SVEUČILIŠTE U SPLITU
GRAĐEVINSKO-ARHITEKTONSKI FAKULTET

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RADNI MATERIJALI ZA POMOĆ PRI IZRADI PROGRAMSKOG ZADATKA IZ PREDMETA: **OSNOVE BETONSKIH KONSTRUKCIJA**

Split, 2008.

NAPOMENA

Ovi radni materijali izrađeni su kao vodilja studentima pri rješavanju programa iz predmeta „Osnove betonskih konstrukcija“ na Sveučilišnom studiju Građevinsko-arhitektonskog fakulteta u Splitu.

Programski zadatak je dimenzionirati jednu relativno jednostavnu armiranobetonsku građevinu. Ovi radni materijali rađeni su s namjerom da budu vodič u izradi programa, ali i uzorni primjerak kako konačni projekt treba izgledati.

Autori

SADRŽAJ

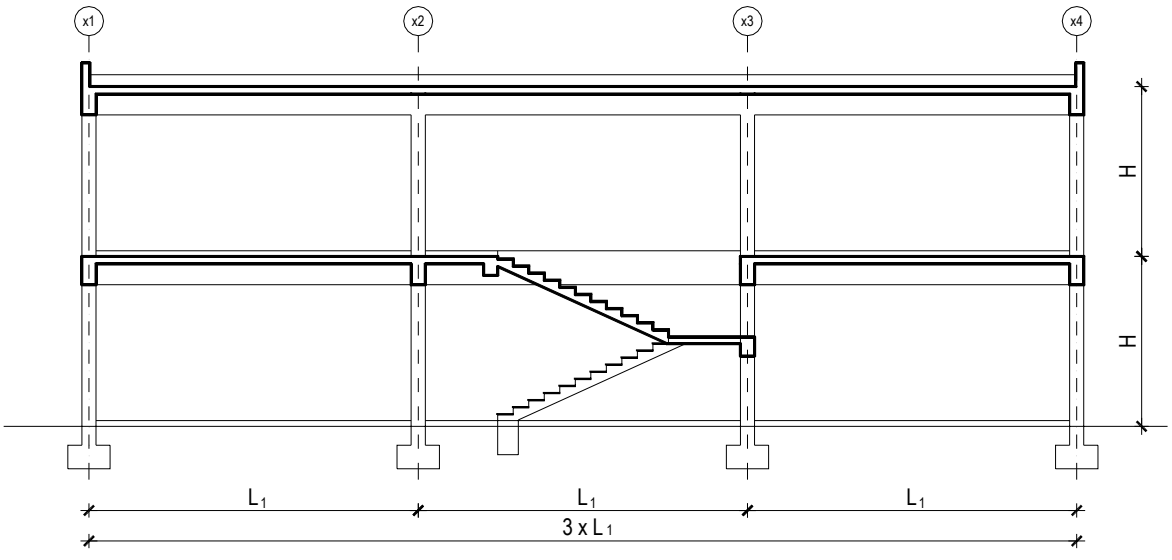
ZADATAK

Na priloženim skicama dana je shema nosivih armirano betonskih konstrukcija jednog objekta. Potrebno je izraditi planove pozicija, proračun i planove armature nosivih armirano betonskih konstrukcija.

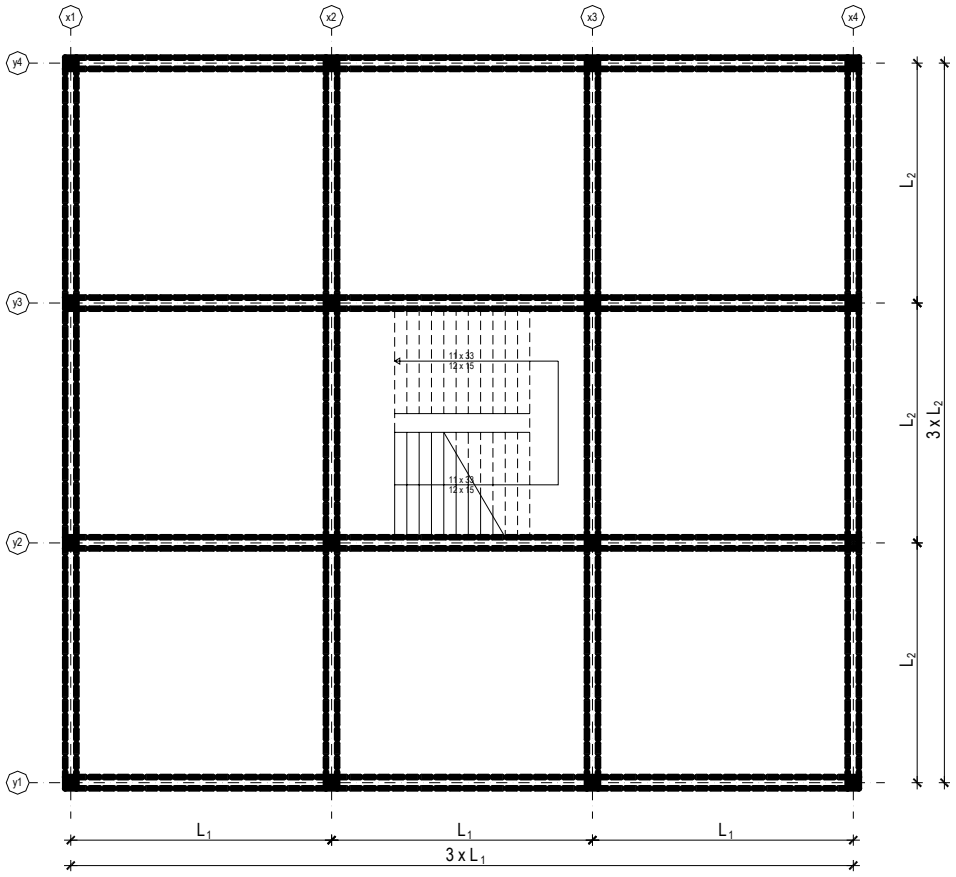
U tablici su dane zadane veličine.

Oznaka	Veličina	Jedinica	Opis
L_1	**7.0**	(m)	'raster' u uzdužnom smijeru
L_2	**6.4**	(m)	'raster' u poprečnom smijeru
H	**3.6**	(m)	visina etaža
p	**4.0**	(kN/m^2)	pokretno opterećenje
$\sigma_{tla,dop}$	**0.50**	(MN/m^2)	dopušteno naprezanje u tlu
Z_v	**3**		zona vjetra
Z_p	**8**		zona potresa
S	**B 500B**		armatura
C	**C 30/37**		klasa betona

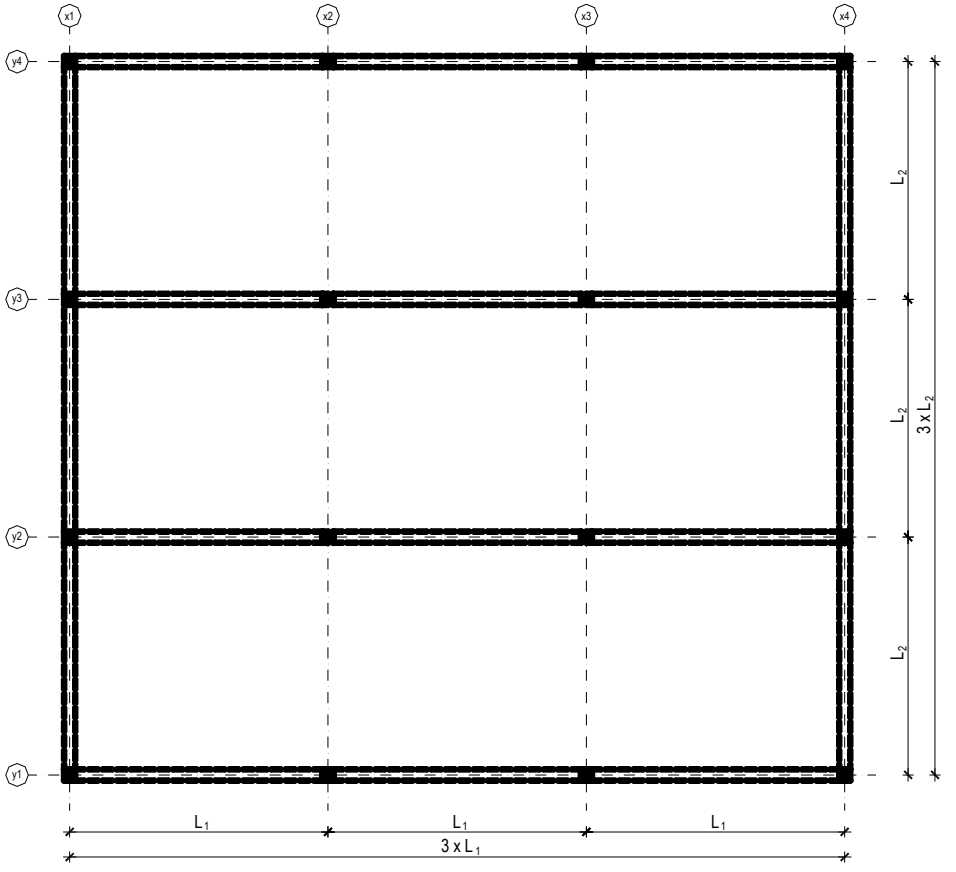
(i) Presjek



(ii) Međuetaže



(iii) Krovna konstrukcija



1. TEHNIČKI OPIS

Predmet ovog projekta su proračun međukatnih i krovnih konstrukcija jedne armiranobetonske građevine.

Predmetna građevina sastoji se od prizemlja i kata, a namjena građevine je poslovna. Završna ploča kata je ujedno i ravni krov građevine.

Sve međukatne konstrukcije su AB ploče debljine **d=16.0 cm**.

Za vertikalnu komunikaciju između katova predviđene je armiranobetonsko stepenište debljine nosive ploče **d=16.0 cm**.

Za predmetnu građevinu su izvršeni geotehnički istražni radovi. Na osnovi tih istraživanja određeno je dozvoljeno naprezanje u tlu, koje na dubini temeljenja se iznosi σ_{dop} **= 0.44 MPa**.

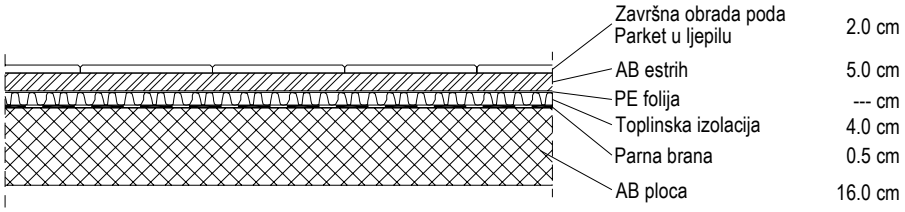
Prema važećim propisima za proračun utjecaja vjetra na građevinu, građevina se gradi se u **III** vjetrovnoj zoni.

Građevina se gradi na lokaciji koja prema važećim propisima spada u **VIII** seizmičku zonu, tj. u kojoj se za povratni period od 500 god, uz vjerojatnost pojave 66.6% očekuje pojava potresa **VIII**° MCS skale.

2. ANALIZA OPTEREĆENJA

2.7 Pozicije 100 – Etaže

a) stalno opterećenje



	d (m)	γ (kN/m^3)	$d \times \gamma$
Pregrade			1.00
Završna obrada poda – parket	0.02	12.0	0.24
AB estrih	0.05	25.0	1.25
Toplinska izolacija	0.04	5.0	0.20
Hidroizolacija	0.005	20.0	0.10
AB. ploča	0.16	25.0	4.00

Ukupno stalno opterećenje: g_{100} = 6.80 (kN/m^2)

b) pokretno opterećenje

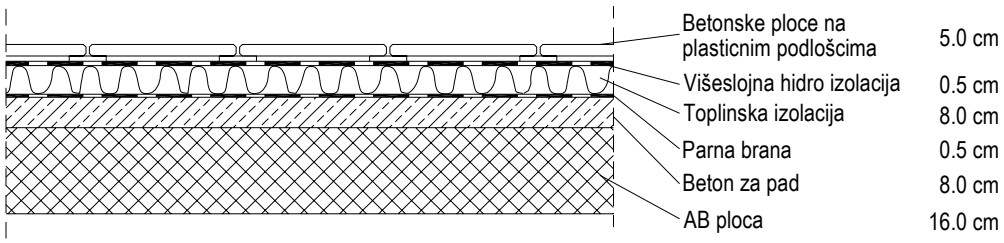
Pokretno opterećenje se uzima prema pravilniku: HRN EN 1991-2-1.

U našem slučaju, zadano je zadatkom.

q_{100} = 4.0 kN/m^2

2.8 Pozicije 200 – Krov

a) stalno opterećenje



	d (m)	γ (kN/m^3)	$d \times \gamma$
Betonske ploče na plastičnim podloščima	0.05	25.0	1.25
Hidroizolacija + parna brana	0.01	20.0	0.20
Toplinska izolacija	0.08	5.0	0.40
Beton za pad	0.08	24.0	1.92
AB. ploča	0.16	25.0	4.00

Ukupno stalno opterećenje: g_{200} = 7.80 (kN/m^2)

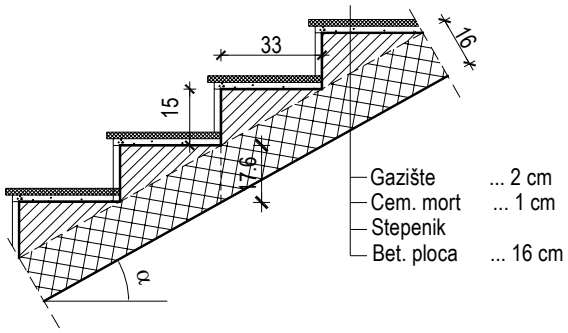
b) pokretno opterećenje

Za pokretno opterećenje uzima se opterećenje snijegom i vjetrom. Opterećenje snijegom za ravne krovove, u područjima gdje je snijeg rijedak (prema pravilniku) iznosi 0.50 kN/m^2, pa se za pokretno opterećenje neprohodnih ravnih krovova može uzeti zamjenjujuća vrijednost:

$q_{200} = s + w \approx 1.0$ kN/m^2

2.9 Stubište

a) stalno opterećenje



$$\text{tg}\,\alpha = \frac{v_{st}}{š_{st}} = \frac{15}{33} = 0.455 \quad ; \quad \alpha = 24.4°$$

$$h' = \frac{h}{\cos\alpha} = \frac{16}{\cos 24.4} = 17.6 \text{ cm}$$

	d (m)	γ (kN/m^3)	$d \times \gamma$
Završna obrada gazišta – kamena ploča	0.02	28.0	0.56
Cementni namaz (max. 1.0 cm)	0.01	20.0	0.20
Stuba	0.075	24.0	1.80
AB. ploča (h'=17.6 cm)	0.176	25.0	4.40

Ukupno stalno opterećenje: g_{st} = 6.96 (kN/m^2)

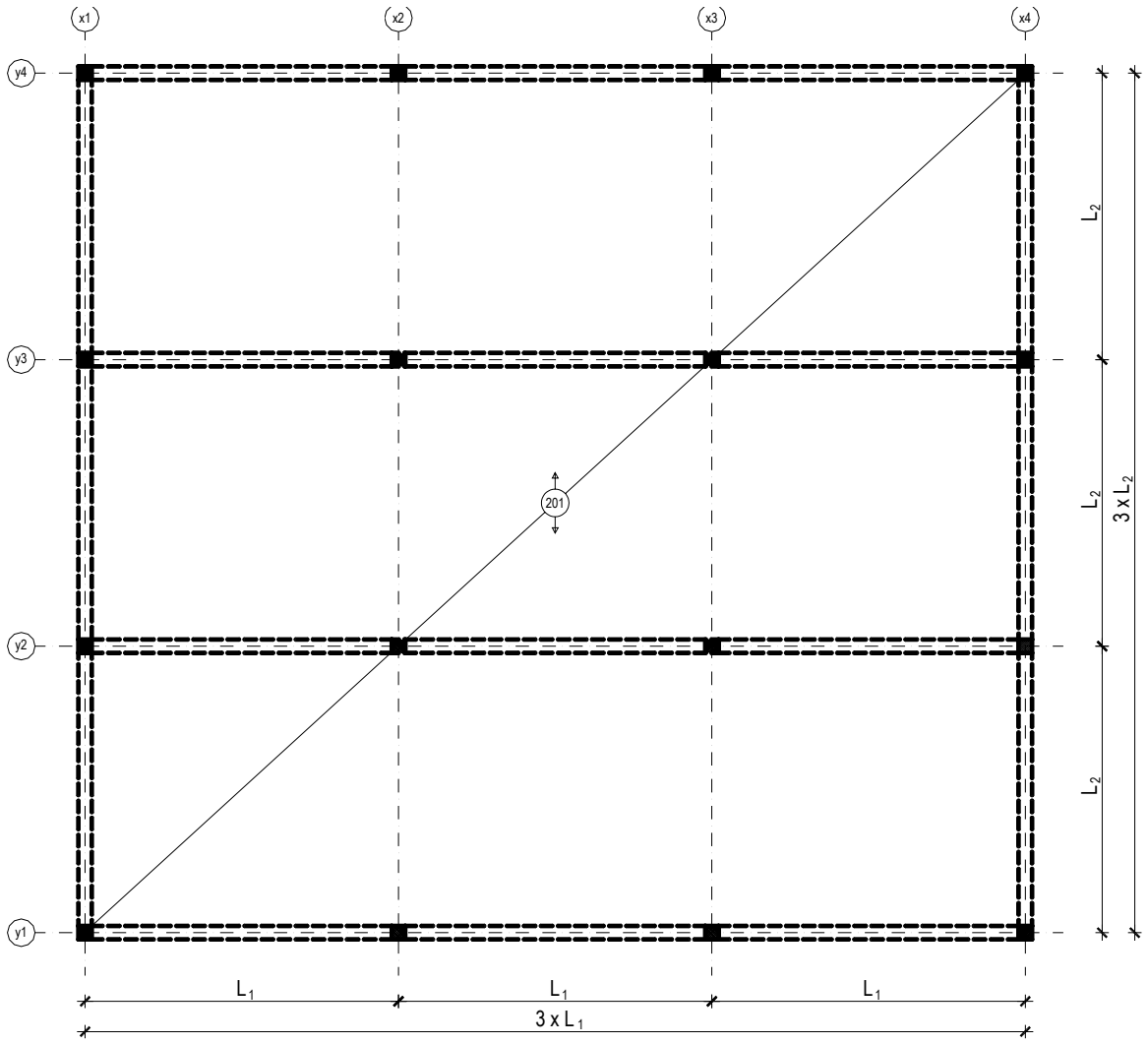
b) pokretno opterećenje

Pokretno opterećenje se uzima prema pravilniku: HRN EN 1991-2-1.

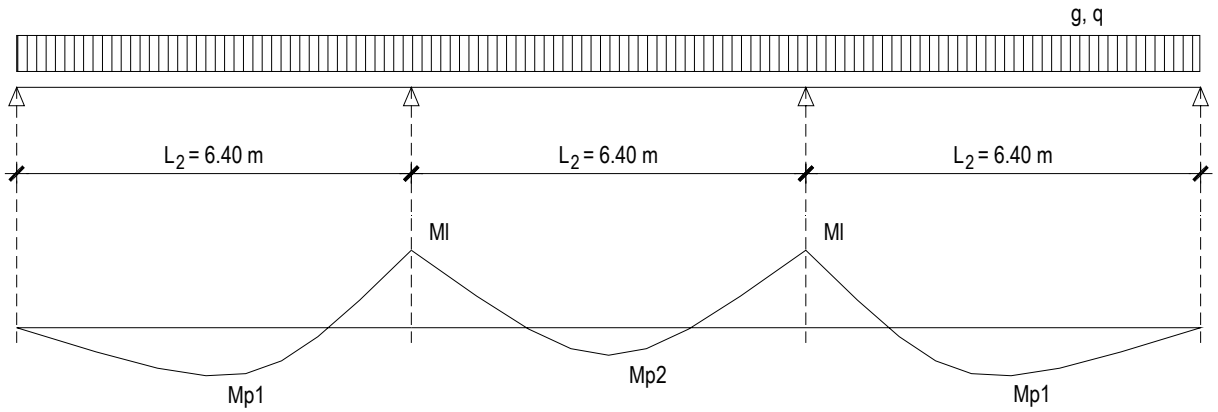
U našem slučaju, uzet ćemo ga jednako kao na pločama.

q_{st} = 4.0 kN/m^2

3. PRORAČUN PLOČA POZICIJA 200



3.1 Proračun pozicije 201



Polje 1

$$M_g = k \cdot g \cdot L_2^2 = 0.080 \cdot 7.80 \cdot 6.4^2 = 25.6 \text{ kNm/m}$$

$$M_q = k \cdot q \cdot L_2^2 = 0.080 \cdot 1.00 \cdot 6.4^2 = 3.3 \text{ kNm/m}$$

$$M_{sd} = \gamma_g \cdot M_g + \gamma_q \cdot M_q = 1.35 \cdot 25.6 + 1.50 \cdot 3.3 = 39.5 \text{ kNm/m}$$

Polje 2

$$M_g = k \cdot g \cdot L_2^2 = 0.025 \cdot 7.80 \cdot 6.4^2 = 8.0 \text{ kNm/m}$$

$$M_q = k \cdot q \cdot L_2^2 = 0.025 \cdot 1.00 \cdot 6.4^2 = 1.0 \text{ kNm/m}$$

$$M_{sd} = \gamma_g \cdot M_g + \gamma_q \cdot M_q = 1.35 \cdot 8.0 + 1.50 \cdot 1.0 = 12.3 \text{ kNm/m}$$

Ležaj

$$M_g = k \cdot g \cdot L_2^2 = -0.100 \cdot 7.80 \cdot 6.4^2 = 31.9 \text{ kNm/m}$$

$$M_q = k \cdot q \cdot L_2^2 = -0.100 \cdot 1.00 \cdot 6.4^2 = 4.1 \text{ kNm/m}$$

$$M_{sd} = \gamma_g \cdot M_g + \gamma_q \cdot M_q = 1.35 \cdot 31.9 + 1.50 \cdot 4.1 = 49.2 \text{ kNm/m}$$

U nastavku je, samo kao orijentacija, prikazan proračun numeričkim modelom. Napravljena su dva modela:

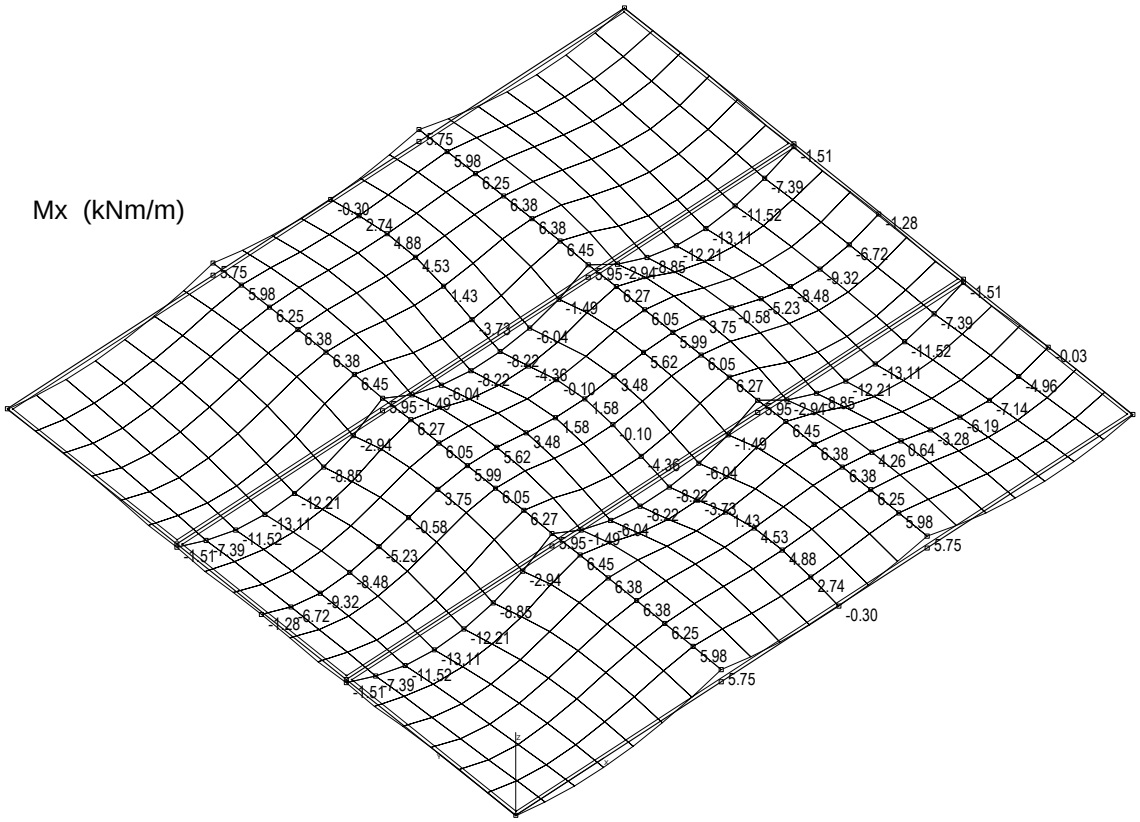
(i) Model sa slobodnim oslanjanjem na sve strane

(ii) Model sa slobodnim oslanjanjem samo u smjeru y osi.

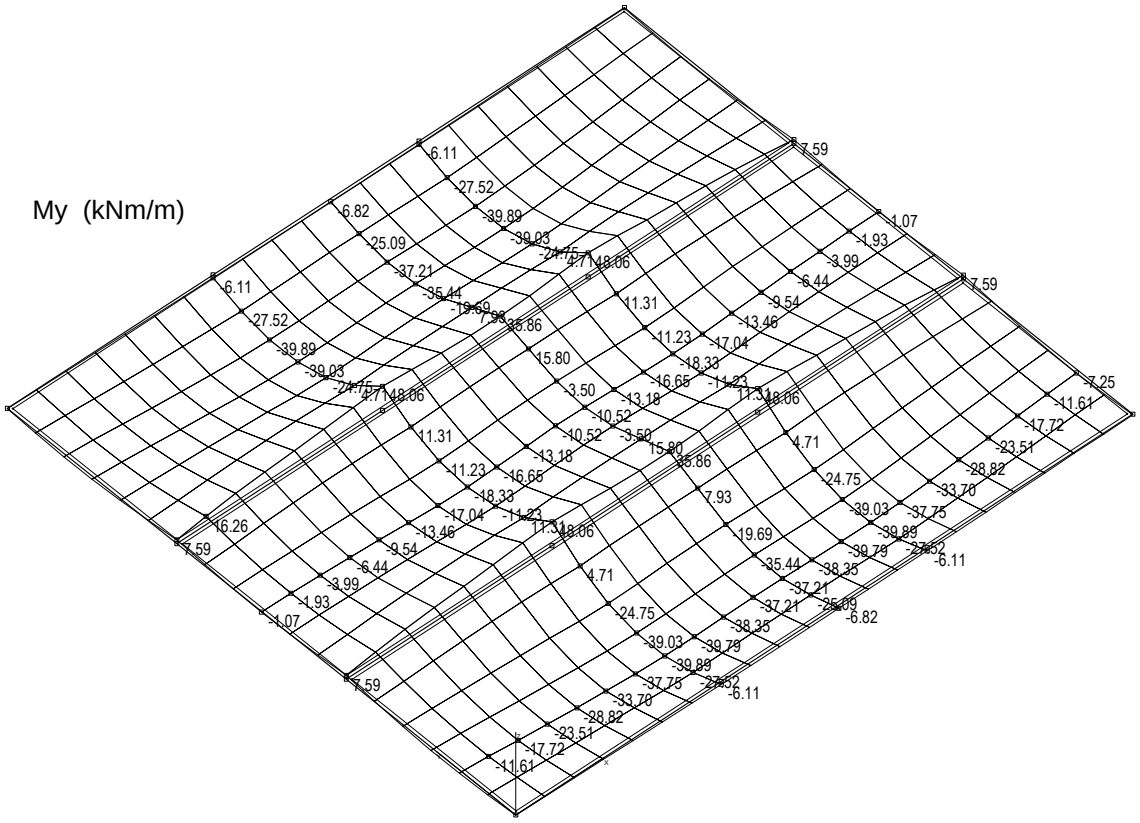
Vidljivo je dobro slaganje „ručno“ i „računalno“ proračunatih veličina. Također je vidljivo da momenti u smjeru x (Mx), koje smo zanemarili ipak postoje.

Prikaz rezultata na numeričkom modelu (i): Model sa slobodnim oslanjanjem na sve strane

Mx (kNm/m)

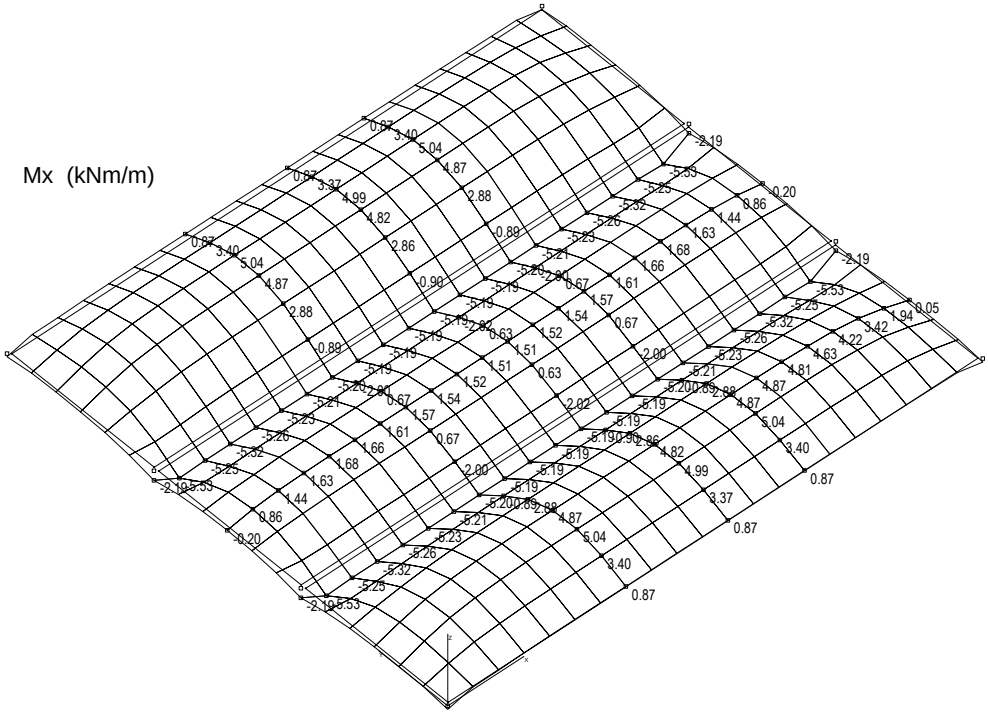


My (kNm/m)

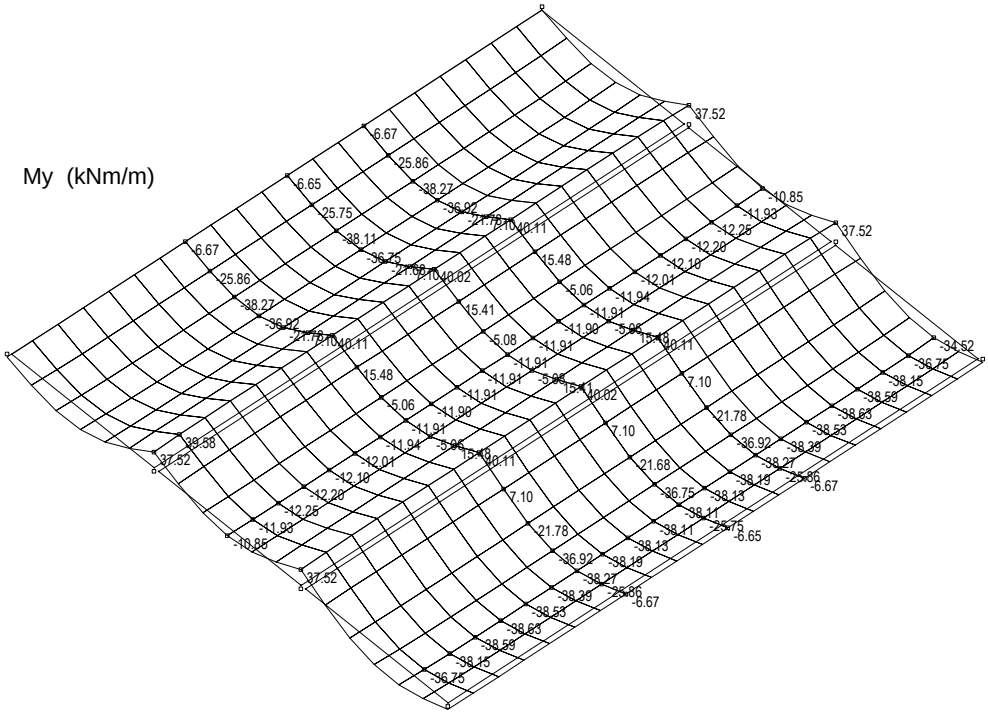


Prikaz rezultata na numeričkom modelu (ii): Model sa slobodnim oslanjanjem samo u smjeru y osi

Mx (kNm/m)



My (kNm/m)

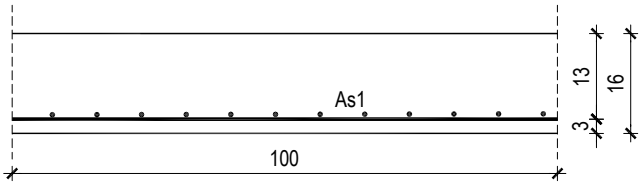


3.2 Dimenzioniranje pozicije 201

Beton: C 30/37; f_{ck}=30.0 MPa $f_{cd} = \frac{f_{ck}}{\gamma_c} = \frac{30.0}{1.5} = 20.0\,\text{MPa}$

Armatura: B 500B; f_{yk}=500.0 MPa $f_{yd} = \frac{f_{yk}}{\gamma_s} = \frac{500.0}{1.15} = 434.8\,\text{MPa}$

Polje 1:



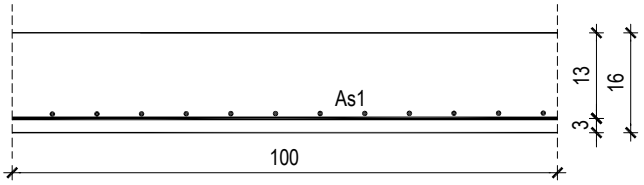
$M_{sd} = 39.5\,\text{kNm}$

$$\mu_{sd} = \frac{M_{sd}}{b_{eff} \cdot d^2 \cdot f_{cd}} = \frac{3950}{100 \cdot 13^2 \cdot 2.0} = 0.117$$

Očitano: $\varepsilon_{s1} = 10.0\,‰ \quad \varepsilon_{c2} = 2.5\,‰ \quad \xi = 0.203 \quad \zeta = 0.920$

$$A_{s1} = \frac{M_{sd}}{\zeta \cdot d \cdot f_{yd}} = \frac{3950}{0.920 \cdot 13 \cdot 43.5} = 7.59\,\text{cm}^2$$

Polje 2:



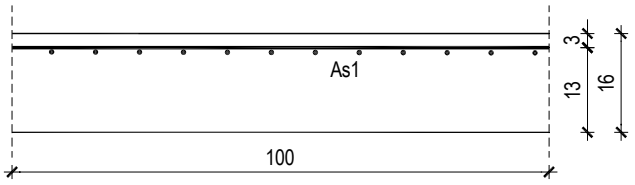
$M_{sd} = 12.3\,\text{kNm}$

$$\mu_{sd} = \frac{M_{sd}}{b_{eff} \cdot d^2 \cdot f_{cd}} = \frac{1230}{100 \cdot 13^2 \cdot 2.0} = 0.036$$

Očitano: $\varepsilon_{s1} = 10.0\,‰ \quad \varepsilon_{c2} = 1.1\,‰ \quad \xi = 0.099 \quad \zeta = 0.965$

$$A_{s1} = \frac{M_{sd}}{\zeta \cdot d \cdot f_{yd}} = \frac{1230}{0.965 \cdot 13 \cdot 43.5} = 2.25\,\text{cm}^2$$

Ležaj:



$M_{sd} = 49.2\,\text{kNm}$

$$\mu_{sd} = \frac{M_{sd}}{b_{eff} \cdot d^2 \cdot f_{cd}} = \frac{4920}{100 \cdot 13^2 \cdot 2.0} = 0.146$$

Očitano: $\varepsilon_{s1} = 10.0\,‰ \quad \varepsilon_{c2} = 3.2\,‰ \quad \xi = 0.241 \quad \zeta = 0.902$

$$A_{s1} = \frac{M_{sd}}{\zeta \cdot d \cdot f_{yd}} = \frac{4920}{0.902 \cdot 13 \cdot 43.5} = 9.65\,\text{cm}^2$$

3.3 Kontrola pukotina ploče pozicije 201

Mjerodavni momenti u ploči računaju se za radnu kombinaciju opterećenja ($q = 1.0 \cdot g + 1.0 \cdot p$).

Polje 1

$$M_g = k \cdot g \cdot L_2^2 = 0.080 \cdot 7.80 \cdot 6.4^2 = 25.6\,\text{kNm/m}$$

$$M_q = k \cdot q \cdot L_2^2 = 0.080 \cdot 1.00 \cdot 6.4^2 = 3.3\,\text{kNm/m}$$

$$M_{sd} = \gamma_g \cdot M_g + \gamma_q \cdot M_q = 1.0 \cdot 25.6 + 1.0 \cdot 3.3 = 28.9\,\text{kNm/m}$$

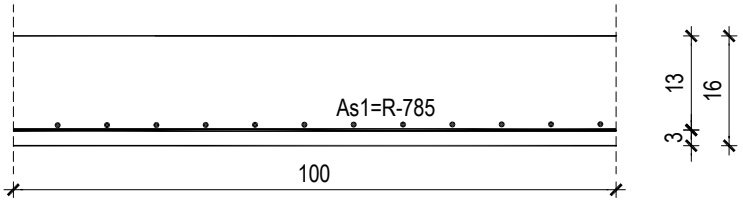
Granična vrijednost širine pukotine: $w_g = 0.3\,\text{mm}$ (EC-2 – uobičajena sredina)

Proračunska vrijednost širine pukotine: (EC-2):

$$w_k = \beta \cdot s_{rm} \cdot \varepsilon_{sm}$$

Armatura ploče donja zona: **R-785** (A_{s1}=7.85 cm^2/m).

Skica armature u polju:



Prognozna širina pukotine:

$$w_k = \beta \cdot s_{rm} \cdot \varepsilon_{sm}$$

β=1.7 - odnos računske i srednje širine pukotina

Proračun srednje deformacije armature:

$$\varepsilon_{sm} = \frac{\sigma_s}{E_s} \cdot \zeta = \frac{\sigma_s}{E_s} \cdot \left[1 - \beta_1 \cdot \beta_2 \cdot \left(\frac{\sigma_{sr}}{\sigma_s} \right)^2 \right]$$

A_{s1} = R-785 = 7.85 cm^2/m'

$E_{cm} = 32.0\,\text{GPa} = 32000.0\,\text{MPa}$ - modul elastičnosti betona

$E_s = 200.0\,\text{GPa} = 200000.0\,\text{MPa}$ - modul elastičnosti armature

$$\alpha_{el} = \frac{E_s}{E_{cm}} = \frac{200}{32} = 6.25$$

$$x = \frac{\alpha_{el} \cdot A_{S1}}{b} \cdot \left(-1 + \sqrt{1 + \frac{2 \cdot b \cdot d}{\alpha_{el} \cdot A_{S1}}} \right) = \frac{6.25 \cdot 7.85}{100} \cdot \left(-1 + \sqrt{1 + \frac{2 \cdot 100 \cdot 13}{6.25 \cdot 7.85}} \right) = 3.11\,cm$$

$$\sigma_s = \frac{M_{sd}}{z \cdot A_s} \approx \frac{M_{sd}}{\left(d - \frac{x}{3}\right) \cdot A_s} = \frac{2890}{\left(13 - \frac{3.11}{3}\right) \cdot 7.85} = 30.77 \frac{kN}{cm^2} = 307.7\,MPa$$

$$\sigma_{sr} = \frac{M_{cr}}{z \cdot A_s} \quad ; \quad M_{cr} = f_{ct,m} \cdot \frac{b \cdot h^2}{6} \quad ; \quad f_{ct,m} \approx 0.3 \cdot (f_{ck})^{2/3} \quad ; \quad f_{ck} = 30.0\,MPa$$

$$f_{ct,m} = 0.3 \cdot (f_{ck})^{2/3} = 0.3 \cdot (30.0)^{2/3} = 2.9\,MPa$$

$$M_{cr} = 0.29 \cdot \frac{100 \cdot 16^2}{6} = 1237.7\,kNcm = 12.38\,kNm$$

$$\sigma_{sr} = \frac{M_{cr}}{z \cdot A_s} \approx \frac{M_{cr}}{\left(d - \frac{x}{3}\right) \cdot A_s} = \frac{1238}{\left(13 - \frac{3.11}{3}\right) \cdot 7.85} = 13.18 \frac{kN}{cm^2} = 131.8\,MPa$$

$\beta_1 = 1.0$ - Rebrasta armatura

$\beta_2 = 0.5$ - Dugotrajno opterećenje

$$\varepsilon_{sm} = \frac{\sigma_s}{E_s} \cdot \left[1 - \beta_1 \cdot \beta_2 \cdot \left(\frac{\sigma_{sr}}{\sigma_s} \right)^2 \right] = \frac{307.7}{200000.0} \cdot \left[1 - 1.0 \cdot 0.5 \cdot \left(\frac{131.8}{307.7} \right)^2 \right] = \frac{307.7}{200000.0} \cdot 0.908 = 1.39 \cdot 10^{-3}$$

Proračun srednjeg razmaka pukotina:

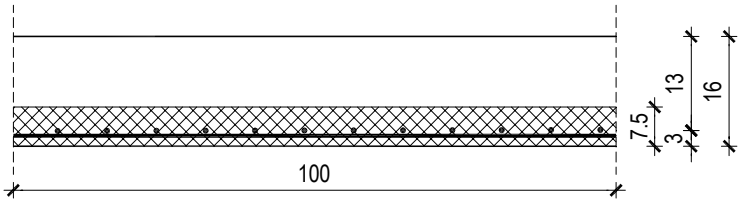
$$s_{rm} = 50 + 0.25 \cdot k_1 \cdot k_2 \cdot \frac{\phi}{\rho_r} \quad [mm]$$

$\phi = 10\,mm$ - Promjer najdeblje šipke (R-785 ⇨ Ø10/10)

$k_1 = 0.8$ - Rebrasta armatura

$k_2 = 0.5$ - Savijanje

$\rho_r = \frac{A_s}{A_{c,eff}} = \frac{7.85}{100 \cdot (2.5 \cdot 3)} = 0.0105$ - Djelotvorni koeficijent armiranja glavnom vlačnom armaturom



$$s_{rm} = 50 + 0.25 \cdot k_1 \cdot k_2 \cdot \frac{\phi}{\rho_r} = 50 + 0.25 \cdot 0.8 \cdot 0.5 \cdot \frac{10}{0.0105} = 145.2\,mm$$

Prognozna širina pukotine:

$$w_k = \beta \cdot s_{rm} \cdot \varepsilon_{sm} = 1.7 \cdot 0.00139 \cdot 145.2 = 0.343\,m > w_g = 0.3\,mm$$

Pukotine ne zadovoljavaju, potrebno je povećati armaturu!
Armatura ploče donja zona: **Q-785**, s preklopom ≥ 50 cm

$$A'_{s1} = A_{s1} \cdot \frac{š_m + p_m}{š_m} = 7.85 \cdot \frac{220 + 50}{220} = 9.63\,cm^2$$

$$x = \frac{\alpha_{el} \cdot A_{S1}}{b} \cdot \left(-1 + \sqrt{1 + \frac{2 \cdot b \cdot d}{\alpha_{el} \cdot A_{S1}}} \right) = \frac{6.25 \cdot 9.63}{100} \cdot \left(-1 + \sqrt{1 + \frac{2 \cdot 100 \cdot 13}{6.25 \cdot 9.63}} \right) = 3.40\,cm$$

$$\sigma_s = \frac{M_{sd}}{z \cdot A_s} \approx \frac{M_{sd}}{\left(d - \frac{x}{3} \right) \cdot A_s} = \frac{2890}{\left(13 - \frac{3.40}{3} \right) \cdot 9.63} = 25.30 \frac{kN}{cm^2} = 253.0\,MPa$$

$$\varepsilon_{sm} = \frac{\sigma_s}{E_s} \cdot \left[1 - \beta_1 \cdot \beta_2 \cdot \left(\frac{\sigma_{sr}}{\sigma_s} \right)^2 \right] = \frac{253.0}{200000.0} \cdot \left[1 - 1.0 \cdot 0.5 \cdot \left(\frac{131.8}{253.0} \right)^2 \right] = \frac{253.0}{200000.0} \cdot 0.864 = 1.09 \cdot 10^{-3}$$

Proračun srednjeg razmaka pukotina:

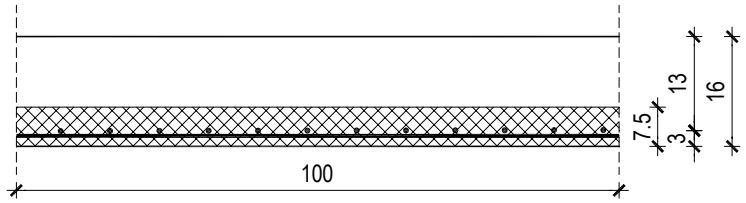
$$s_{rm} = 50 + 0.25 \cdot k_1 \cdot k_2 \cdot \frac{\phi}{\rho_r} \quad [mm]$$

$\phi = 10\,mm$ - Promjer najdeblje šipke (R-785 ⇨ Ø10/10)

$k_1 = 0.8$ - Rebrasta armatura

$k_2 = 0.5$ - Savijanje

$\rho_r = \frac{A_s}{A_{c,eff}} = \frac{9.63}{100 \cdot (2.5 \cdot 3)} = 0.0128$ - Djelotvorni koeficijent armiranja glavnom vlačnom armaturom



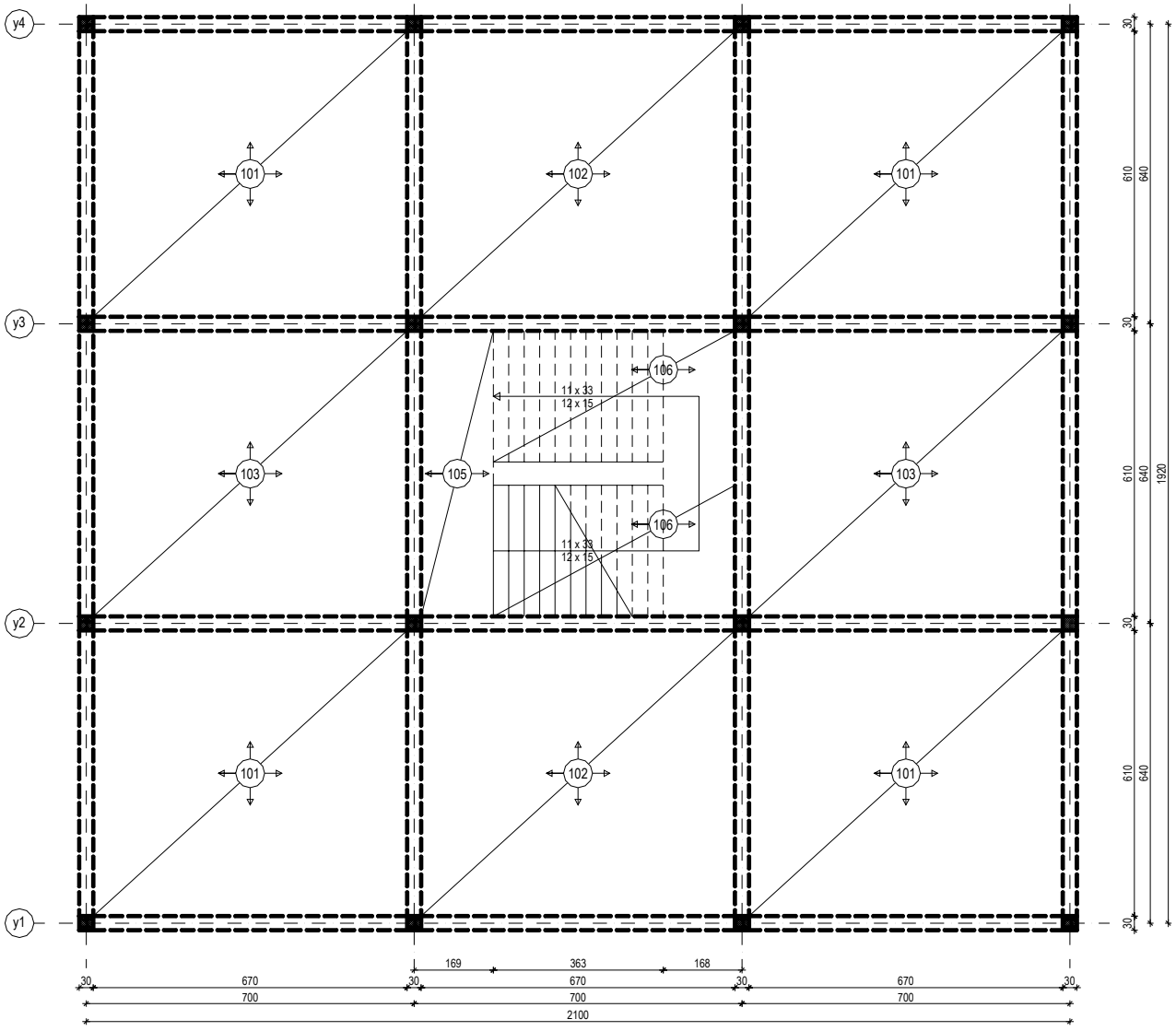
$$s_{rm} = 50 + 0.25 \cdot k_1 \cdot k_2 \cdot \frac{\phi}{\rho_r} = 50 + 0.25 \cdot 0.8 \cdot 0.5 \cdot \frac{10}{0.0128} = 128.1\,mm$$

Prognozna širina pukotine:

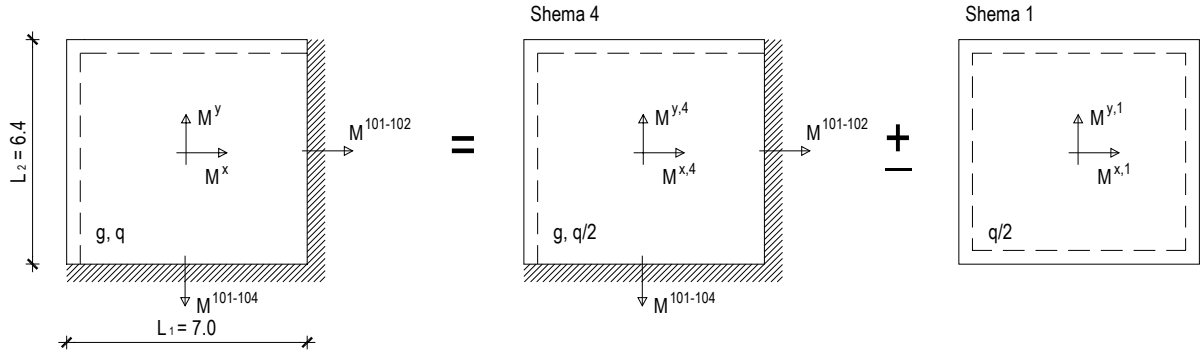
$$w_k = \beta \cdot s_{rm} \cdot \varepsilon_{sm} = 1.7 \cdot 0.00109 \cdot 128.1 = 0.237\,m < w_g = 0.3\,mm$$

Pukotine zadovoljavaju!

4. PRORAČUN PLOČA POZICIJA 100



4.7 Proračun pozicije 101



$$\frac{l_y}{l_x}=\frac{6.4}{7.0}=0.91\approx 0.90 \Rightarrow \quad \text{Shema 4}=\begin{cases} k_x^4=0.0217 \\ k_y^4=0.0324 \\ k_x^a=-0.0598 \\ k_y^b=-0.0798 \end{cases} \qquad \text{Shema 1}=\begin{cases} k_x^1=0.0344 \\ k_y^1=0.0507 \end{cases}$$

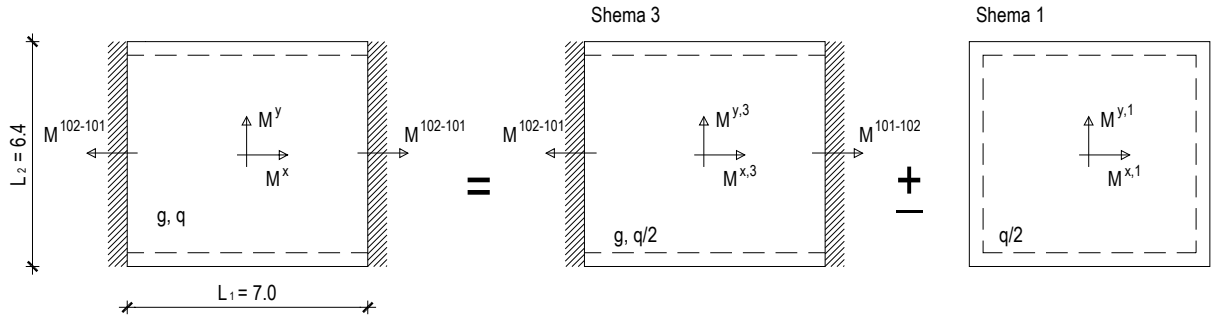
$$M_g^{x,4}=k_x^4\cdot g\cdot L_1^2=0.0217\cdot 6.80\cdot 7.0^2=7.2\,\text{kNm/m}$$
$$M_{q/2}^{x,4}=k_x^4\cdot q/2\cdot L_1^2=0.0217\cdot 4.00/2\cdot 7.0^2=2.1\,\text{kNm/m}$$
$$M_{q/2}^{x,1}=k_x^1\cdot q/2\cdot L_1^2=0.0344\cdot 4.00/2\cdot 7.0^2=3.4\,\text{kNm/m}$$
$$M_{sd,max}^{x}=\gamma_g\cdot M_g^{x,4}+\gamma_q\cdot\left(M_{q/2}^{x,4}+M_{q/2}^{x,1}\right)=1.35\cdot 7.2+1.50\cdot(2.1+3.4)=18.0\,\text{kNm/m}$$
$$M_{sd,min}^{x}=\gamma_g\cdot M_g^{x,4}+\gamma_q\cdot\left(M_{q/2}^{x,4}-M_{q/2}^{x,1}\right)=1.35\cdot 7.2+1.50\cdot(2.1-3.4)=7.8\,\text{kNm/m}$$

$$M_g^{y,4}=k_y^4\cdot g\cdot L_2^2=0.0324\cdot 6.80\cdot 6.4^2=9.0\ \text{kNm/m}$$
$$M_{q/2}^{y,4}=k_y^4\cdot q/2\cdot L_2^2=0.0324\cdot 4.00/2\cdot 6.4^2=2.7\ \text{kNm/m}$$
$$M_{q/2}^{y,1}=k_x^1\cdot q/2\cdot L_2^2=0.0507\cdot 4.00/2\cdot 6.4^2=4.2\ \text{kNm/m}$$
$$M_{sd,max}^{y}=\gamma_g\cdot M_g^{y,4}+\gamma_q\cdot\left(M_{q/2}^{y,4}+M_{q/2}^{y,1}\right)=1.35\cdot 9.0+1.50\cdot(2.7+4.2)=22.5\ \text{kNm/m}$$
$$M_{sd,min}^{y}=\gamma_g\cdot M_g^{y,4}+\gamma_q\cdot\left(M_{q/2}^{y,4}-M_{q/2}^{y,1}\right)=1.35\cdot 9.0+1.50\cdot(2.7-4.2)=9.9\ \text{kNm/m}$$

$$M_g^{101-102}=k_x^a\cdot g\cdot L_1^2=-0.0598\cdot 6.80\cdot 7.0^2=-19.9\,\text{kNm/m}$$
$$M_q^{101-102}=k_x^a\cdot q\cdot L_1^2=-0.0598\cdot 4.00\cdot 7.0^2=-11.7\,\text{kNm/m}$$
$$M_{sd}^{101-102}=\gamma_g\cdot M_g^{101-102}+\gamma_q\cdot M_q^{101-102}=1.35\cdot(-19.9)+1.50\cdot(-11.7)=-44.4\,\text{kNm/m}$$

$$M_g^{101-104}=k_y^b\cdot g\cdot L_2^2=-0.0798\cdot 6.80\cdot 6.4^2=-22.2\,\text{kNm/m}$$
$$M_q^{101-104}=k_y^b\cdot q\cdot L_2^2=-0.0798\cdot 4.00\cdot 6.4^2=-13.1\,\text{kNm/m}$$
$$M_{sd}^{101-104}=\gamma_g\cdot M_g^{101-104}+\gamma_q\cdot M_q^{101-104}=1.35\cdot(-22.2)+1.50\cdot(-13.1)=-49.6\,\text{kNm/m}$$

4.8 Proračun pozicije 102



$$\frac{l_y}{l_x}=\frac{6.4}{7.0}=0.91\approx 0.90 \Rightarrow \quad \text{Shema 3}=\begin{cases} k_x^3=0.0274 \\ k_y^3=0.0270 \\ k_x^a=-0.0644 \end{cases} \qquad \text{Shema 1}=\begin{cases} k_x^1=0.0344 \\ k_y^1=0.0507 \end{cases}$$

$$M_g^{x,3}=k_x^3\cdot g\cdot L_1^2=0.0274\cdot 6.80\cdot 7.0^2=9.1\,\text{kNm/m}$$

$$M_{q/2}^{x,3}=k_x^3\cdot q/2\cdot L_1^2=0.0274\cdot 4.00/2\cdot 7.0^2=2.7\,\text{kNm/m}$$

$$M_{q/2}^{x,1}=k_x^1\cdot q/2\cdot L_1^2=0.0344\cdot 4.00/2\cdot 7.0^2=3.4\,\text{kNm/m}$$

$$M_{sd,max}^{x}=\gamma_g\cdot M_g^{x,3}+\gamma_q\cdot\left(M_{q/2}^{x,3}+M_{q/2}^{x,1}\right)=1.35\cdot 9.1+1.50\cdot(2.7+3.4)=21.4\,\text{kNm/m}$$

$$M_{sd,min}^{x}=\gamma_g\cdot M_g^{x,3}+\gamma_q\cdot\left(M_{q/2}^{x,3}-M_{q/2}^{x,1}\right)=1.35\cdot 9.1+1.50\cdot(2.7-3.4)=11.2\,\text{kNm/m}$$

$$M_g^{y,3}=k_y^3\cdot g\cdot L_2^2=0.0270\cdot 6.80\cdot 6.4^2=7.5\ \text{kNm/m}$$

$$M_{q/2}^{y,3}=k_y^3\cdot q/2\cdot L_2^2=0.0270\cdot 4.00/2\cdot 6.4^2=2.2\ \text{kNm/m}$$

$$M_{q/2}^{y,1}=k_x^1\cdot q/2\cdot L_2^2=0.0507\cdot 4.00/2\cdot 6.4^2=4.2\ \text{kNm/m}$$

$$M_{sd,max}^{y}=\gamma_g\cdot M_g^{y,3}+\gamma_q\cdot\left(M_{q/2}^{y,3}+M_{q/2}^{y,1}\right)=1.35\cdot 7.5+1.50\cdot(2.2+4.2)=19.7\ \text{kNm/m}$$

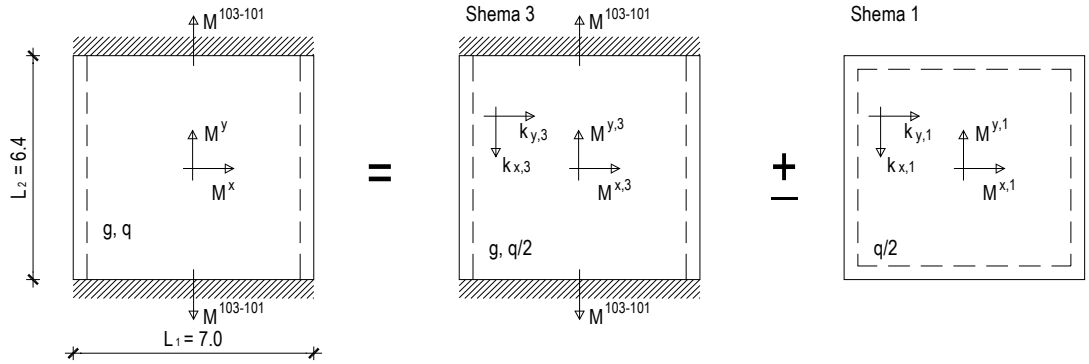
$$M_{sd,min}^{y}=\gamma_g\cdot M_g^{y,3}+\gamma_q\cdot\left(M_{q/2}^{y,3}-M_{q/2}^{y,1}\right)=1.35\cdot 7.5+1.50\cdot(2.2-4.2)=7.1\ \text{kNm/m}$$

$$M_g^{102-101}=k_x^a\cdot g\cdot L_1^2=-0.0644\cdot 6.80\cdot 7.0^2=-21.5\,\text{kNm/m}$$

$$M_q^{102-101}=k_x^a\cdot q\cdot L_1^2=-0.0644\cdot 4.00\cdot 7.0^2=-12.6\,\text{kNm/m}$$

$$M_{sd}^{102-101}=\gamma_g\cdot M_g^{102-101}+\gamma_q\cdot M_q^{102-101}=1.35\cdot(-21.5)+1.50\cdot(-12.6)=-47.9\,\text{kNm/m}$$

4.9 Proračun pozicije 103



$$\frac{l_y}{l_x}=\frac{7.0}{6.4}=1.0941\approx 1.10 \Rightarrow \quad \text{Shema 3}=\begin{cases} k_x^3=0.0335 \\ k_y^3=0.0151 \\ k_x^a=-0.0741 \end{cases} \qquad \text{Shema 1}=\begin{cases} k_x^1=0.0500 \\ k_y^1=0.0353 \end{cases}$$

$$M_g^{x,3}=k_y^3\cdot g\cdot L_1^2=0.0151\cdot 6.80\cdot 7.0^2=5.0\ \text{kNm/m}$$

$$M_{q/2}^{x,3}=k_y^3\cdot q/2\cdot L_1^2=0.0151\cdot 4.00/2\cdot 7.0^2=1.5\ \text{kNm/m}$$

$$M_{q/2}^{x,1}=k_y^1\cdot q/2\cdot L_1^2=0.0353\cdot 4.00/2\cdot 7.0^2=3.5\ \text{kNm/m}$$

$$M_{sd,max}^{x}=\gamma_g\cdot M_g^{x,3}+\gamma_q\cdot\left(M_{q/2}^{x,3}+M_{q/2}^{x,1}\right)=1.35\cdot 5.0+1.50\cdot(1.5+3.5)=14.3\ \text{kNm/m}$$

$$M_{sd,min}^{x}=\gamma_g\cdot M_g^{x,3}+\gamma_q\cdot\left(M_{q/2}^{x,3}-M_{q/2}^{x,1}\right)=1.35\cdot 5.0+1.50\cdot(1.5-3.5)=3.8\ \text{kNm/m}$$

$$M_g^{y,3}=k_x^3\cdot g\cdot L_2^2=0.0335\cdot 6.80\cdot 6.4^2=9.3\ \text{kNm/m}$$

$$M_{q/2}^{y,3}=k_x^3\cdot q/2\cdot L_2^2=0.0335\cdot 4.00/2\cdot 6.4^2=2.7\ \text{kNm/m}$$

$$M_{q/2}^{y,1}=k_x^1\cdot q/2\cdot L_2^2=0.0500\cdot 4.00/2\cdot 6.4^2=4.2\ \text{kNm/m}$$

$$M_{sd,max}^{y}=\gamma_g\cdot M_g^{y,3}+\gamma_q\cdot\left(M_{q/2}^{y,3}+M_{q/2}^{y,1}\right)=1.35\cdot 9.3+1.50\cdot(2.7+4.1)=22.8\ \text{kNm/m}$$

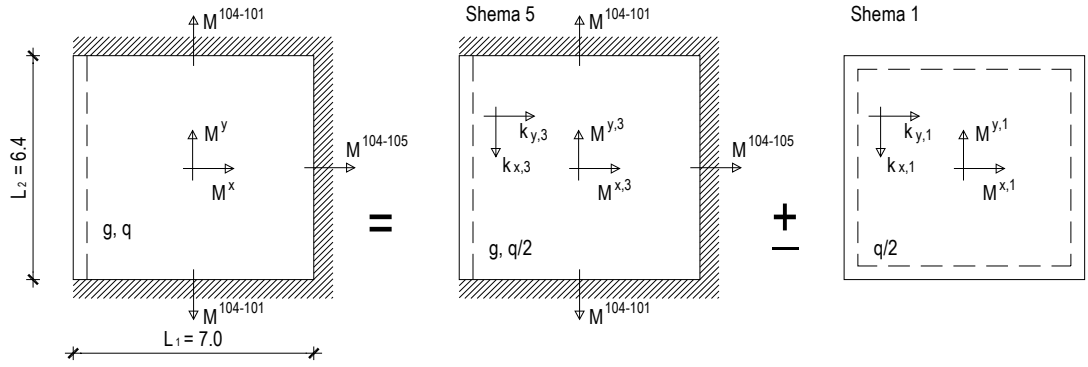
$$M_{sd,min}^{y}=\gamma_g\cdot M_g^{y,3}+\gamma_q\cdot\left(M_{q/2}^{y,3}-M_{q/2}^{y,1}\right)=1.35\cdot 9.3+1.50\cdot(2.7-4.1)=10.5\ \text{kNm/m}$$

$$M_g^{102-101}=k_x^a\cdot g\cdot L_2^2=-0.0741\cdot 6.80\cdot 6.4^2=-20.6\ \text{kNm/m}$$

$$M_q^{102-101}=k_x^a\cdot q\cdot L_2^2=-0.0741\cdot 4.00\cdot 6.4^2=-12.1\ \text{kNm/m}$$

$$M_{sd}^{102-101}=\gamma_g\cdot M_g^{102-101}+\gamma_q\cdot M_q^{102-101}=1.35\cdot(-20.6)+1.50\cdot(-12.1)=-46.0\ \text{kNm/m}$$

4.10 Proračun pozicije 104



$$\frac{l_y}{l_x}=\frac{7.0}{6.4}=1.0941\approx 1.10 \Rightarrow \quad \text{Shema 5}=\begin{cases} k_x^3=0.0287 \\ k_y^3=0.0158 \\ k_x^a=-0.0676 \\ k_y^b=-0.0467 \end{cases} \qquad \text{Shema 1}=\begin{cases} k_x^1=0.0500 \\ k_y^1=0.0353 \end{cases}$$

$$M_g^{x,3}=k_y^3\cdot g\cdot L_1^2=0.0158\cdot 6.80\cdot 7.0^2=5.3\,\text{kNm/m}$$

$$M_{q/2}^{x,3}=k_y^3\cdot q/2\cdot L_1^2=0.0158\cdot 4.00/2\cdot 7.0^2=1.5\,\text{kNm/m}$$

$$M_{q/2}^{x,1}=k_y^1\cdot q/2\cdot L_1^2=0.0353\cdot 4.00/2\cdot 7.0^2=3.5\,\text{kNm/m}$$

$$M_{sd,max}^{x}=\gamma_g\cdot M_g^{x,3}+\gamma_q\cdot\left(M_{q/2}^{x,3}+M_{q/2}^{x,1}\right)=1.35\cdot 5.3+1.50\cdot(1.5+3.5)=14.7\,\text{kNm/m}$$

$$M_{sd,min}^{x}=\gamma_g\cdot M_g^{x,3}+\gamma_q\cdot\left(M_{q/2}^{x,3}-M_{q/2}^{x,1}\right)=1.35\cdot 5.3+1.50\cdot(1.5-3.5)=4.2\,\text{kNm/m}$$

$$M_g^{y,3}=k_x^3\cdot g\cdot L_2^2=0.0287\cdot 6.80\cdot 6.4^2=8.0\ \text{kNm/m}$$

$$M_{q/2}^{y,3}=k_x^3\cdot q/2\cdot L_2^2=0.0287\cdot 4.00/2\cdot 6.4^2=2.4\ \text{kNm/m}$$

$$M_{q/2}^{y,1}=k_x^1\cdot q/2\cdot L_2^2=0.0500\cdot 4.00/2\cdot 6.4^2=4.2\ \text{kNm/m}$$

$$M_{sd,max}^{y}=\gamma_g\cdot M_g^{y,3}+\gamma_q\cdot\left(M_{q/2}^{y,3}+M_{q/2}^{y,1}\right)=1.35\cdot 8.0+1.50\cdot(2.4+4.1)=20.6\ \text{kNm/m}$$

$$M_{sd,min}^{y}=\gamma_g\cdot M_g^{y,3}+\gamma_q\cdot\left(M_{q/2}^{y,3}-M_{q/2}^{y,1}\right)=1.35\cdot 8.0+1.50\cdot(2.4-4.1)=8.3\ \text{kNm/m}$$

$$M_g^{104-101}=k_x^a\cdot g\cdot L_2^2=-0.0676\cdot 6.80\cdot 6.4^2=-18.8\,\text{kNm/m}$$

$$M_q^{104-101}=k_x^a\cdot q\cdot L_2^2=-0.0598\cdot 4.00\cdot 6.4^2=-11.1\,\text{kNm/m}$$

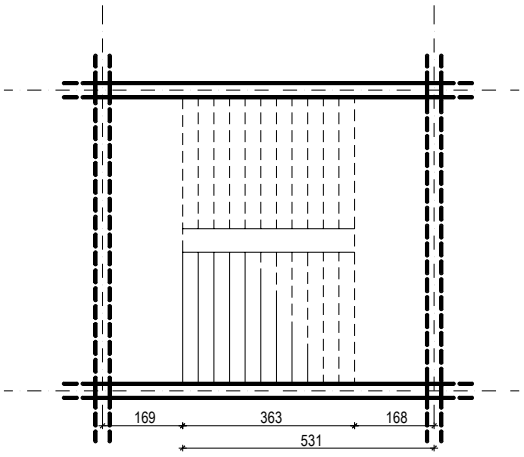
$$M_{sd}^{104-101}=\gamma_g\cdot M_g^{104-101}+\gamma_q\cdot M_q^{104-101}=1.35\cdot(-18.8)+1.50\cdot(-11.1)=-42.0\,\text{kNm/m}$$

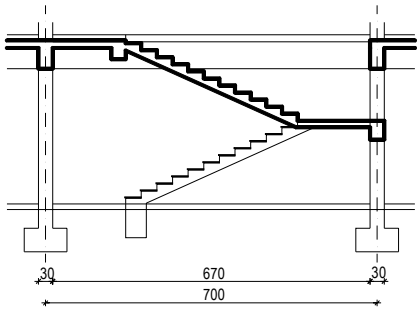
$$M_g^{104-105}=k_y^b\cdot g\cdot L_1^2=-0.0467\cdot 6.80\cdot 7.0^2=-15.6\,\text{kNm/m}$$

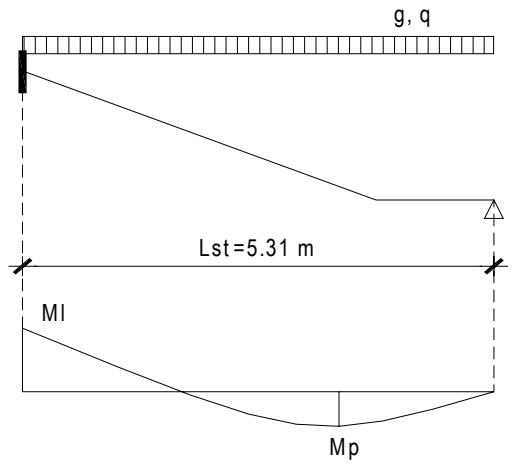
$$M_q^{104-105}=k_y^b\cdot q\cdot L_1^2=-0.0467\cdot 4.00\cdot 7.0^2=-9.2\,\text{kNm/m}$$

$$M_{sd}^{101-104}=\gamma_g\cdot M_g^{104-105}+\gamma_q\cdot M_q^{104-105}=1.35\cdot(-15.6)+1.50\cdot(-9.2)=-34.9\,\text{kNm/m}$$

4.11 Proračun pozicije 106 – Stubište







$g = 6.96\ \text{kN/m}$

$q = 4.00\ \text{kN/m}$

$$M_{g,p} = \frac{g \cdot L_{st}^2}{14} = \frac{6.96 \cdot 5.31^2}{14} = 14.0\ \text{kNm/m}$$

$$M_{q,p} = \frac{q \cdot L_{st}^2}{14} = \frac{4.0 \cdot 5.31^2}{14} = 8.1\ \text{kNm/m}$$

$$M_{sd,p} = \gamma_g \cdot M_{g,p} + \gamma_q \cdot M_{q,p} = 1.35 \cdot 14.0 + 1.50 \cdot 8.1 = 31.1\ \text{kNm/m}$$

$$M_{g,l} = \frac{g \cdot L_{st}^2}{8} = \frac{6.96 \cdot 5.31^2}{8} = 24.5\ \text{kNm/m}$$

$$M_{q,l} = \frac{q \cdot L_{st}^2}{8} = \frac{4.0 \cdot 5.31^2}{8} = 14.1\ \text{kNm/m}$$

$$M_{sd,l} = \gamma_g \cdot M_{g,l} + \gamma_q \cdot M_{q,l} = 1.35 \cdot 24.5 + 1.50 \cdot 14.1 = 54.2\ \text{kNm/m}$$

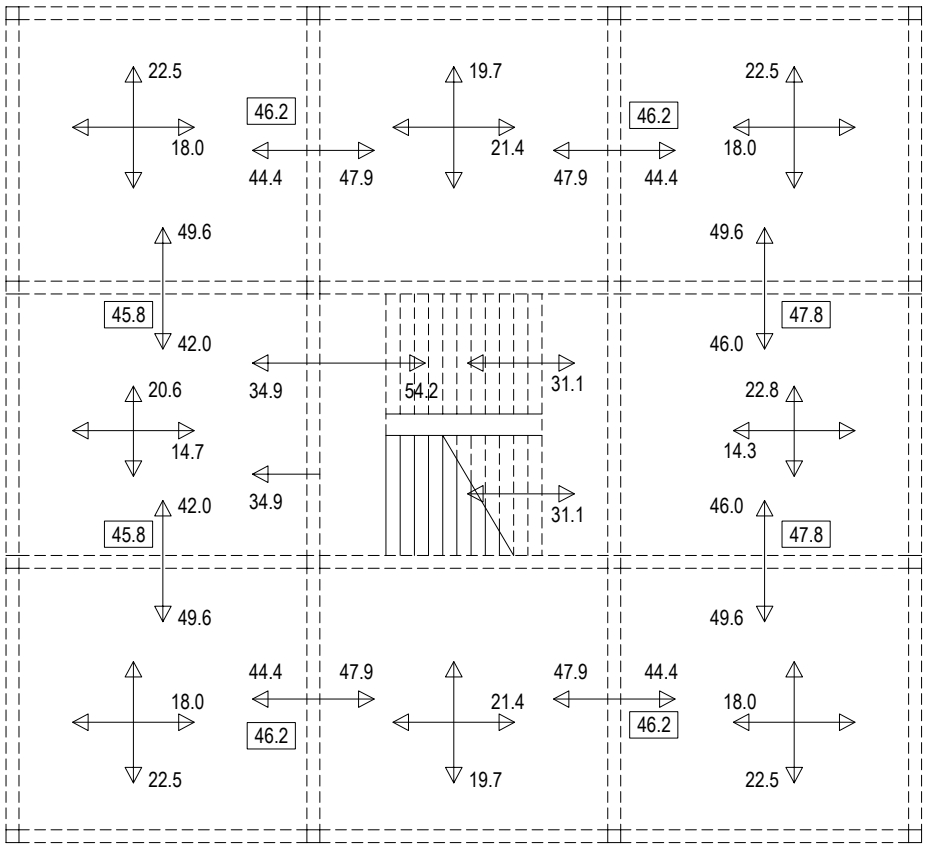
4.12 Proračun pozicije 105 – Ploča uz stubište

Ploča je vrlo kratka. Na njoj se realizira moment upetosti s obje strane. Proračun nije potreban. Armirati u kontinuitetu s pločama 104 i stubištem 106.

4.13 Prikaz dobivenih rezultata na pločama pozicija 100

Konačne momente na ležajevima dobivamo na način da uprosječimo momente s lijeve i desne strane.

$\frac{(44.4+47.9)}{2} = 46.2\,\text{kNm/m}\ldots$ itd.

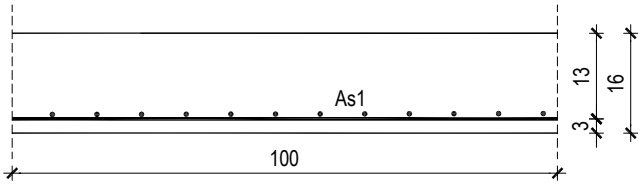


4.14 Dimenzioniranje ploča pozicija 100

Beton: C 30/37; f_{ck}=30.0 MPa $f_{cd} = \frac{f_{ck}}{\gamma_c} = \frac{30.0}{1.5} = 20.0\,\text{MPa}$

Armatura: B 500B; f_{yk}=500.0 MPa $f_{yd} = \frac{f_{yk}}{\gamma_s} = \frac{500.0}{1.15} = 434.8\,\text{MPa}$

Ploča 101 – polje



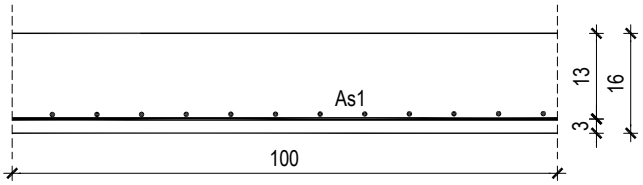
$M_{sd} = 22.5\,\text{kNm/m}$

$$\mu_{sd} = \frac{M_{sd}}{b \cdot d^2 \cdot f_{cd}} = \frac{2250}{100 \cdot 13^2 \cdot 2.0} = 0.067$$

Očitano: $\varepsilon_{s1} = 10.0\,‰ \quad \varepsilon_{c2} = 1.6\,‰ \quad \zeta = 0.949$

$$A_{s1} = \frac{M_{sd}}{\zeta \cdot d \cdot f_{yd}} = \frac{2250}{0.949 \cdot 13 \cdot 43.5} = 4.19\,\text{cm}^2/\text{m}$$

Ploča 102 – polje



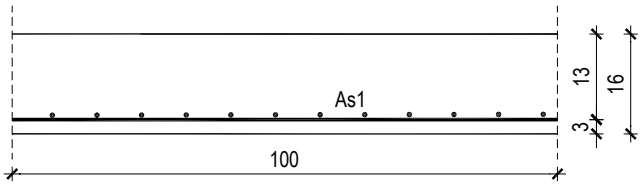
$M_{sd} = 21.40\,\text{kNm/m}$

$$\mu_{sd} = \frac{M_{sd}}{b \cdot d^2 \cdot f_{cd}} = \frac{2140}{100 \cdot 13^2 \cdot 2.0} = 0.063$$

Očitano: $\varepsilon_{s1} = 10.0\,‰ \quad \varepsilon_{c2} = 1.6\,‰ \quad \zeta = 0.949$

$$A_{s1} = \frac{M_{sd}}{\zeta \cdot d \cdot f_{yd}} = \frac{2140}{0.949 \cdot 13 \cdot 43.5} = 3.98\,\text{cm}^2/\text{m}$$

Ploča 103 – polje



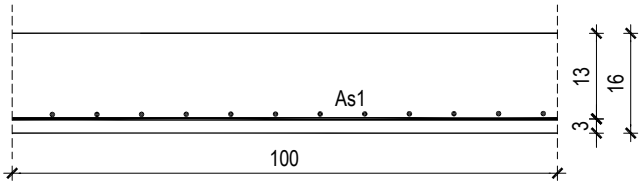
$$M_{sd} = 22.80\,\text{kNm/m}$$

$$\mu_{sd} = \frac{M_{sd}}{b \cdot d^2 \cdot f_{cd}} = \frac{2280}{100 \cdot 13^2 \cdot 2.0} = 0.067$$

Očitano: $\varepsilon_{s1} = 10.0\,‰ \quad \varepsilon_{c2} = 1.6\,‰ \quad \zeta = 0.950$

$$A_{s1} = \frac{M_{sd}}{\zeta \cdot d \cdot f_{yd}} = \frac{2280}{0.950 \cdot 13 \cdot 43.5} = 4.24\,\text{cm}^2/\text{m}$$

Ploča 104 – polje



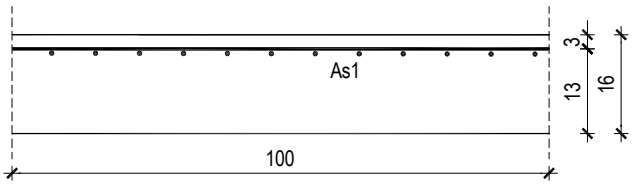
$$M_{sd} = 20.60\,\text{kNm/m}$$

$$\mu_{sd} = \frac{M_{sd}}{b \cdot d^2 \cdot f_{cd}} = \frac{2060}{100 \cdot 13^2 \cdot 2.0} = 0.061$$

Očitano: $\varepsilon_{s1} = 10.0\,‰ \quad \varepsilon_{c2} = 1.5\,‰ \quad \zeta = 0.953$

$$A_{s1} = \frac{M_{sd}}{\zeta \cdot d \cdot f_{yd}} = \frac{2060}{0.953 \cdot 13 \cdot 43.5} = 3.82\,\text{cm}^2/\text{m}$$

Ležaj 101 – 102



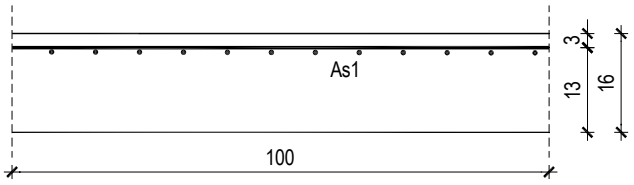
$$M_{sd} = 46.20\,\text{kNm/m}$$

$$\mu_{sd} = \frac{M_{sd}}{b \cdot d^2 \cdot f_{cd}} = \frac{4620}{100 \cdot 13^2 \cdot 2.0} = 0.136$$

Očitano: $\varepsilon_{s1} = 10.0\,‰ \quad \varepsilon_{c2} = 3.0\,‰ \quad \zeta = 0.907$

$$A_{s1} = \frac{M_{sd}}{\zeta \cdot d \cdot f_{yd}} = \frac{4620}{0.907 \cdot 13 \cdot 43.5} = 9.01\,\text{cm}^2/\text{m}$$

Ležaj 101 – 103



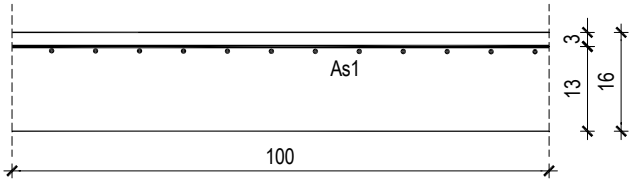
$$M_{sd} = 47.80\,kNm/m$$

$$\mu_{sd} = \frac{M_{sd}}{b \cdot d^2 \cdot f_{cd}} = \frac{4780}{100 \cdot 13^2 \cdot 2.0} = 0.141$$

Očitano: $\varepsilon_{s1} = 10.0\,‰ \quad \varepsilon_{c2} = 3.1\,‰ \quad \zeta = 0.904$

$$A_{s1} = \frac{M_{sd}}{\zeta \cdot d \cdot f_{yd}} = \frac{4780}{0.904 \cdot 13 \cdot 43.5} = 9.35\,cm^2/m$$

Ležaj 101 – 104



$$M_{sd} = 45.80\,kNm/m$$

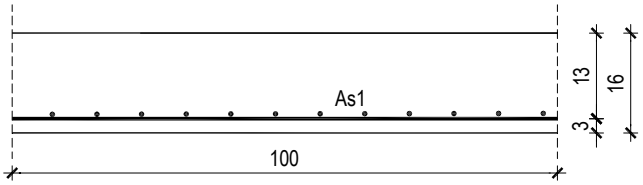
$$\mu_{sd} = \frac{M_{sd}}{b \cdot d^2 \cdot f_{cd}} = \frac{4580}{100 \cdot 13^2 \cdot 2.0} = 0.136$$

Očitano: $\varepsilon_{s1} = 10.0\,‰ \quad \varepsilon_{c2} = 2.9\,‰ \quad \zeta = 0.910$

$$A_{s1} = \frac{M_{sd}}{\zeta \cdot d \cdot f_{yd}} = \frac{4580}{0.910 \cdot 13 \cdot 43.5} = 8.90\,cm^2/m$$

4.15 Dimenzioniranje stubišta

Polje



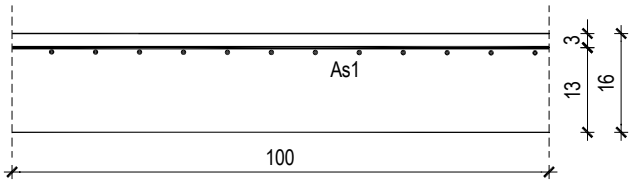
$$M_{sd} = 31.1\,kNm/m$$

$$\mu_{sd} = \frac{M_{sd}}{b \cdot d^2 \cdot f_{cd}} = \frac{3110}{100 \cdot 13^2 \cdot 2.0} = 0.092$$

Očitano: $\varepsilon_{s1} = 10.0\,‰ \quad \varepsilon_{c2} = 2.1\,‰ \quad \zeta = 0.934$

$$A_{s1} = \frac{M_{sd}}{\zeta \cdot d \cdot f_{yd}} = \frac{3110}{0.934 \cdot 13 \cdot 43.5} = 5.88\,cm^2/m$$

Ležaj stubište – 105



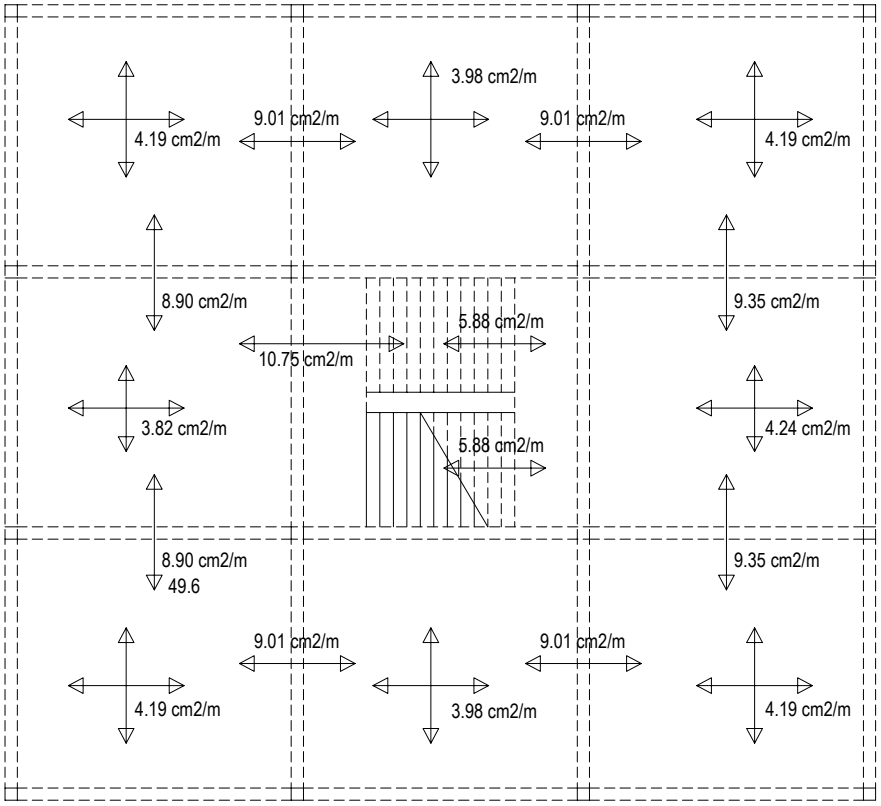
$$M_{sd} = 54.20\,\text{kNm/m}$$

$$\mu_{sd} = \frac{M_{sd}}{b \cdot d^2 \cdot f_{cd}} = \frac{5420}{100 \cdot 13^2 \cdot 2.0} = 0.160$$

Očitano: $\varepsilon_{s1} = 10.0\,‰ \quad \varepsilon_{c2} = 3.5\,‰ \quad \zeta = 0.892$

$$A_{s1} = \frac{M_{sd}}{\zeta \cdot d \cdot f_{yd}} = \frac{5420}{0.892 \cdot 13 \cdot 43.5} = 10.75\,\text{cm}^2/\text{m}$$

Iskaz potrebne armature po pozicijama:

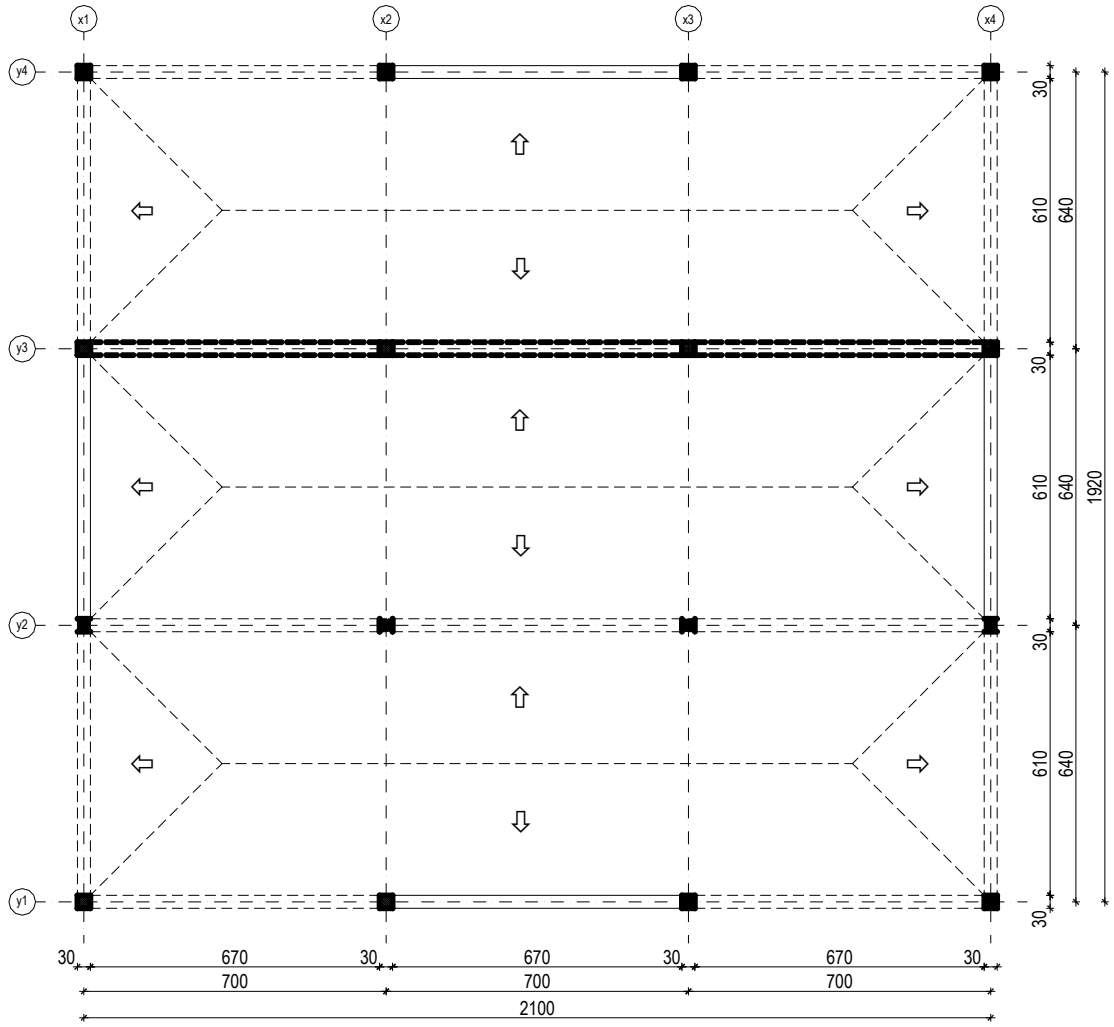


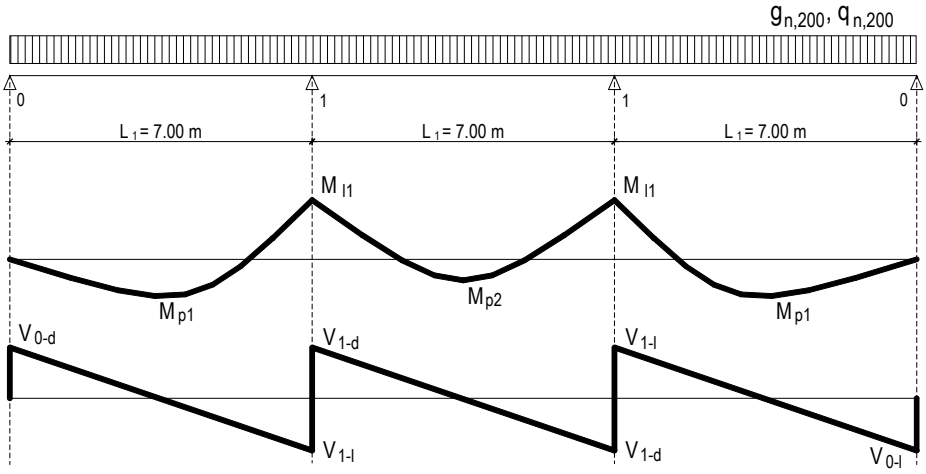
Tablica stvarne površine mreže R/Q-785 za različite širine preklopa:

Mreža	Preklop (cm)	Površina A_s
		[cm^2/m']
R/Q- 785	30	8.92
R/Q- 785	40	9.28
R/Q- 785	50	9.63
R/Q- 785	60	9.99
R/Q- 785	70	10.35

5. PRORAČUN KONTINUIRANOG NOSAČA POZICIJA 200

5.1 Skica sustava



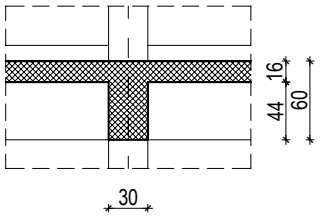


5.2 Analiza opterećenja

Stalno opterećenje:

Opterećenje od ploče: $g_{pl,200} = g_{200} \cdot L_2 = 7.80 \cdot 6.40 = 49.92 \ \ kN/m'$

Opterećenje od grede: $g_{gr,200} = b_{gr} \cdot h_{sv} \cdot \gamma_{ab} = 0.30 \cdot 0.44 \cdot 25.0 = 3.30 \ \ kN/m'$



Ukupno opterećenje na nosaču: $g_{n,200} = g_{pl,200} + g_{gr,200} = 49.92 + 3.30 = 53.22 \ \ kN/m'$

Korisno opterećenje:

Opterećenje od ploče: $q_{pl,200} = q_{200} \cdot L_2 = 1.00 \cdot 6.40 = 6.40 \ \ kN/m'$

Ukupno opterećenje na nosaču: $q_{n,200} = q_{pl,200} = 6.4 \ \ kN/m'$

5.3 Proračun nosača

Momenti:

$$M_{g,p1} = k_{p1} \cdot g \cdot L_1^2 = 0.080 \cdot 53.22 \cdot 7.0^2 = 208.6\,\text{kNm}$$

$$M_{q,p1} = k_{p1} \cdot q \cdot L_1^2 = 0.080 \cdot 6.40 \cdot 7.0^2 = 25.1\,\text{kNm}$$

$$M_{sd,p1} = \gamma_g \cdot M_{g,p1} + \gamma_q \cdot M_{q,p1} = 1.35 \cdot 208.6 + 1.50 \cdot 25.1 = 319.3\,\text{kNm}$$

$$M_{g,p2} = k_{p2} \cdot g \cdot L_1^2 = 0.025 \cdot 53.22 \cdot 7.0^2 = 65.2\,\text{kNm}$$

$$M_{q,p2} = k_{p2} \cdot q \cdot L_1^2 = 0.025 \cdot 6.40 \cdot 7.0^2 = 7.9\,\text{kNm}$$

$$M_{sd,p1} = \gamma_g \cdot M_{g,p2} + \gamma_q \cdot M_{q,p2} = 1.35 \cdot 65.2 + 1.50 \cdot 7.9 = 100.0\,\text{kNm}$$

$$M_{g,l} = k_l \cdot g \cdot L_1^2 = -0.100 \cdot 53.22 \cdot 7.0^2 = -260.8\,\text{kNm}$$

$$M_{q,l} = k_l \cdot q \cdot L_1^2 = -0.100 \cdot 6.40 \cdot 7.0^2 = -31.4\,\text{kNm}$$

$$M_{sd,l} = \gamma_g \cdot M_{g,l} + \gamma_q \cdot M_{q,l} = 1.35 \cdot (-260.8) + 1.50 \cdot (-31.4) = 399.2\,\text{kNm}$$

Poprečne sile:

$$V_{g,0-d} = k_{0-d} \cdot g \cdot L_1 = 0.400 \cdot 53.22 \cdot 7.0 = 149.0 \;\text{kN}$$

$$V_{q,0-d} = k_{0-d} \cdot q \cdot L_1 = 0.400 \cdot 6.40 \cdot 7.0 = 17.9 \;\text{kN}$$

$$V_{sd,0-d} = \gamma_g \cdot V_{g,0-d} + \gamma_q \cdot V_{q,0-d} = 1.35 \cdot 149.0 + 1.50 \cdot 17.9 = 228.0 \;\text{kN}$$

$$V_{g,1-l} = k_{1-l} \cdot g \cdot L_1 = -0.600 \cdot 53.22 \cdot 7.0 = -223.5 \;\text{kN}$$

$$V_{q,1-l} = k_{1-l} \cdot q \cdot L_1 = -0.600 \cdot 6.40 \cdot 7.0 = -26.9 \;\text{kN}$$

$$V_{sd,1-l} = \gamma_g \cdot V_{g,1-l} + \gamma_q \cdot V_{q,1-l} = 1.35 \cdot (-223.5) + 1.50 \cdot (-26.9) = -342.1 \;\text{kN}$$

$$V_{g,1-d} = k_{1-d} \cdot g \cdot L_1 = 0.500 \cdot 53.22 \cdot 7.0 = 186.3 \;\text{kN}$$

$$V_{q,1-d} = k_{1-d} \cdot q \cdot L_1 = 0.500 \cdot 6.40 \cdot 7.0 = 22.4 \;\text{kN}$$

$$V_{sd,1-d} = \gamma_g \cdot V_{g,1-d} + \gamma_q \cdot V_{q,1-d} = 1.35 \cdot 186.3 + 1.50 \cdot 22.4 = 285.1 \;\text{kN}$$

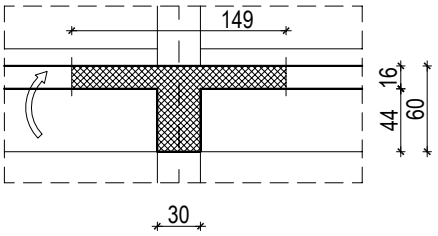
5.4 Dimenzioniranje nosača na moment savijanja

Beton: C 30/37; f_{ck}=30.0 MPa $f_{cd} = \frac{f_{ck}}{\gamma_c} = \frac{30.0}{1.5} = 20.0\,\text{MPa}$

Armatura: B 500B; f_{yk}=500.0 MPa $f_{yd} = \frac{f_{yk}}{\gamma_s} = \frac{500.0}{1.15} = 434.8\,\text{MPa}$

Polje p1:

Utjecajna širina: $b_{eff} = b_0 + \frac{l_0}{5} \le e \quad \Rightarrow \quad b_{eff} = 30 + \frac{0.85 \cdot 700}{5} = 149\,\text{cm} < 640\,\text{cm}$



$M_{sd} = 319.3\,\text{kNm}$

$\mu_{sd} = \frac{M_{sd}}{b_{eff} \cdot d^2 \cdot f_{cd}} = \frac{31930}{149 \cdot 55^2 \cdot 2.0} = 0.035$

Očitano: $\varepsilon_{s1} = 10.0\,‰ \quad \varepsilon_{c2} = 1.1\,‰ \quad \xi = 0.099 \quad \zeta = 0.965$

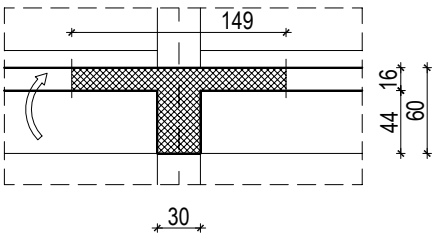
$x = \xi \cdot d = 0.099 \cdot 55 = 5.4\,\text{cm} < h_{pl}$

$A_{s1} = \frac{M_{sd}}{\zeta \cdot d \cdot f_{yd}} = \frac{31930}{0.965 \cdot 55 \cdot 43.5} = 13.83\,\text{cm}^2$

Odabrano 4Ø22 (As=15.21 cm^2)

Polje p2:

Utjecajna širina: $b_{eff} = b_0 + \frac{l_0}{5} \le e \quad \Rightarrow \quad b_{eff} = 30 + \frac{0.70 \cdot 700}{5} = 128\,\text{cm} < 640\,\text{cm}$



$M_{sd} = 100.0\,\text{kNm}$

$\mu_{sd} = \frac{M_{sd}}{b_{eff} \cdot d^2 \cdot f_{cd}} = \frac{10000}{128 \cdot 55^2 \cdot 2.0} = 0.013$

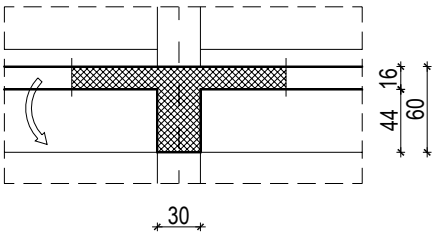
Očitano: $\varepsilon_{s1} = 10.0\,‰ \quad \varepsilon_{c2} = 0.6‰ \quad \xi = 0.057 \quad \zeta = 0.981$

$x = \xi \cdot d = 0.057 \cdot 55 = 3.1\,\text{cm} < h_{pl}$

$A_{s1} = \frac{M_{sd}}{\zeta \cdot d \cdot f_{yd}} = \frac{10000}{0.981 \cdot 55 \cdot 43.5} = 4.26\,\text{cm}^2$

Odabrano 2Ø22 (As=7.60 cm^2)

Ležaj 1:



$M_{sd} = 399.2\,\text{kNm}$

$$\mu_{sd} = \frac{M_{sd}}{b_w \cdot d^2 \cdot f_{cd}} = \frac{39920}{30 \cdot 55^2 \cdot 2.0} = 0.220$$

Očitano: $\varepsilon_{s1} = 10.0\,‰ \quad \varepsilon_{c2} = 3.5\,‰ \quad \zeta_{lim} = 0.892 \quad \mu_{sd,lim} = 0.159$

$$M_{Rd,lim} = \mu_{sd,lim} \cdot b_w \cdot d^2 \cdot f_{cd} = 0.159 \cdot 30 \cdot 55^2 \cdot 2.0 = 288.6\,\text{kNm}$$

$M_{Rd,lim} < M_{sd}$ - dvostruko armiranje

$$A_{s1} = \frac{M_{Rd,lim}}{\zeta_{lim} \cdot d \cdot f_{yd}} + \frac{(M_{sd} - M_{Rd,lim})}{(d - d_2) \cdot f_{yd}} = \frac{28860}{0.892 \cdot 55 \cdot 43.5} + \frac{(39920 - 28860)}{(55 - 5) \cdot 43.5} = 13.52 + 5.09 = 18.61\,\text{cm}^2$$

Odabrano 5Ø22 (As=19.01 cm^2)

$$A_{s2} = \frac{(M_{sd} - M_{Rd,lim})}{(d - d_2) \cdot f_{yd}} = \frac{(39920 - 28860)}{(55 - 5) \cdot 43.5} = 5.09\,\text{cm}^2$$

Odabrano 2Ø22 (As=7.60 cm^2)

5.5 Dimenzioniranje nosača na poprečnu silu

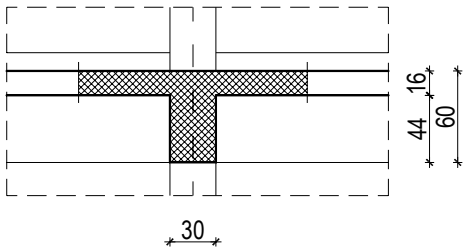
Ležaj 0

C 30/37
τ_{Rd}=0.34 MPa

d_1=5 cm

V_{sd} =228.0 kN

N_{sd}=0.0 kN



$$V_{Rd1} = \left[\tau_{Rd} \cdot k \cdot (1.2 + 40 \cdot \rho_l) + 0.15 \cdot \sigma_{cp}\right] \cdot b_w \cdot d =$$

$b_w = 30$ cm ; $d = 55$ cm

$$k = 1.6 - d = 1.6 - 0.55 = 1.05$$

$$\rho_l = \frac{A_s}{A_c} = \frac{4\phi 22 + 2\phi 22}{30 \cdot 60} = \frac{22.81}{1800} = 0.013 = 1.3\%$$

$$\sigma_{cp} = \frac{N_{sd}}{A_c} = 0.0$$

$$V_{Rd1} = \left[0.034 \cdot 1.05 \cdot (1.2 + 40 \cdot 0.013) + 0.15 \cdot 0.0\right] \cdot 30 \cdot 55$$

$$V_{Rd1} = 101.32 \text{ kN} < V_{sd}$$

$$\nu = 0.7 - \frac{f_{ck}}{200} = 0.7 - \frac{30}{200} = 0.55 \geq 0.5$$

$$V_{Rd2} = 0.5 \cdot \nu \cdot f_{cd} \cdot b_w \cdot z = 0.5 \cdot 0.55 \cdot 2.0 \cdot 30 \cdot 0.9 \cdot 55 = 816.8 \text{ kN} > V_{sd}$$

Potrebna računska poprečna armatura!

$$\frac{V_{sd}}{V_{Rd2}} \approx \frac{342.1}{816.8} = 0.42$$

$$s_{w,max} \leq \begin{cases} 0.6 \cdot d = 0.6 \cdot 55 = 33 \text{ cm} \\ 30 \text{ cm} \end{cases} \quad ; \quad s_w = 30 \text{ cm}$$

$$A_{sw,min} = \frac{\rho_{min} \cdot s_w \cdot b_w}{m} = \frac{0.0011 \cdot 30 \cdot 30}{2} = 0.495 \text{ cm}^2$$

Odabrane minimalne spone: **Ø10/30** (A_{sw}=0.79 cm^2)

$$V_{wd} = \frac{m \cdot A_{sw} \cdot f_{yw,d} \cdot z}{s_w} = \frac{2 \cdot 0.79 \cdot 43.5 \cdot (0.9 \cdot 55)}{30} = 113.4 \text{ kN}$$

$$V_{Rd} = V_{wd} + V_{Rd1} = 101.3 + 113.4 = 214.7 \text{ kN}$$

Na mjestu maksimalne poprečne sile:

$$s_w \leq \frac{m \cdot A_{sw} \cdot f_{yw,d} \cdot z}{(V_{wd} - V_{Rd1})} = \frac{2 \cdot 0.79 \cdot 43.5 \cdot (0.9 \cdot 55)}{(228.0 - 101.3)} = 26.85 \text{ cm}$$

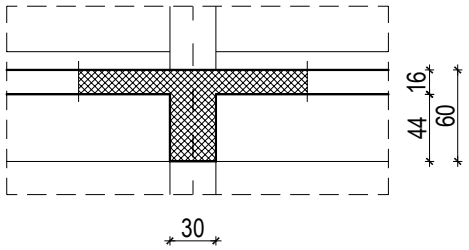
Postaviti spone **Ø10/25** (A_{sw}=0.79 cm^2)

Ležaj 1

C 30/37
τ_{Rd}=0.34 MPa

V_{sd} =342.1 kN

N_{sd}=0.0 kN



$$V_{Rd1} = \left[\tau_{Rd} \cdot k \cdot (1.2 + 40 \cdot \rho_l) + 0.15 \cdot \sigma_{cp}\right] \cdot b_w \cdot d =$$

$b_w = 30$ cm ; $d = 55$ cm

$$k = 1.6 - d = 1.6 - 0.55 = 1.05$$

$$\rho_l = \frac{A_s}{A_c} = \frac{2\phi 22 + 5\phi 22}{30 \cdot 60} = \frac{26.61}{1800} = 0.015 = 1.5\%$$

$$\sigma_{cp} = \frac{N_{sd}}{A_c} = 0.0$$

$$V_{Rd1} = \left[0.034 \cdot 1.05 \cdot (1.2 + 40 \cdot 0.015) + 0.15 \cdot 0.0\right] \cdot 30 \cdot 55$$

$$V_{Rd1} = 106.03 \text{ kN} < V_{sd}$$

$$\nu = 0.7 - \frac{f_{ck}}{200} = 0.7 - \frac{30}{200} = 0.55 \geq 0.5$$

$$V_{Rd2} = 0.5 \cdot \nu \cdot f_{cd} \cdot b_w \cdot z = 0.5 \cdot 0.55 \cdot 2.0 \cdot 30 \cdot 0.9 \cdot 55 = 816.8 \text{ kN} > V_{sd}$$

Potrebna računska poprečna armatura!

$$\frac{V_{sd}}{V_{Rd2}} \approx \frac{342.1}{816.8} = 0.42$$

$$s_{w,max} \leq \begin{cases} 0.6 \cdot d = 0.6 \cdot 55 = 33 \text{ cm} \\ 30 \text{ cm} \end{cases} \quad ; \quad s_w = 30 \text{ cm}$$

$$A_{sw,min} = \frac{\rho_{min} \cdot s_w \cdot b_w}{m} = \frac{0.0011 \cdot 30 \cdot 30}{2} = 0.495 \text{ cm}^2$$

Odabrane minimalne spone: **Ø10/30** (A_{sw}=0.79 cm^2),

$$V_{Rd} = V_{wd} + V_{Rd1} = 106.0 + 113.4 = 219.4 \text{ kN}$$

Na mjestu maksimalne poprečne sile:

$$s_w \leq \frac{m \cdot A_{sw} \cdot f_{yw,d} \cdot z}{(V_{wd} - V_{Rd1})} = \frac{2 \cdot 0.79 \cdot 43.5 \cdot (0.9 \cdot 55)}{(342.1 - 106.03)} = 14.41 \text{ cm}$$

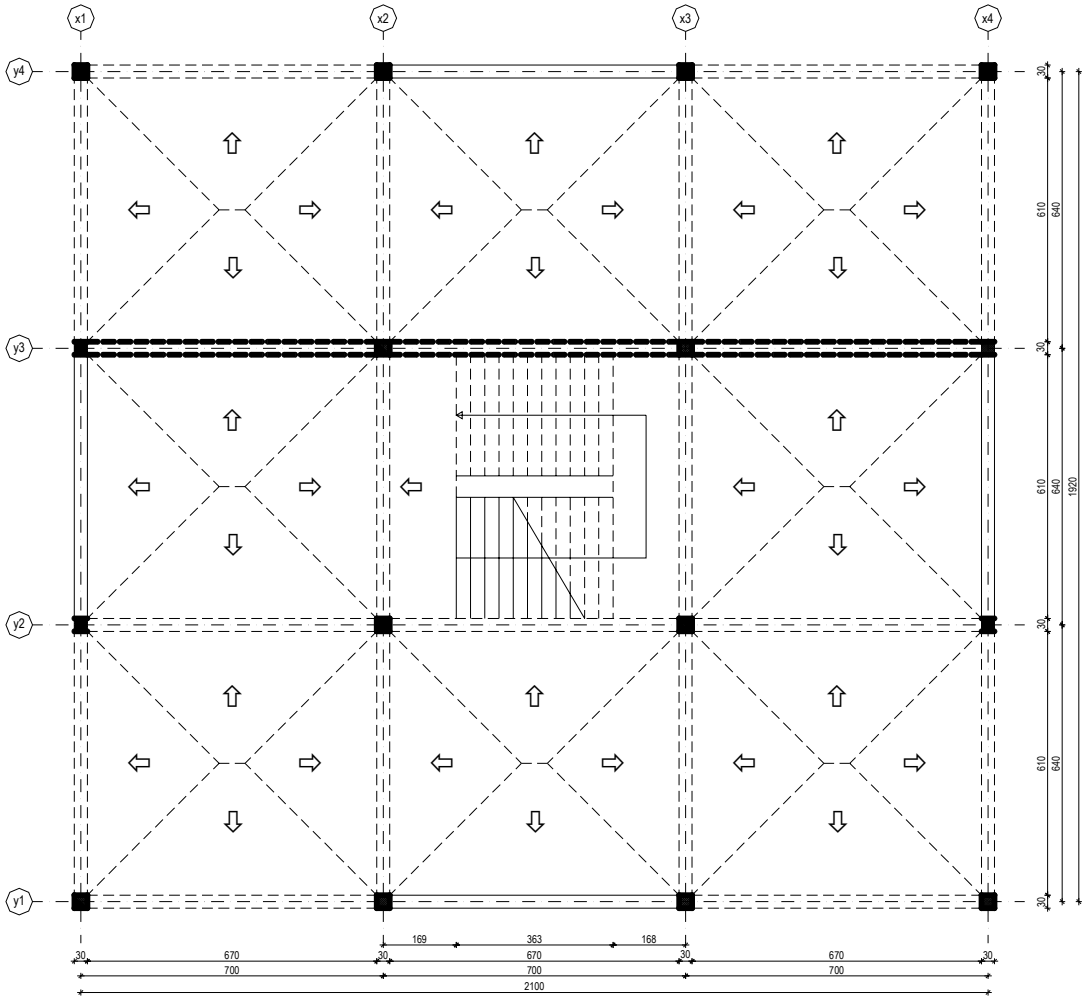
Postaviti spone **Ø10/12.5** (A_{sw}=0.79 cm^2)

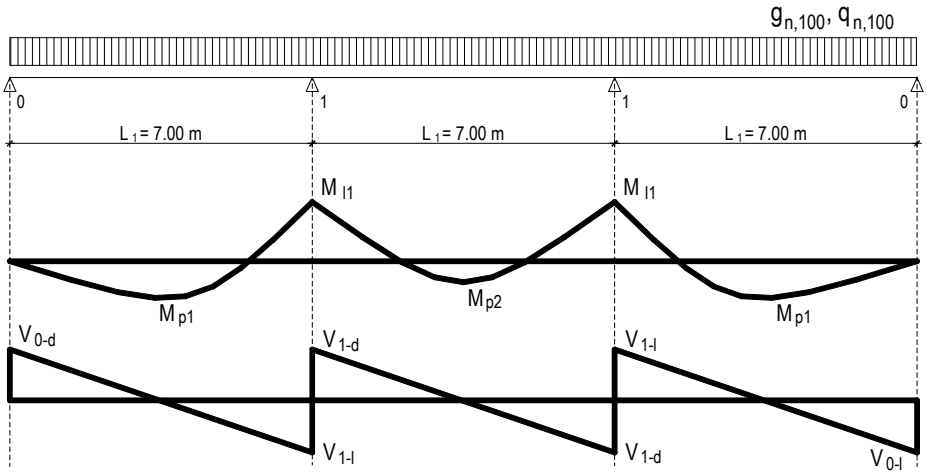
Tablica nosivosti na poprečne sile za različite razmake postavljanja spona:

Spone	Površina A_{sw}	Nosivost betona V_{Rd1}	Nosivost spona V_{wd}	Ukupna nosivost $V_{Rd3} = V_{Rd1} + V_{wd}$
	[cm^2]	[kN]	[kN]	[kN]
Ø 10 / 30	0.79	101.30	112.74	214.04
Ø 10 / 20	0.79	101.30	169.12	270.42
Ø 10 / 15	0.79	101.30	225.49	326.79
Ø 10 / 12.5	0.79	101.30	270.59	371.89

6. PRORAČUN KONTINUIRANOG NOSAČA POZICIJA 100

6.1 Skica sustava





6.2 Analiza opterećenja

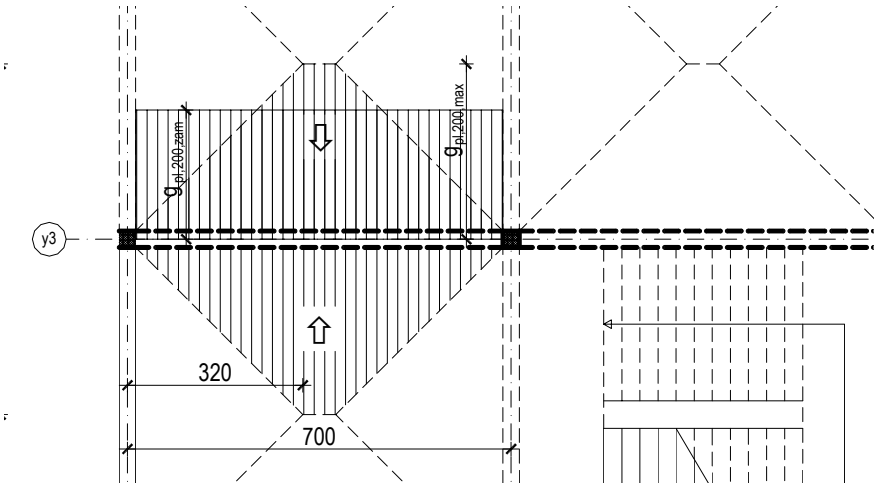
Stalno opterećenje:

Opterećenje od ploče: $g_{pl,100,max} = g_{100} \cdot \frac{L_2}{2} = 6.80 \cdot \frac{6.40}{2} = 21.76 \ \ kN/m'$

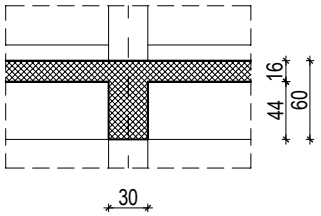
Zamjenjujuće opterećenje od ploče: $\alpha = \frac{320}{700} = 0.46;\ k = \left(1 - 2 \cdot \alpha^2 + \alpha^3\right) = \left(1 - 2 \cdot 0.46^2 + 0.46^3\right) = 0.674$

$g_{pl,100,zam} = k \cdot g_{pl,100,max} = 0.674 \cdot 21.76 = 14.67 \ \ kN/m'$

Opterećenje od zida prema stubišta: $g_{zid,100} = d_z \cdot h_z \cdot \gamma_{zid} \approx 0.20 \cdot 3.6 \cdot 18.0 = 12.96 \ \ kN/m'$



Opterećenje od grede: $g_{gr,100} = b_{gr} \cdot h_{sv} \cdot \gamma_{ab} = 0.30 \cdot 0.44 \cdot 25.0 = 3.30 \, kN/m'$



Ukupno opterećenje na nosaču 1. polje: $g_{n,100,1} = 2 \cdot g_{pl,100,zam} + g_{gr,100} = 2 \cdot 14.67 + 3.30 = 32.64 \ \ kN/m'$

Ukupno opterećenje na nosaču 2. polje:

$$g_{n,100,2} = 1 \cdot g_{pl,100,zam} + g_{zid,100} + g_{gr,100} = 1 \cdot 14.67 + 12.96 + 3.30 = 30.93 \ \ kN/m'$$

Korisno opterećenje:

Opterećenje od ploče: $q_{pl,100,max} = q_{100} \cdot \frac{L_2}{2} = 4.00 \cdot \frac{6.40}{2} = 12.80 \, kN/m'$

Zamjenjujuće opterećenje od ploče: $k = 0.674$

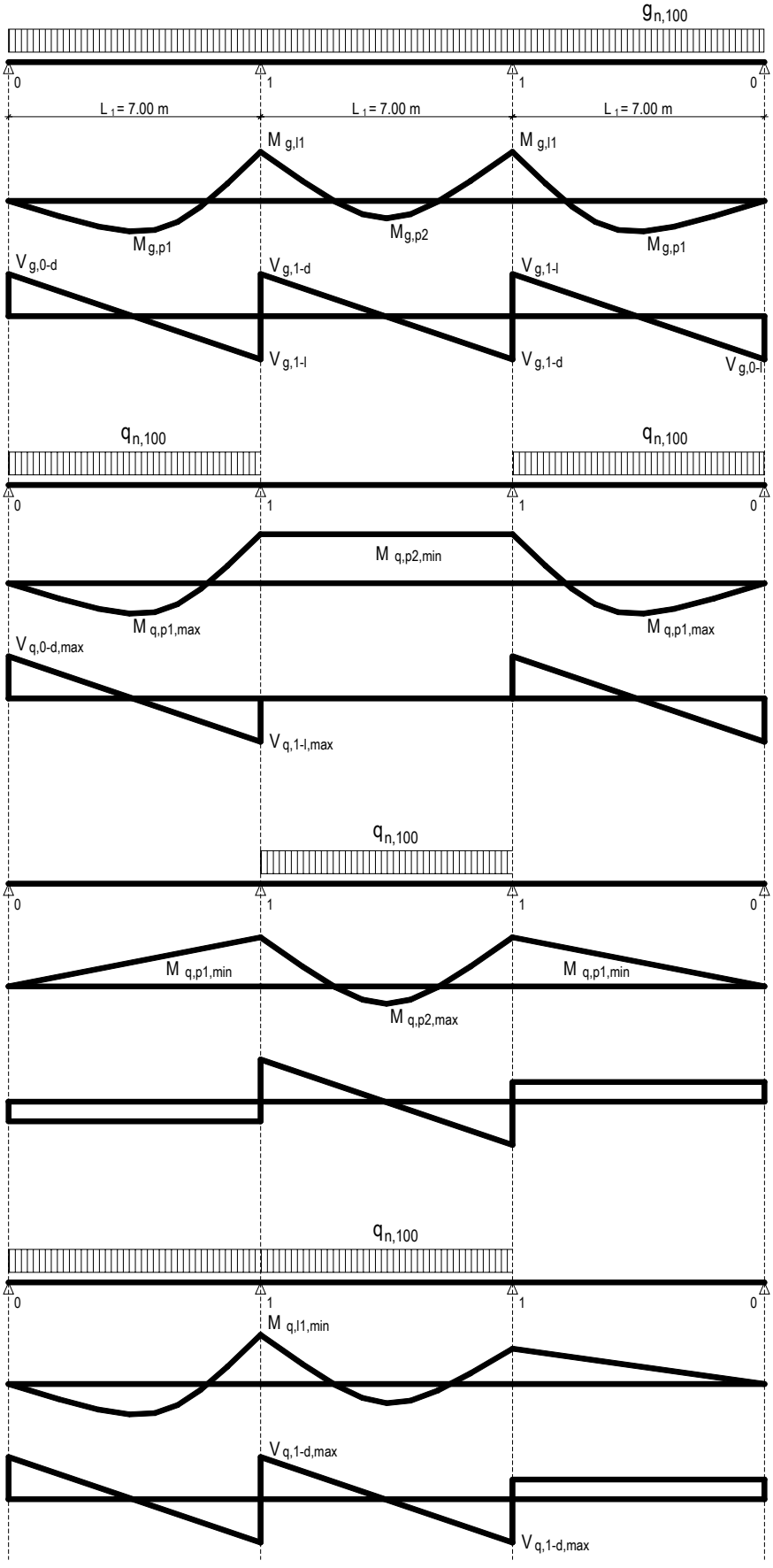
$q_{pl,100,zam} = k \cdot q_{pl,100,max} = 0.674 \cdot 12.80 = 8.63 \, kN/m'$

Ukupno opterećenje na nosaču 1. polje: $q_{n,100,1} = 2 \cdot q_{pl,100,zam} = 2 \cdot 8.63 = 17.26 \, kN/m'$

Ukupno opterećenje na nosaču 2. polje: $q_{n,100,2} = 1 \cdot q_{pl,100,zam} = 1 \cdot 8.63 = 8.63 \ \ kN/m'$

NAPOMENA: *Vidljivo je da je opterećenje na nosaču srednjeg polja nešto manje. Da bi pojednostavnili proračun, usvojit ćemo isto opterećenje u svim poljima.*

6.3 Proračun nosača



Momenti:

$$M_{g,p1} = k_{p1} \cdot g \cdot L_1^2 = 0.080 \cdot 32.64 \cdot 7.0^2 = 127.9 \text{ kNm}$$

$$M_{q,p1,max} = k_{p1,max} \cdot q \cdot L_1^2 = 0.101 \cdot 17.26 \cdot 7.0^2 = 85.4 \text{ kNm}$$

$$M_{q,p1,min} = k_{p1,min} \cdot q \cdot L_1^2 = -0.025 \cdot 17.26 \cdot 7.0^2 = -21.1 \text{ kNm}$$

$$M_{sd,p1,max} = \gamma_g \cdot M_{g,p1} + \gamma_q \cdot M_{q,p1,max} = 1.35 \cdot 127.9 + 1.50 \cdot 85.4 = 300.8 \text{ kNm}$$

$$M_{sd,p1,min} = \gamma_g \cdot M_{g,p1} + \gamma_q \cdot M_{q,p1,min} = 1.35 \cdot 127.9 + 1.50 \cdot (-21.1) = 141.0 \text{ kNm}$$

$$M_{g,p2} = k_{p2} \cdot g \cdot L_1^2 = 0.025 \cdot 32.64 \cdot 7.0^2 = 40.0 \text{ kNm}$$

$$M_{q,p2,max} = k_{p2,max} \cdot q \cdot L_1^2 = 0.075 \cdot 17.26 \cdot 7.0^2 = 63.4 \text{ kNm}$$

$$M_{q,p2,min} = k_{p2,max} \cdot q \cdot L_1^2 = -0.050 \cdot 17.26 \cdot 7.0^2 = -42.3 \text{ kNm}$$

$$M_{sd,p2,max} = \gamma_g \cdot M_{g,p2} + \gamma_q \cdot M_{q,p2,max} = 1.35 \cdot 40.0 + 1.50 \cdot 63.4 = 149.1 \text{ kNm}$$

$$M_{sd,p2,min} = \gamma_g \cdot M_{g,p2} + \gamma_q \cdot M_{q,p2,min} = 1.35 \cdot 40.0 + 1.50 \cdot (-42.3) = -9.5 \text{ kNm}$$

$$M_{g,l} = k_l \cdot g \cdot L_1^2 = -0.100 \cdot 32.64 \cdot 7.0^2 = -159.9 \text{ kNm}$$

$$M_{q,l,max} = k_l \cdot q \cdot L_1^2 = 0.017 \cdot 17.26 \cdot 7.0^2 = 14.4 \text{ kNm}$$

$$M_{q,l,min} = k_l \cdot q \cdot L_1^2 = -0.117 \cdot 17.26 \cdot 7.0^2 = -99.0 \text{ kNm}$$

$$M_{sd,l,max} = \gamma_g \cdot M_{g,l} + \gamma_q \cdot M_{q,l,max} = 1.35 \cdot (-159.9) + 1.50 \cdot 14.4 = -194.3 \text{ kNm}$$

$$M_{sd,l,min} = \gamma_g \cdot M_{g,l} + \gamma_q \cdot M_{q,l,min} = 1.35 \cdot (-159.9) + 1.50 \cdot (-99.0) = -364.4 \text{ kNm}$$

Poprečne sile:

$$V_{g,0-d} = k_{0-d} \cdot g \cdot L_1 = 0.400 \cdot 32.64 \cdot 7.0 = 91.4 \text{ kN}$$

$$V_{q,0-d,max} = k_{0-d,max} \cdot q \cdot L_1 = 0.450 \cdot 17.26 \cdot 7.0 = 54.4 \text{ kN}$$

$$V_{q,0-d,min} = k_{0-d,min} \cdot q \cdot L_1 = -0.050 \cdot 17.26 \cdot 7.0 = -6.0 \text{ kN}$$

$$V_{sd,0-d,max} = \gamma_g \cdot V_{g,0-d} + \gamma_q \cdot V_{q,0-d,max} = 1.35 \cdot 91.4 + 1.50 \cdot 54.4 = 205.0 \text{ kN}$$

$$V_{sd,0-d,min} = \gamma_g \cdot V_{g,0-d} + \gamma_q \cdot V_{q,0-d,min} = 1.35 \cdot 91.4 + 1.50 \cdot (-6.0) = 114.4 \text{ kN}$$

$$V_{g,1-l} = k_{1-l} \cdot g \cdot L_1 = -0.600 \cdot 32.64 \cdot 7.0 = -137.1 \text{ kN}$$

$$V_{q,1-l,max} = k_{1-l,max} \cdot q \cdot L_1 = 0.017 \cdot 17.26 \cdot 7.0 = 2.1 \text{ kN}$$

$$V_{q,1-l,min} = k_{1-l,min} \cdot q \cdot L_1 = -0.617 \cdot 17.26 \cdot 7.0 = -74.5 \text{ kN}$$

$$V_{sd,1-l,max} = \gamma_g \cdot V_{g,1-l} + \gamma_q \cdot V_{q,1-l} = 1.35 \cdot (-137.1) + 1.50 \cdot 2.1 = -181.9 \text{ kN}$$

$$V_{sd,1-l,min} = \gamma_g \cdot V_{g,1-l} + \gamma_q \cdot V_{q,1-l} = 1.35 \cdot (-137.1) + 1.50 \cdot (-74.5) = -296.8 \text{ kN}$$

$$V_{g,1-d} = k_{1-d} \cdot g \cdot L_1 = 0.500 \cdot 32.64 \cdot 7.0 = 114.2 \text{ kN}$$

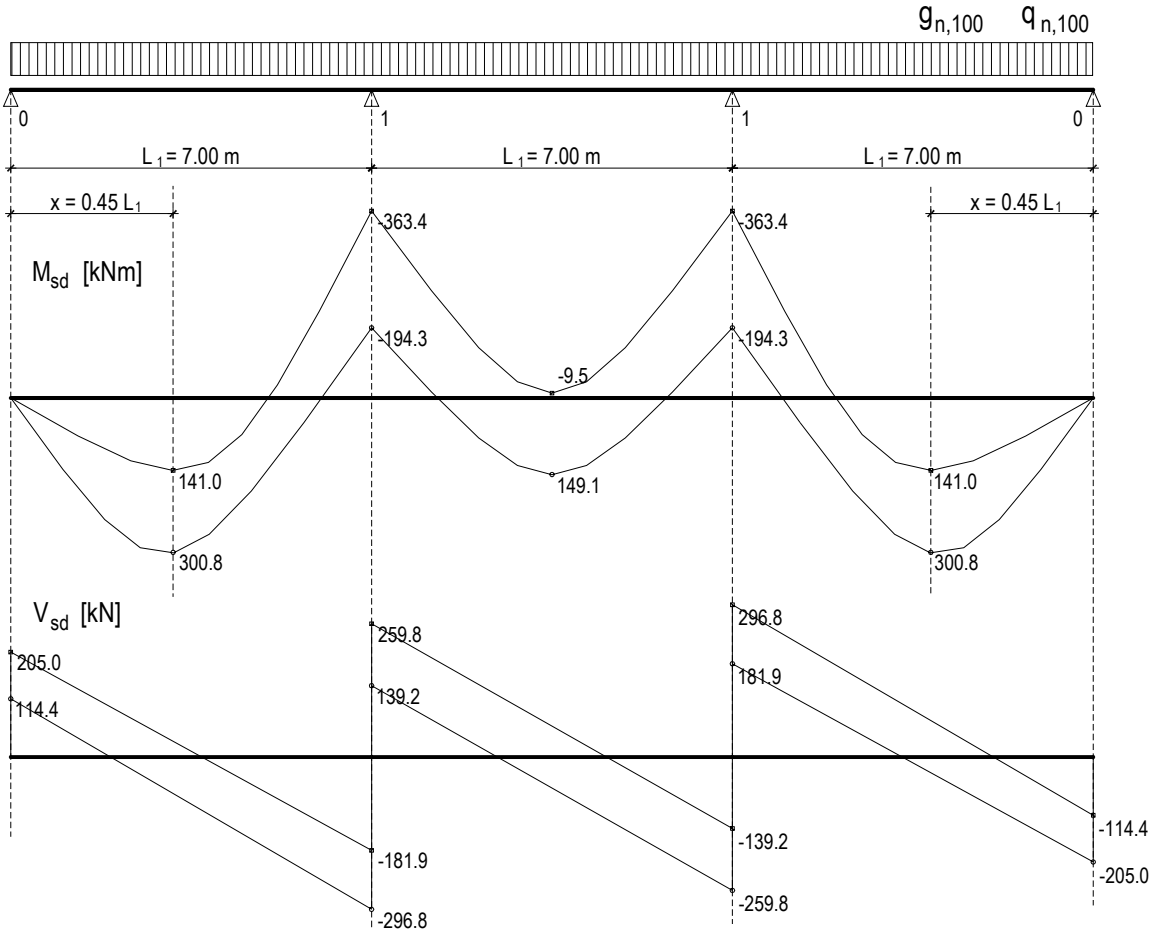
$$V_{q,1-d,max} = k_{1-d,max} \cdot q \cdot L_1 = 0.583 \cdot 17.26 \cdot 7.0 = 70.4 \text{ kN}$$

$$V_{q,1-d,min} = k_{1-d,min} \cdot q \cdot L_1 = -0.083 \cdot 17.26 \cdot 7.0 = -10.0 \text{ kN}$$

$$V_{sd,1-d,max} = \gamma_g \cdot V_{g,1-d} + \gamma_q \cdot V_{q,1-d,max} = 1.35 \cdot 114.2 + 1.50 \cdot 70.4 = 259.8 \text{ kN}$$

$$V_{sd,1-d,min} = \gamma_g \cdot V_{g,1-d} + \gamma_q \cdot V_{q,1-d,min} = 1.35 \cdot 114.2 + 1.50 \cdot (-10.0) = 139.2 \text{ kN}$$

Anvelopa momenata i poprečnih sila na nosaču:



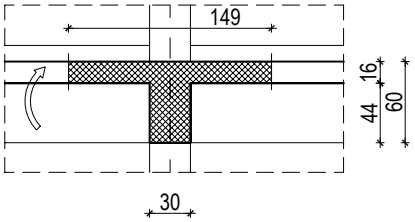
6.4 Dimenzioniranje nosača na moment savijanja

Beton: C 30/37; f_{ck}=30.0 MPa $f_{cd} = \frac{f_{ck}}{\gamma_c} = \frac{30.0}{1.5} = 20.0\,\text{MPa}$

Armatura: B 500B; f_{yk}=500.0 MPa $f_{yd} = \frac{f_{yk}}{\gamma_s} = \frac{500.0}{1.15} = 434.8\,\text{MPa}$

Polje p1:

Utjecajna širina: $b_{eff} = b_0 + \frac{l_0}{5} \le e \quad \Rightarrow \quad b_{eff} = 30 + \frac{0.85 \cdot 700}{5} = 149\,\text{cm} < 640\,\text{cm}$



$M_{sd} = 300.8\,\text{kNm}$

$\mu_{sd} = \frac{M_{sd}}{b_{eff} \cdot d^2 \cdot f_{cd}} = \frac{30080}{149 \cdot 55^2 \cdot 2.0} = 0.033$

Očitano: $\varepsilon_{s1} = 10.0\,‰ \quad \varepsilon_{c2} = 1.0\,‰ \quad \xi = 0.091 \quad \zeta = 0.968$

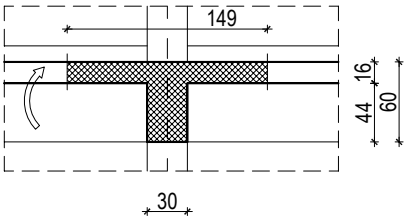
$x = \xi \cdot d = 0.091 \cdot 55 = 5.0\,\text{cm} < h_{pl}$

$A_{s1} = \frac{M_{sd}}{\zeta \cdot d \cdot f_{yd}} = \frac{30080}{0.968 \cdot 55 \cdot 43.5} = 12.99\,\text{cm}^2$

Odabrano 4Ø22 (As=15.21 cm²)

Polje p2 – pozitivni moment:

Utjecajna širina: $b_{eff} = b_0 + \frac{l_0}{5} \le e \quad \Rightarrow \quad b_{eff} = 30 + \frac{0.70 \cdot 700}{5} = 128\,\text{cm} < 640\,\text{cm}$



$M_{sd} = 149.1\,\text{kNm}$

$\mu_{sd} = \frac{M_{sd}}{b_{eff} \cdot d^2 \cdot f_{cd}} = \frac{14910}{128 \cdot 55^2 \cdot 2.0} = 0.019$

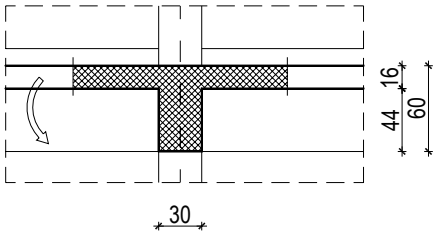
Očitano: $\varepsilon_{s1} = 10.0\,‰ \quad \varepsilon_{c2} = 0.7‰ \quad \xi = 0.065 \quad \zeta = 0.977$

$x = \xi \cdot d = 0.065 \cdot 55 = 3.6\,\text{cm} < h_{pl}$

$A_{s1} = \frac{M_{sd}}{\zeta \cdot d \cdot f_{yd}} = \frac{14910}{0.977 \cdot 55 \cdot 43.5} = 6.38\,\text{cm}^2$

Odabrano 2Ø22 (As=7.60 cm²)

Polje p2 – negativni moment:



$M_{sd} = -9.5\ \text{kNm}$

$$\mu_{sd} = \frac{M_{sd}}{b_w \cdot d^2 \cdot f_{cd}} = \frac{950}{30 \cdot 55^2 \cdot 2.0} = 0.005$$

Očitano: $\varepsilon_{s1} = 10.0\ ‰ \quad \varepsilon_{c2} = 0.4\ ‰ \quad \zeta = 0.988$

$$A_{s1} = \frac{M_{sd}}{\zeta \cdot d \cdot f_{yd}} = \frac{950}{0.988 \cdot 55 \cdot 43.5} = 0.40\ \text{cm}^2$$

$$A_{s1,min} = 0.1\% \cdot A_c = \frac{0.1}{100} \cdot 30 \cdot 60 = 1.80\ \text{cm}^2$$

Odabrano 2Ø22 (As=7.60 cm^2)

Ležaj 1:

$M_{sd} = 363.4\ \text{kNm}$

$$\mu_{sd} = \frac{M_{sd}}{b_w \cdot d^2 \cdot f_{cd}} = \frac{36340}{30 \cdot 55^2 \cdot 2.0} = 0.220$$

Očitano: $\varepsilon_{s1} = 10.0\ ‰ \quad \varepsilon_{c2} = 3.5\ ‰ \quad \zeta_{lim} = 0.892 \quad \mu_{sd,lim} = 0.159$

$$M_{Rd,lim} = \mu_{sd,lim} \cdot b_w \cdot d^2 \cdot f_{cd} = 0.159 \cdot 30 \cdot 55^2 \cdot 2.0 = 288.6\ \text{kNm}$$

$M_{Rd,lim} < M_{sd}$ - dvostruko armiranje

$$A_{s1} = \frac{M_{Rd,lim}}{\zeta_{lim} \cdot d \cdot f_{yd}} + \frac{(M_{sd} - M_{Rd,lim})}{(d - d_2) \cdot f_{yd}} = \frac{28860}{0.892 \cdot 55 \cdot 43.5} + \frac{(36340 - 28860)}{(55 - 5) \cdot 43.5} = 13.52 + 3.44 = 16.96\ \text{cm}^2$$

Odabrano 5Ø22 (As=19.01 cm^2)

$$A_{s2} = \frac{(M_{sd} - M_{Rd,lim})}{(d - d_2) \cdot f_{yd}} = \frac{(36340 - 28860)}{(55 - 5) \cdot 43.5} = 3.44\ \text{cm}^2$$

Odabrano 2Ø22 (As=7.60 cm^2)

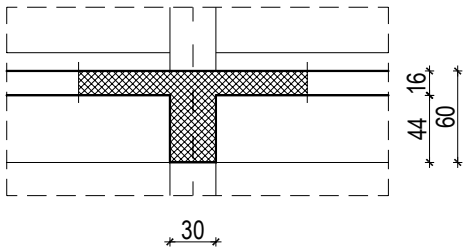
6.5 Dimenzioniranje nosača na poprečnu silu

Ležaj 0

C 30/37
τ_{Rd}=0.34 MPa

V_{sd} =205.0 kN

N_{sd}=0.0 kN



$$V_{Rd1} = \left[\tau_{Rd} \cdot k \cdot (1.2 + 40 \cdot \rho_l) + 0.15 \cdot \sigma_{cp}\right] \cdot b_w \cdot d =$$

$$b_w = 30 \text{ cm} ; \; d = 55 \text{ cm}$$

$$k = 1.6 - d = 1.6 - 0.55 = 1.05$$

$$\rho_l = \frac{A_s}{A_c} = \frac{4\phi 22 + 2\phi 22}{30 \cdot 60} = \frac{22.81}{1800} = 0.013 = 1.3\%$$

$$\sigma_{cp} = \frac{N_{sd}}{A_c} = 0.0$$

$$V_{Rd1} = \left[0.034 \cdot 1.05 \cdot (1.2 + 40 \cdot 0.013) + 0.15 \cdot 0.0\right] \cdot 30 \cdot 55$$

$$V_{Rd1} = 101.3 \text{ kN} < V_{sd}$$

$$\nu = 0.7 - \frac{f_{ck}}{200} = 0.7 - \frac{30}{200} = 0.55 \geq 0.5$$

$$V_{Rd2} = 0.5 \cdot \nu \cdot f_{cd} \cdot b_w \cdot z = 0.5 \cdot 0.55 \cdot 2.0 \cdot 30 \cdot 0.9 \cdot 55 = 816.8 \text{ kN} > V_{sd}$$

Potrebna računska poprečna armatura!

$$\frac{V_{sd}}{V_{Rd2}} \approx \frac{228.0}{816.8} = 0.28$$

$$s_{w,max} \leq \begin{cases} 0.6 \cdot d = 0.6 \cdot 60 = 36 \text{ cm} \\ 30 \text{ cm} \end{cases} ; \quad s_w = 30 \text{ cm}$$

$$A_{sw,min} = \frac{\rho_{min} \cdot s_w \cdot b_w}{m} = \frac{0.0011 \cdot 30 \cdot 30}{2} = 0.495 \text{ cm}^2$$

Odabrane minimalne spone: **Ø10/30** (A_{sw}=0.79 cm^2)

$$V_{wd} = \frac{m \cdot A_{sw} \cdot f_{yw,d} \cdot z}{s_w} = \frac{2 \cdot 0.79 \cdot 43.5 \cdot (0.9 \cdot 55)}{30} = 113.4 \text{ kN}$$

$$V_{Rd} = V_{wd} + V_{Rd1} = 113.4 + 101.3 = 214.7 \text{ kN}$$

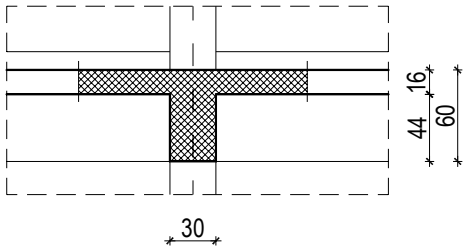
$$V_{Rd} \geq V_{sd}$$

Ležaj 1

C 30/37
τ_{Rd}=0.34 MPa

V_{sd} =296.8 kN

N_{sd}=0.0 kN



$$V_{Rd1} = \left[\tau_{Rd} \cdot k \cdot (1.2 + 40 \cdot \rho_l) + 0.15 \cdot \sigma_{cp}\right] \cdot b_w \cdot d =$$

$b_w = 30$ cm ; $d = 55$ cm

$$k = 1.6 - d = 1.6 - 0.55 = 1.05$$

$$\rho_l = \frac{A_s}{A_c} = \frac{2\phi 22 + 5\phi 22}{30 \cdot 60} = \frac{26.61}{1800} = 0.0015 = 0.15\%$$

$$\sigma_{cp} = \frac{N_{sd}}{A_c} = 0.0$$

$$V_{Rd1} = \left[0.034 \cdot 1.05 \cdot (1.2 + 40 \cdot 0.015) + 0.15 \cdot 0.0\right] \cdot 30 \cdot 55$$

$$V_{Rd1} = 106.03 \text{ kN} < V_{sd}$$

$$\nu = 0.7 - \frac{f_{ck}}{200} = 0.7 - \frac{30}{200} = 0.55 \geq 0.5$$

$$V_{Rd2} = 0.5 \cdot \nu \cdot f_{cd} \cdot b_w \cdot z = 0.5 \cdot 0.55 \cdot 2.0 \cdot 30 \cdot 0.9 \cdot 55 = 816.8 \text{ kN} > V_{sd}$$

Potrebna računska poprečna armatura!

$$\frac{V_{sd}}{V_{Rd2}} \approx \frac{342.1}{816.8} = 0.42$$

$$s_{w,max} \leq \begin{cases} 0.6 \cdot d = 0.6 \cdot 60 = 36 \text{ cm} \\ 30 \text{ cm} \end{cases} \quad ; \quad s_w = 30 \text{ cm}$$

$$A_{sw,min} = \frac{\rho_{min} \cdot s_w \cdot b_w}{m} = \frac{0.0011 \cdot 30 \cdot 30}{2} = 0.495 \text{ cm}^2$$

Odabrane minimalne spone: **Ø10/30** (A_{sw}=0.79 cm^2), $V_{Rd} = 219.07$ kN

Na mjestu maksimalne poprečne sile:

$$s_w \leq \frac{m \cdot A_{sw} \cdot f_{yw,d} \cdot z}{(V_{wd} - V_{Rd1})} = \frac{2 \cdot 0.79 \cdot 43.5 \cdot (0.9 \cdot 55)}{(296.8 - 106.03)} = 17.83 \text{ cm}$$

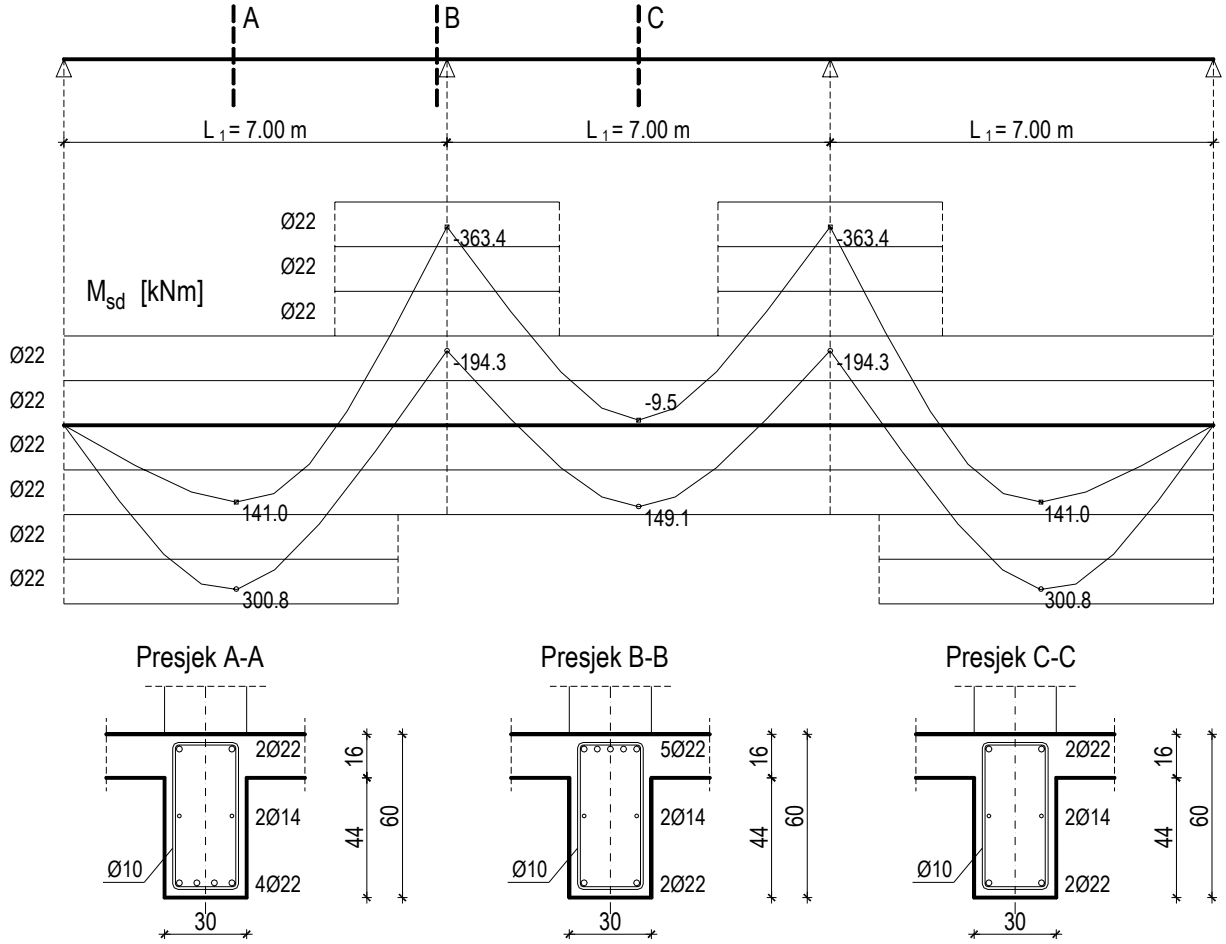
Postaviti spone **Ø10/15** (A_{sw}=0.79 cm^2)

Tablica nosivosti na poprečne sile za različite razmake postavljanja spona:

Spone	Površina A_{sw}	Nosivost betona V_{Rd1}	Nosivost spona V_{wd}	Ukupna nosivost $V_{Rd3} = V_{Rd1} + V_{wd}$
	[cm^2]	[kN]	[kN]	[kN]
Ø 10 / 30	0.79	101.30	112.74	214.04
Ø 10 / 25	0.79	101.30	135.29	236.59
Ø 10 / 20	0.79	101.30	169.12	270.42
Ø 10 / 15	0.79	101.30	225.49	326.79

6.6 Kontrola pukotina u 1. polju

Širinu pukotina kontroliramo za nefaktorizirano opterećenje i bez utjecaja puzanja.



$$M_{g,p1} = k_{p1} \cdot g \cdot L_1^2 = 0.080 \cdot 32.64 \cdot 7.0^2 = 127.9\ \text{kNm}$$

$$M_{q,p1,max} = k_{p1,max} \cdot q \cdot L_1^2 = 0.101 \cdot 17.26 \cdot 7.0^2 = 85.4\ \text{kNm}$$

$$M_{sd,p1,max} = \gamma_g \cdot M_{g,p1} + \gamma_q \cdot M_{q,p1,max} = 1.0 \cdot 127.9 + 1.0 \cdot 85.4 = 213.3\ \text{kNm}$$

Prognozna širina pukotine:

$$w_k = \beta \cdot s_{rm} \cdot \varepsilon_{sm}$$

β=1.7 - odnos računske i srednje širine pukotina

Proračun srednje deformacije armature:

$$\varepsilon_{sm} = \frac{\sigma_s}{E_s} \cdot \zeta = \frac{\sigma_s}{E_s} \cdot \left[1 - \beta_1 \cdot \beta_2 \cdot \left(\frac{\sigma_{sr}}{\sigma_s} \right)^2 \right]$$

A_{s1} = 4Ø22 = 15.21 cm^2

$E_{cm} = 32.0\ \text{GPa} = 32000.0\ \text{MPa}$ - modul elastičnosti betona

$E_s = 200.0\ \text{GPa} = 200000.0\ \text{MPa}$ - modul elastičnosti armature

$$\alpha_{el} = \frac{E_s}{E_{cm}} = \frac{200}{32} = 6.25$$

$$x = \frac{\alpha_{el}\cdot A_{S1}}{b}\cdot\left(-1+\sqrt{1+\frac{2\cdot b\cdot d}{\alpha_{el}\cdot A_{S1}}}\right) = \frac{6.25\cdot 15.21}{30}\cdot\left(-1+\sqrt{1+\frac{2\cdot 30\cdot 55}{6.25\cdot 15.21}}\right) = 15.8\ \text{cm}$$

$$\sigma_s = \frac{M_{sd}}{z\cdot A_s} \approx \frac{M_{sd}}{\left(d-\frac{x}{3}\right)\cdot A_s} = \frac{21330}{\left(55-\frac{15.8}{3}\right)\cdot 15.21} = 28.20\,\frac{\text{kN}}{\text{cm}^2} = 282.0\ \text{MPa}$$

$$\sigma_{sr} = \frac{M_{cr}}{z\cdot A_s} \quad ; \quad M_{cr} = f_{ct,m}\cdot\frac{b\cdot h^2}{6} \quad ; \quad f_{ct,m} \approx 0.3\cdot\left(f_{ck}\right)^{2/3} \quad ; \quad f_{ck} = 30.0\ \text{MPa}$$

$$f_{ct,m} = 0.3\cdot\left(f_{ck}\right)^{2/3} = 0.3\cdot(30.0)^{2/3} = 2.9\ \text{MPa}$$

$$M_{cr} = 0.29\cdot\frac{30\cdot 60^2}{6} = 5220.0\ \text{kNcm} = 52.20\ \text{kNm}$$

$$\sigma_{sr} = \frac{M_{cr}}{z\cdot A_s} \approx \frac{M_{cr}}{\left(d-\frac{x}{3}\right)\cdot A_s} = \frac{5220}{\left(55-\frac{15.8}{3}\right)\cdot 15.21} = 6.90\,\frac{\text{kN}}{\text{cm}^2} = 69.0\ \text{MPa}$$

$\beta_1 = 1.0$ - Rebrasta armatura

$\beta_2 = 0.5$ - Dugotrajno opterećenje

$$\varepsilon_{sm} = \frac{\sigma_s}{E_s}\cdot\left[1-\beta_1\cdot\beta_2\cdot\left(\frac{\sigma_{sr}}{\sigma_s}\right)^2\right] = \frac{282.0}{200000.0}\cdot\left[1-1.0\cdot 0.5\cdot\left(\frac{69.0}{282.0}\right)^2\right] = 0.00137$$

Proračun srednjeg razmaka pukotina:

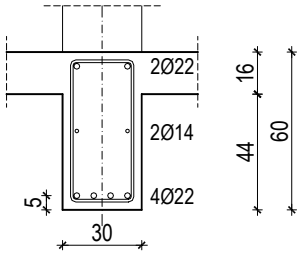
$$s_{rm} = 50 + 0.25\cdot k_1\cdot k_2\cdot\frac{\phi}{\rho_r} \quad [\text{mm}]$$

$\phi = 22$ mm - Promjer najdeblje šipke

$k_1 = 0.8$ - Rebrasta armatura

$k_2 = 0.5$ - Savijanje

$\rho_r = \frac{A_s}{A_{c,eff}} = \frac{15.21}{30\cdot(2.5\cdot 5)} = 0.0406$ - Djelotvorni koeficijent armiranja glavnom vlačnom armaturom



$$s_{rm} = 50 + 0.25\cdot k_1\cdot k_2\cdot\frac{\phi}{\rho_r} = 50 + 0.25\cdot 0.8\cdot 0.5\cdot\frac{22}{0.0406} = 104.2\ \text{mm}$$

Prognozna širina pukotine:

$$w_k = \beta\cdot s_{rm}\cdot\varepsilon_{sm} = 1.7\cdot 0.00137\cdot 104.2 = 0.242\ \text{mm} < w_g = 0.3\ \text{mm}$$

6.7 Kontrola progiba za 1. polje

Progib kontroliramo za nefaktorizirano opterećenje i bez utjecaja puzanja.

$$M_{g,p1} = k_{p1} \cdot g \cdot L_1^2 = 0.080 \cdot 32.64 \cdot 7.0^2 = 127.9 \text{ kNm}$$

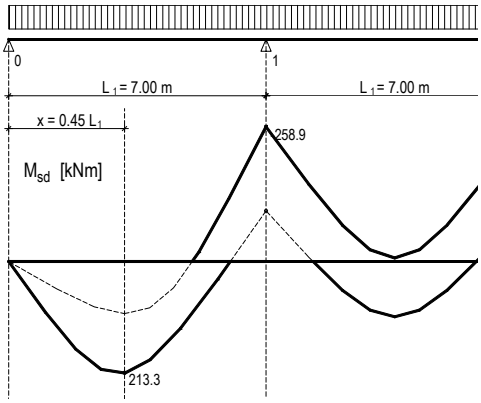
$$M_{q,p1,max} = k_{p1,max} \cdot q \cdot L_1^2 = 0.101 \cdot 17.26 \cdot 7.0^2 = 85.4 \text{ kNm}$$

$$M_{sd,p1,max} = \gamma_g \cdot M_{g,p1} + \gamma_q \cdot M_{q,p1,max} = 1.0 \cdot 127.9 + 1.0 \cdot 85.4 = 213.3 \text{ kNm}$$

$$M_{g,l} = k_l \cdot g \cdot L_1^2 = -0.100 \cdot 32.64 \cdot 7.0^2 = -159.9 \text{ kNm}$$

$$M_{q,l,min} = k_l \cdot q \cdot L_1^2 = -0.117 \cdot 17.26 \cdot 7.0^2 = -99.0 \text{ kNm}$$

$$M_{sd,l,min} = \gamma_g \cdot M_{g,l} + \gamma_q \cdot M_{q,l,min} = 1.0 \cdot (-159.9) + 1.0 \cdot (-99.0) = -258.9 \text{ kNm}$$



Granični progib:

$$\nu_{lim} = \frac{L}{250} = \frac{700}{250} = 2.80 \text{ cm}$$

Beton: C 30/37; f_{ck}=30.0 MPa

$$E_{cm} = 32000 \text{ MPa}$$

$$f_{ct,m} = 0.3 \cdot (f_{ck})^{2/3} = 0.3 \cdot (30.0)^{2/3} = 2.9 \text{ MPa}$$

Čelik: B500B; E_s=200.0 GPa

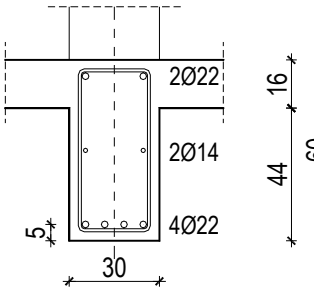
$$\alpha_{el} = \frac{E_s}{E_{cm}} = \frac{200.0}{32.0} = 6.25$$

$$\nu_{tot} = k \cdot L^2 \cdot \frac{1}{r_{tot}}$$

$$\beta = |M_A + M_B| / |M_F| = |0.0 + 258.9| / |213.3| = 1.21$$

$$k = \frac{5}{48} \cdot (1 - 0.1 \cdot \beta) = 0.104 \cdot (1 - 0.1 \cdot 1.21) = 0.091$$

Progib homogenog presjeka:



A_{s1} = 4∅22 = 15.21 cm²

A_{s2} = 2∅22 = 7.60 cm²

$$I_l = \frac{bh^3}{12} + \alpha_{el} \cdot \left[A_{s1} \cdot \left(\frac{h}{2} - d_2 \right)^2 + A_{s2} \cdot \left(\frac{h}{2} - d_1 \right)^2 \right]$$

$$= \frac{30 \cdot 60^3}{12} + 6.25 \cdot \left[15.21 \cdot \left(\frac{60}{2} - 5 \right)^2 + 7.60 \cdot \left(\frac{60}{2} - 5 \right)^2 \right] =$$

$$= 540000.0 + 89100.0 = 629100.0 \text{ cm}^4$$

$$E_{c,eff} = E_{cm} = 32.0 \text{ GN/m}^2 = 3200.0 \text{ kN/cm}^2$$

$$\frac{1}{r_l} = \frac{M_{Sd}}{E_{c,eff} \cdot I_l} = \frac{21330}{3200 \cdot 629100} = 0.0000106 \frac{1}{\text{cm}}$$

Progib potpuno raspucanog presjeka:

$x = 15.8\ \text{cm}$

$$I_{II} = \frac{bx^3}{12} + bx \cdot \left(\frac{x}{2}\right)^2 + \alpha_{el} \cdot \left[A_{s1} \cdot (d-x)^2 + A_{s2} \cdot (x-d_2)^2\right]$$

$$= \frac{30 \cdot 15.80^3}{12} + (30 \cdot 15.80) \cdot \left(\frac{15.80}{2}\right)^2 + 6.25 \cdot \left[15.21 \cdot (55-15.80)^2 + 7.60 \cdot (15.80-5)^2\right]$$

$$= 39\,400.0 + 151\,600.0 = 191\,000.0\ \text{cm}^4$$

$$\frac{1}{r_{II}} = \frac{M_{Sd}}{E_{c,eff} \cdot I_{II}} = \frac{21330}{3200 \cdot 191000} = 0.0000349\ \frac{1}{\text{cm}}$$

Ukupni progib

$\sigma_s = 282.0\ \text{MPa}$

$\sigma_{sr} = 69.0\ \text{MPa}$

$\beta_1 = 1.0$ - Rebrasta armatura

$\beta_2 = 0.5$ - Dugotrajno opterećenje

$$\zeta = 1 - \beta_1 \cdot \beta_2 \cdot \left(\frac{\sigma_{sr}}{\sigma_s}\right)^2 = 1 - 1.0 \cdot 0.5 \cdot \left(\frac{69.0}{282.0}\right)^2 = 0.97$$

$$\frac{1}{r_I} = 0.0000106\ \frac{1}{\text{cm}}$$

$$\frac{1}{r_{II}} = 0.0000349\ \frac{1}{\text{cm}}$$

$$\frac{1}{r_m} = (1-\zeta) \cdot \frac{1}{r_I} + \zeta \cdot \frac{1}{r_{II}} = (1-0.97) \cdot 0.0000106 + 0.97 \cdot 0.0000349 = 0.0000342\ \frac{1}{\text{cm}}$$

$k = 0.091$

$L = 700.0\ \text{cm}$

$$\nu_{tot,t=0} = k \cdot L^2 \cdot \frac{1}{r_{tot}} = 0.091 \cdot 700.0^2 \cdot 0.0000342 = 1.52\ \text{cm} < \nu_{lim} = 2.80\ \text{cm}$$