Projekt nosive armiranobetonske konstrukcije poslovnog objekta

Dodig, Šime

SVEUČILIŠTE U SPLITU

FAKULTET GRAĐEVINARSTVA, ARHITEKTURE I GEODEZIJE

ZAVRŠNI RAD

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Split, Matice hrvatske 15

STUDIJ: **STRUČNI STUDIJ GRAĐEVINARSTVA**

KANDIDAT: Šime Dodig

BROJ INDEKSA: 1562

KATEDRA: **Katedra za betonske konstrukcije i mostove**

PREDMET: Betonske konstrukcije 1

ZADATAK ZA ZAVRŠNI RAD

Tema: Projekt nosive armiranobetonske konstrukcije poslovnog objekta

Opis zadatka:

Zadana je shema nosive konstrukcije armiranobetonskog objekta poslovne namjene, sa svim potrebnim dimenzijama (prilog zadatku). Također su zadana djelovanja na konstrukciju. Potrebno je proračunati nosivu konstrukciju, te za neke elemente nacrtati planove oplate i armature. Statički proračun i armaturne planove izraditi sukladno propisima i pravilima struke.

U Splitu, 28.10.2016.

Voditelj Završnog rada:

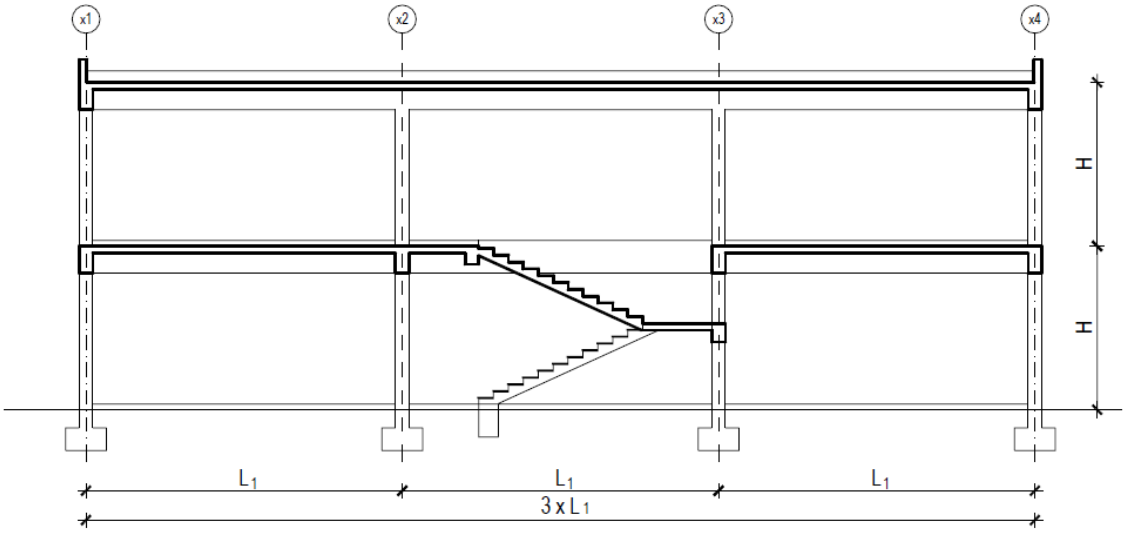
.dr.sc. Nikola Grgić

PRILOG:

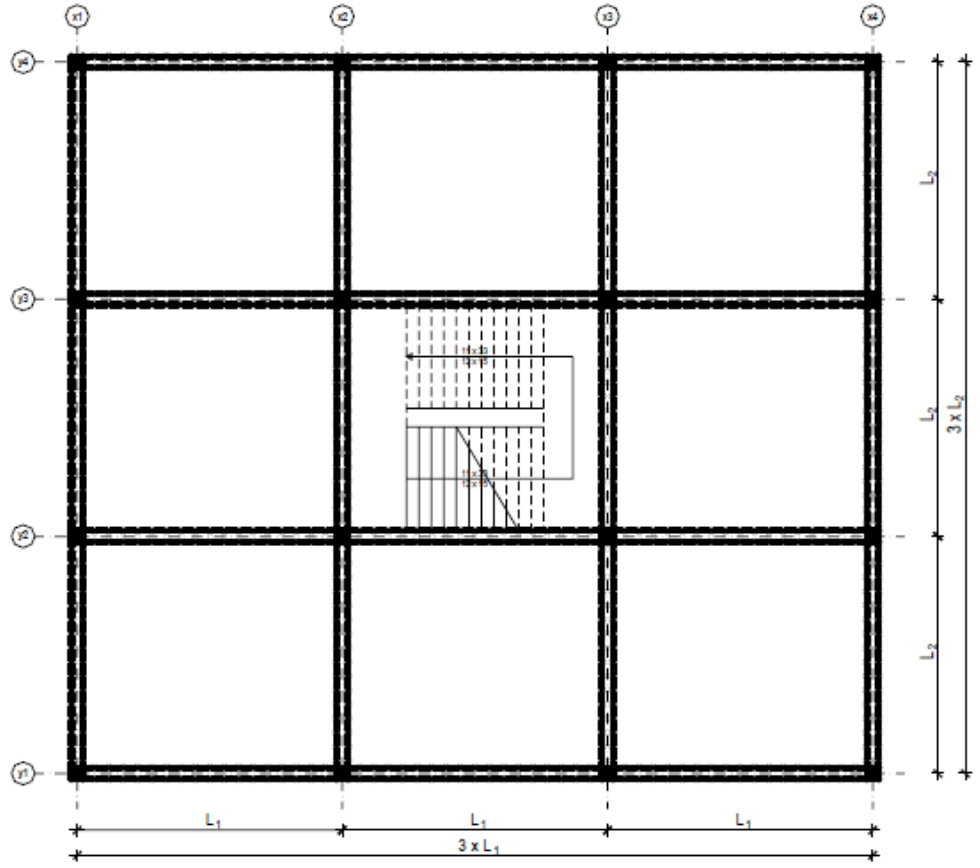
Na priloženim skicama dana je shema nosive armiranobetonske konstrukcije objekta. U tablici su zadane sve potrebne dimenzije i djelovanja na konstrukciju.

Oznaka	Veličina	Jedinica	Opis
L_1	6,5	(m)	„raster“ u uzdužnom smjeru
L_2	6,0	(m)	„raster “ u poprečnom smjeru
H	3,5	(m)	visina etaža
q	3,7	(kN/m^2)	uporabno opterećenje
Z_v	II		zona vjetra
a_g	0,25g	(m/s^2)	proračunsko ubrzanje tla
S	B 450 BC		armatura
C	C 30/37		klasa betona

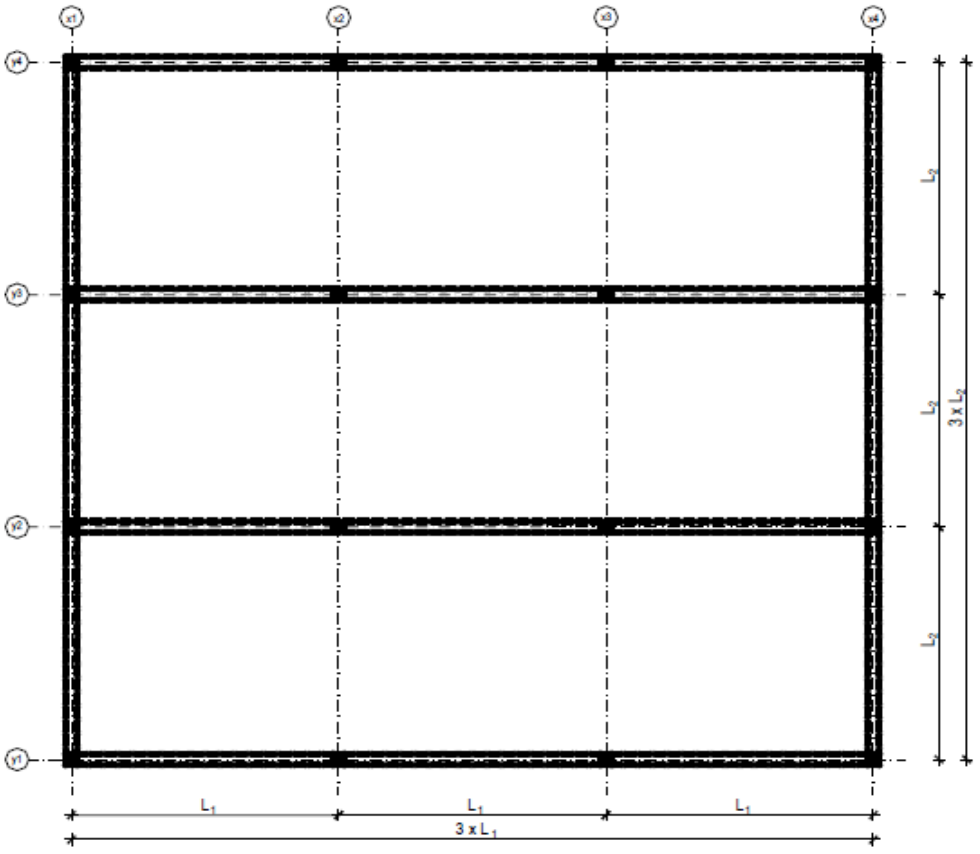
(i) **Presjek**



(ii) **Međuetaže**



(iii) **Krovna konstrukcija**



SAŽETAK:

Zadana je shema nosive konstrukcije armiranobetonskog objekta poslovne namjene sa svim potrebnim dimenzijama (prilog zadatku). Također su zadana djelovanja na konstrukciju,te za neke elemente nacrtati planove oplate i armature. Statički proračun i armaturne planove izraditi sukladno propisima i pravilima struke.

KLJUČNE RIJEČI:

Armiranobetonski objekt poslovne namjene,numerički model,statički proracun,plan armature.

ABSTRACT:

The default scheme bearing structures reinforced concrete facility for business purposes, with all the required dimensions (Annex task). Also the default action on the structure, and for some elements draw plans and reinforcement. Structural analysis and reinforcement plans develop in accordance with the regulations and rules of the profession.

KEYWORDS:

Reinforced concrete building for business purposes , numerical model , static analysis , reinforcement plan

SADRŽAJ:

1. *TEHNIČKI OPIS*

Predmet ovog rada je projekt armiranobetonske nosive konstrukcije poslovnog objekta. Predmetna građevina sastoji se od prizemlja i kata. Završna ploča kata je ujedno i ravni krov građevine.

Visina građevine iznosi 7,00 m, a tlocrtna površina građevine iznosi 19,50 x 18,00 m.

Nosiva konstrukcija objekta je okvirna,a čine je stupovi i grede iznad koje su armiranobetonske ploče. Stupovi se oslanjaju na temelje samce. Rezne sile u pločama i gredama dobivene su pomoću programa *AspalathosLinear*,a korišten je ravninski model. Sve armiranobetonske ploče su debljine d=18.0cm. Poprečne grede su dimenzija b/h=30/60 cm,a uzdužne grede dimenzija b/h=30/60 cm. Rezne sile u stupovima za različite kombinacije opterećenja dobivene su pomoću programa *AspalathosLinear*,a korišten je prostorni model (okvir). Odabrane su dimenzije stupova 35/35 cm i temelji samci 190x190x70 cm. Za vertikalnu komunikaciju između katova predviđeno je armiranobetonsko stepenište debljine nosive ploče d=18.0 cm.

Izračunato stalno opterećenje za poziciju 200(krov) iznosi 8,30 kN/m2,a uporabno opterećenje (prema propisima) iznosi 1,0 kN/m2. Zadano je uporabno opterećenje za poziciju 100 (međukatne konstrukcije) i iznosi 3,7 kN/m2, a stalno opterećenje je 7,70 kN/m2. Građevina se nalazi u II. vjetrovnoj zoni s osnovnom brzinom vjetra vb0= 30 m/s.

Dozvoljeno naprezanje u tlu na dubini temeljenja iznosi $б_{dop}$ = 0.50 Ma.

Za nosivu armiranobetonsku konstrukciju odabran je beton C 30/37 i čelik za armiranje B 450BC.

Za sve armiranobetonske nosive elemente izvršen je proračun za granično stanje nosivosti,a za neke elemente izvršena je provjera graničnog stanja uporabljivosti. Na osnovi proračunskih vrijednosti momenata i dobivenih površina armature, odabrana je armatura (mreže i šipki) te su napravljeni armaturni planovi za neke elemente konstrukcije. Svi nacrti i prikazi krojenja armaturnih mreža ploče, grede i stupova nacrtani su pomoću programa AutoCAD priloženi su u radu.

Statički sustav i armaturni planovi izrađeni su sukladno propisima i pravilima struke.

2. GEOMETRIJSKE KARAKTERISTIKE NOSIVIHELEMENATA

-visina ploče:

$$d_{pl} = \frac{L_2}{35} = \frac{600}{35} = 17{,}14$$

$\Rightarrow$ odabrano: $d_{pl} = 18\,\text{cm}$

visina grede:

$$\frac{L_0}{12} = \frac{L_1}{12} = \frac{650}{12} = 54{,}2\text{cm}$$

odabrano : $h_{G1} = 60{,}0\text{cm}$

$$\frac{L_0}{12} = \frac{L_1}{12} = \frac{600}{12} = 50{,}0\text{cm}$$

odabrano : $h_{G1} = 60{,}0\text{cm}$

-širina grede:

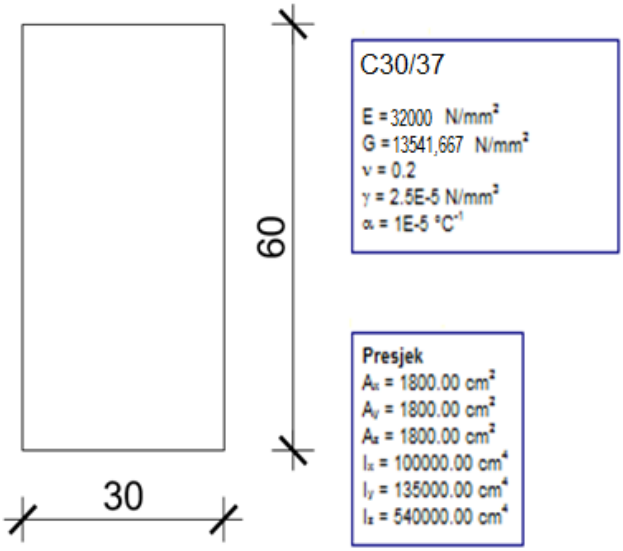
$$\frac{h_{G1}}{2} = \frac{60}{2} = 30\text{cm}$$

odabrano : $b_{G1} = 30\text{cm}$

$$\frac{h_{G2}}{2} = \frac{60}{2} = 30\text{cm}$$

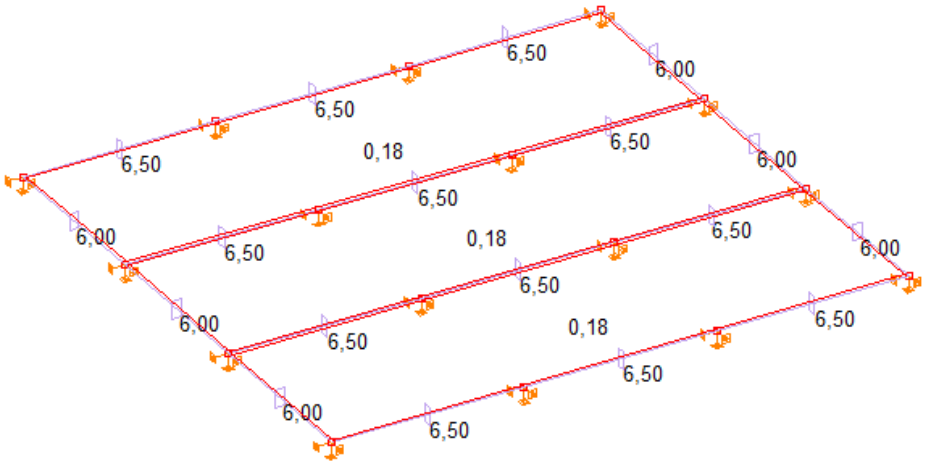
odabrano : $b_{G2} = 30\text{cm}$

PRESJEK 1

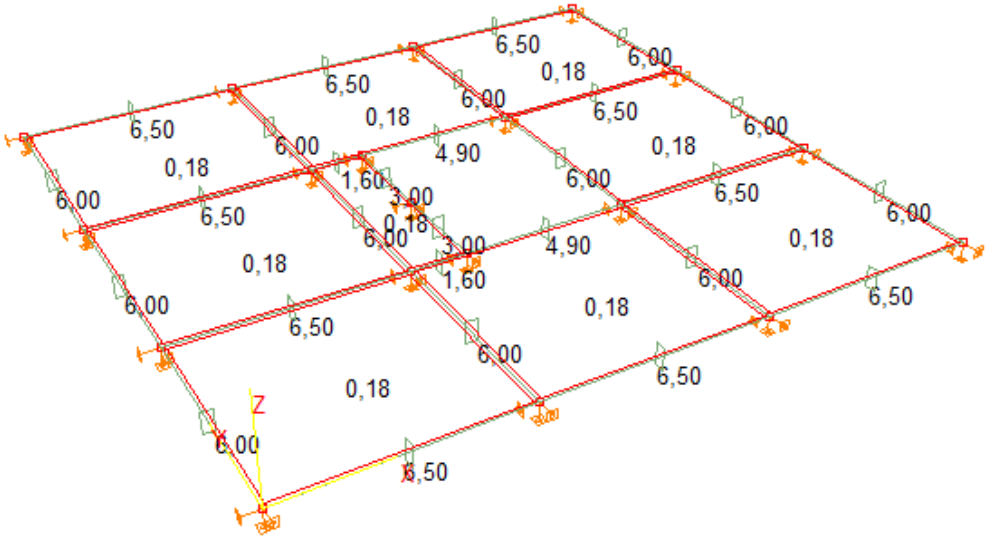


Slika 2.1. Poprečni presjek grede

- Za sve nosive elemente u x i y smjeru na pozicijama 100 i 200 odabran je isti presjek grede, dimenzija 60x30 cm.



Slika 2.2. Prikaz dimenzija greda i ploča poz. 200

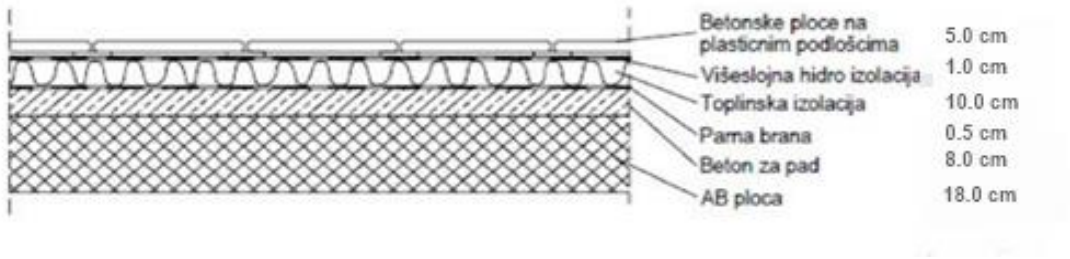


Slika 2.3. Prikaz dimenzija greda i ploča poz. 100

3. ANALIZA OPTEREĆENJA

3.1. **POZICIJA 200 – KROV**

3.1.1. Stalno opterećenje



Slika 3.1. Presjek ploče poz. 200

Tablica 3.1.Stalno opterećenje poz.200

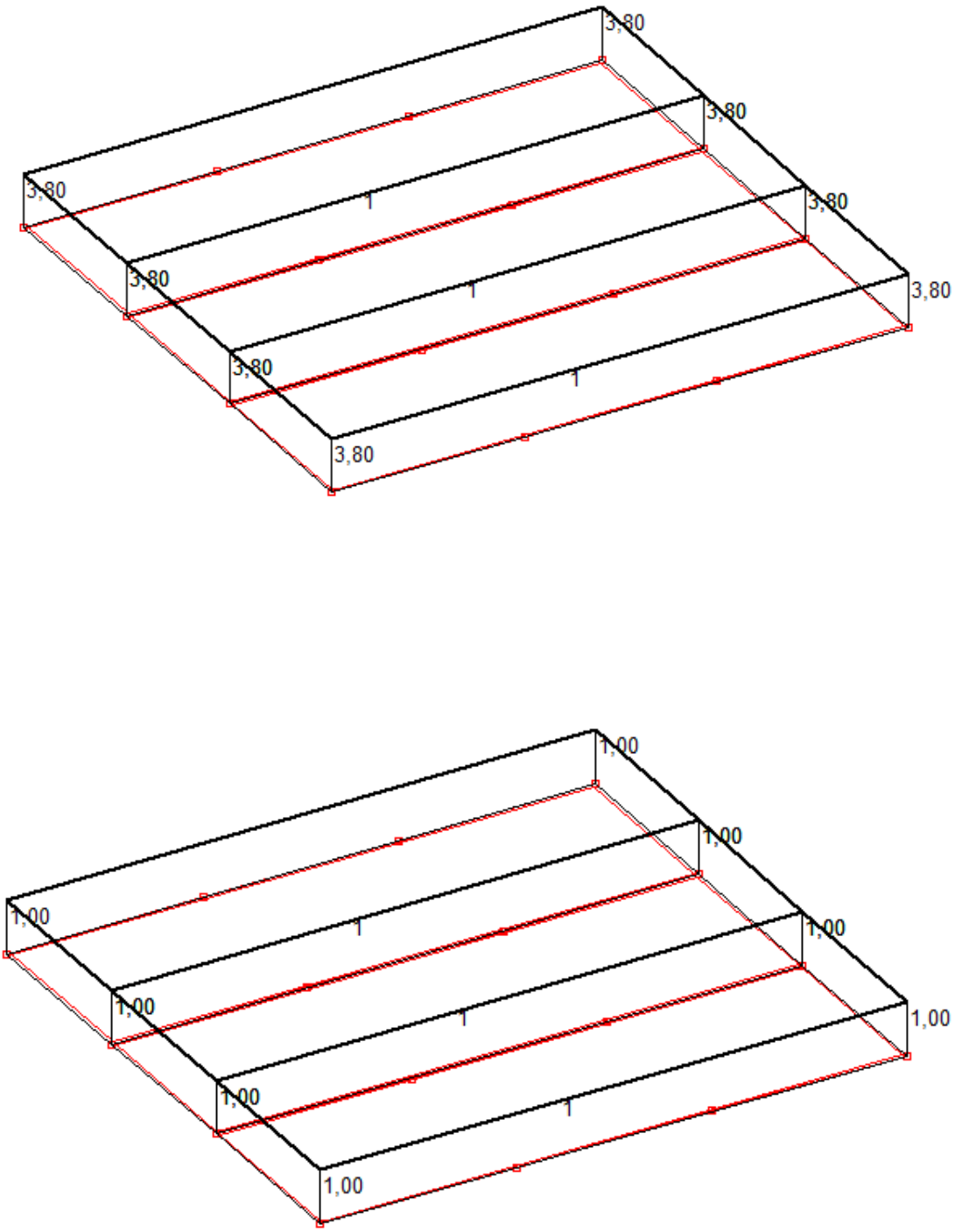
	d (m)	γ (kN/m^3)	d·γ (kN/m^2)
Betonske ploče na plastičnim podlošcima	0.05	25.0	1.25
Hidroizolacija + parna brana	0.01	20.0	0.20
Toplinska izolacija	0.10	5.0	0.50
Beton za pad	0.08	24.0	1.92
AB ploča	0.18	25.0	4.5

Ukupno stalno opterećenje: g_{200} = 8.30 (kN/m^2)

3.1.2. Uporabno opterećenje

Za uporabno 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 uporabno opterećenje neprohodnih ravnih krovova može uzeti zamjenjujuća vrijednost:

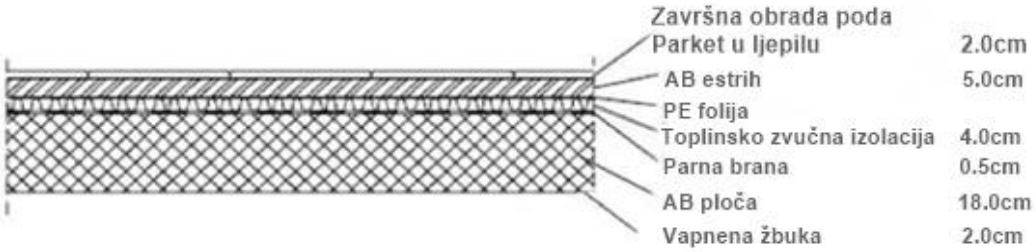
q_{200}= s + w ≈ 1.0 kN/m^2



Slika 3.2. Prikaz dodatnog stalnog opterećenja G_0 i uporabnog opterećenja Q

3.2. **POZICIJA 100 – ETAŽE**

3.2.1. Stalno opterećenje



Slika 3.3. Presjek ploče poz. 100

Tablica 3.2. Stalno opterećenje poz. 100

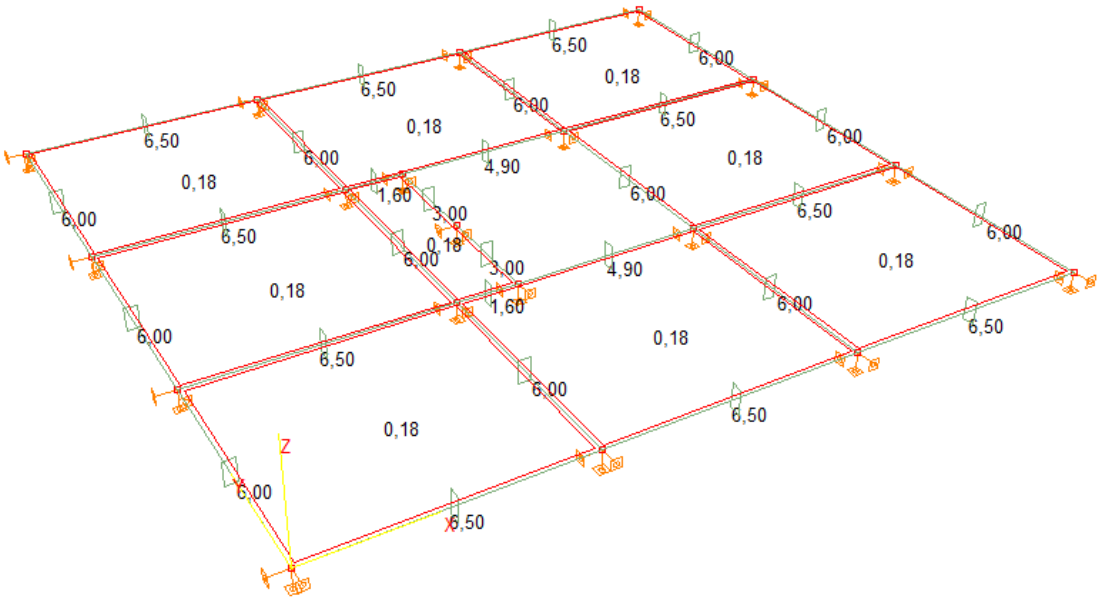
	d (m)	γ (kN/m^3)	d·γ (kN/m^2)
Pregrade			1.00
Završna obrada poda-parket	0.02	12.0	0.24
AB estrih	0.05	25.0	1.25
Toplinska izolacija	0.04	5.0	0.20
Hidroizolacija	0.005	20.0	0.10
AB. Ploča	0.18	25.0	4.50
Pogled (vapnena žbuka)	0,02	19,00	0,38

Ukupno stalno opterećenje g_{100}= 7,70 (kN/m^2)

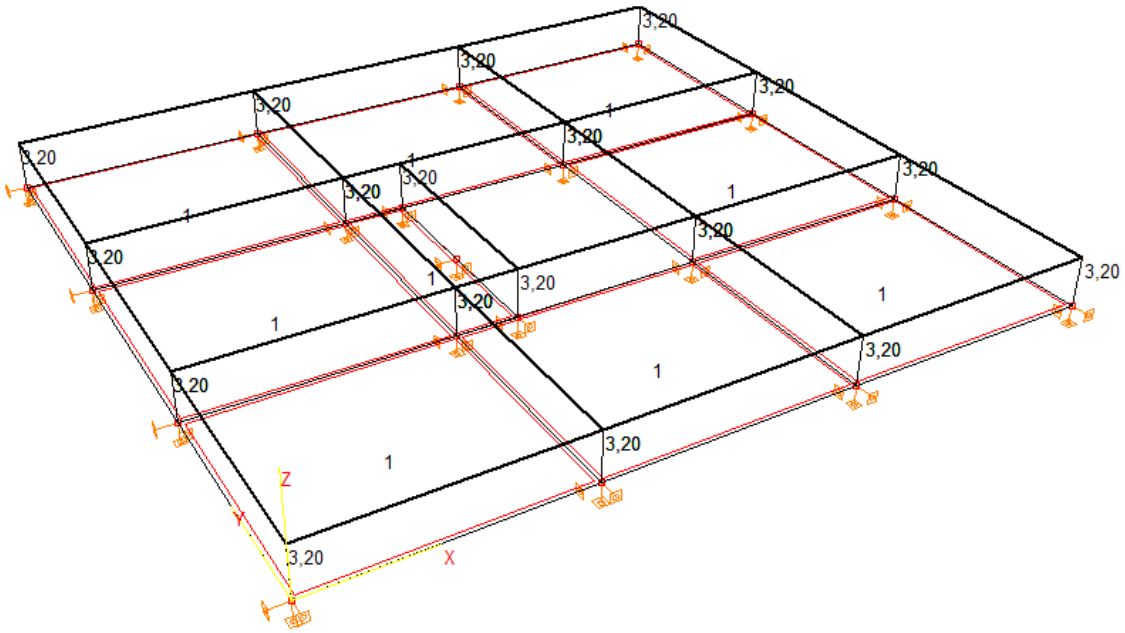
3.2.2. Uporabno opterećenje

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

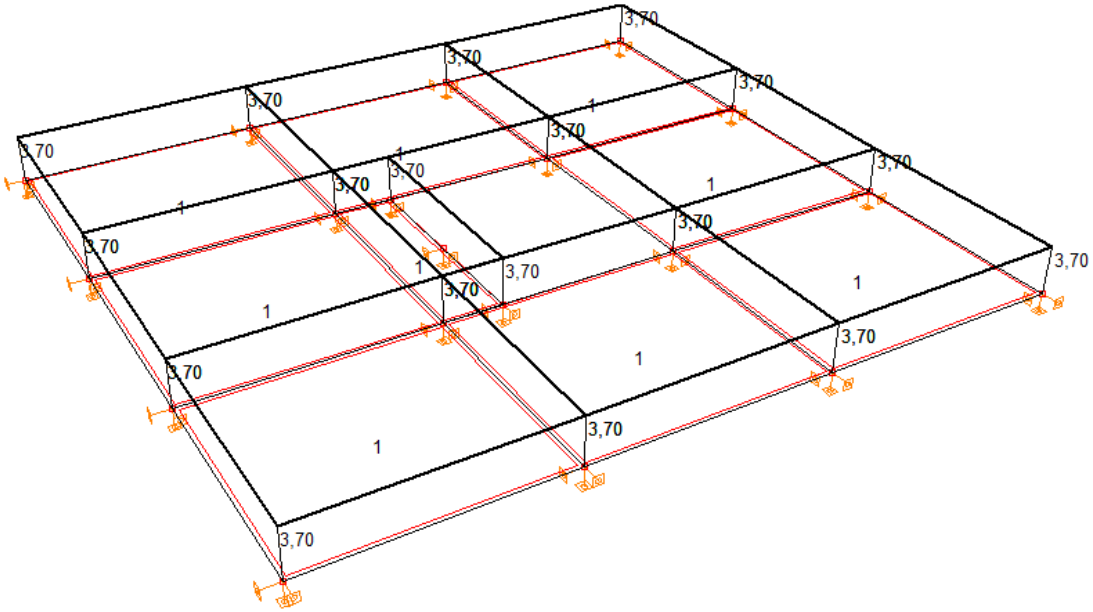
U našem slučaju, zadano je zadatkomq_{100}=3.7 kN/m^2



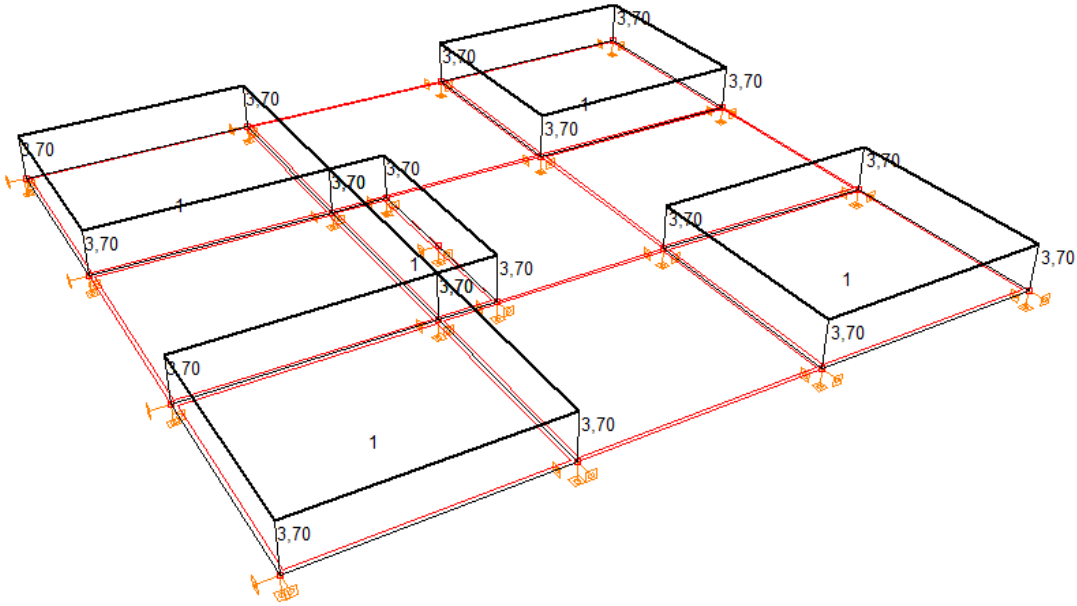
Slika 3.4. Geometrija etaže 100



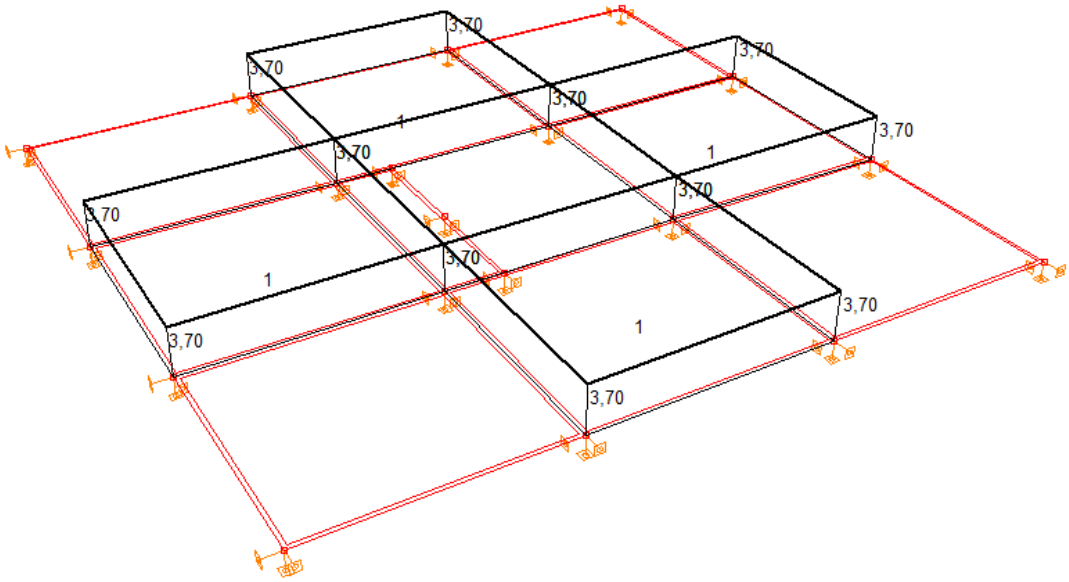
Slika3.5 Prikaz dodatnog stalnog opterećenja G_0



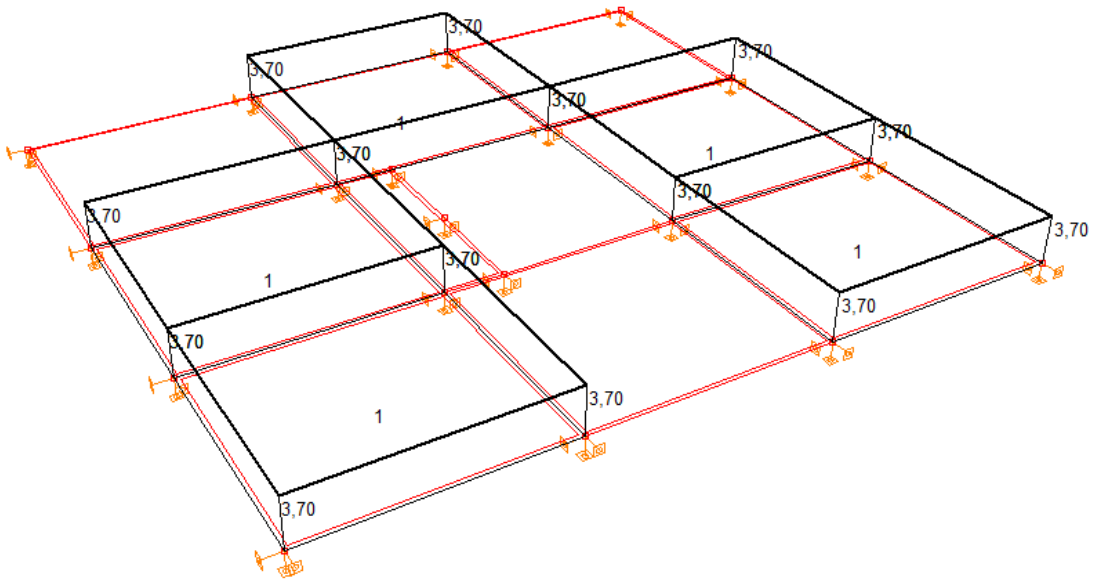
Slika 3.6 Prikaz uporabnog opterećenja shema 1 (max sile na ležajevima kod ploča)



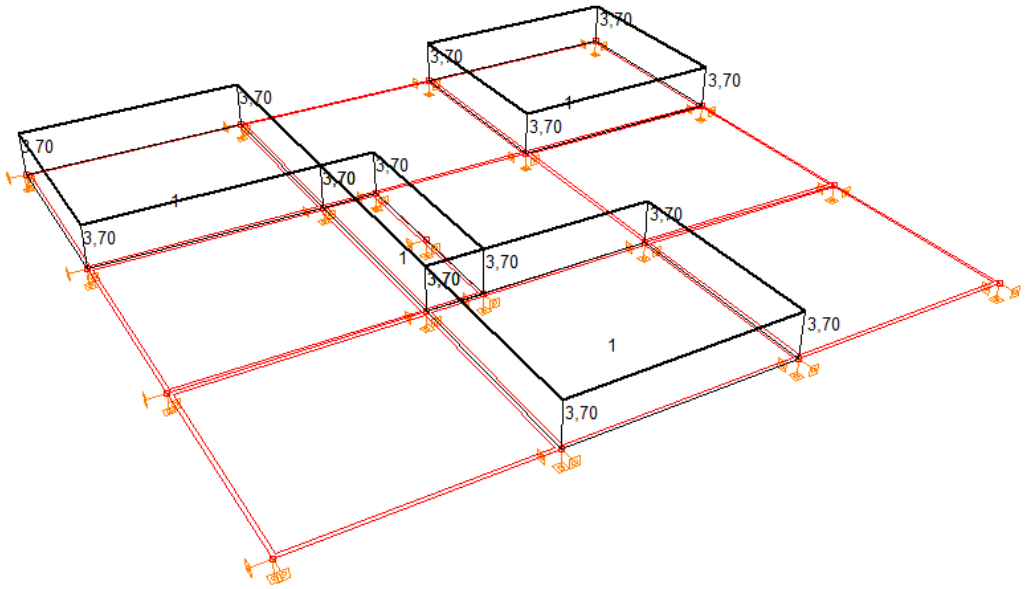
Slika 3.7. Prikaz uporabnog opterećenja shema 2(max sile u krajnjim poljima kod ploča)



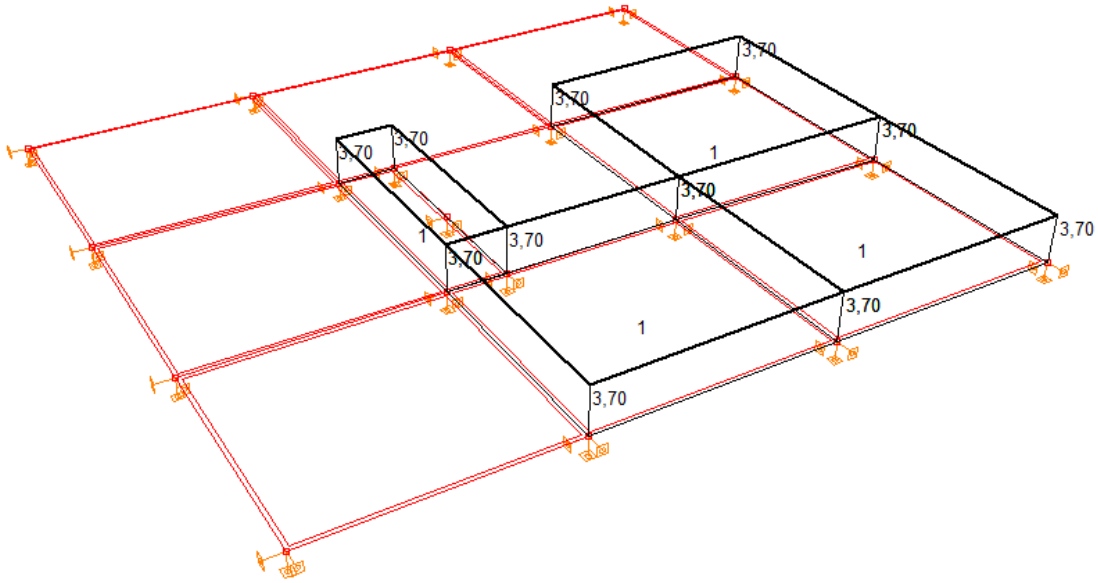
Slika 3.8. Prikaz uporabnog opterećenja shema 3(max sile u srednjem polju kod ploča)



Slika 3.9. Prikaz uporabnog opterećenja shema 4(max sile u krajnjem polju kod grede)



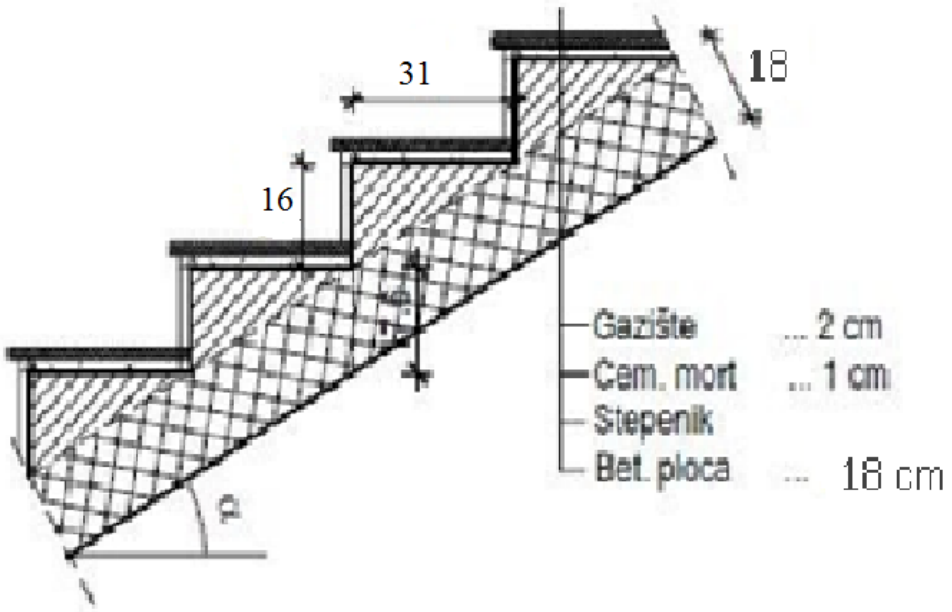
Slika 3.10. Prikaz uporabnog opterećenja shema 5 (max sile u srednjem polju kod grede)



Slika 3.11. Prikaz uporabnog opterećenja shema 6(max sile na ležaju kod grede)

3.3. **STUBIŠTE**

3.3.1. Stalno opterećenje



Slika 3.12. Presjek stubišta

- Broj stuba (za jedan stubišni krak):

ns = H/2·v = 3,50/2·0,1 = 11 stuba

- Širina stube:

2·vs + šs = 63 ⇒šs = 63-2·0,16 = 31 cm

- Duljina kraka:

Lk = ns·šs = 11 ·31 = 340 cm

- Kut α:

tgα = 0,5·H/Lk = 1,75 ·3,4 = 0,595 ⇒

α = 30,75°

- Odabrana duljina podesta:

Lp ≥ 1,20 m Lp=(L-Lk)/2=(6,5-3,4)/2=1,6m

$$h' = \frac{h}{\cos\alpha} = \frac{18}{\cos 30{,}75} = 20{,}95\text{cm}$$

Tablica 3.3. Stalno opterećenje stubišta

	d (m)	γ (kN/m^3)	d·γ (kN/m^2)
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'=20,95 cm)	0.21	25.0	5,25

Ukupno stalno opterećenje : g_{st} = 7,81 (kN/m^2)

3.3.2. Uporabno opterećenje

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

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

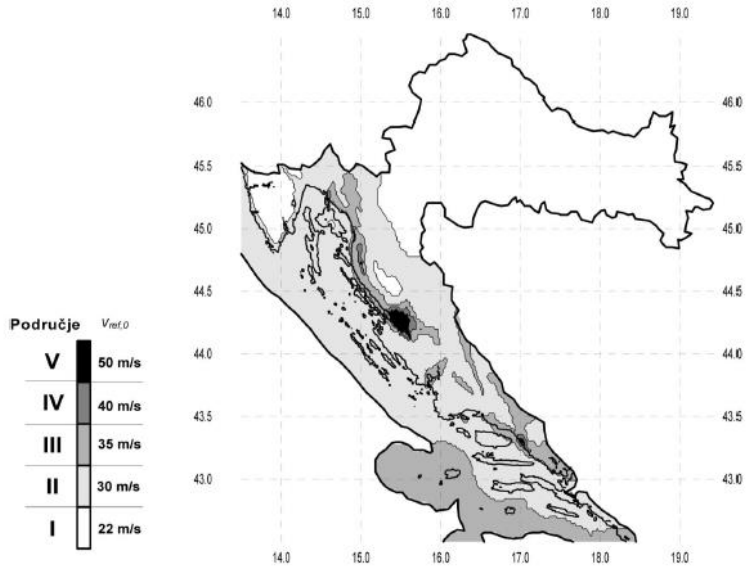
q_{st}= 5,25 (kN/m^2)

3.4. **OPTEREĆENJE VJETROM**

Dimenzije zgrade su: L_1=6.5m,L_2=6.0m,H =3.5m.

Objekt se nalazi u II. vjetrovnoj zoni, na visini od 150 m.n.m

Osnovna brzina vjetra: $\mathrm{v_{b,0}} = 30\ \mathrm{m/s}$ (za II. Zonu)



Slika 3.13. Zemljovid područja opterećenja vjetrom

Referentna brzina vjetra: $v_b = c_{DIR} \cdot c_{TEM} \cdot c_{ALT} \cdot v_{b,0}$

$\mathrm{c_{DIR}}$ - koeficijent smjera vjetra → $\mathrm{c_{DIR}} = 1.0$

$\mathrm{c_{TEM}}$ - koeficijent ovisan o godišnjem dobu → $\mathrm{c_{TEM}} = 1.0$

$\mathrm{c_{ALT}}$ - koeficijent nadmorske visine → $\mathrm{c_{ALT}} = 1 + 0{,}0001 \cdot \mathrm{a_s}$

$c_{ALT} = 1 + 0{,}0001 \cdot 150 = 1{,}015$

$v_b = 1{,}00 \cdot 1{,}00 \cdot 1{,}015 \cdot 30 = 30{,}45\ m/s$

Zgrada ima veću širinu od visine,a za mjerodavnu visinu uzimamo ukupnu visinu. Pretpostavimo da je na vrhu izgrađen AB parapet visine 0,5 m, mjerodavna visina tada iznosi:

$$z_e = 2 \cdot 3{,}5 + 0{,}5 = 7{,}5\ m$$

Mjerodavna visina je veća od minimalne (2,00 m), pa je koeficijent hrapavosti:

$$c_{r(z)} = k_r \cdot \ln(\frac{z_e}{z_0})$$

Koeficijent terena k_r određuje se iz odgovarajuće tablice ovisno o kategoriji zemljišta. Odabiremo III. kategoriju zemljišta.

Tablica 3.4. Kategorije terena i pripadni parametri

Kategorija terena	Opis	K_r	z_0 [m]	Z_{min} [m]
0	More ili područje uz more otvoreno prema moru	0.156	0.003	1
I	Uzburkano otvoreno more ili jezero, s najmanje 5 km dužine navjetrine i gladak ravan teren bez prepreka	0.170	0.01	1
II	Poljoprivredno zemljište s ogradama, povremenim malim poljoprivrednim objektima, kućama ili drvećem	0.190	0.05	2
III	Predgrađa ili industrijske zone i stalne šume	0.215	0.30	5
IV	Urbane zone u kojima je najmanje 15% površine pokriveno zgradama čija je srednja visina veća od 15 m	0.234	1.00	10

$$k_r = 0{,}215 \rightarrow c_{r(z)} = 0{,}215 \cdot \ln\left(\frac{7{,}5}{0{,}30}\right) = 0{,}762$$

Srednja brzina vjetra tako iznosi:V_m(z)=C_r(z)· C_0(z)· V_b

C_0 - koeficijent topografije (uglavnom se uzima 1.0)

$$v_m = 0{,}762 \cdot 1{,}0 \cdot 30{,}45 = 23{,}20\ m/s$$

Turbulencija:

$$I_v(z) = \frac{1}{c_0(z) \cdot \ln\left({}^{z_e}/_{z_0}\right)} = \frac{1}{1{,}0 \cdot \ln\left({}^{7{,}5}/_{0{,}30}\right)} = 0{,}282$$

Maksimalni tlak pri vršnoj brziniq$_p$(z_e):

$$\rho_{zr} = 1{,}25\ kg/m^3$$

$$q_p(z) = [1 + 7 \cdot I_v(z)] \cdot \frac{\rho_{zr}}{2} \cdot {v_m}^2(z) = c_e(z) \cdot v_b(z)$$

$$q_p(z) = [1 + 7 \cdot 0{,}282] \cdot \frac{1{,}25}{2} \cdot 23{,}20^2 = 1000{,}45\frac{N}{m^2} = 1{,}00\ \frac{kN}{m^2}$$

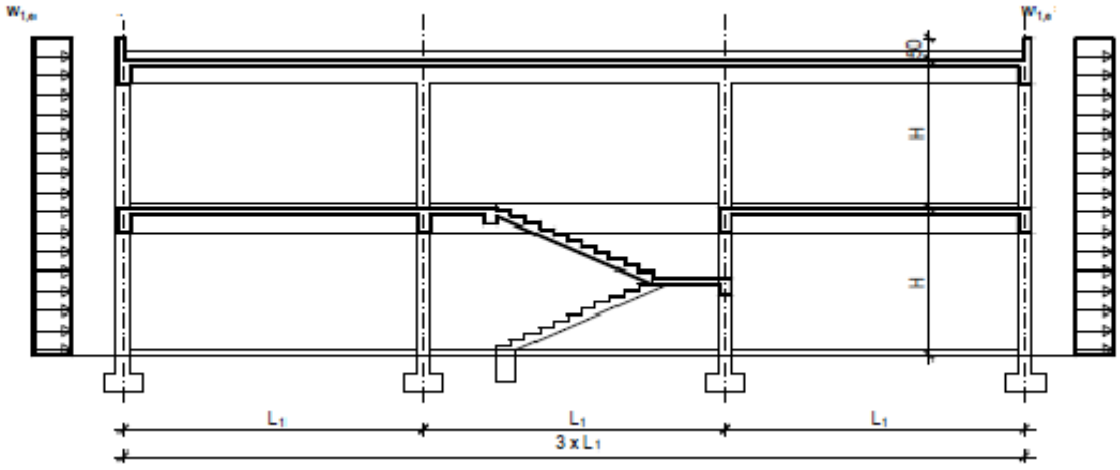
Djelovanje na zgradu:

$$w_{1,e} = 0{,}8 \cdot q_p(z) = 0{,}8 \cdot 1{,}00 = 0{,}80\ \frac{kN}{m^2}$$

$$w_{2,e} = 0{,}5 \cdot q_p(z) = 0{,}5 \cdot 1{,}00 = 0{,}50\ \frac{kN}{m^2}$$

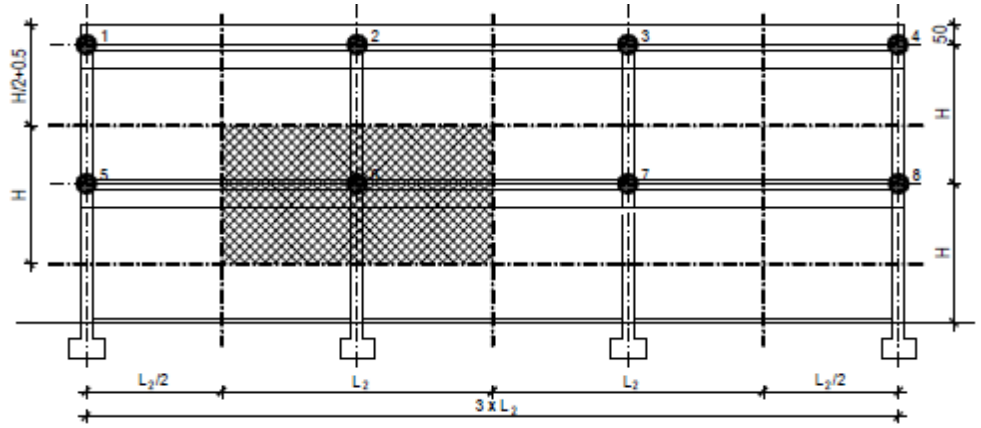
$$w_{1,I} = 0{,}75 \cdot w_{1,e} = 0{,}75 \cdot 0{,}80 = 0{,}60\ \frac{kN}{m^2}$$

$$w_{2,I} = 0{,}75 \cdot w_{2,e} = 0{,}75 \cdot 0{,}50 = 0{,}375\ \frac{kN}{m^2}$$



Slika 3.14.Opterećenje vjetrom

Silu vjetra zadajemo u čvorovima modela. Određivanje sila u čvorovima modela vršimo prema utjecajnim površinama djelovanja vjetra.



Slika 3.15. Utjecajne površine djelovanja vjetra

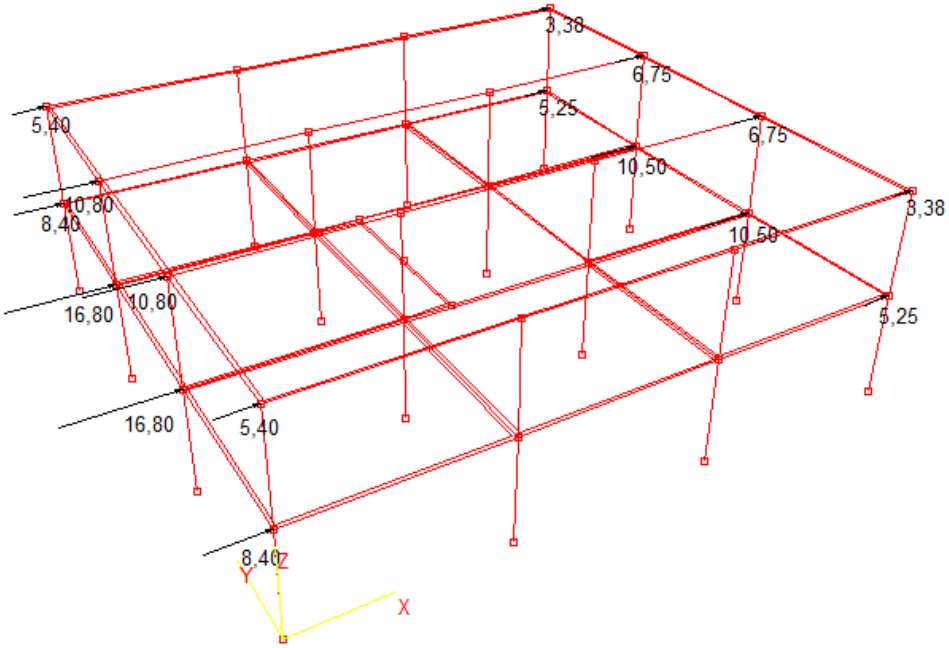
- **X smjer**

Tablica 3.5. Lijevi bok

Čvor	Utjecajna površina			Tlak vjetra(kN/m²)	Sila u čvoru(kN)
	Širina(m)	Visina(m)	Površina(m²)		
1	3.0	2.25	6.75	0.80	5,40
2	6.0	2.25	13.50	0.80	10,80
3	6.0	2.25	13.50	0.80	10,80
4	3.0	2.25	6.75	0.80	5,40
5	3.0	3.5	10.50	0.80	8,40
6	6.0	3.5	21.0	0.80	16,80
7	6.0	3.5	21.0	0.80	16.80
8	3.0	3.5	10.50	0.80	8.40

Tablica 3.6. Desni bok

Čvor	Utjecajna površina			Tlak vjetra(kN/m²)	Sila u čvoru(kN)
	Širina(m)	Visina(m)	Površina(m²)		
1	3.0	2.25	6.75	0.50	3.375
2	6.0	2.25	13.50	0.50	6,75
3	6.0	2.25	13.50	0.50	6,75
4	3.0	2.25	6.75	0.50	3.375
5	3.0	3.5	10.50	0.50	5.25
6	6.0	3.5	21.0	0.50	10.50
7	6.0	3.5	21.0	0.50	10.50
8	3.0	3.5	10.50	0.50	5.25



Slika 3.16. Djelovanje vjetra u X smjeru (sile u kN)

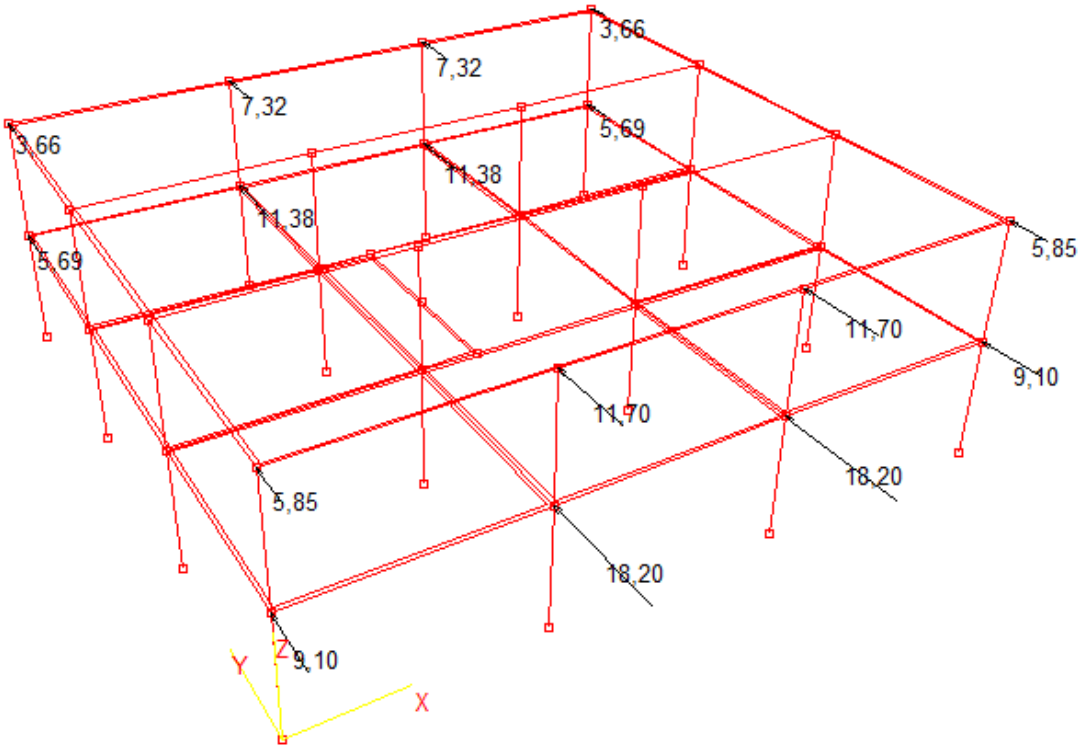
- **Y smjer**

Tablica 3.7. Prednja strana

Čvor	Utjecajna površina			Tlak vjetra(kN/m²)	Sila u čvoru(kN)
	Širina(m)	Visina(m)	Površina(m²)		
1	3.25	2.25	7,313	0.80	5,85
2	6.50	2.25	14,63	0.80	11,70
3	6.50	2.25	14,63	0.80	11,70
4	3.25	2.25	7,313	0.80	5,85
5	3.25	3.5	11,38	0.80	9,10
6	6.50	3.5	22,75	0.80	18,20
7	6.50	3.5	22,75	0.80	18.20
8	3.25	3.5	11,38	0.80	9.10

Tablica 3.8. Stražnja strana

Čvor	Utjecajna površina			Tlak vjetra(kN/m²)	Sila u čvoru(kN)
	Širina(m)	Visina(m)	Površina(m²)		
1	3.25	2.25	7,313	0.50	3,66
2	6.50	2.25	14,63	0.50	7.32
3	6.50	2.25	14,63	0.50	7.32
4	3.25	2.25	7,313	0.50	3.66
5	3.25	3.5	11,38	0.50	5.69
6	6.50	3.5	22,75	0.50	11,38
7	6.50	3.5	22,75	0.50	11,38
8	3.25	3.5	11,38	0.50	5.69



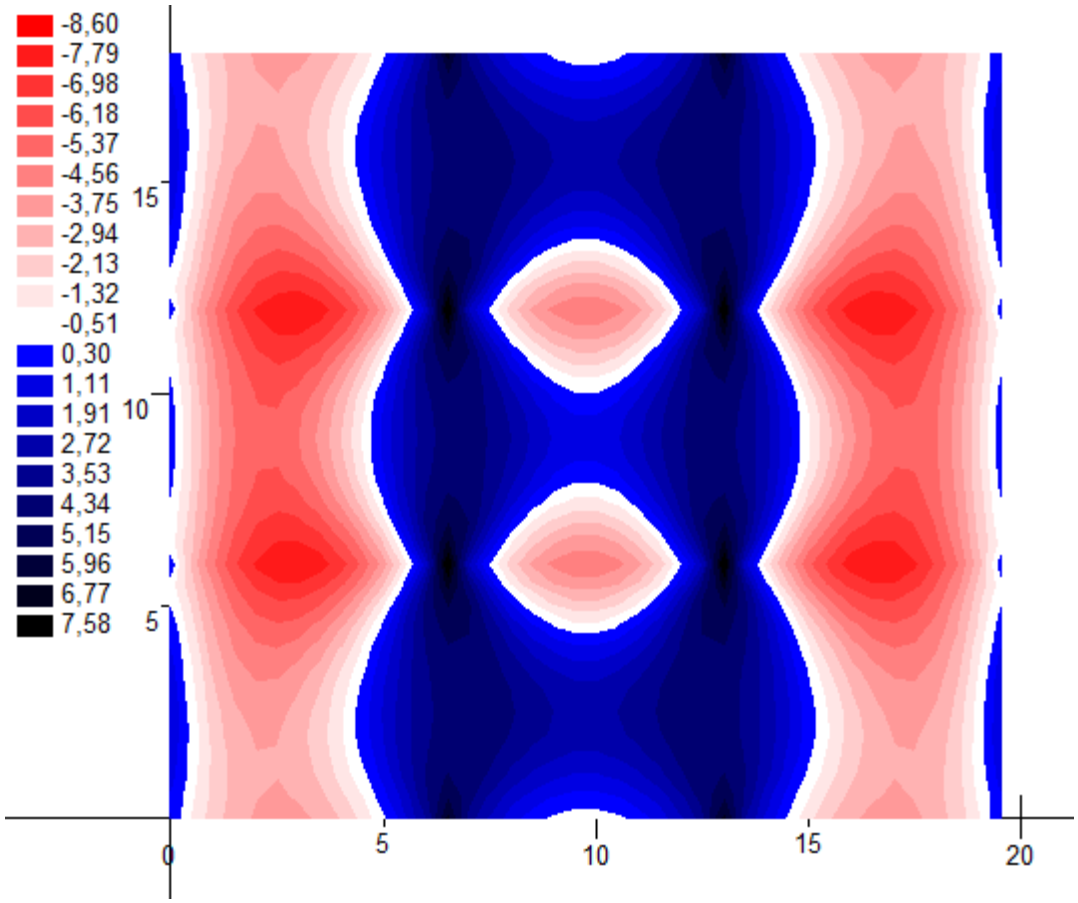
Slika 3.17.Djelovanje vjetra u Y smjeru (sile u kN)

4. PRORAČUN PLOČA POZICIJE 200

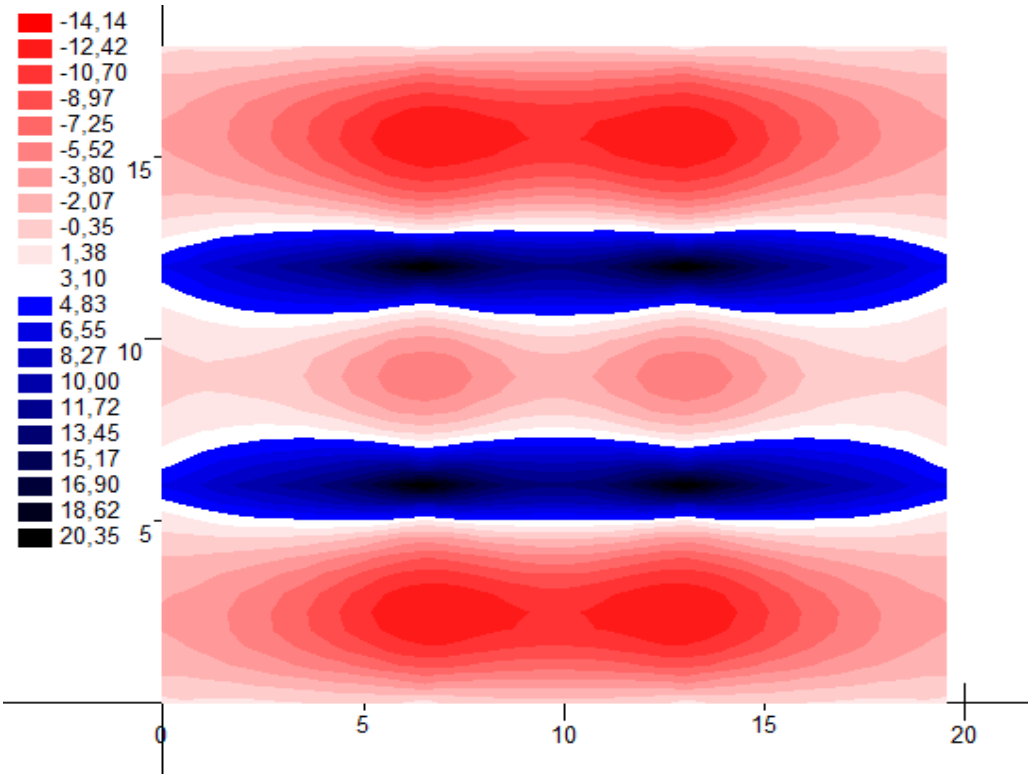
- Proračun reznih sila vršio se kompjuterskim programom *AspalathosLinear*. Prikaz rezultata dan je odvojeno za ploče i grede.

4.1. **MOMENTI SAVIJANJA U PLOČI POZICIJE 200**

4.1.1. Vlastita težina

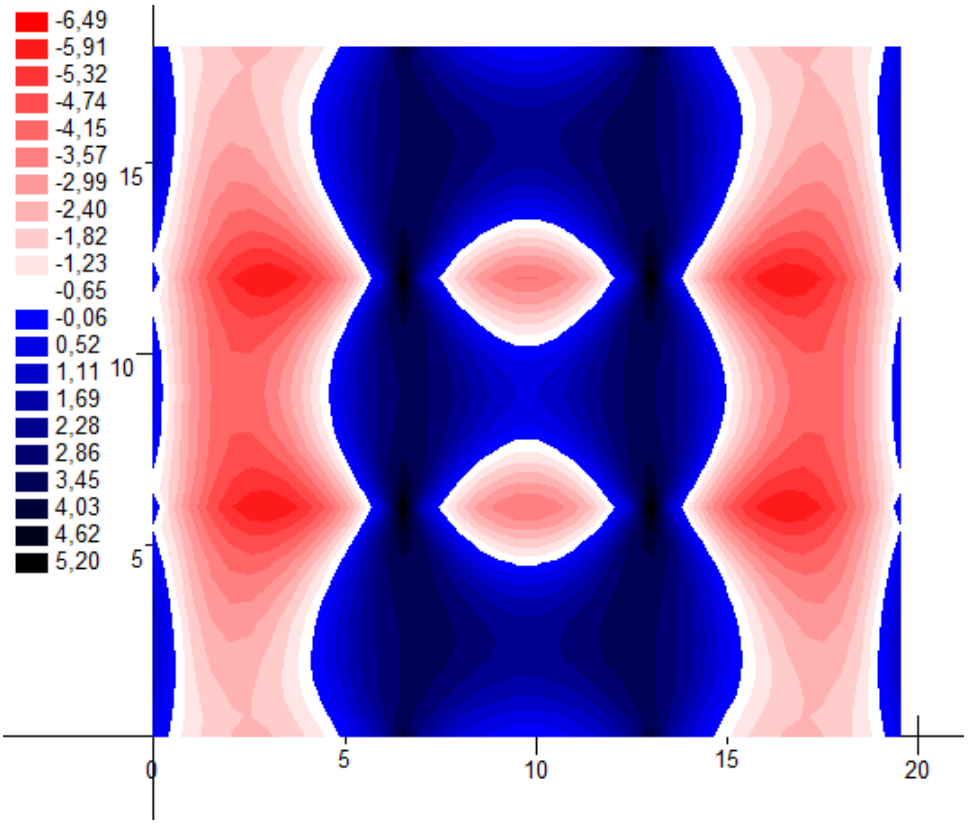


Slika 4.1. Momenti Mx (kNm)

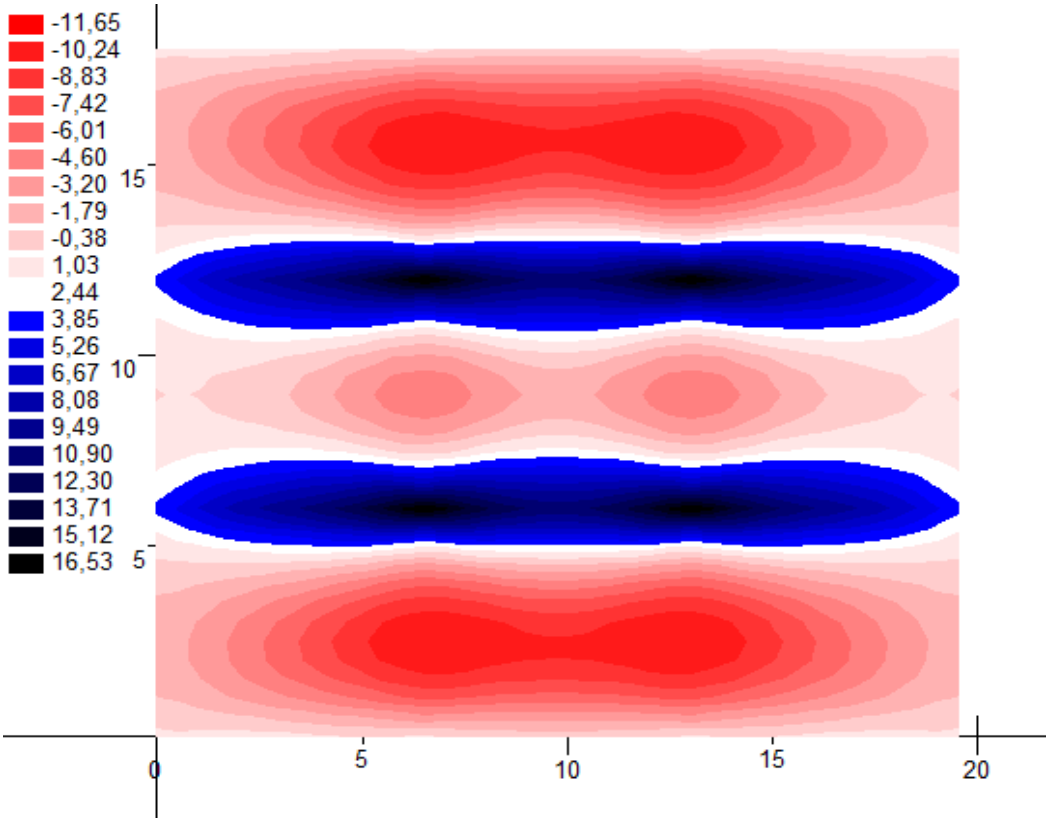


Slika 4.2. Momenti My (kNm)

4.1.2. Dodatno stalno opterećenje

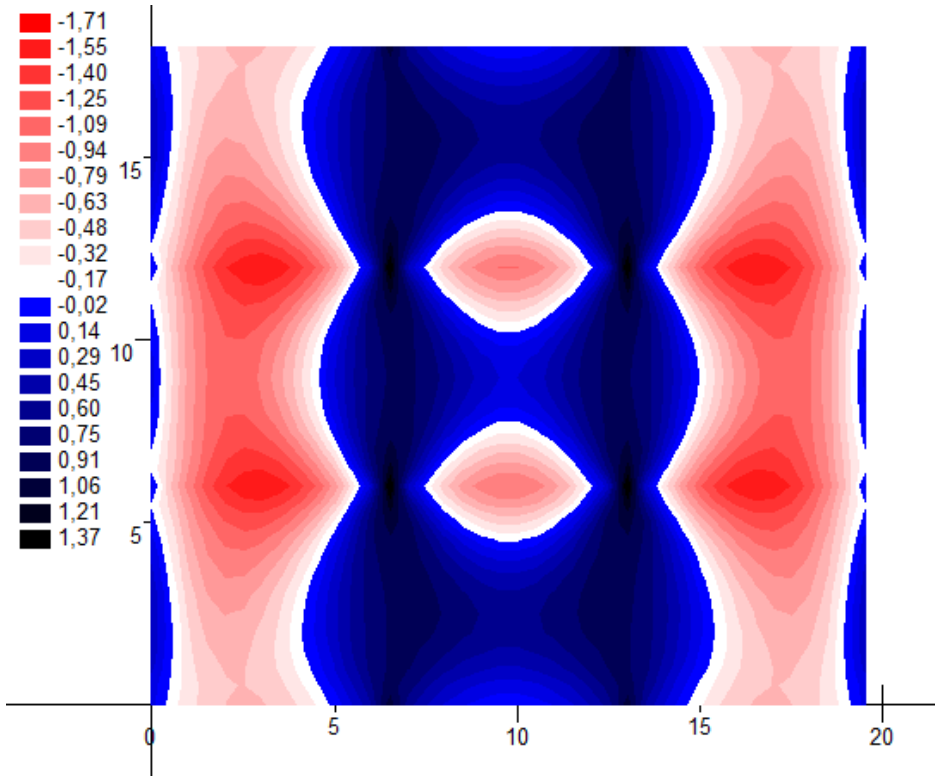


Slika 4.3. Momenti Mx (kNm)

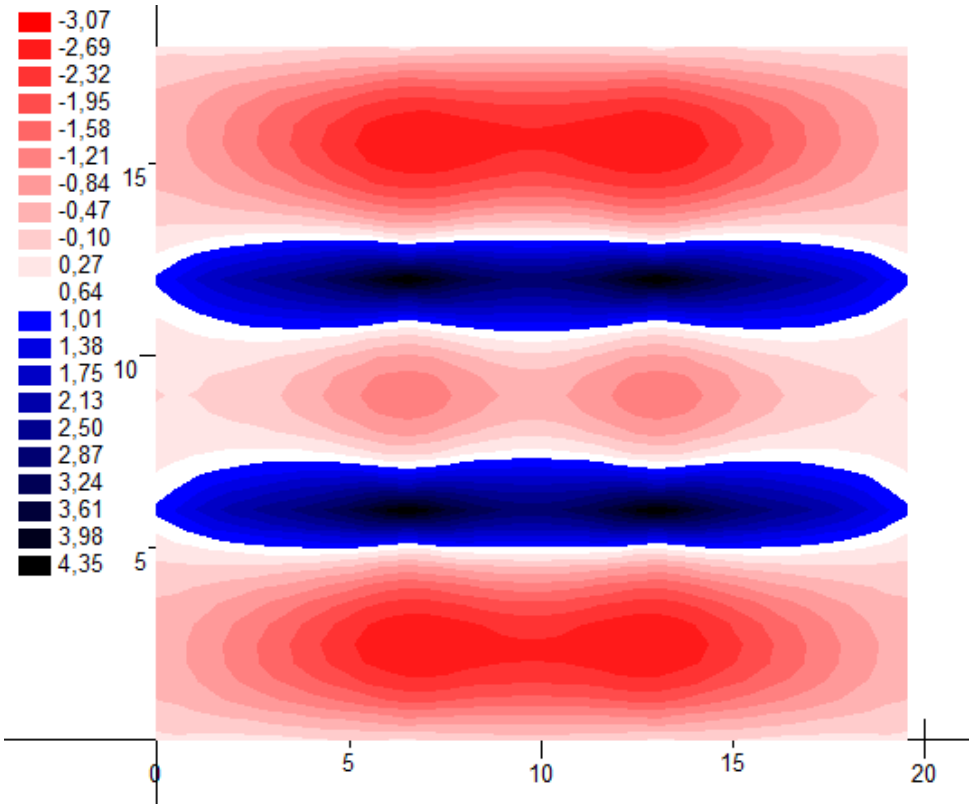


Slika 4.4. Momenti My(kNm)

*4.1.3. Uporabnooptere*ć*enje*



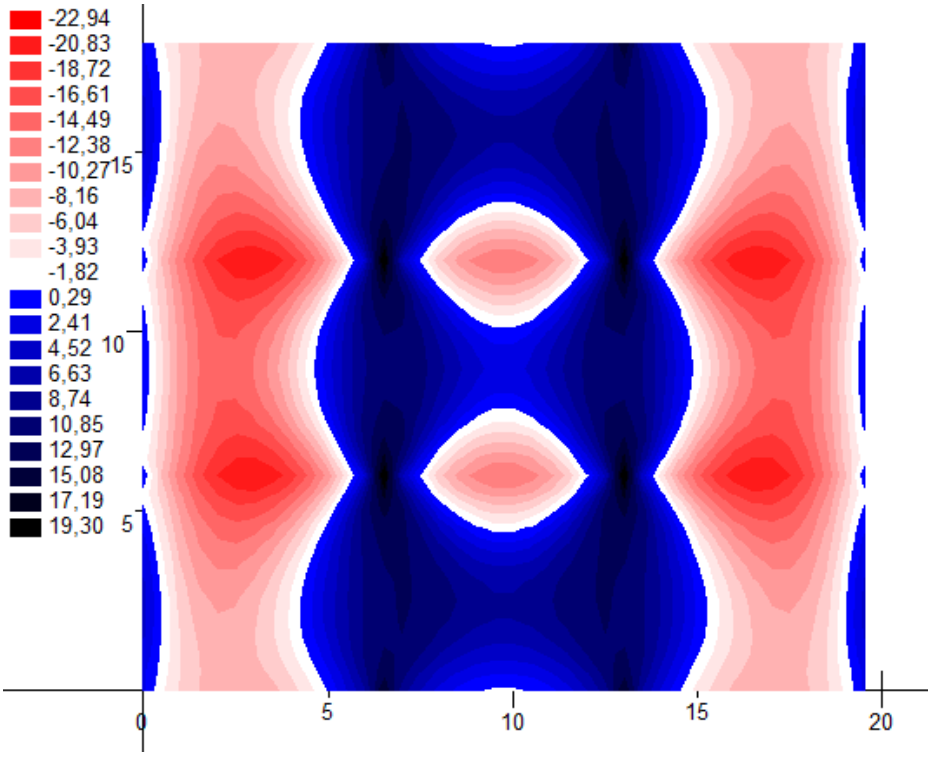
Slika 4.5. Momenti Mx (kNm)



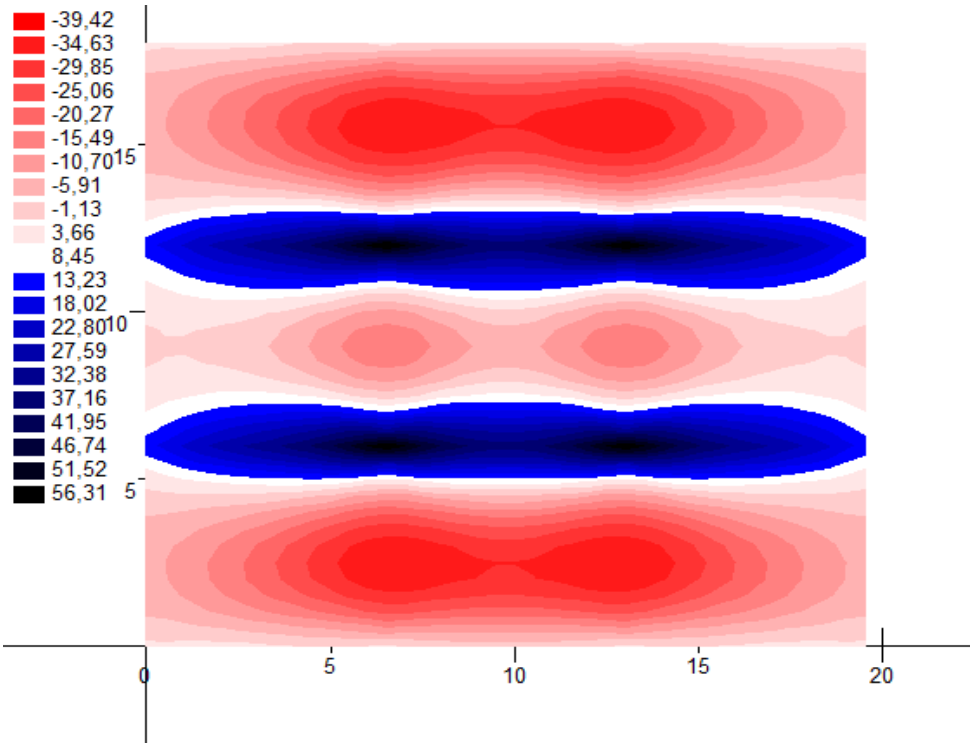
Slika 4.6. Momenti My (kNm)

4.1.4. Granično stanje nosivosti

Mjerodavna kombinacija: $M_{ed}=1,35*(M_g+M_{\Delta g})+1,5*M_q$



Slika 4.7. Momenti Mx (kNm)



Slika 4.8. Momenti My (kNm)

4.2. **DIMENZIONIRANJE PLOČA POZICIJE 200**

BETON:C 30/37;

$f_{ck} = 30{,}0$ MPa =30 N/mm^2 ; γ_c =1.5

$f_{cd} = f_{ck}/\gamma_c = 30{,}0/1{,}5 = 20{,}0$ MPa = 20,0 N/mm^2 =2,0 kN/cm^2

ARMATURA:B 450 BC;

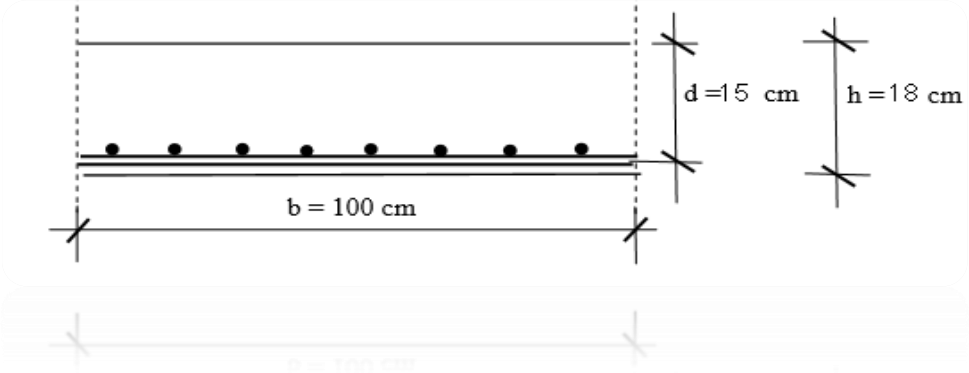
$f_{yk} = 450{,}0$ MPa = 450 N/mm^2 ; γ_s=1,15

$f_{yd} = f_{yk}/\gamma_s = 450{,}0/1{,}15 = 391{,}3$ MPa =391,3 N/mm^2=39,13 kN/cm^2

DEBLJINA PLOČE: h=18 cm

ZAŠTITNI SLOJ: c=3 cm

STATIČKA VISINA PLOČE:



Slika 4.9. Poprečni presjek ploče

$d = h - d_1$

$d_1 = c + \frac{\emptyset}{2} = 2{,}5 + 0{,}5 = 3$ cm

c → zaštitni sloj

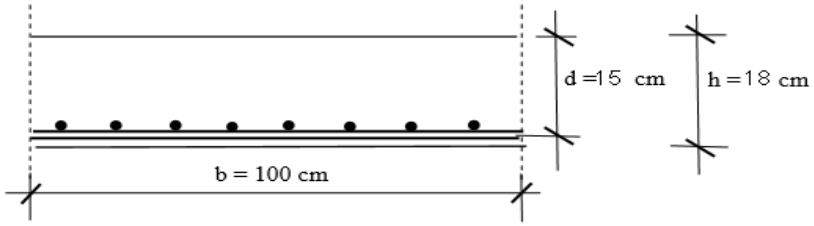
STATIČKA VISINA PLOČE:

d = 18 - 3 = 15cm

Za sve presjeke odabrana je statička visina ploče d=15 cm. Izvršen je proračun armature za kombinaciju :

1.35 × vl.težina + 1.35 × dodatno stalno + 1.5 ×uporabno

Ploča 201 – Polje



M_{ed}= 39,42 kNm/m

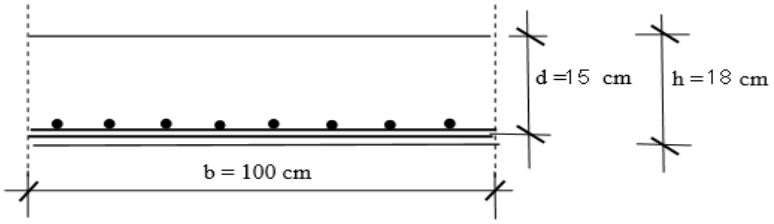
$$\mu_{sd} = \frac{M_{ed}}{b_{eff} \cdot d^2 . f_{cd}} = \frac{3942}{100 * 15^2 * 2,0} = 0,088$$

Očitano: : ε_{s1} = 10,0 ‰ ε_{c2} = 2,0 ‰ ζ = 0,938 ξ = 0,167

$$A_{s1} = \frac{M_{ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{3942}{0,938 * 15 * 39,13} = 7,15 \text{ cm}^2/\text{m}$$

ODABRANO: **R-785**(As =7,85 cm^2/m)

Ploča 202 - Polje



M_{ed}=19,30 kNm/m

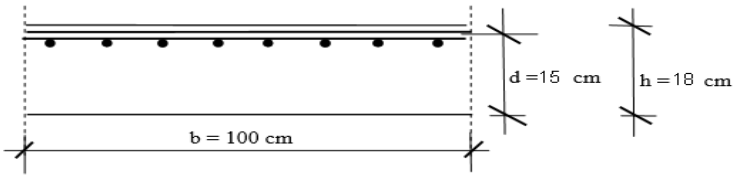
$$\mu_{sd} = \frac{M_{ed}}{b_{eff} \cdot d^2 . f_{cd}} = \frac{1930}{100 \cdot 15^2 \cdot 2,0} = 0,042$$

Očitano: : ε_{s1} = 10,0 ‰ ε_{c2} = 1,3 ‰ ζ = 0,959 ξ = 0,048

$$A_{s1} = \frac{M_{ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{1930}{0,959 \cdot 15 \cdot 39,13} = 3,43 \text{ cm}^2/m$$

ODABRANO: **R-385**(As = 3,85 cm^2/m)

Ležaj 201-202



M_{ed}= 56,31 kNm/m

$$\mu_{sd} = \frac{M_{ed}}{b_{eff} \cdot d^2 . f_{cd}} = \frac{5631}{100 \cdot 15^2 \cdot 2,0} = 0,125$$

Očitano: : ε_{s1} = 10,0 ‰ ε_{c2} = 2,7‰ ζ = 0,916 ξ = 0,136

$$A_{s1} = \frac{M_{ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{5631}{0,916 \cdot 15 \cdot 39,13} = 10,4 \text{ cm}^2/\text{m}$$

ODABRANO: **R-785** (As = 7,85 cm^2 /m) + preklop povećan na 80 cm

$$A'_{s1} = A_{s1} \cdot \frac{š_m + p_m}{š_m} = 7,85 \cdot \frac{215 + 80}{215} = 10,8 \text{ cm}^2/m$$

Minimalna armatura:

As1,min ≥ 0,26 · [fct,m / fyk]· bt · d ≥ 0,0011 ·bt · d

bt – širina vlačne zone

d – statička visina presjeka

fyk – karakt. granica popuštanja čelika u N/mm2

[fyk = 450 N/mm2 za čelik B 450 BC]

fct,m - srednja vlačna čvrstoća betona (iz tablice)

[fctm = 2,9 N/mm2 za C 30/37]

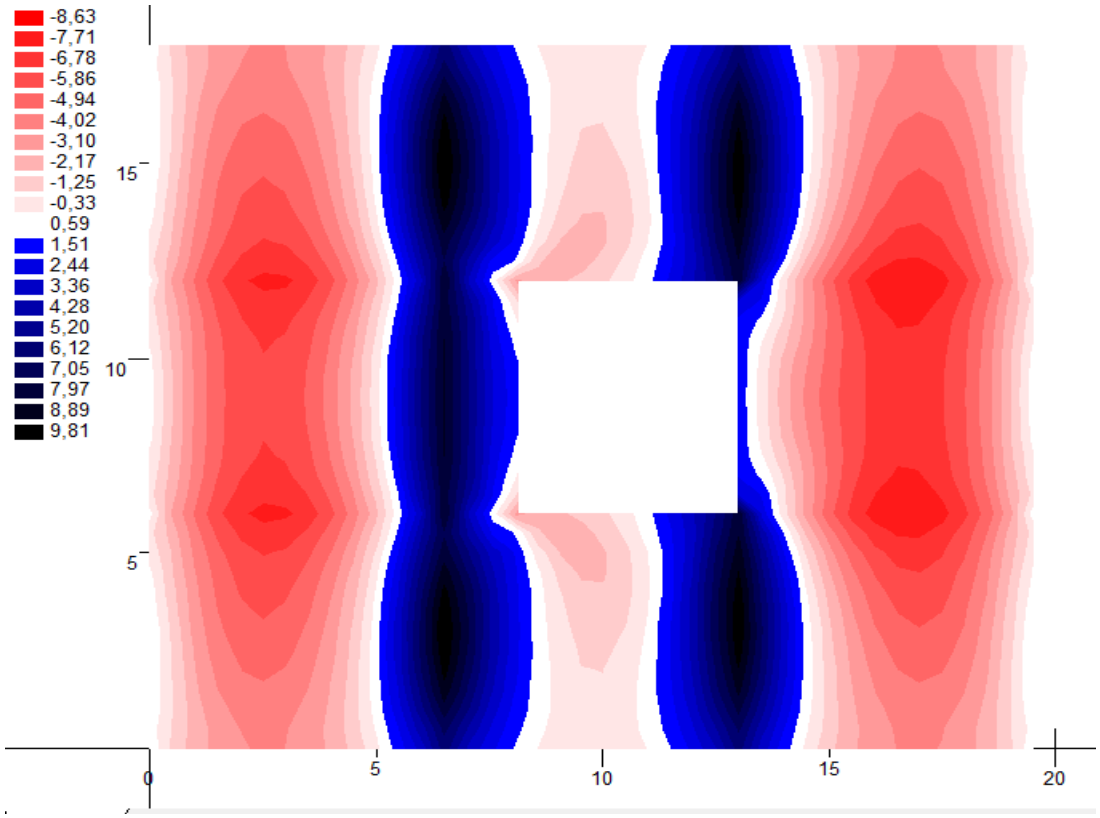
As1,min ≥ 0,26 ·2,9/ 450 ·100 ·15,0 = 2.51 cm2 /m

As1,min ≥ 0,0011 ·bt · d = 0,0011 ·100 ·15,0 = 1,65 cm2 /m

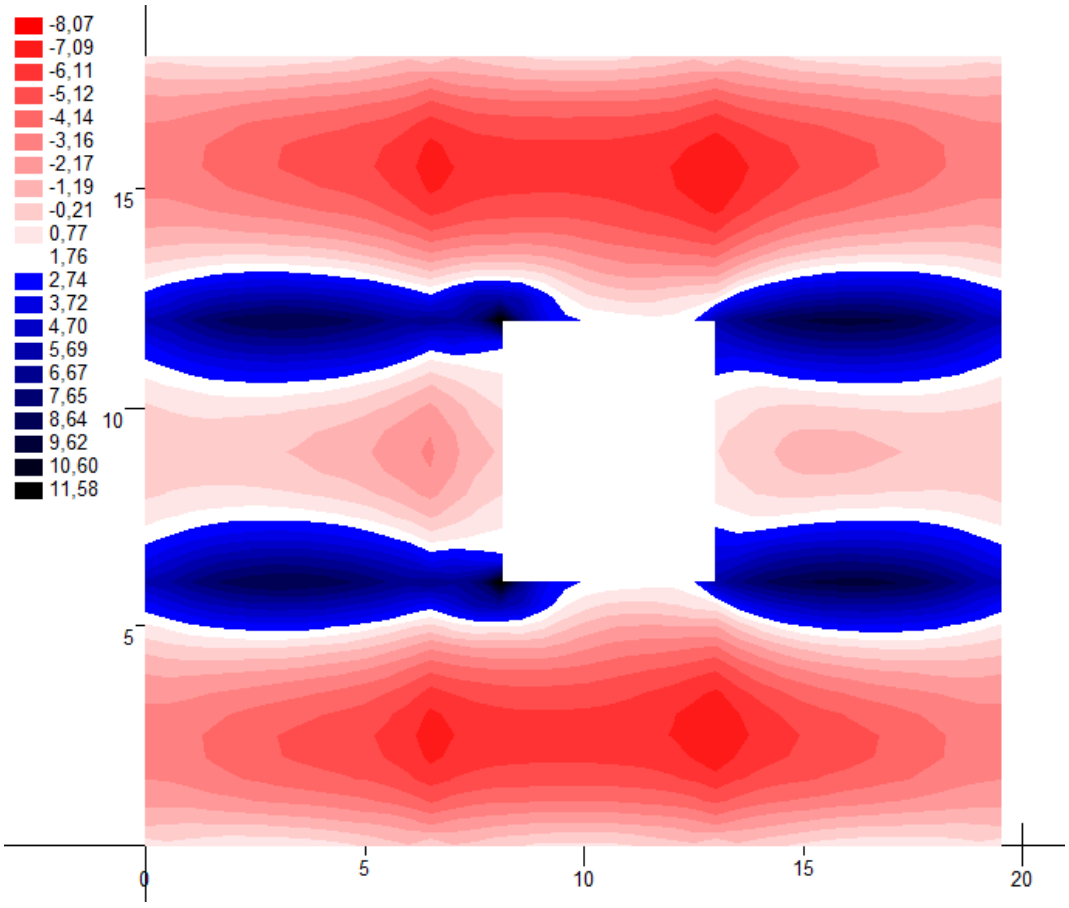
5. *PRORAČUN PLOČA POZICIJE 100*

5.1. MOMENTI SAVIJANJA U PLOČI POZICIJE 100

5.1.1. Vlastita težina

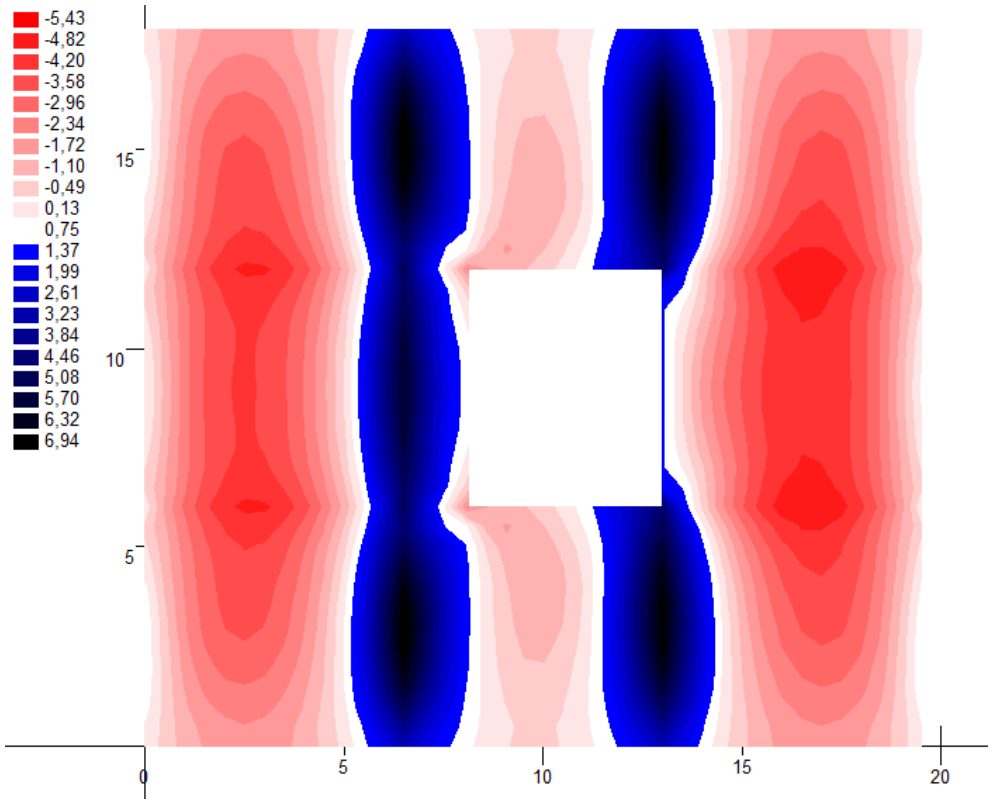


Slika 5.1. Momenti Mx (kNm)

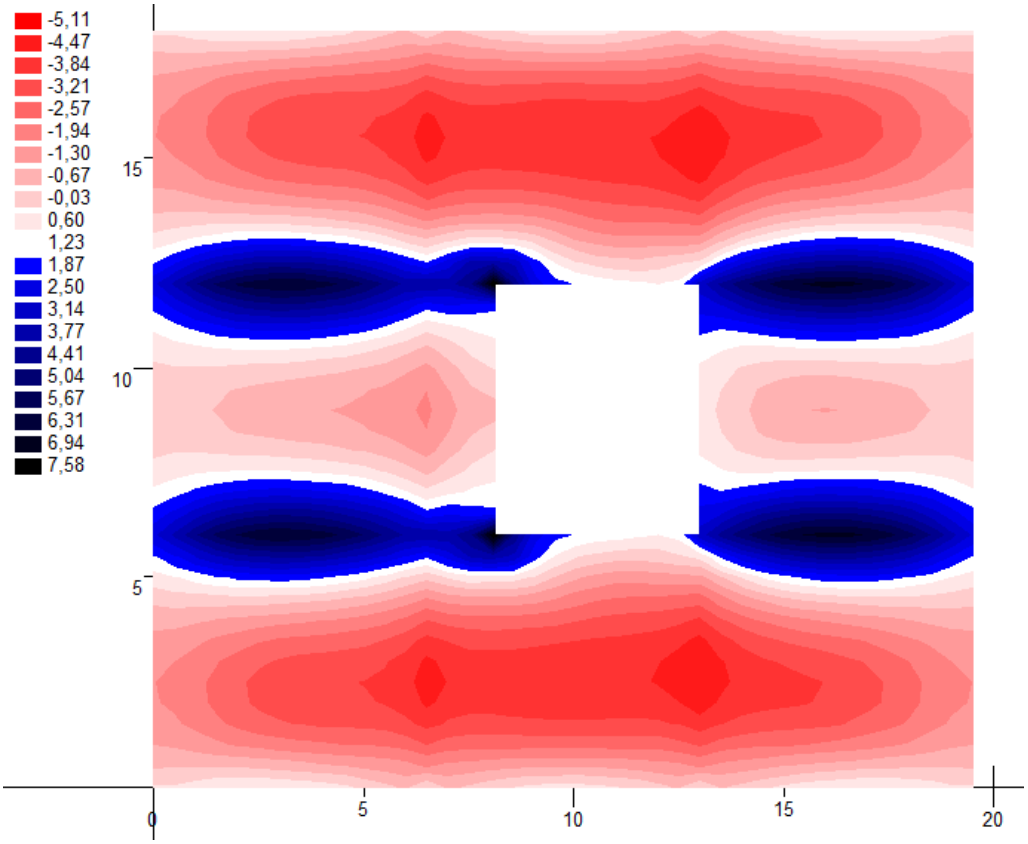


Slika 5.2. Momenti My (kNm)

5.1.2. Dodatno stalno opterećenje

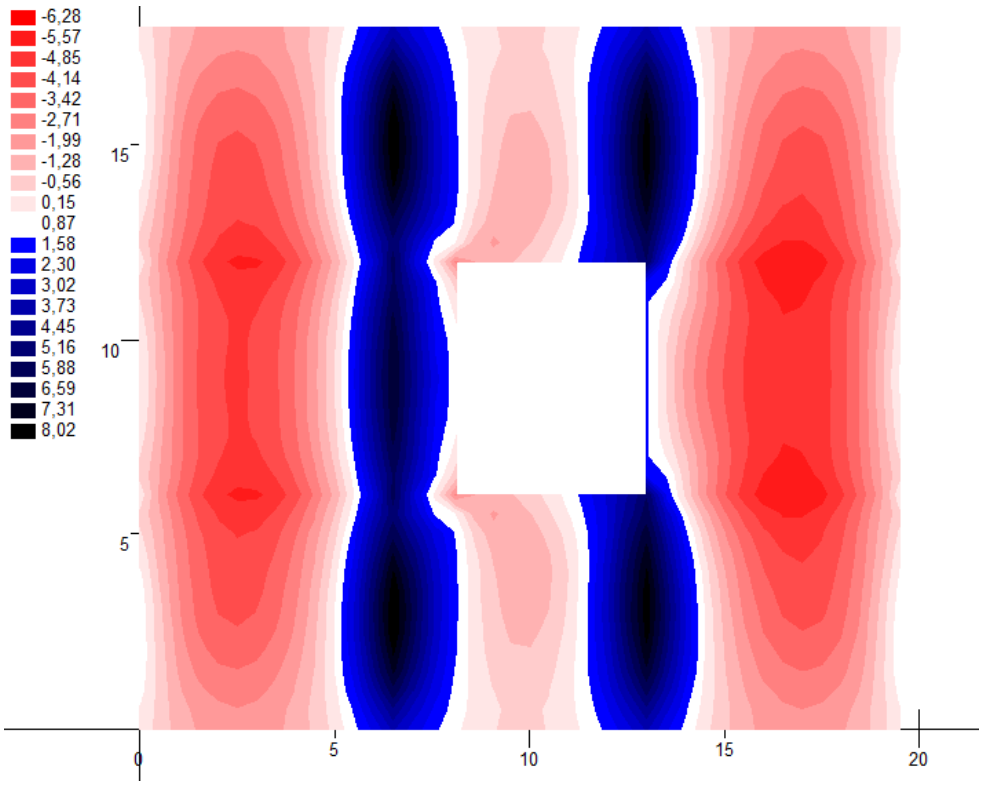


Slika 5.3. Momenti Mx (kNm)

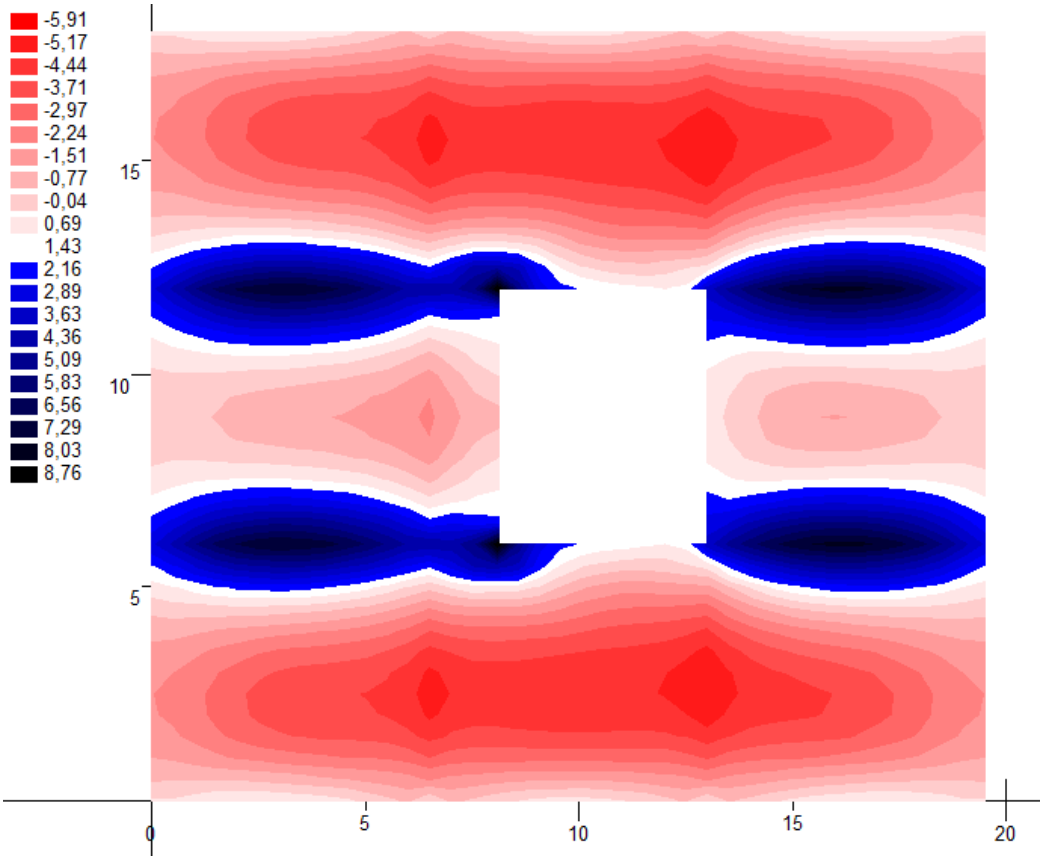


Slika 5.4. Momenti My (kNm)

5.1.3. Uporabno opterećenje shema 1 (max momenti na ležajevima)

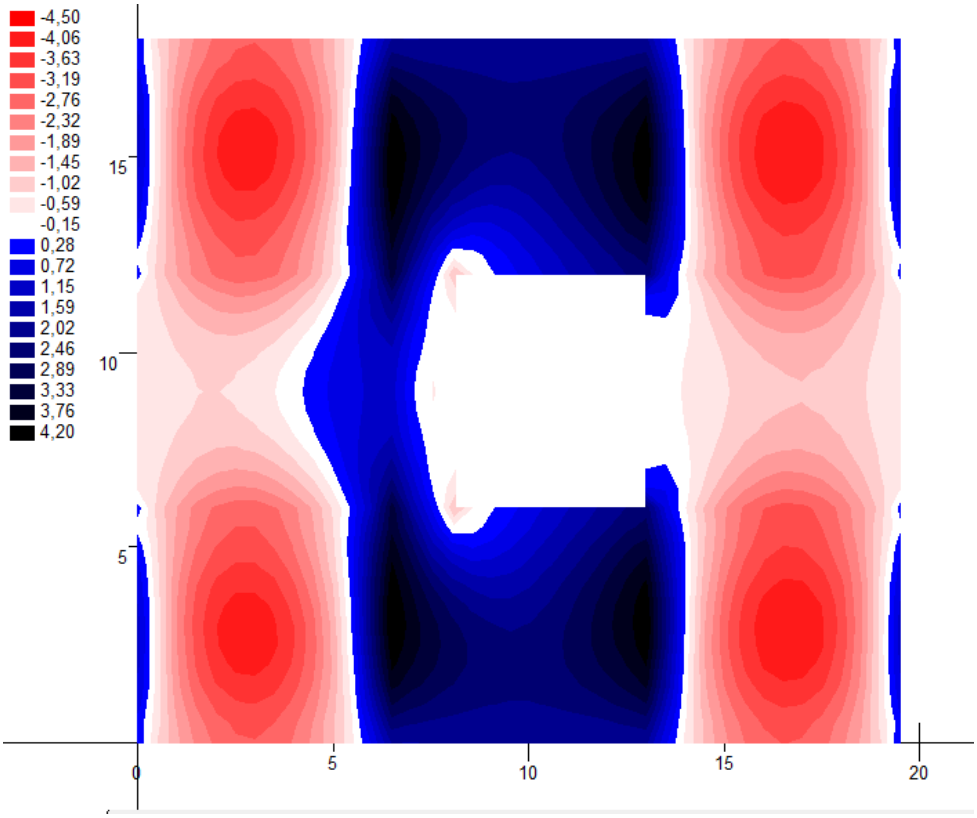


Slika 5.5. Momenti Mx (kNm)

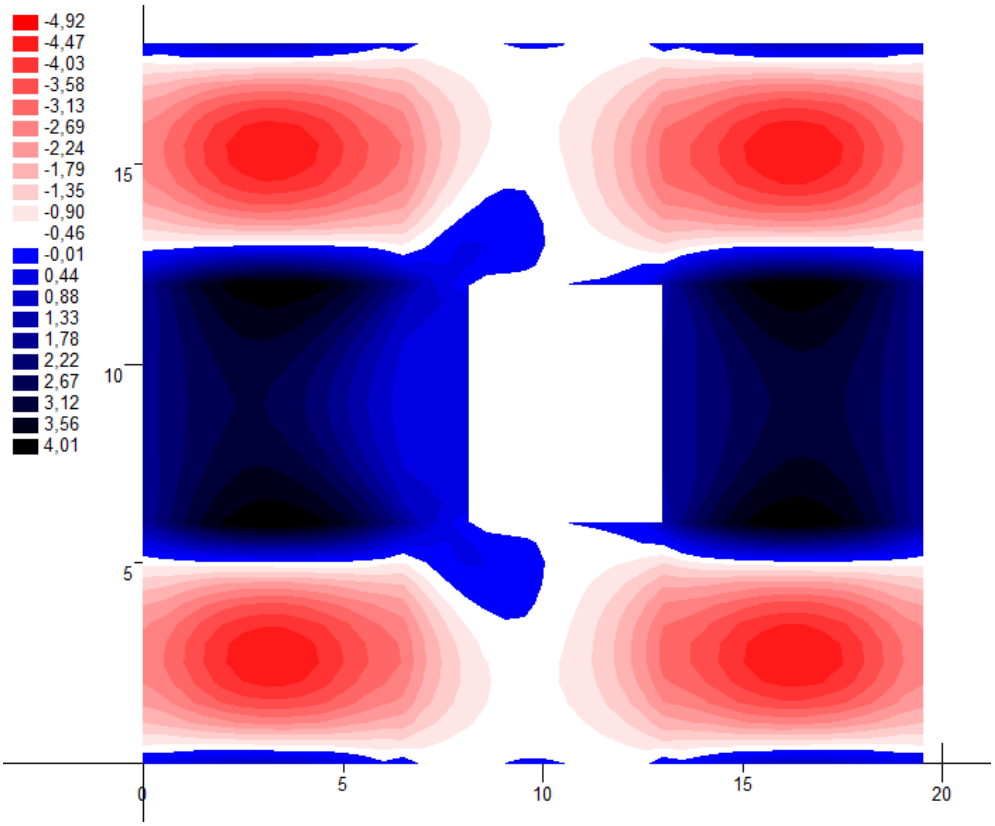


Slika 5.6. Momenti My (kNm)

5.1.4. Uporabno-opterećenje shema 2(max momenti u krajnjim poljima)

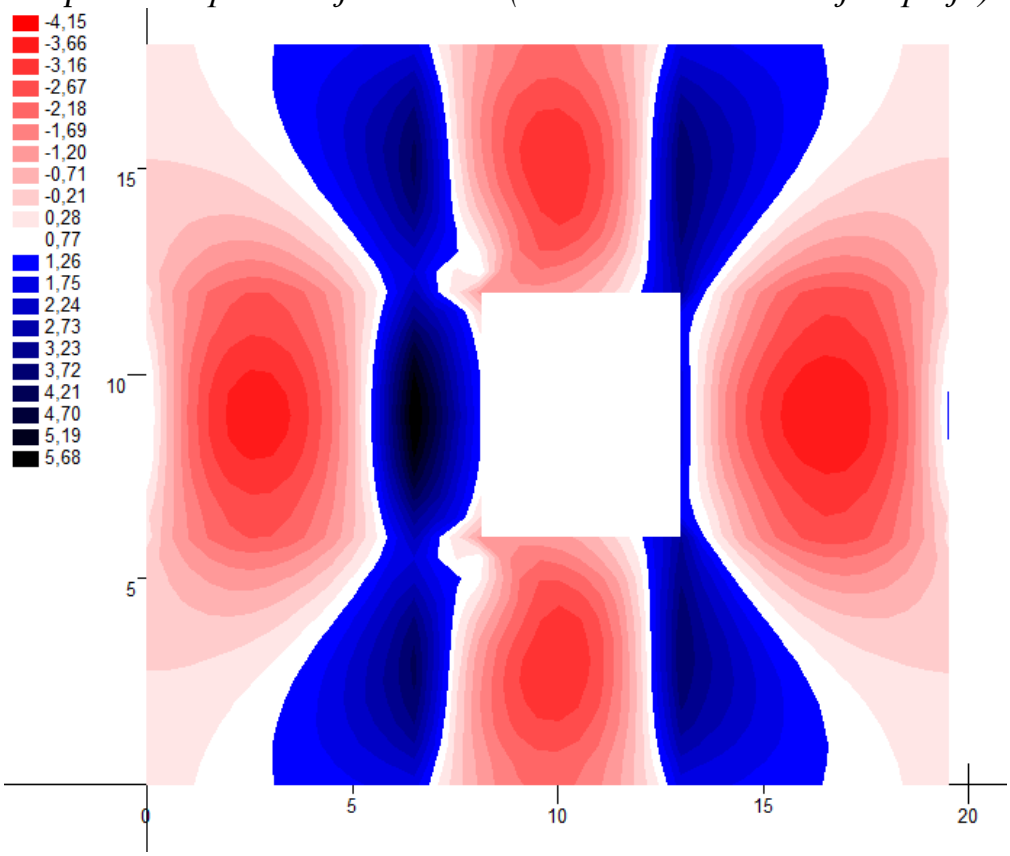


Slika 5.7. Momenti Mx (kNm)

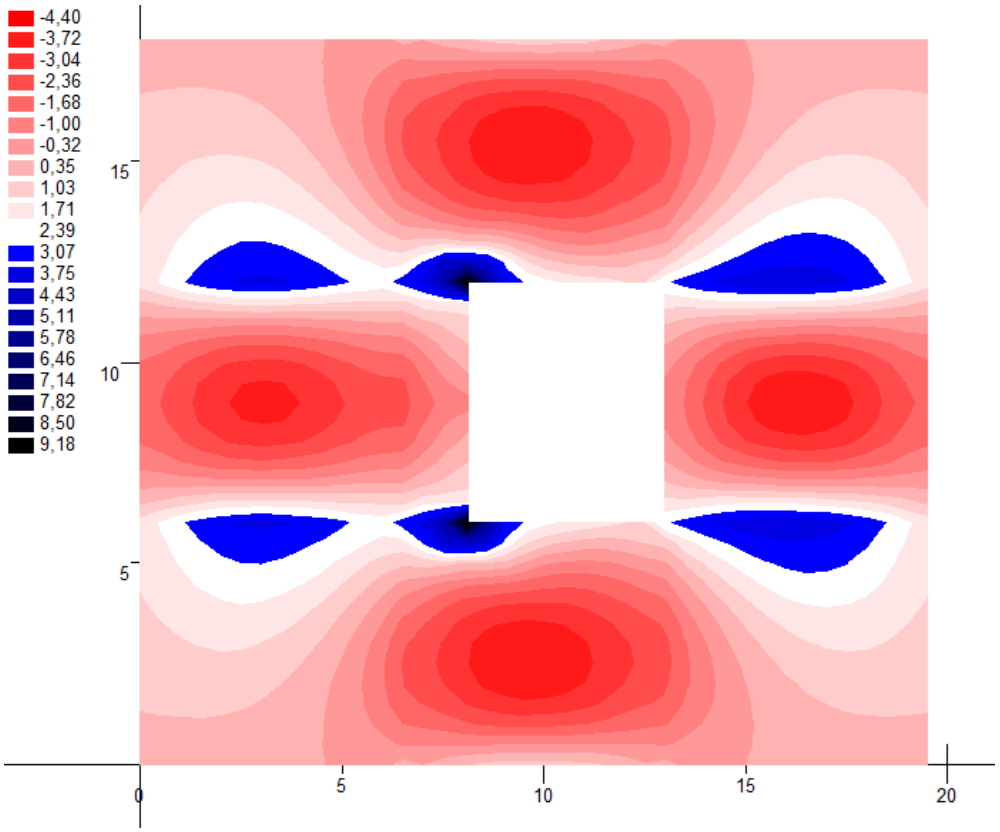


Slika 5.8. Momenti My (kNm)

5.1.5. Uporabnoopterećenje shema 3 (max momenti u srednjem polju)



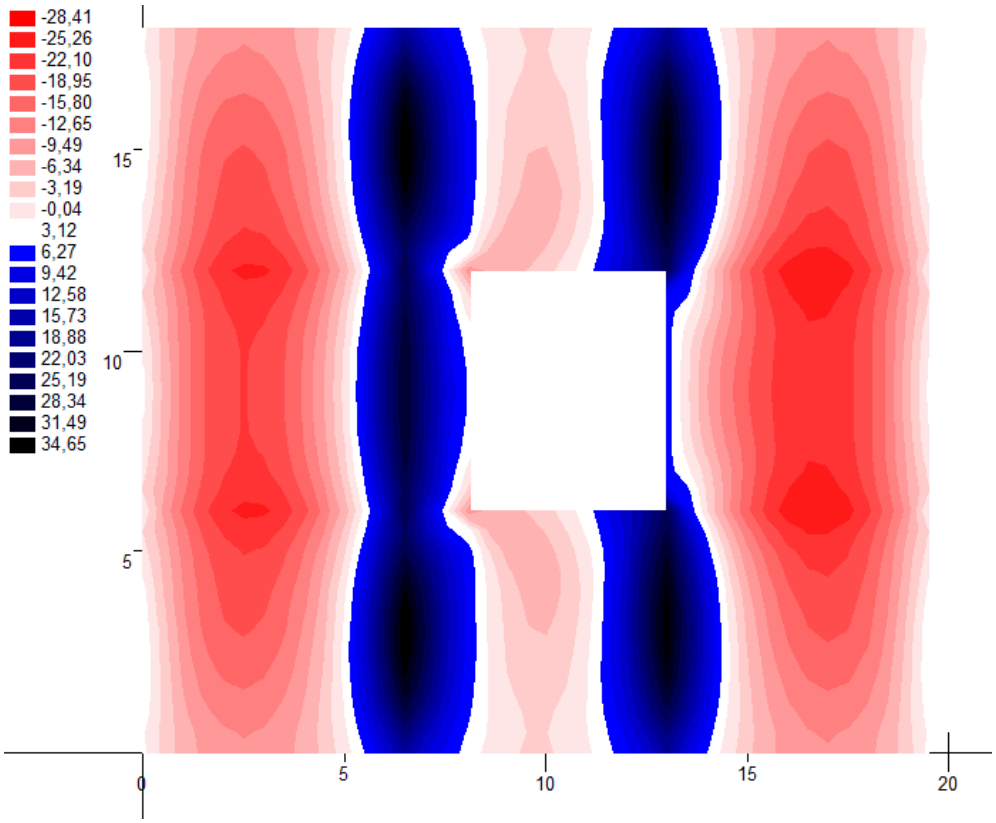
Slika 5.9. Momenti Mx (kNm)



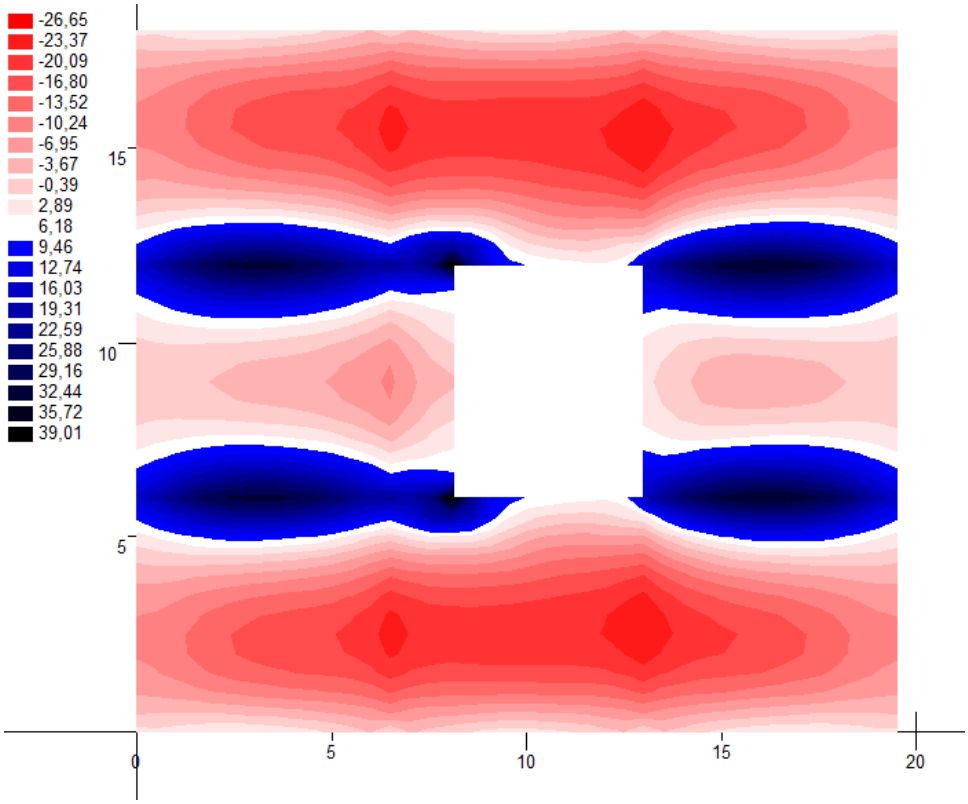
Slika 5.10. Momenti My (kNm)

5.1.6. GSN za ležajeve

Mjerodavna kombinacija za proračun GSN: $M_{ed}=1,35*(M_g+M_{\Delta g})+1,5*M_q$

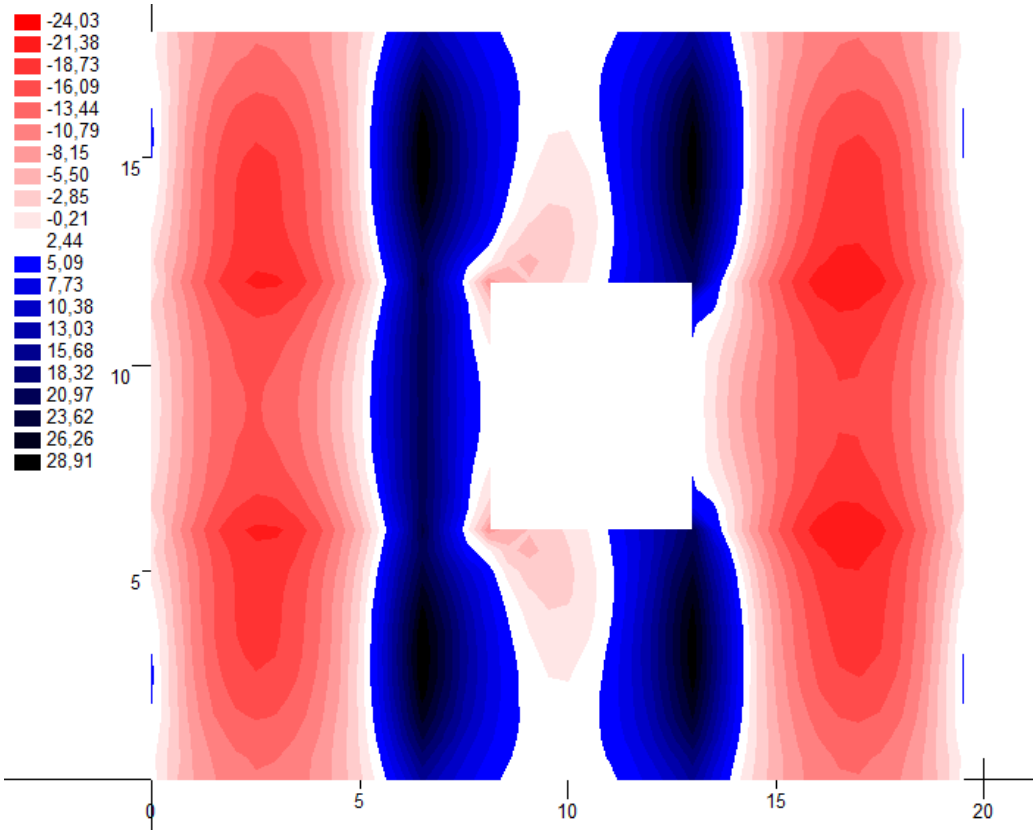


Slika 5.11. Momenti Mx (kNm)

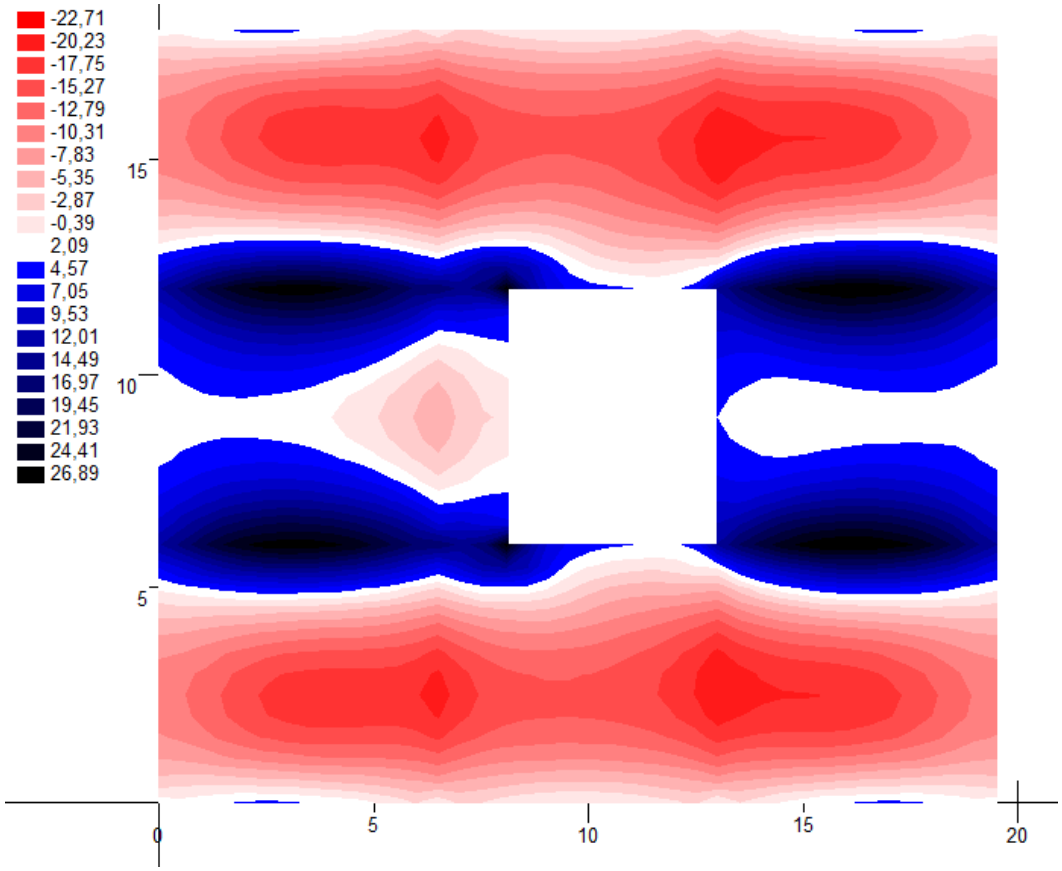


Slika 5.12. Momenti My (kNm)

5.1.7. GSN za krajnja polja

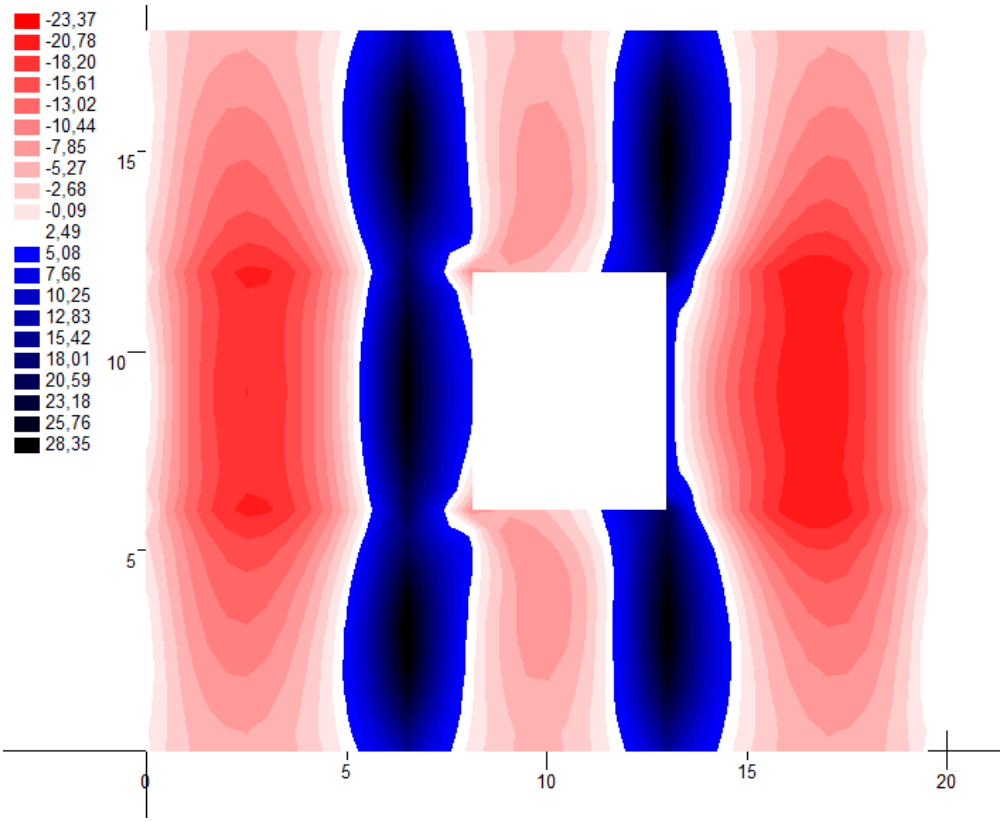


Slika 5.13. Momenti Mx (kNm)

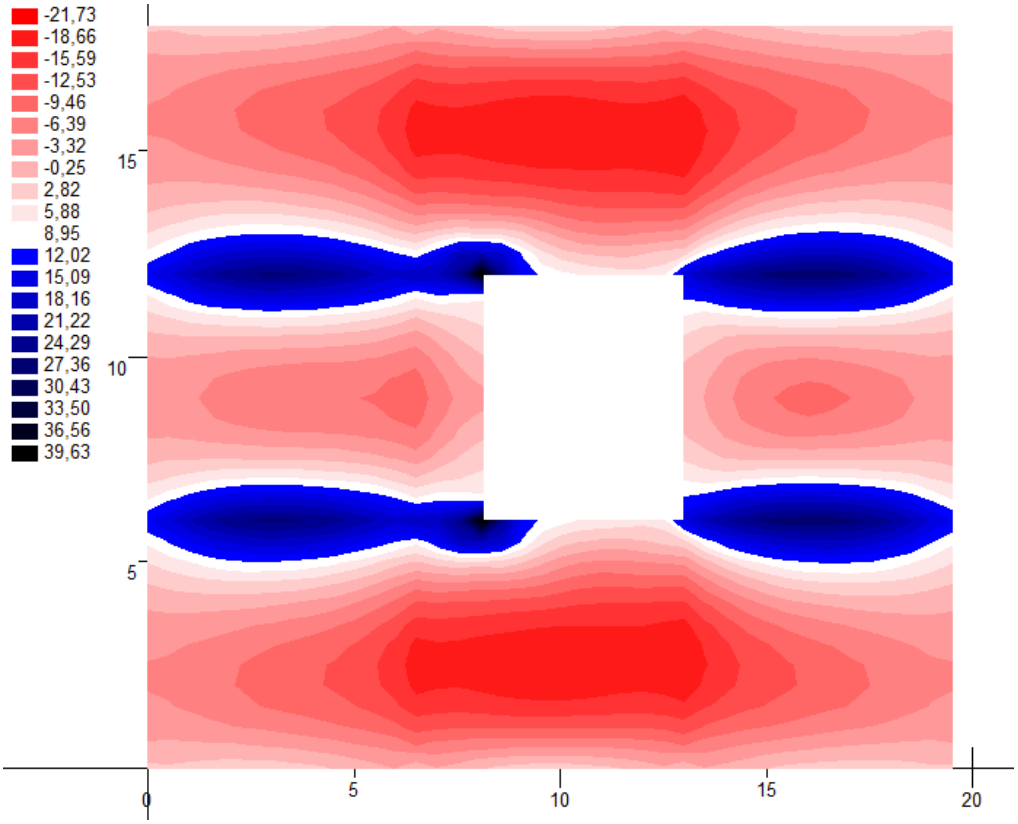


Slika 5.14. Momenti My (kNm)

5.1.8. GSN za srednje polje



Slika 5.15. Momenti Mx (kNm)



Slika 5.16. Momenti My (kNm)

5.2. **DIMENZIONIRANJE PLOČA POZICIJE 100**

BETON: C 30/37;

$f_{ck} = 30{,}0$ MPa= 30 N/mm^2 ; γ_c=1.5

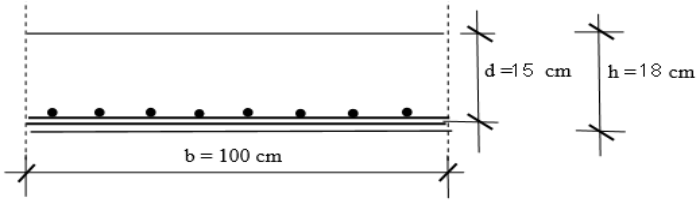
$f_{cd} = f_{ck}/\gamma_c = 30{,}0/1{,}5 = 20{,}0$ MPa = 20,0 N/mm^2 = 2,0 kN/cm ^{2}

ARMATURA:B 450 BC;

$f_{yk} = 450{,}0$ MPa = 450 N/mm^2 ; γ_s = 1,15

$f_{yd} = f_{yk}/\gamma_s = 450{,}0/1{,}15 = 391{,}30$MPa = 391,30 N/mm^2= 39,13 kN/cm^2

Ploča 101 – polje



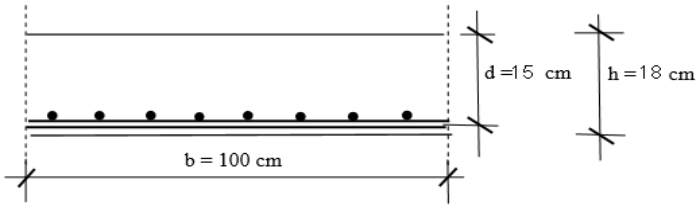
$M_{Ed} = 24{,}03\,kNm/m$

$$\mu_{sd} = \frac{M_{Ed}}{b \cdot d^2 \cdot f_{cd}} = \frac{2403}{100 \cdot 15^2 \cdot 2.0} = 0.053$$

Očitano: $\varepsilon_{s1} = 10.0$ ‰ $\varepsilon_{c2} = 1.4$ ‰ $\xi = 0.123$ $\zeta = 0.956$

$$A_{s1} = \frac{M_{Ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{2403}{0.956 \cdot 15 \cdot 39{,}13} = 4{,}28\,cm^2/m$$

Ploča 102 – polje



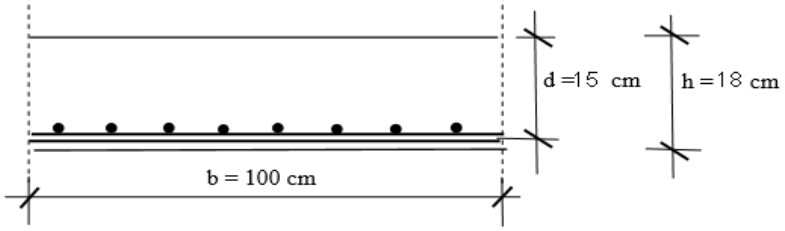
$M_{Ed} = 21{,}73\,kNm/m$

$$\mu_{sd} = \frac{M_{Ed}}{b \cdot d^2 \cdot f_{cd}} = \frac{2173}{100 \cdot 15^2 \cdot 2.0} = 0.048$$

Očitano: $\varepsilon_{s1} = 10.0$ ‰ $\varepsilon_{c2} = 1.3$ ‰ $\xi = 0.115$ $\zeta = 0.959$

$$A_{s1} = \frac{M_{Ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{2173}{0.959 \cdot 15 \cdot 39{,}13} = 3.86\,cm^2/m$$

Ploča 103 – polje



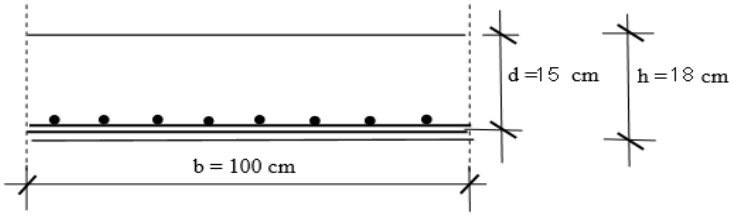
$M_{Ed} = 23{,}37\ kNm/m$

$$\mu_{sd} = \frac{M_{Ed}}{b \cdot d^2 \cdot f_{cd}} = \frac{2337}{100 \cdot 15^2 \cdot 2.0} = 0.051$$

Očitano: $\varepsilon_{s1} = 10.0\,‰ \quad \varepsilon_{c2} = 1.4\,‰ \quad \xi = 0.123 \quad \zeta = 0.956$

$$A_{s1} = \frac{M_{Ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{2337}{0.956 \cdot 15 \cdot 39{,}13} = 4{,}16\,cm^2/m$$

Ploča 104 – polje



$M_{Ed} = 18{,}20\ kNm/m$

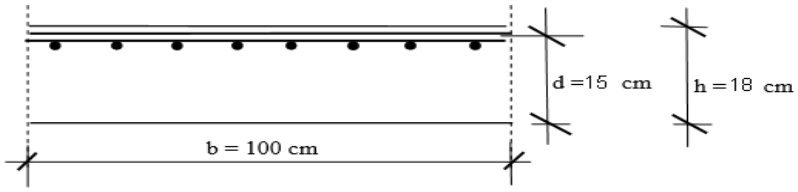
$$\mu_{sd} = \frac{M_{Ed}}{b \cdot d^2 \cdot f_{cd}} = \frac{1820}{100 \cdot 15^2 \cdot 2.0} = 0.040$$

Očitano: $\varepsilon_{s1} = 10.0\,‰ \quad \varepsilon_{c2} = 1.2\,‰ \quad \xi = 0.107 \quad \zeta = 0.962$

$$A_{s1} = \frac{M_{Ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{1820}{0.962 \cdot 15 \cdot 39{,}13} = 3{,}22\,cm^2/m$$

Odabrano za sve ploče: Q-503 (5,03 cm^2/m)

Ležaj 101 – 102



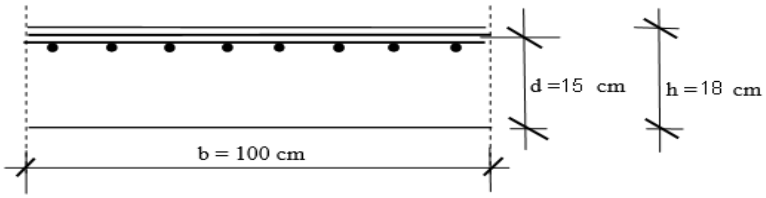
$M_{Ed} = 34{,}65\,kNm/m$

$$\mu_{sd} = \frac{M_{Ed}}{b \cdot d^2 \cdot f_{cd}} = \frac{3465}{100 \cdot 15^2 \cdot 2.0} = 0.077$$

Očitano: $\varepsilon_{s1} = 10.0\,‰ \quad \varepsilon_{c2} = 1.8\,‰ \quad \xi = 0.153 \quad \zeta = 0.944$

$$A_{s1} = \frac{M_{Ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{3456}{0.944 \cdot 15 \cdot 39{,}13} = 6{,}24\,cm^2/m$$

Ležaj 101 – 103



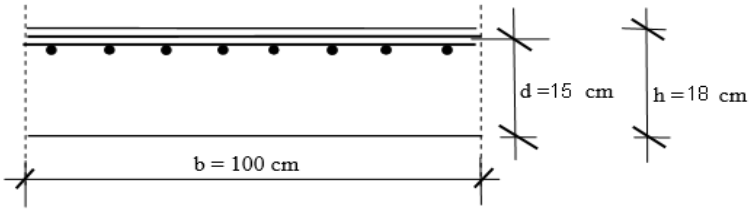
$M_{Ed} = 39{,}01\,kNm/m$

$$\mu_{sd} = \frac{M_{Ed}}{b \cdot d^2 \cdot f_{cd}} = \frac{3901}{100 \cdot 15^2 \cdot 2.0} = 0.086$$

Očitano: $\varepsilon_{s1} = 10.0\,‰ \quad \varepsilon_{c2} = 2{,}0\,‰ \quad \xi = 0.167 \quad \zeta = 0.938$

$$A_{s1} = \frac{M_{Ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{3901}{0.938 \cdot 15 \cdot 39{,}13} = 7{,}1\,cm^2/m$$

Ležaj 103 – 104



$M_{Ed} = 26{,}89\, kNm/m$

$$\mu_{sd} = \frac{M_{Ed}}{b \cdot d^2 \cdot f_{cd}} = \frac{2689}{100 \cdot 15^2 \cdot 2.0} = 0.059$$

Očitano: $\varepsilon_{s1} = 10.0\,‰ \quad \varepsilon_{c2} = 1.5\,‰ \quad \xi = 0.130 \quad \zeta = 0.953$

$$A_{s1} = \frac{M_{Ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{2689}{0.953 \cdot 15 \cdot 39{,}13} = 4.81\, cm^2/m$$

Odabrana mreža za sve ležaje: R-785 (A_s = 7,85 cm^2/m)

Minimalna armatura:

As1,min ≥ 0,26 · [fct,m / fyk]· bt · d ≥ 0,0011 ·bt · d

b t – širina vlačne zone

d – statička visina presjeka

fyk – karakt. granica popuštanja čelika u N/mm2

[fyk = 450 N/mm2 za čelik B 450B]

fct,m - srednja vlačna čvrstoća betona (iz tablice)

[fctm = 2,9 N/mm2 za C 30/37]

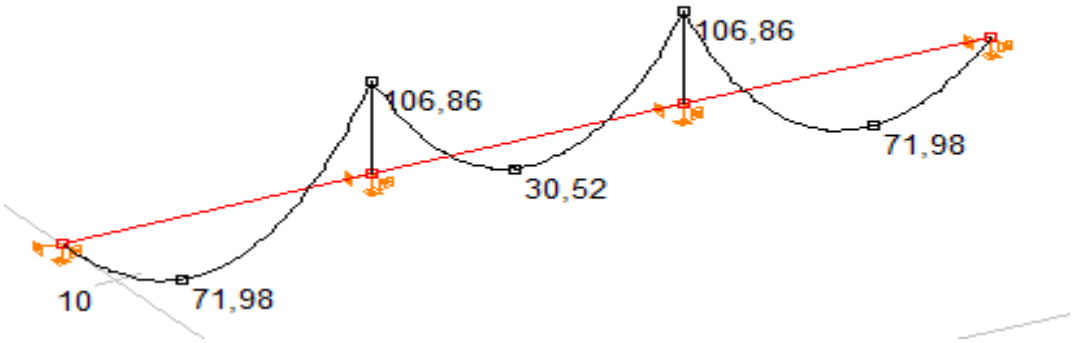
As1,min ≥ 0,26 ·2,9/ 450 ·100 ·15,0 = 2.51 cm2 /m

As1,min ≥ 0,0011 ·bt · d = 0,0011 ·100 ·15,0 = 1,65 cm2 /m

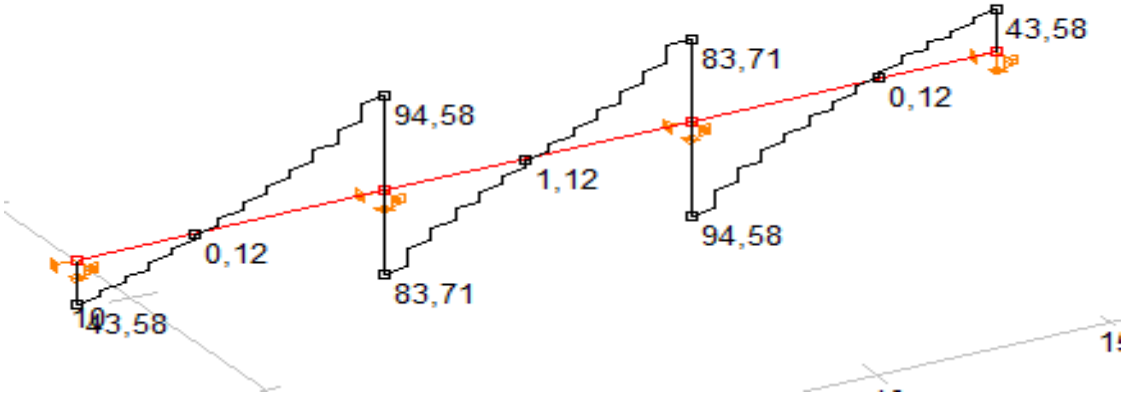
6. *PRORAČUN KONTINUIRANOG NOSAČA POZICIJE 200*

6.1. MOMENTI SAVIJANJA I POPREČNE SILE GREDE POZICIJE 200

6.1.1. Vlastita težina

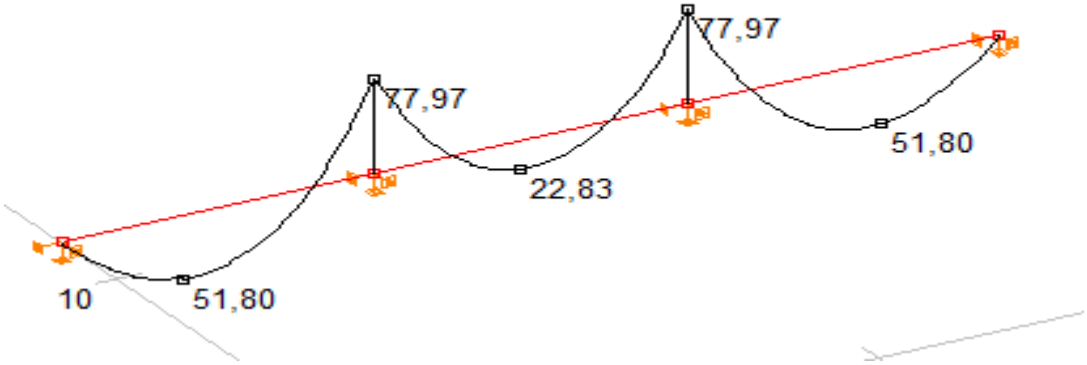


Slika 6.1. Momenti Mz (kNm)

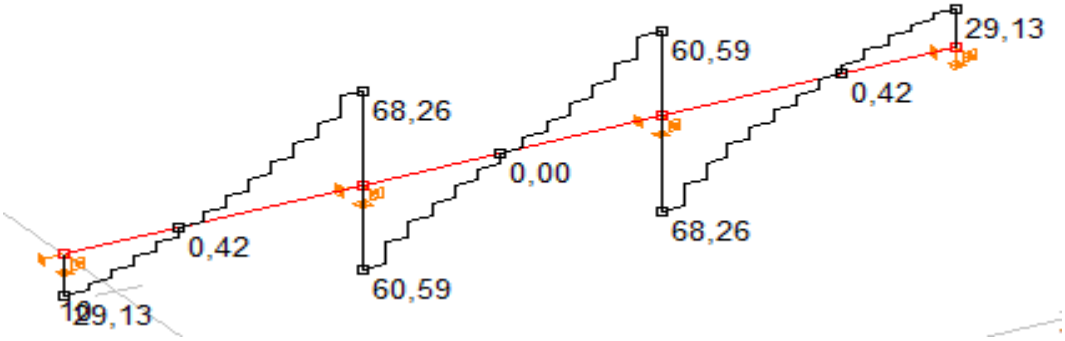


Slika 6.2. Poprečne sile Ty (kN)

6.1.2. Dodatno stalno opterećenje

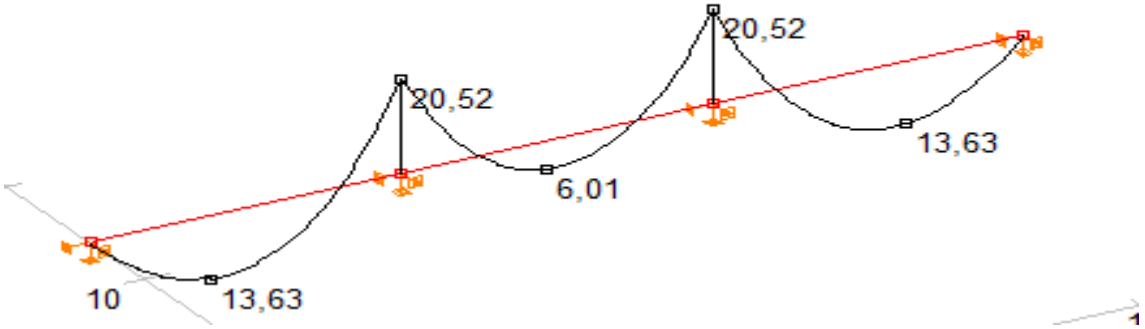


Slika 6.3. Momenti Mz (kNm)

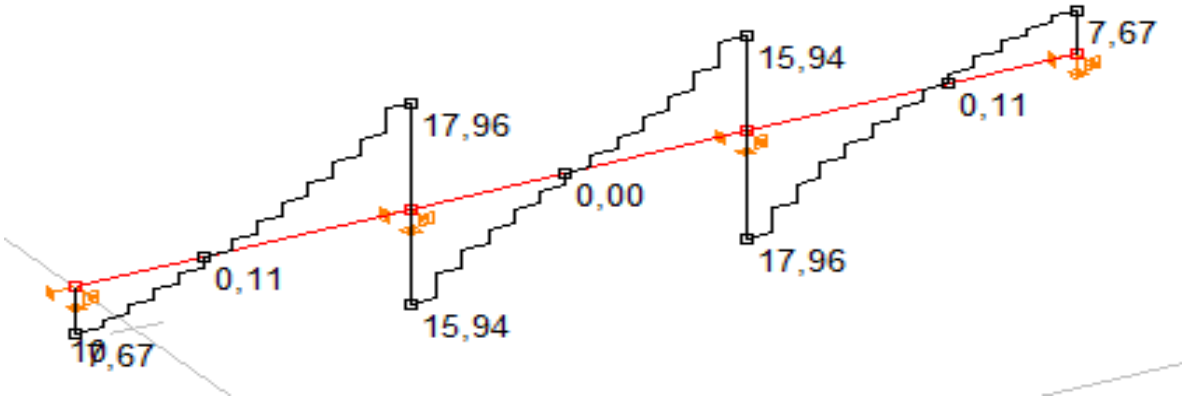


Slika 6.4. Poprečne sile Ty (kN)

6.1.3. Uporabno opterećenje



Slika 6.5. Momenti Mz (kNm)



Slika 6.6. Poprečne sile Ty (kN)

6.1.4. Granično stanje nosivosti

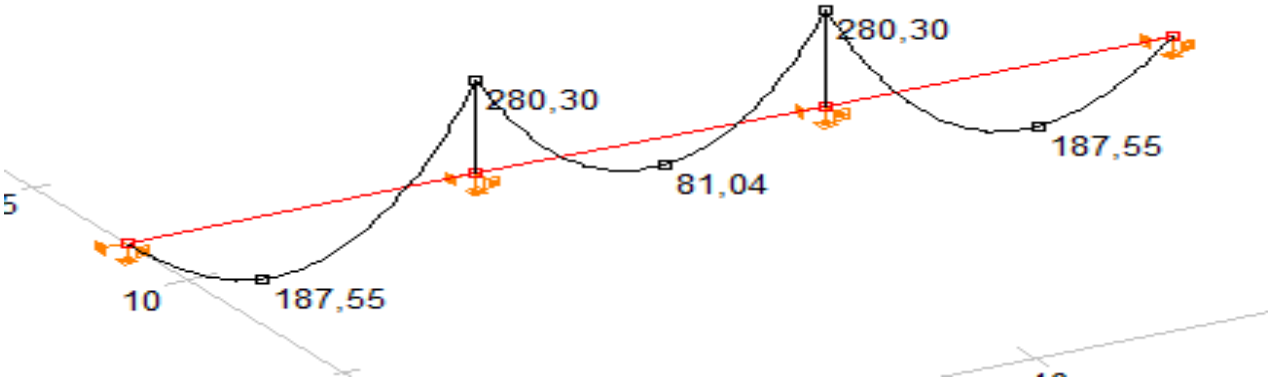
Mjerodavna kombinacija: $M_{ed}=1,35*(M_g+M_{\Delta g})+1,5*M_q$

Momenti:

$M_{Ed,polje1} = 187,55\,kNm$

$M_{Ed,ležaj} = -280,30\,kNm$

$M_{Ed,polje2} = 81,04kNm$

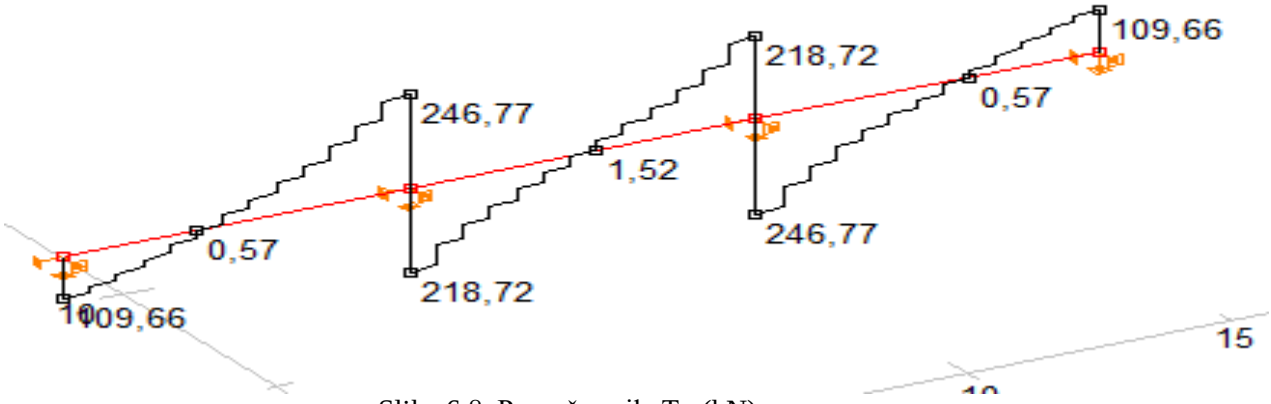


Slika 6.7. Momenti Mz (kNm)

Poprečne sile:

$V_{Ed,ležaj1} = 246,77\,kN$

$V_{Ed,ležaj0} = 109,66kN$



Slika 6.8. Poprečne sile Ty (kN)

6.2. **DIMENZIONIRANJE GREDE NA MOMENT SAVIJANJA**

BETON: C 30/37;

$f_{ck} = 30{,}0$ MPa= 30 N/mm^2 ; γ_c=1.5

$f_{cd} = f_{ck}/\gamma_c = 30{,}0/1{,}5 = 20{,}0$ MPa = 20,0 N/mm^2 = 2,0 kN/cm ^{2}

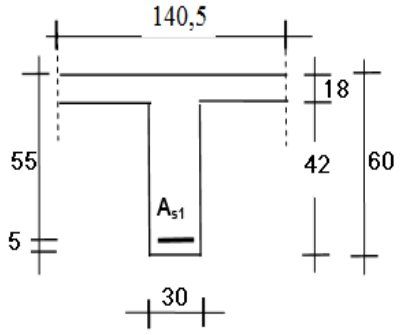
ARMATURA:B 450 BC;

$f_{yk} = 450{,}0$ MPa = 450 N/mm^2 ; γ_s = 1,15

$f_{yd} = f_{yk}/\gamma_s = 450{,}0/1{,}15 = 391{,}30$MPa = 391,30 N/mm^2= 39,13 kN/cm^2

Polje 1:

Utjecajna širina: $b_{eff} = b_0 + \frac{l_0}{5} \Rightarrow b_{eff} = 30 + \frac{0.85 \cdot 650}{5} = 140{,}5\ cm$



$d_1 = 5cm$

$d = h - d_1 = 60 - 5 = 55cm$

$M_{Ed} = 187{,}55\ kNm$

$\mu_{sd} = \frac{M_{Ed}}{b_{eff} \cdot d^2 \cdot f_{cd}} = \frac{18755}{140{,}5 \cdot 55^2 \cdot 2.0} = 0.022$

Očitano:

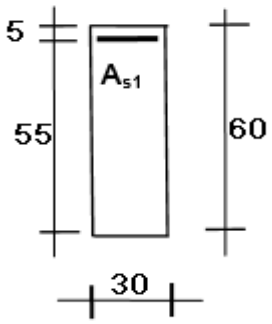
$\varepsilon_{s1} = 10.0\ ‰ \quad \varepsilon_{c2} = 0.9‰ \quad \xi = 0.083 \quad \zeta = 0.971$

$x = \xi \cdot d = 0.083 \cdot 55 = 4.565\ cm < h_{pl} = 18\ cm$

$A_{s1} = \frac{M_{Ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{18755}{0.971 \cdot 55 \cdot 39{,}13} = 8{,}97\ cm^2$

Odabrano 6Ø16 (As=12,06 cm^2)

Ležaj:



$d_1 = 5cm$

$d = h - d_1 = 60 - 5 = 55cm$

$M_{Ed} = 280{,}30\ kNm$

$\mu_{sd} = \frac{M_{Ed}}{b_w \cdot d^2 \cdot f_{cd}} = \frac{28030}{30 \cdot 55^2 \cdot 2.0} = 0.154$

Očitano:

$\varepsilon_{s1} = 5.0\ ‰ \quad \varepsilon_{c2} = 2.2‰ \quad \xi = 0.181 \quad \zeta = 0.883$

$x = \xi \cdot d = 0.181 \cdot 55 = 9{,}96\ cm$

$A_{s1} = \frac{M_{Ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{28030}{0.883 \cdot 55 \cdot 39{,}13} = 14{,}75\ cm^2$

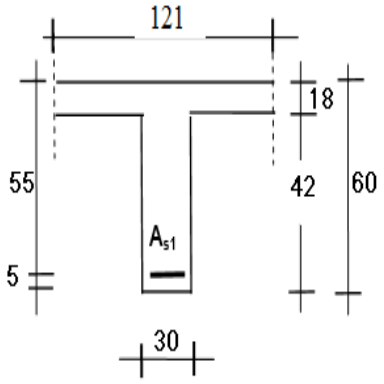
Odabrano 8Ø16 (As=16,08 cm^2)

Polje 2:

Utjecajna širina: $b_{eff} = b_0 + \frac{l_0}{5} \quad \Rightarrow \quad b_{eff} = 30 + \frac{0.70 \cdot 650}{5} = 121cm$

$d_1 = 5cm$

$d = h - d_1 = 60 - 5 = 55cm$



$M_{Ed} = 81{,}04\,kNm$

$\mu_{sd} = \frac{M_{Ed}}{b_{eff} \cdot d^2 \cdot f_{cd}} = \frac{8104}{121 \cdot 55^2 \cdot 2.0} = 0.011$

Očitano:

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

$x = \xi \cdot d = 0.057 \cdot 55 = 3.14\,cm < h_{pl} = 18cm$

$A_{s1} = \frac{M_{Ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{8104}{0.981 \cdot 55 \cdot 39{,}13} = 3{,}84\,cm^2$

Odabrano 2Ø16 (As=4,02 cm^2)

Minimalna armatura:

As1,min ≥ 0,26 · [fct,m / fyk]· bt · d ≥ 0,0011 ·bt · d

b t – širina vlačne zone

d – statička visina presjeka

fyk – karakt. granica popuštanja čelika u N/mm2

[fyk = 450 N/mm2 za čelik B 450 BC]

fct,m - srednja vlačna čvrstoća betona (iz tablice)

[fctm = 2,9 N/mm2 za C 30/37]

As1,min ≥ 0,26 ·2,9/ 450 ·30 ·55 = 2,76 cm2

As1,min ≥ 0,0011 ·bt · d = 0,0011 ·30 ·55 = 1,815 cm2

Maksimalna armatura:

As1,max=0.04·Ac=0.04·30·60=72 cm2

6.3. **DIMENZIONIRANJE GREDE NA POPREČNU SILU**

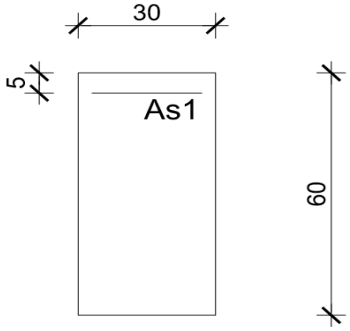
Ležaj 1

C 30/37

V_{Ed} =246,8kN

N_{Ed}=0.0 kN

,



As1=8Ø16 =16,08 cm²

$$V_{Rdc} = \left[C_{Rdc} \cdot k \cdot (100 \cdot \rho_l \cdot fck)^{\frac{1}{3}} + k_1 \cdot \sigma_{cp} \right] \cdot b_w \cdot d$$

$$b_w = 30\,cm \quad ; \quad d = 55\,cm$$

$$k = 1 + \sqrt{\frac{200}{d}} = 1 + \sqrt{\frac{200}{550}} = 1.60 \le 2$$

$$k_1 = 0.15$$

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

$$\Sigma A_s = 8\phi 16 = 16{,}08 cm^2$$

$$\rho_l = \frac{\Sigma A_s}{A_c} = \frac{16{,}08}{30 \cdot 55} = \frac{16{,}08}{1650} = 0.0097$$

$$C_{Rdc} = \frac{0.18}{\gamma_c} = \frac{0.18}{1.5} = 0.12$$

$$V_{Rdc} = \left[0.12 \cdot 1.60 \cdot (100 \cdot 0.0097 \cdot 30)^{\frac{1}{3}} \right] \cdot 300 \cdot 550 = 97{,}44 kN$$

$$V_{Rdc} \ge \left[\nu_{\min} + k_1 \cdot \sigma_{cp} \right] \cdot b_w \cdot d$$

$$\nu_{\min} = 0.035 \cdot k^{\frac{3}{2}} \cdot f_{ck}{}^{\frac{1}{2}} = 0.035 \cdot 1.60^{\frac{3}{2}} \cdot 30^{\frac{1}{2}} = 0.388$$

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

$$V_{Rdc} \ge \nu_{\min} \cdot b_w \cdot d = 0.388 \cdot 300 \cdot 550 = 64{,}02 kN \le V_{Ed}$$

$$V_{Ed,\max} = V_{Ed} = 246{,}77 kN$$

$$V_{Rd,\max} = 0.5 \cdot \nu \cdot b_w \cdot d \cdot f_{cd}$$

$$\nu = 0.6 \cdot \left[1 - \frac{f_{ck}}{250} \right] = 0.6 \cdot \left[1 - \frac{30}{250} \right] = 0.528$$

$$V_{Rd,\max} = 0.5 \cdot 0.528 \cdot 300 \cdot 550 \cdot 20{,}0 = 871{,}2 kN > V_{Ed,\max} = V_{Ed}$$

$$V_{Ed,\max} / V_{Rd,\max} = 246{,}77 / 871{,}2 = 0.28 \approx 0.30 \Rightarrow V_{Ed} = 0.30 V_{Rd,\max}$$

$$s_{\max} = \min\{0.55 \cdot d; 30\} = \min\{30.25; 30\} \Rightarrow s_{\max} = 30.0 cm$$

$$\rho_{\min} = 0.0011$$

Površina minimalne armature:

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

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

$$f_{yw,d} = \frac{f_{yk}}{\gamma_s}; B450BC \Rightarrow f_{ywd} = \frac{450}{1.15} = 391{,}3 MPa = 39{,}13 kN / cm^2$$

$$V_{Rd} = V_{Rd,s} = \frac{A_{sw}}{s} \cdot z \cdot f_{ywd} \cdot m \cdot ctg\theta = \frac{0.79}{30} \cdot (0.9 \cdot 55) \cdot 39{,}13 \cdot 2 \cdot 1 = 102{,}01 kN$$

$$V_{Ed} > V_{Rd}$$

Na mjestu maksimalne poprečne sile:

$$s_w \le \frac{m \cdot A_{sw} \cdot f_{yw,d} \cdot z}{V_{Ed}} = \frac{2 \cdot 0.79 \cdot 39{,}13 \cdot 0.9 \cdot 55}{246{,}77} = 12{,}40 cm$$

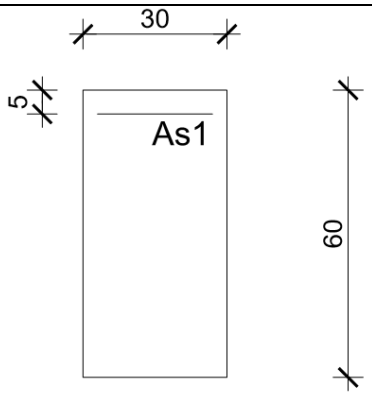
Odabrane spone:**Ø10/10cm** (A_{sw}=0.79 cm^2)

Ležaj 0

C 30/37

V_{Ed} =109,66 kN

N_{Ed}=0.0 kN



As1=6Ø16 =12,06 cm²

$$V_{Rdc} = \left[C_{Rdc} \cdot k \cdot (100 \cdot \rho_l \cdot fck)^{\frac{1}{3}} + k_1 \cdot \sigma_{cp} \right] \cdot b_w \cdot d$$

$$b_w = 30\,cm \quad ; \quad d = 55\,cm$$

$$k = 1 + \sqrt{\frac{200}{d}} = 1 + \sqrt{\frac{200}{550}} = 1.60 \le 2$$

$$k_1 = 0.15$$

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

$$\Sigma A_s = 6\phi 16 = 12{,}06 cm^2$$

$$\rho_l = \frac{\Sigma A_s}{A_c} = \frac{12{,}06}{30 \cdot 55} = \frac{12{,}06}{1650} = 0.0073$$

$$C_{Rdc} = \frac{0.18}{\gamma_c} = \frac{0.18}{1.5} = 0.12$$

$$V_{Rdc} = \left[0.12 \cdot 1.60 \cdot (100 \cdot 0.0073 \cdot 30)^{\frac{1}{3}} \right] \cdot 300 \cdot 550 = 88{,}63 kN$$

$$V_{Rdc} \ge \left[\nu_{\min} + k_1 \cdot \sigma_{cp} \right] \cdot b_w \cdot d$$

$$\nu_{\min} = 0.035 \cdot k^{\frac{3}{2}} \cdot f_{ck}^{\frac{1}{2}} = 0.035 \cdot 1.60^{\frac{3}{2}} \cdot 30^{\frac{1}{2}} = 0.388$$

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

$$V_{Rdc} \ge \nu_{\min} \cdot b_w \cdot d = 0.388 \cdot 300 \cdot 550 = 64{,}02 kN \le V_{Ed}$$

$$V_{Ed,\max} = V_{Ed} = 109{,}66 kN$$

$$V_{Rd,\max} = 0.5 \cdot \nu \cdot b_w \cdot d \cdot f_{cd}$$

$$\nu = 0.6 \cdot \left[1 - \frac{f_{ck}}{250} \right] = 0.6 \cdot \left[1 - \frac{30}{250} \right] = 0.528$$

$$V_{Rd,\max} = 0.5 \cdot 0.528 \cdot 300 \cdot 550 \cdot 20{,}0 = 871{,}2 kN > V_{Ed,\max} = V_{Ed}$$

$V_{Ed,\max} / V_{Rd,\max} = 109{,}66 / 871{,}2 = 0.126 \approx 0.15 \Rightarrow V_{Ed} = 0.15 V_{Rd,\max}$

$s_{\max} = \min\{0.75 \cdot d; 30\} = \min\{41.25; 30\} \Rightarrow s_{\max} = 30.0 cm$

$\rho_{\min} = 0.0011$

Površina minimalne armature:

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

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

$$f_{yw,d} = \frac{f_{yk}}{\gamma_s}; B450BC \Rightarrow f_{ywd} = \frac{450}{1.15} = 391{,}3 MPa = 39{,}13 kN/cm^2$$

$$V_{Rd} = V_{Rd,s} = \frac{A_{sw}}{s} \cdot z \cdot f_{ywd} \cdot m \cdot ctg\theta$$

$$= \frac{0.79}{30} \cdot (0.9 \cdot 55) \cdot 39{,}13 \cdot 2 \cdot 1 = 102{,}01 kN$$

$V_{Ed} > V_{Rd}$

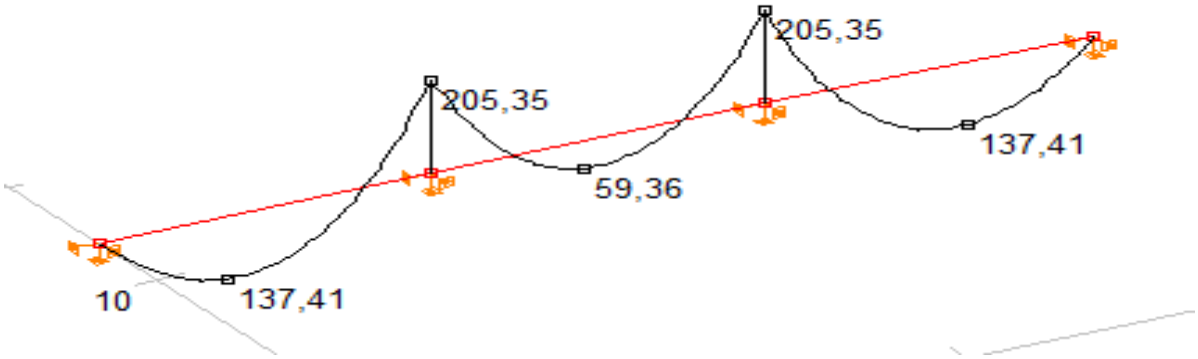
Na mjestu maksimalne poprečne sile:

$$s_w \le \frac{m \cdot A_{sw} \cdot f_{yw,d} \cdot z}{V_{Ed}} = \frac{2 \cdot 0.79 \cdot 39{,}13 \cdot 0.9 \cdot 55}{109{,}66} = 24{,}64 cm$$

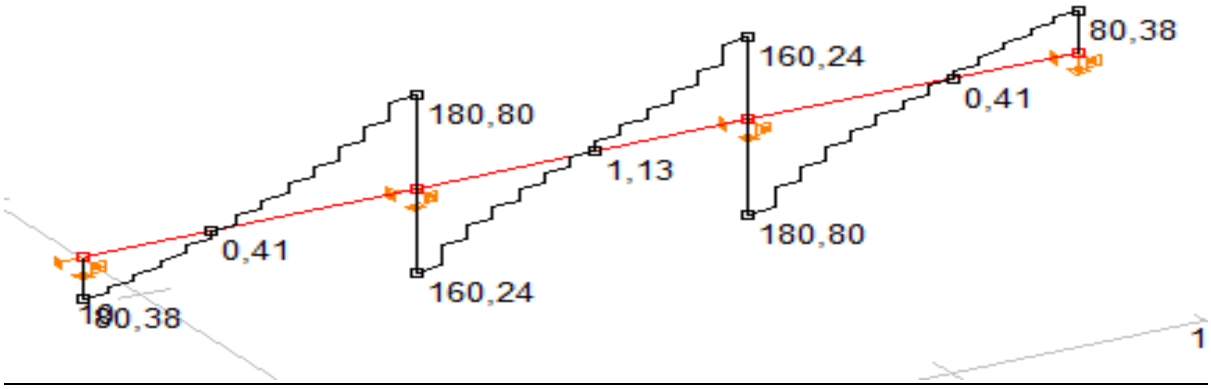
Odabrane spone:**Ø10/20cm** (A_{sw}=0.79 cm^2)

6.4. **KONTROLA PUKOTINA GREDE POZICIJE 200**

- Kontrola pukotina i progib grede proračunava se na granično stanje uporabljivosti. Mjerodavna kombinacija djelovanja za proračun graničnog stanja uporabljivosti je: 1.0 vlastita težina "+" 1.0 dodatno stalno "+" 1.0 uporabno



Slika 6.9.Moment (kNm)



Slika 6.10.Poprečna sila (kN)

<u>Polje 1</u>:

M_{Ed} = 137,41kNm

Prognoza širine pukotine:

$w_k = S_{r,max} \cdot (\varepsilon_{s,m} - \varepsilon_{c,m})$

Proračun srednje deformacije armature:

$$(\varepsilon_{sm} - \varepsilon_{cm}) = \frac{\sigma_s - k_t \cdot \frac{f_{ct,eff}}{\rho_{p,eff}} \cdot (1 + \alpha_e \cdot \rho_{p,eff})}{E_s} \geq 0.6 \cdot \frac{\sigma_s}{E_s}$$

E_{cm} = 32.00 GPa = 32000 MPa – modul elastičnosti betona

E_s = 200.0 GPa = 200000.0 MPa – modul elastičnosti armature

$f_{ctm} = 2{,}9$ MPa - za betone klase C 30/37

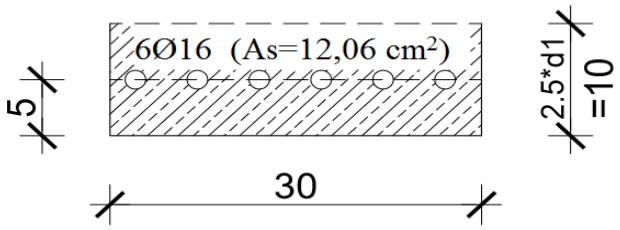
$k_t = 0.4$ - dugotrajno opterećenje

$$\alpha_e = \frac{E_s}{E_{cm}} = \frac{200}{35{,}0} = 5.71$$

$$x = \frac{\alpha_e \cdot A_{s1}}{b} \cdot \left(-1 + \sqrt{\frac{2 \cdot b \cdot d}{\alpha_e \cdot A_{s1}}}\right) = \frac{5.71 \cdot 12{,}06}{30} \cdot \left(-1 + \sqrt{1 + \frac{2 \cdot 30 \cdot 55}{5.71 \cdot 12{,}06}}\right) = 13{,}75 \text{ cm}$$

$$\sigma_s = \frac{M_{Ed}}{z \cdot A_{s1}} \approx \frac{M_{Ed}}{\left(d - \frac{x}{3}\right) \cdot A_{s1}} = = \frac{13741}{\left(55 - \frac{13{,}75}{3}\right) \cdot 12{,}06} = 22{,}60 \text{ kN/cm}^2 = 225{,}98 \text{MPa}$$

$$\rho_{p,eff} = \frac{A_{s1}}{A_{c,eff}} = \frac{A_{s1}}{b \cdot 2.5 \cdot d_1} = \frac{12{,}06}{30 \cdot 2.5 \cdot 5.0} = 0.032$$



$$(\varepsilon_{sm} - \varepsilon_{cm}) = \frac{225{,}98 - 0.4 \cdot \frac{2{,}9}{0.032} \cdot (1 + 5.71 \cdot 0.032)}{200000} \geq 0.6 \cdot \frac{225{,}98}{200000}$$

$$\frac{183{,}11}{200000} > \frac{135{,}59}{200000}$$

$$(\varepsilon_{sm} - \varepsilon_{cm}) = 0.00092$$

Proračun srednjeg razmaka pukotina:

$$S_{r,max} = k_3 \cdot c + k_1 \cdot k_2 \cdot k_4 \cdot \frac{\phi}{\rho_{p,eff}}$$

φ = 16 mm – promjer najdeblje šipke

k_1 = 0.8 - Rebrasta armatura

k_2 = 0.5 – Savijanje

k_3=3.4

k_4=0.425

$c = d_1 - \frac{\phi}{2} = 50 - \frac{16}{2} = 42$ mm - zaštitni sloj uzdužne armature

$S_{r,max} = 3.4 \cdot 42 + 0.8 \cdot 0.5 \cdot 0.425 \cdot \frac{16}{0.034}$ =222,8 mm

$W_k = w_k = S_{r,max} \cdot (\varepsilon_{s,m} - \varepsilon_{c,m}) = 222{,}8 \cdot 0.00092 = 0.205 \text{ mm} \leq 0.300 \text{ mm}$

→ pukotine zadovoljavaju

<u>Ležaj</u>:

M_{Ed} = 205,35 kNm

Prognoza širine pukotine:

$w_k = S_{r,max} \cdot (\varepsilon_{s,m} - \varepsilon_{c,m})$

Proračun srednje deformacije armature:

$$(\varepsilon_{sm} - \varepsilon_{cm}) = \frac{\sigma_s - k_t \cdot \frac{f_{ct,eff}}{\rho_{p,eff}} \cdot (1 + \alpha_e \cdot \rho_{p,eff})}{E_s} \geq 0.6 \cdot \frac{\sigma_s}{E_s}$$

E_{cm} = 32.00 GPa = 32000 MPa – modul elastičnosti betona

E_s = 200.0 GPa = 200000.0 MPa – modul elastičnosti armature

$f_{ctm} = 2{,}9$ MPa - za betone klase C 30/37

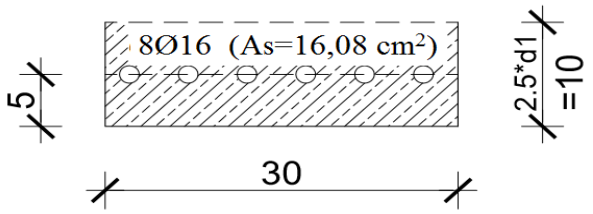
$k_t = 0.4$ - dugotrajno opterećenje

$\alpha_e = \frac{E_s}{E_{cm}} = \frac{200}{35{,}0} = 5.71$

$x = \frac{\alpha_e \cdot A_{s1}}{b} \cdot \left(-1 + \sqrt{\frac{2 \cdot b \cdot d}{\alpha_e \cdot A_{s1}}}\right) = \frac{5.71 \cdot 16{,}08}{30} \cdot \left(-1 + \sqrt{1 + \frac{2 \cdot 30 \cdot 55}{5.71 \cdot 16{,}08}}\right) = 15{,}55$ cm

$\sigma_s = \frac{M_{Ed}}{z \cdot A_{s1}} \approx \frac{M_{Ed}}{\left(d - \frac{x}{3}\right) \cdot A_{s1}} = \frac{20535}{\left(55 - \frac{15{,}55}{3}\right) \cdot 16{,}08} = 25{,}63$ kN /cm^2 = 256,32Mpa

$$\rho_{p,eff} = \frac{A_{s1}}{A_{c,eff}} = \frac{A_{s1}}{b \cdot 2.5 \cdot d_1} = \frac{16,08}{30 \cdot 2.5 \cdot 5.0} = 0.043$$



$$(\varepsilon_{sm} - \varepsilon_{cm}) = \frac{256,32 - 0.4 \cdot \frac{2,9}{0.043} \cdot (1 + 5.71 \cdot 0.043)}{200000} \geq 0.6 \cdot \frac{256,32}{200000}$$

$$\frac{222,72}{200000} > \frac{153,79}{200000}$$

$$(\varepsilon_{sm} - \varepsilon_{cm}) = 0.00111$$

Proračun srednjeg razmaka pukotina:

$$S_{r,max} = k_3 \cdot c + k_1 \cdot k_2 \cdot k_4 \cdot \frac{\phi}{\rho_{p,eff}}$$

φ = 16 mm – promjer najdeblje šipke

k_1 = 0.8 - Rebrasta armatura

k_2 = 0.5 – Savijanje

k_3=3.4

k_4=0.425

$c = d_1 - \frac{\phi}{2} = 50 - \frac{16}{2} = 42$ mm - zaštitni sloj uzdužne armature

$S_{r,max} = 3.4 \cdot 42 + 0.8 \cdot 0.5 \cdot 0.425 \cdot \frac{16}{0.043} = 206,06$ mm

$W_k = w_k = S_{r,max} \cdot (\varepsilon_{s,m} - \varepsilon_{c,m}) = 206,06 \cdot 0.00111 = 0.229 \text{ mm} \leq 0.300 \text{ mm}$

→ pukotine zadovoljavaju

6.5. **KONTROLA PROGIBA GREDE POZICIJE 200**

Progib kontroliramo za nefaktorizirano opterećenje i bez utjecaja puzanja.

Kontrola progiba za Polje 1:

Granični progib:

$$v_{\lim} = \frac{L}{250} = \frac{650}{250} = 2.6\,cm$$

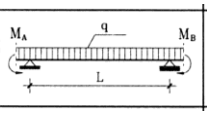
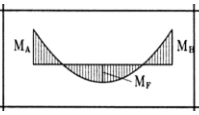
Beton: C 30/37; f_{ck}=30.0 MPa

$$E_{cm} = 9500 \cdot \sqrt[3]{\text{fck} + 8} = 9500 \cdot \sqrt[3]{30 + 8} \approx 35000\ MPa$$

$$f_{ctm} = 0.3 \cdot \left(f_{ck}\right)^{2/3} = 0.3 \cdot \left(30.0\right)^{2/3} = 2{,}9\ MPa$$

Čelik: B450BC ; E_s= 200.0 GPa

$$\alpha_{eI} = \frac{E_s}{E_{cm}} = \frac{200.0}{35} = 5.71$$

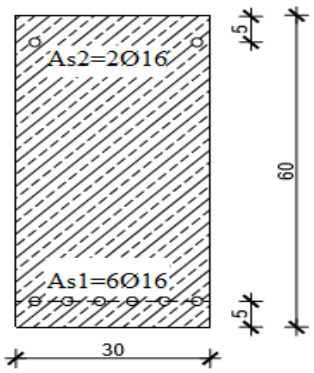
Red	Tip opterećenja	Dijagram momenata savijanja	Koeficijent k iz izraza (5.131)
7			$k = \frac{5}{48}(1 - 0{,}1\beta)$ $\beta = \lvert M_A + M_B \rvert / \lvert M_F \rvert$

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

$$\beta = \left|M_A + M_B\right| / \left|M_F\right| = \left|0.0 + 205{,}35\right| / \left|137{,}41\right| = 1.494$$

$$k = \frac{5}{48} \cdot \left(1 - 0.1 \cdot \beta\right) = 0.104 \cdot \left(1 - 0.1 \cdot 1.494\right) = 0.0885$$

Presjek u polju :



$A_{s1} = 6\varnothing 16 = 12{,}06\ cm^2$

$A_{s1} = 2\varnothing 16 = 4{,}02\ cm^2$

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

$$= \frac{30 \cdot 60^3}{12} + 5.71 \cdot \left[15.27 \cdot \left(\frac{60}{2} - 5 \right)^2 + 4{,}02 \cdot \left(\frac{60}{2} - 5 \right)^2 \right] =$$

$$= 60884{,}19\ cm^4$$

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

$$\frac{1}{r_I} = \frac{M_{Ed}}{E_{c,eff} \cdot I_I} = \frac{13741}{3200 \cdot 60884{,}19} = 0.00000705 \frac{1}{cm}$$

Progib potpuno raspucanog presjeka:

$x = 13{,}75\ cm$ (izračunato kod pukotina)

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

$$= \frac{30 \cdot 13{,}75^3}{12} + (30 \cdot 13{,}75) \cdot \left(\frac{13{,}75}{2} \right)^2 + 5.71 \cdot \left[12{,}06 \cdot (55 - 13{,}75)^2 + 4{,}02 \cdot (13{,}75 - 5)^2 \right]$$

$$= 13890{,}17 cm^4$$

$$\frac{1}{r_{II}} = \frac{M_{Ed}}{E_{c,eff} \cdot I_{II}} = \frac{13741}{3200 \cdot 13890{,}17} = 0.0000309 \frac{1}{cm}$$

$\sigma_s = 225{,}98\ MPa$

$$\sigma_{sr} = \frac{M_{cr}}{(d - \frac{x}{3}) \cdot A_{s1}}$$

$$M_{cr} = f_{ctm} \cdot W = f_{ctm} \cdot \frac{b \cdot h^2}{6} = 0.35 \cdot \frac{30 \cdot 60^2}{6} = 6300 kNcm$$

$$\sigma_{sr} = \frac{6300}{(55 - \frac{13{,}75}{3}) \cdot 12{,}06} = 10{,}36 \frac{kN}{cm^2} = 103{,}6 MPa$$

$\beta_1 = 1.0$ - Rebrasta armatura

$\beta_2 = 0.5$ - Dugotrajno opterećenje

$$\zeta = 1 - \beta_1 \cdot \beta_2 \cdot \left(\frac{\sigma_{sr}}{\sigma_s} \right)^2 = 1 - 1.0 \cdot 0.5 \cdot \left(\frac{103{,}6}{225{,}98} \right)^2 = 0.895$$

$$\frac{1}{r_I} = 0.00000705 \frac{1}{cm}$$

$$\frac{1}{r_{II}} = 0.0000309 \frac{1}{cm}$$

$$\frac{1}{r_m} = (1 - \zeta) \cdot \frac{1}{r_I} + \zeta \cdot \frac{1}{r_{II}} = (1 - 0.895) \cdot 0.00000705 + 0.895 \cdot 0.0000309 = 0.000029 \frac{1}{cm}$$

$k = 0.0885$

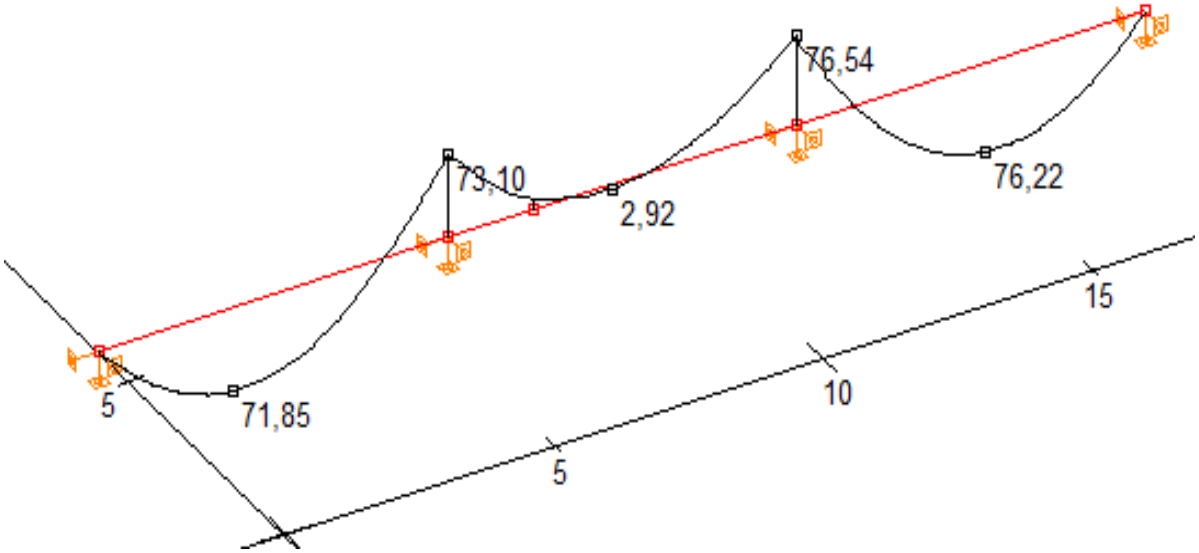
$L = 650.0\ cm$

$$v_{tot,t=0} = k \cdot L^2 \cdot \frac{1}{r_{tot}} = 0.0885 \cdot 650.0^2 \cdot 0.000029 = 1.08\ cm < v_{\lim} = 2.6 cm$$

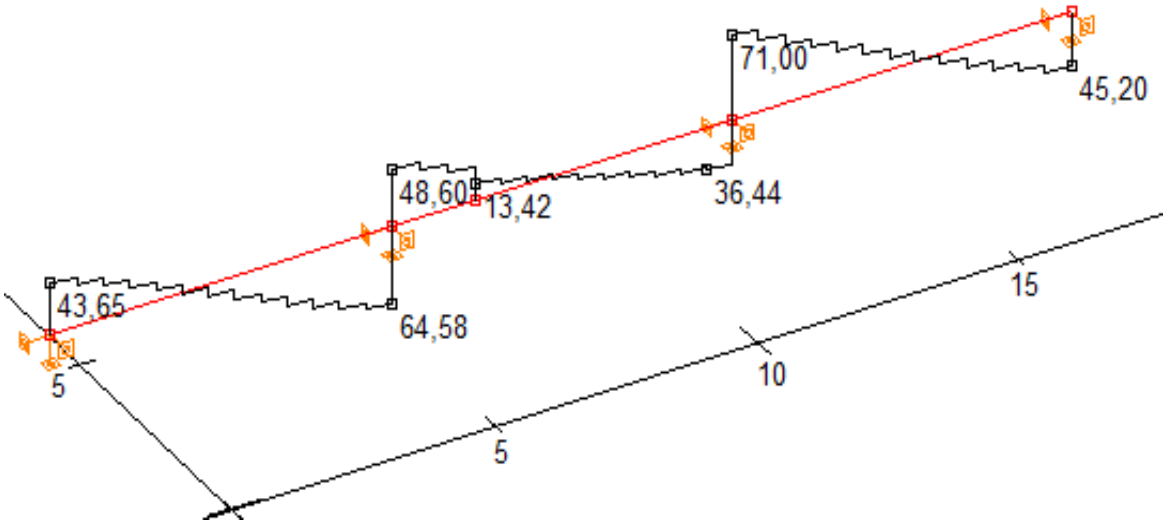
7. PRORAČUN KONTINUIRANOG NOSAČA POZICIJE 100

7.1. MOMENTI SAVIJANJA I POPREČNE SILE GREDE POZICIJE 100

7.1.1. Vlastita težina

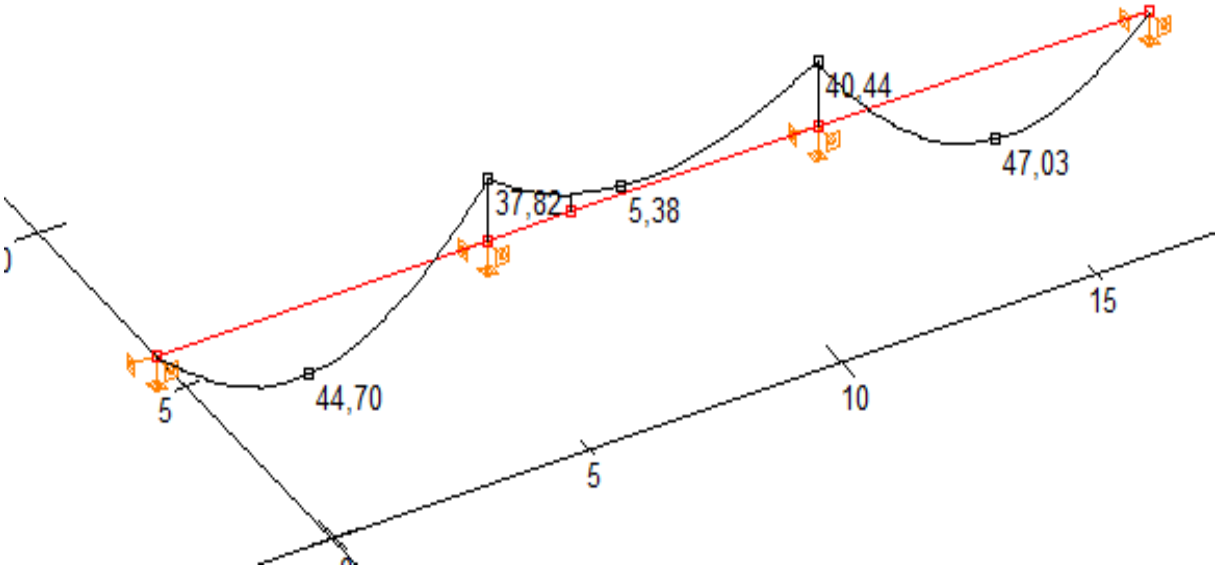


Slika 7.1. Momenti Mz (kNm)

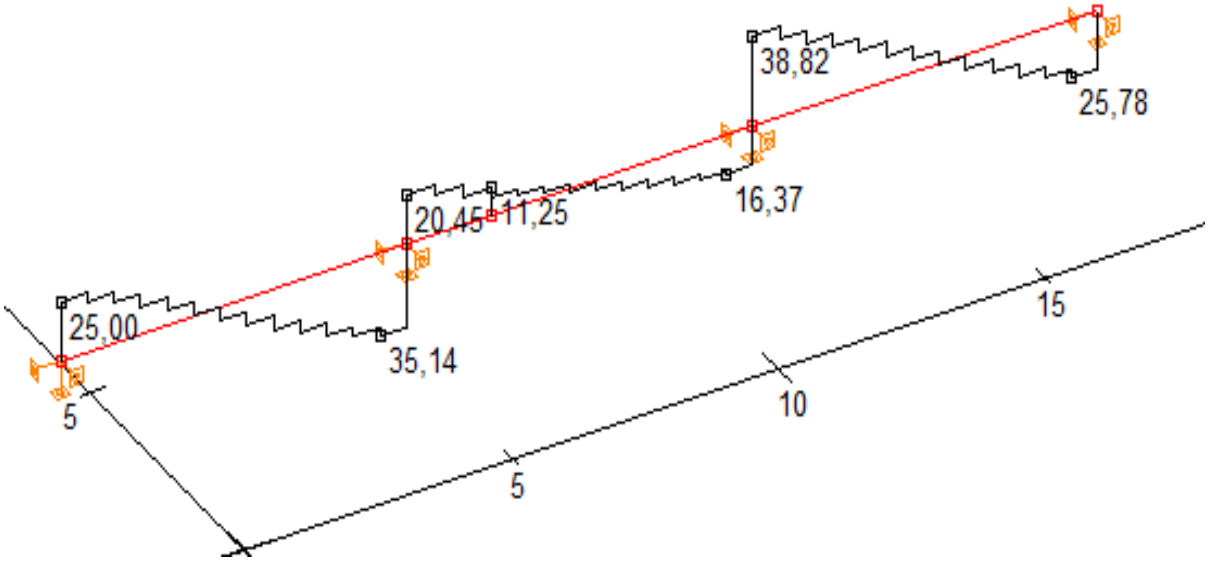


Slika 7.2. Poprečne sile Vy (kN)

7.1.2. Dodatno stalno opterećenje

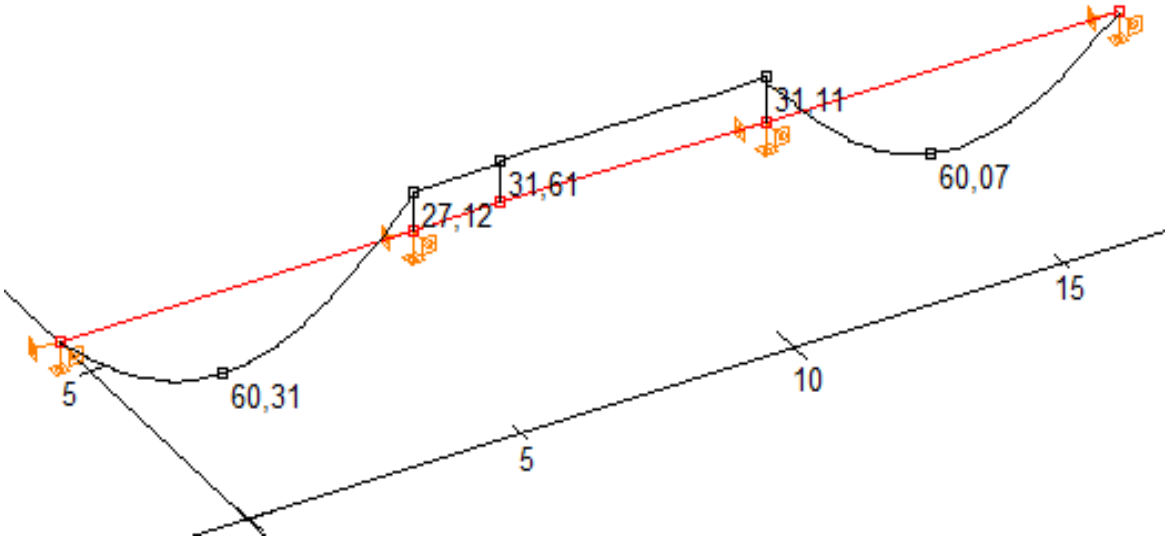


Slika 7.3. Momenti Mz (kNm)

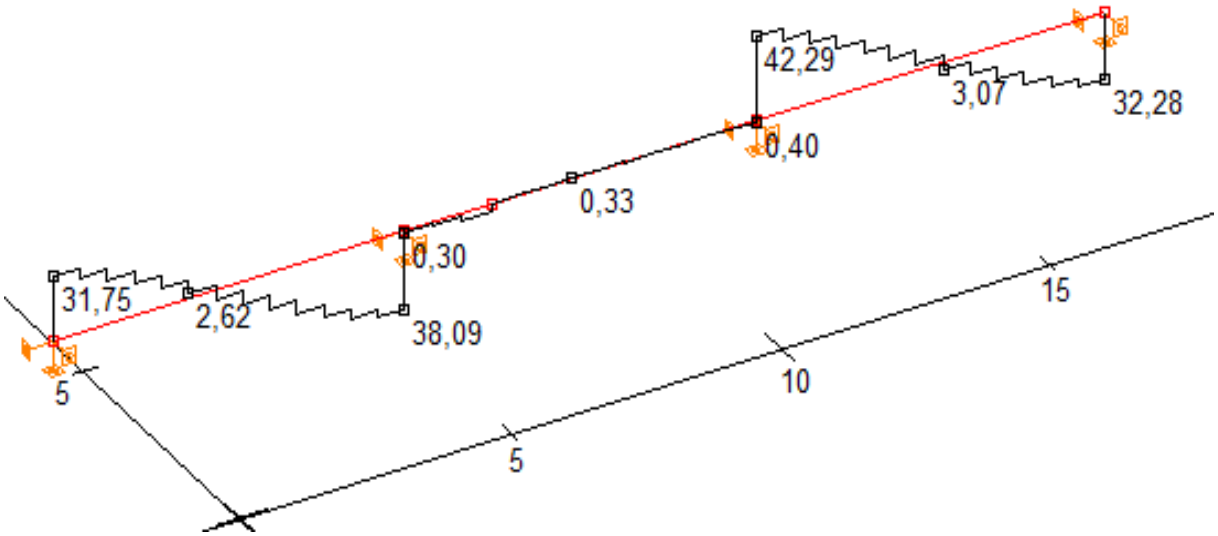


Slika 7.4. Poprečne sile Vy (kN)

7.1.3. Uporabno opterećenje shema 4 (max sile u krajnjim poljima)

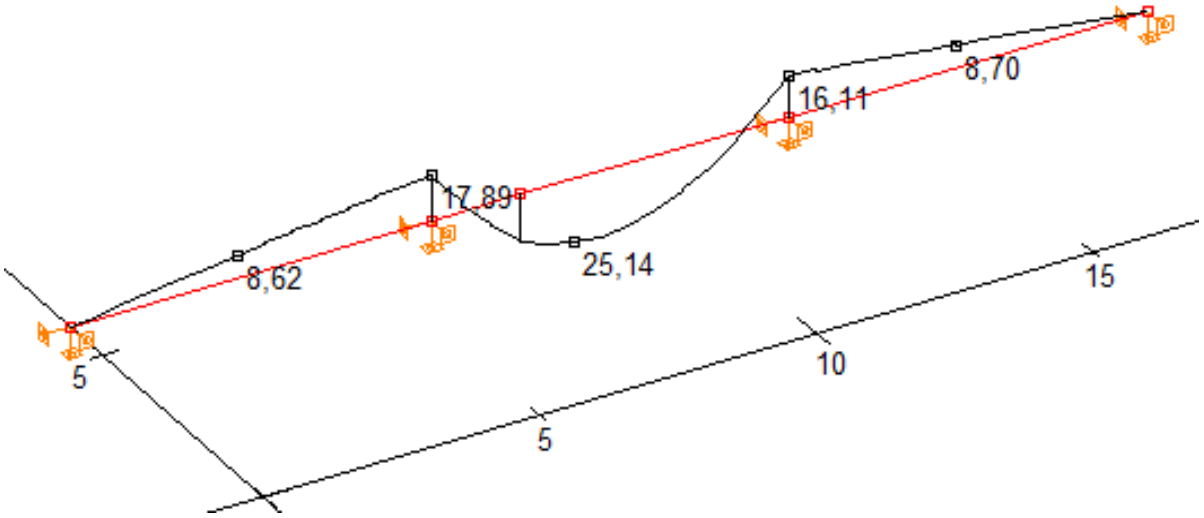


Slika 7.5. Momenti Mz (kNm)

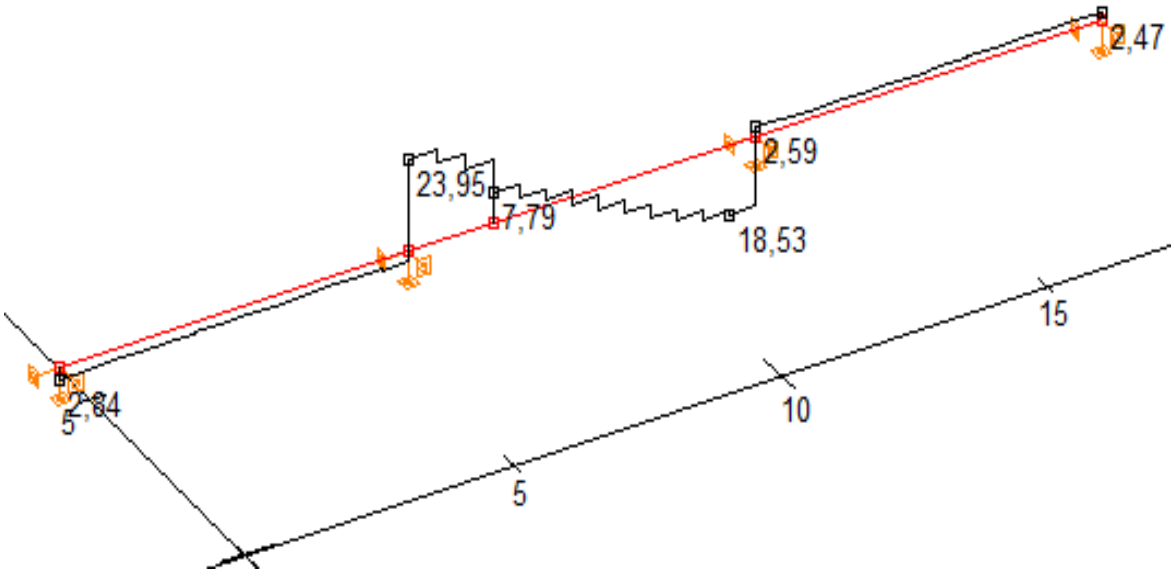


Slika 7.6. Poprečne sile Vy (kN)

7.1.4. Uporabno opterećenje shema 5 (max sile u srednjem polju)

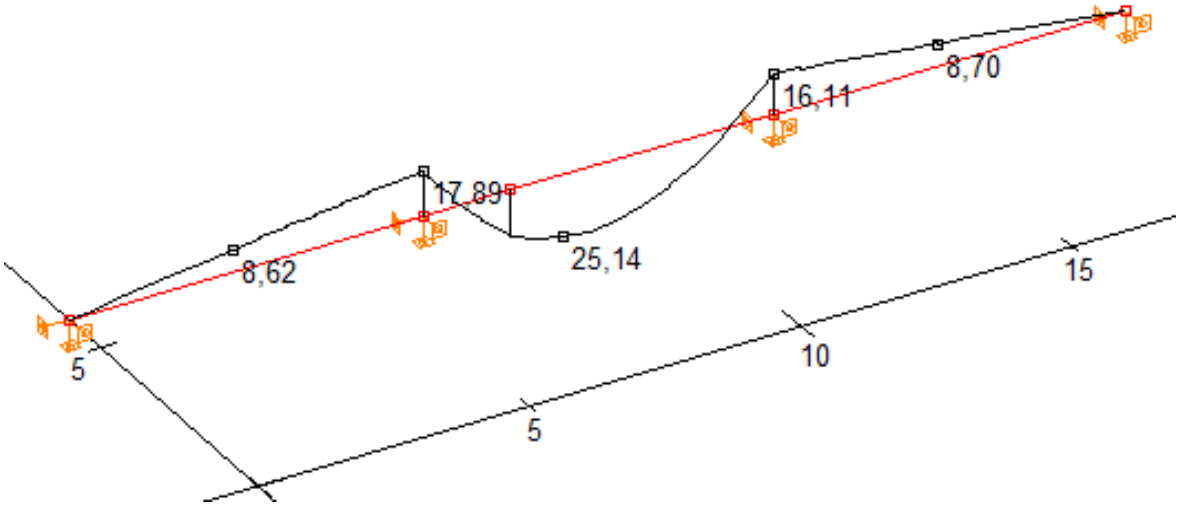


Slika 7.7. Momenti Mz (kNm)

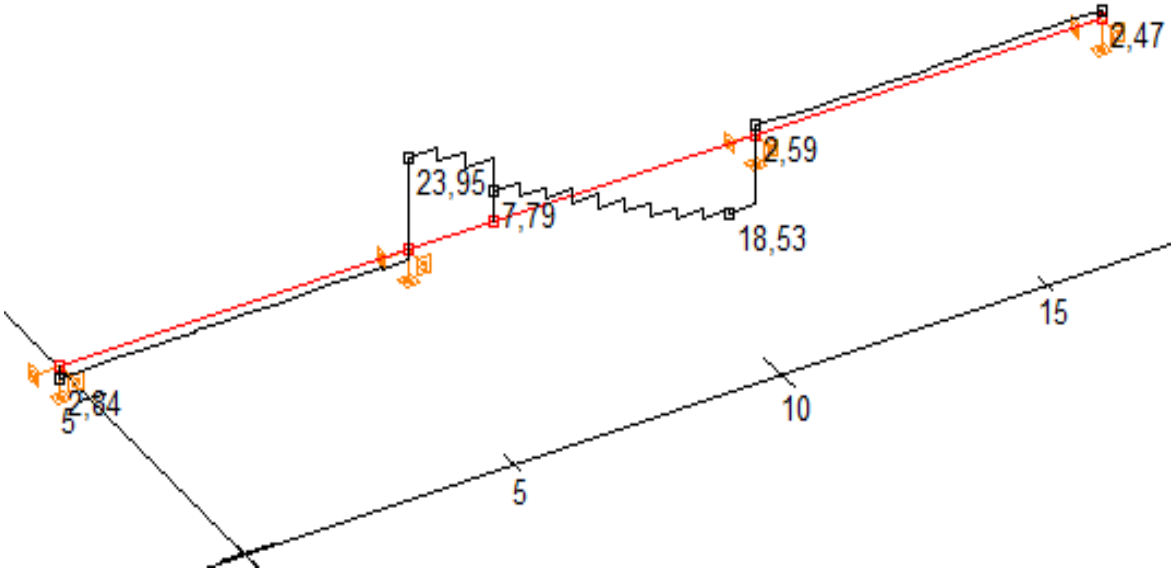


Slika 7.8. Poprečne sile Vy (kN)

7.1.5. Uporabno opterećenje shema 6 (max sile na ležaju)



Slika 7.9. Momenti Mz (kNm)



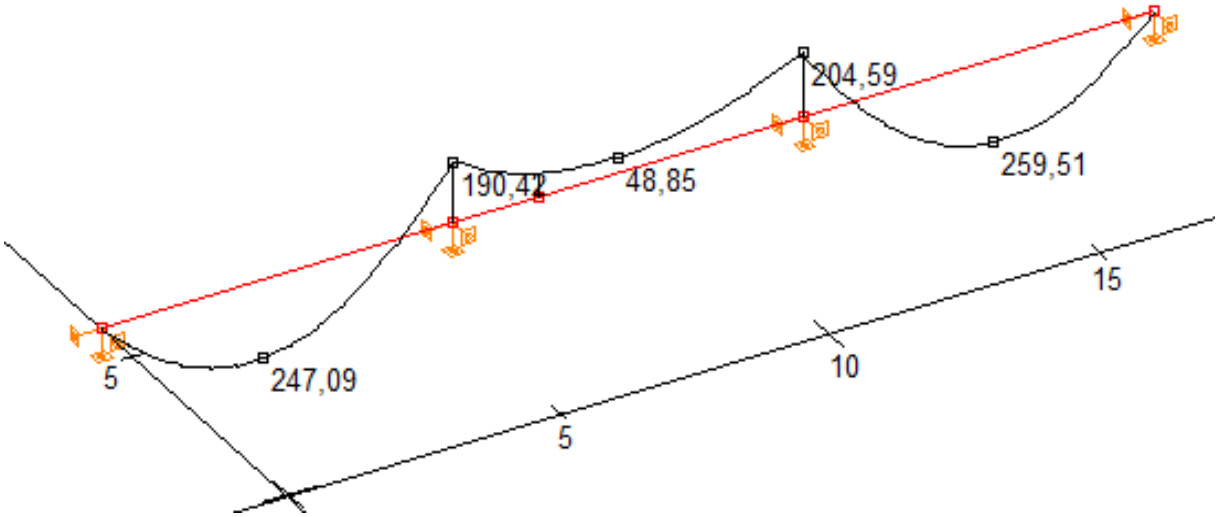
Slika 7.10. Poprečne sile Vy (kN)

7.1.6. GSN za kranja polja

Mjerodavna kombinacija za proračun GSN: $M_{ed}=1,35*(M_g+M_{\Delta g})+1,5*M_q$

Momenti:

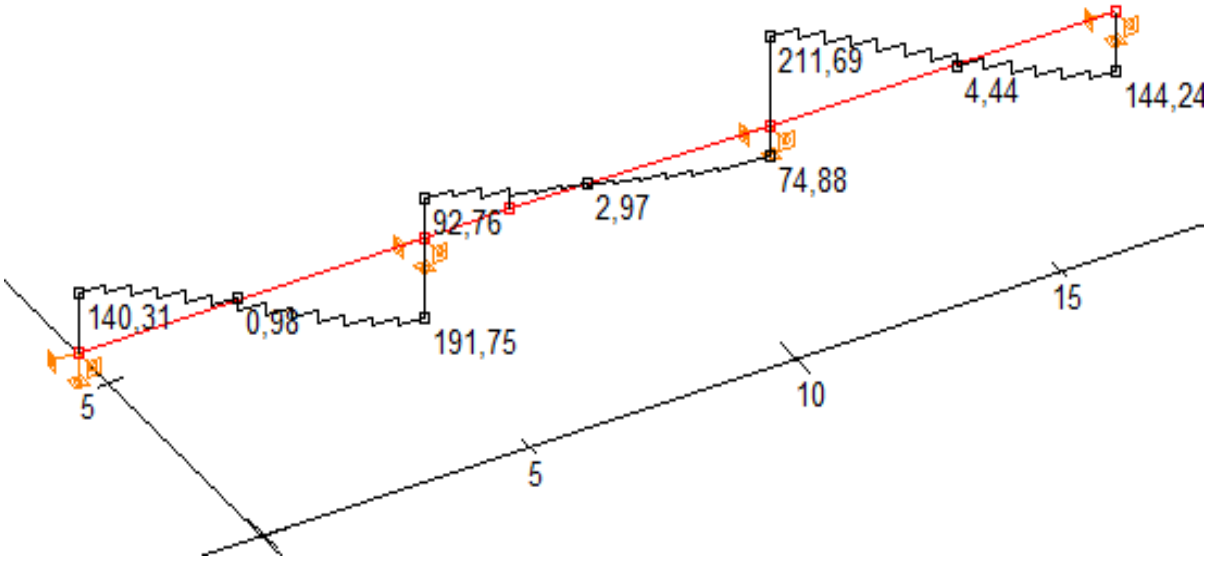
$$M_{Ed,krajnje\ polje} = 259{,}51\,kNm$$



Slika 7.11. Momenti Mz (kNm)

Poprečne sile:

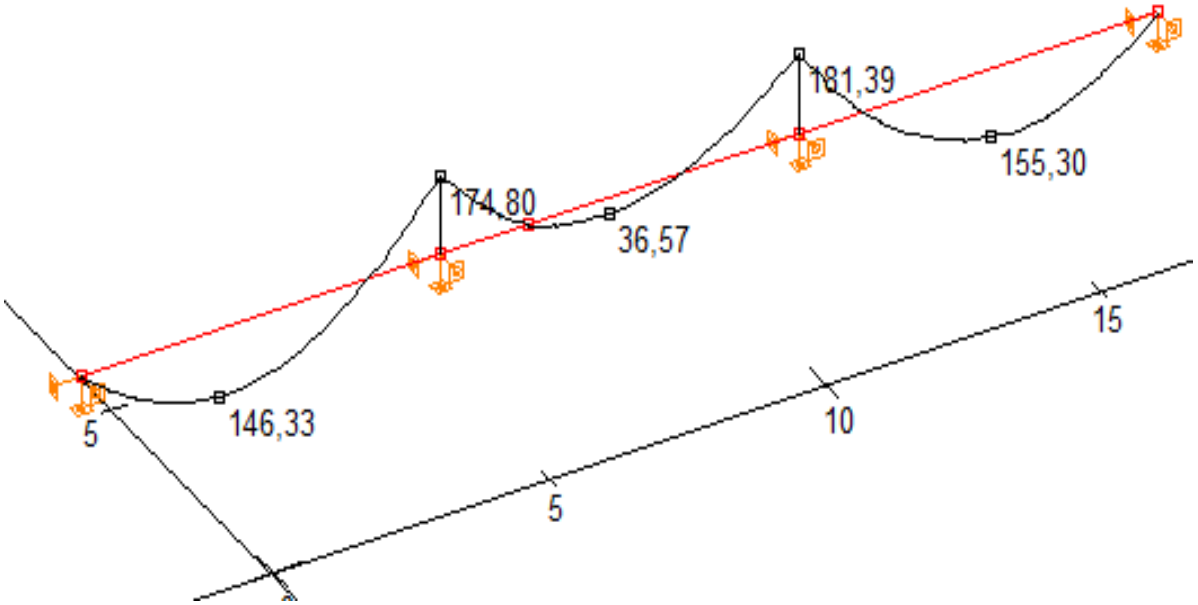
$$V_{Ed,ležaj0} = 144{,}24\,kN$$



Slika 7.12. Poprečne sile Vy (kN)

7.1.7. GSN za srednje polje

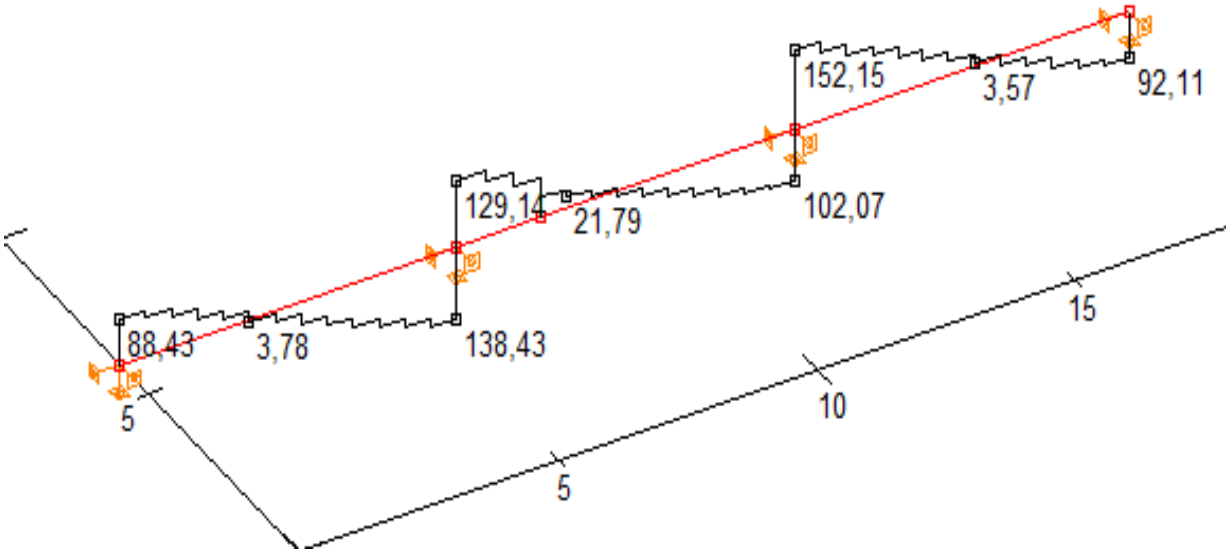
$M_{Ed,srednja\ polje} = 36{,}57\ kNm$



Slika 7.13. Momenti Mz (kNm)

Poprečne sile:

$V_{Ed,ležaj1} = 152{,}15 kN$

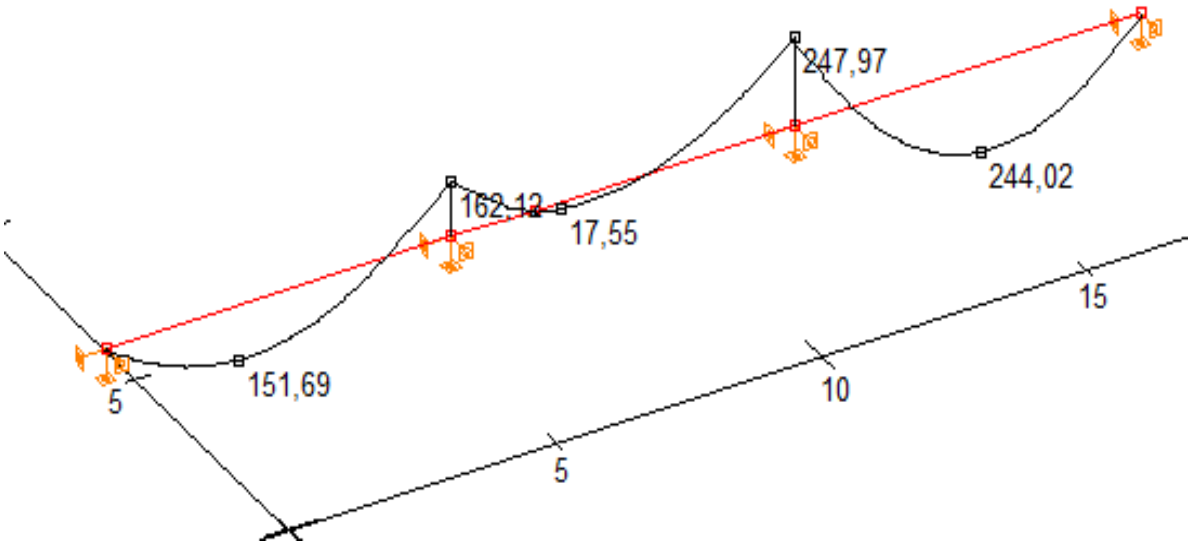


Slika 7.14. Poprečne sile Vy (kN)

7.1.8. GSN za ležaj

Momenti:

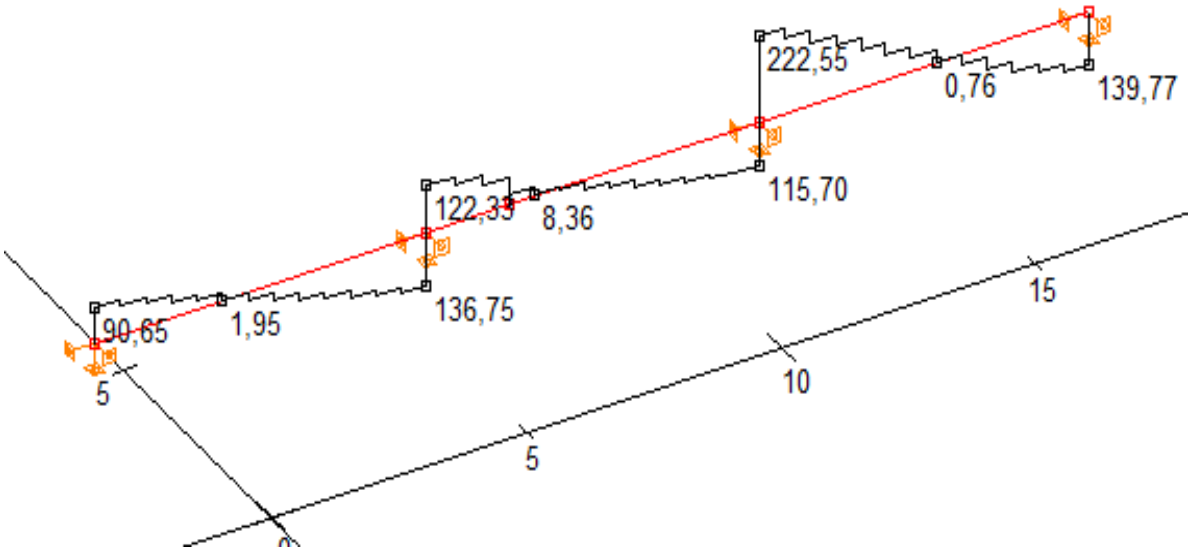
$$M_{Ed,ležaj} = -247,97\ kNm$$



Slika 7.15. Momenti Mz (kNm)

Poprečne sile:

$$V_{Ed,ležaj1} = 222,55kN$$



Slika 7.16. Poprečne sile Vy (kN)

7.2. **DIMENZIONIRANJE GREDE NA MOMENT SAVIJANJA**

BETON:C 30/37;

$f_{ck} = 30{,}0$ MPa =30 N/mm^2 ; γ_c =1.5

$f_{cd} = f_{ck}/\gamma_c = 30{,}0/1{,}5 = 20{,}0$ MPa = 20,0 N/mm^2 =2,0 kN/cm^2

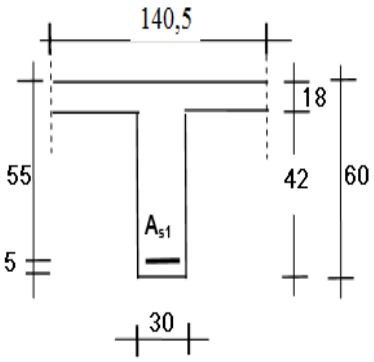
ARMATURA:B 450 BC;

$f_{yk} = 450{,}0$ MPa = 450 N/mm^2 ; γ_s=1,15

$f_{yd} = f_{yk}/\gamma_s = 450{,}0/1{,}15 = 393{,}1$MPa =391,3N/mm^2=39,13 kN/cm^2

<u>Krajnje polje:</u>

Utjecajna širina: $b_{eff} = b_0 + \frac{l_0}{5} \Rightarrow b_{eff} = 30 + \frac{0.85 \cdot 650}{5} = 140{,}5\,cm$



$M_{Ed} = 259{,}51\,kNm$

$\mu_{sd} = \frac{M_{Ed}}{b_{eff} \cdot d^2 \cdot f_{cd}} = \frac{25951}{140{,}5 \cdot 55^2 \cdot 2.0} = 0.031$

Očitano:

$\varepsilon_{s1} = 10.0\,‰ \quad \varepsilon_{c2} = 1{,}0\,‰ \quad \xi = 0.091 \quad \zeta = 0.968$

$x = \xi \cdot d = 0.091 \cdot 55 = 5{,}01\,cm < h_{pl} = 18\,cm$

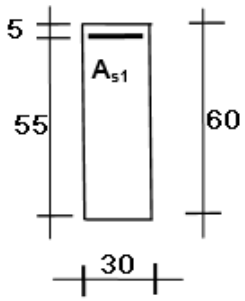
$A_{s1} = \frac{M_{Ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{25951}{0.968 \cdot 55 \cdot 39{,}13} = 12.46\,cm^2$

$d_1 = 5cm$

$d = h - d_1 = 60 - 5 = 55cm$

Odabrano 7Ø16 (As=14,07 cm^2)

<u>Ležaj 1:</u>



$M_{Ed} = -247{,}97\,kNm$

$\mu_{sd} = \frac{M_{Ed}}{b_w \cdot d^2 \cdot f_{cd}} = \frac{24797}{30 \cdot 55^2 \cdot 2.0} = 0.136$

Očitano:

$\varepsilon_{s1} = 10.0\,‰ \quad \varepsilon_{c2} = 3{,}0\,‰ \quad \xi = 0.225 \quad \zeta = 0.907$

$x = \xi \cdot d = 0.225 \cdot 55 = 12{,}38\,cm$

$A_{s1} = \frac{M_{Ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{24797}{0.907 \cdot 55 \cdot 39{,}13} = 12.70\,cm^2$

$d_1 = 5cm$

$d = h - d_1 = 60 - 5 = 55cm$

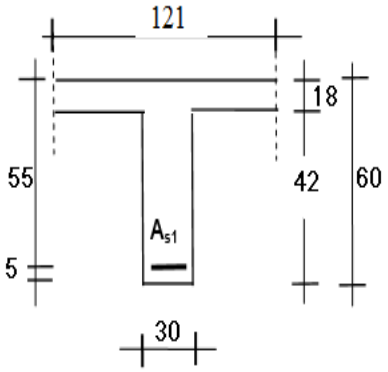
Odabrano 7Ø16 (As=14,07 cm^2)

Srednje polje – pozitivni moment:

Utjecajna širina: $b_{eff} = b_0 + \frac{l_0}{5} \quad \Rightarrow \quad b_{eff} = 30 + \frac{0.70 \cdot 650}{5} = 121 cm$

$d_1 = 5cm$

$d = h - d_1 = 60 - 5 = 55cm$



$M_{Ed} = 36{,}57\ kNm$

$\mu_{sd} = \frac{M_{Ed}}{b_{eff} \cdot d^2 \cdot f_{cd}} = \frac{3657}{121 \cdot 55^2 \cdot 2.0} = 0.0049$

Očitano:

$\varepsilon_{s1} = 10.0\ ‰ \quad \varepsilon_{c2} = 0.4‰ \quad \xi = 0.038 \quad \zeta = 0.987$

$x = \xi \cdot d = 0.038 \cdot 55 = 2.09\ cm < h_{pl} = 18\ \text{cm}$

$A_{s1} = \frac{M_{Ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{3657}{0.987 \cdot 55 \cdot 39{,}13} = 1.72 cm^2$

Odabrano 2Ø16 (As=4,02 cm^2)

Minimalna armatura:

As1,min ≥ 0,26 · [fct,m / fyk]· bt · d ≥ 0,0011 ·bt · d

b t – širina vlačne zone

d – statička visina presjeka

fyk – karakt. granica popuštanja čelika u N/mm2

[fyk = 450 N/mm2 za čelik B 450BC]

fct,m - srednja vlačna čvrstoća betona (iz tablice)

[fctm = 2,9 N/mm2 za C 30/37]

As1,min ≥ 0,26 ·2,9/ 450 ·30 ·55 = 2,76 cm2

As1,min ≥ 0,0011 ·bt · d = 0,0011 ·30 ·55 = 1,815 cm2

Maksimalna armatura:

As1,max=0.04·Ac=0.04·30·60=72 cm2

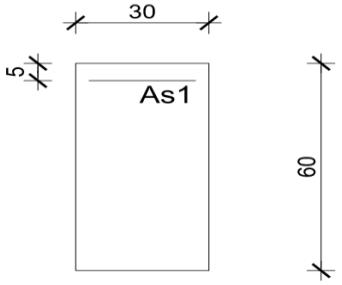
7.3. **DIMENZIONIRANJE GREDE NA POPREČNU SILU**

Ležaj 1

C 30/37

V_{Ed} =222,55 kN

N_{Ed}=0.0 kN



As1= 7Ø16 =14,07 cm²

$$V_{Rdc} = \left[C_{Rdc} \cdot k \cdot (100 \cdot \rho_l \cdot fck)^{\frac{1}{3}} + k_1 \cdot \sigma_{cp} \right] \cdot b_w \cdot d$$

$$b_w = 30\,cm \quad ; \quad d = 55\,cm$$

$$k = 1 + \sqrt{\frac{200}{d}} = 1 + \sqrt{\frac{200}{550}} = 1.60 \le 2$$

$$k_1 = 0.15$$

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

$$\Sigma A_s = 7\phi 16 = 14{,}07\,\text{cm}^2$$

$$\rho_l = \frac{\Sigma A_s}{A_c} = \frac{7\phi 16}{30 \cdot 55} = \frac{14{,}07}{1650} = 0.0085$$

$$C_{Rdc} = \frac{0.18}{\gamma_c} = \frac{0.18}{1.5} = 0.12$$

$$V_{Rdc} = \left[0.12 \cdot 1.60 \cdot (100 \cdot 0.0085 \cdot 30)^{\frac{1}{3}} \right] \cdot 300 \cdot 550 = 93{,}25kN$$

$$V_{Rdc} \ge \left[\nu_{\min} + k_1 \cdot \sigma_{cp} \right] \cdot b_w \cdot d$$

$$\nu_{\min} = 0.035 \cdot k^{\frac{3}{2}} \cdot f_{ck}{}^{\frac{1}{2}} = 0.035 \cdot 1.60^{\frac{3}{2}} \cdot 30^{\frac{1}{2}} = 0.388$$

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

$$V_{Rdc} \ge \nu_{\min} \cdot b_w \cdot d = 0.388 \cdot 300 \cdot 550 = 64{,}02kN \le V_{Ed}$$

$$V_{Ed,\max} = V_{Ed} = 222{,}55kN$$

$$V_{Rd,\max} = 0.5 \cdot \nu \cdot b_w \cdot d \cdot f_{cd}$$

$$\nu = 0.6 \cdot \left[1 - \frac{f_{ck}}{250} \right] = 0.6 \cdot \left[1 - \frac{30}{250} \right] = 0.528$$

$$V_{Rd,\max} = 0.5 \cdot 0.528 \cdot 300 \cdot 550 \cdot 20{,}0 = 871{,}2kN > V_{Ed,\max} = V_{Ed}$$

$$V_{Ed,\max} / V_{Rd,\max} = 222{,}55 / 871{,}2 = 0.255 \approx 0.22 \Rightarrow V_{Ed} = 0.22 V_{Rd,\max}$$

$$s_{\max} = \min\{0.75 \cdot d; 30\} = \min\{41{,}25; 30\} \Rightarrow s_{\max} = 30.0\,cm$$

$$\rho_{\min} = 0{,}0011$$

Površina minimalne armature:

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

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

$$f_{yw,d} = \frac{f_{yk}}{\gamma_s}; B450BC \Rightarrow f_{ywd} = \frac{450}{1.15} = 391{,}3MPa = 39{,}13kN/cm^2$$

$$V_{Rd} = V_{Rd,s} = \frac{A_{sw}}{s} \cdot z \cdot f_{ywd} \cdot m \cdot ctg\theta = \frac{0.79}{30} \cdot 0.9 \cdot 55 \cdot 39{,}13 \cdot 2 \cdot 1$$

$$V_{Rd} = 102{,}01kN$$

$$V_{Ed} > V_{Rd}$$

Na mjestu maksimalne poprečne sile:

$$s_w \le \frac{m \cdot A_{sw} \cdot f_{yw,d} \cdot z}{V_{Ed}} = \frac{2 \cdot 0.79 \cdot 39{,}13 \cdot 0.9 \cdot 55}{222{,}55} = 15{,}28\,cm$$

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

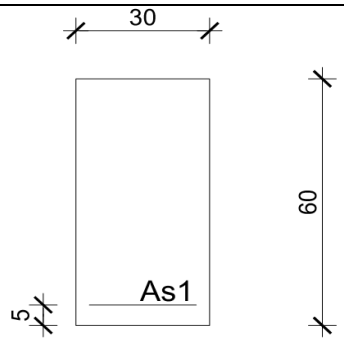
Ležaj 0

C 30/37

V_{Ed} =152,15kN

N_{Ed}=0.0 kN

B



As1= 7Ø16 =14,07 cm²

$$V_{Rdc} = \left[C_{Rdc} \cdot k \cdot (100 \cdot \rho_l \cdot fck)^{\frac{1}{3}} + k_1 \cdot \sigma_{cp} \right] \cdot b_w \cdot d$$

$$b_w = 30\,cm \quad ; \quad d = 55\,cm$$

$$k = 1 + \sqrt{\frac{200}{d}} = 1 + \sqrt{\frac{200}{550}} = 1.60 \le 2$$

$$k_1 = 0.15$$

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

$$\Sigma A_s = 7\phi 16 = 14{,}07 \text{cm}^2$$

$$\rho_l = \frac{\Sigma A_s}{A_c} = \frac{7\phi 16}{30 \cdot 55} = \frac{14{,}07}{1650} = 0.0085$$

$$C_{Rdc} = \frac{0.18}{\gamma_c} = \frac{0.18}{1.5} = 0.12$$

$$V_{Rdc} = \left[0.12 \cdot 1.60 \cdot (100 \cdot 0.0085 \cdot 0)^{\frac{1}{3}} \right] \cdot 300 \cdot 550 = 93{,}25kN$$

$$V_{Rdc} \ge \left[\nu_{\min} + k_1 \cdot \sigma_{cp} \right] \cdot b_w \cdot d$$

$$\nu_{\min} = 0.035 \cdot k^{\frac{3}{2}} \cdot f_{ck}{}^{\frac{1}{2}} = 0.035 \cdot 1.60^{\frac{3}{2}} \cdot 30^{\frac{1}{2}} = 0.388$$

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

$$V_{Rdc} \ge \nu_{\min} \cdot b_w \cdot d = 0.388 \cdot 300 \cdot 550 = 64{,}02kN \le V_{Ed}$$

$$V_{Ed,\max} = V_{Ed} = 152{,}15kN$$

$$V_{Rd,\max} = 0.5 \cdot \nu \cdot b_w \cdot d \cdot f_{cd}$$

$$\nu = 0.6 \cdot \left[1 - \frac{f_{ck}}{250} \right] = 0.6 \cdot \left[1 - \frac{30}{250} \right] = 0.528$$

$$V_{Rd,\max} = 0.5 \cdot 0.528 \cdot 300 \cdot 550 \cdot 20{,}0 = 871{,}2kN > V_{Ed,\max} = V_{Ed}$$

$$V_{Ed,\max} / V_{Rd,\max} = 152{,}15 / 871{,}2 = 0.16 \approx 0.14 \Rightarrow V_{Ed} = 0.14 V_{Rd,\max}$$

$$s_{\max} = \min\{0.75 \cdot d; 30\} = \min\{41.25; 30\} \Rightarrow s_{\max} = 30.0cm$$

$$\rho_{\min} = 0{,}0011$$

Površina minimalne armature:

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

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

$$f_{yw,d} = \frac{f_{yk}}{\gamma_s}; B450BC \Rightarrow f_{ywd} = \frac{450}{1.15} = 391{,}3MPa = 39{,}13kN/cm^2$$

$$V_{Rd} = V_{Rd,s} = \frac{A_{sw}}{s} \cdot z \cdot f_{ywd} \cdot m \cdot ctg\theta = \frac{0.79}{30} \cdot 0.9 \cdot 55 \cdot 39{,}13 \cdot 2 \cdot 1$$

$$V_{Rd} = 102{,}01kN$$

$$V_{Ed} > V_{Rd}$$

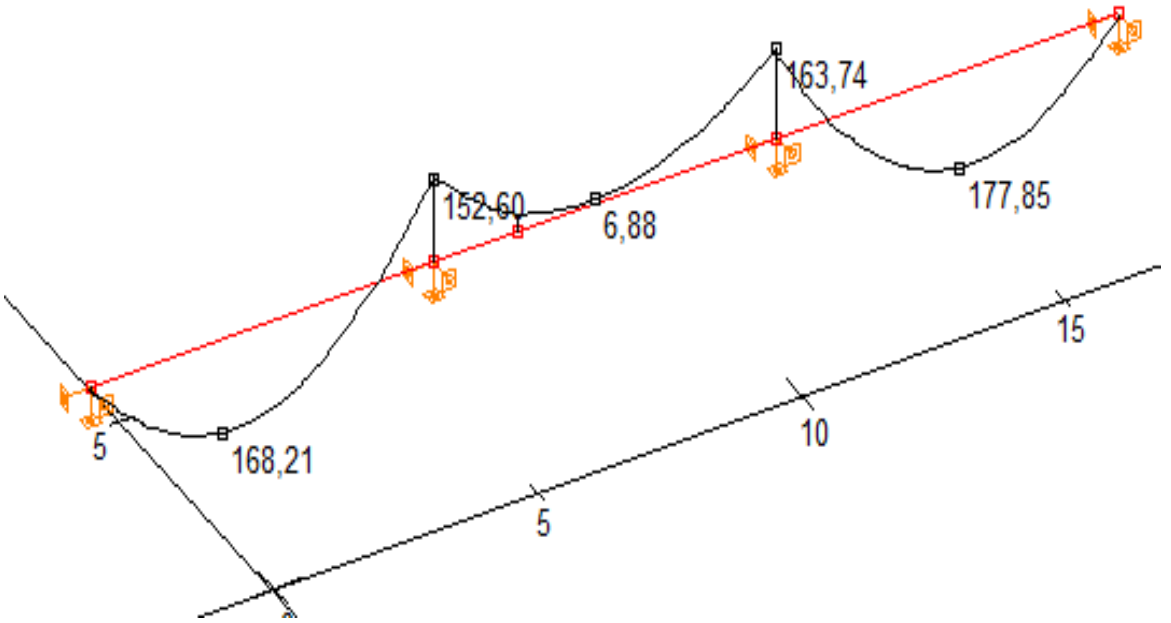
Na mjestu maksimalne poprečne sile:

$$s_w \le \frac{m \cdot A_{sw} \cdot f_{yw,d} \cdot z}{V_{Ed}} = \frac{2 \cdot 0.79 \cdot 39{,}13 \cdot 0.9 \cdot 55}{152{,}15} = 20{,}12cm$$

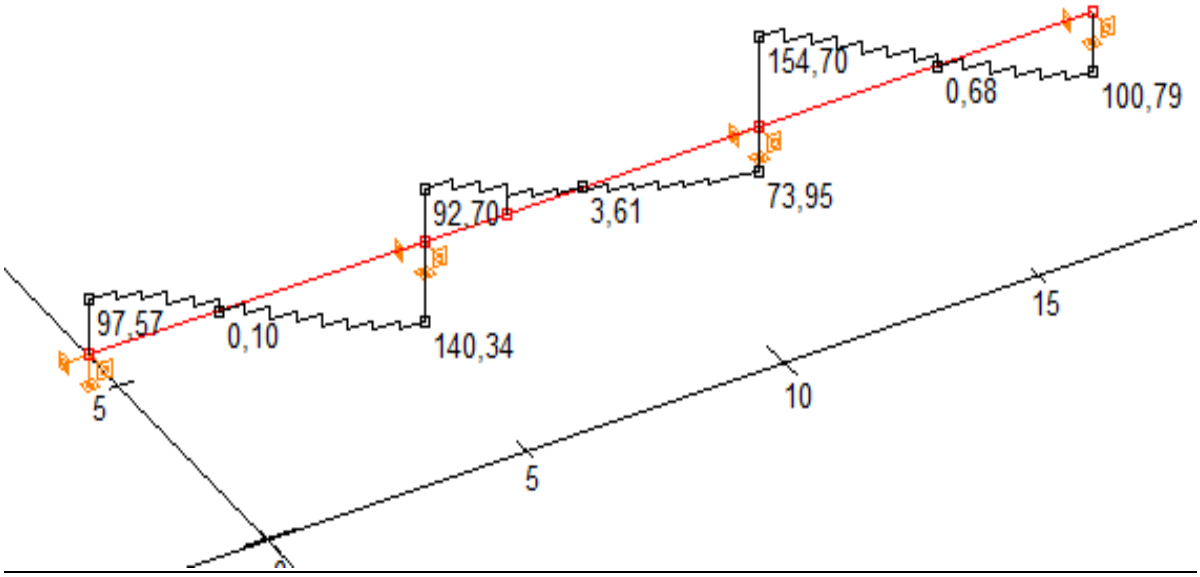
Odabrane spone **Ø10/20cm** (A_{sw}=0.79 cm^2)

7.4. **KONTROLA PUKOTINA GREDE POZICIJE 100**

Granično stanje uporabljivosti: 1.0 vlastita težina "+" 1.0 dodatno stalno "+" 1.0 uporabno



Slika7.17.Moment (kNm)



Slika7.18.Poprečna sila (kN)

Polje :

M_{Ed} =177,85 kNm

Prognoza širine pukotine:

$w_k = S_{r,max} \cdot (\varepsilon_{s,m} - \varepsilon_{c,m})$

Proračun srednje deformacije armature:

$$(\varepsilon_{sm} - \varepsilon_{cm}) = \frac{\sigma_s - k_t \cdot \frac{f_{ct,eff}}{\rho_{p,eff}} \cdot (1 + \alpha_e \cdot \rho_{p,eff})}{E_s} \geq 0.6 \cdot \frac{\sigma_s}{E_s}$$

E_{cm} = 32.00 GPa = 32000 MPa – modul elastičnosti betona

E_s = 200.0 GPa = 200000.0 MPa – modul elastičnosti armature

$f_{ctm} = 2{,}9$ MPa - za betone klase C 30/37

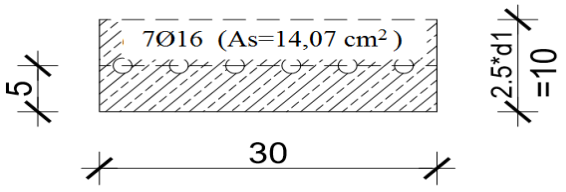
$k_t = 0.4$ - dugotrajno opterećenje

$$\alpha_e = \frac{E_s}{E_{cm}} = \frac{200}{35{,}0} = 5.71$$

$$x = \frac{\alpha_e \cdot A_{s1}}{b} \cdot \left(-1 + \sqrt{\frac{2 \cdot b \cdot d}{\alpha_e \cdot A_{s1}}}\right) = \frac{5.71 \cdot 14{,}07}{30} \cdot \left(-1 + \sqrt{1 + \frac{2 \cdot 30 \cdot 55}{5.71 \cdot 14{,}07}}\right) = 14{,}70 \text{ cm}$$

$$\sigma_s = \frac{M_{Ed}}{z \cdot A_{s1}} \approx \frac{M_{Ed}}{\left(d - \frac{x}{3}\right) \cdot A_{s1}} = \frac{17785}{\left(55 - \frac{14{,}70}{3}\right) \cdot 14{,}07} = 25{,}23 \text{ kN/cm}^2 = 252{,}30 \text{ Mpa}$$

$$\rho_{p,eff} = \frac{A_{s1}}{A_{c,eff}} = \frac{A_{s1}}{b \cdot 2.5 \cdot d_1} = \frac{14{,}07}{30 \cdot 2.5 \cdot 5.0} = 0.0375$$



$$(\varepsilon_{sm} - \varepsilon_{cm}) = \frac{252{,}30 - 0.4 \cdot \frac{2{,}9}{0.0375} \cdot (1 + 5.71 \cdot 0.0375)}{200000} \geq 0.6 \cdot \frac{252{,}30}{200000}$$

$$\frac{214{,}74}{200000} > \frac{151{,}38}{200000}$$

$$(\varepsilon_{sm} - \varepsilon_{cm}) = 0.00107$$

Proračun srednjeg razmaka pukotina:

$$S_{r,max} = k_3 \cdot c + k_1 \cdot k_2 \cdot k_4 \cdot \frac{\phi}{\rho_{p,eff}}$$

φ = 16 mm – promjer najdeblje šipke

k_1 = 0.8 – Rebrasta armatura

k_2 = 0.5 – Savijanje

k_3=3.4

k_4=0.425

$c = d_1 - \frac{\phi}{2} = 50 - \frac{16}{2} = 42$ mm - zaštitni sloj uzdužne armature

$S_{r,max} = 3.4 \cdot 42 + 0.8 \cdot 0.5 \cdot 0.425 \cdot \frac{16}{0.375} = 150{,}05$ mm

$W_k = w_k = S_{r,max} \cdot (\varepsilon_{s,m} - \varepsilon_{c,m}) = 150{,}05 \cdot 0.00107 = 0.161 \text{ mm} < 0.300\ mm$

→ pukotine zadovoljavaju

<u>Ležaj</u>:

M_{Ed} = 163,74 kNm

Prognoza širine pukotine:

$w_k = S_{r,max} \cdot (\varepsilon_{s,m} - \varepsilon_{c,m})$

Proračun srednje deformacije armature:

$$(\varepsilon_{sm} - \varepsilon_{cm}) = \frac{\sigma_s - k_t \cdot \frac{f_{ct,eff}}{\rho_{p,eff}} \cdot (1 + \alpha_e \cdot \rho_{p,eff})}{E_s} \geq 0.6 \cdot \frac{\sigma_s}{E_s}$$

E_{cm} = 32.00 GPa = 32000 MPa – modul elastičnosti betona

E_s = 200.0 GPa = 200000.0 MPa – modul elastičnosti armature

$f_{ctm} = 2{,}9$ MPa - za betone klase C 30/37

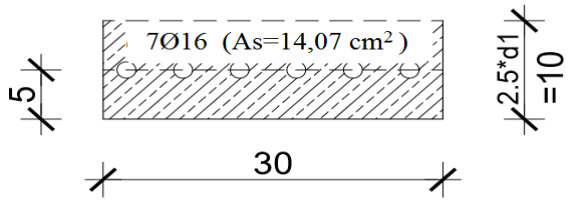
$k_t = 0.4$ - dugotrajno opterećenje

$\alpha_e = \frac{E_s}{E_{cm}} = \frac{200}{35{,}0} = 5.71$

$x = \frac{\alpha_e \cdot A_{s1}}{b} \cdot \left(-1 + \sqrt{\frac{2 \cdot b \cdot d}{\alpha_e \cdot A_{s1}}}\right) = \frac{5.71 \cdot 14{,}07}{30} \cdot \left(-1 + \sqrt{1 + \frac{2 \cdot 30 \cdot 55}{5.71 \cdot 14{,}07}}\right) = 14{,}70$ cm

$\sigma_s = \frac{M_{Ed}}{z \cdot A_{s1}} \approx \frac{M_{Ed}}{\left(d - \frac{x}{3}\right) \cdot A_{s1}} = \frac{16374}{\left(55 - \frac{14{,}70}{3}\right) \cdot 14{,}07} = 23{,}23$ kN /cm^2 = 232,28Mpa

$$\rho_{p,eff} = \frac{A_{s1}}{A_{c,eff}} = \frac{A_{s1}}{b \cdot 2.5 \cdot d_1} = \frac{14,07}{30 \cdot 2.5 \cdot 5.0} = 0.0375$$



$$(\varepsilon_{sm} - \varepsilon_{cm}) = \frac{232,82 - 0.4 \cdot \frac{2,9}{0.0375} \cdot (1 + 5.71 \cdot 0.0375)}{200000} \geq 0.6 \cdot \frac{232,82}{200000}$$

$$\frac{195,26}{200000} > \frac{139,69}{200000}$$

$$(\varepsilon_{sm} - \varepsilon_{cm}) = 0.00098$$

Proračun srednjeg razmaka pukotina:

$$S_{r,max} = k_3 \cdot c + k_1 \cdot k_2 \cdot k_4 \cdot \frac{\phi}{\rho_{p,eff}}$$

φ = 16 mm – promjer najdeblje šipke

k_1 = 0.8 - Rebrasta armatura

k_2 = 0.5 – Savijanje

k_3=3.4

k_4=0.425

$c = d_1 - \frac{\phi}{2} = 50 - \frac{16}{2} = 42$ mm - zaštitni sloj uzdužne armature

$S_{r,max} = 3.4 \cdot 42 + 0.8 \cdot 0.5 \cdot 0.425 \cdot \frac{16}{0.0375}$ =215,33 mm

$W_k = w_k = S_{r,max} \cdot (\varepsilon_{s,m} - \varepsilon_{c,m}) = 215,33 \cdot 0.00098 = 0.211 \text{ mm} \leq 0.300 \text{ mm}$

→ pukotine zadovoljavaju!

7.5. **KONTROLA PROGIBA GREDE POZICIJE 100**

Progib kontroliramo za nefaktorizirano opterećenje i bez utjecaja puzanja.

Kontrola progiba za Polje 1:

Granični progib:

$$\nu_{\lim} = \frac{\mathrm{L}}{250} = \frac{650}{250} = 2.6\,\mathrm{cm}$$

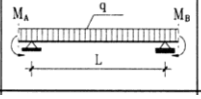
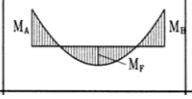
Beton: C 30/37; f_{ck}=30.0 MPa

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

$$f_{ctm} = 0.3 \cdot \left(f_{ck}\right)^{2/3} = 0.3 \cdot \left(30.0\right)^{2/3} = 2{,}9\,MPa$$

Čelik: B450BC ; E_s= 200.0 GPa

$$\alpha_{eI} = \frac{E_s}{E_{cm}} = \frac{200.0}{35} = 5.71$$

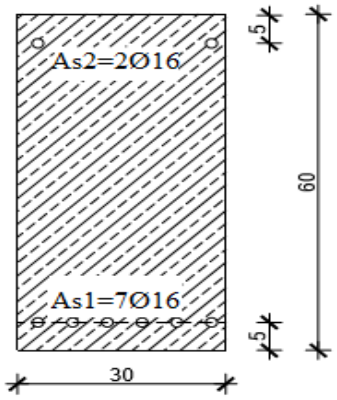
Red	Tip opterećenja	Dijagram momenata savijanja	Koeficijent k iz izraza (5.131)
7			$k = \frac{5}{48}(1-0{,}1\beta)$ $\beta = \lvert M_A + M_B \rvert / \lvert M_F \rvert$

$$\nu_{tot} = \mathrm{k} \cdot \mathrm{L}^2 \cdot \frac{1}{\mathrm{r}_{tot}}$$

$$\beta = \left|M_A + M_B\right| / \left|M_F\right| = \left|0.0 + 163{,}74\right| / \left|177{,}85\right| = 0.921$$

$$k = \frac{5}{48} \cdot \left(1 - 0.1 \cdot \beta\right) = 0.104 \cdot \left(1 - 0.1 \cdot 0.921\right) = 0.0944$$

Presjek u polju:



A_{s1} = 7∅16 = 14,07 cm^2

A_{s2} =2∅16= 4,02 cm^2

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

$$= \frac{30 \cdot 60^3}{12} + 5.71 \cdot \left[14{,}07 \cdot \left(\frac{60}{2} - 5 \right)^2 + 4{,}02 \cdot \left(\frac{60}{2} - 5 \right)^2 \right] =$$

$$= 604558{,}69\, cm^4$$

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

$$\frac{1}{r_I} = \frac{M_{Ed}}{E_{c,eff} \cdot I_I} = \frac{17785}{3200 \cdot 604558{,}69} = 0.0000092 \frac{1}{cm}$$

Progib potpuno raspucanog presjeka:

$$x = 14{,}70\, cm$$

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

$$= \frac{30 \cdot 14{,}70^3}{12} + (30 \cdot 14{,}70) \cdot \left(\frac{14{,}70}{2} \right)^2 + 5.71 \cdot \left[14{,}07 \cdot (55 - 14{,}70)^2 + 4{,}02 \cdot (14{,}70 - 5)^2 \right]$$

$$= 171152{,}45 cm^4$$

$$\frac{1}{r_{II}} = \frac{M_{Ed}}{E_{c,eff} \cdot I_{II}} = \frac{17785}{3200 \cdot 171152{,}45} = 0.0000325 \frac{1}{cm}$$

Ukupni progib:

$\sigma_s = 232{,}28\,MPa$

$$\sigma_{sr} = \frac{M_{cr}}{(d - \frac{x}{3}) \cdot A_{s1}}$$

$$M_{cr} = f_{ctm} \cdot W = f_{ctm} \cdot \frac{b \cdot h^2}{6} = 2{,}9 \cdot \frac{30 \cdot 60^2}{6} = 52200$$

$$\sigma_{sr} = \frac{52200}{(55 - \frac{14{,}70}{3}) \cdot 14{,}07} = 74{,}05 MPa$$

$\beta_1 = 1.0$ - Rebrasta armatura

$\beta_2 = 0.5$ - Dugotrajno opterećenje

$$\zeta = 1 - \beta_1 \cdot \beta_2 \cdot \left(\frac{\sigma_{sr}}{\sigma_s} \right)^2 = 1 - 1.0 \cdot 0.5 \cdot \left(\frac{74{,}05}{232{,}28} \right)^2 = 0.949$$

$$\frac{1}{r_I} = 0.0000092 \frac{1}{cm}$$

$$\frac{1}{r_{II}} = 0.0000325 \frac{1}{cm}$$

$$\frac{1}{r_m} = (1 - \zeta) \cdot \frac{1}{r_I} + \zeta \cdot \frac{1}{r_{II}} = (1 - 0.949) \cdot 0.0000092 + 0.949 \cdot 0.0000325 = 0.0000313 \frac{1}{cm}$$

$k = 0.0944$

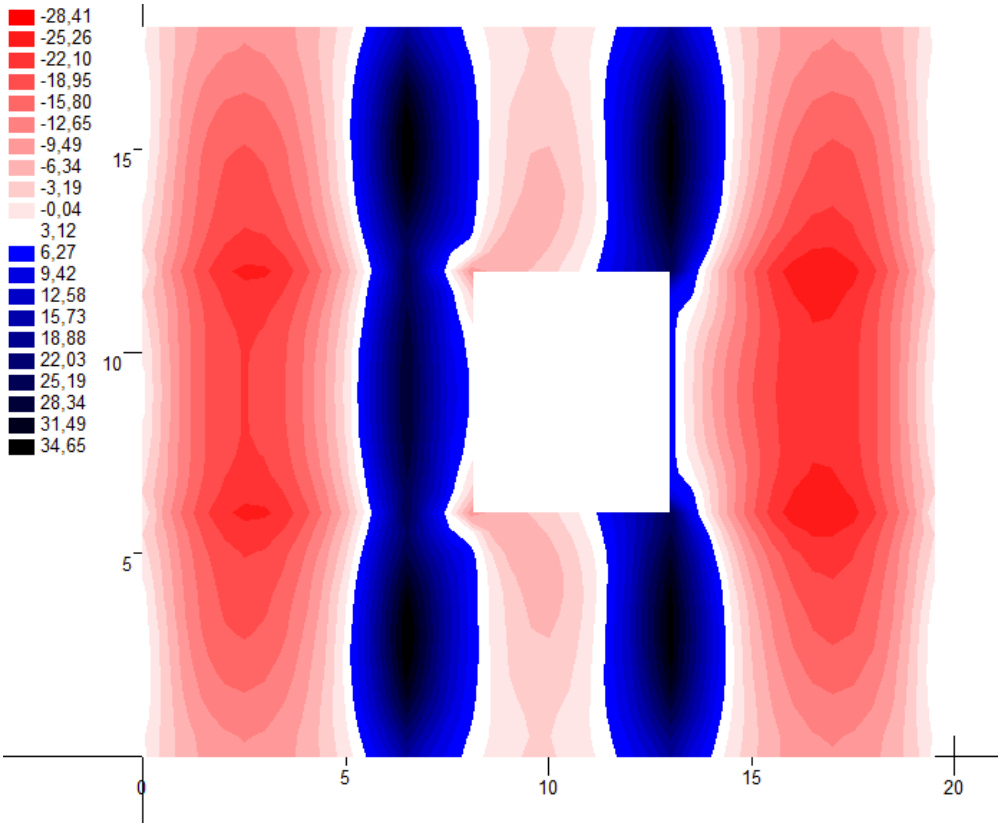
$L = 650.0\,cm$

$$v_{tot,t=0} = k \cdot L^2 \cdot \frac{1}{r_{tot}} = 0.0944 \cdot 650.0^2 \cdot 0.0000313 = 1.25\,cm < v_{\lim} = 2.6 cm$$

8. *PRORAČUN STUBIŠTA*

8.1. **MJERODAVNE REZNE SILE**

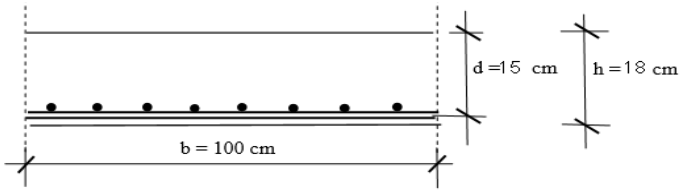
- Moment savijanja mjerodavan za dimenzioniranje stubišta dobiva se iz kombinacije za granično stanje nosivosti na ležajevima pozicije 100.



Slika 8.1. Moment Mx (kNm) za GSN na ležajevima pozicije 100

8.2. **DIMENZIONIRANJE STUBIŠTA**

Polje



$M_{Ed} = 25{,}26\, kNm/m$

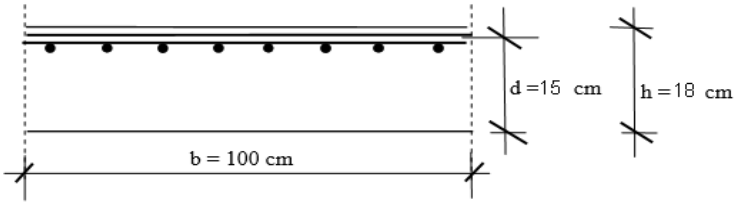
$$\mu_{sd} = \frac{M_{Ed}}{b \cdot d^2 \cdot f_{cd}} = \frac{2526}{100 \cdot 15^2 \cdot 2.0} = 0.056$$

Očitano: $\varepsilon_{s1} = 10.0\,‰ \quad \varepsilon_{c2} = 1.5\,‰ \quad \xi = 0.130 \; \zeta = 0.953$

$$A_{s1} = \frac{M_{Ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{2526}{0.953 \cdot 15 \cdot 39{,}13} = 4{,}51\, cm^2/m$$

Odabrana mreža: **R-503** - As = 5,03 cm^2/m

Ležaj stubište – 105



$M_{Ed} = 31{,}49\, kNm/m$

$$\mu_{sd} = \frac{M_{Ed}}{b \cdot d^2 \cdot f_{cd}} = \frac{3149}{100 \cdot 15^2 \cdot 2.0} = 0.069$$

Očitano: $\varepsilon_{s1} = 10.0\,‰ \quad \varepsilon_{c2} = 1.7\,‰ \quad \xi = 0.145 \quad \zeta = 0.947$

$$A_{s1} = \frac{M_{Ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{3149}{0.947 \cdot 15 \cdot 39{,}13} = 5{,}67\, cm^2/m$$

Odabrana armatura:**R-785** - As = 7,85 cm^2/m

9. PRORAČUN STUPOVA

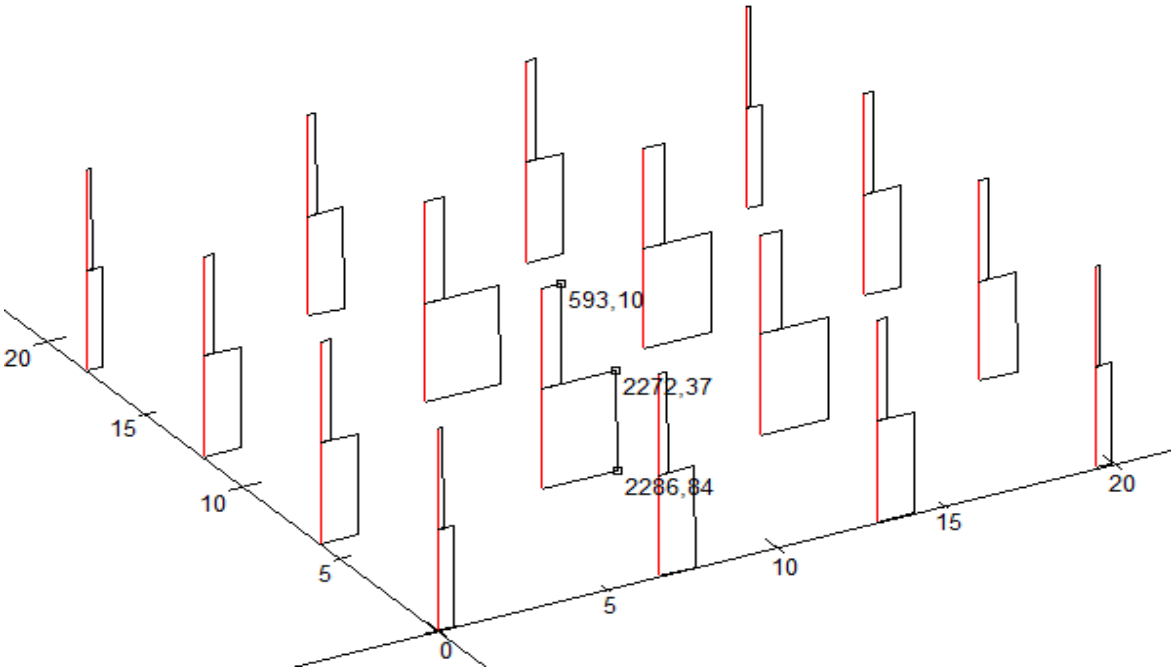
9.1. MOMENTI SAVIJANJA I UZDUŽNE SILE STUPOVA

Kombinacije opterećenja s VJETROM :

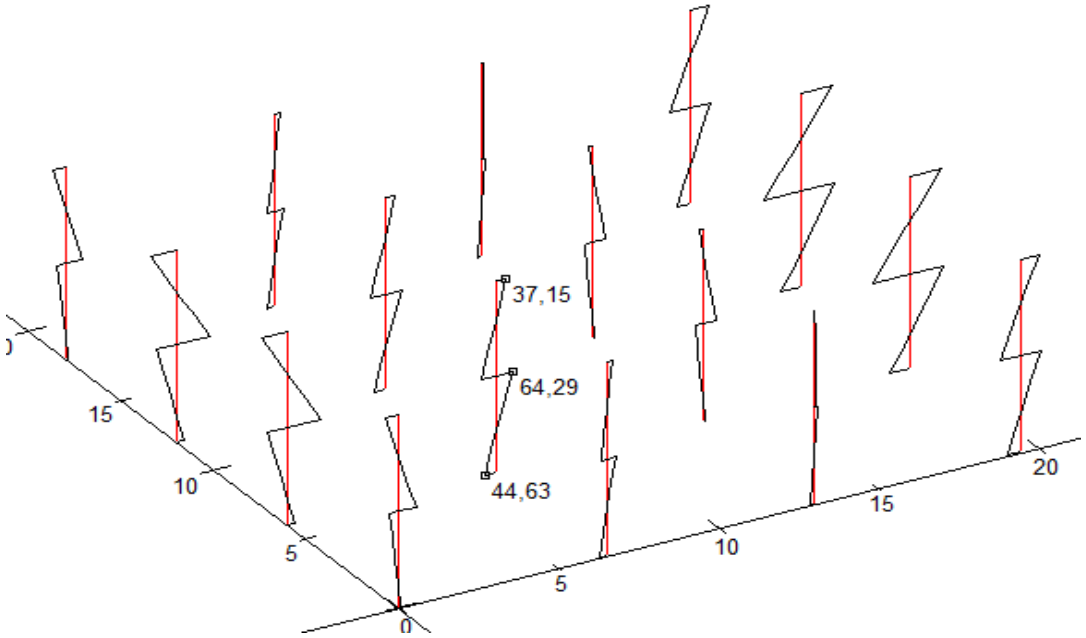
1. kombinacija opterećenja: $1{,}35\cdot(g+\Delta g)+1{,}5\cdot q+1{,}5\cdot W_x$

2. kombinacija opterećenja: $1{,}35\cdot(g+\Delta g)+1{,}5\cdot q+1{,}5\cdot W_y$

9.1.1. Kombinacija 1

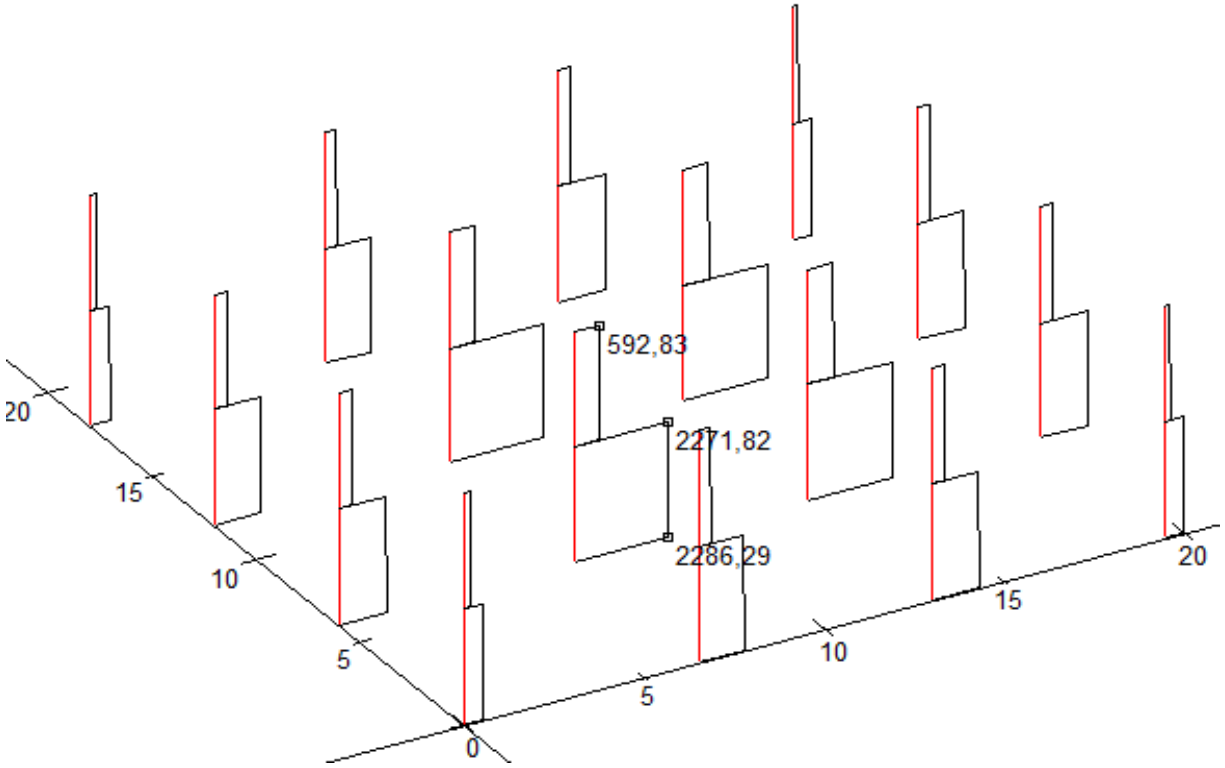


Slika 9.1. Dijagram uzdužnih sila

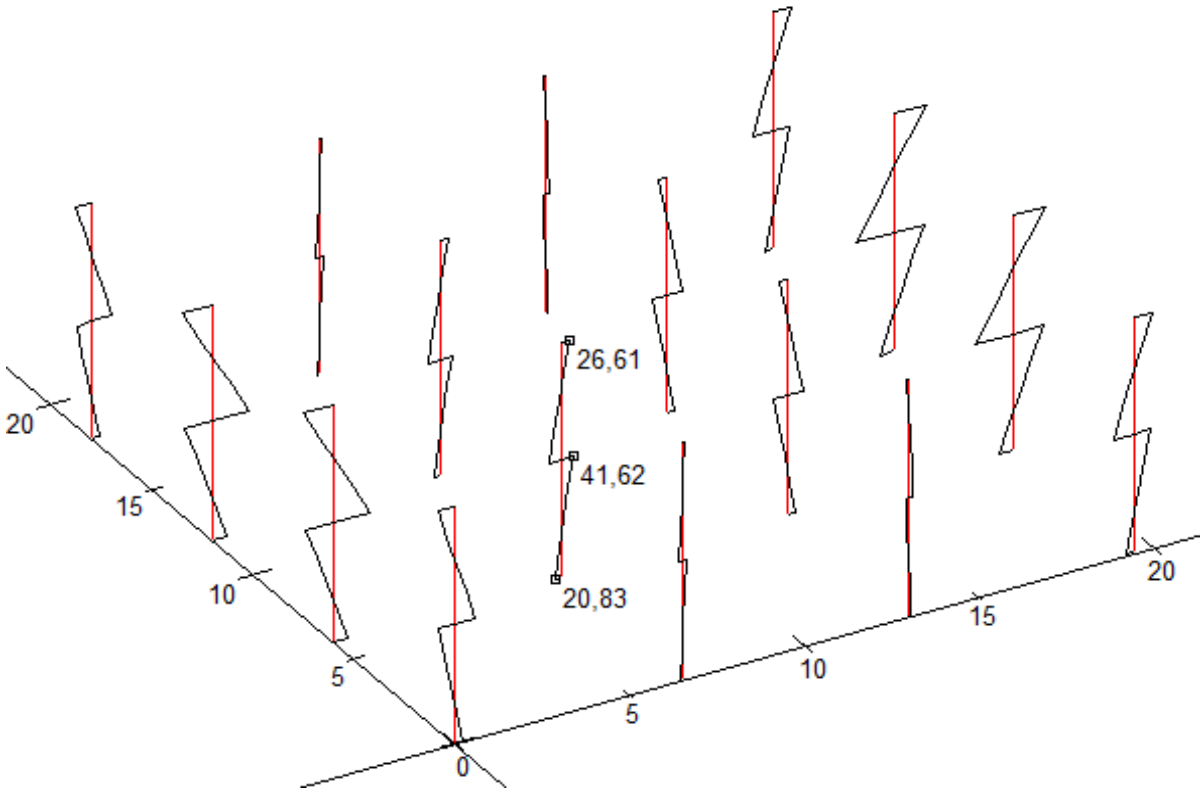


Slika 9.2. Dijagram momenta savijanja

9.1.2. Kombinacija 2



Slika 9.3. Dijagram uzdužnih sila



Slika 9.4. Dijagram momenta savijanja

Tablica 9.1. Rezne sile u stupovima

		M(kNm)	N(kN)
1. Kombinacija	MaxN	64,29	-2286,84
2. Kombinacija	Max N	41,62	-2286,29

9.2. **DIMENZIONIRANJE STUPA**

9.2.1. Određivanje dimenzija stupova

Najnepovoljniji utjecaj je na srednji stup. Vanjske stupove na koje otpada nešto manje vertikalno opterećenje nećemo razmatrati posebno već ćemo sve stupove tretirati kao da su središnji.

$$N_{100} = \left(\gamma_g \cdot (g_{100} + \Delta g_{100}) + \gamma_q \cdot q_{100}\right) \cdot L_1 \cdot L_2$$

$$N_{100} = (1.35 \cdot 7.7 + 1.5 \cdot 3.7) \cdot 6.5 \cdot 6.0$$

$$N_{100} = 621{,}86 \text{ kN}$$

$$N_{200} = \left(\gamma_g \cdot (g_{200} + \Delta g_{200}) + \gamma_q \cdot q_{200}\right) \cdot L_1 \cdot L_2$$

$$N_{200} = (1.35 \cdot 8.30 + 1.5 \cdot 1.0) \cdot 6.5 \cdot 6.0$$

$$N_{200} = 495{,}5 \text{kN}$$

$$N = 1117{,}36 \text{ kN}$$

Klasa betona: C30/37 → $f_{cd} = \frac{30}{1.5} = 20{,}0$ MPa

Radi puzanja naprezanja u betonu ograničavamo na 45% tlačne čvrstoće betona.

Ac,potr= b ·h >(1,35 ·NG+ 1,5 ·NQ) / 0,45 ·fcd= 1117,36 / 0,45 ·2,0 = 1241,5cm2

Zbog simetričnosti konstrukcije, a uzimajući u obzir da je stup centrično opterećen, odabiremo kvadratni presjek stupa.

$a = \sqrt{A} = \sqrt{1241{,}5} = 0.3192\ m = 35{,}23\ cm$

odabrano: $a = 35$ cm

9.2.2. Dimenzioniranje pomoću dijagrama interakcije

Rezne sile dobivene u programu *AspalathosLinear*su po teoriji I. reda.

Tablica 9.2. Rezne sile u stupovima

M(kNm)	N(kN)
64,29	-2286,84
41,62	-2286,29

Pretpostavljamo:

(za α=1,0 –simetrična armatura; β=d1/h = d2/h = 5/45=0,1)

$$v_{sd1} = \frac{N_{Ed1}}{b \cdot h \cdot f_{cd}} = \frac{-2286,84}{35 \cdot 35 \cdot 2.0} = -0,93$$

$$v_{sd2} = \frac{N_{Ed2}}{b \cdot h \cdot f_{cd}} = \frac{-2286,29}{35 \cdot 35 \cdot 2.0} = -0,93$$

$$\mu_{Sd1} = \frac{M_{Ed1}}{b \cdot h^2 \cdot f_{cd}} = \frac{64,29 \cdot 100}{35 \cdot 35^2 \cdot 2.0} = 0,08$$

$$\mu_{Sd2} = \frac{M_{Ed2}}{b \cdot h^2 \cdot f_{cd}} = \frac{41,62 \cdot 100}{35 \cdot 35^2 \cdot 2.0} = 0,05$$

mehanički koeficijent armiranja ω_1= 0,05

ω_2= 0,05

$$A_{S1=}A_{S2=}\omega \cdot \frac{f_{cd}}{f_{yd}} \cdot b \cdot h = 0.05 \cdot \frac{2.0}{39,13} \cdot 35 \cdot 35 = 3.13\ cm^2$$

Ukupna površina armature za simetrično armiranje

As1+ As2 = 3.13·2=6,26 cm2

As,min = 0,1 · NEd / fyd = 0,1 · 2286 / 39,13 = 5,8 cm2

As,min = 0,002 · Ac = 0,002 · 1241,5 = 2.5 cm2

Odabrane šipke: 4Ø16+4Ø16*(*A_s=8,04+8.04=16,08 cm2)

9.2.3. Proračun poprečne armature stupa

Površinu poprečne armature uzima se kao kod greda ϕ10(As= 0.79 cm^2)

Razmak spona:

S= min (b= 45 cm ; 15×ϕ= 15×1.6= 27 cm)

ODABRANO: Spone ϕ10/25cm

U blizini ležaja razmak spona umanjivamo faktorom 0.6 i razmak iznosi 15 cm.

10. PRORAČUN TEMELJA SAMCA ISPOD STUPA

10.1. **DIMENZIONIRANJE TEMELJA**

Temelj je proračunat za granično stanje nosivosti. Za dobivanje mjerodavnih naprezanja na spoju stup – temelj korištene su slijedeće kombinacije opterećenja:

$$1{,}35 \cdot g_{\text{vl.težina}} + 1{,}35 \cdot g_{\text{dodatno stalno}} + 1{,}5 \cdot q + 1{,}5 \cdot w_x$$

$$1{,}35 \cdot g_{\text{vl.težina}} + 1{,}35 \cdot g_{\text{dodatno stalno}} + 1{,}5 \cdot q + 1{,}5 \cdot w_y$$

Iz navedenih kombinacija dobiveni su parovi maksimalnih uzdužnih sila i pripadnih momenata, te maksimalnih momenata i pripadnih uzdužnih sila od kojih odabiremo dva para sila mjerodavna za dimenzioniranje temelja.

Odabrane mjerodavne sile na spoju:

- 1. kombinacija: $N_{max} = 2286{,}64\ \text{kN}$
  $M_{pripadno} = 64{,}29\ \text{kNm}$

- 2. kombinacija: $M_{max} = 41{,}62\ \text{kNm}$
  $N_{pripadno} = 2286{,}29\ \text{kN}$

10.1.1. Preliminarno određivanje dimenzija temelja

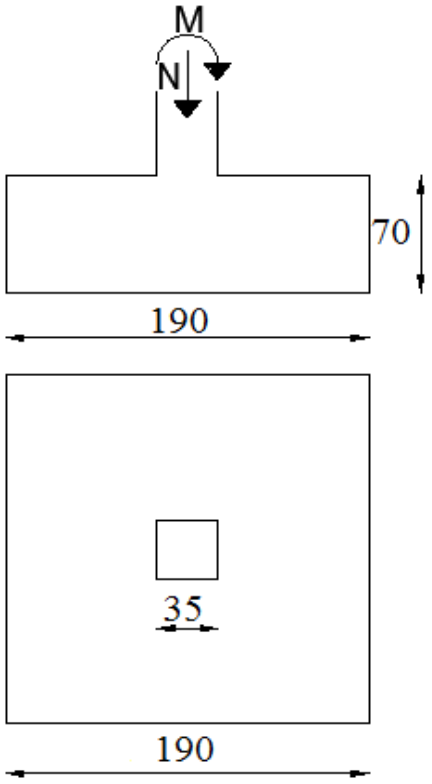
Temelj je centrično opterećen zbog čega odabiremo kvadratni poprečni presjek.

Dopuštena naprezanja u tlu (ovise o vrsti tla): $\sigma_{dop} = 0{,}5\ \mathrm{MN/m^2}$

Širina i duljina temelja: $d = š = b = a_{stup} \cdot \sqrt{\frac{f_{cd}^*}{\sigma_{t,dop}}} = a_{stup} \cdot \sqrt{\frac{0{,}45 f_{ck}}{\sigma_{t,dop}}} = 0{,}35 \cdot \sqrt{\frac{0{,}45 \cdot 30}{0{,}50}} = 1{,}85\ \mathrm{m}$

Visina temelja: $v = 2 \cdot a_{stup} = 2 \cdot 0{,}35 = 0{,}70\ \mathrm{m} = 70\ \mathrm{cm}$

Težina temelja: $N_t = 1{,}9 \cdot 1{,}9 \cdot 0{,}7 \cdot 25 = 63{,}18\,(kN)$



Slika 10.1.Preliminarne dimenzije temelja

10.2. **NAPREZANJA NA DODIRNOJ PLOHI TEMELJ – TLO**

$$\sigma_{1,2} = \frac{N}{A} \pm \frac{M}{W}$$

$$A = 1{,}9 \cdot 1{,}9 = 3{,}61\ m^2$$

$$W = \frac{bh^2}{6} = \frac{1{,}9 \cdot 1{,}9^2}{6} = 1.14\ m^3$$

- **1. kombinacija**

$$N_{max} = 2286{,}64\ kN \qquad \rightarrow N_{Ed} = N_{max} + N_t = 2286{,}64 + 63{,}18 = 2349{,}82\ kN$$

$$M_{pripadno} = 64{,}29\ kNm$$

$$\sigma_{1,2} = \frac{N}{A} \pm \frac{M}{W} = \frac{2349{,}82}{3{,}61} \pm \frac{64{,}29}{1.14} = 650{,}92 \pm 56{,}39$$

$$\sigma_1 = 707{,}31\ kN/m^2$$

$$\sigma_2 = 594{,}53\ kN/m^2$$

- **2. Kombinacija**

$$M_{max} = 41{,}62\ kNm$$

$$N_{pripadno} = 2286{,}29\ kN \qquad \rightarrow N_{Ed} = N_{prip} + N_t = 2286{,}29 + 63{,}18 = 2349{,}47\ kN$$

$$\sigma_{1,2} = \frac{N}{A} \pm \frac{M}{W} = \frac{2349{,}47}{3{,}61} \pm \frac{41{,}62}{1.14} = 650{,}82 \pm 36{,}51$$

$$\sigma_1 = 687{,}32\ \frac{kN}{m^2}$$

$$\sigma_2 = 614{,}21\ kN$$

10.3. **PRORAČUN ARMATURE TEMELJA**

➢ **Momenti u presjeku 1-1**

$$M_{1-1} = \sigma_{1-1} \cdot b_1 \cdot \frac{b_1}{2} + (\sigma_1 - \sigma_{1-1}) \cdot \frac{b_1}{2} \cdot \frac{2}{3} \cdot b_1$$

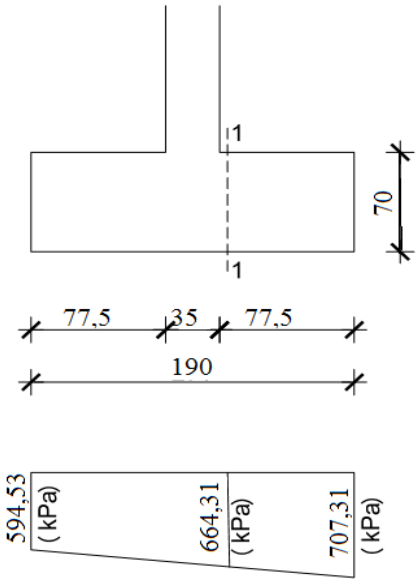
$$\sigma_{1-1} = \sigma_1 - \frac{b_1}{b} \cdot (\sigma_1 - \sigma_2)$$

- **1. kombinacija**

$$\sigma_{1-1} = 707{,}31 - \frac{0.775}{1{,}9} \cdot (707{,}31 - 594{,}53) = 664{,}31 \text{ kPa}$$

$$M_{1-1} = 664{,}31 \cdot 0.775 \cdot \frac{0.775}{2} + (707{,}31 - 664{,}31) \cdot \frac{0.775}{2} \cdot \frac{2}{3} \cdot 0.775$$

$$M_{1-1} = 208{,}1 \text{ kNm}$$



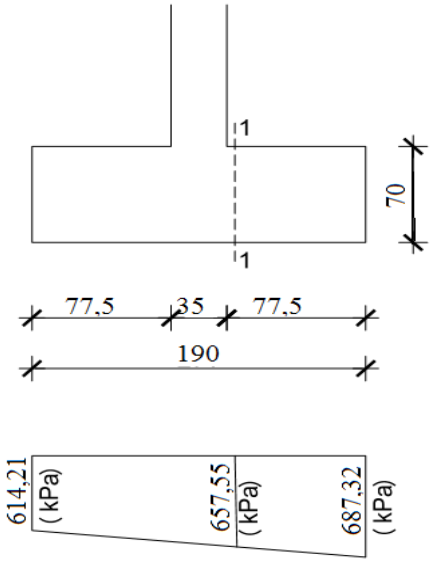
Slika 10.2. Naprezanje ispod temelja za kombinaciju 1

- **2. kombinacija**

$$\sigma_{1-1} = 687{,}32 - \frac{0.775}{1{,}9} \cdot (687{,}32 - 614{,}21) = 657{,}55 \text{ kPa}$$

$$M_{1-1} = 657{,}55 \cdot 0.775 \cdot \frac{0.775}{2} + (687{,}32 - 657{,}55) \cdot \frac{0.775}{2} \cdot \frac{2}{3} \cdot 0.775$$

$$M_{1-1} = 203{,}43 \text{kNm}$$



Slika 10.3. Naprezanje ispod temelja za kombinaciju 2

Mjerodavni moment za proračun armature:

$M_{sd}^{1-1} = 208{,}1\ \text{kNm}$

Klasa betona: C30/37 $\rightarrow f_{ck} = 30\ \text{MPa} \quad \rightarrow f_{cd} = \frac{30}{1{,}5} = 20{,}0\ \text{MPa} = 2{,}0\ \text{kN/cm}^2$

Zadana armatura: B450BC $\rightarrow f_{yk} = 450\ \text{MPa} \ \rightarrow f_{yd} = \frac{450}{1{,}15} = 391{,}3\ \text{MPa} = 39{,}13\ \text{kN/cm}^2$

$$\mu_{sd} = \frac{M_{ed}}{b \cdot d^2 \cdot f_{cd}} = \frac{208{,}1 \cdot 100}{100 \cdot 65^2 \cdot 2{,}0} = 0{,}024$$

Očitano: $\varepsilon_{s1} = 10.0\ ‰, \quad \varepsilon_{c2} = 0{,}8\ ‰, \quad \xi = 0{,}074$, ζ=0,974

$$A_{s1} = \frac{M_{ed,1-1}}{f_{yd} \cdot \zeta \cdot d} = \frac{208{,}1 \cdot 100}{39{,}13 \cdot 0{,}974 \cdot 65} = 8{,}40\ \text{cm}^2/\text{m}'$$

$$A_{s1} = \frac{8{,}40}{1{,}9} = 4{,}4\left(\frac{\text{cm}^2}{\text{m}'}\right)$$

Odabrana armatura:

$$A_{s1,\text{potrebno}} = 4{,}4\left(\frac{\text{cm}^2}{\text{m}}\right)$$

U donju zonu temelja:

Odabrana armatura: mreža Q503 ($A_{s1} = 5{,}03\ \text{cm}^2/\text{m}$)

Konstruktivna armatura u gornjoj zoni: mreža Q226 ($A_{s1} = 2{,}26\ \text{cm}^2/\text{m}$)

11. PRILOZI

11.1. **ARMATURA PLOČE POZICIJA 100- DONJA ZONA**

11.2. **ARMATURA PLOČE POZICIJA 100- GORNJA ZONA**

11.3. **ARMATURA PLOČE POZICIJA 200- DONJA ZONA**

11.4. **ARMATURA PLOČE POZICIJA 200- GORNJA ZONA**

11.5. **ARMATURNI PLAN GREDE POZICIJE 100**

11.6. **ARMATURNI PLAN GREDE POZICIJE 200**

11.7. **ARMATURNI PLAN STUBIŠTA**

11.8. **ARMATURNI PLAN STUPA**

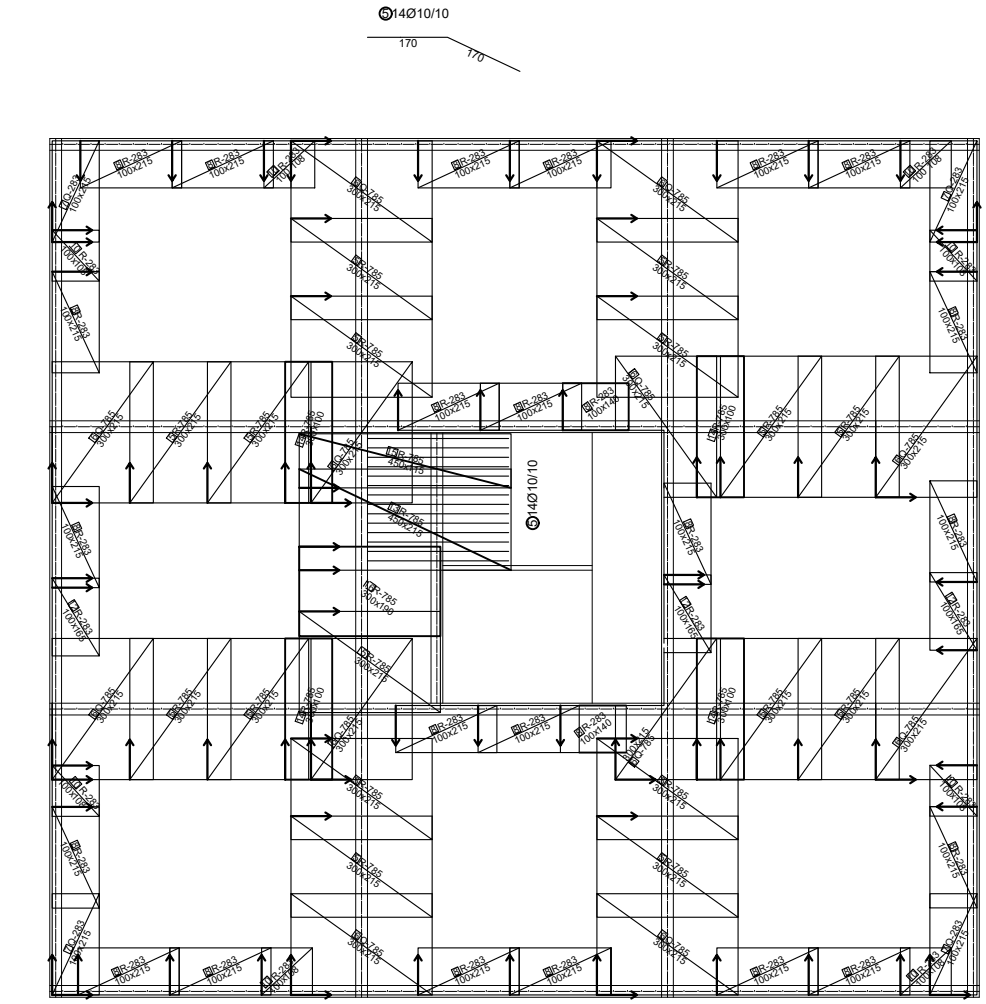
12. LITERATURA

Radnić J.,Harapin A. Osnove betonskih konstrukcija, interna skripta.
Fakultet građevinarstva arhitekture i geodezije Splitu, studeni 2013.

V. Herak Marović: Betonske konstrukcije 2, nastavni tekst (predavanja, vježbe)
http://cigla.gradst.hr/moodle26/course/view.php?id=151

V. Herak Marović: Betonske konstrukcije 1, nastavni tekst (predavanja, vježbe)
http://cigla.gradst.hr/moodle26/course/view.php?id=150

ARMATURA PLOČE POZICIJA 100 GORNJA ZONA
MJ 1:100



KLASA BETONA:
BETON C 30/37
ARMATURA B450BC
PREKLOP MREŽA ≥50 cm
ZAŠTITNI SLOJ C=3 cm

Mreže-specifikacija

Pozicija	Oznka mreže	B [cm]	L [cm]	n	Jedinična težina [kg/m2]	Ukupna težina [kg]
POZICIJE 100 GORNJA ZONA						
5	R-785	215	300	17	7,35	805,93
6	Q-785	215	300	12	12,46	964,40
7	Q-283	215	100	4	4.48	38.53
8	R-283	215	100	22	2.77	131,02
9	R-283	140	100	2	2.77	7,80
10	R-283	108	100	8	2.77	23,93
12	R-283	165	100	3	2.77	13,70
13	R-785	215	450	1	7.35	71.11
14	R-785	100	300	4	7.35	88,20
15	R-785	115	450	1	7.35	38.00
16	R-785	190	300	1	7.35	41,90
Ukupno						2224,5

Šipke specifikacija

ozn.	oblik i dimenzije [cm]	Ø	lg [m]	n [kom.]	lgn [m]	Jedinična-težina [kg/m']	Ukupna težina [kg]
POZICIJE 100 GORNJA ZONA							
5	170 / 170 / 91 / 43	10	3.40	14	47.60	0.79	37.60
						Ukupna težina:	37.60

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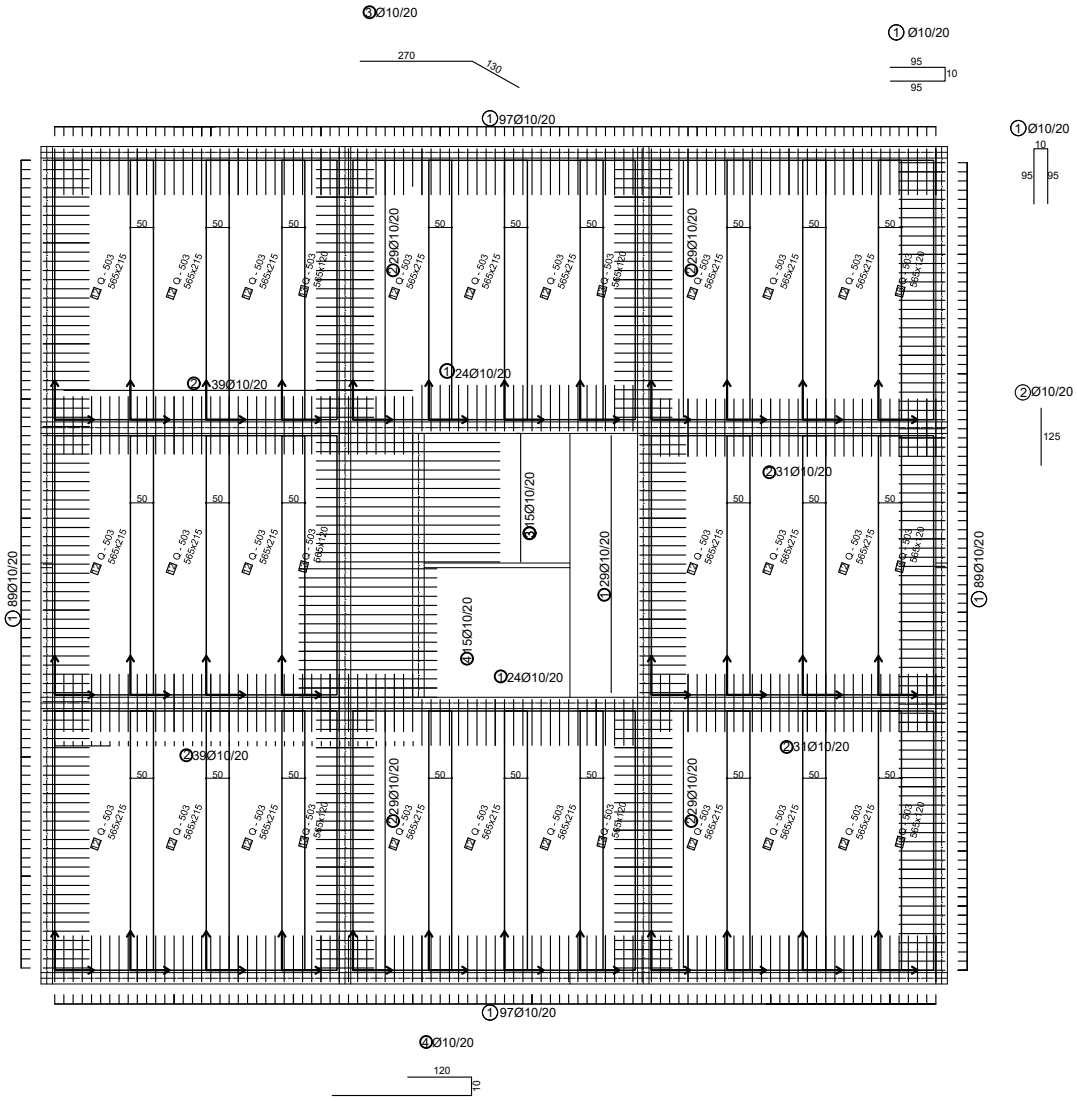
ZAVRŠNI RAD		
IZRADIO	ŠIME DODIG	
AKADEMSKA GODINA 2016/2017		20.7.2017.
ARMATURA POZ.100 GORNJA ZONA		M 1:100

ARMATURA PLOČE POZICIJA 100 DONJA ZONA
MJ 1:100



KLASA BETONA:
BETON C 30/37
ARMATURA B450BC
PREKLOP MREŽA ≥50 cm
ZAŠTITNI SLOJ C=3 cm

Mreže-specifikacija

Pozicija	Oznka mreže	B [cm]	L [cm]	n	Jedinična težina [kg/m2]	Ukupna težina [kg]
POZICIJE 100 DONJA ZONA						
12	Q-503	215	565	24	8.03	2341.00
13	Q-503	120	565	8	8.03	436.55
Ukupno						2777.55

Šipke specifikacija

ozn.	oblik i dimenzije [cm]	Ø	lg [m]	n [kom.]	lgn [m]	Jedinična-težina [kg/m']	Ukupna težina [kg]
POZICIJE 100 DONJA ZONA							
1	95 / 10 / 95	10	2.00	449	898.00	0.79	709.42
2	125	10	1.25	256	320.00	0.79	252.80
3	270 / 118 / 130 / 55	10	4.00	15	60.00	0.79	47.40
4	120 / 10 / 270	10	4.00	15	60.00	0.79	47.40
					Ukupna težina:		1057.02

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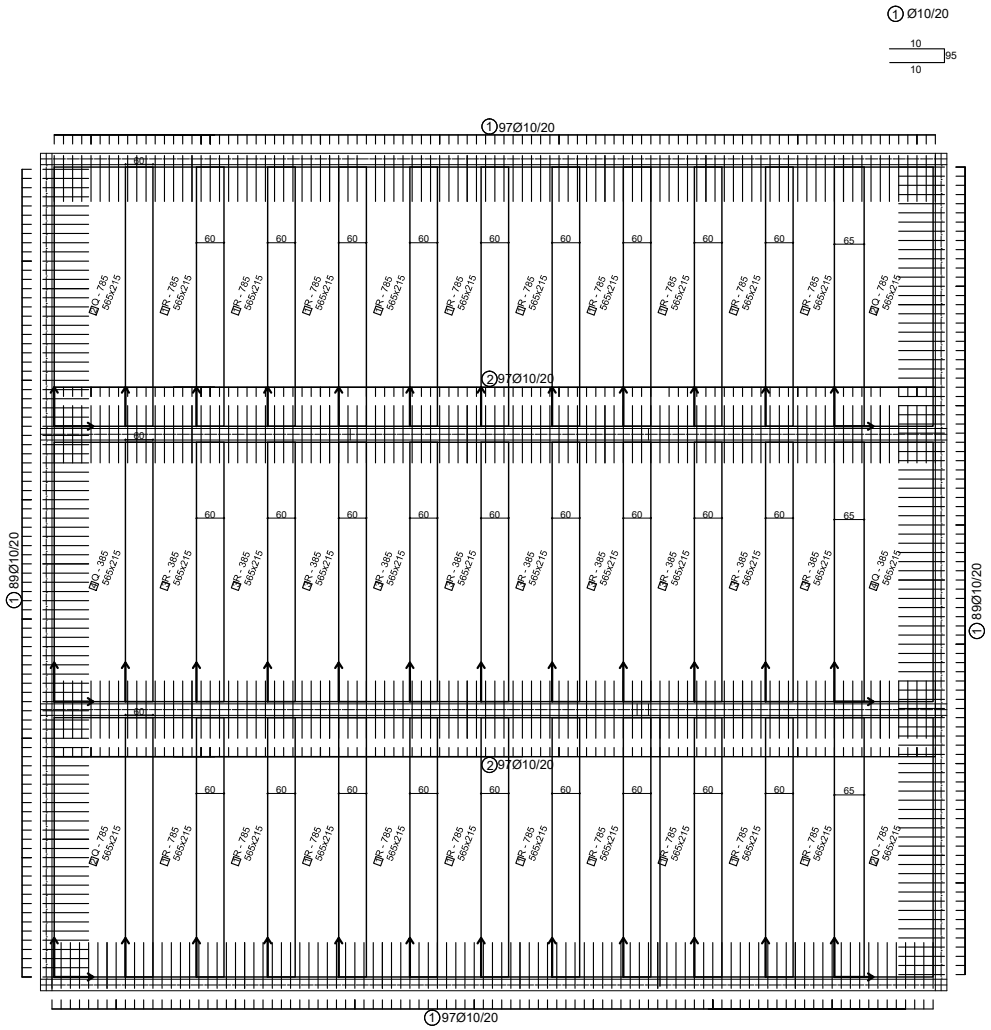
IZRADIO	ŠIME DODIG
AKADEMSKA GODINA 2016/2017	20.7.2017.
ARMATURA POZ.100 DONJA ZONA	M 1:100

ARMATURA PLOČE POZICIJA 200 DONJA ZONA
MJ 1:100



KLASA BETONA:
BETON C 30/37
ARMATURA B450BC
PREKLOP MREŽA ≥60 cm
ZAŠTITNI SLOJ C=3 cm

Mreže-specifikacija						
Pozicija	Oznka mreže	B [cm]	L [cm]	n	Jedinična težina [kg/m2]	Ukupna težina [kg]
POZICIJE 200 DONJA ZONA						
I	R-785	215	565	20	7.35	1760,78
2	Q-785	215	565	4	12.46	605,43
3	R-385	215	565	10	3.68	447,03
4	Q-385	215	565	2	6.10	148,20
Ukupno						2961,44

Šipke specifikacija								
ozn.	oblik i dimenzije [cm]	Ø	lg [m]	n [kom.]	lgn [m]	Jedinična-težina [kg/m']	Ukupna težina [kg]
POZICIJE 200 DONJA ZONA							
1	95 / 10 / 95	10	2.00	372	744.00	0.79	587.80
2	125	10	1.25	194	242.50	0.79	191.58
						Ukupna težina:	779.40

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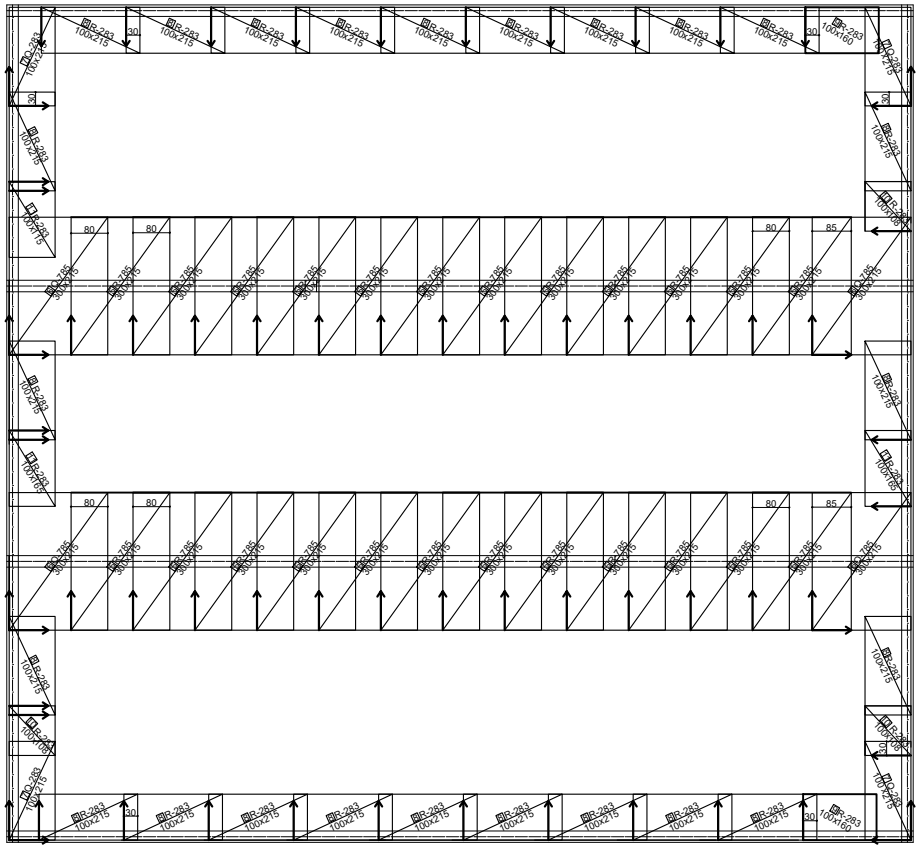
IZRADIO	ŠIME DODIG
AKAEMSKA GODINA 2016/2017	20.7.2017.
ARMATURA POZ.200 DONJA ZONA	M 1:100

ARMATURA PLOČE POZICIJA 200 GORNJA ZONA
MJ 1:100



KLASA BETONA:
BETON C 30/37
ARMATURA B450BC
PREKLOP MREŽA ≥85 cm
ZAŠTITNI SLOJ C=3 cm

Mreže-specifikacija

Pozicija	Oznaka mreže	B [cm]	L [cm]	n	Jedinična težina [kg/m2]	Ukupna težina [kg]
POZICIJA 200 GORNJA ZONA						
5	R-785	215	300	24	7.38	1142.42
6	Q-785	215	300	4	12.46	325.08
7	Q-283	215	100	4	4.48	38.53
8	R-283	215	100	24	2.77	142.93
9	R-283	160	100	2	2.77	8.86
10	R-283	108	100	4	2.77	11.97
11	R-283	165	100	2	2.77	9.15
Ukupna težina:						1681.94

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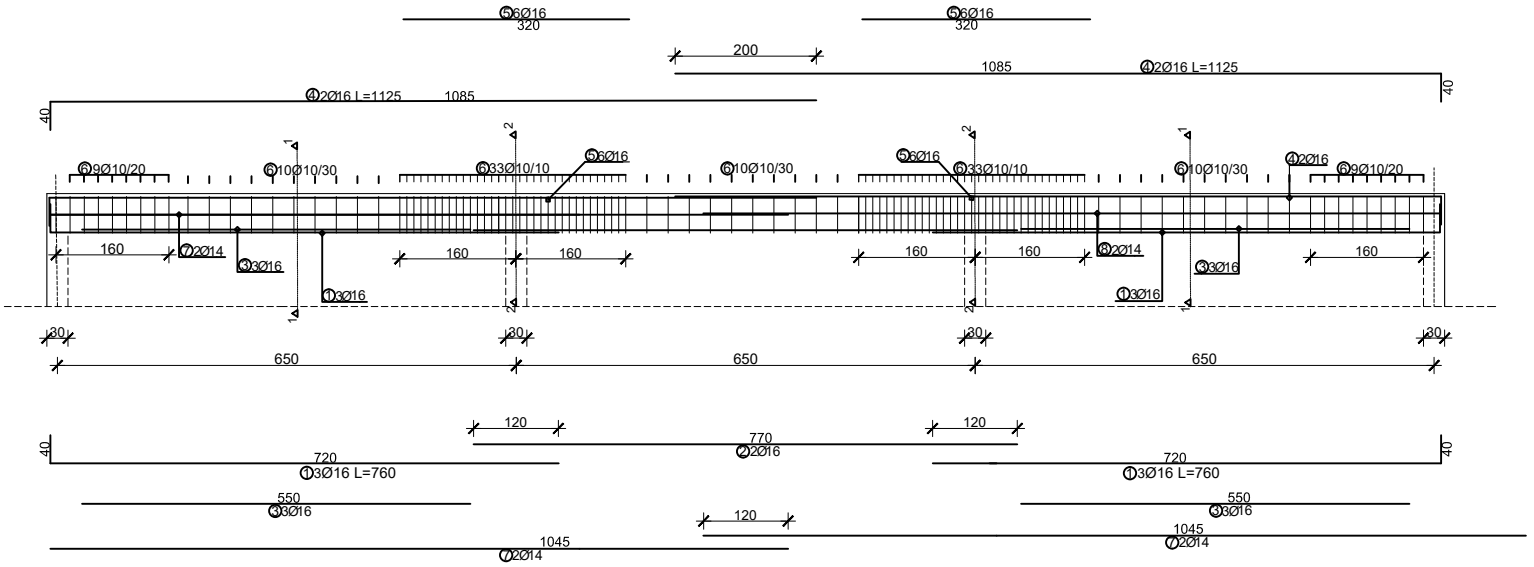
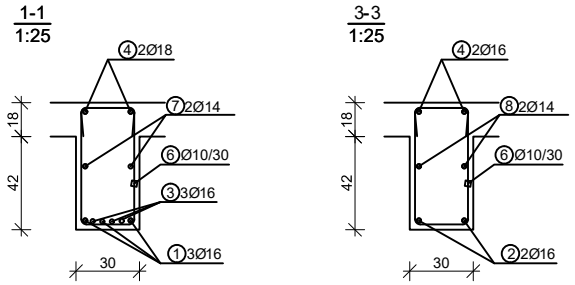
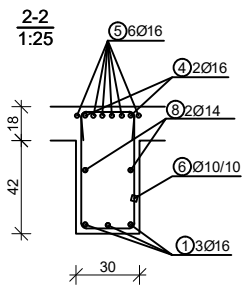
ARMATURA POZ.200 GORNJA ZONA	M 1:100

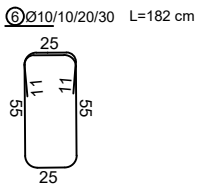
ARMATURA GREDE POZICIJA 200

MJ 1:65









KLASA BETONA:
BETON C 30/37
ARMATURA B450BC
ZAŠTITNI SLOJ C=3 cm

Šipke specifikacija

ozn.	oblik i dimenzije [cm]	∅	lg [m]	n [kom.]	lgn [m]	Jedinična-težina [kg/m']	Ukupna težina [kg]
1	40, 720	16	7.60	6	45.60	1.578	71.96
2	770	16	7.70	2	15.40	1.578	24.30
3	550	16	5.50	6	33.00	1.578	52.07
4	1085, 40	16	11.25	4	45.00	1.578	70.01
5	320	16	3.20	12	38.40	1.578	60.60
6	55, 11, 11, 55, 25, 20	10	1.82	114	207.48	0.617	128.02
7	1045	14	10.45	4	41.80	1.208	50.50

Ukupna težina: 457.50 [kg]

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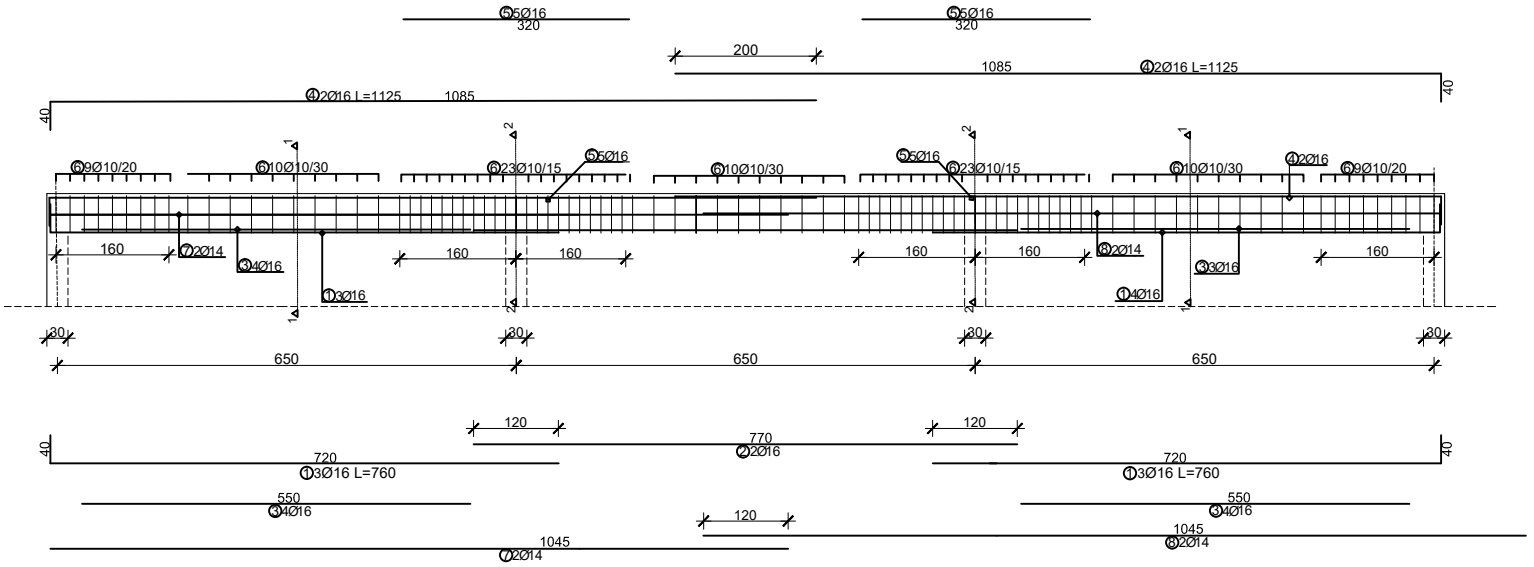
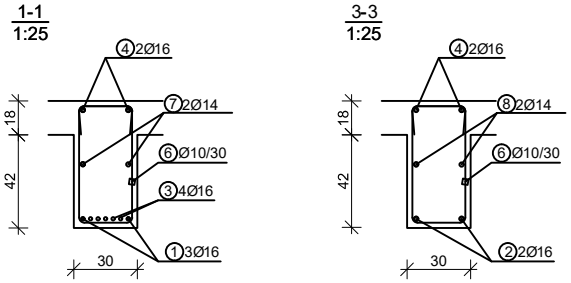
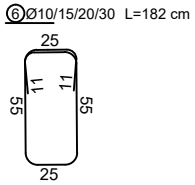
ARMATURA GREDE POZ.200	M 1:65

ARMATURA GREDE POZICIJA 100

MJ 1:65







KLASA BETONA:
BETON C 30/37
ARMATURA B450BC
ZAŠTITNI SLOJ C=3 cm

Šipke specifikacija

ozn.	oblik i dimenzije [cm]	∅	lg [m]	n [kom.]	lgn [m]	Jedinična-težina [kg/m']	Ukupna težina [kg]
1	40, 720	16	7.60	6	45.60	1.578	71.96
2	770	16	7.70	2	15.40	1.578	24.30
3	550	16	5.50	8	44.00	1.578	69.43
4	1085, 40	16	11.25	4	45.00	1.578	70.01
5	320	16	3.20	10	32.00	1.578	50.50
6	55, 11, 11, 55, 25, 20	10	1.82	114	207.48	0.617	128.02
7	1045	14	10.45	4	41.80	1.208	50.50

Ukupna težina: 464.72 [kg]

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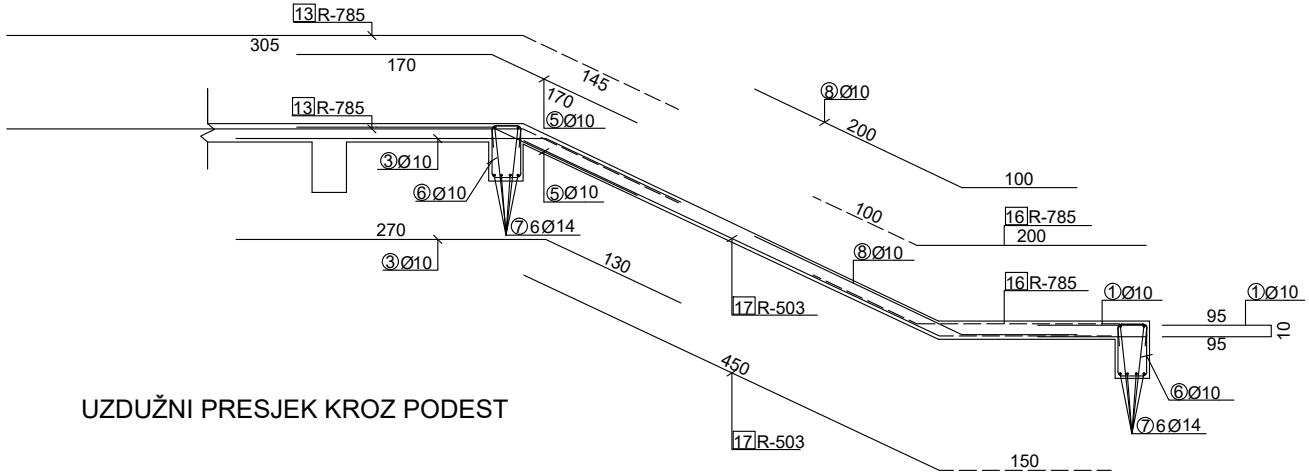
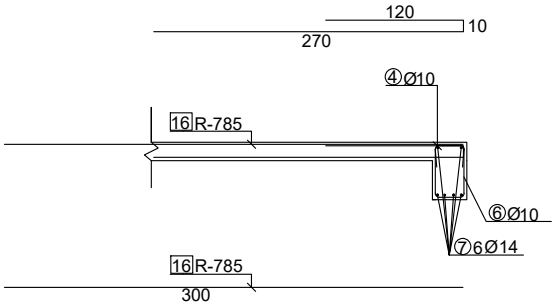
ARMATURA GREDE POZ.100	M 1:65

ARMATURA STUBIŠTA
MJ 1:40

UZDUŽNI PRESJEK KROZ STUBIŠTE



UZDUŽNI PRESJEK KROZ PODEST



KLASA BETONA:
BETON C 30/37
ARMATURA B450BC
ZAŠTITNI SLOJ C=3 cm

Šipke specifikacija

ozn.	oblik i dimenzije [cm]	Ø	lg [m]	n [kom.]	lgn [m]	Jedinična-težina [kg/m']	Ukupna težina [kg]
POZICIJE 100 GORNJA ZONA							
1	95, 10, 95	10	2.00	10	20.00	0.79	15.80
3	270, 118, 130, 55	10	4.00	15	60.00	0.79	47.40
4	120, 10, 270	10	4.00	16	64.00	0.79	50.56
5	170, 91, 170, 43	10	3.40	14	47.60	0.79	37.60
6	600	14	6.00	12	72.00	1.208	87.00
8	200, 100	10	3.00	14	42.00	0.79	33.18
						Ukupna težina:	271.54

Mreže-specifikacija

Pozicija	Oznka mreže	B [cm]	L [cm]	n	Jedinična težina [kg/m2]	Ukupna težina [kg]
ARMATURA STUBIŠTA						
13	R-785	215	450	1	7.35	71.11
15	R-785	115	450	1	7.35	38.00
16	R-785	215	300	2	7.35	94.82
17	R-503	215	600	1	4.89	63.00
18	R-503	115	600	1	4.89	38.74
Ukupno						300.67

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ZAVRŠNI RAD

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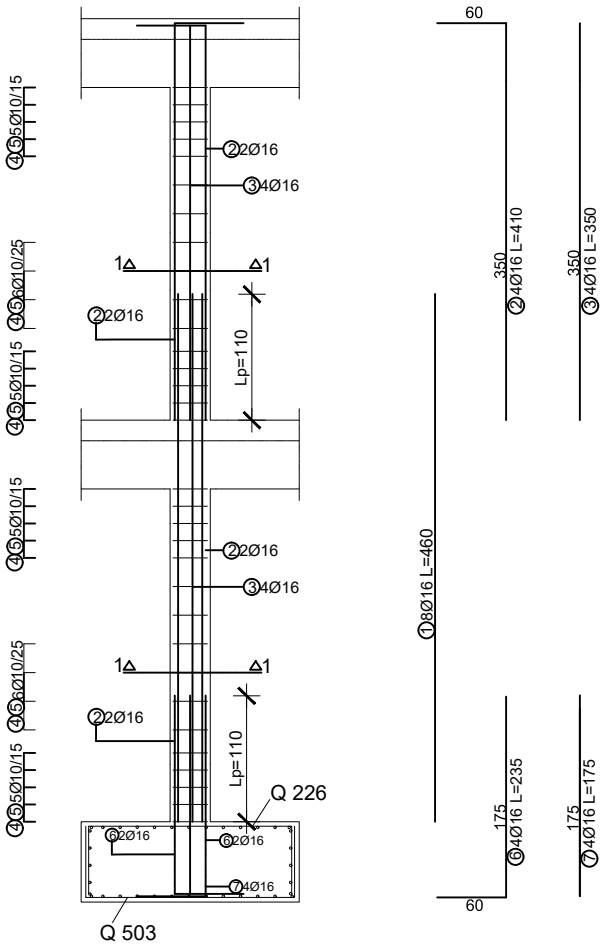
ARMATURA STUBIŠTA	M 1:40

ARMATURA STUPA KROZ 2 ETAŽE

MJ 1:40



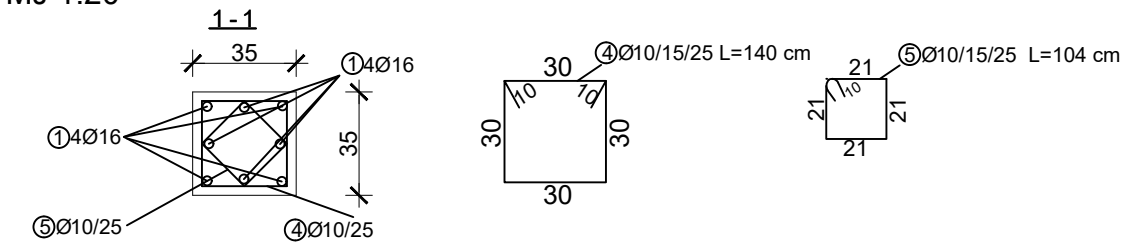
KLASA BETONA:
BETON C 30/37
ARMATURA B450BC
ZAŠTITNI SLOJ C=3 cm

Šipke specifikacija

ozn.	oblik i dimenzije [cm]	Ø	lg [m]	n [kom.]	lgn [m]	Jedinična-težina [kg/m']	Ukupna težina [kg]
	STUP 2.ETAŽA						
1	460	16	4.60	8	36.80	1.578	58.07
2	350, 60	16	4.10	4	16.40	1.578	25.88
3	350	16	3.50	4	14.00	1.578	22.09
4	30, 30, 30, 30	10	1.4	32	44.80	0.79	35.40
5	26, 26, 26, 26	10	1.04	32	33.30	0.79	26.31
6	175, 60	16	2.35	4	9.40	1.578	14.83
7	175	16	1.75	4	7.00	1.578	11.05

Ukupna težina: 193.63 [kg]

MJ 1:20



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IZRADIO	ŠIME DODIG
AKADEMSKA GODINA 2016/2017	20.7.2017.
ARMATURA STUPA KROZ 2 ETAŽE	M 1:40