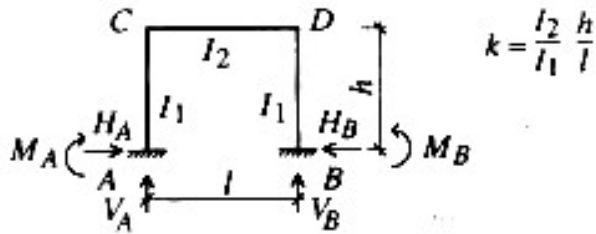
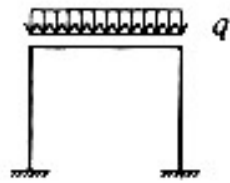


Proračun uklještenih ramova – vertikalno opterećenje

1



$$k = \frac{I_2}{I_1} \frac{h}{l}$$



$$H = H_A = H_B = \frac{ql^2}{4h(k+2)}$$

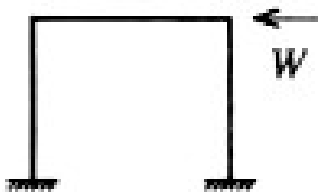
$$V_A = V_B = \frac{ql}{2}$$

$$M_A = M_B = \frac{ql^2}{12(k+2)} = H \frac{h}{3}$$

$$M_C = M_D = \frac{ql^2}{6(k+2)} = -2H \frac{h}{3}$$

Uklješteni ramovi – horizontalno opterećenje

2



$$H_A = -H_B = \frac{W}{2}$$

$$V_A = -V_B = \frac{3Whk}{l(6k+1)}$$

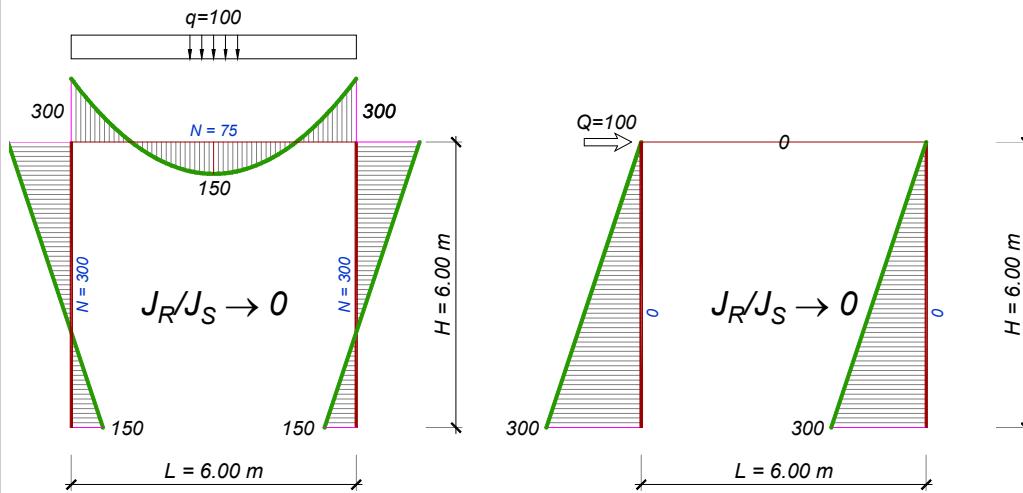
$$M_A = -M_B = \frac{Wh}{2} \frac{3k+1}{6k+1}$$

$$M_C = -M_D = \frac{Wh}{2} \frac{3k}{6k+1}$$

$$k = \frac{J_2}{J_1} \times \frac{H}{L}$$

“beskonačno” kruta ploča

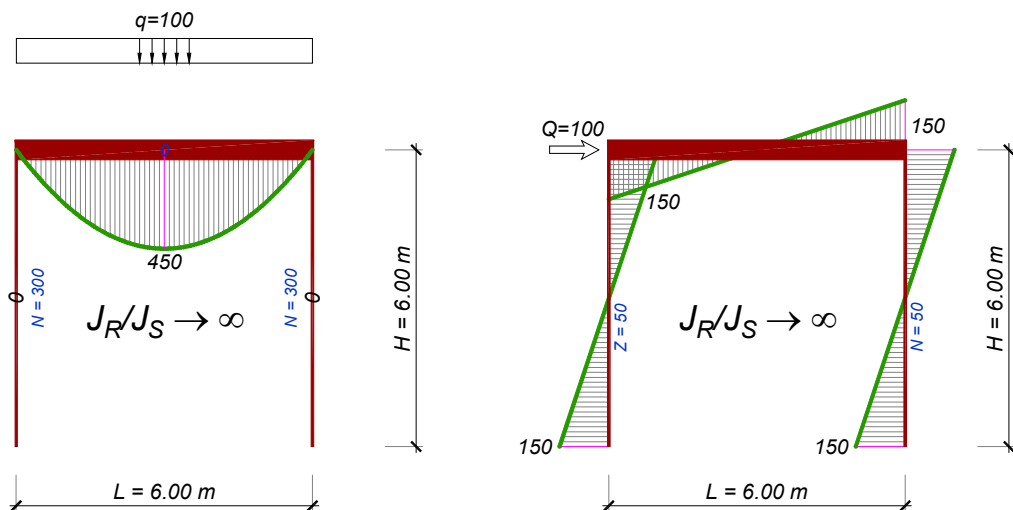
3



$$dx = \frac{Q_1 H^3}{3EJ_1} ; L_i = 2H$$

“beskonačno” kruta greda

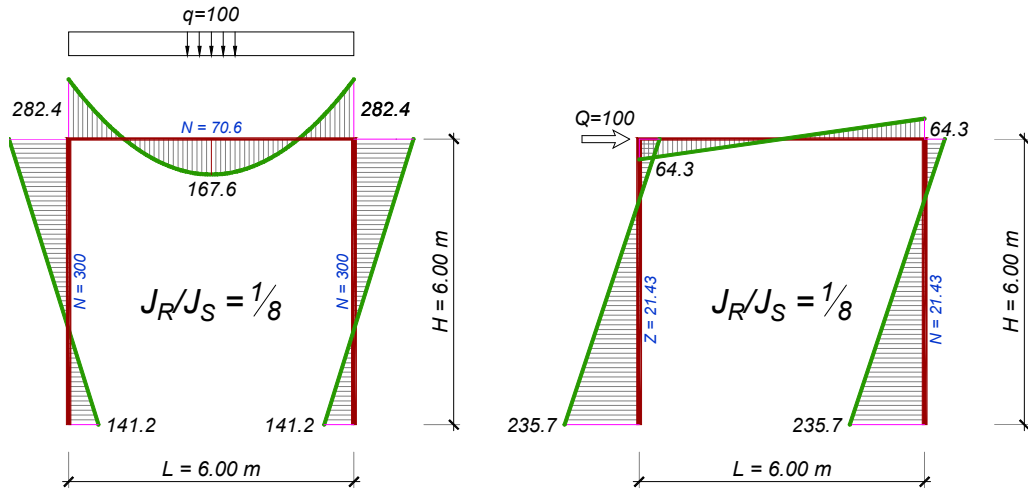
4



$$dx = \frac{Q_1 H^3}{12EJ_1} ; L_i = H$$

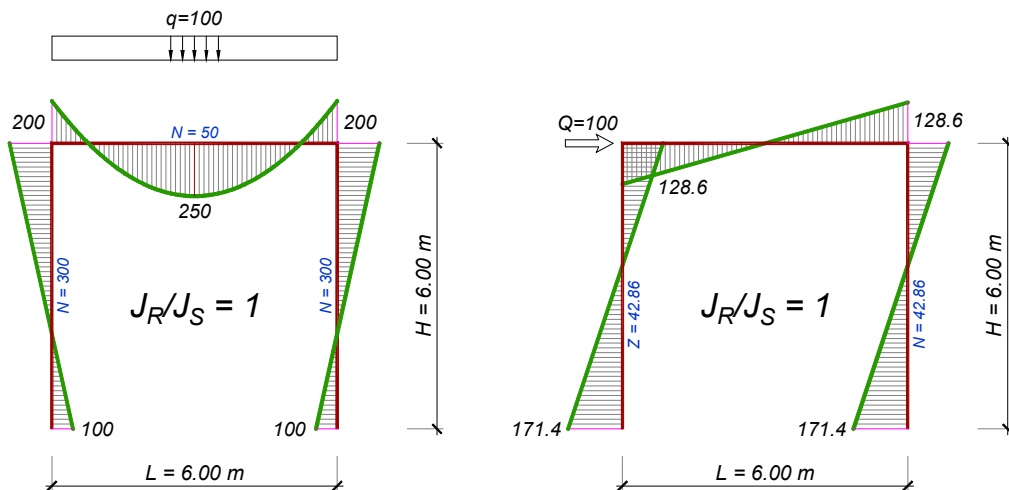
Greda 30/30 cm, stubovi 30/60 cm

5



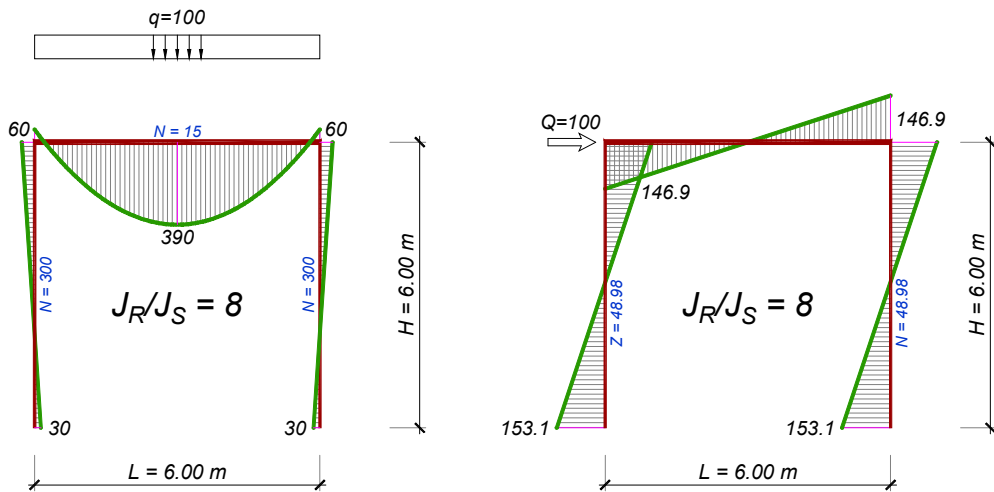
Greda 30/60 cm, stubovi 30/60 cm

6



Greda 30/60 cm, stubovi 30/30 cm

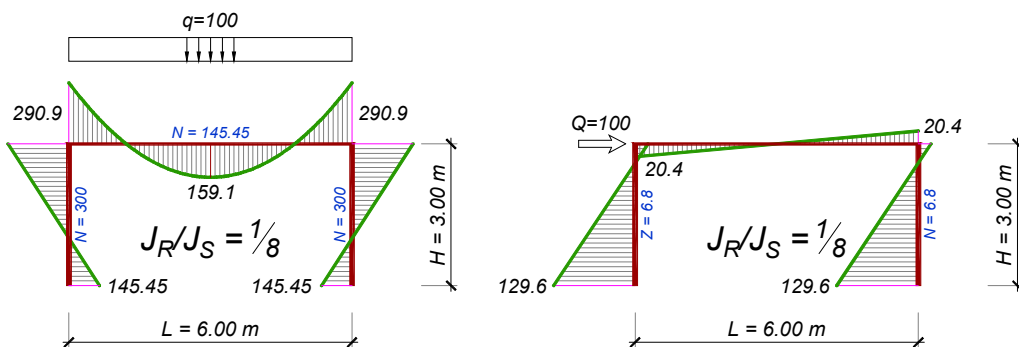
7



$$dx \approx \frac{Q_1 H^3}{12 E J_1} ; L_i \approx H$$

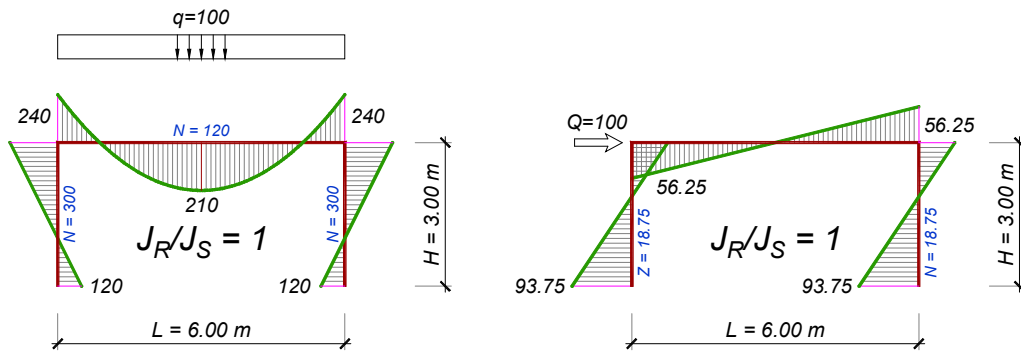
Greda 30/30 cm, kratki stubovi 30/60 cm

8



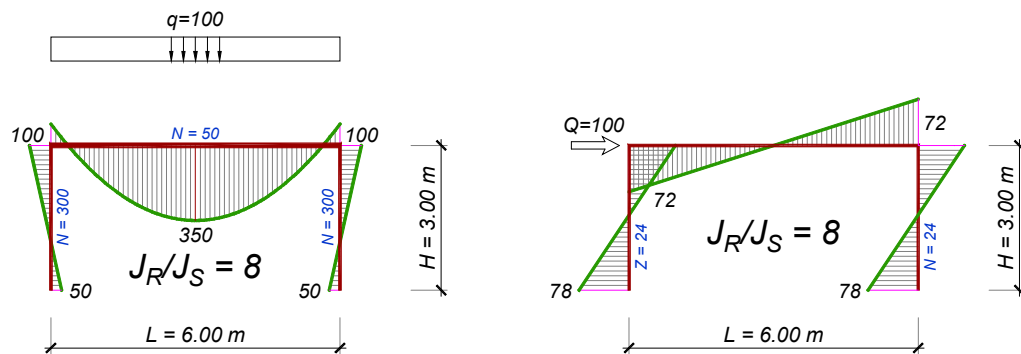
Greda 30/60 cm, kratki stubovi 30/60 cm

9



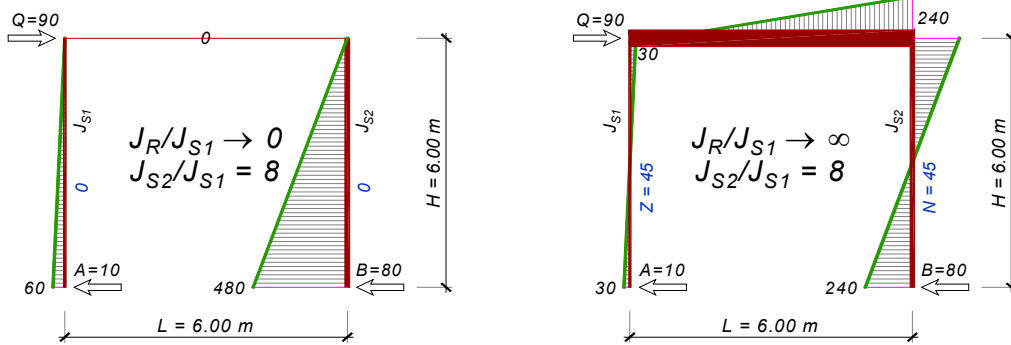
Greda 30/60 cm, kratki stubovi 30/30 cm

10



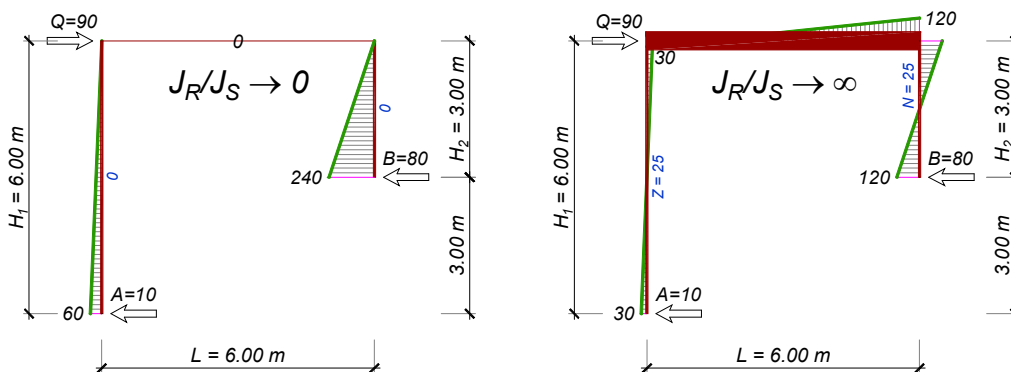
Stubovi različite krutosti

11



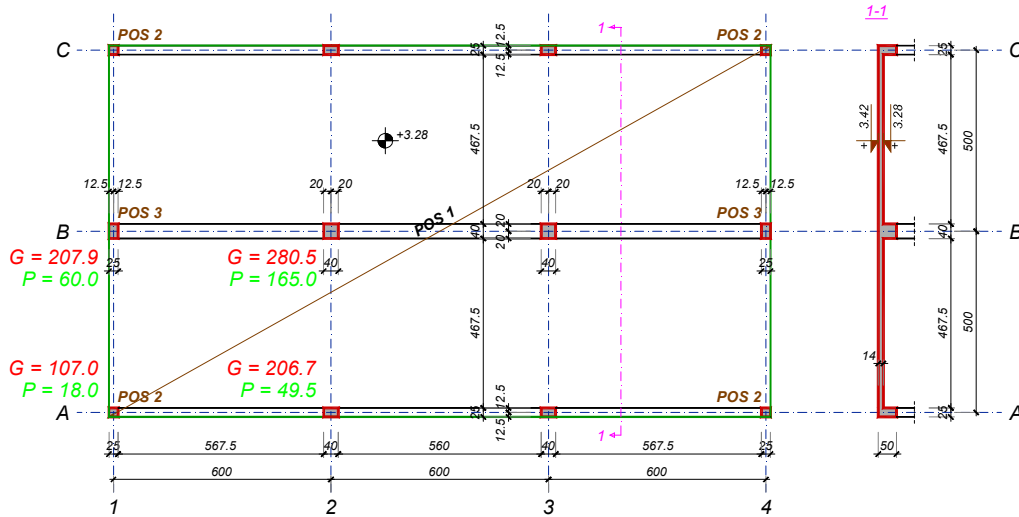
Stubovi različite krutosti i visine

12



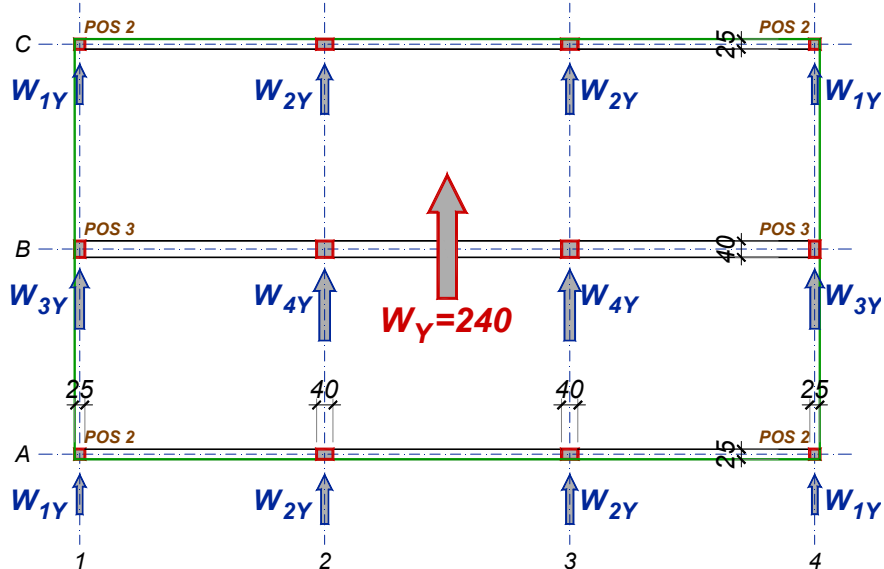
Sile u stubovima (vertikalno opterećenje) - konstrukcija iz primera P7 -

13



Vetar - poprečni pravac

14



Vetar - poprečni pravac

15

$$W_Y = 4W_{1Y} + 4W_{2Y} + 2W_{3Y} + 2W_{4Y} = 240 \text{ kN}$$

$$J_{y,S1} = \frac{25 \times 25^3}{12} = 32,552 \text{ cm}^4 ; J_{y,S2} = \frac{40 \times 25^3}{12} = 52,083 \text{ cm}^4$$

$$J_{y,S3} = \frac{25 \times 40^3}{12} = 133,333 \text{ cm}^4 ; J_{y,S4} = \frac{40 \times 40^3}{12} = 213,333 \text{ cm}^4$$

$$J_y = 4 \times (32,552 + 52,083) + 2 \times (133,333 + 213,333) = 1,031,875 \text{ cm}^4$$

$$W_{1Y} = \frac{32552}{1031875} \times 240 = 7.57 \text{ kN} \Rightarrow M_{S1,Y} = W_{1Y} \times H = 7.57 \times 3.5 = 26.5 \text{ kNm}$$

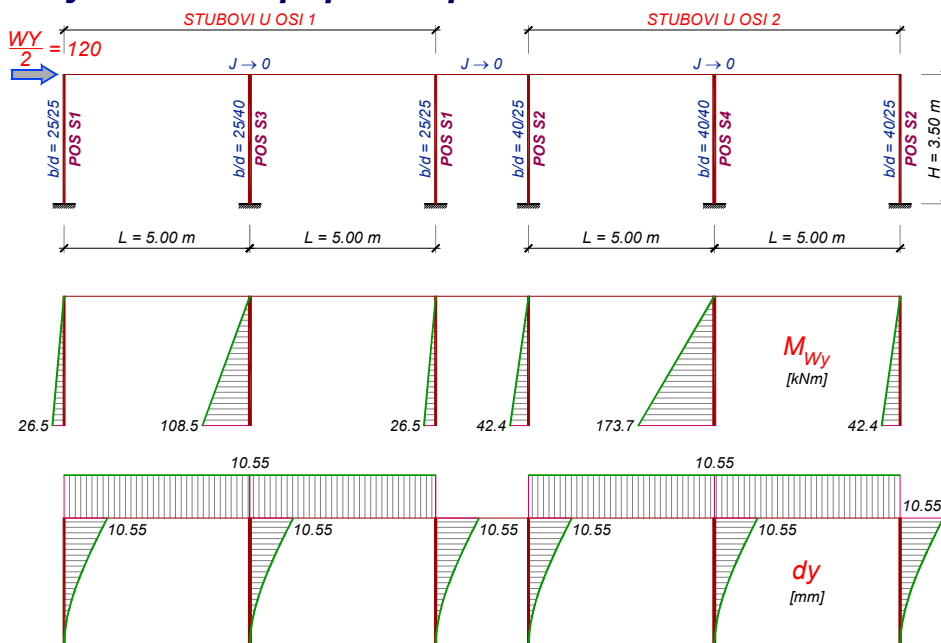
$$W_{2Y} = \frac{52083}{1031875} \times 240 = 12.11 \text{ kN} \Rightarrow M_{S2,Y} = 12.11 \times 3.5 = 42.4 \text{ kNm}$$

$$W_{3Y} = \frac{133333}{1031875} \times 240 = 31.01 \text{ kN} \Rightarrow M_{S3,Y} = 31.01 \times 3.5 = 108.5 \text{ kNm}$$

$$W_{4Y} = \frac{213333}{1031875} \times 240 = 49.62 \text{ kN} \Rightarrow M_{S4,Y} = 49.62 \times 3.5 = 173.7 \text{ kNm}$$

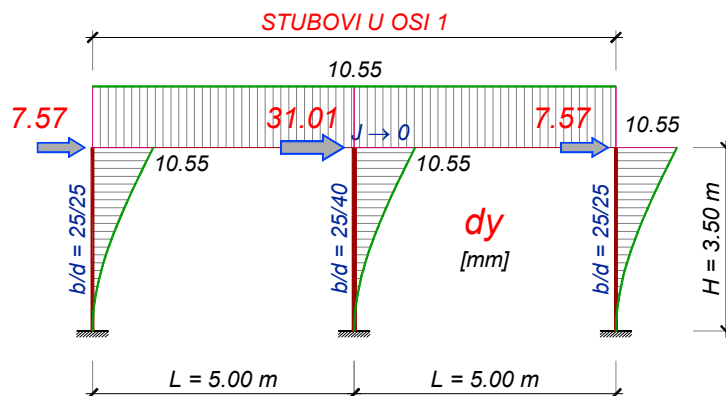
Utjecaji od vetra - poprečni pravac

16



$$dy = \frac{W_y \times H^3}{3EJ_y} = \frac{240 \times 3.5^3}{3 \times 31.5 \times 10^6 \times 1031875 \times 10^{-8}} = 10.55 \times 10^{-3} \text{ m} = 10.55 \text{ mm}$$

17



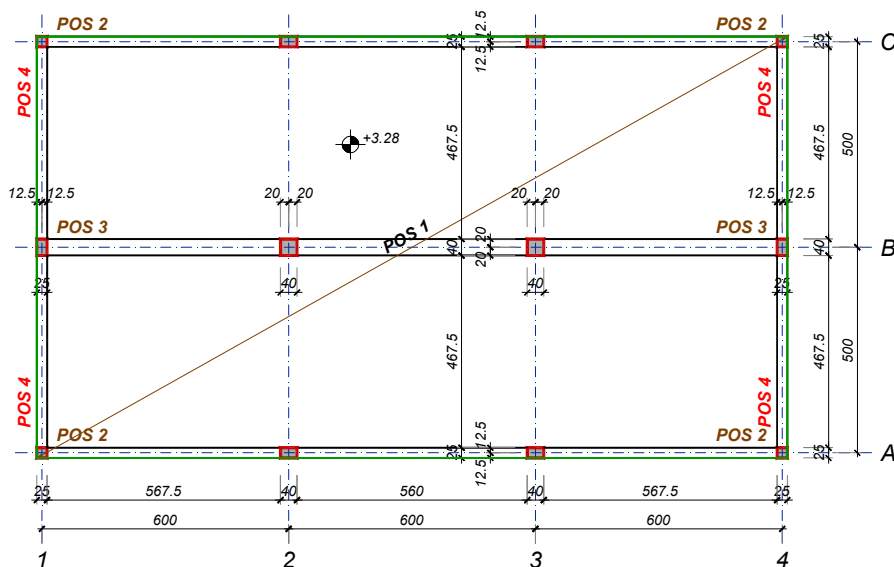
$$dy = \frac{W_{1Y} \times H^3}{3EJ_{y,S1}} = \frac{7.57 \times 3.5^3}{3 \times 31.5 \times 10^6 \times 32552 \times 10^{-8}} = 10.55 \times 10^{-3} \text{ m} = 10.55 \text{ mm}$$

$$dy_{dop.} = \frac{H}{600} = \frac{3.5}{600} = 5.83 \times 10^{-3} \text{ m} = 5.83 \text{ mm}$$

Ojačavanje konstrukcije u poprečnom pravcu

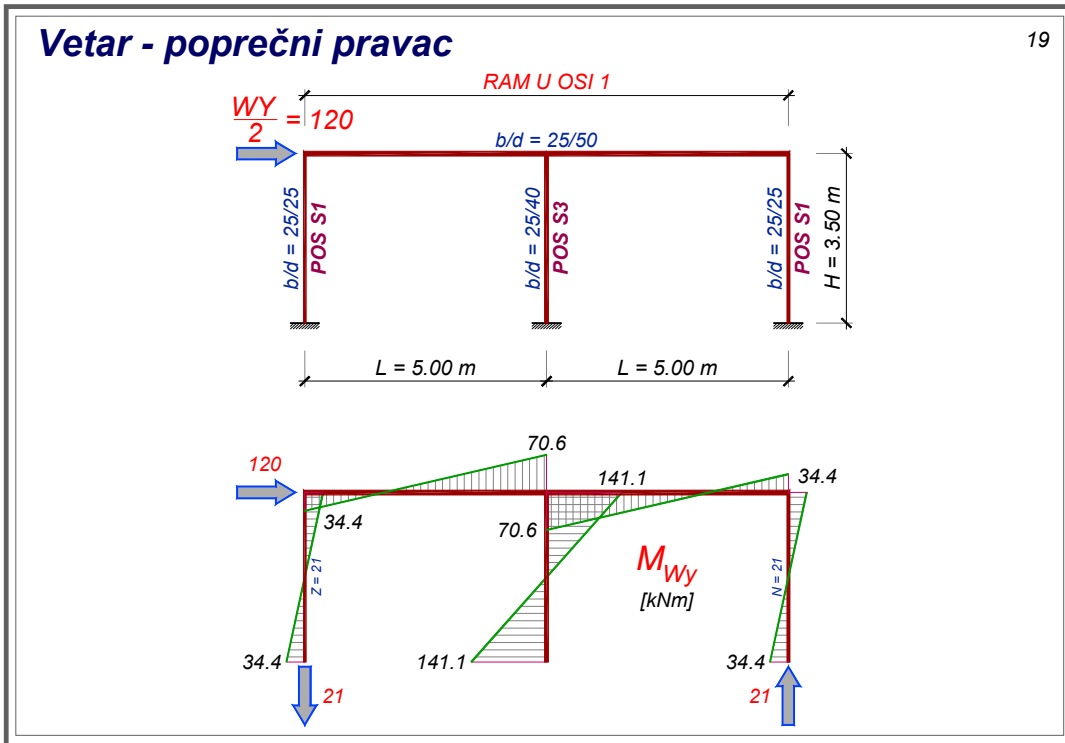
18

Formiranje ramova u osama 1 i 4 (postojeći stubovi povezani gredama **POS 4**, istih dimenzija kao POS 2 u osama A i C)



Vetar - poprečni pravac

19



$$W_Y/2 = 2W_{1Y} + W_{3Y} = 240/2 = 120 \text{ kN}$$

20

$$J_{y,S1} = \frac{25 \times 25^3}{12} = 32\,552 \text{ cm}^4 ; J_{y,S3} = \frac{25 \times 40^3}{12} = 133\,333 \text{ cm}^4$$

$$J_y = 2 \times 32\,552 + 133\,333 = 198\,438 \text{ cm}^4$$

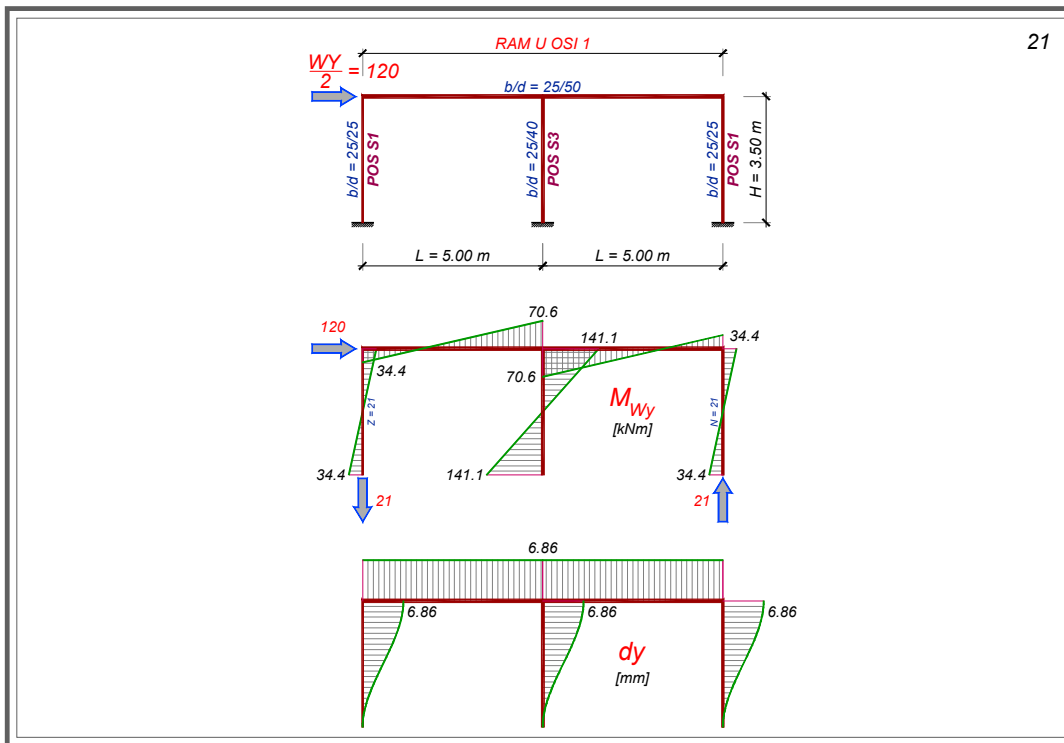
$$W_{1Y} = \frac{32\,552}{198\,438} \times 120 = 19.69 \text{ kN} \Rightarrow M_{S1,Y} \approx \frac{19.69 \times 3.5}{2} = 34.4 \text{ kNm}$$

$$W_{3Y} = \frac{133\,333}{198\,438} \times 120 = 80.63 \text{ kN} \Rightarrow M_{S3,Y} \approx \frac{80.63 \times 3.5}{2} = 141.1 \text{ kNm}$$

$$-A_{Wy} = C_{Wy} = \frac{34.4 + \frac{141.1}{2}}{5.0} = 21 \text{ kN}$$

$$dy = \frac{W_Y \times H^3}{12EJ_y} = \frac{120 \times 3.5^3}{12 \times 31.5 \times 198\,438 \times 10^{-2}} = 6.86 \times 10^{-3} \text{ m}$$

$$dy \approx 6.86 \text{ mm} > dy_{dop.} = 5.83 \text{ mm} = \frac{H}{600}$$



22

Ojačavanje konstrukcije u poprečnom pravcu

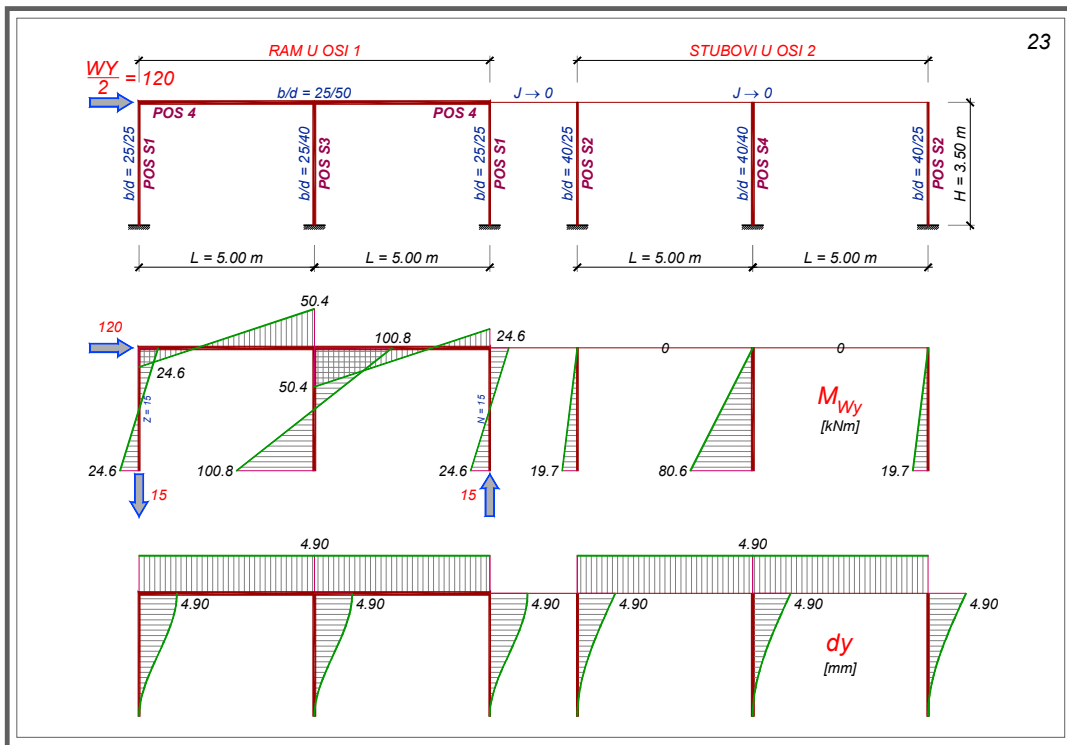
Kako je pomeranje i dalje prekoračeno, postoji opcija da se stubovi povećaju dovoljno da se pomeranje smanji do dopuštene vrednosti, ili da se u proračun uključe i elementi koji realno postoje u konstrukciji, ali je njihova krutost manja od krutosti ramova pa su u prethodnom koraku zanemareni (konzolni stubovi u osama 2 i 3).

Horizontalna sila će ponovo biti raspodeljena na pojedine stubove izjednačavanjem pomeranja njihovih vrhova, pri čemu će za pomeranja u ramovima (ose 1 i 4) biti usvojena približna vrednost

$$dy \approx \frac{W_i \times H^3}{12EJ_i}$$

a za pomeranja konzolnih stubova (ose 2 i 3):

$$dy = \frac{W_i \times H^3}{3EJ_i}$$



$$W_Y/2 = 2W_{1Y} + W_{3Y} + 2W_{2Y} + W_{4Y} = 240/2 = 120 \text{ kN}$$

$$J_{y,S1} = \frac{25 \times 25^3}{12} = 32\,552 \text{ cm}^4 ; J_{y,S2} = \frac{40 \times 25^3}{12} = 52\,083 \text{ cm}^4$$

$$J_{y,S3} = \frac{25 \times 40^3}{12} = 133\,333 \text{ cm}^4 ; J_{y,S4} = \frac{40 \times 40^3}{12} = 213\,333 \text{ cm}^4$$

$$\frac{J_y}{2} = 2 \times (4 \times 32\,552 + 52\,083) + (4 \times 133\,333 + 213\,333) = 1\,111\,250 \text{ cm}^4$$

$$S_{1Y} = \frac{4 \times 32\,552}{1\,111\,250} \times 120 = 14.06 \text{ kN} \Rightarrow M_{S1,Y} \approx \frac{14.06 \times 3.5}{2} = 24.6 \text{ kNm}$$

$$S_{2Y} = \frac{52\,083}{1\,111\,250} \times 120 = 5.62 \text{ kN} \Rightarrow M_{S2,Y} = 5.62 \times 3.5 = 19.7 \text{ kNm}$$

$$S_{3Y} = \frac{4 \times 133\,333}{1\,111\,250} \times 120 = 57.59 \text{ kN} \Rightarrow M_{S3,Y} \approx \frac{57.59 \times 3.5}{2} = 100.8 \text{ kNm}$$

$$S_{4Y} = \frac{213\,333}{1\,111\,250} \times 120 = 23.04 \text{ kN} \Rightarrow M_{S4,Y} = 23.04 \times 3.5 = 80.6 \text{ kNm}$$

Aksijalne sile u stubovima u osi 1 (i osi 4) usled vetra:

25

$$-A_{sy} = C_{sy} = \frac{24.6 + \frac{100.8}{2}}{5.0} = 15 \text{ kN}$$

Pomeranje u poprečnom pravcu:

$$dy \approx \frac{W_{1Y} \times H^3}{12EJ_{y,S1}} = \frac{14.06 \times 3.5^3}{12 \times 31.5 \times 10^6 \times 32552 \times 10^{-8}} = 4.90 \times 10^{-3} \text{ m}$$

odnosno:

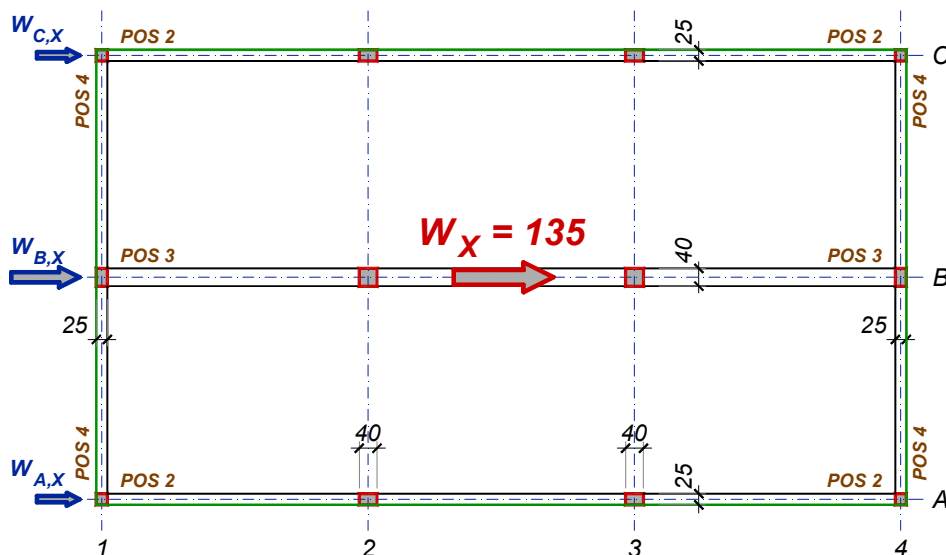
$$dy = \frac{W_{2Y} \times H^3}{3EJ_{y,S2}} = \frac{5.62 \times 3.5^3}{3 \times 31.5 \times 10^6 \times 52083 \times 10^{-8}} = 4.90 \times 10^{-3} \text{ m}$$

$$dy \approx 4.90 \text{ mm} < dy_{dop.} = 5.83 \text{ mm} = \frac{H}{600}$$

Kako je pomeranje u poprečnom pravcu manje od dopuštenog, rešenje se usvaja i pristupa se proveri podužnog pravca.

Vetar – podužni pravac

26



Vetar – podužni pravac

27

$$W_X = W_{X,A} + W_{X,B} + W_{X,C} = 2W_{X,A} + W_{X,B} = 135 \text{ kN}$$

$$\frac{J_{x,B}}{J_{x,A}} = \frac{b_B}{b_A} = \frac{40}{25} = 1.6 \Rightarrow W_{X,A} = W_X \times \frac{J_{x,A}}{J_x} = W_X \times \frac{J_{x,A}}{J_{x,A} \times (1 + 1.6 + 1)} = \frac{W_X}{3.6}$$

Sila koju prihvataju ramovi u osama A i C:

$$W_{X,A} = \frac{135}{3.6} = 37.5 \text{ kN}$$

Sila koju prihvata ram u osi B:

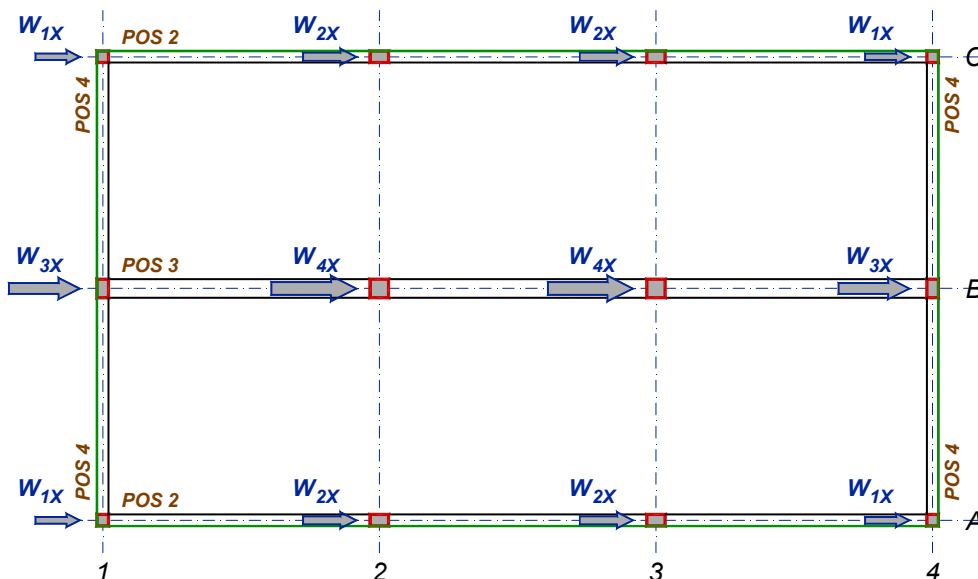
$$W_{X,B} = \frac{1.6 \times 135}{3.6} = 60 \text{ kN}$$

Raspodela na pojedine stubove u okviru ramova se sprovodi na isti način kao kod poprečnog pravca.

U nastavku su prikazani dijagrami uticaja za ramove u osama A i B.

Vetar - podužni pravac

28



Vetar - podužni pravac

29

$$W_X = 4W_{1X} + 4W_{2X} + 2W_{3X} + 2W_{4X} = 135 \text{ kN}$$

$$J_{x,S1} = \frac{25 \times 25^3}{12} = 32\,552 \text{ cm}^4 ; J_{x,S2} = \frac{25 \times 40^3}{12} = 133\,333 \text{ cm}^4$$

$$J_{x,S3} = \frac{40 \times 25^3}{12} = 52\,083 \text{ cm}^4 ; J_{x,S4} = \frac{40 \times 40^3}{12} = 213\,333 \text{ cm}^4$$

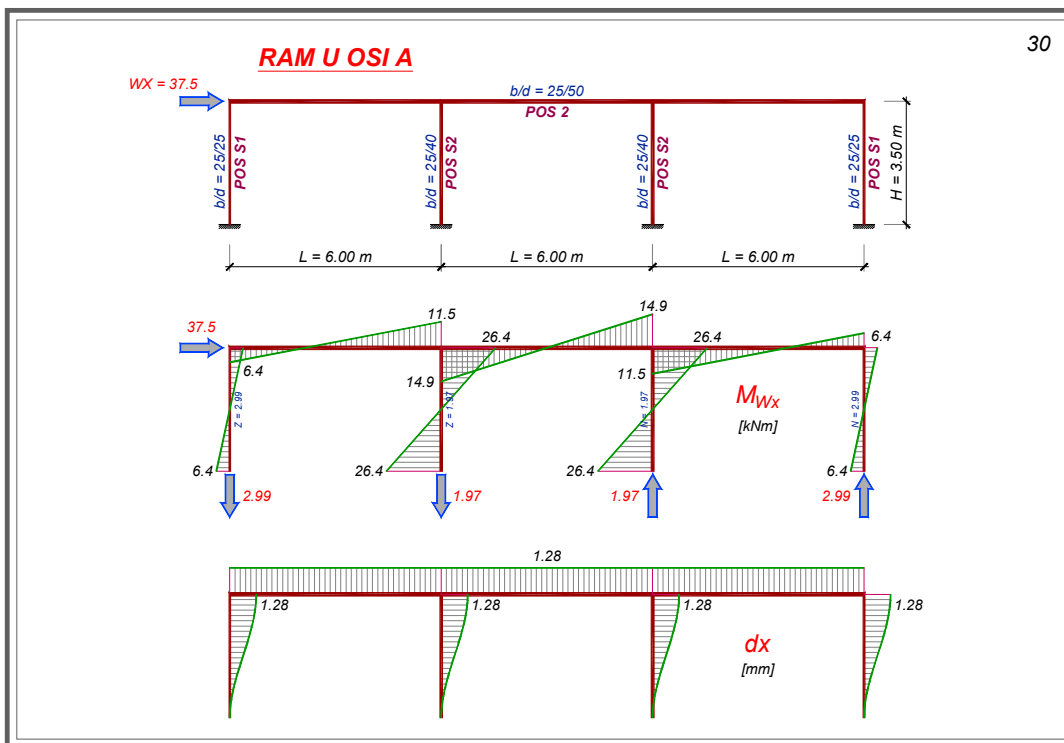
$$J_x = 4 \times (32\,552 + 133\,333) + 2 \times (52\,083 + 213\,333) = 1\,194\,375 \text{ cm}^4$$

$$W_{1X} = \frac{32\,552}{1\,194\,375} \times 135 = 3.68 \text{ kN} \Rightarrow M_{S1,X} \approx \frac{W_{1X} \times H}{2} = \frac{3.68 \times 3.5}{2} = 6.4 \text{ kNm}$$

$$W_{2X} = \frac{133\,333}{1\,194\,375} \times 135 = 15.07 \text{ kN} \Rightarrow M_{S2,X} \approx \frac{15.07 \times 3.5}{2} = 26.4 \text{ kNm}$$

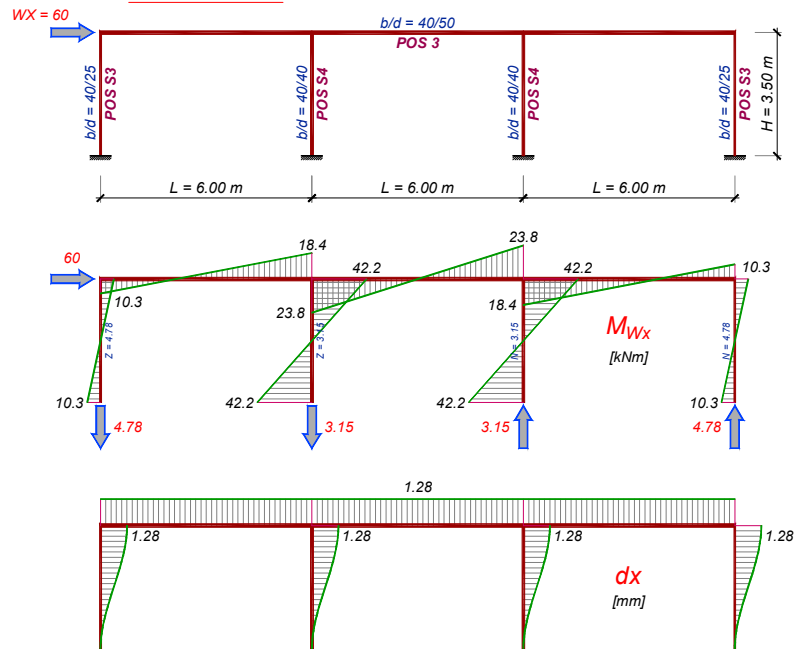
$$W_{3X} = \frac{52\,083}{1\,194\,375} \times 135 = 5.89 \text{ kN} \Rightarrow M_{S3,X} \approx \frac{5.89 \times 3.5}{2} = 10.3 \text{ kNm}$$

$$W_{4X} = \frac{213\,333}{1\,194\,375} \times 135 = 24.11 \text{ kN} \Rightarrow M_{S4,X} = \frac{24.11 \times 3.5}{2} = 42.2 \text{ kNm}$$



RAM U OSI B

31



Vetar - podužni pravac

32

Kontrola pomeranja konstrukcije u podužnom pravcu:

$$dx \approx \frac{W_{1X} \times H^3}{12EJ_{x,S1}} = \frac{3.68 \times 3.5^3}{12 \times 31.5 \times 10^6 \times 32552 \times 10^{-8}} = 1.28 \times 10^{-3} \text{ m}$$

Ili, sa ukupnom silom i ukupnim momentom inercije:

$$dx \approx \frac{W_x \times H^3}{12EJ_x} = \frac{135 \times 3.5^3}{12 \times 31.5 \times 10^6 \times 1194375 \times 10^{-8}} = 1.28 \times 10^{-3} \text{ m}$$

$$dx \approx 1.28 \text{ mm} < dx_{dop.} = 5.83 \text{ mm} = \frac{H}{600}$$

Kako je pomeranje i u podužnom pravcu manje od dopuštenog, rešenje se usvaja i pristupa dimenzionisanju stubova.

Dimenzionisanje stubova B1,B4

33

U poprečnom pravcu, ovi stubovi su dimenzija $b/d = 25/40$ cm (srednji stubovi u ivičnim ramovima, osa 1, slajd 23). Dužina izvijanja stuba je PRIBLIŽNO jednaka spratnoj visini:

$$i_d = \frac{40}{\sqrt{12}} = 11.55 \text{ cm} \Rightarrow \lambda = \frac{L_{i,d}}{i_d} = \frac{350}{11.55} = 30.3 \quad \frac{a}{d} = \frac{4.5}{40} = 0.113$$

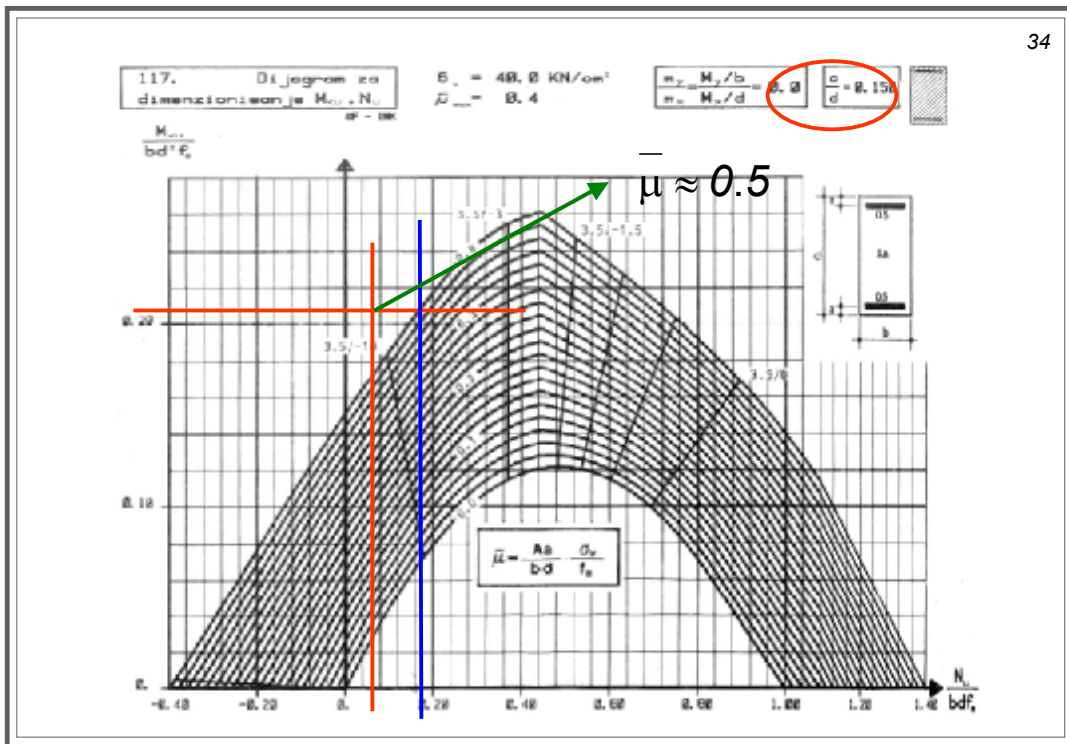
ZANEMARUJE SE UTICAJ IZVIJANJA !!!

Kako su momenti alternativni, presek se armira simetrično i dimenzioniše pomoću dijagrama interakcije

$$\pm M_u = 1.8 \times 100.8 = 181.4 \text{ kNm (vetar } W_y, \text{ srednji stub)}$$

$$N_{u,\min} = 1.0 \times 207.9 = 207.9 \text{ kN (slajd 13, slajd 23: } N_w=0)$$

$$\left. \begin{aligned} m_u &= \frac{181.4 \times 10^2}{25 \times 40^2 \times 2.05} = 0.221 \\ n_u &= \frac{207.9}{25 \times 40 \times 2.05} = 0.101 \end{aligned} \right\} \frac{a}{d} = \frac{6}{40} = 0.15 \Rightarrow \bar{\mu} \approx 0.5$$



34

Dimenzionisanje stubova B1,B4

35

$$N_{u,max} = 1.6 \times 207.9 + 1.8 \times 60 = 440.7 \text{ kN (slajd 13, slajd 23)}$$

$$\left. \begin{aligned} m_u &= \frac{181.4 \times 10^2}{25 \times 40^2 \times 2.05} = 0.221 \\ n_u &= \frac{440.7}{25 \times 40 \times 2.05} = 0.215 \end{aligned} \right\} \frac{a}{d} = \frac{6}{40} = 0.15 \Rightarrow \bar{\mu} \approx 0.4 < 0.5$$

$$A_{a1} = A_{a2} = \frac{0.5}{2} \times \frac{25 \times 40 \times 2.05}{40} = 12.87 \text{ cm}^2$$

$$A_{a1,min.} = 0.2 \times 10^{-2} \times 25 \times 40 = 2.0 \text{ cm}^2 < 12.87 \text{ cm}^2$$

Merodavna je kombinacija sa MINIMALNOM normalnom silom.

usvojeno: **±5RØ19** (± 14.20 cm²)

Dimenzionisanje stubova B1,B4

36

Kao delovi podužnih ramova, ovi stubovi su dimenzija $b/d = 40/25 \text{ cm}$
(krajnji stubovi u srednjem ramu, osa B, slajd 31).

$$\pm M_u = 1.8 \times 10.3 = 18.5 \text{ kNm (vetar, podužni pravac)}$$

$$N_{u,min} = 1.0 \times 207.9 + 1.8 \times (-4.78) = 199.3 \text{ kN (slajd 13, slajd 31)}$$

$$m_u = \frac{18.5 \times 10^2}{40 \times 25^2 \times 2.05} = 0.036$$

$$n_u = \frac{199.3}{40 \times 25 \times 2.05} = 0.097$$

$$\frac{a}{d} = \frac{4.5}{25} = 0.18 \Rightarrow \bar{\mu} = 0$$

