Projekt nosive armiranobetonske konstrukcije poslovnog objekta

Biloš, Ante

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SVEUČILIŠTE U SPLITU

FAKULTET GRAĐEVINARSTVA, ARHITEKTURE I GEODEZIJE

ZAVRŠNI RAD

Ante Biloš

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FAKULTET GRAĐEVINARSTVA, ARHITEKTURE I GEODEZIJE

Split, Matice hrvatske 15

STUDIJ: **STRUČNI STUDIJ GRAĐEVINARSTVA**

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

PREDMET: Betonske konstrukcije 2

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.

Voditelji Završnog rada:

mr.sc. Vladica Herak Marović, v.pred.

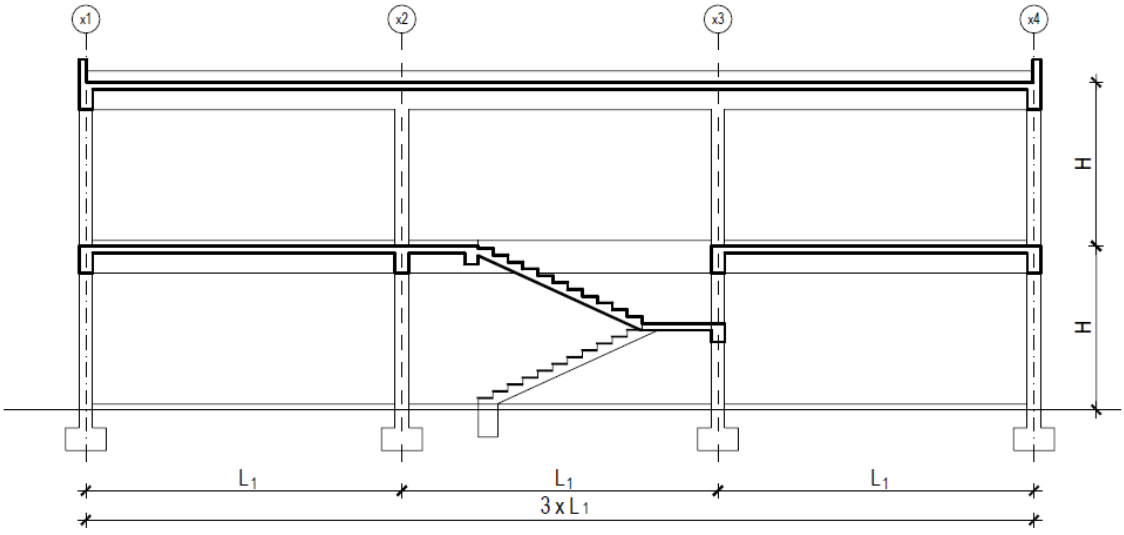
dr.sc. Nikola Grgić

PRILOG:

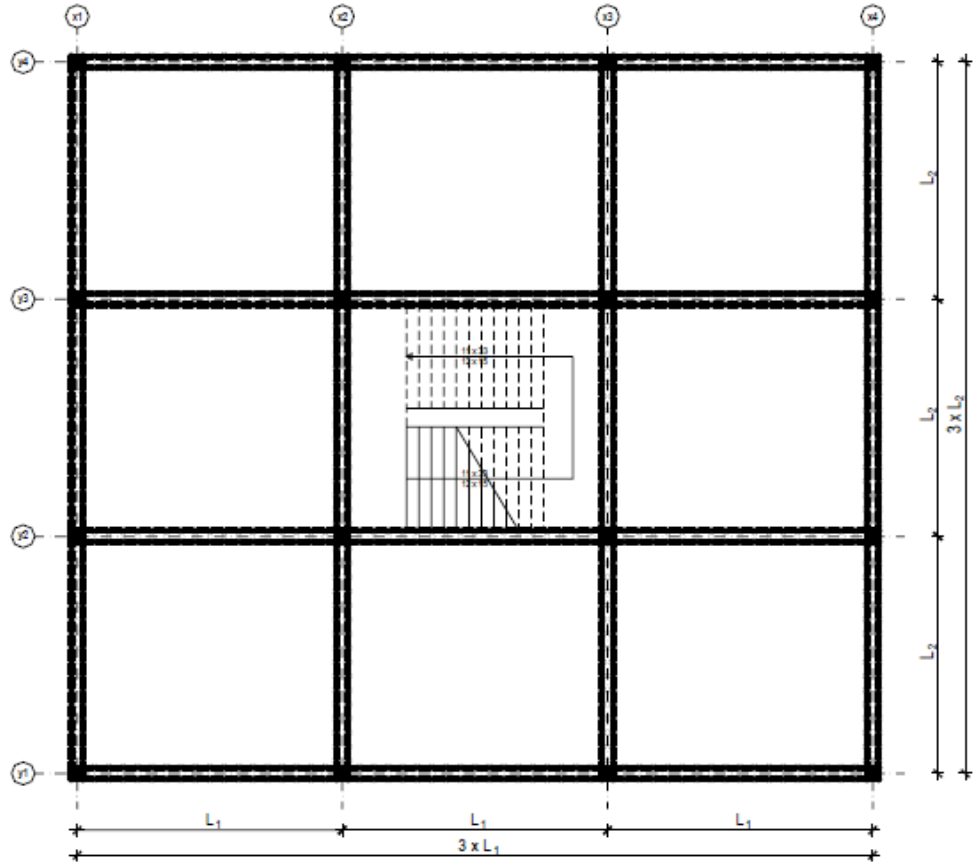
Na priloženim skicama dana je shema nosive armiranobetonske konstrukcije objekta. U tablici su zadane sve potrebne dimenzije i djelovanja na konstrukciju.

Oznaka	Veličina	Jedinica	Opis
L_1	6,9	(m)	„raster“ u uzdužnom smjeru
L_2	6,2	(m)	„raster “ u poprečnom smjeru
H	3,0	(m)	visina etaža
q	3,5	(kN/m^2)	uporabno opterećenje
Z_v	III		zona vjetra
a_g		(m/s^2)	proračunsko ubrzanje tla
S	B 500 B		armatura
C	C 40/50		klasa betona

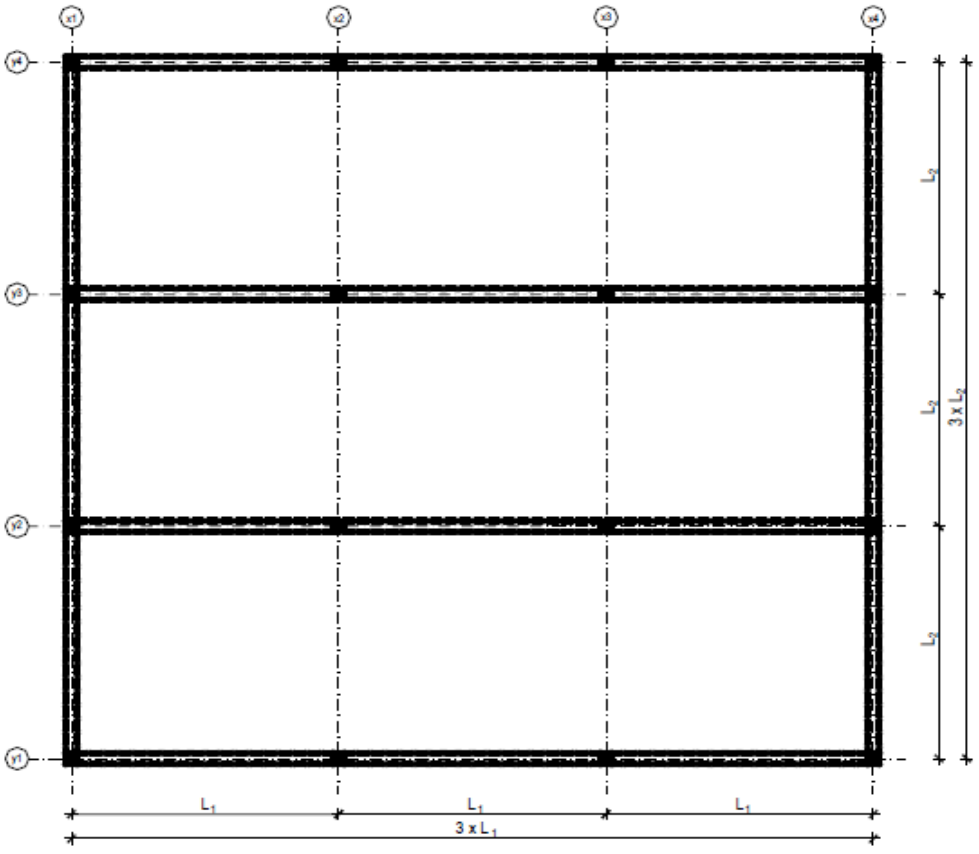
(i) Presjek



(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:

Thedefaultschemebearingstructuresreinforcedconcretefacility for businesspurposes, with all therequireddimensions (Annextask). Alsothedefaultaction on the structure, and for some elementsdrawplansandreinforcement.
Structuralanalysisandreinforcementplansdevelopinaccordancewiththeregulationsandrulesof theprofession.

KEYWORDS:

Reinforcedconcretebuilding for businesspurposes, numerical model, staticanalysis, reinforcement plan.

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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 6,00 m, a tlocrtna površina građevine iznosi 20,70 x 18,60 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 210x210x70 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 8,50 kN/m2,a uporabno opterećenje (prema propisima) iznosi 1,0 kN/m2. Zadano je uporabno opterećenje za poziciju 100 (međukatne konstrukcije) i iznosi 3,5 kN/m2, a stalno opterećenje je 7,70 kN/m2. Građevina se nalazi u III. vjetrovnoj zoni s osnovnom brzinom vjetra vb0= 35 m/s.

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

Za nosivu armiranobetonsku konstrukciju odabran je beton C 40/50 i čelik za armiranje B 500B.

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:

$$d_{pl} = \frac{L_2}{35} = \frac{620}{35} = 17,7$$

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

visina grede:

$$\frac{L_0}{12} = \frac{L_1}{12} = \frac{690}{12} = 57,5\text{cm}$$

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

$$\frac{L_0}{12} = \frac{L_1}{12} = \frac{620}{12} = 51,6\text{cm}$$

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

-širina grede:

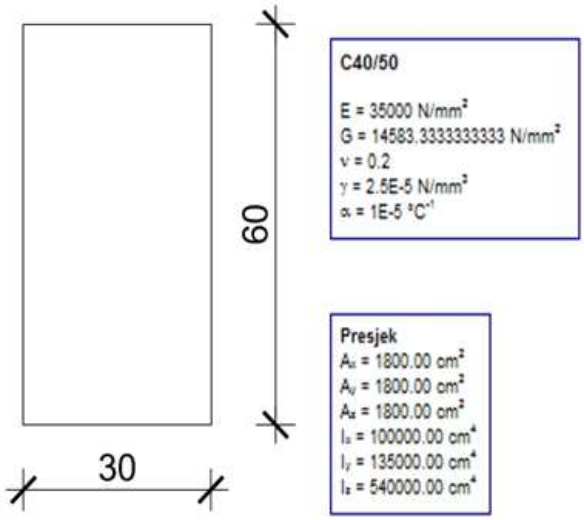
$$\frac{h_{G1}}{2} = \frac{60}{2} = 30\text{cm}$$

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

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

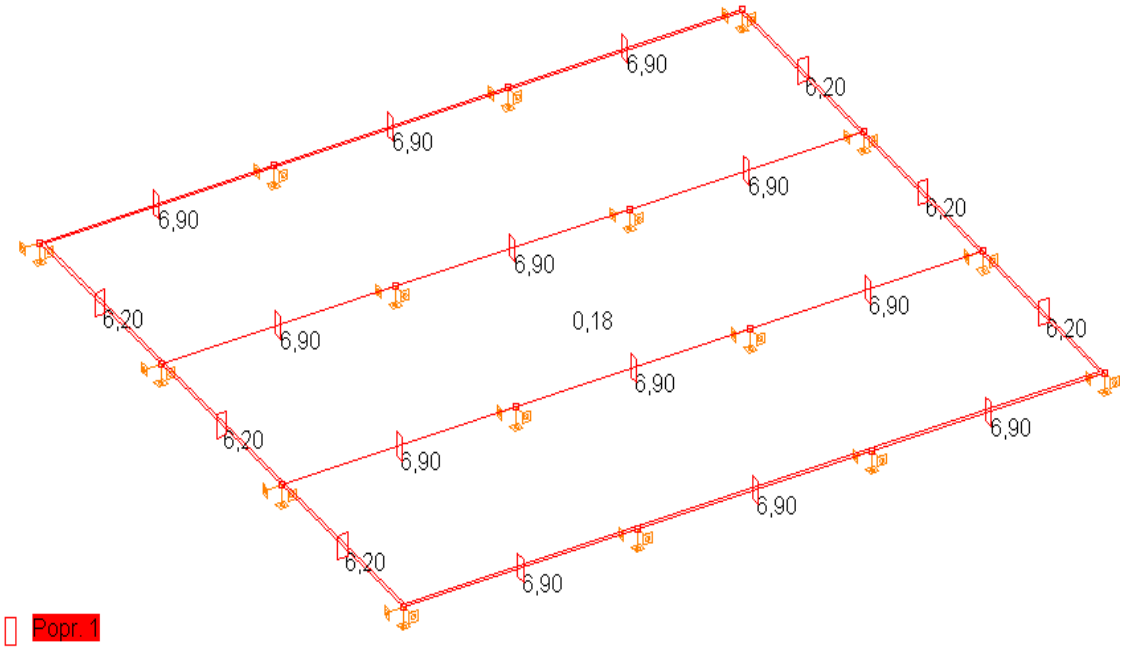
$$\text{odabrano}: b_{G2} = 30\text{cm}$$

PRESJEK 1

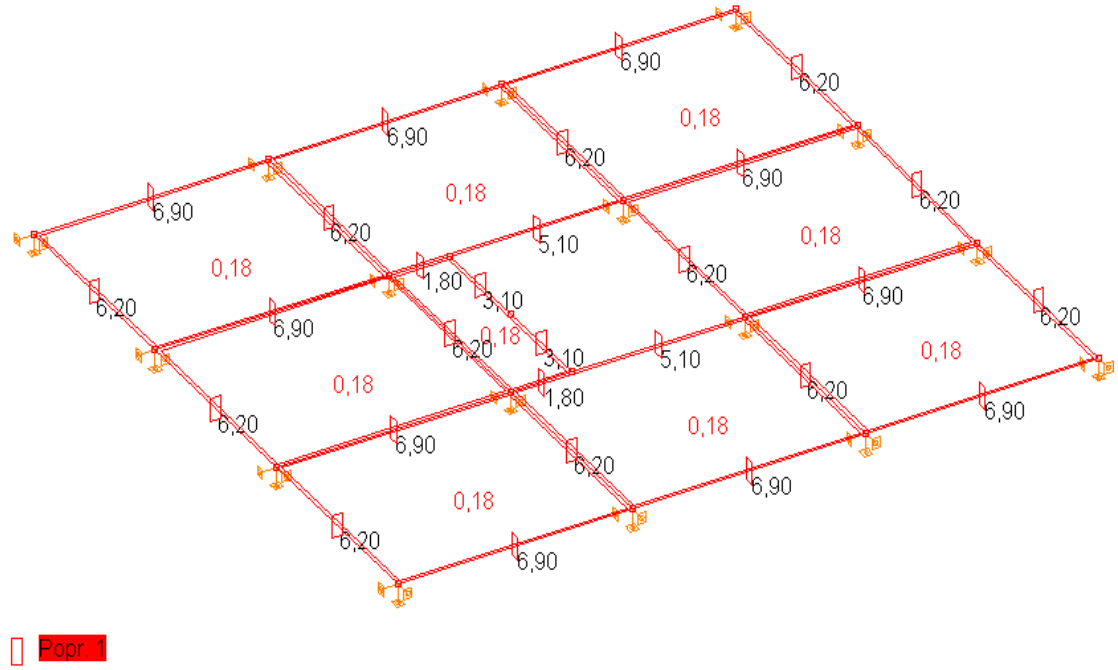


Slika 2.1. Poprečni presjek grede

- 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 pločapoz. 200

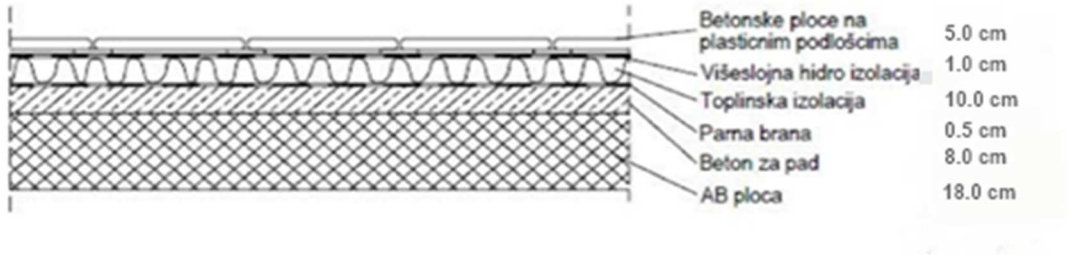


Slika 2.3. Prikaz dimenzija greda i ploča poz. 100

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

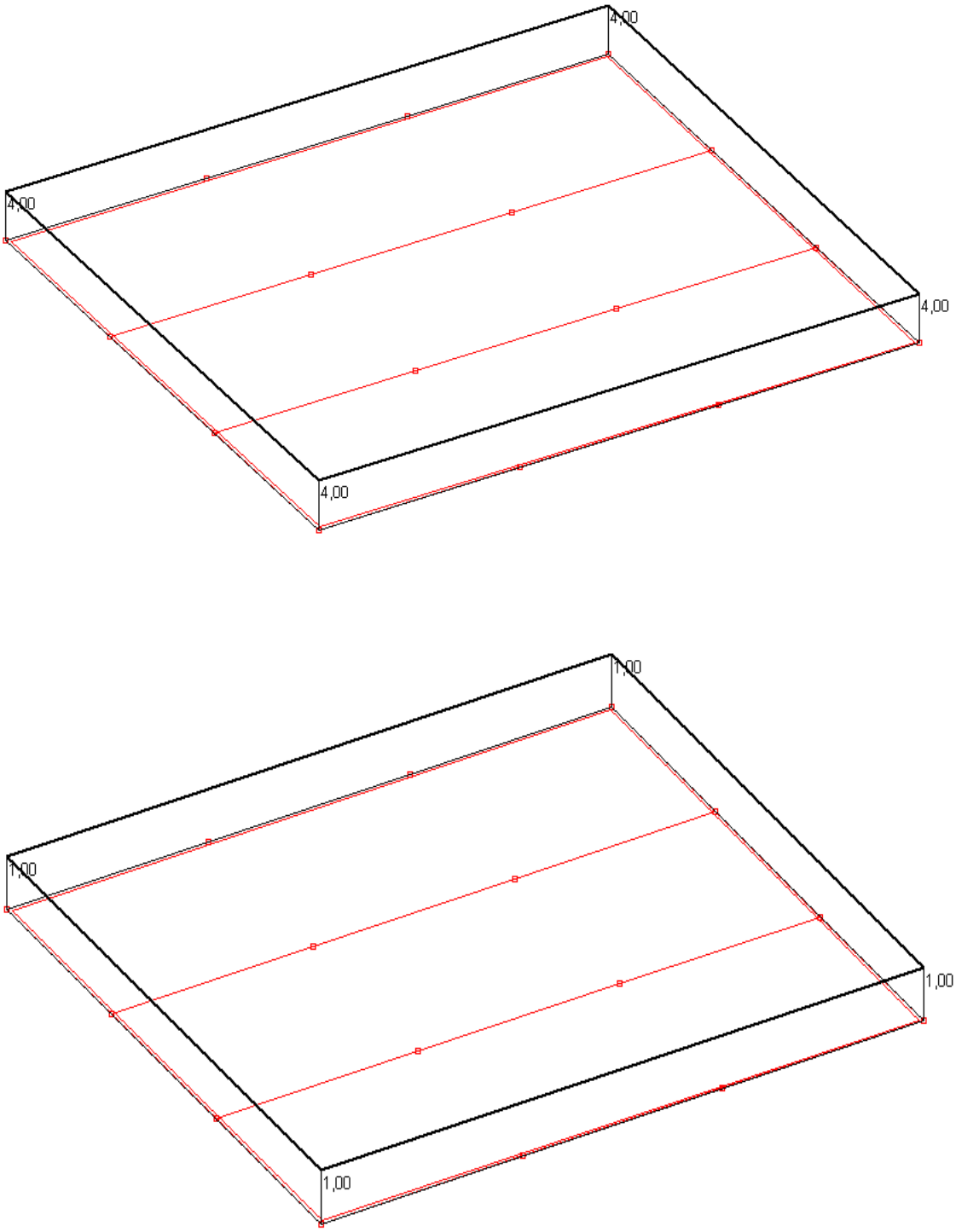
	d (m)	γ (kN/m^3)	d·γ (kN/m^2)
Betonske ploče na plastičnim podlošcima	0.05	25.0	1.25
Hidroizolacija + parna brana	0.01	20.0	0.20
Toplinska izolacija	0.10	5.0	0.50
Beton za pad	0.08	24.0	1.92
AB ploča	0.18	25.0	4.5

Ukupno stalno opterećenje: $g_{200} = 8.50$ (kN/m^2)

3.1.2. Uporabno opterećenje

Za uporabno opterećenje uzima se opterećenje snijegom i vjetrom. Opterećenje snijegom za ravnekrovove, 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:

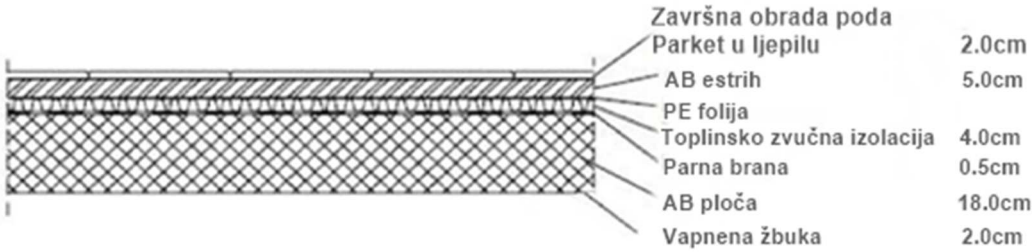
q_{200}= s + w ≈ 1.0 kN/m^2



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

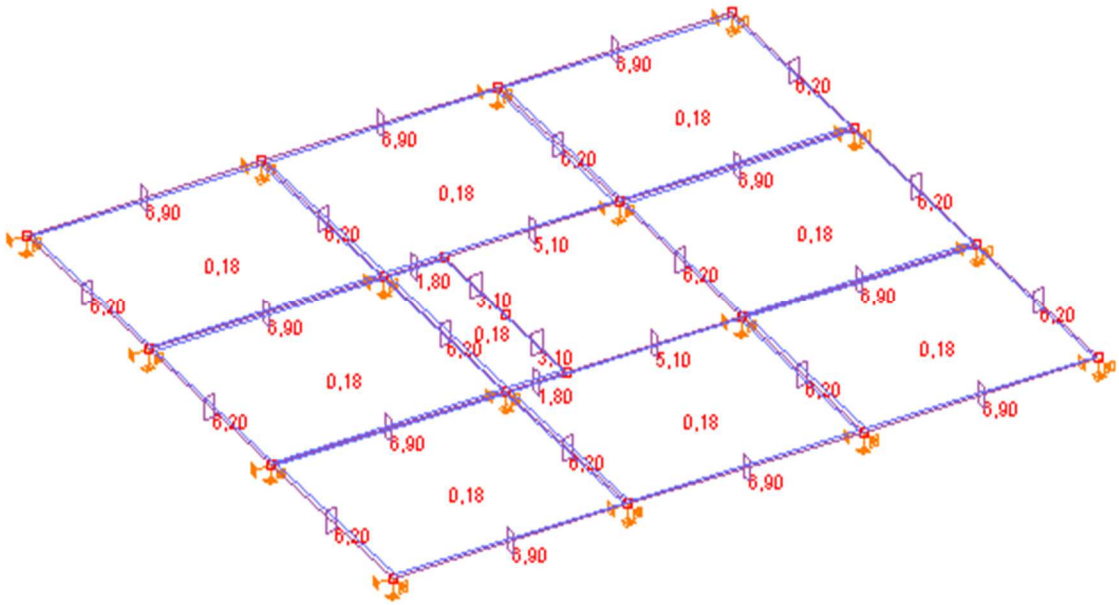
	d (m)	γ (kN/m^3)	d·γ (kN/m^2)
Pregrade			1.00
Završna obrada poda-parket	0.02	12.0	0.24
AB estrih	0.05	25.0	1.25
Toplinska izolacija	0.04	5.0	0.20
Hidroizolacija	0.005	20.0	0.10
AB. Ploča	0.18	25.0	4.50
Pogled (vapnena žbuka)	0,02	19,00	0,38

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

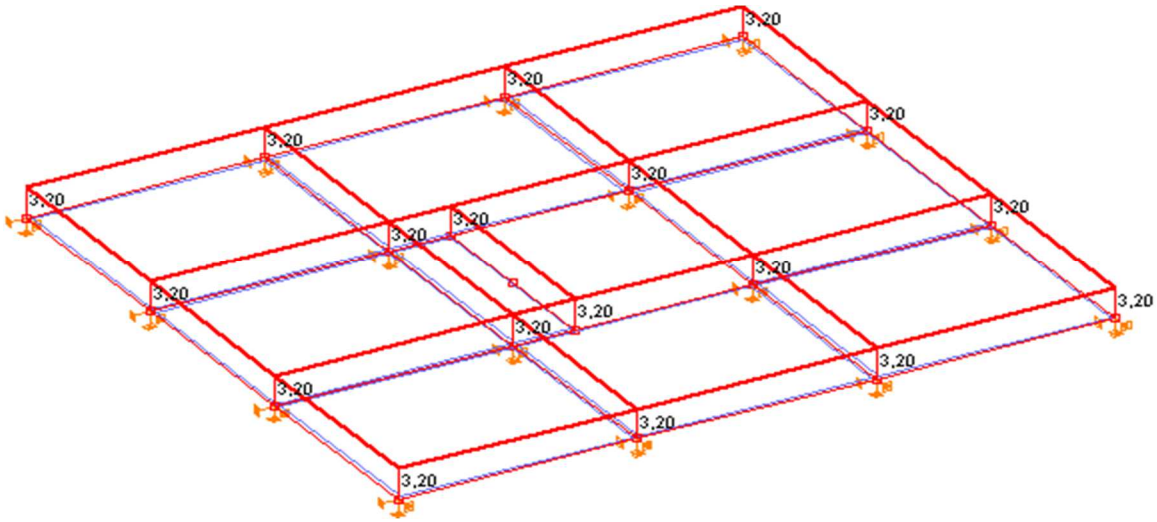
3.2.2. Uporabno opterećenje

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

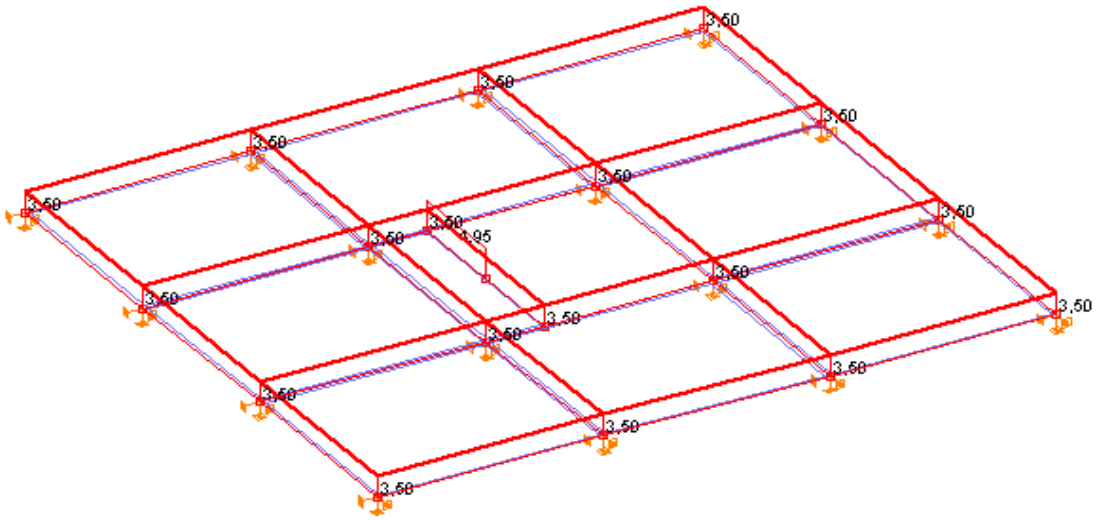
U našem slučaju, zadano je zadatkomq_{100}=3.5 kN/m^2



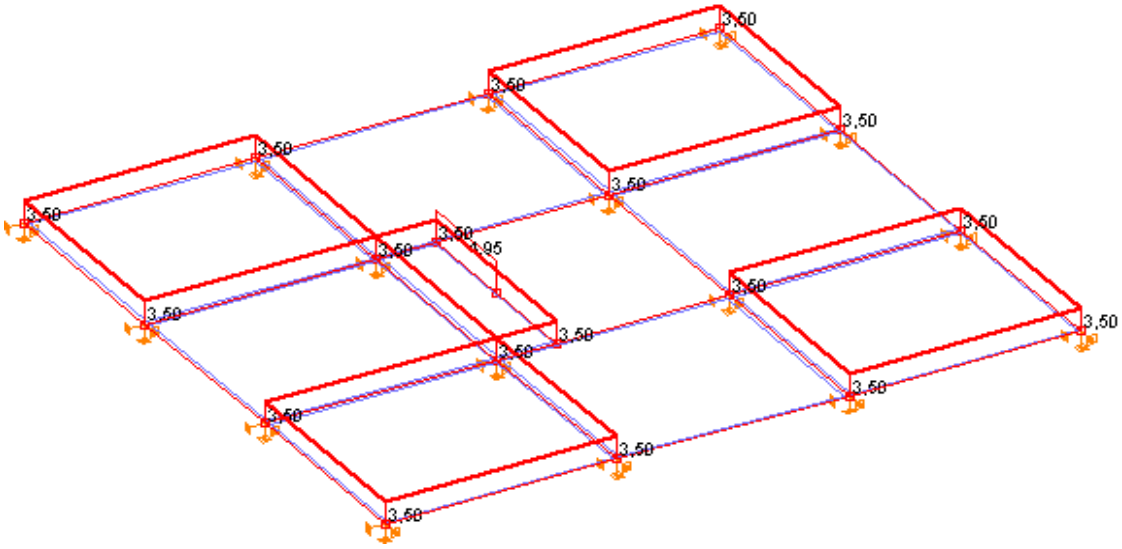
Slika 3.4. Geometrija etaže 100



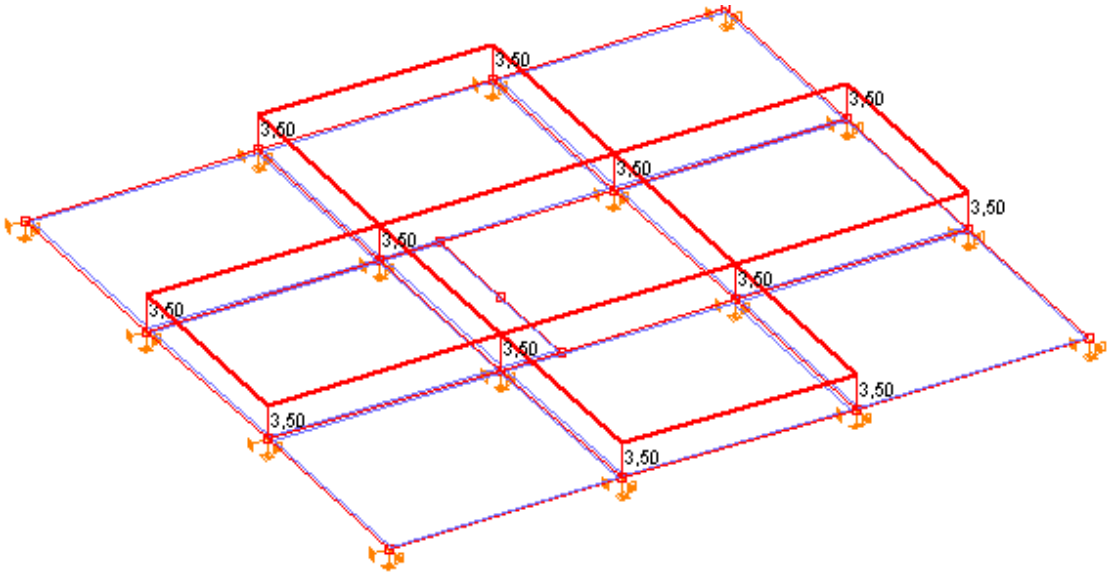
Slika3.5 Prikaz dodatnog stalnog opterećenja G_0



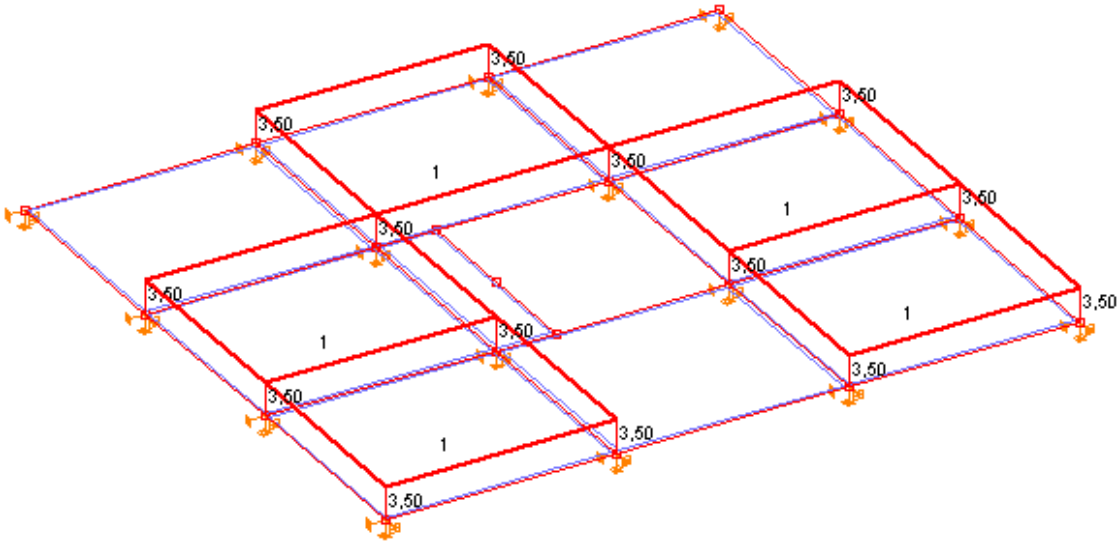
Slika 3.6 Prikaz uporabnog opterećenja shema 1 (max sile na ležajevima kod ploča*)*



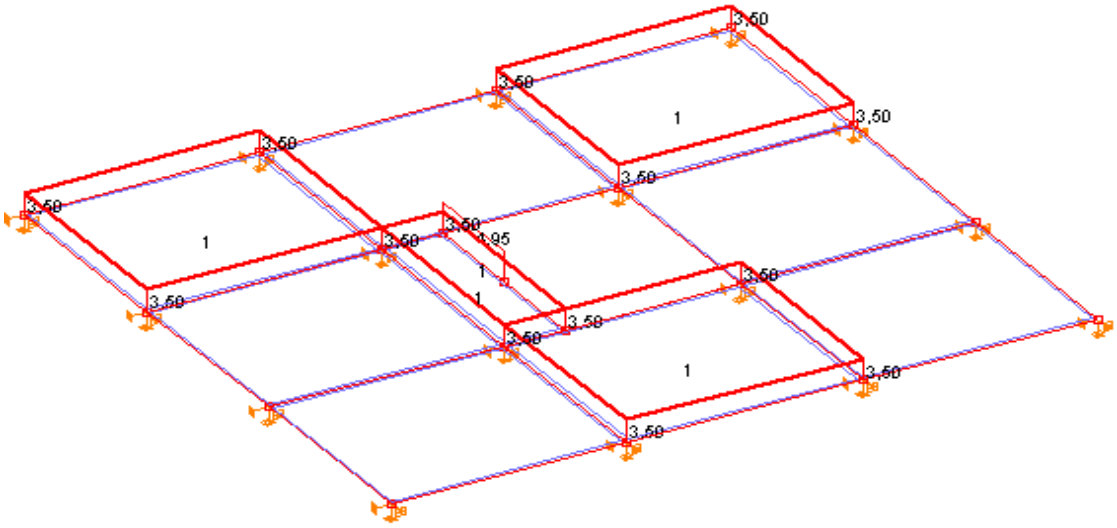
Slika 3.7. Prikaz uporabnog opterećenja shema 2(max sile u krajnjim poljima kod ploča)



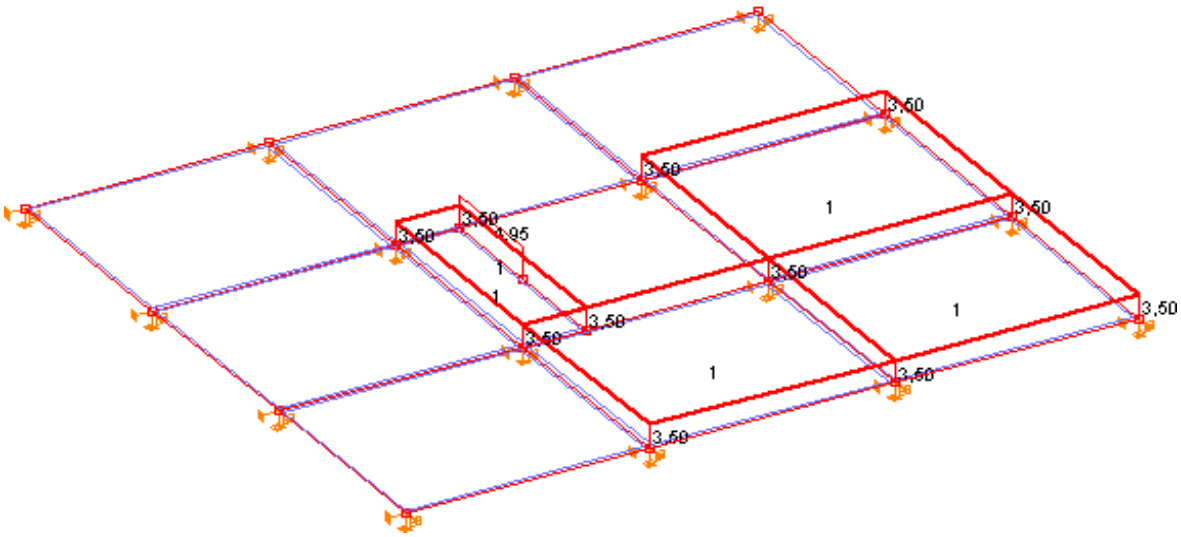
Slika 3.8. Prikaz uporabnog opterećenja shema 3(max sile u srednjem polju kod ploča)



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



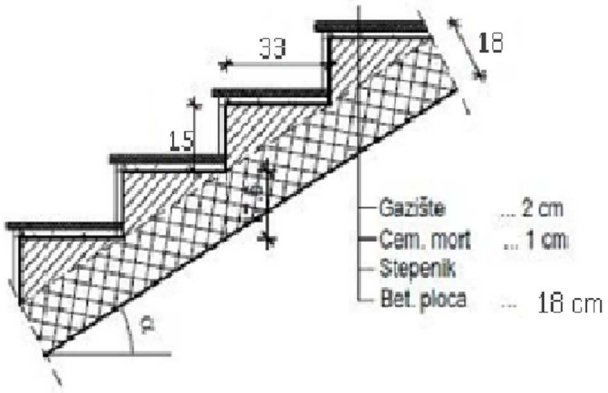
Slika 3.10. Prikaz uporabnog opterećenja shema 5 (max sile u srednjem polju kod grede)



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 = 3,00/2·0,15 = 10 stuba

- Širina stube:

2·vs + šs = 63 ⇒šs = 63-2·0,15 = 33 cm

- Duljina kraka:

Lk = ns·šs = 10 ·33 = 330 cm

- Kut α:

tgα = 0,5·H/Lk = 1,5 ·3,3 = 0,455 ⇒

α = 24,44°

- Odabrana duljina podesta:

Lp ≥ 1,20 m Lp=(L-Lk)/2=(6,9-3,3)/2=1,8m

$$h' = \frac{h}{\cos\alpha} = \frac{18}{\cos 24{,}44}\ 19{,}77\text{cm}$$

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'=19,77 cm)	0.198	25.0	4,95

Ukupno stalno opterećenje : g_{st} = 7,31 (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:

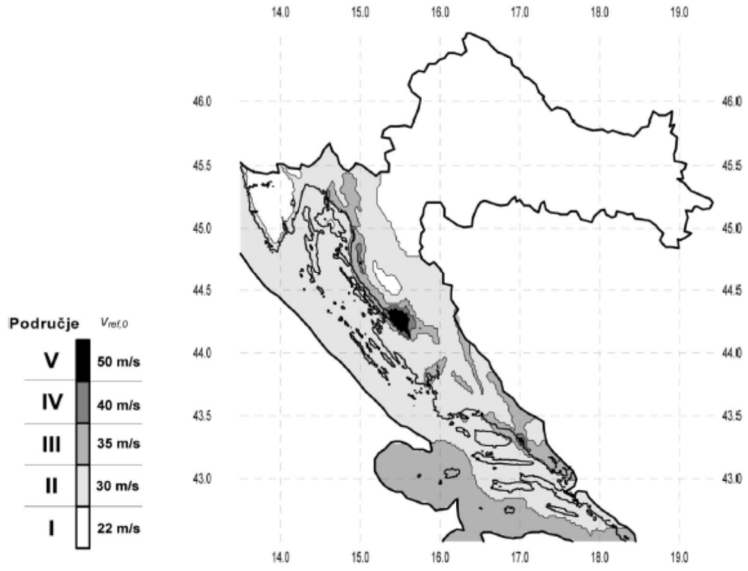
q_{st}= 4,95 (kN/m^2)

3.4. **OPTEREĆENJE VJETROM**

Dimenzije zgrade su: L_1=6.9m,L_2=6.2m,H =3.0m.

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

Osnovna brzina vjetra: $\mathrm{v_{b,0}} = 35\ \mathrm{m/s}$ (za III. 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 → $\mathrm{c_{ALT}} = 1 + 0{,}0001 \cdot \mathrm{a_s}$

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

$v_b = 1{,}00 \cdot 1{,}00 \cdot 1{,}015 \cdot 35 = 35{,}525\ m/s$

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:

$$z_e = 2 \cdot 3{,}0 + 0{,}5 = 6{,}5\ m$$

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

$$k_r = 0{,}215 \rightarrow c_{r(z)} = 0{,}215 \cdot \ln\left(\frac{6{,}5}{0{,}30}\right) = 0{,}661$$

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)

$$v_m = 0{,}661 \cdot 1{,}0 \cdot 35{,}525 = 23{,}48\ m/s$$

Turbulencija:

$$I_v(z) = \frac{1}{c_0(z) \cdot \ln\left({}^{z_e}/_{z_0}\right)} = \frac{1}{1{,}0 \cdot \ln\left({}^{6{,}5}/_{0{,}30}\right)} = 0{,}325$$

Maksimalni tlak pri vršnoj brzini$q_p(z_e)$:

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

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

$$q_p(z) = [1 + 7 \cdot 0{,}325] \cdot \frac{1{,}25}{2} \cdot 23{,}48^2 = 1128{,}46\frac{N}{m^2} = 1{,}13\ \frac{kN}{m^2}$$

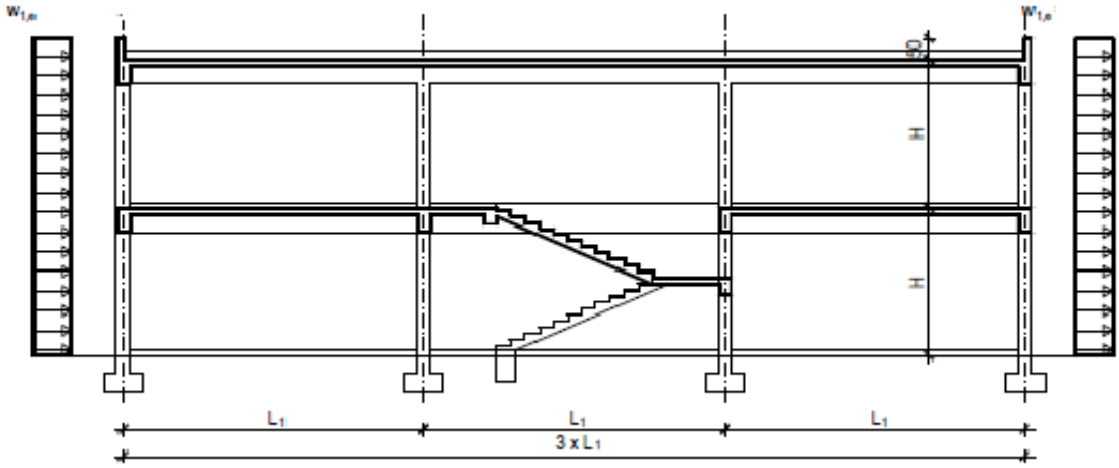
Djelovanje na zgradu:

$$w_{1,e} = 0{,}8 \cdot q_p(z) = 0{,}8 \cdot 1{,}13 = 0{,}90\ \frac{kN}{m^2}$$

$$w_{2,e} = 0{,}5 \cdot q_p(z) = 0{,}5 \cdot 1{,}13 = 0{,}57\frac{kN}{m^2}$$

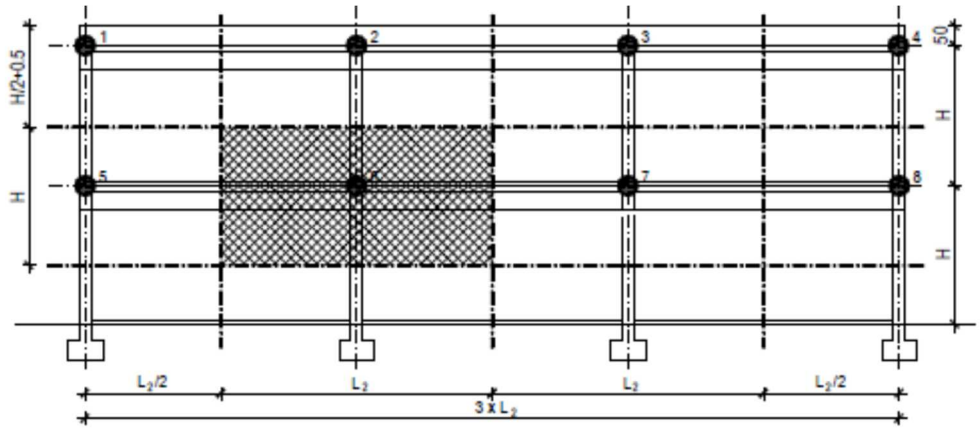
$$w_{1,I} = 0{,}75 \cdot w_{1,e} = 0{,}75 \cdot 0{,}90 = 0{,}68\ \frac{kN}{m^2}$$

$$w_{2,I} = 0{,}75 \cdot w_{2,e} = 0{,}75 \cdot 0{,}57 = 0{,}43\frac{kN}{m^2}$$



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

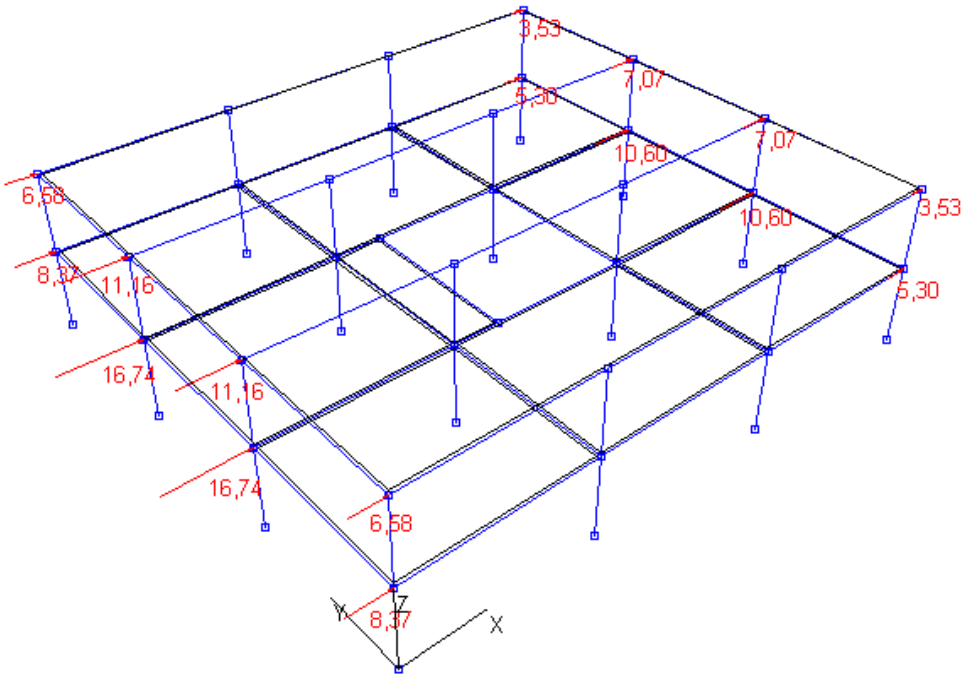
- **X smjer**

Tablica 3.5. Lijevi bok

Čvor	Utjecajna površina			Tlak vjetra(kN/m²)	Sila u čvoru(kN)
	Širina(m)	Visina(m)	Površina(m²)		
1	3.10	2.0	6.20	0.90	6.580
2	6.20	2.0	12.40	0.90	11.160
3	6.20	2.0	12.40	0.90	11.160
4	3.10	2.0	6.20	0.90	6.580
5	3.10	3.0	9.30	0.90	8.370
6	6.20	3.0	18.60	0.90	16.740
7	6.20	3.0	18.60	0.90	16.740
8	3.10	3.0	9.30	0.90	8.370

Tablica 3.6. Desni bok

Čvor	Utjecajna površina			Tlak vjetra(kN/m²)	Sila u čvoru(kN)
	Širina(m)	Visina(m)	Površina(m²)		
1	3.10	2.0	6.20	0.57	3.534
2	6.20	2.0	12.40	0.57	7.068
3	6.20	2.0	12.40	0.57	7.068
4	3.10	2.0	6.20	0.57	3.534
5	3.10	3.0	9.30	0.57	5.301
6	6.20	3.0	18.60	0.57	10.602
7	6.20	3.0	18.60	0.57	10.602
8	3.10	3.0	9.30	0.57	5.301



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

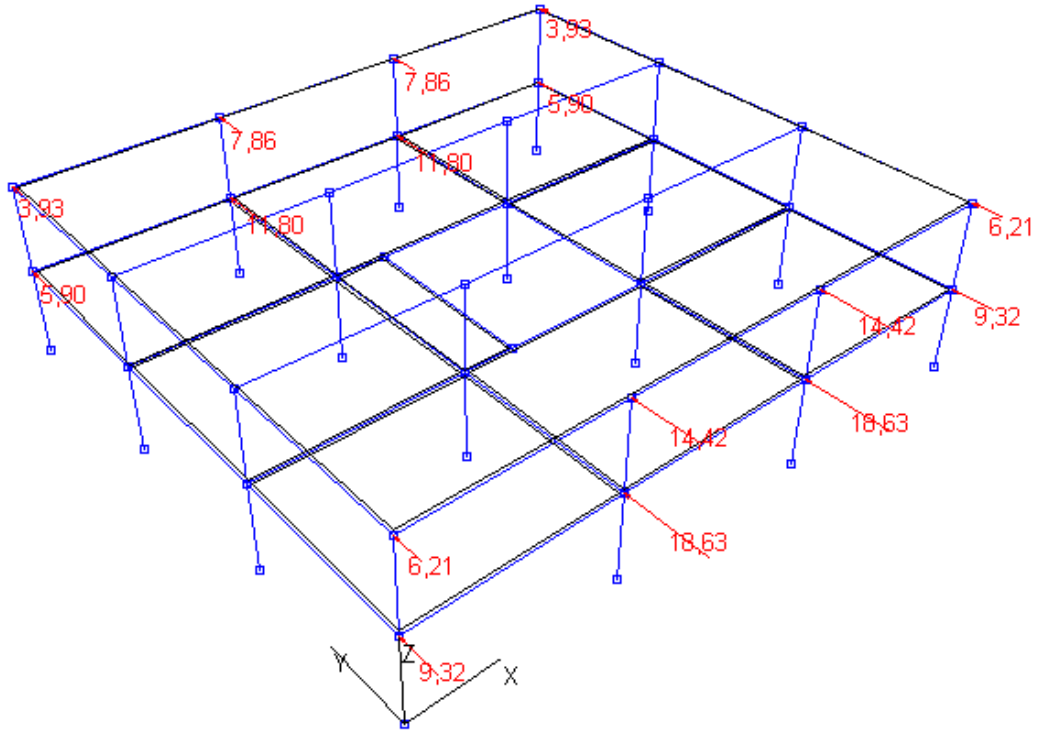
- **Y smjer**

Tablica 3.7. Prednja strana

Čvor	Utjecajna površina			Tlak vjetra(kN/m²)	Sila u čvoru(kN)
	Širina(m)	Visina(m)	Površina(m²)		
1	3.45	2.0	6.90	0.90	6.210
2	6.90	2.0	13.80	0.90	14.420
3	6.90	2.0	13.80	0.90	14.420
4	3.45	2.0	6.90	0.90	6.210
5	3.45	3.0	10.35	0.90	9.315
6	6.90	3.0	20.70	0.90	18.630
7	6.90	3.0	20.70	0.90	18.630
8	3.45	3.0	10.35	0.90	9.315

Tablica 3.8. Stražnja strana

Čvor	Utjecajna površina			Tlak vjetra(kN/m²)	Sila u čvoru(kN)
	Širina(m)	Visina(m)	Površina(m²)		
1	3.45	2.0	6.90	0.57	3.933
2	6.90	2.0	13.80	0.57	7.866
3	6.90	2.0	13.80	0.57	7.866
4	3.45	2.0	6.90	0.57	3.933
5	3.45	3.0	10.35	0.57	5.899
6	6.90	3.0	20.70	0.57	11.799
7	6.90	3.0	20.70	0.57	11.799
8	3.45	3.0	10.35	0.57	5.899



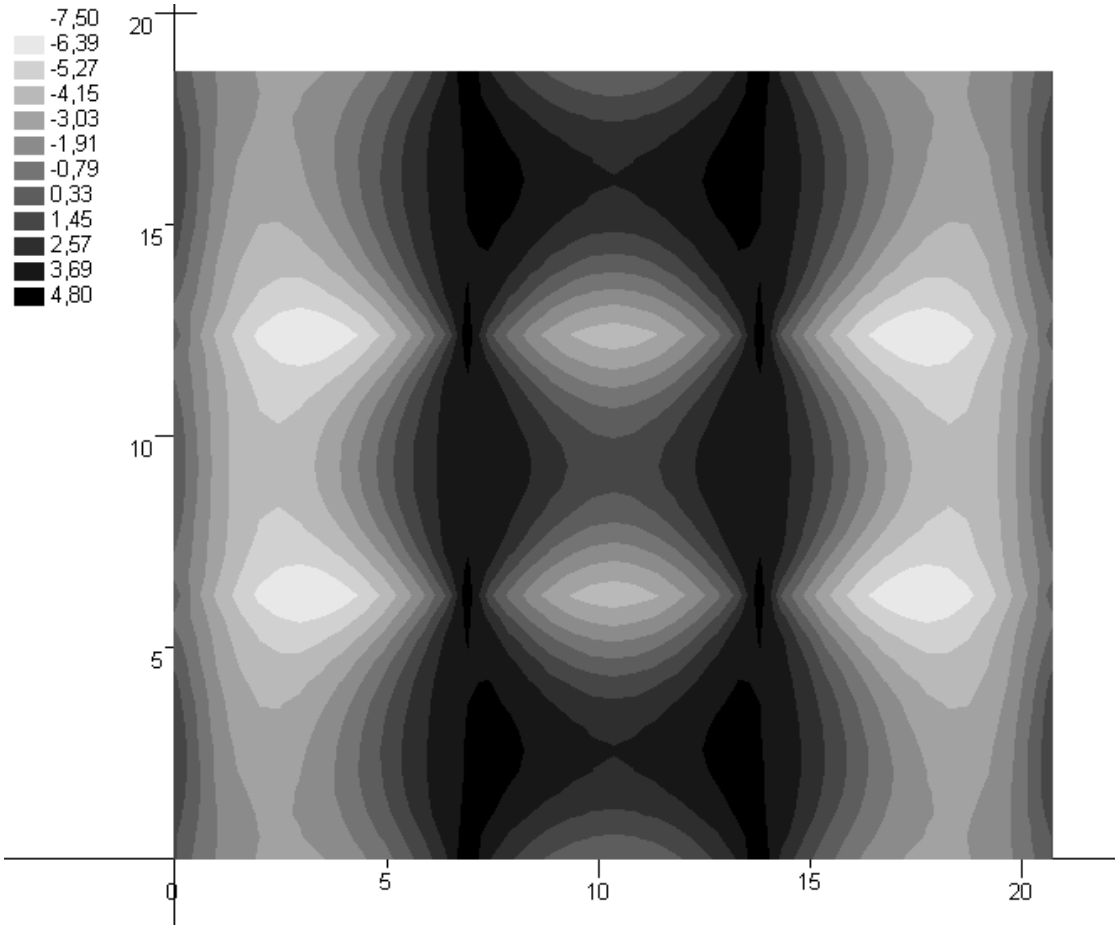
Slika 3.17.Djelovanje vjetra u Y smjeru (sile u kN)

4. PRORAČUN PLOČA POZICIJE 200

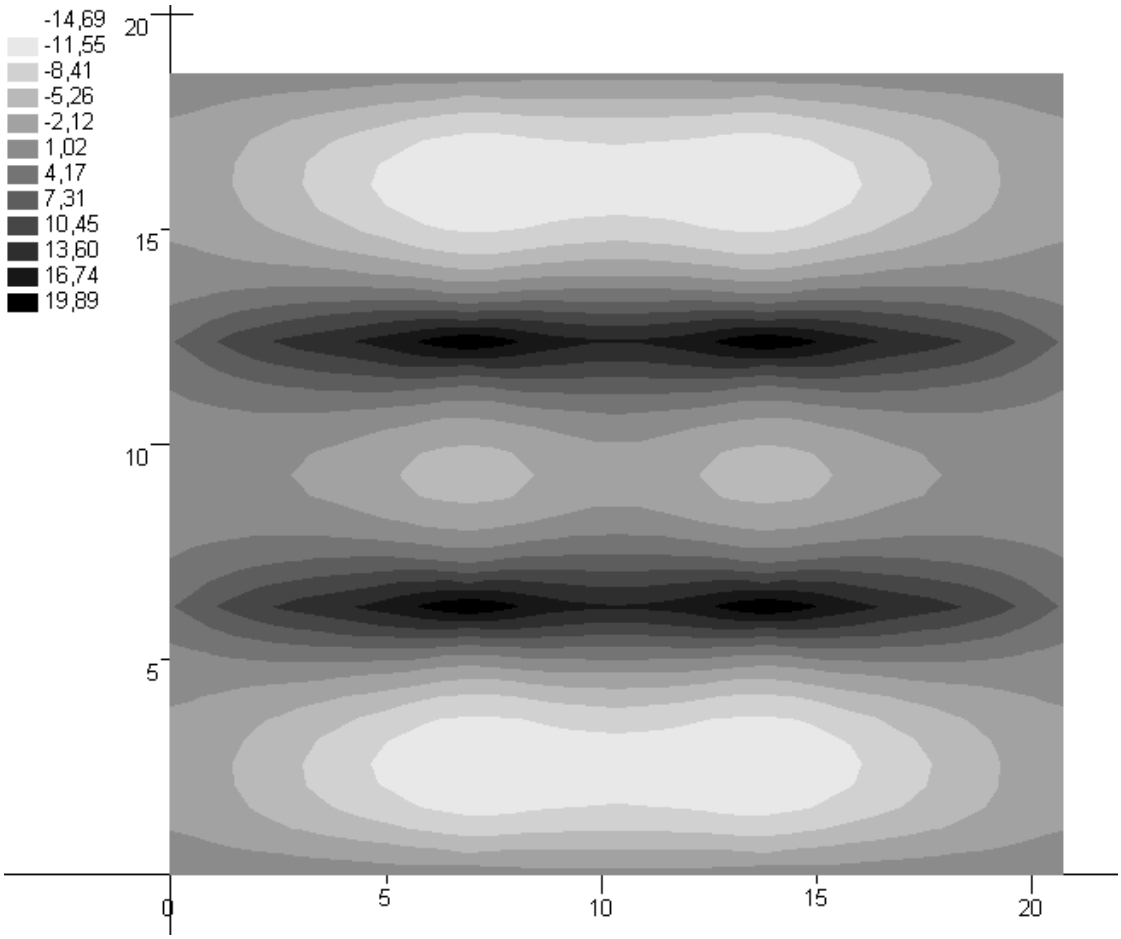
- Proračun reznih sila vršio se kompjuterskim programom *AspalathosLinear*. Prikaz rezultata dan je odvojeno za ploče i grede.

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

4.1.1. Vlastita težina

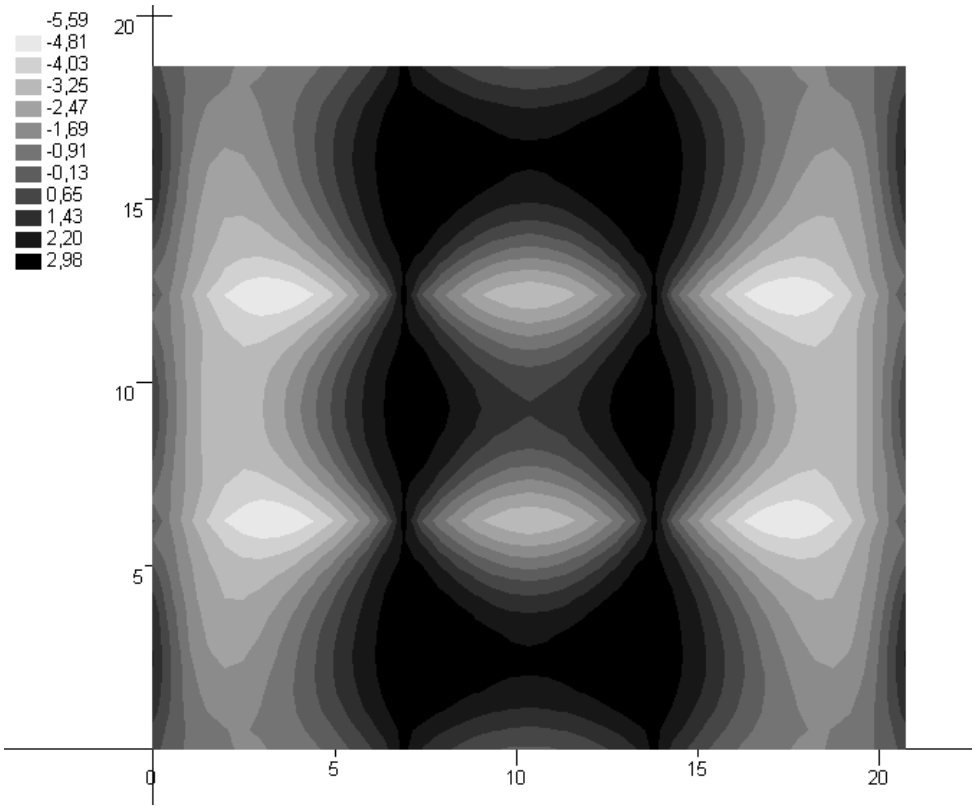


Slika 4.1. Momenti Mx (kNm)

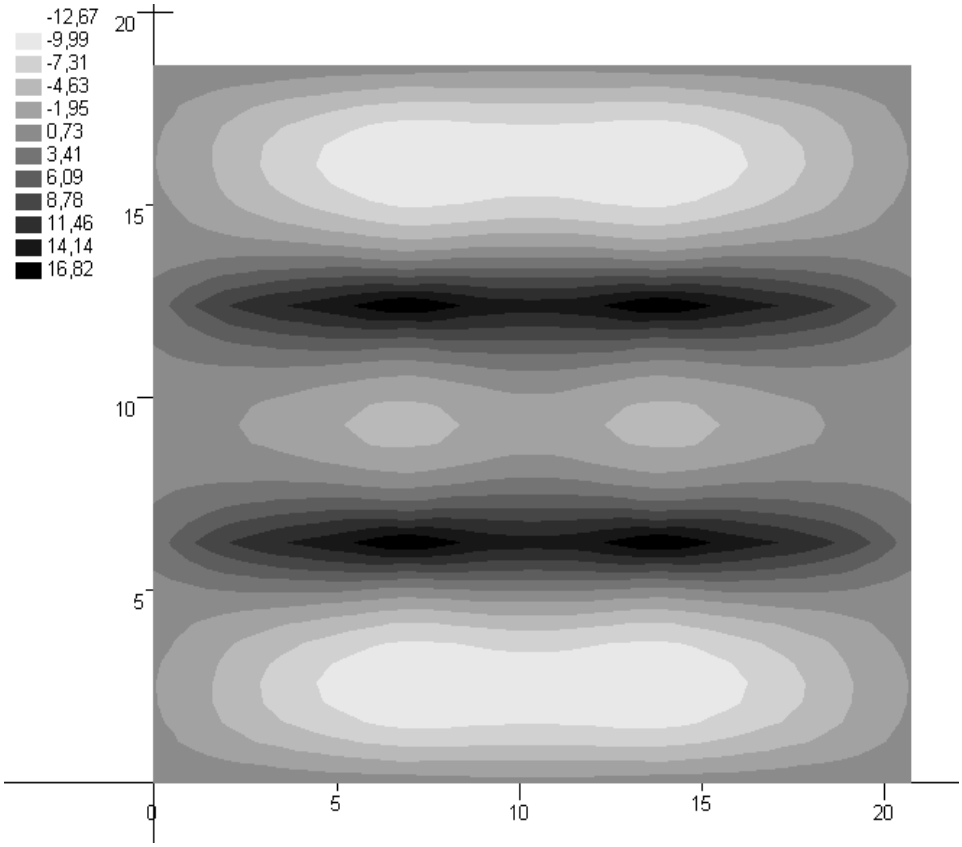


Slika 4.2. Momenti My (kNm)

4.1.2. Dodatno stalno opterećenje

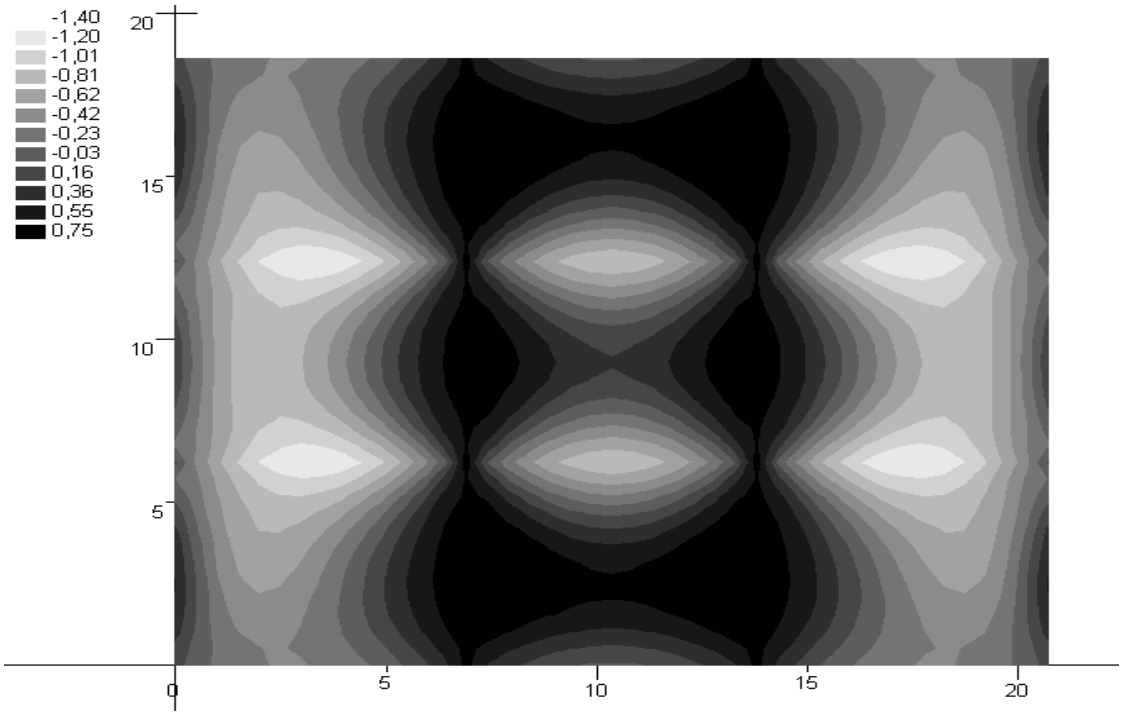


Slika 4.3. Momenti Mx (kNm)

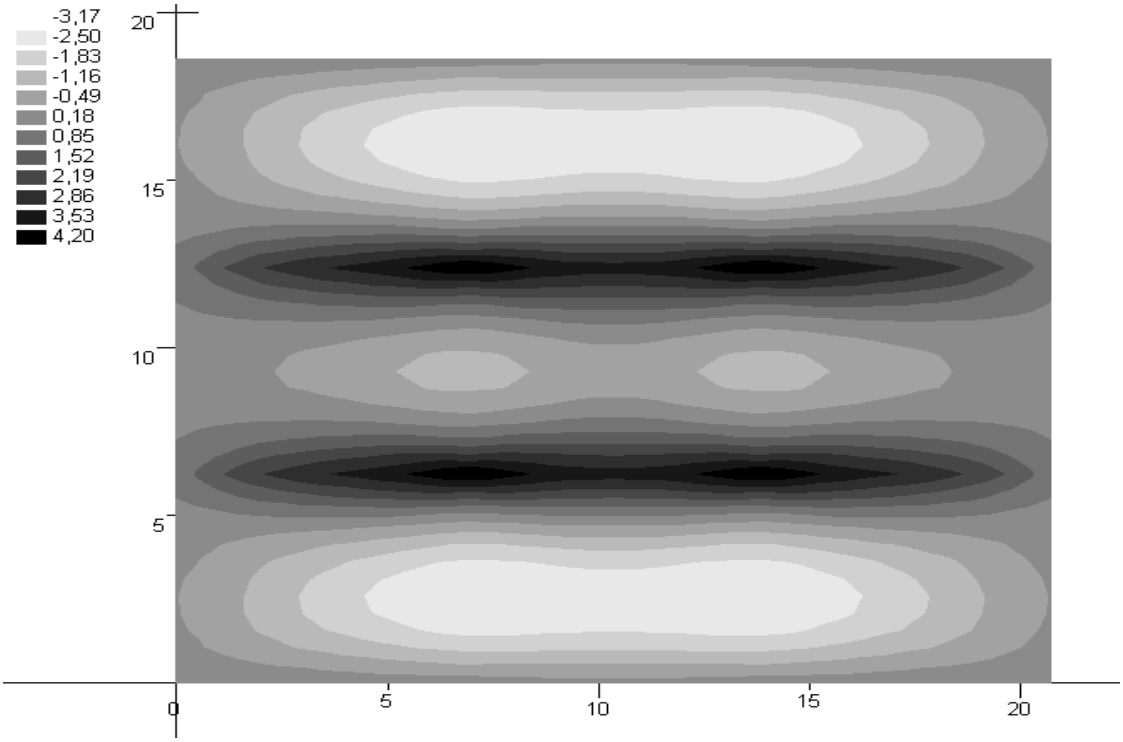


Slika 4.4. Momenti My(kNm)

4.1.3. Uporabnoopterećenje



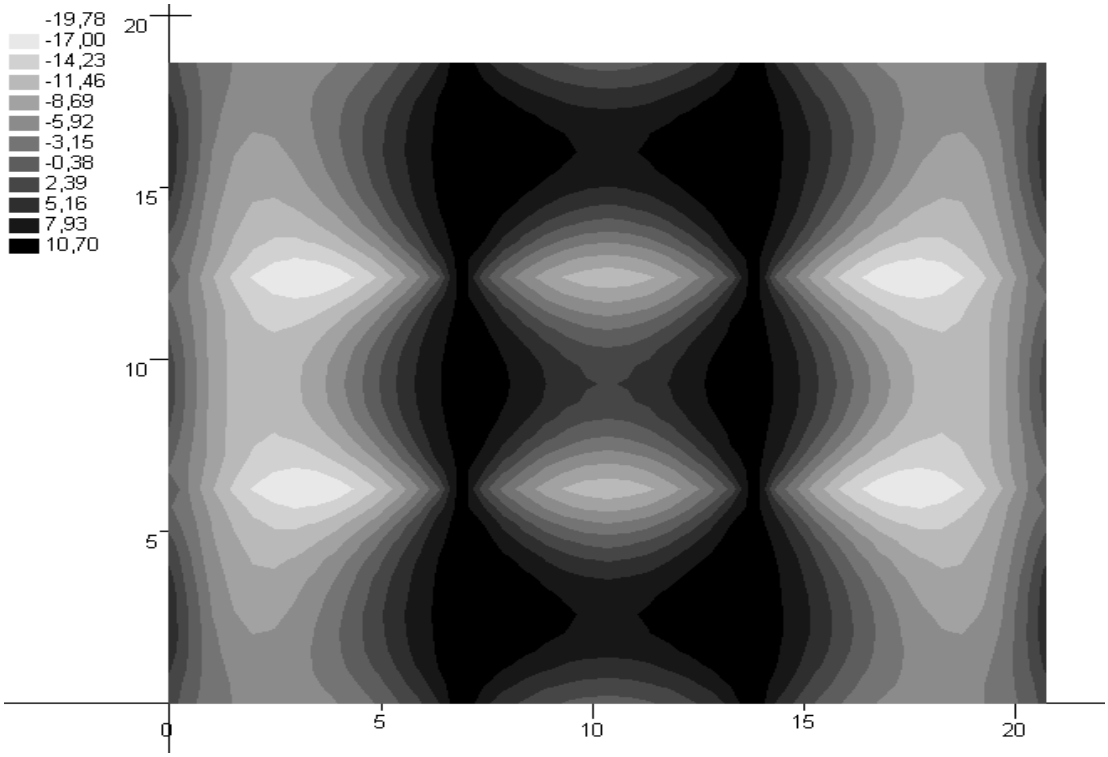
Slika 4.5. Momenti Mx (kNm)



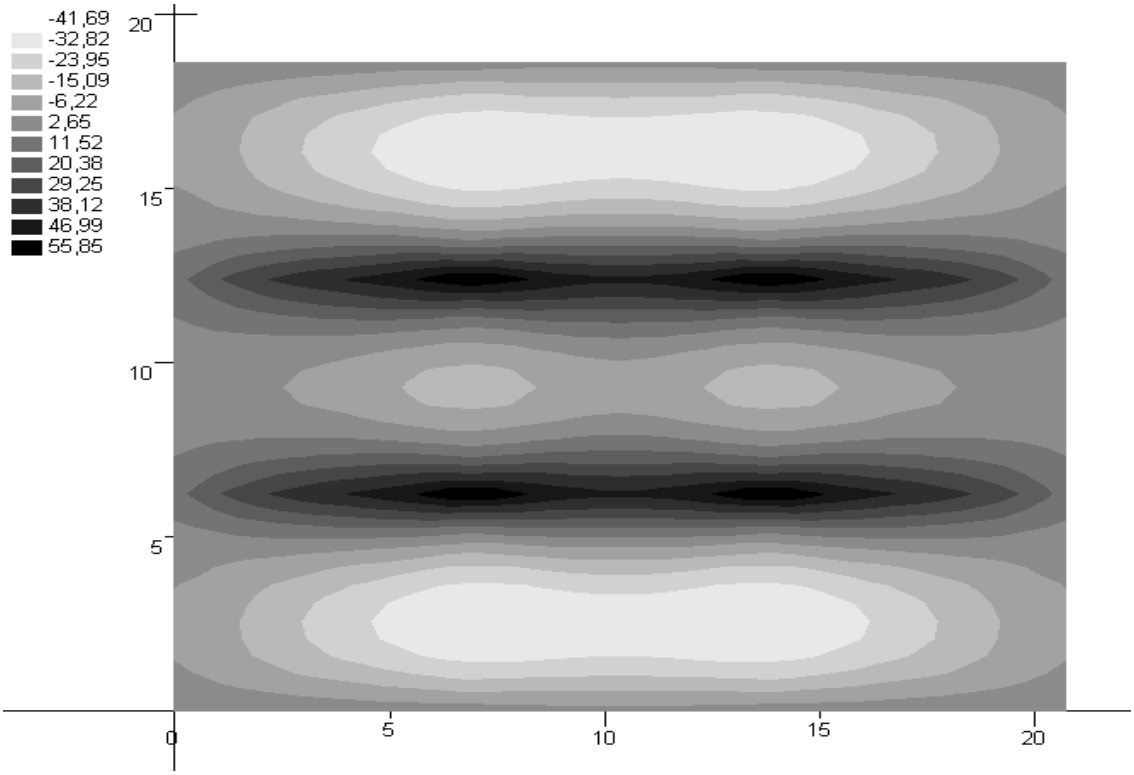
Slika 4.6. Momenti My (kNm)

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 40/50;

$f_{ck} = 40{,}0$ MPa =40 N/mm^2 ; γ_c =1.5

$f_{cd} = f_{ck}/\gamma_c = 40{,}0/1{,}5 = 26{,}67$ MPa = 26.67 N/mm^2 =2,67 kN/cm^2

ARMATURA:B 500 B;

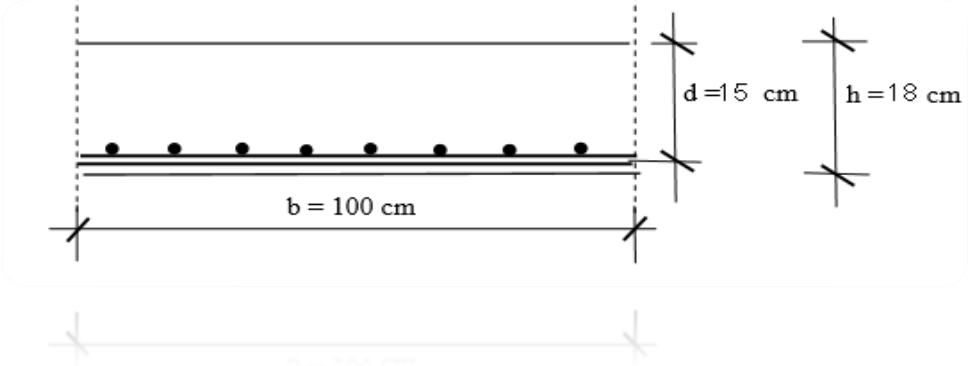
$f_{yk} = 500{,}0$ MPa = 500 N/mm^2 ; γ_s=1,15

$f_{yd} = f_{yk}/\gamma_s = 500{,}0/1{,}15 = 434{,}78$ MPa =434.78 N/mm^2=43.48 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

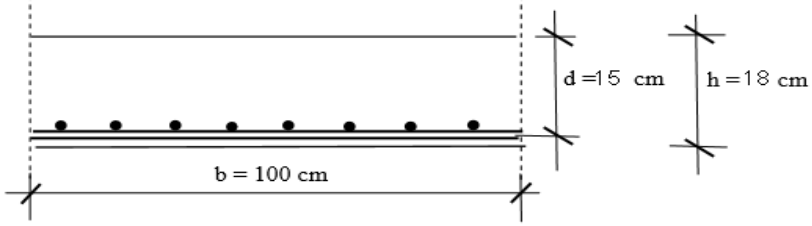
STATIČKA VISINA PLOČE:

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}= 41,69kNm/m

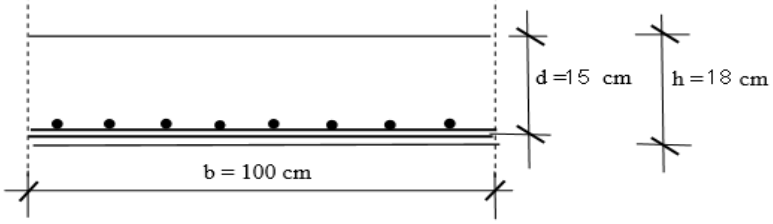
$$\mu_{sd} = \frac{M_{ed}}{b_{eff} \cdot d^2 . f_{cd}} = \frac{4169}{100 * 15^2 * 2,67} = 0,069$$

Očitano: : ε_{s1} = 10,0 ‰ ε_{c2} = 1,7 ‰ ζ = 0,947 ξ = 0,145

$$A_{s1} = \frac{M_{ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{4169}{0,947 * 15 * 43,48} = 6,75 \text{ cm}^2/\text{m}$$

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

Ploča 202 - Polje



M_{ed}=18,53kNm/m

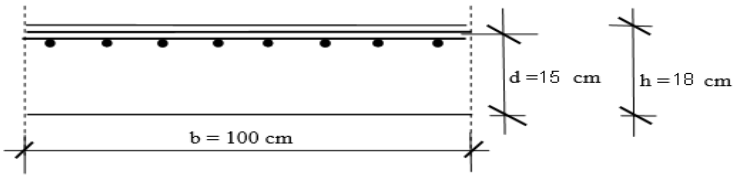
$$\mu_{sd} = \frac{M_{ed}}{b_{eff} \cdot d^2 . f_{cd}} = \frac{1853}{100 \cdot 15^2 \cdot 2,67} = 0,031$$

Očitano: : ε_{s1} = 10,0 ‰ ε_{c2} = 1,0 ‰ ζ = 0,968 ξ = 0,091

$$A_{s1} = \frac{M_{ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{1853}{0,968 \cdot 15 \cdot 43,48} = 2,94 \text{ cm}^2/m$$

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

Ležaj 201-202



M_{ed}= 55,85kNm/m

$$\mu_{sd} = \frac{M_{ed}}{b_{eff} \cdot d^2 . f_{cd}} = \frac{5585}{100 \cdot 15^2 \cdot 2,67} = 0,093$$

Očitano: : ε_{s1} = 10,0 ‰ ε_{c2} = 2,1‰ ζ = 0,934 ξ = 0,174

$$A_{s1} = \frac{M_{ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{5585}{0,934 \cdot 15 \cdot 43,48} = 9,17 \text{ cm}^2/\text{m}$$

ODABRANO: **R-785** (As = 7,85 cm^2 /m) + preklop povećan na 40 cm

$$A'_{s1} = A_{s1} \cdot \frac{š_m + p_m}{š_m} = 7,85 \cdot \frac{215 + 40}{215} = 9,31 \text{ cm}^2/m$$

Minimalna armatura:

As1,min ≥ 0,26 · [fct,m / fyk]· bt · d ≥ 0,0013 ·bt · d

bt – širina vlačne zone

d – statička visina presjeka

fyk – karakt. granica popuštanja čelika u N/mm2

[fyk = 500 N/mm2 za čelik B 500B]

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

[fctm = 356 N/mm2 za C 40/50]

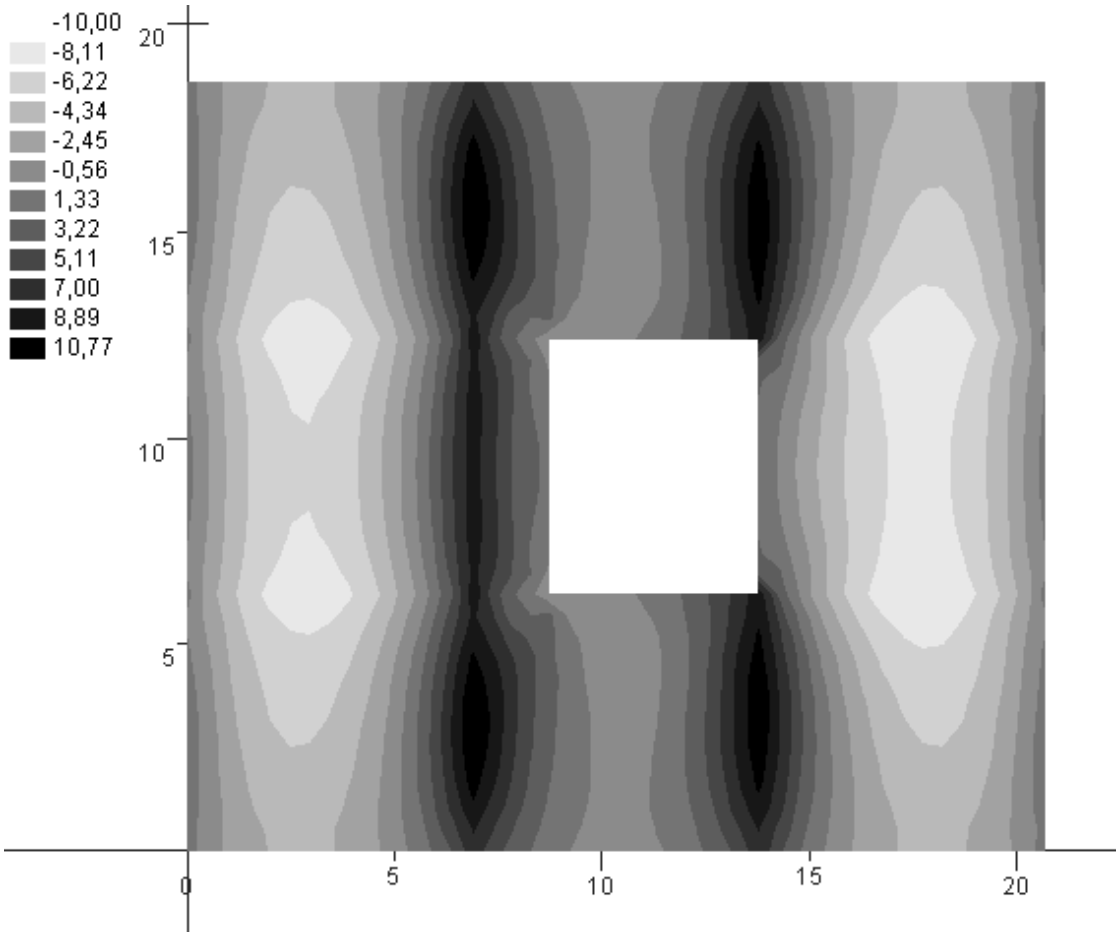
As1,min ≥ 0,26 ·3.5/ 500 ·100 ·15,0 = 2.73 cm2 /m

As1,min ≥ 0,0013 ·bt · d = 0,0013 ·100 ·15,0 = 1,95 cm2 /m

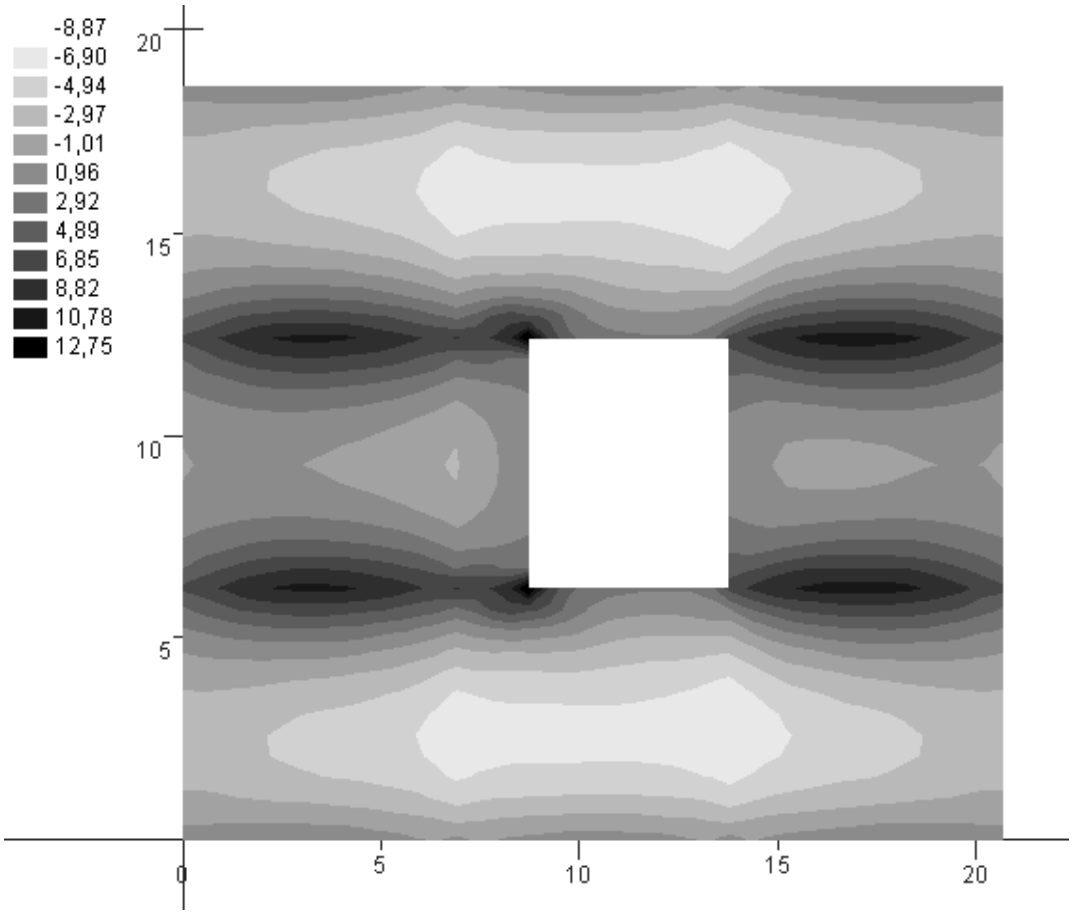
5. PRORAČUN PLOČA POZICIJE 100

5.1. **MOMENTI SAVIJANJA U PLOČI POZICIJE 100**

5.1.1. Vlastita težina

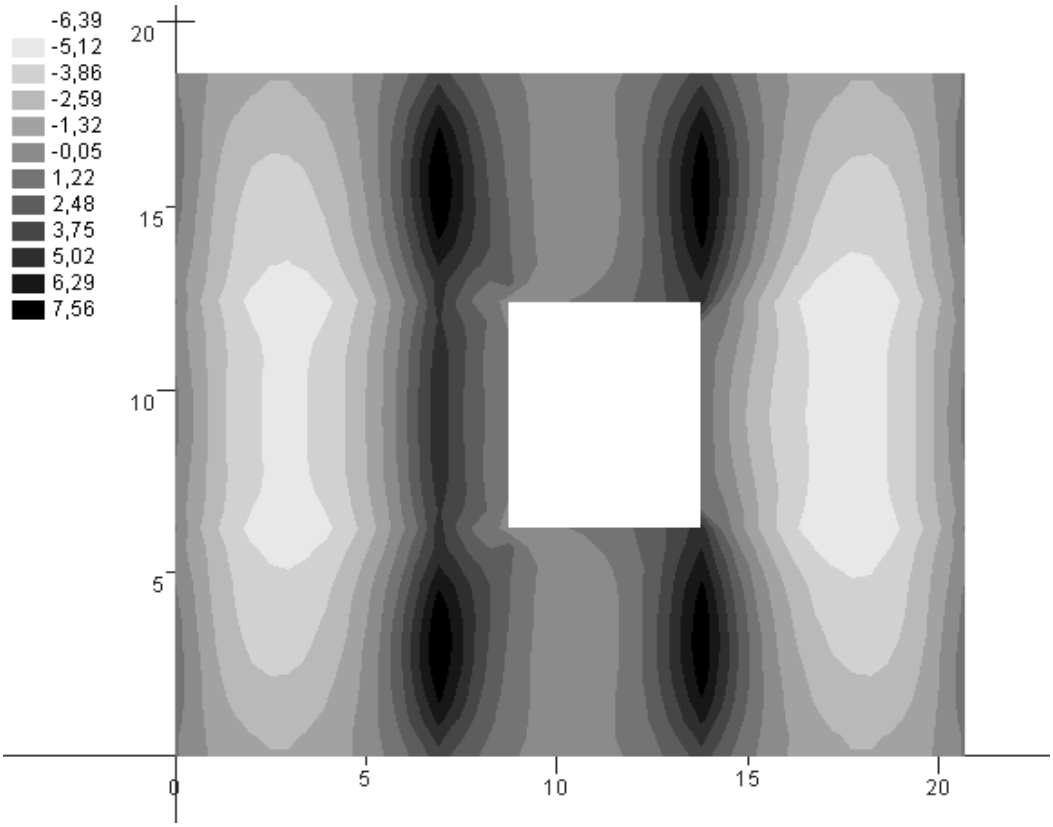


Slika 5.1. Momenti Mx (kNm)

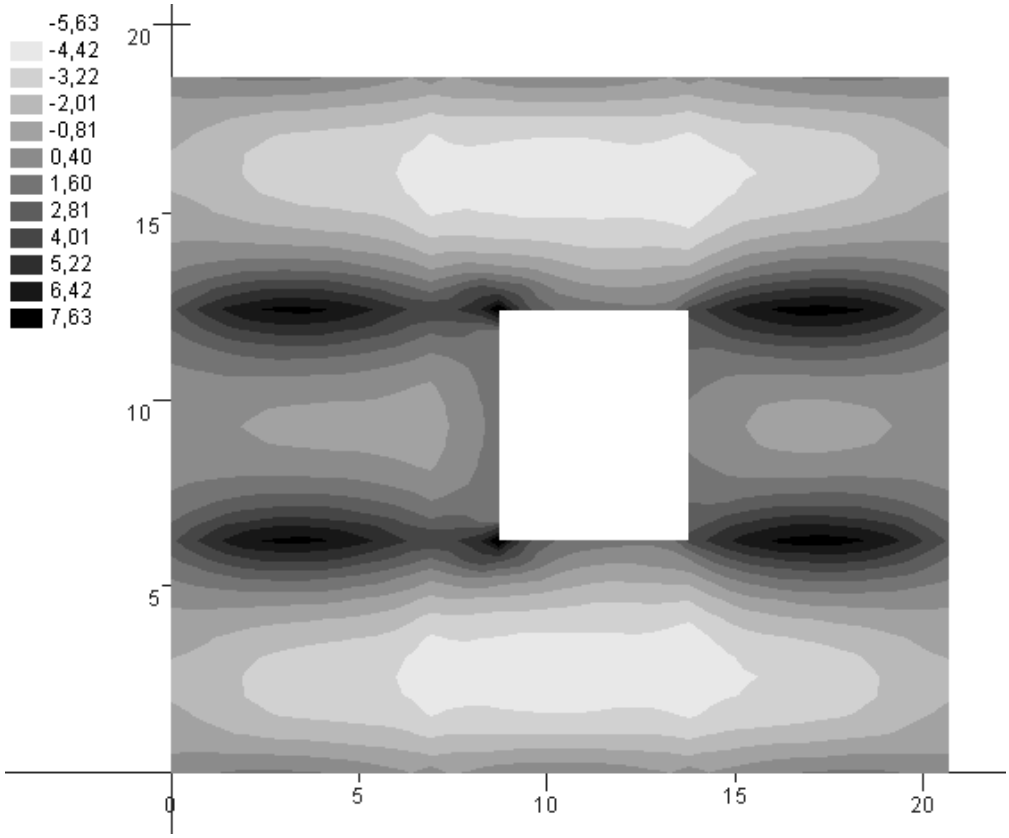


Slika 5.2. Momenti My (kNm)

5.1.2. Dodatno stalno opterećenje

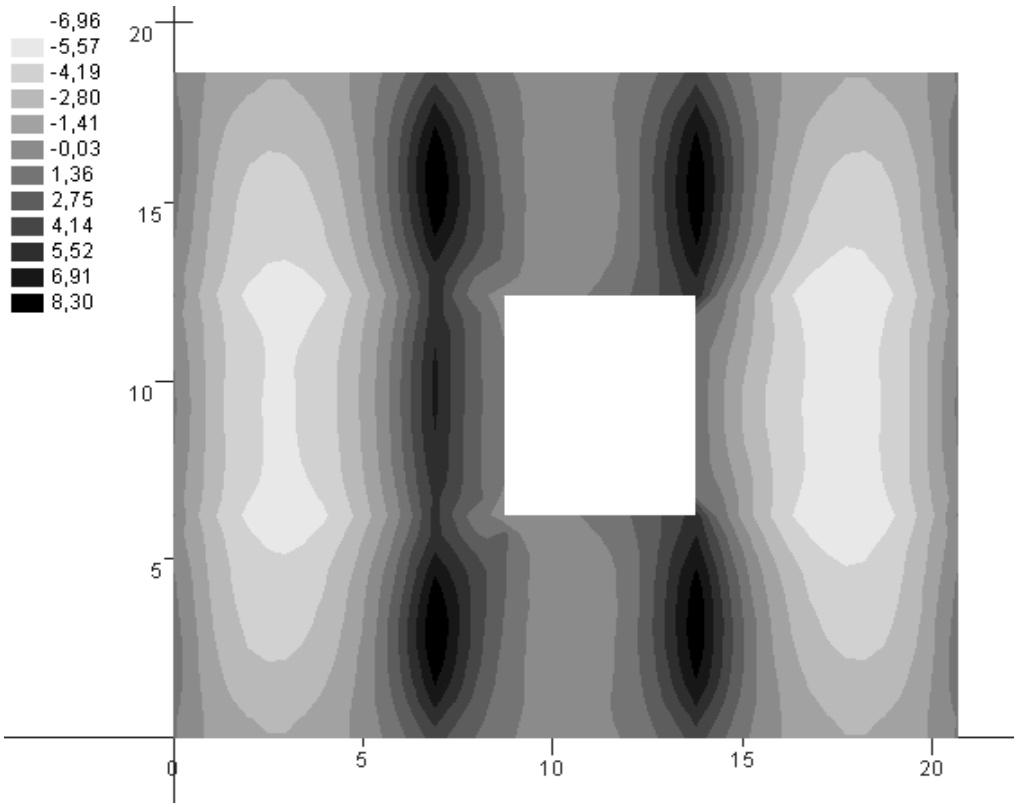


Slika 5.3. Momenti Mx (kNm)

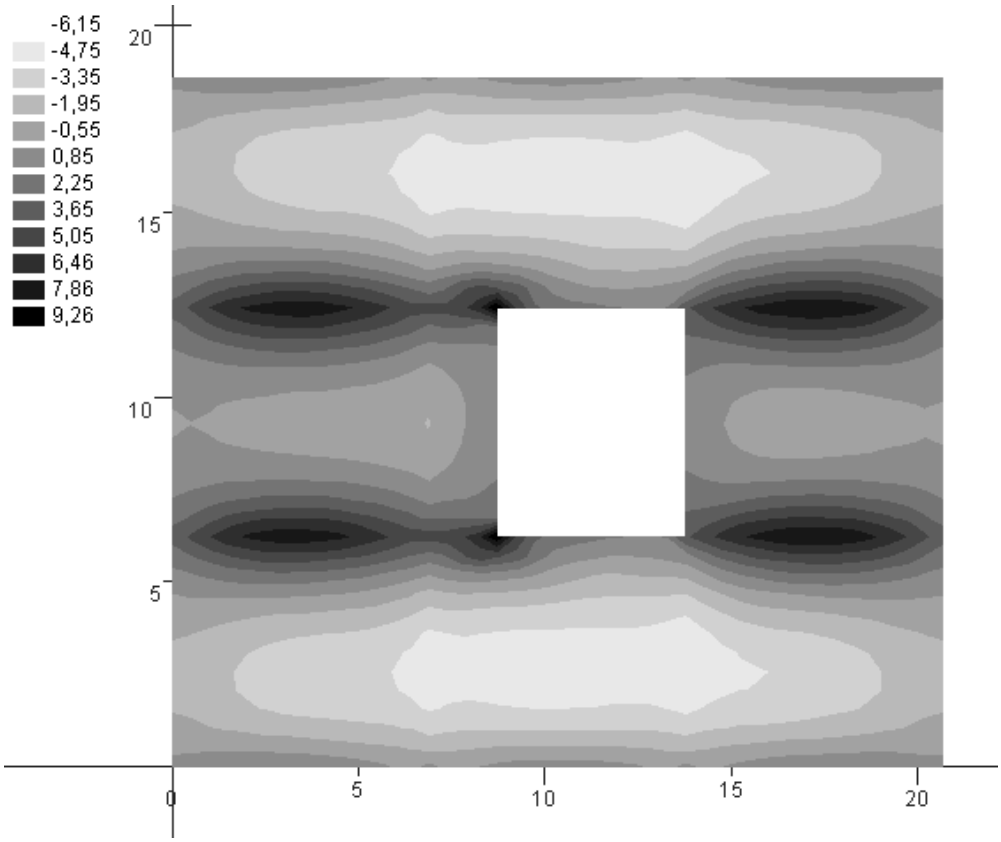


Slika 5.4. Momenti My (kNm)

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

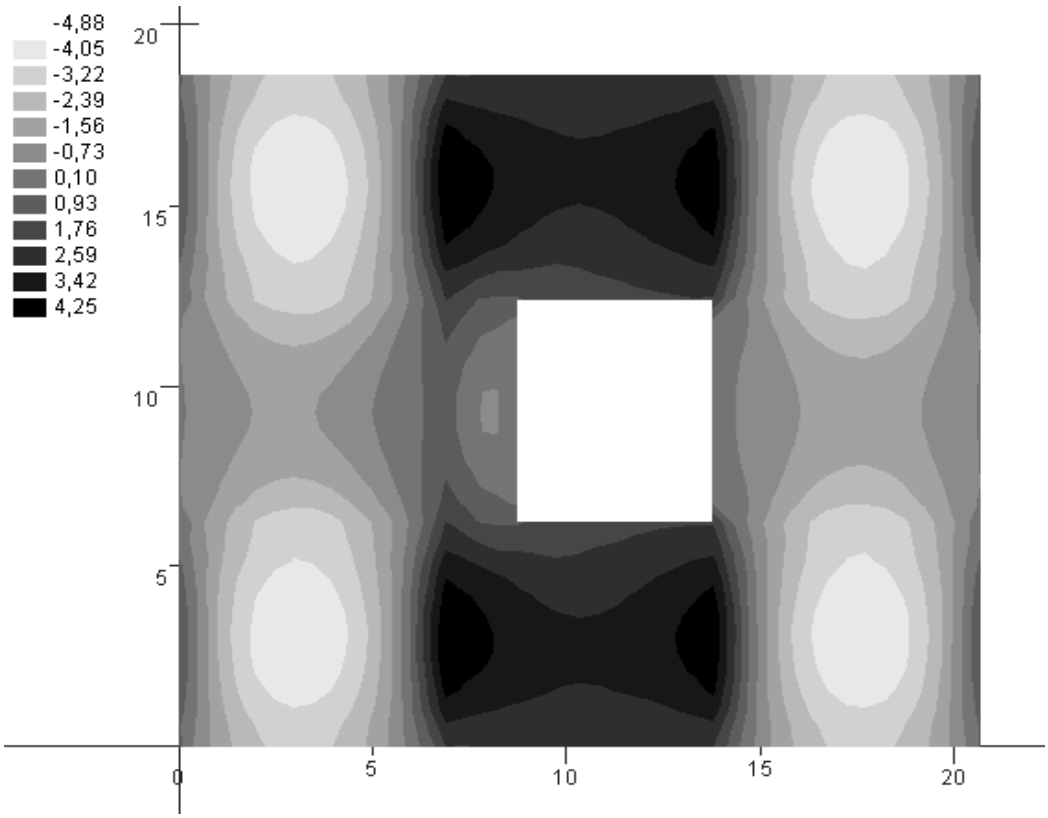


Slika 5.5. Momenti Mx (kNm)

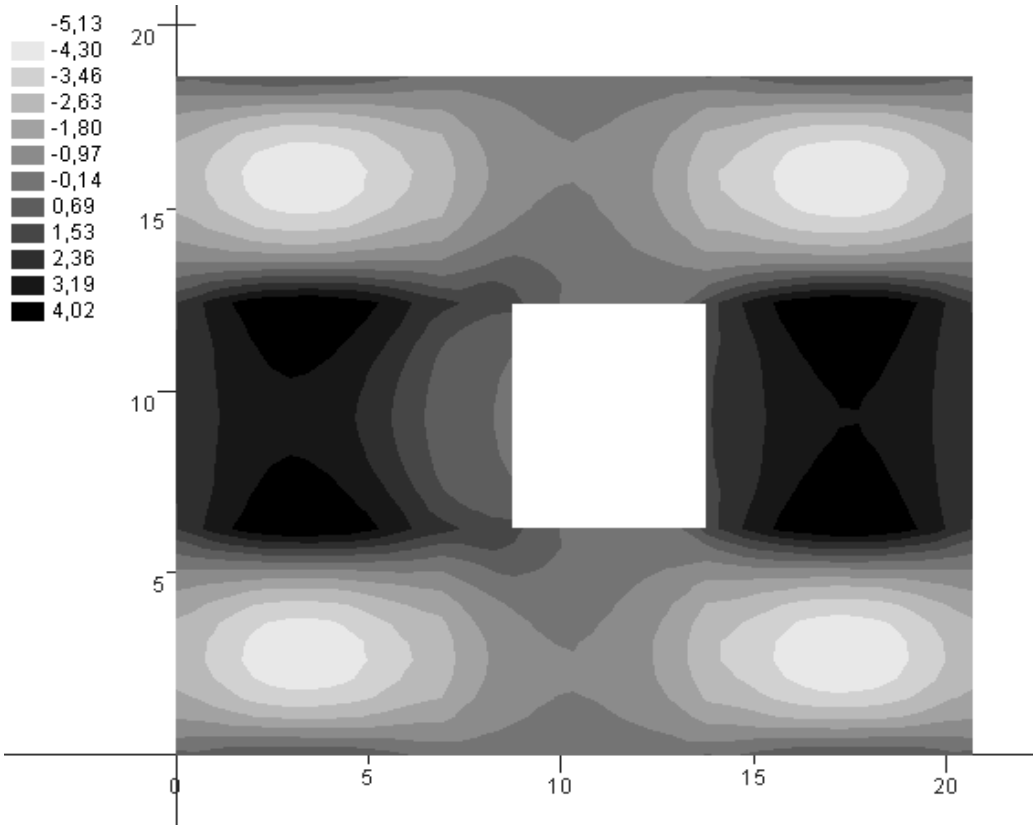


Slika 5.6. Momenti My (kNm)

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

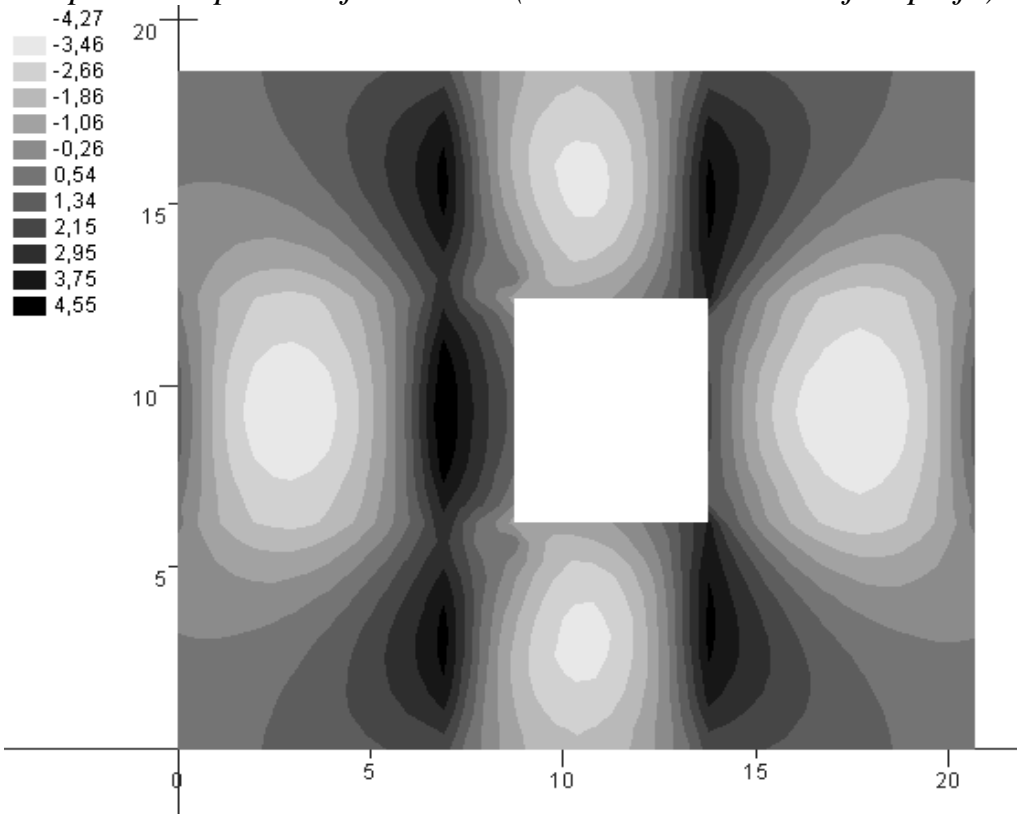


Slika 5.7. Momenti Mx (kNm)

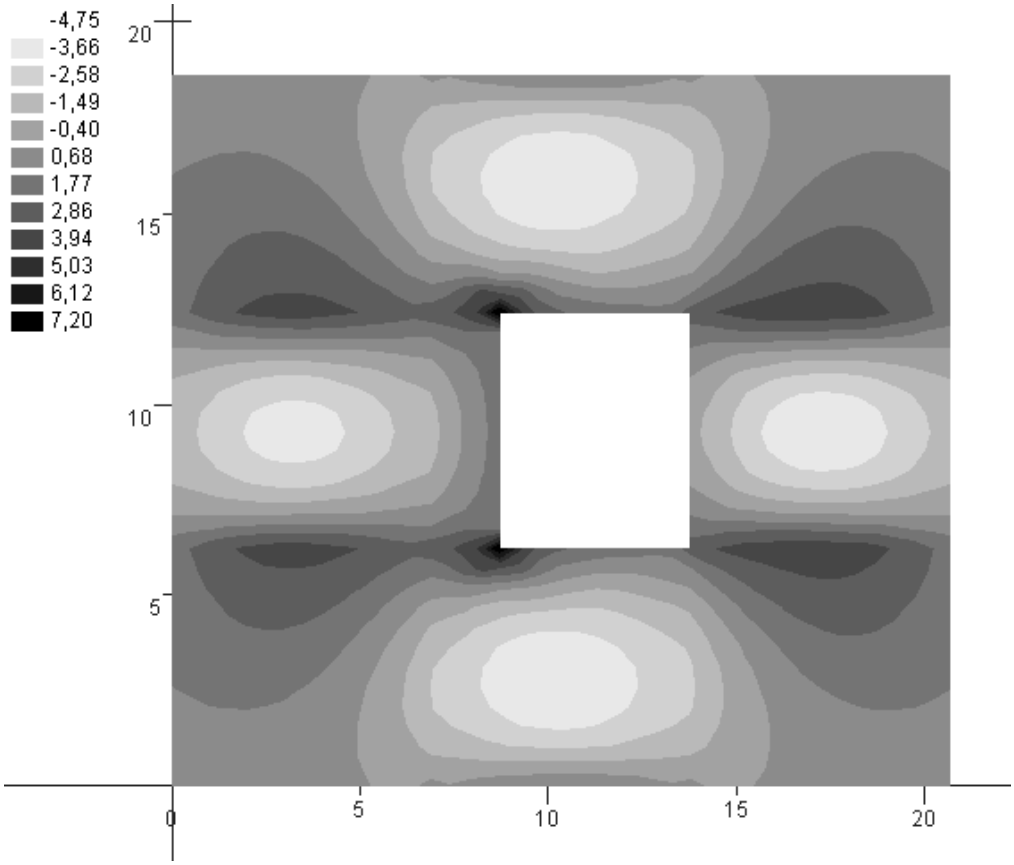


Slika 5.8. Momenti My (kNm)

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



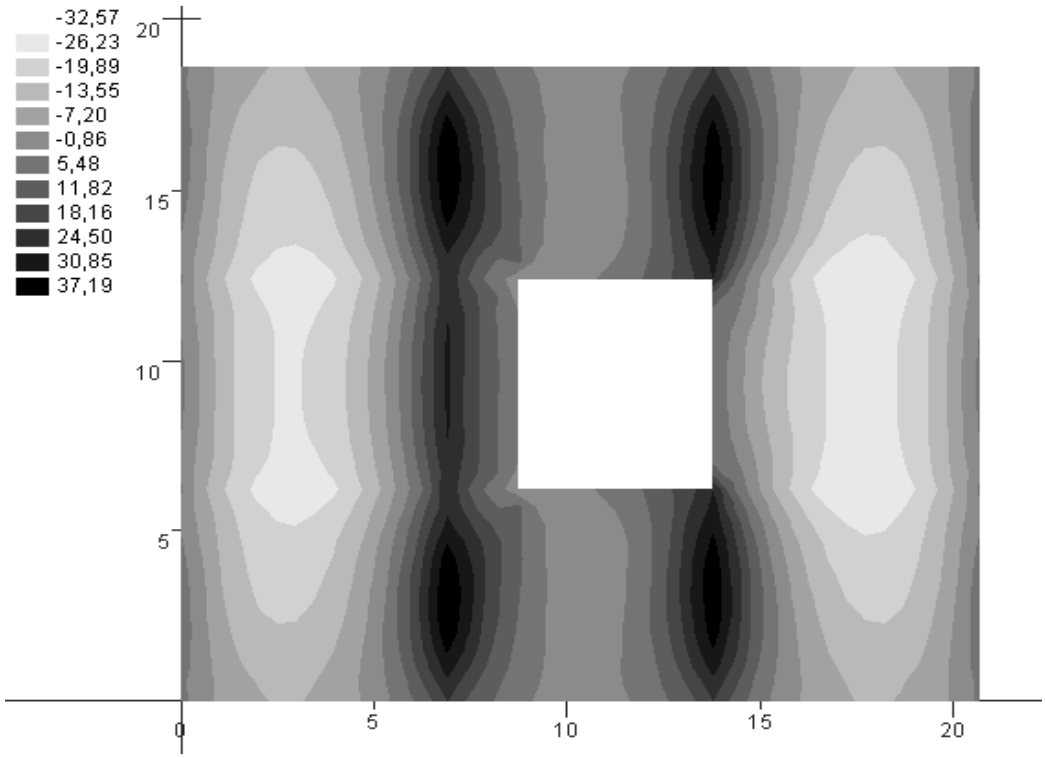
Slika 5.9. Momenti Mx (kNm)



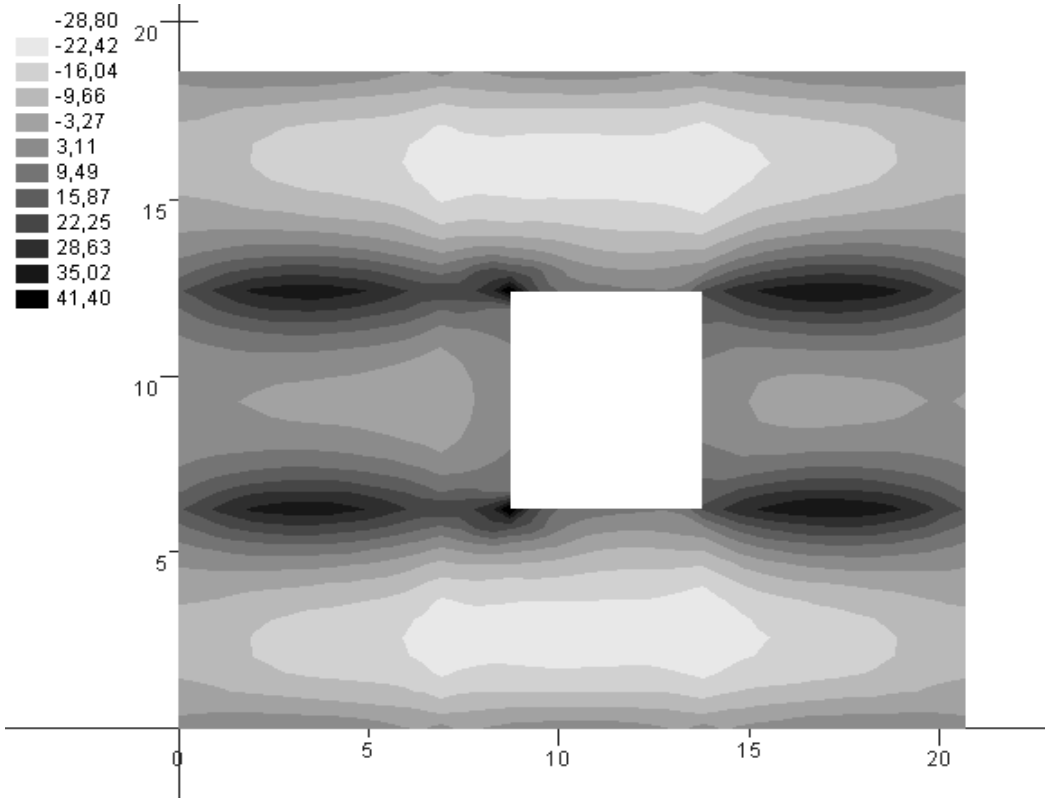
Slika 5.10. Momenti My (kNm)

5.1.6. GSN za ležajeve

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

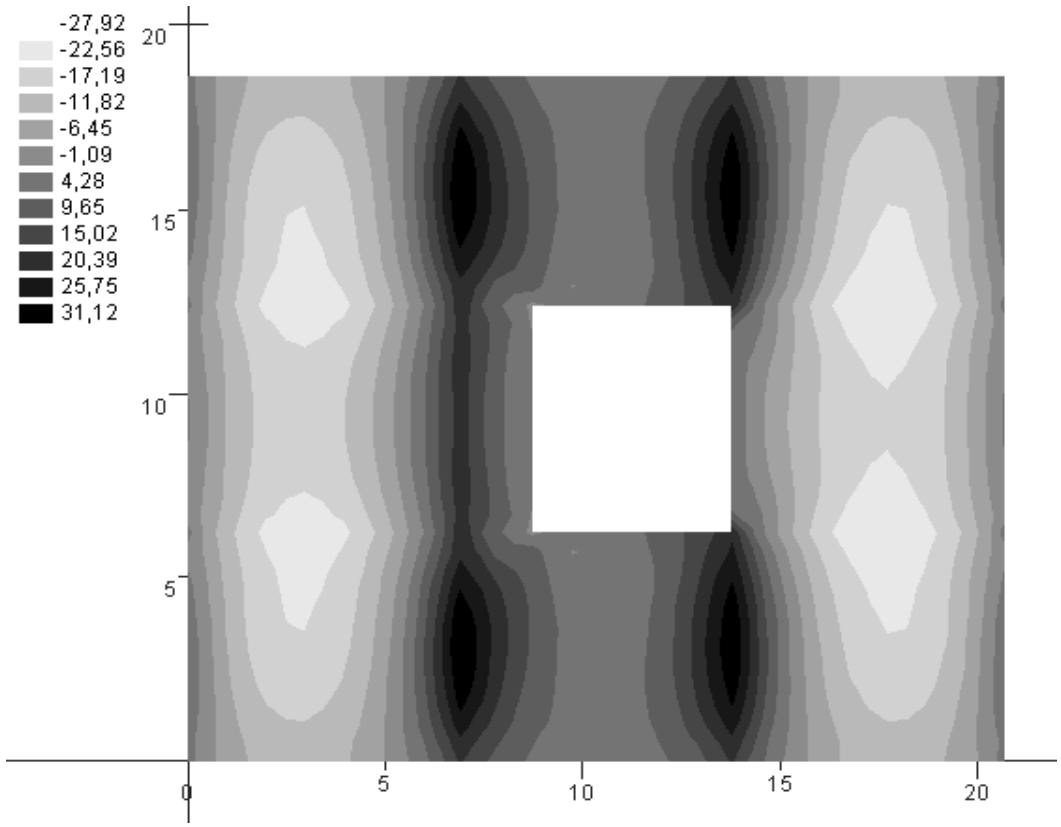


Slika 5.11. Momenti Mx (kNm)

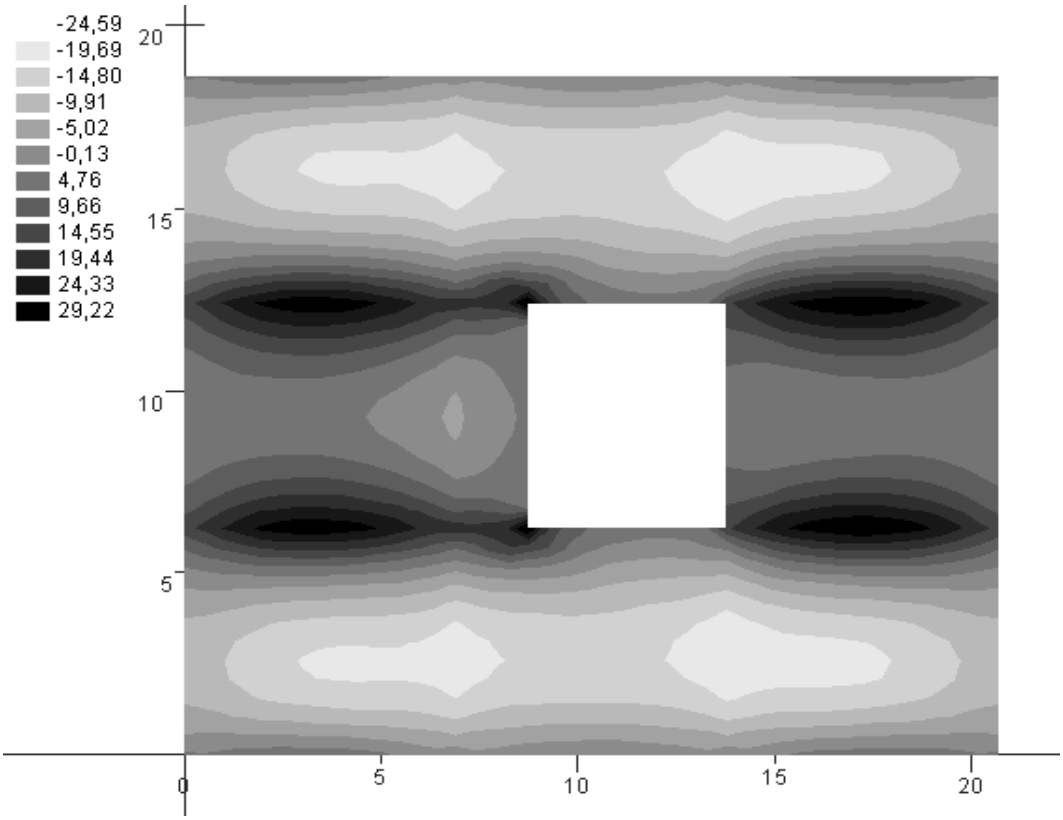


Slika 5.12. Momenti My (kNm)

5.1.7. GSN za krajnja polja

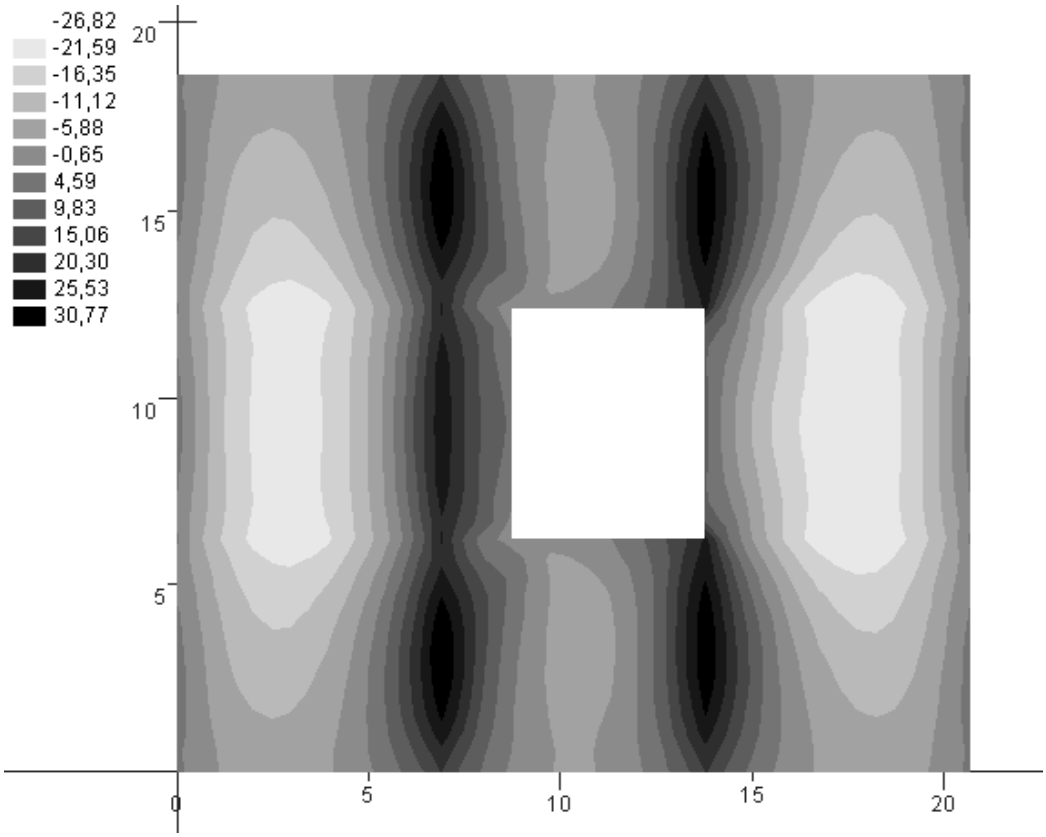


Slika 5.13. Momenti Mx (kNm)

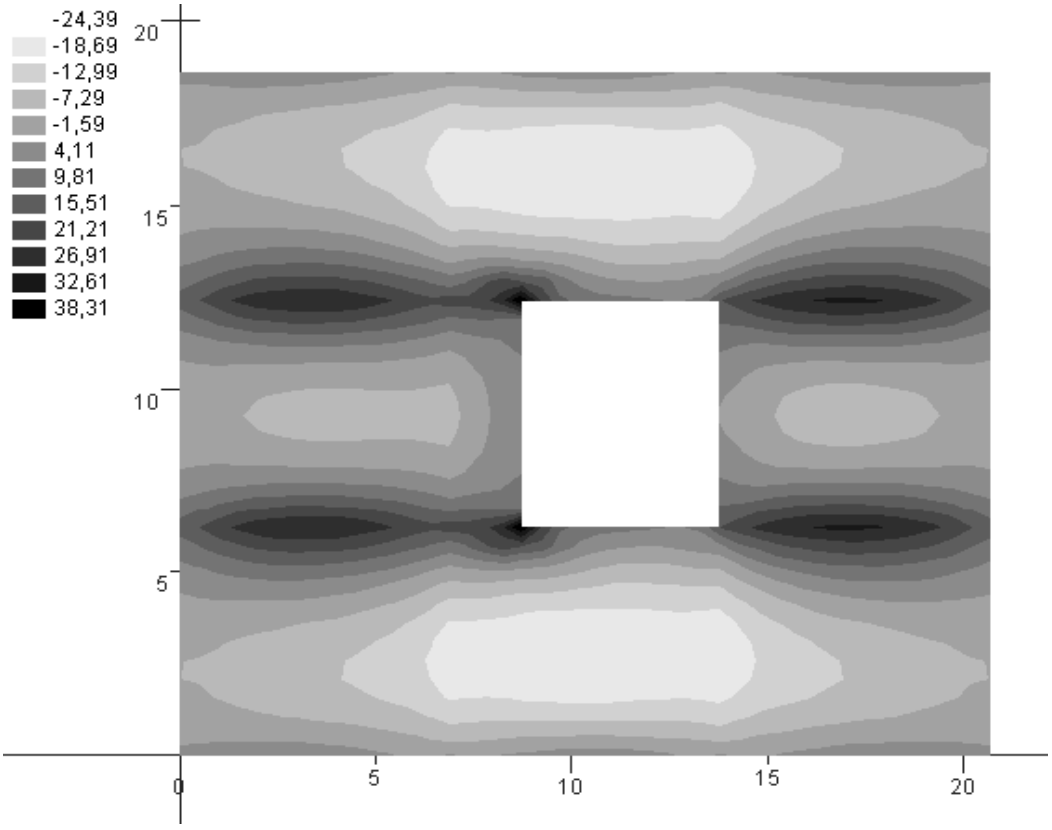


Slika 5.14. Momenti My (kNm)

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 40/50;

$f_{ck} = 40{,}0$ MPa= 40 N/mm^2 ; γ_c=1.5

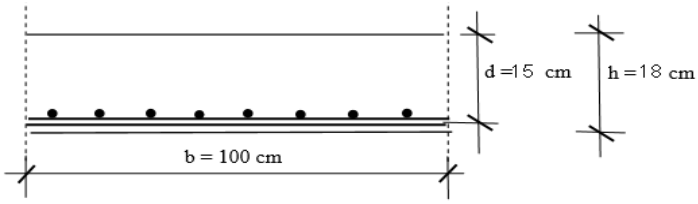
$f_{cd} = f_{ck}/\gamma_c = 40{,}0/1{,}5 = 26{,}67$ MPa = 26.67 N/mm^2 = 2,67 kN/cm ^{2}

ARMATURA:B 500 B;

$f_{yk} = 500{,}0$ MPa = 500 N/mm^2 ; γ_s = 1,15

$f_{yd} = f_{yk}/\gamma_s = 500{,}0/1{,}15 = 434{,}78$ MPa = 434.78 N/mm^2= 43.48 kN/cm^2

Ploča 101 – polje



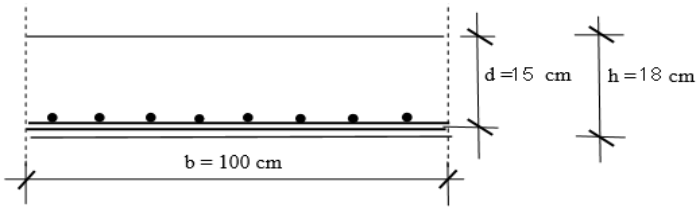
$M_{Ed} = 27.92\ kNm/m$

$$\mu_{sd} = \frac{M_{Ed}}{b \cdot d^2 \cdot f_{cd}} = \frac{2792}{100 \cdot 15^2 \cdot 2.67} = 0.046$$

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

$$A_{s1} = \frac{M_{Ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{2792}{0.959 \cdot 15 \cdot 43.48} = 4{,}46\,cm^2/m$$

Ploča 102 – polje



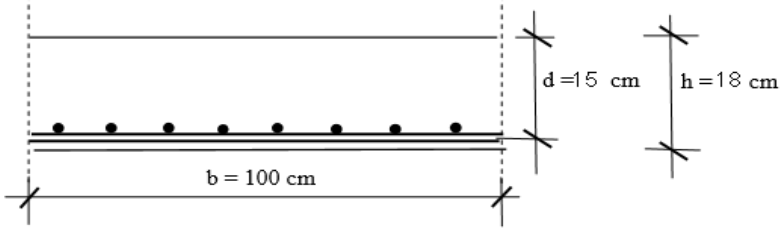
$M_{Ed} = 24.39\ kNm/m$

$$\mu_{sd} = \frac{M_{Ed}}{b \cdot d^2 \cdot f_{cd}} = \frac{2439}{100 \cdot 15^2 \cdot 2.67} = 0.041$$

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

$$A_{s1} = \frac{M_{Ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{2439}{0.962 \cdot 15 \cdot 43.48} = 3.89\ cm^2/m$$

Ploča 103 – polje



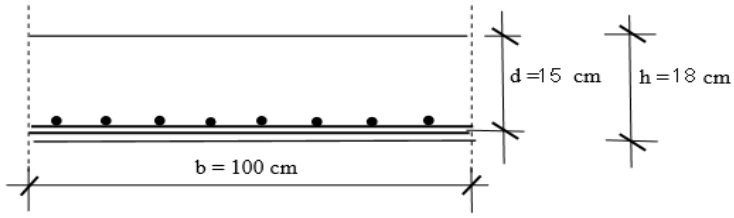
$$M_{Ed} = 26.82\ kNm/m$$

$$\mu_{sd} = \frac{M_{Ed}}{b \cdot d^2 \cdot f_{cd}} = \frac{2682}{100 \cdot 15^2 \cdot 2.67} = 0.045$$

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

$$A_{s1} = \frac{M_{Ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{2682}{0.959 \cdot 15 \cdot 43.48} = 4{,}30\,cm^2/m$$

Ploča 104 – polje



$$M_{Ed} = 16.84\ kNm/m$$

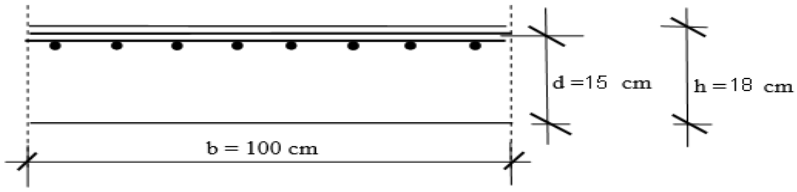
$$\mu_{sd} = \frac{M_{Ed}}{b \cdot d^2 \cdot f_{cd}} = \frac{1684}{100 \cdot 15^2 \cdot 2.67} = 0.028$$

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

$$A_{s1} = \frac{M_{Ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{1684}{0.968 \cdot 15 \cdot 43.48} = 2.67\ cm^2/m$$

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

Ležaj 101 – 102



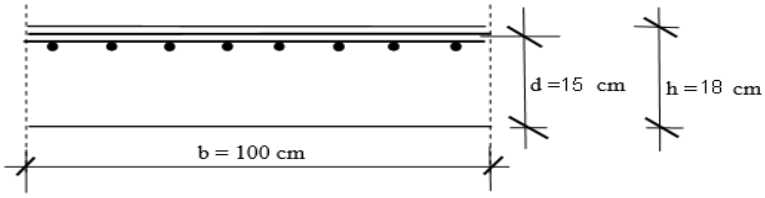
$M_{Ed} = 37.19\ kNm/m$

$$\mu_{sd} = \frac{M_{Ed}}{b \cdot d^2 \cdot f_{cd}} = \frac{3719}{100 \cdot 15^2 \cdot 2.67} = 0.062$$

Očitano: $\varepsilon_{s1} = 10.0\,‰ \quad \varepsilon_{c2} = 1.6\,‰ \quad \xi = 0.138 \quad \zeta = 0.950$

$$A_{s1} = \frac{M_{Ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{3719}{0.950 \cdot 15 \cdot 43.48} = 6{,}00\ cm^2/m$$

Ležaj 101 – 103



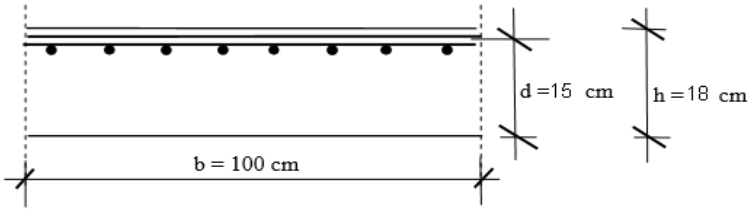
$M_{Ed} = 41.40\ kNm/m$

$$\mu_{sd} = \frac{M_{Ed}}{b \cdot d^2 \cdot f_{cd}} = \frac{4140}{100 \cdot 15^2 \cdot 2.67} = 0.069$$

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

$$A_{s1} = \frac{M_{Ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{4140}{0.947 \cdot 15 \cdot 43.48} = 6{,}7\ cm^2/m$$

Ležaj 103 – 104



$M_{Ed} = 29.44\ kNm/m$

$$\mu_{sd} = \frac{M_{Ed}}{b \cdot d^2 \cdot f_{cd}} = \frac{2944}{100 \cdot 15^2 \cdot 2.67} = 0.049$$

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

$$A_{s1} = \frac{M_{Ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{2944}{0.956 \cdot 15 \cdot 43.48} = 4.72\ cm^2/m$$

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 ≥ 0,0013 ·bt · d

b t – širina vlačne zone

d – statička visina presjeka

fyk – karakt. granica popuštanja čelika u N/mm2

[fyk = 500 N/mm2 za čelik B 500B]

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

[fctm = 3.5 N/mm2 za C 40/50]

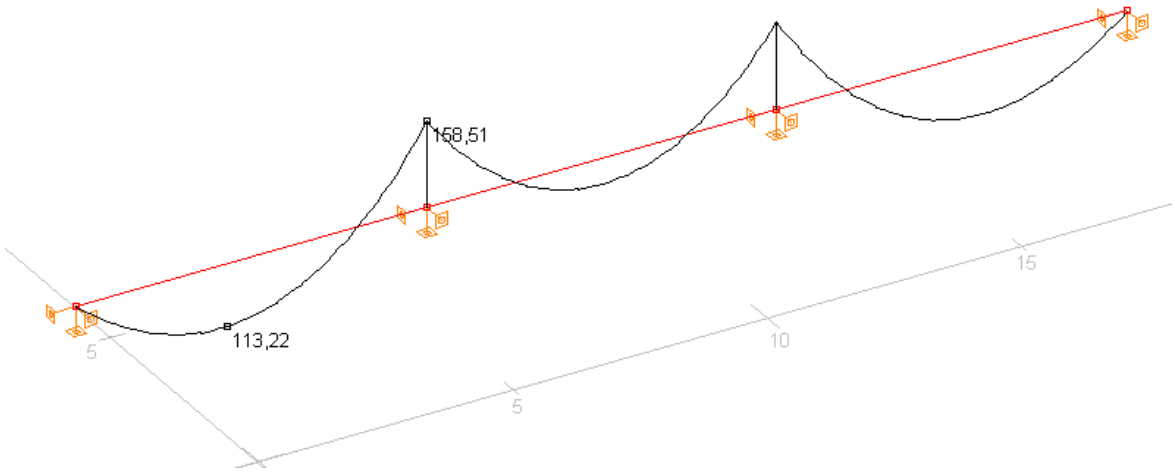
As1,min ≥ 0,26 ·3.5/ 500 ·100 ·15,0 = 2.73 cm2 /m

As1,min ≥ 0,0013 ·bt · d = 0,0013 ·100 ·15,0 = 1,95 cm2 /m

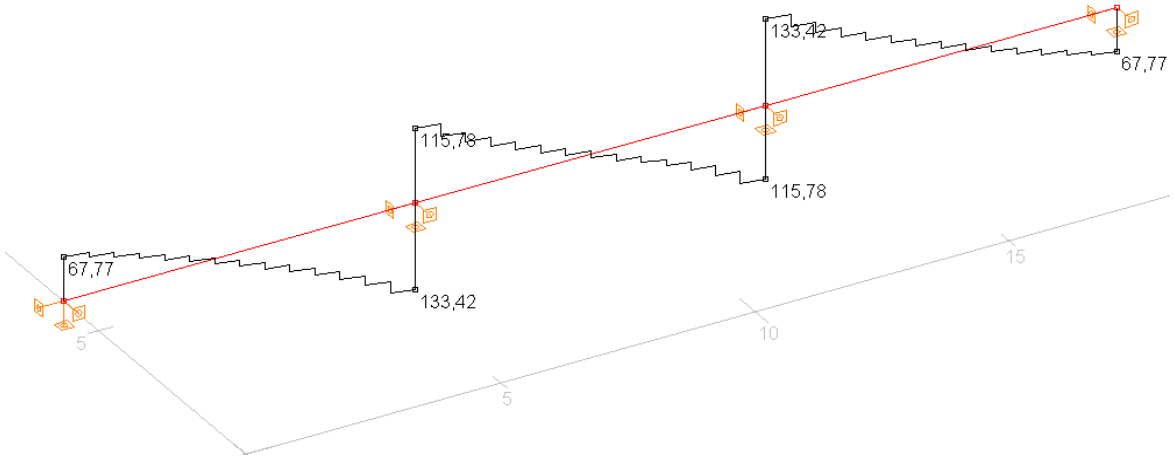
6. *PRORAČUN KONTINUIRANOG NOSAČA POZICIJE 200*

6.1. **MOMENTI SAVIJANJA I POPREČNE SILE GREDE POZICIJE 200**

6.1.1. Vlastita težina

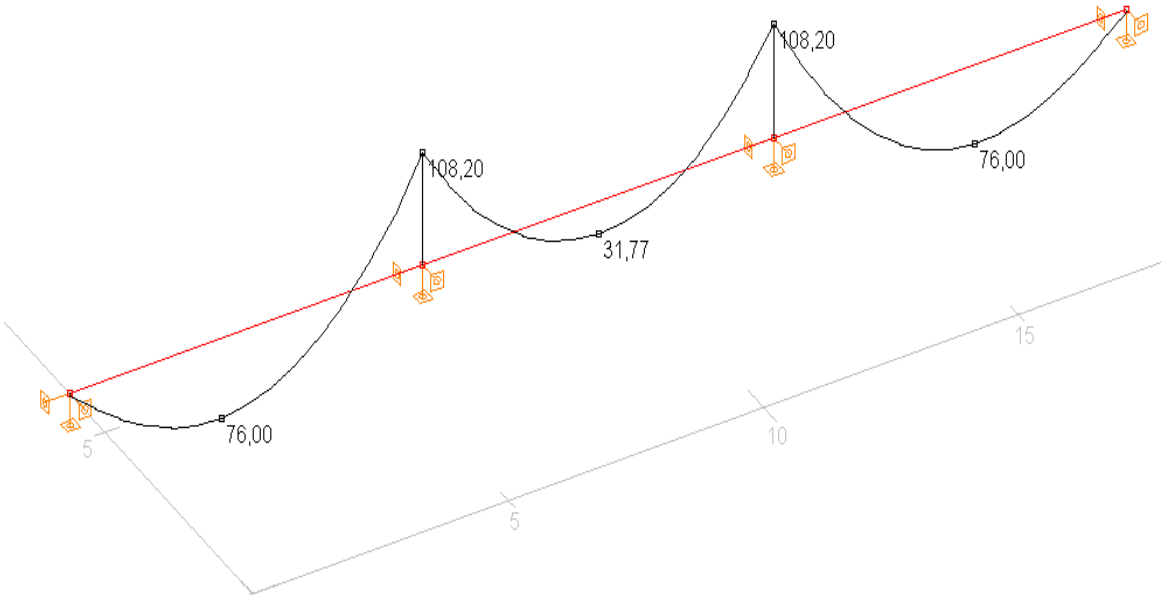


Slika 6.1. Momenti Mz (kNm)

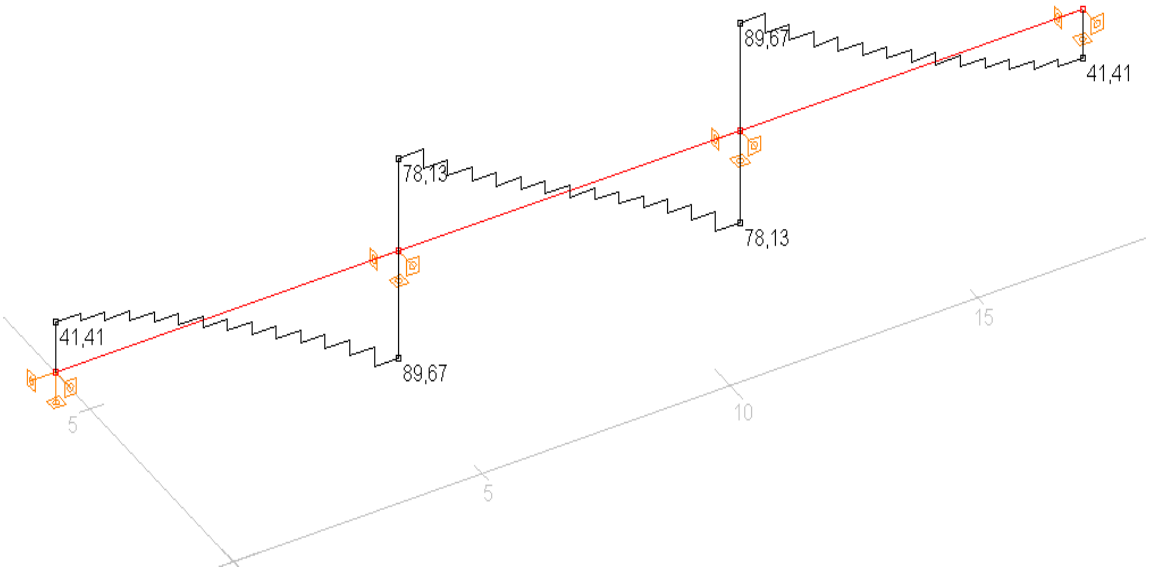


Slika 6.2. Poprečne sile Vy (kN)

6.1.2. Dodatno stalno opterećenje

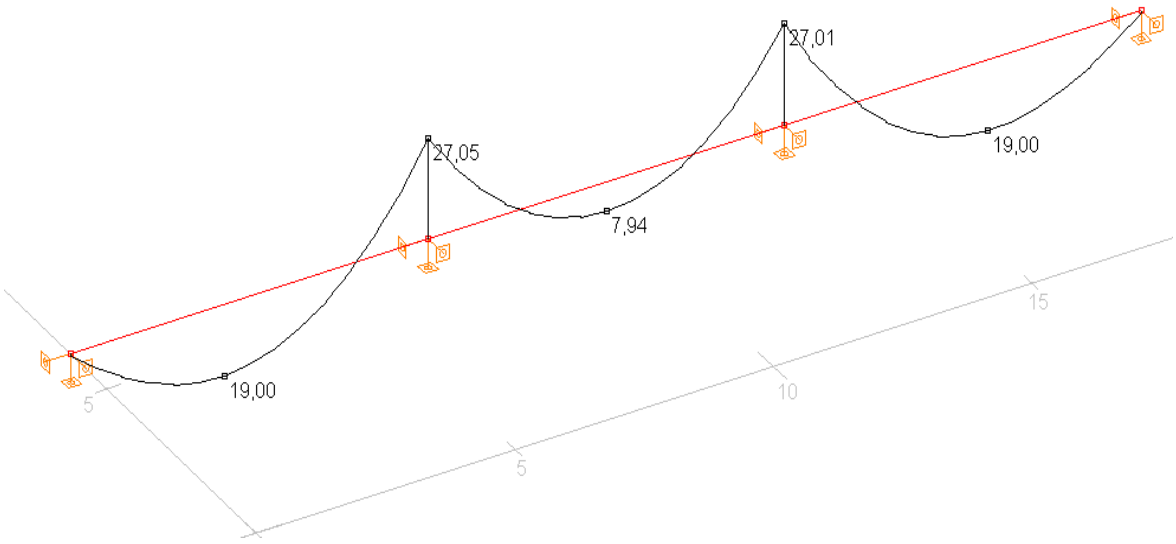


Slika 6.3. Momenti Mz (kNm)

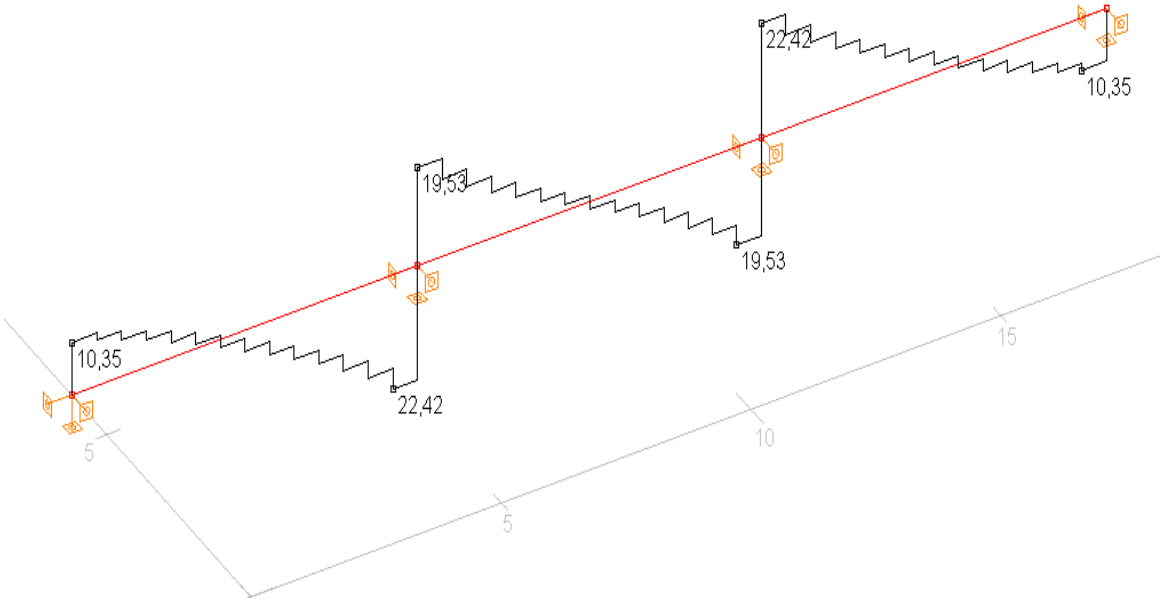


Slika 6.4. Poprečne sile Vy (kN)

*6.1.3. Uporabnooptere*ć*enje*



Slika 6.5. Momenti Mz (kNm)



Slika 6.6. Poprečne sile Vy (kN)

6.1.4. Granično stanje nosivosti

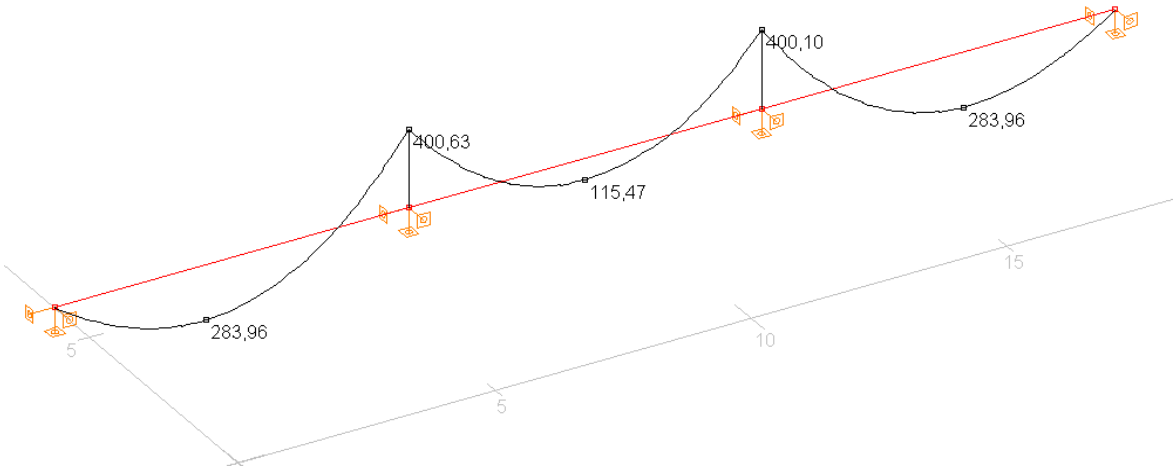
Mjerodavna kombinacija: $M_{ed}=1,35*(M_g+M_{\Delta g})+1,5*M_q$

Momenti:

$M_{Ed,polje1} = 283,96\ kNm$

$M_{Ed,ležaj} = -400,63\ kNm$

$M_{Ed,polje2} = 115,47 kNm$

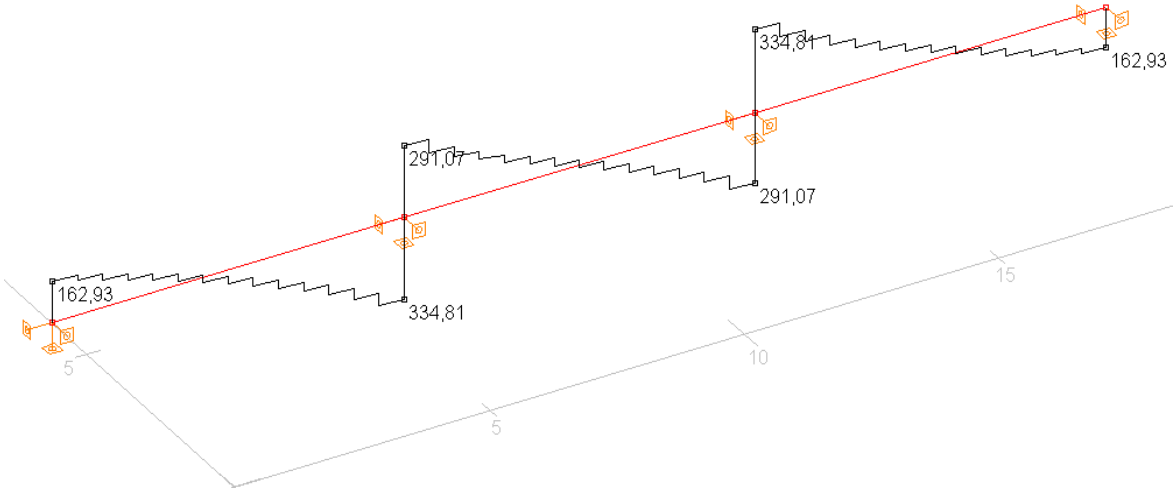


Slika 6.7. Momenti Mz (kNm)

Poprečne sile:

$V_{Ed,ležaj1} = 334,81\ kN$

$V_{Ed,ležaj0} = 162,93\ kN$



Slika 6.8. Poprečne sile Vy (kN)

6.2. **DIMENZIONIRANJE GREDE NA MOMENT SAVIJANJA**

BETON: C 40/50;

$f_{ck} = 40{,}0$ MPa= 40 N/mm^2 ; γ_c=1.5

$f_{cd} = f_{ck}/\gamma_c = 40{,}0/1{,}5 = 26{,}67$ MPa = 26.67 N/mm^2 = 2,67 kN/cm ^{2}

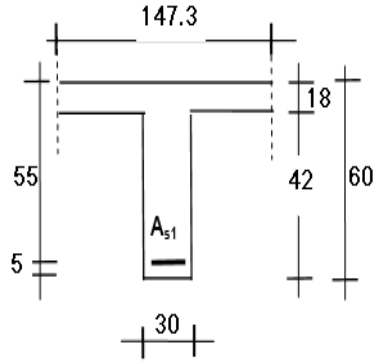
ARMATURA:B 500 B;

$f_{yk} = 500{,}0$ MPa = 500 N/mm^2 ; γ_s = 1,15

$f_{yd} = f_{yk}/\gamma_s = 500{,}0/1{,}15 = 434{,}78$ MPa = 434.78 N/mm^2= 43.48 kN/cm^2

Polje 1:

Utjecajna širina: $b_{eff} = b_0 + \frac{l_0}{5} \quad \Rightarrow \quad b_{eff} = 30 + \frac{0.85 \cdot 690}{5} = 147.3\ cm$



$d_1 = 5cm$

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

$M_{Ed} = 283.96\ kNm$

$\mu_{sd} = \frac{M_{Ed}}{b_{eff} \cdot d^2 \cdot f_{cd}} = \frac{28396}{147.3 \cdot 55^2 \cdot 2.67} = 0.024$

Očitano:

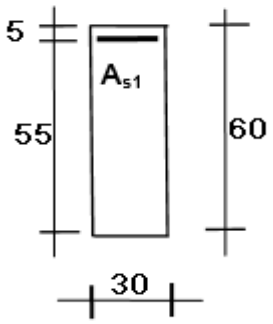
$\varepsilon_{s1} = 10.0\,‰ \quad \varepsilon_{c2} = 0.9‰ \quad \xi = 0.083 \quad \zeta = 0.971$

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

$A_{s1} = \frac{M_{Ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{28396}{0.971 \cdot 55 \cdot 43.48} = 12.23\ cm^2$

Odabrano 6Ø18 (As=15.27 cm^2)

Ležaj:



$d_1 = 5cm$

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

$M_{Ed} = 400.63\ kNm$

$\mu_{sd} = \frac{M_{Ed}}{b_w \cdot d^2 \cdot f_{cd}} = \frac{40063}{30 \cdot 55^2 \cdot 2.67} = 0.165$

Očitano:

$\varepsilon_{s1} = 5.0\,‰ \quad \varepsilon_{c2} = 2.3‰ \quad \xi = 0.190 \quad \zeta = 0.879$

$x = \xi \cdot d = 0.190 \cdot 55 = 10.45\ cm$

$A_{s1} = \frac{M_{Ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{40063}{0.879 \cdot 55 \cdot 43.48} = 19.06\ cm^2$

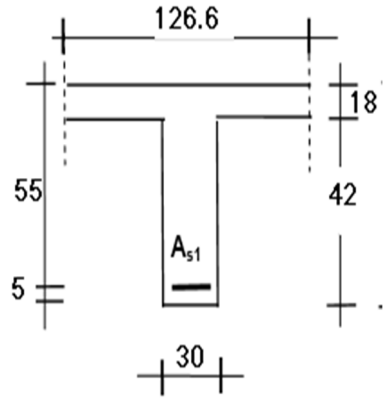
Odabrano 8Ø18 (As=20.36 cm^2)

Polje 2:

Utjecajna širina: $b_{eff} = b_0 + \frac{l_0}{5} \quad \Rightarrow \quad b_{eff} = 30 + \frac{0.70 \cdot 690}{5} = 126.6cm$

$d_1 = 5cm$

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



$M_{Ed} = 115.47\ kNm$

$$\mu_{sd} = \frac{M_{Ed}}{b_{eff} \cdot d^2 \cdot f_{cd}} = \frac{11547}{126.6 \cdot 55^2 \cdot 2.67} = 0.011$$

Očitano:

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

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

$$A_{s1} = \frac{M_{Ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{11547}{0.981 \cdot 55 \cdot 43.48} = 4.92\ cm^2$$

Odabrano 2Ø18 (As=5.09 cm^2)

Minimalna armatura:

As1,min ≥ 0,26 · [fct,m / fyk]· bt · d ≥ 0,0013 ·bt · d

b t – širina vlačne zone

d – statička visina presjeka

fyk – karakt. granica popuštanja čelika u N/mm2

[fyk = 500 N/mm2 za čelik B 500B]

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

[fctm = 3.5 N/mm2 za C 40/50]

As1,min ≥ 0,26 ·3.5/ 500 ·30 ·55 = 3.00 cm2

As1,min ≥ 0,0013 ·bt · d = 0,0013 ·30 ·55 = 2.145 cm2

Maksimalna armatura:

As1,max=0.04·Ac=0.04·30·60=72 cm2

6.3. **DIMENZIONIRANJE GREDE NA POPREČNU SILU**

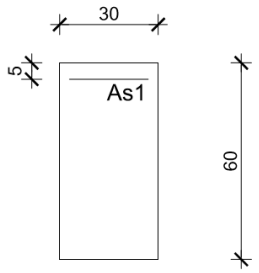
Ležaj 1

C 40/50

V_{Ed} =334.81kN

N_{Ed}=0.0 kN

,



As1=8ø18=20.36 cm2

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

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

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

$$k_1 = 0.15$$

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

$$\Sigma A_s = 8\phi 18 = 20.36 cm^2$$

$$\rho_l = \frac{\Sigma A_s}{A_c} = \frac{20.36}{30 \cdot 55} = \frac{20.36}{1650} = 0.0123$$

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

$$V_{Rdc} = \left[0.12 \cdot 1.60 \cdot (100 \cdot 0.0123 \cdot 40)^{\frac{1}{3}} \right] \cdot 300 \cdot 550 = 116.08 kN$$

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

$$\nu_{\min} = 0.035 \cdot k^{\frac{3}{2}} \cdot f_{ck}{}^{\frac{1}{2}} = 0.035 \cdot 1.60^{\frac{3}{2}} \cdot 40^{\frac{1}{2}} = 0.448$$

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

$$V_{Rdc} \ge \nu_{\min} \cdot b_w \cdot d = 0.448 \cdot 300 \cdot 550 = 73.92 kN \le V_{Ed}$$

$$V_{Ed,\max} = V_{Ed} = 334.81 kN$$

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

$$v = 0.6 \cdot \left[1 - \frac{f_{ck}}{250} \right] = 0.6 \cdot \left[1 - \frac{40}{250} \right] = 0.504$$

$$V_{Rd,\max} = 0.5 \cdot 0.504 \cdot 300 \cdot 550 \cdot 26.67 = 1108.94 kN > V_{Ed,\max} = V_{Ed}$$

$V_{Ed,\max} / V_{Rd,\max} = 334.81/1108.94 = 0.0302 \approx 0.030 \Rightarrow V_{Ed} = 0.30 V_{Rd,\max}$

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

$\rho_{\min} = 0.0013$

Površina minimalne armature:

$$A_{sw,\min} = \frac{\rho_{\min} \cdot s_w \cdot b_w}{m} = \frac{0.0013 \cdot 30 \cdot 30}{2} = 0.585 cm^2$$

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

$$f_{yw,d} = \frac{f_{yk}}{\gamma_s}; B500B \Rightarrow f_{ywd} = \frac{500}{1.15} = 434.8 MPa = 43.48 kN/cm^2$$

$$V_{Rd} = V_{Rd,s} = \frac{A_{sw}}{s} \cdot z \cdot f_{ywd} \cdot m \cdot ctg\theta = \frac{0.79}{30} \cdot (0.9 \cdot 55) \cdot 43.48 \cdot 2 \cdot 1 = 113.35$$

$V_{Ed} > V_{Rd}$

Na mjestu maksimalne poprečne sile:

$$s_w \le \frac{m \cdot A_{sw} \cdot f_{yw,d} \cdot z}{V_{Ed}} = \frac{2 \cdot 0.79 \cdot 43.48 \cdot 0.9 \cdot 55}{334.81} = 10.15 cm$$

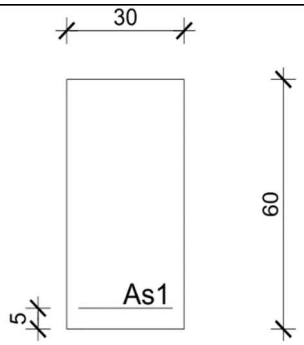
Odabrane spone:**Ø10/10cm** (A_{sw}=0.79 cm^2)

Ležaj 0

C 40/50

V_{Ed} =162.93 kN

N_{Ed}=0.0 kN



As1=6ø18=15.27cm2

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

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

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

$$k_1 = 0.15$$

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

$$\Sigma A_s = 6\phi 18 = 15.27 cm^2$$

$$\rho_l = \frac{\Sigma A_s}{A_c} = \frac{}{30 \cdot 55} = \frac{15.27}{1650} = 0.0093$$

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

$$V_{Rdc} = \left[0.12 \cdot 1.60 \cdot (100 \cdot 0.0093 \cdot 40)^{\frac{1}{3}} \right] \cdot 300 \cdot 550 = 105.75 kN$$

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

$$\nu_{\min} = 0.035 \cdot k^{\frac{3}{2}} \cdot f_{ck}{}^{\frac{1}{2}} = 0.035 \cdot 1.60^{\frac{3}{2}} \cdot 40^{\frac{1}{2}} = 0.448$$

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

$$V_{Rdc} \ge \nu_{\min} \cdot b_w \cdot d = 0.448 \cdot 300 \cdot 550 = 73.92 kN \le V_{Ed}$$

$$V_{Ed,\max} = V_{Ed} = 162.93 kN$$

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

$$v = 0.6 \cdot \left[1 - \frac{f_{ck}}{250} \right] = 0.6 \cdot \left[1 - \frac{40}{250} \right] = 0.504$$

$$V_{Rd,\max} = 0.5 \cdot 0.504 \cdot 300 \cdot 550 \cdot 26.67 = 1108.94 kN > V_{Ed,\max} = V_{Ed}$$

$$V_{Ed,\max} / V_{Rd,\max} = 162.93/1108.94 = 0.147 \approx 0.15 \Rightarrow V_{Ed} = 0.15 V_{Rd,\max}$$

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

$$\rho_{\min} = 0.0013$$

Površina minimalne armature:

$$A_{sw,\min} = \frac{\rho_{\min} \cdot s_w \cdot b_w}{m} = \frac{0.0013 \cdot 30 \cdot 30}{2} = 0.585 cm^2$$

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

$$f_{yw,d} = \frac{f_{yk}}{\gamma_s}; B500B \Rightarrow f_{ywd} = \frac{500}{1.15} = 434.8 MPa = 43.48 kN/cm^2$$

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

$$= \frac{0.79}{30} \cdot (0.9 \cdot 55) \cdot 43.48 \cdot 2 \cdot 1 = 113.35 kN$$

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

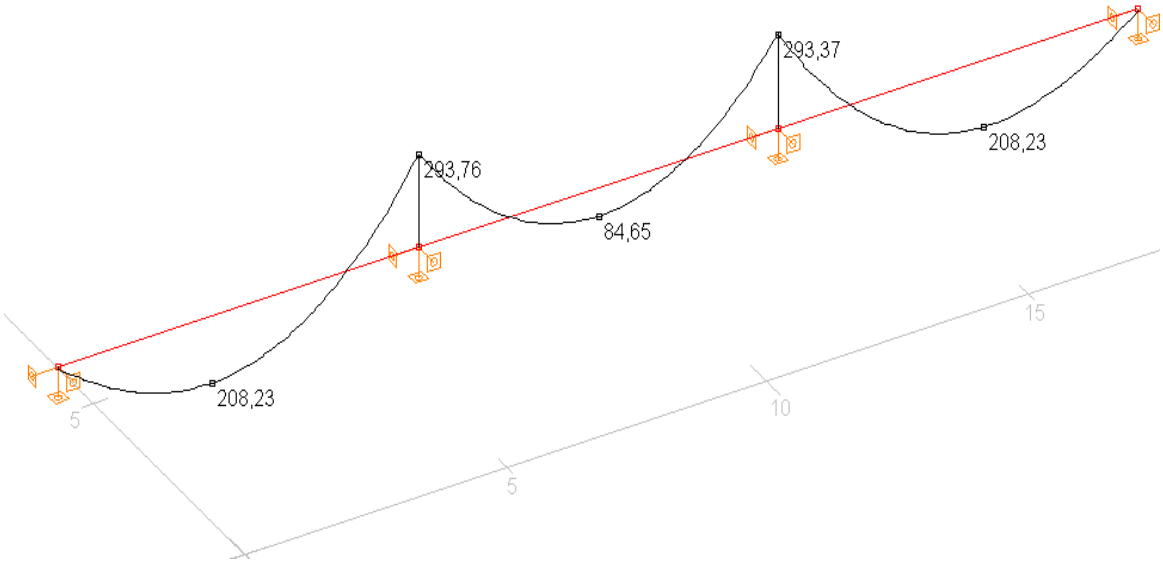
Na mjestu maksimalne poprečne sile:

$$s_w \le \frac{m \cdot A_{sw} \cdot f_{yw,d} \cdot z}{V_{Ed}} = \frac{2 \cdot 0.79 \cdot 43.48 \cdot 0.9 \cdot 55}{162.93} = 20.87 cm$$

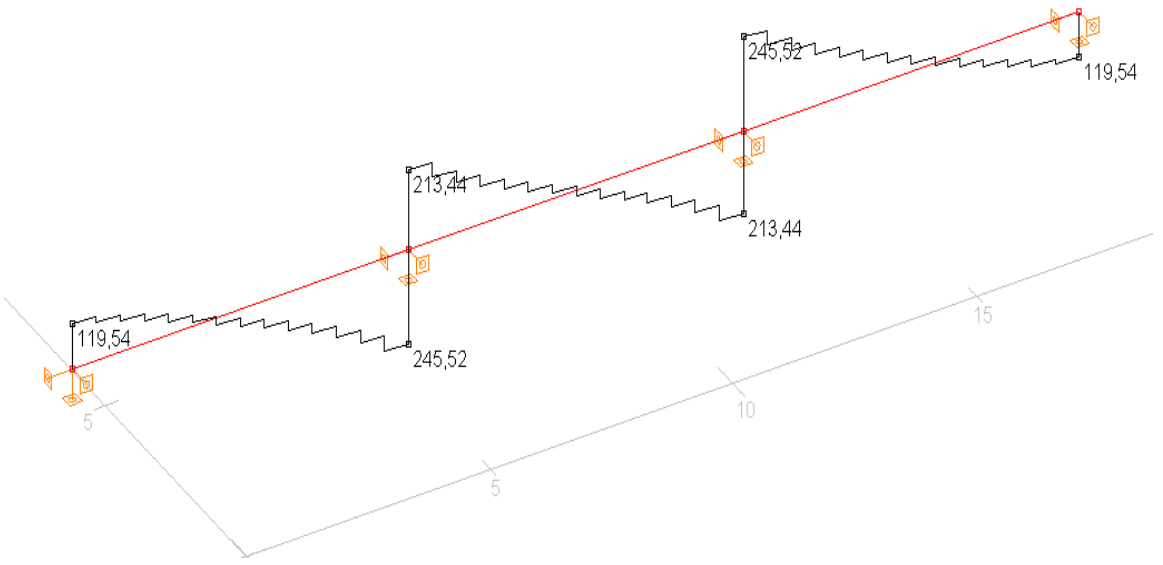
Odabrane spone:**Ø10/20cm** (A_{sw}=0.79 cm^2)

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)

Polje 1:

M_{Ed} = 208.23kNm

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} = 35.00 GPa = 35000 MPa – modul elastičnosti betona

E_s = 200.0 GPa = 200000.0 MPa – modul elastičnosti armature

$f_{ctm} = 3.5$ MPa - za betone klase C 40/50

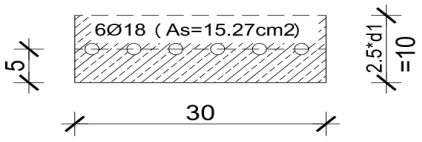
$k_t = 0.4$ - dugotrajno opterećenje

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

$x = \frac{\alpha_e \cdot A_{s1}}{b} \cdot \left(-1 + \sqrt{\frac{2 \cdot b \cdot d}{\alpha_e \cdot A_{s1}}}\right) = \frac{5.71 \cdot 15.27}{30} \cdot \left(-1 + \sqrt{1 + \frac{2 \cdot 30 \cdot 55}{5.71 \cdot 15.27}}\right) = 15.21$ cm

$\sigma_s = \frac{M_{Ed}}{z \cdot A_{s1}} \approx \frac{M_{Ed}}{\left(d - \frac{x}{3}\right) \cdot A_{s1}} = = \frac{20823}{\left(55 - \frac{15.21}{3}\right) \cdot 15.27} = 27.31$ kN /cm^2 =273.11MPa

$$\rho_{p,eff} = \frac{A_{s1}}{A_{c,eff}} = \frac{A_{s1}}{b \cdot 2.5 \cdot d_1} = \frac{15.27}{30 \cdot 2.5 \cdot 5.0} = 0.040$$



$$(\varepsilon_{sm} - \varepsilon_{cm}) = \frac{273.11 - 0.4 \cdot \frac{3.5}{0.040} \cdot (1 + 5.71 \cdot 0.040)}{200000} \geq 0.6 \cdot \frac{273.11}{200000}$$

$$\frac{230.12}{200000} > \frac{163.86}{200000}$$

$$(\varepsilon_{sm} - \varepsilon_{cm}) = 0.00115$$

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 = 18 mm – promjer najdeblje šipke

k_1 = 0.8 - Rebrasta armatura

k_2 = 0.5 – Savijanje

k_3=3.4

k_4=0.425

$c = d_1 - \frac{\phi}{2} = 50 - \frac{18}{2} = 41$ mm - zaštitni sloj uzdužne armature

$S_{r,max} = 3.4 \cdot 41 + 0.8 \cdot 0.5 \cdot 0.425 \cdot \frac{18}{0.034}$ =229.4 mm

$W_k = w_k = S_{r,max} \cdot (\varepsilon_{s,m} - \varepsilon_{c,m}) = 229.4 \cdot 0.00115 = 0.264 \text{ mm} \leq 0.300 \text{ mm}$

→ pukotine zadovoljavaju

<u>Ležaj</u>:

M_{Ed} = 293.76kNm

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} = 35.00 GPa = 35000 MPa – modul elastičnosti betona

E_s = 200.0 GPa = 200000.0 MPa – modul elastičnosti armature

$f_{ctm} = 3.5$ MPa - za betone klase C 40/50

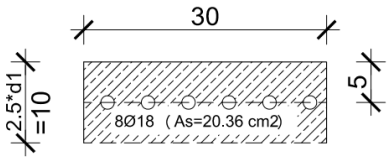
$k_t = 0.4$ - dugotrajno opterećenje

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

$x = \frac{\alpha_e \cdot A_{s1}}{b} \cdot \left(-1 + \sqrt{\frac{2 \cdot b \cdot d}{\alpha_e \cdot A_{s1}}}\right) = \frac{5.71 \cdot 20.26}{30} \cdot \left(-1 + \sqrt{1 + \frac{2 \cdot 30 \cdot 55}{5.71 \cdot 20.26}}\right) = 17.10$ cm

$\sigma_s = \frac{M_{Ed}}{z \cdot A_{s1}} \approx \frac{M_{Ed}}{\left(d - \frac{x}{3}\right) \cdot A_{s1}} = \frac{29376}{\left(55 - \frac{17.10}{3}\right) \cdot 20.26} = 29.41$ kN /cm^2 = 290.41Mpa

$$\rho_{p,eff} = \frac{A_{s1}}{A_{c,eff}} = \frac{A_{s1}}{b \cdot 2.5 \cdot d_1} = \frac{20.26}{30 \cdot 2.5 \cdot 5.0} = 0.054$$



$$(\varepsilon_{sm} - \varepsilon_{cm}) = \frac{290.41 - 0.4 \cdot \frac{3.5}{0.054} \cdot (1 + 5.71 \cdot 0.054)}{200000} \geq 0.6 \cdot \frac{290.41}{200000}$$

$$\frac{256.49}{200000} > \frac{174.25}{200000}$$

$$(\varepsilon_{sm} - \varepsilon_{cm}) = 0.00128$$

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 = 18 mm – promjer najdeblje šipke

k_1 = 0.8 - Rebrasta armatura

k_2 = 0.5 – Savijanje

k_3=3.4

k_4=0.425

$c = d_1 - \frac{\phi}{2} = 50 - \frac{18}{2} = 41$ mm - zaštitni sloj uzdužne armature

$S_{r,max} = 3.4 \cdot 41 + 0.8 \cdot 0.5 \cdot 0.425 \cdot \frac{18}{0.054} = 196.07$ mm

$W_k = w_k = S_{r,max} \cdot (\varepsilon_{s,m} - \varepsilon_{c,m}) = 196.07 \cdot 0.00128 = 0.251 \text{ mm} \geq 0.300 \text{ mm}$

→ 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:

$$v_{\lim} = \frac{L}{250} = \frac{690}{250} = 2.76\,cm$$

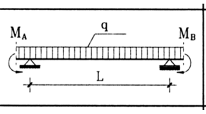
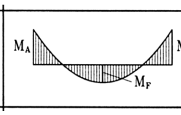
Beton: C 40/50; f_{ck}=40.0 MPa

$$E_{cm} = 9500 \cdot \sqrt[3]{\text{fck} + 8} = 9500 \cdot \sqrt[3]{40 + 8} \approx 35000\ MPa$$

$$f_{ctm} = 0.3 \cdot (f_{ck})^{2/3} = 0.3 \cdot (40.0)^{2/3} = 3.5\ MPa$$

Čelik: B500B ; E_s= 200.0 GPa

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

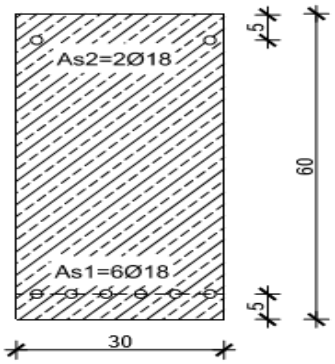
Red	Tip opterećenja	Dijagram momenata savijanja	Koeficijent k iz izraza (5.131)
7			$k = \frac{5}{48}(1 - 0{,}1\beta)$ $\beta = \lvert M_A + M_B \rvert / \lvert M_F \rvert$

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

$$\beta = |M_A + M_B| / |M_F| = |0.0 + 293.76| / |208.23| = 1.411$$

$$k = \frac{5}{48} \cdot (1 - 0.1 \cdot \beta) = 0.104 \cdot (1 - 0.1 \cdot 1.411) = 0.0893$$

Presjek u polju :



$A_{s1} = 6\varnothing 18 = 15.27\ cm^2$

$A_{s1} = 2\varnothing 18 = 5.09\ cm^2$

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

$$= \frac{30 \cdot 60^3}{12} + 5.71 \cdot \left[15.27 \cdot \left(\frac{60}{2} - 5 \right)^2 + 5.09 \cdot \left(\frac{60}{2} - 5 \right)^2 \right] =$$

$$= 612659.75\ cm^4$$

$$E_{c,eff} = E_{cm} = 35.0\ GN/m^2 = 3500.0\ kN/cm^2$$

$$\frac{1}{r_I} = \frac{M_{Ed}}{E_{c,eff} \cdot I_I} = \frac{20823}{3500 \cdot 612659.75} = 0.00000971 \frac{1}{cm}$$

Progib potpuno raspucanog presjeka:

$x = 15.21\ cm$ (izračunato kod pukotina)

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

$$= \frac{30 \cdot 15.21^3}{12} + (30 \cdot 15.21) \cdot \left(\frac{15.21}{2} \right)^2 + 5.71 \cdot \left[15.27 \cdot (55 - 15.21)^2 + 5.09 \cdot (15.21 - 5)^2 \right]$$

$$= 176262.92 cm^4$$

$$\frac{1}{r_{II}} = \frac{M_{Ed}}{E_{c,eff} \cdot I_{II}} = \frac{20823}{3500 \cdot 176262.92} = 0.0000338\ \frac{1}{cm}$$

$\sigma_s = 273.11\ MPa$

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

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

$$\sigma_{sr} = \frac{6300}{(55 - \frac{15.21}{3}) \cdot 15.27} = 8.26 \frac{kN}{cm^2} = 82.6 MPa$$

$\beta_1 = 1.0$ - Rebrasta armatura

$\beta_2 = 0.5$ - Dugotrajno opterećenje

$$\zeta = 1 - \beta_1 \cdot \beta_2 \cdot \left(\frac{\sigma_{sr}}{\sigma_s} \right)^2 = 1 - 1.0 \cdot 0.5 \cdot \left(\frac{82.6}{273.11} \right)^2 = 0.954$$

$$\frac{1}{r_I} = 0.00000971 \frac{1}{cm}$$

$$\frac{1}{r_{II}} = 0.0000338 \frac{1}{cm}$$

$$\frac{1}{r_m} = (1 - \zeta) \cdot \frac{1}{r_I} + \zeta \cdot \frac{1}{r_{II}} = (1 - 0.954) \cdot 0.00000971 + 0.954 \cdot 0.0000338 = 0.000033 \frac{1}{cm}$$

$k = 0.0893$

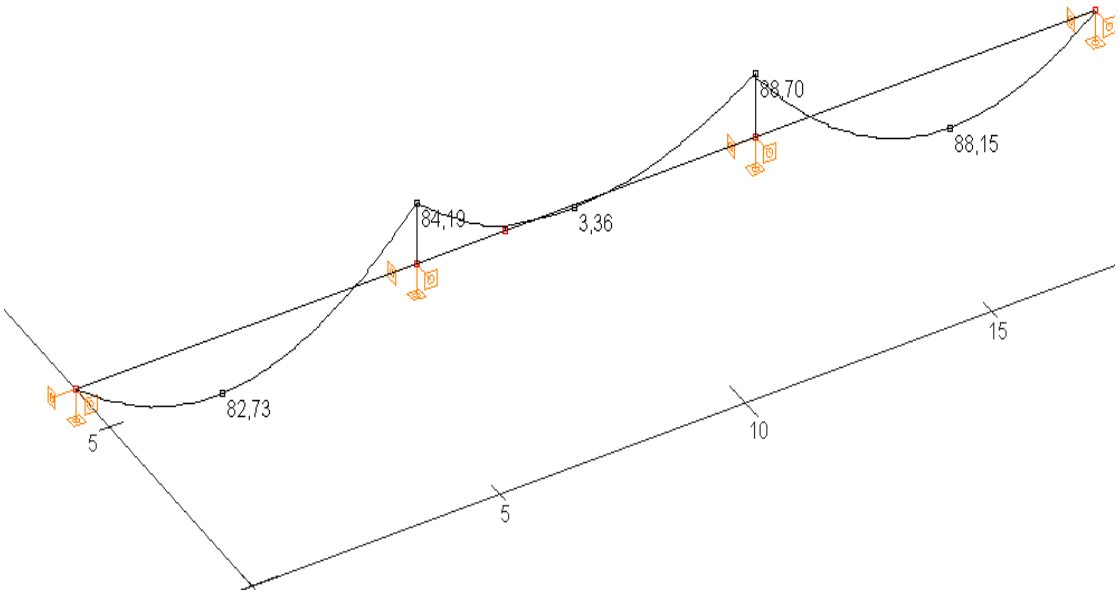
$L = 690.0\ cm$

$$v_{tot,t=0} = k \cdot L^2 \cdot \frac{1}{r_{tot}} = 0.0893 \cdot 690.0^2 \cdot 0.000033 = 1.40\ cm < v_{\lim} = 2.76 cm$$

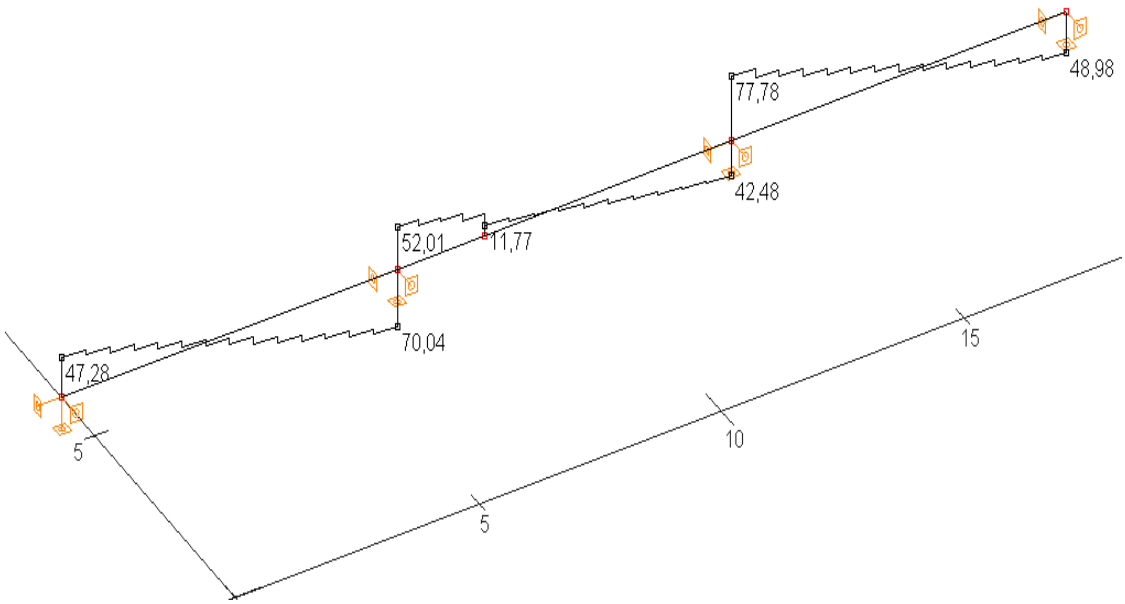
7. *PRORAČUN KONTINUIRANOG NOSAČA POZICIJE 100*

7.1. MOMENTI SAVIJANJA I POPREČNE SILE GREDE POZICIJE 100

7.1.1. Vlastita težina

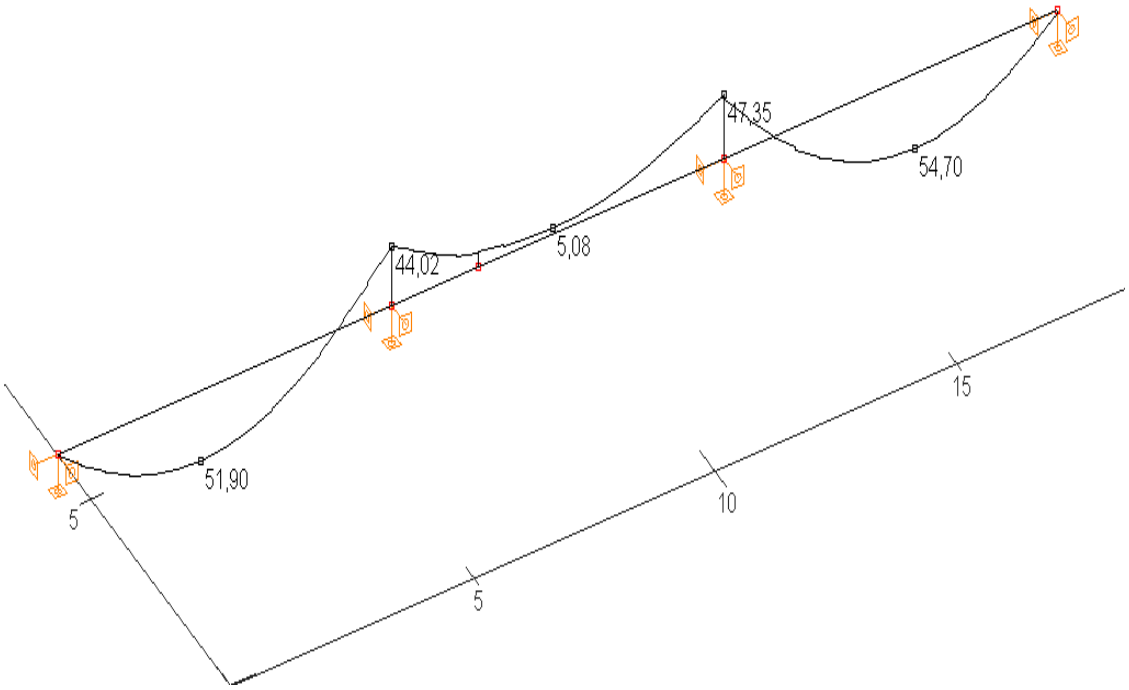


Slika 7.1. Momenti Mz (kNm)

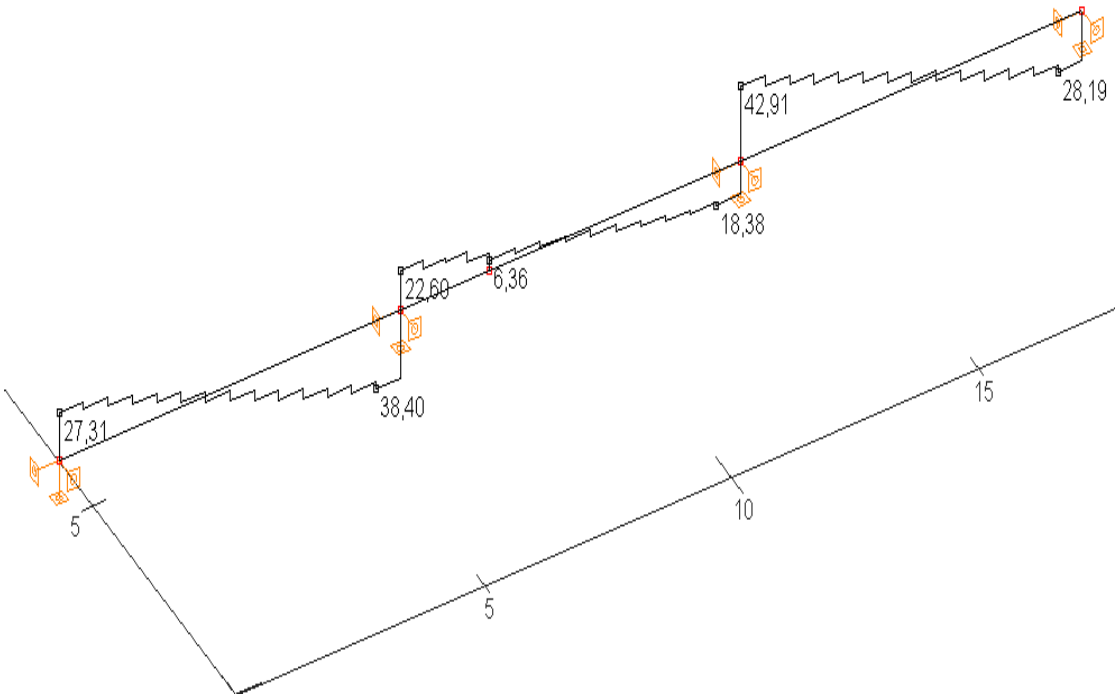


Slika 7.2. Poprečne sile Vy (kN)

7.1.2. Dodatno stalno opterećenje

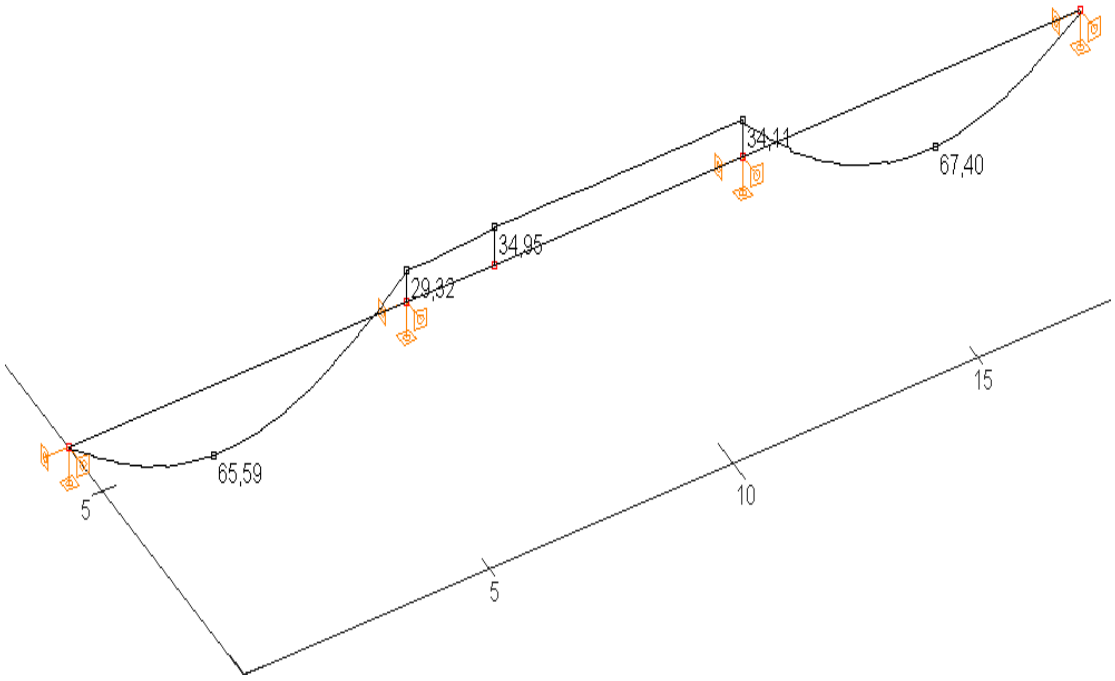


Slika 7.3. Momenti Mz (kNm)

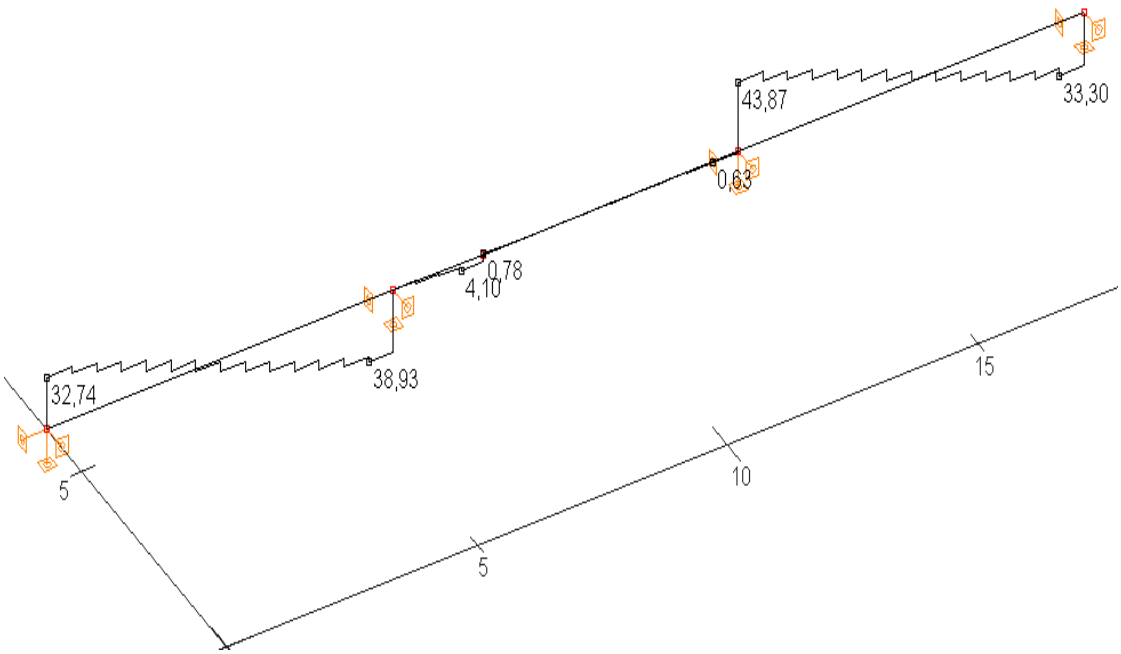


Slika 7.4. Poprečne sile Vy (kN)

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

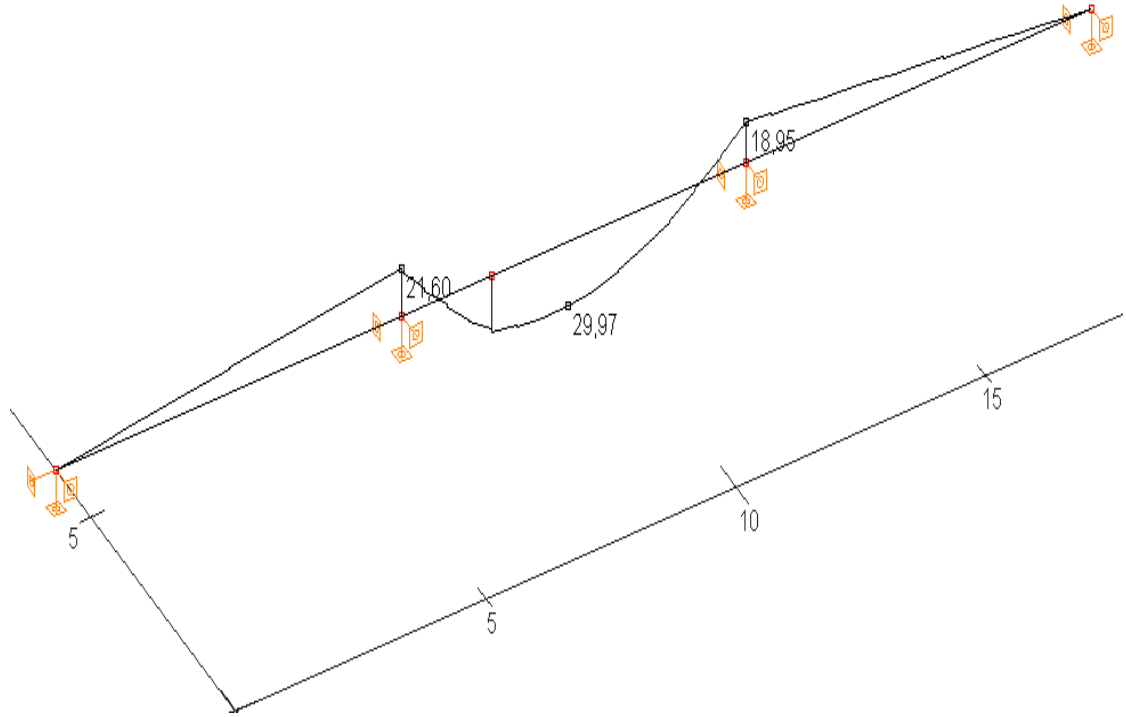


Slika 7.5. Momenti Mz (kNm)

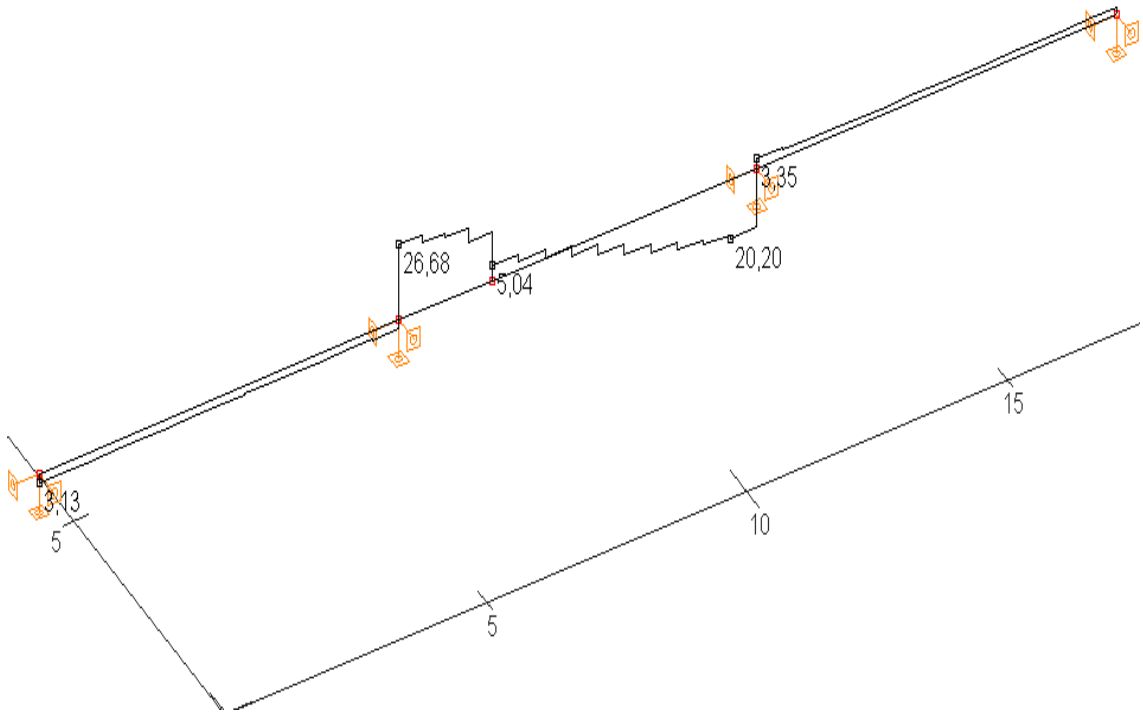


Slika 7.6. Poprečne sile Vy (kN)

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

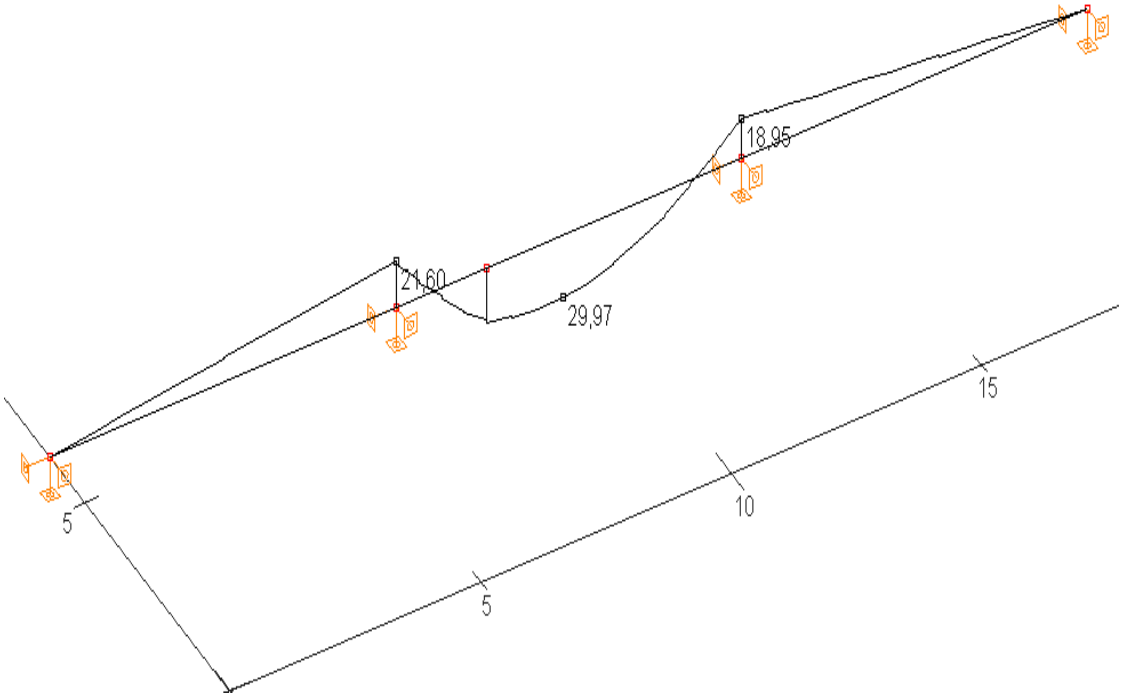


Slika 7.7. Momenti Mz (kNm)

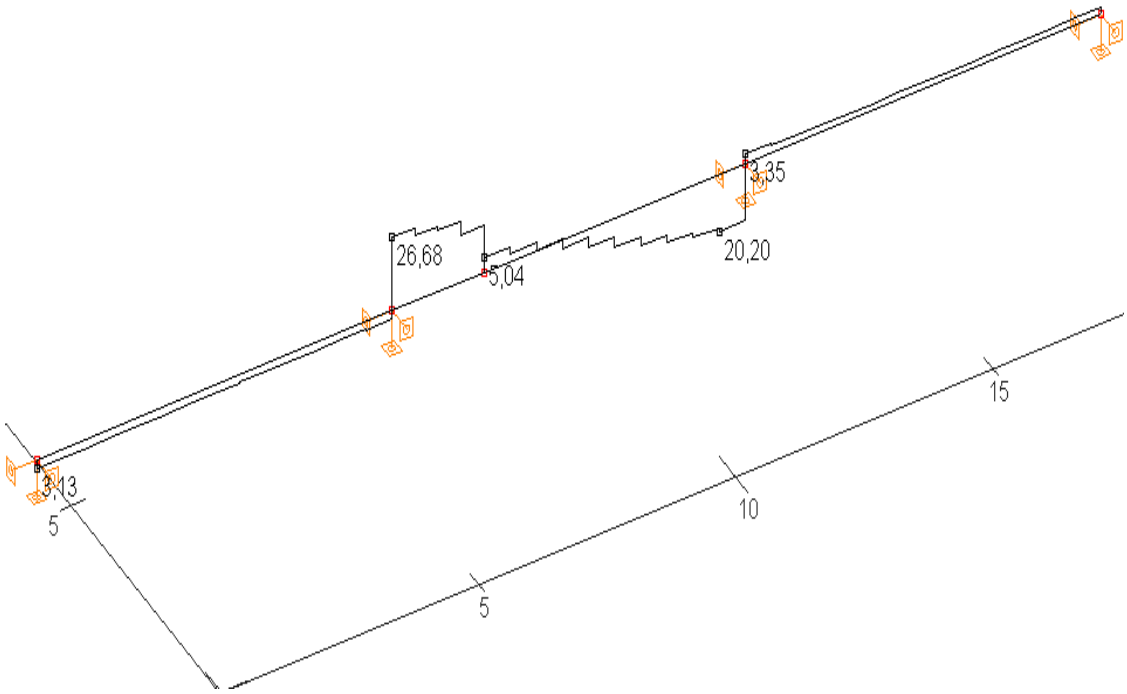


Slika 7.8. Poprečne sile Vy (kN)

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



Slika 7.9. Momenti Mz (kNm)



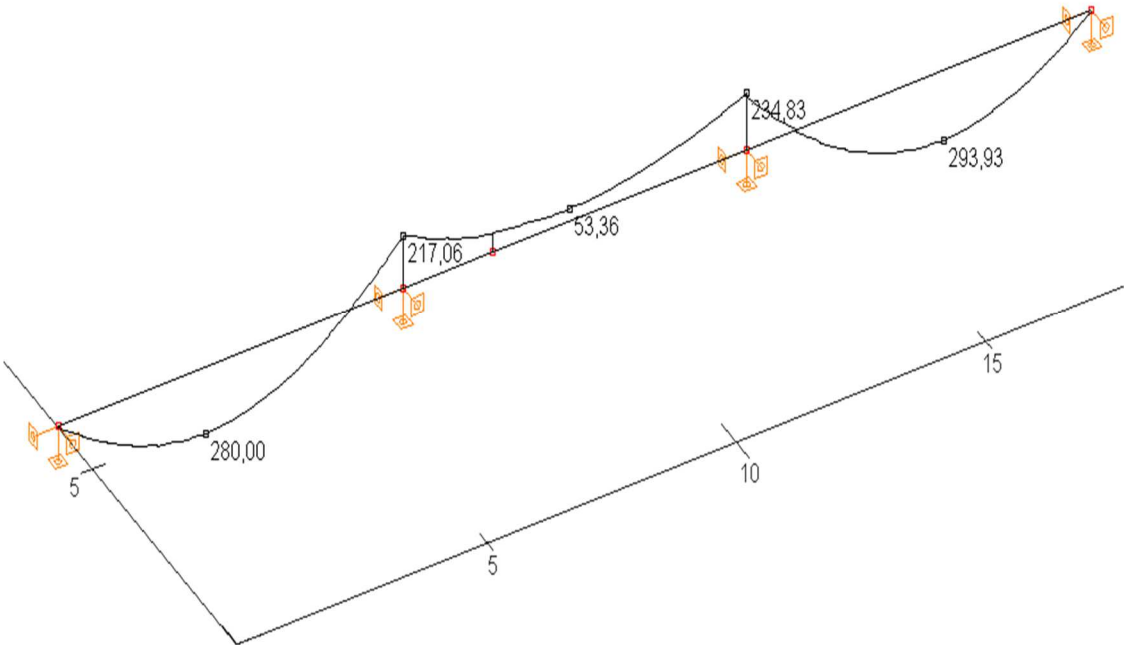
Slika 7.10. Poprečne sile Vy (kN)

7.1.6. GSN za kranjapolja

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

Momenti:

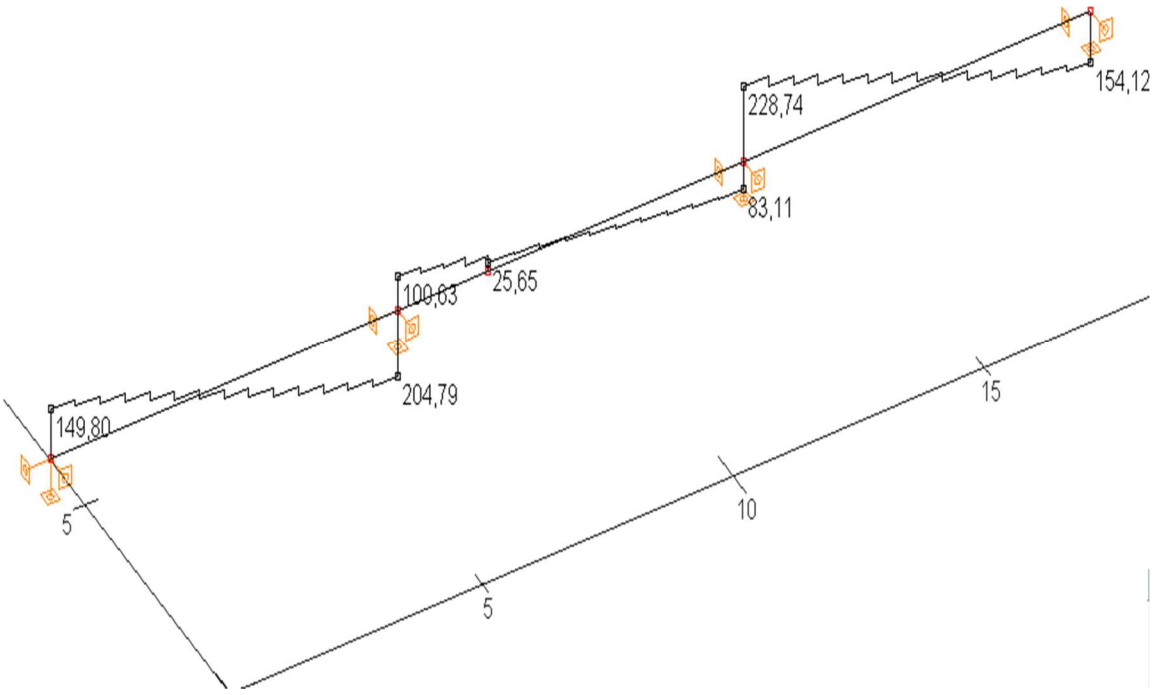
$$M_{Ed,krajnje\,polje} = 293.93\,kNm$$



Slika 7.11. Momenti Mz (kNm)

Poprečne sile:

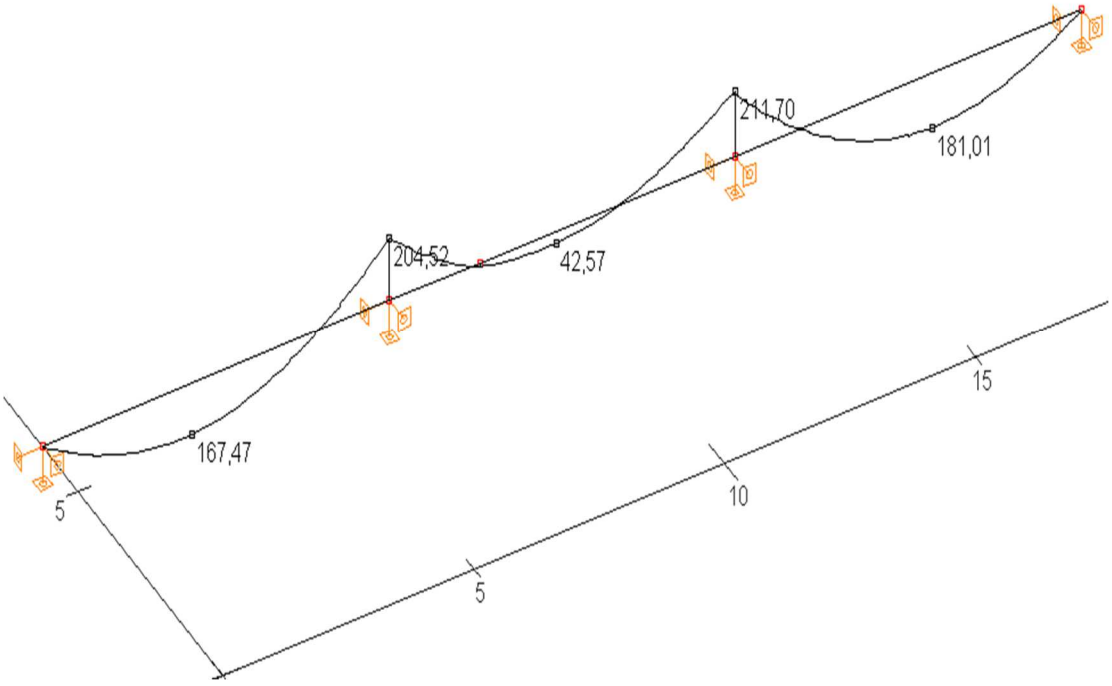
$$V_{Ed,ležaj0} = 154{,}12\,kN$$



Slika 7.12. Poprečne sile Vy (kN)

7.1.7. GSN za srednje polje

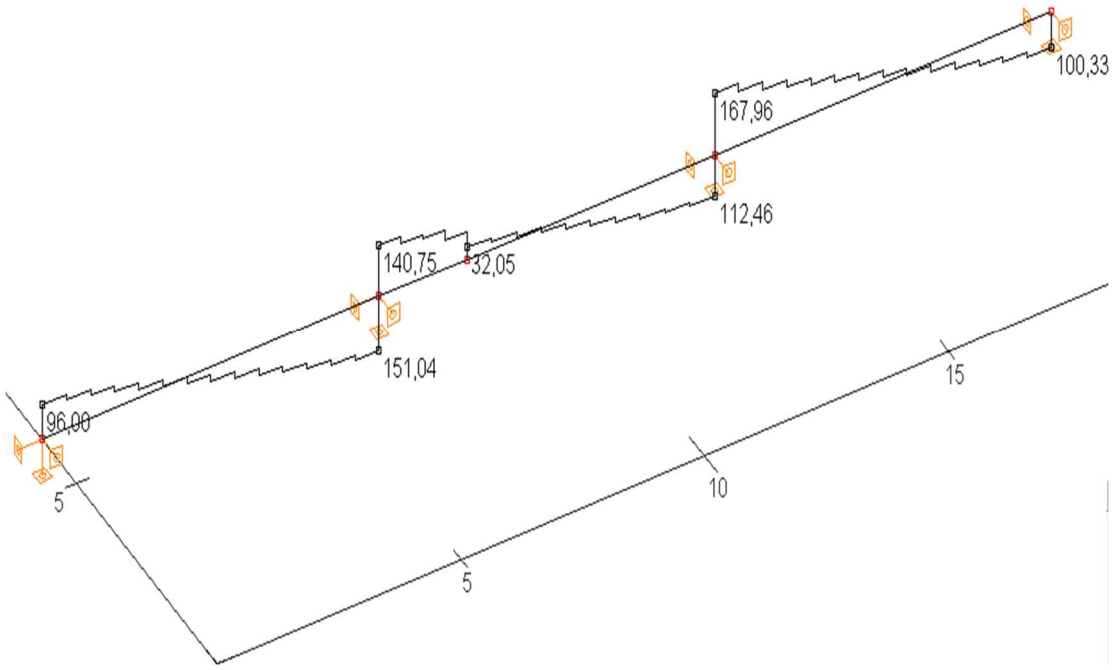
$$M_{Ed,srednja\,polje} = 42.57\ kNm$$



Slika 7.13. Momenti Mz (kNm)

Poprečne sile:

$$V_{Ed,ležaj1} = 167{,}96kN$$

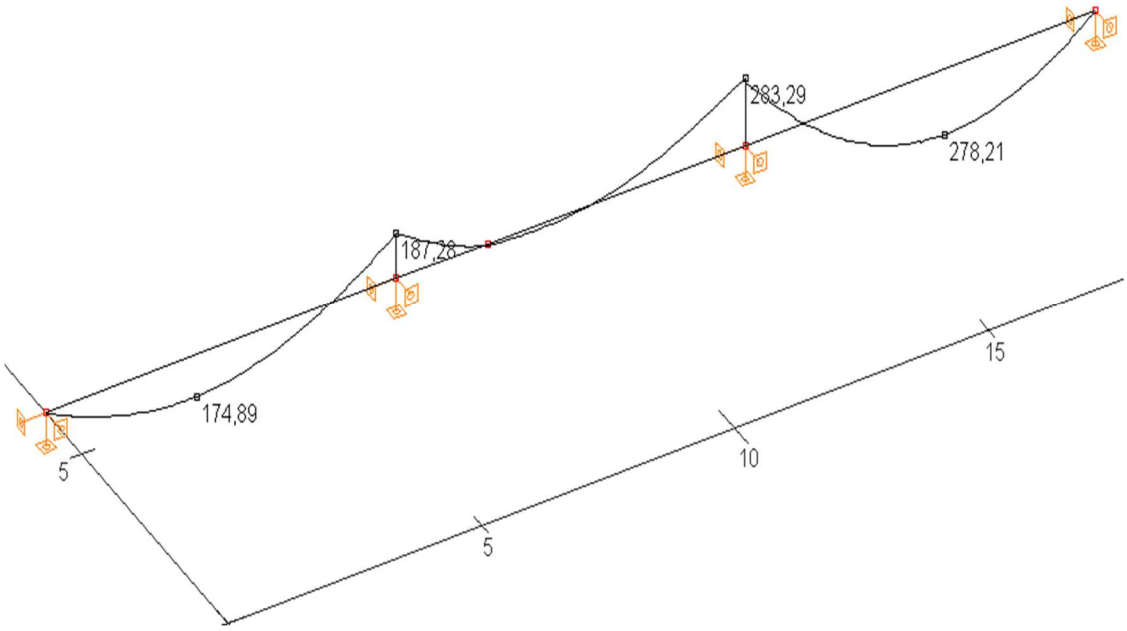


Slika 7.14. Poprečne sile Vy (kN)

7.1.8. GSN za ležaj

Momenti:

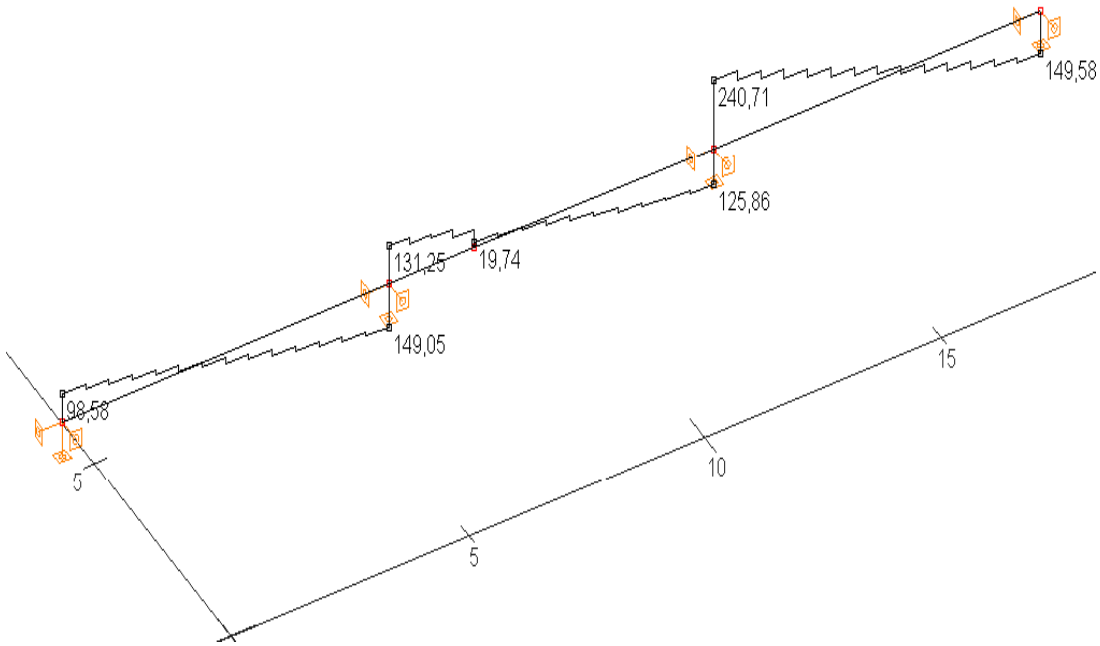
$$M_{Ed,ležaj} = -283.29\ kNm$$



Slika 7.15. Momenti Mz (kNm)

Poprečne sile:

$$V_{Ed,ležaj\,1} = 240{,}71\ kN$$



Slika 7.16. Poprečne sile Vy (kN)

7.2. **DIMENZIONIRANJE GREDE NA MOMENT SAVIJANJA**

BETON:C 40/50;

$f_{ck} = 40{,}0$ MPa =40 N/mm^2 ; γ_c =1.5

$f_{cd} = f_{ck}/\gamma_c = 40{,}0/1{,}5 = 26{,}67$ MPa = 26.67 N/mm^2 =2,67 kN/cm^2

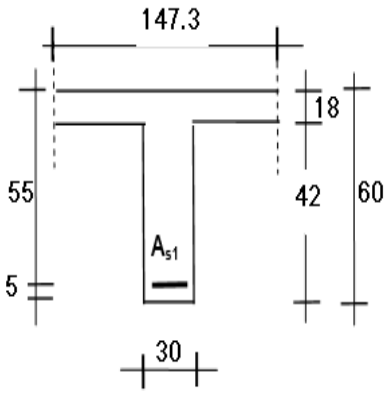
ARMATURA:B 500 B;

$f_{yk} = 500{,}0$ MPa = 500 N/mm^2 ; γ_s=1,15

$f_{yd} = f_{yk}/\gamma_s = 500{,}0/1{,}15 = 434{,}78$ MPa =434.78 N/mm^2=43.48 kN/cm^2

Krajnje polje:

Utjecajna širina: $b_{eff} = b_0 + \frac{l_0}{5} \Rightarrow b_{eff} = 30 + \frac{0.85 \cdot 690}{5} = 147.3\ cm$



$M_{Ed} = 293.93\ kNm$

$\mu_{sd} = \frac{M_{Ed}}{b_{eff} \cdot d^2 \cdot f_{cd}} = \frac{29393}{147.3 \cdot 55^2 \cdot 2.67} = 0.025$

Očitano:

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

$x = \xi \cdot d = 0.074 \cdot 63 = 4.662\ cm < h_{pl} = 18\ cm$

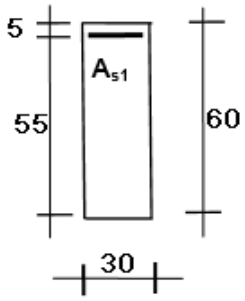
$A_{s1} = \frac{M_{Ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{29393}{0.971 \cdot 55 \cdot 43.48} = 12.66\ cm^2$

$d_1 = 5cm$

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

Odabrano 6Ø18 (As=15.27 cm^2)

Ležaj 1:



$M_{Ed} = -283.29\ kNm$

$\mu_{sd} = \frac{M_{Ed}}{b_w \cdot d^2 \cdot f_{cd}} = \frac{28329}{30 \cdot 55^2 \cdot 2.67} = 0.117$

Očitano:

$\varepsilon_{s1} = 10.0\,‰ \quad \varepsilon_{c2} = 2.6\,‰ \quad \xi = 0.206 \quad \zeta = 0.919$

$x = \xi \cdot d = 0.206 \cdot 55 = 11.33\ cm$

$A_{s1} = \frac{M_{Ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{28329}{0.919 \cdot 55 \cdot 43.48} = 12.90\ cm^2$

$d_1 = 5cm$

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

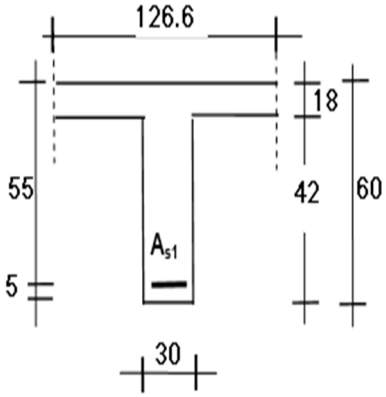
Odabrano 6Ø18 (As=15.27 cm^2)

Srednje polje – pozitivni moment:

Utjecajna širina: $b_{eff} = b_0 + \frac{l_0}{5} \quad \Rightarrow \quad b_{eff} = 30 + \frac{0.70 \cdot 690}{5} = 126.6\ cm$

$d_1 = 5cm$

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



$M_{Ed} = 42.57\ kNm$

$$\mu_{sd} = \frac{M_{Ed}}{b_{eff} \cdot d^2 \cdot f_{cd}} = \frac{4257}{126.6 \cdot 55^2 \cdot 2.67} = 0.004$$

Očitano:

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

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

$$A_{s1} = \frac{M_{Ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{4257}{0.987 \cdot 55 \cdot 43.48} = 1.8cm^2$$

Odabrano 2Ø18 (As=5.09 cm^2)

Minimalna armatura:

As1,min ≥ 0,26 · [fct,m / fyk]· bt · d ≥ 0,0013 ·bt · d

b t – širina vlačne zone

d – statička visina presjeka

fyk – karakt. granica popuštanja čelika u N/mm2

[fyk = 500 N/mm2 za čelik B 500B]

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

[fctm = 3.5 N/mm2 za C 40/50]

As1,min ≥ 0,26 ·3.5/ 500 ·30 ·55 = 3.00 cm2

As1,min ≥ 0,0013 ·bt · d = 0,0013 ·30 ·55 = 2.145 cm2

Maksimalna armatura:

As1,max=0.04·Ac=0.04·30·60=72 cm2

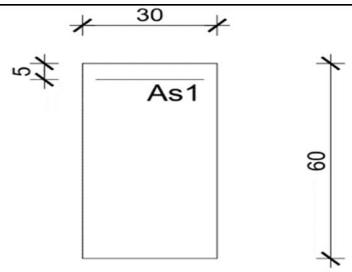
7.3. **DIMENZIONIRANJE GREDE NA POPREČNU SILU**

Ležaj 1

C 40/50

V_{Ed} =240.71 kN

N_{Ed}=0.0 kN



As1=6ø18=15.27cm2

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

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

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

$$k_1 = 0.15$$

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

$$\Sigma A_s = 6\phi 18 = 15.27\ \text{cm}^2$$

$$\rho_l = \frac{\Sigma A_s}{A_c} = \frac{6\phi 18}{30 \cdot 55} = \frac{15.27}{1650} = 0.0093$$

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

$$V_{Rdc} = \left[0.12 \cdot 1.60 \cdot (100 \cdot 0.0093 \cdot 40)^{\frac{1}{3}} \right] \cdot 300 \cdot 550 = 105.75kN$$

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

$$\nu_{\min} = 0.035 \cdot k^{\frac{3}{2}} \cdot f_{ck}{}^{\frac{1}{2}} = 0.035 \cdot 1.60^{\frac{3}{2}} \cdot 40^{\frac{1}{2}} = 0.448$$

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

$$V_{Rdc} \ge \nu_{\min} \cdot b_w \cdot d = 0.448 \cdot 300 \cdot 550 = 73.92kN \le V_{Ed}$$

$$V_{Ed,\max} = V_{Ed} = 240.71kN$$

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

$$v = 0.6 \cdot \left[1 - \frac{f_{ck}}{250} \right] = 0.6 \cdot \left[1 - \frac{40}{250} \right] = 0.504$$

$$V_{Rd,\max} = 0.5 \cdot 0.504 \cdot 300 \cdot 550 \cdot 26.67 = 1108.94kN > V_{Ed,\max} = V_{Ed}$$

$$V_{Ed,\max} / V_{Rd,\max} = 240.71 / 1108.94 = 0.217 \approx 0.22 \Rightarrow V_{Ed} = 0.22 V_{Rd,\max}$$

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

$$\rho_{\min} = 0,0013$$

Površina minimalne armature:

$$A_{sw,\min} = \frac{\rho_{\min} \cdot s_w \cdot b_w}{m} = \frac{0.0013 \cdot 30 \cdot 30}{2} = 0.585 cm^2$$

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

$$f_{yw,d} = \frac{f_{yk}}{\gamma_s}; B500B \Rightarrow f_{ywd} = \frac{500}{1.15} = 434.8MPa = 43.48kN/cm^2$$

$$V_{Rd} = V_{Rd,s} = \frac{A_{sw}}{s} \cdot z \cdot f_{ywd} \cdot m \cdot ctg\theta = \frac{0.79}{30} \cdot 0.9 \cdot 55 \cdot 43.48 \cdot 2 \cdot 1$$

$$V_{Rd} = 113.35kN$$

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

Na mjestu maksimalne poprečne sile:

$$s_w \le \frac{m \cdot A_{sw} \cdot f_{yw,d} \cdot z}{V_{Ed}} = \frac{2 \cdot 0.79 \cdot 43.48 \cdot 0.9 \cdot 55}{204.71} = 18.46\, cm$$

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

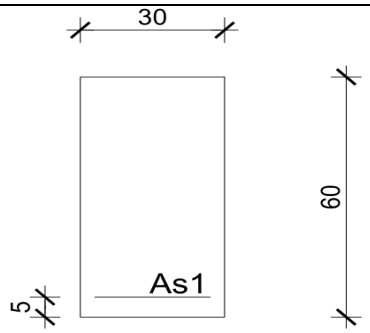
Ležaj 0

C 40/50

V_{Ed} =154.12kN

N_{Ed}=0.0 kN

B



As1=6ø18=15.27cm2

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

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

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

$$k_1 = 0.15$$

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

$$\Sigma A_s = 6\phi 18 = 15{,}27\ \mathrm{cm}^2$$

$$\rho_l = \frac{\Sigma A_s}{A_c} = \frac{6\phi 18}{30 \cdot 55} = \frac{15.27}{1650} = 0.0093$$

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

$$V_{Rdc} = \left[0.12 \cdot 1.60 \cdot (100 \cdot 0.0093 \cdot 40)^{\frac{1}{3}} \right] \cdot 300 \cdot 550 = 105.75kN$$

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

$$\nu_{\min} = 0.035 \cdot k^{\frac{3}{2}} \cdot f_{ck}{}^{\frac{1}{2}} = 0.035 \cdot 1.60^{\frac{3}{2}} \cdot 40^{\frac{1}{2}} = 0.448$$

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

$$V_{Rdc} \ge \nu_{\min} \cdot b_w \cdot d = 0.448 \cdot 300 \cdot 550 = 73.92kN \le V_{Ed}$$

$$V_{Ed,\max} = V_{Ed} = 154.12kN$$

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

$$\nu = 0.6 \cdot \left[1 - \frac{f_{ck}}{250} \right] = 0.6 \cdot \left[1 - \frac{40}{250} \right] = 0.504$$

$$V_{Rd,\max} = 0.5 \cdot 0.504 \cdot 300 \cdot 550 \cdot 26.67 = 1108.94kN > V_{Ed,\max} = V_{Ed}$$

$$V_{Ed,\max} / V_{Rd,\max} = 154.12 / 1108.94 = 0.139 \approx 0.14 \Rightarrow V_{Ed} = 0.14 V_{Rd,\max}$$

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

$$\rho_{\min} = 0{,}0013$$

Površina minimalne armature:

$$A_{sw,\min} = \frac{\rho_{\min} \cdot s_w \cdot b_w}{m} = \frac{0.0013 \cdot 30 \cdot 30}{2} = 0.585cm^2$$

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

$$f_{yw,d} = \frac{f_{yk}}{\gamma_s}; B500B \Rightarrow f_{ywd} = \frac{500}{1.15} = 434.8MPa = 43.48kN/cm^2$$

$$V_{Rd} = V_{Rd,s} = \frac{A_{sw}}{s} \cdot z \cdot f_{ywd} \cdot m \cdot ctg\theta = \frac{0.79}{30} \cdot 0.9 \cdot 55 \cdot 43.48 \cdot 2 \cdot 1$$

$$V_{Rd} = 113.35kN$$

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

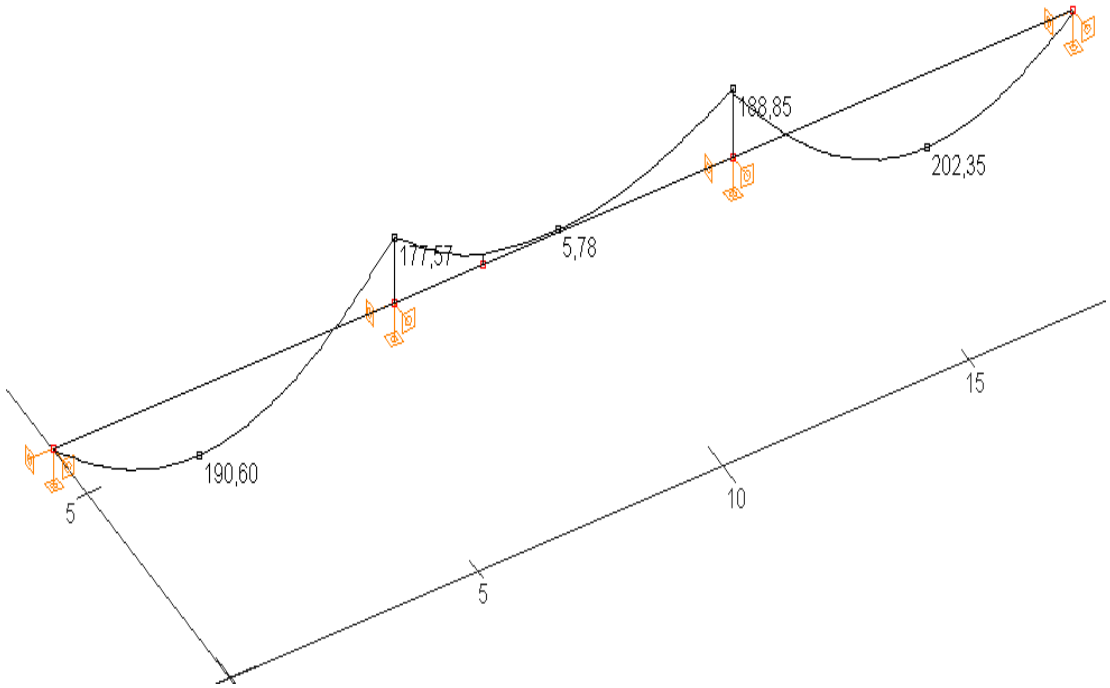
Na mjestu maksimalne poprečne sile:

$$s_w \le \frac{m \cdot A_{sw} \cdot f_{yw,d} \cdot z}{V_{Ed}} = \frac{2 \cdot 0.79 \cdot 43.48 \cdot 0.9 \cdot 55}{154.12} = 22.06cm$$

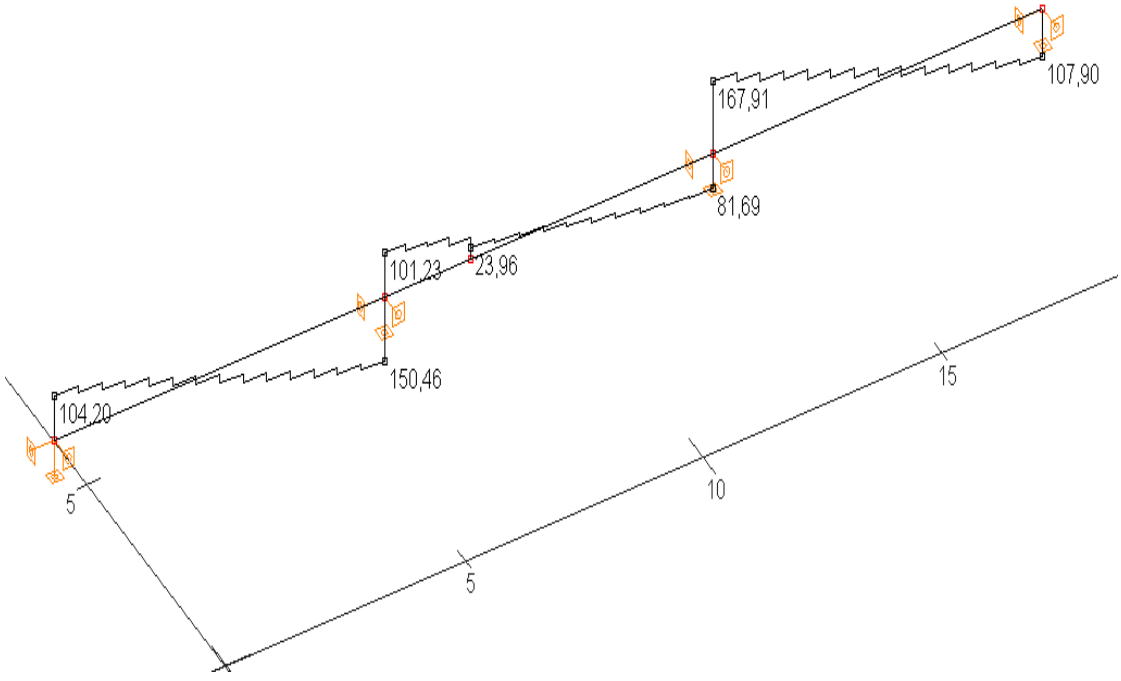
Odabrane spone **Ø10/20cm** (A_{sw}=0.79 cm^2)

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} =202.35kNm

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} = 35.00 GPa = 35000 MPa – modul elastičnosti betona

E_s = 200.0 GPa = 200000.0 MPa – modul elastičnosti armature

$f_{ctm} = 3.5$ MPa - za betone klase C 40/50

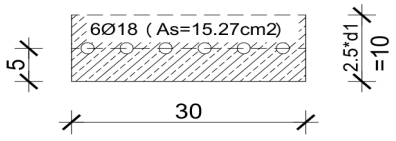
$k_t = 0.4$ - dugotrajno opterećenje

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

$$x = \frac{\alpha_e \cdot A_{s1}}{b} \cdot \left(-1 + \sqrt{\frac{2 \cdot b \cdot d}{\alpha_e \cdot A_{s1}}}\right) = \frac{5.71 \cdot 15.27}{30} \cdot \left(-1 + \sqrt{1 + \frac{2 \cdot 30 \cdot 55}{5.71 \cdot 15.27}}\right) = 15.21 \text{ cm}$$

$$\sigma_s = \frac{M_{Ed}}{z \cdot A_{s1}} \approx \frac{M_{Ed}}{\left(d - \frac{x}{3}\right) \cdot A_{s1}} = \frac{20235}{\left(55 - \frac{15.21}{3}\right) \cdot 15.27} = 26.54 \text{ kN/cm}^2 = 265.41 \text{Mpa}$$

$$\rho_{p,eff} = \frac{A_{s1}}{A_{c,eff}} = \frac{A_{s1}}{b \cdot 2.5 \cdot d_1} = \frac{15.27}{30 \cdot 2.5 \cdot 5.0} = 0.0407$$



$$(\varepsilon_{sm} - \varepsilon_{cm}) = \frac{265.41 - 0.4 \cdot \frac{3.5}{0.0407} \cdot (1 + 5.71 \cdot 0.0407)}{200000} \geq 0.6 \cdot \frac{265.41}{200000}$$

$$\frac{223.02}{200000} > \frac{159.25}{200000}$$

$$(\varepsilon_{sm} - \varepsilon_{cm}) = 0.00115$$

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 = 18 mm – promjer najdeblje šipke

k_1 = 0.8 – Rebrasta armatura

k_2 = 0.5 – Savijanje

k_3=3.4

k_4=0.425

$c = d_1 - \frac{\phi}{2} = 50 - \frac{18}{2} = 41$ mm - zaštitni sloj uzdužne armature

$S_{r,max} = 3.4 \cdot 41 + 0.8 \cdot 0.5 \cdot 0.425 \cdot \frac{18}{0.0407}$ =214.58 mm

$W_k = w_k = S_{r,max} \cdot (\varepsilon_{s,m} - \varepsilon_{c,m}) = 214.58 \cdot 0.00115 = 0.247 \text{ mm} < 0.300\ mm$

→ pukotine zadovoljavaju

<u>Ležaj</u>:

M_{Ed} = 188.85 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} = 35.00 GPa = 35000 MPa – modul elastičnosti betona

E_s = 200.0 GPa = 200000.0 MPa – modul elastičnosti armature

$f_{ctm} = 3.5$ MPa - za betone klase C 40/50

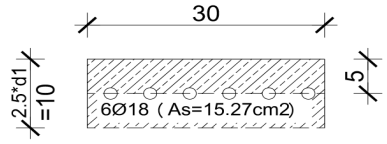
$k_t = 0.4$ - dugotrajno opterećenje

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

$x = \frac{\alpha_e \cdot A_{s1}}{b} \cdot \left(-1 + \sqrt{\frac{2 \cdot b \cdot d}{\alpha_e \cdot A_{s1}}}\right) = \frac{5.71 \cdot 15.27}{30} \cdot \left(-1 + \sqrt{1 + \frac{2 \cdot 30 \cdot 55}{5.71 \cdot 15.27}}\right) = 15.21$ cm

$\sigma_s = \frac{M_{Ed}}{z \cdot A_{s1}} \approx \frac{M_{Ed}}{\left(d - \frac{x}{3}\right) \cdot A_{s1}} = \frac{18885}{\left(55 - \frac{15.21}{3}\right) \cdot 15.27} = 24.769$ kN /cm^2 = 247.69Mpa

$$\rho_{p,eff} = \frac{A_{s1}}{A_{c,eff}} = \frac{A_{s1}}{b \cdot 2.5 \cdot d_1} = \frac{15.27}{30 \cdot 2.5 \cdot 5.0} = 0.0407$$



$$(\varepsilon_{sm} - \varepsilon_{cm}) = \frac{247.69 - 0.4 \cdot \frac{3.5}{0.0407} \cdot (1 + 5.71 \cdot 0.0407)}{200000} \geq 0.6 \cdot \frac{247.69}{200000}$$

$$\frac{205.297}{200000} > \frac{148.61}{200000}$$

$$(\varepsilon_{sm} - \varepsilon_{cm}) = 0.001026$$

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 = 18 mm – promjer najdeblje šipke

k_1 = 0.8 - Rebrasta armatura

k_2 = 0.5 – Savijanje

k_3=3.4

k_4=0.425

$c = d_1 - \frac{\phi}{2} = 50 - \frac{18}{2} = 41$ mm - zaštitni sloj uzdužne armature

$S_{r,max} = 3.4 \cdot 41 + 0.8 \cdot 0.5 \cdot 0.425 \cdot \frac{18}{0.0407}$ =214.58 mm

$W_k = w_k = S_{r,max} \cdot (\varepsilon_{s,m} - \varepsilon_{c,m}) = 214.58 \cdot 0.001026 = 0.220 \text{ mm} \leq 0.300 \text{ mm}$

→ pukotinezadovoljavaju!

7.5. **KONTROLA PROGIBA GREDE POZICIJE 100**

Progib kontroliramo za nefaktorizirano opterećenje i bez utjecaja puzanja.

Kontrola progiba za Polje 1:

Granični progib:

$$\nu_{lim} = \frac{L}{250} = \frac{690}{250} = 2.76\,\text{cm}$$

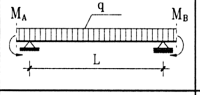
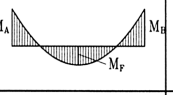
Beton: C 40/50; f_{ck}=40.0 MPa

$$E_{cm} = 35000MPa$$

$$f_{ctm} = 0.3 \cdot (f_{ck})^{2/3} = 0.3 \cdot (40.0)^{2/3} = 3.5\,MPa$$

Čelik: B500B ; E_s= 200.0 GPa

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

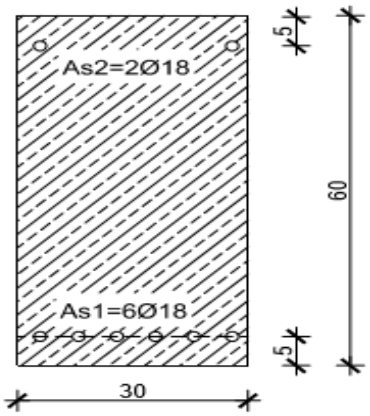
Red	Tip opterećenja	Dijagram momenata savijanja	Koeficijent k iz izraza (5.131)
7			$k = \frac{5}{48}(1-0{,}1\beta)$ $\beta = \lvert M_A + M_B \rvert / \lvert M_F \rvert$

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

$$\beta = |M_A + M_B| / |M_F| = |0.0 + 188.85| / |202.35| = 0.933$$

$$k = \frac{5}{48} \cdot (1 - 0.1 \cdot \beta) = 0.104 \cdot (1 - 0.1 \cdot 0.933) = 0.0943$$

Presjek u polju:



$A_{s1} = 6\varnothing 18 = 15.27\ cm^2$

$A_{s2} = 2\varnothing 18 = 5.09\ cm^2$

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

$$= \frac{30 \cdot 60^3}{12} + 5.71 \cdot \left[15.27 \cdot \left(\frac{60}{2} - 5 \right)^2 + 5.09 \cdot \left(\frac{60}{2} - 5 \right)^2 \right] =$$

$$= 612659.75\ cm^4$$

$$E_{c,eff} = E_{cm} = 35.0\ GN/m^2 = 3500.0\ kN/cm^2$$

$$\frac{1}{r_I} = \frac{M_{Ed}}{E_{c,eff} \cdot I_I} = \frac{20235}{3500 \cdot 612659.75} = 0.0000094 \frac{1}{cm}$$

Progib potpuno raspucanog presjeka:

$$x = 15.21\ cm$$

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

$$= \frac{30 \cdot 15.21^3}{12} + (30 \cdot 15.21) \cdot \left(\frac{15.21}{2} \right)^2 + 5.71 \cdot \left[15.27 \cdot (55 - 15.21)^2 + 5.09 \cdot (15.21 - 5)^2 \right]$$

$$= 176262.92 cm^4$$

$$\frac{1}{r_{II}} = \frac{M_{Ed}}{E_{c,eff} \cdot I_{II}} = \frac{20235}{3500 \cdot 176262.92} = 0.0000328 \frac{1}{cm}$$

Ukupni progib:

$\sigma_s = 265.41 MPa$

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

$$M_{cr} = f_{ctm} \cdot W = f_{ctm} \cdot \frac{b \cdot h^2}{6} = 3.5 \cdot \frac{30 \cdot 60^2}{6} = 63000$$

$$\sigma_{sr} = \frac{63000}{(55 - \frac{15.21}{3}) \cdot 15.27} = 82.63 MPa$$

$\beta_1 = 1.0$ - Rebrasta armatura

$\beta_2 = 0.5$ - Dugotrajno opterećenje

$$\zeta = 1 - \beta_1 \cdot \beta_2 \cdot \left(\frac{\sigma_{sr}}{\sigma_s} \right)^2 = 1 - 1.0 \cdot 0.5 \cdot \left(\frac{82.63}{265.41} \right)^2 = 0.952$$

$$\frac{1}{r_I} = 0.0000094 \frac{1}{cm}$$

$$\frac{1}{r_{II}} = 0.0000328 \frac{1}{cm}$$

$$\frac{1}{r_m} = (1 - \zeta) \cdot \frac{1}{r_I} + \zeta \cdot \frac{1}{r_{II}} = (1 - 0.952) \cdot 0.0000094 + 0.952 \cdot 0.0000328 = 0.0000317 \frac{1}{cm}$$

$k = 0.0943$

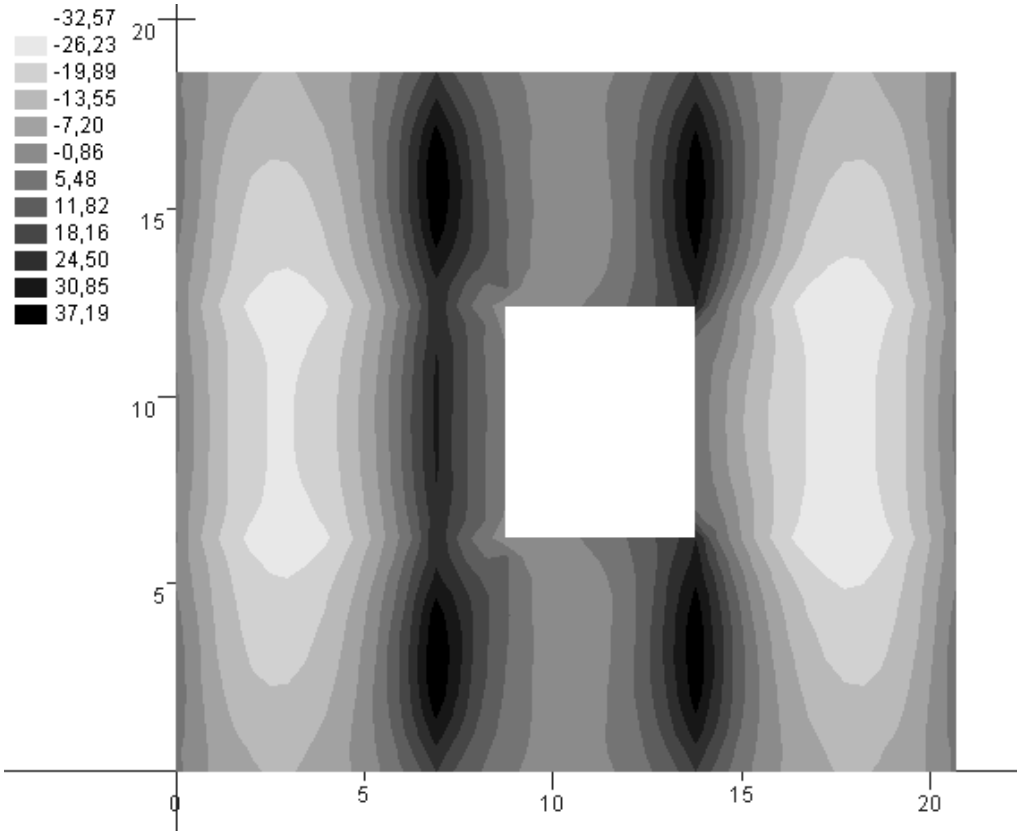
$L = 690.0\ cm$

$$v_{tot,t=0} = k \cdot L^2 \cdot \frac{1}{r_{tot}} = 0.0943 \cdot 690.0^2 \cdot 0.0000317 = 1.42\ cm < v_{\lim} = 2.72 cm$$

8. PRORAČUN STUBIŠTA

8.1. **MJERODAVNE REZNE SILE**

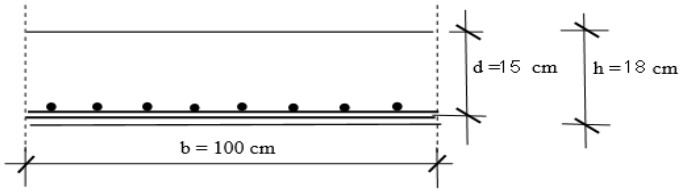
- Moment savijanja mjerodavan za dimenzioniranje stubišta dobiva se iz kombinacije za granično stanje nosivosti na ležajevima pozicije 100.



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

8.2. **DIMENZIONIRANJE STUBIŠTA**

Polje



$M_{Ed} = 24.82\ kNm/m$

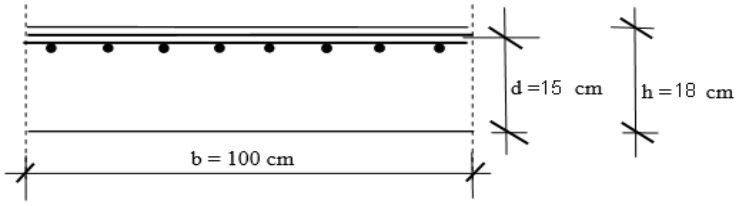
$$\mu_{sd} = \frac{M_{Ed}}{b \cdot d^2 \cdot f_{cd}} = \frac{2482}{100 \cdot 15^2 \cdot 2.67} = 0.041$$

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

$$A_{s1} = \frac{M_{Ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{2482}{0.962 \cdot 15 \cdot 43.48} = 4{,}00\ cm^2/m$$

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

Ležaj stubište – 105



$M_{Ed} = 29.44\ kNm/m$

$$\mu_{sd} = \frac{M_{Ed}}{b \cdot d^2 \cdot f_{cd}} = \frac{2944}{100 \cdot 15^2 \cdot 2.67} = 0.049$$

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

$$A_{s1} = \frac{M_{Ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{2944}{0.956 \cdot 15 \cdot 43.48} = 4.72\ cm^2/m$$

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

9. PRORAČUN STUPOVA

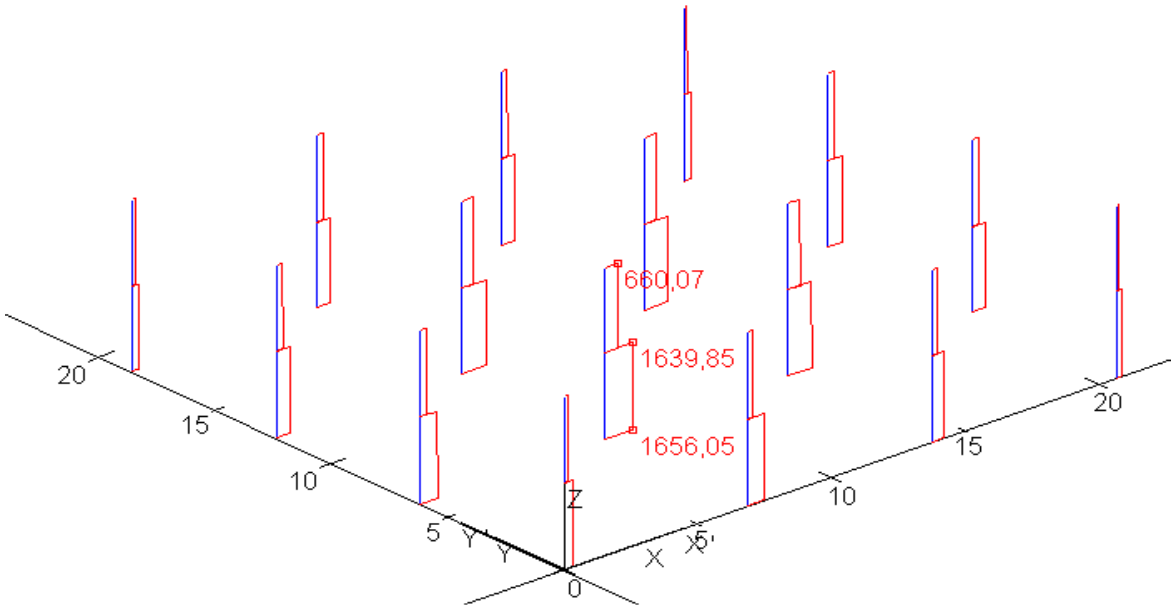
9.1. MOMENTI SAVIJANJA I UZDUŽNE SILE STUPOVA

Kombinacije opterećenja s VJETROM :

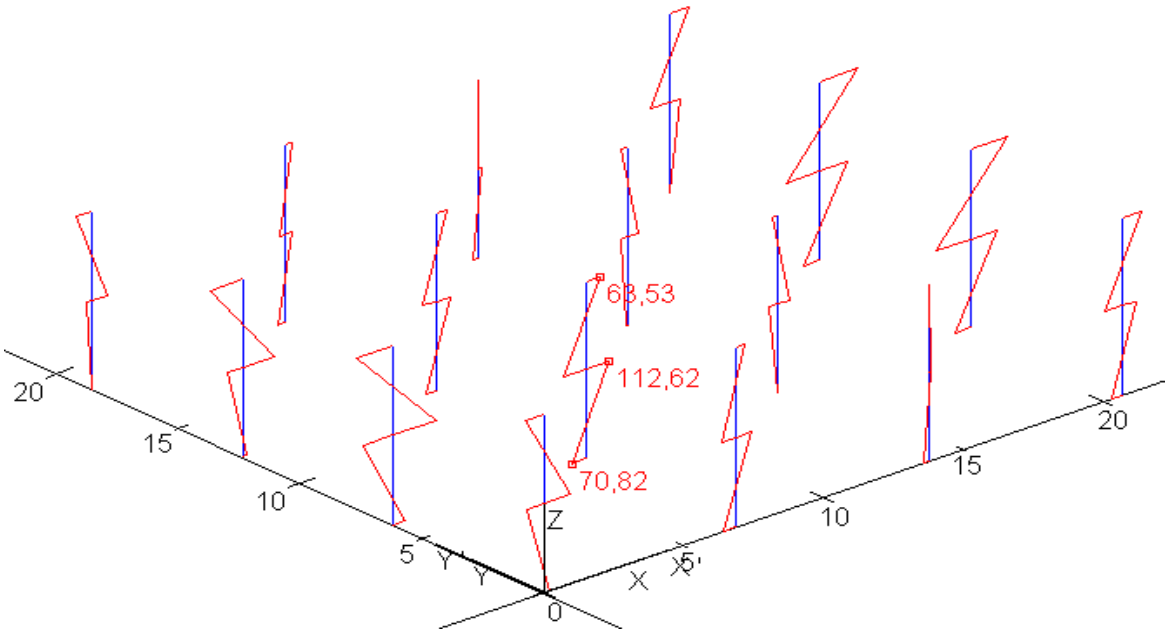
1. kombinacija opterećenja: $1{,}35\cdot(g+\Delta g)+1{,}5\cdot q+1{,}5\cdot W_x$

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

9.1.1. Kombinacija 1

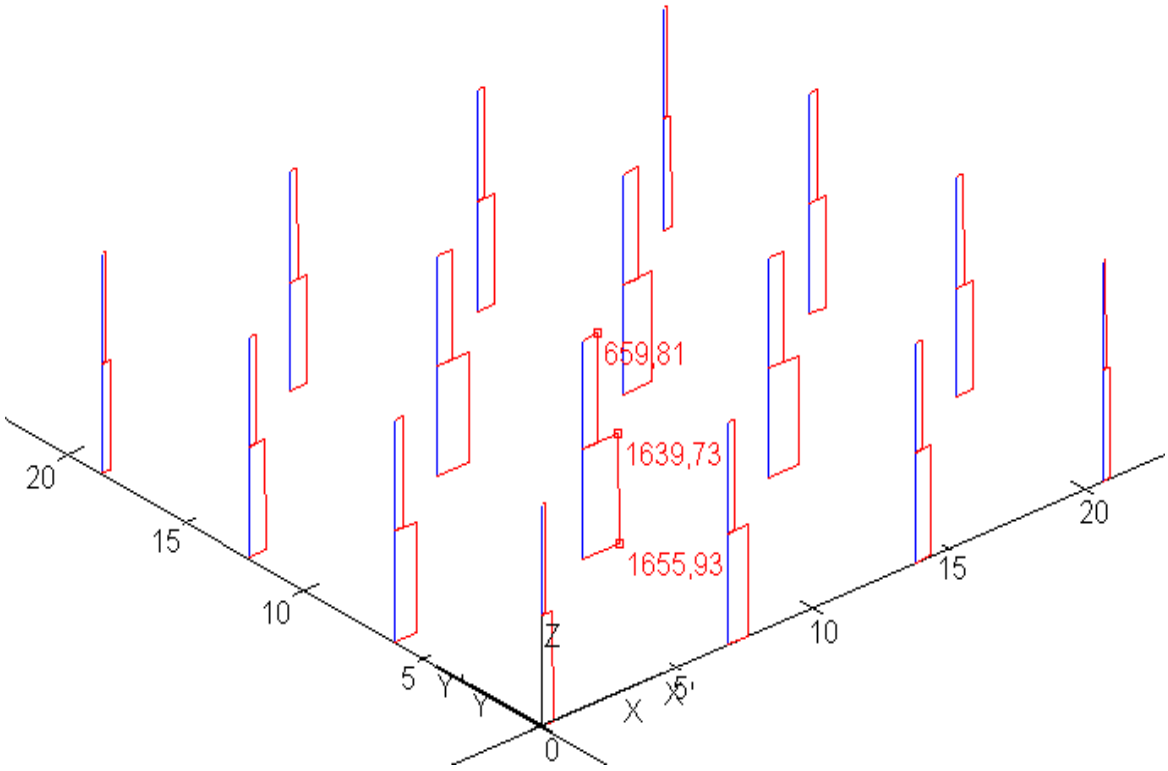


Slika 9.1. Dijagram uzdužnih sila

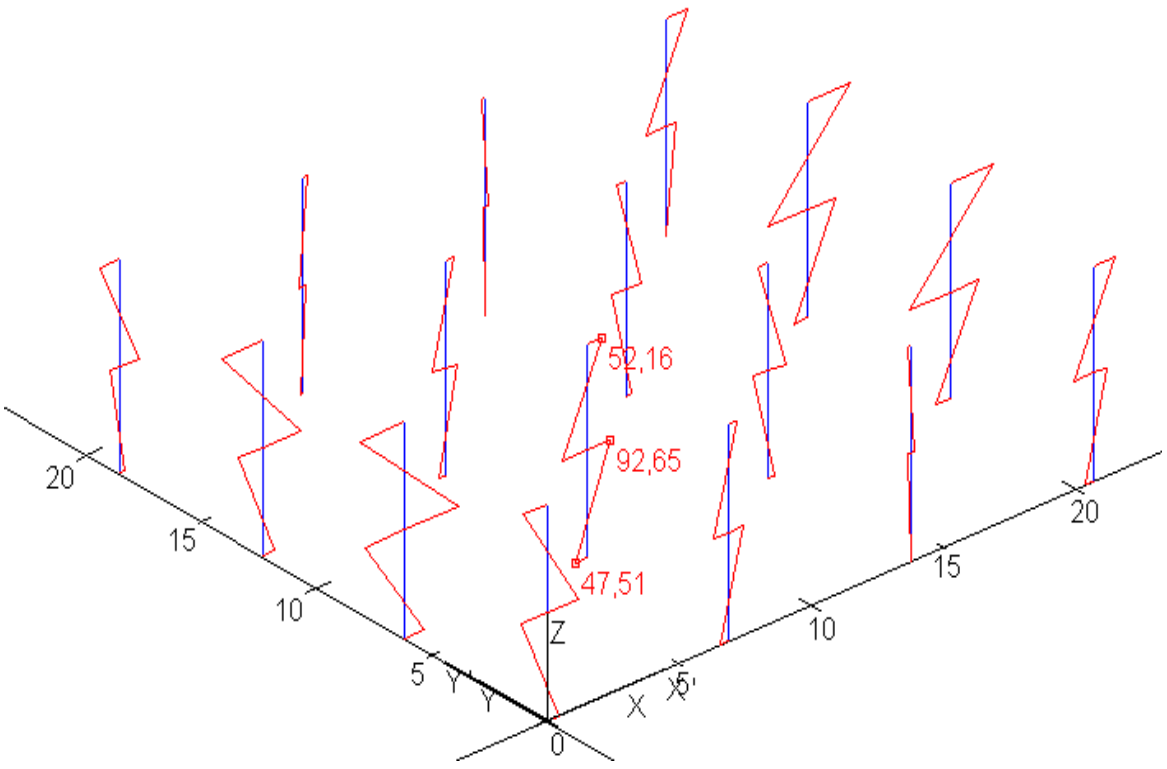


Slika 9.2. Dijagram momenta savijanja

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	112.62	-1656.05
2. Kombinacija	Max N	92.65	-1655.93

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.

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

$$N_{100} = (1.35 \cdot 7.7 + 1.5 \cdot 3.5) \cdot 6.9 \cdot 6.2$$

$$N_{100} = 669.30 \text{ kN}$$

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

$$N_{200} = (1.35 \cdot 8.50 + 1.5 \cdot 1.0) \cdot 6.9 \cdot 6.2$$

$$N_{200} = 555.10 \text{kN}$$

$$N = 1224.37 \text{ kN}$$

Klasa betona: C40/50 → $f_{cd} = \frac{40}{1.5} = 26.67$ 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= 1224.37 / 0,45 ·2,67 = 1019 cm2

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

$a = \sqrt{A} = \sqrt{1019} = 0.3192\ m = 31.92\ cm$

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)
112.62	-1656.05
92.65	-1655.93

Pretpostavljamo:

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

$$v_{sd1} = \frac{N_{Ed1}}{b \cdot h \cdot f_{cd}} = \frac{-1656.05}{35 \cdot 35 \cdot 2.67} = -0{,}51$$

$$v_{sd2} = \frac{N_{Ed2}}{b \cdot h \cdot f_{cd}} = \frac{-1655.93}{45 \cdot 45 \cdot 2.67} = -0{,}51$$

$$\mu_{Sd1} = \frac{M_{Ed1}}{b \cdot h^2 \cdot f_{cd}} = \frac{112.62 \cdot 100}{35 \cdot 35^2 \cdot 2.67} = 0{,}10$$

$$\mu_{Sd2} = \frac{M_{Ed2}}{b \cdot h^2 \cdot f_{cd}} = \frac{92.65 \cdot 100}{35 \cdot 35^2 \cdot 2.67} = 0{,}08$$

mehanički koeficijent armiranja ω_1= 0,05

ω_2= 0,05

$$A_{S1=}A_{S2=}\omega \cdot \frac{f_{cd}}{f_{yd}} \cdot b \cdot h = 0.05 \cdot \frac{2.67}{43.48} \cdot 35 \cdot 35 = 3.76\ cm^2$$

Ukupna površina armature za simetrično armiranje

As1+ As2 = 3.76·2=7.50 cm2

As,min = 0,1 · NEd / fyd = 0,1 · 1656 / 43,48 = 3,8 cm2

As,min = 0,002 · Ac = 0,002 · 1225 = 2.45 cm2

Odabrane šipke: 4Ø18+4Ø16(A_s=10.18+8.04=18.22 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= 15×1.8= 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: $N_{max} = 1656.05$ kN
  $M_{pripadno} = 112.62$ kNm

- 2. kombinacija: $M_{max} = 92.65$ kNm
  $N_{pripadno} = 1655.93$ kN

10.1.1. Preliminarno određivanje dimenzija temelja

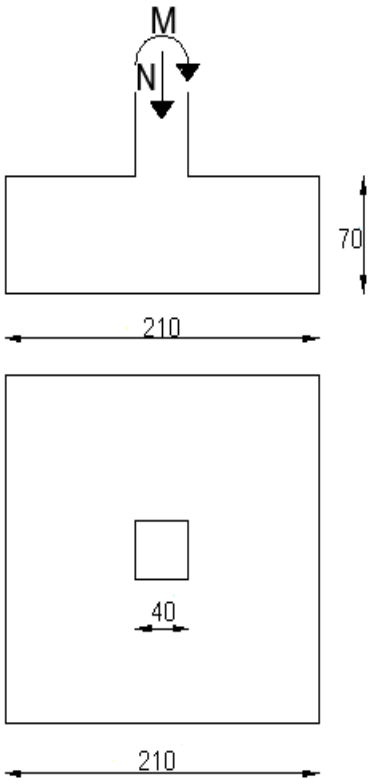
Temelj je centrično opterećen zbog čega odabiremo kvadratni poprečni presjek.

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

Širina i duljina temelja: $d = š = b = a_{stup} \cdot \sqrt{\frac{f_{cd}^*}{\sigma_{t,dop}}} = a_{stup} \cdot \sqrt{\frac{0{,}45 f_{ck}}{\sigma_{t,dop}}} = 0{,}35 \cdot \sqrt{\frac{0{,}45 \cdot 40}{0{,}50}} = 2{,}1\ \mathrm{m}$

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

Težina temelja: $N_t = 2{,}1 \cdot 2{,}1 \cdot 0{,}7 \cdot 25 = 77.175\ (kN)$



Slika 10.1.Preliminarne dimenzije temelja

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

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

$$A = 2{,}1 \cdot 2{,}1 = 4.41\ m^2$$

$$W = \frac{bh^2}{6} = \frac{2{,}1 \cdot 2{,}1^2}{6} = 1.54\ m^3$$

- **1. kombinacija**

$$N_{max} = 1656.05\ kN \quad \rightarrow N_{Ed} = N_{max} + N_t = 1656.05 + 77.175 = 1733.23\ kN$$

$$M_{pripadno} = 112.62\ kNm$$

$$\sigma_{1,2} = \frac{N}{A} \pm \frac{M}{W} = \frac{1733.23}{4.41} \pm \frac{112.62}{1.54}\ 393.00 \pm 73.13$$

$$\sigma_1 = 466.13\ kN/m^2$$

$$\sigma_2 = 319.87\ kN/m^2$$

- **2. Kombinacija**

$$M_{max} = 92.65\ kNm$$

$$N_{pripadno} = 1655.93\ kN \quad \rightarrow N_{Ed} = N_{prip} + N_t = 1655.93 + 77.175 = 1733.10\ kN$$

$$\sigma_{1,2} = \frac{N}{A} \pm \frac{M}{W} = \frac{1733.10}{4.41} \pm \frac{92.65}{1.54} = 393.00 \pm 60.16$$

$$\sigma_1 = 453.16\ \frac{kN}{m^2}$$

$$\sigma_2 = 332.84\ kN$$

10.3. **PRORAČUN ARMATURE TEMELJA**

- **Momenti u presjeku 1-1**

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

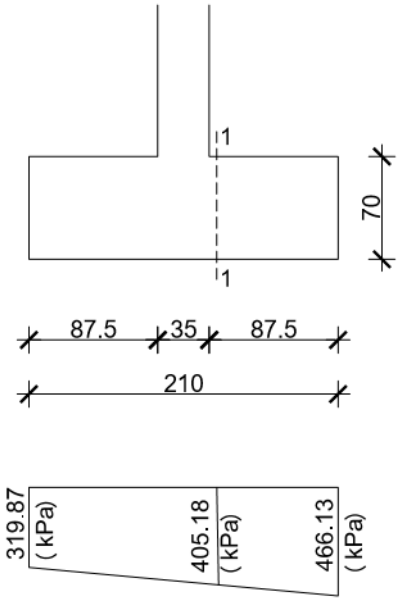
$$\sigma_{1-1} = \sigma_1 - \frac{b_1}{b} \cdot (\sigma_1 - \sigma_2)$$

- **1. kombinacija**

$$\sigma_{1-1} = 466.13 - \frac{0.875}{2{,}10} \cdot (466.16 - 319.87) = 405.18 \text{ kPa}$$

$$M_{1-1} = 405.18 \cdot 0.875 \cdot \frac{0.875}{2} + (466.16 - 405.18) \cdot \frac{0.875}{2} \cdot \frac{2}{3} \cdot 0.875$$

$$M_{1-1} = 170.67 \text{ kNm}$$



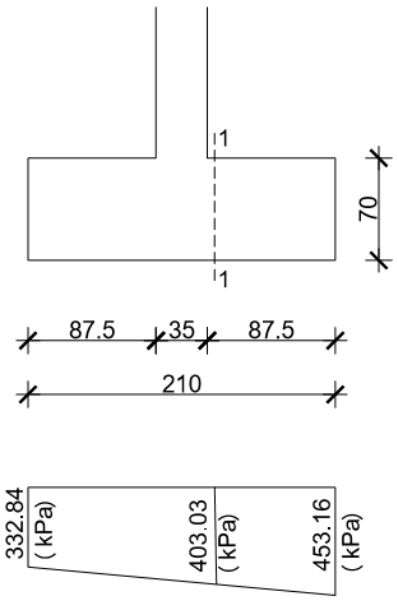
Slika 10.2. Naprezanje ispod temelja za kombinaciju 1

- **2. kombinacija**

$$\sigma_{1-1} = 453.16 - \frac{0.875}{2{,}10} \cdot (453.16 - 332.84) = 403.03 \text{ kPa}$$

$$M_{1-1} = 403.03 \cdot 0.875 \cdot \frac{0.875}{2} + (453.16 - 403.03) \cdot \frac{0.875}{2} \cdot \frac{2}{3} \cdot 0.875$$

$$M_{1-1} = 167.08 \text{ kNm}$$



Slika 10.3. Naprezanje ispod temelja za kombinaciju 2

Mjerodavni moment za proračun armature:

$M_{sd}^{1-1} = 170.67\ \text{kNm}$

Klasa betona: C40/50 → $f_{ck} = 40\ \text{MPa} \quad \rightarrow f_{cd} = \frac{40}{1,5} = 26,67\ \text{MPa} = 2,67\ \text{kN/cm}^2$

Zadana armatura: B500B → $f_{yk} = 500\ \text{MPa} \rightarrow f_{yd} = \frac{500}{1,15} = 434,78\ \text{MPa} = 43,48\ \text{kN/cm}^2$

$$\mu_{sd} = \frac{M_{ed}}{b \cdot d^2 \cdot f_{cd}} = \frac{170.67 \cdot 100}{100 \cdot 65^2 \cdot 2,67} = 0,015$$

Očitano: $\varepsilon_{s1} = 10.0\ ‰,\ \ \varepsilon_{c2} = 0,7\ ‰,\ \ \xi = 0,065\ ,\ \zeta$=0,977

$$A_{s1} = \frac{M_{ed,1-1}}{f_{yd} \cdot \zeta \cdot d} = \frac{170.67 \cdot 100}{43,48 \cdot 0,977 \cdot 65} = 6,18\ \text{cm}^2/\text{m}'$$

$$A_{s1} = \frac{6.18}{2,1} = 2,94\left(\frac{\text{cm}^2}{\text{m}'}\right)$$

Odabrana armatura:

$$A_{s1,\text{potrebno}} = 2,94\left(\frac{\text{cm}^2}{\text{m}}\right)$$

U donju zonu temelja:

Odabrana armatura: mreža Q335 ($A_{s1} = 3.35\ \text{cm}^2/\text{m}$)

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**

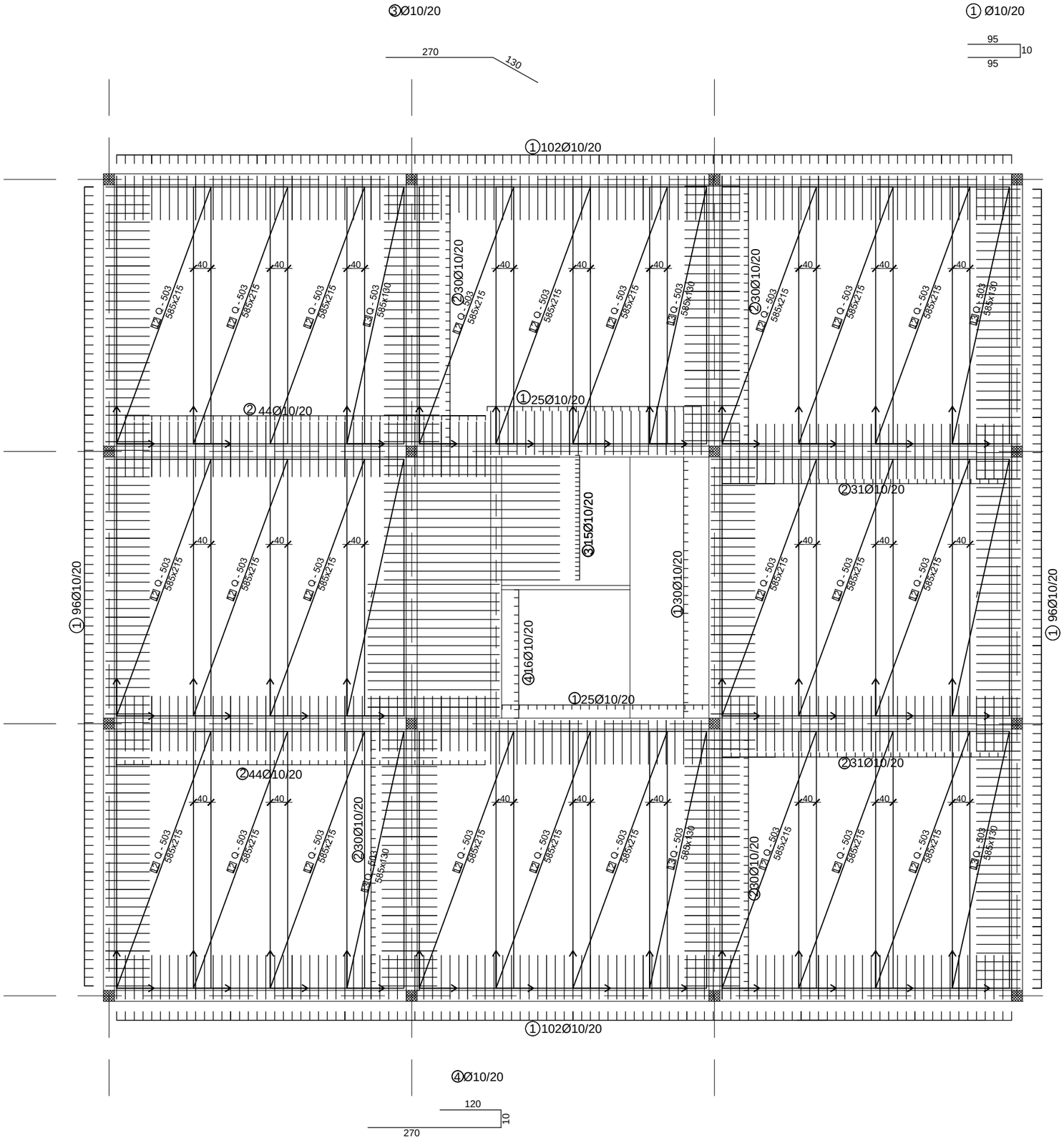
12. LITERATURA

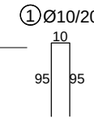
Radnić J.,Harapin A. Osnove betonskih konstrukcija, interna skripta.
Fakultet građevinarstva arhitekture i geodezije Splitu, studeni 2013.

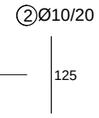
V. Herak Marović: Betonske konstrukcije 2, nastavni tekst (predavanja, vježbe)
http://cigla.gradst.hr/moodle26/course/view.php?id=151

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

ARMATURA PLOČE POZICIJA 100 DONJA ZONA
MJ 1:100







KLASA BETONA:
BETON C 40/50
ARMATURA B500B
PREKLOP MREŽA ≥45 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	585	24	8.03	2424.00
13	Q-503	130	585	8	8.03	488.55
Ukupno						2912.55

Šipke specifikacija

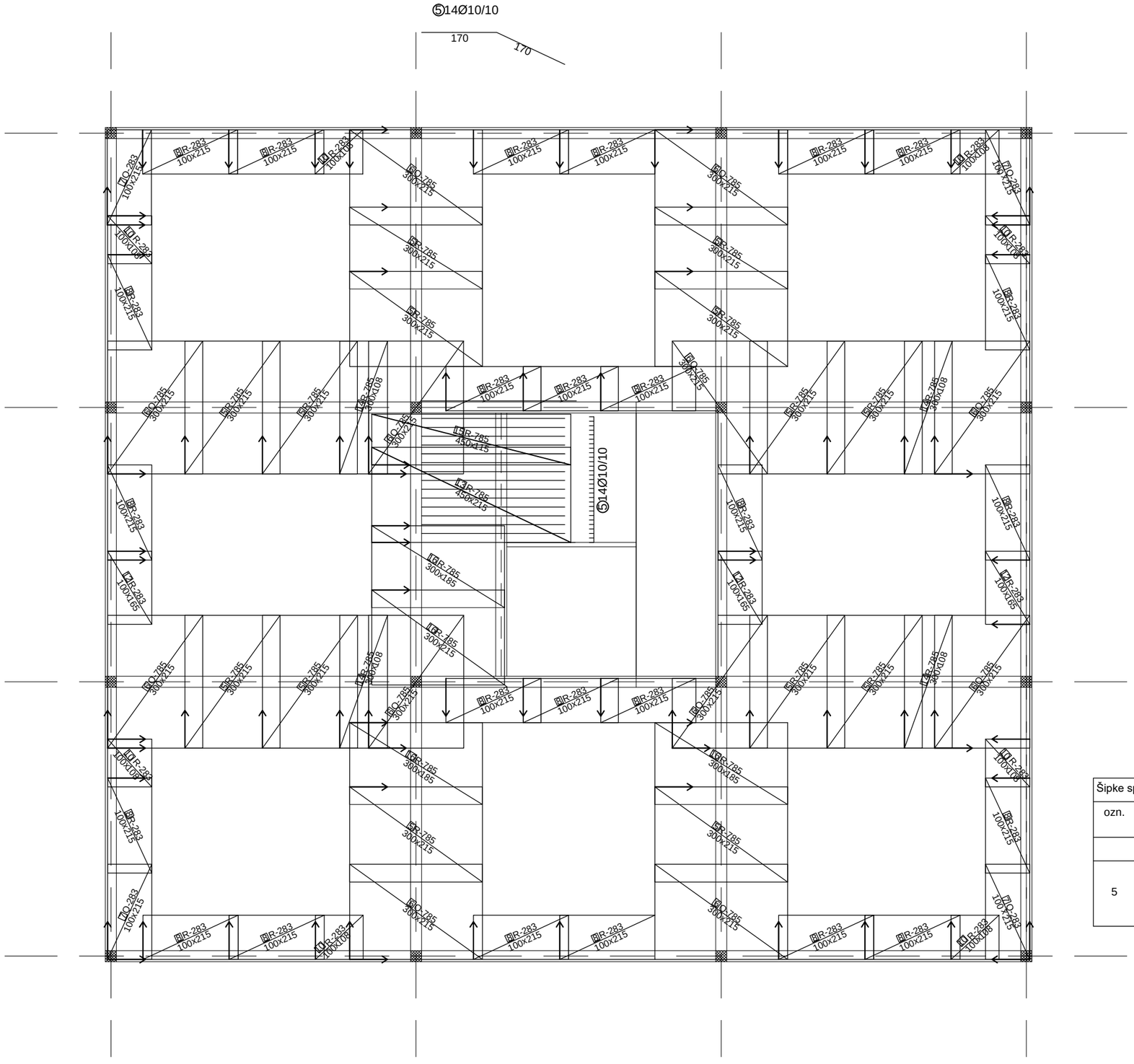
ozn.	oblik i dimenzije [cm]	Ø	lg [m]	n [kom.]	lgn [m]	Jedinična-težina [kg/m']	Ukupna težina [kg]
POZICIJE 100 DONJA ZONA							
1	95; 10; 95	10	2.00	446	892.00	0.79	704.68
2	125	10	1.25	270	337.50	0.79	266.63
3	270; 118; 130; 55	10	4.00	15	60.00	0.79	47.40
4	120; 10; 270	10	4.00	16	64.00	0.79	50.56
					Ukupna težina:		1069.00

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ZAVRŠNI RAD

IZRADIO	ANTE BILOŠ
AKADEMSKA GODINA 2016/2017	13.3.2017.
ARMATURA POZ.100 DONJA ZONA	M 1:100

ARMATURA PLOČE POZICIJA 100 GORNJA ZONA
MJ 1:100



KLASA BETONA:
BETON C 40/50
ARMATURA B500B
PREKLOP MREŽA ≥45 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	Q-785	215	300	10	12.46	803.67
6	R-785	215	300	17	7.35	805.93
7	Q-283	215	100	4	4.48	38.53
8	R-283	215	100	25	2.77	148.80
10	R-283	108	100	8	2.77	23.93
12	R-283	165	100	2	2.77	9.14
13	R-785	215	450	1	7.35	71.11
14	R-785	108	300	4	7.35	95.25
15	R-785	115	450	1	7.35	38.00
16	R-785	185	300	1	7.35	40.95
Ukupno						2075.30

Šipke specifikacija

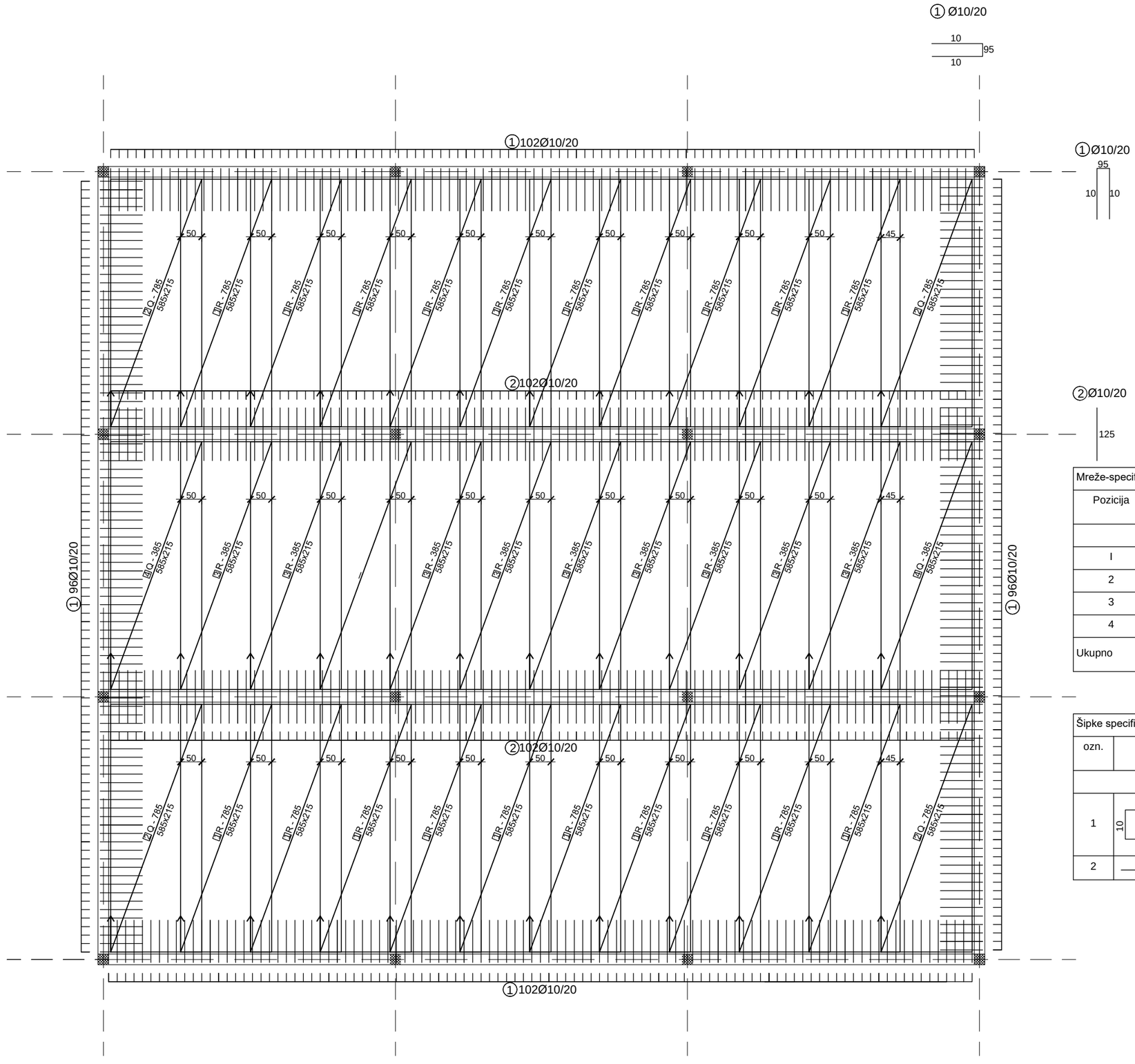
ozn.	oblik i dimenzije [cm]	Ø	lg [m]	n [kom.]	lgn [m]	Jedinična-težina [kg/m']	Ukupna težina [kg]
POZICIJE 100 GORNJA ZONA							
5	170 / 170 / 91 / 43	10	3.40	14	47.60	0.79	37.60
						Ukupna težina:	37.60

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ZAVRŠNI RAD

IZRADIO	ANTE BILOŠ
AKADEMSKA GODINA 2016/2017	13.3.2017.
ARMATURA POZ.100 GORNJA ZONA	M 1:100

ARMATURA PLOČE POZICIJA 200 DONJA ZONA
MJ 1:100



KLASA BETONA:
BETON C 40/50
ARMATURA B500B
PREKLOP MREŽA ≥45 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	585	20	7.35	1848.90
2	Q-785	215	585	4	12.46	626.86
3	R-385	215	585	10	3.68	462.85
4	Q-385	215	585	2	6.10	153.44
Ukupno						3092.05

Šipke specifikacija

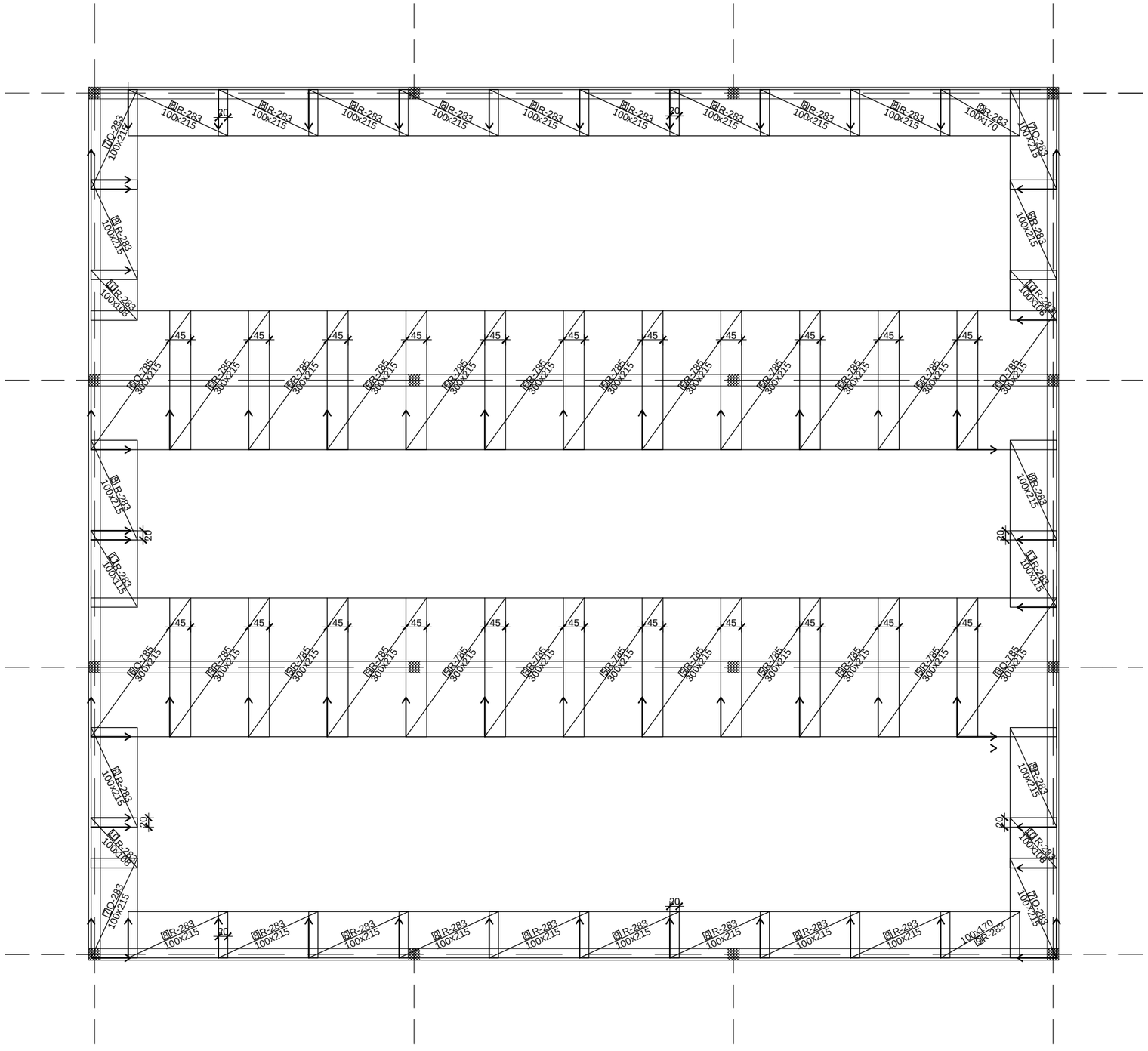
ozn.	oblik i dimenzije [cm]	Ø	lg [m]	n [kom.]	lgn [m]	Jedinična-težina [kg/m']	Ukupna težina [kg]
POZICIJE 200 DONJA ZONA							
1	95 / 10 / 95	10	2.00	396	792.00	0.79	625.68
2	125	10	1.25	204	255.00	0.79	201.45
						Ukupna težina:	827.00

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IZRADIO	ANTE BILOŠ
AKAEMSKA GODINA 2016/2017	13.3.2017.
ARMATURA POZ.200 DONJA ZONA	M 1:100

ARMATURA PLOČE POZICIJA 200 GORNJA ZONA
MJ 1:100



KLASA BETONA:
BETON C 40/50
ARMATURA B500B
PREKLOP MREŽA ≥45 cm
ZAŠTITNI SLOJ C=3 cm

Mreže-specifikacija

Pozicija	Oznka mreže	B [cm]	L [cm]	n	Jedinična težina [kg/m2]	Ukupna težina [kg]
POZICIJA 200 GORNJA ZONA						
5	R-785	215	300	18	7.38	856.82
6	Q-785	215	300	4	12.46	321.50
7	Q-283	215	100	4	4.48	38.53
8	R-283	215	100	23	2.77	136.98
9	R-283	170	100	2	2.77	9.42
10	R-283	108	100	4	2.77	11.97
11	R-283	165	100	2	2.77	9.15
Ukupna težina:						1374.94

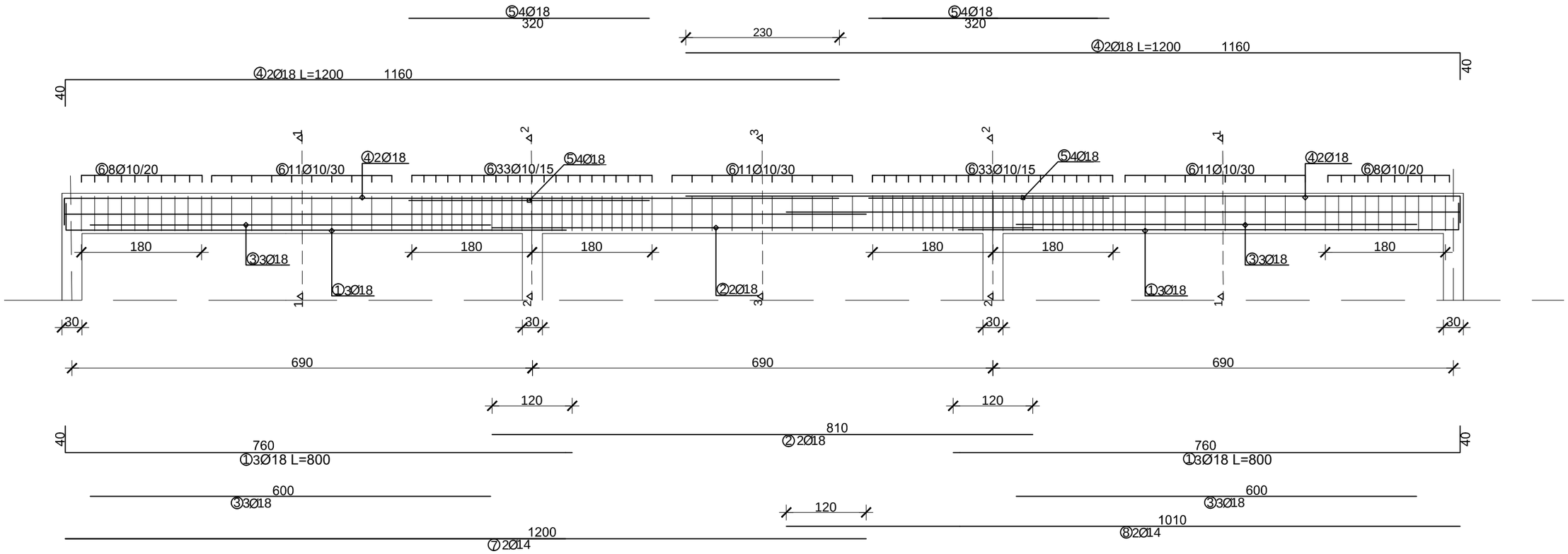
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ZAVRŠNI RAD

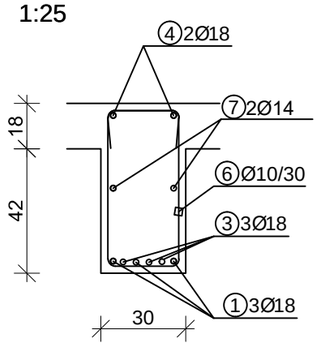
IZRADIO	ANTE BILOŠ
AKADEMSKA GODINA 2016/2017	13.3.2017.
ARMATURA POZ.200 GORNJA ZONA	M 1:100

ARMATURA GREDE POZICIJA 100

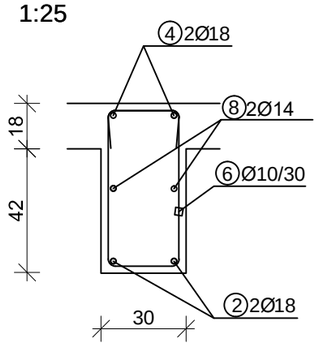
MJ 1:65



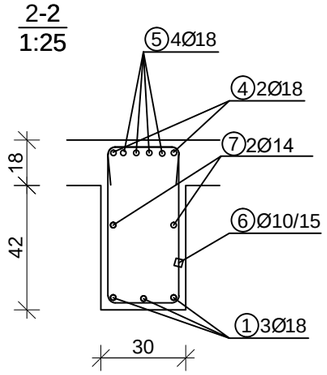
1-1
1:25



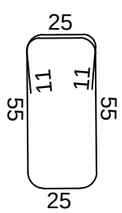
3-3
1:25



2-2
1:25



⑥Ø10/15/20/30 L=182 cm



KLASA BETONA:
BETON C 40/50
ARMATURA B500B
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, 760	18	8.00	6	48.00	1.998	95.90
2	810	18	8.10	2	16.20	1.998	32.37
3	600	18	6.00	6	36.00	1.998	71.93
4	1160, 40	18	12.00	4	48.00	1.998	95.90
5	360	18	3.60	8	28.8	1.998	57.54
6	55, 11, 11, 55, 25, 25	10	1.82	100	167.44	0.79	143.78
7	1200	14	12.00	2	24.00	1.208	29.00
8	1010	14	10.10	2	20.20	1.208	26.82

Ukupna težina: 553.24 [kg]

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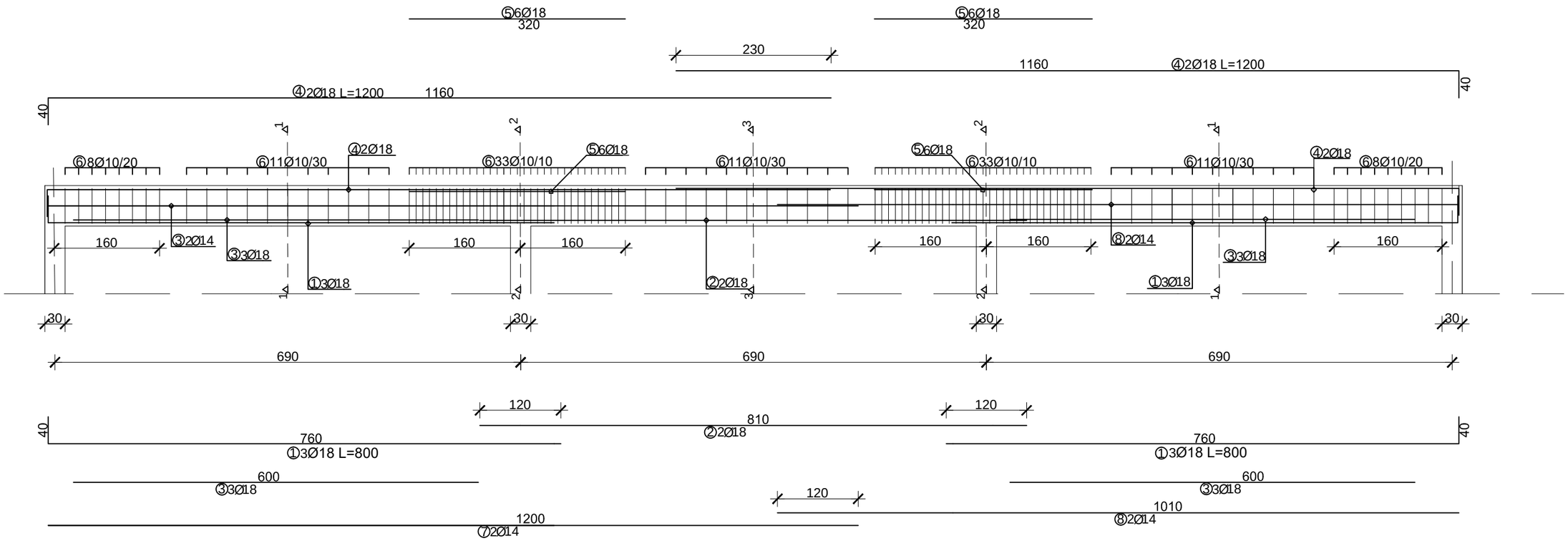
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ZAVRŠNI RAD

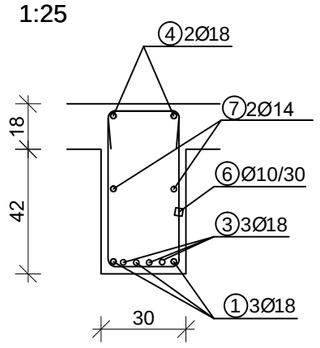
IZRADIO	ANTE BILOŠ
AKADEMSKA GODINA 2016/2017	13.3.2017.
ARMATURA GREDE POZ.100	M 1:65

ARMATURA GREDE POZICIJA 200

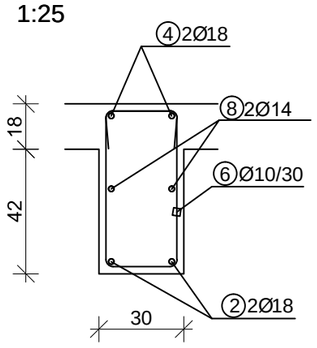
MJ 1:65



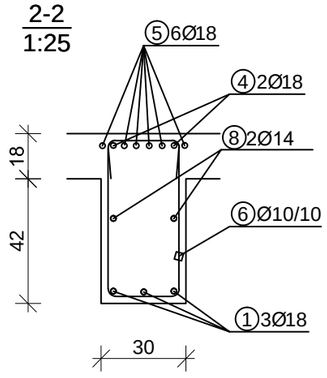
1-1
1:25



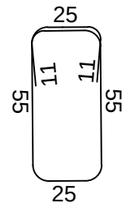
3-3
1:25



2-2
1:25



⑥Ø10/10/20/30 L=182 cm



KLASA BETONA:
BETON C 40/50
ARMATURA B500B
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, 760	18	8.00	6	48.00	1.998	95.90
2	810	18	8.10	2	16.20	1.998	32.37
3	600	18	6.00	6	36.00	1.998	71.93
4	1160, 40	25	12.00	4	48.00	1.998	95.90
5	320	25	3.20	12	38.40	1.998	76.72
6	55, 11, 11, 55, 25, 25	10	1.82	115	209.3	0.79	165.52
7	1200	14	12.00	2	24.00	1.208	29.00
8	1010	14	10.10	2	20.20	1.208	26.82
						Ukupna težina:	594.16 [kg]

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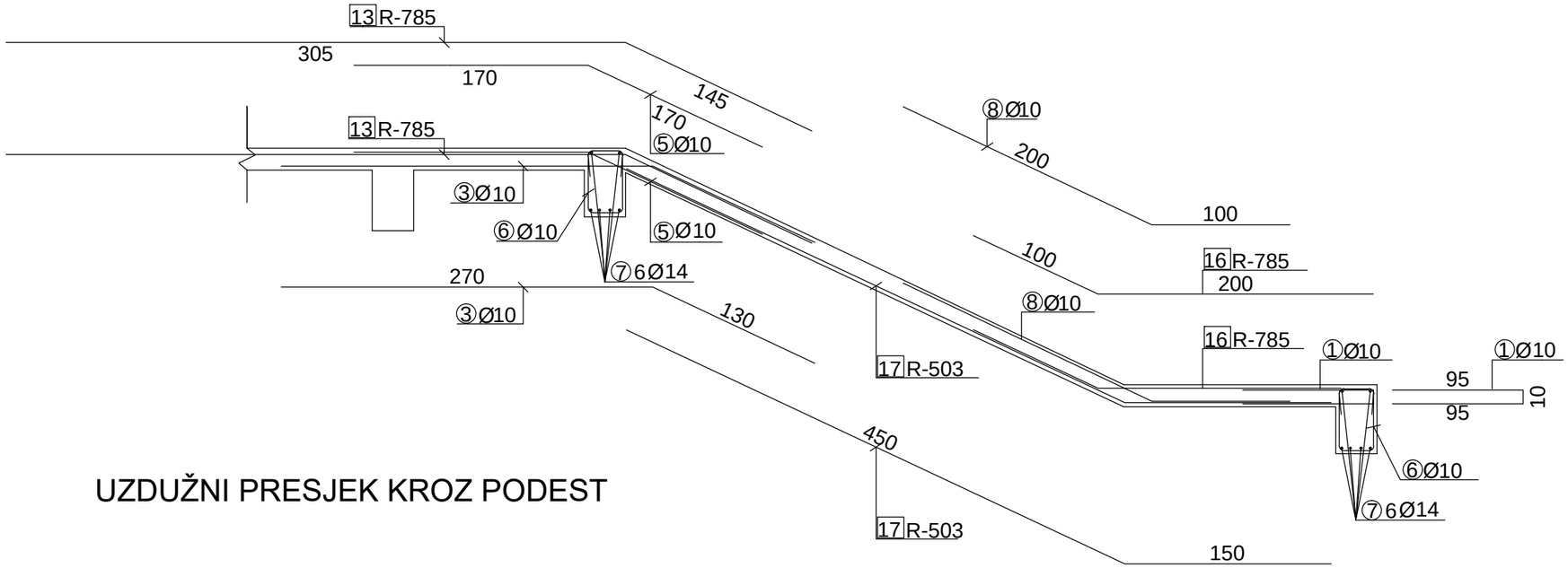
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ZAVRŠNI RAD

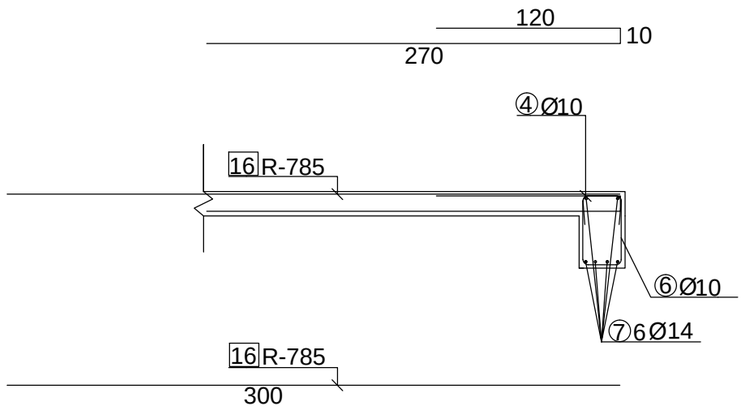
IZRADIO	ANTE BILOŠ
AKADEMSKA GODINA 2016/2017	13.3.2017.
ARMATURA GREDE POZ.200	M 1:65

ARMATURA STUBIŠTA
MJ 1:40

UZDUŽNI PRESJEK KROZ STUBIŠTE



UZDUŽNI PRESJEK KROZ PODEST



KLASA BETONA:
BETON C 40/50
ARMATURA B500B
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

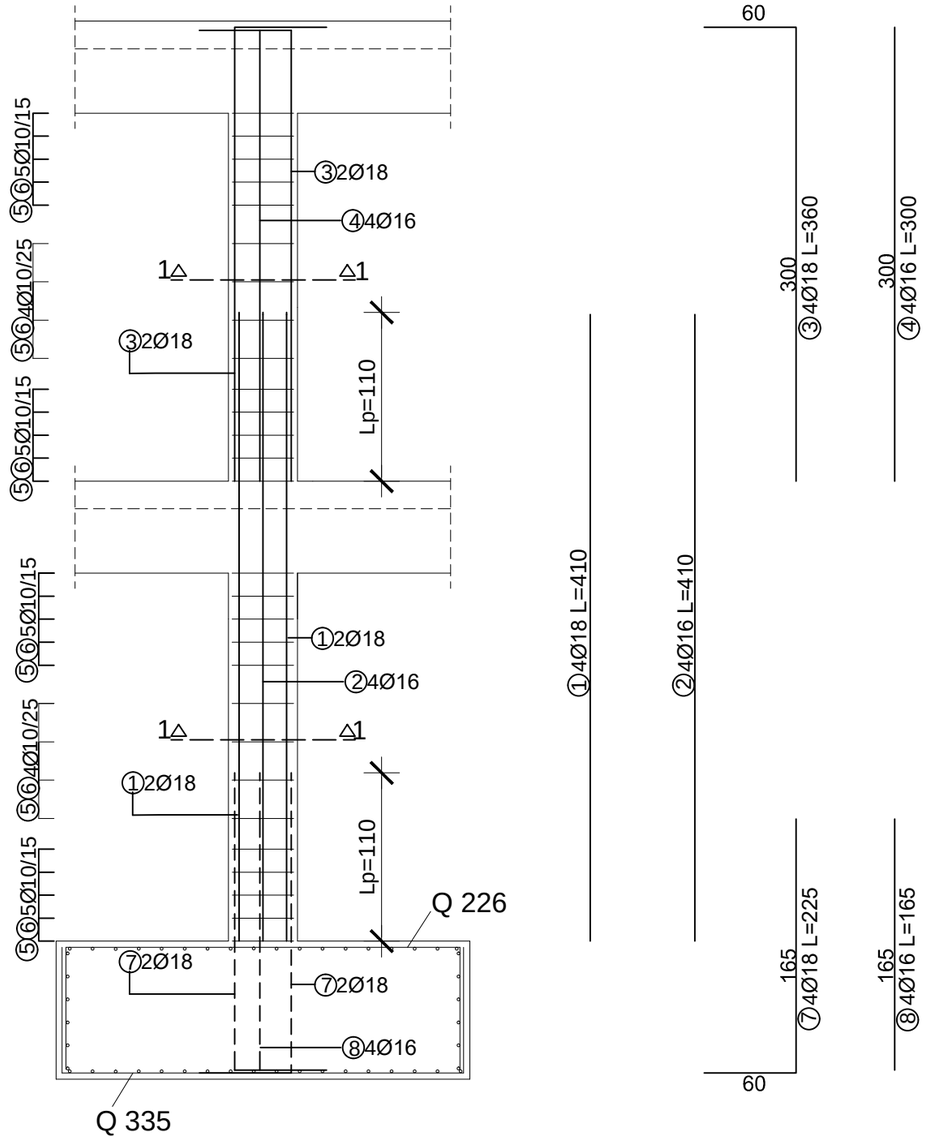
IZRADIO: ANTE BILOŠ

AKADEMSKA GODINA 2016/2017 | 13.3.2017.

ARMATURA STUBIŠTA | M 1:40

ARMATURA STUPA KROZ 2 ETAŽE

MJ 1:40



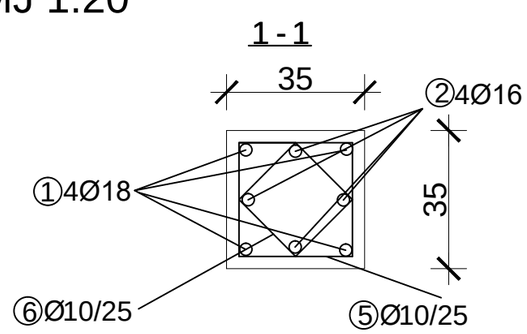
KLASA BETONA:
BETON C 40/50
ARMATURA B500B
ZAŠTITNI SLOJ C=3 cm

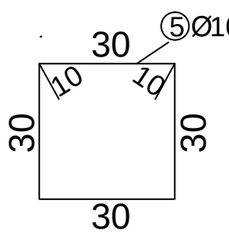
Šipke specifikacija

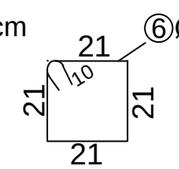
ozn.	oblik i dimenzije [cm]	Ø	lg [m]	n [kom.]	lgn [m]	Jedinična-težina [kg/m']	Ukupna težina [kg]
STUP 2.ETAŽA							
1	410	18	4.10	4	16.40	1.998	32.77
2	410	16	4.10	4	16.40	1.578	25.88
3	300, 60	18	3.60	4	14.40	1.998	28.77
4	300	16	3.00	4	12.00	1.578	18.94
5	30, 30, 30, 30	10	1.4	28	39.20	0.79	30.97
6	26, 26, 26, 26	10	1.04	28	29.12	0.79	23.00
7	165, 60	18	2.25	4	9.00	1.998	17.98
8	165	16	1.65	4	6.60	1.578	10.41

Ukupna težina: 188.72 [kg]

MJ 1:20







SVEUČILIŠTE U SPLITU
FAKULTET GRAĐEVINARSTVA, ARHITEKTURE I GEODEZIJE
UNIVERSITY OF SPLIT
FACULTY OF CIVIL ENGINEERING, ARCHITECTURE AND GEODESY

ZAVRŠNI RAD	
IZRADIO	ANTE BILOŠ
AKADEMSKA GODINA 2016/2017	13.3.2017.
ARMATURA STUPA KROZ 2 ETAŽE	M 1:40