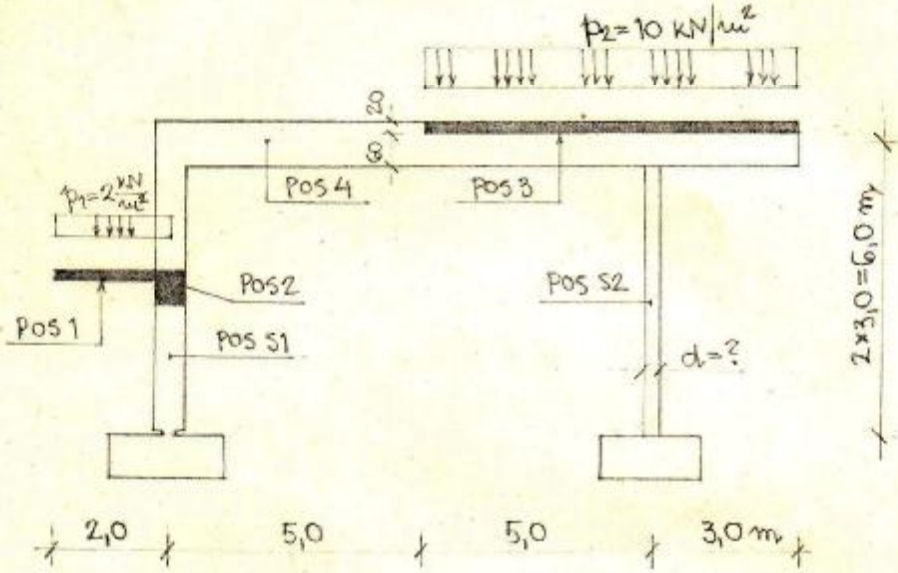
GRADJEVINSKI FAKULTET U BEOGRADU
ODSEK ZA KONSTRUKCIJE
BETONSKE KONSTRUKCIJE I
TEORIJA BETONSKIH KONSTRUKCIJA

11.

Pismeni ispit

25.11.1990.



MB 30
GA 240/360
p_1= 2 kN/m^2
p_2=10 kN/m^2
λ= 6,0 m

Za neko srednje polje konstrukcije prikazane na gornjoj slici potrebno je:

1. Odrediti potrebnu površinu armature za ploču POS 1. Za usvojeni raspored armature potrebno je sračunati srednje rastojanje prslina i njihovu karakterističnu širinu.

2. Izvršiti analizu opterećenja za POS 2 i nacrtati dijagrame sila u presecima, a zatim izvršiti osiguranje od glavnih napona zatezanja u oslonačkom preseku.

3. Izvršiti analizu opterećenja za POS 4, POS S1, POS S2 i nacrtati dijagrame sila u presecima za stalno i korisno opterećenje.

4. Dimenzionisati POS 4 i POS S1 prema M, T, N sračunatim u prethodnoj tački u svim karakterističnim presecima. Osiguranje od glavnih napona zatezanja u preseku levo od stuba S2 izvršiti vertikalnim uzengijama i kosim profilima.

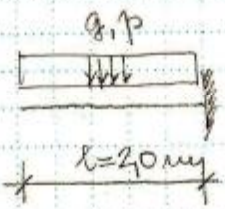
5. Odrediti nepoznatu dimenziju stuba S2 i potrebnu površinu armature po klasičnoj teoriji (l_i=l=6,0m). ~~Za usvojeni presek i armaturu sračunati skraćenje stuba.~~

6. Nacrtati pregledno u približnoj razmeri plan armature za POS 4, POS S1, POS S2 i prikazati karakteristične poprečne preseke sa svim potrebnim kotama i oznakama.

Dimenzije elemenata:

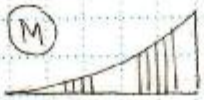
POS 1:	d = 12 cm	POS 4:	b/d = 40/80 cm
POS 2:	b/d = 50/60 cm	POS S1:	b/d = 40/50 cm
POS 3:	d = 20 cm	POS S2:	b/d = 40/??

POS 1 – КОНЗОЛНА ПЛОЧА



$g = 0{,}12 \cdot 25 = 3{,}0$ kN/m²
$p = p_1 = 2{,}0$ kN/m²

$M_g = 3{,}0 \cdot 2{,}0^2/2 = 6{,}0$ kNm/m'
$M_p = 2{,}0 \cdot 2{,}0^2/2 = 4{,}0$ kNm/m'



$R_g = 3{,}0 \cdot 2{,}0 = 6{,}0$ kN/m'
$R_p = 2{,}0 \cdot 2{,}0 = 4{,}0$ kN/m'

MB 30 → $f_b = 2{,}05$ kN/cm²
GA 240/360 → $\sigma_v = 24{,}0$ kN/cm²

ДИМЕНЗИОНИСАЊЕ НА ОСЛОНЦУ:

$M_u = 1{,}6 \cdot 6{,}0 + 1{,}8 \cdot 4{,}0 = 16{,}8$ kNm/m'

$b/d/h_r = 100/12/9{,}5$ cm → $k = \dfrac{9{,}5}{\sqrt{\frac{16{,}8}{2{,}05}}} = 3{,}319$ → $\varepsilon_b/\varepsilon_a = 1{,}8/10$‰
$\mu = 9{,}610$ %

$A_a = 9{,}610 \cdot 9{,}5 \cdot \dfrac{2{,}05}{24} = 7{,}80$ cm²/m' → усв. Ø10/10 (7,85 cm²/m')

$A_{ap} = 0{,}2 \cdot 7{,}80 = 1{,}56$ cm²/m'
$\min A_{ap} = 0{,}10 \cdot \dfrac{9{,}5 \cdot 100}{100} = 0{,}95$ cm²/m'
→ усв. Ø8/30 (1,67 cm²/m')

СРЕДЊЕ РАСТОЈАЊЕ ПРСЛИНА

$$l_{ps} = 2\left(a_o + \frac{e_\phi}{10}\right) + k_1 \cdot k_2 \cdot \frac{\phi}{\mu_{r,ef}}$$

$a_o = a_1 - \phi/2 = 2{,}5 - \dfrac{1{,}0}{2} = 2{,}0$ cm
$e_\phi = 10$ cm

$k_1 = 0{,}8$ (GA)
$k_2 = 0{,}125$ (САВИЈАЊЕ)

$h_{vz,ef.} = \min\begin{cases} 2{,}5 + 7{,}5 \cdot 1{,}0 = 10 \text{ cm} \\ d_p/2 = 12/2 = 6 \text{ cm} \end{cases} = 6{,}0$ cm

$\mu_{ef.} = \dfrac{A_{a1}}{b \cdot h_{vz,ef}} = \dfrac{7{,}85}{100 \cdot 6{,}0} = 1{,}309$ %

$l_{ps} = 2 \cdot (2{,}0 + \dfrac{10}{10}) + 0{,}8 \cdot 0{,}125 \cdot \dfrac{1{,}0}{1{,}309 \cdot 10^{-2}} = 13{,}64$ cm

$l_{ps} = 13{,}64$ cm

ПРОРАЧУН КАРАКТЕРИСТИЧНЕ ШИРИНЕ ПРСЛИНА

$a_{pk} = 1{,}7 \cdot a_{ps} = 1{,}7 \cdot \varepsilon_{a1s} \cdot l_{ps}$

$\varepsilon_{a1s} = \xi_a \cdot \varepsilon_{a1}$ $\qquad \xi_a = 1 - \beta_1\beta_2\left(\frac{\sigma_{a1}^*}{\sigma_{a1}}\right)^2 \leq 1{,}0 \geq 0{,}4$

$\varepsilon_{a1} = \frac{\sigma_{a1}}{E_a}$

МОМЕНТ У ЕКСПЛОАТАЦИЈИ: $M = M_g + M_p = 6{,}0 + 4{,}0 = 10{,}0$ kNm/m'

МОМЕНТ ОТВАРАЊА ПРСЛИНЕ: $M^* = f_{bzs} \cdot W_{i1} \approx f_{bzs} \cdot W_{b1}$

$W_{b1} = \frac{bd^2}{6} = \frac{100 \cdot 12^2}{6} = 2400\ cm^3$

$f_{bzs} = 0{,}7 \cdot f_{bzm} \cdot \left(0{,}6 + \frac{0{,}4}{\sqrt[4]{d}}\right) = 0{,}7 \cdot 2{,}4 \cdot \left(0{,}6 + \frac{0{,}4}{\sqrt[4]{0{,}12}}\right) = 2{,}15$ MPa

$f_{bzs} = 0{,}215$ kN/cm²

$M^* \approx 0{,}215 \cdot 2400 = 516$ kNcm $= 5{,}16$ kNm

– ПОЛОЖАЈ НЕУТРАЛНЕ ЛИНИЈЕ:

$s^2 + 2n\mu_1 \cdot s - 2n\mu_1 = 0$

$\mu_1 = \frac{A_{a1}}{bh} = \frac{7{,}85}{100 \cdot 9{,}5} = 0{,}827\%$

$n = \frac{E_a}{E_b} = \frac{210}{31{,}5} = 6{,}67$

$s^2 + 2 \cdot 0{,}827 \cdot 10^{-2} \cdot 6{,}67 \cdot s - 2 \cdot 0{,}827 \cdot 10^{-2} \cdot 6{,}67 = 0$

$s^2 + 0{,}110 \cdot s - 0{,}110 = 0 \rightarrow s = 0{,}281$

$z_b = \xi_b \cdot h = \left(1 - \frac{s}{3}\right) \cdot h = \left(1 - \frac{0{,}281}{3}\right) \cdot 9{,}5 = 8{,}61$ cm $(= 0{,}906 \cdot h)$

$\sigma_{a1} = \frac{M}{z_b \cdot A_{a1}} = \frac{10{,}0 \cdot 10^2}{8{,}61 \cdot 7{,}85} = 14{,}79$ kN/cm² $\rightarrow \varepsilon_{a1} = \frac{14{,}79}{21 \cdot 10^3} = 0{,}704\%$

$\sigma_{a1}^* = \frac{M^*}{z_b \cdot A_{a1}} = \frac{5{,}16 \cdot 10^2}{8{,}61 \cdot 7{,}85} = 7{,}63$ kN/cm²

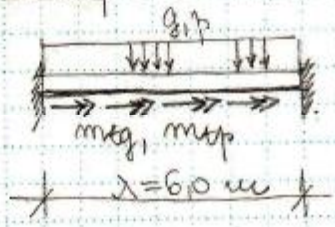
$\left.\begin{matrix}\beta_1 = 0{,}5\ (G/A) \\ \beta_2 = 1{,}0\ (t=0)\end{matrix}\right\}\ \xi_a = 1 - 0{,}5 \cdot 1{,}0 \cdot \left(\frac{7{,}63}{14{,}79}\right)^2 = 0{,}867$

$\varepsilon_{a1s} = \xi_a \cdot \varepsilon_{a1} = 0{,}867 \cdot 0{,}704\% = 0{,}611\%$

$a_{pk} = 1{,}7 \cdot 0{,}611 \cdot 10^{-3} \cdot 13{,}64\ cm = 14 \cdot 10^{-3}\ cm$

$\underline{a_{pk} = 0{,}14\ mm}$ $\qquad (< a_{pk,dop.} = 0{,}2\ mm)$

POS 2 – КОНТИНУАЛНА ГРЕДА



– СОПСТВ. ТЕЖИНА: $0{,}50 \cdot 0{,}60 \cdot 25 = 7{,}5$ kN/m'
– ОД POS 1: СТАЛНО ОПТ. $R_g = 6{,}0$ kN/m'

$$g = 13{,}5 \text{ kN/m'}$$

– ОД POS 1: КОРИСНО ОПТ. $R_{p1} = 4{,}0$ kN/m'

$$p = 4{,}0 \text{ kN/m'}$$

ОСЛОНАЧКИ МОМЕНТИ ИЗ ПЛОЧЕ POS1 СУ РАСПОДЕЉЕНИ МОМЕНТИ ТОРЗИЈЕ ЗА POS 2:

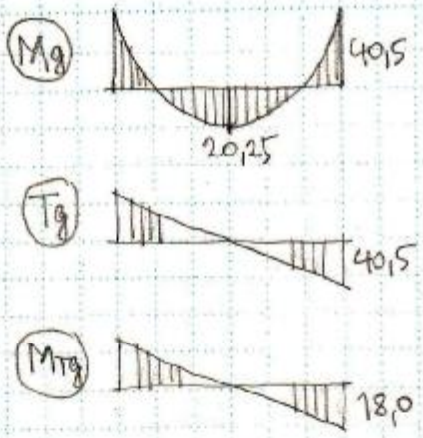
$m_{tg} = M_{g1} = 6{,}0$ kNm/m'
$m_{tp} = M_{p1} = 4{,}0$ kNm/m'

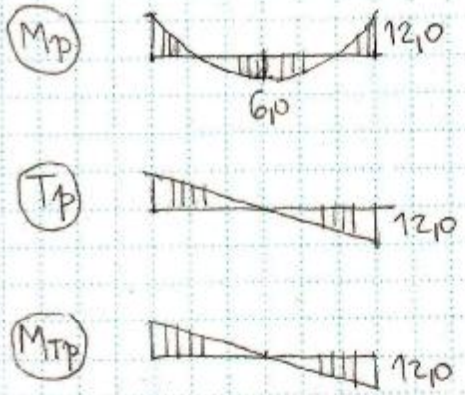
а) СТАЛНО ОПТЕРЕЋЕЊЕ

$M_g^o = 13{,}5 \cdot 6{,}0^2/12 = 40{,}5$ kNm
$M_g^{\bullet} = 13{,}5 \cdot 6{,}0^2/24 = 20{,}25$ kNm
$R_g = 13{,}5 \cdot 6{,}0/2 = 40{,}5$ kN
$M_{tg} = 6{,}0 \cdot 6{,}0/2 = 18{,}0$ kNm

б) КОРИСНО ОПТЕРЕЋЕЊЕ

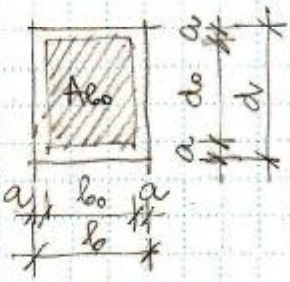
$M_p^o = 4{,}0 \cdot 6{,}0^2/12 = 12{,}0$ kNm
$M_p^{\bullet} = 4{,}0 \cdot 6{,}0^2/24 = 6{,}0$ kNm
$R_p = 4{,}0 \cdot 6{,}0/2 = 12{,}0$ kN
$M_{tp} = 4{,}0 \cdot 6{,}0/2 = 12{,}0$ kNm





ОСИГУРАЊЕ ОД ГЛАВНИХ НАПОНА ЗАТЕЗАЊА:

$T_u = 1{,}6 \cdot 40{,}5 + 1{,}8 \cdot 12{,}0 = 86{,}4$ kN
$M_{tu} = 1{,}6 \cdot 18{,}0 + 1{,}8 \cdot 12{,}0 = 50{,}4$ kNm



$b/d/h = 50/60/55$ cm

ПРЕТП. $a = 4$ cm $\left(= a_0 + \phi_u + \frac{\phi_p}{2} = 2{,}5 + 1{,}0 + \frac{1{,}0}{2}\right)$

$b_0 = b - 2a = 50 - 8 = 42$ cm
$d_0 = d - 2a = 60 - 8 = 52$ cm

$A_{bo} = b_o \cdot d_o = 42 \cdot 52 = 2184\ cm^2$ $\qquad \Sigma \sim o_p h = 0{,}9 \cdot 55 = 49{,}5\ cm$

$O_{bo} = 2(b_o + d_o) = 2 \cdot (42+52) = 188\ cm$

$\delta_o \leq \frac{d_{min}}{8} = \frac{b_o}{8} = \frac{42}{8} = 5{,}25\ cm$

$T_n(T) = \frac{T_u}{b \cdot z} = \frac{86{,}4}{50 \cdot 49{,}5} = 0{,}035\ kN/cm^2$

$T_n(M_T) = \frac{M_{Tu}}{2 A_{bo} \delta_o} = \frac{50{,}4 \cdot 10^2}{2 \cdot 2184 \cdot 5{,}25} = 0{,}220\ kN/cm^2$

$T_n = T_n(T) + T_n(M_T) = 0{,}035 + 0{,}220 = 0{,}255\ kN/cm^2$ $\qquad > T_r = 0{,}11\ kN/cm^2$ $\qquad < 3T_r$

$T_{Bu} = \frac{1}{2} \cdot \frac{0{,}035}{0{,}255} \cdot (3 \cdot 0{,}11 - 0{,}255) \cdot 50 \cdot 49{,}5 = 12{,}77\ kN$

$T_{Ru} = 86{,}4 - 12{,}77 = 73{,}63\ kN$

$T_{Rn} = \frac{73{,}63}{50 \cdot 49{,}5} = 0{,}030\ kN/cm^2$

$M_{TBu} = \frac{0{,}220}{0{,}255} \cdot (3 \cdot 0{,}11 - 0{,}255) \cdot 2184 \cdot 5{,}25 \cdot 10^{-2} = 7{,}45\ kNm$

$M_{TRu} = 50{,}4 - 7{,}45 = 42{,}95\ kNm$

ОСИГУРАЊЕ ВЕРТИКАЛНИМ УЗЕНГИЈАМА:

$$a_u^{(1)} = \frac{b \cdot T_{Ru} \cdot e_u}{m \cdot \sigma_v (\cos\alpha + \sin\alpha \operatorname{ctg}\theta)} + \frac{M_{TRu}}{2 A_{bo} \sigma_v} \cdot e_u \cdot \operatorname{tg}\theta$$

УСВ. $m=2$; $\theta = 45°$; $\alpha = 90°$:

$$a_u^{(1)} = \left(\frac{50 \cdot 0{,}030}{2 \cdot 24{,}0} + \frac{42{,}95 \cdot 10^2}{2 \cdot 2184 \cdot 24{,}0} \right) \cdot e_u = (0{,}031 + 0{,}041)\, e_u = 0{,}072 \cdot e_u$$

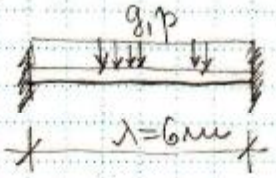
УСВ. $U\phi 10 \rightarrow a_u^{(1)} = 0{,}785\ cm^2 \rightarrow e_u \leq \frac{0{,}785}{0{,}072} = 10{,}9\ cm$

УСВ. $\boxed{U\phi 10/10}$ → ЗАЈЕДНИЧКЕ УЗЕНГИЈЕ ЗА T И M_T

$$\Sigma A_a = \frac{M_{Tu}}{2 A_{bo} \sigma_v} \cdot O_{bo} \cdot \operatorname{ctg}\theta = \frac{50{,}4 \cdot 10^2}{2 \cdot 2184 \cdot 24} \cdot 188 \cdot 1{,}0 = 9{,}04\ cm^2$$

УСВ. $\underline{12\phi 10}$ $\quad (9{,}42\ cm^2)$

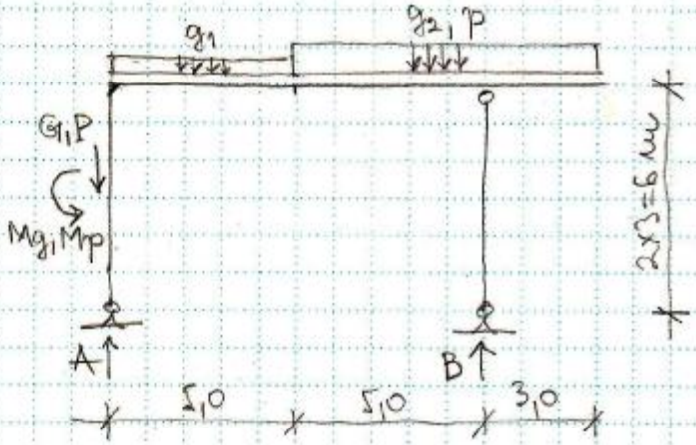
POS 3 – КОНТИНУАЛНА ПЛОЧА



$g = 0{,}20 \cdot 25{,}0 = 5{,}0$ kN/м²
$p = p_2 = 10{,}0$ kN/м²

$Rg = 5{,}0 \cdot 6{,}0/2 = 15{,}0$ kN/м'
$Rp = 10{,}0 \cdot 6{,}0/2 = 30{,}0$ kN/м'

POS 4, POS S1, POS S2 – АНАЛИЗА ОПТЕРЕЋЕЊА И УТИЦАЈИ



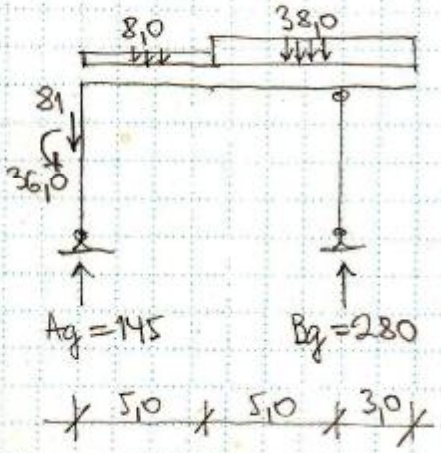
– СОПСТВЕНА ТЕЖИНА POS4: $0{,}40 \cdot 0{,}80 \cdot 25 = 8{,}0$ kN/м'
– СА ПЛОЧЕ POS 3: $2Rg_3 = 2 \cdot 15{,}0 = 30{,}0$ kN/м'; $2Rp_3 = 2 \cdot 30{,}0 = 60{,}0$ kN/м'

} $g_1 = 8{,}0$ kN/м'; $g_2 = 38{,}0$ kN/м'; $p = 60{,}0$ kN/м'

– СА ГРЕДЕ POS 2: $G = 2Rg_2 = 2 \cdot 40{,}5 = 81{,}0$ kN
$P = 2Rp_2 = 2 \cdot 12 = 24{,}0$ kN

$Mg = 2 \cdot M_{Tg_2} = 2 \cdot 18 = 36{,}0$ kNm
$Mp = 2 \cdot M_{Tp_2} = 2 \cdot 12 = 24{,}0$ kNm

а) СТАЛНО ОПТЕРЕЋЕЊЕ

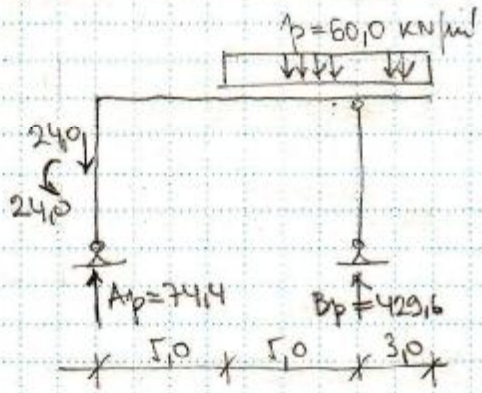


$Ag = \frac{1}{10} \cdot [36{,}0 + 81{,}0 \cdot 10{,}0 + 8{,}0 \cdot 5{,}0 \cdot 7{,}5 + 38{,}0 \cdot 8{,}0 \cdot 1{,}0]$

$Bg = \frac{1}{10} \cdot [-36{,}0 + 8{,}0 \cdot 5{,}0 \cdot 2{,}5 + 38{,}0 \cdot 8{,}0 \cdot 9{,}0]$

$Ag = 145{,}0$ kN
$Bg = 280{,}0$ kN

б) КОРИСНО ОПТЕРЕЋЕЊЕ



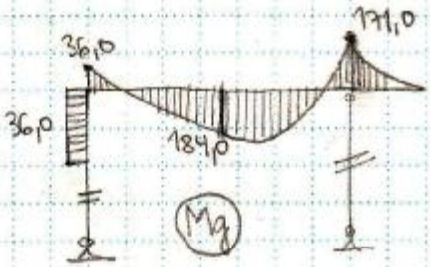
$$A_p = \frac{1}{10}\cdot[24{,}0\cdot 24{,}0\cdot 10{,}0 + 60{,}0\cdot 8{,}0\cdot 1{,}0]$$

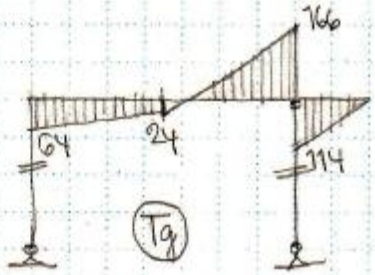
$$B_p = \frac{1}{10}\cdot[-24{,}0 + 60{,}0\cdot 8{,}0\cdot 9{,}0]$$

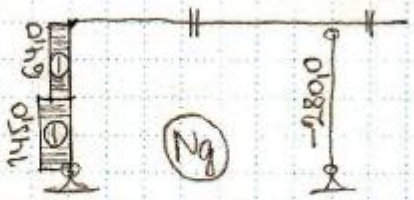
$A_p = 74{,}4$ kN
$B_p = 429{,}6$ kN

ДИЈАГРАМИ СТАТИЧКИХ УТИЦАЈА

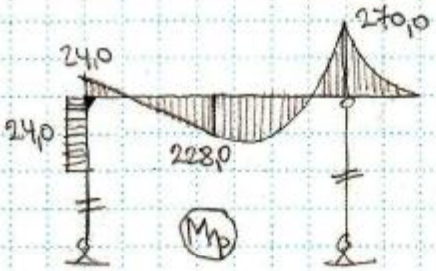
а) СТАЛНО ОПТЕРЕЋЕЊЕ

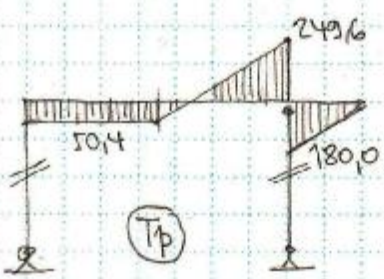


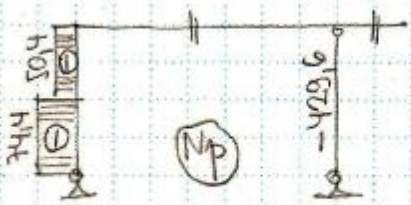




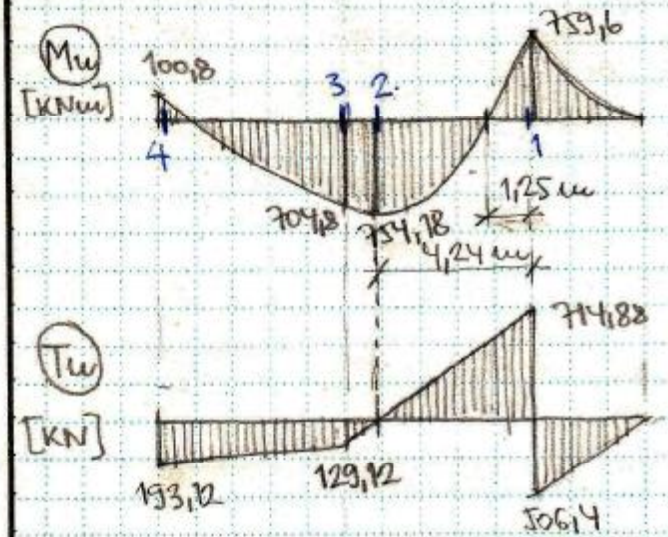
б) КОРИСНО ОПТЕРЕЋЕЊЕ







ДИЈАГРАМИ ГРАНИЧНИХ РАЧУНСКИХ УТИЦАЈА ЗА POS 4:



$M_u^1 = 1{,}6 \cdot 171 + 1{,}8 \cdot 270 = 759{,}6$ kNm

$M_u^3 = 1{,}6 \cdot 184 + 1{,}8 \cdot 228 = 704{,}8$ kNm

$M_u^4 = 1{,}6 \cdot 36 + 1{,}8 \cdot 24 = 100{,}8$ kNm

$T_u^{10} = 1{,}6 \cdot 114 + 1{,}8 \cdot 180 = 506{,}4$ kN

$T_u^{12} = 1{,}6 \cdot 166 + 1{,}8 \cdot 249{,}6 = 714{,}88$ kN

$T_u^3 = 1{,}6 \cdot 24 + 1{,}8 \cdot 50{,}4 = 129{,}12$ kN

$T_u^4 = 1{,}6 \cdot 64 + 1{,}8 \cdot 50{,}4 = 193{,}12$ kN

$q_{u2} = 1{,}6 g_2 + 1{,}8 p = 1{,}6 \cdot 38{,}0 + 1{,}8 \cdot 60{,}0 = 168{,}8$ kN/m'

МАКСИМАЛНИ M_u У ПОЉУ ЈЕ У ПРЕСЕКУ 2 ($x' = 4{,}24$ m) → $T_u = 0$:

$$\text{MAX. } M_u = -759{,}6 - 168{,}8 \cdot 4{,}24^2/2 + 714{,}88 \cdot 4{,}24 = 754{,}18 \text{ kNm}$$

$$\text{MAX. } M_u = M_u^2 = 754{,}18 \text{ kNm}$$

ДИМЕНЗИОНИСАЊЕ

ПРЕСЕК 1-1: $M_u^1 = 759{,}6$ kNm

$b/d/h = 40/80/72$ cm → $k = \dfrac{72}{\sqrt{\frac{759{,}6 \cdot 10^2}{40 \cdot 2{,}05}}} = 2{,}366$ → $\varepsilon_b/\varepsilon_a = 3{,}325/10\,‰$, $\bar{\mu} = 19{,}950\,‰$

$$A_{a1} = 19{,}950 \cdot \frac{40 \cdot 72}{100} \cdot \frac{3{,}05}{24} = 49{,}08 \text{ cm}^2 \rightarrow \boxed{10\phi25} \quad (49{,}09 \text{ cm}^2)$$

ПРЕСЕК 2-2: $M_u^2 = 754{,}18$ kNm

$$B = \min \begin{cases} b_0 + 20 d_p = 40 + 20 \cdot 20 = 440 \text{ cm} \\ b_0 + 1/4\, l_0 = 40 + 0{,}25 \cdot 375 = 134 \text{ cm} \\ \lambda = 600 \text{ cm} \end{cases} = 134 \text{ cm}$$

($l_0 \sim 5{,}0 - 1{,}25 = 3{,}75$ m)

ПРЕТПОСТАВЉАМО ДА ЈЕ НЕУТРАЛНА ЛИНИЈА У ПЛОЧИ:

$B|d|h_r = 134|80|73$ cm $\quad (a_1 = 7$ cm$)$

$$k = \frac{73}{\sqrt{\frac{714{,}18 \cdot 10^2}{134 \cdot 2{,}05}}} = 4{,}406 \rightarrow \begin{matrix} \varepsilon_b|\varepsilon_{a1} = 1{,}225|10‰ \\ \overline{\mu} = 5{,}320\% \\ \zeta = 0{,}109 \rightarrow \zeta \cdot h_r = 8 \text{ cm} < d_p = 20 \text{ cm} \end{matrix}$$

ПРЕТПОСТАВКА ЈЕ БИЛА ТАЧНА, ПА ЈЕ:

$$A_{a1} = 5{,}320 \cdot \frac{134 \cdot 73}{100} \cdot \frac{2{,}05}{24} = 44{,}45 \text{ cm}^2 \rightarrow \text{УСВ. } \boxed{9\phi25} \ (44{,}18 \text{ cm}^2)$$

ПРЕСЕК 3-3: $M_u = 704{,}8$ kNm

МЕРОДАВАН ЗА ДИМЕНЗИОНИСАЊЕ ЈЕ ПРЕСЕК 3^L (ПРАВОУГАОНИ):

$$b|d|h_r = 40|80|73 \text{ cm} \rightarrow k = \frac{73}{\sqrt{\frac{704{,}8}{0{,}4 \cdot 2{,}05}}} = 2{,}490 \rightarrow \begin{matrix} \varepsilon_b|\varepsilon_{a1} = 2{,}975|10‰ \\ \overline{\mu}_1 = 17{,}791\% \end{matrix}$$

$$A_{a1} = 17{,}791 \cdot \frac{40 \cdot 73}{100} \cdot \frac{2{,}05}{24} = 44{,}37 \text{ cm}^2 \rightarrow \text{УСВ. } \boxed{9\phi25} \ (44{,}18 \text{ cm}^2)$$

ПРЕСЕК 4-4: $M_u = 100{,}8$ kNm

$$b|d|h_r = 40|80|75 \text{ cm} \rightarrow k = \frac{75}{\sqrt{\frac{100{,}8}{0{,}4 \cdot 2{,}05}}} = 6{,}765 \rightarrow \begin{matrix} \varepsilon_b|\varepsilon_{a1} = 0{,}75|10‰ \\ \overline{\mu}_1 = 2{,}289\% \end{matrix}$$

$$\left.\begin{matrix} A_{a1} = 2{,}289 \cdot \frac{40 \cdot 75}{100} \cdot \frac{2{,}05}{24} = 5{,}87 \text{ cm}^2 \\ \min A_{a1} = 0{,}25 \cdot \frac{40 \cdot 75}{100} = 7{,}5 \text{ cm}^2 \end{matrix}\right\} \text{УСВ. } \boxed{3\phi18} \ (7{,}63 \text{ cm}^2)$$

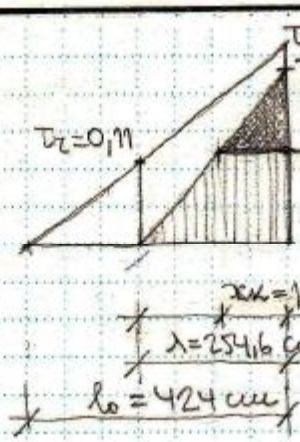
ОСИГУРАЊЕ ОД ГЛАВНИХ НАПОНА ЗАТЕЗАЊА

$$\left.\begin{matrix} T_u^{1L} = 714{,}88 \text{ kN} \\ z = 0{,}9 h_r = 0{,}9 \cdot 72 = 64{,}8 \text{ cm} \end{matrix}\right\} \tau_n = \frac{714{,}88}{40 \cdot 64{,}8} = 0{,}276 \text{ kN/cm}^2 \quad \begin{matrix} > \tau_{r2} = 0{,}11 \\ < 3\tau_{r2} \end{matrix}$$

$$T_{bu} = \frac{1}{2}(3 \cdot 0{,}11 - 0{,}276) \cdot 40 \cdot 64{,}8 = 70{,}24 \text{ kN}$$

$$T_{Ru} = 714{,}88 - 70{,}24 = 644{,}64 \text{ kN}$$

$$\tau_{Ru} = \frac{644{,}64}{40 \cdot 64{,}8} = 0{,}249 \text{ kN/cm}^2$$



$l_0 = 4{,}24$ m

$\lambda = l_0 \cdot \left(1 - \frac{\tau_r}{\tau_R}\right)$

$\lambda = 4{,}24 \cdot \left(1 - \frac{0{,}11}{0{,}276}\right) = 2{,}546$ m

$x_K = \lambda \left(1 - \frac{\tau_{m,\mu}}{\tau_{Rm}}\right)$

$x_K = 2{,}546 \cdot \left(1 - \frac{0{,}126}{0{,}249}\right) = 1{,}26$ m

УСВ. $\underline{U\phi 10/15}$ ($\underline{m=4}$; $\alpha = 90°$; $\theta = 45°$)

$\mu_{m,z} = \frac{m a_i^{(1)}}{b \cdot e_m} = \frac{4 \cdot 0{,}785}{40 \cdot 15} = 0{,}524\,\% > \mu_{min,z} = 0{,}2\,\%$

$\tau_{m,\mu} = \frac{4 \cdot 0{,}785}{40 \cdot 15} \cdot 24{,}0 = 0{,}126$ kN/cm²

$H_{m,K} = \frac{0{,}249 - 0{,}126}{2} \cdot 126{,}0 \cdot 40{,}0 = 310{,}0$ kN

$Z_K = \frac{H_{m,K}}{\sqrt{2}} = 219{,}2$ kN

$A_{aK} = \frac{Z_K}{\sigma_V} = \frac{219{,}2}{24{,}0} = 9{,}13$ cm² → УСВ. $\boxed{2\phi 25}$ (9,82 cm²)

$\underline{\text{ПРЕСЕК 1}^D}$: $T_m = T_R = 506{,}4$ kN → $\tau_R = \frac{506{,}4}{40 \cdot 64{,}8} = 0{,}195$ kN/cm² $> \tau_r$ $< 3\tau_r$

$T_{Rm} = \frac{1}{2}(3 \cdot 0{,}11 - 0{,}195) \cdot 40 \cdot 64{,}8 = 174{,}48$ kN

$T_{Rm} = 506{,}4 - 174{,}48 = 331{,}92$ kN

$\tau_{Rm} = \frac{331{,}92}{40 \cdot 64{,}8} = 0{,}128$ kN/cm²

УСВ. $m = 4$ $\underline{U\phi 10/15}$ ($\tau_{m,\mu} = 0{,}126$ kN/cm² ~ τ_{Rm})

$\lambda = 3{,}0 \cdot \left(1 - \frac{0{,}11}{0{,}195}\right) = 1{,}31$ m → ДУЖИНА ОСИГУРАЊА

$\underline{\text{ПРЕСЕК 4}}$: $T_R = 193{,}12$ kN ; $z \approx 0{,}9 \cdot 75{,}0 = 67{,}5$ cm

$\tau_R = \frac{193{,}12}{40 \cdot 67{,}5} = 0{,}072$ kN/cm² $< \tau_r = 0{,}11$ kN/cm²

НИЈЕ ПОТРЕБНО ОСИГУРАЊЕ АРМАТУРОМ.

POS S1

$M_u = 1{,}6 \cdot 36{,}0 + 1{,}8 \cdot 24{,}0 = 100{,}8$ kNm
$N_u = 1{,}6 \cdot 64{,}0 + 1{,}8 \cdot 50{,}4 = 193{,}12$ kN

$b/d/h = 40/50/45$ cm $\rightarrow a_1 = 5$ cm

$M_{au} = 100{,}8 + 193{,}12 \cdot \left(\frac{0{,}50}{2} - 0{,}05\right) = 139{,}42$ kNm

$k = \frac{45}{\sqrt{\frac{139{,}42}{0{,}4 \cdot 2{,}05}}} = 3{,}451 \rightarrow \varepsilon_b/\varepsilon_a = 1{,}7/10\,‰$, $\mu_1 = 8{,}851\,\%$

$A_{a1} = 8{,}851 \cdot \frac{40 \cdot 45}{100} \cdot \frac{2{,}05}{24} - \frac{193{,}12}{24} = 13{,}61 - 8{,}05 = 5{,}56$ cm^2

$\min A_{a1} = 0{,}25 \cdot \frac{40 \cdot 45}{100} = 4{,}5$ cm$^2 < A_{a1} \rightarrow$ усв. $\boxed{3\text{Ø}16}$ (6,03 cm^2)

POS S2

$N = N_g + N_p = 280 + 429{,}6 = 709{,}6$ kN

MB 30 $\rightarrow \sigma_s = 8{,}0$ MPa ; $l_i = l = 6{,}0$ m

1. KORAK: PRETP. $d = 30$ cm $\rightarrow i_{min} = \frac{30}{\sqrt{12}} = 8{,}66$ cm

$\lambda = \frac{l_i}{i_{min}} = \frac{600}{8{,}66} = 69{,}28 > 50$

$\sigma_K = 1{,}4\sigma_s - 0{,}4 - (\sigma_s - 1)\frac{\lambda}{125} = 1{,}4 \cdot 8{,}0 - 0{,}4 - (8{,}0 - 1) \cdot \frac{69{,}28}{125} = 6{,}92$ MPa

$\sigma_K = 0{,}692$ kN/cm^2

$\mu_{MIN.} = \frac{\lambda}{50} - 0{,}4 = \frac{69{,}28}{50} - 0{,}4 = 0{,}986\,\%$

$A_{B,POTR.} = \frac{N}{\sigma_K(1 + m\mu)} = \frac{709{,}6}{0{,}692(1 + 10 \cdot 0{,}986 \cdot 10^{-2})} = 933{,}4$ cm

POTR. $d = \frac{A_{B,POTR.}}{b} = \frac{933{,}4}{40} = 23{,}3$ cm $\neq 30$ cm $= d_{PRETP.}$

2. KORAK: PRETP. $d = 25$ cm $\rightarrow i_{min} = \frac{25}{\sqrt{12}} = 7{,}22$ cm

$\lambda = \frac{600}{7{,}22} = 83{,}14$

$\sigma_K = 1{,}4 \cdot 8{,}0 - 0{,}4 - (8{,}0 - 1) \cdot \frac{83{,}14}{125} = 6{,}14$ MPa $= 0{,}614$ kN/cm^2

POTR. $\mu = \frac{83{,}14}{50} - 0{,}4 = 1{,}263\,\%$

$A_{B,POTR.} = \frac{709{,}6}{0{,}614 \cdot (1 + 10 \cdot 1{,}263 \cdot 10^{-2})} = 1025{,}4$ cm^2

$d_{POTR.} = \frac{1025{,}4}{40} = 25{,}6$ cm ~ 25 cm $= d_{PRETP.}$

усв. $b/d = 40/25$ см $\rightarrow A_b = 1000$ см^2

$D_b = A_b \cdot \sigma_K = 1000 \cdot 0{,}614 = 614$ kN

$D_a = N - D_b = 709{,}6 - 614 = 95{,}6$ kN

$\sigma_a = n\sigma_b = n \cdot \sigma_K = 10 \cdot 6{,}14 = 61{,}4$ MPa $= 6{,}14$ kN/см^2

потр. $A_a = \frac{D_a}{\sigma_a} = \frac{95{,}6}{6{,}14} = 15{,}49$ см^2 $\rightarrow$ усв. $\boxed{8\text{Ø}16}$ (16,08 см^2)

$\mu = \frac{A_a}{A_b} = 1{,}549\% > \mu_{потр.} = 1{,}263\%$

$$\text{MAX. } e_u = \text{MIN.} \begin{cases} 15\text{Ø} = 15 \cdot 1{,}6 = 24 \text{ см} \\ d = 25 \text{ см} \\ 30 \text{ см} \end{cases} = 24 \text{ см} \rightarrow \text{U}\text{Ø}6/24$$