



SVEUČILIŠTE U SPLITU  
GRAĐEVINSKO-ARHITEKTONSKI FAKULTET  
KATEDRA ZA BETONSKE KONSTRUKCIJE I MOSTOVE

Predmet: MOSTOVI


# Upute za izradu numeričkog modela i proračun mosta





Most koji proračunavamo je u stvari nadvožnjak (glavna trasa prolazi ispod objekta). Sličnih objekata ima cijelom trasom autoceste Zagreb-Split-Dubrovnik. Prikazani nadvožnjak se nalazi između Dugopolja i Biskog.

Za proračun je vrlo bitan rang, tj. širina prometnice koja prelazi preko objekta.



Nadvožnjak se sastoji od dva jednaka raspona i stupom, V-oblika, u sredini.

Konstrukcija je polumontažna – predgotovljeni uzdužni nosači koji se monolitiziraju poprečnim nosačima i monolitnom pločom.

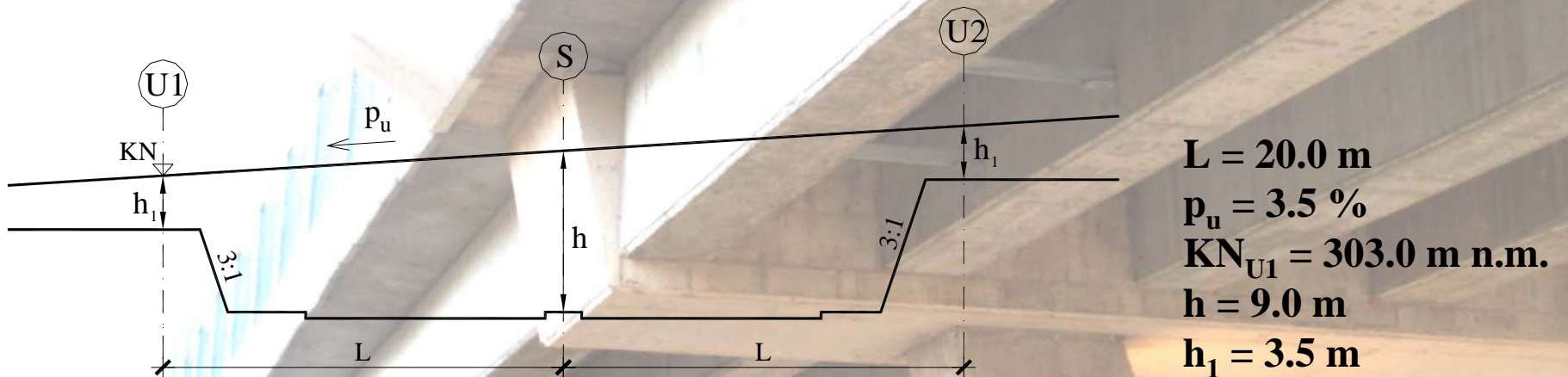
Na upornjaku je konstrukcija oslonjena na neoprenske ležajeve, a stup je kruto spojen s poprečnim nosačem.

## PROGRAMSKI ZADATAK:

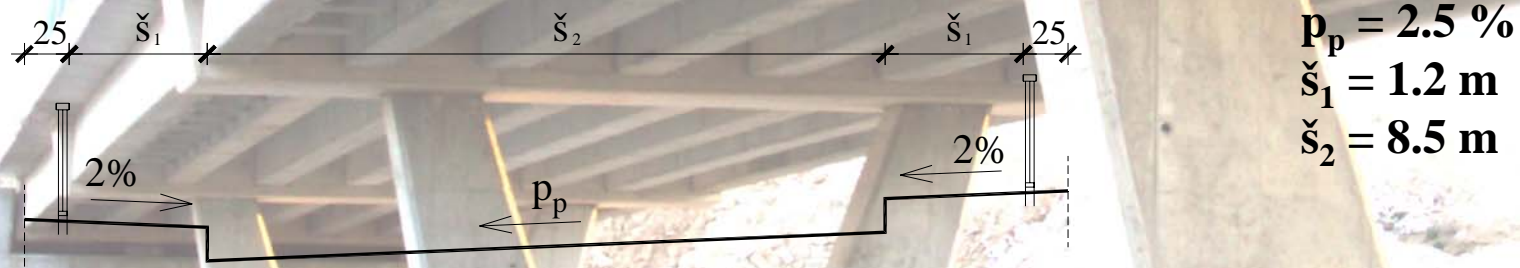
Prema zadanim skicama potrebno je izraditi projekt mosta (nadvožnjaka) koji treba sadržavati:

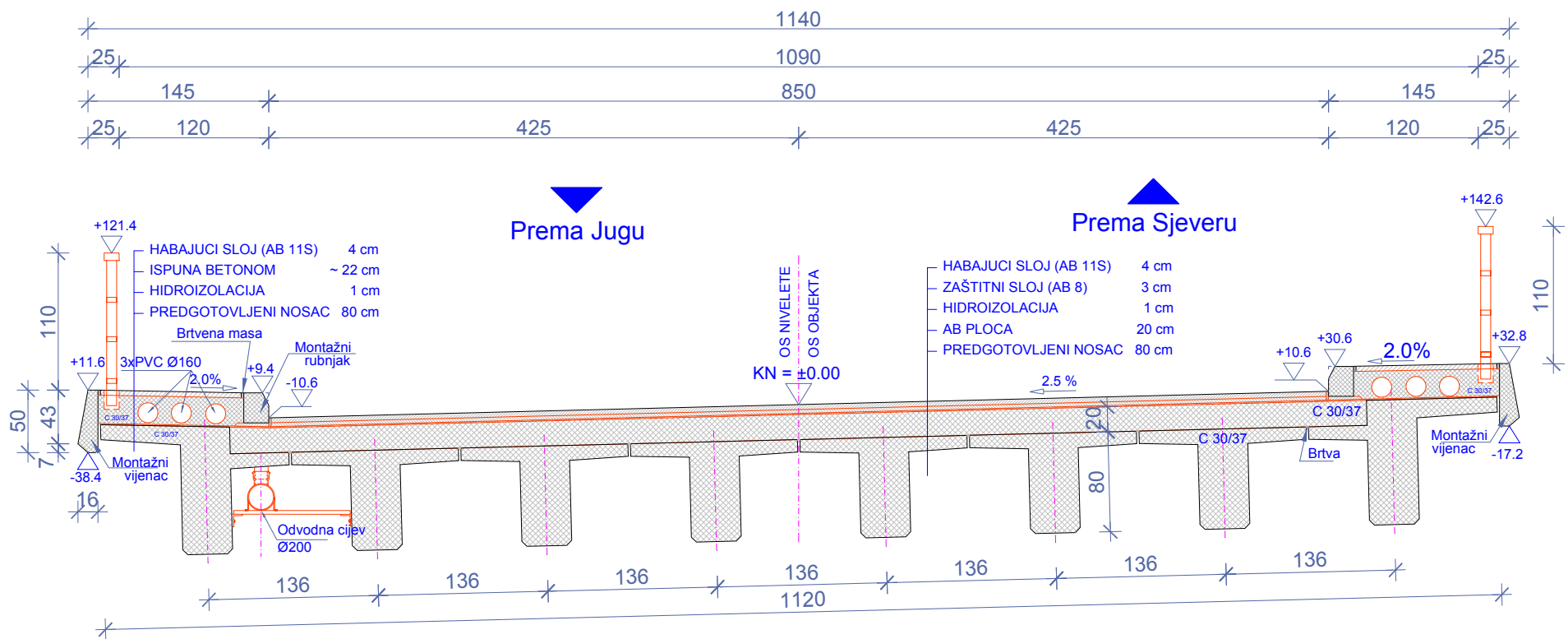
1. Tehnički opis
2. Građevinske nacрте
3. Troškovnik
4. Proračun rasponske konstrukcije

### (i) Uzdužna dispozicija

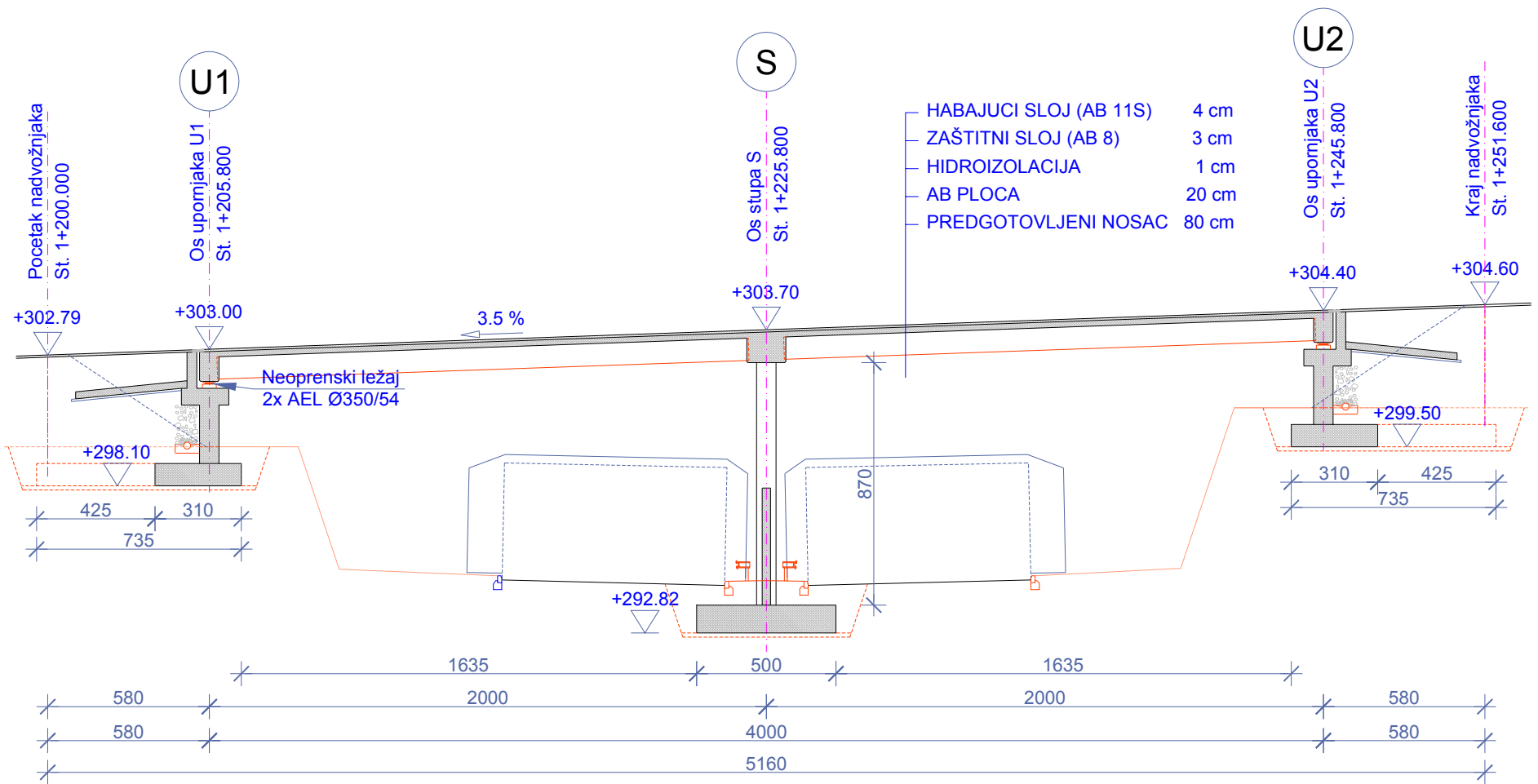


### (ii) Poprečna dispozicija





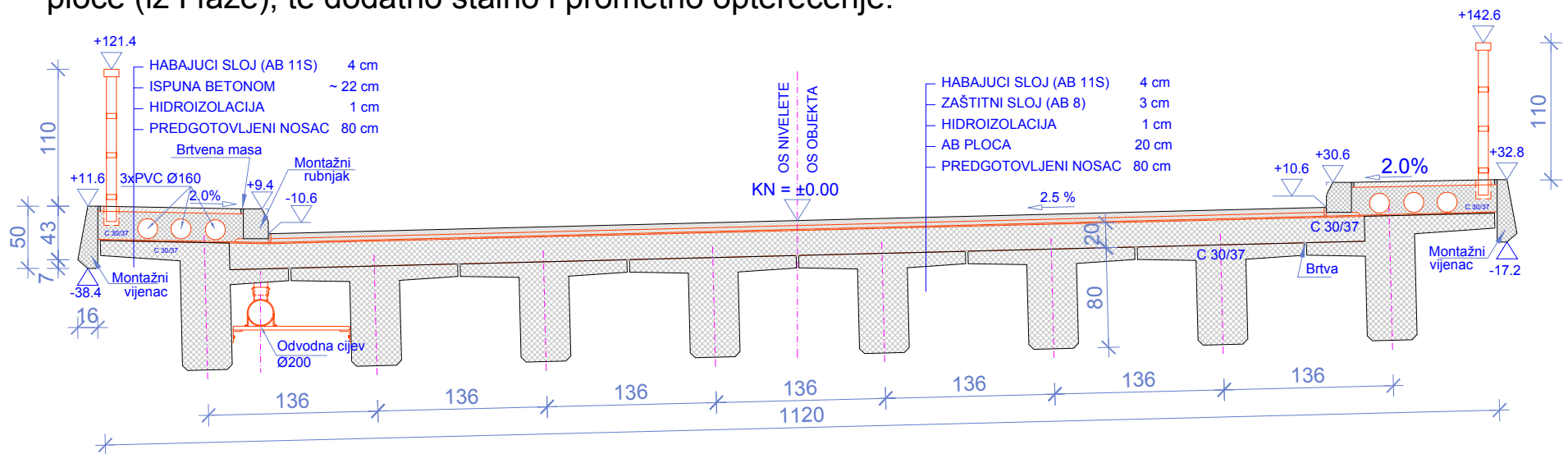
## POPREČNI PRESJEK MOSTA



## UZDUŽNI PRESJEK MOSTA

## OSVRT NA FAZNOST GRADNJE

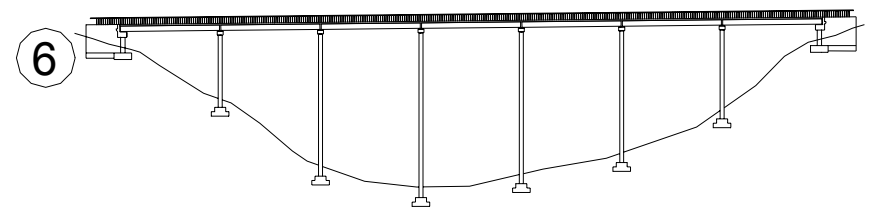
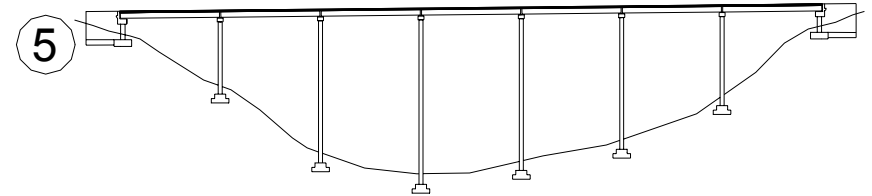
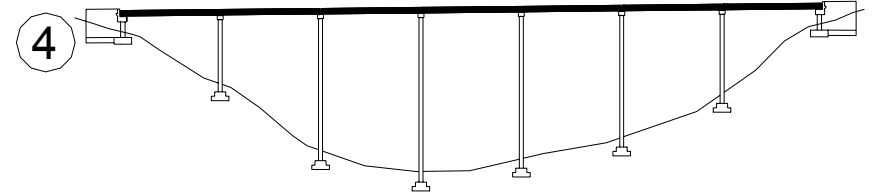
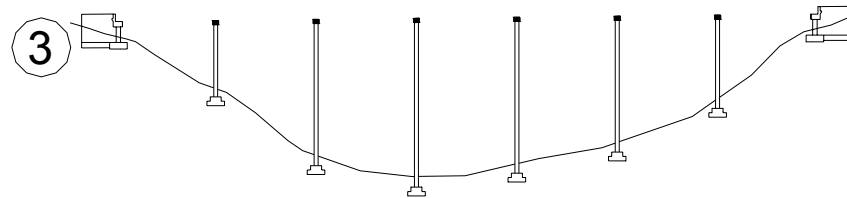
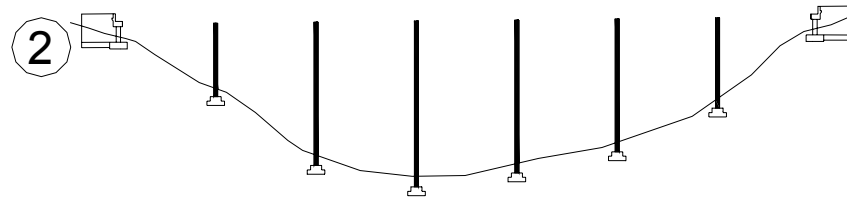
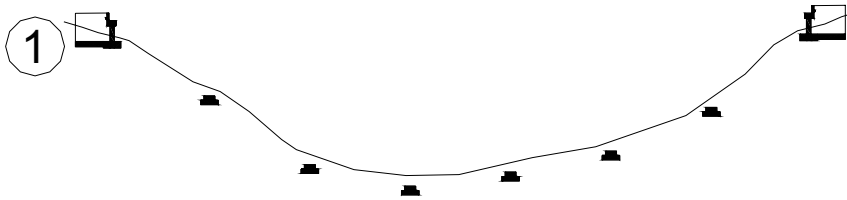
Faze gradnje predstavljaju bitan faktor pri proračunu mosta. Kod polumontažne gradnje dijelovi rasponske konstrukcije (glavni nosači) se izvode sa strane, dovode na most, te na neki način montiraju u svoj konačni položaj. Nakon postavljanja svih glavnih nosača, vrši se izvedba betonske ploče i poprečnih nosača, koji služe za monolitizaciju, tj. povezivanje nosača u jednu cjelinu. Ako promotrimo nosivi sustav mosta u trenutku neposredno nakon što smo izveli ploču i poprečni nosač, možemo zaključiti da je tip prijenosa opterećenja i dalje prosta greda. Naime, cjelokupno opterećenje i dalje prenose samo glavni montažni nosači jer je beton ploče još mekan i predstavlja samo opterećenje. Ovo nam predstavlja I fazu proračuna za rasponsku konstrukciju. U ovoj fazi montažne nosače moramo tako proračunati da budu sposobni prenijeti svoju vlastitu težinu te težinu betonske ploče. Na izvedenu betonsku ploču postavlja se hidroizolacija, asfaltni zastor, pješački hodnici, odbojnici, ograda i sl., što predstavlja dodatno stalno opterećenje mosta. Konačno, na potpuno završeni most se pušta promet. Dodatno stalno i prometno opterećenje djeluju na statičkom sustavu koji nije više prosta greda već kontinuirani nosač, jer se beton betonske ploče i poprečnog nosača stvrdnuo i preuzeo dio nosive funkcije. Ovo predstavlja II fazu proračuna. Dakle, u II fazi montažni nosač, ali sada potpomognut i betonskom pločom koja je s njim spregnuta mora izdržati ukupno opterećenje – vlastitu težinu nosača i ploče (iz I faze), te dodatno stalno i prometno opterećenje.



## OSVRT NA FAZNOST GRADNJE

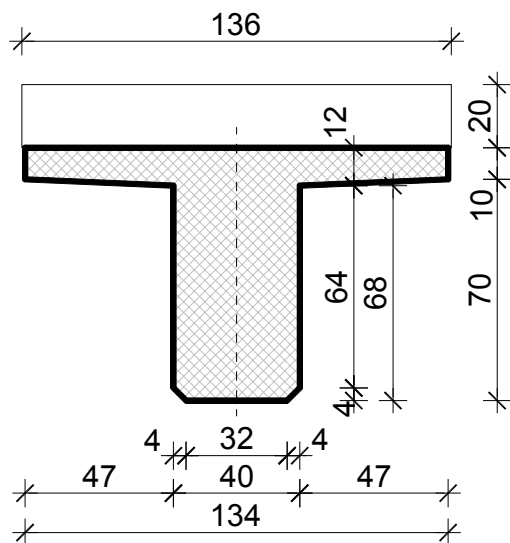
Ukupnu gradnju nekog vijadukta možemo podijeliti u npr. 6 faza:

- 1. faza – izgradnja upornjaka i temelja stupova;
- 2. faza – izgradnja stupova;
- 3. faza – izgradnja naglavnica na stupovima;
- 4. faza – montiranje rasponskih nosača;
- 5. faza – monolitizacija rasponskih nosača – betoniranje kolovozne ploče;
- 6. faza – asfaltiranje kolničkog zastora; ugradnja ograda, odbojnika i ostale opreme.



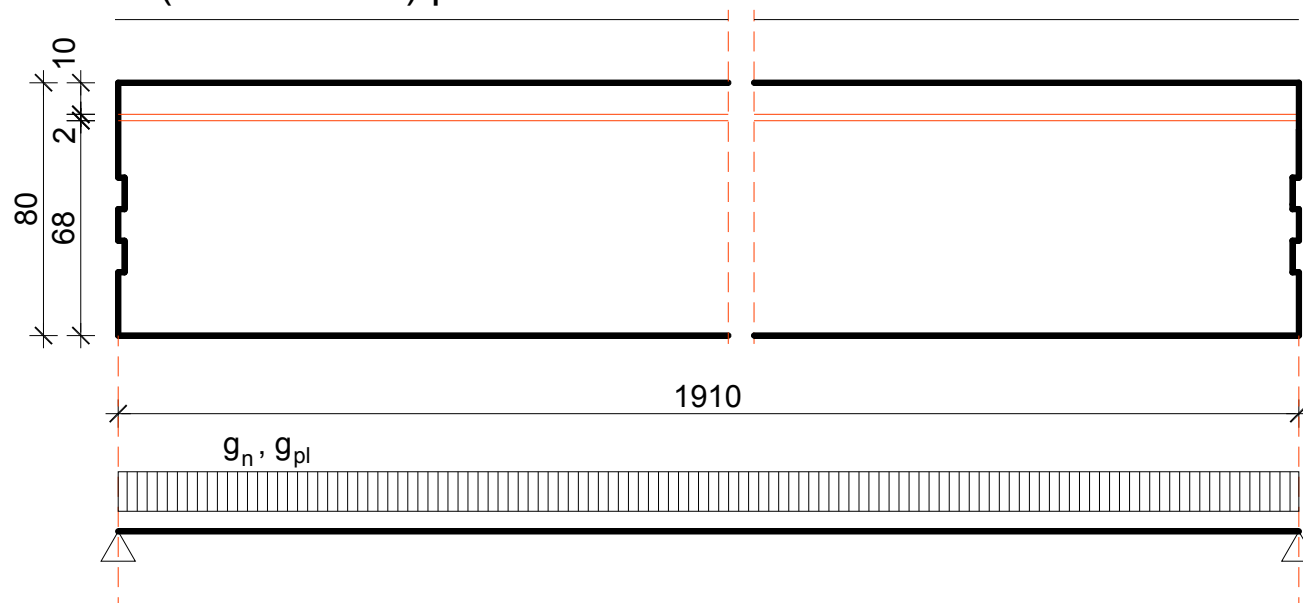
# PRORAČUN RASPONSKIH NOSAČA U 1. fazi

U 1. fazi montažni nosači su sustava proste grede. Opterećeni su svojom težinom i težinom betonske (neočvrsnute) ploče.



$$A_n = 0.422 \text{ m}^2$$

$$\gamma_n = 25.5 \text{ kN/m}^3$$



## Rezne sile i reakcije od vlastite težine nosača

$$g_n = 0.422 \cdot 25.5 = 10.76 \text{ kN/m'}$$

$$R_{g1}^A = R_{g1}^B = \frac{g_n \cdot l}{2} = \frac{10.76 \cdot 19.10}{2} = 102.8 \text{ kN}$$

$$M_{g1}^{1/2} = \frac{g_n \cdot l^2}{8} = \frac{10.76 \cdot 19.10^2}{8} = 490.7 \text{ kNm}$$

$$V_{g1} = R_{g1}^A = 102.8 \text{ kN}$$

## Rezne sile i reakcije od težine kolovozne ploče

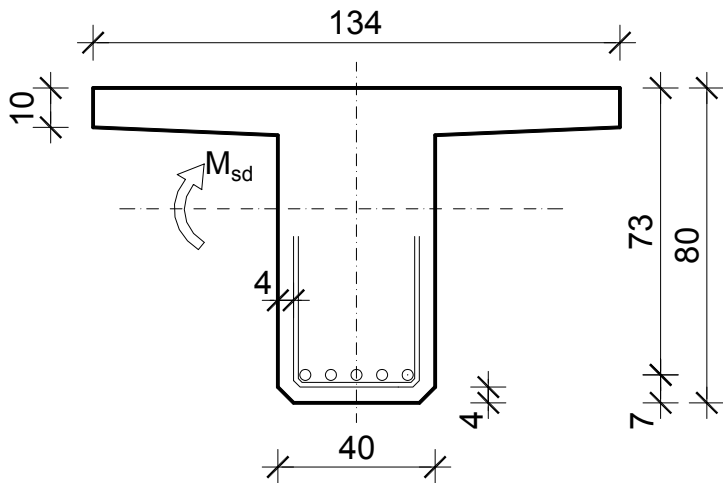
$$g_{pl} = 0.20 \cdot 1.36 \cdot 25.5 = 6.94 \text{ kN/m'}$$

$$R_{g2}^A = R_{g2}^B = \frac{g_{pl} \cdot l}{2} = \frac{6.94 \cdot 19.10}{2} = 66.3 \text{ kN}$$

$$M_{g2}^{1/2} = \frac{g_{pl} \cdot l^2}{8} = \frac{6.94 \cdot 19.10^2}{8} = 316.5 \text{ kNm}$$

$$V_{g2} = R_{g2}^A = 66.3 \text{ kN}$$

# DIMENZIONIRANJE RASPONSKIH NOSAČA NA MOMENT SAVIJANJA



$$C\ 35/45 \Rightarrow f_{ck} = 35.0\ \text{MPa} \Rightarrow f_{cd} = \frac{f_{ck}}{\gamma_c} = \frac{35.0}{1.5} = 23.3\ \text{MPa}$$

$$B\ 450C \Rightarrow f_{yk} = 450.0\ \text{MPa} \Rightarrow f_{yd} = \frac{f_{yk}}{\gamma_s} = \frac{450.0}{1.15} = 392.3\ \text{MPa}$$

$$M_{g1} = 490.7\ \text{kNm} ; \quad M_{g2} = 316.5\ \text{kNm}$$

$$M_{sd} = \gamma_g \cdot (M_{g1} + M_{g2}) = 1.35 \cdot (490.7 + 316.5) = 1089.7\ \text{kNm}$$

$$\mu_{sd} = \frac{M_{sd}}{b d^2 f_{cd}} = \frac{1089.7 \cdot 100}{134 \cdot 73^2 \cdot 2.33} = 0.065$$

za  $\varepsilon_{s1} = 10\text{‰}$ ; ocitano :  $\varepsilon_{c2} = 1.6\text{‰}$ ;  $\xi = 0.138$ ;  $\zeta = 0.950$

$$x = \xi \cdot d = 0.138 \cdot 73 = 10.1\ \text{cm} \approx h_{pl} = 10.0\ \text{cm}$$

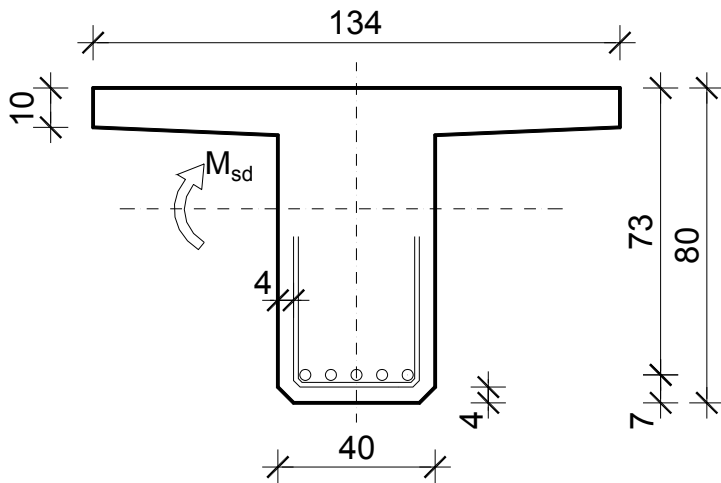
$$A_{s1,1} = \frac{M_{sd}}{\zeta d f_{yd}} = \frac{1089.7 \cdot 100}{0.950 \cdot 73 \cdot 39.2} = 40.1\ \text{cm}^2$$

Lom preko armature  $\varepsilon_{s1} = 10.0\ \text{‰}$

$\varepsilon_{c2}$ [‰]	$\varepsilon_{s1}$ [‰]	$\xi = x/d$	$\zeta = z/d$	$\omega_1$	$k_d$	$\mu_{sds}$
0.1	10.0	0.010	0.997	0.000	49.242	0.000
0.2	10.0	0.020	0.993	0.002	24.996	0.002
0.3	10.0	0.029	0.990	0.004	16.920	0.003
0.4	10.0	0.038	0.987	0.006	12.885	0.006
0.5	10.0	0.048	0.984	0.009	10.468	0.009
0.6	10.0	0.057	0.981	0.013	8.860	0.013
0.7	10.0	0.065	0.977	0.017	7.714	0.017
0.8	10.0	0.074	0.974	0.022	6.857	0.021
0.9	10.0	0.083	0.971	0.027	6.193	0.026
1.0	10.0	0.091	0.968	0.032	5.664	0.031
1.1	10.0	0.099	0.965	0.038	5.233	0.037
1.2	10.0	0.107	0.962	0.044	4.876	0.042
1.3	10.0	0.115	0.959	0.050	4.576	0.048
1.4	10.0	0.123	0.956	0.056	4.321	0.054
1.5	10.0	0.130	0.953	0.062	4.102	0.059
1.6	10.0	0.138	0.950	0.069	3.912	0.065
1.7	10.0	0.145	0.947	0.075	3.747	0.071
1.8	10.0	0.153	0.944	0.082	3.602	0.077
1.9	10.0	0.160	0.941	0.088	3.474	0.083

# DIMENZIONIRANJE RASPONSKIH NOSAČA NA POPREČNU SILU

Beton		C35/45
$f_{ck}$ (MPa)	Čvrstoća na valjku	35.0
$\tau_{Rd}$ (MPa)	Posmična čvrstoća	0.37



$$V_{g1} = 102.8 \text{ kN}$$

$$V_{g2} = 66.3 \text{ kN}$$

$$\begin{aligned} V_{sd} &= \gamma_g \cdot (V_{g1} + V_{g2}) = \\ &= 1.35 \cdot (102.8 + 66.3) \\ &= 228.3 \text{ kN} \end{aligned}$$

$$V_{Rd1} < V_{sd} < V_{Rd2}$$

$$\sum A_s \approx 40.0 \text{ cm}^2$$

$$\rho_l = \frac{\sum A_s}{A_c} = \frac{40.0}{40 \cdot 80} = 0.0125$$

Dio poprečne sile koju preuzima beton i uzdužna armatura:

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

$$k = 1.6 - d = 1.6 - 0.73 = 0.87 < 1.0 \Rightarrow k = 1.0$$

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

$$V_{Rd1} = [0.037 \cdot 1.0 \cdot (1.2 + 40 \cdot 0.0125) + 0.15 \cdot 0.0] \cdot 40 \cdot 73$$

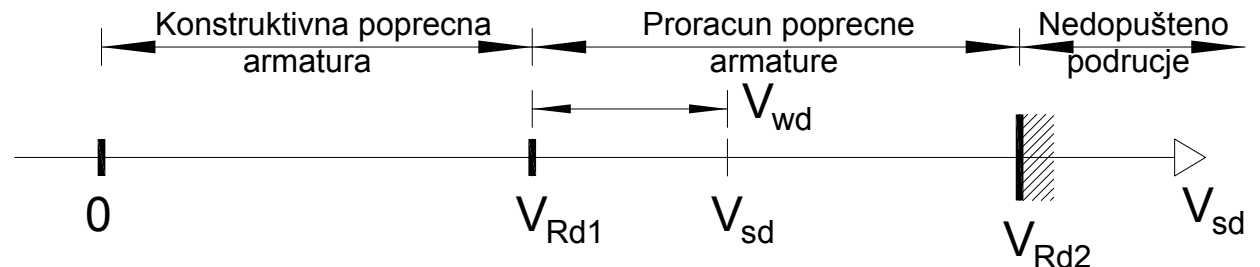
$$V_{Rd1} = 183.7 \text{ kN}$$

Dio poprečne sile koju mogu preuzeti tlačne dijagonale:

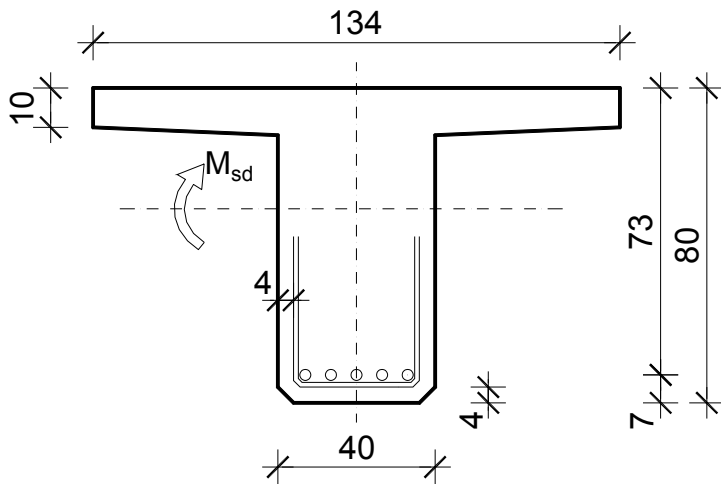
$$V_{Rd2} = 0.5 \cdot v \cdot f_{cd} \cdot b_w \cdot z$$

$$v = 0.7 - \frac{f_{ck}}{200} = 0.7 - \frac{35}{200} = 0.525 > 0.5 \Rightarrow v = 0.525$$

$$V_{Rd2} = 0.5 \cdot 0.525 \cdot 2.33 \cdot 40 \cdot (0.9 \cdot 73) = 1607.4 \text{ kN}$$



# DIMENZIONIRANJE RASPONSKIH NOSAČA NA POPREČNU SILU



$$V_{g1} = 102.8 \text{ kN}$$

$$V_{g2} = 66.3 \text{ kN}$$

$$\begin{aligned} V_{sd} &= \gamma_g \cdot (V_{g1} + V_{g2}) = \\ &= 1.35 \cdot (102.8 + 66.3) \\ &= 228.3 \text{ kN} \end{aligned}$$

$$V_{sd} < V_{Rd} = V_{Rd1} + V_{wd}$$

Maksimalna poprečna sila:

$$V_{sd} = 228.3 \text{ kN}$$

$$V_{sd}/V_{Rd2} = 228.3/1607.4 \approx 0.14 \Rightarrow V_{sd} = 0.14 V_{Rd2}$$

$$s_{w,max} = \min \{0.8 \cdot d; 30.0 \text{ cm}\} =$$

$$\min \{0.8 \cdot 73 = 58.4; 30.0\} \Rightarrow s_{w,max} = 30.0 \text{ cm}$$

$$\rho_{min} = 0.0011 \text{ (C35/45)}$$

Odabrane spone  $\varnothing 10$  ( $A_{sw} = 0.79 \text{ cm}^2$ ):

$$s_{w,pot} \leq \frac{m \cdot A_{sw,min}}{\rho_{min} \cdot b_w} = \frac{2 \cdot 0.79}{0.0011 \cdot 40} = 35.9 \text{ cm}$$

Odabrane spone  $\varnothing 10/30$ . Ukupna nosivost betona i odabrane poprečne armature:

$$f_{yw,d} = \frac{f_{yk}}{\gamma_s}; \text{ B 450C} \Rightarrow$$

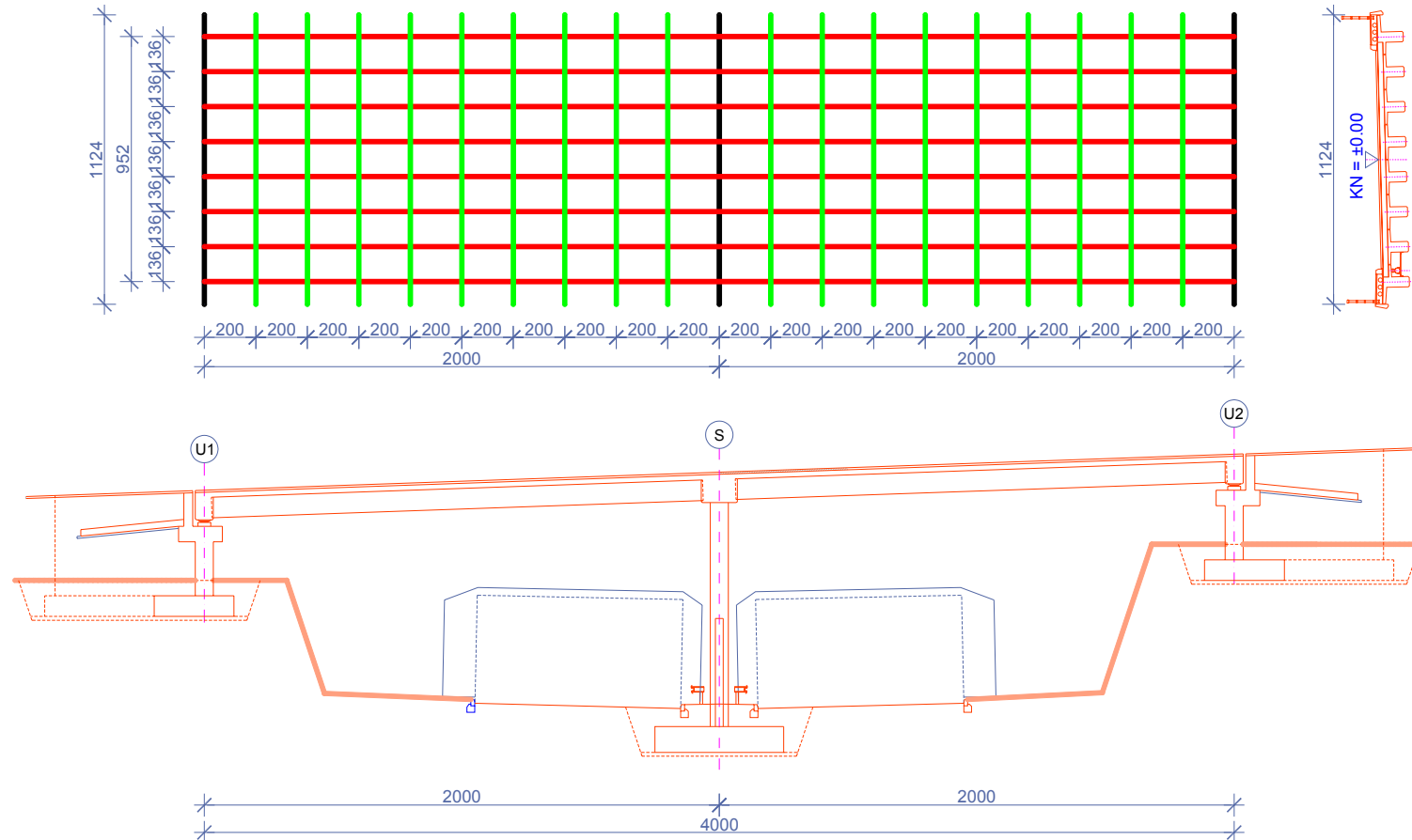
$$f_{yw,d} = \frac{450.0}{1.15} = 391.3 \text{ MPa} = 39.13 \text{ kN/cm}^2$$

$$\begin{aligned} V_{Rd} &= V_{Rd1} + V_{wd} = V_{Rd1} + \frac{m \cdot A_{sw} \cdot f_{yw,d} \cdot z}{s_w} \\ &= 183.7 + \frac{2 \cdot 0.79 \cdot 39.13 \cdot (0.9 \cdot 73)}{30} = \\ &= 183.7 + 135.4 = 319.1 \text{ kN} \end{aligned}$$

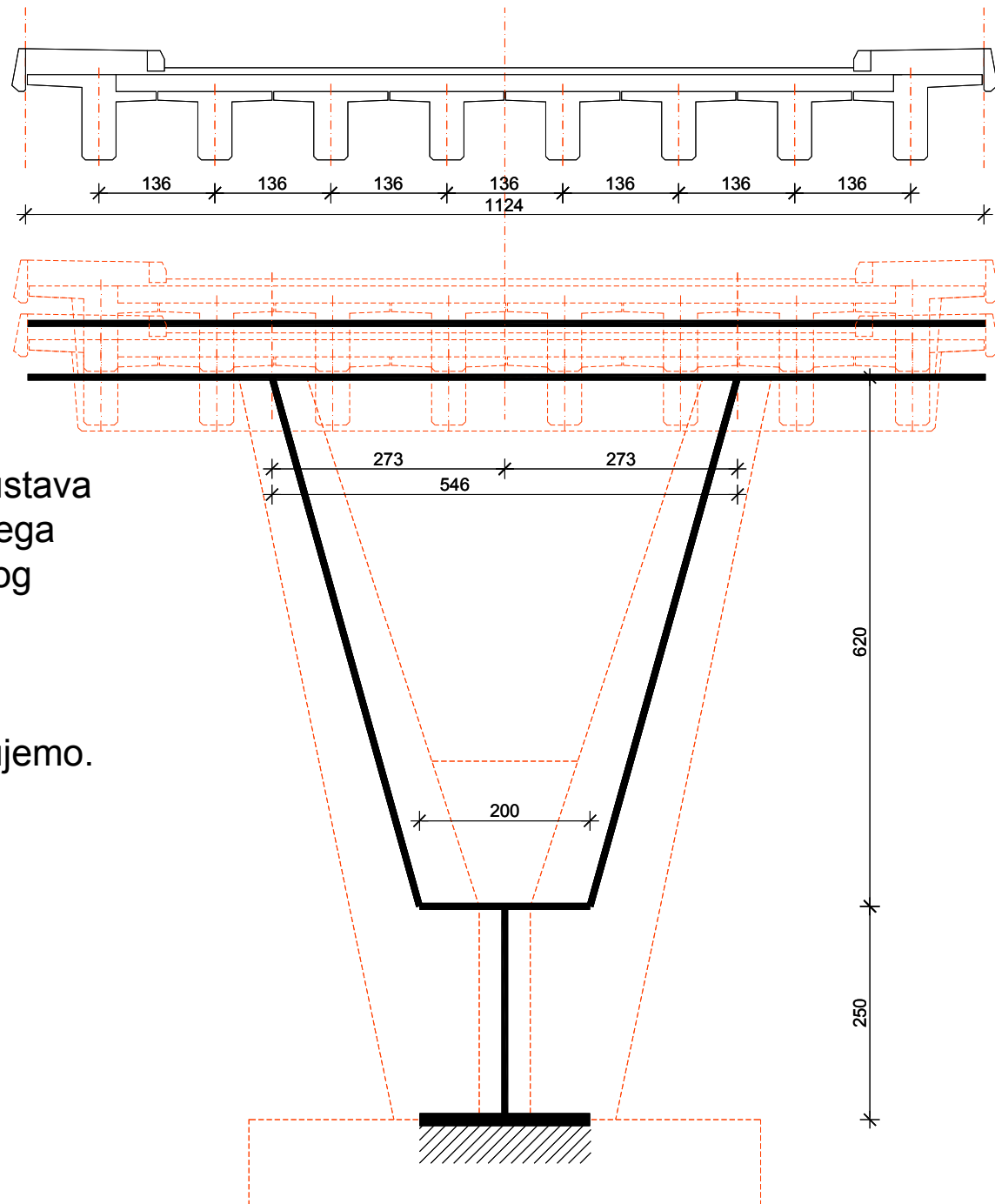
## 2. FAZA - NUMERIČKI MODEL

Nakon sprezanja montažnih nosača s kolničkom pločom i njihovog kontinuiranja, rasponski sklop je sustava “roštilja”. Roštiljno djelovanje osigurava prvenstveno kolnička ploča, zajedno s poprečnim nosačima. Rezne sile i reakcije oslonaca za djelovanja koja se javljaju na rasponski sklop nakon formiranja ovog sustava određena su na modelu konstrukcije prikazanom u nastavku.

Na priloženim crtežima prikazan je računski model rasponskog sklopa nakon kontinuiranja i sprezanja montažnih nosača s kolničkom pločom. Nosači i ploča su simulirani “štapnim” elementima adekvatne krutosti.

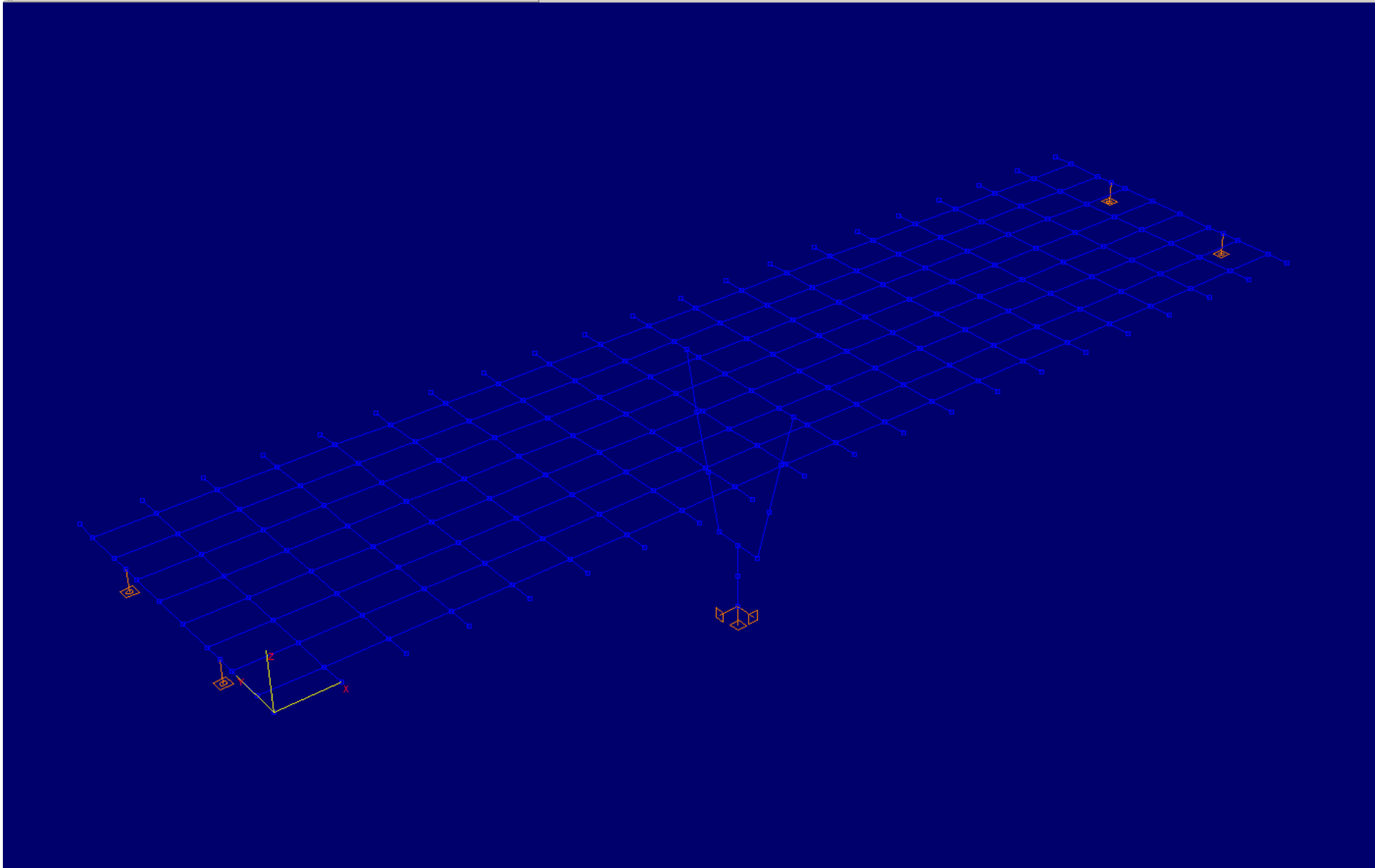


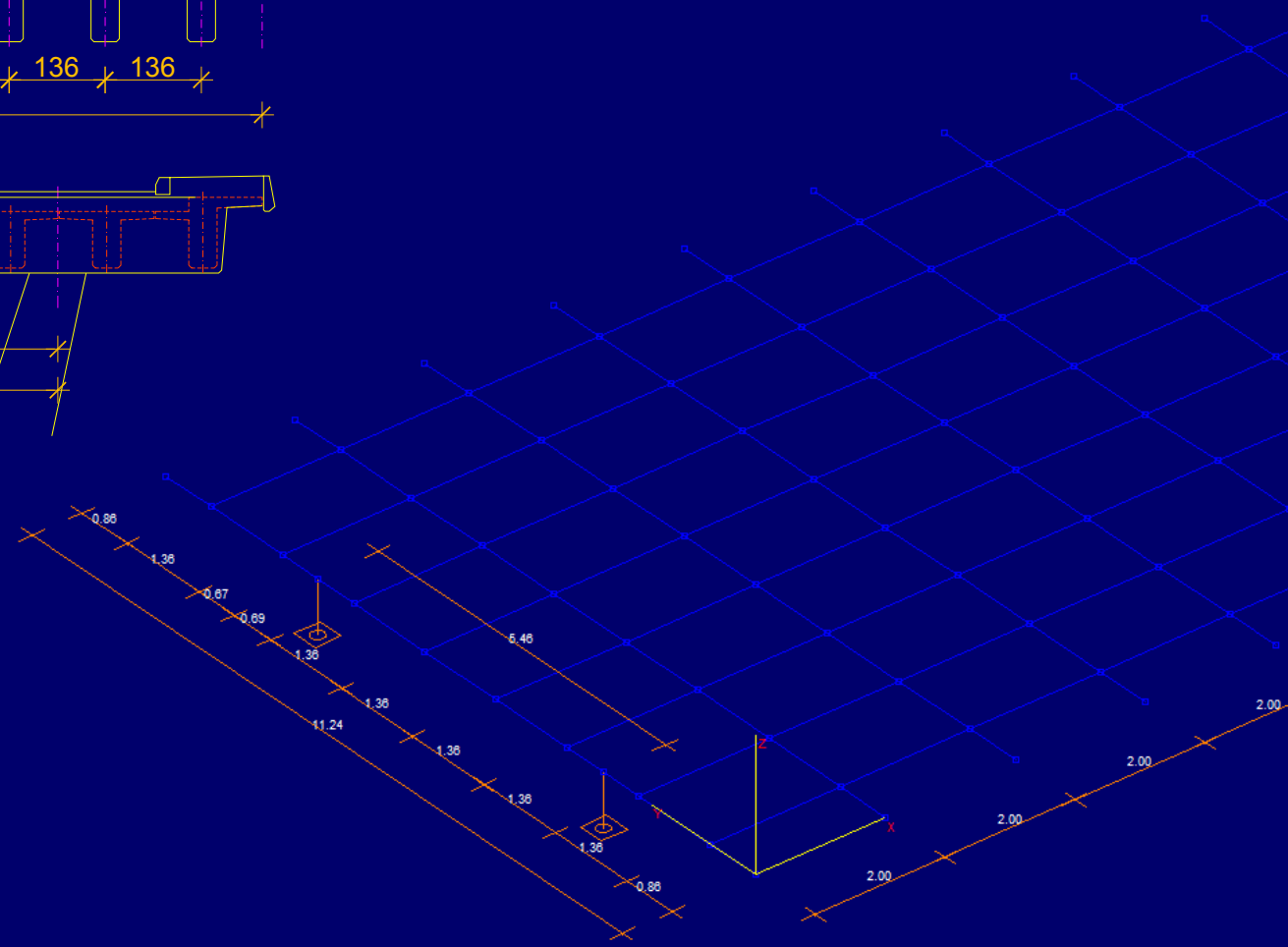
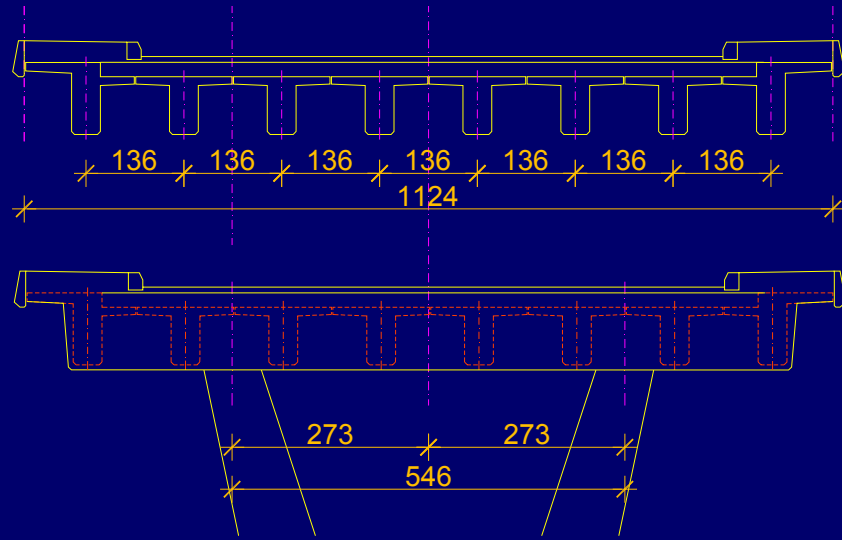
# NUMERIČKI MODEL

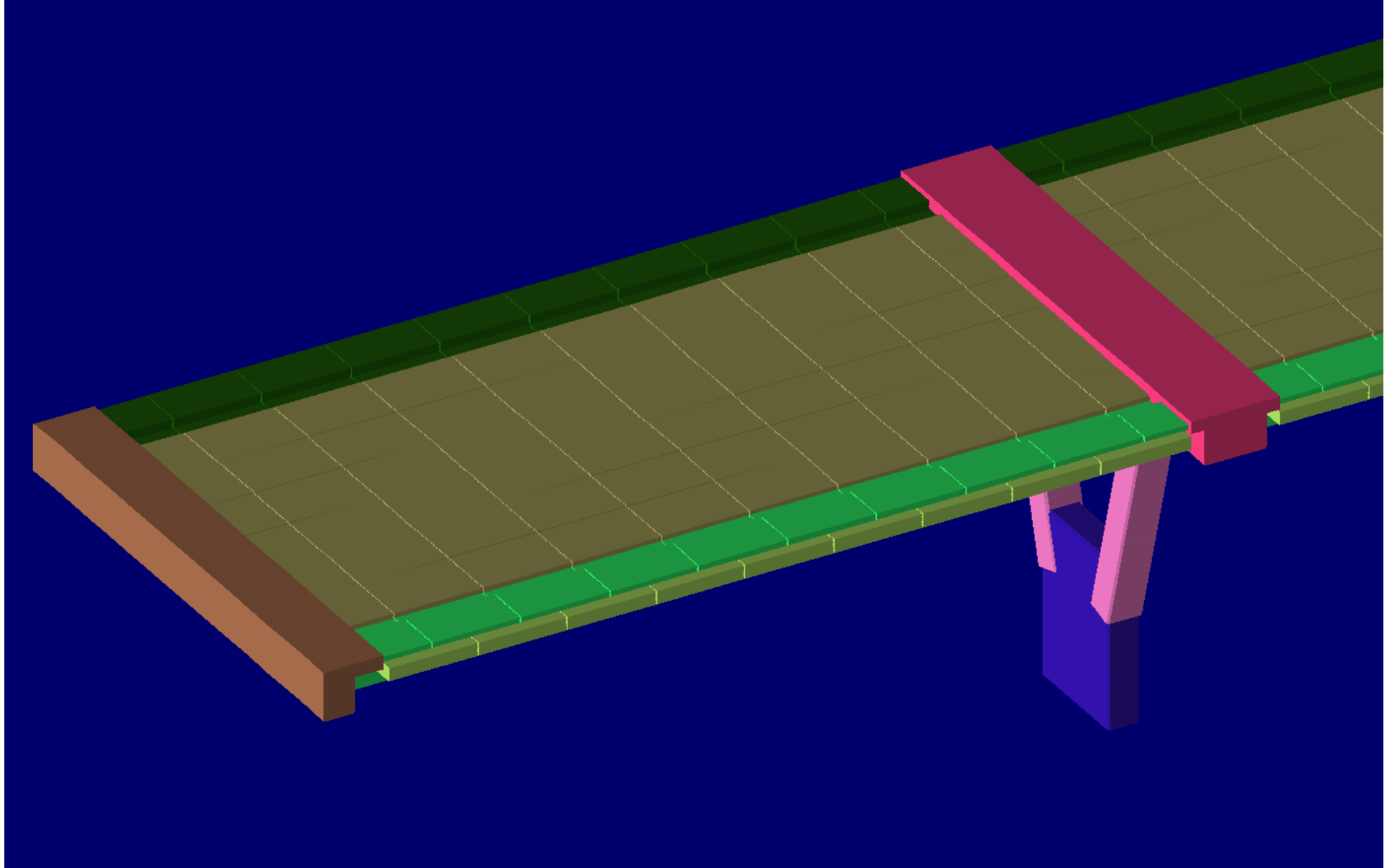


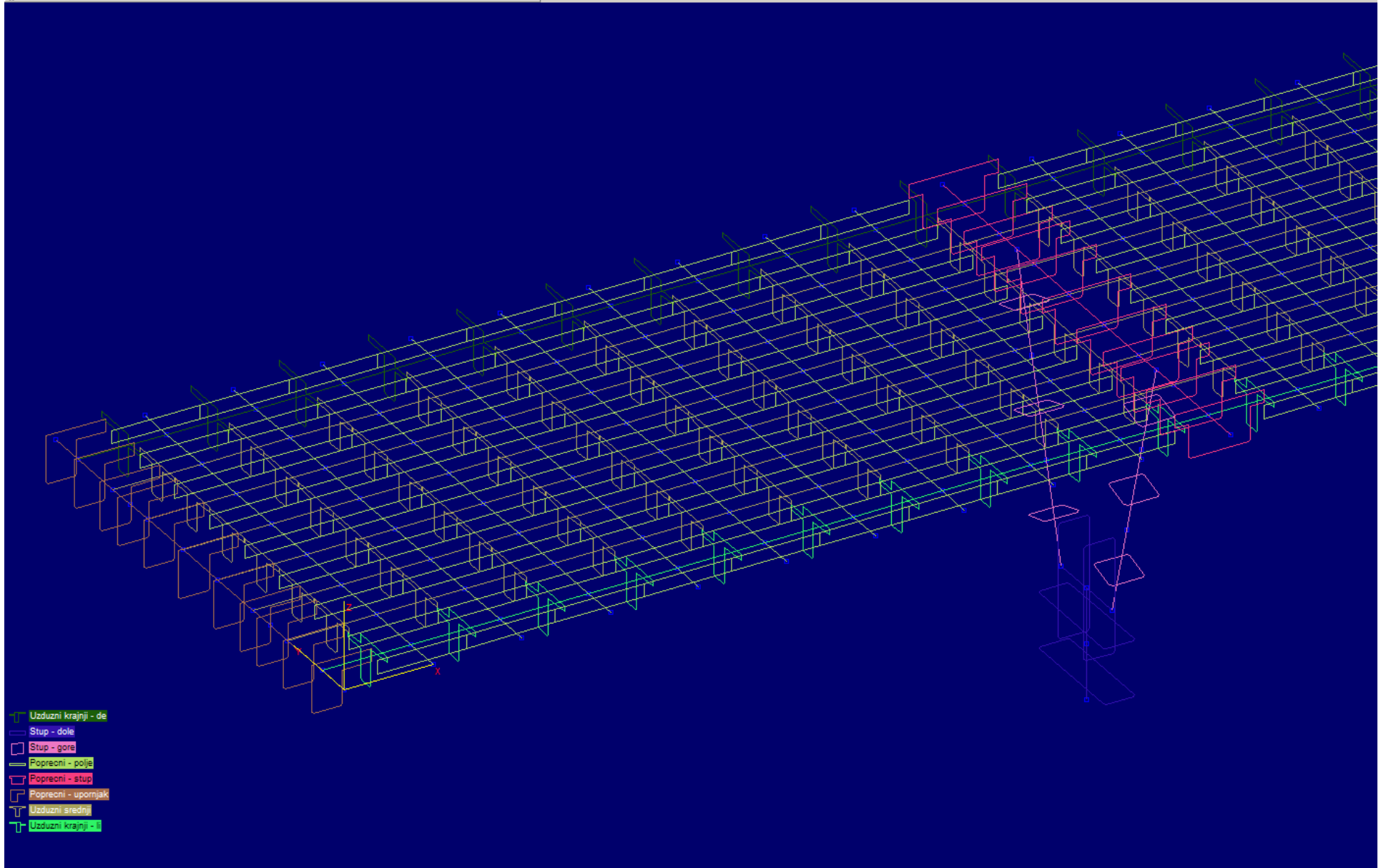
Kako je stup dio rasponskog sustava (jer je kruto povezan s njim), njega modeliramo u sklopu rasponskog sustava.

Da bi poštivali centre krutosti (težišta) pojedinih elemenata, konstrukciju, u biti, malo skraćujemo.









- Uzduzni krajnji - de
- Stup - dole
- Stup - gore
- Poprečni - poje
- Poprečni - stup
- Poprečni - upornjak
- Uzduzni srednji
- Uzduzni krajnji - 1

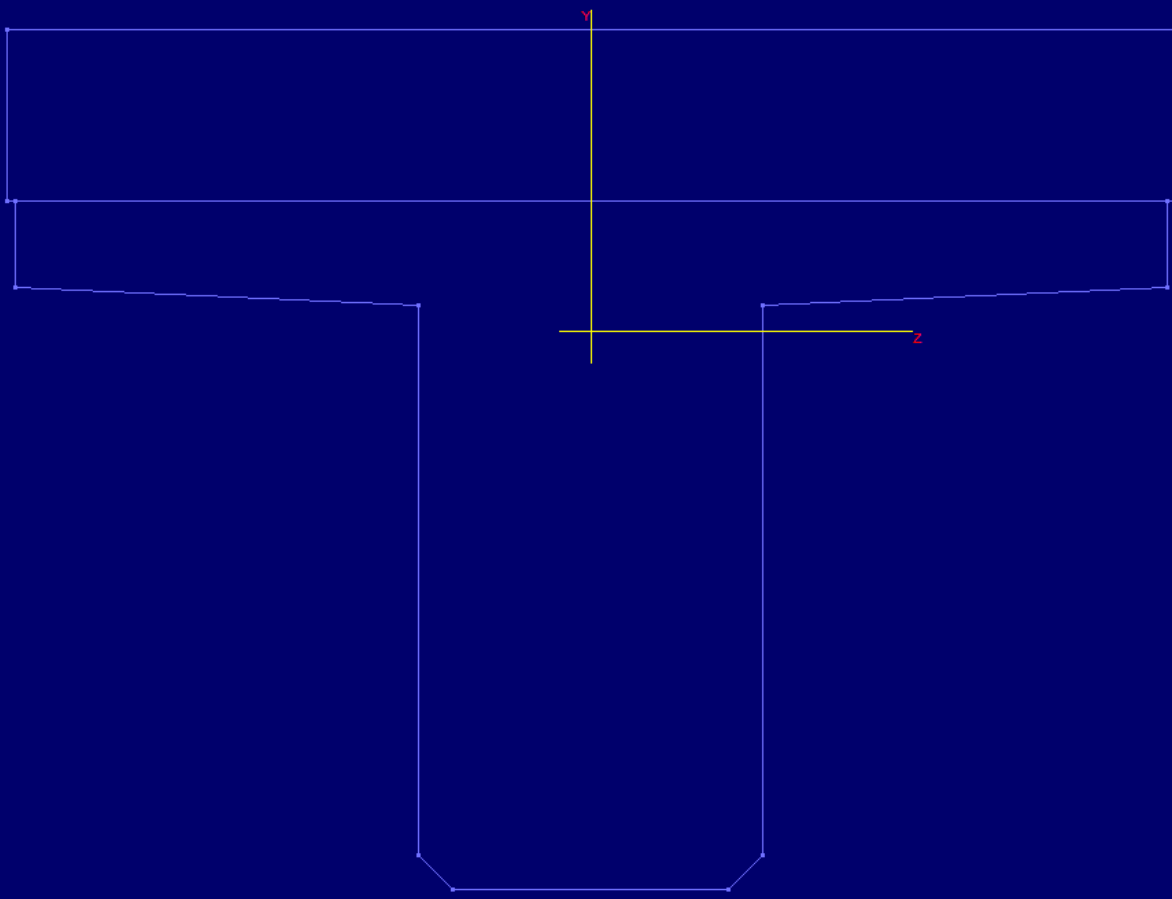
Pogled 1 Pogled 2

Opt. 1 ORTO Pan



- Uzduzni krajnji - li
- Uzduzni srednji**
- Poprečni - upornjak
- Poprečni - stup
- Poprečni - polje
- Stup - gore
- Stup - dole
- Uzduzni krajnji - de

Uzduzni srednji	
$A_x$	= 6938.00 cm <sup>2</sup>
$A_y$	= 6938.00 cm <sup>2</sup>
$A_z$	= 6938.00 cm <sup>2</sup>
$I_x$	= 1233575.0788 cm <sup>4</sup>
$I_y$	= 6696371.6667 cm <sup>4</sup>
$I_z$	= 5535884.6772 cm <sup>4</sup>
<b>1</b>	
C 35/45	
$A_x$	= 4218.00 cm <sup>2</sup>
$A_y$	= 4218.00 cm <sup>2</sup>
$A_z$	= 4218.00 cm <sup>2</sup>
$I_x$	= 2503945.00 cm <sup>4</sup>
$I_y$	= 3722127.1566 cm <sup>4</sup>
<b>2</b>	
C 35/45	
$A_x$	= 2720.00 cm <sup>2</sup>
$A_y$	= 2720.00 cm <sup>2</sup>
$A_z$	= 2720.00 cm <sup>2</sup>
$I_x$	= 4192426.6667 cm <sup>4</sup>
$I_y$	= 1813757.5206 cm <sup>4</sup>



## DODATNO STALNO OPTEREĆENJE

Kolnički zastor:  $0.08 \cdot 22 = 1.76 \text{ kN/m}^2$

Hodnik:  $0.30 \cdot 25 = 7.50 \text{ kN/m}^2$

Ograda:  $0.65 \text{ kN/m}'$

Cijev za odvodnju:  $0.50 \text{ kN/m}'$

Vijenac:  $1.50 \text{ kN/m}'$

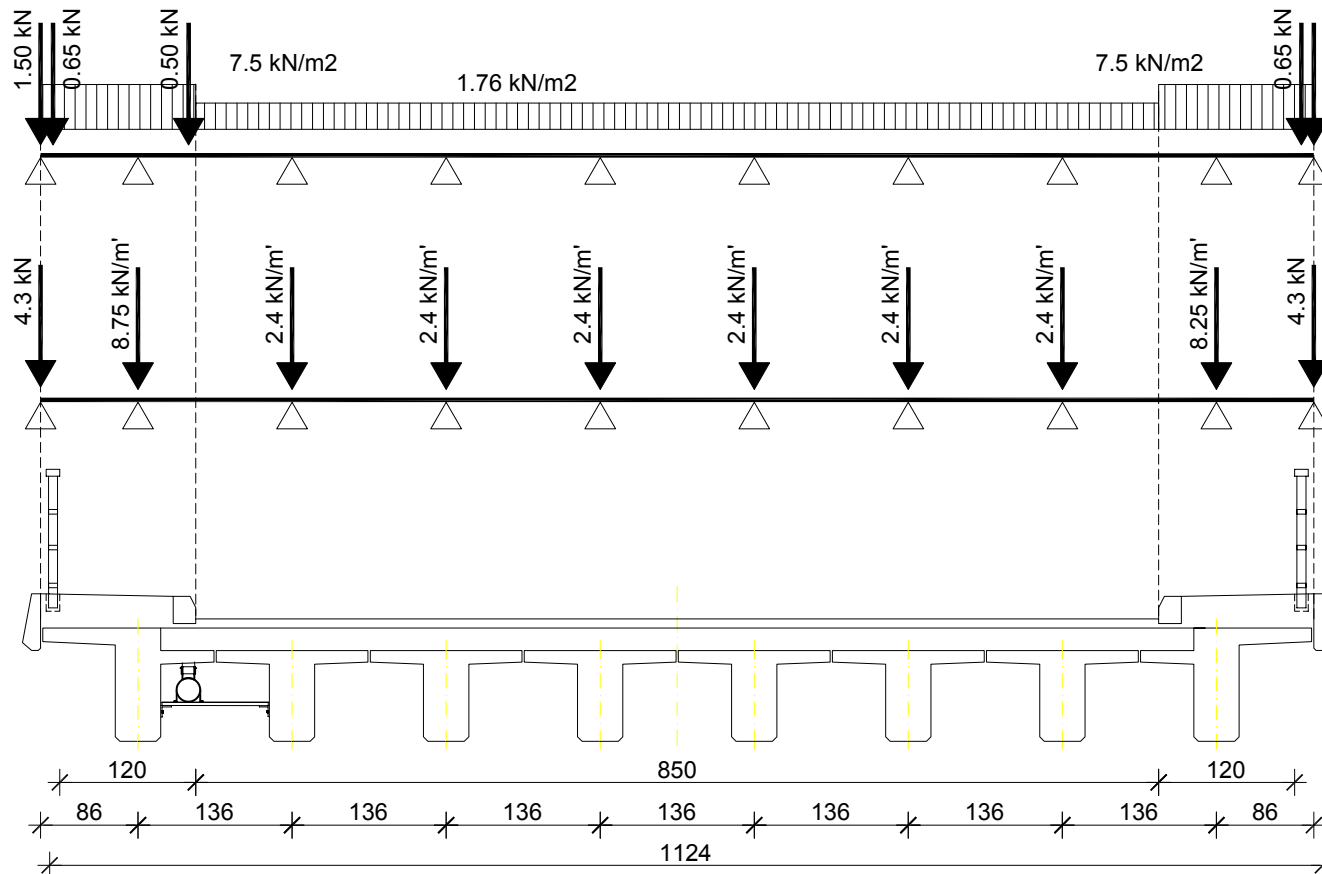
Pretpostavlja se da se ukupno opterećenje raspodjeljuje na uzdužne nosače:

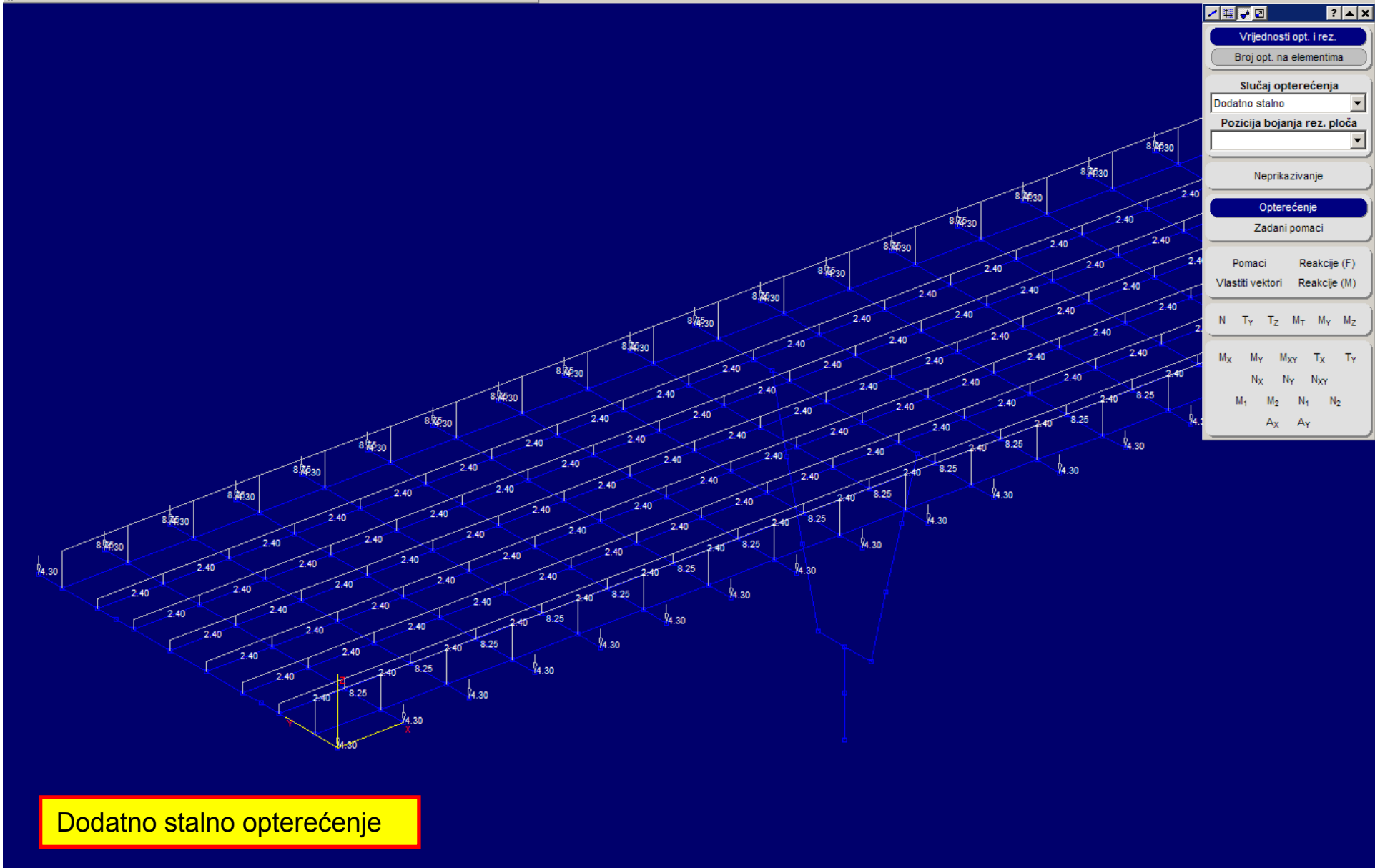
Srednji nosači:  $1.76 \cdot 1.36 = 2.40 \text{ kN/m}'$

Krajnji nosač lijevo:  $7.50 \cdot \frac{1.36 + 0.86}{2} + 0.5 = 8.75 \text{ kN/m}'$

Krajnji nosač desno:  $7.50 \cdot \frac{1.36 + 0.86}{2} = 8.25 \text{ kN/m}'$

Rubovi:  $(1.50 + 0.65) \cdot 2.0 = 4.30 \text{ kN}$





Vrijednosti opt. i rez.

Broj opt. na elementima

Slučaj opterećenja

Dodatno stalno

Pozicija bojanja rez. ploča

Neprikazivanje

Opterećenje

Zadani pomaci

Pomaci Reakcije (F)

Vlastiti vektori Reakcije (M)

N T<sub>x</sub> T<sub>z</sub> M<sub>T</sub> M<sub>y</sub> M<sub>z</sub>

M<sub>x</sub> M<sub>y</sub> M<sub>xy</sub> T<sub>x</sub> T<sub>y</sub>

N<sub>x</sub> N<sub>y</sub> N<sub>xy</sub>

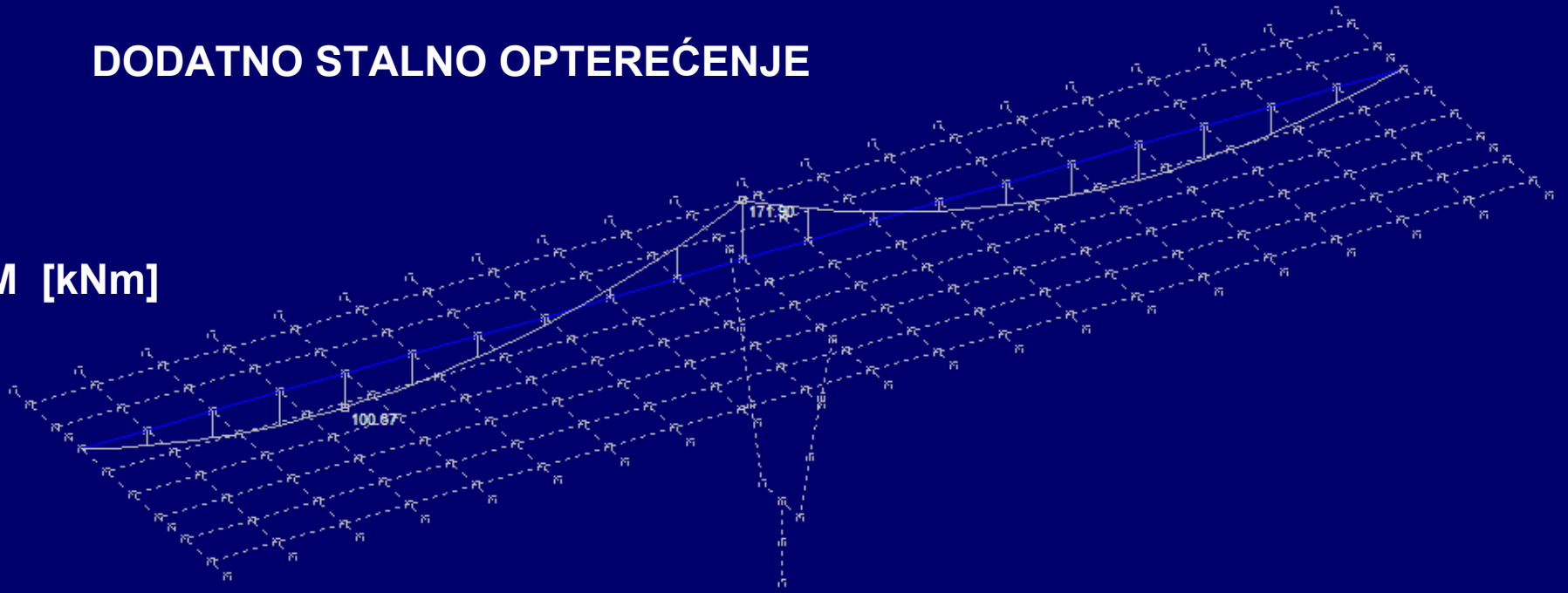
M<sub>1</sub> M<sub>2</sub> N<sub>1</sub> N<sub>2</sub>

A<sub>x</sub> A<sub>y</sub>

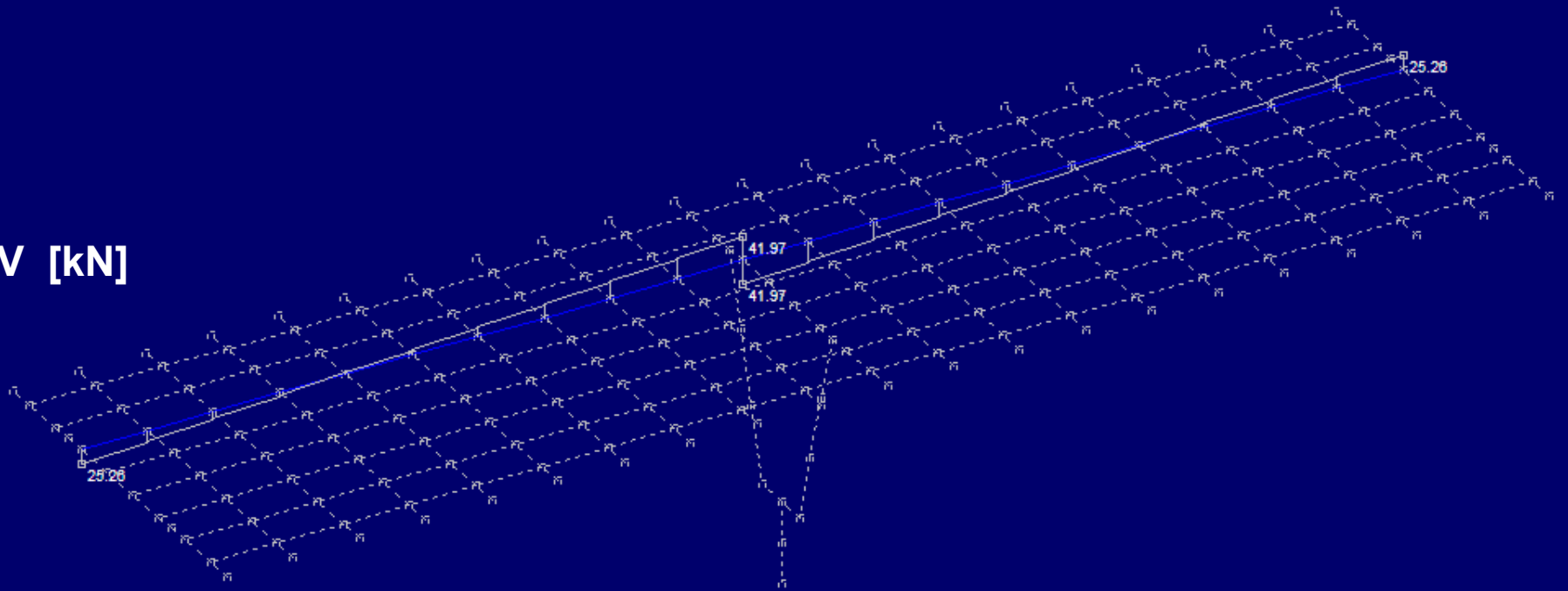
Dodatno stalno opterećenje

# DODATNO STALNO OPTEREĆENJE

M [kNm]



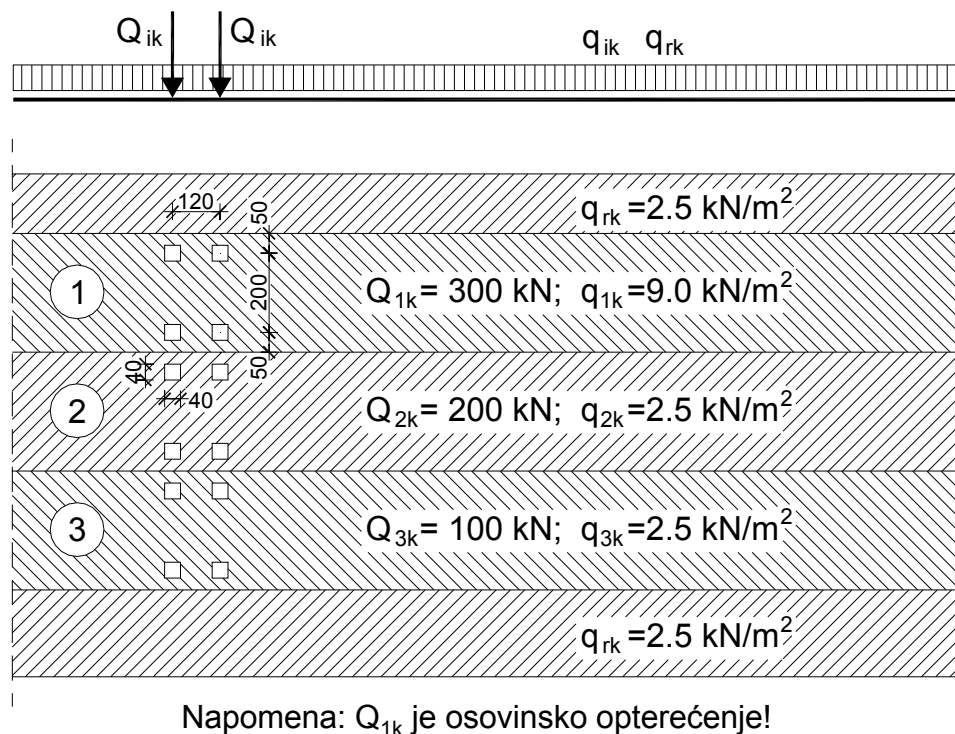
V [kN]



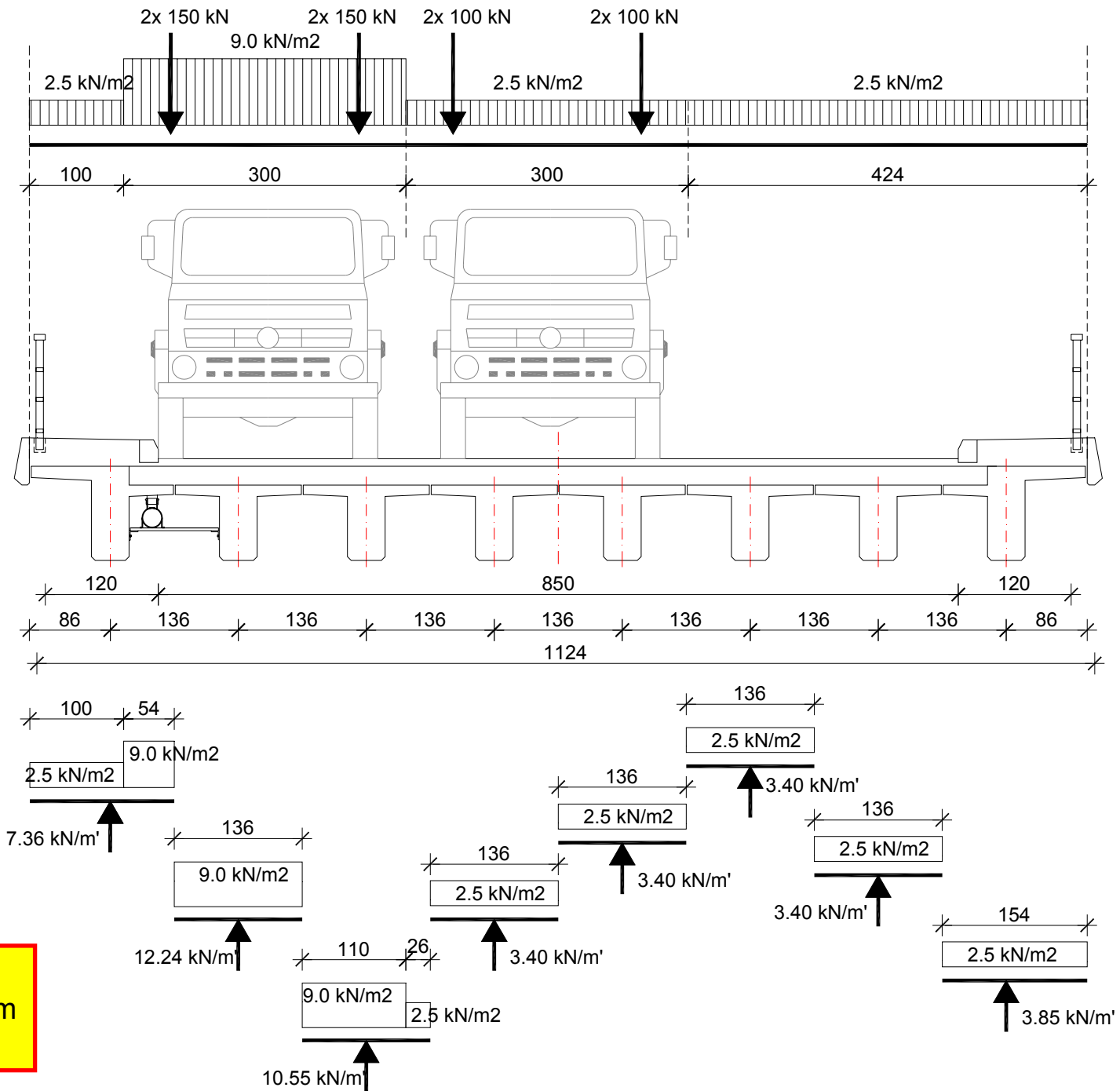
## POKRETNÓ OPTEREĆENJE

Na mostu ukupne širine kolnika  $w$  predviđa se  $n$  specifično opterećenih prometnih trakova širine od 2.7 do 3.0 m, te preostala ploha do pune širine mosta. Na autocestama gdje su kolničke površine odvojene, ali se nalaze na zajedničkoj kolničkoj konstrukciji, predviđaju se tri prometna traka, dok za slučaj odvojenih kolničkih konstrukcija svaka kolnička ploha se razmatra kao zasebni most.

Širina kolnika $w$ (m)	Broj prometnih trakova	Širina prometnog traka (m)	Preostala širina kolnika (m)
$w < 5.4$ m	1	3	$w - 3$
$5.4 \text{ m} \leq w < 6.0$ m	2	$w/2$	0
$w \geq 6.0$ m	$n = \text{Int}(w/3)$	3	$w - 3 \cdot n$

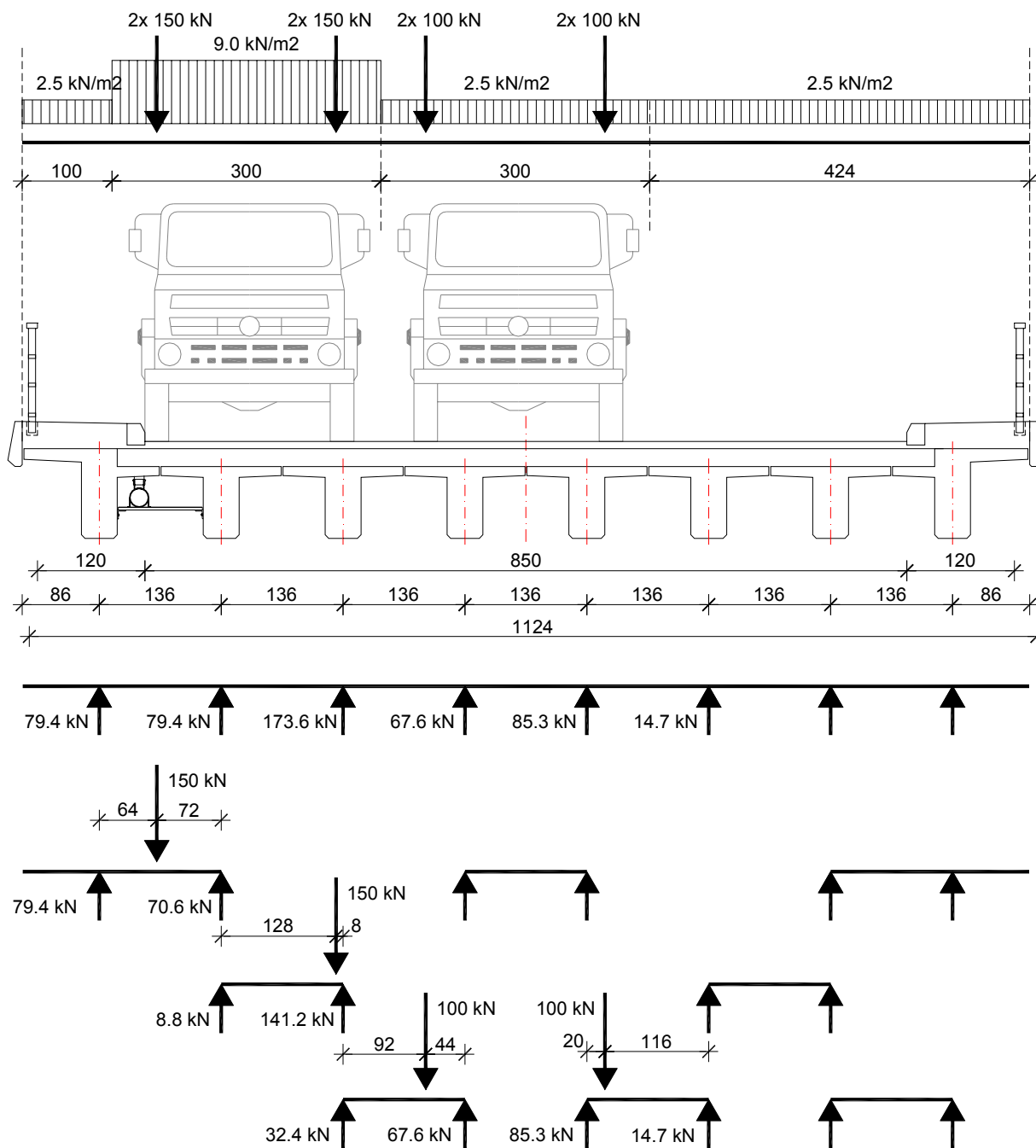


# ANALIZA POKRETNOG OPTEREĆENJA U POPREČNOM PRESJEKU

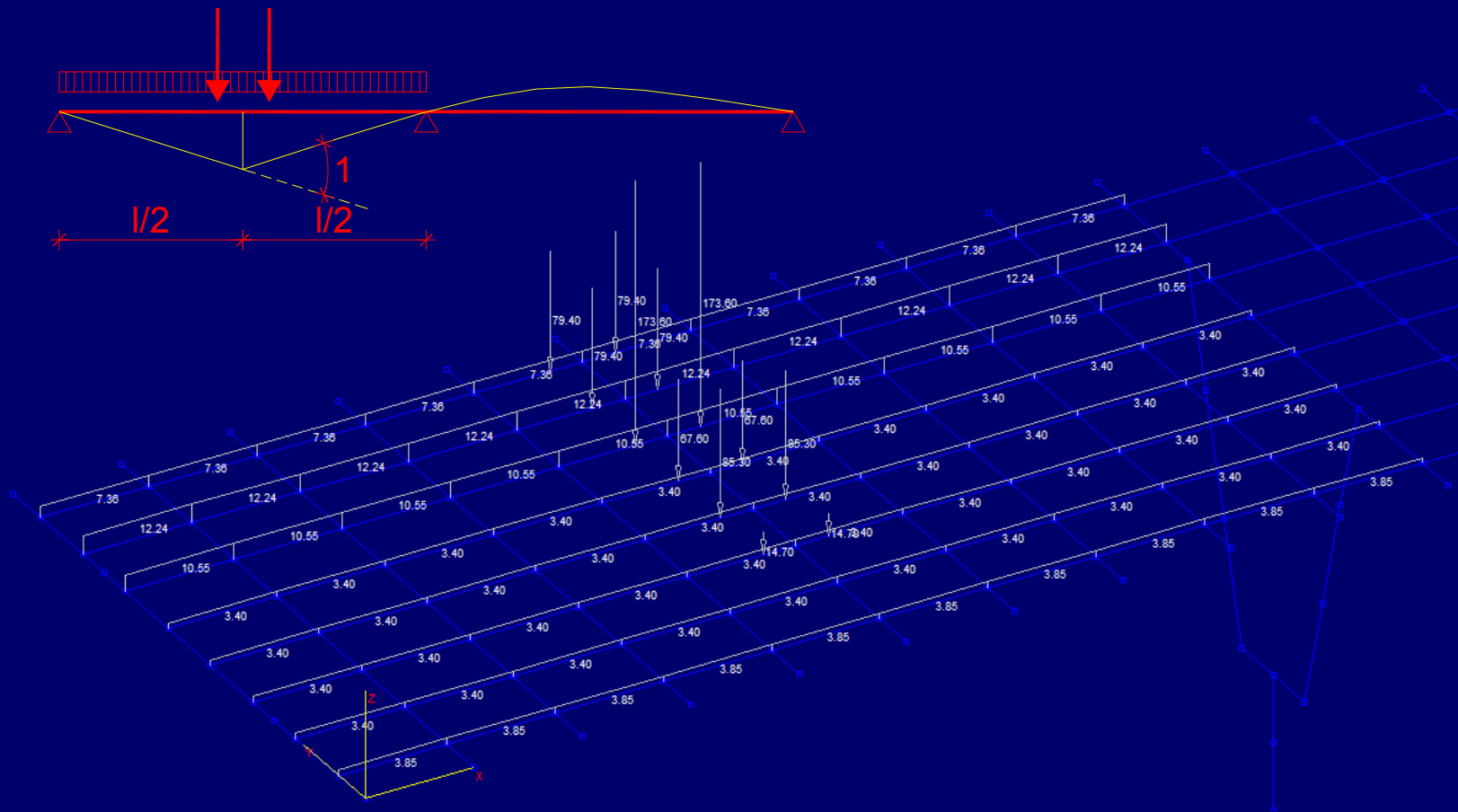


Analiza kontinuiranog opterećenja na uzdužnim nosačima

# ANALIZA POKRETNOG OPTEREĆENJA U POPREČNOM PRESJEKU



Analiza koncentriranih  
sila od vozila



Vrijednosti opt. i rez.

Broj opt. na elementima

Slučaj opterećenja

Pokretno - max M u polju

Pozicija bojanja rez. ploča

Neprikazivanje

Opterećenje

Zadani pomaci

Pomaci Reakcije (F)

Vlastiti vektori Reakcije (M)

N	T <sub>y</sub>	T <sub>z</sub>	M <sub>T</sub>	M <sub>y</sub>	M <sub>z</sub>
M <sub>x</sub>	M <sub>y</sub>	M <sub>x<sub>y</sub></sub>	T <sub>x</sub>	T <sub>y</sub>	
	N <sub>x</sub>	N <sub>y</sub>	N <sub>x<sub>y</sub></sub>		
	M <sub>1</sub>	M <sub>2</sub>	N <sub>1</sub>	N <sub>2</sub>	
	A <sub>x</sub>	A <sub>y</sub>			

Pokretno opterećenje –  
 Shema: Maksimalni moment u polju

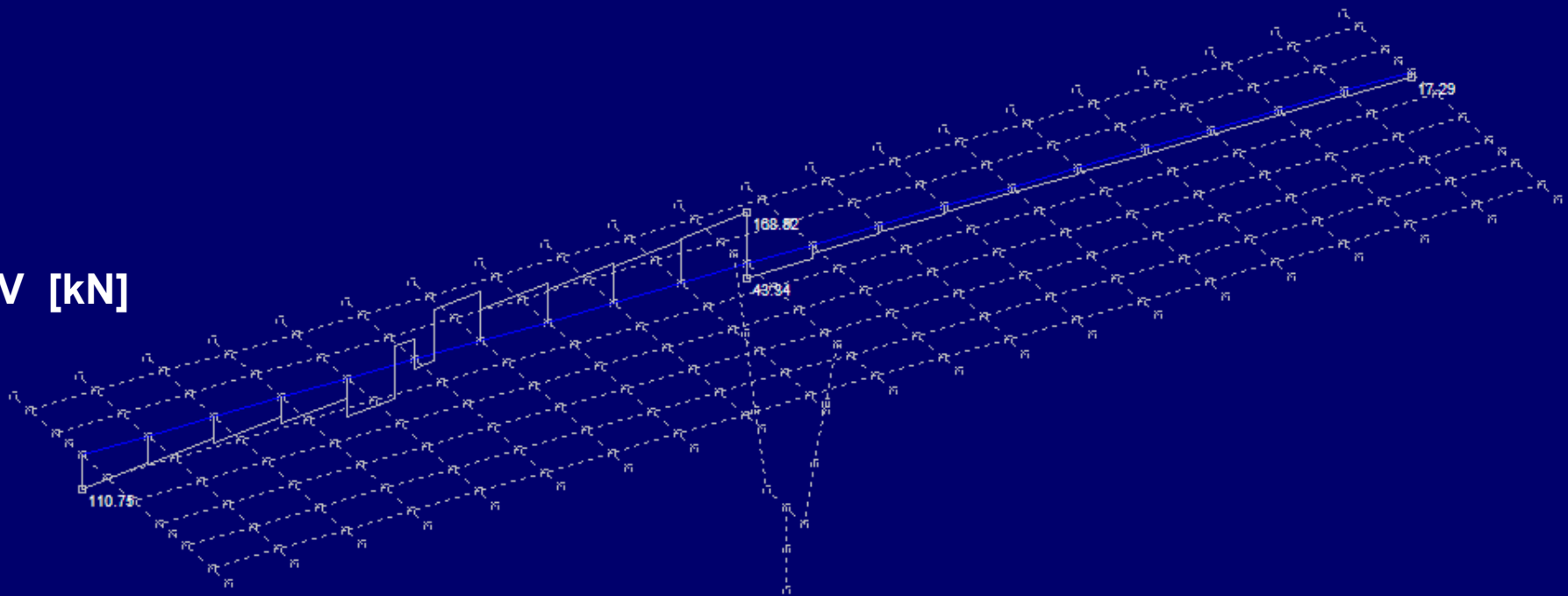
# POKRETNNO OPTEREĆENJE

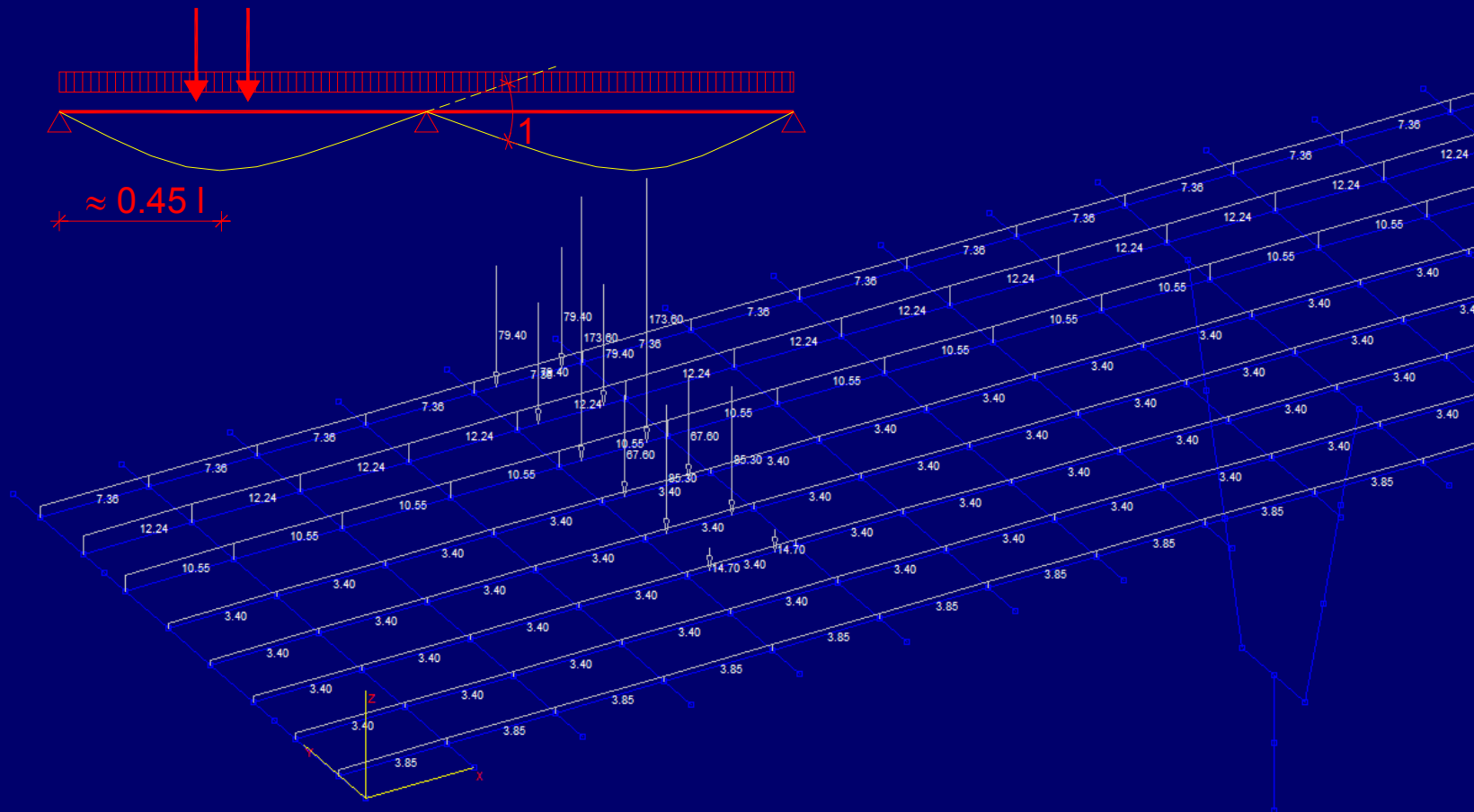
## Maksimalni moment u polju

M [kNm]



V [kN]





Vrijednosti opt. i rez.

Broj opt. na elementima

Slučaj opterećenja

Pokretno - max M na stupu

Pozicija bojanja rez. ploča

Neprikazivanje

Opterećenje

Zadani pomaci

Pomaci    Reakcije (F)

Vlastiti vektori    Reakcije (M)

N	T <sub>y</sub>	T <sub>z</sub>	M <sub>T</sub>	M <sub>y</sub>	M <sub>z</sub>
M <sub>x</sub>	M <sub>y</sub>	M <sub>x<sub>y</sub></sub>	T <sub>x</sub>	T <sub>y</sub>	
	N <sub>x</sub>	N <sub>y</sub>	N <sub>x<sub>y</sub></sub>		
	M <sub>1</sub>	M <sub>2</sub>	N <sub>1</sub>	N <sub>2</sub>	
	A <sub>x</sub>	A <sub>y</sub>			

Pokretno opterećenje –  
 Shema: Maksimalni moment na ležaju – nad stupom

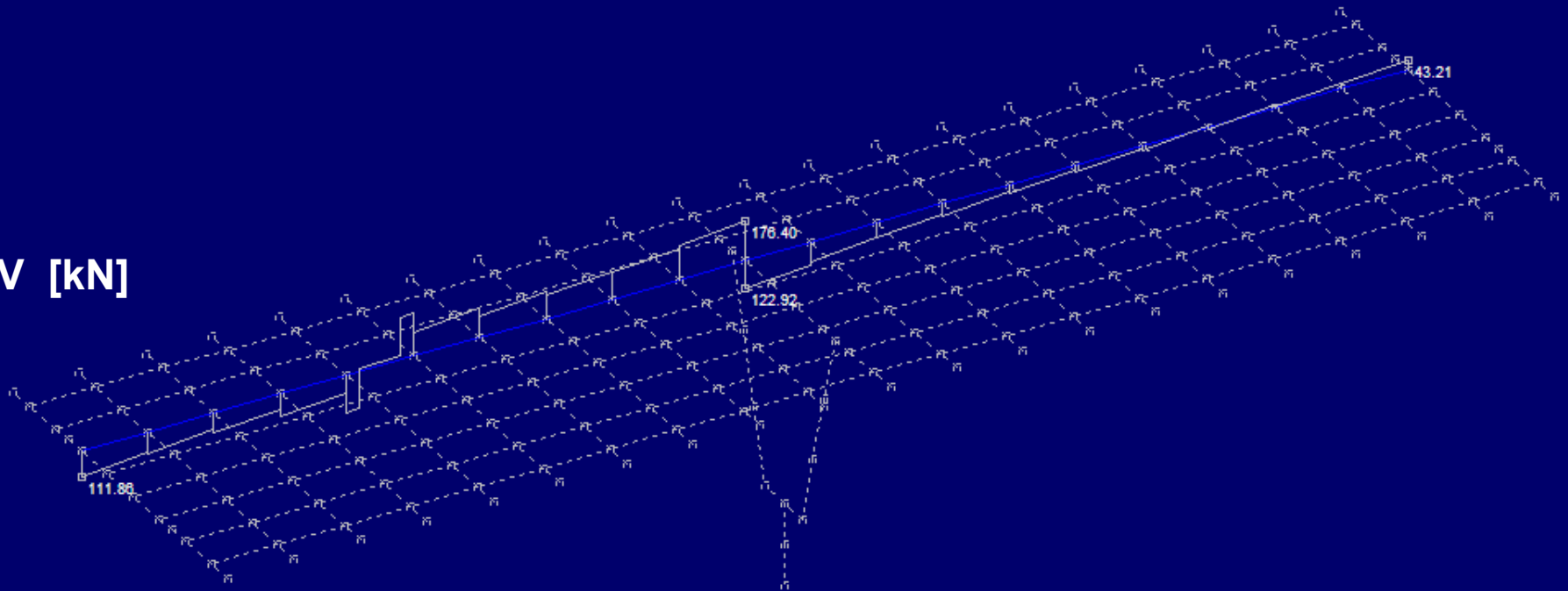
# POKRETNNO OPTEREĆENJE

## Maksimalni moment nad stupom

M [kNm]



V [kN]

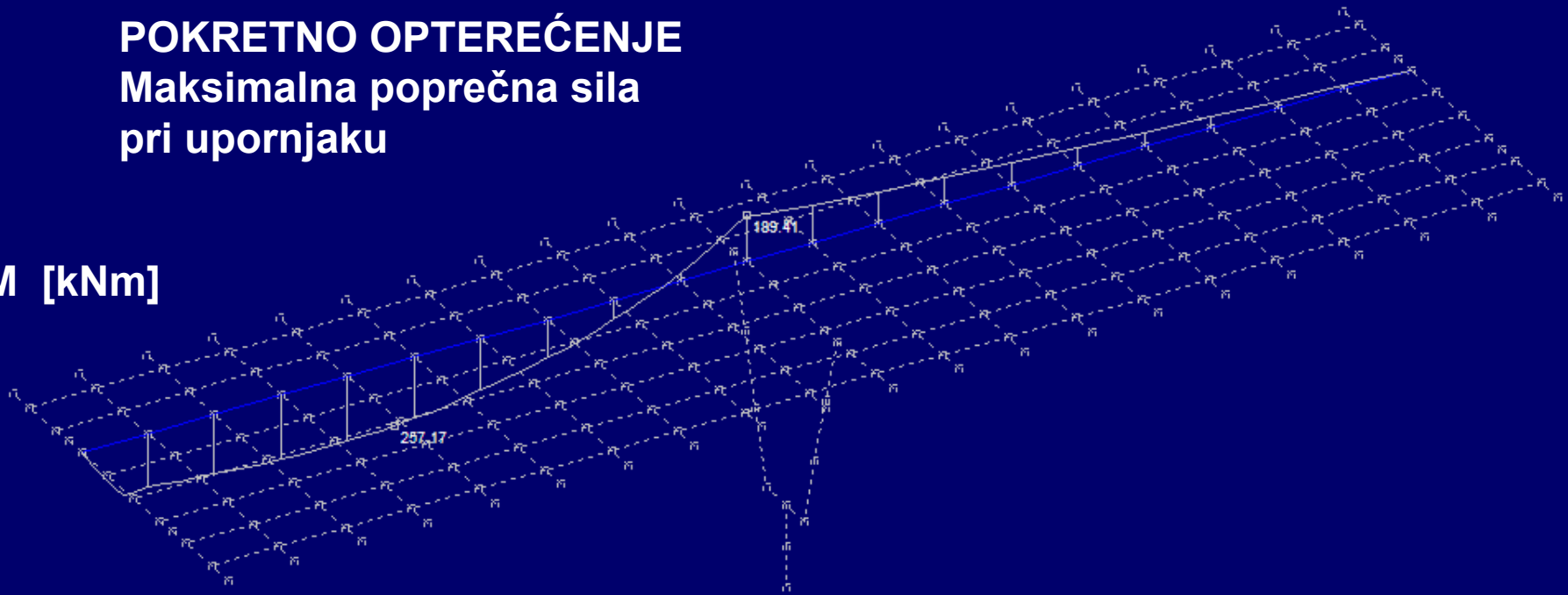




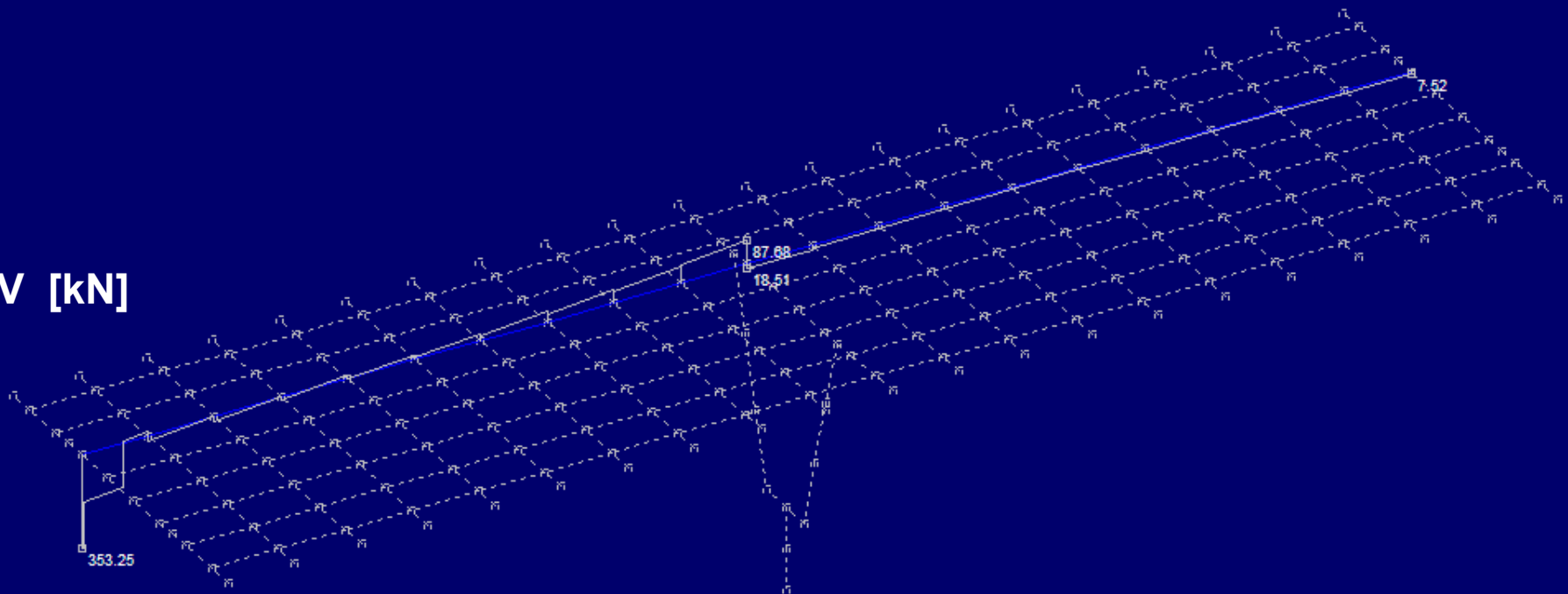
# POKRETNO OPTEREĆENJE

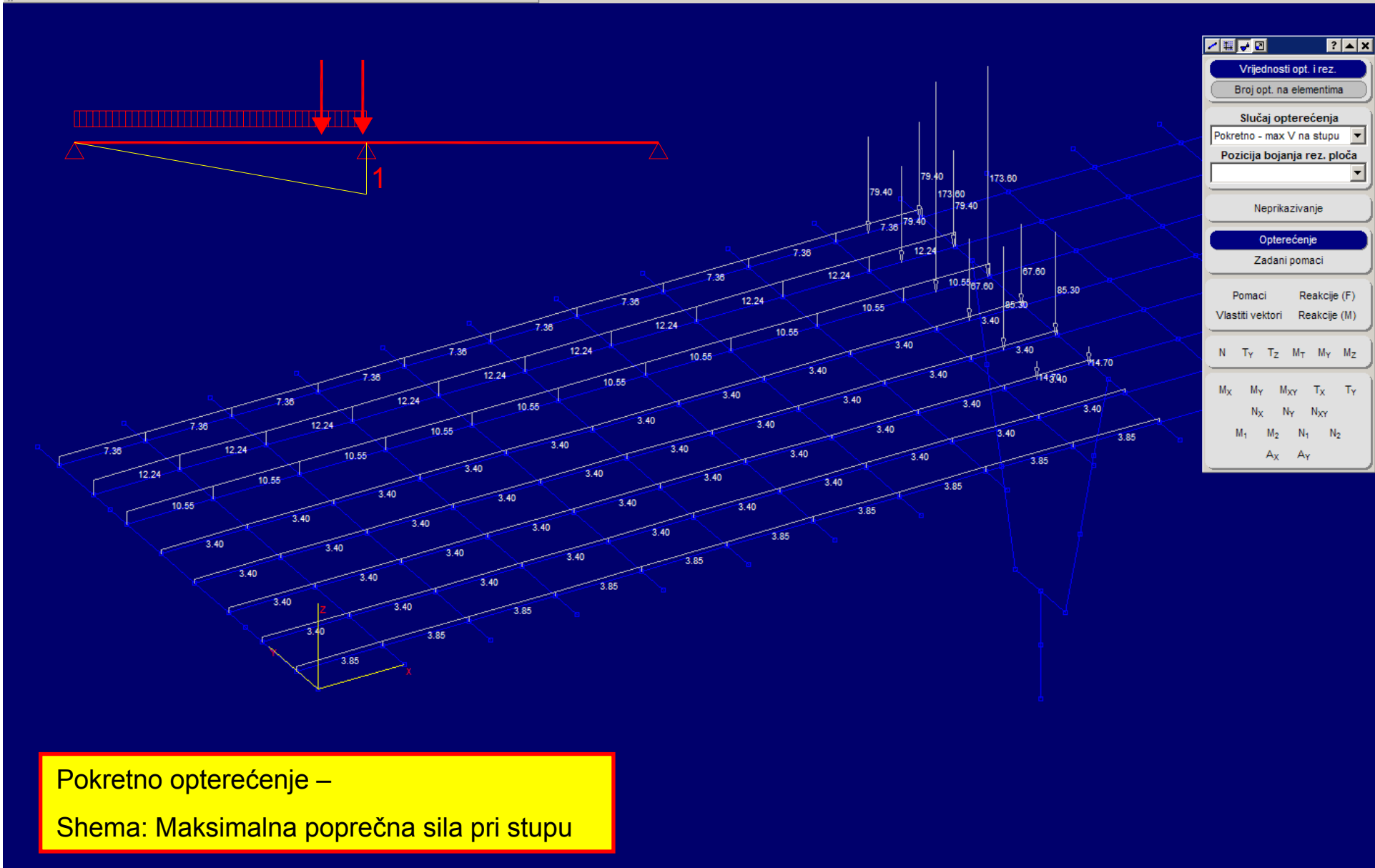
## Maksimalna poprečna sila pri upornjaku

M [kNm]



V [kN]



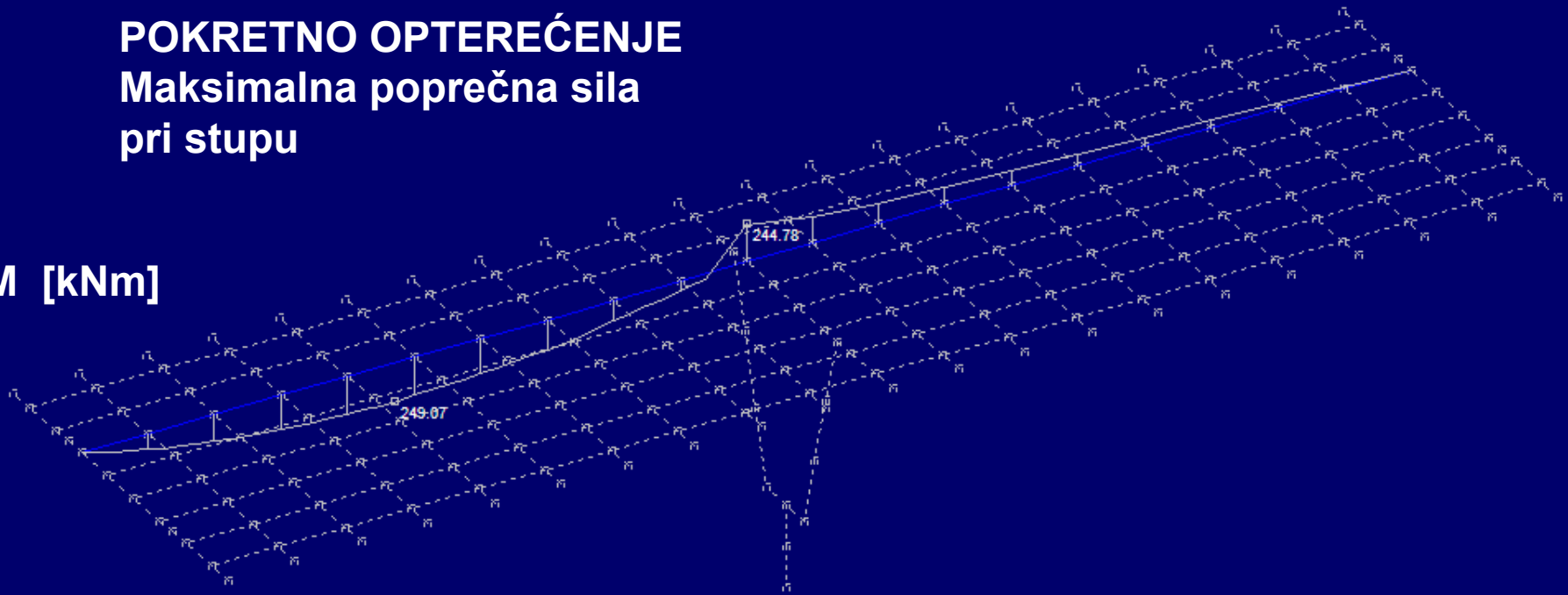


Pokretno opterećenje –  
 Shema: Maksimalna poprečna sila pri stupu

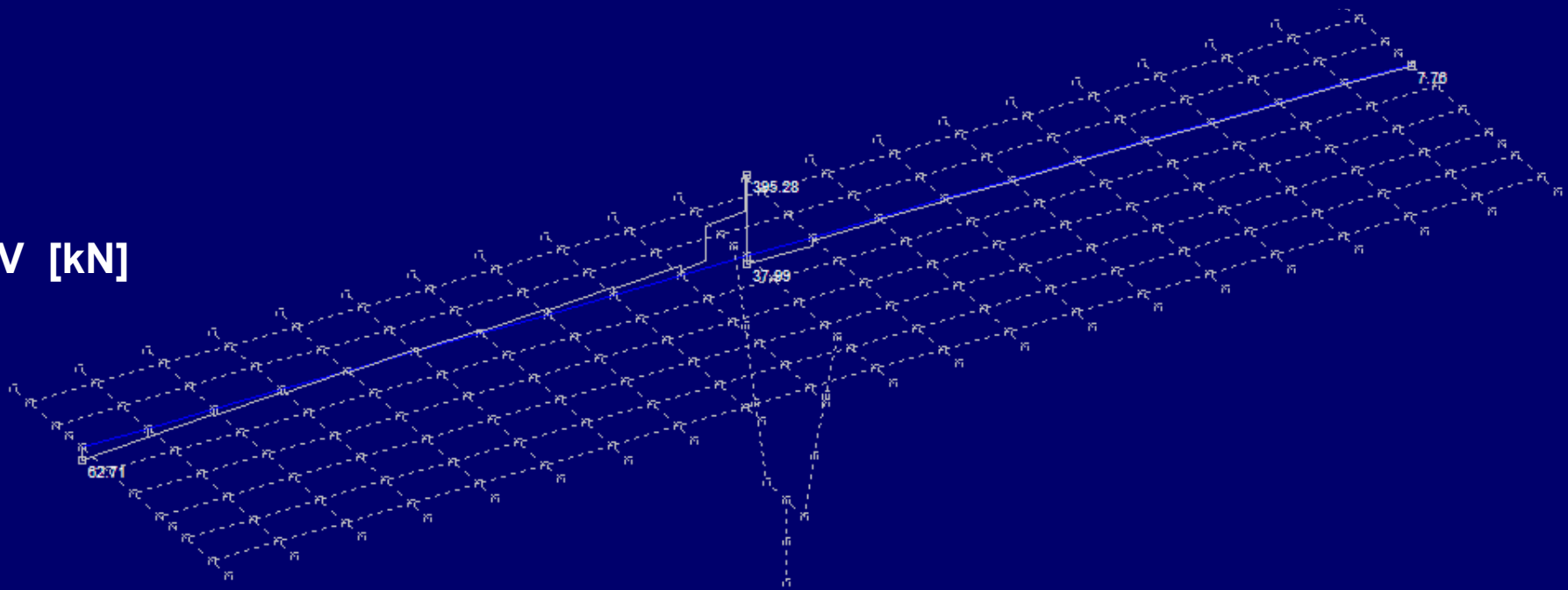
# POKRETNO OPTEREĆENJE

## Maksimalna poprečna sila pri stupu

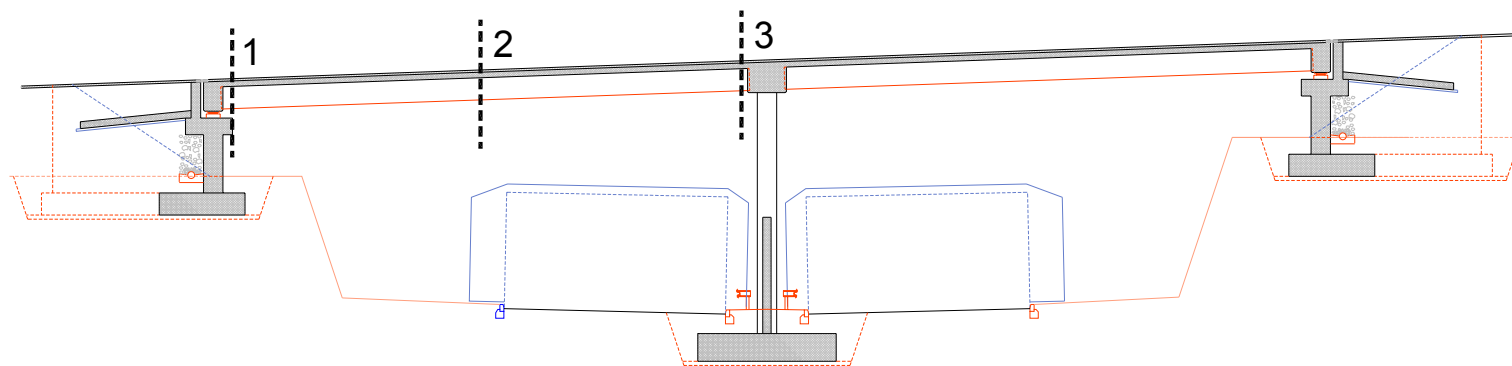
M [kNm]



V [kN]



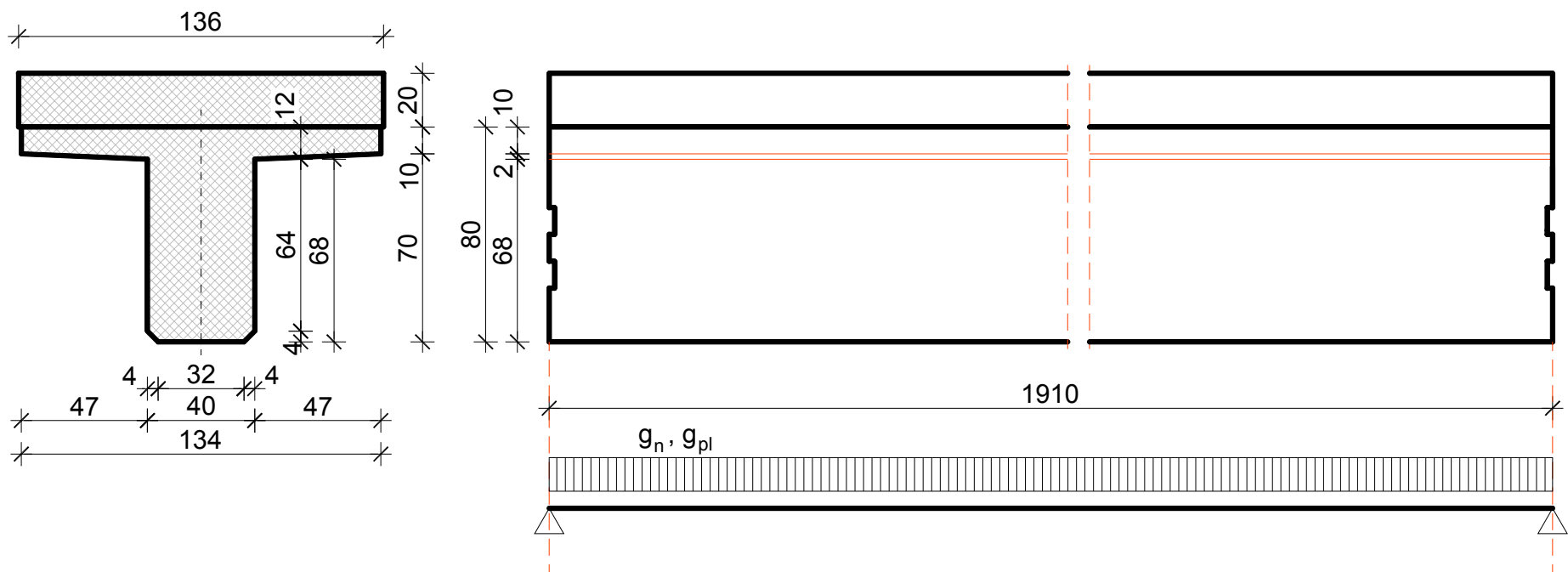
## Mjerodavne rezne sile za maksimalno opterećeni nosač



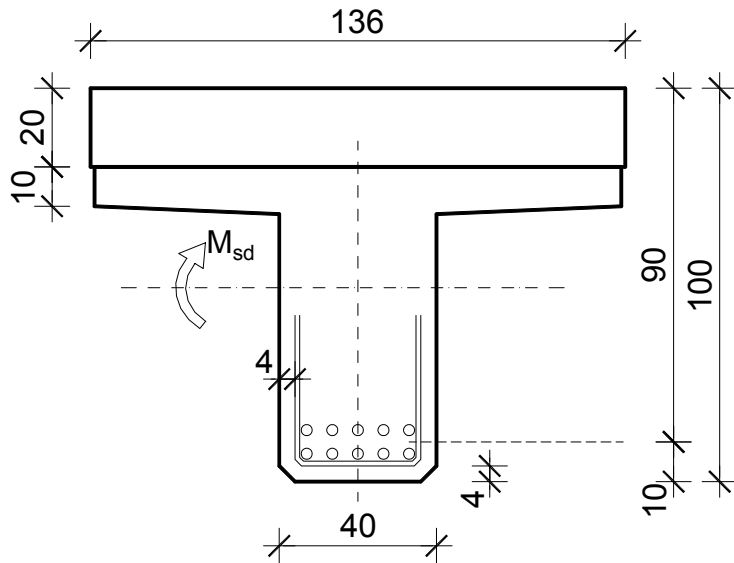
Utjecaj		1-1	2-2	3-3
Vlastita težina nosača	$M_{g1}$ [kNm]	0.0	490.7	0.0
	$V_{g1}$ [kN]	102.8	0.0	102.8
Težina kolničke ploče	$M_{g2}$ [kNm]	0.0	316.5	0.0
	$V_{g2}$ [kN]	66.3	0.0	66.3
Dodatni stalni teret	$M_{\Delta g}$ [kNm]	0.0	100.7	171.9
	$V_{\Delta g}$ [kN]	25.3	0.0	42.0
Najnepovoljnije prometno opterećenje	$M_q$ [kNm]	0.0	828.3	593.5
	$V_q$ [kN]	353.3	0.0	395.3

# PRORAČUN RASPONSKIH NOSAČA U 2. fazi

U 2. fazi montažni nosači su spregnuti s pločom. Opterećeni su dodatnim stalnim i prometnim opterećenjem.



# DIMENZIONIRANJE RASPONSKIH NOSAČA NA MOMENT SAVIJANJA U POLJU



$$C\ 35/45 \Rightarrow f_{ck} = 35.0\ \text{MPa} \Rightarrow f_{cd} = \frac{f_{ck}}{\gamma_c} = \frac{35.0}{1.5} = 23.3\ \text{MPa}$$

$$B\ 450C \Rightarrow f_{yk} = 450.0\ \text{MPa} \Rightarrow f_{yd} = \frac{f_{yk}}{\gamma_s} = \frac{450.0}{1.15} = 392.3\ \text{MPa}$$

$$M_{\Delta g} = 100.7\ \text{kNm} ; \quad M_q = 828.3\ \text{kNm}$$

$$M_{sd} = \gamma_g \cdot M_{\Delta g} + \gamma_q \cdot M_q = 1.35 \cdot 100.7 + 1.50 \cdot 828.3 = 1378.4\ \text{kNm}$$

$$\mu_{sd} = \frac{M_{sd}}{b d^2 f_{cd}} = \frac{1378.4 \cdot 100}{136 \cdot 90^2 \cdot 2.33} = 0.054$$

za  $\varepsilon_{s1} = 10\text{‰}$ ; ocitano :  $\varepsilon_{c2} = 1.4\text{‰}$ ;  $\xi = 0.123$ ;  $\zeta = 0.956$

$$x = \xi \cdot d = 0.123 \cdot 90 = 11.1\ \text{cm} < h_{pl} = 30.0\ \text{cm}$$

$$A_{s1,2} = \frac{M_{sd}}{\zeta d f_{yd}} = \frac{1378.4 \cdot 100}{0.956 \cdot 90 \cdot 39.2} = 40.9\ \text{cm}^2$$

$$A_{s1,1} = 40.1\ \text{cm}^2$$

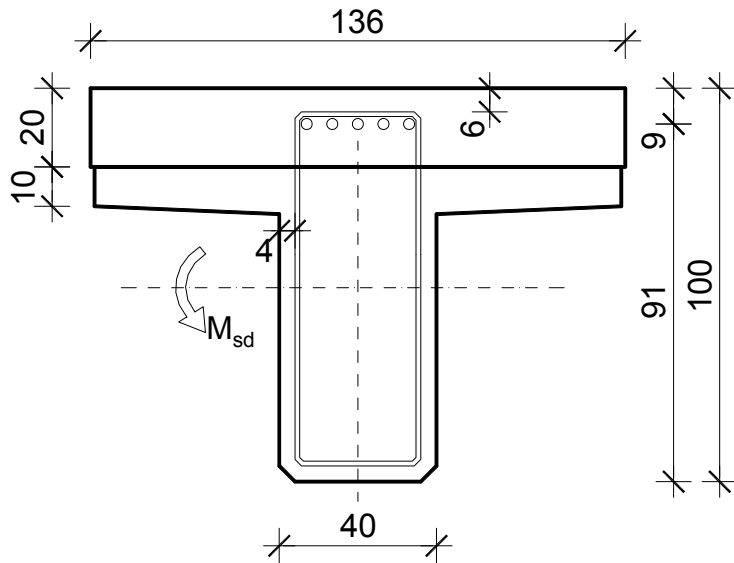
$$A_{s1} = A_{s1,1} + A_{s1,2} = 40.1 + 40.9 = 81.0\ \text{cm}^2$$

**Odabrano: 10 Ø32 = 80.42 cm<sup>2</sup>**

Lom preko armature  $\varepsilon_{s1} = 10.0\ \text{‰}$

$\varepsilon_{c2}$ [‰]	$\varepsilon_{s1}$ [‰]	$\xi = x/d$	$\zeta = z/d$	$\omega_1$	$k_d$	$\mu_{sds}$
0.1	10.0	0.010	0.997	0.000	49.242	0.000
0.2	10.0	0.020	0.993	0.002	24.996	0.002
0.3	10.0	0.029	0.990	0.004	16.920	0.003
0.4	10.0	0.038	0.987	0.006	12.885	0.006
0.5	10.0	0.048	0.984	0.009	10.468	0.009
0.6	10.0	0.057	0.981	0.013	8.860	0.013
0.7	10.0	0.065	0.977	0.017	7.714	0.017
0.8	10.0	0.074	0.974	0.022	6.857	0.021
0.9	10.0	0.083	0.971	0.027	6.193	0.026
1.0	10.0	0.091	0.968	0.032	5.664	0.031
1.1	10.0	0.099	0.965	0.038	5.233	0.037
1.2	10.0	0.107	0.962	0.044	4.876	0.042
1.3	10.0	0.115	0.959	0.050	4.576	0.048
1.4	10.0	0.123	0.956	0.056	4.321	0.054
1.5	10.0	0.130	0.953	0.062	4.102	0.059
1.6	10.0	0.138	0.950	0.069	3.912	0.065
1.7	10.0	0.145	0.947	0.075	3.747	0.071
1.8	10.0	0.153	0.944	0.082	3.602	0.077

# DIMENZIONIRANJE RASPONSKIH NOSAČA NA MOMENT SAVIJANJA NA LEŽAJU



$$C\ 35/45 \Rightarrow f_{ck} = 35.0\ \text{MPa} \Rightarrow f_{cd} = \frac{f_{ck}}{\gamma_c} = \frac{35.0}{1.5} = 23.3\ \text{MPa}$$

$$B\ 450C \Rightarrow f_{yk} = 450.0\ \text{MPa} \Rightarrow f_{yd} = \frac{f_{yk}}{\gamma_s} = \frac{450.0}{1.15} = 392.3\ \text{MPa}$$

$$M_{\Delta g} = 171.9\ \text{kNm} ; \quad M_q = 593.5\ \text{kNm}$$

$$M_{sd} = \gamma_g \cdot M_{\Delta g} + \gamma_q \cdot M_q = 1.35 \cdot 171.9 + 1.50 \cdot 593.5 = 1122.3\ \text{kNm}$$

$$\mu_{sd} = \frac{M_{sd}}{b d^2 f_{cd}} = \frac{1122.3 \cdot 100}{40 \cdot 91^2 \cdot 2.33} = 0.145$$

za  $\varepsilon_{s1} = 10\text{‰}$ ; ocitano :  $\varepsilon_{c2} = 3.2\text{‰}$ ;  $\zeta = 0.901$

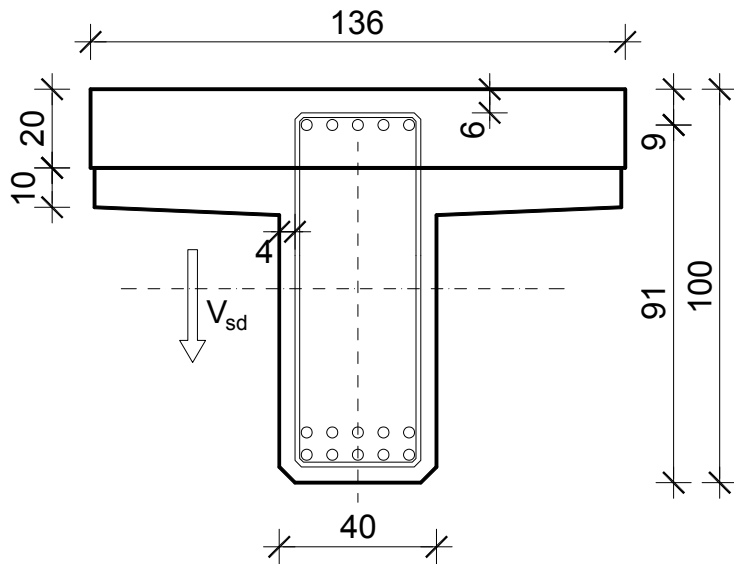
$$A_{s,2} = \frac{M_{sd}}{\zeta d f_{yd}} = \frac{1122.3 \cdot 100}{0.901 \cdot 91 \cdot 39.2} = 34.9\ \text{cm}^2$$

**Odabrano: 12 Ø20 = 37.70 cm<sup>2</sup>**

Lom preko armature  $\varepsilon_{s1} = 10.0\ \text{‰}$

$\varepsilon_{c2}$ [‰]	$\varepsilon_{s1}$ [‰]	$\xi = x/d$	$\zeta = z/d$	$\omega_1$	$k_d$	$\mu_{sds}$
0.1	10.0	0.010	0.997	0.000	49.242	0.000
0.2	10.0	0.020	0.993	0.002	24.996	0.002
0.3	10.0	0.029	0.990	0.004	16.920	0.003
0.4	10.0	0.038	0.987	0.006	12.885	0.006
1.3	10.0	0.187	0.928	0.113	3.090	0.105
2.4	10.0	0.194	0.925	0.119	3.017	0.110
2.5	10.0	0.200	0.922	0.125	2.950	0.115
2.6	10.0	0.206	0.919	0.130	2.889	0.120
2.7	10.0	0.213	0.916	0.136	2.833	0.125
2.8	10.0	0.219	0.913	0.142	2.781	0.129
2.9	10.0	0.225	0.910	0.147	2.733	0.134
3.0	10.0	0.231	0.907	0.153	2.689	0.138
3.1	10.0	0.237	0.904	0.158	2.647	0.143
3.2	10.0	0.242	0.901	0.163	2.609	0.147
3.3	10.0	0.248	0.898	0.168	2.573	0.151
3.4	10.0	0.254	0.895	0.173	2.539	0.155
3.5	10.0	0.259	0.892	0.178	2.507	0.159

# DIMENZIONIRANJE RASPONSKIH NOSAČA NA POPREČNU SILU PRI UPORNJAKU



Betón		C35/45
$f_{ck}$ (MPa)	Čvrstoća na valjku	35.0
$\tau_{Rd}$ (MPa)	Posmična čvrstoća	0.37

$$\sum A_s \approx 80.0 \text{ cm}^2$$

$$\rho_l = \frac{\sum A_s}{A_c} = \frac{80.0}{40 \cdot 80} = 0.025 > 0.02$$

$$\rho_l = 0.02$$

Dio poprečne sile koju preuzima beton i uzdužna armatura:

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

$$k = 1.6 - d = 1.6 - 0.93 = 0.67 < 1.0 \Rightarrow k = 1.0$$

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

$$V_{Rd1} = [0.037 \cdot 1.0 \cdot (1.2 + 40 \cdot 0.02) + 0.15 \cdot 0.0] \cdot 40 \cdot 93$$

$$V_{Rd1} = 275.3 \text{ kN}$$

Dio poprečne sile koju mogu preuzeti tlačne dijagonale:

$$V_{Rd2} = 0.5 \cdot v \cdot f_{cd} \cdot b_w \cdot z$$

$$v = 0.7 - \frac{f_{ck}}{200} = 0.7 - \frac{35}{200} = 0.525 > 0.5 \Rightarrow v = 0.525$$

$$V_{Rd2} = 0.5 \cdot 0.525 \cdot 2.33 \cdot 40 \cdot (0.9 \cdot 93) = 2047.7 \text{ kN}$$

$$V_{g1} = 102.8 \text{ kN} ; V_{g2} = 66.3 \text{ kN}$$

$$V_{\Delta g} = 25.3 \text{ kN} ; V_q = 353.3 \text{ kN}$$

$$V_{sd} = \gamma_g \cdot (V_{g1} + V_{g2} + V_{\Delta g}) + \gamma_q \cdot V_q =$$

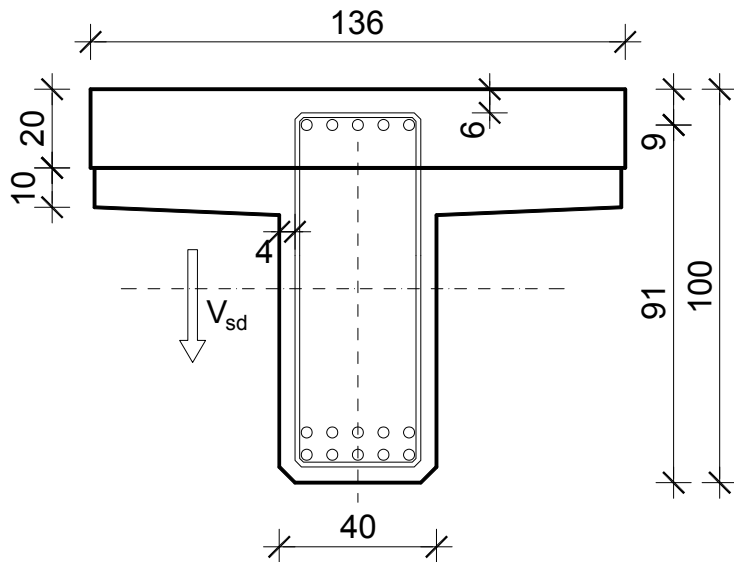
$$= 1.35 \cdot (102.8 + 66.3 + 25.3)$$

$$+ 1.5 \cdot 353.3 =$$

$$= 792.4 \text{ kN}$$

$$V_{Rd1} < V_{sd} < V_{Rd2}$$

# DIMENZIONIRANJE RASPONSKIH NOSAČA NA POPREČNU SILU PRI UPORNJAKU



$$V_{g1} = 102.8 \text{ kN} \quad ; \quad V_{g2} = 66.3 \text{ kN}$$

$$V_{\Delta g} = 25.3 \text{ kN} \quad ; \quad V_q = 353.3 \text{ kN}$$

$$V_{sd} = \gamma_g \cdot (V_{g1} + V_{g2} + V_{\Delta g}) + \gamma_q \cdot V_q =$$

$$= 1.35 \cdot (102.8 + 66.3 + 25.3)$$

$$+ 1.5 \cdot 353.3 =$$

$$= 792.4 \text{ kN}$$

$$V_{Rd1} < V_{sd} < V_{Rd2}$$

Maksimalna poprečna sila:

$$V_{sd} = 792.4 \text{ kN}$$

$$V_{sd}/V_{Rd2} = 792.4/2047.7 \approx 0.38 \Rightarrow V_{sd} = 0.38 V_{Rd2}$$

$$s_{w,max} = \min \{0.6 \cdot d; 30.0 \text{ cm}\} =$$

$$\min \{0.6 \cdot 93 = 55.8; 30.0\} \Rightarrow s_{w,max} = 30.0 \text{ cm}$$

$$\rho_{min} = 0.0011 \quad (\text{C35/45})$$

Odabrane spone  $\varnothing 12$  ( $A_{sw} = 1.13 \text{ cm}^2$ ):

$$s_{w,pot} \leq \frac{m \cdot A_{sw,min}}{\rho_{min} \cdot b_w} = \frac{2 \cdot 1.13}{0.0011 \cdot 40} = 51.4 \text{ cm}$$

Odabrane spone  $\varnothing 12$ . Potrebni razmak spona:

$$f_{yw,d} = \frac{f_{yk}}{\gamma_s}; \quad \text{B 450C} \Rightarrow$$

$$f_{yw,d} = \frac{450.0}{1.15} = 391.3 \text{ MPa} = 39.1 \text{ kN/cm}^2$$

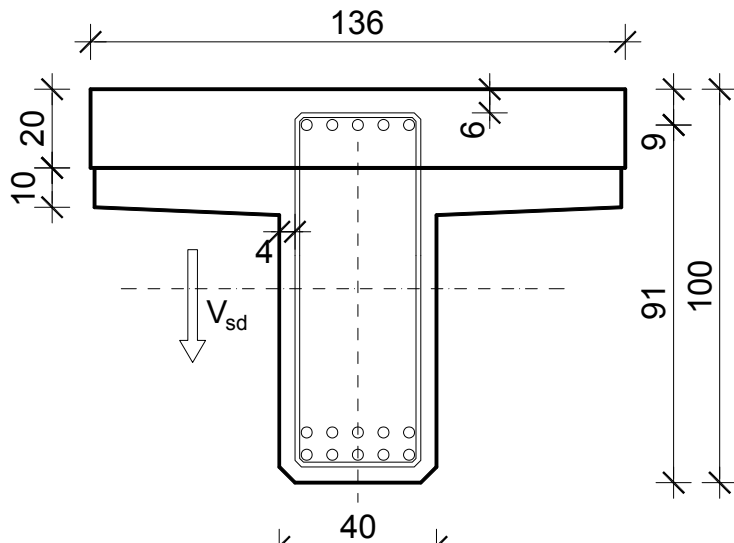
$$s_{w,pot} \leq \frac{m \cdot A_{sw} \cdot f_{yw,d} \cdot z}{V_{Rd} - V_{Rd1}}$$

$$= \frac{2 \cdot 1.13 \cdot 39.1 \cdot (0.9 \cdot 93)}{792.4 - 183.7} =$$

$$s_{w,pot} \leq 12.2 \text{ cm}$$

Odabrane spone  $\varnothing 12/12$  – pri upornjaku.

# DIMENZIONIRANJE RASPONSKIH NOSAČA NA POPREČNU SILU PRI STUPU



$$V_{g1} = 102.8 \text{ kN} ; V_{g2} = 66.3 \text{ kN}$$

$$V_{\Delta g} = 25.3 \text{ kN} ; V_q = 395.3 \text{ kN}$$

$$V_{sd} = \gamma_g \cdot (V_{g1} + V_{g2} + V_{\Delta g}) + \gamma_q \cdot V_q =$$

$$= 1.35 \cdot (102.8 + 66.3 + 25.3)$$

$$+ 1.5 \cdot 395.3 =$$

$$= 855.4 \text{ kN}$$

$$V_{Rd1} < V_{sd} < V_{Rd2}$$

Betón		C35/45
$f_{ck}$ (MPa)	Čvrstoća na valjku	35.0
$\tau_{Rd}$ (MPa)	Posmična čvrstoća	0.37

$$\sum A_s \approx 80.0 \text{ cm}^2$$

$$\rho_l = \frac{\sum A_s}{A_c} = \frac{80.0}{40 \cdot 80} = 0.025 > 0.02$$

$$\rho_l = 0.02$$

Dio poprečne sile koju preuzima beton i uzdužna armatura:

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

$$k = 1.6 - d = 1.6 - 0.93 = 0.67 < 1.0 \Rightarrow k = 1.0$$

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

$$V_{Rd1} = [0.037 \cdot 1.0 \cdot (1.2 + 40 \cdot 0.02) + 0.15 \cdot 0.0] \cdot 40 \cdot 93$$

$$V_{Rd1} = 275.3 \text{ kN}$$

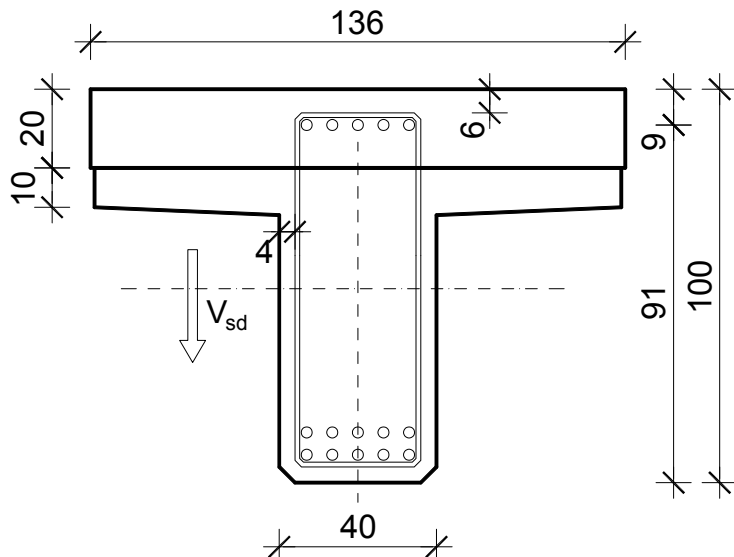
Dio poprečne sile koju mogu preuzeti tlačne dijagonale:

$$V_{Rd2} = 0.5 \cdot v \cdot f_{cd} \cdot b_w \cdot z$$

$$v = 0.7 - \frac{f_{ck}}{200} = 0.7 - \frac{35}{200} = 0.525 > 0.5 \Rightarrow v = 0.525$$

$$V_{Rd2} = 0.5 \cdot 0.525 \cdot 2.33 \cdot 40 \cdot (0.9 \cdot 93) = 2047.7 \text{ kN}$$

# DIMENZIONIRANJE RASPONSKIH NOSAČA NA POPREČNU SILU PRI STUPU



$$V_{g1} = 102.8 \text{ kN} \quad ; \quad V_{g2} = 66.3 \text{ kN}$$

$$V_{\Delta g} = 25.3 \text{ kN} \quad ; \quad V_q = 395.3 \text{ kN}$$

$$V_{sd} = \gamma_g \cdot (V_{g1} + V_{g2} + V_{\Delta g}) + \gamma_q \cdot V_q =$$

$$= 1.35 \cdot (102.8 + 66.3 + 25.3) + 1.5 \cdot 395.3 =$$

$$= 855.4 \text{ kN}$$

$$V_{Rd1} < V_{sd} < V_{Rd2}$$

Maksimalna poprečna sila:

$$V_{sd} = 855.4 \text{ kN}$$

$$V_{sd}/V_{Rd2} = 855.4/2047.7 \approx 0.42 \Rightarrow V_{sd} = 0.42 V_{Rd2}$$

$$s_{w,max} = \min \{0.6 \cdot d; 30.0 \text{ cm}\} =$$

$$\min \{0.6 \cdot 93 = 55.8; 30.0\} \Rightarrow s_{w,max} = 30.0 \text{ cm}$$

$$\rho_{min} = 0.0011 \quad (\text{C35/45})$$

Odabrane spone  $\varnothing 12$  ( $A_{sw} = 1.13 \text{ cm}^2$ ):

$$s_{w,pot} \leq \frac{m \cdot A_{sw,min}}{\rho_{min} \cdot b_w} = \frac{2 \cdot 1.13}{0.0011 \cdot 40} = 51.4 \text{ cm}$$

Odabrane spone  $\varnothing 12$ . Potrebni razmak spona:

$$f_{yw,d} = \frac{f_{yk}}{\gamma_s}; \quad \text{B 450C} \Rightarrow$$

$$f_{yw,d} = \frac{450.0}{1.15} = 391.3 \text{ MPa} = 39.1 \text{ kN/cm}^2$$

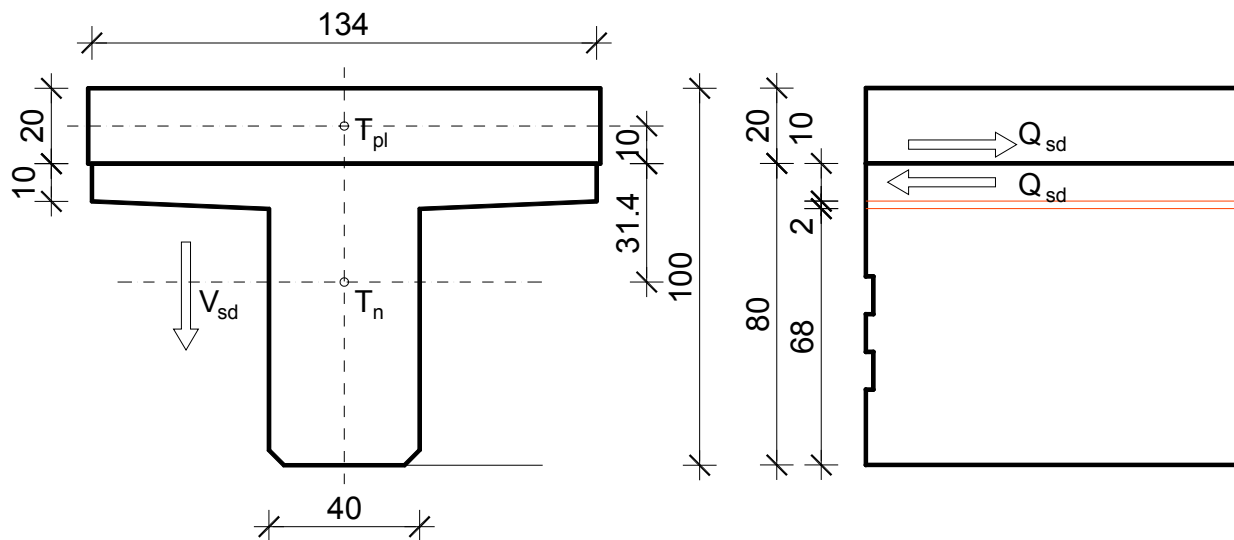
$$s_{w,pot} \leq \frac{m \cdot A_{sw} \cdot f_{yw,d} \cdot z}{V_{Rd} - V_{Rd1}}$$

$$= \frac{2 \cdot 1.13 \cdot 39.1 \cdot (0.9 \cdot 93)}{855.4 - 183.7} =$$

$$s_{w,pot} \leq 11.0 \text{ cm}$$

Odabrane spone  $\varnothing 12/11$  – pri stupu.

# KONTROLA SPREZANJA



$$A_n = 0.422 \text{ m}^2$$

$$h_{t,n} = 0.314 \text{ m}$$

$$A_{pl} = 0.272 \text{ m}^2$$

$$h_{t,pl} = 0.10 \text{ m}$$

$$S = A_{pl} \cdot h_{t,pl} = 0.272 \cdot 0.10 = 0.0272 \text{ m}^3$$

$$I_n = 0.0250 \text{ m}^4$$

$$I_{pl} = 0.00091 \text{ m}^4$$

$$\begin{aligned} I &= (I_n + A_n \cdot h_{t,n}^2) + (I_{pl} + A_{pl} \cdot h_{t,pl}^2) = \\ &= 0.0250 + 0.422 \cdot 0.314^2 + \\ &+ 0.00091 + 0.272 \cdot 0.10^2 = \\ &= 0.070 \text{ m}^4 \end{aligned}$$

$$V_{sd,max} = 855.4 \text{ kN}$$

$$Q_{sd} = \frac{V_{sd,max} \cdot S}{I} = \frac{855.4 \cdot 0.0272}{0.070} = 332.4 \text{ kN}$$

$$f_{yw,d} = \frac{f_{yk}}{\gamma_s}; \quad \text{B 450C} \Rightarrow$$

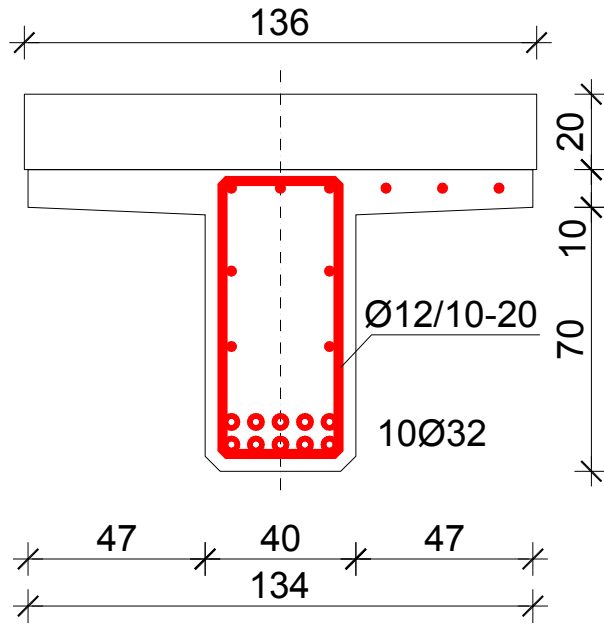
$$f_{yw,d} = \frac{450.0}{1.15} = 391.3 \text{ MPa} = 39.1 \text{ kN/cm}^2$$

$$A_{s,req} = \frac{Q_{sd}}{f_{yw,d}} = \frac{332.4}{39.1} = 8.5 \text{ cm}^2 / 1.34 \text{ m/m}'$$

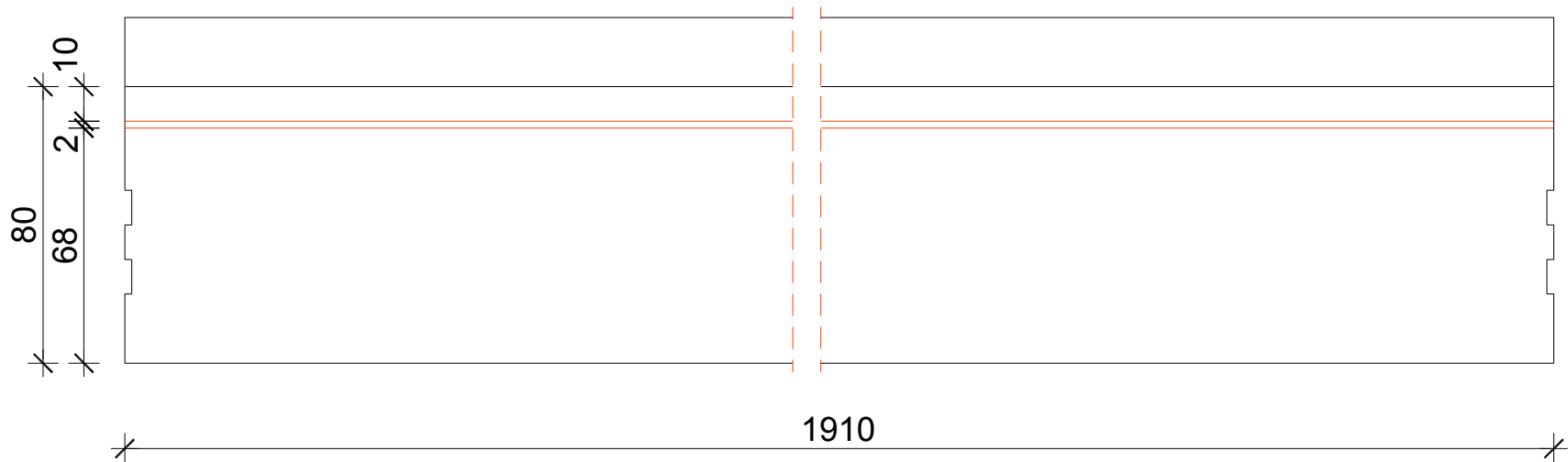
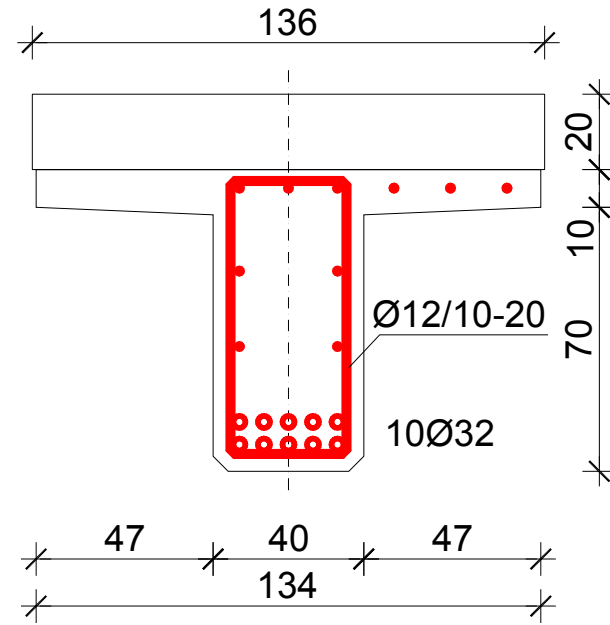
**Odabrane spone 4Ø10 – po presjeku ( $A=3.16 \text{ cm}^2$ ),  
na svakih 20 cm dužine nosača  
= 5x 3.16 = 15.8 cm<sup>2</sup>.**

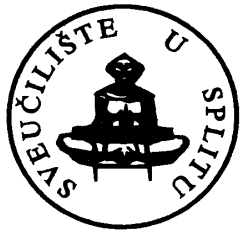
# SKICA ARMATURE

Presjek A-A



Presjek B-B





**SVEUČILIŠTE U SPLITU**  
**GRAĐEVINSKO-ARHITEKTONSKI FAKULTET**  
**KATEDRA ZA BETONSKE KONSTRUKCIJE I MOSTOVE**

**Predmet: MOSTOVI**

# Upute za proračun mosta - KRAJ -

