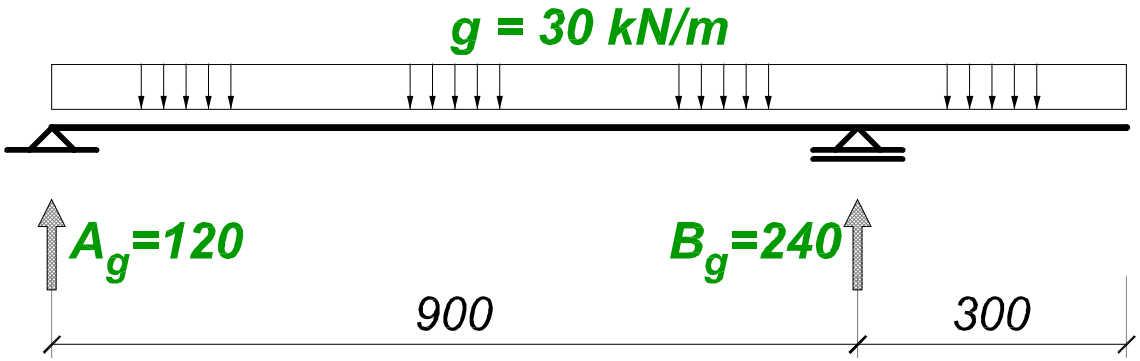
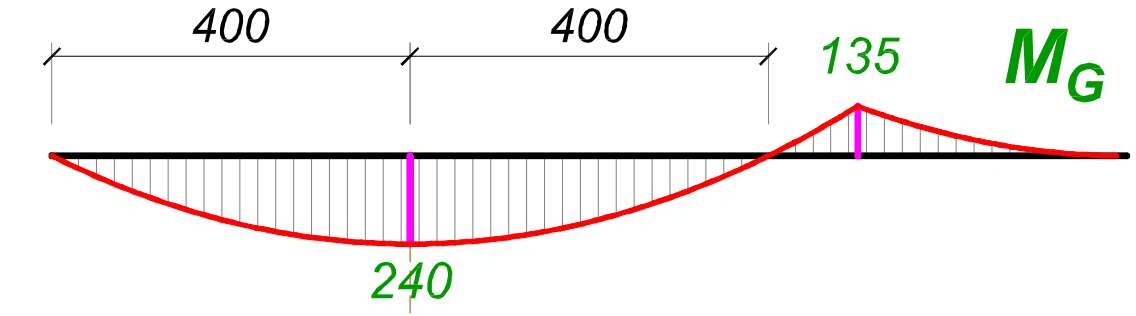
Stalno opterećenje



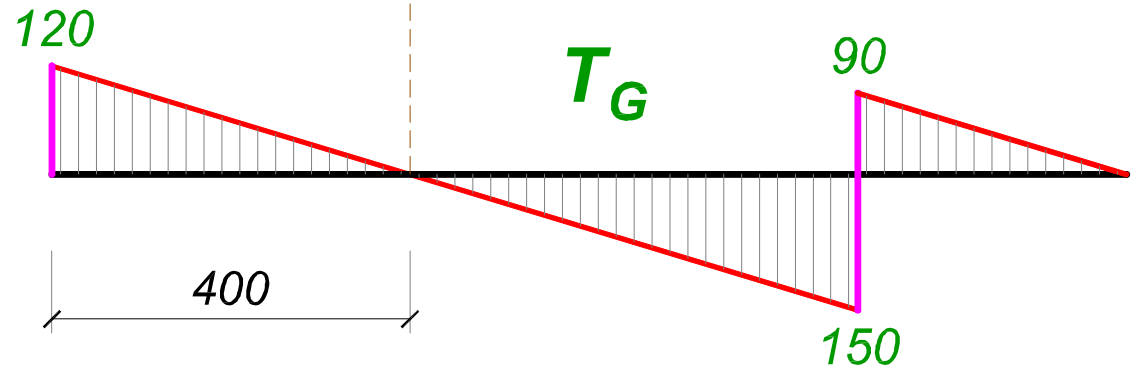
$B_g = (30 \times 12^2/2)/9 = 240\ kN$

$A_g = 30 \times 12 - 240 = 120\ kN$



$M_g^{OSL} = 30 \times 3.0^2/2$

$M_g^{OSL} = 135\ kNm$



maks. M u polju

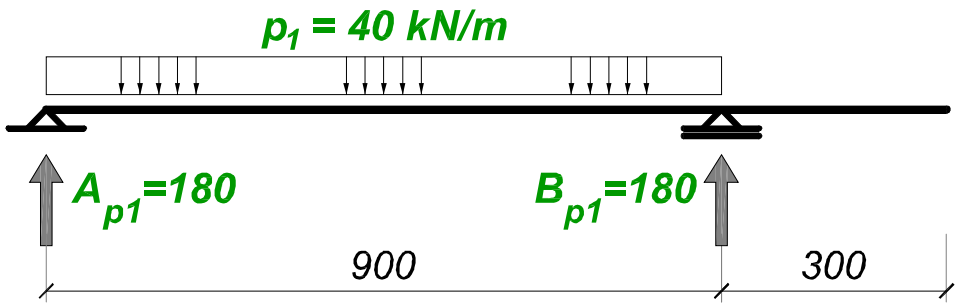
$x_{max} = T_g^{A,desno}/g$

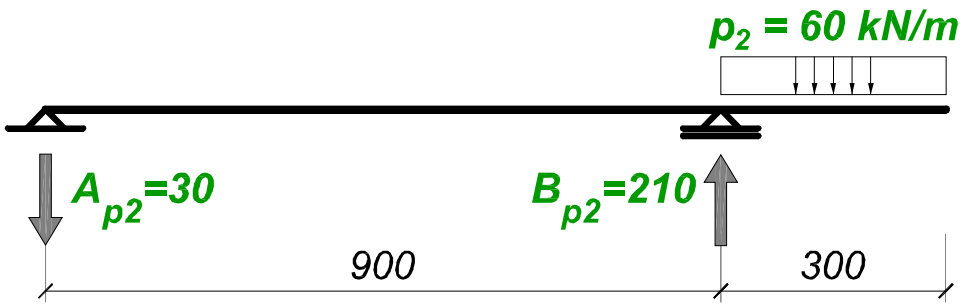
$x_{max} = 120/30 = 4.0\ m$

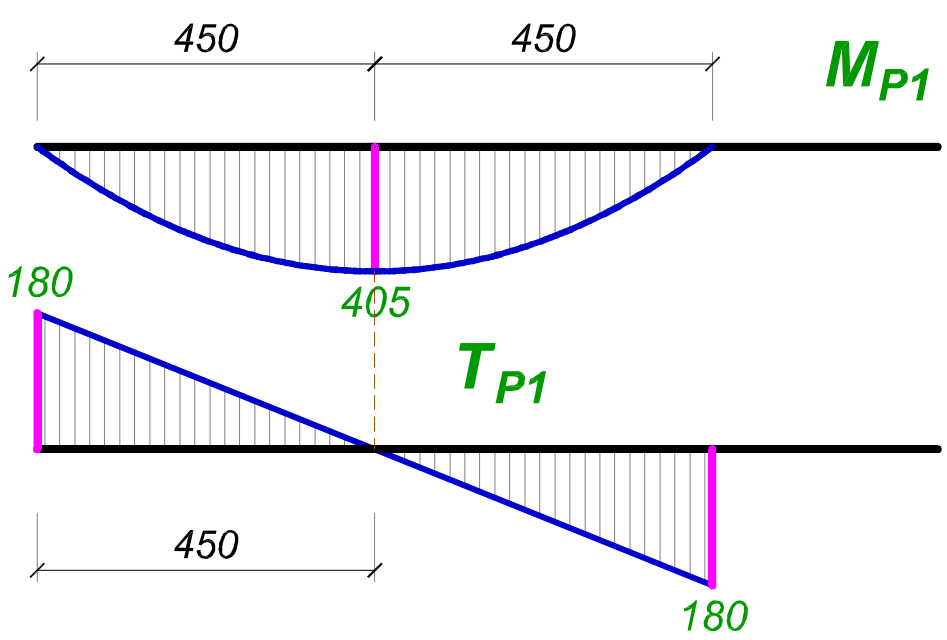
$_{max}M_g = 120 \times 4 - 30 \times 4^2/2$

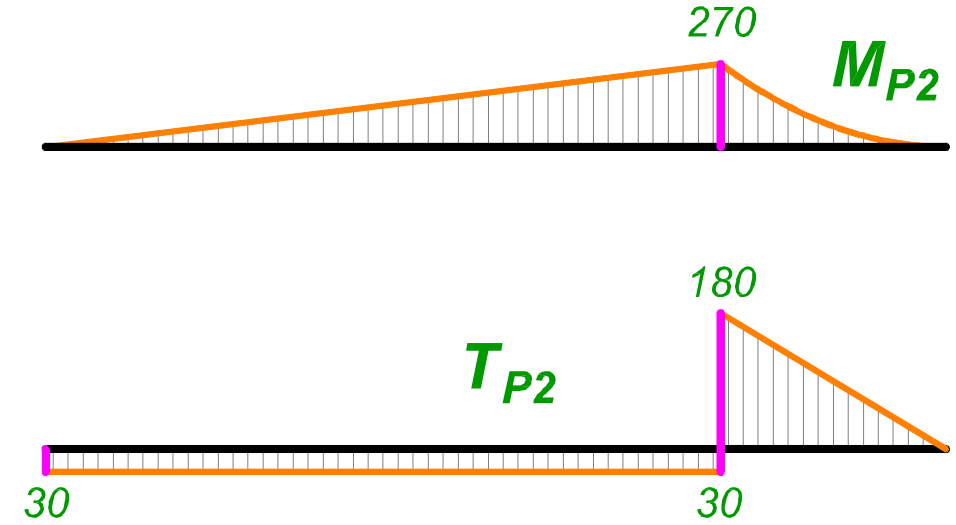
$_{max}M_g = 240\ kNm$

Povremeno opterećenje

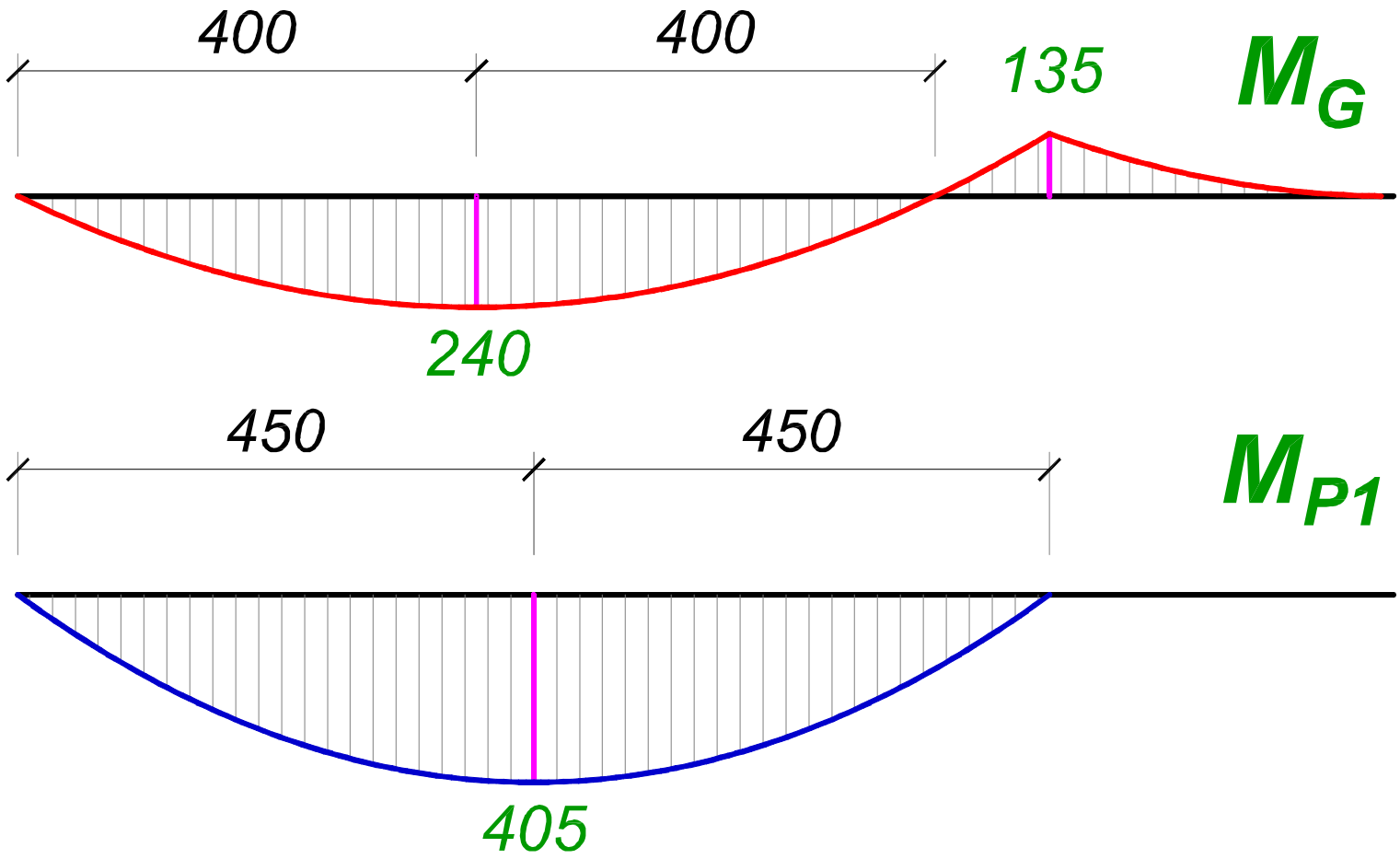




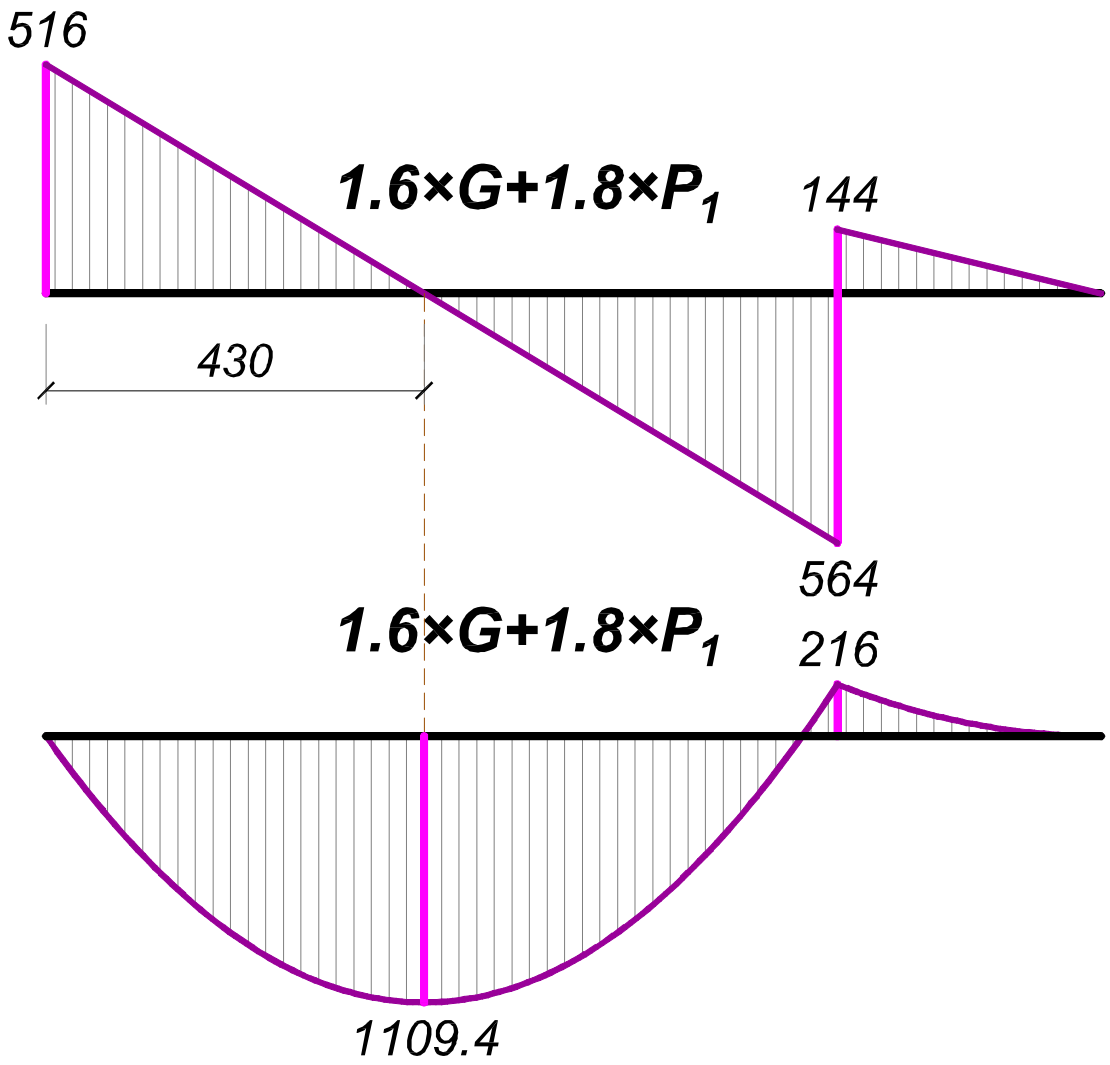




Maksimalni moment u polju



Maksimalni moment u polju



$T_{u1} = 1.6\times120+1.8\times180 = 516$ kN

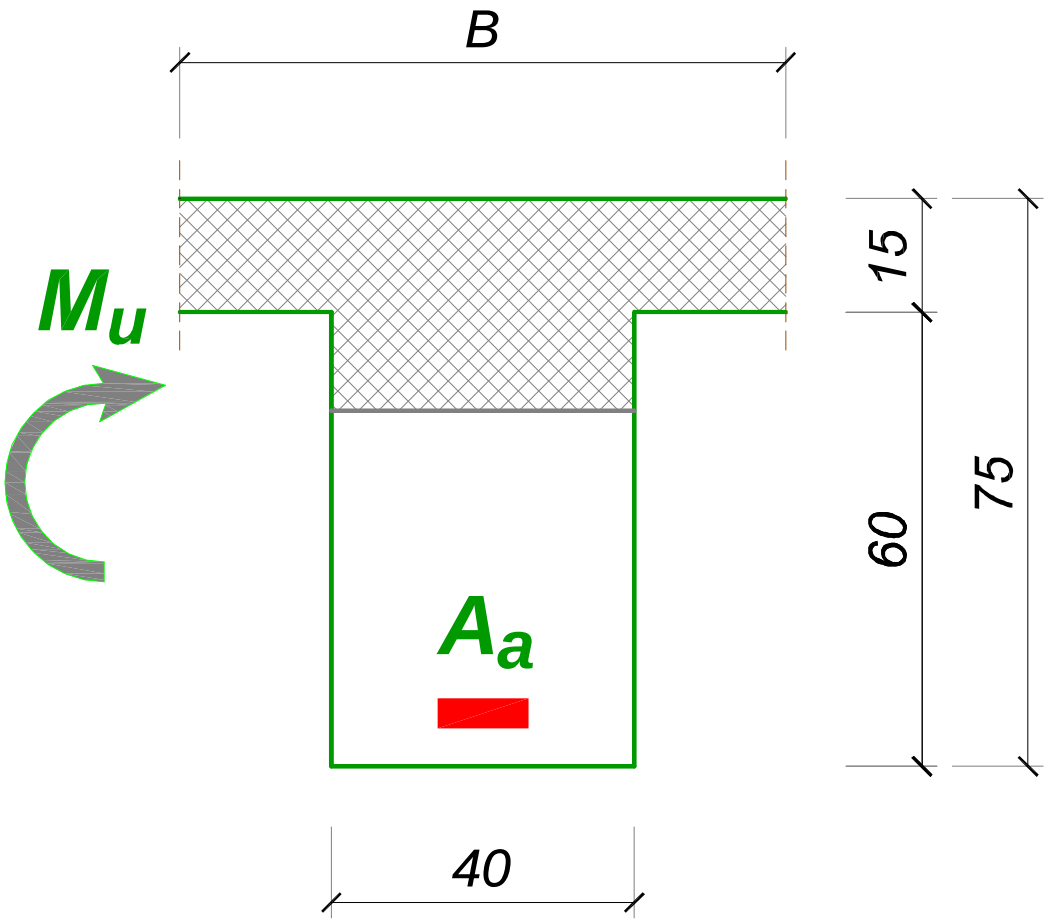
$q_{u1} = 1.6\times30+1.8\times40 = 120$ kN/m

$x_{max.} = 516/120 = 4.3$ m

$M_{u,max.} = 516\times4.3 - 120\times4.3^2/2$

$M_{u,max.} = 1109.4$ kNm

Dimenzionisanje - presek u polju



$$B = min.\begin{Bmatrix} b + 0.25 \times l_0 \\ b + 20 \times d_p \\ e \end{Bmatrix}$$

$$l_0 = 8.60\,m$$

$$B = min.\begin{Bmatrix} 40 + 0.25 \times 860 = 255 \\ 40 + 20 \times 15 = 340 \end{Bmatrix}$$

$$B = 255\,cm$$

Dimenzionisanje - presek u polju

pretp. a_1 = 7 cm Þ h = 75 – 7 = 68 cm

$$k = \frac{68}{\sqrt{\frac{1109.4 \times 10^2}{255 \times 2.05}}} = 4.668 \xrightarrow{TABL.} \begin{array}{c} \varepsilon_b / \varepsilon_a = 1.15 / 10‰ \\ s = 0.103 \\ \bar{\mu} = 4.794\% \end{array}$$

$x = 0.103 \times 68 = 7.0$ cm < d_p = 15 cm

Pretpostavka o položaju neutralne linije je dobra, pa se presek dimenzioniše kao pravougaoni, širine B = 255 cm.

Dimenzionisanje - presek u polju

ε_a	ε_b	s	α_b	η	ζ	μ_{1M} %	k
10	**1.15**	**0.103**	**0.465**	**0.353**	**0.964**	**4.794**	**4.653**

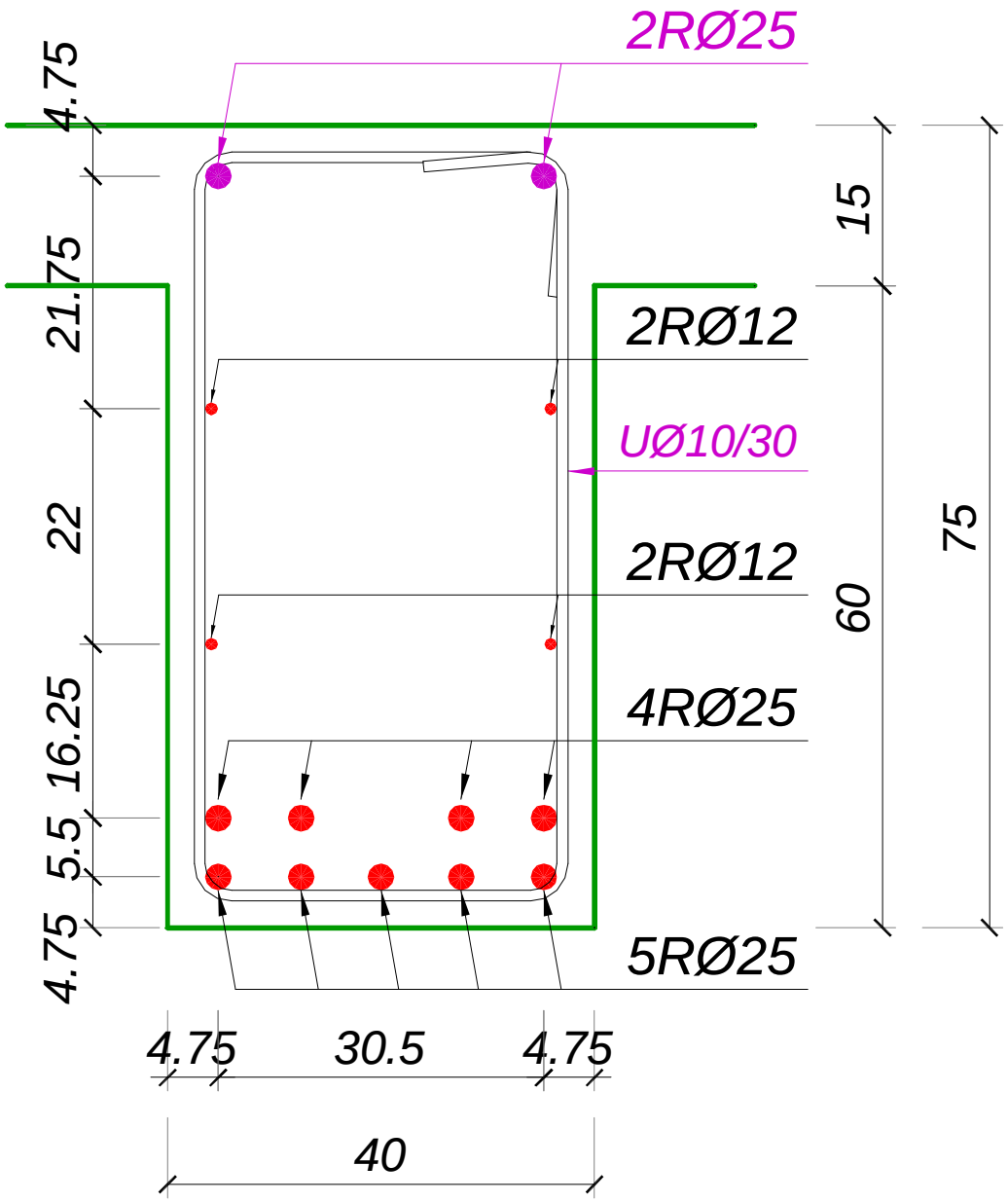
$$A_a = 4.794 \times \frac{255 \times 68}{100} \times \frac{2.05}{40} = 42.60\,cm^2$$

ili:

$$A_a = \frac{1109.4 \times 10^2}{0.964 \times 68 \times 40} = 42.33\,cm^2$$

usvojeno: **9RØ25** *(44.18 cm²)*

Dimenzionisanje - presek u polju



$a^{I} = 2.5 + 1.0 + 2.5/2 = 4.75$ cm

$a^{II} = 4.75 + 3.0 + 2.5 = 10.25$ cm

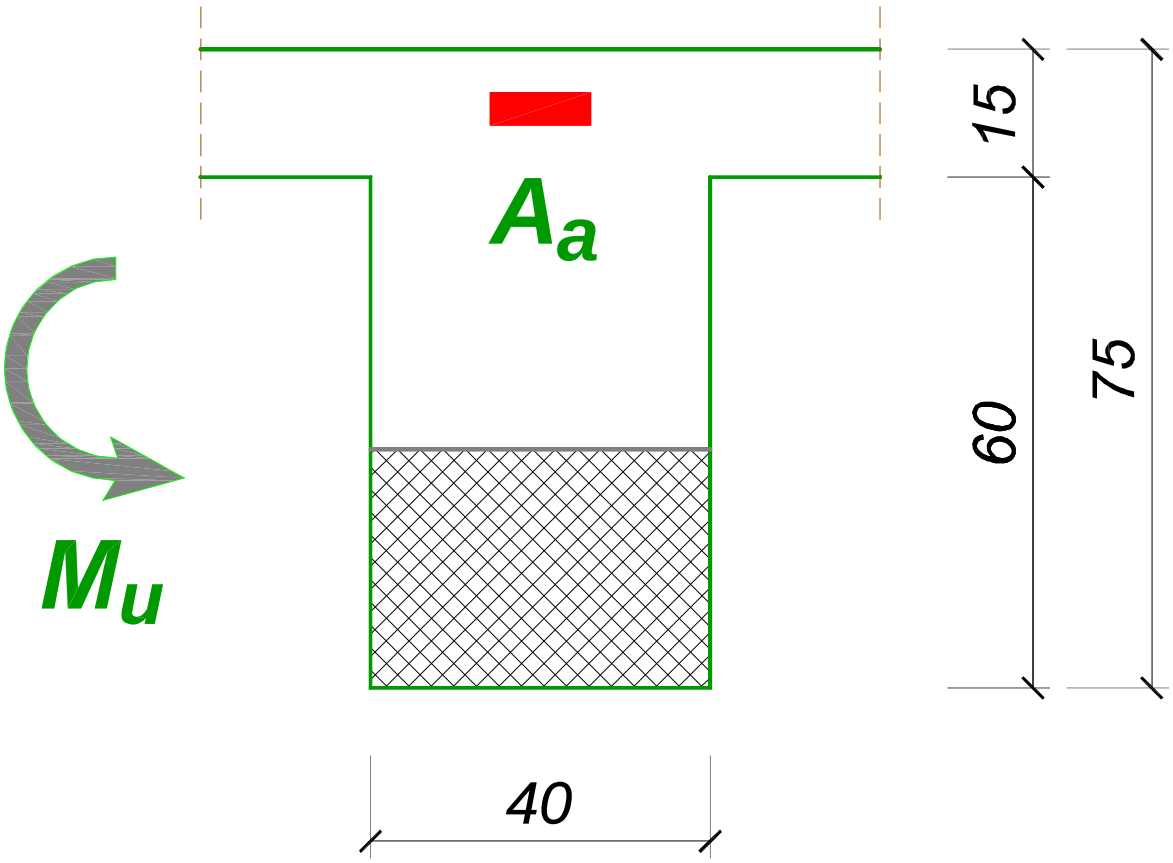
$a_1 = (5 \times 4.75 + 4 \times 10.25)/9$

$a_1 = 7.19$ cm

$h = 75 - 7.19 = 67.81$ cm

$h \approx 68$ cm $= h_{rač.}$

Dimenzionisanje - oslonac



$M_u = 1.6 \times M_g + 1.8 \times M_{p2}$

$M_u = 1.6 \times 135 + 1.8 \times 270$

$M_u = 702$ kNm

pretp. $a_1 = 7$ cm

$h = 75 - 7 = 68$ cm

Dimenzionisanje - oslonac

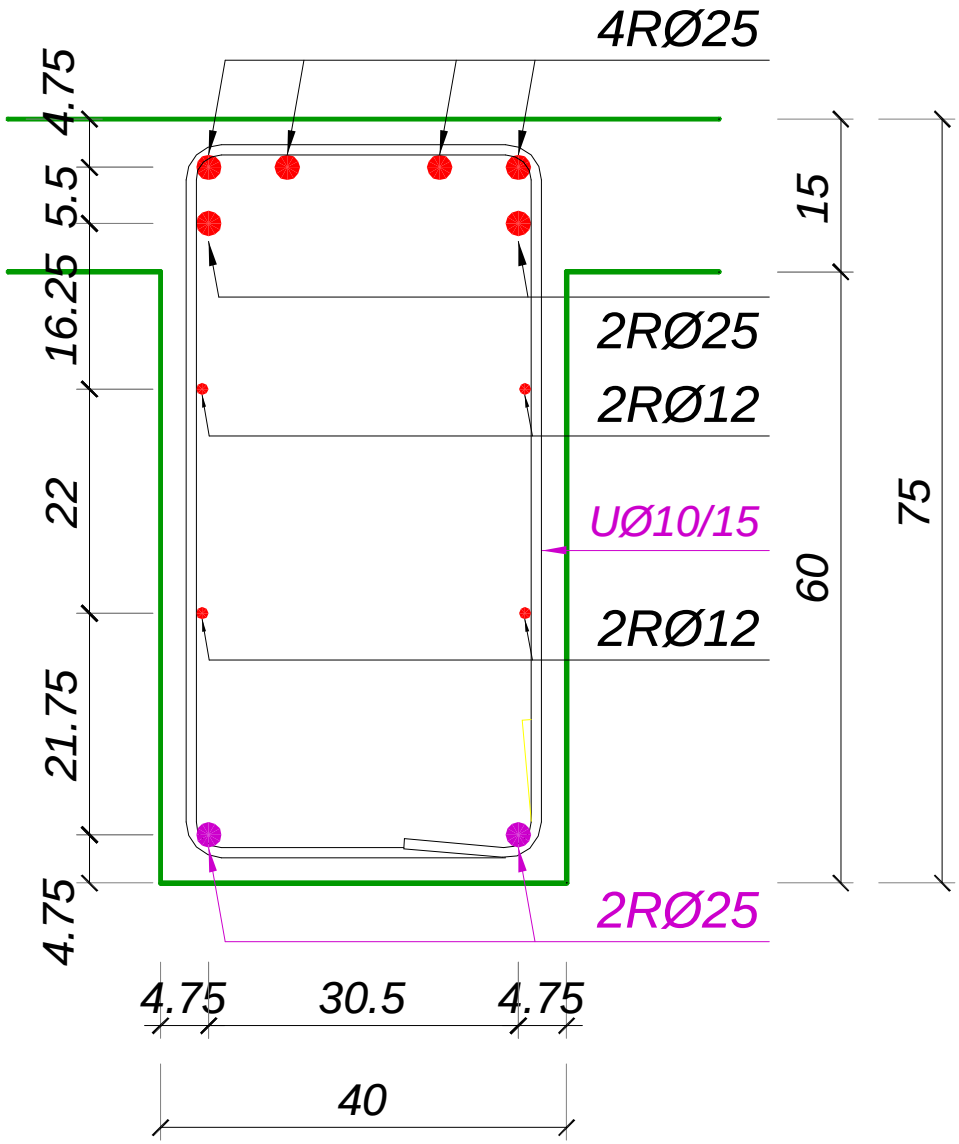
$$k = \frac{68}{\sqrt{\frac{702 \times 10^2}{40 \times 2.05}}} = 2.324 \xrightarrow{TABL.} \begin{matrix} \varepsilon_b / \varepsilon_a = 3.45 / 10‰ \\ \bar{\mu} = 20.694\% \end{matrix}$$

ε_a	ε_b	s	α_b	η	ζ	μ_{1M} %	k
10	**3.45**	**0.257**	**0.807**	**0.415**	**0.894**	**20.694**	**2.325**

$$A_a = 20.694 \times \frac{40 \times 68}{100} \times \frac{2.05}{40} = 28.85\,cm^2$$

usvojeno: **6RØ25** ($29.45\ cm^2$)

Dimenzionisanje - oslonac



$a^{I} = 2.5 + 1.0 + 2.5/2 = 4.75$ cm

$a^{II} = 4.75 + 3.0 + 2.5 = 10.25$ cm

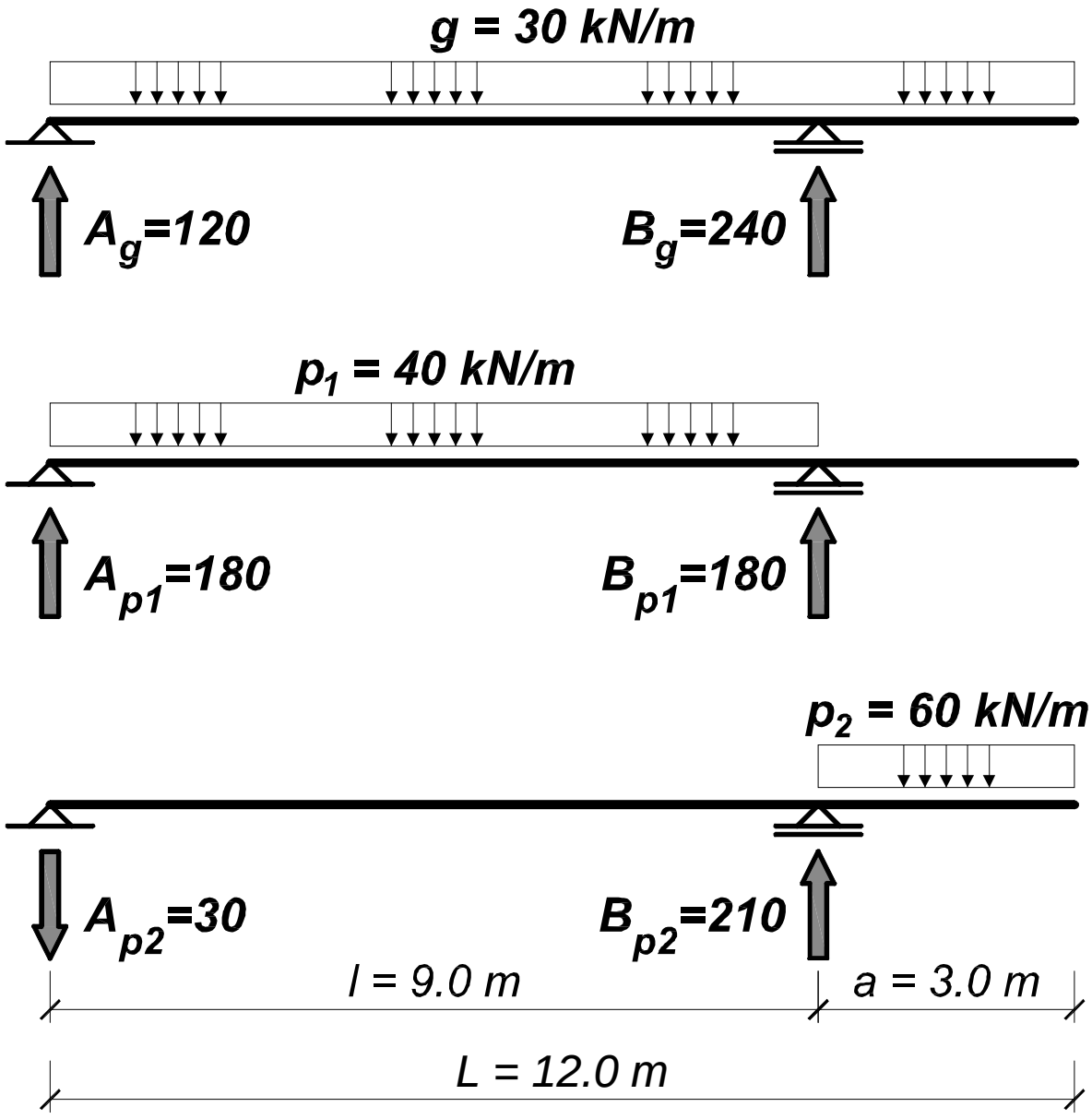
$a_1 = (4 \times 4.75 + 2 \times 10.25)/6$

$a_1 = 6.58$ cm

$h = 75 - 6.58 = 68.42$ cm

$h \approx 68$ cm $= h_{rač.}$

Reakcije oslonaca



$B_g = (30 \times 12^2/2)/9 = 240\ kN$

$A_g = 30 \times 12 - 240 = 120\ kN$

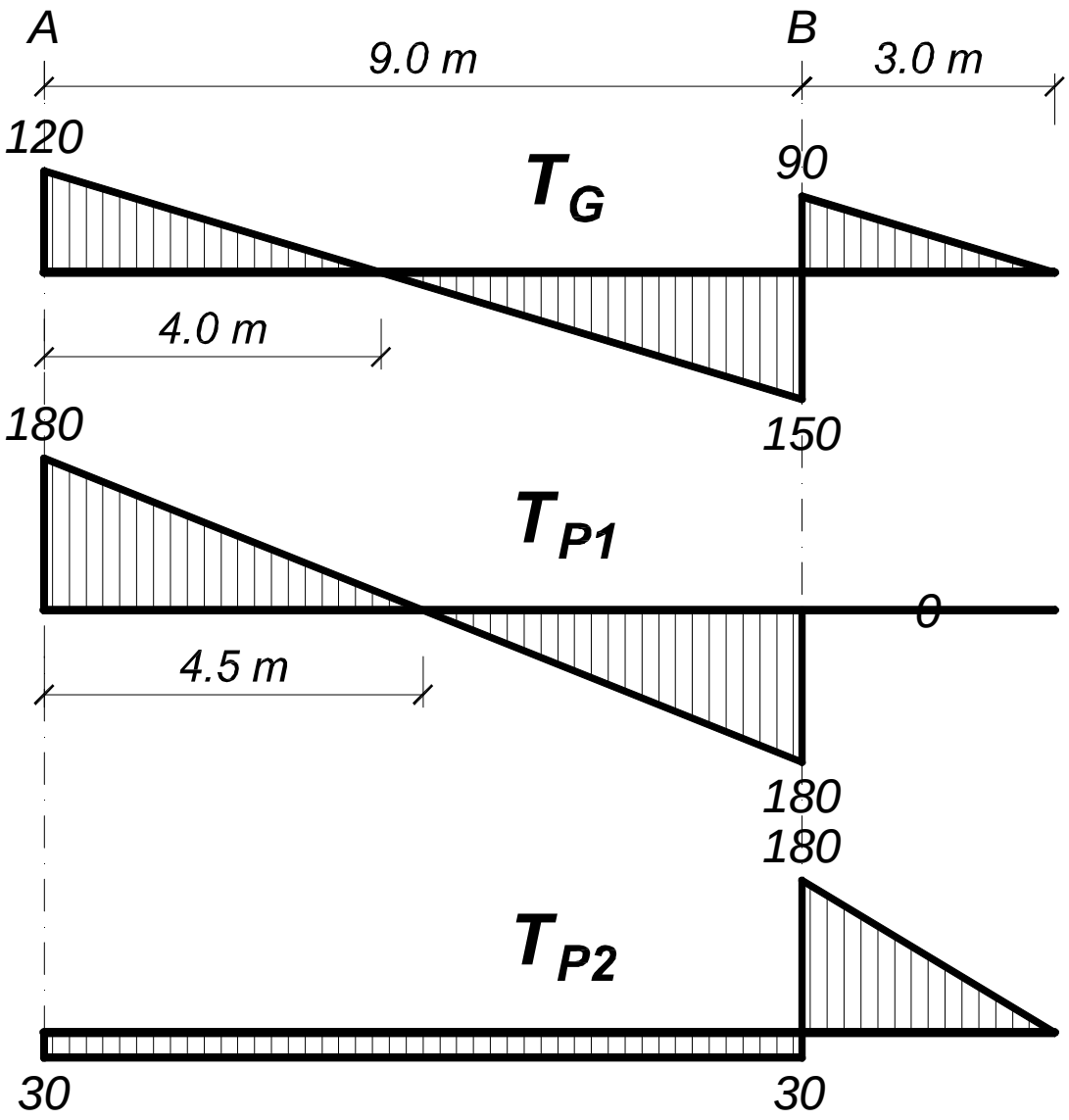
$A_{p1} = B_{p1} = 40 \times 9/2 = 180\ kN$

$B_{p2} = [(60 \times 3 \times (9+3/2)]/9$

$B_{p2} = 210\ kN$

$A_{p2} = 60 \times 3 - 210 = -30\ kN$

Dijagrami transverzalnih sila



$T_g^A = A_g = 120\ kN$

B desno:

$T_g^{B,d} = g \times a = 30 \times 3 = 90\ kN$

B levo:

$T_g^{B,l} = T_g^{B,d} - B_g$

$T_g^{B,l} = 90 - 240 = -150\ kN$

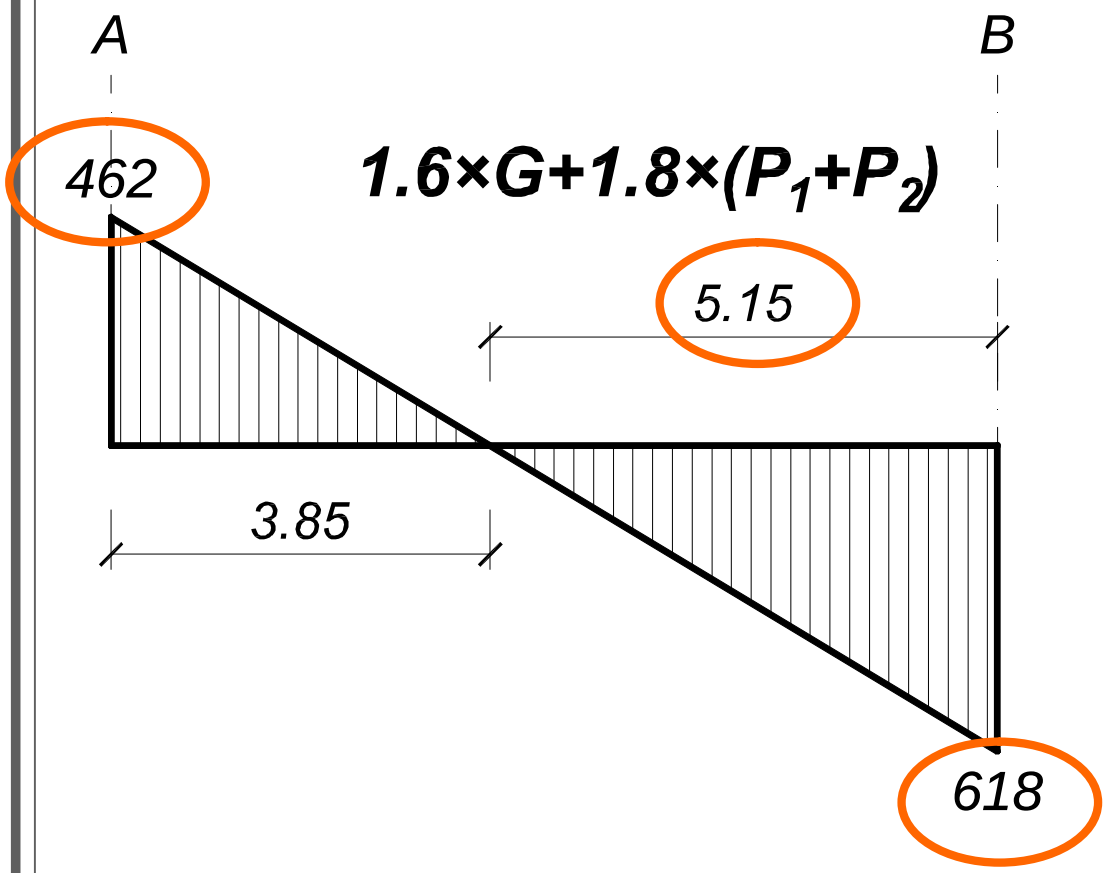
$T_{p1}^A = -T_{p1}^{B,l} = 180\ kN$

$T_{p2}^A = A_{p2} = -30\ kN = T_{p2}^{B,l}$

$T_{p2}^{B,d} = 60 \times 3 = 180\ kN$

Presek B levo: određivanje sile T_u

Maksimalna sila T_u se javlja u preseku B levo, pri istovremenom delovanju svih opterećenja.



presek B levo:

$$_{max.}T_u^{B,l} = 1.6\times150 + 1.8\times(180+30)$$

$$_{max.}T_u^{B,l} = 618\ kN$$

presek A:

$$_{odg.}T_u^{A} = 1.6\times120 + 1.8\times(180-30)$$

$$_{odg.}T_u^{A} = 462\ kN$$

$$l_{0,T} = 618/(618+462)\times9.0$$

$$l_{0,T} = 5.15\ m$$

Proračun nominalnog napona smicanja

$$\tau_n = \frac{T_{mu}}{b \times z}$$

usvojeno za sve preseke:

$$z \approx 0.9 \times h = 0.9 \times 68 = 61.2 \text{ cm}$$

$$\tau_n = \frac{618}{40 \times 61.2} = 0.252 \frac{kN}{cm^2} > \tau_r = 0.11 \frac{kN}{cm^2}$$

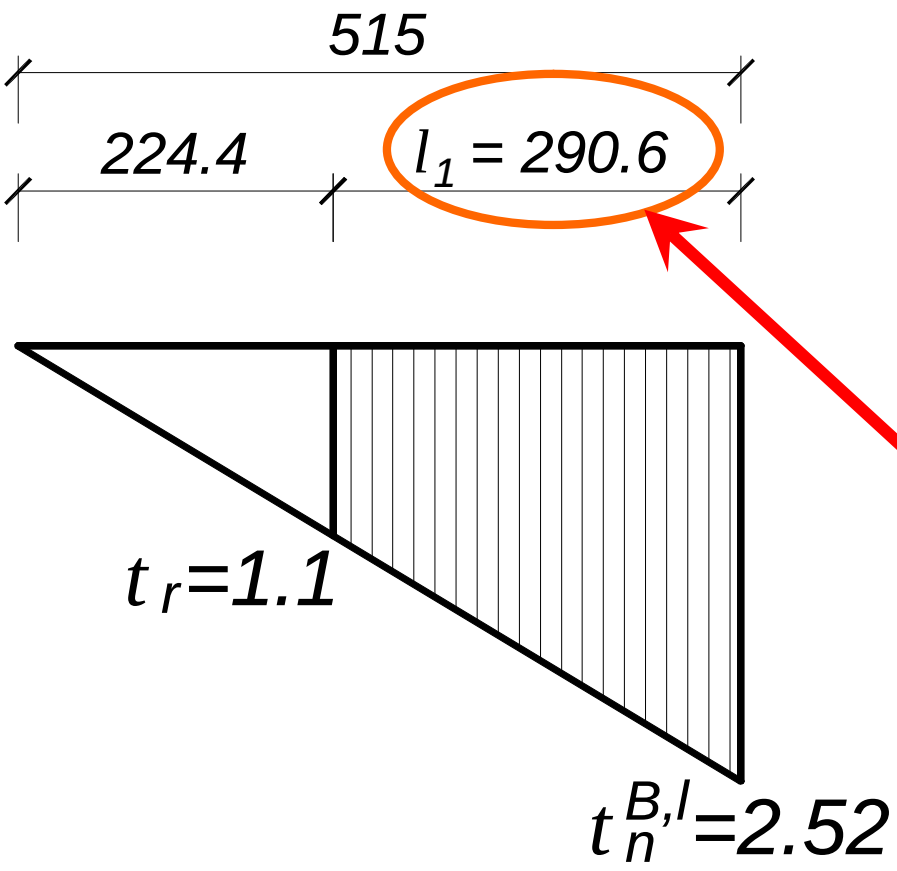
MB	15	20	30	40	50	60	[MPa]
t_r	0.6	0.8	1.1	1.3	1.5	1.6	[MPa]

(član 89 Pravilnika BAB 87)

Određivanje dužine osiguranja

Dužina na kojoj je prekoračen nominalni napon smicanja.

Na ovom delu nosača je potrebno proračunati POPREČNU i PODUŽNU armaturu za prihvatanje uticaja od dejstva T sila



$$\lambda_1 = l_{0,T} \times \left(1 - \frac{\tau_r}{\tau_n^{B,levo}}\right)$$

$$\lambda_1 = 515 \times \left(1 - \frac{1.1}{2.52}\right)$$

$$\boxed{l_1 = 290.6 \text{ cm}}$$

Određivanje redukovane T sile

Kako je $t_n < 3t_r$, proračunava se REDUKOVANA TRANSVERZALNA SILA (član 91 PBAB 87):

$$T_{Ru} = T_{mu} - T_{bu}$$

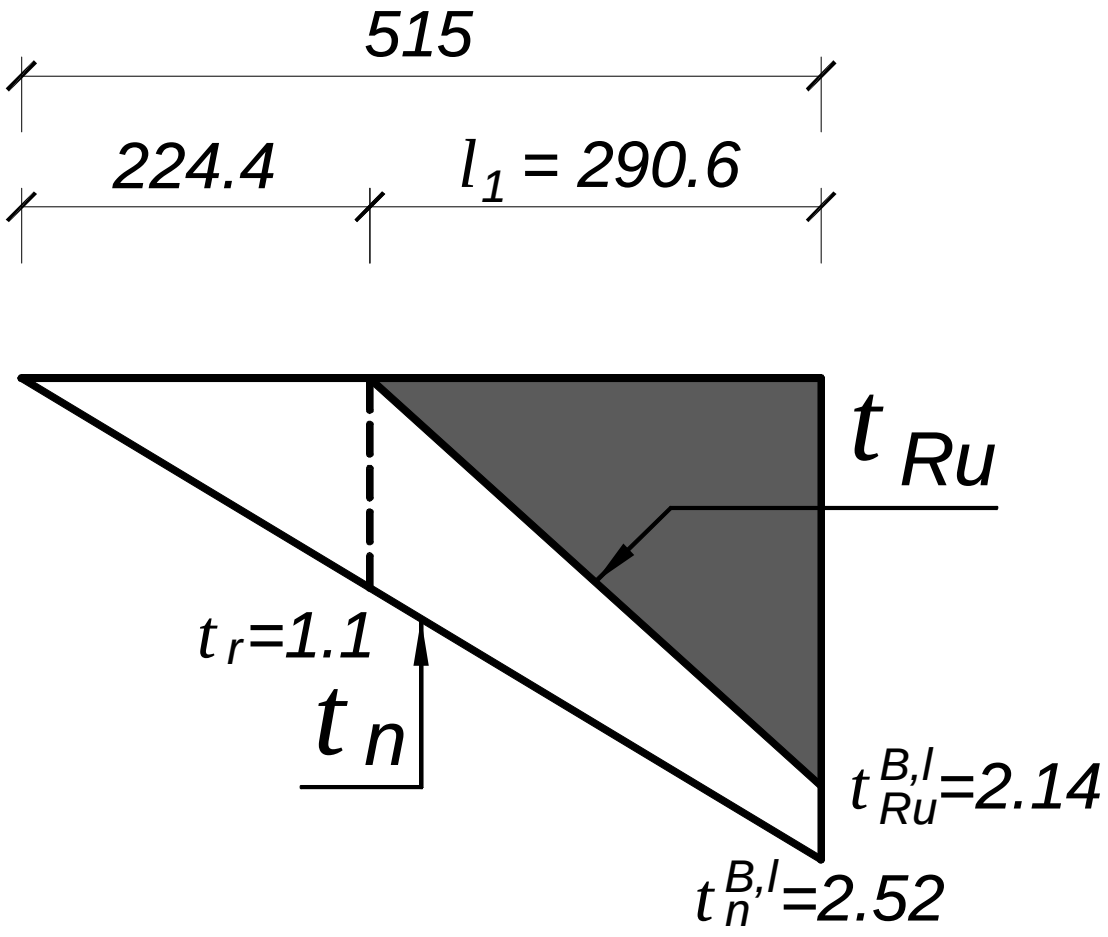
$$T_{bu} = \frac{1}{2} \times (3\tau_r - \tau_n) \times b \times z$$

$$T_{bu} = \frac{1}{2} \times (3 \times 0.11 - 0.252) \times 40 \times 61.2 = 94.9\,kN$$

$$T_{Ru} = T_{mu} - T_{bu} = 618 - 94.9 = 523.1\,kN$$

$$\tau_{Ru} = \frac{T_{Ru}}{b \times z} = \frac{523.1}{40 \times 61.2} = 0.214\,\frac{kN}{cm^2}$$

Određivanje redukovanog napona t_{Ru}



$$\tau_{Ru} = \frac{3}{2} \times (\tau_n - \tau_r)$$

$$\tau_{Ru}^{B,l} = \frac{3}{2} \times (2.52 - 1.1)$$

$$\tau_{Ru}^{B,l} = 2.14\,MPa$$

Određivanje poprečne armature

OSIGURANJE UZENGIJAMA

$$\tau_{u,u} = \frac{m \times a_u^{(1)}}{b \times e_u} \times \sigma_v \times \left(\cos\alpha + \sin\alpha \times ctg\theta\right)$$

usvojeno: ***m = 2*** ***(dvosečne uzengije)***

q = 45°

a = 90° ***(vertikalne uzengije)***

Izjednačavanjem napona koji mogu prihvatitii uzengije i maksimalnog REDUKOVANOG napona smicanja t_{Ru}***, sledi:***

Određivanje poprečne armature

$$e_u = \frac{m \times a_u^{(1)}}{b \times \tau_{Ru,MAX.}} \times \sigma_v \times \left(\cos\alpha + \sin\alpha \times ctg\theta\right)$$

$$e_u = \frac{2 \times a_u^{(1)}}{40 \times 0.214} \times 40 \times \left(\cos 90° + \sin 90° \times ctg\,45°\right)$$

$$e_u = 9.36 \times a_u^{(1)}$$

Ø10 Þ $a_u^{(1)} = 0.785\ cm^2$

$e_u = 9.36 \times 0.785 = 7.35\ cm$

potrebno: URØ10/7

Određivanje poprečne armature

Kako je rastojanje uzengija vrlo malo, na raspolaganju stoje sledeće mogućnosti:

- povećanje prečnika (max. RØ12, Ø16, čl. 140 BAB 87)

Ø12 Þ $a_u^{(1)}$ = 1.13 cm²: e_u = 9.36×1.13 = 10.6 cm

potrebno: URØ12/10 (m=2)

- povećanje sečnosti (m=4)

$$e_u = \frac{m \times a_u^{(1)}}{b \times \tau_{Ru,MAX.}} \times \sigma_v \times (\cos\alpha + \sin\alpha \times ctg\theta)$$

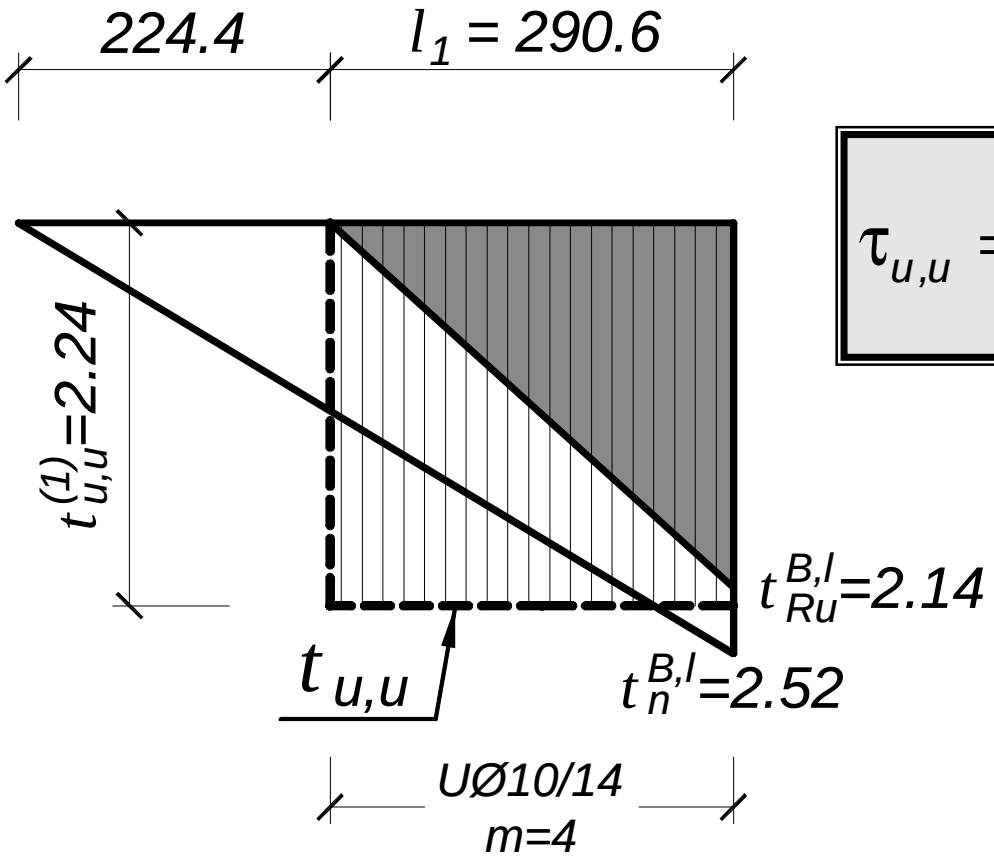
e_u = 2×7.35 = 14.7 cm

potrebno: URØ10/14 (m=4)

- primena KOSO POVIJENIH profila

Određivanje poprečne armature

Usvajanjem URØ10/14 (m=4) na čitavoj dužini osiguranja l_1 proračun bi mogao biti završen. Nosivost usvojenih uzengija prikazana je dijagramom $t_{u,u}$



$$\tau_{u,u} = \frac{m \cdot a_u^{(1)}}{b \cdot e_u} \cdot \sigma_v \cdot \left(\cos\alpha + \sin\alpha \cdot ctg\theta\right)$$

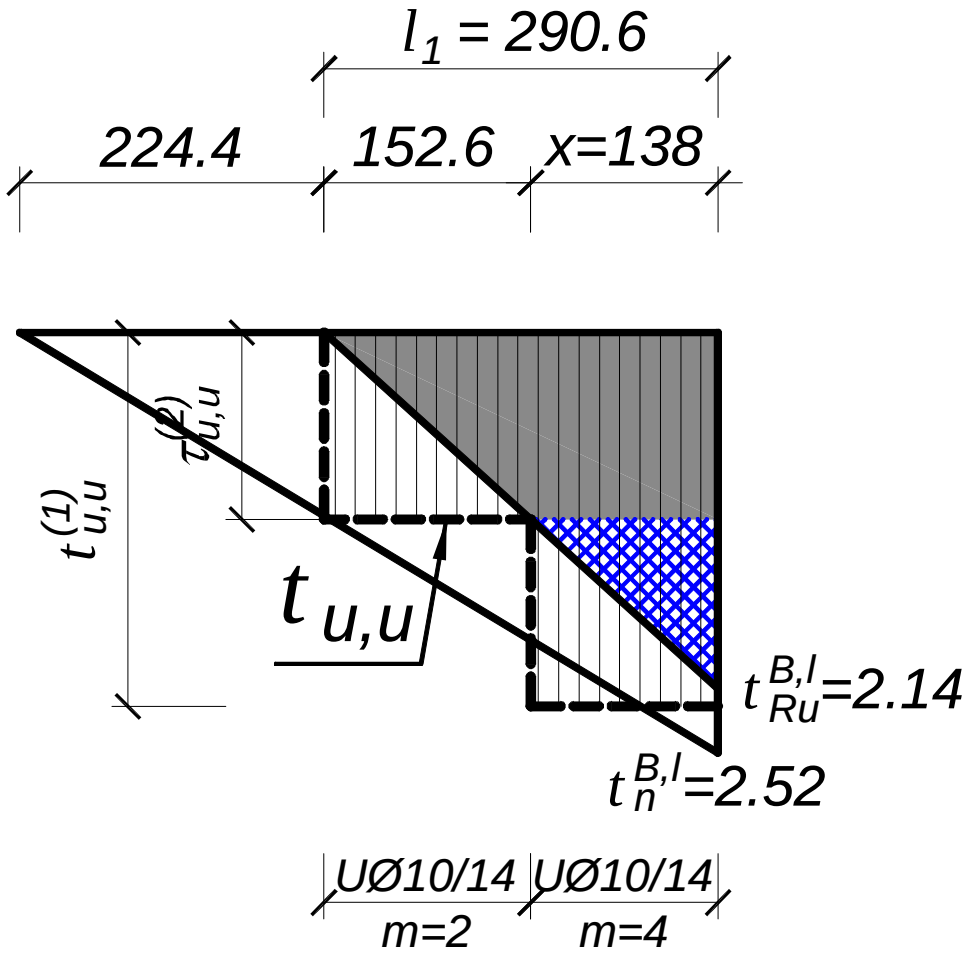
$$\alpha = 90^\circ \;;\; \theta = 45^\circ :$$

$$\cos\alpha + \sin\alpha \cdot ctg\theta = 1$$

$$\tau^{(1)}_{u,u} = \frac{4 \times 0.785}{40 \times 14} \times 40 = 0.224 \frac{kN}{cm^2}$$

Određivanje poprečne armature

S obzirom na veliku količinu armature za osiguranje i oblik dijagrama t_{Ru}, racionalno je odrediti dužinu na kojoj su dovoljne dvosečne uzengije URØ10/14:



$$\tau^{(2)}_{u,u} = \frac{2 \times 0.785}{40 \times 14} \times 40 = 0.112 \frac{kN}{cm^2}$$

$$x = \lambda_1 \times \left(1 - \frac{\tau^{(2)}_{u,u}}{\tau_{Ru}} \right)$$

$$x = 290.6 \times \left(1 - \frac{1.12}{2.14} \right) = 138\,cm$$

Na delu nosača dužine x=138 cm potrebno je usvojiti četvorosečne uzengije ili koso povijene profile

Određivanje poprečne armature

PRIMENA KOSO POVIJENIH PROFILA

Potrebno je na dužini osiguranja obezbediti makar MINIMALNE vertikalne uzengije:

$$\mu_{uz} = \frac{m \cdot a_u^{(1)}}{b \cdot e_u} \geq 0.2\%$$

Pored toga, na dužini osiguranja MAKSIMALNO RASTOJANJE uzengija mora zadovoljiti sledeće uslove:

$$e_u \leq \left\{ \begin{array}{c} 25\,cm \\ b = 40 \\ h/2 = 68/2 = 34 \end{array} \right\} = 25\,cm$$

Određivanje poprečne armature

Za presek širine b=40 cm, armiran DVOSEČNIM uzengijama, sledi:

$$e_u = \frac{m \cdot a_u^{(1)}}{b \cdot \mu_{uz,min.}} = \frac{2 \times a_u^{(1)}}{40 \times 0.2 \times 10^{-2}} = 25 \times a_u^{(1)}$$

UØ8 Þ ***$e_{u,max}$ = 25 × 0.503 = 12.6 cm*** Þ ***RØ8/12.5***

UØ10 Þ ***$e_{u,max}$ = 25 × 0.785 = 19.6 cm*** Þ ***RØ10/15***

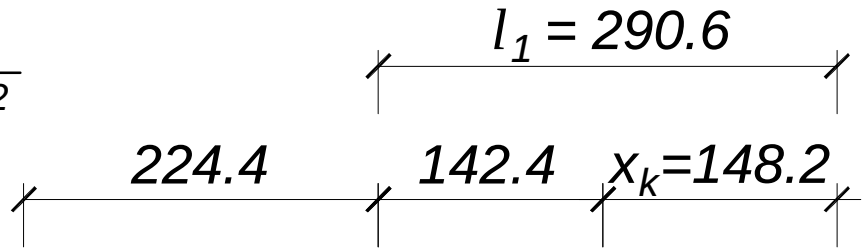
UØ12 Þ ***$e_{u,max}$ = 25 × 1.13 = 28.3 cm*** Þ ***RØ12/25***

usvojeno: URØ10/15 (m=2)

Određivanje poprečne armature

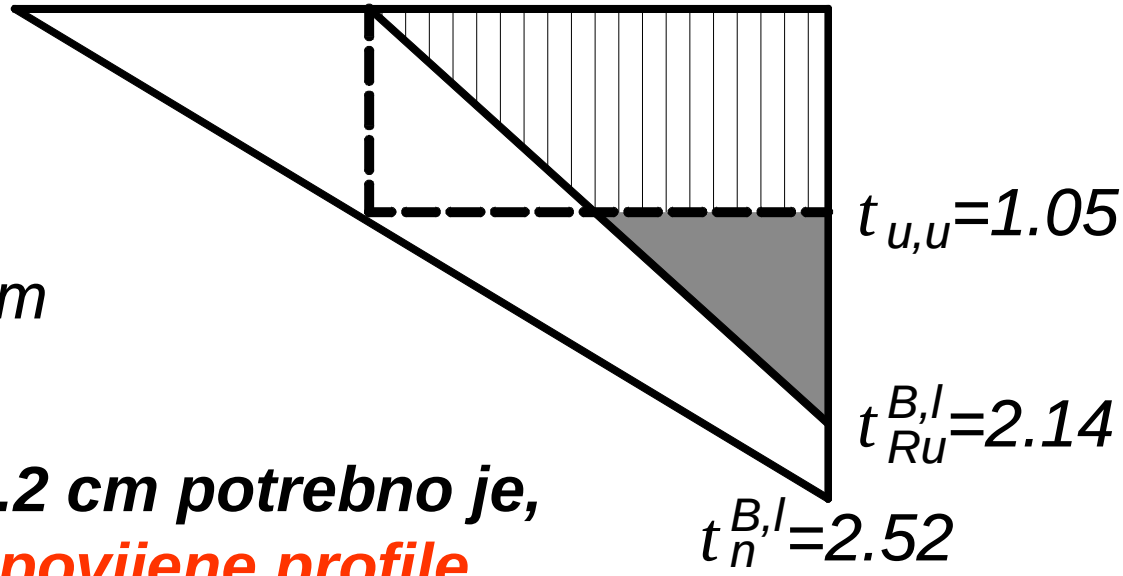
usvojeno: ***URØ10/15*** *(m=2)*

$$\tau_{u,u} = \frac{2 \times 0.785}{40 \times 15} \times 40 = 0.105 \frac{kN}{cm^2}$$



$$x_k = \lambda_1 \times \left(1 - \frac{\tau_{u,u}}{\tau_{Ru}}\right)$$

$$x_k = 290.6 \times \left(1 - \frac{1.05}{2.14}\right) = 148.2\,cm$$



Na delu nosača dužine x_k=148.2 cm potrebno je, pored uzengija, usvojiti koso povijene profile

Određivanje poprečne armature

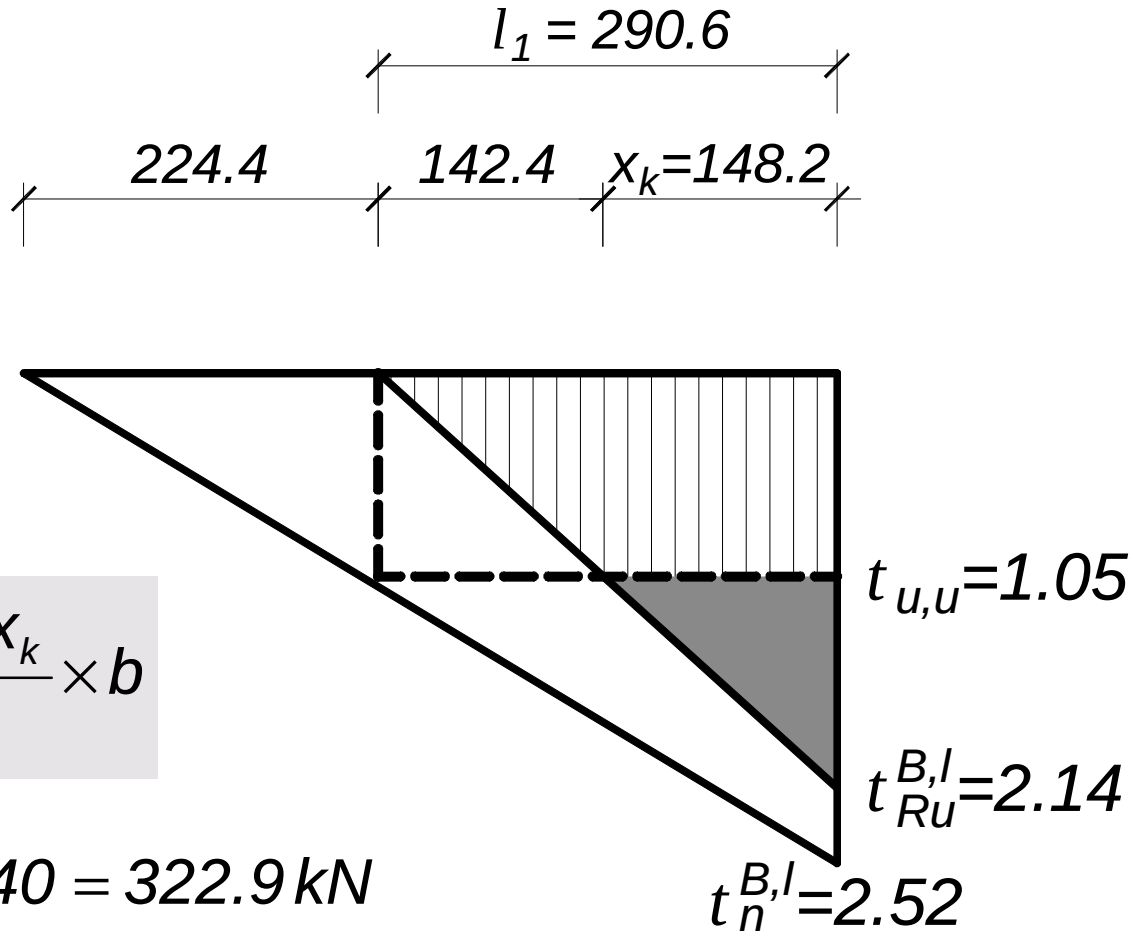
Ukupna sila smicanja, tj. horizontalna sila veze na dužini osiguranja nosača $l = b - a$:

$$H_{vu} = \int_{x=a}^{x=b} \frac{T_{Ru}}{z} dx$$

$$H_{vu} = \int_{x=a}^{x=b} \frac{b \cdot z \cdot \tau_{Ru}}{z} dx$$

$$H_{vuk} = b \cdot \int_{x=a}^{x=b} \tau_{Ru} dx = \frac{(\tau_{Ru} - \tau_{u,u}) \times x_k}{2} \times b$$

$$H_{vuk} = \frac{(0.214 - 0.105) \times 148.2}{2} \times 40 = 322.9\,kN$$



Određivanje poprečne armature

Potrebna površina armature $A_{a,k}$ povijene pod uglom a_k u odnosu na osu nosača:

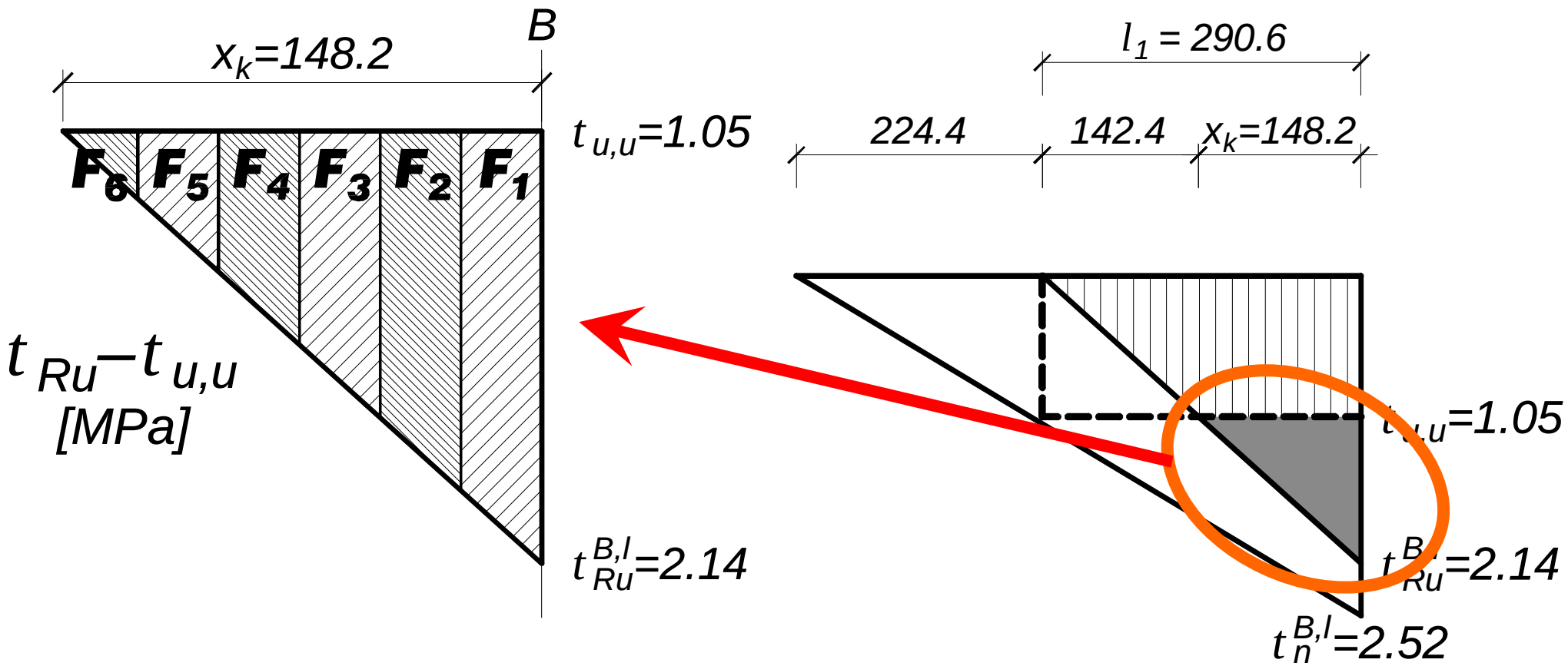
$$A_{a,k} = \frac{H_{vu,k}}{\sigma_v \cdot (\cos\alpha_k + \sin\alpha_k \cdot ctg\theta)}$$

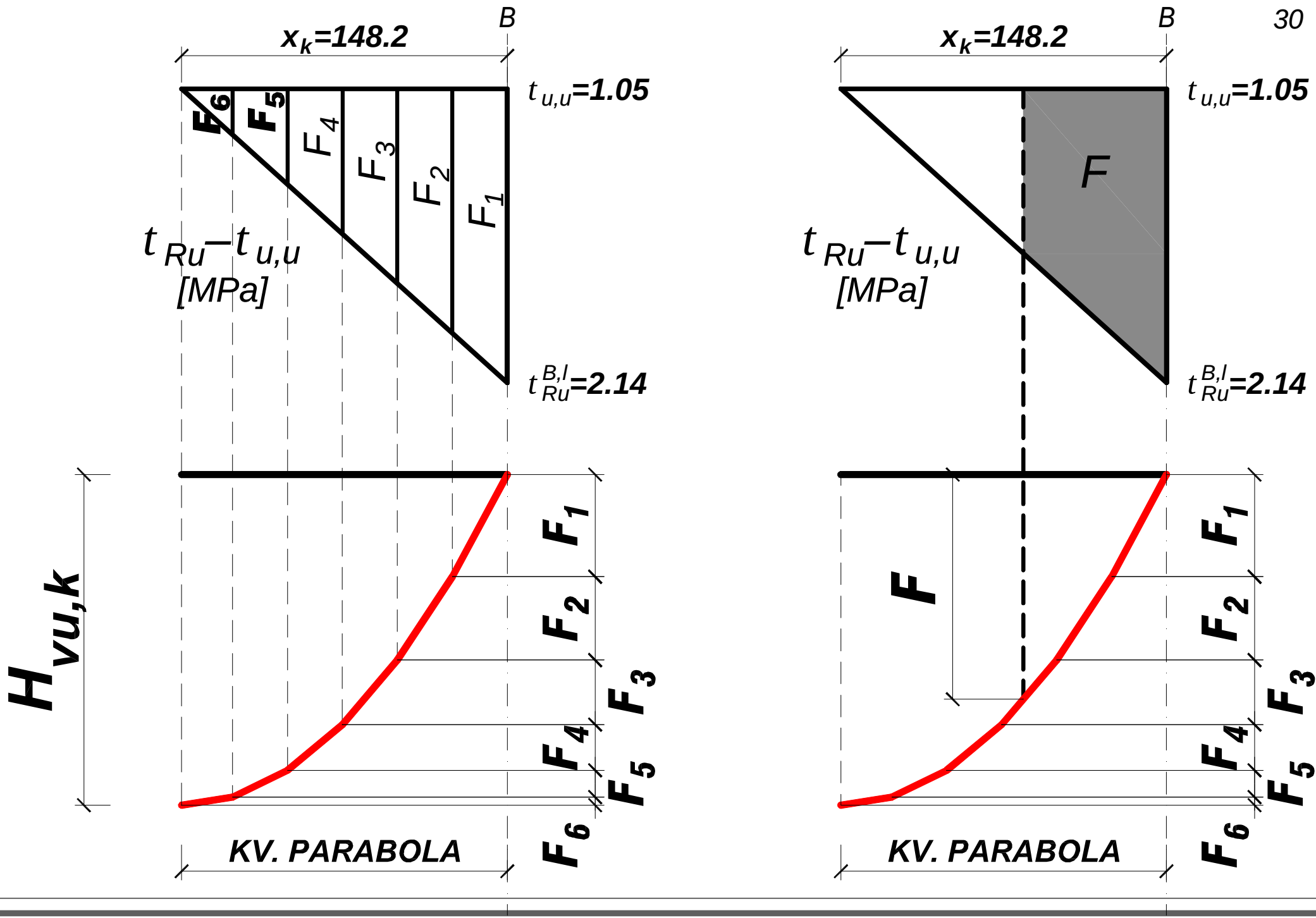
$$\left.\begin{array}{l} \alpha_k = 45° \\ \theta = 45° \end{array}\right\} \Rightarrow \cos\alpha_k + \sin\alpha_k \cdot ctg\theta = \sqrt{2}$$

$$A_{a,k} = \frac{322.9}{40 \times \sqrt{2}} = 5.71\,cm^2$$

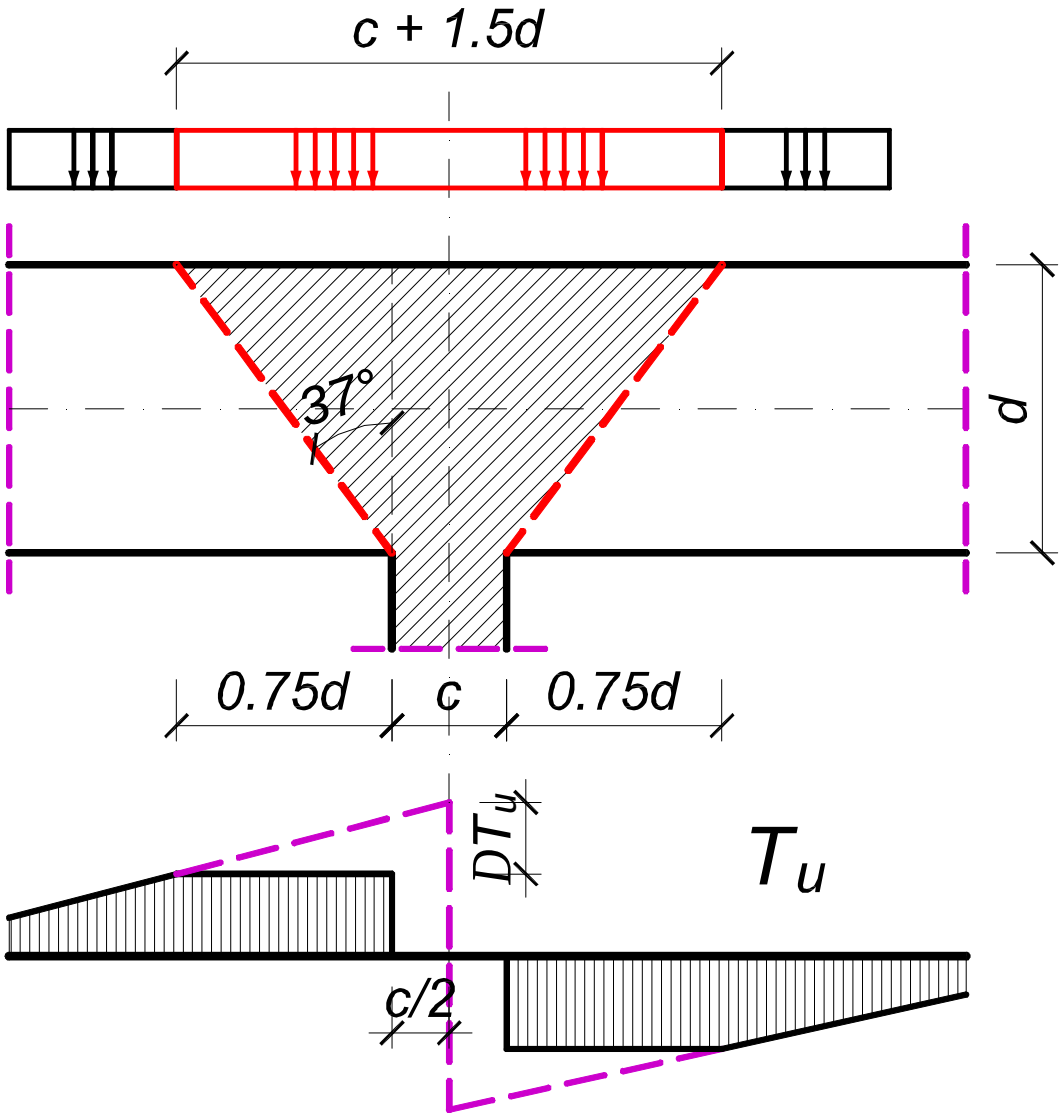
usvojeno: 2RØ25 (9.82 cm²)

Određivanje mesta povijanja kosih profila




B
x_k=148.2
$t_{u,u}$=1.05
F_6
F_5
F_4
F_3
F_2
F_1
$t_{Ru}-t_{u,u}$
[MPa]
$t^{B,l}_{Ru}$=2.14
$H_{vu,k}$
F_1
F_2
F_3
F_4
F_5
F_6
KV. PARABOLA
B
x_k=148.2
$t_{u,u}$=1.05
F
$t_{Ru}-t_{u,u}$
[MPa]
$t^{B,l}_{Ru}$=2.14
F
F_1
F_2
F_3
F_4
F_5
F_6
KV. PARABOLA

Redukcija transverzalnih sila u zoni oslonaca



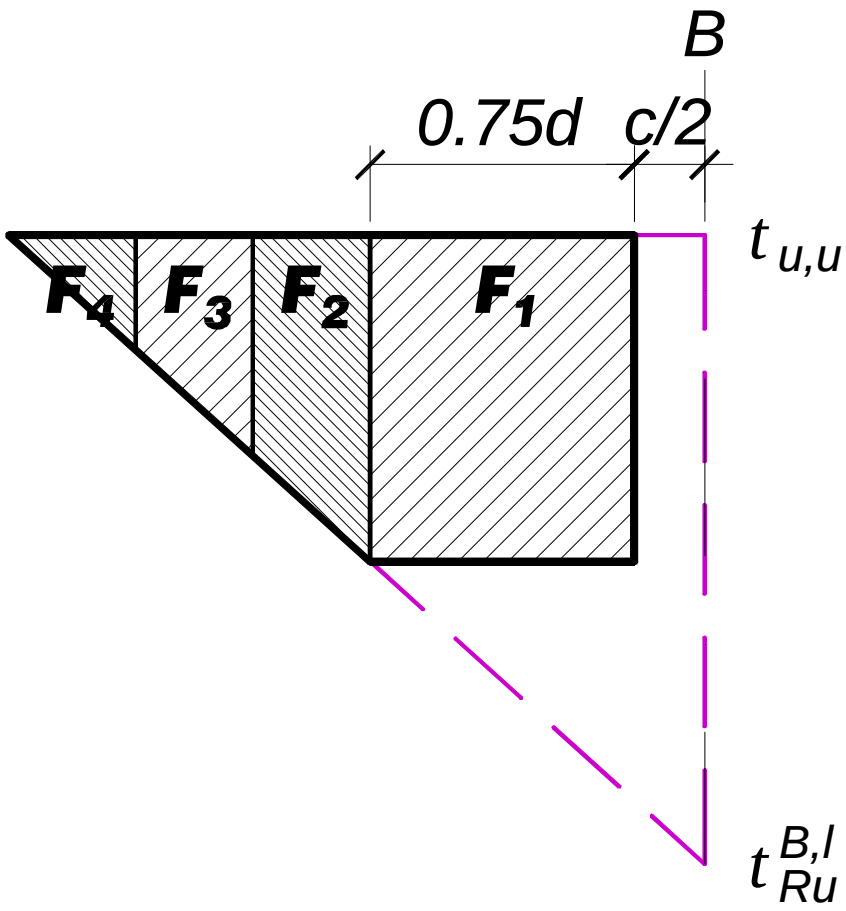
Može se vršiti ublažavanje uticaja transverzalnih sila T_u u zoni oslonca a prema skici levo

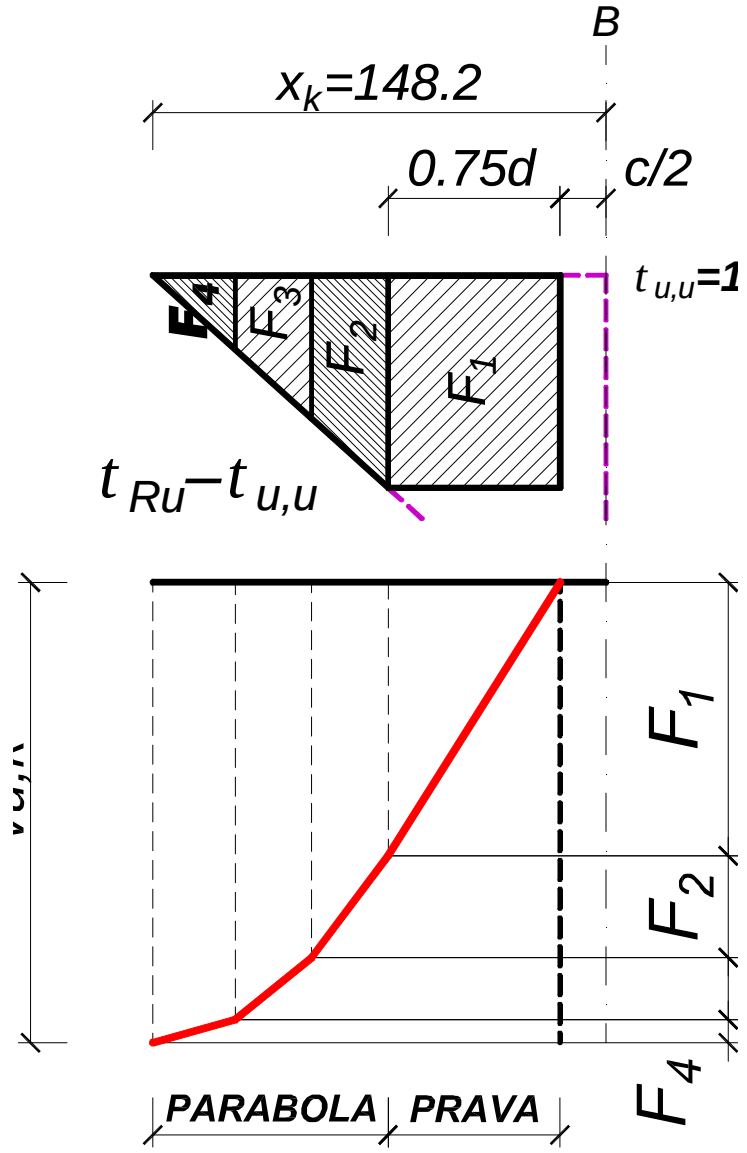
Ovu redukciju dopuštaju:

Član 95. PBAB 87 (proračun po graničnoj nosivosti)

Član 132. PBAB 87 (proračun po dopuštenim naponima)

Određivanje mesta povijanja kosih profila



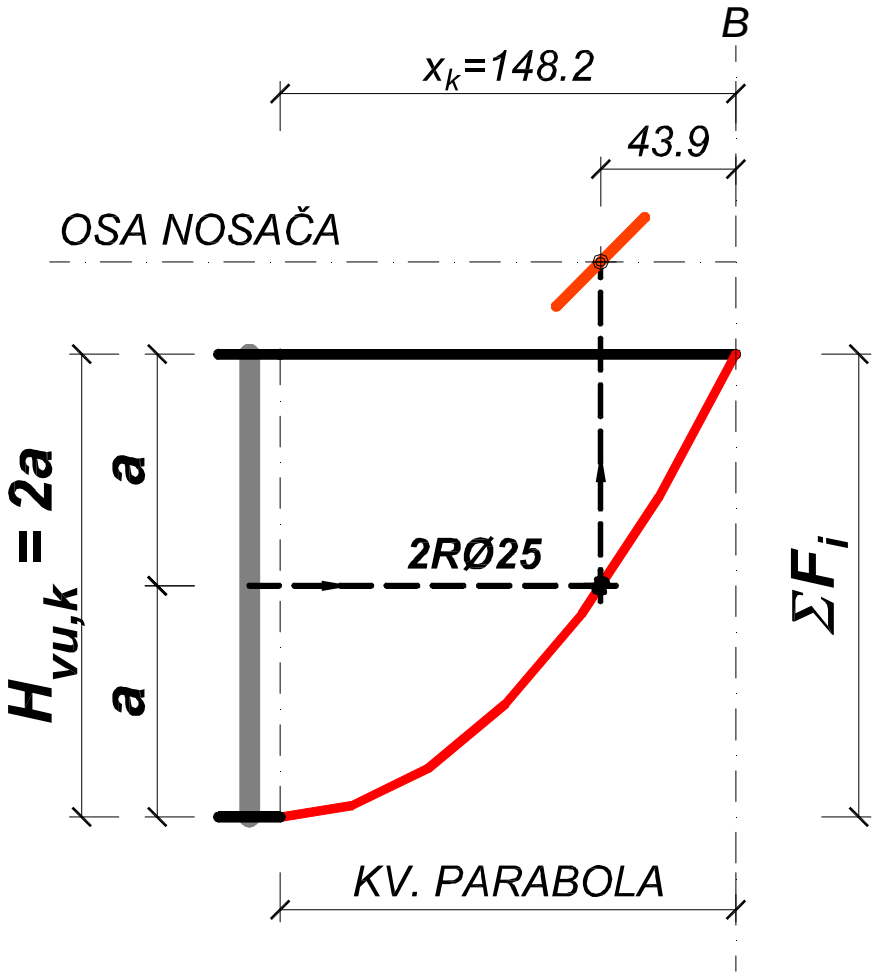


c = 30 cm - širina oslonca

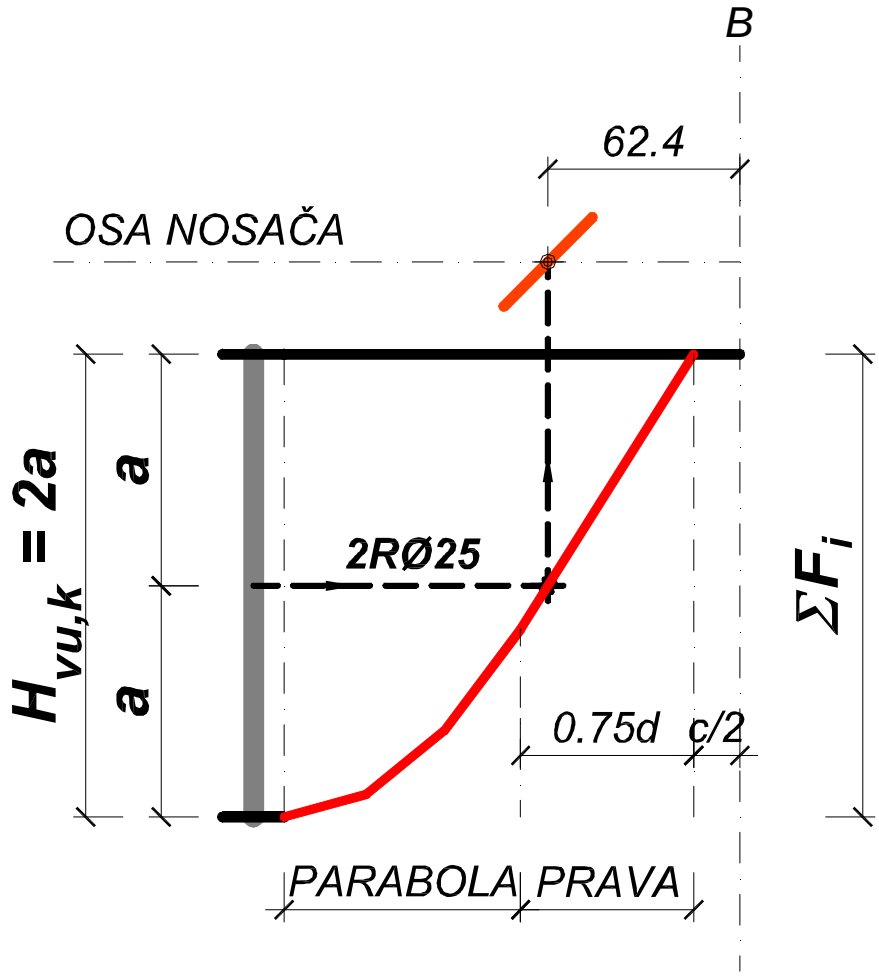
d = 75 cm - visina grede

Određivanje mesta povijanja kosih profila

BEZ REDUKCIJE T-SILA NA OSLONCU

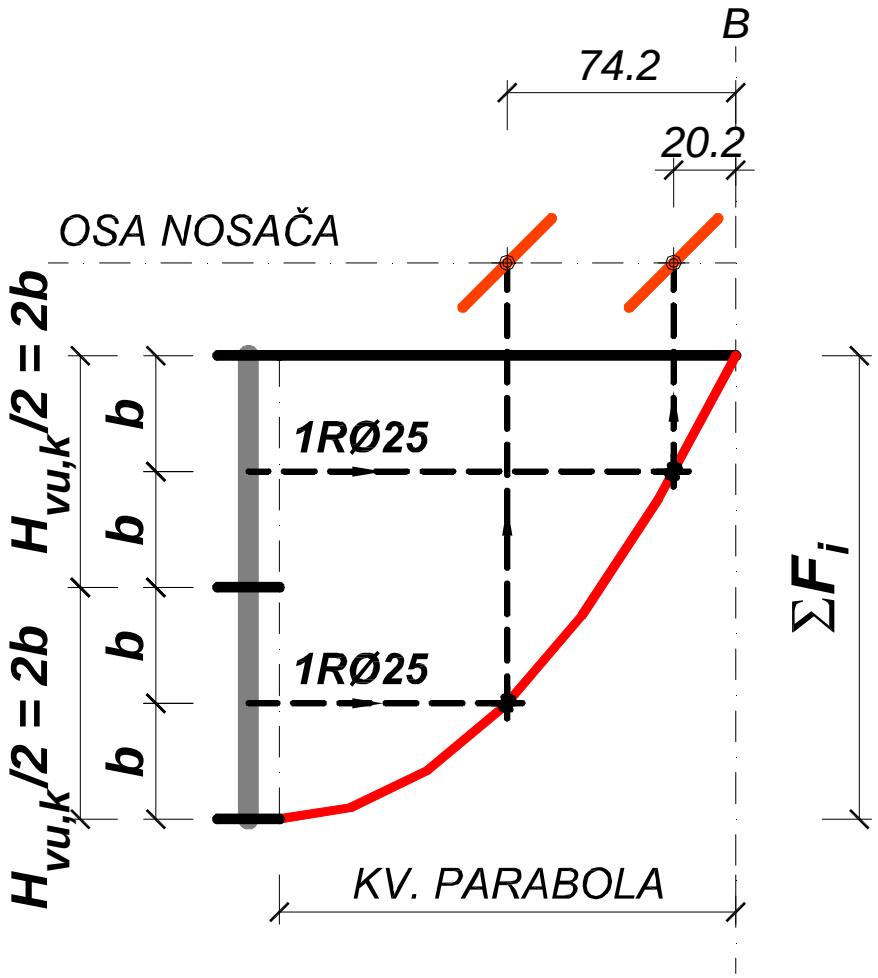


SA REDUKCIJOM T-SILA NA OSLONCU

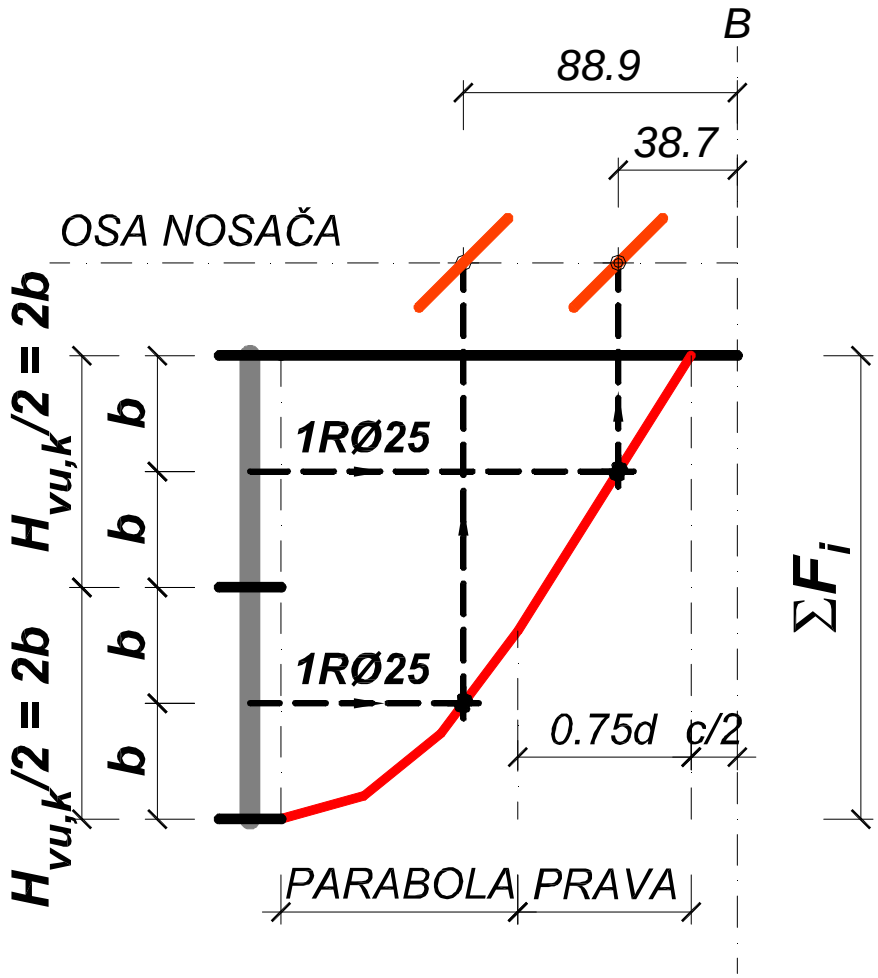


Određivanje mesta povijanja kosih profila

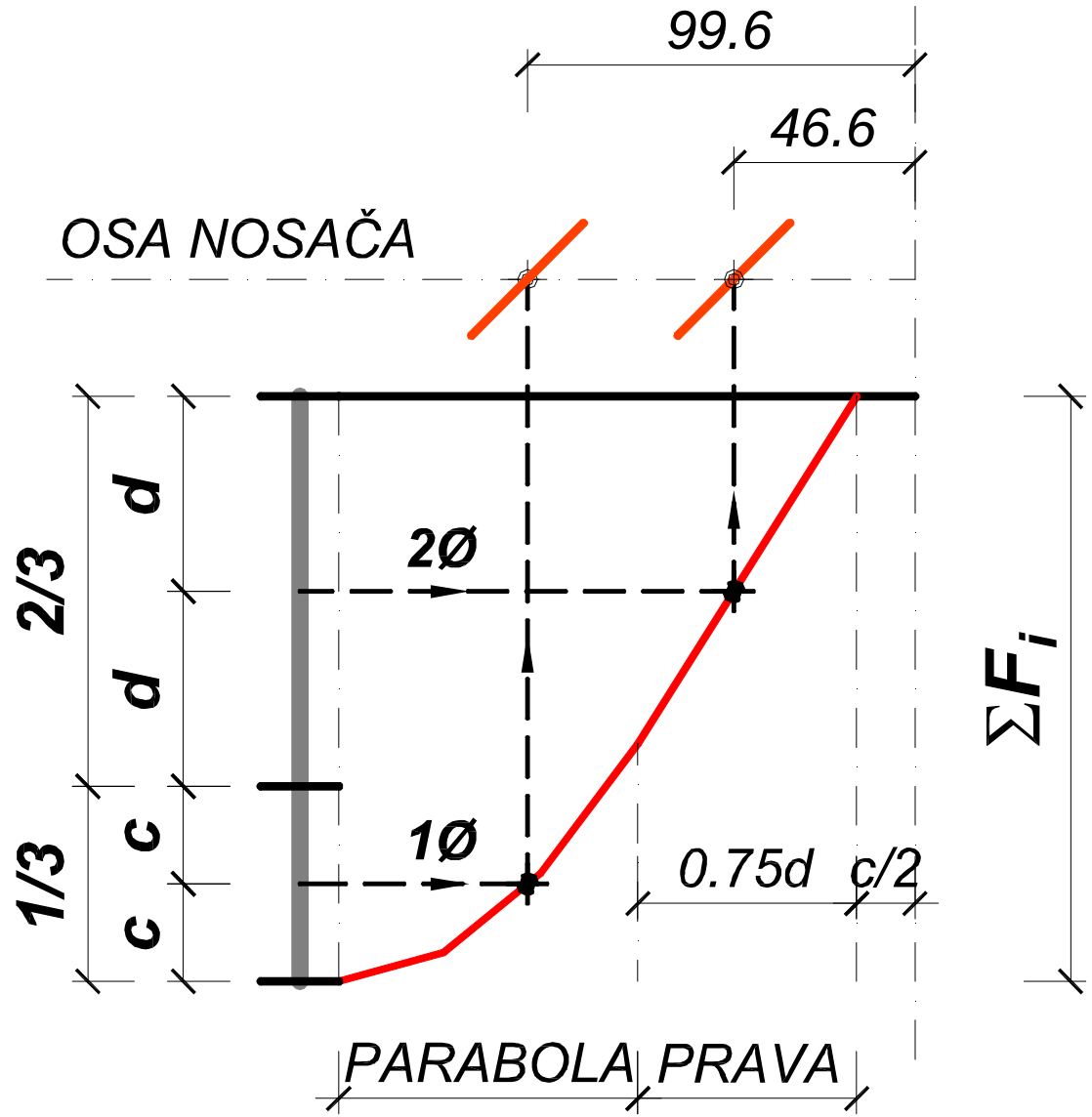
BEZ REDUKCIJE T-SILA NA OSLONCU



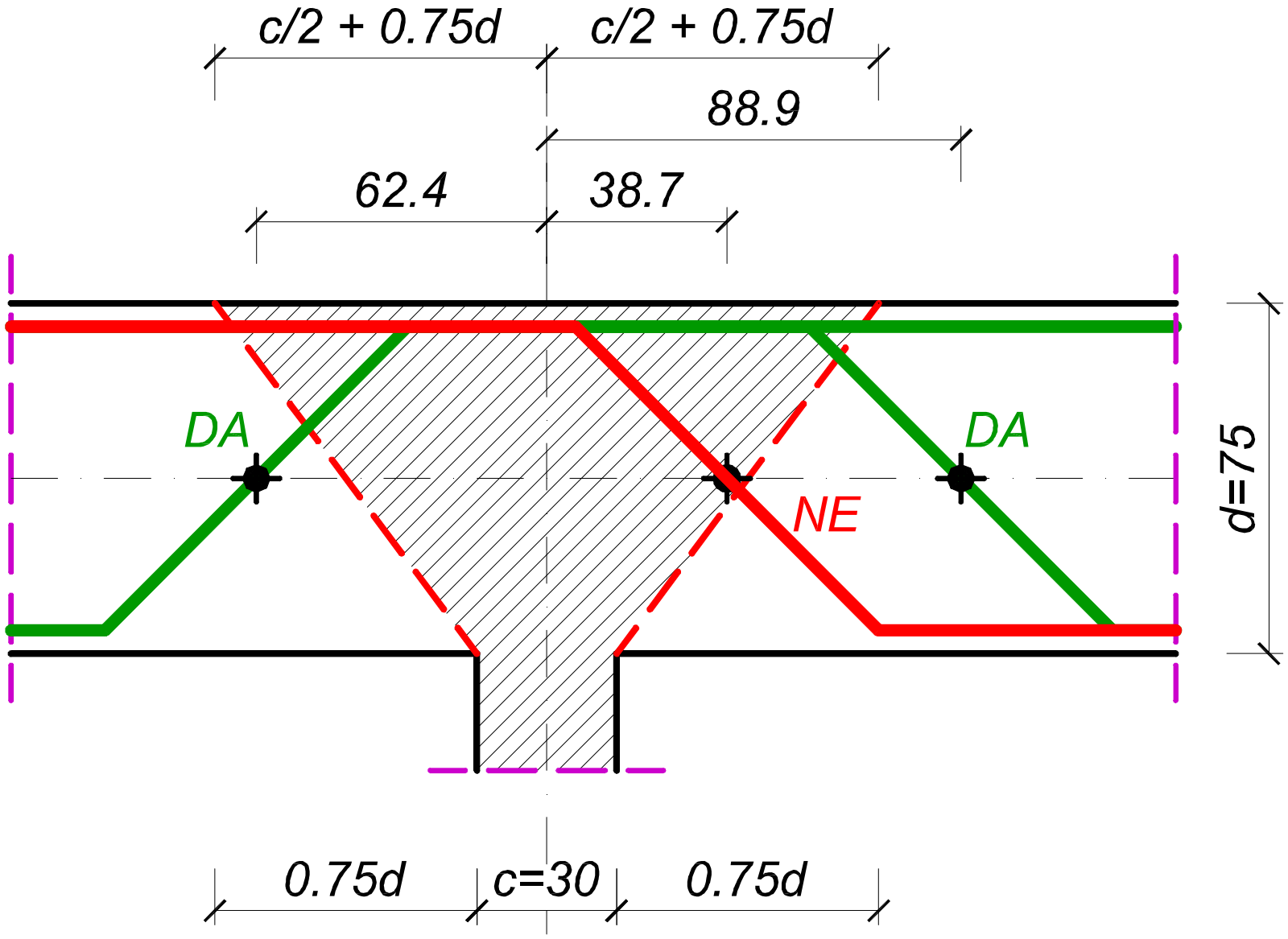
SA REDUKCIJOM T-SILA NA OSLONCU



Određivanje mesta povijanja kosih profila



Određivanje mesta povijanja kosih profila



Određivanje podužne armature

Potrebna površina dodatne podužne armature DA_a usled dejstva T sila, koja se sabira sa postojećom podužnom armaturom sračunatom za M, dobija se iz izraza (član 93 PBAB 87):

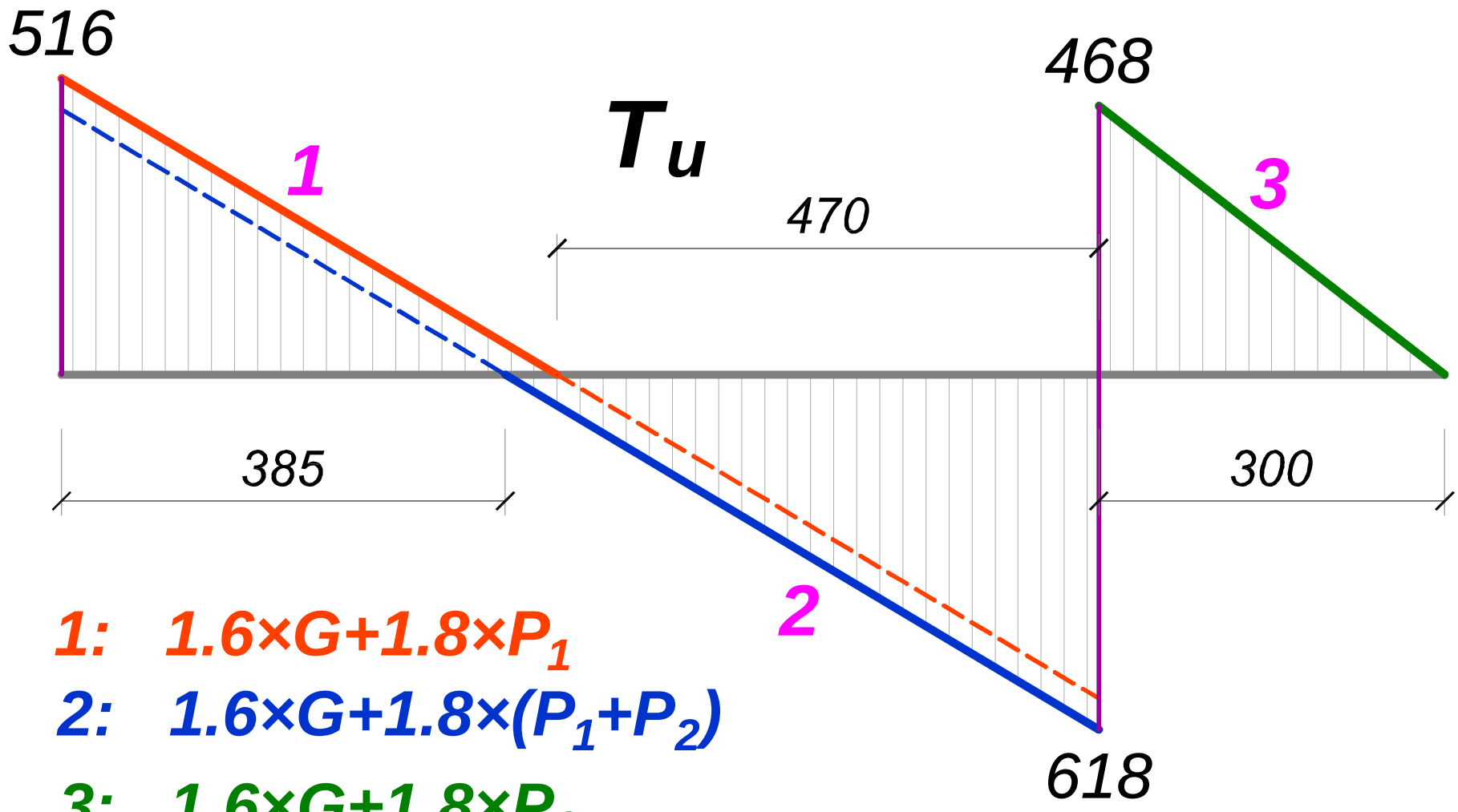
$$\Delta A_a = \frac{T_{mu}}{2\sigma_v} \times (ctg\theta - ctg\alpha)$$

U oblastima momentnih špiceva (npr. srednji oslonci kontinualnih nosača) nema potrebe za armaturom DA_a usled T sila (str. 268. BAB 87, Tom 1 - Priručnik)

Pomeranje linije zatežućih sila:

$$v = \frac{z}{2} \times (ctg\theta - ctg\alpha) \geq \begin{cases} 0.75 \times h \ \ (U\emptyset) \\ 0.50 \times h \ \ (U\emptyset + A_{ak}) \end{cases}$$

Dijagram transverzalnih sila - anvelopa



1: $1.6 \times G + 1.8 \times P_1$

2: $1.6 \times G + 1.8 \times (P_1 + P_2)$

3: $1.6 \times G + 1.8 \times P_2$