# Projekt nosive armiranobetonske konstrukcije obiteljske kuće

**Tutić, Mihael**

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SVEUČILIŠTE U SPLITU, FAKULTET GRAĐEVINARSTVA, ARHITEKTURE I GEODEZIJE

STUDIJ: STRUČNI STUDIJ GRAĐEVINARSTVA

# PROJEKT NOSIVE ARMIRANOBETONSKE KONSTRUKCIJE OBITELJSKE KUĆE

ZAVRŠNI RAD

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SPLIT, 2017.

**SVEUČILIŠTE U SPLITU**

**FAKULTET GRAĐEVINARSTVA, ARHITEKTURE I GEODEZIJE**

Split, Matice hrvatske 15

| | |
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| 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 obiteljske kuće

Opis zadatka:

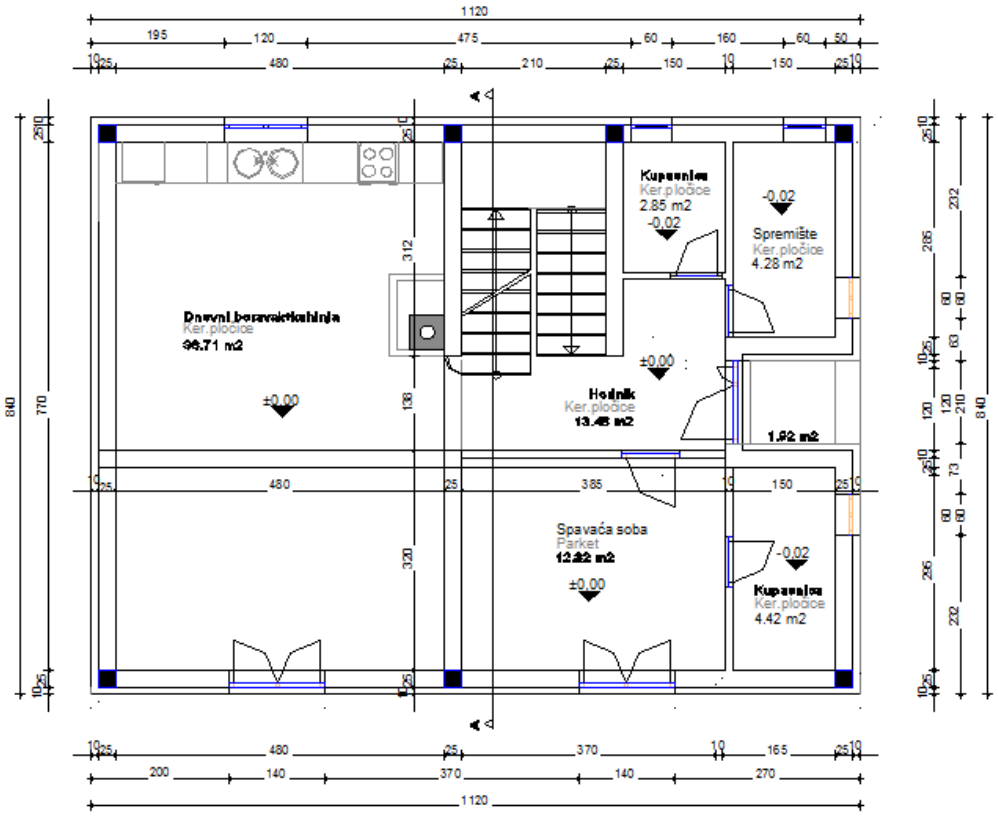
Zadana je shema nosive konstrukcije armiranobetonske obiteljske kuće, sa svim potrebnim dimenzijama (prilog zadatku). Također su zadana djelovanja na konstrukciju. Potrebno je proračunati nosivu konstrukciju, te za neke elemente nacrtati planove armature.Statički proračun i armaturne planove izraditi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

U Splitu, 19.07.2017.

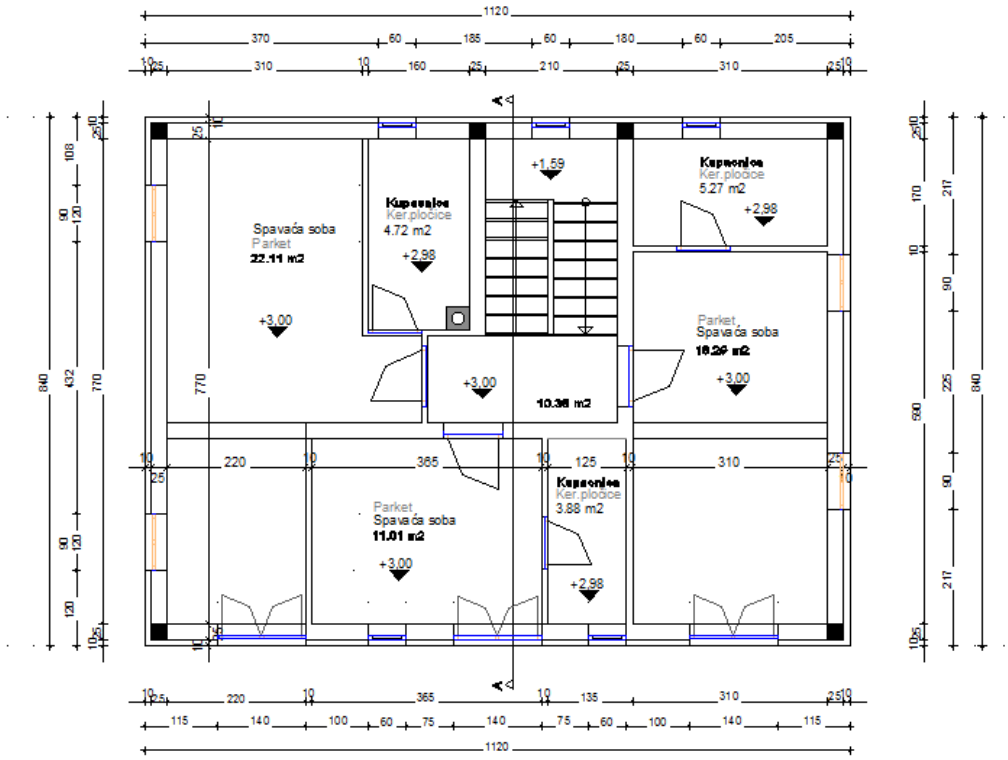
Voditelji Završnog rada:

dr.sc. Nikola Grgić

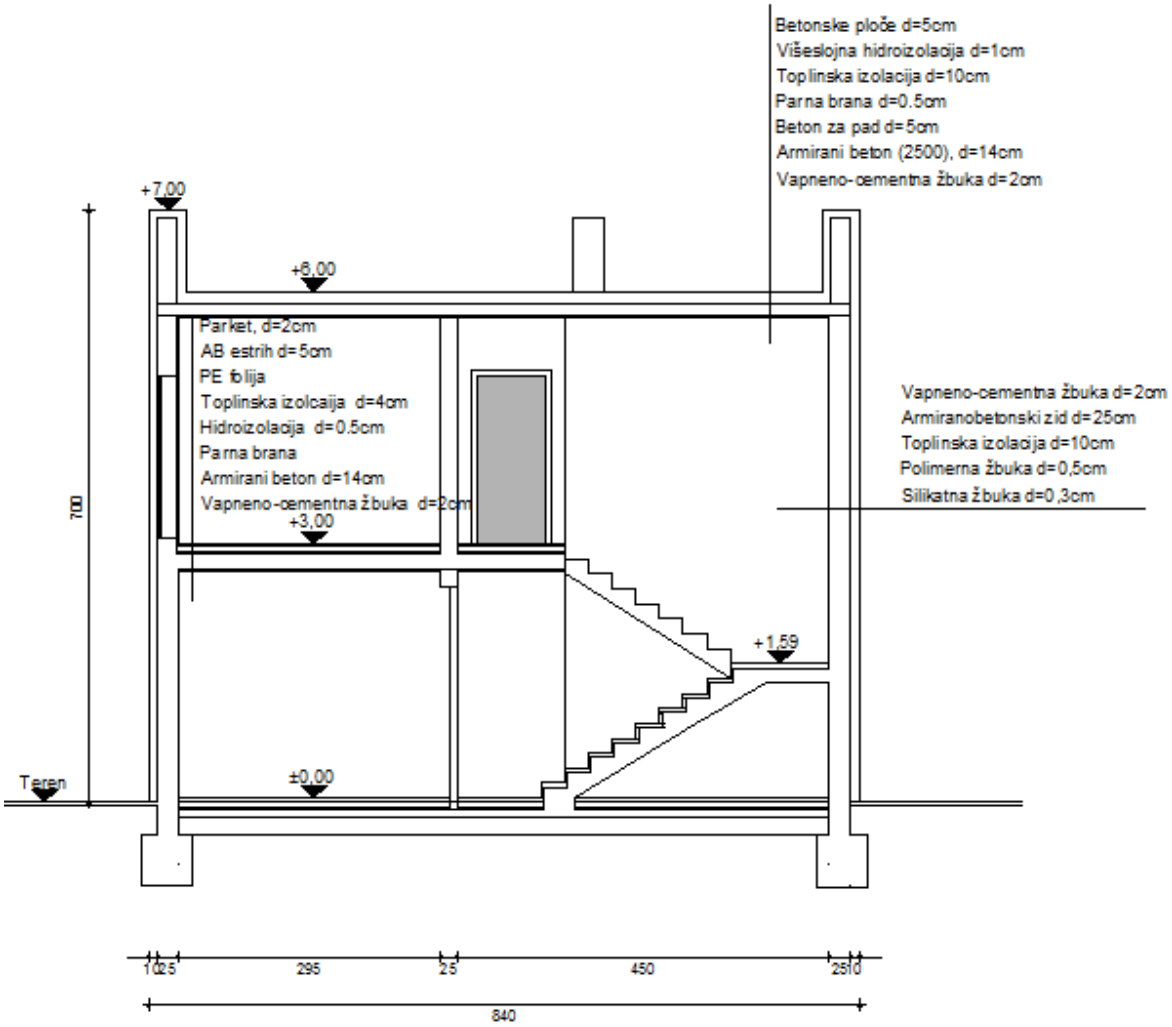
TLOCRT PRIZEMLJA




TLOCRT KATA



**PRESJEK A-A**

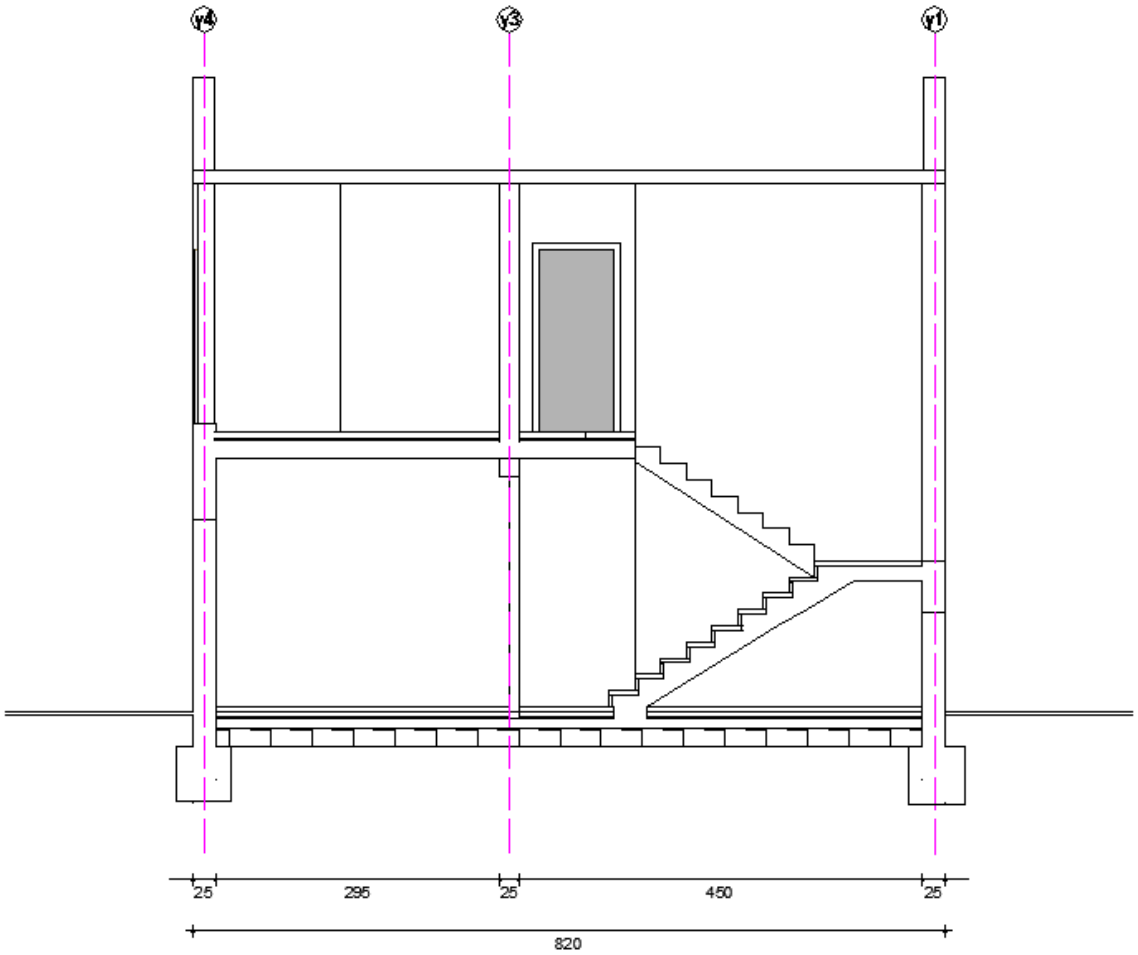

Betonske ploče d=5cm
Višeslojna hidroizolacija d=1cm
Toplinska izolacija d=10cm
Parna brana d=0.5cm
Beton za pad d=5cm
Armirani beton (2500), d=14cm
Vapneno-cementna žbuka d=2cm
+7,00
+6,00
Parket, d=2cm
AB estrih d=5cm
PE folija
Toplinska izolcaija d=4cm
Hidroizolacija d=0.5cm
Parna brana
Armirani beton d=14cm
Vapneno-cementna žbuka d=2cm
Vapneno-cementna žbuka d=2cm
Armiranobetonski zid d=25cm
Toplinska izolacija d=10cm
Polimerna žbuka d=0,5cm
Silikatna žbuka d=0,3cm
+3,00
+1,59
700
Teren
±0,00
10
25
295
25
450
25
10
840

**PRILOG:**

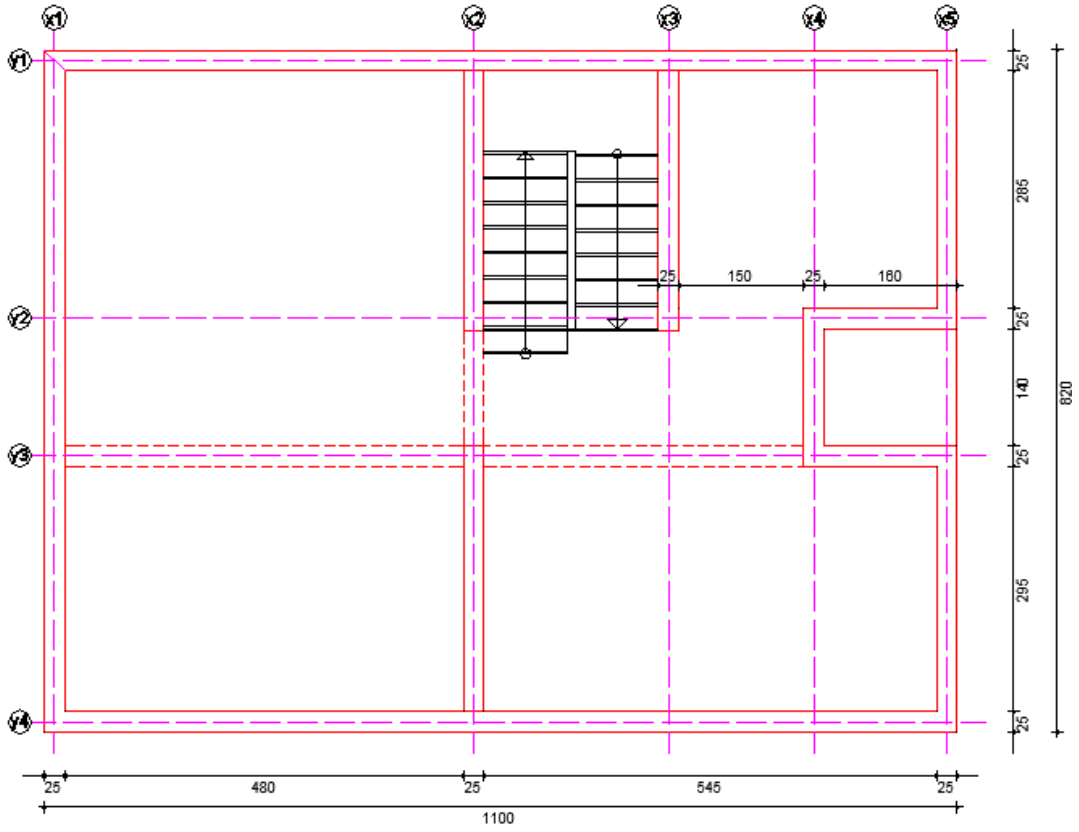
Na priloženim skicama dana je shema nosive armiranobetonske konstrukcije objekta. U tablici su zadane sve potrebne dimenzije i djelovanja na konstrukciju.

| Oznaka | Veličina | Jedinica | Opis |
|---|---|---|---|
| H | 3,0 | (m) | visina etaža |
| q | 3,5 | ($kN/m^2$) | uporabno opterećenje |
| $Z_v$ | III | | zona vjetra |
| $a_g$ | 0,50 | ($m/s^2$) | proračunsko ubrzanje tla |
| S | B 500 B | | armatura |
| C | C 30/37 | | klasa betona |

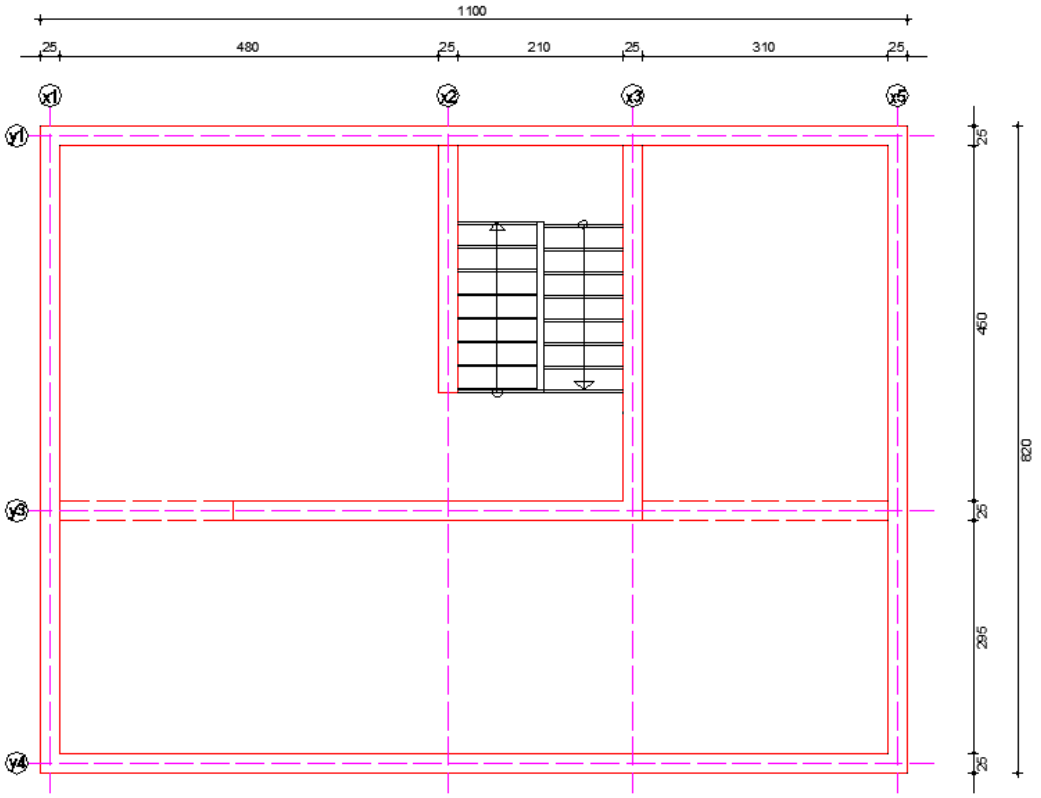
(I) Presjek



(II) Međuetaža




(III) Krovna konstrukcija



SAŽETAK:

Zadana je shema nosive konstrukcije armiranobetonske obiteljske kuće 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:

Armiranobetonska obiteljska kuća, numerički model, statički proracun, plan armature.

ABSTRACT:

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

KEYWORDS:

Reinforced concrete family house, numerical model, static analysis, reinforcement plan

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# 1. *TEHNIČKI OPIS*

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

Visina građevine iznosi 7,00 m, a tlocrtna površina građevine iznosi 10,75 x 7,95 m.

Nosiva konstrukcija objekta je okvirna,a čine je zidovi i grede iznad koje je armiranobetonska ploča. Stupovi se oslanjaju na trakaste temelje. Rezne sile u pločama i gredama dobivene su pomoću programa *AspalathosLinear*,a korišten je ravninski model. Sve armiranobetonske ploče su debljine d=14.0cm. Grede su dimenzija b/h=20/40 cm. Rezne sile u zidovima za različite kombinacije opterećenja dobivene su pomoću programa *AspalathosLinear*,a korišten je prostorni model (okvir). Odabrane su dimenzije zidova debljine 25 cm i trakastih temelja širine 65 cm. Za vertikalnu komunikaciju između katova predviđeno je armirano-betonsko stepenište debljine nosive ploče d=17.0 cm.

Izračunato stalno opterećenje za poziciju 200(krov) iznosi 7,03 kN/m$^2$,a uporabno opterećenje (prema propisima) iznosi 1,0 kN/m$^2$. Zadano je uporabno opterećenje za poziciju 100 i iznosi 3,5 kN/m$^2$, stalno opterećenje je 6,70 kN/m$^2$. Građevina se nalazi u III. vjetrovnoj zoni s dozvoljenom brzinom vjetra vb0= 35 m/s.

Dozvoljeno naprezanje u tlu na dubini temeljenja iznosi $\sigma_{dop}$ = 0.50 Mpa.

Za nosivu armiranobetosnsku konstrukciju odabran je beton C 30/37 i čelik za armiranje B500B.

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, te odabranih mrežai šipaka napravljeni su armaturni planovi za neke elemente konstrukcije. Svi nacrti i prikazi krojenja armaturnih mreža ploče, grede i zidova nacrtani su pomoću programa AutoCAD priloženi su u radu.

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

# 2. *GEOMETRIJSKE KARAKTERISTIKE NOSIVIH ELEMENATA*

-visina ploče:

$$d_{pl} = \frac{L_x}{35} = \frac{475}{35} = 13{,}57 \quad \textit{PRESJEK 1}$$

$\Rightarrow$ odabrano: $d_{pl} = 14\,\text{cm}$

visina grede:

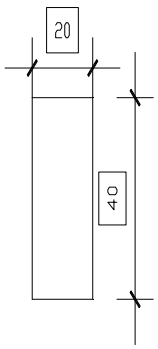
$$\frac{L_0}{12} = \frac{L_1}{12} = \frac{480}{12} = 40{,}0\text{cm}$$

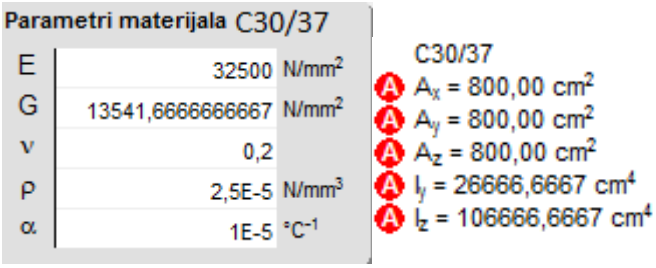
odabrano : $h_G = 40{,}0\text{cm}$

-širina grede:

$$\frac{h_{G1}}{2} = \frac{40}{2} = 20\text{cm}$$

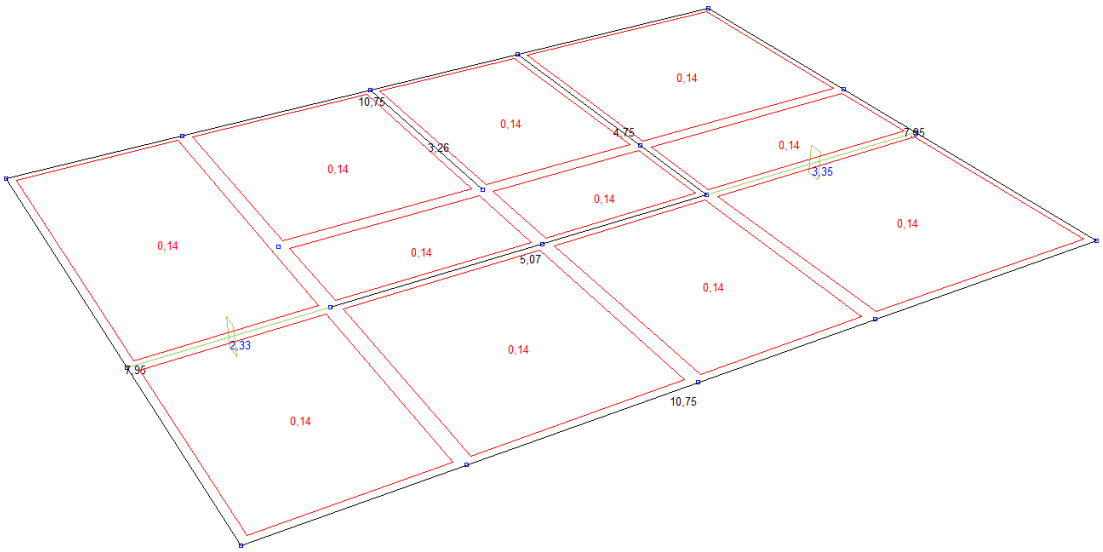
odabrano : $b_G = 20\text{cm}$




Slika 2.1. Poprečni presjek grede

- Za sve nosive elemente u x i y smijeru na pozicijama 100 i 200 odabran je isti presjek grede, dimenzija 40x20 cm.

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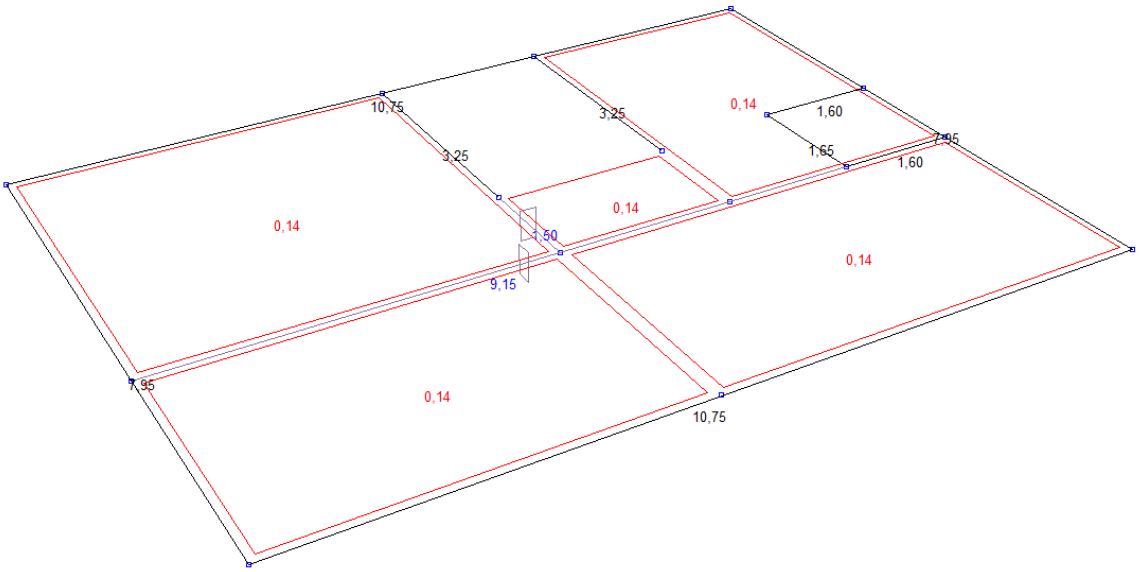
Slika 2.2. Prikaz dimenzija greda i ploča poz. 200

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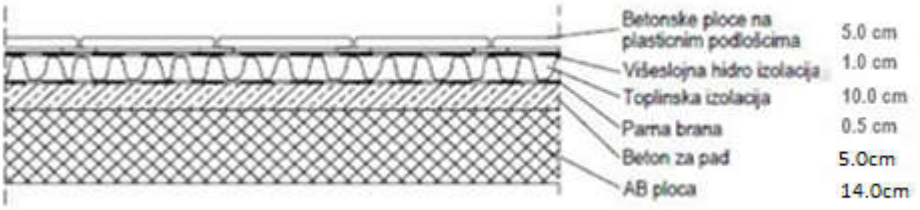
Slika 2.3. Prikaz dimenzija greda i ploča poz. 100

# 3. *ANALIZA OPTEREĆENJA*

## 3.1 **POZICIJA 200 – KROV**

### 3.1.1. *Stalno opterećenje*




Slika 3.1. Presjek ploče poz. 200

Tablica 3.1. Stanlno opterećenje poz.200

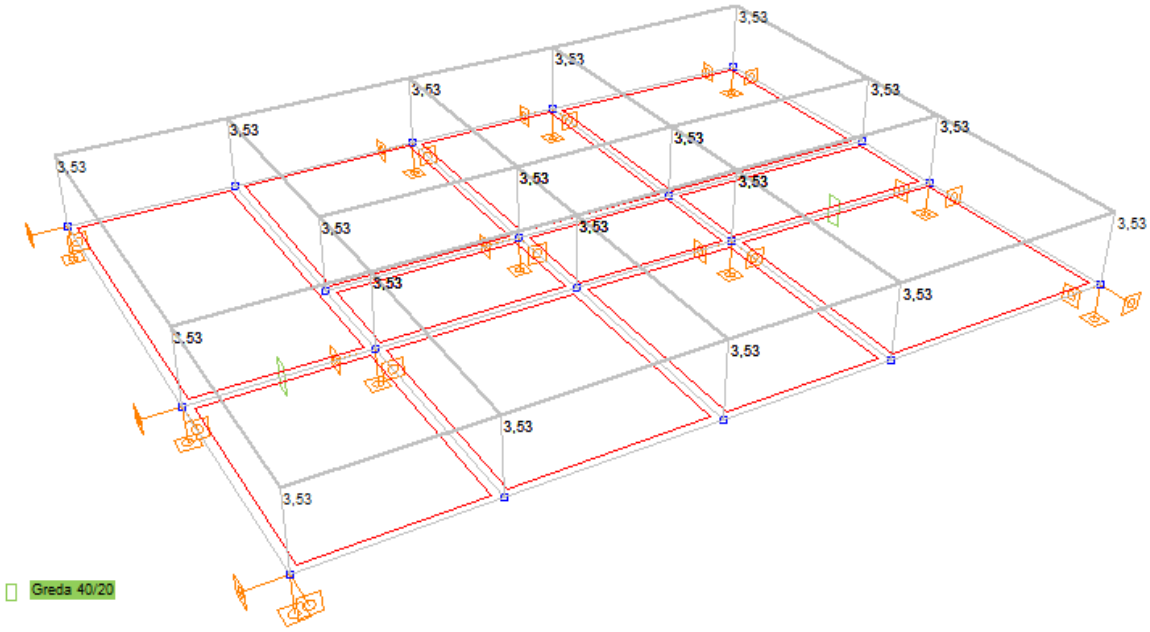
| | d (m) | $\gamma$ (kN/m$^3$) | d·$\gamma$ (kN/m$^2$) |
|---|---|---|---|
| Betonske ploče na plastičnim podloščima | 0.05 | 25.0 | 1.25 |
| Hidroizolacija + parna brana | 0.01 | 20.0 | 0.20 |
| Toplinska izolacija | 0.10 | 5.0 | 0.50 |
| Beton za pad | 0.05 | 24.0 | 1.20 |
| AB ploča | 0.14 | 25.0 | 3.50 |
| Cementna žbuka | 0.02 | 19.0 | 0.38 |

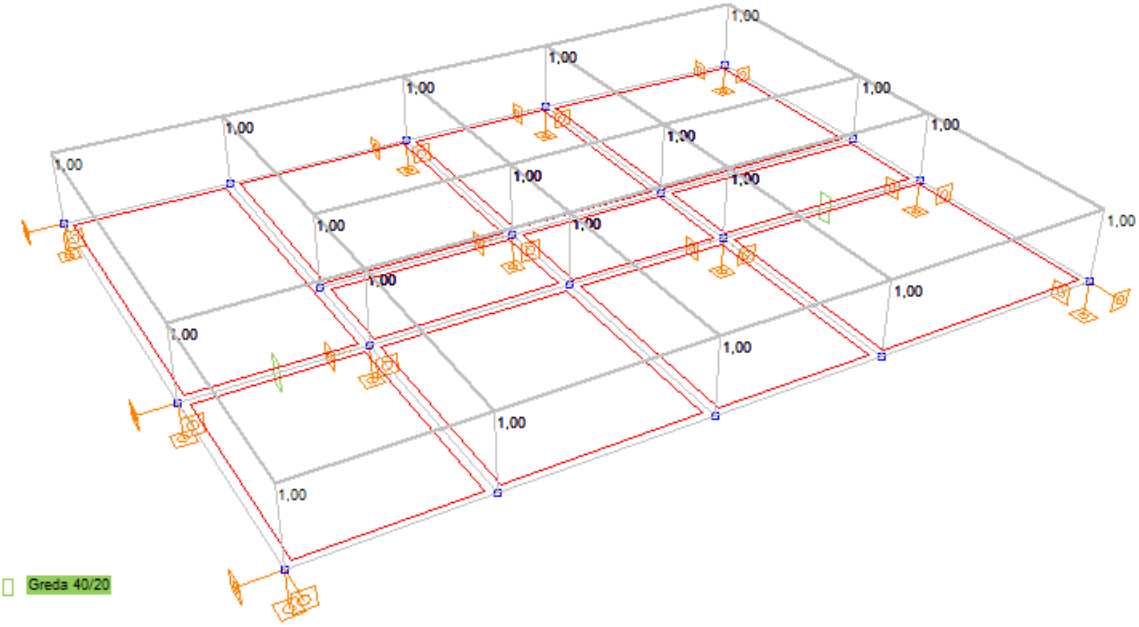
Ukupno stalno opterećenje: $g_{200} = 7.03$ (kN/m$^2$)

### 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:

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

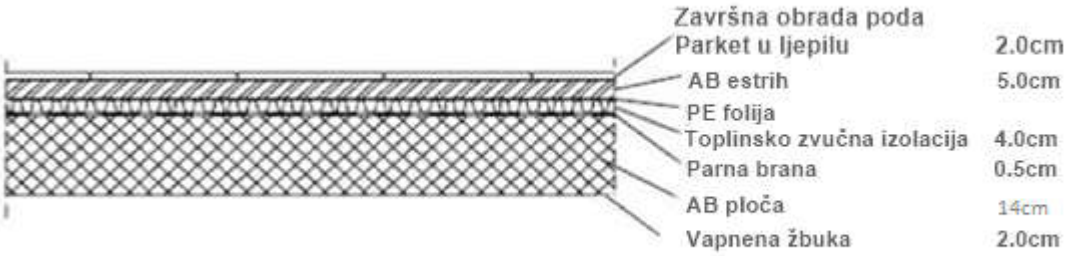



Slika 3.2. Prikaz dodatnog stalnog opterećenja $G_0$ i korisnog opterećenja Q

## 3.2. POZICIJA 100 – ETAŽA

### 3.2.1. *Stalno opterećenje*




Slika 3.3. Presjek ploče poz. 100

Tablica 3.2. Stalno opterećenje poz. 100

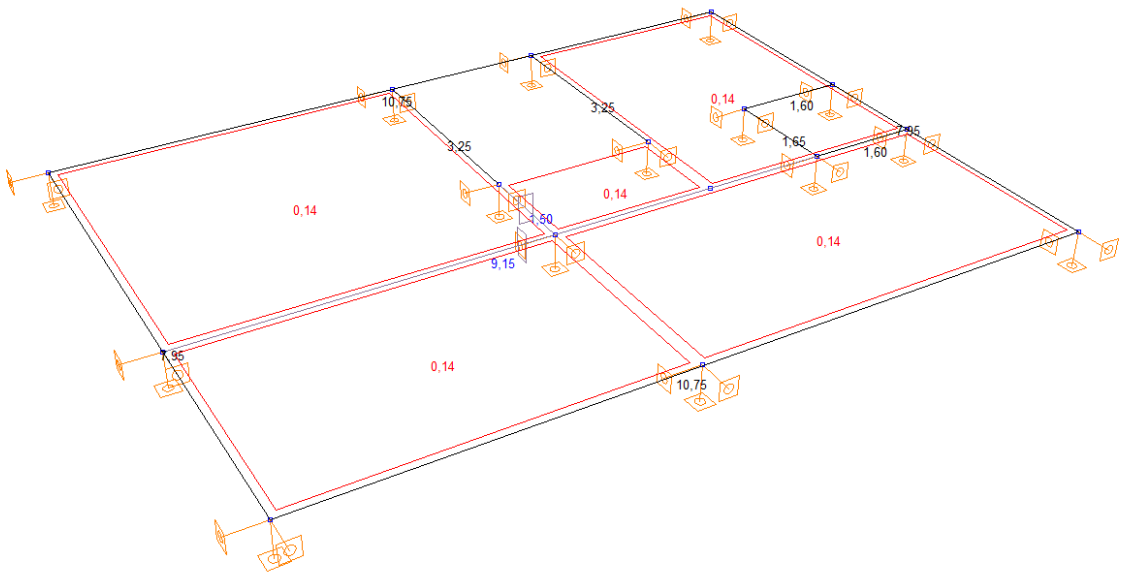
| | d (m) | $\gamma$ (kN/m$^3$) | d·$\gamma$ (kN/m$^2$) |
|---|---|---|---|
| Pregrade | | | 1.00 |
| Završna obrada poda-parket | 0.02 | 12.0 | 0.24 |
| AB estrih | 0.05 | 25.0 | 1.25 |
| Toplinska izolacija | 0.04 | 5.0 | 0.20 |
| Hidroizolacija | 0.005 | 20.0 | 0.10 |
| AB. Ploča | 0.14 | 25.0 | 3.50 |
| Pogled (vapnena žbuka) | 0,02 | 19,00 | 0,38 |

Ukupno stalno opterećenje $g_{100}$= 6,70 (kN/m$^2$)

### 3.2.2. *Uporabno opterećenje*

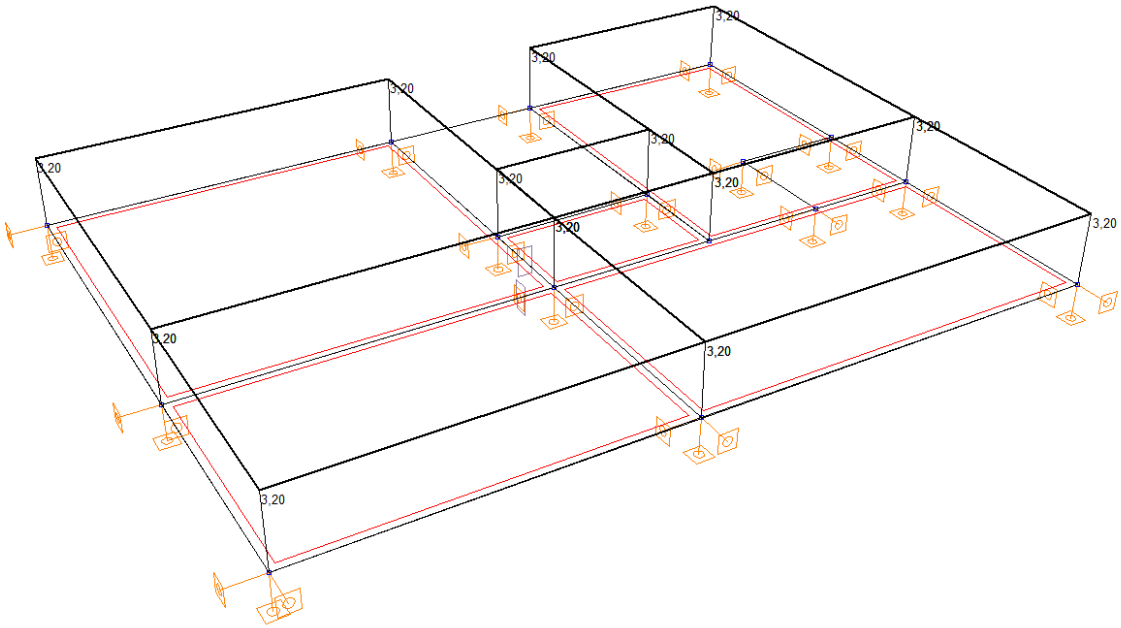
Uporabno opterećenje se uzima prema pravilniku: HRN EN 1991-2-1.

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




40/20

Slika 3.4. Geometrija etaže 100

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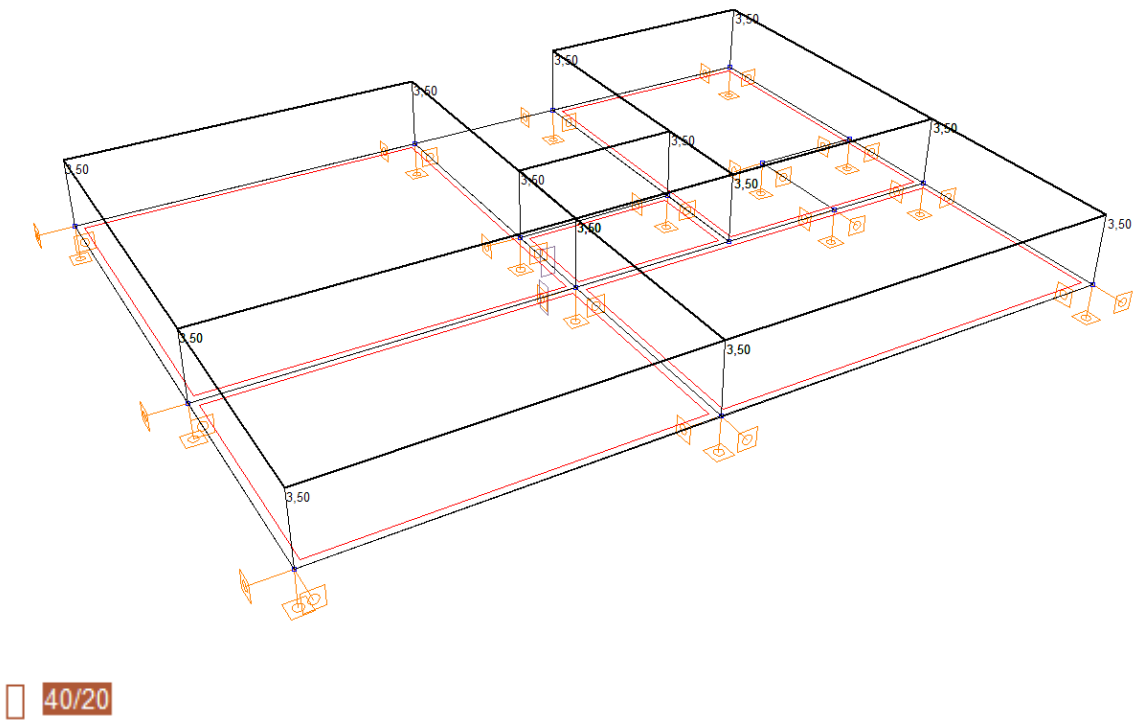
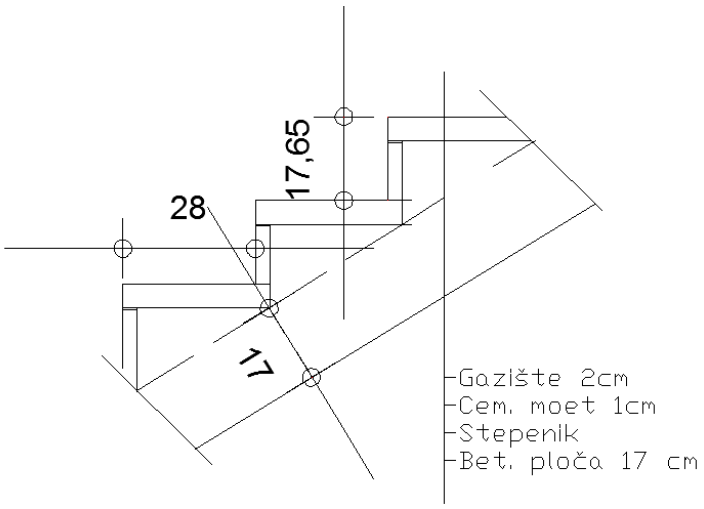
Slika3.5 Prikaz dodatnog stalnog opterećenja $G_0$




Slika 3.6 Prikaz uporabnog opterećenja Q

## 3.3. STUBIŠTE

### 3.3.1. *Stalno opterećenje*




Slika 3.7. Presjek stubišta

- Broj stuba :

n s = H/v = 3,00/0,1765 = 17 stuba

- Širina stube:

2·vs + šs = 63 ⇒šs = 63-2·0,1765 = 28 cm

- Duljina kraka:

L k = ns·šs = 7 ·28 = 196 cm

- Kut α:

tgα = 0,5·H/Lk = 1,5 ·3,3 = 0,765 ⇒

α = 39,1°

- Odabrana duljina podesta:

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

h'=h/cosα=17/cos39,1=19,87cm

Tablica 3.3. Stalno opterećenje stubišta

| | d (m) | $\gamma$ (kN/m$^3$) | d·$\gamma$ (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'= cm) | 0.199 | 25.0 | 4.96 |

Ukupno stalno opterećenje : $g_{st}$ =7,52 (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:

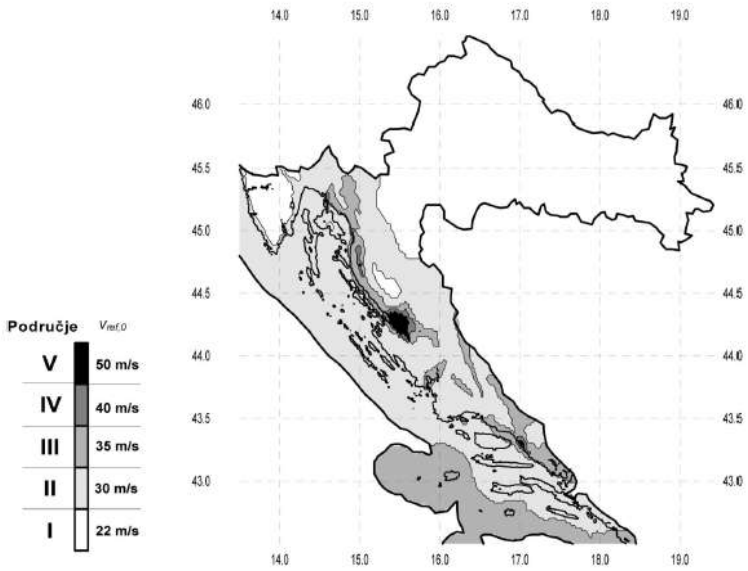
$q_{st}$= 4,95 (kN/m$^2$)

## 3.4. OPTEREĆENJE VJETROM

Dimenzije zgrade su: D=10,75m,Š =7,95m,H =7,00m.

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

Osnovna brzina vjetra: $v_{b,0} = 35\ m/s$ (za III. Zonu)




Slika 3.8. Zemljovid područja opterećenja vjetrom

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

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

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

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

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

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

Zgrada ima veću širinu od visine,a za mjerodavnu visinu uzimamo ukupnu visinu. Mjerodavna visina iznosi: 7,00

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

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

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 → $c_{r(z)}$= 0,215*ln(7,00/0,30)=0,677

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)

$$v_m=0,677*1,0*35,525=24,050 \text{ m/s}$$

Turbulencija:

$$I_v(z)=1/ c_o(z)*\ln(z_e/z_o)=1/1,0*\ln(7,00/0,30)=0,317$$

Maksimalni tlak brzine vjetra $q_p(z_e)$:

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

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

$$q_p(z)=(1+7*0,317)*1,25/2*24,050^2=1163,67 \text{ N/m}^2=1,16\text{kN/m}^2$$

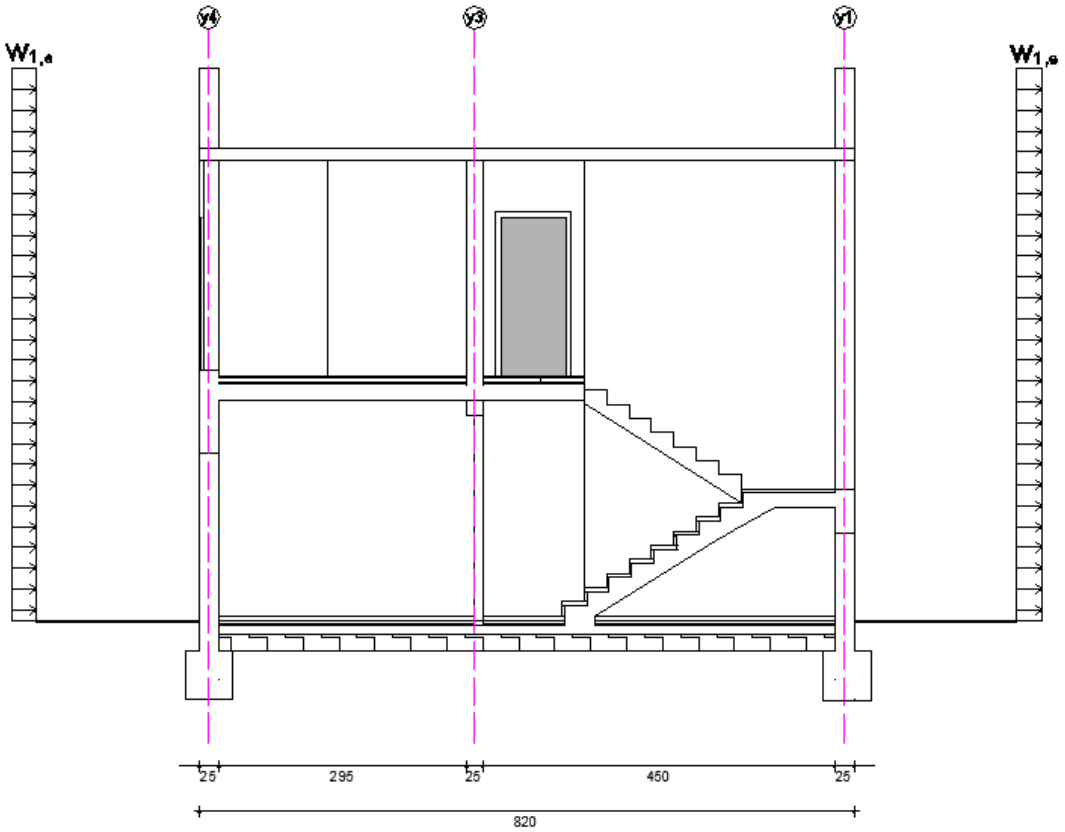
Djelovanje na zgradu:

$$W_{1,e}=0,8*q_p(z)=0,8*1,16=0,928\ kN/m^2$$

$$W_{2,e}=0,5*q_p(z)=0,5*1,16=0,580\ kN/m^2$$

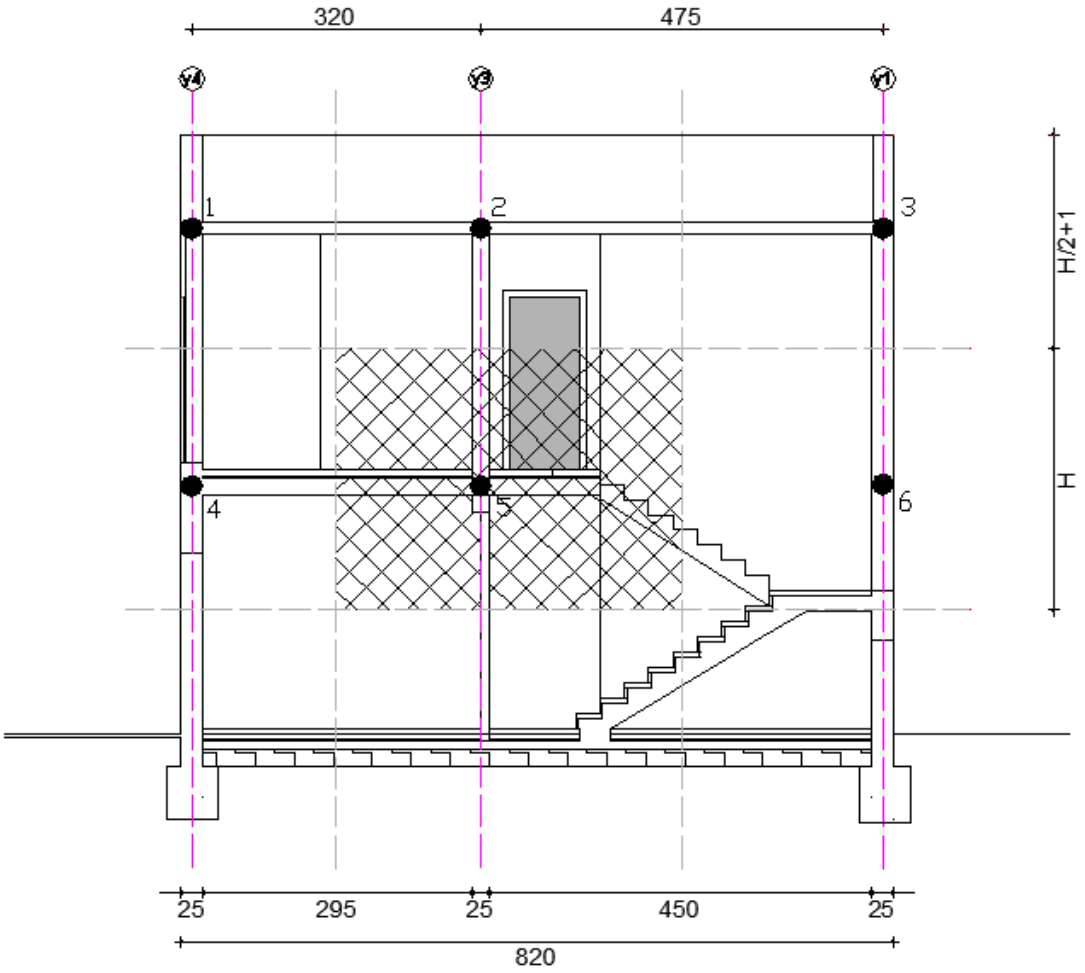
$$W_{1,l}=0,75*w_{1,e}=0,75*0,928=0,696\ kN/m^2$$

$$W_{2,l}=0,75*w_{2,e}=0,75*0,580=0,435\ kN/m^2$$




Slika 3.9.Opterećenje vjetrom

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




Slika 3.10. Utjecajne površine djelovanja vjetra

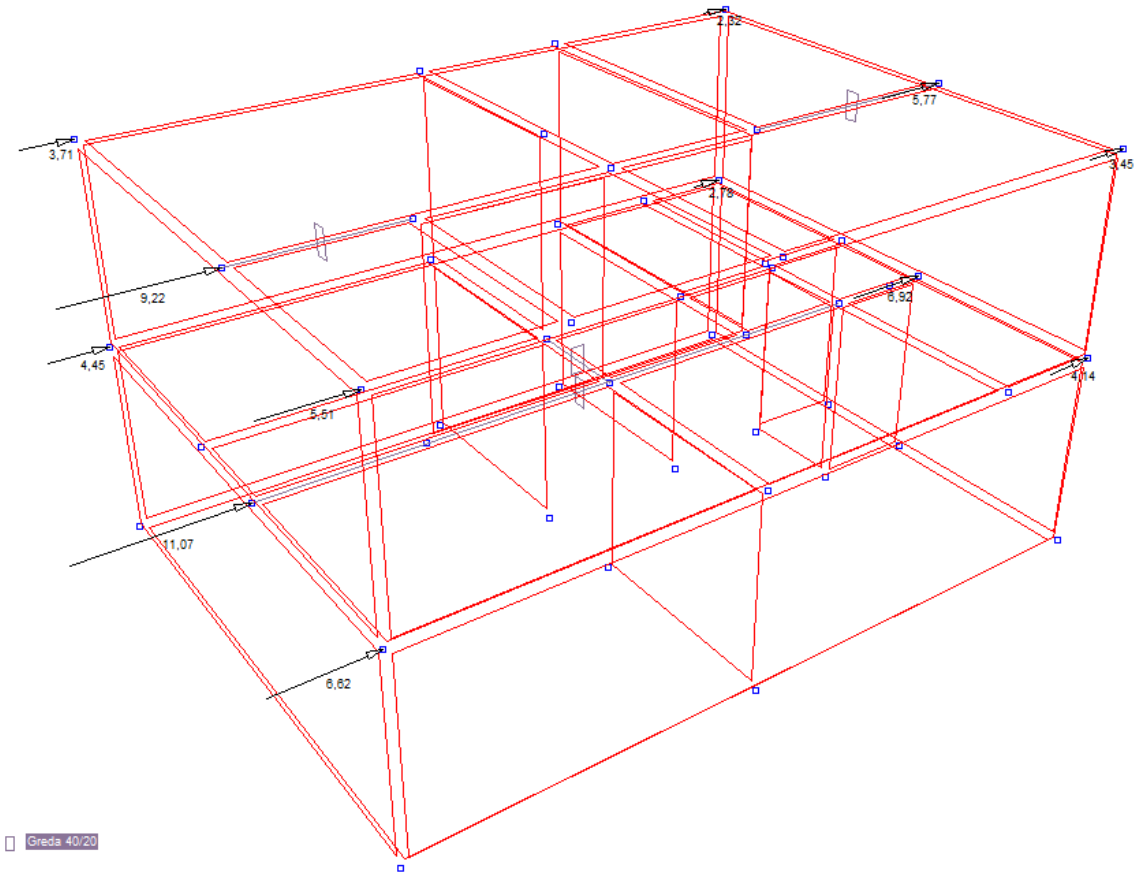
- **X smjer**

Tablica 3.5. Lijevi bok

| Čvor | Utjecajna površina | | | Tlak vjetra(kN/m²) | Sila u čvoru(kN) |
|---|---|---|---|---|---|
| | Širina(m) | Visina(m) | Površina(m²) | | |
| 1 | 1.60 | 2.5 | 4.00 | 0.928 | 3.71 |
| 2 | 3.975 | 2.5 | 9.94 | 0.928 | 9.22 |
| 3 | 2.375 | 2.5 | 5.94 | 0.928 | 5.51 |
| 4 | 1.60 | 3.0 | 4.80 | 0.928 | 4.45 |
| 5 | 3.975 | 3.0 | 11.93 | 0.928 | 11.07 |
| 6 | 2.375 | 3.0 | 7.13 | 0.98 | 6.62 |

Tablica 3.6. Desni bok

| Čvor | Utjecajna površina | | | Tlak vjetra(kN/m²) | Sila u čvoru(kN) |
|---|---|---|---|---|---|
| | Širina(m) | Visina(m) | Površina(m²) | | |
| 1 | 1.60 | 2.5 | 4.00 | 0.58 | 2.32 |
| 2 | 3.975 | 2.5 | 9.94 | 0.58 | 5.77 |
| 3 | 2.375 | 2.5 | 5.94 | 0.58 | 3.45 |
| 4 | 1.60 | 3.0 | 4.80 | 0.58 | 2.78 |
| 5 | 3.975 | 3.0 | 11.93 | 0.58 | 6.92 |
| 6 | 2.375 | 3.0 | 7.13 | 0.58 | 4.14 |




Slika 3.11. Djelovanje vjetra u X smjeru (sile u kN)

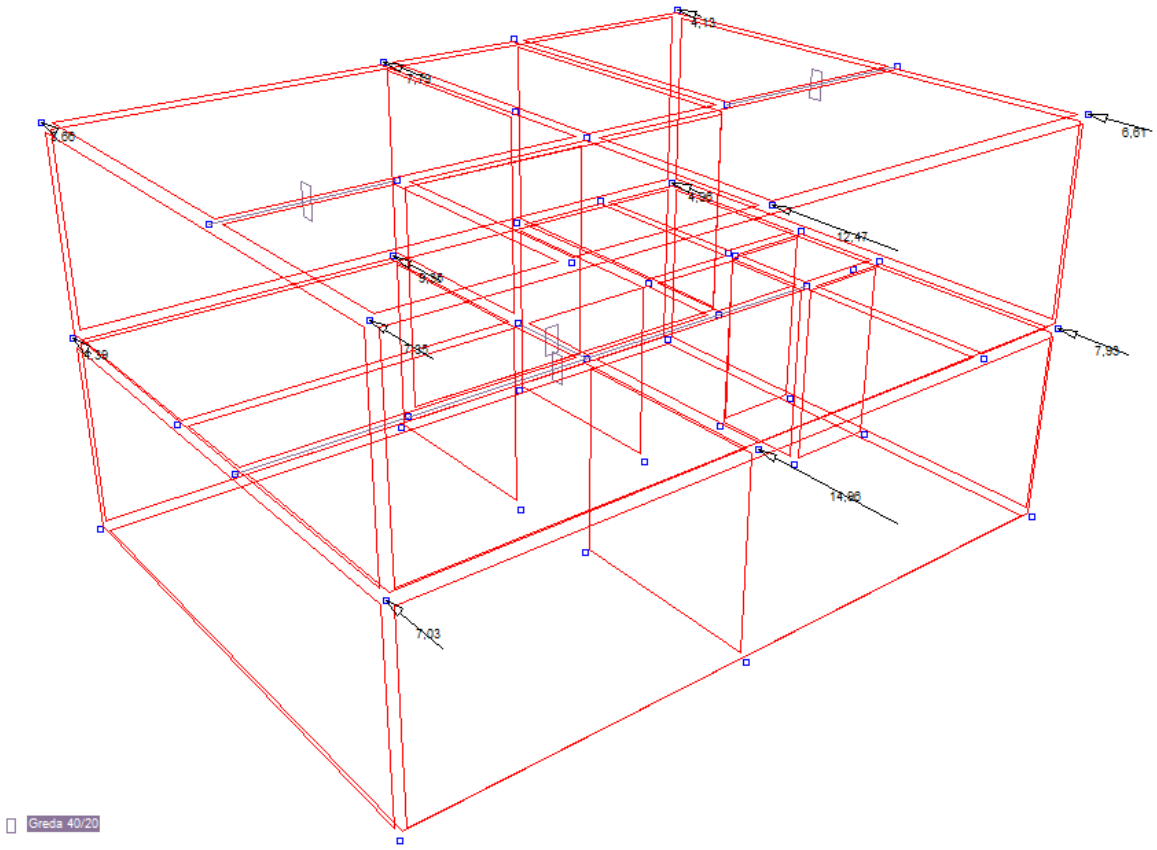
- **<u>Y smjer</u>**

Tablica 3.7. Prednja strana

| Čvor | Utjecajna površina | | | Tlak vjetra(kN/m²) | Sila u čvoru(kN) |
|---|---|---|---|---|---|
| | Širina(m) | Visina(m) | Površina(m²) | | |
| 1 | 2.525 | 2.5 | 6.313 | 0.928 | 7.35 |
| 2 | 5.375 | 2.5 | 13.438 | 0.928 | 12.47 |
| 3 | 2.85 | 2.5 | 7.125 | 0.928 | 6.61 |
| 4 | 2.525 | 3.0 | 7.575 | 0.928 | 7.03 |
| 5 | 5.375 | 3.0 | 16.125 | 0.928 | 14.96 |
| 6 | 2.85 | 3.0 | 8.55 | 0.928 | 7.93 |

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 | 2.5 | 6.313 | 0.58 | 3.66 |
| 2 | 6.90 | 2.5 | 13.438 | 0.58 | 7.79 |
| 3 | 6.90 | 2.5 | 7.125 | 0.58 | 4.13 |
| 4 | 3.45 | 3.0 | 7.575 | 0.58 | 4.39 |
| 5 | 3.45 | 3.0 | 16.125 | 0.58 | 9.35 |
| 6 | 6.90 | 3.0 | 8.55 | 0.58 | 4.96 |



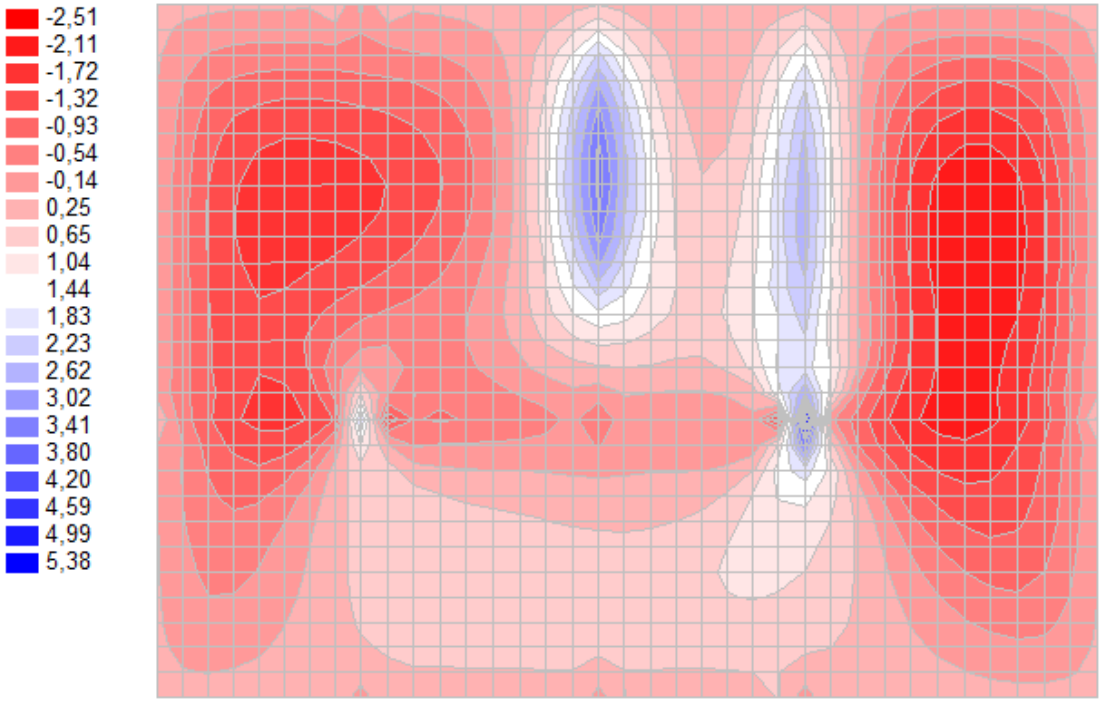

Slika 3.12.Djelovanje vjetra u Y smjeru (sile u kN)

# *4. PRORAČUN PLOČE POZICIJE 200*

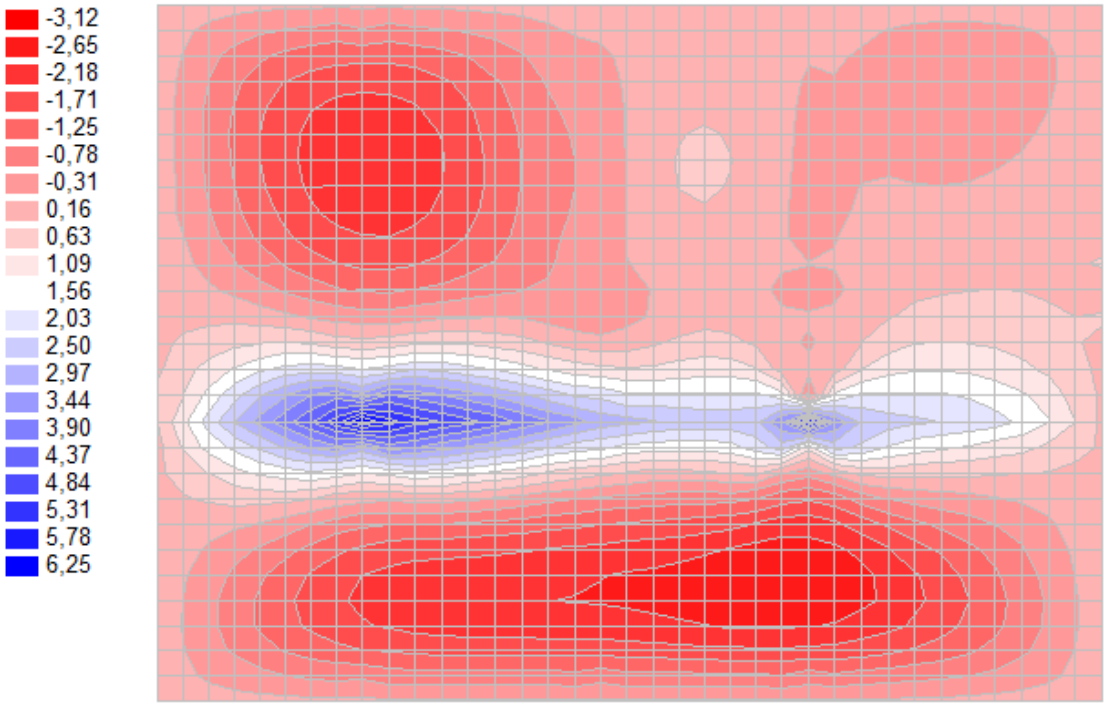
- Proračun reznih sila vršio se kompjuterskim programom *AspalathosLinear*. Prikaz rezultata dan je odvojeno za ploče i grede.

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

### 4.1.1 *Vlastita težina*

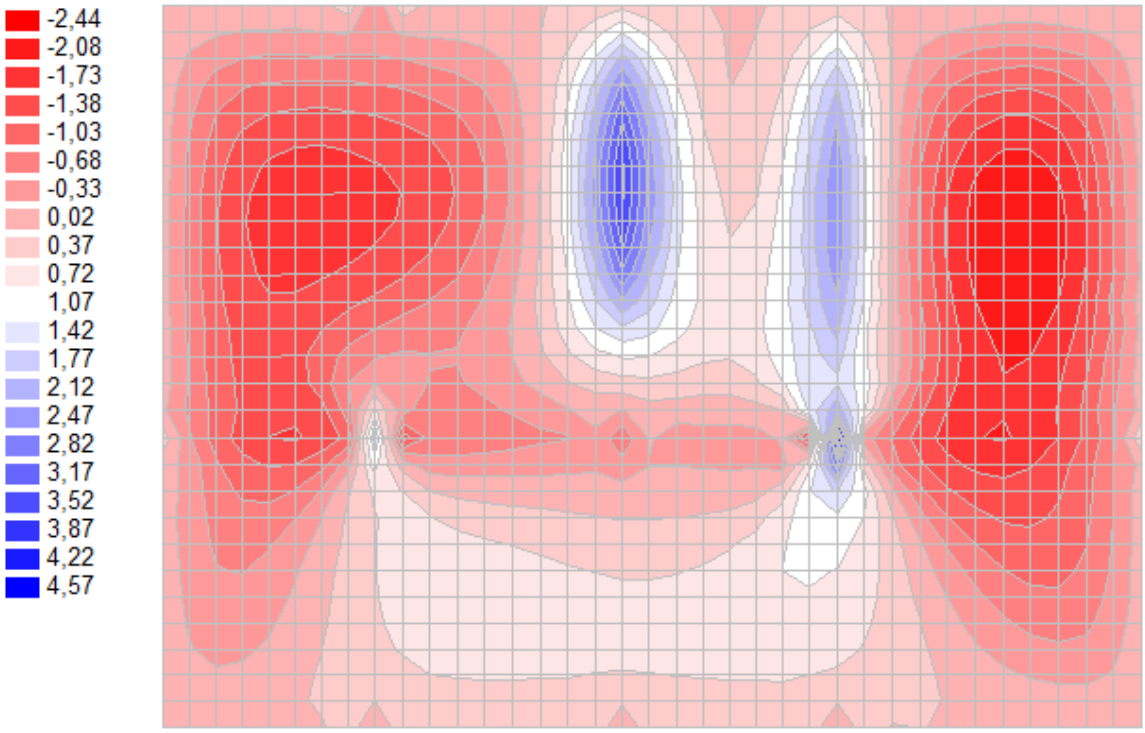



Slika 4.1. Momenti Mx (kNm)

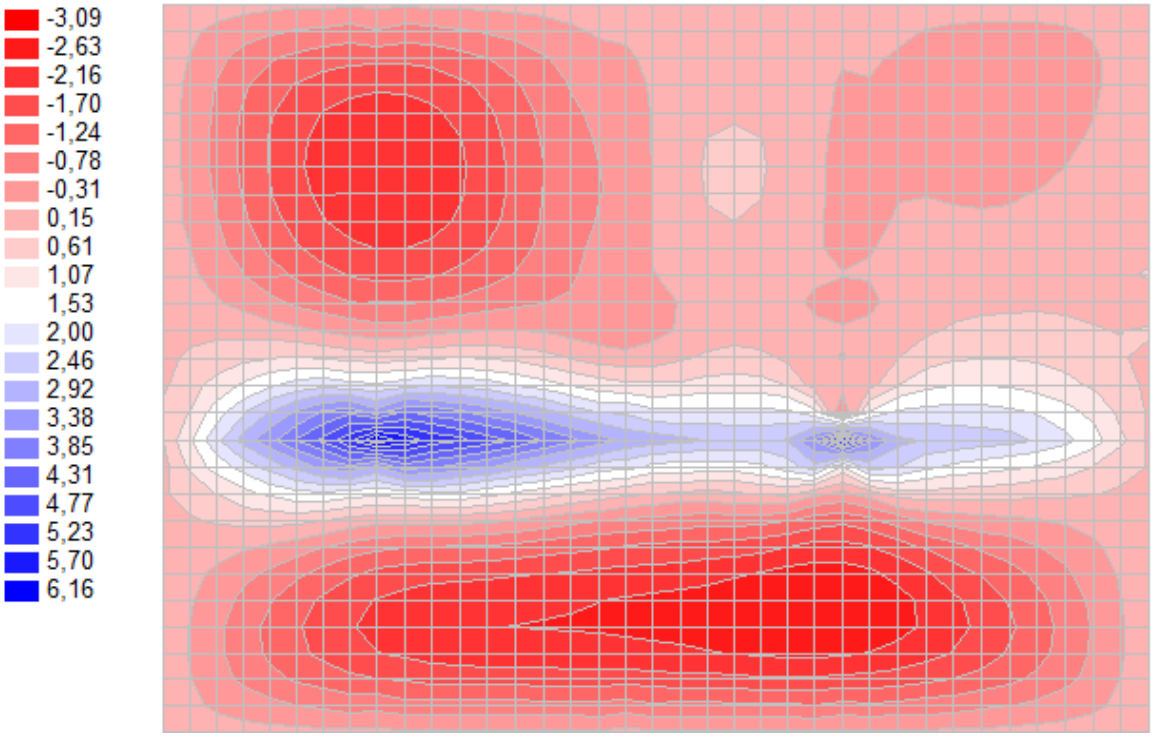



Slika 4.2. Momenti My (kNm)

### 4.1.2. *Dodatno stalno opterećenje*

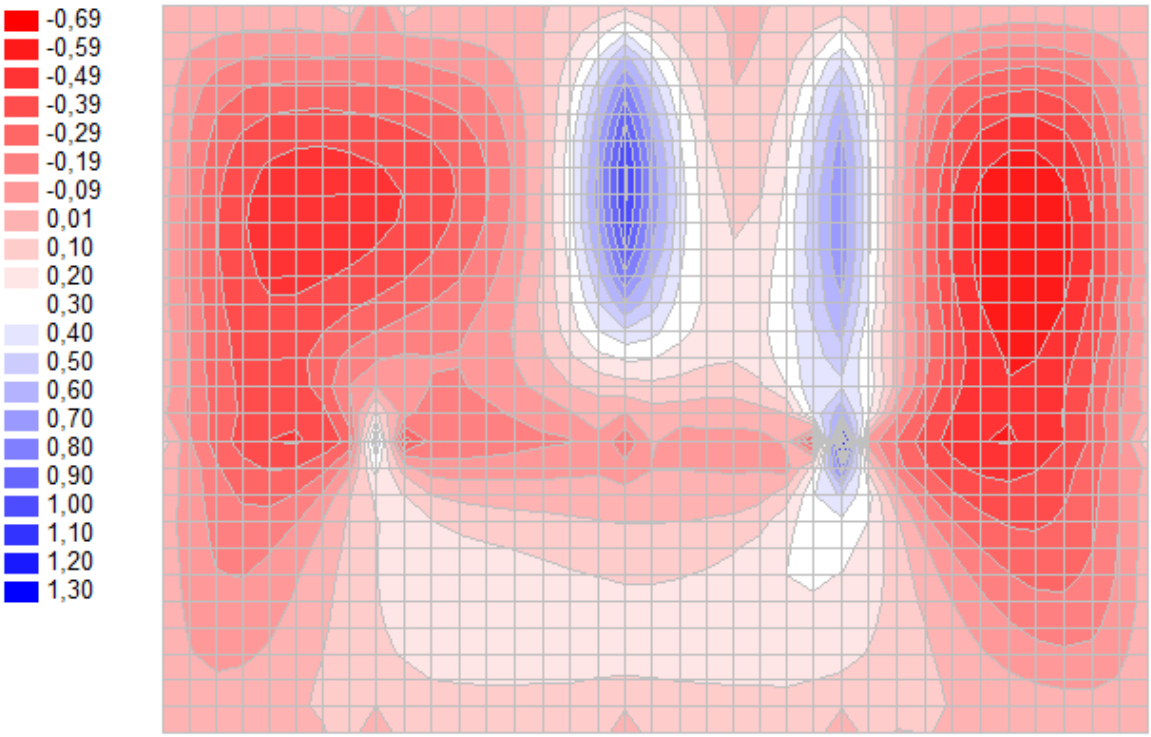



Slika 4.3. Momenti Mx (kNm)

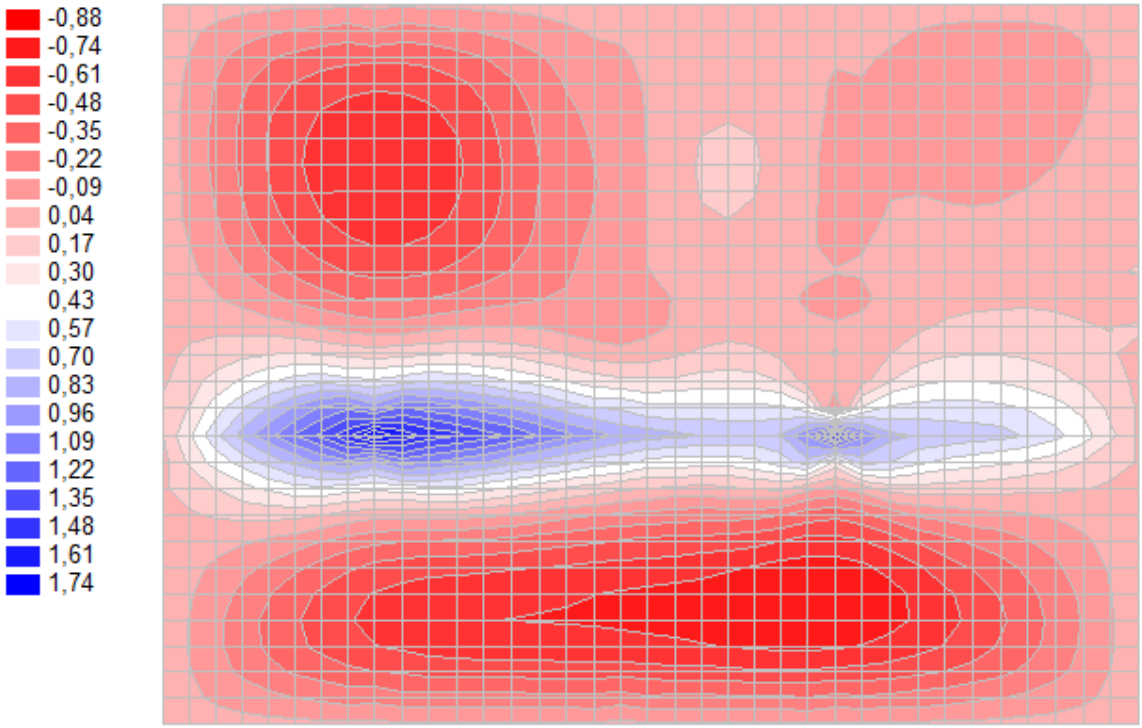



Slika 4.4. Momenti My(kNm)

### 4.1.3 *Uporabno opterećenje*



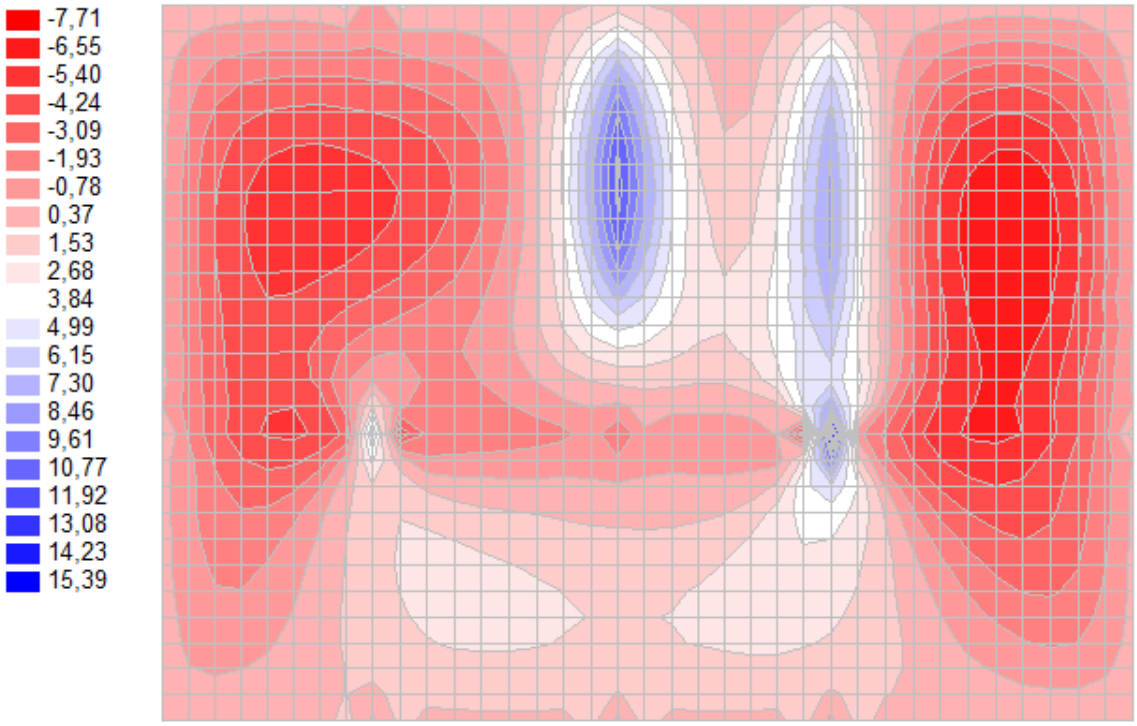

Slika 4.5. Momenti Mx (kNm)



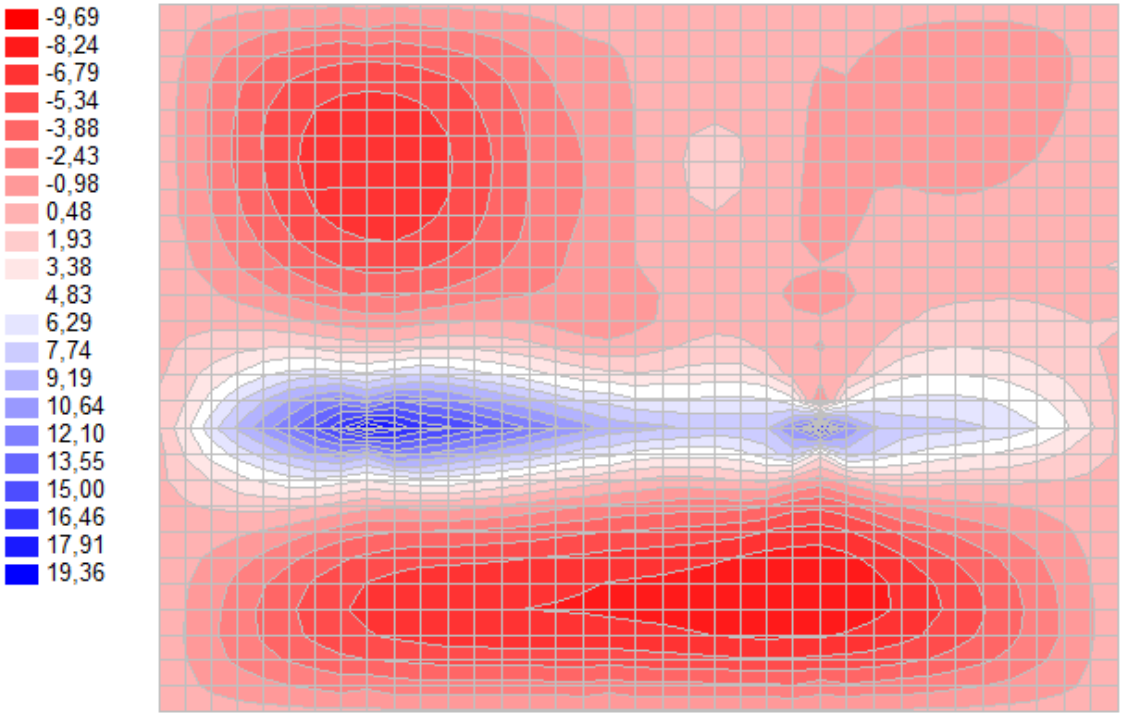

Slika 4.6. Momenti My (kNm)

### 4.1.4. *Granično stanje nosivosti*

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




Slika 4.7. Momenti Mx (kNm)




Slika 4.8. Momenti My (kNm)

## 4.2. DIMENZIONIRANJE PLOČE POZICIJE 200 (krov)

BETON:C 30/37;

$f_{ck}$ =30,0Mpa=30,0 N/mm$^2$ ; $\gamma_c$ =1.5

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

ARMATURA:B 500 B;

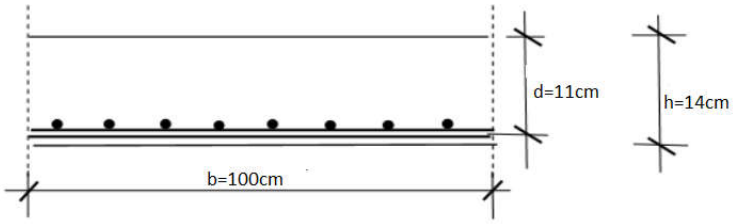
$f_{yk} = 500{,}0\ MPa$ = 500 N/mm$^2$ ; $\gamma_s$=1,15

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

DEBLJINA PLOČE: h=14 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

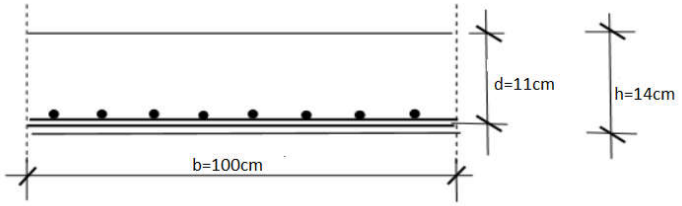
STATIČKA VISINA PLOČE:

d = 14 - 3 = 11cm

Za sve presjeke odabrana je statička visina ploče d=14 cm. Izvršen je proračun armature za kombinaciju :

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

**Ploča - Polje**




$M_{Ed}$= 9,69kNm

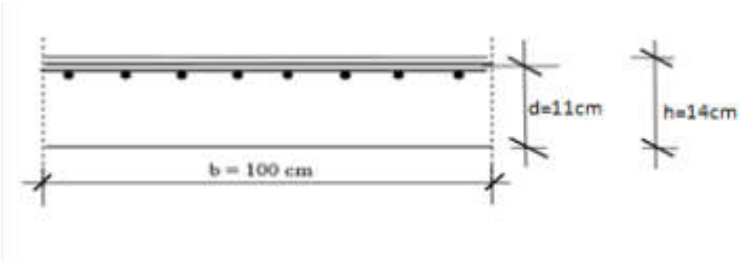
$\mu_{sd}=M_{Ed}/b_{eff}*d^2*f_{cd}=969/100*14^2*2,0=0,025$

Očitano: : $\varepsilon_{s1}$ = 10,0 ‰ $\varepsilon_{c2}$ = 0,9 ‰ $\zeta$ = 0,971 $\xi$ = 0,083

$A_{s1}=M_{Ed}/\ \zeta*d*f_{yd}=969/0,971*14*43,48=1,64cm^2/m$

ODABRANO: **Q-166**(As =1,66 $cm^2$/m)

**Ploča - Ležaj**




$M_{Ed}$= 19,36kNm

$\mu_{sd}=M_{Ed}/b_{eff}*d^2*f_{cd}=1936/100*14^2*2,0=0,049$

Očitano: : $\varepsilon_{s1}$ = 10,0 ‰ $\varepsilon_{c2}$ =1,4 ‰ $\zeta$ = 0,956 $\xi$ = 0,123

$A_{s1}=M_{Ed}/\ \zeta*d*f_{yd}=1936/0,956*14*43,48=3,33cm^2/m$

ODABRANO: **R-** 335( As =3,35 $cm^2$ ) + preklop povećan na 40 cm

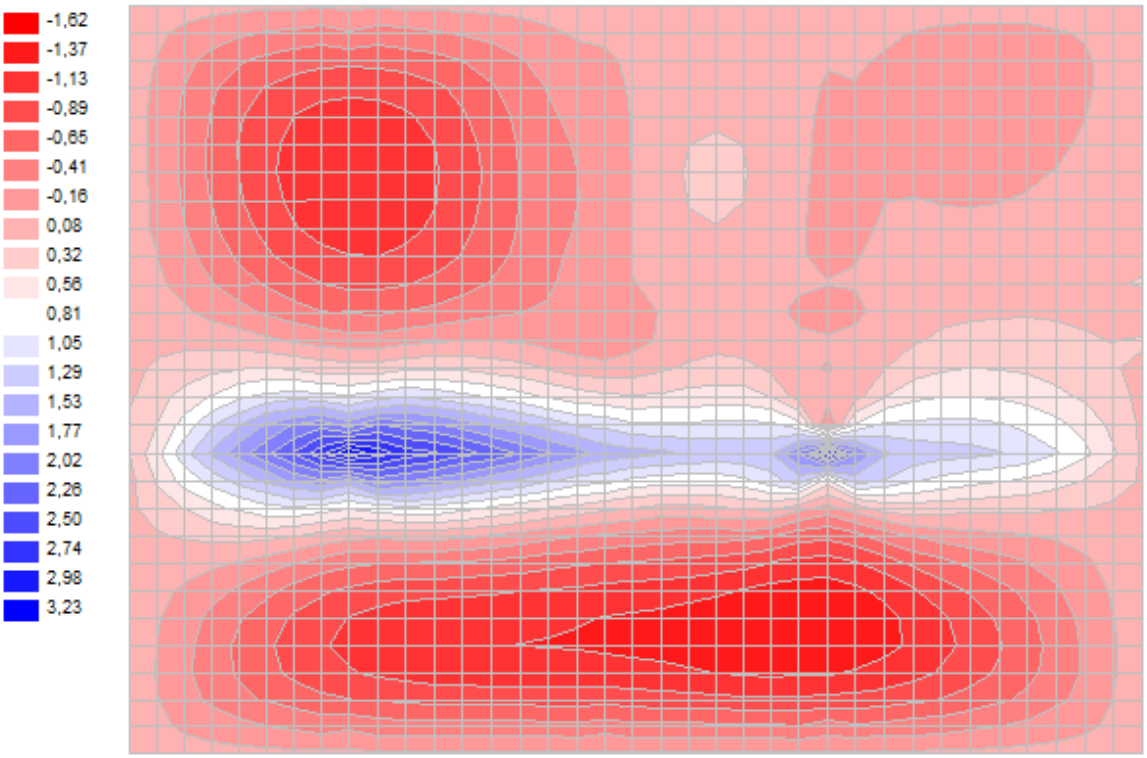
$A_{s1}=A_{s1}*š_m+p_m/š_m=3,35*215+40/215=3,97cm^2/m$

Koeficijenti za proračun potrebne površine armature za ploču:

$$A_{s1} = \frac{M_{Ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{M_{Ed}}{0,9 \cdot 14 \cdot 43,48} = 0,167 \cdot M_{Ed}$$

koef. za stalno opterećenje: 1,35 * 0,167 = 0,225

koef. za promjenjivo opterećenje : 1,5 * 0,167 = 0,25




Slika 4.10. Količina potrebne armature My ($cm^2/m'$)

Zbog sigurnosti proračunali smo i grafičku armaturnu kombinaciju.Proračuni pokazivaju istu vrijednost pa ostajemo pri odabranoj armaturi.

ODABRANO: **R-335** ( As =3,35 $cm^2/m$ ) + preklop 40 cm

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

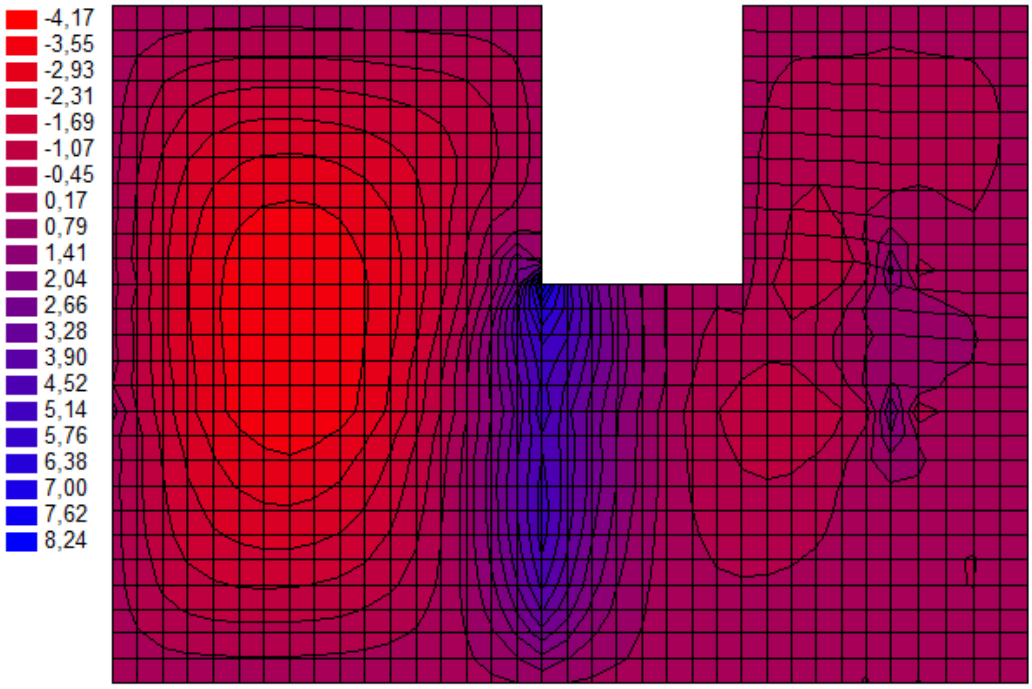
As1,min ≥ 0,26 ·2,9/ 500 ·100 ·14,0 = 2.11 cm2 /m

As1,min ≥ 0,0013 ·bt · d = 0,0013 ·100 ·14,0 = 1,82 cm2 /m

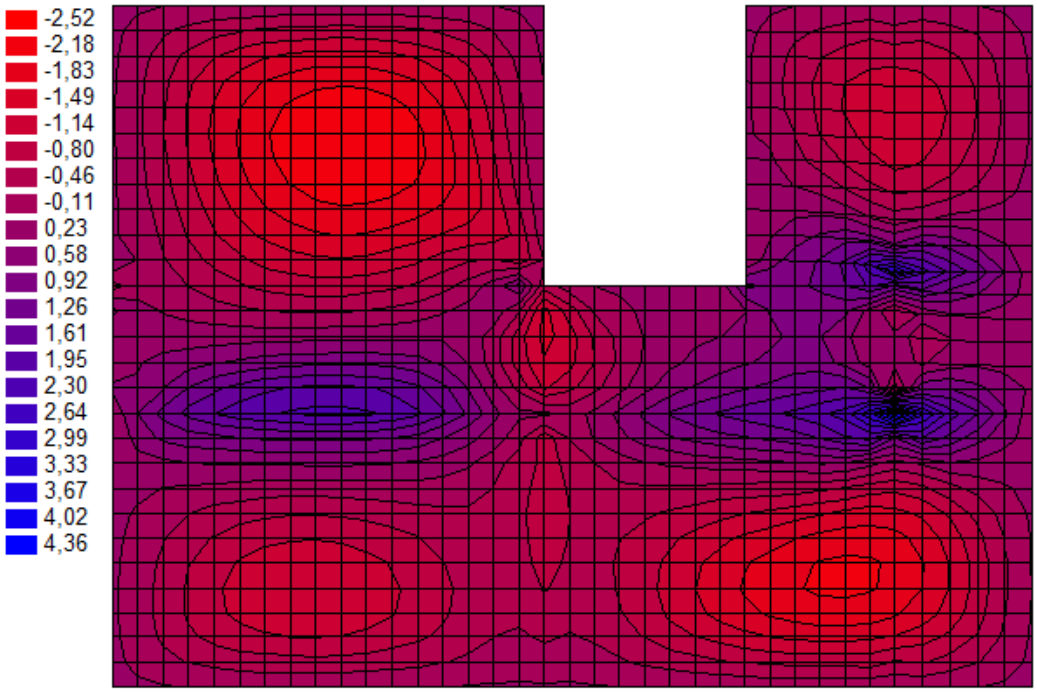
# 5. *PRORAČUN PLOČE POZICIJE 100*

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

### 5.1.1 *Vlastita težina*

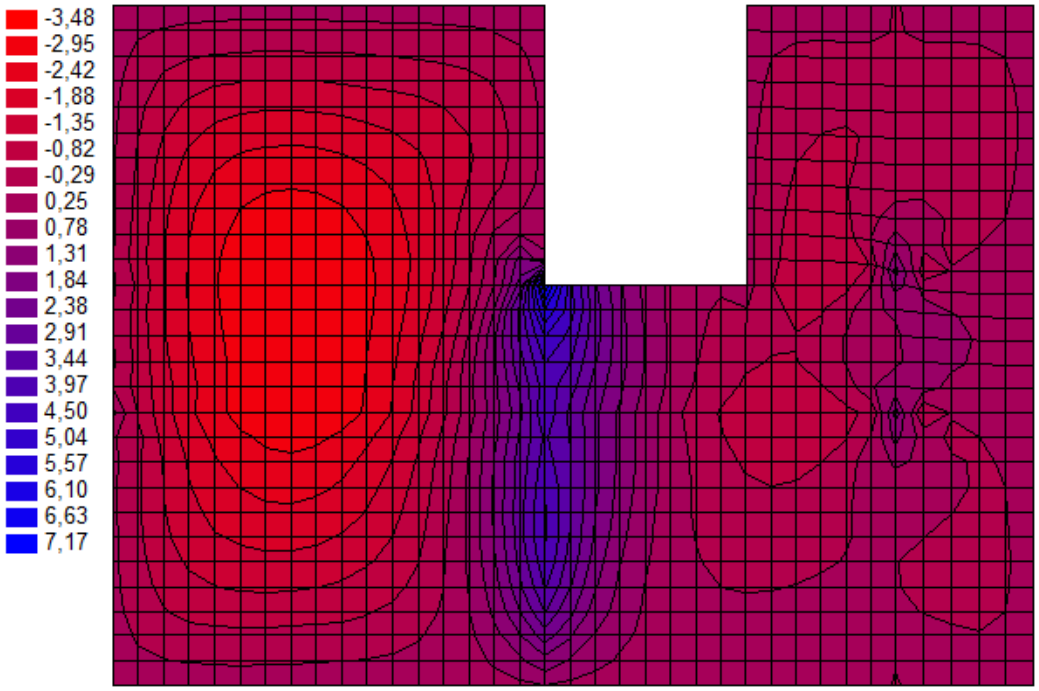



Slika 5.1. Momenti Mx (kNm)

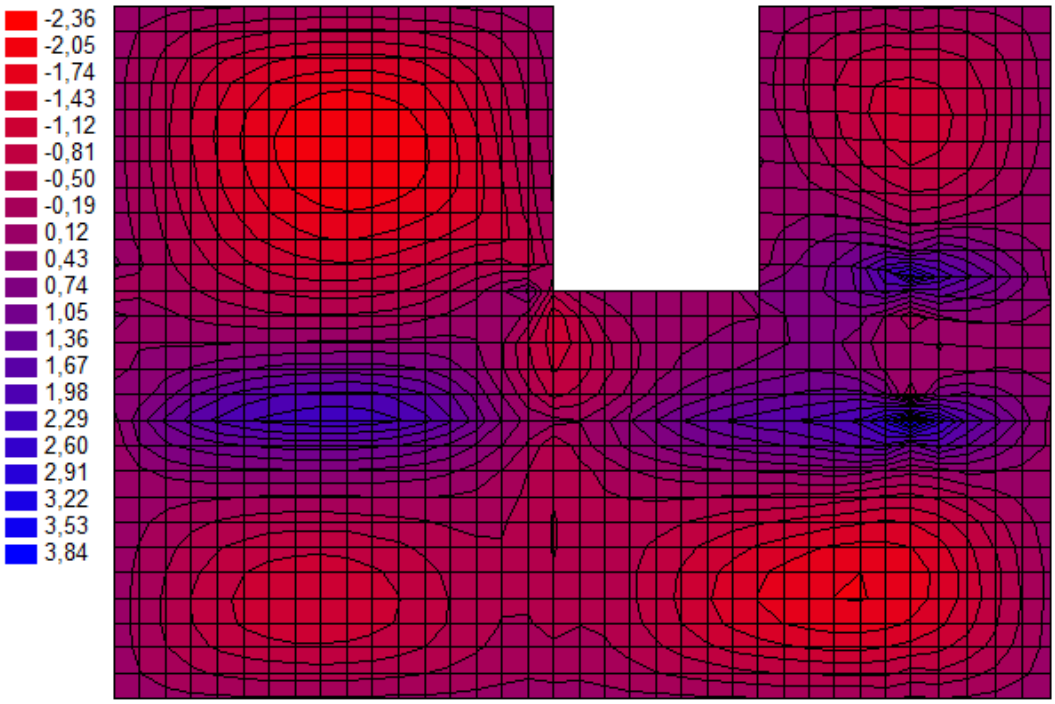



Slika 5.2. Momenti My (kNm)

### 5.1.2. *Dodatno stalno opterećenje*

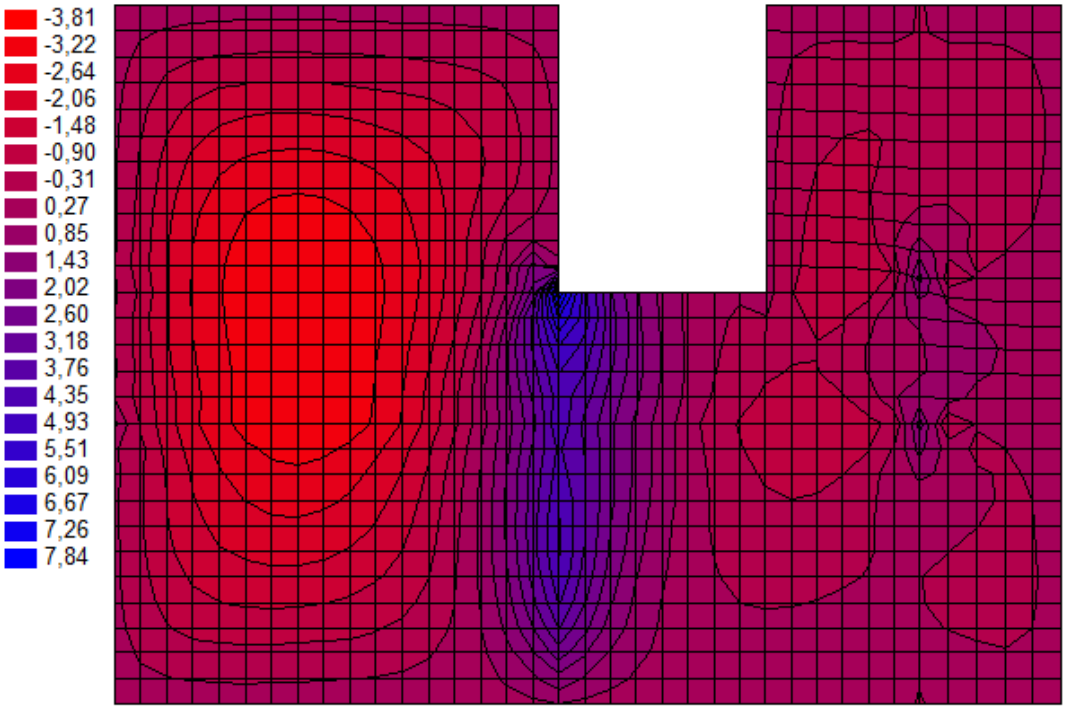



Slika 5.3. Momenti Mx (kNm)

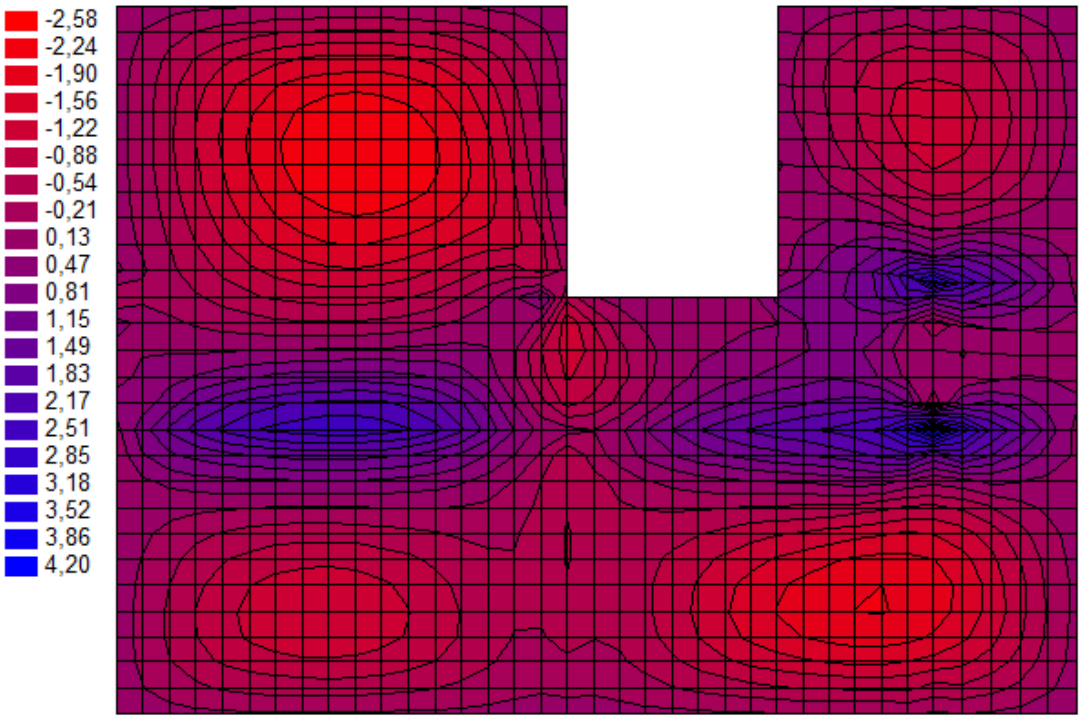



Slika 5.4. Momenti My (kNm)

### 5.1.3. *Uporabno opterećenje*



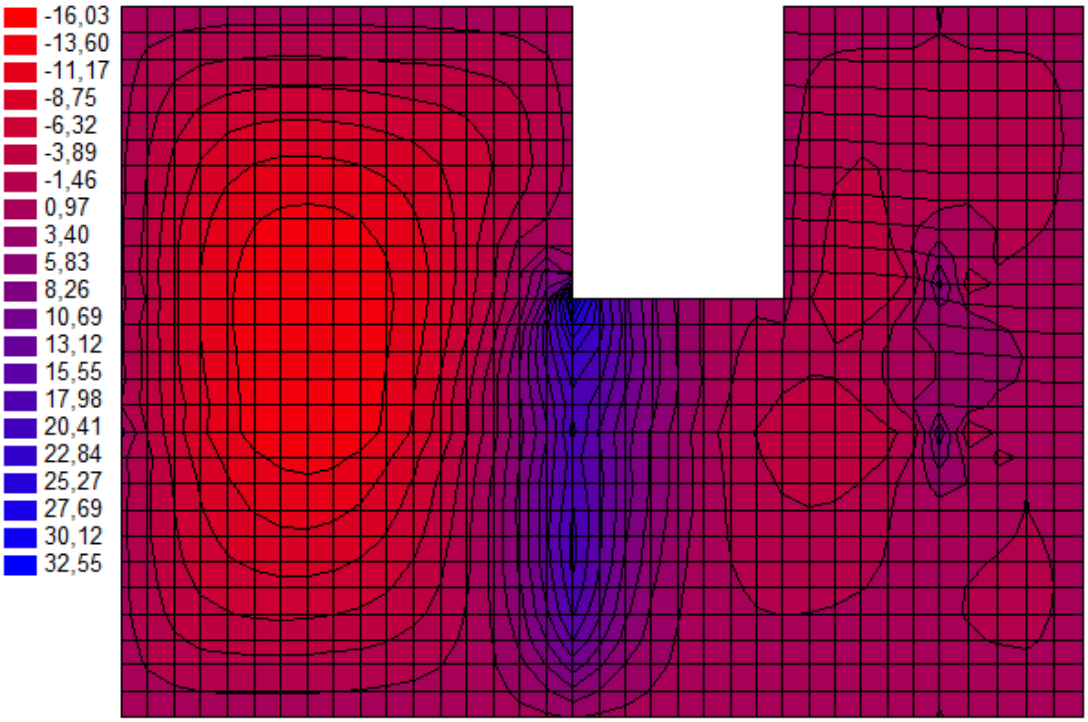

Slika 5.5. Momenti Mx (kNm)



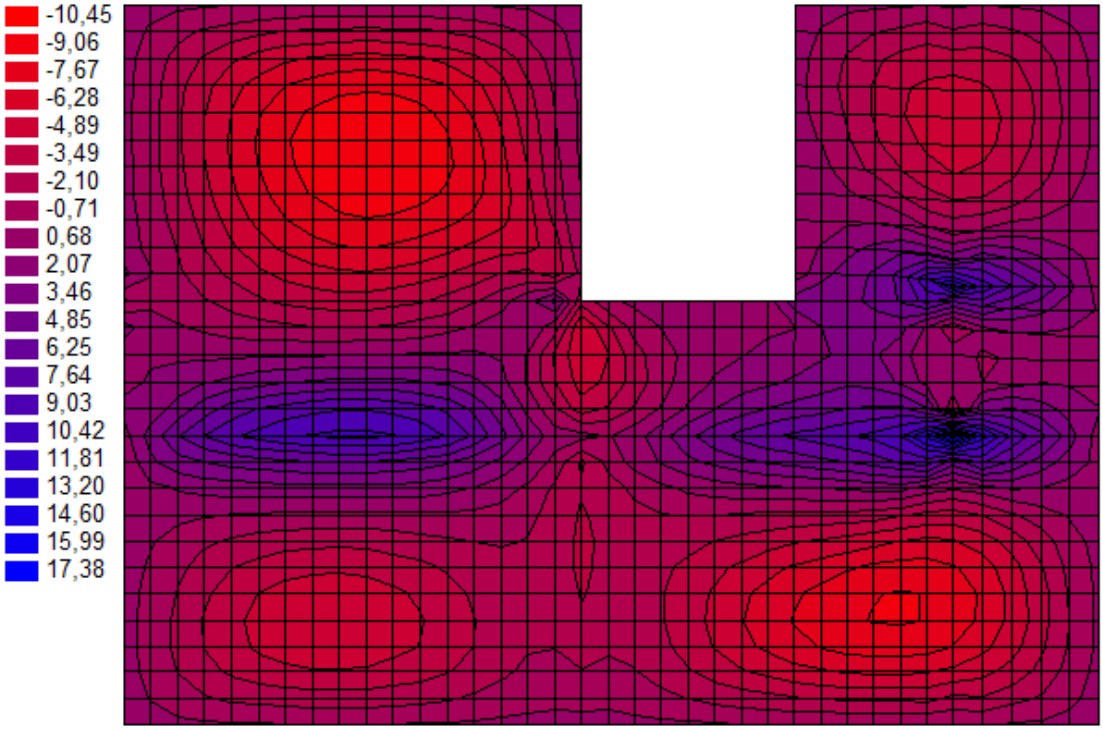

Slika 5.6. Momenti My (kNm)

### 5.1.4. *Granično stanje nosivosti*

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




Slika 5.7. Momenti Mx (kNm)




Slika 5.8. Momenti My (kNm)

## 5.2. DIMENZIONIRANJE PLOČE POZICIJE 100

BETON: C 30/37;

$f_{ck}$ =30,0Mpa=30,0 N/mm$^2$ ; $\gamma_c$ =1.5

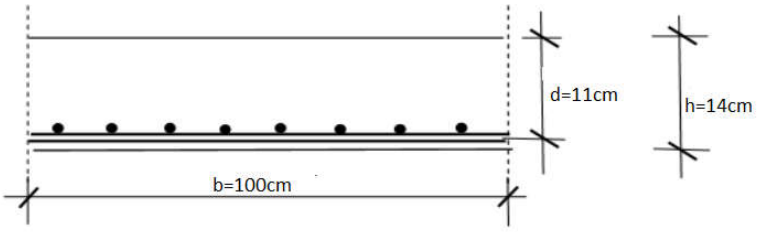
$f_{cd}$=$f_{ck}$/ $\gamma_c$ = 20,0 N/mm$^2$ =2,0 kN/cm$^2$

ARMATURA:B 500 B;

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

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

**<u>Ploča – polje</u>**




$M_{Ed}$=16,03kNm/m

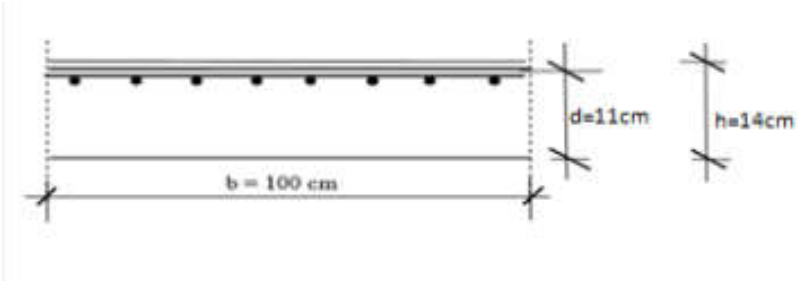
$\mu_{sd}$=$M_{Ed}$/b*d$^2$*$f_{cd}$=1603/100*14$^2$*2,0=0,041

Očitano: : $\varepsilon_{s1}$ = 10,0 ‰ $\varepsilon_{c2}$ = 1,2 ‰ $\zeta$ = 0,962 $\xi$ = 0,107

$A_{s1}$=$M_{Ed}$/ $\zeta$*d*$f_{yd}$=1603/0,962*14*43,48=2,74cm$^2$/m

Odabrano za sve ploče: Q-283 ($A_s$=2,83 cm$^2$/m)

**<u>Ploča - Ležaj</u>**




$M_{Ed}$=32,55kNm/m

$\mu_{sd}$=$M_{Ed}$/b*d$^2$*$f_{cd}$=3255/100*14$^2$*2,0=0,083

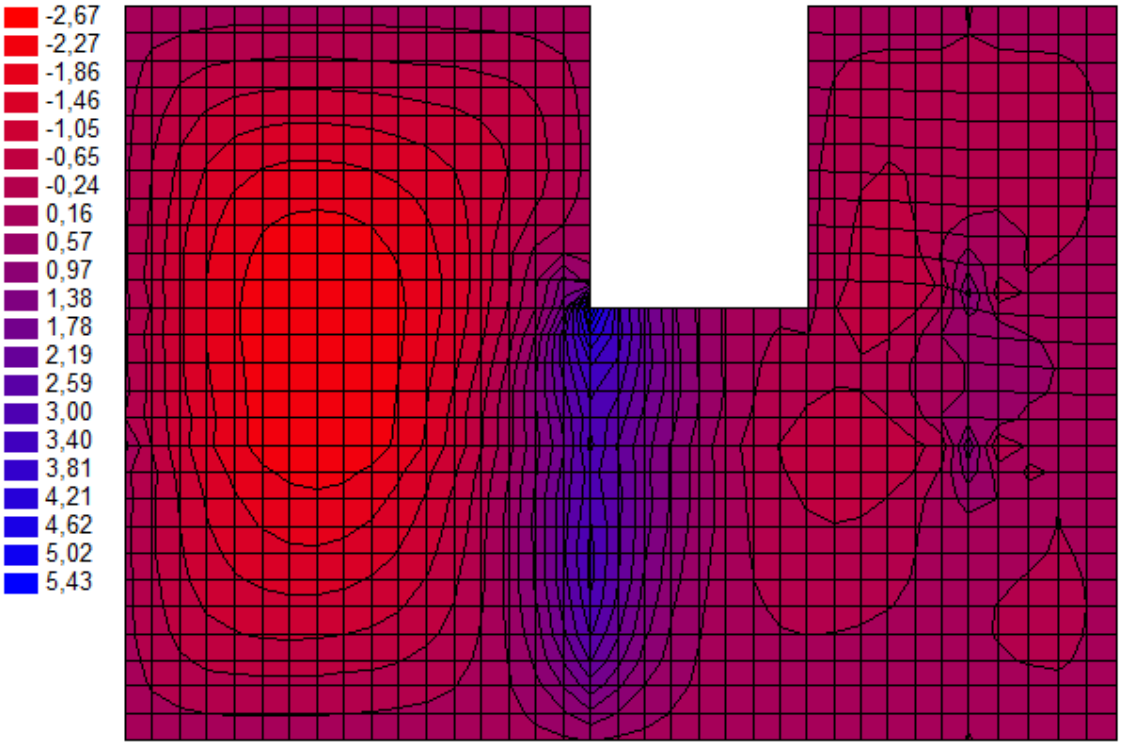
Očitano: : $\varepsilon_{s1}$ = 10,0 ‰ $\varepsilon_{c2}$ = 1,9 ‰ $\zeta$ = 0,941 $\xi$ = 0,160

$A_{s1}$=$M_{Ed}$/ $\zeta$*d*$f_{yd}$=3255/0,941*14*43,48=5,68cm$^2$/m

Odabrana mreža: R-636 ($A_s$ = 6,36 cm$^2$/m)

koef. za stalno opterećenje: 1,35 * 0,167 = 0,225

koef. za promjenjivo opterećenje : 1,5 * 0,167 = 0,25




Slika 5.9. Količina potrebne armature My ($cm^2/m'$)

Zbog sigurnosti proračunali smo i grafičku armaturnu kombinaciju.Proračuni pokazivaju istu vrijednost pa ostajemo pri odabranoj armaturi.

ODABRANO: **R-** 636( As = 6,36 $cm^2$ ) + preklop 40 cm

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

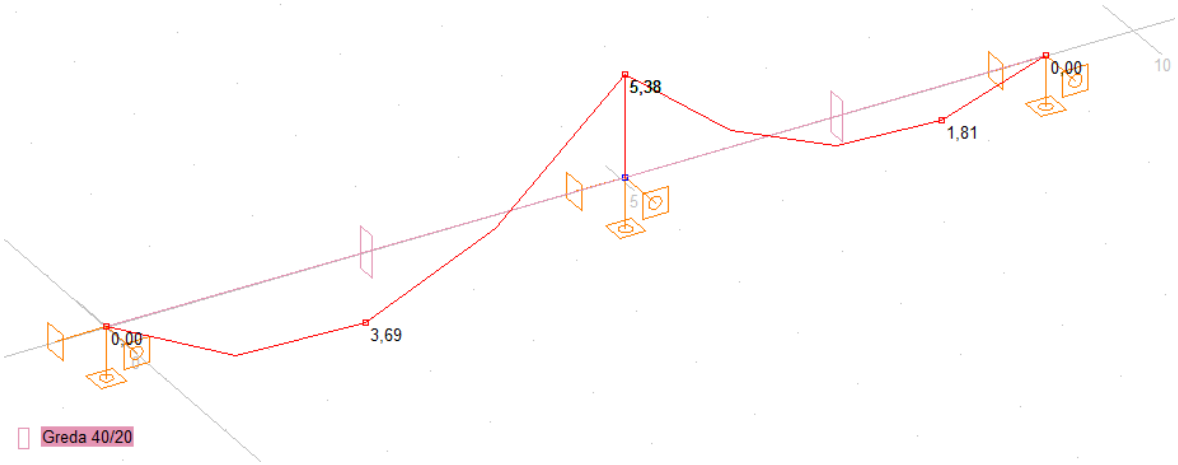
As1,min ≥ 0,26 ·2,9/ 500 ·100 ·14,0 = 2.11 cm2 /m

As1,min ≥ 0,0013 ·bt · d = 0,0013 ·100 ·14,0 = 1,82 cm2 /m

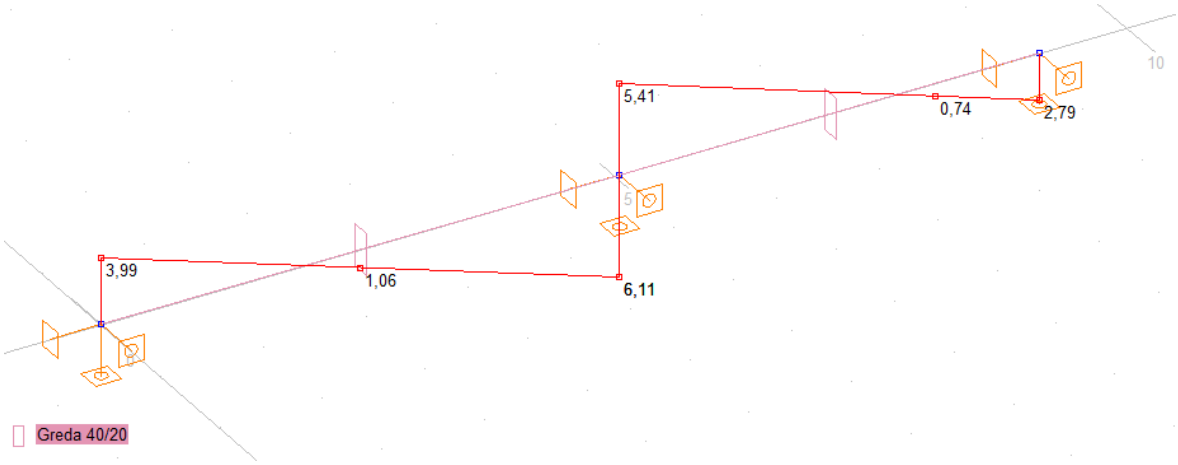
# 6. *PRORAČUN KONTINUIRANOG NOSAČA POZICIJE 100*

## 6.1. MOMENTI SAVIJANJA I POPREČNE SILE GREDE POZICIJE 100

### 6.1.1. Vlastita *težina*

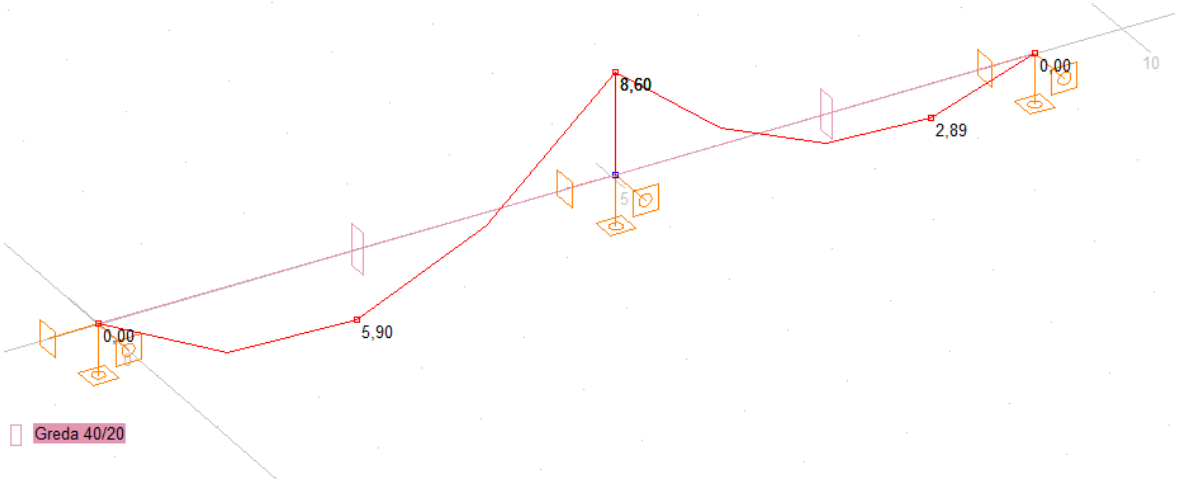



Slika 6.1. Momenti Mz (kNm)

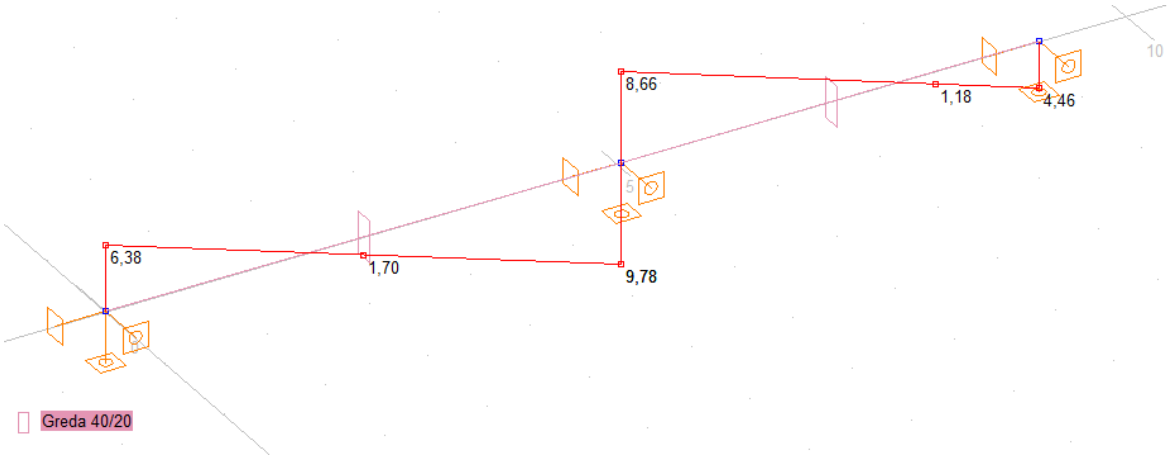



Slika 6.2. Poprečne sile Ty (kN)

### 6.1.2. *Dodatno stalno opterećenje*

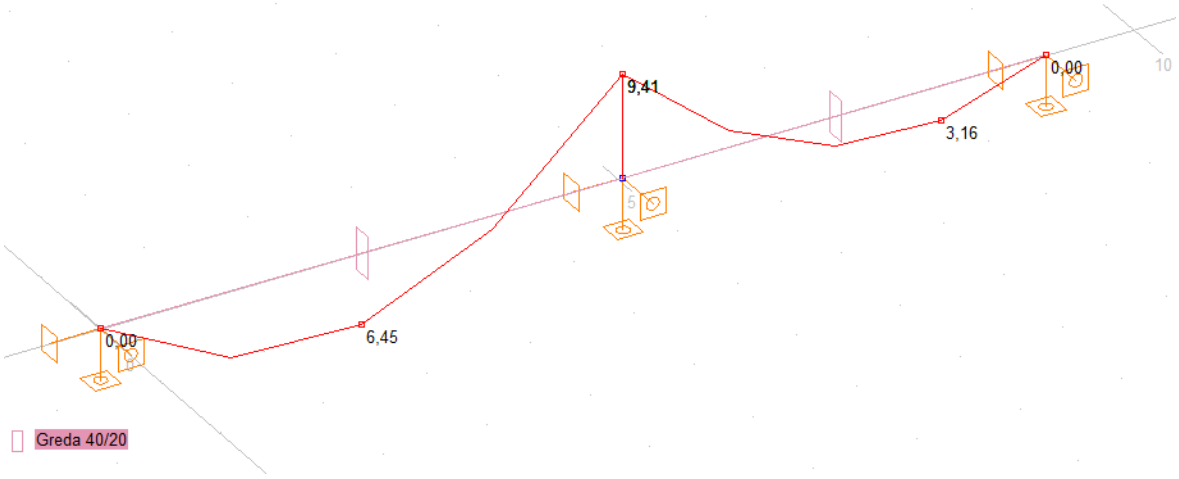



Slika 6.3. Momenti Mz (kNm)

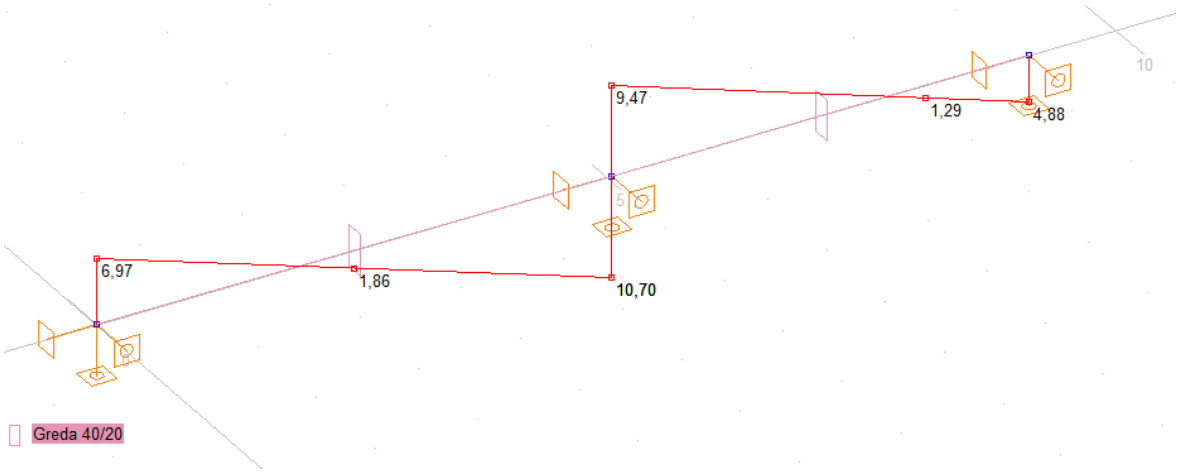



Slika 6.4. Poprečne sile Ty (kN)

### 6.1.3. *Uporabno opterećenje*




Slika 6.5. Momenti Mz (kNm)



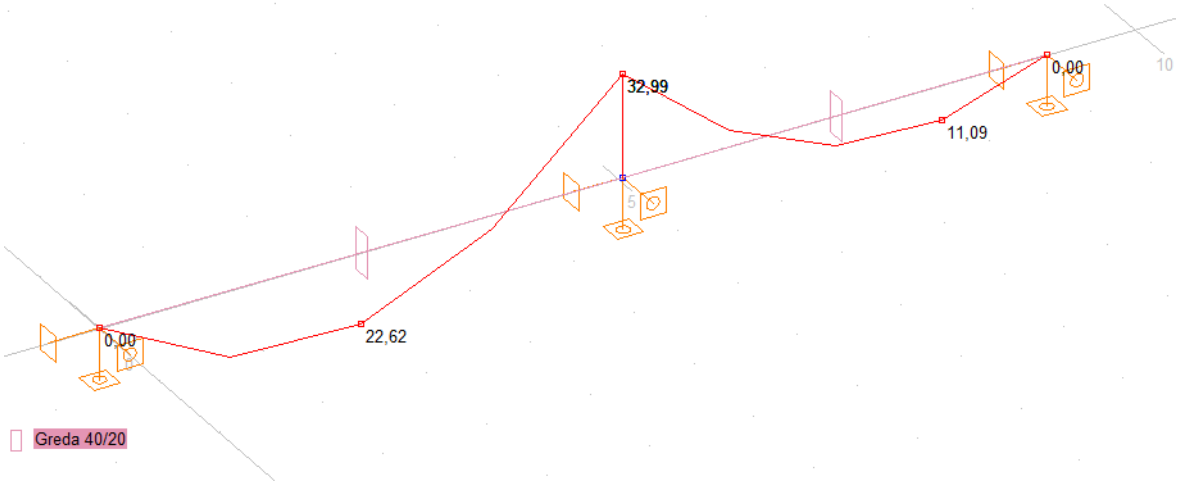

Slika 6.6. Poprečne sile Ty (kN)

### 6.1.4. *Granično stanje nosivosti*

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

Momenti:

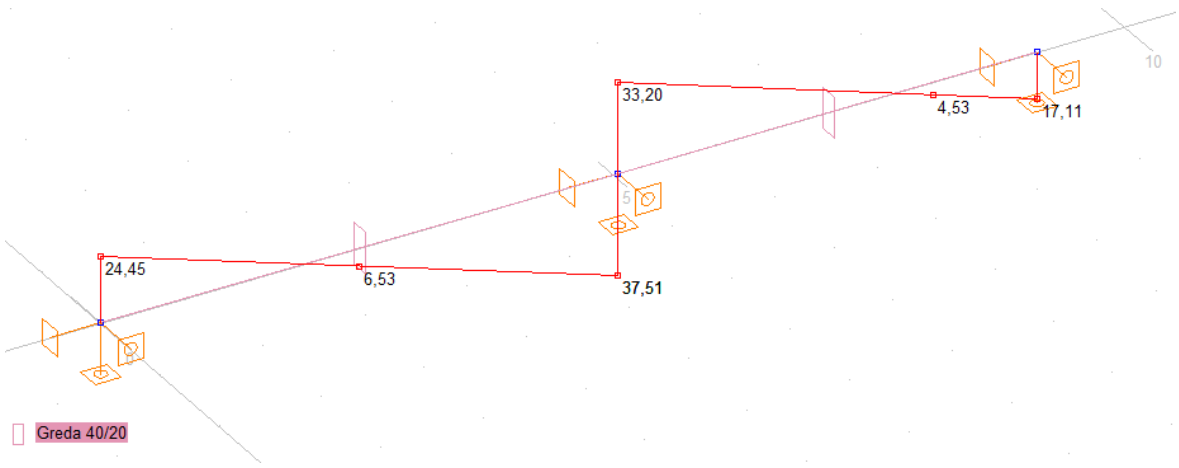
$$M_{Ed,polje1} = 22,62\ kNm$$
$$M_{Ed,ležaj} = -32,99\ kNm$$
$$M_{Ed,polje2} = 11,09 kNm$$




Slika 6.7. Momenti Mz (kNm)

Poprečne sile:

$$V_{Ed,ležaj1} = 37,51\ kN$$
$$V_{Ed,ležaj0} = 24,45\ kN$$




Slika 6.8. Poprečne sile Ty (kN)

## 6.2.DIMENZIONIRANJE NA MOMENT SAVIJANJA

BETON: C 30/37;

$f_{ck}$ =30,0Mpa=30,0 N/mm$^2$ ; $\gamma_c$ =1.5

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

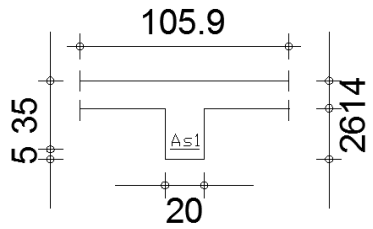
ARMATURA:B 500 B;

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

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

**<u>Polje:</u>**

Utjecajna širina: $b_{eff}$=$b_o$+$l_o$/5=20+0,85*505/5=105,9




$$M_{Ed} = 22{,}62 kNm$$

$$\mu_{sd} = \frac{M_{Ed}}{b_{eff} \cdot d^2 \cdot f_{cd}} = \frac{22{,}62}{105{,}9 \cdot 35^2 \cdot 2.0} = 0{,}009$$

Očitano: $\varepsilon_{s1} = 10.0$ ‰ $\varepsilon_{c2} = 0{,}5$ ‰ $\xi = 0.048$ $\zeta = 0.964$

$$x = \xi \cdot d = 0{,}048 \cdot 35 = 1{,}68 cm < h_{pl} = 14\ cm$$

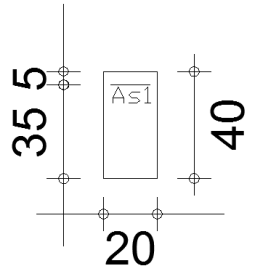
$$A_{s1} = \frac{M_{Ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{2262}{0.964 \cdot 35 \cdot 43.48} = 1{,}54 cm^2$$

$$d_1 = 5cm$$

$$d = h - d_1 = 40 - 5 = 35cm$$

Odabrano 2Ø10 (As=1,57 cm$^2$)

**Ležaj 1:**




$$M_{Ed} = 32{,}99 kNm$$

$$\mu_{sd} = \frac{M_{Ed}}{b_w \cdot d^2 \cdot f_{cd}} = \frac{3299}{20 \cdot 35^2 \cdot 2.0} = 0{,}067$$

Očitano: $\varepsilon_{s1} = 10.0$ ‰ $\varepsilon_{c2} = 1{,}7$‰ $\xi = 0{,}145$ $\zeta = 0{,}947$

$$x = \xi \cdot d = 0{,}145 \cdot 35 = 5{,}075 \ cm$$

$$A_{s1} = \frac{M_{Ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{3299}{0{,}947 \cdot 35 \cdot 43.48} = 2{,}29 \ cm^2$$

$$d_1 = 5cm$$

$$d = h - d_1 = 40 - 5 = 35cm$$

Odabrano 3Ø10 (As= 2,36cm$^2$)

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

As1,min ≥ 0,26 ·2,9/ 500 ·20 ·35 = 1,056 cm2

As1,min ≥ 0,0013 ·bt · d = 0,0013 ·20 ·35 = 0,91 cm2

Maksimalna armatura:

As1,max=0.04·Ac=0.04·20·40=32

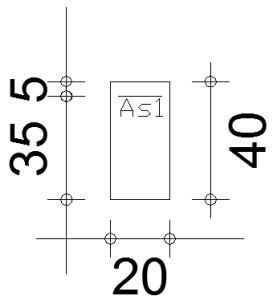
## 6.3.DIMENZIONIRANJE NA POPREČNU SILU

Ležaj 1

C 30/37

$V_{Ed}$ =37,51 kN

$N_{Ed}$=0.0 kN




As1=3Ø10=2,36cm$^2$

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

$$b_w = 20\ cm \quad ; \quad d = 35\ cm$$

$$k = 1 + \sqrt{\frac{200}{d}} = 1 + \sqrt{\frac{200}{350}} = 1.76 \le 2$$

$$k_1 = 0.15$$

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

$$\Sigma A_s = 4\phi 10 = 3{,}14\text{cm}^2$$

$$\rho_l = \frac{\Sigma A_s}{A_c} = \frac{3\phi 10}{20 \cdot 35} = \frac{2{,}36}{700} = 0{,}0034$$

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

$$V_{Rdc} = \left[ 0.12 \cdot 1.76 \cdot (100 \cdot 0.0034 \cdot 30)^{\frac{1}{3}} \right] \cdot 200 \cdot 350 = 32{,}06kN$$

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

$$\nu_{\min} = 0.035 \cdot k^{\frac{3}{2}} \cdot f_{ck}{}^{\frac{1}{2}} = 0.035 \cdot 1.76^{\frac{3}{2}} \cdot 30^{\frac{1}{2}} = 0.448$$

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

$$V_{Rdc} \ge \nu_{\min} \cdot b_w \cdot d = 0.448 \cdot 200 \cdot 350 = 31{,}36kN \le V_{Ed}$$

$$V_{Ed,\max} = V_{Ed} = 37{,}51kN$$

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

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

$$V_{Rd,\max} = 0.5 \cdot 0.528 \cdot 200 \cdot 350 \cdot 20{,}0 = 369{,}60kN > V_{Ed,\max} = V_{Ed}$$

$$V_{Ed,\max} / V_{Rd,\max} = 37{,}51 / 369{,}60 = 0.1014 \approx 0.10 \Rightarrow V_{Ed} = 0.10 V_{Rd,\max}$$

$$s_{\max} = \min\{0.75 \cdot d; 30\} = \min\{26,25; 30\} \Rightarrow s_{\max} = 30.0\,cm$$

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

Površina minimalne armature:

$$A_{sw,\min} = \frac{\rho_{\min} \cdot s_w \cdot b_w}{m} = \frac{0.0011 \cdot 30 \cdot 20}{2} = 0.33cm^2$$

Odabrane minimalne spone: **Ø7/30** ($A_{sw}$=0.38 $cm^2$)

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

$$V_{Rd} = V_{Rd,s} = \frac{A_{sw}}{s} \cdot z \cdot f_{ywd} \cdot m \cdot ctg\theta = \frac{0.38}{30} \cdot (0.9 \cdot 35) \cdot 43.48 \cdot 2 \cdot 1$$

$$V_{Rd} = 34,69kN$$

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

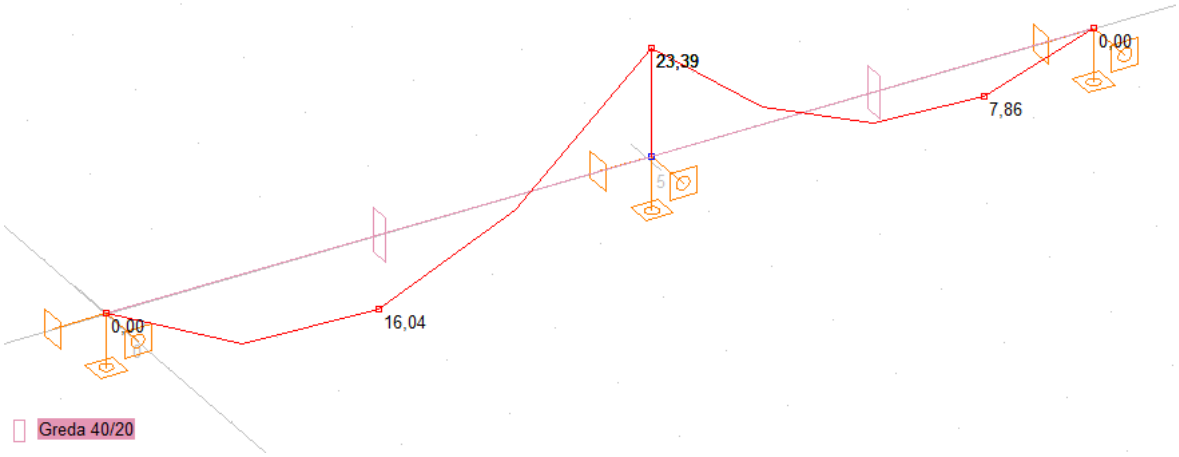
Na mjestu maksimalne poprečne sile:

$$s_w \leq \frac{m \cdot A_{sw} \cdot f_{yw,d} \cdot z}{V_{Ed}} = \frac{2 \cdot 0.38 \cdot 43.48 \cdot 0.9 \cdot 35}{37,51} = 13,88\,cm$$

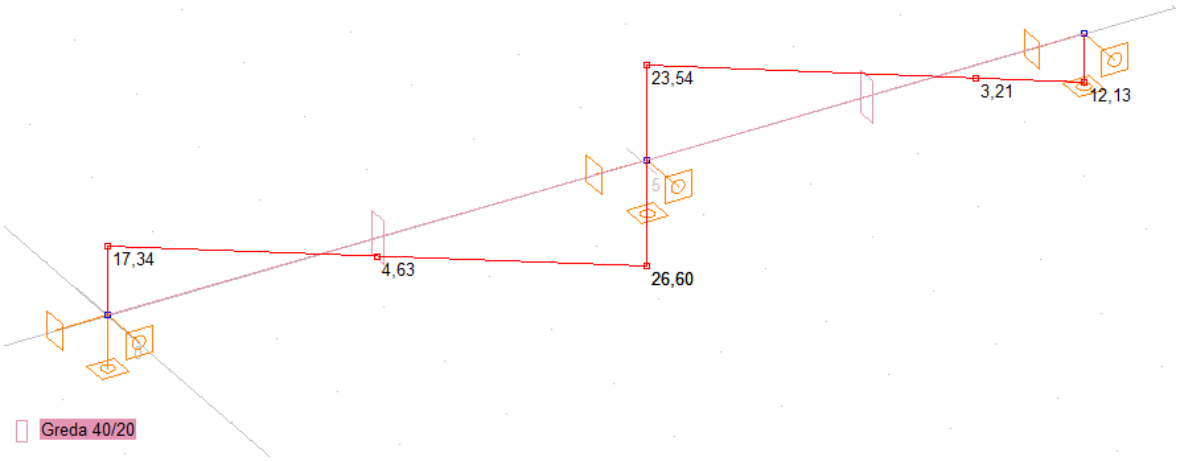
Postaviti spone **Ø7/12**($A_{sw}$=0.38 $cm^2$)

## 6.4.KONTROLA PUKOTINA GREDE POZICIJE 100

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




Slika6.9.Moment (kNm)




Slika6.10.Poprečna sila (kN)

Polje :

$M_{Ed}$ =16,04kNm

Prognoza širine pukotine:

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

Proračun srednje deformacije armature:

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

$A_{s1}$ = 2Ø10 = 1,57 $cm^2$

$E_{cm}$ = 35.00 GPa = 35000 MPa – modul elastičnosti betona

$E_s$ = 200.0 GPa = 200000.0 MPa – modul elastičnosti armature

$f_{ctm}$=2.9 MPa - za betone klase C 30/37

$k_t = 0.4$ - dugotrajno opterećenje

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

$$x = \frac{\alpha_e \cdot A_{s1}}{b} \cdot \left(-1 + \sqrt{\frac{2 \cdot b \cdot d}{\alpha_e \cdot A_{s1}}}\right) = \frac{5,71 \cdot 1,57}{20} \cdot \left(-1 + \sqrt{1 + \frac{2 \cdot 20 \cdot 35}{5,71 \cdot 1,57}}\right) = 5,17 \text{ cm}$$

$$\sigma_s = \frac{M_{Ed}}{z \cdot A_{s1}} \approx \frac{M_{Ed}}{\left(d - \frac{x}{3}\right) \cdot A_{s1}} = = \frac{1604}{\left(35 - \frac{5,17}{3}\right) \cdot 1,57} = 30,71 \text{ kN /cm}^2 = 307,12 \text{MPa}$$

$$\rho_{p,eff} = \frac{A_{s1}}{A_{c,eff}} = \frac{A_{s1}}{b \cdot 2.5 \cdot d_1} = \frac{1,57}{20 \cdot 2.5 \cdot 5.0} = 0.00628$$

$$(\varepsilon_{sm} - \varepsilon_{cm}) = \frac{307.12 - 0.4 \cdot \frac{2.9}{0.00628} \cdot (1 + 5.71 \cdot 0.00628)}{200000} \geq 0.6 \cdot \frac{307.12}{200000}$$

$$\frac{115.783}{200000} > \frac{184.272}{200000}$$

$$(\varepsilon_{sm} - \varepsilon_{cm}) = 0.000579$$

→ neće doći do pojave pukotina!

Ležaj:

$M_{Ed}$ = 23,39 kNm

Prognoza širine pukotine:

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

Proračun srednje deformacije armature:

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

$A_{s1}$ = 3Ø10 = 2,36 $cm^2$

$E_{cm}$ = 35.00 GPa = 35000 MPa – modul elastičnosti betona

$E_s$ = 200.0 GPa = 200000.0 MPa – modul elastičnosti armature

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

$k_t = 0.4$ - dugotrajno opterećenje

$$\alpha_e = \frac{E_s}{E_{cm}} = \frac{200}{35.0} = 5.71$$

$$x = \frac{\alpha_e \cdot A_{s1}}{b} \cdot \left(-1 + \sqrt{\frac{2 \cdot b \cdot d}{\alpha_e \cdot A_{s1}}}\right) = \frac{5.71 \cdot 2.36}{20} \cdot \left(-1 + \sqrt{1 + \frac{2 \cdot 20 \cdot 35}{5.71 \cdot 2.36}}\right) = 6{,}23 \text{ cm}$$

$$\sigma_s = \frac{M_{Ed}}{z \cdot A_{s1}} \approx \frac{M_{Ed}}{\left(d - \frac{x}{3}\right) \cdot A_{s1}} = \frac{2339}{\left(35 - \frac{6.23}{3}\right) \cdot 2.36} = 30{,}10 \text{kN/cm}^2 = 301{,}03 \text{Mpa}$$

$$\rho_{p,eff} = \frac{A_{s1}}{A_{c,eff}} = \frac{A_{s1}}{b \cdot 2.5 \cdot d_1} = \frac{2.36}{20 \cdot 2.5 \cdot 5.0} = 0.00944$$

$$(\varepsilon_{sm} - \varepsilon_{cm}) = \frac{301.03 - 0.4 \cdot \frac{2.9}{0.00944} \cdot (1 + 5.71 \cdot 0.00944)}{200000} \geq 0.6 \cdot \frac{301.03}{200000}$$

$$\frac{171.53}{200000} > \frac{180.618}{200000}$$

$$(\varepsilon_{sm} - \varepsilon_{cm}) = 0.000859$$

→ neće doći do pojave pukotina!

## 6.5.KONTROLA PROGIBA GREDE POZICIJE 100

Progib kontroliramo za nefaktorizirano opterećenje i bez utjecaja puzanja.

Kontrola progiba za Polje :

Granični progib:

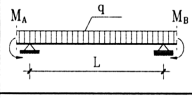
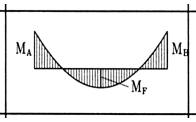
$$\nu_{lim} = \frac{L}{250} = \frac{505}{250} = 2.02\,cm$$

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

$$E_{cm} = 35000\ MPa$$
$$f_{ctm} = 0.3 \cdot (f_{ck})^{2/3} = 0.3 \cdot (30.0)^{2/3} = 2.9\ MPa$$

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 |   |   | $k = \frac{5}{48}(1-0{,}1\beta)$ <br> $\beta = \lvert M_A + M_B \rvert / \lvert M_F \rvert$ |

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

$$\beta = |M_A + M_B| / |M_F| = |0.0 + 23.39| / |16.04| = 1.458$$
$$k = \frac{5}{48} \cdot (1 - 0.1 \cdot \beta) = 0.104 \cdot (1 - 0.1 \cdot 1.1458) = 0.0888$$

Progib homogenog presjeka:

$A_{s1} = 2\varnothing 10 = 1{,}57\ cm^2$

$A_{s2} = 3\varnothing 10 = 2{,}36\ cm^2$

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

$$= \frac{20 \cdot 40^3}{12} + 5.71 \cdot \left[ 1{,}57 \cdot \left( \frac{40}{2} - 5 \right)^2 + 2{,}36 \cdot \left( \frac{40}{2} - 5 \right)^2 \right] =$$

$$= 111715{,}73\ cm^4$$

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

$$\frac{1}{r_I} = \frac{M_{Ed}}{E_{c,eff} \cdot I_I} = \frac{1604}{3500 \cdot 111715{,}73} = 0.0000041 \frac{1}{cm}$$

Progib potpuno raspucanog presjeka:

$$x = 5{,}17\ cm$$

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

$$= \frac{20 \cdot 5.17^3}{12} + (20 \cdot 5.17) \cdot \left( \frac{5.17}{2} \right)^2 + 5.71 \cdot \left[ 1.57 \cdot (35 - 5.17)^2 + 2.36 \cdot (5.17 - 5)^2 \right]$$

$$= 8898.69 cm^4$$

$$\frac{1}{r_{II}} = \frac{M_{Ed}}{E_{c,eff} \cdot I_{II}} = \frac{1604}{3500 \cdot 8898.69} = 0.0000515 \frac{1}{cm}$$

Ukupni progib:

$$\sigma_s = 307.12\ MPa$$

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

$$M_{cr} = f_{ctm} \cdot W = f_{ctm} \cdot \frac{b \cdot h^2}{6} = 3.5 \cdot \frac{20 \cdot 40^2}{6} = 18666.67$$

$$\sigma_{sr} = \frac{18666.67}{(35 - \frac{5.17}{3}) \cdot 5.17} = 108.50 MPa$$

$\beta_1 = 1.0$ - Rebrasta armatura

$\beta_2 = 0.5$ - Dugotrajno opterećenje

$$\zeta = 1 - \beta_1 \cdot \beta_2 \cdot \left(\frac{\sigma_{sr}}{\sigma_s}\right)^2 = 1 - 1.0 \cdot 0.5 \cdot \left(\frac{108.50}{307.12}\right)^2 = 0.938$$

$$\frac{1}{r_I} = 0.0000041 \frac{1}{cm}$$

$$\frac{1}{r_{II}} = 0.0000515 \frac{1}{cm}$$

$$\frac{1}{r_m} = (1-\zeta) \cdot \frac{1}{r_I} + \zeta \cdot \frac{1}{r_{II}} = (1-0.938) \cdot 0.0000041 + 0.938 \cdot 0.0000515 = 0.0000486 \frac{1}{cm}$$

$$k = 0.0888$$

$$L = 505.0\ cm$$

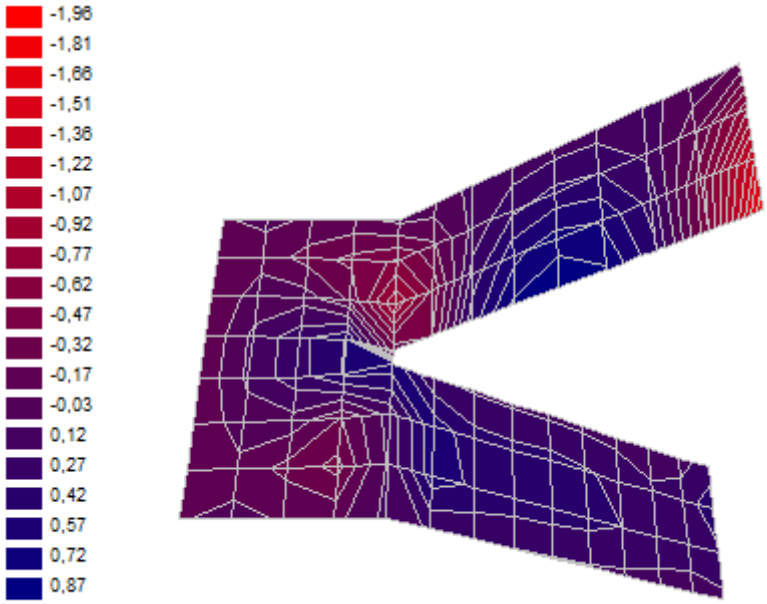
$$v_{tot,t=0} = k \cdot L^2 \cdot \frac{1}{r_{tot}} = 0.0888 \cdot 505.0^2 \cdot 0.0000486 = 1.11\ cm < v_{\lim} = 2.72 cm$$

# 7. *PRORAČUN STUBIŠTA*

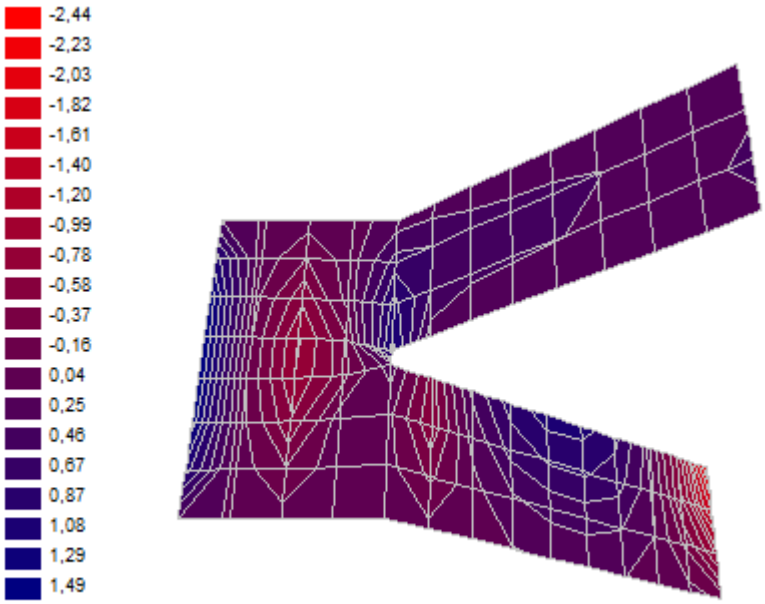
## 7.1.MOMENTI SAVIJANJA

- *Granično stanje nosivosti*

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



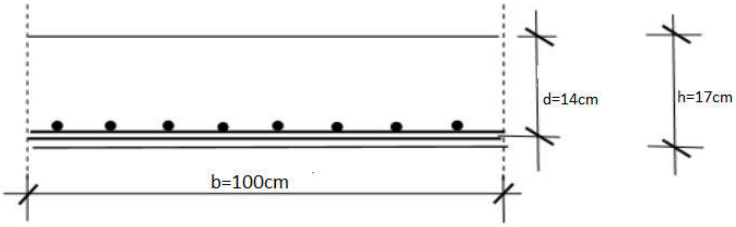

Slika 7.1. Moment Mx (kNm)




Slika 7.2. Moment My (kNm)

## 7.2.DIMENZIONIRANJE STUBIŠTA

**Polje**




$$M_{Ed} = 1{,}49 kNm/m$$

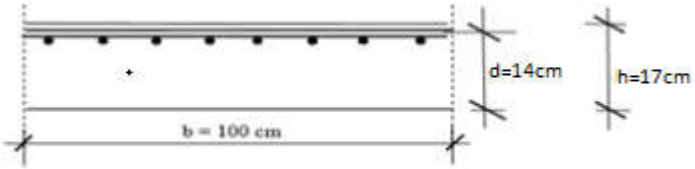
$$\mu_{sd} = \frac{M_{Ed}}{b \cdot d^2 \cdot f_{cd}} = \frac{149}{100 \cdot 14^2 \cdot 2.0} = 0.004$$

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

$$A_{s1} = \frac{M_{Ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{149}{0.987 \cdot 14 \cdot 43.48} = 0{,}25\ cm^2/m$$

Odabrana mreža: **R-166** (As = 1,66 $cm^2$/m)

**Ležaj**




$$M_{Ed} = 2{,}44 kNm/m$$

$$\mu_{sd} = \frac{M_{Ed}}{b \cdot d^2 \cdot f_{cd}} = \frac{244}{100 \cdot 14^2 \cdot 2.0} = 0.0062$$

Očitano: $\varepsilon_{s1} = 10.0$ ‰ $\varepsilon_{c2} = 0.5$‰ $\xi = 0.048$ $\zeta = 0.984$

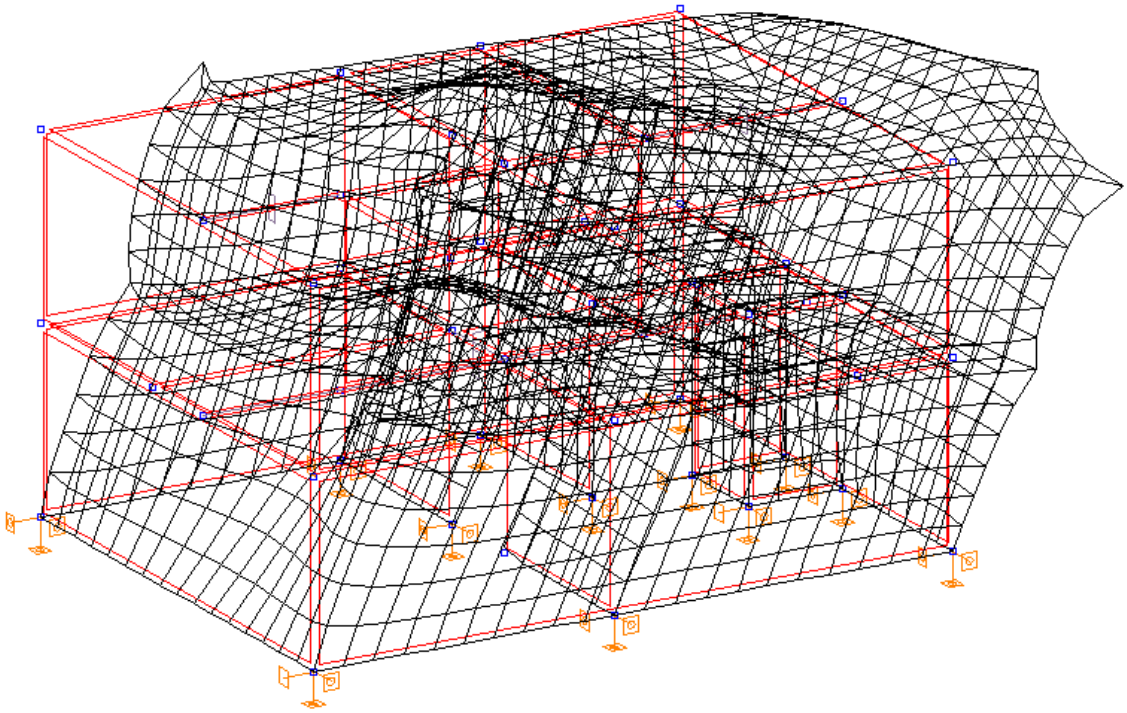
$$A_{s1} = \frac{M_{Ed}}{\zeta \cdot d \cdot f_{yd}} = \frac{244}{0.984 \cdot 14 \cdot 43.48} = 0{,}41 cm^2/m$$

Odabrana armatura:**R-** 166 (As = 1,66 $cm^2$/m)

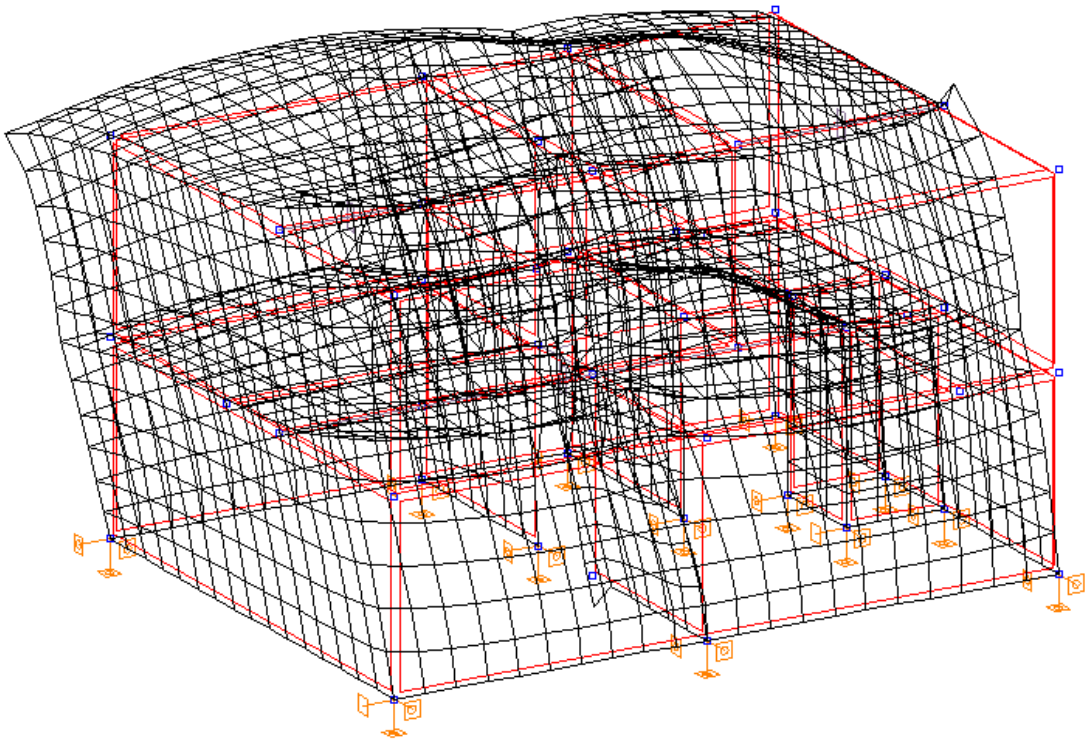
# 8. *PRORAČUN ZIDOVA*

## 8.1.POMACI

### *8.1.1.Prostorni model*

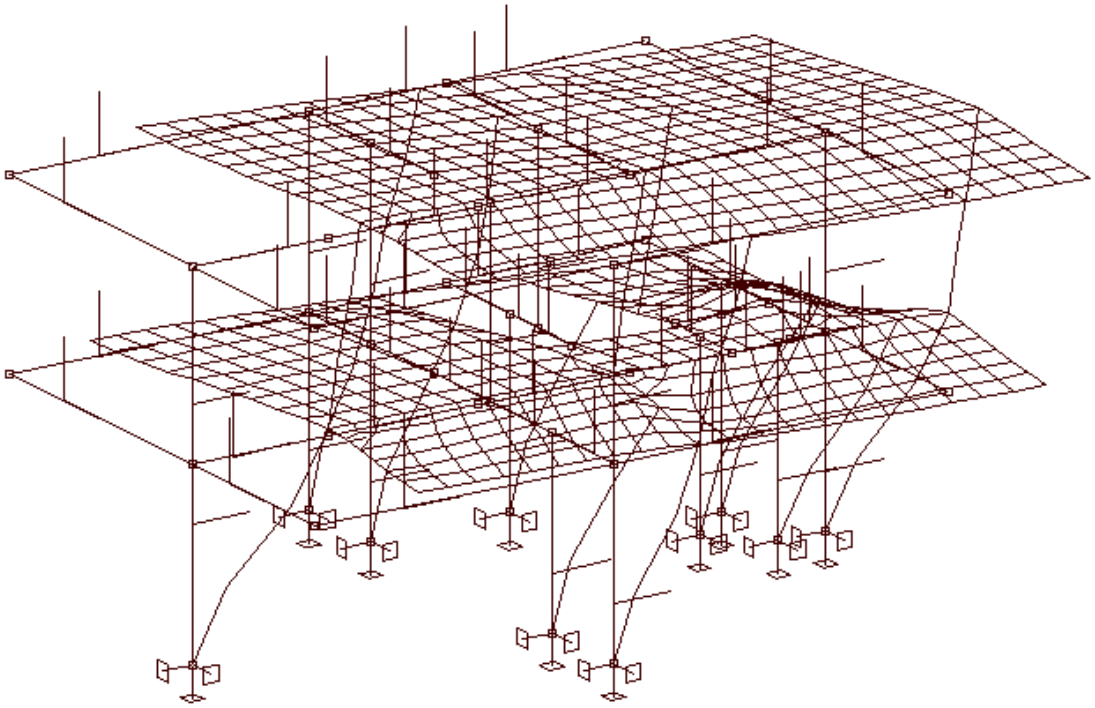


Slika 8.1. Pomaci x-smjer

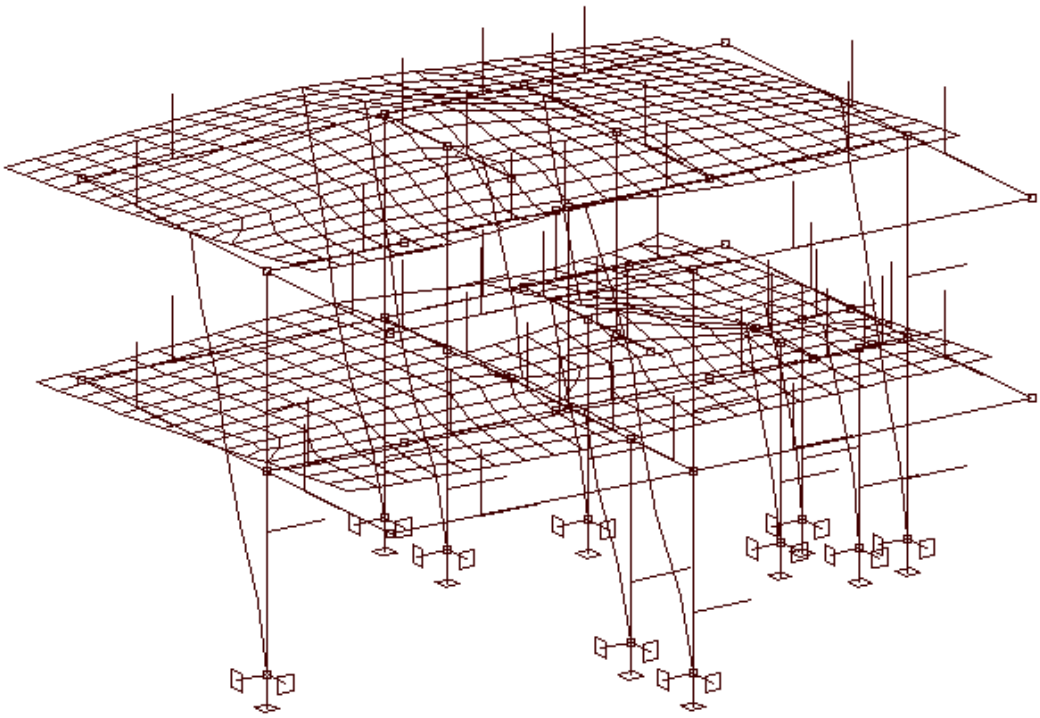


Slika 8.2. Pomaci y-smjer

### *8.1.2.Štapni model*



Slika 8.3. Pomaci x-smjer



Slika 8.4. Pomaci y-smjer

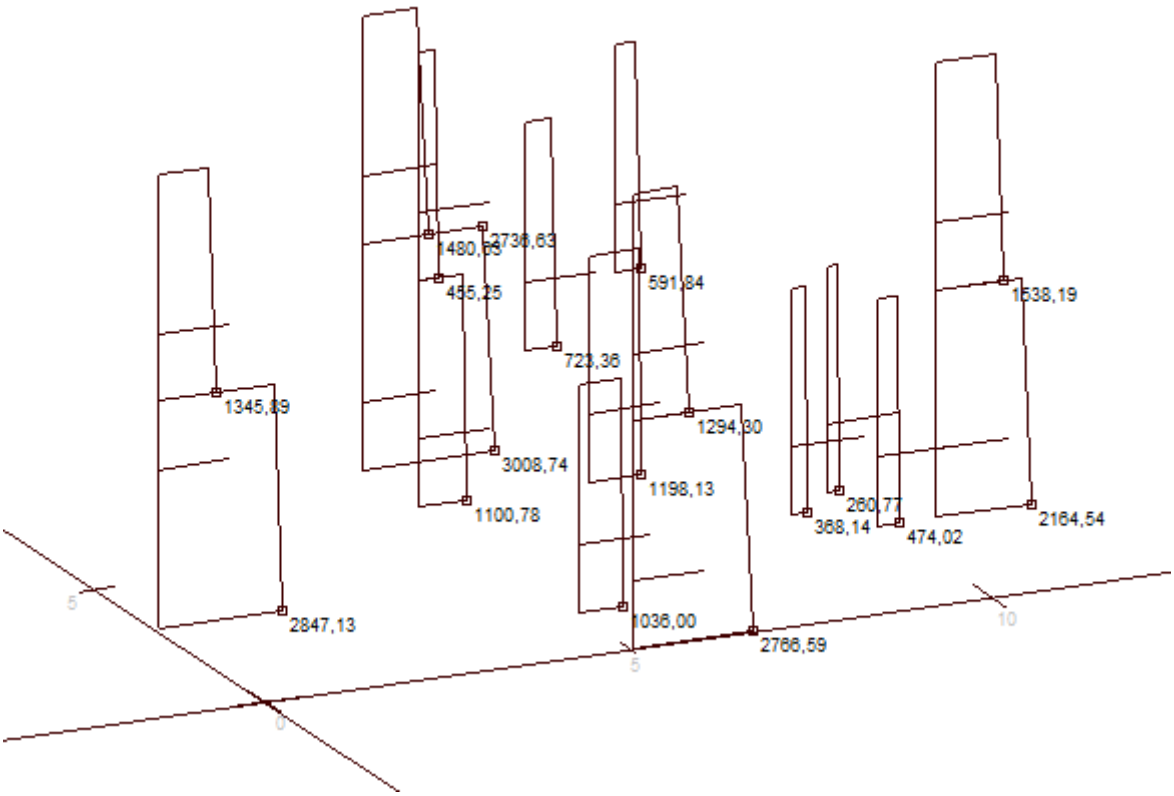
## 8.2.MOMENTI SAVIJANJA I UZDUŽNE SILE ZIDOVA

<u>Kombinacije opterećenja s VJETROM (uobičajena kombinacija):</u>

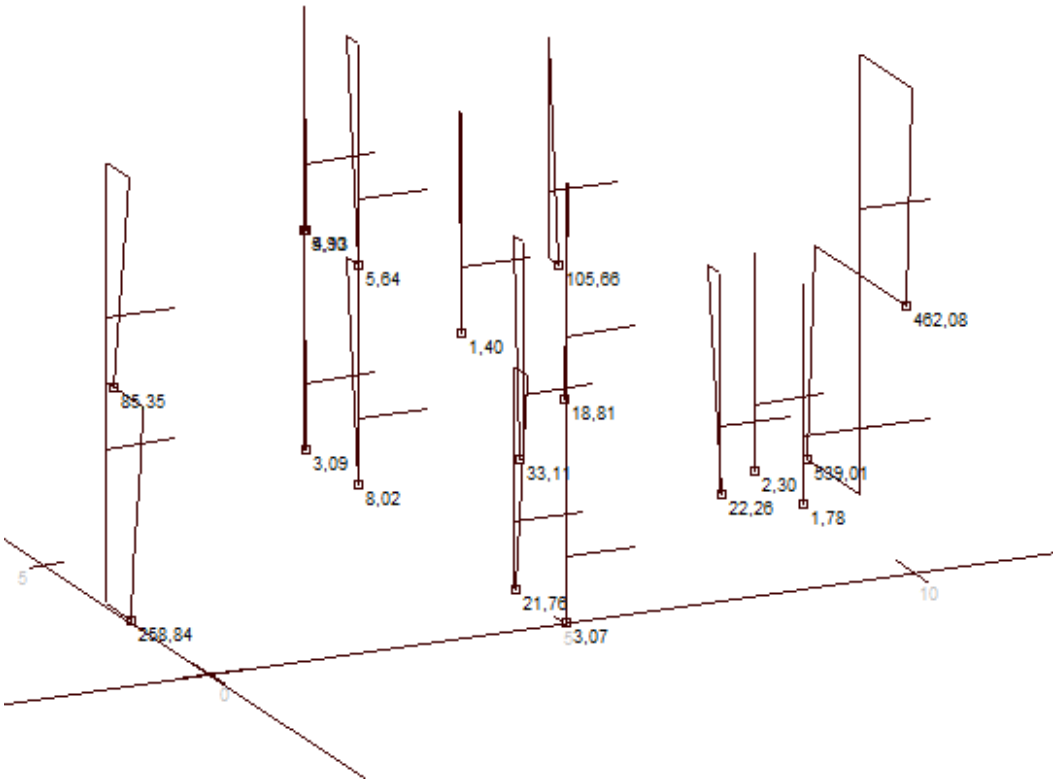
1. kombinacija opterećenja: $1{,}35 \cdot (g + \Delta g) + 1{,}5 \cdot q + 1{,}5 \cdot W_x$

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

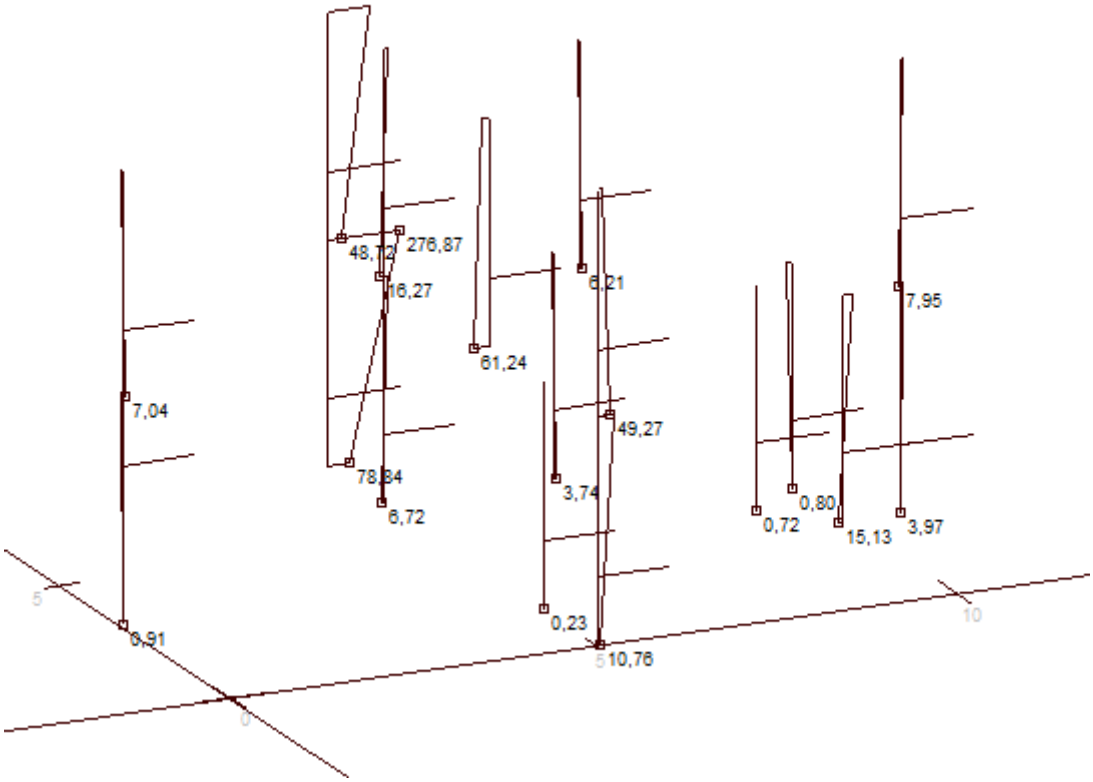
### *8.2.1. Kombinacija 1*




Slika 8.5. Dijagram uzdužnih sila

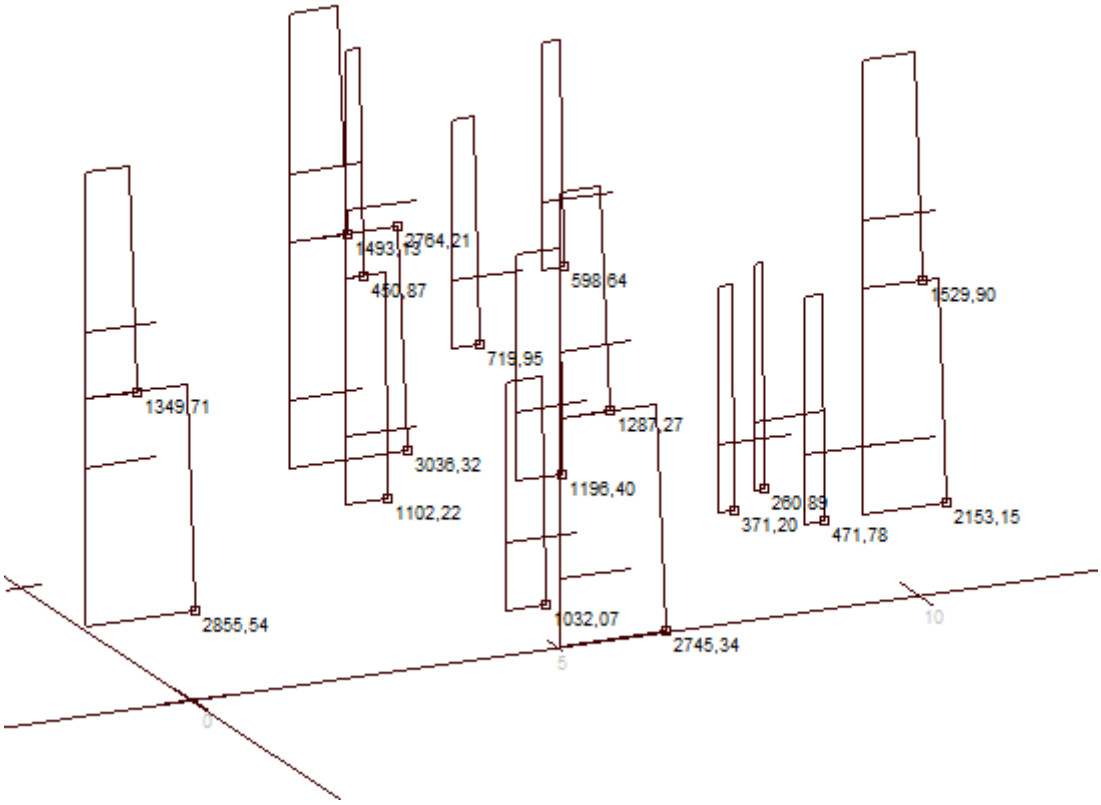



Slika 8.6. Dijagram momenta savijanja My

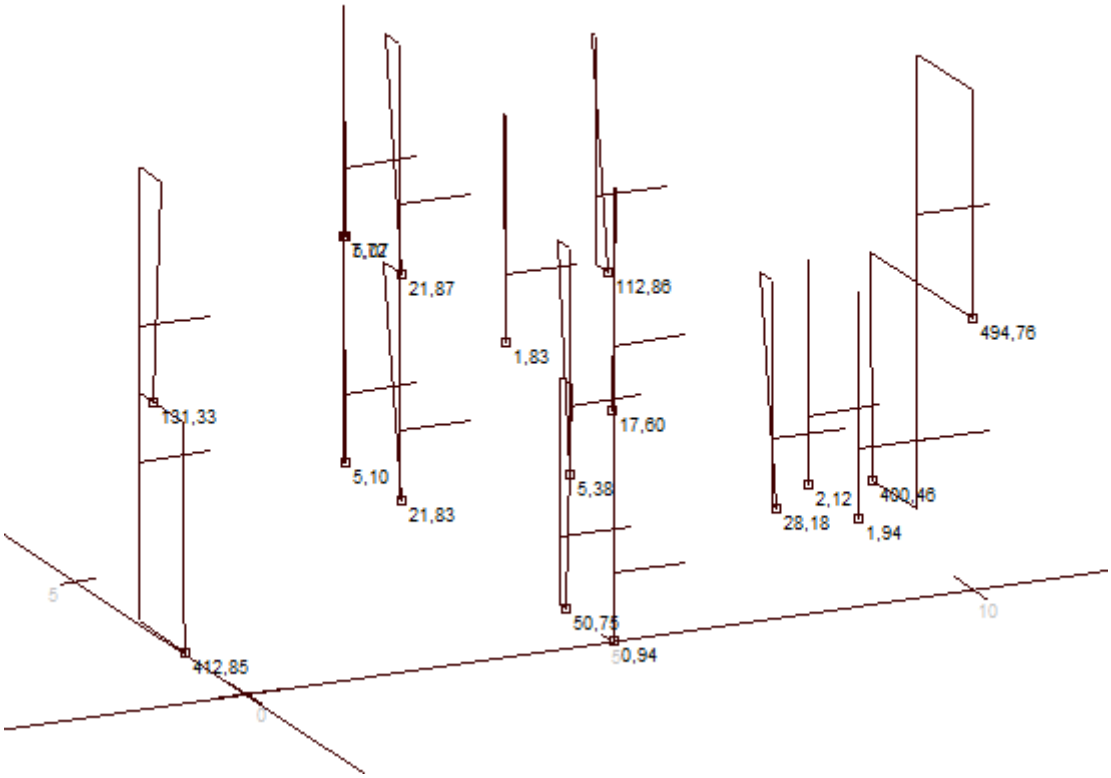



Slika 8.7. Dijagram momenta savijanja Mz

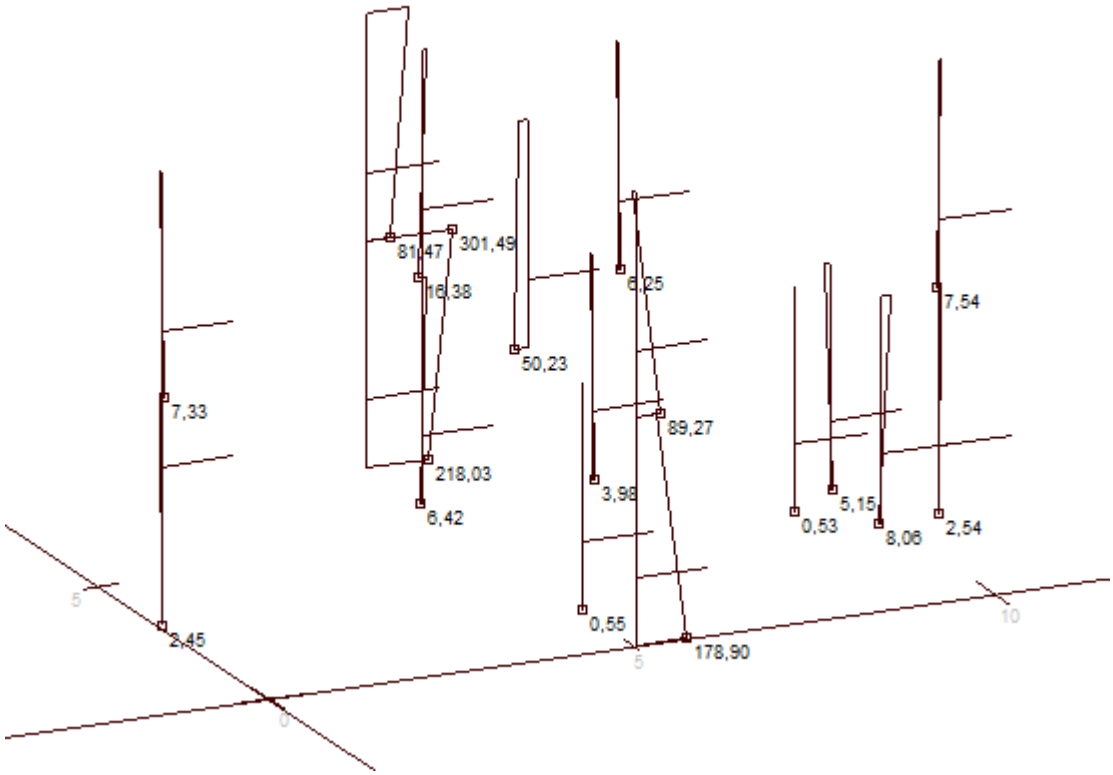
## 8.2.2. *Kombinacija 2*




Slika 8.8. Dijagram uzdužnih sila




Slika 8.9. Dijagram momenta savijanja My




Slika 8.10. Dijagram momenta savijanja Mz

Tablica 8.1. Rezne sile u stupovima

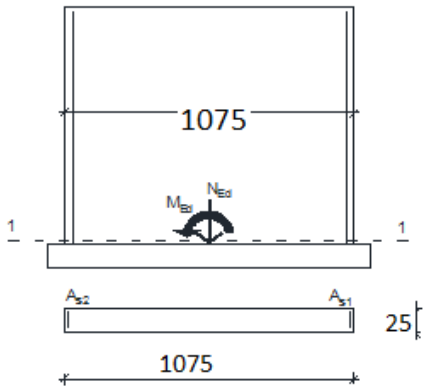
| | | M(kNm) | N(kN) |
|---|---|---|---|
| 1. Kombinacija | MaxN | 276,87 | -3008,74 |
| 2. Kombinacija | Max N | 301,49 | -3036,32 |

## 8.3.DIMENZIONIRANJE ZIDOVA

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

Tablica 8.2. Rezne sile u stupovima

| M(kNm) | N(kN) |
|---|---|
| 276,87 | -3008,74 |
| 301,49 | -3036,32 |




$M_{Eds} = M_{Ed} + N_{Ed} \cdot L_2/2$

$M_{Eds} = 301{,}49 + 3036{,}32 \cdot \frac{10{,}75}{2} = 16621{,}93$ kNm

$A_{s1} = M_{Eds}/z \cdot f_{yd} - N_{Ed}/f_{yd}$

$A_{s1} = \frac{16621{,}93}{22{,}5 \cdot 43{,}48} - \frac{3036{,}32}{43{,}48} = -52{,}84\ cm^2$

>Potrebna je samo konstruktivna armatura!

# 9. *PRORAČUN TEMELJA*

## 9.1.DIMENZIONIRANJE TEMELJA

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

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

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

- 1. kombinacija:N= $3008{,}74\ kN$

  $M = 267{,}87\ kNm$

- 2. kombinacija: $N = 3036{,}32\ kN$

  $M = 301{,}49 kNm$

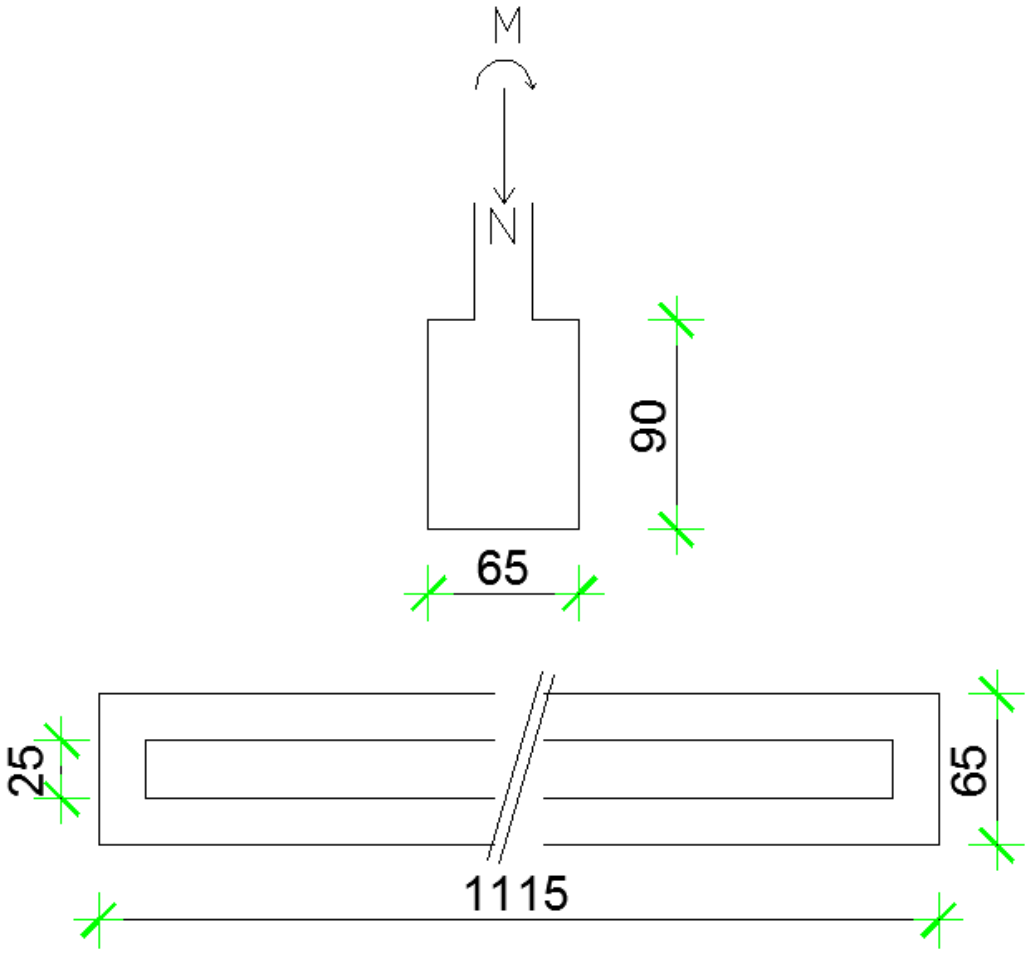
Dopuštena naprezanja u tlu (ovise o vrsti tla): $\sigma_{dop} = 0{,}5\ MN/m^2$

Širina temelja: 0,65 m

Duljina temelja: 11,15 m

Visina temelja: 0,90 m

Težina temelja: $N_t$=11,15*0,65*0,9*25=163,10 kN




Slika 9.1.Dimenzije temelja

## 9.2.KONTROLA NAPREZANJA NA DODIRNOJ PLOHI TEMELJ – TLO

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

A=11,15*0,65=7,23m$^2$

$$W = \frac{bh^2}{6} = \frac{0{,}65 \cdot 11{,}15^2}{6} = 13{,}47\ m^3$$

- **1. kombinacija**

N=3008,74kN >$N_{Ed}$=N+$N_t$=3008,74+163,10=3171,84 kN

M=267,87 kNm

$$\sigma_{1,2} = \frac{N}{A} \pm \frac{M}{W} = \frac{3171{,}84}{7.23} \pm \frac{267{,}87}{13{,}47} 438{,}71 \pm 19{,}89$$

$$\sigma_1 = 458{,}6\ kN/m^2 < \sigma_{dop,tlo} = 500\ kN/m^2$$

$$\sigma_2 = 418{,}82\ kN/m^2 < \sigma_{dop,tlo} = 500\ kN/m^2$$

- **2. Kombinacija**

N=3036,32kN >$N_{Ed}$=N+$N_t$=3036,32+163,10=3199,42 kN

M=301,49 kNm

$$\sigma_{1,2} = \frac{N}{A} \pm \frac{M}{W} = \frac{3199{,}42}{7.23} \pm \frac{301{,}49}{13{,}47} 442{,}52 \pm 22{,}38$$

$$\sigma_1 = 464{,}90\ kN/m^2 < \sigma_{dop,tlo} = 500\ kN/m^2$$

$$\sigma_2 = 420{,}14\ kN/m^2 < \sigma_{dop,tlo} = 500\ kN/m^2$$

## 9.3.PRORAČUN ARMATURE TEMELJA

- **Momenti u presjeku 1-1**

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

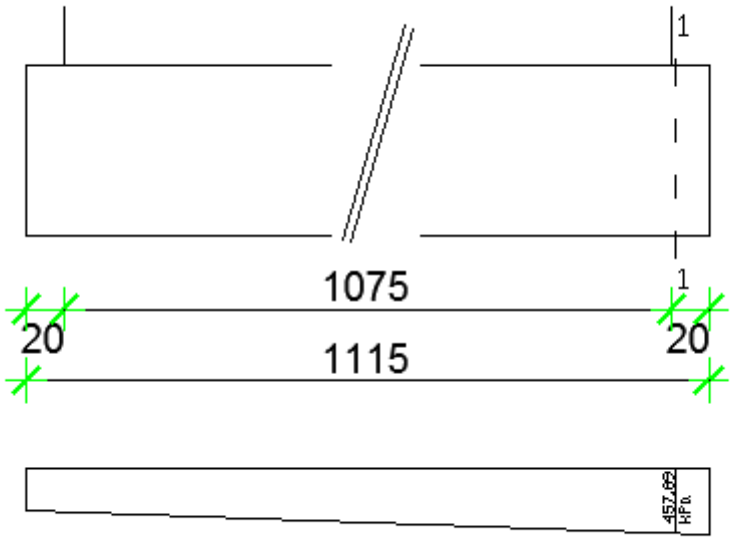
$$\sigma_{1-1} = \sigma_1 - \frac{b_1}{b} \cdot (\sigma_1 - \sigma_2)$$

- **1. kombinacija**

$$\sigma_{1-1} = 458{,}6 - \frac{0{,}20}{11{,}15} \cdot (458{,}6 - 418{,}82) = 457{,}89\ \text{kPa}$$

$$M_{1-1} = 457{,}89 \cdot 0{,}20 \cdot \frac{0{,}20}{2} + (458{,}6 - 457{,}89) \cdot \frac{0{,}20}{2} \cdot \frac{2}{3} \cdot 0{,}20$$

$$M_{1-1} = 9{,}15\ \text{kNm}$$



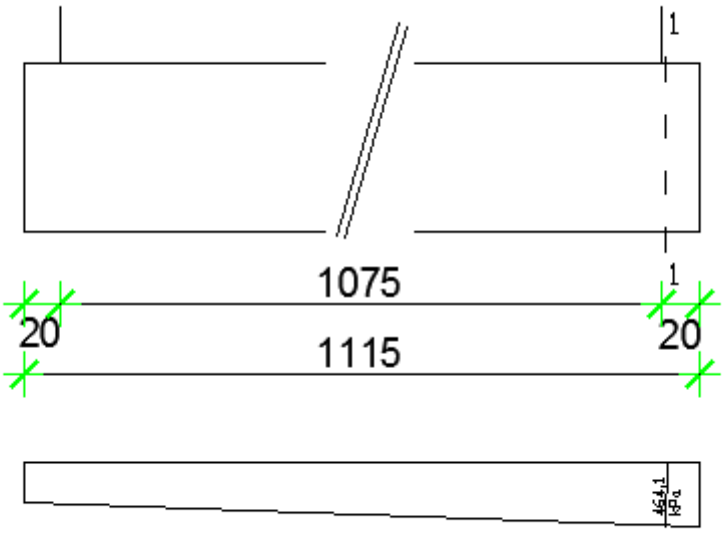

Slika 10.2. Naprezanje ispod temelja za kombinaciju 1

- **2. kombinacija**

$$\sigma_{1-1} = 469{,}90 - \frac{0{,}20}{11{,}15} \cdot (469{,}90 - 420{,}14) = 464{,}1\,\text{kPa}$$

$$M_{1-1} = 464{,}1 \cdot 0{,}20 \cdot \frac{0{,}20}{2} + (469{,}90 - 464{,}1) \cdot \frac{0{,}20}{2} \cdot \frac{2}{3} \cdot 0{,}20$$

$$M_{1-1} = 9{,}36\,\text{kNm}$$




Slika 10.3. Naprezanje ispod temelja za kombinaciju 2

Mjerodavni moment za proračun armature:

$$M_{1-1} = 9{,}36\,kNm$$

Klasa betona: C40/50 → $f_{ck} = 30\ MPa \quad \rightarrow f_{cd} = \frac{30}{1{,}5} = 20{,}00\ MPa = 2{,}00\ kN/cm^2$

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

$$\mu_{sd} = \frac{M_{sd}}{b \cdot d^2 \cdot f_{cd}} = \frac{9{,}36 \cdot 100}{100 \cdot 85^2 \cdot 2{,}00} = 0{,}001$$

Očitano: $\varepsilon_{s1} = 10.0$ ‰, $\varepsilon_{c2} = 0{,}2$ ‰, $\xi = 0{,}020$ , ζ=0,993

$$A_{s1} = \frac{M_{sd,1-1}}{f_{yd} \cdot \zeta \cdot d} = \frac{9{,}36 \cdot 100}{43{,}48 \cdot 0{,}993 \cdot 85} = 0{,}25\ cm^2/m'$$

$$A_{s1} = \frac{0{,}25}{0{,}65} = 0{,}38\left(\frac{cm^2}{m'}\right)$$

Odabrana armatura:

$$A_{s1,odabrano} = 0{,}38\left(\frac{cm^2}{m'}\right)$$

U donju zonu temelja:

Odabrana armatura: mreža Q131 ($A_{s1} = 1{,}31\ cm^2/m'$)

Konstruktivna armatura u gornjoj zoni: mreža Q131 ($A_{s1} = 1{,}31\ cm^2/m$)

# 10.*PRILOZI*

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

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

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

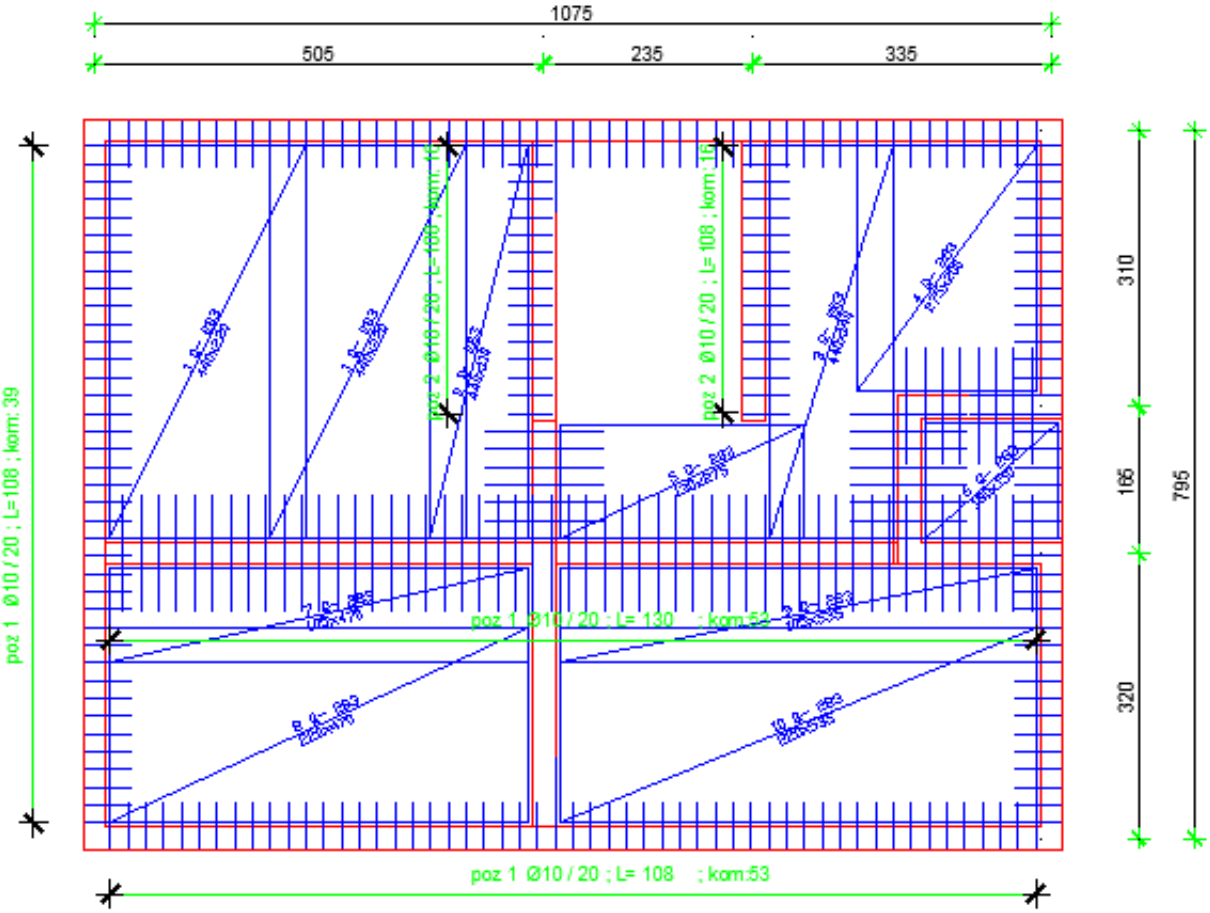
**10.4. ARMATURA PLOČE POZICIJA 200- GORNJA ZONA**

**10.5. ARMATURNI PLAN GREDE**

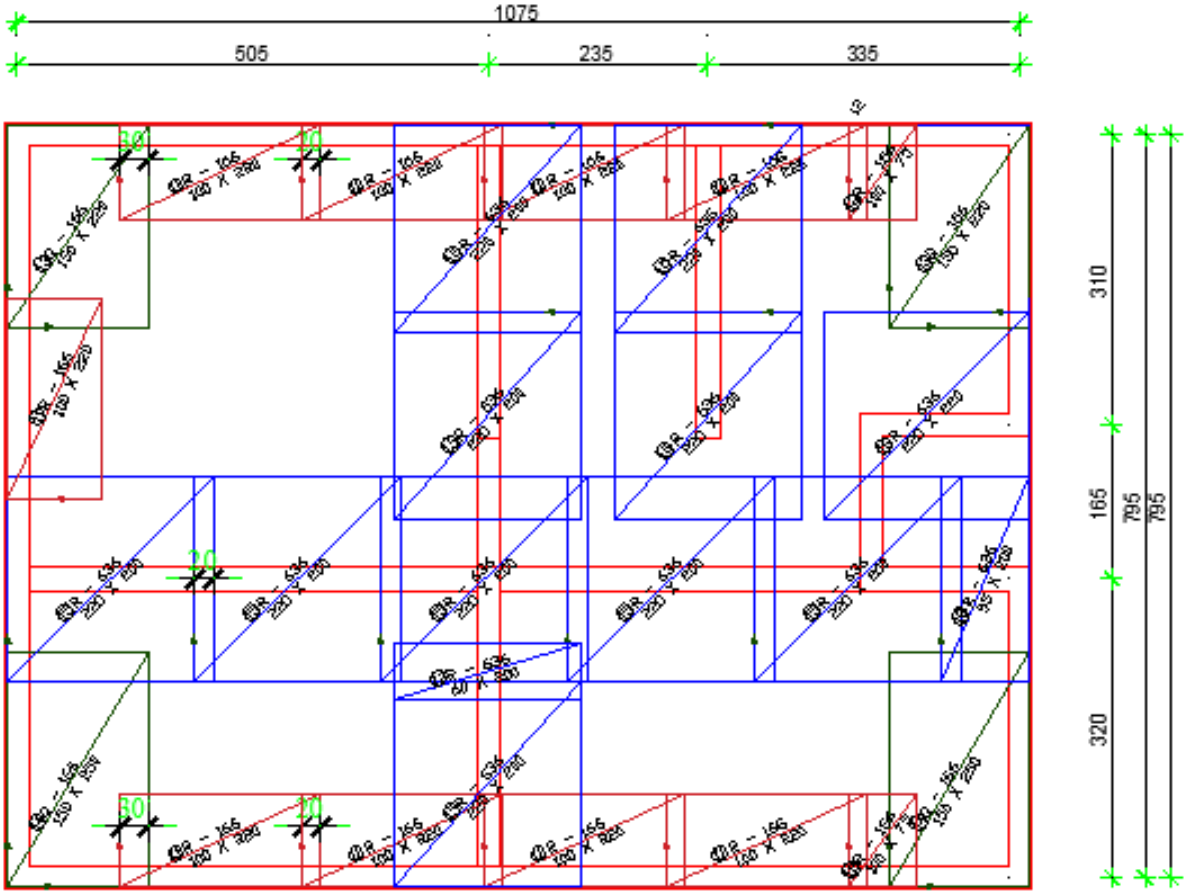
**10.6. ARMATURNI PLAN STUBIŠTA**

# Armatura ploče pozicija 100 - donja zona

1:100



Armatura ploče pozicija 100 - gornja zona zona 1:100



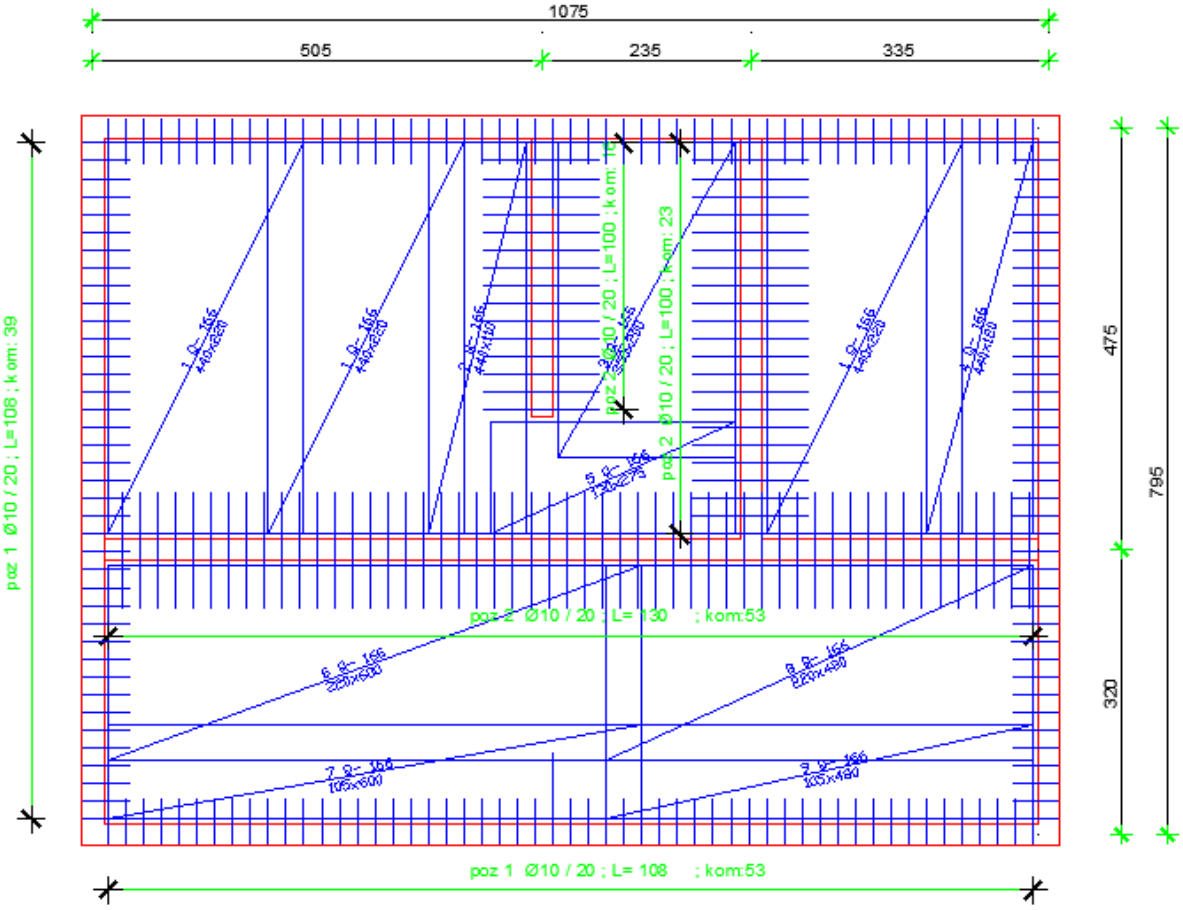
# ISKAZ MREŽASTE ARMATURE
## Čelik B500B

| POZ. | TIP MREŽE | OBLIK | DIMENZIJE (cm) | KOM. | MASA (kg/m2) | UKUPNA MASA |
|---|---|---|---|---|---|---|
| 1 | Q-283 | | 220x440 | 2 | 4,48 | 8,96 |
| 2 | Q-283 | | 110x440 | 1 | 4,48 | 4,48 |
| 3 | Q-283 | | 140x440 | 1 | 4,48 | 4,48 |
| 4 | Q-283 | | 200x275 | 1 | 4,48 | 4,48 |
| 5 | Q-283 | | 130x275 | 1 | 4,48 | 4,48 |
| 6 | Q-283 | | 130x150 | 1 | 4,48 | 4,48 |
| 7 | Q-283 | | 105x470 | 1 | 4,48 | 4,48 |
| 8 | Q-283 | | 220x470 | 1 | 4,48 | 4,48 |
| 9 | Q-283 | | 105x535 | 1 | 4,48 | 4,48 |
| 10 | Q-283 | | 220x535 | 1 | 4,48 | 4,48 |
| 11 | R-166 | | 100x220 | 9 | 1,76 | 15,84 |
| 12 | R-166 | | 100x75 | 2 | 1,76 | 3,52 |
| 13 | Q-166 | | 150x220 | 2 | 2,64 | 5,28 |
| 14 | Q-166 | | 150x250 | 2 | 2,64 | 5,28 |
| 15 | R-636 | | 220x200 | 10 | 5,95 | 59,5 |
| 16 | R-636 | | 220x220 | 1 | 5,95 | 5,95 |
| 17 | R-636 | | 60x200 | 1 | 5,95 | 5,95 |
| 18 | R-636 | | 95x200 | 1 | 5,95 | 5,95 |

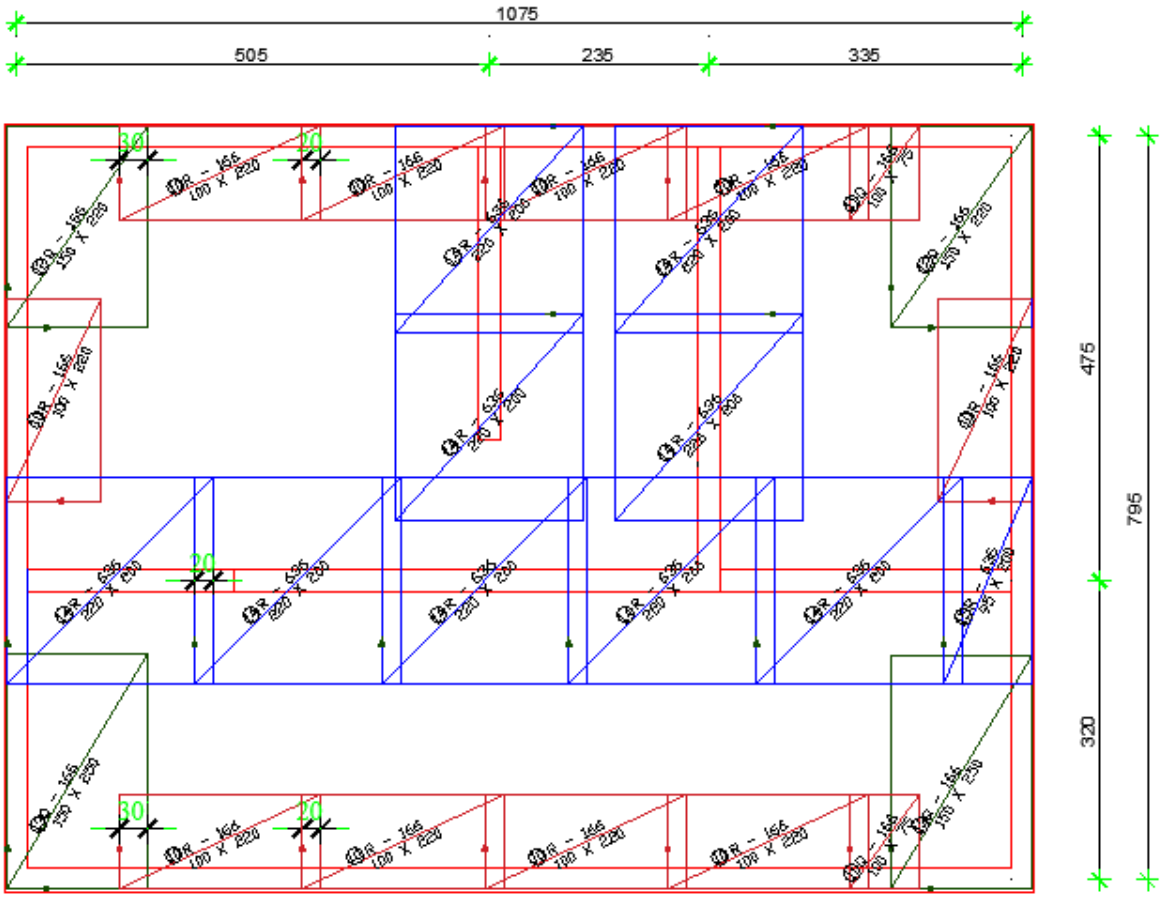
UKUPNO:156,55(KG)

# Armatura ploče pozicija 200 - donja zona

1:100



Armatura ploče pozicija 200 - gornja zona zona 1:100



# ISKAZ MREŽASTE ARMATURE
## Čelik B500B

| POZ. | TIP MREŽE | OBLIK | DIMENZIJE (cm) | KOM. | MASA (kg/m2) | UKUPNA MASA |
|---|---|---|---|---|---|---|
| 1 | Q-166 | 440 220 | 220x440 | 3 | 2,64 | 7,92 |
| 2 | Q-166 | 440 110 | 110x440 | 1 | 2,64 | 2,64 |
| 3 | Q-166 | 350 200 | 200x350 | 1 | 2,64 | 2,64 |
| 4 | Q-166 | 440 120 | 120x440 | 1 | 2,64 | 2,64 |
| 5 | Q-166 | 275 130 | 130x275 | 1 | 2,64 | 2,64 |
| 6 | Q-166 | 600 220 | 220x600 | 1 | 2,64 | 2,64 |
| 7 | Q-166 | 600 105 | 105x600 | 1 | 2,64 | 2,64 |
| 8 | Q-166 | 480 220 | 220x480 | 1 | 2,64 | 2,64 |
| 9 | Q-166 | 480 105 | 105x480 | 1 | 2,64 | 2,64 |
| 10 | R-166 | 220 100 | 100x220 | 10 | 1,76 | 17,60 |
| 11 | R-166 | 75 100 | 100x75 | 2 | 1,76 | 3,52 |
| 12 | Q-166 | 220 150 | 150x220 | 2 | 2,64 | 5,28 |
| 13 | Q-166 | 250 150 | 150x250 | 2 | 2,64 | 5,28 |
| 14 | R-636 | 200 220 | 220x200 | 9 | 5,95 | 53,55 |
| 15 | R-636 | 200 95 | 95x200 | 1 | 5,95 | 5,95 |

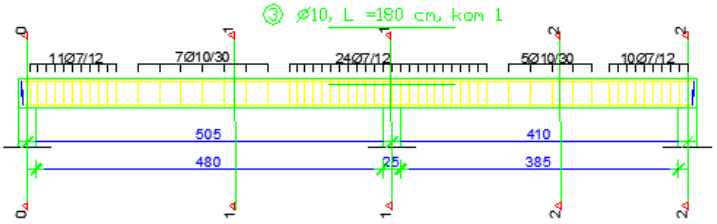
UKUPNO:120,22(KG)

# ARMATURNI PLAN GREDE

GORNJA ZONA

② ø10, L =935 cm, kom 2

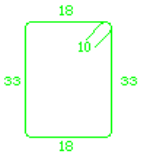
③ ø10, L =180 cm, kom 1




DONJA ZONA

① ø10, L =935 cm, kom 2

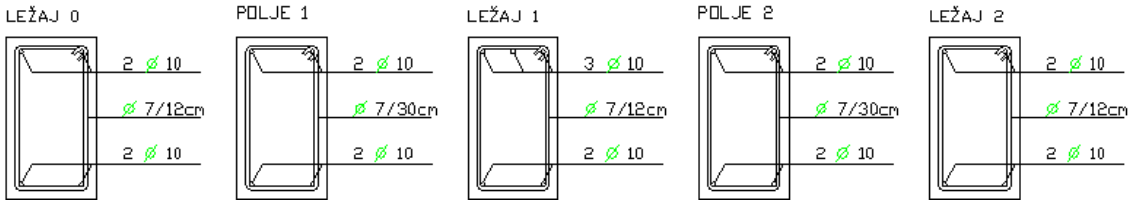
④ ø7/12/30cm , L=122 cm, 61 kom



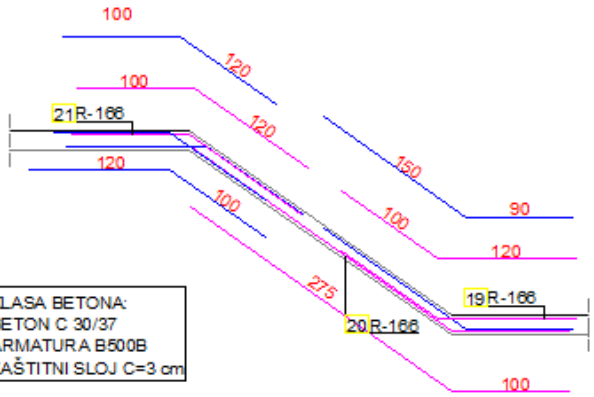

| ISKAZ UZDUŽNIH SIPKI B 500 B | | | | | |
|---|---|---|---|---|---|
| POZ | ∅ | OBLIK I DIMANZIJE | DULJINA (m) | KOMADA | UKUPNA DULJINA PO PROFILIMA (m) |
| 1 | 10 | 20 915 20 | 9,55 | 2 | 18,9 |
| 2 | 10 | 20 915 20 | 9,55 | 2 | 18,9 |
| 3 | 10 | 180 | 1,8 | 1 | 1,8 |

| ISKAZ VILICA B 500 B | | | | | |
|---|---|---|---|---|---|
| POZ | ∅ | OBLIK I DIMANZIJE | DULJINA (m) | KOMADA | UKUPNA DULJINA (m) |
| 4 | 7 | 33 18 33 18 | 1,22 | 57 | 70 |

PRIKAZ UZDUŽNE ARMATURE




# ARMATURNI PLAN STUBIŠTA




KLASA BETONA:
BETON C 30/37
ARMATURA B500B
ZAŠTITNI SLOJ C=3 cm

| Pozicija | Oznka mreže | B [cm] | L [cm] | n | Jedinična težina [kg/m2] | Ukupna težina [kg] |
|---|---|---|---|---|---|---|
| ARMATURA STUBIŠTA | | | | | | |
| 19 | R-166 | 90 | 220 | 2 | 1,76 | 6,97 |
| 20 | R-166 | 90 | 375 | 2 | 1,76 | 11,88 |
| 21 | R-166 | 90 | 220 | 1 | 1,76 | 3,48 |
| Ukupno | | | | | | 22,33 |

| oblik i dimenzije [cm] | Ø | lg [m] | Jedinična-težina [kg/m'] |
|---|---|---|---|
| 100 120 | 10 | 2,20 | 0.79 |
| 100 120 | 10 | 2,20 | 0.79 |
| 150 90 | 10 | 2,40 | 0.79 |

# *11.LITERATURA*

Radnić J.,Harapin A. Osnove betonskih konstrukcija,interna skripta.

Fakultet građevinarstva arhitekture i geodezijeu Splitu,studeni 2013.

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