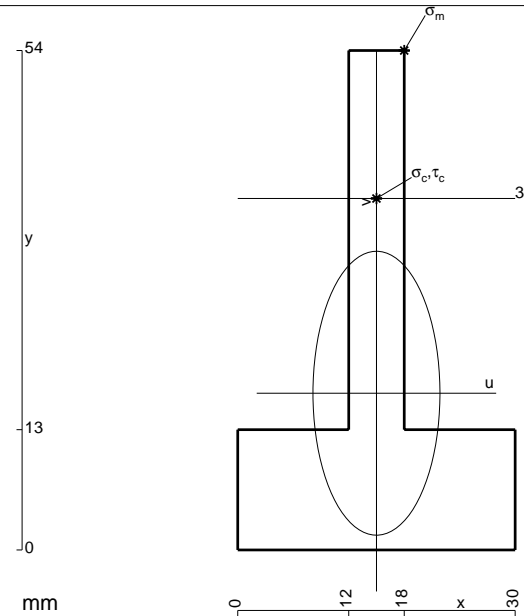
$$L_{FC}^{xo} = \int_0^b (-1/2 + 1/2 x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx$$

$$= [-1/2 x + 1/4 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/4 b + 1/6 b - 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/3 b + 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$



- 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> = 16.94 mm
- N = -1744. N
- T<sub>y</sub> = -872.1 N
- M<sub>x</sub> = 877500. Nmm
- x<sub>m</sub> = 18. mm
- y<sub>m</sub> = 54. 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> = -219.6 N/mm<sup>2</sup>
- x<sub>c</sub> = 15. mm
- y<sub>c</sub> = 38. mm
- v<sub>c</sub> = 21.06 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = -126. N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.704 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 126.1 N/mm<sup>2</sup>
- S = 2789. mm<sup>3</sup>









$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/4 b) Fb 1/EJ + (b) \theta = 3/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + 1/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-1/2 x + 1/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

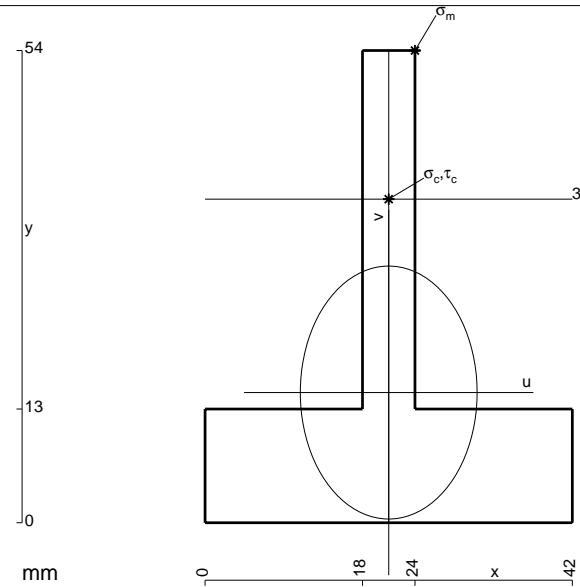
$$L_{FC}^{xo} = \int_0^b (-1/2 + 1/2 x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx$$

$$= [-1/2 x + 1/4 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/4 b + 1/6 b - 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$

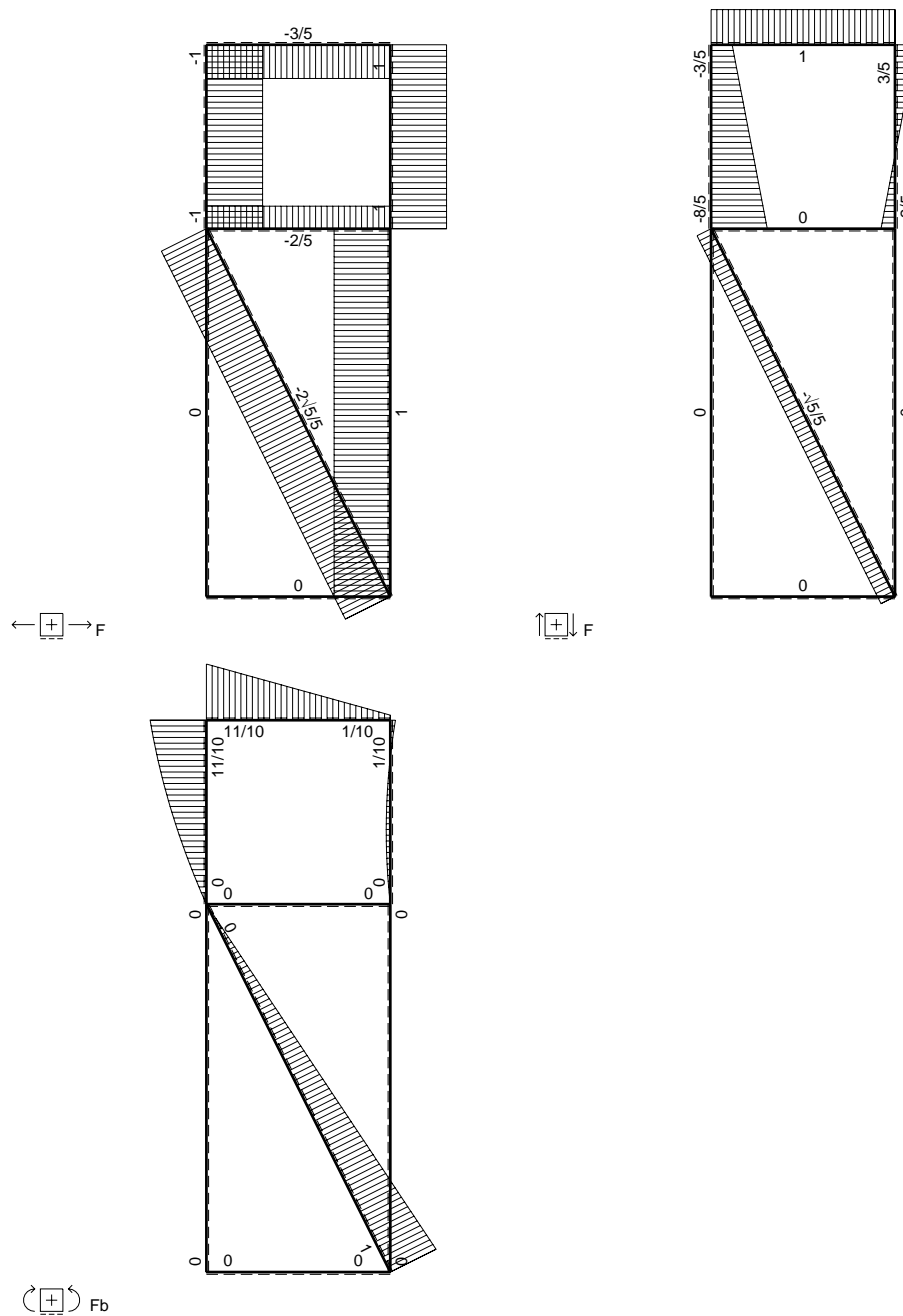
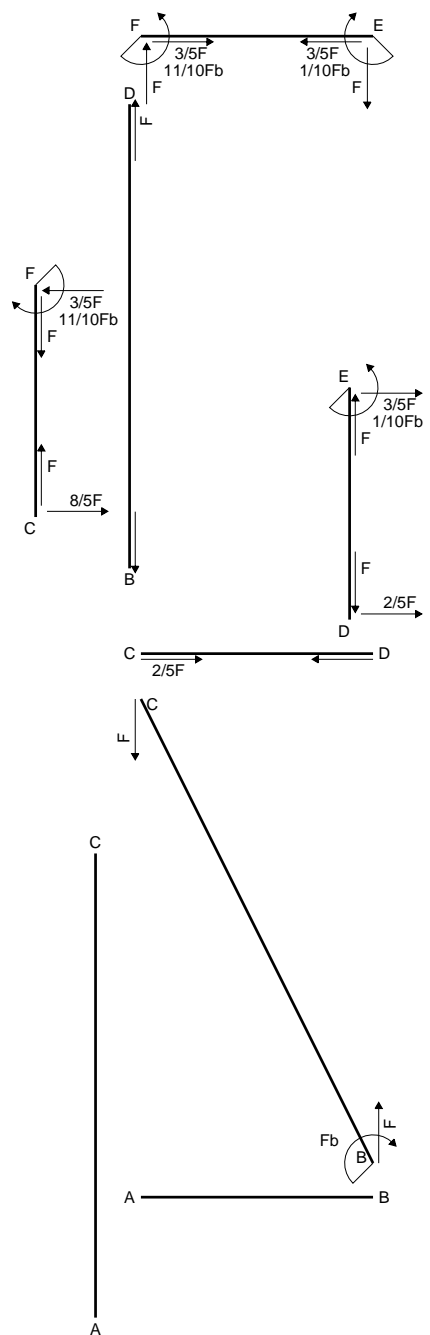
$$L_{CF}^{xo} = \int_0^b (-x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

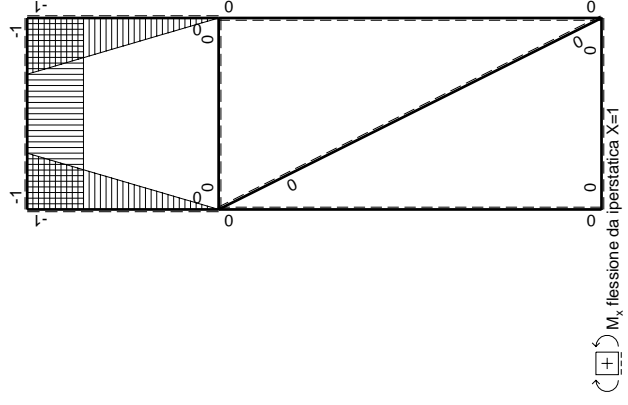
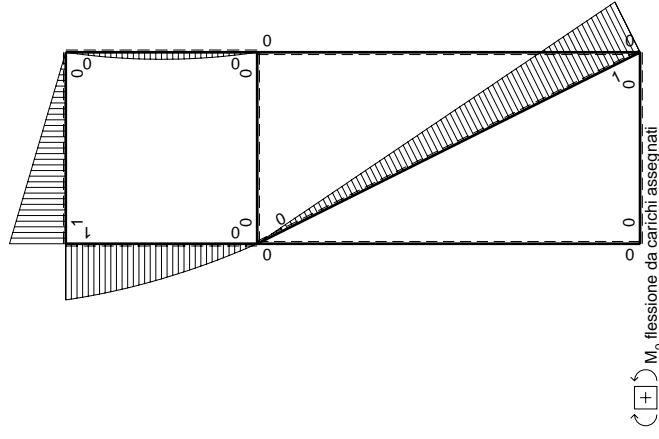
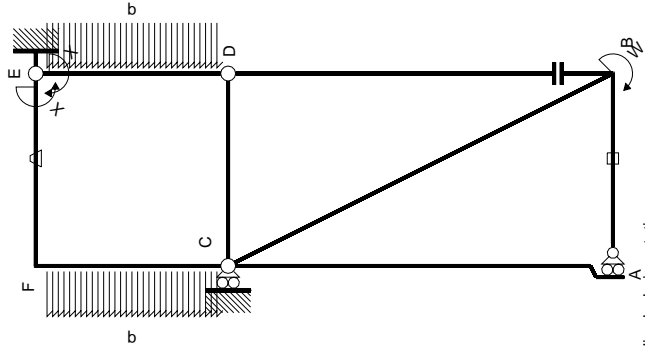
$$= (-1/3 b + 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$



- 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> = -3970. N
- M<sub>x</sub> = -972650. 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> = 229.5 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> = 129.7 N/mm<sup>2</sup>
- τ<sub>c</sub> = 12.46 N/mm<sup>2</sup>
- σ<sub>q</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 131.5 N/mm<sup>2</sup>
- S = 3123. mm<sup>3</sup>







Quadro contributi PLV per iperstatica  $X=W_{EF}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x (M_0/EJ + \theta) dx$	$\int M_x M_x / EJ dx$
AB b	0	0	0	0	0	0	0	0
BA b	0	0	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$Fb - \sqrt{5}Fx$	0	0	0	0	0	0
CA 2b	0	0	0	0	0	0	0	0
AC 2b	0	0	0	0	0	0	0	0
DB 2b	0	0	0	0	0	0	0	0
BD 2b	0	0	0	0	0	0	0	0
DE b	$-x/b$	$-1/2Fx + 1/2qx^2$	0	$1/2Fx^2/b - 1/2qx^3/b$	0	0	$x^2/b^2$	0
ED b	$1-x/b$	$1/2Fx - 1/2qx^2$	0	$1/2Fx - Fx^2/b + 1/2qx^3/b$	0	0	$1-2x/b + x^2/b^2$	$(1/24+0)Fb^2/EJ$
CD b	0	0	0	0	0	0	0	0
DC b	0	0	0	0	0	0	0	0
EF b	-1	Fx	$-Fb/EJ$	-Fx	$Fb/EJ$	1	1	$(-1/2+1)Fb^2/EJ$
FE b	1	$-Fb+Fx$	$Fb/EJ$	$-Fb+Fx$	$Fb/EJ$	1	1	$Xb/EJ$
FC b	$-1+x/b$	$Fb - 1/2Fx - 1/2qx^2$	0	$-Fb + 3/2Fx - 1/2qx^3/b$	0	0	$1-2x/b + x^2/b^2$	$(-3/8+0)Fb^2/EJ$
CF b	$x/b$	$-3/2Fx + 1/2qx^2$	0	$-3/2Fx^2/b + 1/2qx^3/b$	0	0	$x^2/b^2$	$1/3Xb/EJ$
totali								
iperstatica $X=W_{EF}$								
								$-1/10Fb$
								$1/6Fb^2/EJ$
								$5/3Xb/EJ$

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (b) \theta = 1/2 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

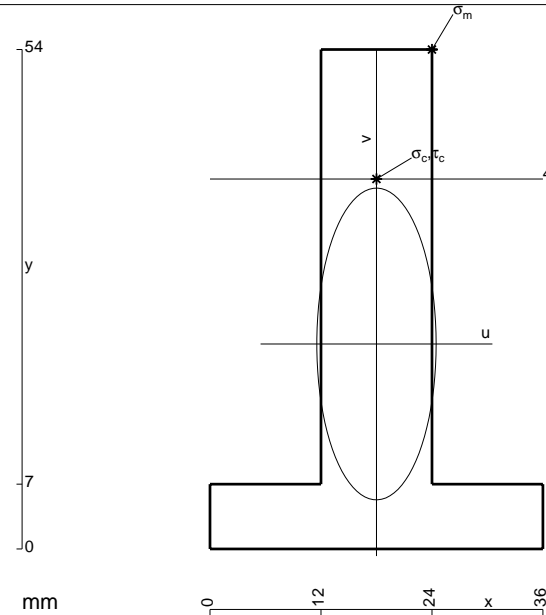
$$= (-b + 1/2 b) Fb 1/EJ + (-b) \theta = 1/2 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-1 + 3/2 x/b - 1/2 x^3/b^3) Fb 1/EJ dx = [-x + 3/4 x^2/b - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-b + 3/4 b - 1/8 b) Fb 1/EJ = -3/8 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-3/2 x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/2 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

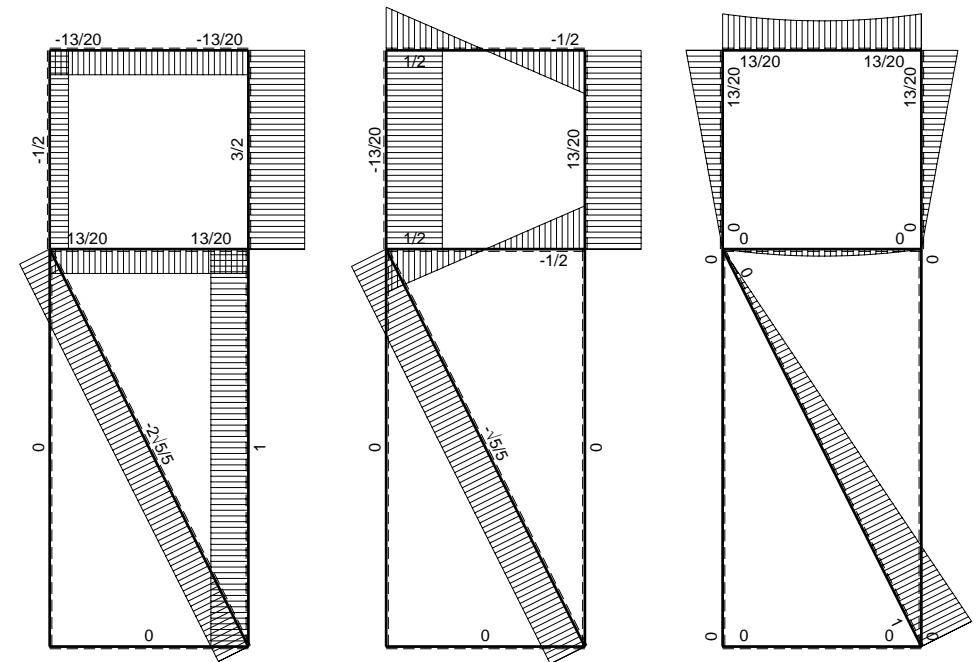
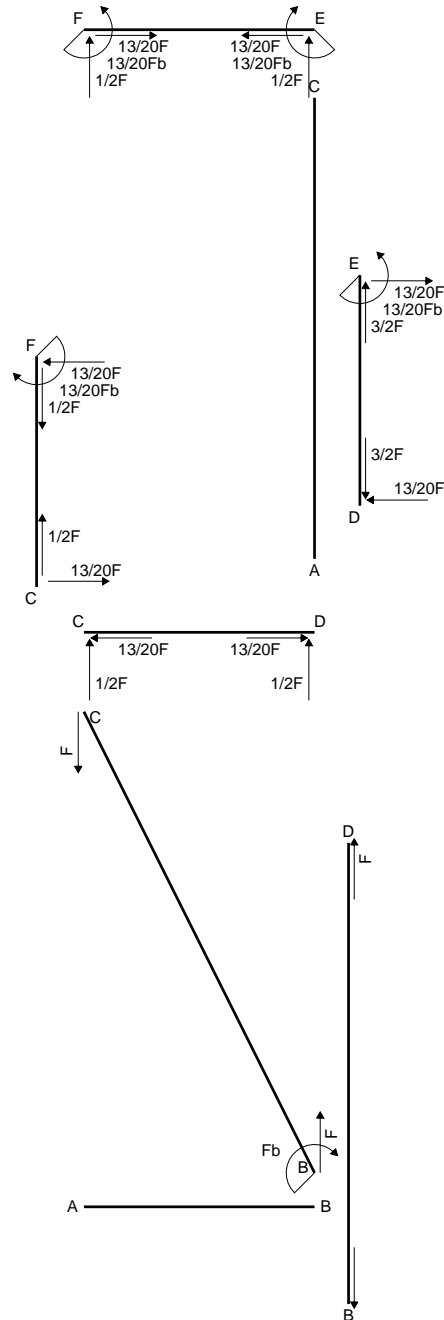
$$= (-1/2 b + 1/8 b) Fb 1/EJ = -3/8 Fb^2/EJ$$



- A = 816. mm<sup>2</sup>
- J<sub>u</sub> = 231827. mm<sup>4</sup>
- J<sub>v</sub> = 33984. mm<sup>4</sup>
- y<sub>g</sub> = 22.16 mm
- N = -2898. N
- T<sub>y</sub> = -1449. N
- M<sub>x</sub> = 1717200. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 31.84 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = -239.4 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> = N/A-Mv/J<sub>u</sub> = -135.7 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.173 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 = 4173. mm<sup>3</sup>







← ⊕ → F

↑ ⊕ ↓ F

⊕ ⊖ F<sub>b</sub>



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

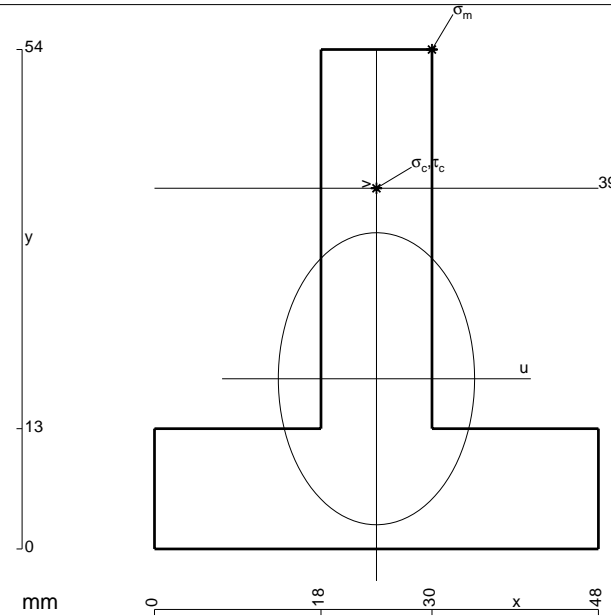
$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (1/4 b - 1/6 b) Fb 1/EJ + (b) \theta = 13/12 Fb^2/EJ$$

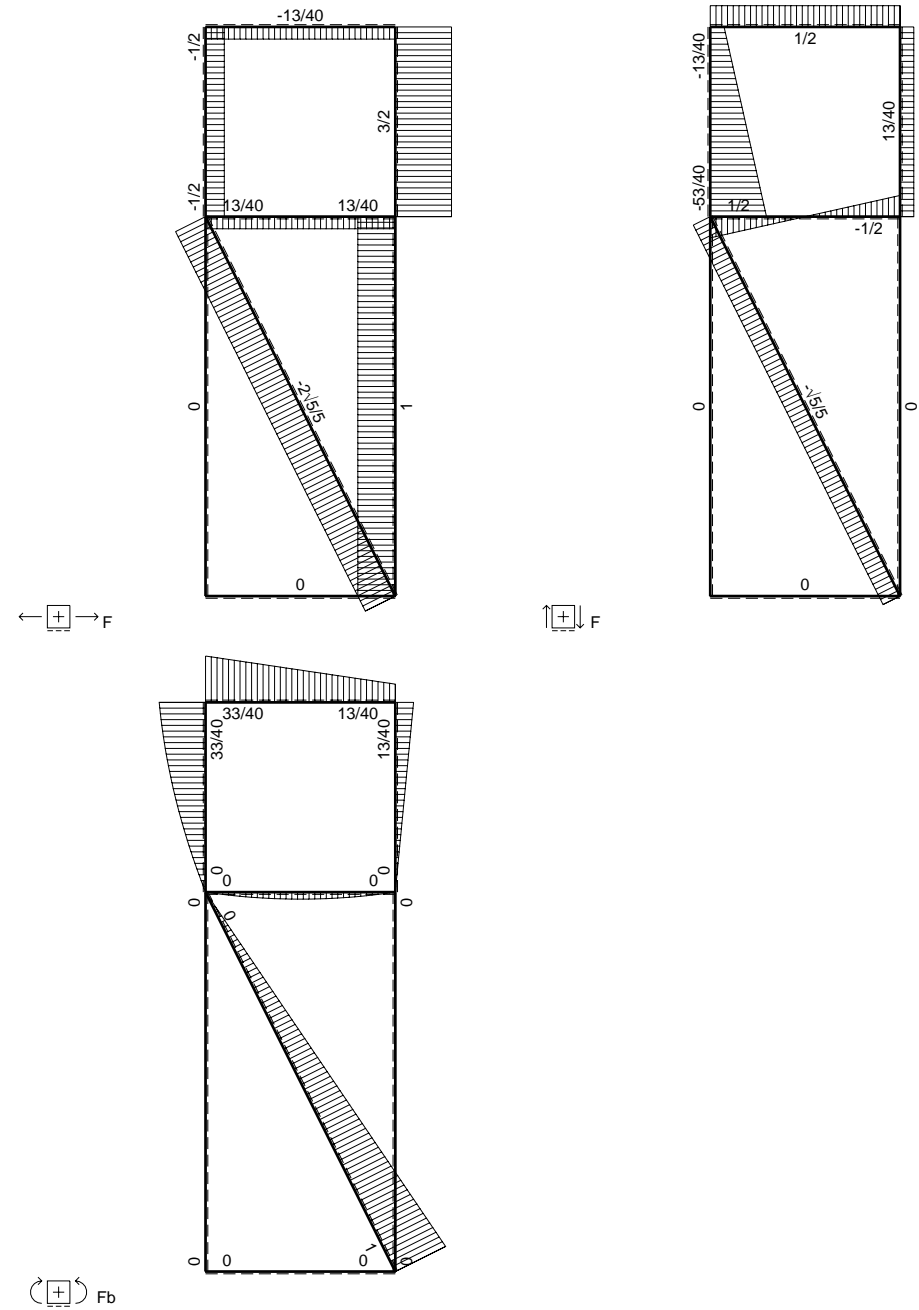
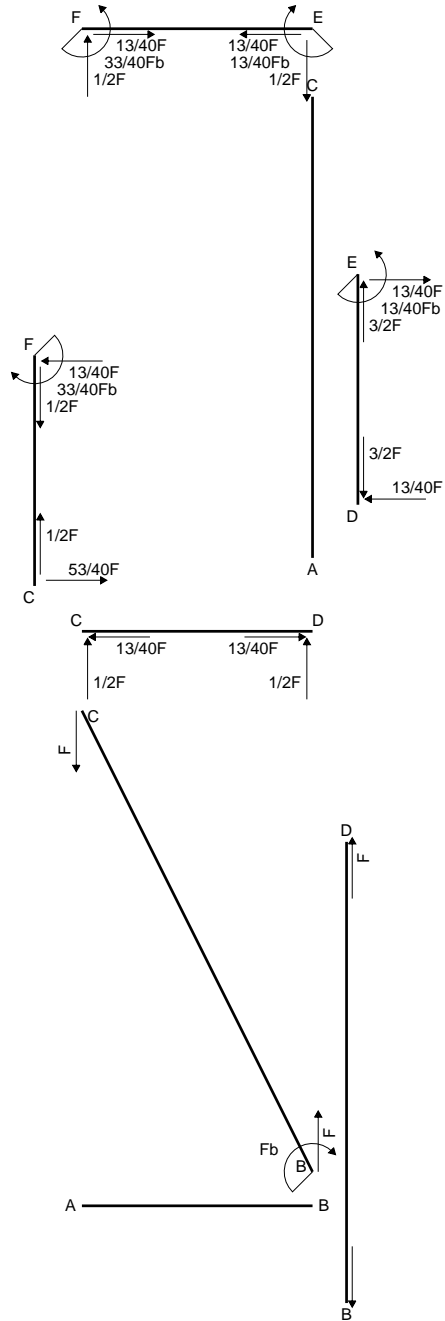
$$L_{FE}^{xo} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (1/4 b - 1/6 b) Fb 1/EJ + (-b) \theta = 13/12 Fb^2/EJ$$



- 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
- N = -2424. N
- T<sub>y</sub> = -1212. N
- M<sub>x</sub> = 1544700. 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> = N/A-Mv/J<sub>u</sub> = -199.8 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> = N/A-Mv/J<sub>u</sub> = -116.5 N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.836 N/mm<sup>2</sup>
- σ<sub>o</sub> = √(σ<sup>2</sup>+3τ<sup>2</sup>) = 116.6 N/mm<sup>2</sup>
- S = 5057. mm<sup>3</sup>





$\left( \begin{matrix} + \\ + \end{matrix} \right) Fb$



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/4 b) Fb 1/EJ + (b) \theta = 3/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + 1/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-1/2 x + 1/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

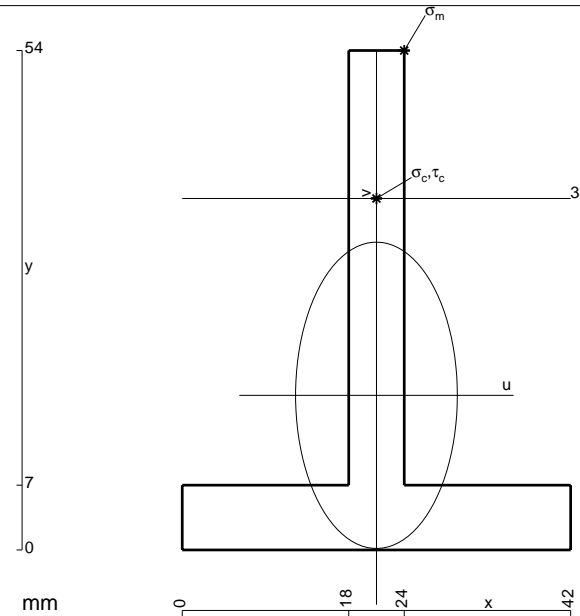
$$L_{FC}^{xo} = \int_0^b (-1/2 + 1/2 x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx$$

$$= [-1/2 x + 1/4 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/4 b + 1/6 b - 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

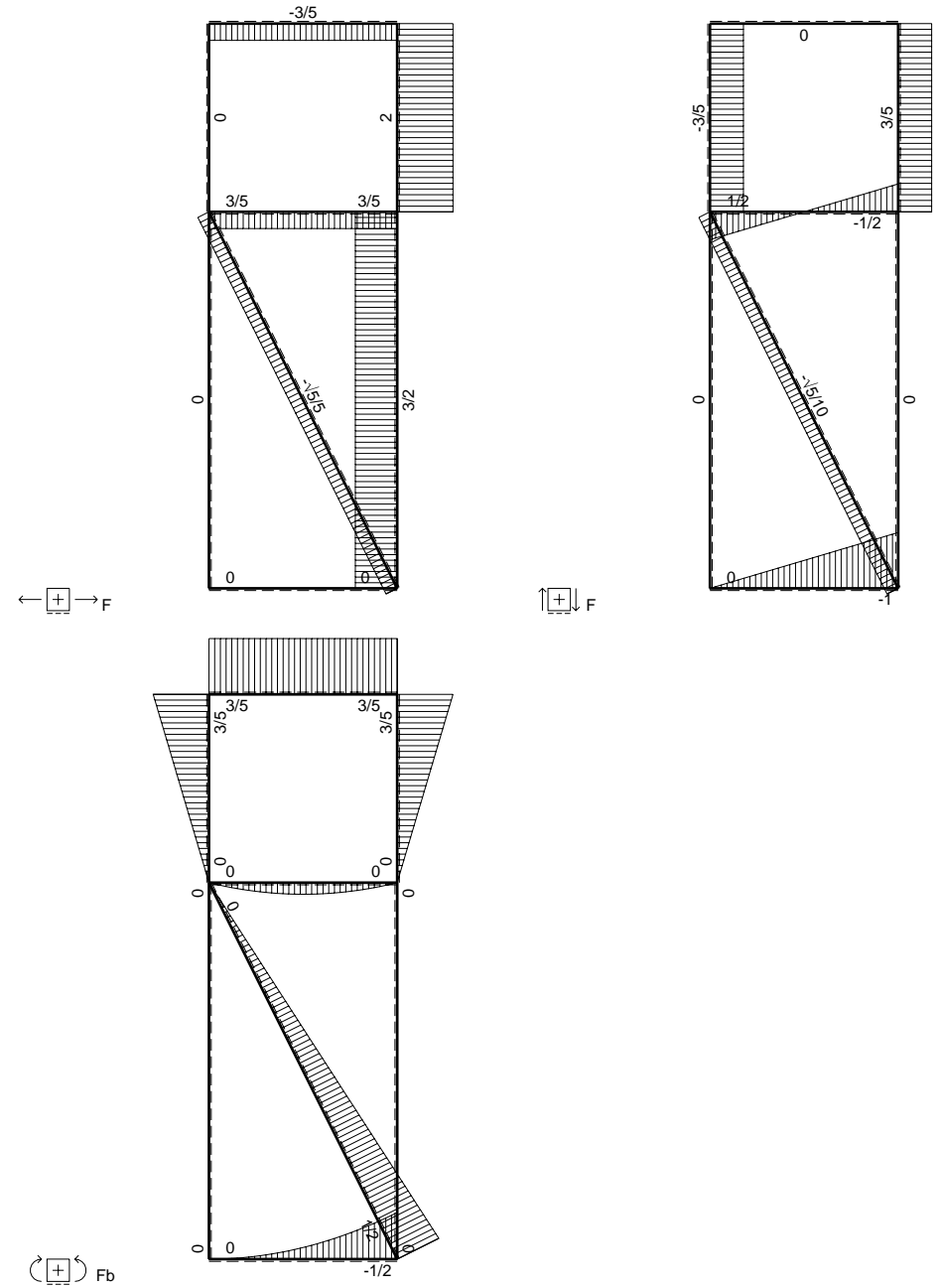
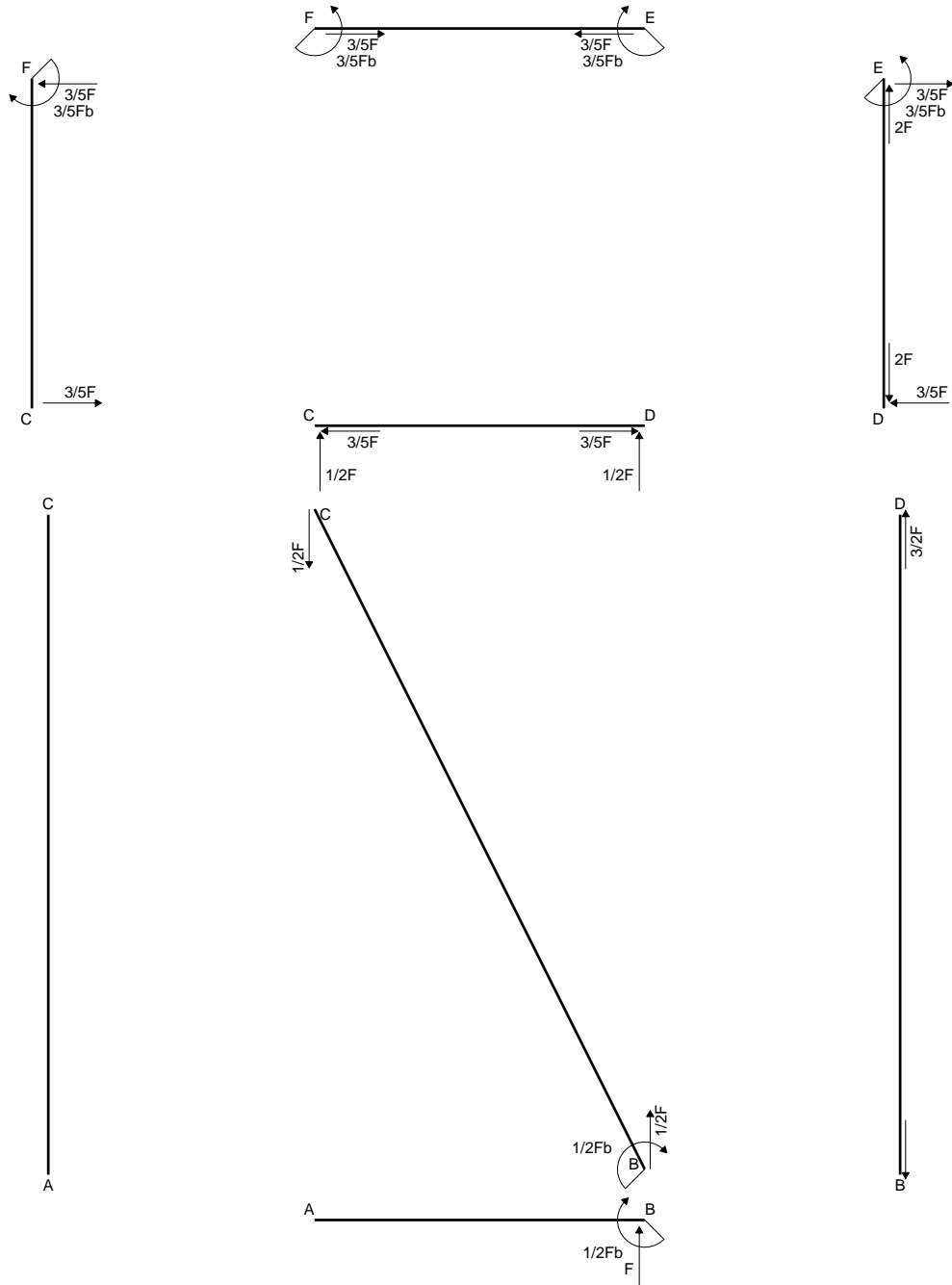
$$= (-1/3 b + 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$

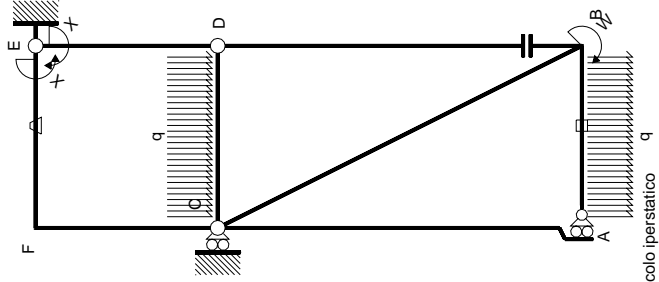


- A = 576. mm<sup>2</sup>
- J<sub>u</sub> = 158042. mm<sup>4</sup>
- J<sub>v</sub> = 44064. mm<sup>4</sup>
- y<sub>g</sub> = 16.72 mm
- N = -1306. N
- T<sub>y</sub> = -652.9 N
- M<sub>x</sub> = 876000. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 54. mm
- u<sub>m</sub> = 3. mm
- v<sub>m</sub> = 37.28 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = -208.9 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 38. mm
- v<sub>c</sub> = 21.28 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = -120.2 N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.936 N/mm<sup>2</sup>
- σ<sub>o</sub> = √(σ<sup>2</sup>+3τ<sup>2</sup>) = 120.3 N/mm<sup>2</sup>
- S = 2811. mm<sup>3</sup>

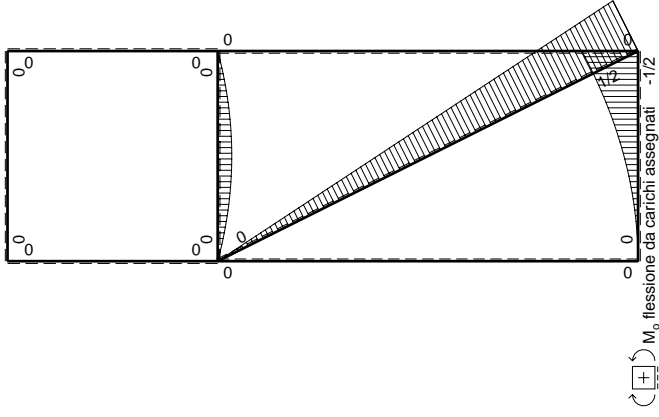








Schema di calcolo iperstatico



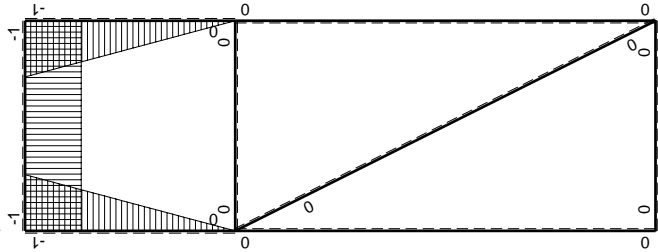
$M_0$  flessione da carichi assegnati -1/2

Quadro contributi PLV per iperstatica  $X=W_{EF}$

→	$M_x(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$
AB b	0	$-1/2qx^2$	0	0	0	0	0+0	0
BA b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0+0	0
BC $\sqrt{5}b$	0	$1/2Fb-\sqrt{5}/10Fx$	0	0	0	0	0	0
AC 2b	0	0	0	0	0	0	0+0	0
CA 2b	0	0	0	0	0	0	0+0	0
DB 2b	0	0	0	0	0	0	0+0	0
BD 2b	0	0	0	0	0	0	0+0	0
DE b	$-x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3Xb/EJ$
ED b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	0
CD b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0
DC b	0	$-1/2Fx+1/2qx^2$	0	0	0	0	0+0	0
EF b	-1	0	$-Fb/EJ$	0	$Fb/EJ$	1	$(0+1)Fb^2/EJ$	$Xb/EJ$
FE b	1	0	$Fb/EJ$	0	$Fb/EJ$	1		
FC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$
CF b	$x/b$	0	0	0	0	$x^2/b^2$	$Fb^2/EJ$	$5/3Xb/EJ$
totali								
iperstatica $X=W_{EF}$								
$-3/5Fb$								

Sviluppi di calcolo iperstatica

$M_x$  flessione da iperstatica  $X=1$



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

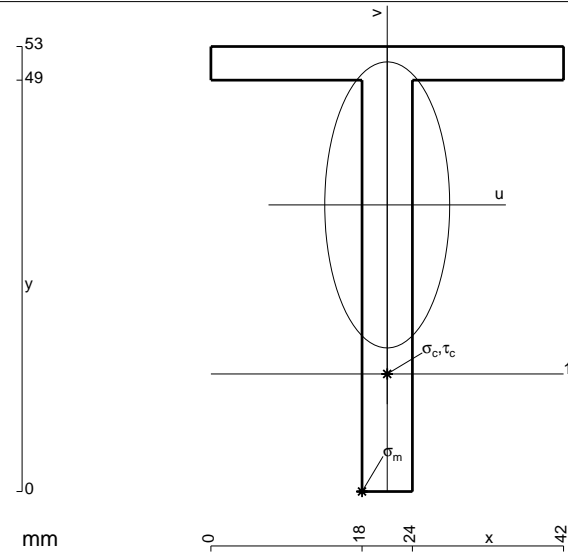
$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (1) \theta dx = [x]_0^b \theta$$

$$= (b) \theta = Fb^2/EJ$$

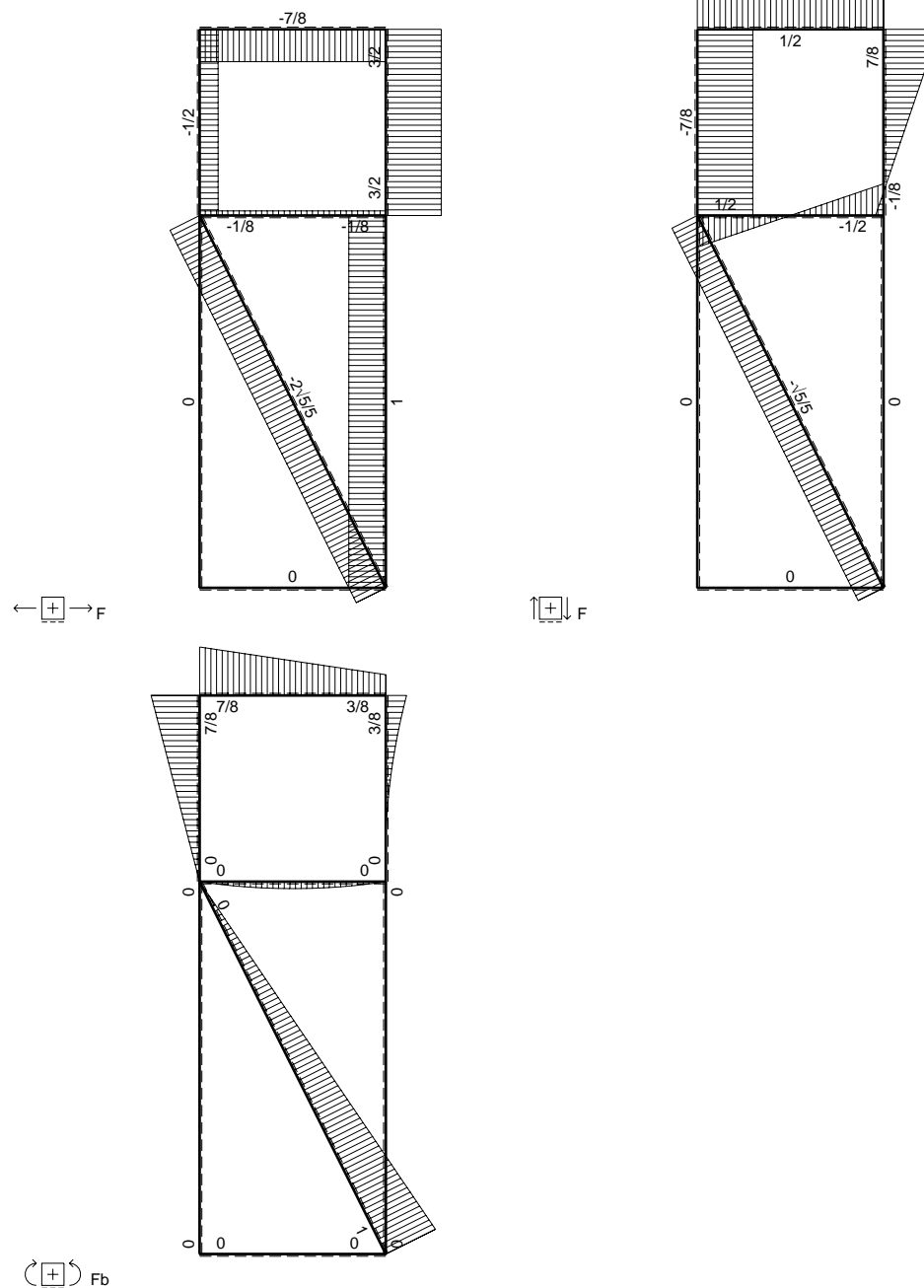
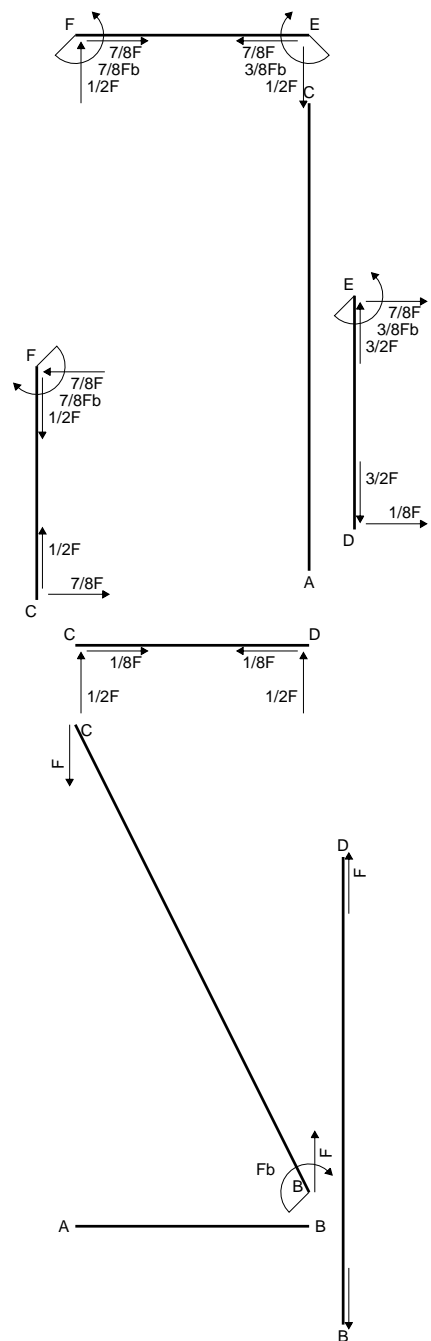
$$L_{FE}^{xo} = \int_0^b (-1) \theta dx = [-x]_0^b \theta$$

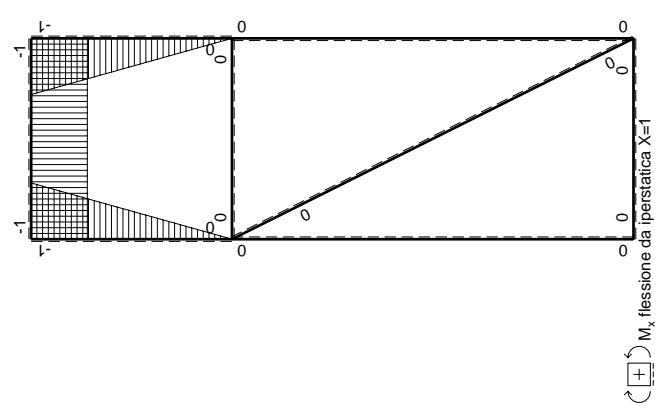
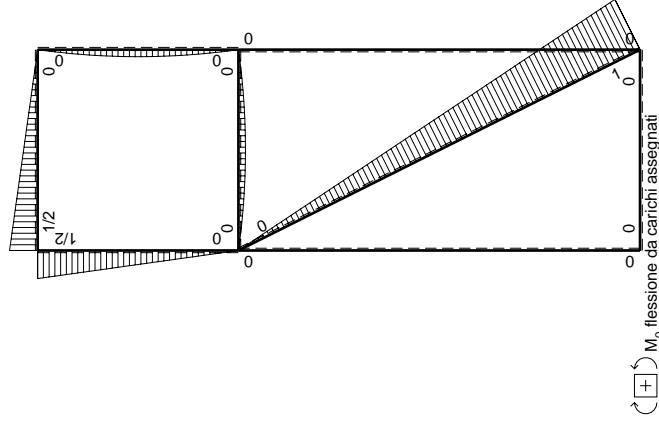
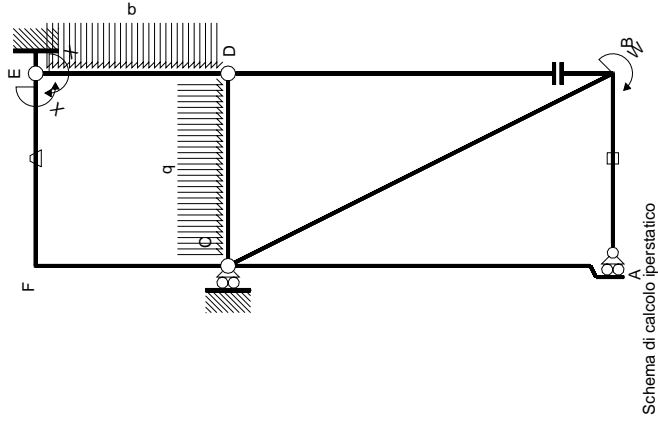
$$= (-b) \theta = Fb^2/EJ$$



$A = 462. \text{ mm}^2$   
 $J_u = 134125. \text{ mm}^4$   
 $J_v = 25578. \text{ mm}^4$   
 $y_g = 34.14 \text{ mm}$   
 $T_y = -2780. \text{ N}$   
 $M_x = -861800. \text{ Nmm}$   
 $x_m = 18. \text{ mm}$   
 $u_m = -3. \text{ mm}$   
 $v_m = -34.14 \text{ mm}$   
 $\sigma_m = -Mv/J_u = -219.3 \text{ N/mm}^2$   
 $x_c = 21. \text{ mm}$   
 $y_c = 14. \text{ mm}$   
 $v_c = -20.14 \text{ mm}$   
 $\sigma_c = -Mv/J_u = -129.4 \text{ N/mm}^2$   
 $\tau_c = 7.874 \text{ N/mm}^2$   
 $\sigma_o = \sqrt{\sigma^2 + 3\tau^2} = 130.1 \text{ N/mm}^2$   
 $S = 2279. \text{ mm}^3$







Quadro contributi PLV per iperstatica X=W<sup>EF</sup>

←	M <sup>x</sup> (x)	M <sup>o</sup> (x)	θ	M <sup>x</sup> M <sup>o</sup>	M <sup>x</sup> θ	M <sup>x</sup> M <sup>x</sup>	$\int M^x(M^o/EJ+\theta)dx$	$\int M^x M^x/EJdx$
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0	0
BC √5b	0	Fb-√5/5Fx	0	0	0	0	0	0
CA 2b	0	0	0	0	0	0	0+0	0
DB 2b	0	0	0	0	0	0	0	0
BD 2b	0	0	0	0	0	0	0+0	0
DE 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>	1/3Xb/EJ
ED 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>	1/3Xb/EJ
CD b	0	1/2Fx-1/2qx <sup>2</sup>	0	0	0	0	0	0
DC b	0	-1/2Fx+1/2qx <sup>2</sup>	0	0	0	0	0	0
EF b	-1	1/2Fx	-Fb/EJ	-1/2Fx	Fb/EJ	1	1	Xb/EJ
FE b	1	-1/2Fb+1/2Fx	Fb/EJ	-1/2Fb+1/2Fx	Fb/EJ	1	1	Xb/EJ
FC b	-1+x/b	1/2Fb-1/2Fx	0	-1/2Fb+Fx-1/2Fx <sup>2</sup> /b	0	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	1/3Xb/EJ
CF b	x/b	-1/2Fx	0	-1/2Fx <sup>2</sup> /b	0	0	x <sup>2</sup> /b <sup>2</sup>	1/3Xb/EJ
totali								5/8Fb <sup>2</sup> /EJ
								-3/8Fb

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/4 b) Fb 1/EJ + (b) \theta = 3/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + 1/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-1/2 x + 1/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

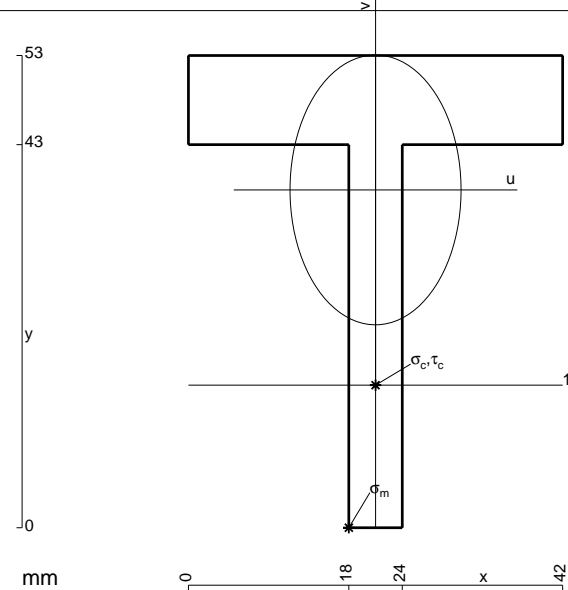
$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ$$

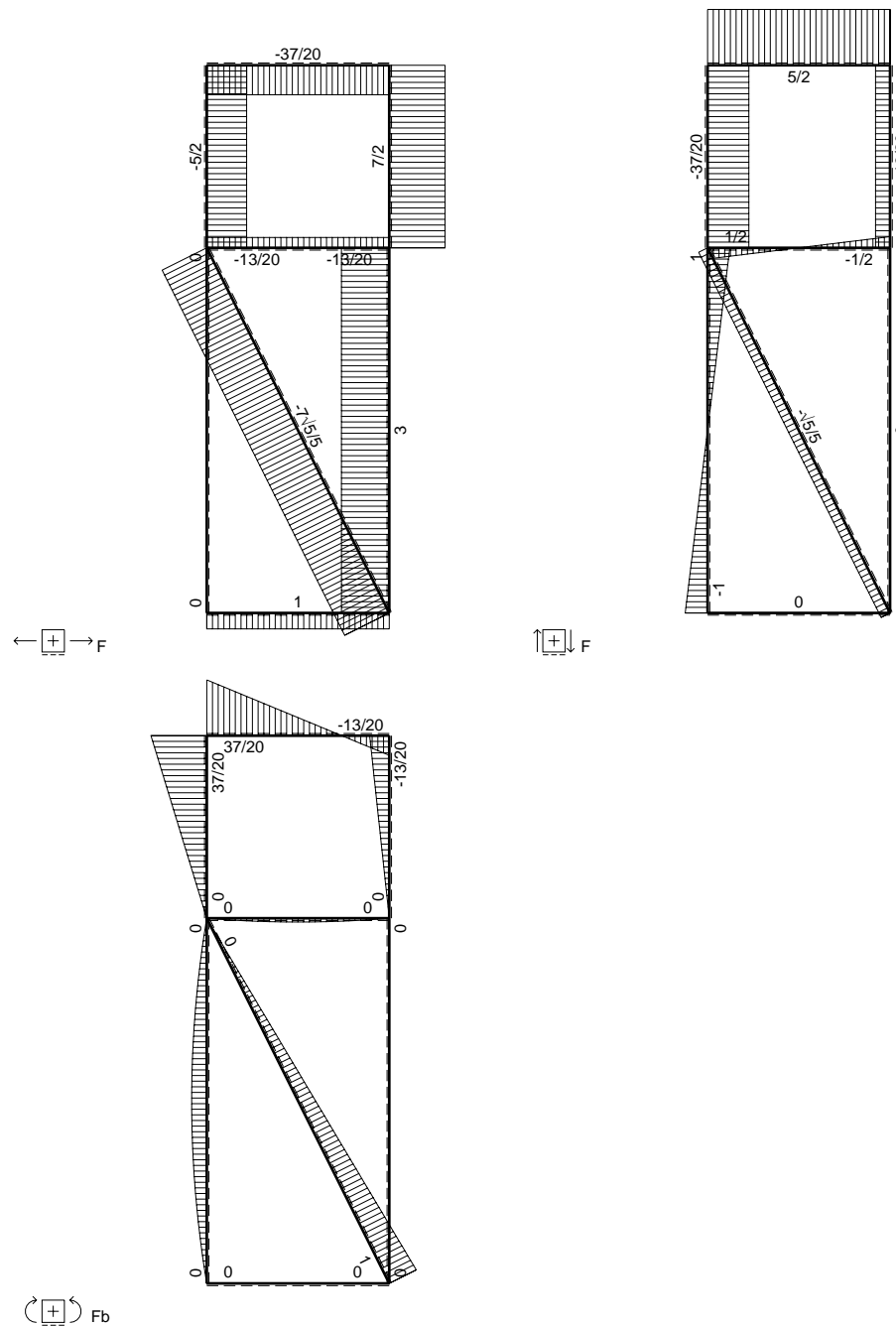
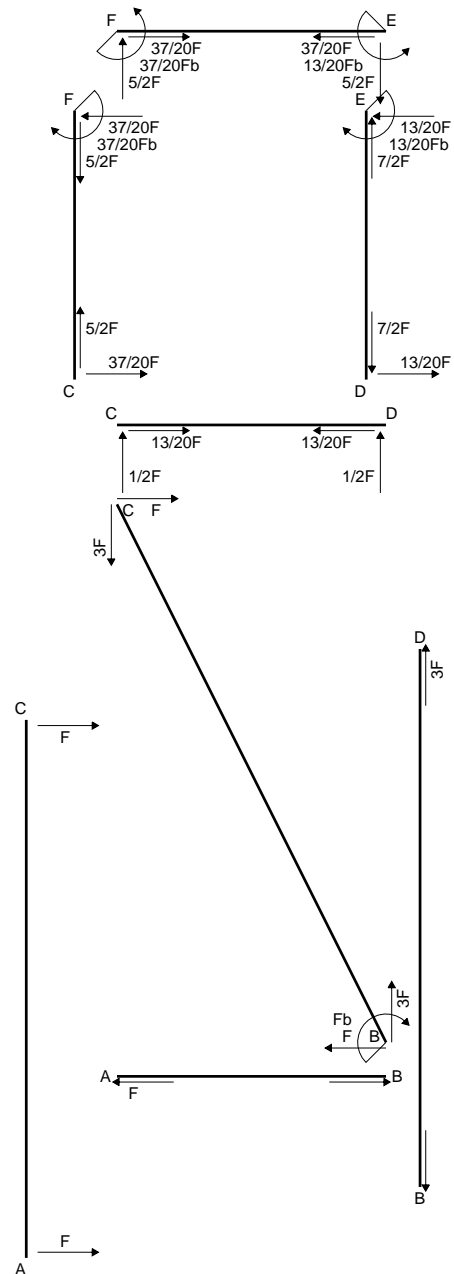
$$= (-1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$



- A = 678. mm<sup>2</sup>
- J<sub>u</sub> = 155489. mm<sup>4</sup>
- J<sub>v</sub> = 62514. mm<sup>4</sup>
- y<sub>g</sub> = 37.92 mm
- N = -1288. N
- T<sub>y</sub> = -644. N
- M<sub>x</sub> = 950400. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -37.92 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = 229.9 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 16. mm
- v<sub>c</sub> = -21.92 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = 132.1 N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.982 N/mm<sup>2</sup>
- σ<sub>φ</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 132.1 N/mm<sup>2</sup>
- S = 2872. mm<sup>3</sup>







(+) F<sub>b</sub>



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-5/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-5/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-5/4 b) Fb 1/EJ + (b) \theta = -1/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-5/2 + 5/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-5/2 x + 5/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

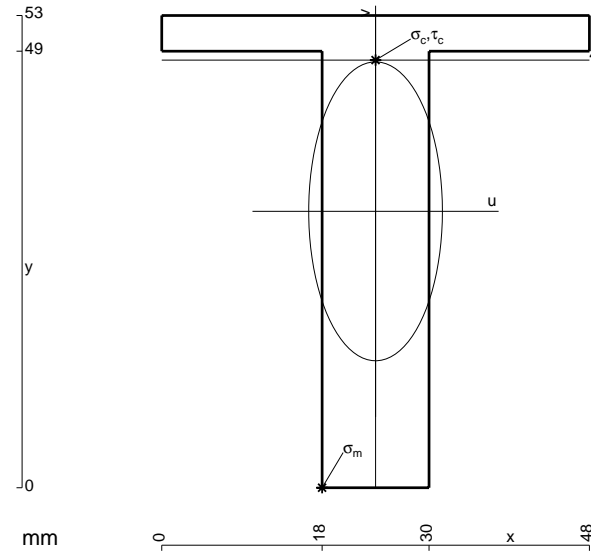
$$= (-5/2 b + 5/4 b) Fb 1/EJ + (-b) \theta = -1/4 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = [-5/2 x + 5/2 x^2/b - 5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$



$$A = 780. \text{ mm}^2$$

$$J_u = 219548. \text{ mm}^4$$

$$J_v = 43920. \text{ mm}^4$$

$$y_g = 31.02 \text{ mm}$$

$$N = -7889. \text{ N}$$

$$T_y = -1127. \text{ N}$$

$$M_x = 1764000. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$u_m = -6. \text{ mm}$$

$$v_m = -31.02 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 239.1 \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 48. \text{ mm}$$

$$v_c = 16.98 \text{ mm}$$

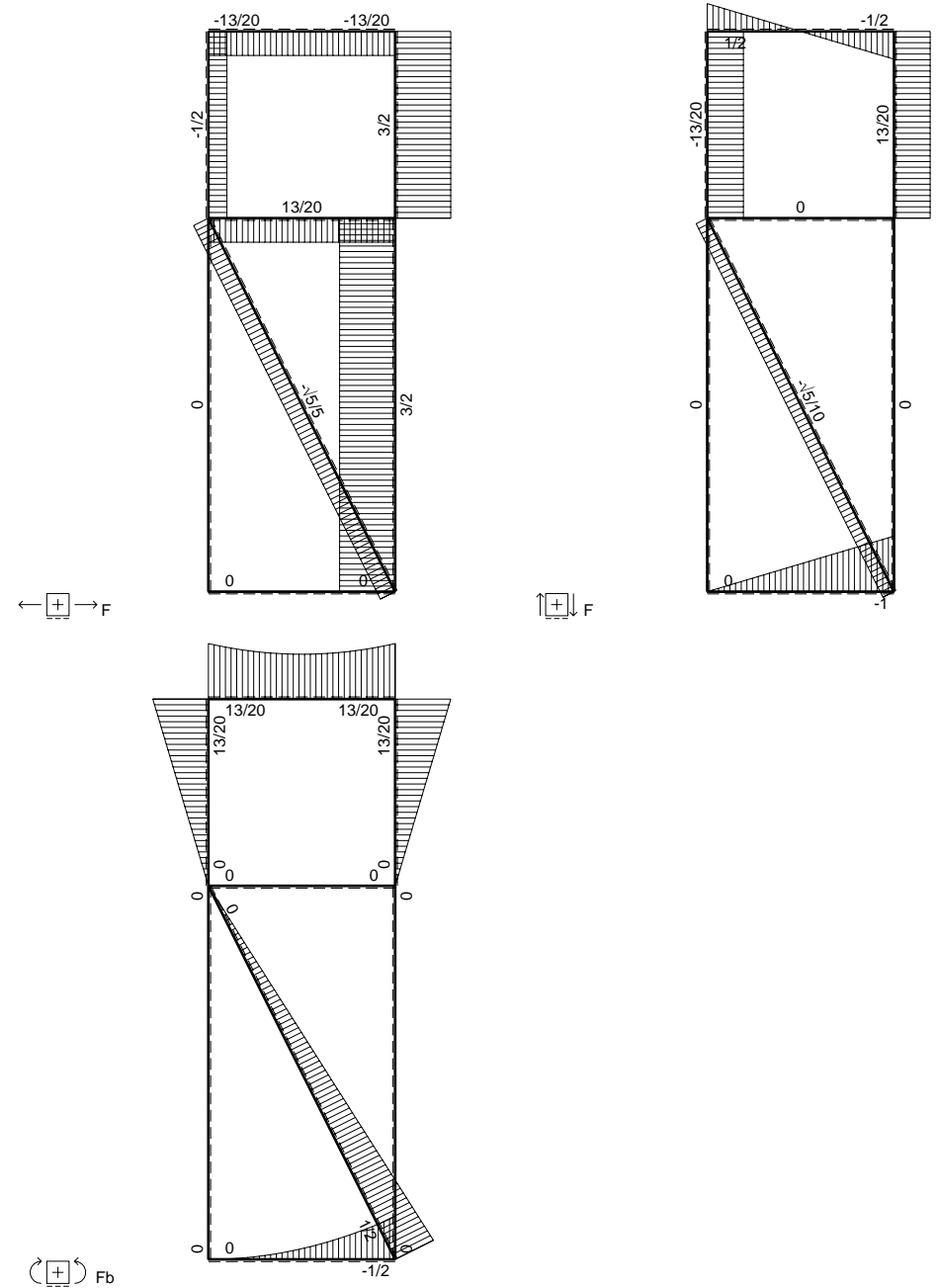
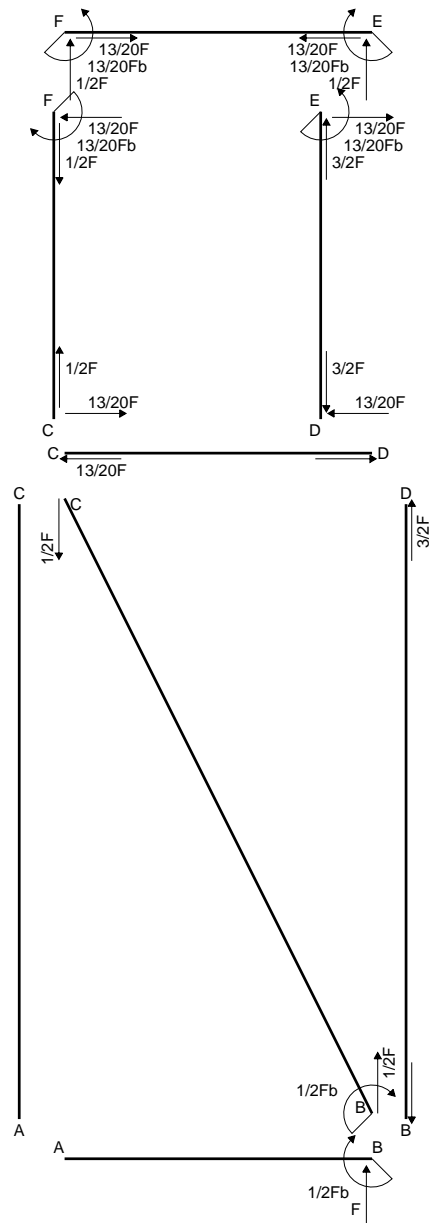
$$\sigma_c = N/A - Mv/J_u = -146.5 \text{ N/mm}^2$$

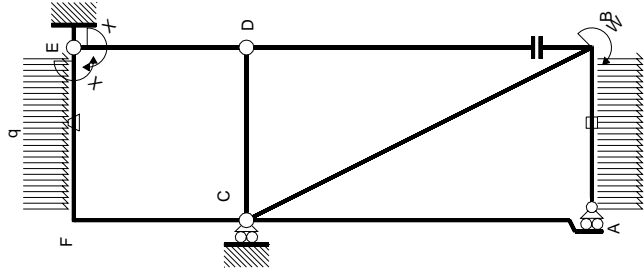
$$\tau_c = 1.73 \text{ N/mm}^2$$

$$\sigma_\varphi = \sqrt{\sigma^2 + 3\tau^2} = 146.5 \text{ N/mm}^2$$

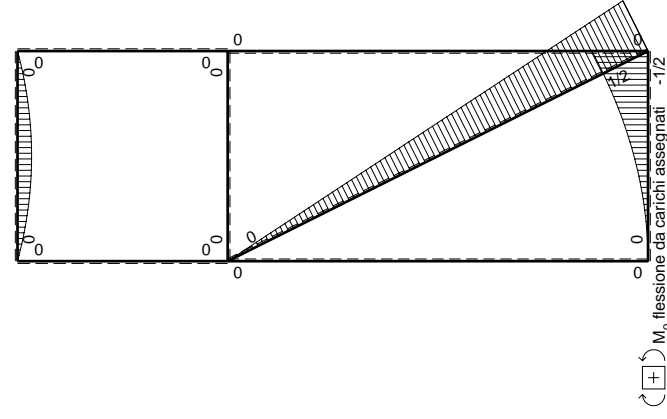
$$S = 4045. \text{ mm}^3$$







Schema di calcolo iperstatico

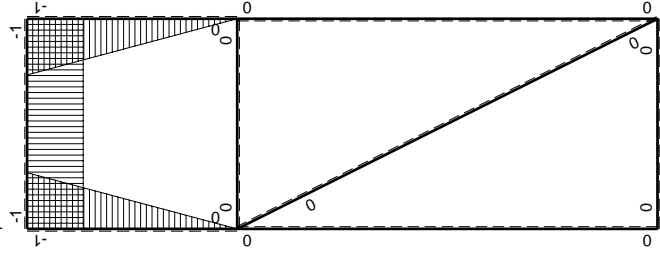


Quadro contributi PLV per iperstatica  $X=W_{EP}$

$\leftarrow$	$M_x(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	0	$-1/2qx^2$	0	0	0	0	0	0
BA b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$1/2Fb-\sqrt{5}/10Fx$	0	0	0	0	0	0
AC 2b	0	0	0	0	0	0	0	0
CA 2b	0	0	0	0	0	0	0	0
DB 2b	0	0	0	0	0	0	0	0
BD 2b	0	0	0	0	0	0	0	0
DE b	$-x/b$	0	0	0	0	0	$x^2/b^2$	0
ED b	$1-x/b$	0	0	0	0	0	$1-2x/b+x^2/b^2$	$1/3Xb/EJ$
CD b	0	0	0	0	0	0	0	0
DC b	0	0	0	0	0	0	0	0
EF b	-1	$-1/2Fx+1/2qx^2$	$-Fb/EJ$	$1/2Fx-1/2Fx^2/b$	$Fb/EJ$	1	$(1/12+1)Fb^2/EJ$	$Xb/EJ$
FE b	1	$1/2Fx-1/2qx^2$	$Fb/EJ$	$1/2Fx-1/2Fx^2/b$	$Fb/EJ$	1	$(1/12+1)Fb^2/EJ$	$1/3Xb/EJ$
FC b	$-1+x/b$	0	0	0	0	0	$1-2x/b+x^2/b^2$	0
CF b	$x/b$	0	0	0	0	0	$x^2/b^2$	$1/3Xb/EJ$
totali							$13/12Fb^2/EJ$	$5/3Xb/EJ$
								$-13/20Fb$

Sviluppi di calcolo iperstatica

$M_x$  flessione da iperstatica  $X=1$



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

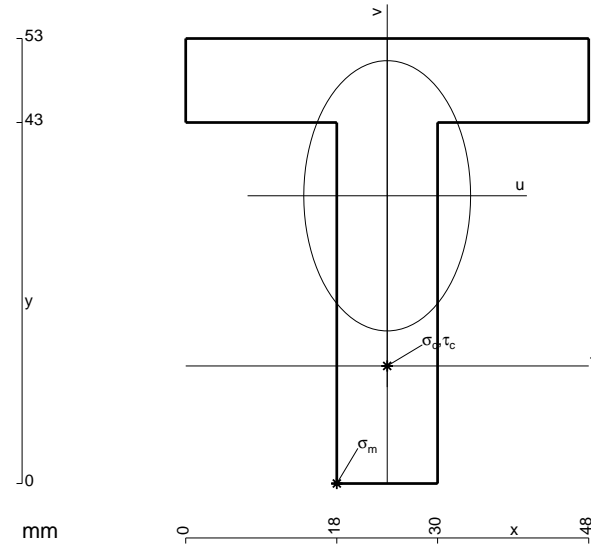
$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (1/4 b - 1/6 b) Fb 1/EJ + (b) \theta = 13/12 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (1/2 x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [1/4 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

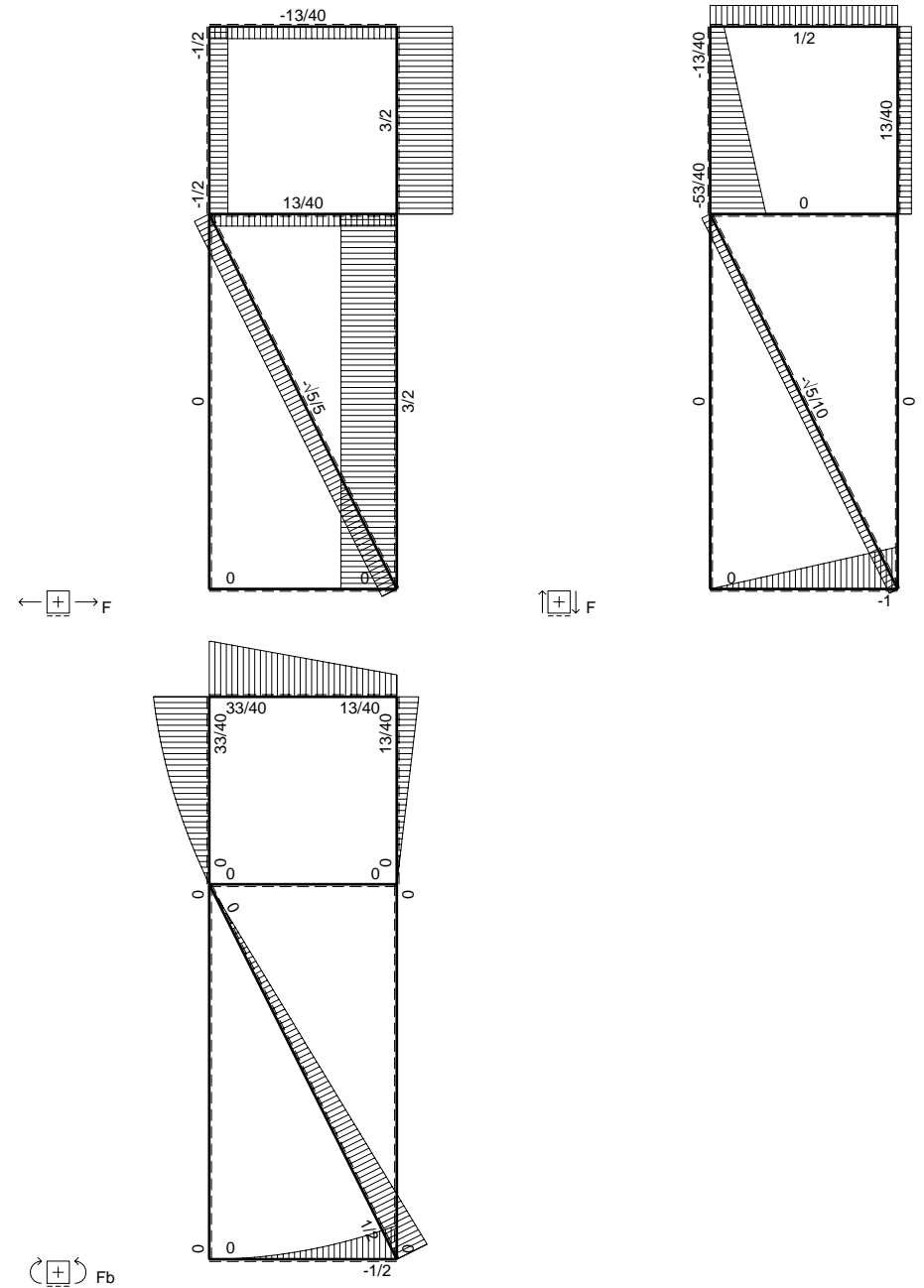
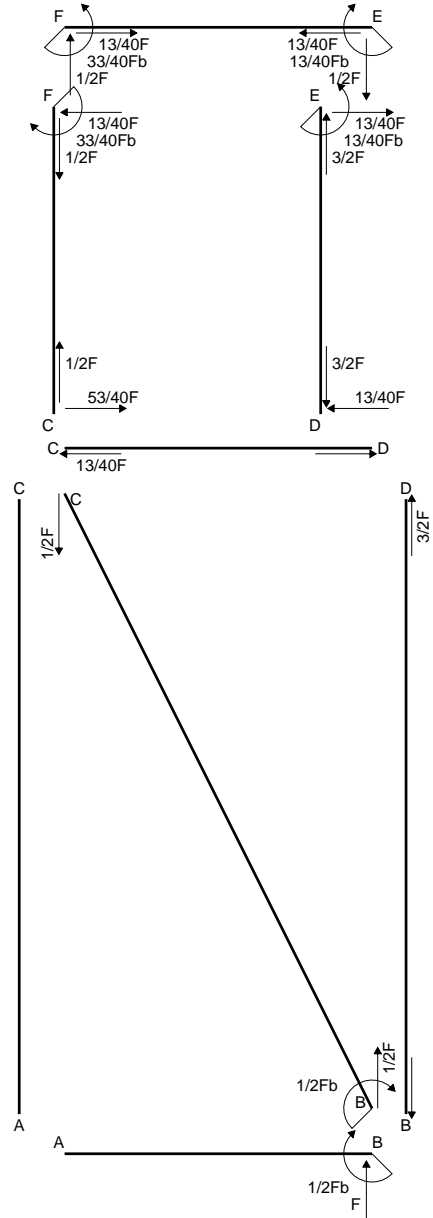
$$= (1/4 b - 1/6 b) Fb 1/EJ + (-b) \theta = 13/12 Fb^2/EJ$$



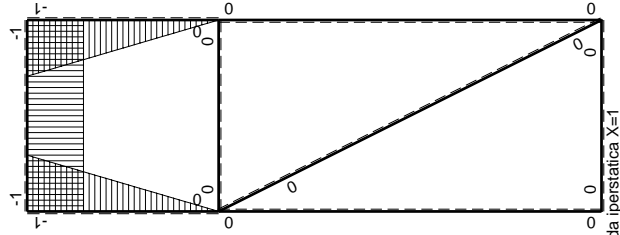
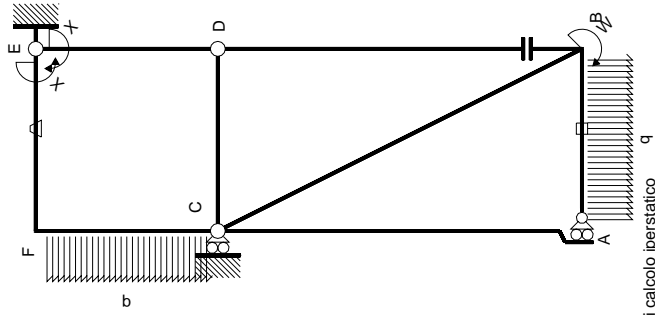
- A = 996. mm<sup>2</sup>
- J<sub>u</sub> = 258139. mm<sup>4</sup>
- J<sub>v</sub> = 98352. mm<sup>4</sup>
- y<sub>g</sub> = 34.27 mm
- T<sub>y</sub> = -8140. N
- M<sub>x</sub> = -1505900. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -34.27 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -199.9 N/mm<sup>2</sup>
- x<sub>c</sub> = 24. mm
- y<sub>c</sub> = 14. mm
- v<sub>c</sub> = -20.27 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -118.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 12.04 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup> + 3τ<sup>2</sup> = 120.1 N/mm<sup>2</sup>
- S = 4582. mm<sup>3</sup>







⊕ F<sub>b</sub>



$M_x$ , flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica $X=W_{EF}$		Sviluppi di calcolo iperstatica						
$\rightarrow$	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M^0$	$M^x \theta$	$M^x M^x$	$\int M^x(M^0/EJ+\theta)dx$	$\int M^x M^x/EJ dx$
AB b	0	$-1/2qx^2$	0	0	0	0	0+0	0
BA b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$1/2Fb-\sqrt{5}/10Fx$	0	0	0	0	0+0	0
AC 2b	0	0	0	0	0	0	0+0	0
CA 2b	0	0	0	0	0	0	0+0	0
DB 2b	0	0	0	0	0	0	0+0	0
BD 2b	0	0	0	0	0	0	0+0	0
DE b	-x/b	0	0	0	0	$x^2/b^2$	0+0	1/3Xb/EJ
ED b	1-x/b	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	1/3Xb/EJ
CD b	0	0	0	0	0	0	0+0	0
DC b	0	0	0	0	0	0	0+0	0
EF b	-1	$1/2Fx$	-Fb/EJ	-1/2Fx	Fb/EJ	1	$(-1/4+1)Fb^2/EJ$	Xb/EJ
FE b	1	$-1/2Fb+1/2Fx$	Fb/EJ	$-1/2Fb+1/2Fx$	Fb/EJ	1	$(-1/4+1)Fb^2/EJ$	Xb/EJ
FC b	-1+x/b	$1/2Fb-1/2qx^2$	0	$-1/2Fb+1/2Fx+1/2Fx^2/b-1/2qx^3/b$	0	$1-2x/b+x^2/b^2$	$(-5/24+0)Fb^2/EJ$	1/3Xb/EJ
CF b	x/b	$-Fx+1/2qx^2$	0	$-Fx^2/b+1/2qx^3/b$	0	$x^2/b^2$	$13/24Fb^2/EJ$	5/3Xb/EJ
totali								
iperstatica $X=W_{EF}$								

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/4 b) Fb 1/EJ + (b) \theta = 3/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + 1/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-1/2 x + 1/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

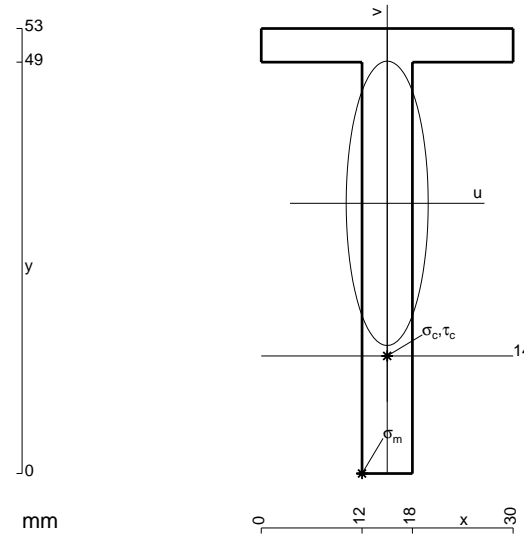
$$L_{FC}^{xo} = \int_0^b (-1/2 + 1/2 x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx$$

$$= [-1/2 x + 1/4 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/4 b + 1/6 b - 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$

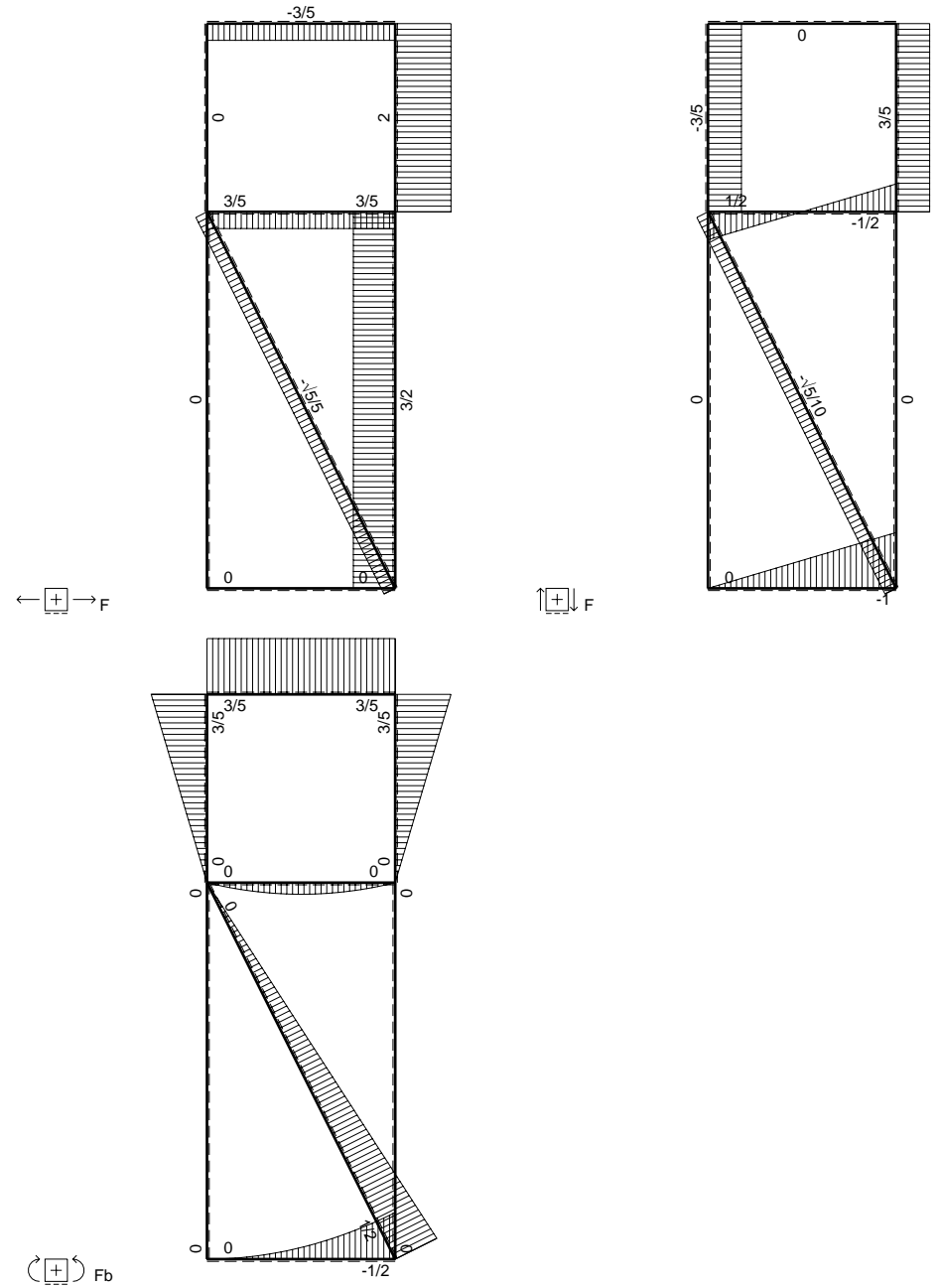
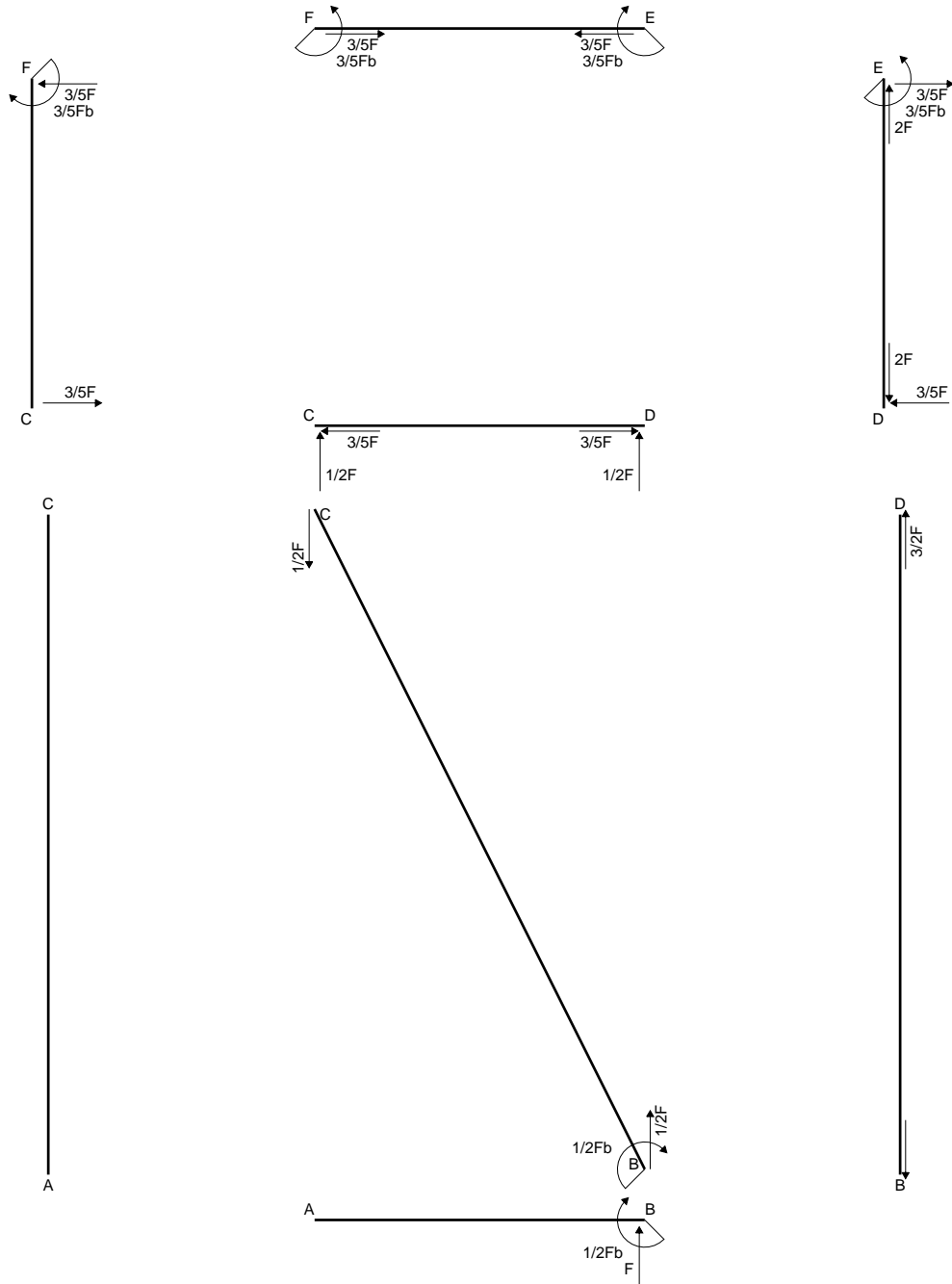
$$L_{CF}^{xo} = \int_0^b (-x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

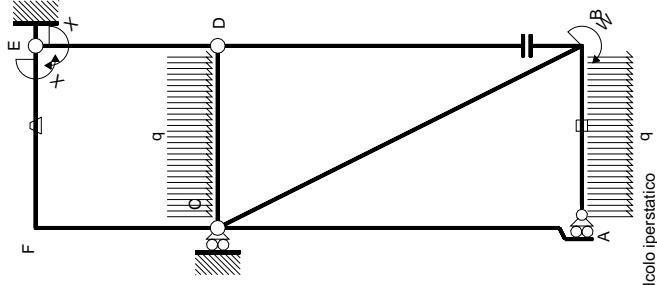
$$= (-1/3 b + 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$



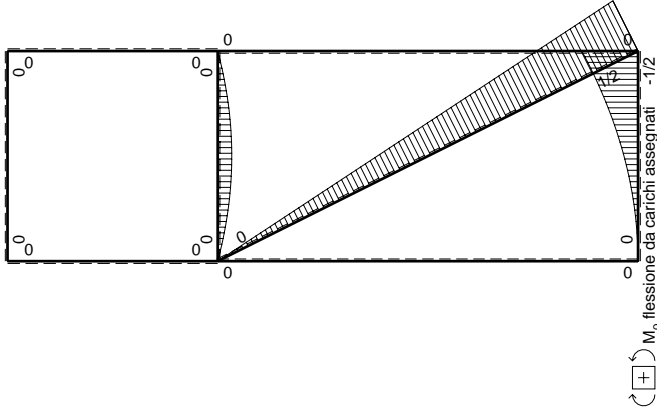
- A = 414. mm<sup>2</sup>
- J<sub>u</sub> = 118828. mm<sup>4</sup>
- J<sub>v</sub> = 9882. mm<sup>4</sup>
- y<sub>g</sub> = 32.18 mm
- T<sub>y</sub> = -3870. N
- M<sub>x</sub> = -774000. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -32.18 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -209.6 N/mm<sup>2</sup>
- x<sub>c</sub> = 15. mm
- y<sub>c</sub> = 14. mm
- v<sub>c</sub> = -18.18 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = -118.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 11.48 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 120.1 N/mm<sup>2</sup>
- S = 2115. mm<sup>3</sup>







Schema di calcolo iperstatico



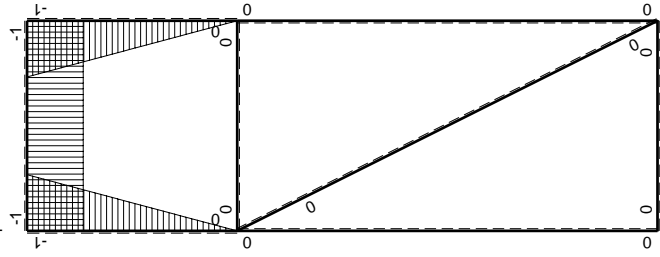
$M_0$  flessione da carichi assegnati -1/2

Quadro contributi PLV per iperstatica  $X=W_{EF}$

→	$M_x(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int X M_x M_x/EJ dx$
AB b	0	$-1/2qx^2$	0	0	0	0	0+0	0
BA b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0+0	0
BC $\sqrt{5}b$	0	$1/2Fb-\sqrt{5}/10Fx$	0	0	0	0	0	0
AC 2b	0	0	0	0	0	0	0+0	0
CA 2b	0	0	0	0	0	0	0+0	0
DB 2b	0	0	0	0	0	0	0+0	0
BD 2b	0	0	0	0	0	0	0+0	0
DE b	$-x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3Xb/EJ$
ED b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$
CD b	0	$1/2Fx-1/2qx^2$	0	0	0	0	0+0	0
DC b	0	$-1/2Fx+1/2qx^2$	0	0	0	0	0+0	0
EF b	-1	0	$-Fb/EJ$	0	$Fb/EJ$	1	$(0+1)Fb^2/EJ$	$Xb/EJ$
FE b	1	0	$Fb/EJ$	0	$Fb/EJ$	1	$(0+1)Fb^2/EJ$	$Xb/EJ$
FC b	$-1+x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0+0	$1/3Xb/EJ$
CF b	$x/b$	0	0	0	0	$x^2/b^2$	0+0	$1/3Xb/EJ$
	totali						$Fb^2/EJ$	$5/3Xb/EJ$
	iperstatica $X=W_{EF}$						$-3/5Fb$	

Sviluppi di calcolo iperstatica

$M_x$  flessione da iperstatica  $X=1$



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

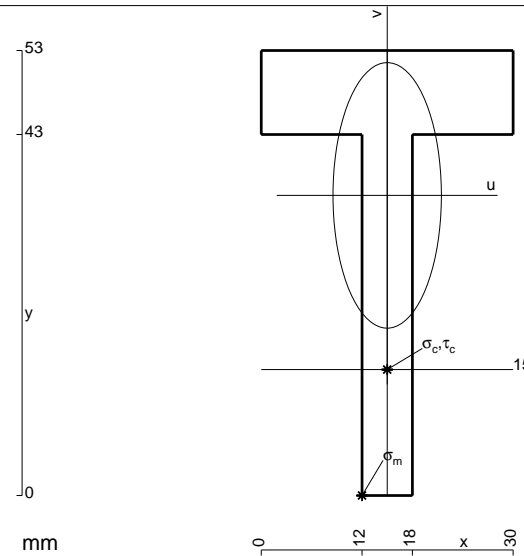
$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (1) \theta dx = [x]_0^b \theta$$

$$= (b) \theta = Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1) \theta dx = [-x]_0^b \theta$$

$$= (-b) \theta = Fb^2/EJ$$



$$A = 558. \text{ mm}^2$$

$$J_u = 139662. \text{ mm}^4$$

$$J_v = 23274. \text{ mm}^4$$

$$y_g = 35.75 \text{ mm}$$

$$T_y = -3900. \text{ N}$$

$$M_x = -858000. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -35.75 \text{ mm}$$

$$\sigma_m = -Mv/J_u = -219.6 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 15. \text{ mm}$$

$$v_c = -20.75 \text{ mm}$$

$$\sigma_c = -Mv/J_u = -127.5 \text{ N/mm}^2$$

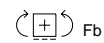
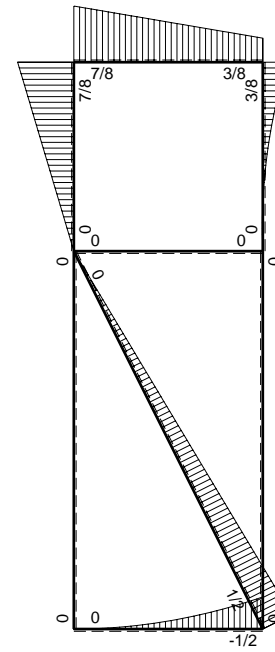
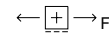
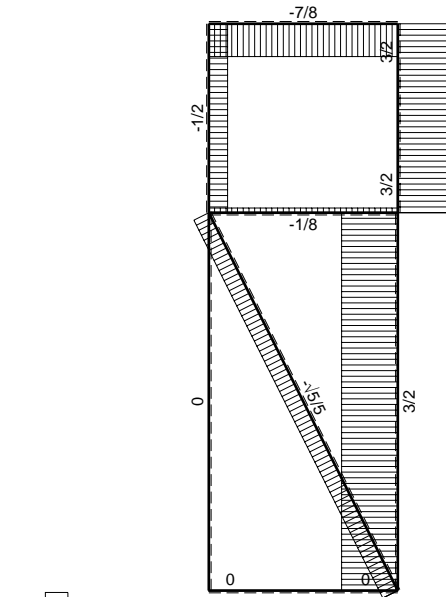
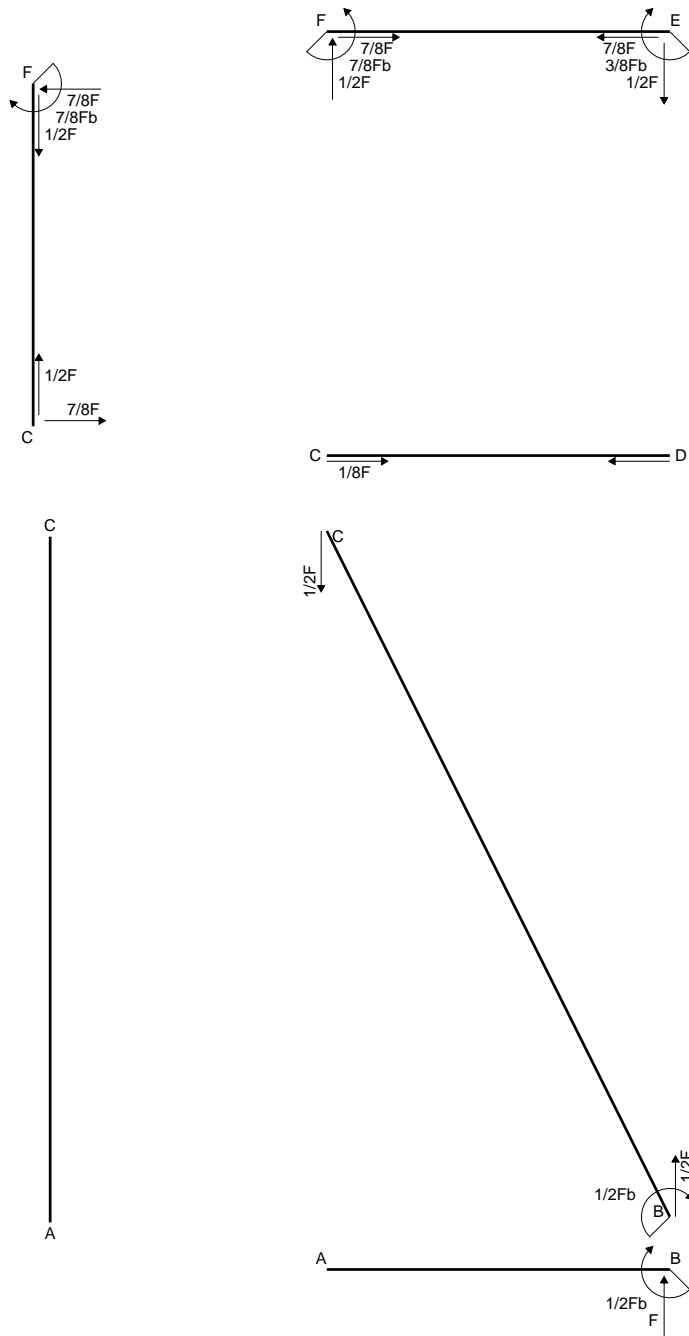
$$\tau_c = 11.83 \text{ N/mm}^2$$

$$\sigma_o = \sqrt{\sigma^2 + 3\tau^2} = 129.1 \text{ N/mm}^2$$

$$S = 2542. \text{ mm}^3$$









$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/4 b) Fb 1/EJ + (b) \theta = 3/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + 1/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-1/2 x + 1/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

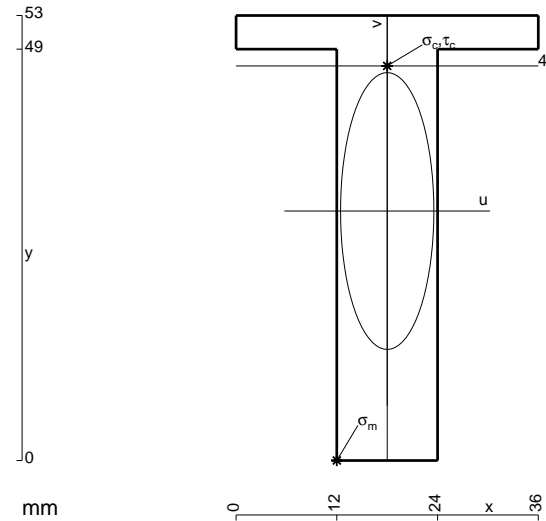
$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

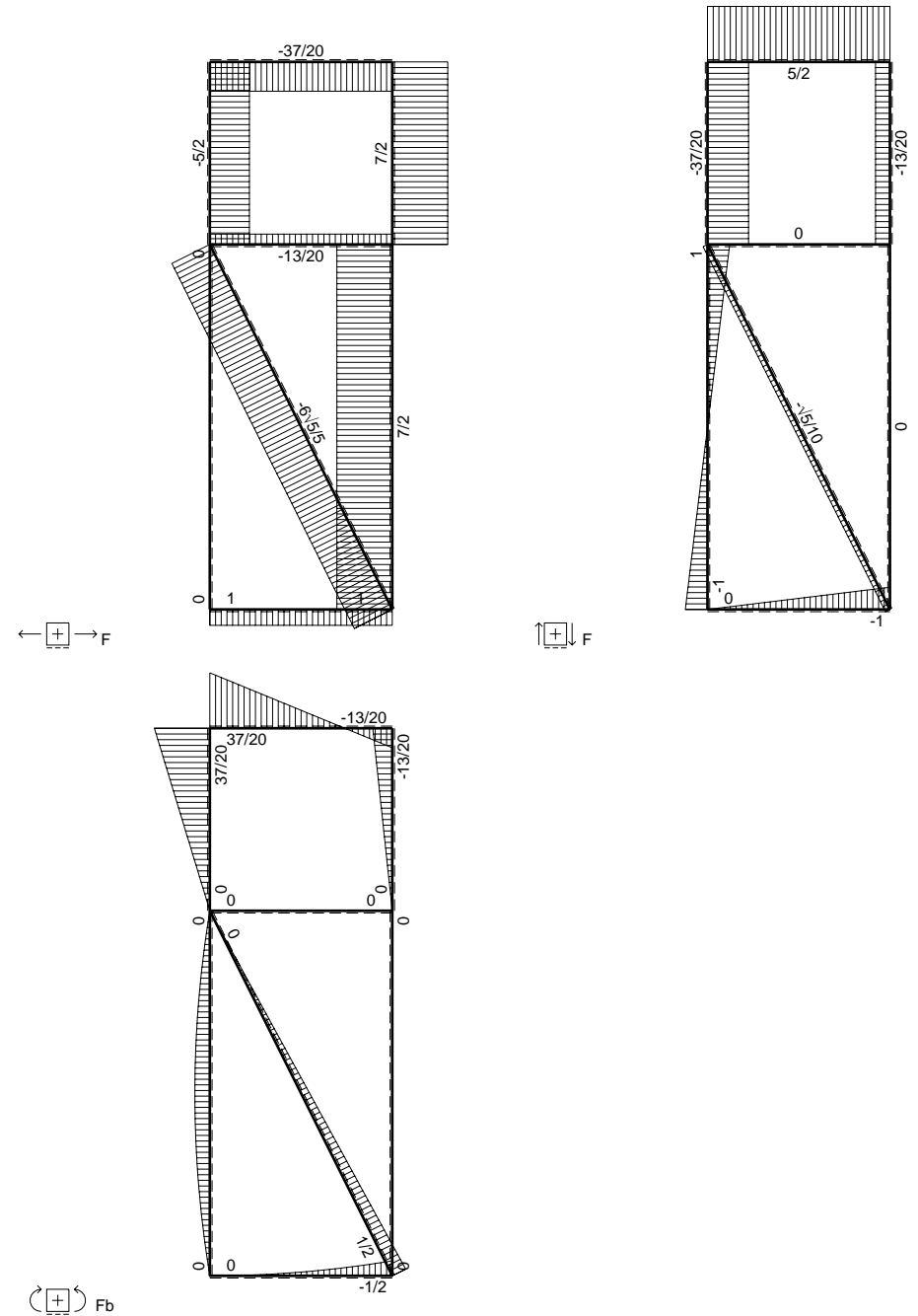
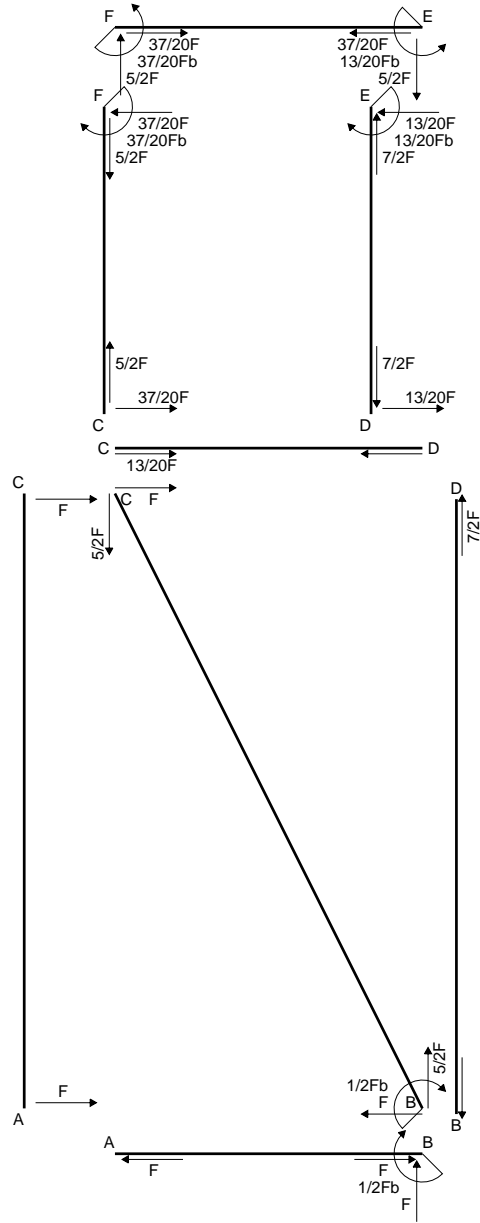
$$L_{CF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ$$

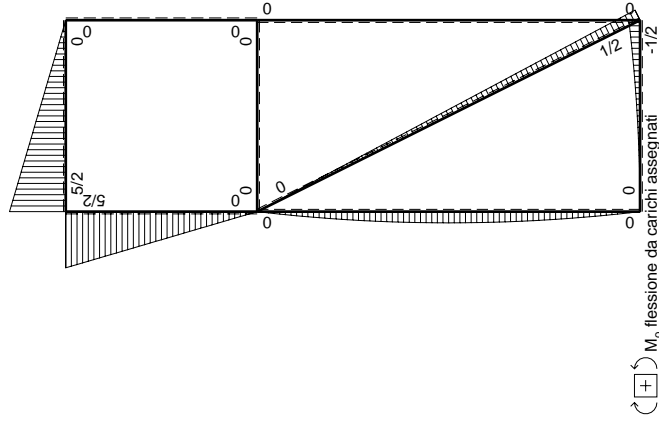
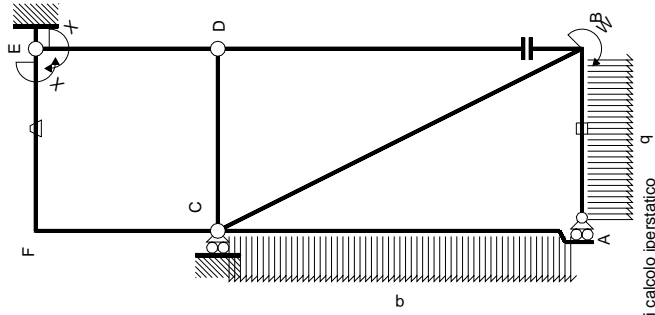
$$= (-1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$



- A = 732. mm<sup>2</sup>
- J<sub>u</sub> = 199072. mm<sup>4</sup>
- J<sub>v</sub> = 22608. mm<sup>4</sup>
- y<sub>g</sub> = 29.71 mm
- T<sub>y</sub> = -6420. N
- M<sub>x</sub> = -1540800. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -6. mm
- v<sub>m</sub> = -29.71 mm
- σ<sub>m</sub> = -Mv/J<sub>u</sub> = -230. N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 47. mm
- v<sub>c</sub> = 17.29 mm
- σ<sub>c</sub> = -Mv/J<sub>u</sub> = 133.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 9.417 N/mm<sup>2</sup>
- σ<sub>o</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 134.8 N/mm<sup>2</sup>
- S = 3504. mm<sup>3</sup>







Quadro contributi PLV per iperstatica  $X=W_{EP}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M M_0$	$M \theta$	$M M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	0	$-1/2qx^2$	0	0	0	0	0	0
BA b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$1/2Fb-\sqrt{5}/10Fx$	0	0	0	0	0	0
AC 2b	0	$-Fx+1/2qx^2$	0	0	0	0	0	0
CA 2b	0	$Fx-1/2qx^2$	0	0	0	0	0	0
DB 2b	0	0	0	0	0	0	0	0
BD 2b	0	0	0	0	0	0	0	0
DE b	$-x/b$	0	0	0	0	$x^2/b^2$	0	0
ED b	$1-x/b$	0	0	0	0	$1-2x/b+x^2/b^2$	0	0
CD b	0	0	0	0	0	0	0	0
DC b	0	0	0	0	0	0	0	0
EF b	-1	$5/2Fx$	$-Fb/EJ$	$-5/2Fx$	$Fb/EJ$	1	$(-5/4+1)Fb^2/EJ$	$Xb/EJ$
FE b	1	$-5/2Fb+5/2Fx$	$Fb/EJ$	$-5/2Fb+5/2Fx$	$Fb/EJ$	1	$(-5/4+1)Fb^2/EJ$	$Xb/EJ$
FC b	$-1+x/b$	$5/2Fb-5/2Fx$	0	$-5/2Fb+5Fx-5/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-5/6+0)Fb^2/EJ$	$1/3Xb/EJ$
CF b	$x/b$	$-5/2Fx$	0	$-5/2Fx^2/b$	0	$x^2/b^2$	$-13/12Fb^2/EJ$	$5/3Xb/EJ$
totali								
iperstatica $X=W_{EP}$								

Sviluppi di calcolo iperstatica



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-5/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-5/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-5/4 b) Fb 1/EJ + (b) \theta = -1/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-5/2 + 5/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-5/2 x + 5/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

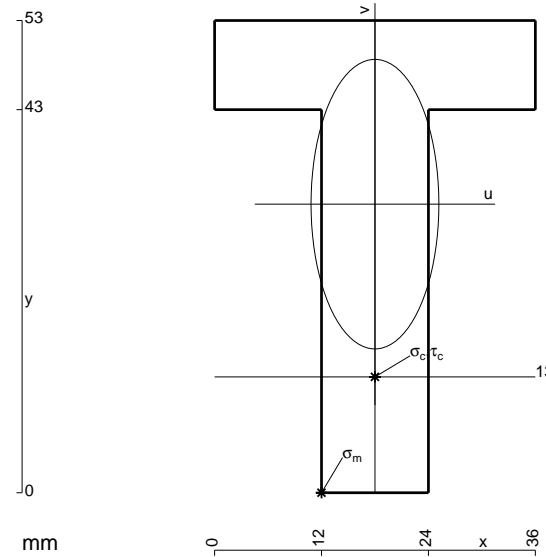
$$= (-5/2 b + 5/4 b) Fb 1/EJ + (-b) \theta = -1/4 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = [-5/2 x + 5/2 x^2/b - 5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$



$$A = 876. \text{ mm}^2$$

$$J_u = 231422. \text{ mm}^4$$

$$J_v = 45072. \text{ mm}^4$$

$$y_g = 32.39 \text{ mm}$$

$$N = 6940. \text{ N}$$

$$T_y = -6940. \text{ N}$$

$$M_x = -1769700. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -6. \text{ mm}$$

$$v_m = -32.39 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -239.8 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 13. \text{ mm}$$

$$v_c = -19.39 \text{ mm}$$

$$\sigma_c = N/A - Mv/J_u = -140.4 \text{ N/mm}^2$$

$$\tau_c = 10.09 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 141.4 \text{ N/mm}^2$$

$$S = 4039. \text{ mm}^3$$









$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/6 b) Fb 1/EJ + (b) \theta = 5/6 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx$$

$$= [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

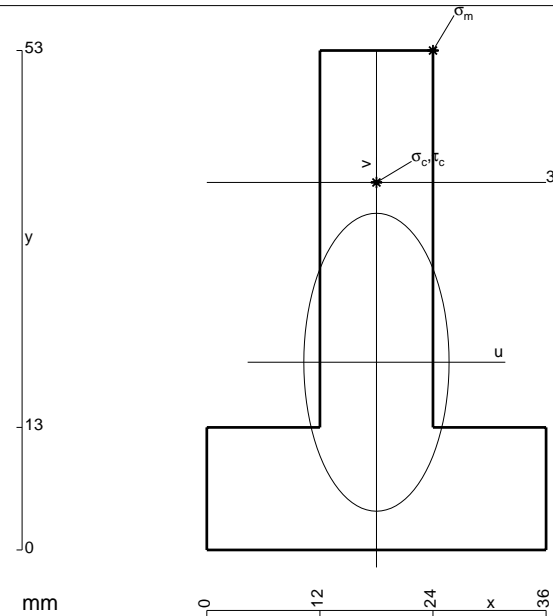
$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ + (-b) \theta = 5/6 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

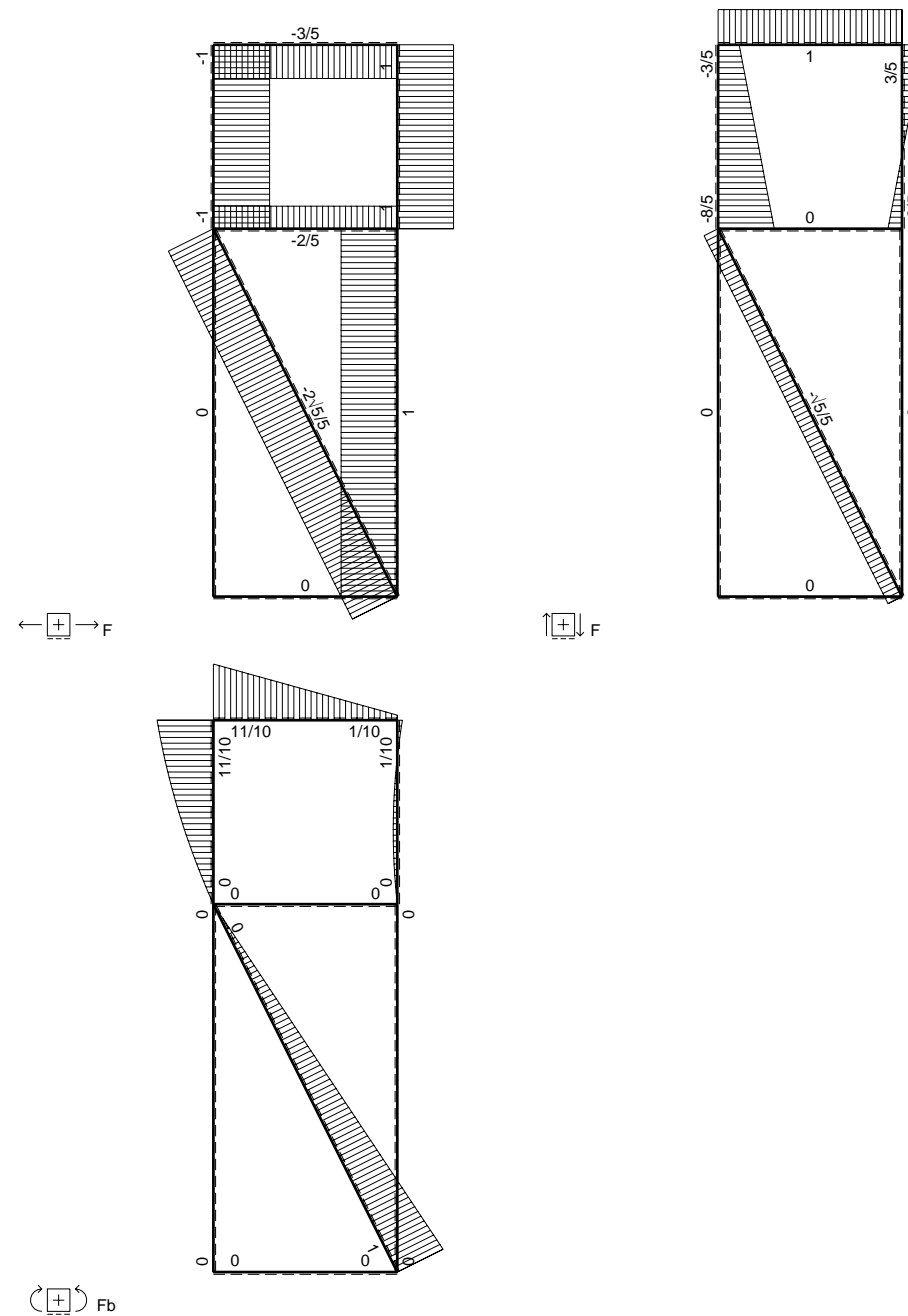
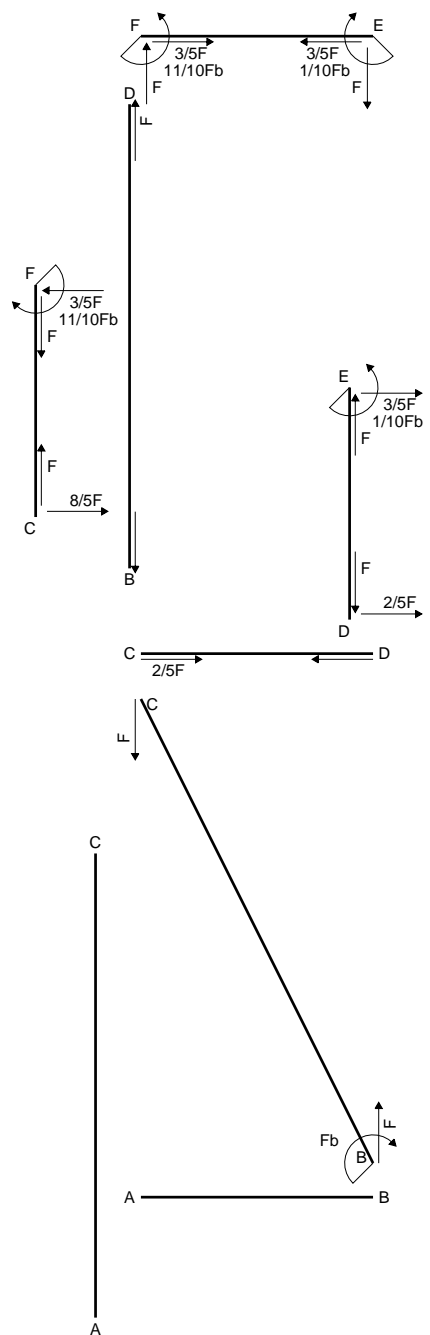
$$L_{CF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$



- A = 948. mm<sup>2</sup>
- J<sub>u</sub> = 236998. mm<sup>4</sup>
- J<sub>v</sub> = 56304. mm<sup>4</sup>
- y<sub>g</sub> = 19.92 mm
- N = -2299. N
- T<sub>y</sub> = -1149. N
- M<sub>x</sub> = 1413500. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 53. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 33.08 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = -199.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 18. 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> = -116.2 N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.771 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup>+3τ<sup>2</sup>) = 116.3 N/mm<sup>2</sup>
- S = 4382. mm<sup>3</sup>







$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/2 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/2 b) Fb 1/EJ + (b) \theta = 1/2 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1 + x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-x + 1/2 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

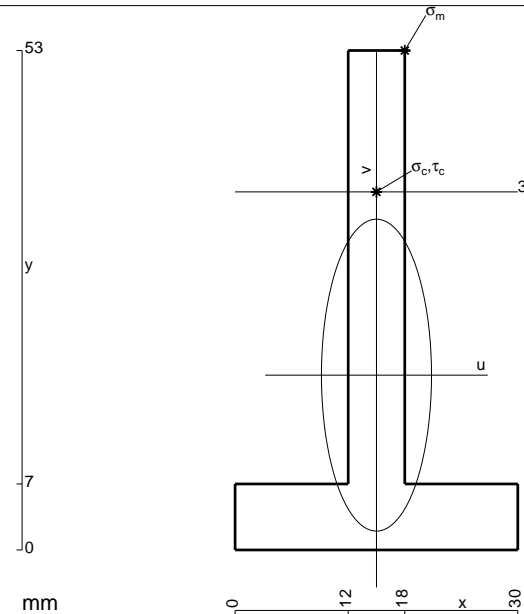
$$= (-b + 1/2 b) Fb 1/EJ + (-b) \theta = 1/2 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-1 + 3/2 x/b - 1/2 x^3/b^3) Fb 1/EJ dx = [-x + 3/4 x^2/b - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-b + 3/4 b - 1/8 b) Fb 1/EJ = -3/8 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-3/2 x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/2 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/8 b) Fb 1/EJ = -3/8 Fb^2/EJ$$



$$A = 486. \text{ mm}^2$$

$$J_u = 133275. \text{ mm}^4$$

$$J_v = 16578. \text{ mm}^4$$

$$y_g = 18.55 \text{ mm}$$

$$N = -1216. \text{ N}$$

$$T_y = -608.2 \text{ N}$$

$$M_x = 802400. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$y_m = 53. \text{ mm}$$

$$u_m = 3. \text{ mm}$$

$$v_m = 34.45 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -209.9 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 38. \text{ mm}$$

$$v_c = 19.45 \text{ mm}$$

$$\sigma_c = N/A - Mv/J_u = -119.6 \text{ N/mm}^2$$

$$\tau_c = 1.845 \text{ N/mm}^2$$

$$\sigma_\varrho = \sqrt{\sigma^2 + 3\tau^2} = 119.7 \text{ N/mm}^2$$

$$S = 2426. \text{ mm}^3$$









$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/4 b) Fb 1/EJ + (b) \theta = 3/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + 1/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-1/2 x + 1/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

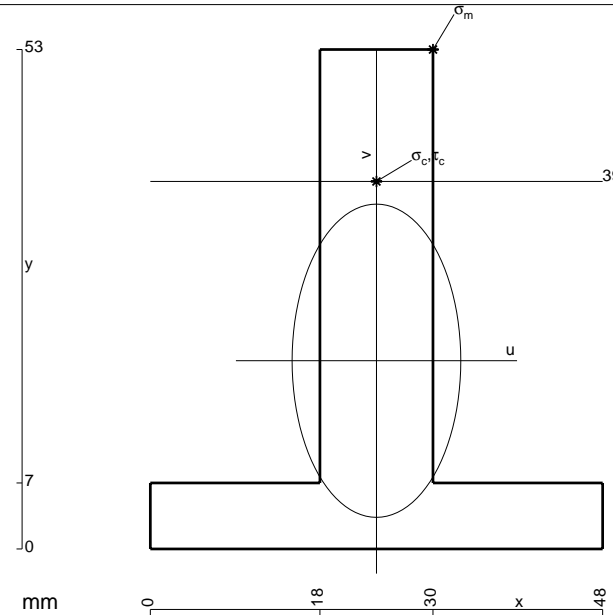
$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

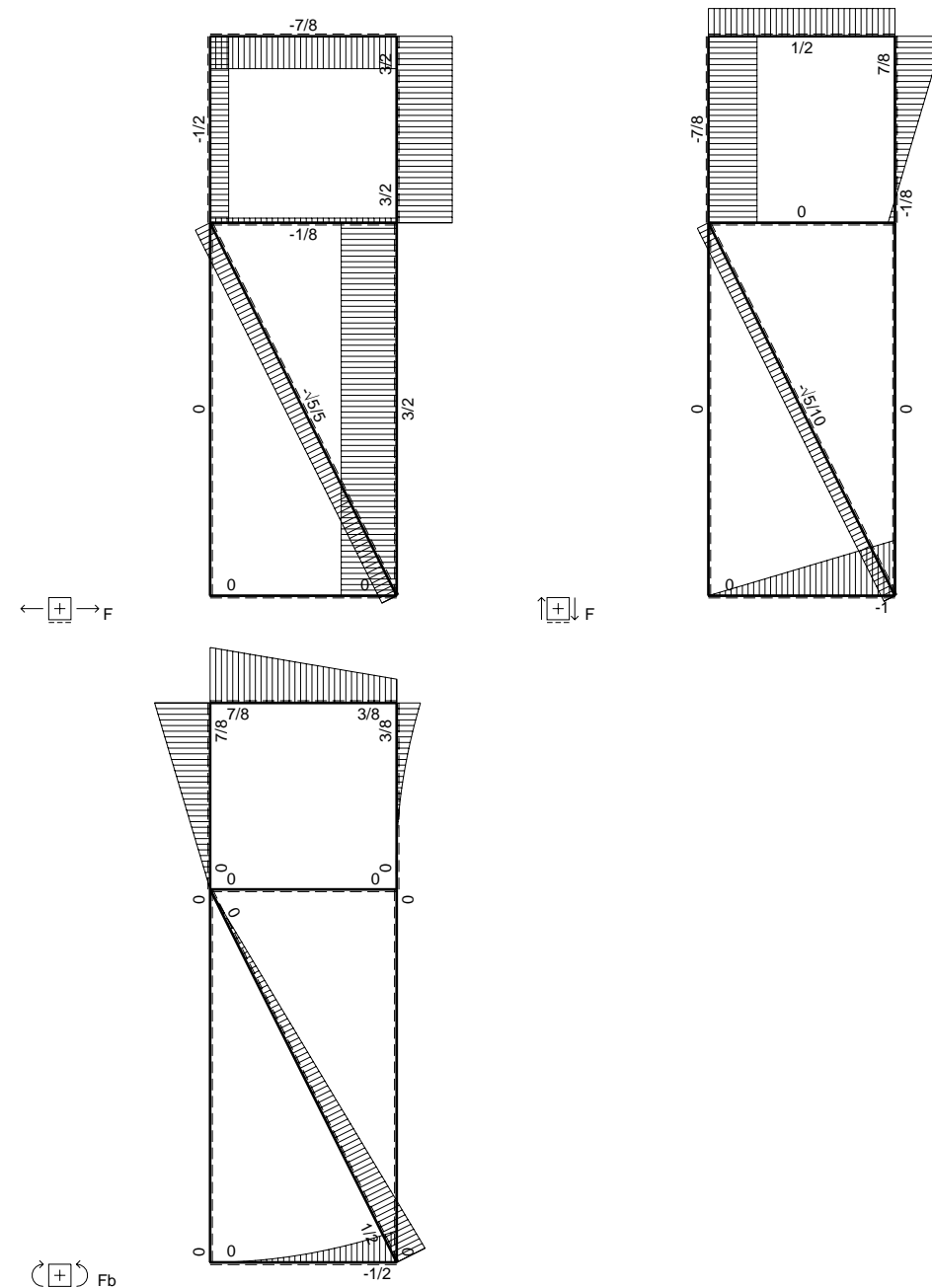
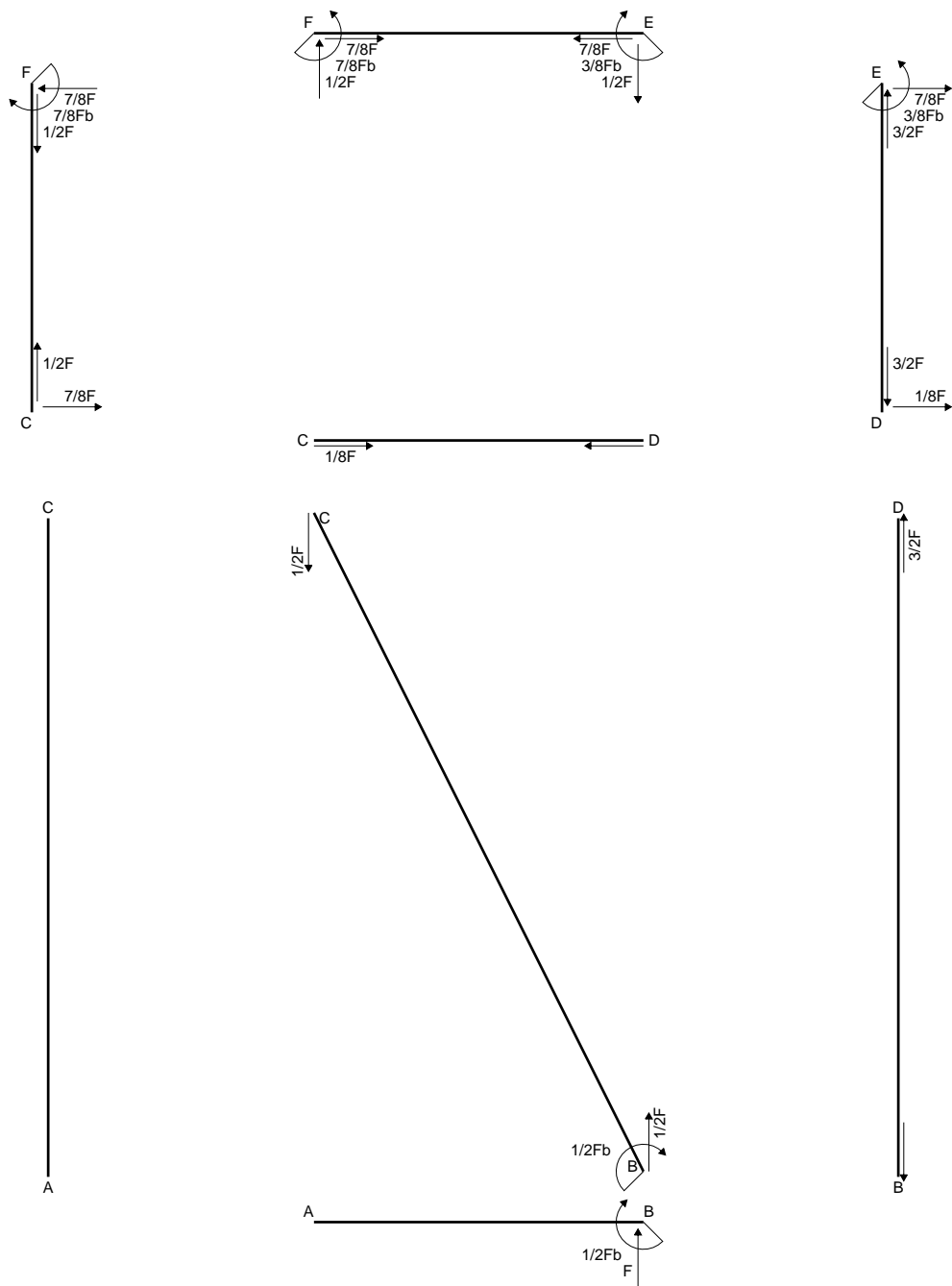
$$L_{CF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$



- A = 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
- N = -2326. N
- T<sub>y</sub> = -1163. N
- M<sub>x</sub> = 1612000. 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> = N/A-Mv/J<sub>u</sub> = -219.6 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> = N/A-Mv/J<sub>u</sub> = -127.6 N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.727 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup>+3τ<sup>2</sup>) = 127.6 N/mm<sup>2</sup>
- S = 4373. mm<sup>3</sup>







$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/4 b) Fb 1/EJ + (b) \theta = 3/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + 1/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-1/2 x + 1/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

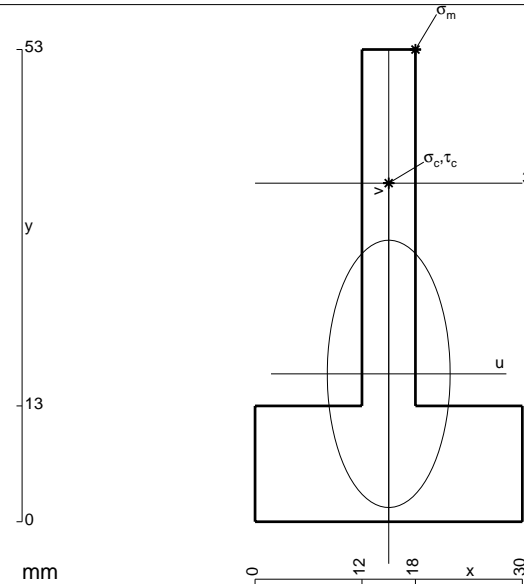
$$= (-1/2 b + 1/4 b) Fb 1/EJ + (-b) \theta = 3/4 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx = [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ$$

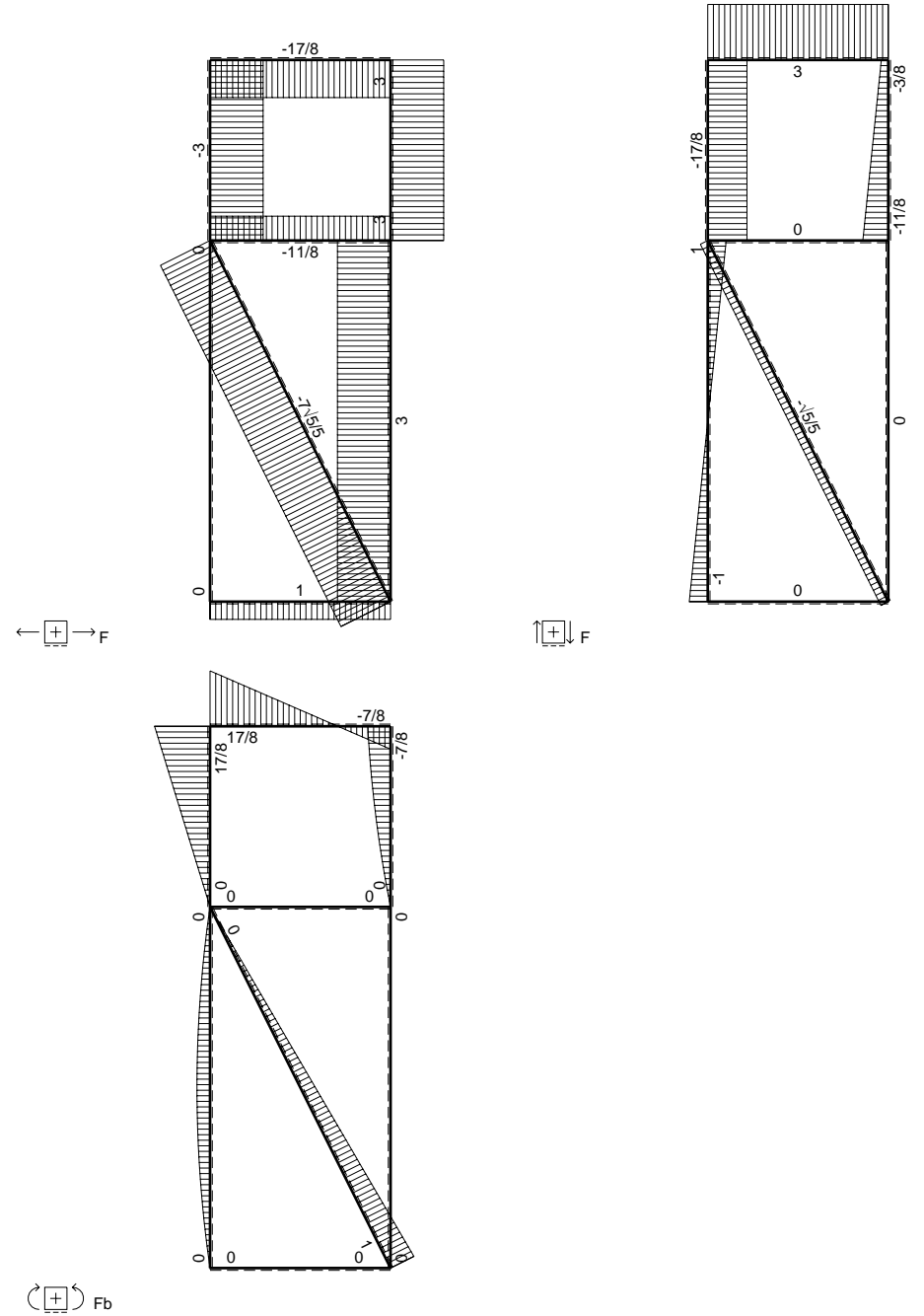
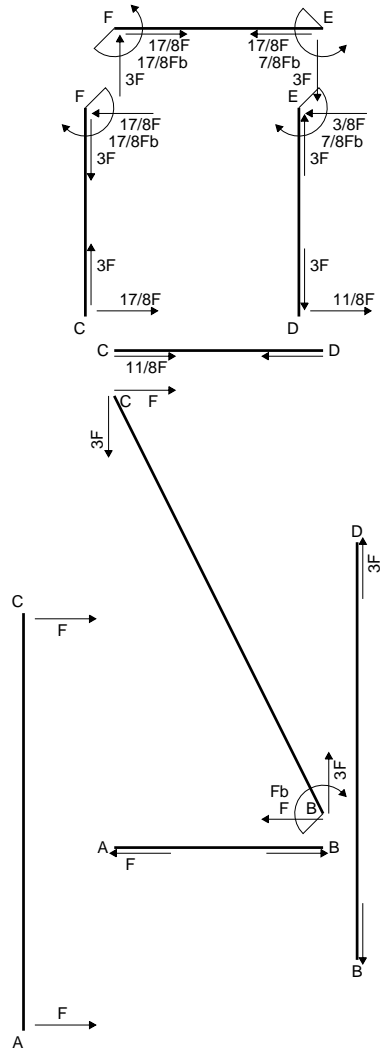
$$= (-1/6 b) Fb 1/EJ = -1/6 Fb^2/EJ$$



- A = 630. mm<sup>2</sup>
- J<sub>u</sub> = 141827. mm<sup>4</sup>
- J<sub>v</sub> = 29970. mm<sup>4</sup>
- y<sub>g</sub> = 16.6 mm
- T<sub>y</sub> = -2710. N
- M<sub>x</sub> = -894300. 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>c</sub> = -M<sub>v</sub>/J<sub>u</sub> = 229.6 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> = -M<sub>v</sub>/J<sub>u</sub> = 135. N/mm<sup>2</sup>
- τ<sub>c</sub> = 8.285 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 = 2601. mm<sup>3</sup>









$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-3x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-3/2 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-3/2 b) Fb 1/EJ + (b) \theta = -1/2 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-3 + 3x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-3x + 3/2 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

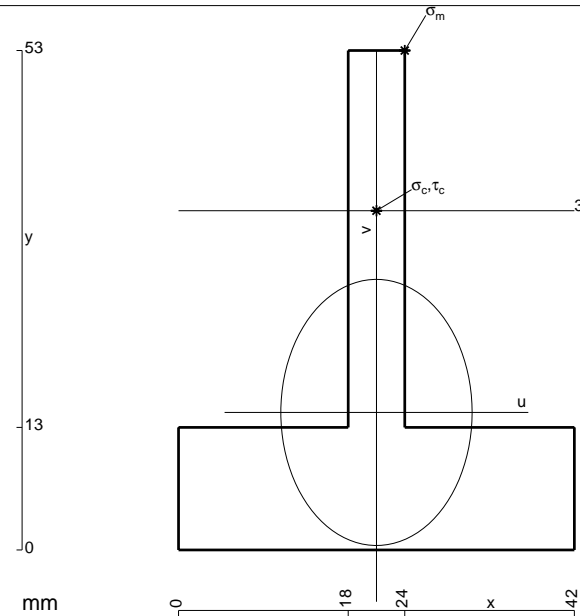
$$= (-3b + 3/2 b) Fb 1/EJ + (-b) \theta = -1/2 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-3 + 6x/b - 3x^2/b^2) Fb 1/EJ dx = [-3x + 3x^2/b - x^3/b^2]_0^b Fb 1/EJ$$

$$= (-3b + 3b - b) Fb 1/EJ = - Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-3x^2/b^2) Fb 1/EJ dx = [-x^3/b^2]_0^b Fb 1/EJ$$

$$= (-b) Fb 1/EJ = - Fb^2/EJ$$



- A = 786. mm<sup>2</sup>
- J<sub>u</sub> = 156767. mm<sup>4</sup>
- J<sub>v</sub> = 80982. mm<sup>4</sup>
- y<sub>g</sub> = 14.59 mm
- N = -4257. N
- T<sub>y</sub> = -608.2 N
- M<sub>x</sub> = 952000. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 53. mm
- u<sub>m</sub> = 3. mm
- v<sub>m</sub> = 38.41 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = -238.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 36. mm
- v<sub>c</sub> = 21.41 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = -135.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.973 N/mm<sup>2</sup>
- σ<sub>q</sub> = √(σ<sup>2</sup>+3τ<sup>2</sup>) = 135.5 N/mm<sup>2</sup>
- S = 3051. mm<sup>3</sup>







$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-2x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-b - 1/6 b) Fb 1/EJ + (b) \theta = -1/6 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-5/2 + 3x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx$$

$$= [-5/2 x + 3/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

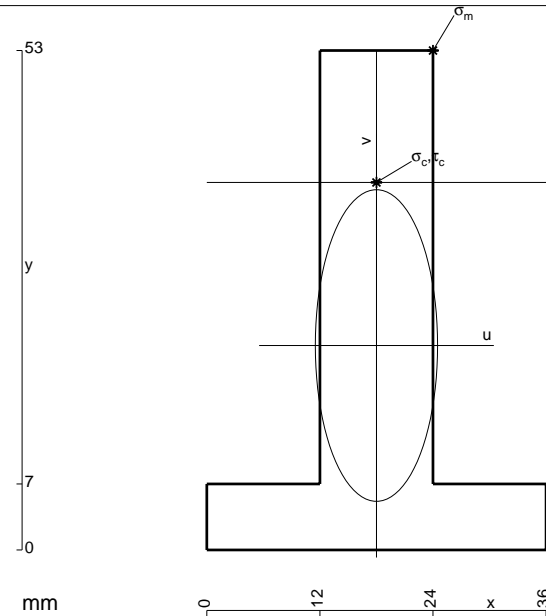
$$= (-5/2 b + 3/2 b - 1/6 b) Fb 1/EJ + (-b) \theta = -1/6 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = [-5/2 x + 5/2 x^2/b - 5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

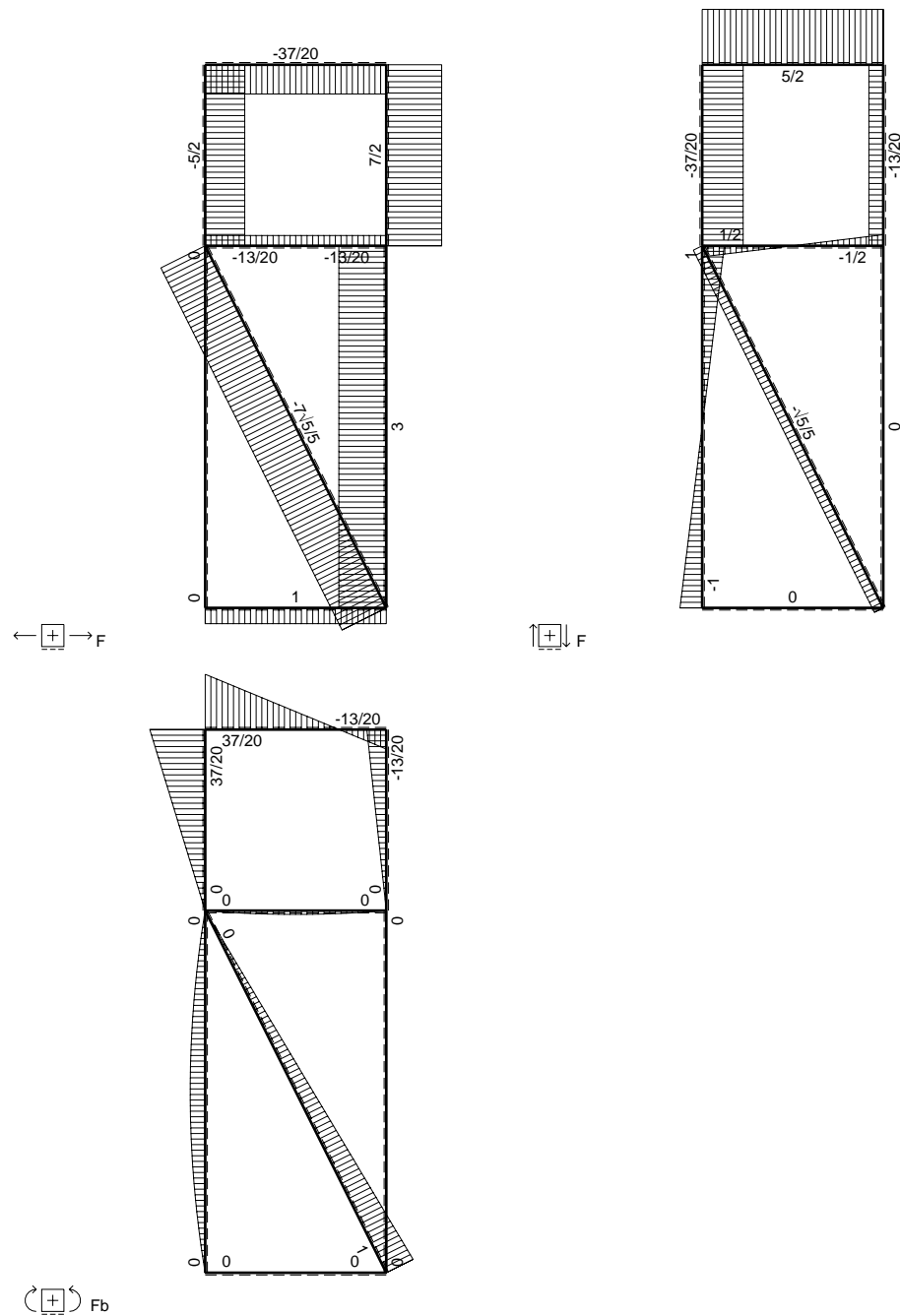
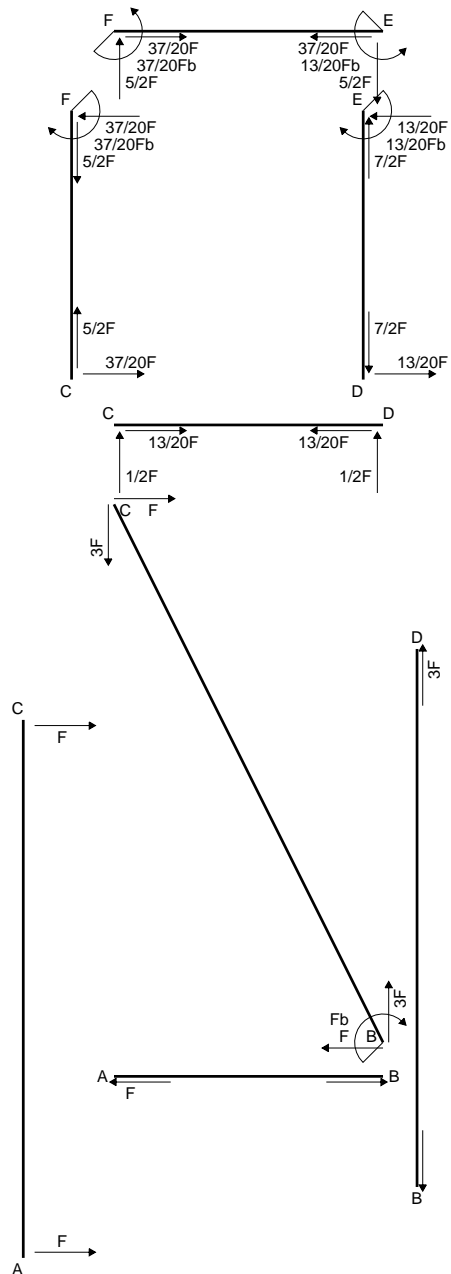
$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$



- A = 804. mm<sup>2</sup>
- J<sub>u</sub> = 219865. mm<sup>4</sup>
- J<sub>v</sub> = 33840. mm<sup>4</sup>
- y<sub>g</sub> = 21.69 mm
- N = -11051. N
- T<sub>y</sub> = -1579. N
- M<sub>x</sub> = 1306100. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 53. mm
- u<sub>m</sub> = 6. mm
- v<sub>m</sub> = 31.31 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = -199.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 18. mm
- y<sub>c</sub> = 39. mm
- v<sub>c</sub> = 17.31 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = -116.6 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.443 N/mm<sup>2</sup>
- σ<sub>o</sub> = √(σ<sup>2</sup>+3τ<sup>2</sup>) = 116.6 N/mm<sup>2</sup>
- S = 4083. mm<sup>3</sup>









$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = \left[ \frac{1}{3} x^3/b^2 \right]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = \left[ x \right]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = \left[ x \right]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = \left[ x - x^2/b + 1/3 x^3/b^2 \right]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = \left[ \frac{1}{3} x^3/b^2 \right]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-5/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = \left[ -5/4 x^2/b \right]_0^b Fb 1/EJ + \left[ x \right]_0^b \theta$$

$$= (-5/4 b) Fb 1/EJ + (b) \theta = -1/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-5/2 + 5/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = \left[ -5/2 x + 5/4 x^2/b \right]_0^b Fb 1/EJ + \left[ -x \right]_0^b \theta$$

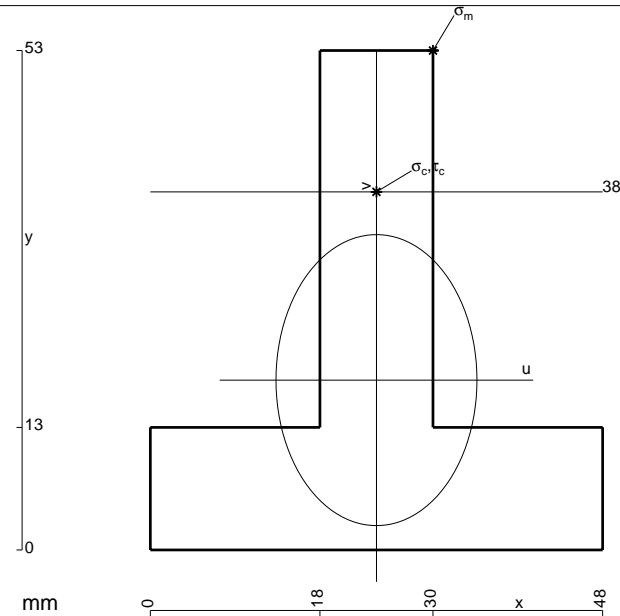
$$= (-5/2 b + 5/4 b) Fb 1/EJ + (-b) \theta = -1/4 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = \left[ -5/2 x + 5/2 x^2/b - 5/6 x^3/b^2 \right]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = \left[ -5/6 x^3/b^2 \right]_0^b Fb 1/EJ$$

$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$



$$A = 1104. \text{ mm}^2$$

$$J_u = 263311. \text{ mm}^4$$

$$J_v = 125568. \text{ mm}^4$$

$$y_g = 18.02 \text{ mm}$$

$$N = -11739. \text{ N}$$

$$T_y = -1677. \text{ N}$$

$$M_x = 1500000. \text{ Nmm}$$

$$x_m = 30. \text{ mm}$$

$$y_m = 53. \text{ mm}$$

$$u_m = 6. \text{ mm}$$

$$v_m = 34.98 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = -209.9 \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 38. \text{ mm}$$

$$v_c = 19.98 \text{ mm}$$

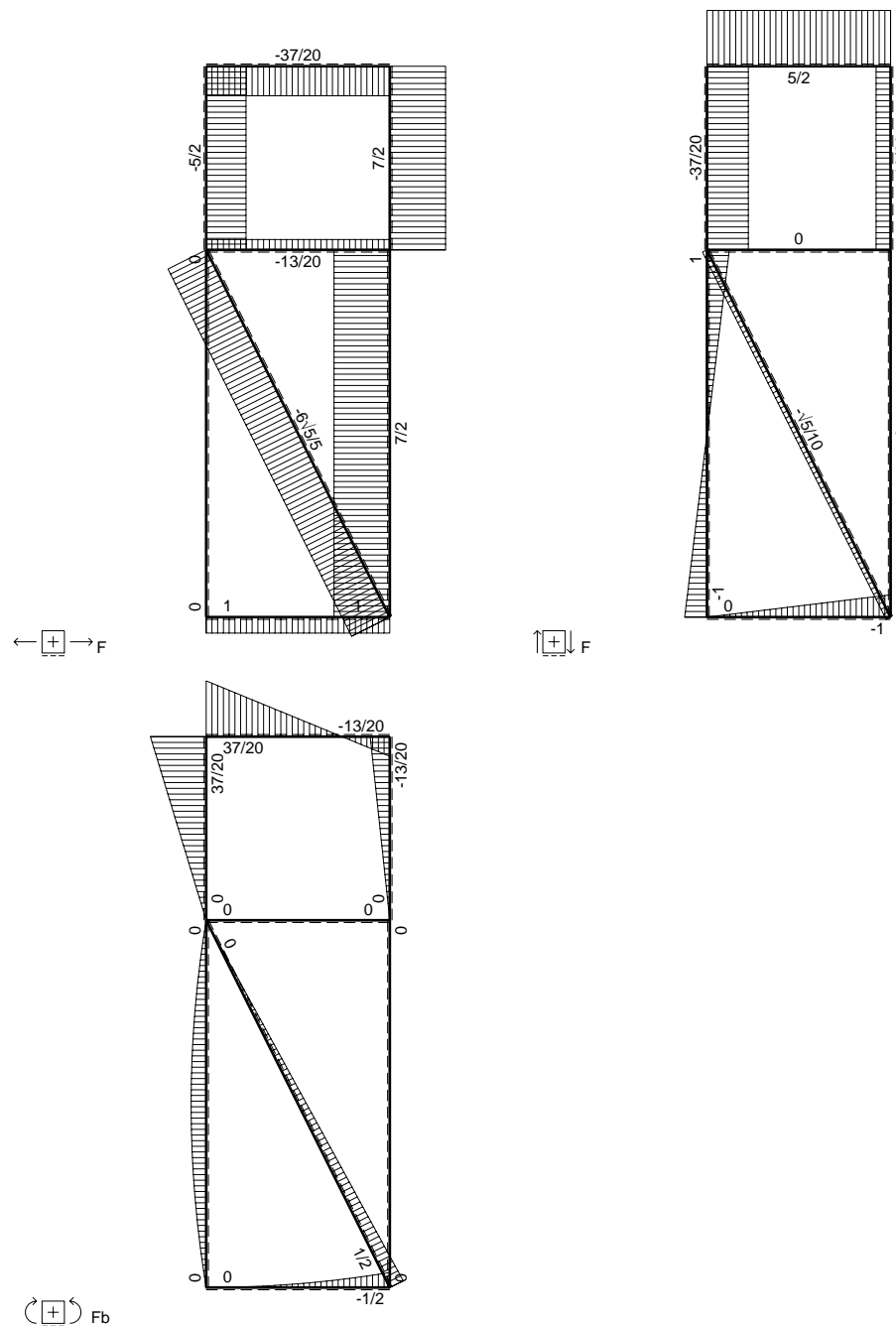
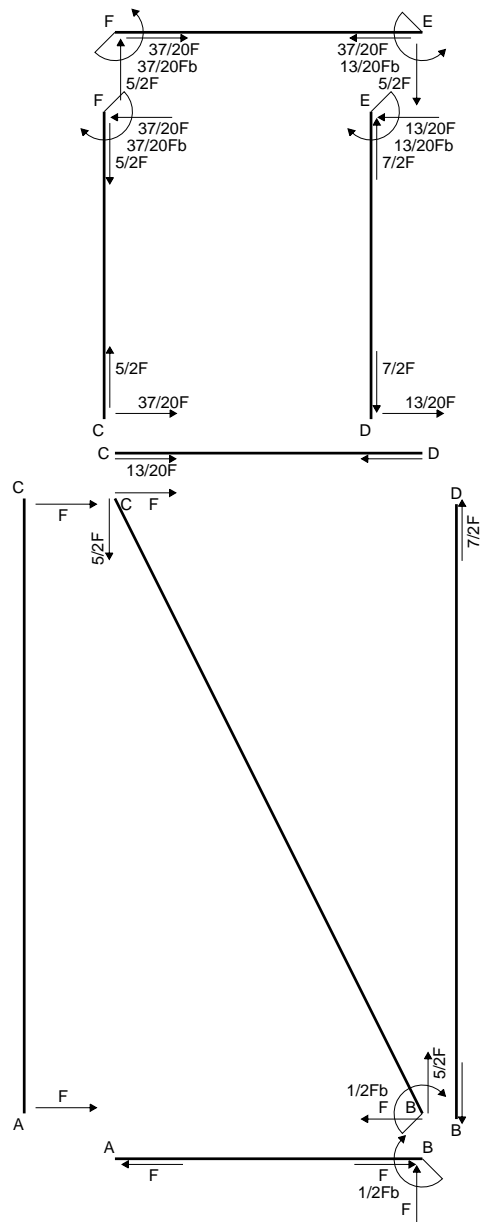
$$\sigma_c = N/A - Mv/J_u = -124.4 \text{ N/mm}^2$$

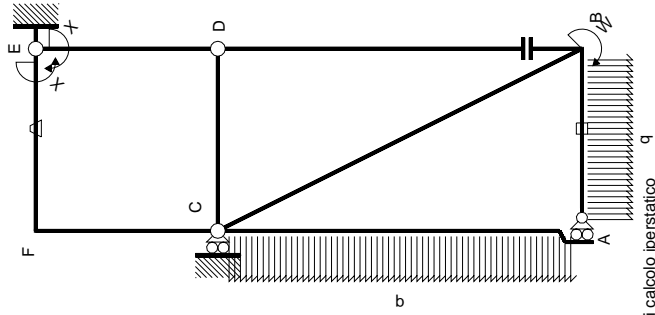
$$\tau_c = 2.625 \text{ N/mm}^2$$

$$\sigma_o = \sqrt{\sigma^2 + 3\tau^2} = 124.5 \text{ N/mm}^2$$

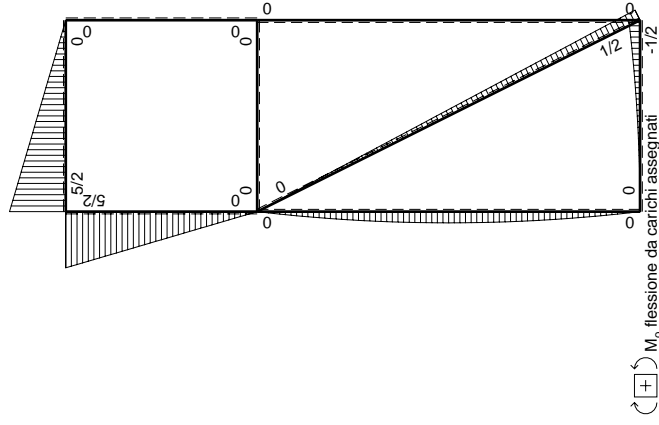
$$S = 4946. \text{ mm}^3$$



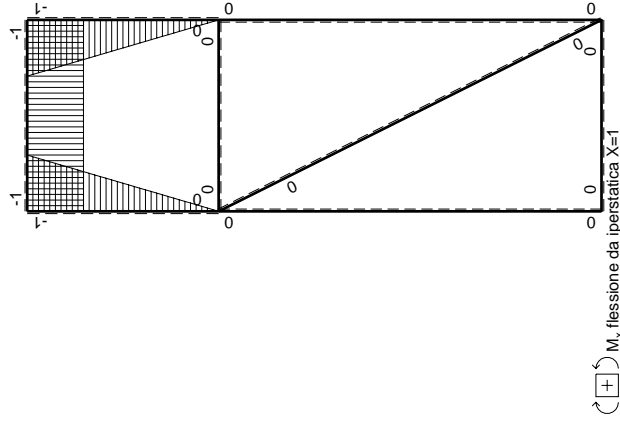




Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica X=1

Quadro contribuiti PLV per iperstatica X=V<sup>EP</sup>

→	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	0	$-1/2qx^2$	0	0	0	0	0	0
BA b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0	0
BC √5b	0	$1/2Fb-\sqrt{5}/10Fx$	0	0	0	0	0	0
AC 2b	0	$-Fx+1/2qx^2$	0	0	0	0	0	0
CA 2b	0	$Fx-1/2qx^2$	0	0	0	0	0	0
DB 2b	0	0	0	0	0	0	0	0
BD 2b	0	0	0	0	0	0	0	0
DE b	$-x/b$	0	0	0	0	0	0	0
ED b	$1-x/b$	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
EF b	-1	$5/2Fx$	$-Fb/EJ$	$-5/2Fx$	$Fb/EJ$	1	$(-5/4+1)Fb^2/EJ$	$Xb/EJ$
FE b	1	$-5/2Fb+5/2Fx$	$Fb/EJ$	$-5/2Fb+5/2Fx$	$Fb/EJ$	1	$(-5/4+1)Fb^2/EJ$	$Xb/EJ$
FC b	$-1+x/b$	$5/2Fb-5/2Fx$	0	$-5/2Fb+5Fx-5/2Fx^2/b$	0	$1-2x/b+x^2/b^2$	$(-5/6+0)Fb^2/EJ$	$1/3Xb/EJ$
CF b	$x/b$	$-5/2Fx$	0	$-5/2Fx^2/b$	0	$x^2/b^2$	$-13/12Fb^2/EJ$	$5/3Xb/EJ$
totali								
iperstatica X=V <sup>EP</sup>								

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{x\theta} = \int_0^b (-5/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-5/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-5/4 b) Fb 1/EJ + (b) \theta = -1/4 Fb^2/EJ$$

$$L_{FE}^{x\theta} = \int_0^b (-5/2 + 5/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-5/2 x + 5/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

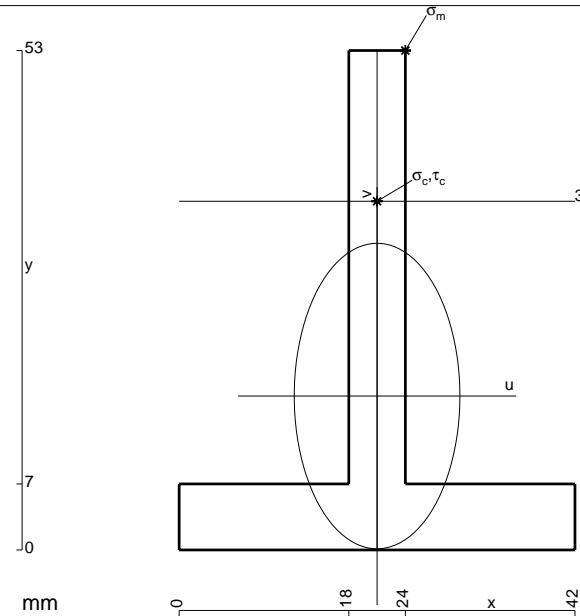
$$= (-5/2 b + 5/4 b) Fb 1/EJ + (-b) \theta = -1/4 Fb^2/EJ$$

$$L_{FC}^{x\theta} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = [-5/2 x + 5/2 x^2/b - 5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

$$L_{CF}^{x\theta} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

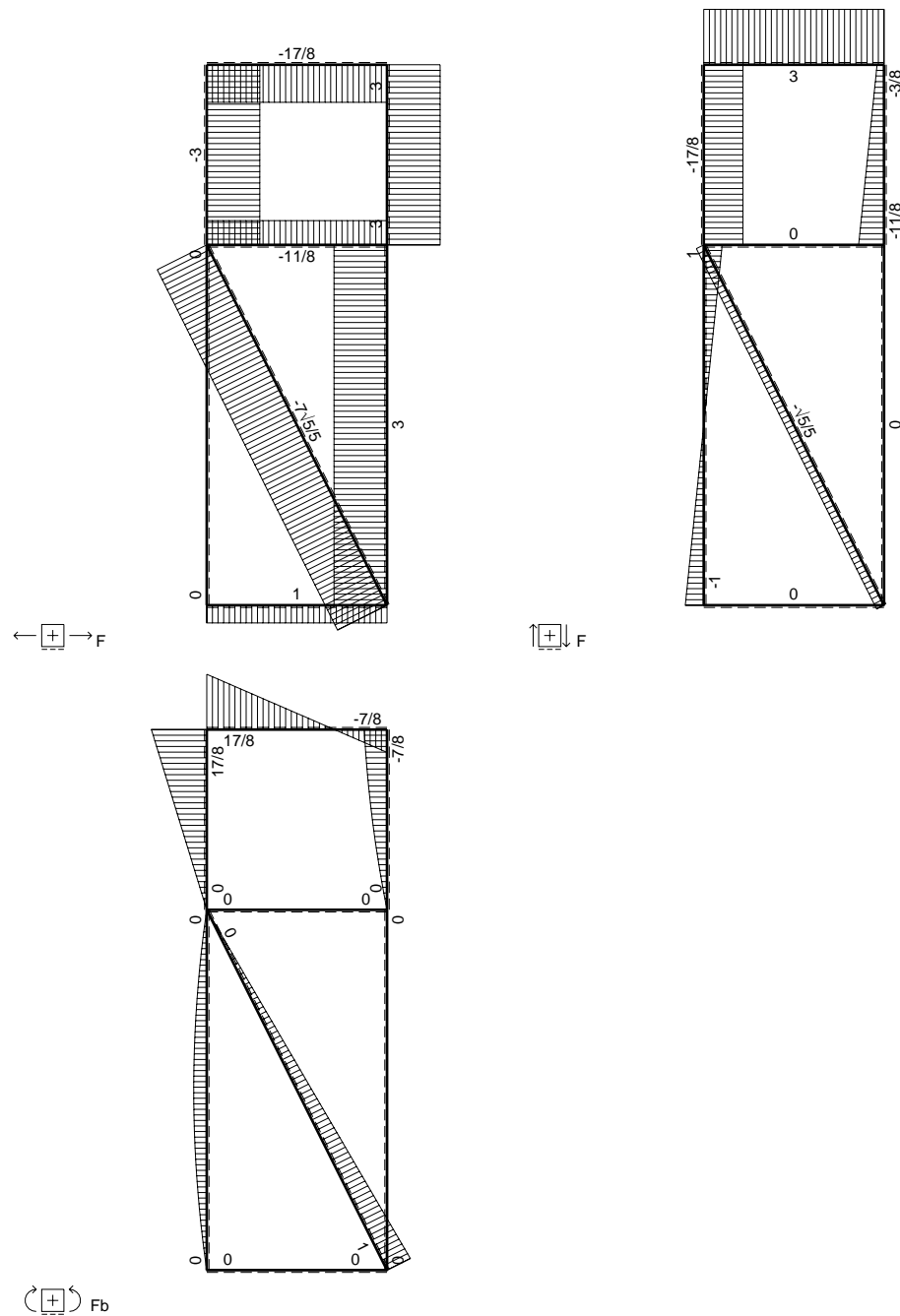
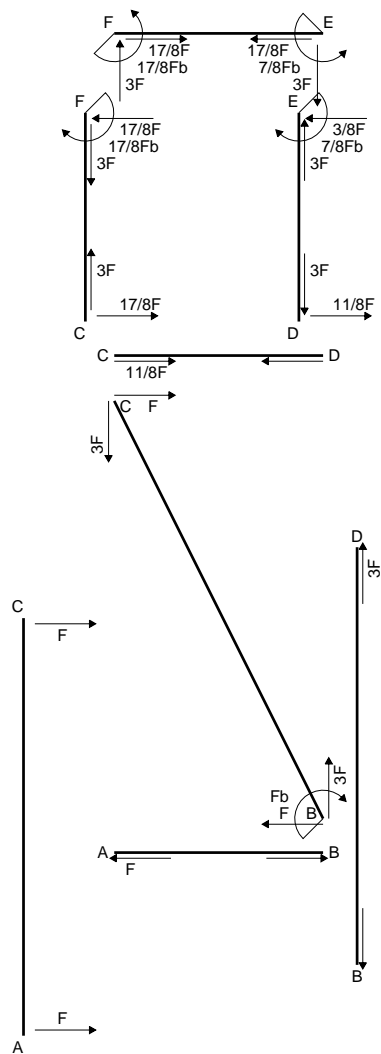
$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

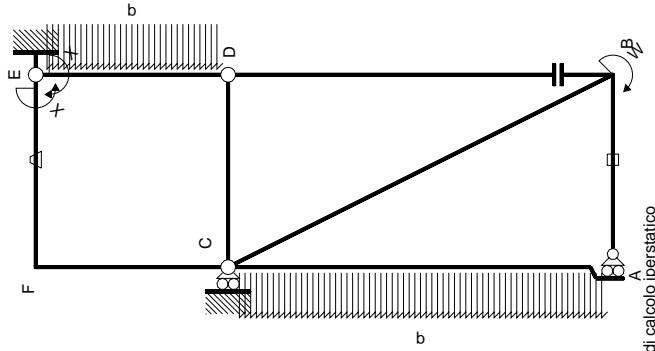


- A = 570. mm<sup>2</sup>
- J<sub>u</sub> = 149839. mm<sup>4</sup>
- J<sub>v</sub> = 44046. mm<sup>4</sup>
- y<sub>g</sub> = 16.33 mm
- N = 3950. N
- T<sub>y</sub> = -3950. N
- M<sub>x</sub> = -869000. Nmm
- x<sub>m</sub> = 24. mm
- y<sub>m</sub> = 53. mm
- u<sub>m</sub> = 3. mm
- v<sub>m</sub> = 36.67 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = 219.6 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 37. mm
- v<sub>c</sub> = 20.67 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = 126.8 N/mm<sup>2</sup>
- τ<sub>c</sub> = 12.09 N/mm<sup>2</sup>
- σ<sub>o</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 128.5 N/mm<sup>2</sup>
- S = 2752. mm<sup>3</sup>

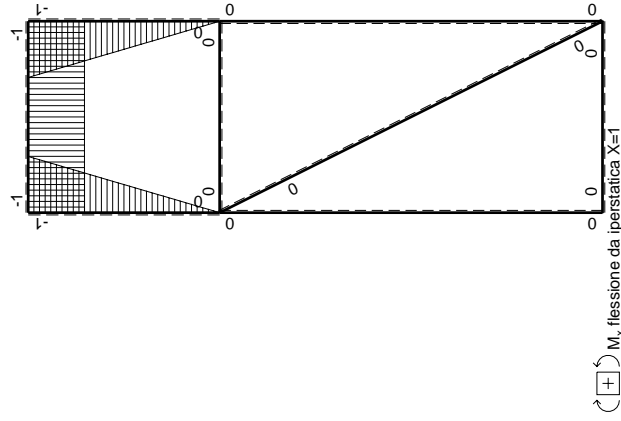








$M_0$  flessione da carichi assegnati



Quadro contributi PLV per iperstatica  $X=W_{EF}$

$\leftarrow$	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x (M_0/EJ + \theta) dx$	$\int M^x M_x / EJ dx$
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$Fb - \sqrt{5}/5Fx$	0	0	0	0	0	0
CA 2b	0	$-Fx + 1/2qx^2$	0	0	0	0	0+0	0
DB 2b	0	0	0	0	0	0	0+0	0
BD 2b	0	0	0	0	0	0	0+0	0
DE b	$-x/b$	$-1/2Fx + 1/2qx^2$	0	$1/2Fx^2/b - 1/2qx^3/b$	0	0	$x^2/b^2$	$1/3xb/EJ$
ED b	$1-x/b$	$1/2Fx - 1/2qx^2$	0	$1/2Fx - Fx^2/b + 1/2qx^3/b$	0	0	$1-2x/b+x^2/b^2$	$1/3xb/EJ$
CD b	0	0	0	0	0	0	0+0	0
DC b	0	0	0	0	0	0	0+0	0
EF b	-1	$3Fx$	$-Fb/EJ$	$-3Fx$	$Fb/EJ$	1	$(-3/2+1)Fb^2/EJ$	$Xb/EJ$
FE b	1	$-3Fb+3Fx$	$Fb/EJ$	$-3Fb+3Fx$	$Fb/EJ$	1	$(-3/2+1)Fb^2/EJ$	$Xb/EJ$
FC b	$-1+x/b$	$3Fb-3Fx$	0	$-3Fb+6Fx-3Fx^2/b$	0	0	$1-2x/b+x^2/b^2$	$(-1+0)Fb^2/EJ$
CF b	$x/b$	$-3Fx$	0	$-3Fx^2/b$	0	0	$x^2/b^2$	$1/3xb/EJ$
totali								$5/3xb/EJ$
								$7/8Fb$

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-3x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-3/2 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-3/2 b) Fb 1/EJ + (b) \theta = -1/2 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-3 + 3x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-3x + 3/2 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

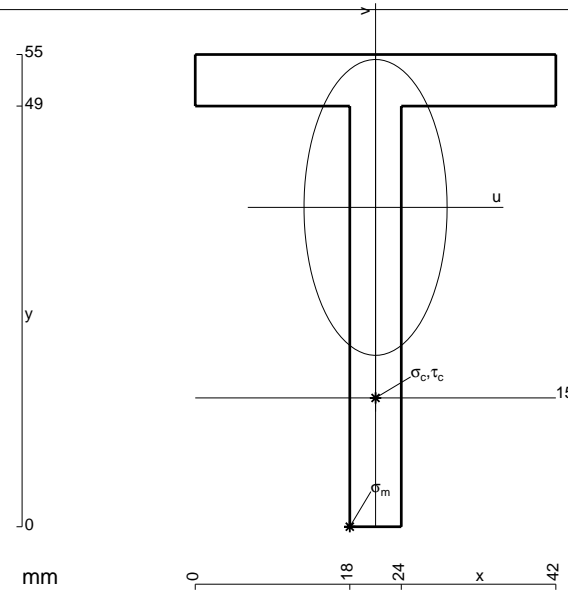
$$= (-3b + 3/2 b) Fb 1/EJ + (-b) \theta = -1/2 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-3 + 6x/b - 3x^2/b^2) Fb 1/EJ dx = [-3x + 3x^2/b - x^3/b^2]_0^b Fb 1/EJ$$

$$= (-3b + 3b - b) Fb 1/EJ = - Fb^2/EJ$$

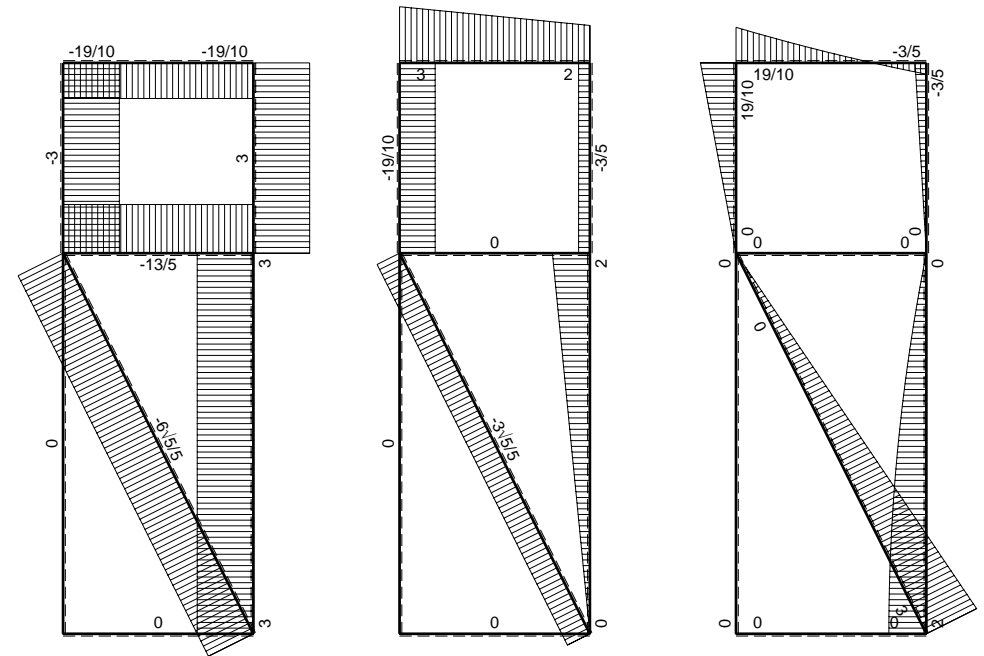
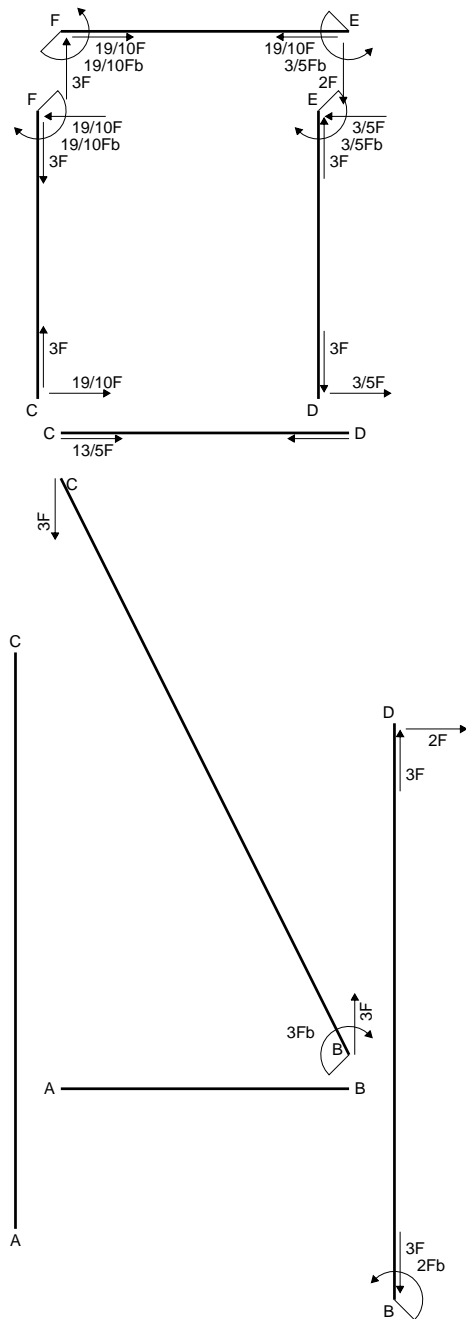
$$L_{CF}^{xo} = \int_0^b (-3x^2/b^2) Fb 1/EJ dx = [-x^3/b^2]_0^b Fb 1/EJ$$

$$= (-b) Fb 1/EJ = - Fb^2/EJ$$



- A = 546. mm<sup>2</sup>
- J<sub>u</sub> = 162198. mm<sup>4</sup>
- J<sub>v</sub> = 37926. mm<sup>4</sup>
- y<sub>g</sub> = 37.19 mm
- N = -6605. N
- T<sub>y</sub> = -943.6 N
- M<sub>x</sub> = 1055000. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -37.19 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = 229.8 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 15. mm
- v<sub>c</sub> = -22.19 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = 132.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.591 N/mm<sup>2</sup>
- σ<sub>φ</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 132.3 N/mm<sup>2</sup>
- S = 2672. mm<sup>3</sup>

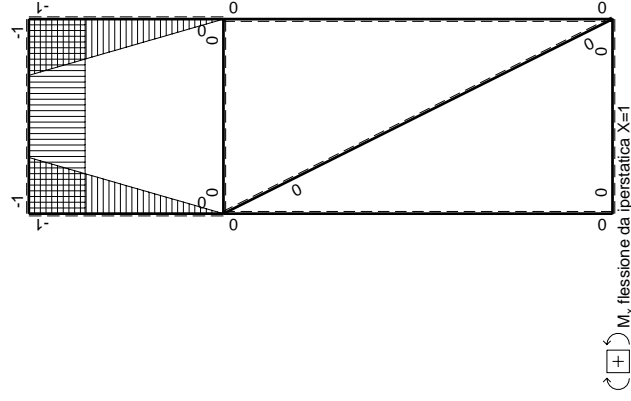
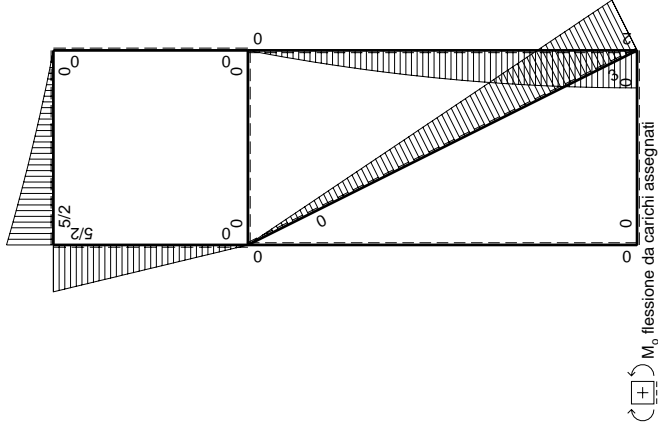
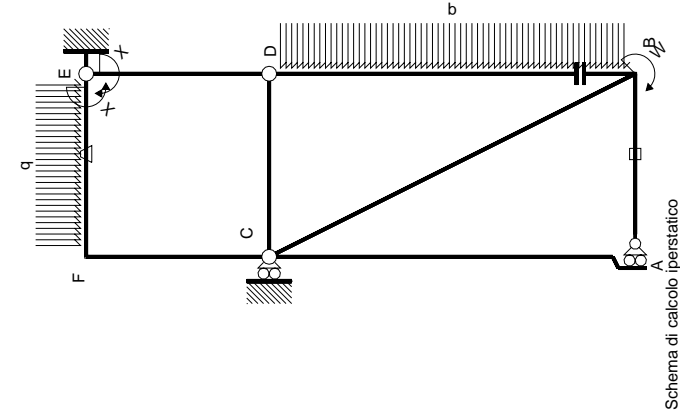




← ⊕ → F

↑ ⊕ ↓ F

⊕ ⊖ F<sub>b</sub>



Quadro contribuiti PLV per iperstatica  $X=W_{EF}$

$\rightarrow$	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x (M_0/EJ + \theta) dx$	$\int M^x M_x / EIdx$
AB b	0	0	0	0	0	0	0	0
BA b	0	0	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$3Fb-3\sqrt{5}/5Fx$	0	0	0	0	0	0
AC 2b	0	0	0	0	0	0	0	0
CA 2b	0	0	0	0	0	0	0	0
DB 2b	0	$2Fx-1/2qx^2$	0	0	0	0	0	0
BD 2b	0	$-2Fb+1/2qx^2$	0	0	0	0	0	0
DE b	$-x/b$	0	0	0	0	0	0	0
ED b	$1-x/b$	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
EF b	-1	$2Fx+1/2qx^2$	$-Fb/EJ$	$-2Fx-1/2Fx^2/b$	$Fb/EJ$	1	1	$Xb/EJ$
FE b	1	$-5/2Fb+3Fx-1/2qx^2$	$Fb/EJ$	$-5/2Fb+3Fx-1/2Fx^2/b$	$Fb/EJ$	1	1	$Xb/EJ$
FC b	$-1+x/b$	$5/2Fb-5/2Fx$	0	$-5/2Fb+5Fx-5/2Fx^2/b$	0	0	0	$1/3Xb/EJ$
CF b	$x/b$	$-5/2Fx$	0	$-5/2Fx^2/b$	0	0	0	$1/3Xb/EJ$
totali								$5/3Xb/EJ$
iperstatica $X=W_{EF}$								$3/5Fb$

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-2x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-b - 1/6 b) Fb 1/EJ + (b) \theta = -1/6 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-5/2 + 3x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx$$

$$= [-5/2 x + 3/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

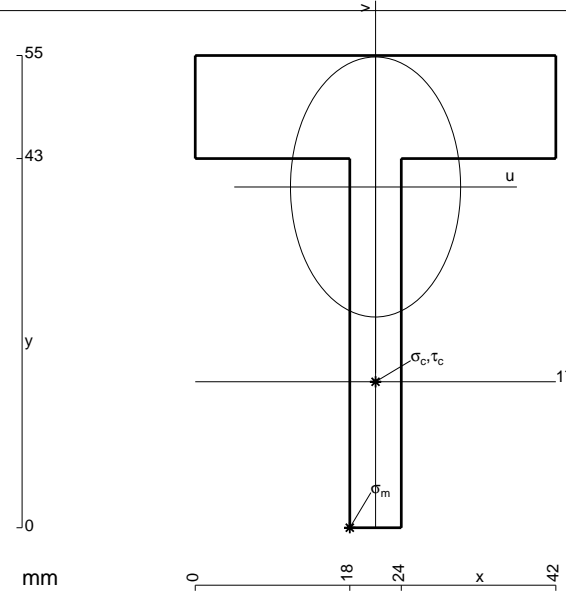
$$= (-5/2 b + 3/2 b - 1/6 b) Fb 1/EJ + (-b) \theta = -1/6 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = [-5/2 x + 5/2 x^2/b - 5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

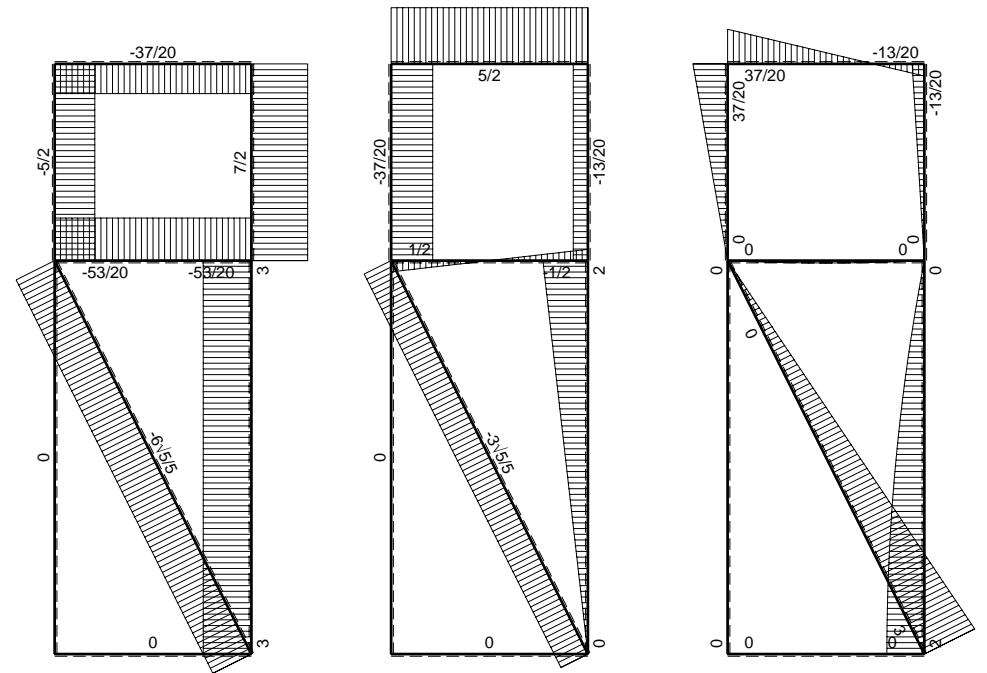
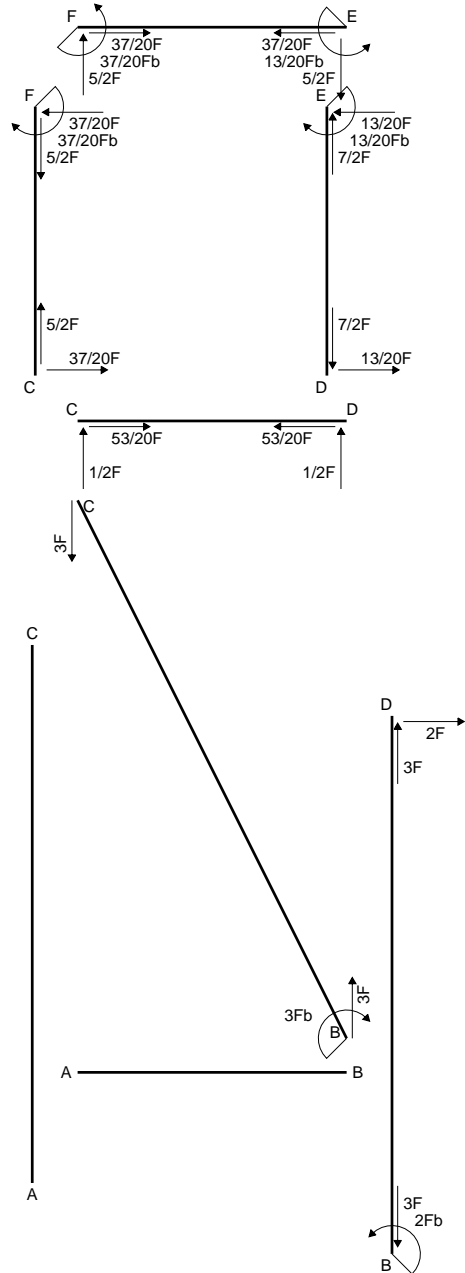
$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$



- A = 762. mm<sup>2</sup>
- J<sub>u</sub> = 174852. mm<sup>4</sup>
- J<sub>v</sub> = 74862. mm<sup>4</sup>
- y<sub>g</sub> = 39.69 mm
- N = -1744. N
- T<sub>y</sub> = -872.1 N
- M<sub>x</sub> = 1053000. Nmm
- x<sub>m</sub> = 18. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -39.69 mm
- σ<sub>m</sub> = N/A - Mv/J<sub>u</sub> = 236.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 21. mm
- y<sub>c</sub> = 17. mm
- v<sub>c</sub> = -22.69 mm
- σ<sub>c</sub> = N/A - Mv/J<sub>u</sub> = 134.3 N/mm<sup>2</sup>
- τ<sub>c</sub> = 2.644 N/mm<sup>2</sup>
- σ<sub>φ</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 134.4 N/mm<sup>2</sup>
- S = 3181. mm<sup>3</sup>







← ⊕ → F

⊕ F

⊕ F<sub>b</sub>



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-5/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-5/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-5/4 b) Fb 1/EJ + (b) \theta = -1/4 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-5/2 + 5/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-5/2 x + 5/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

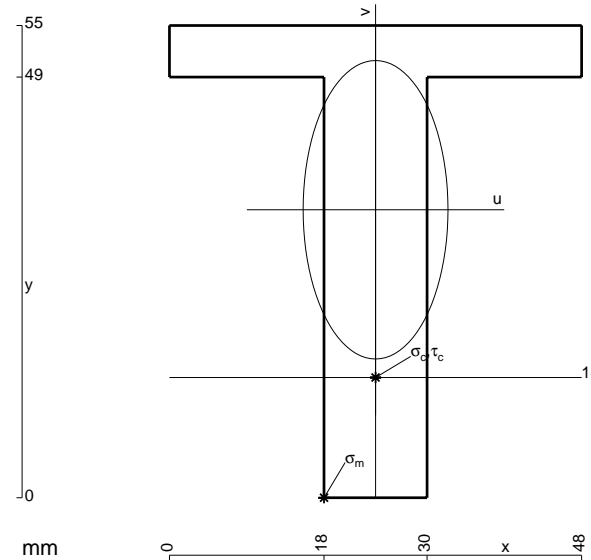
$$= (-5/2 b + 5/4 b) Fb 1/EJ + (-b) \theta = -1/4 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = [-5/2 x + 5/2 x^2/b - 5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$



$$A = 876. \text{ mm}^2$$

$$J_u = 264708. \text{ mm}^4$$

$$J_v = 62352. \text{ mm}^4$$

$$y_g = 33.54 \text{ mm}$$

$$N = -2442. \text{ N}$$

$$T_y = -1221. \text{ N}$$

$$M_x = 1583400. \text{ Nmm}$$

$$x_m = 18. \text{ mm}$$

$$u_m = -6. \text{ mm}$$

$$v_m = -33.54 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 197.8 \text{ N/mm}^2$$

$$x_c = 24. \text{ mm}$$

$$y_c = 14. \text{ mm}$$

$$v_c = -19.54 \text{ mm}$$

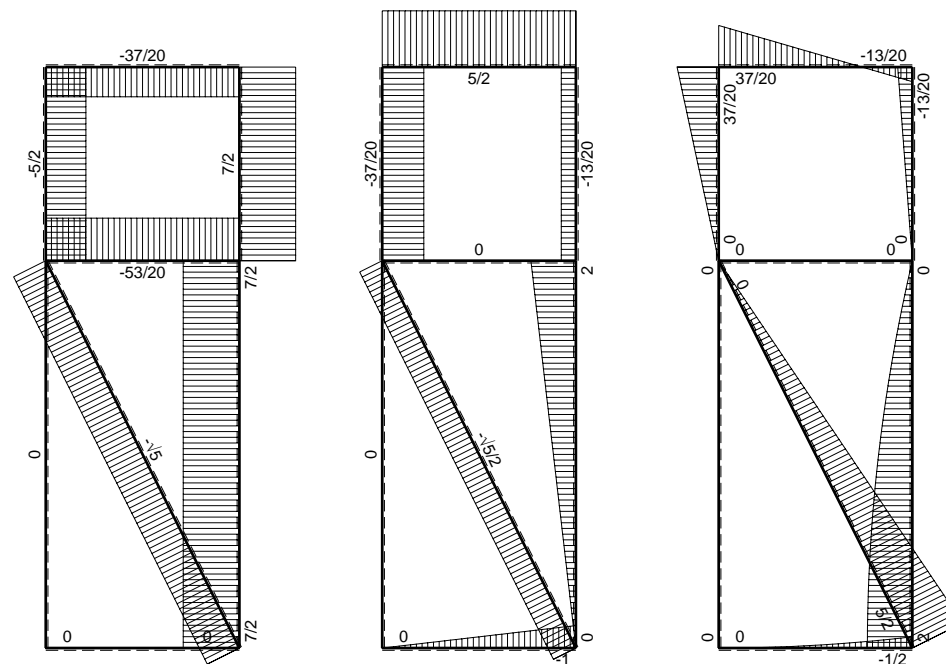
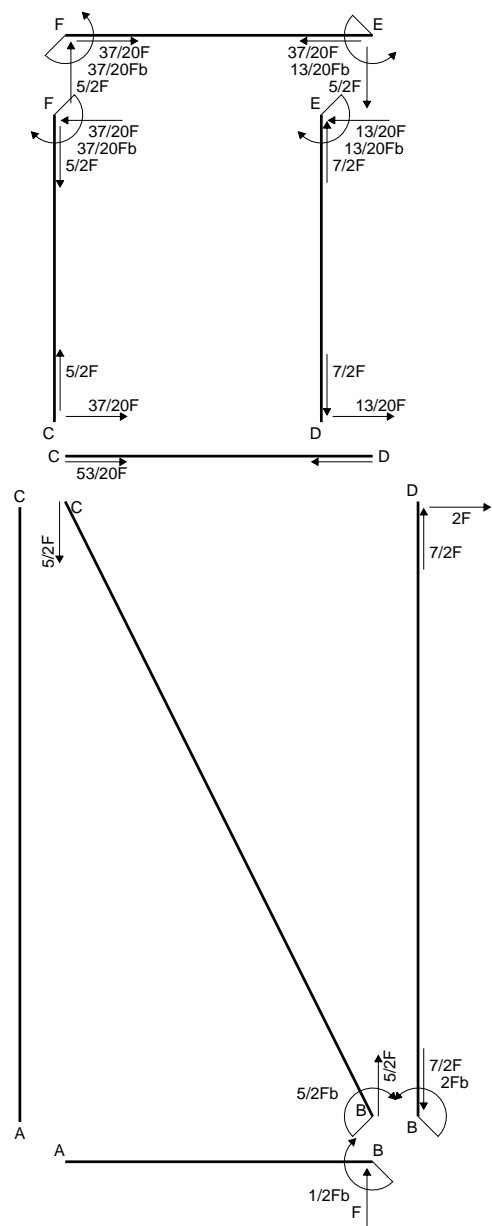
$$\sigma_c = N/A - Mv/J_u = 114.1 \text{ N/mm}^2$$

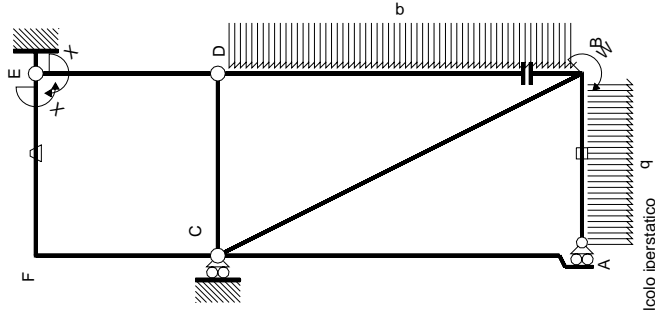
$$\tau_c = 1.714 \text{ N/mm}^2$$

$$\sigma_\rho = \sqrt{\sigma^2 + 3\tau^2} = 114.1 \text{ N/mm}^2$$

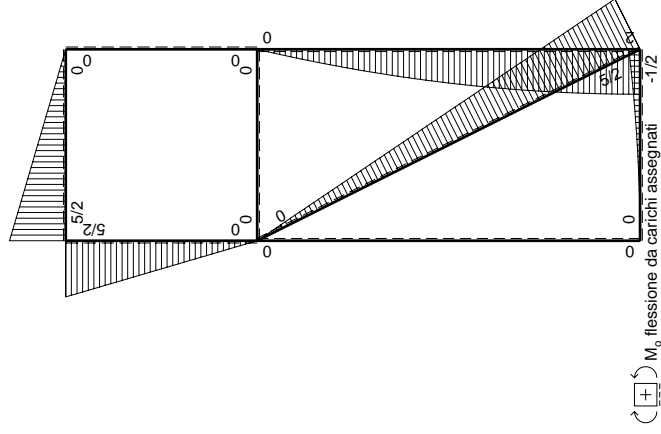
$$S = 4459. \text{ mm}^3$$



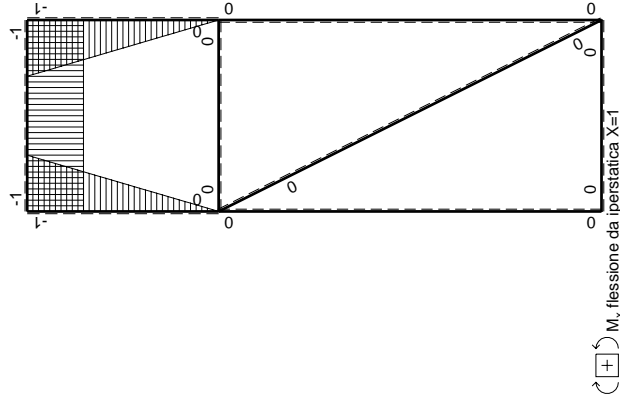




Schema di calcolo iperstatico



$M_0$  flessione da carichi assegnati



$M_x$  flessione da iperstatica  $X=1$

Quadro contributi PLV per iperstatica  $X=W_{EP}$

$\rightarrow$	$M(x)$	$M_0(x)$	$\theta$	$M_x M_0$	$M_x \theta$	$M_x M_x$	$\int M_x(M_0/EJ+\theta)dx$	$\int M_x M_x/EJ dx$
AB b	0	$-1/2qx^2$	0	0	0	0	0	0
BA b	0	$1/2Fb-Fx+1/2qx^2$	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$5/2Fb-\sqrt{5}2Fx$	0	0	0	0	0	0
CA 2b	0	0	0	0	0	0	0	0
DB 2b	0	$2Fx-1/2qx^2$	0	0	0	0	0	0
BD 2b	0	$-2Fb+1/2qx^2$	0	0	0	0	0	0
DE b	$-x/b$	0	0	0	0	0	0	0
ED b	$1-x/b$	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
EF b	-1	$5/2Fx$	$-Fb/EJ$	$-5/2Fx$	$Fb/EJ$	1	$(-5/4+1)Fb^2/EJ$	$Xb/EJ$
FE b	1	$-5/2Fb+5/2Fx$	$Fb/EJ$	$-5/2Fb+5/2Fx$	$Fb/EJ$	1	$(-5/4+1)Fb^2/EJ$	$Xb/EJ$
FC b	$-1+x/b$	$5/2Fb-5/2Fx$	0	$-5/2Fb+5Fx-5/2Fx^2/b$	0	0	$(-5/6+0)Fb^2/EJ$	$1/3Xb/EJ$
CF b	$x/b$	$-5/2Fx$	0	$-5/2Fx^2/b$	0	0	$x^2/b^2$	$1/3Xb/EJ$
totali							$-13/12Fb^2/EJ$	$5/3Xb/EJ$
							$13/20Fb$	

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{x\theta} = \int_0^b (-5/2 x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-5/4 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-5/4 b) Fb 1/EJ + (b) \theta = -1/4 Fb^2/EJ$$

$$L_{FE}^{x\theta} = \int_0^b (-5/2 + 5/2 x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-5/2 x + 5/4 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

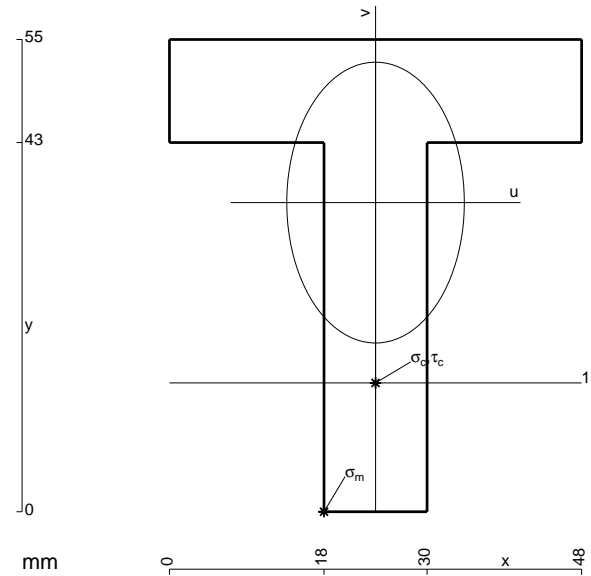
$$= (-5/2 b + 5/4 b) Fb 1/EJ + (-b) \theta = -1/4 Fb^2/EJ$$

$$L_{FC}^{x\theta} = \int_0^b (-5/2 + 5x/b - 5/2 x^2/b^2) Fb 1/EJ dx = [-5/2 x + 5/2 x^2/b - 5/6 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/2 b + 5/2 b - 5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$

$$L_{CF}^{x\theta} = \int_0^b (-5/2 x^2/b^2) Fb 1/EJ dx = [-5/6 x^3/b^2]_0^b Fb 1/EJ$$

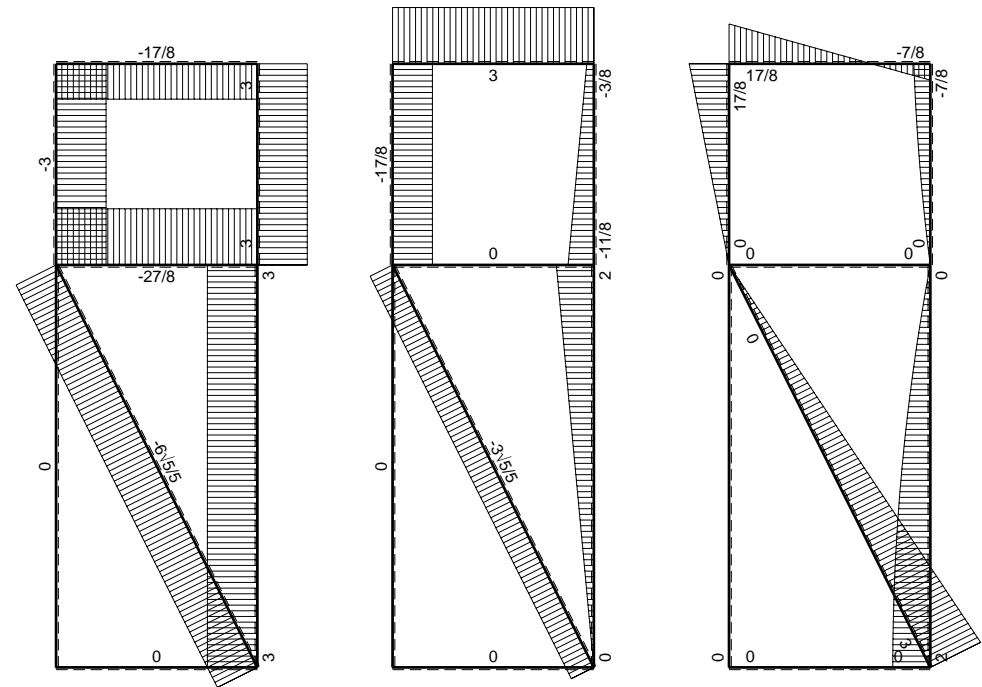
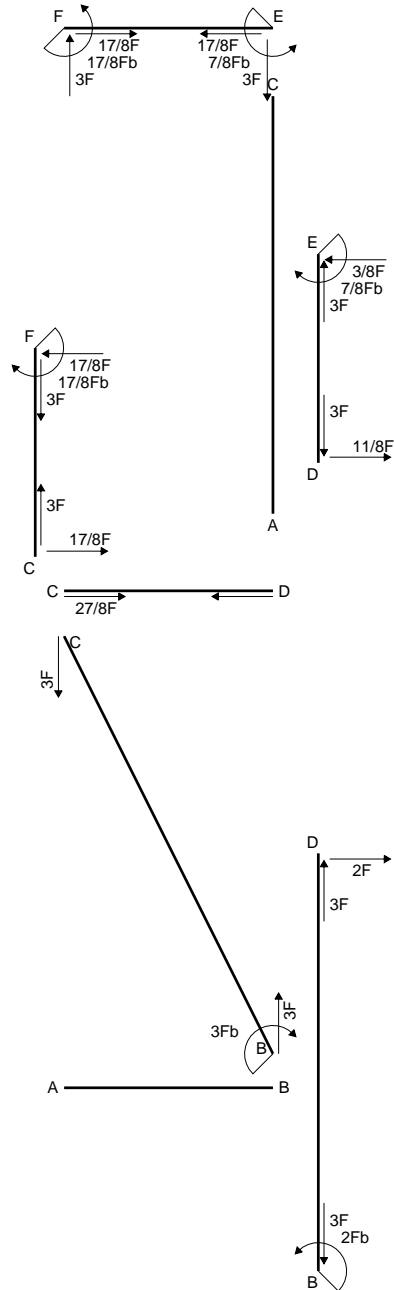
$$= (-5/6 b) Fb 1/EJ = -5/6 Fb^2/EJ$$



- 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 = -2482. N
- T<sub>y</sub> = -1241. N
- M<sub>x</sub> = 1720500. 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> = 121.4 N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.816 N/mm<sup>2</sup>
- σ<sub>φ</sub> = √(σ<sup>2</sup> + 3τ<sup>2</sup>) = 121.4 N/mm<sup>2</sup>
- S = 5131. mm<sup>3</sup>



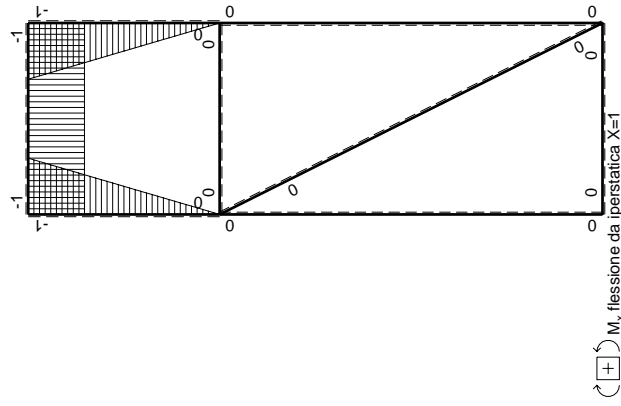
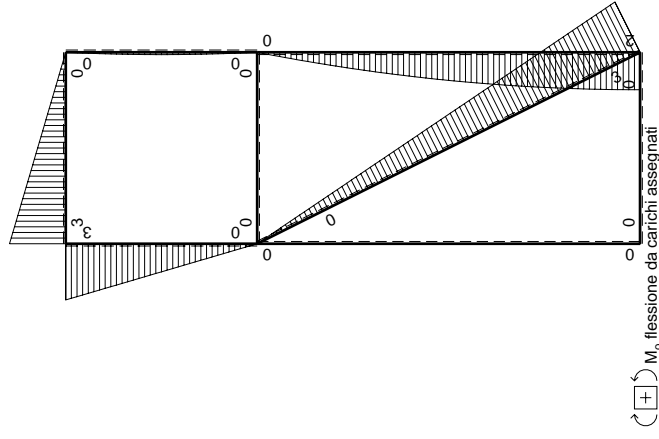
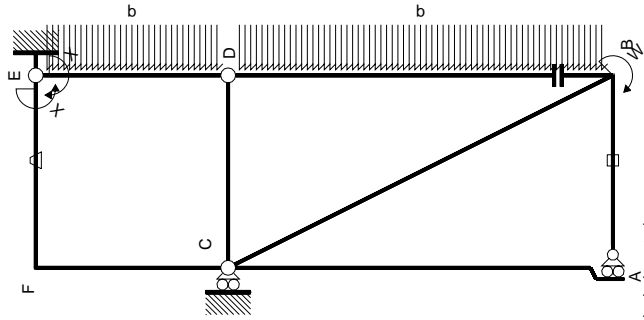




← ⊕ → F

↑ ⊕ ↓ F

⊕ ⊖ F<sub>b</sub>



Quadro contributi PLV per iperstatica  $X=W_{EF}$

$\leftarrow$	$M^x(x)$	$M^0(x)$	$\theta$	$M^x M_0$	$M^x \theta$	$M^x M_x$	$\int M^x (M_0/EJ + \theta) dx$	$\int M^x M_x / EJ dx$
AB b	0	0	0	0	0	0	0+0	0
BA b	0	0	0	0	0	0	0	0
BC $\sqrt{5}b$	0	$3Fb-3\sqrt{5}/5Fx$	0	0	0	0	0+0	0
CA 2b	0	0	0	0	0	0	0+0	0
DB 2b	0	$2Fx-1/2qx^2$	0	0	0	0	0+0	0
BD 2b	0	$-2Fb+1/2qx^2$	0	0	0	0	0+0	0
DE b	$-x/b$	$-1/2Fx+1/2qx^2$	0	$1/2Fx^2/b-1/2qx^3/b$	0	0	$x^2/b^2$	$1/3Xb/EJ$
ED b	$1-x/b$	$1/2Fx-1/2qx^2$	0	$1/2Fx-Fx^2/b+1/2qx^3/b$	0	0	$1-2x/b+x^2/b^2$	$1/3Xb/EJ$
CD b	0	0	0	0	0	0	0+0	0
DC b	0	0	0	0	0	0	0+0	0
EF b	-1	$3Fx$	$-Fb/EJ$	$-3Fx$	$Fb/EJ$	1	$(-3/2+1)Fb^2/EJ$	$Xb/EJ$
FE b	1	$-3Fb+3Fx$	$Fb/EJ$	$-3Fb+3Fx$	$Fb/EJ$	1	$(-3/2+1)Fb^2/EJ$	$Xb/EJ$
FC b	$-1+x/b$	$3Fb-3Fx$	0	$-3Fb+6Fx-3Fx^2/b$	0	0	$1-2x/b+x^2/b^2$	$1/3Xb/EJ$
CF b	$x/b$	$-3Fx$	0	$-3Fx^2/b$	0	0	$x^2/b^2$	$1/3Xb/EJ$
totali							$-35/24Fb^2/EJ$	$5/3Xb/EJ$
							$7/8Fb$	

Sviluppi di calcolo iperstatica

$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{DE}^{xo} = \int_0^b (1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx = [1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/6 b - 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{ED}^{xo} = \int_0^b (1/2 x/b - x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [1/4 x^2/b - 1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (1/4 b - 1/3 b + 1/8 b) Fb 1/EJ = 1/24 Fb^2/EJ$$

$$L_{EF}^{xo} = \int_0^b (-3x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-3/2 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-3/2 b) Fb 1/EJ + (b) \theta = -1/2 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-3 + 3x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-3x + 3/2 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

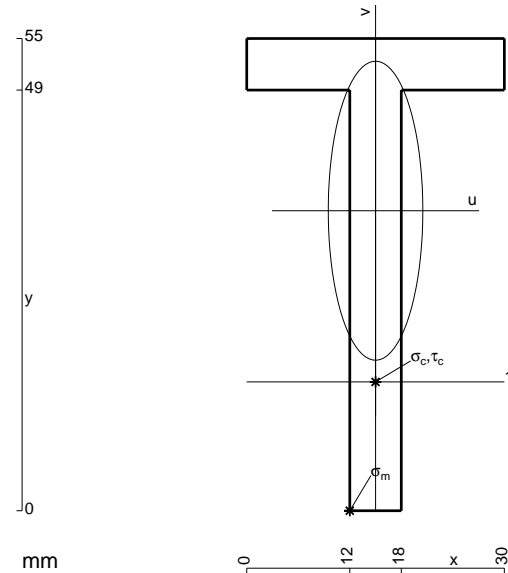
$$= (-3b + 3/2 b) Fb 1/EJ + (-b) \theta = -1/2 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-3 + 6x/b - 3x^2/b^2) Fb 1/EJ dx = [-3x + 3x^2/b - x^3/b^2]_0^b Fb 1/EJ$$

$$= (-3b + 3b - b) Fb 1/EJ = - Fb^2/EJ$$

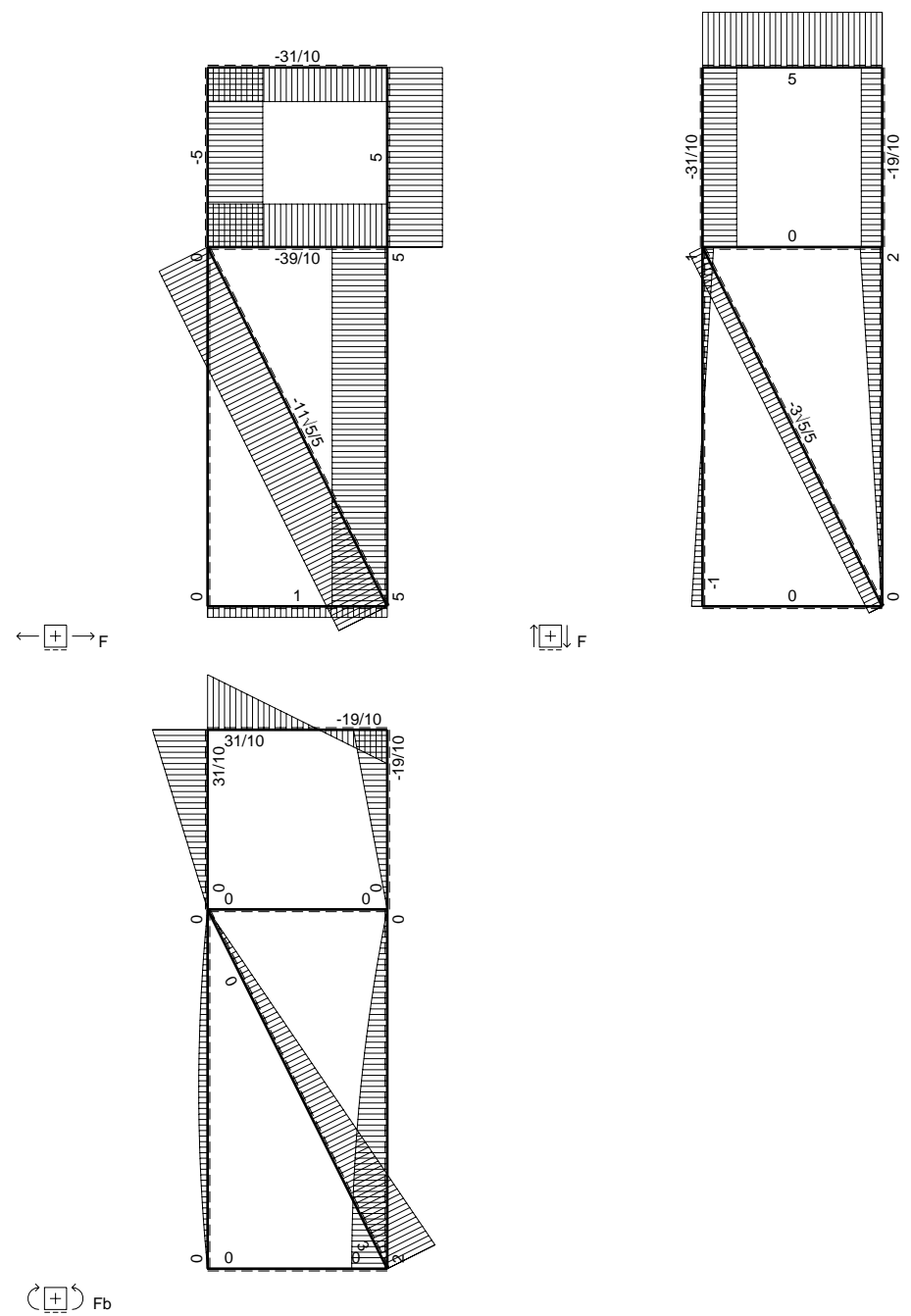
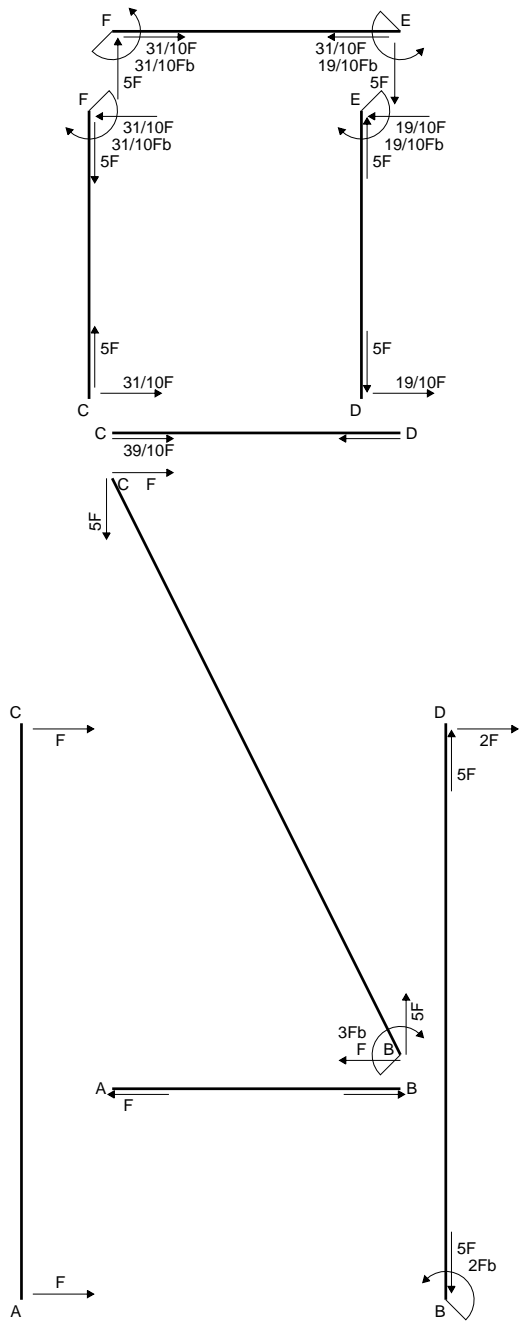
$$L_{CF}^{xo} = \int_0^b (-3x^2/b^2) Fb 1/EJ dx = [-x^3/b^2]_0^b Fb 1/EJ$$

$$= (-b) Fb 1/EJ = - Fb^2/EJ$$



- 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> = 34.94 mm
- N = -1234. N
- T<sub>y</sub> = -617.2 N
- M<sub>x</sub> = 910800. Nmm
- x<sub>m</sub> = 12. mm
- u<sub>m</sub> = -3. mm
- v<sub>m</sub> = -34.94 mm
- σ<sub>m</sub> = N/A-Mv/J<sub>u</sub> = 218.7 N/mm<sup>2</sup>
- x<sub>c</sub> = 15. mm
- y<sub>c</sub> = 15. mm
- v<sub>c</sub> = -19.94 mm
- σ<sub>c</sub> = N/A-Mv/J<sub>u</sub> = 123.7 N/mm<sup>2</sup>
- τ<sub>c</sub> = 1.767 N/mm<sup>2</sup>
- σ<sub>φ</sub> = √σ<sup>2</sup>+3τ<sup>2</sup> = 123.8 N/mm<sup>2</sup>
- S = 2470. mm<sup>3</sup>







$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-5x/b) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-5/2 x^2/b]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-5/2 b) Fb 1/EJ + (b) \theta = -3/2 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-5 + 5x/b) Fb 1/EJ dx + \int_0^b (-1) \theta dx = [-5x + 5/2 x^2/b]_0^b Fb 1/EJ + [-x]_0^b \theta$$

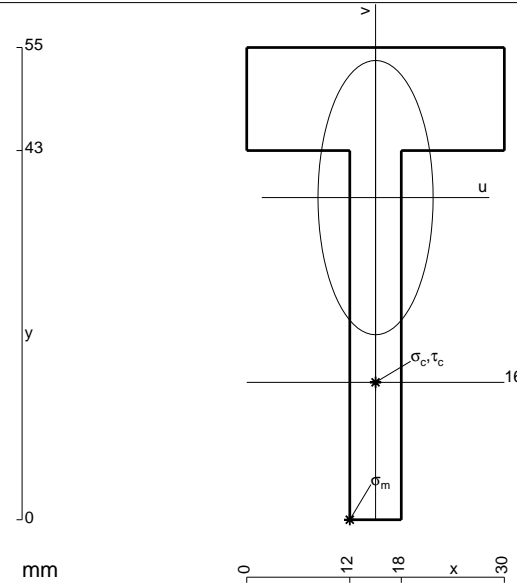
$$= (-5b + 5/2 b) Fb 1/EJ + (-b) \theta = -3/2 Fb^2/EJ$$

$$L_{FC}^{xo} = \int_0^b (-5 + 10x/b - 5x^2/b^2) Fb 1/EJ dx = [-5x + 5x^2/b - 5/3 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5b + 5b - 5/3 b) Fb 1/EJ = -5/3 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-5x^2/b^2) Fb 1/EJ dx = [-5/3 x^3/b^2]_0^b Fb 1/EJ$$

$$= (-5/3 b) Fb 1/EJ = -5/3 Fb^2/EJ$$



$$A = 618. \text{ mm}^2$$

$$J_u = 157731. \text{ mm}^4$$

$$J_v = 27774. \text{ mm}^4$$

$$y_g = 37.52 \text{ mm}$$

$$N = -2263. \text{ N}$$

$$T_y = -617.2 \text{ N}$$

$$M_x = 966000. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -3. \text{ mm}$$

$$v_m = -37.52 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 226.1 \text{ N/mm}^2$$

$$x_c = 15. \text{ mm}$$

$$y_c = 16. \text{ mm}$$

$$v_c = -21.52 \text{ mm}$$

$$\sigma_c = N/A - Mv/J_u = 128.1 \text{ N/mm}^2$$

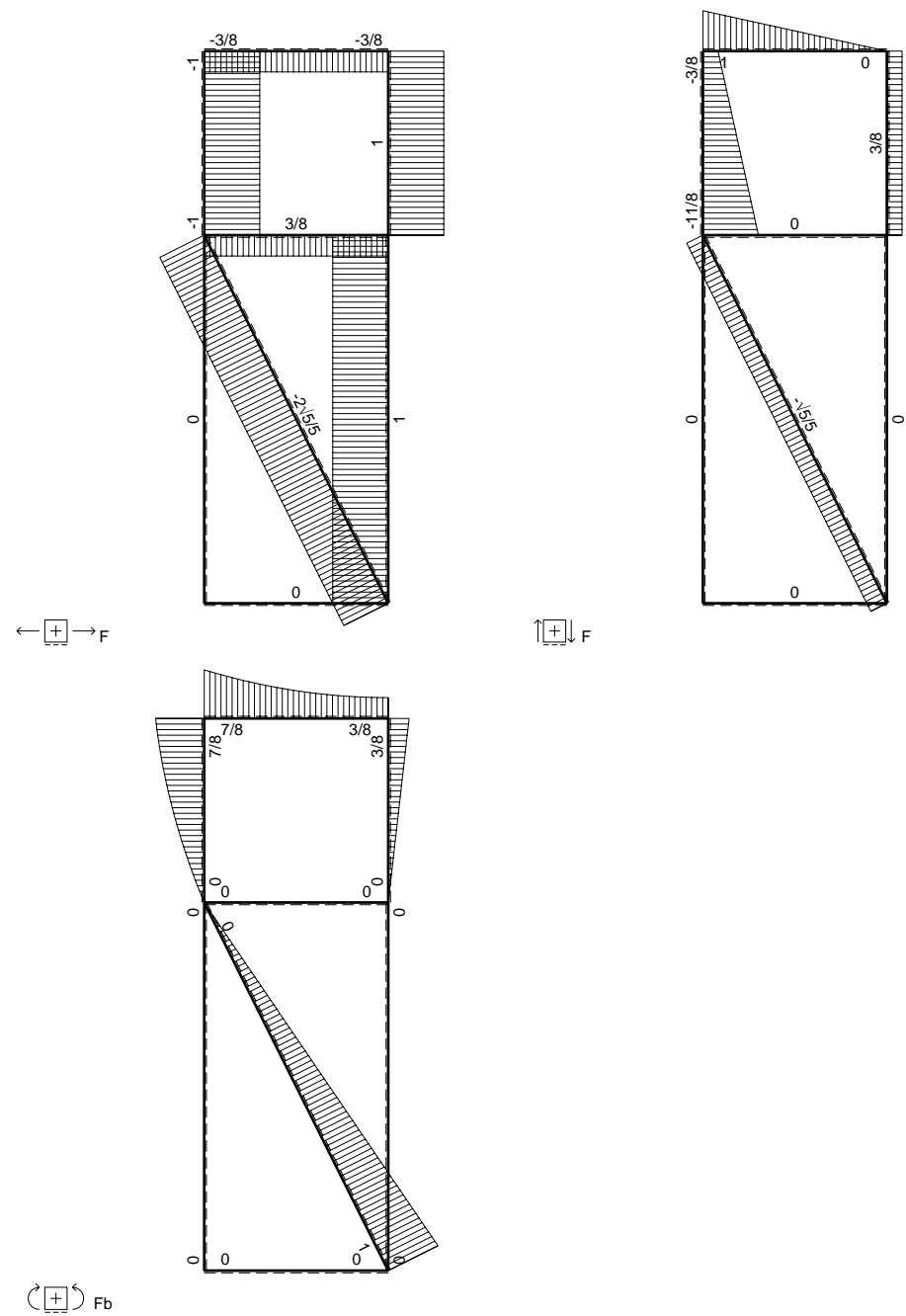
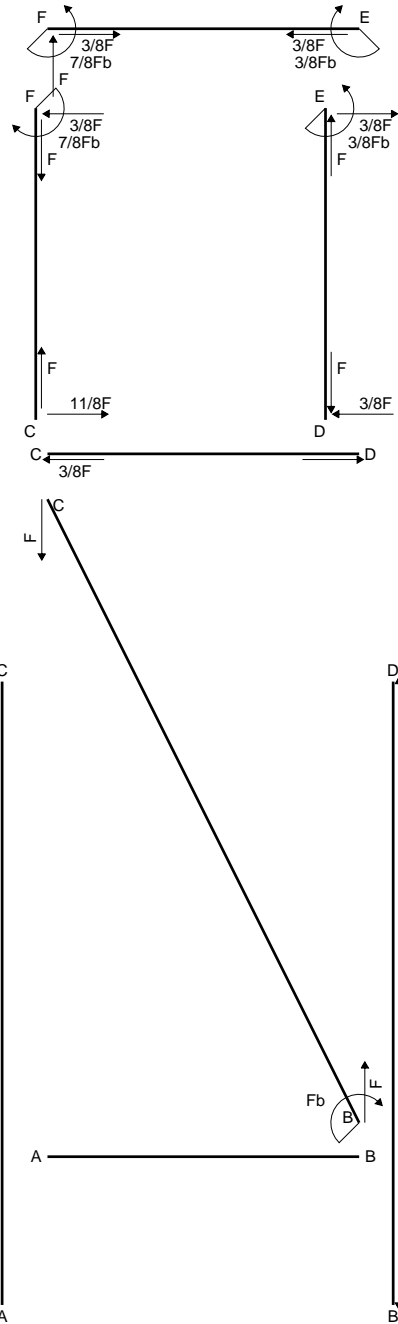
$$\tau_c = 1.848 \text{ N/mm}^2$$

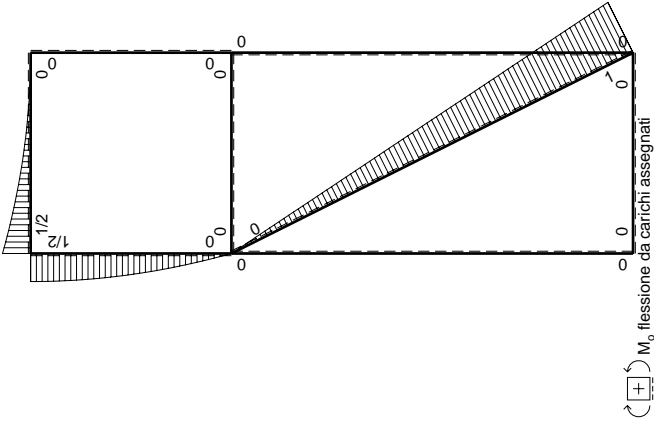
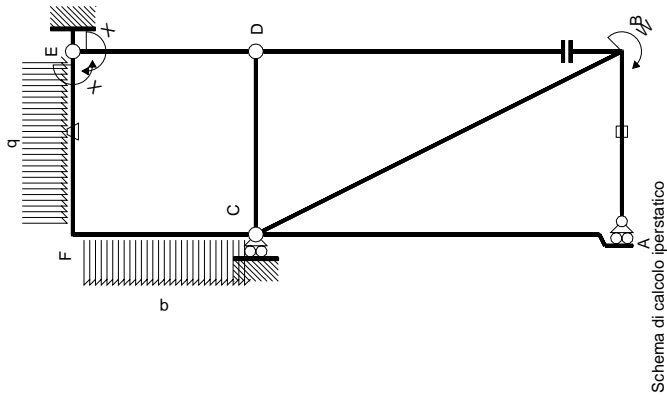
$$\sigma_\varphi = \sqrt{\sigma^2 + 3\tau^2} = 128.2 \text{ N/mm}^2$$

$$S = 2834. \text{ mm}^3$$





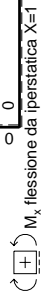




Quadro contributi PLV per iperstatica X=W<sup>EF</sup>

←	M <sub>x</sub> (x)	M <sub>0</sub> (x)	θ	M <sub>0</sub>	M <sub>θ</sub>	M <sub>x</sub>	∫ M <sub>x</sub> (M <sub>0</sub> /EJ+θ)dx	∫ M <sub>x</sub> M <sub>0</sub> /EJdx	AB	BA	BC	AC	CA	CB	DB	BD	DE	ED	totali	iperstatica X=W <sup>EF</sup>																							
AB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1/2qx <sup>2</sup> /b	-Fb/EJ	-1/2Fx <sup>2</sup> /b	Fb/EJ	1	-1/2Fb+Fx-1/2qx <sup>2</sup>	1/2Fb-1/2qx <sup>2</sup>	0	-1/2Fb+1/2Fx+1/2Fx <sup>2</sup> /b-1/2qx <sup>3</sup> /b	0	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	(-5/24+0)Fb <sup>2</sup> /EJ	1/3Xb/EJ	5/8Fb <sup>2</sup> /EJ	-3/8Fb								
BA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1/2qx <sup>2</sup>	-Fb/EJ	-1/2Fx <sup>2</sup> /b	-1/2Fb+Fx-1/2Fx <sup>2</sup> /b	Fb/EJ	1	-1/2Fb+1/2Fx+1/2Fx <sup>2</sup> /b-1/2qx <sup>3</sup> /b	0	0	1-2x/b+x <sup>2</sup> /b <sup>2</sup>	(-5/24+0)Fb <sup>2</sup> /EJ	1/3Xb/EJ	5/8Fb <sup>2</sup> /EJ	-3/8Fb										
BC	0	Fb-√5/5Fx	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0							
AC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0						
CA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0					
CB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0					
DB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0					
BD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
DE	0	-x/b	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
ED	0	1-x/b	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
CD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
DC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
FE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
EF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
FE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
FC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
CF	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
totali																																											

Sviluppi di calcolo iperstatica



$$L_{DE}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{ED}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FE}^{xx} = \int_0^b (1) 1/EJ dx = [x]_0^b 1/EJ$$

$$= (b) 1/EJ = b/EJ$$

$$L_{FC}^{xx} = \int_0^b (1 - 2x/b + x^2/b^2) 1/EJ dx = [x - x^2/b + 1/3 x^3/b^2]_0^b 1/EJ$$

$$= (b - b + 1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{CF}^{xx} = \int_0^b (x^2/b^2) 1/EJ dx = [1/3 x^3/b^2]_0^b 1/EJ$$

$$= (1/3 b) 1/EJ = 1/3 b/EJ$$

$$L_{EF}^{xo} = \int_0^b (-1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (1) \theta dx = [-1/6 x^3/b^2]_0^b Fb 1/EJ + [x]_0^b \theta$$

$$= (-1/6 b) Fb 1/EJ + (b) \theta = 5/6 Fb^2/EJ$$

$$L_{FE}^{xo} = \int_0^b (-1/2 + x/b - 1/2 x^2/b^2) Fb 1/EJ dx + \int_0^b (-1) \theta dx$$

$$= [-1/2 x + 1/2 x^2/b - 1/6 x^3/b^2]_0^b Fb 1/EJ + [-x]_0^b \theta$$

$$= (-1/2 b + 1/2 b - 1/6 b) Fb 1/EJ + (-b) \theta = 5/6 Fb^2/EJ$$

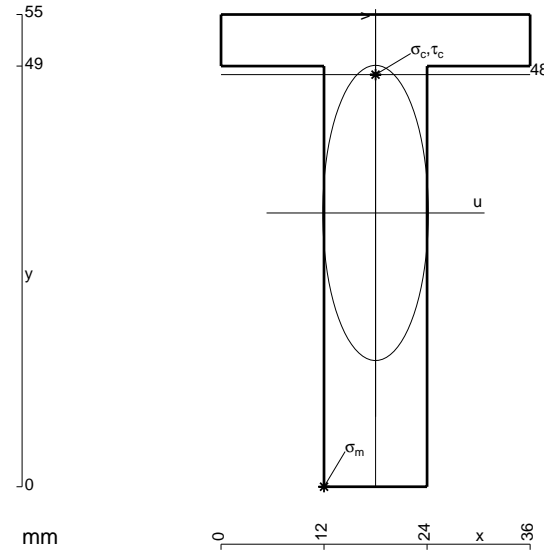
$$L_{FC}^{xo} = \int_0^b (-1/2 + 1/2 x/b + 1/2 x^2/b^2 - 1/2 x^3/b^3) Fb 1/EJ dx$$

$$= [-1/2 x + 1/4 x^2/b + 1/6 x^3/b^2 - 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/2 b + 1/4 b + 1/6 b - 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$

$$L_{CF}^{xo} = \int_0^b (-x^2/b^2 + 1/2 x^3/b^3) Fb 1/EJ dx = [-1/3 x^3/b^2 + 1/8 x^4/b^3]_0^b Fb 1/EJ$$

$$= (-1/3 b + 1/8 b) Fb 1/EJ = -5/24 Fb^2/EJ$$



$$A = 804. \text{ mm}^2$$

$$J_u = 237762. \text{ mm}^4$$

$$J_v = 30384. \text{ mm}^4$$

$$y_g = 31.89 \text{ mm}$$

$$N = -2182. \text{ N}$$

$$T_y = -1091. \text{ N}$$

$$M_x = 1805600. \text{ Nmm}$$

$$x_m = 12. \text{ mm}$$

$$u_m = -6. \text{ mm}$$

$$v_m = -31.89 \text{ mm}$$

$$\sigma_m = N/A - Mv/J_u = 239.4 \text{ N/mm}^2$$

$$x_c = 18. \text{ mm}$$

$$y_c = 48. \text{ mm}$$

$$v_c = 16.11 \text{ mm}$$

$$\sigma_c = N/A - Mv/J_u = -125.1 \text{ N/mm}^2$$

$$\tau_c = 1.738 \text{ N/mm}^2$$

$$\sigma_\varphi = \sqrt{\sigma^2 + 3\tau^2} = 125.1 \text{ N/mm}^2$$

$$S = 4544. \text{ mm}^3$$

