Betonske konstrukcije 2

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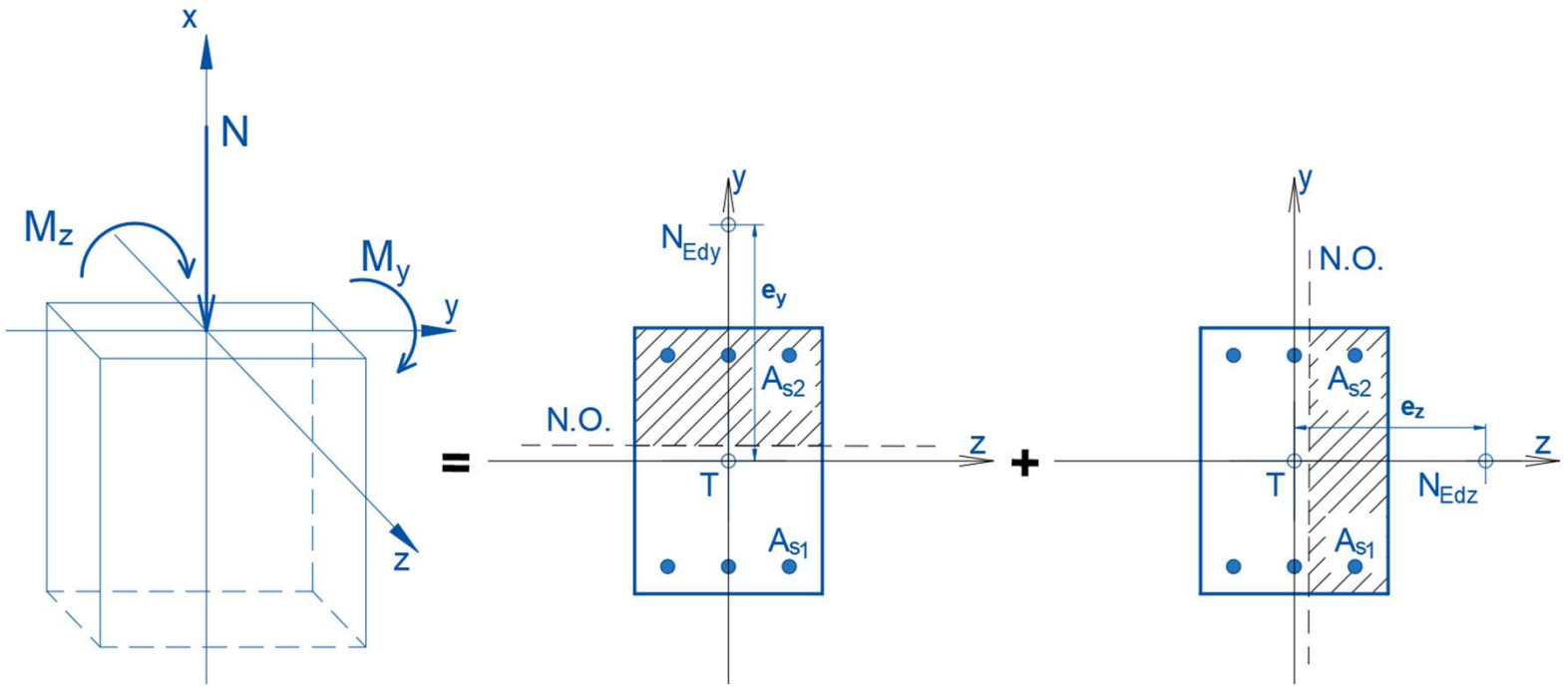
DIMENZIONIRANJE ELEMENATA OPTEREĆENIH DVOOSNIM SAVIJANJEM (I UZDUŽNOM SILOM)

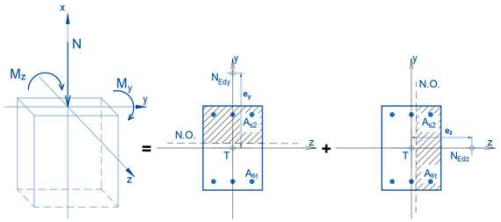
Z. Sorić, T. Kišiček: Betonske konstrukcije 2

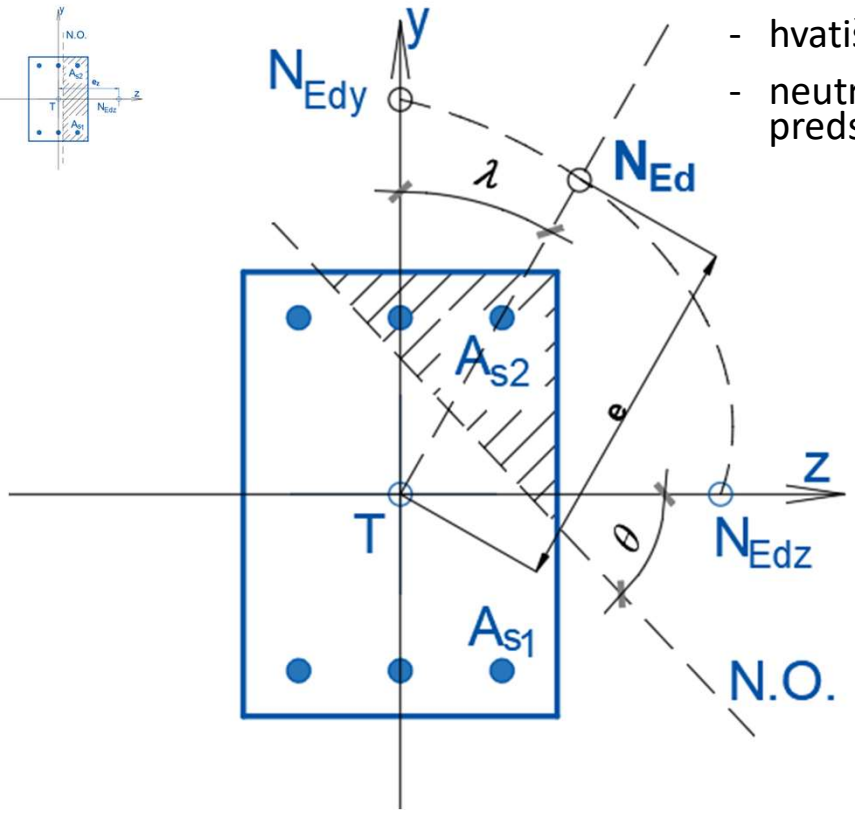
Str. 311 - 334

Dvoosno savijanje



Dvoosno savijanje

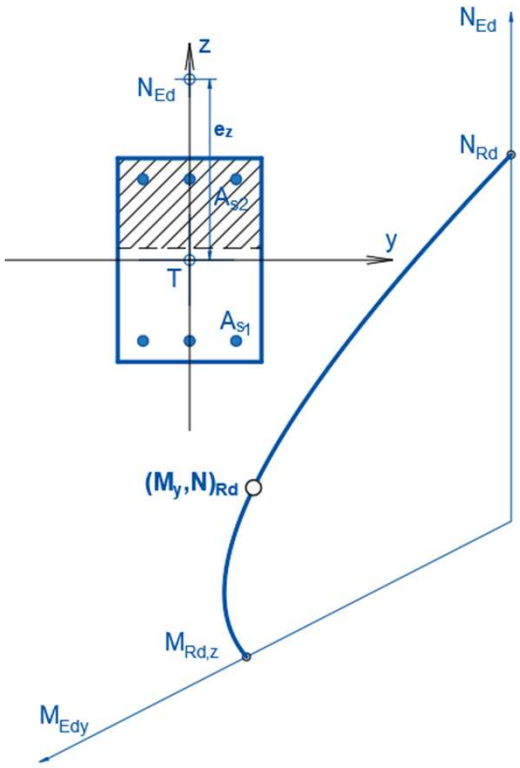




- hvatište sile uvijek izvan glavnih osi
- neutralna os nije okomita na ekscentricitet, već predstavlja os oko koje se štap izvija!

Dvoosno savijanje

$$N_{Rd} = F_{c1d} + F_{sd} = f_{cd} \cdot (A_c - A_{s1} - A_{s2}) + f_{yd} \cdot (A_{s1} + A_{s2})$$



Savijanje oko osi y

$$M_{Edz} = 0$$

$$M_{Rd} = F_{cd} \cdot z = f_{cd} \cdot \alpha_v \cdot \xi \cdot \zeta \cdot d^2 \cdot b = f_{cd} \cdot \mu_{Rd} \cdot d^2 \cdot b$$

μ_{Rd}

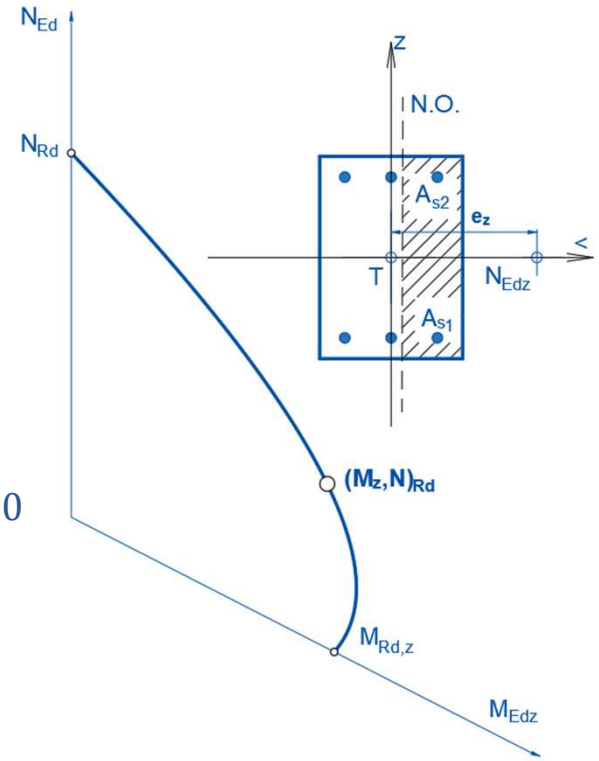
$$M_{Rd} = F_{s1d} \cdot z = A_{s1} \cdot \sigma_{s1} \cdot \zeta \cdot d$$

Dvoosno savijanje

$$N_{Rd} = F_{c1d} + F_{sd} = f_{cd} \cdot (A_c - A_{s1} - A_{s2}) + f_{yd} \cdot (A_{s1} + A_{s2})$$

Savijanje oko osi z

$M_{Edy} = 0$

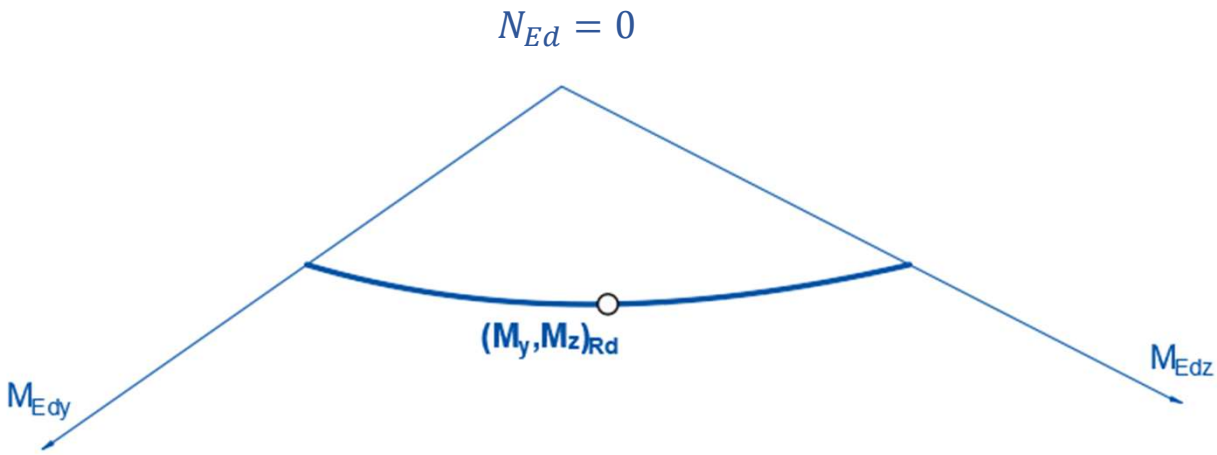


$$M_{Rd} = F_{cd} \cdot z = f_{cd} \cdot \alpha_v \cdot \xi \cdot \zeta \cdot d^2 \cdot b = f_{cd} \cdot \mu_{Rd} \cdot d^2 \cdot b$$

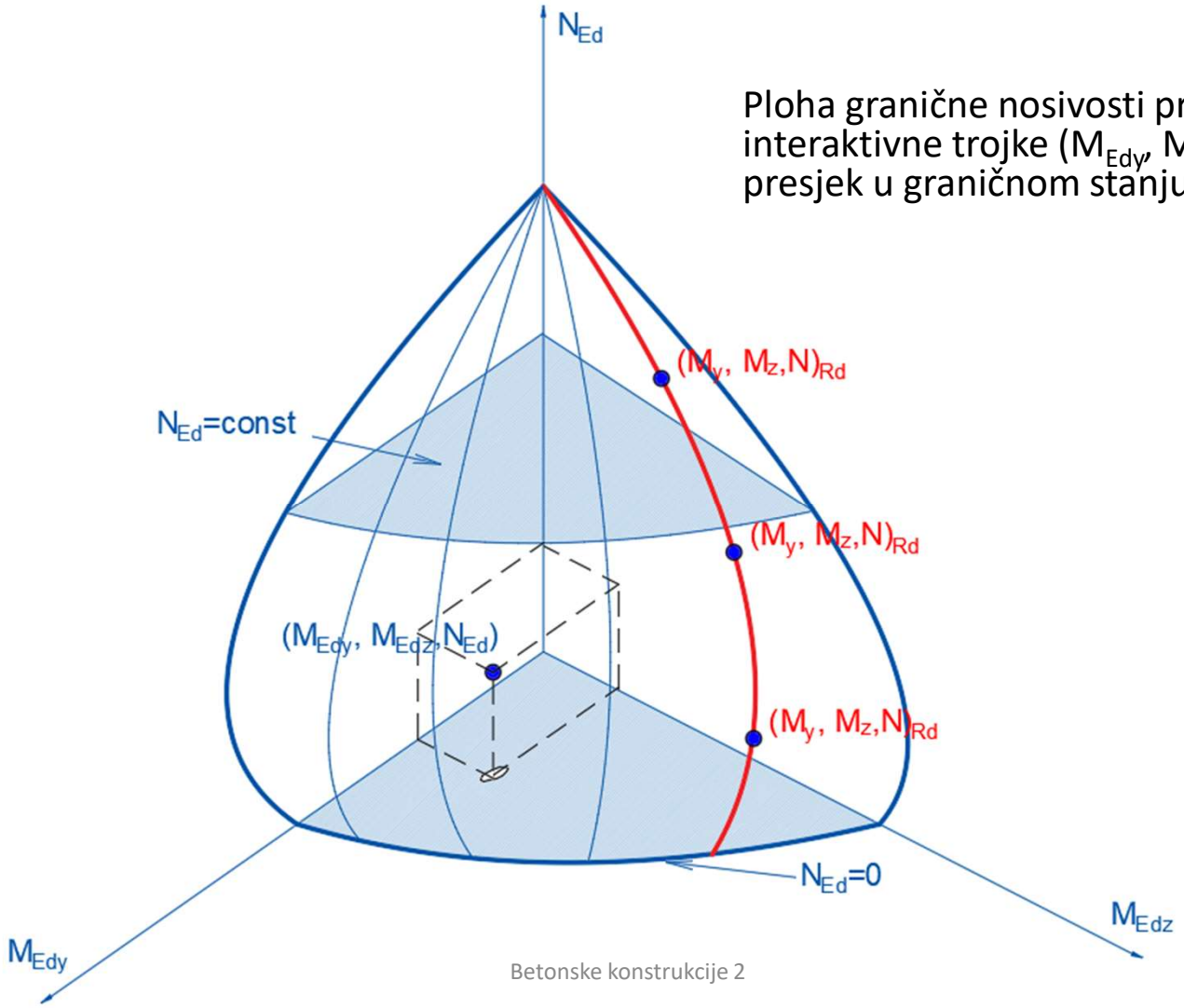
μ_{Rd}

$$M_{Rd} = F_{s1d} \cdot z = A_{s1} \cdot \sigma_{s1} \cdot \zeta \cdot d$$

Dvoosno savijanje

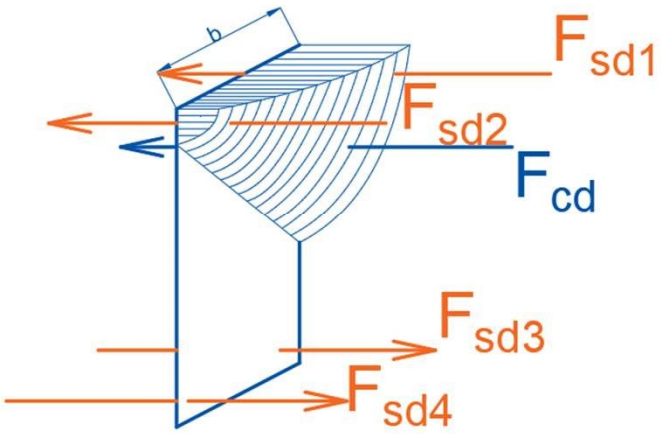


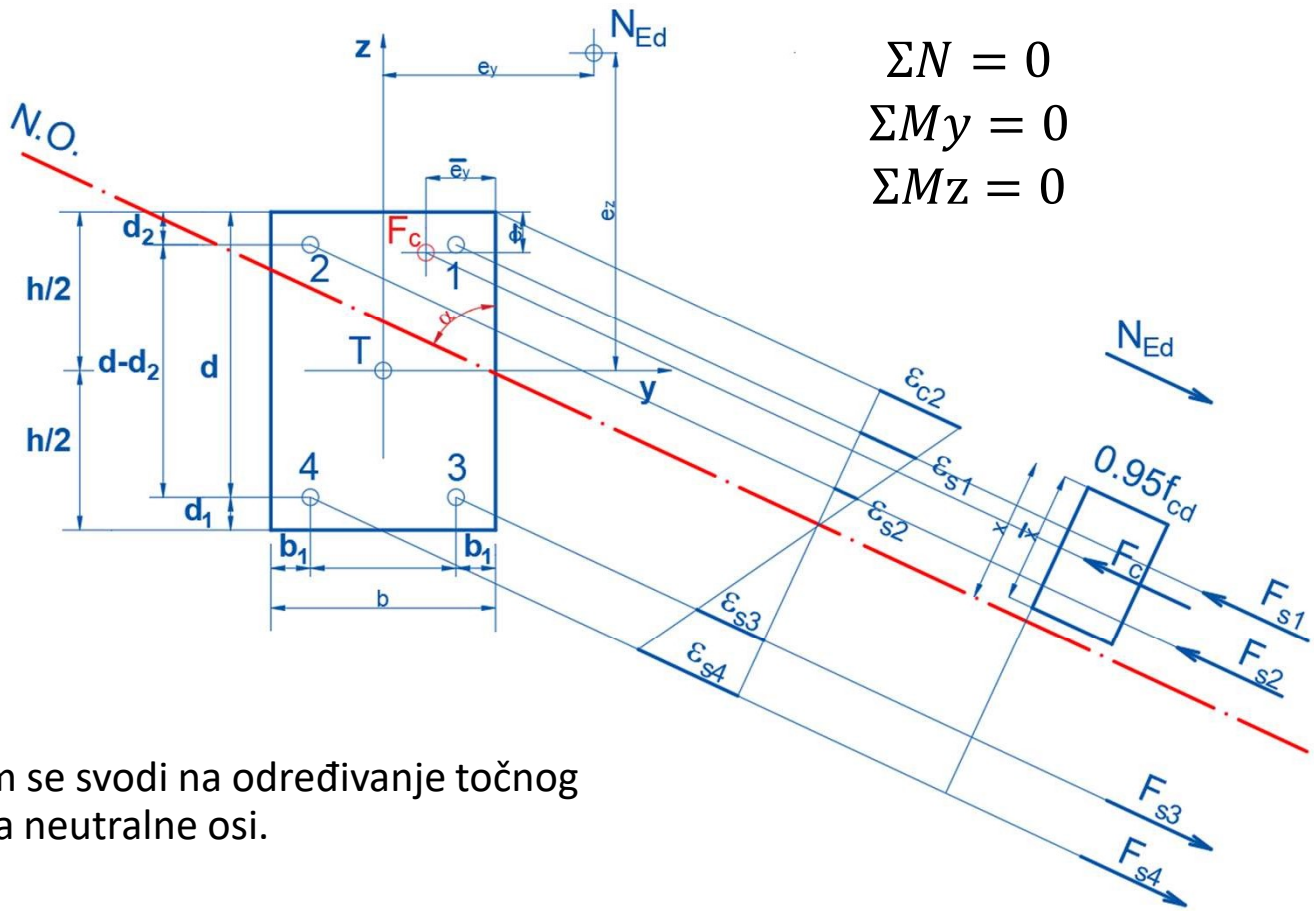
Aproksimacija plohe i krivulja granične nosivosti



Ploha granične nosivosti predstavlja interaktivne trojke (M_{Edy}, M_{Edz}, N_{Ed}) pri kojima je presjek u graničnom stanju!

Dvoosno savijanje



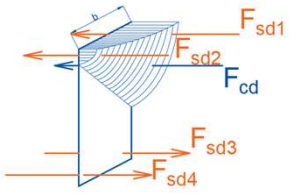


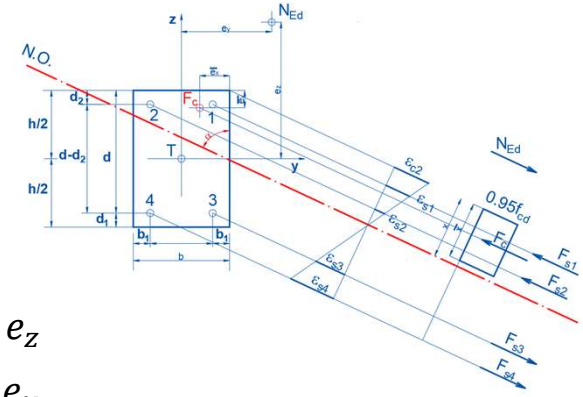
$$\Sigma N = 0$$
$$\Sigma My = 0$$
$$\Sigma Mz = 0$$

$$M_{E\,dy} = N_{Ed} \cdot e_z$$
$$M_{E\,dz} = N_{Ed} \cdot e_y$$

Problem se svodi na određivanje točnog položaja neutralne osi.

Dvoosno savijanje





$$M_{E\,dy} = N_{Ed} \cdot e_z$$

$$M_{E\,dz} = N_{Ed} \cdot e_y$$

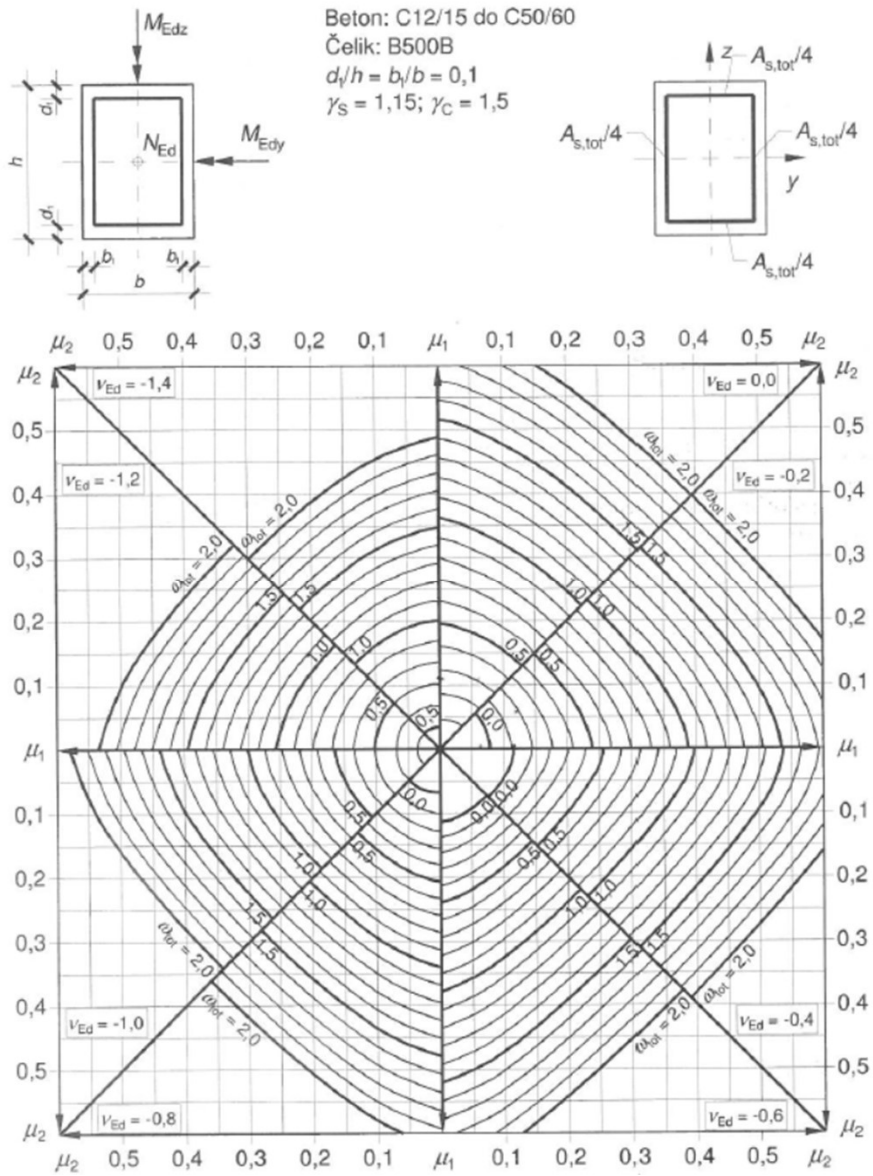
Simultano moraju biti zadovoljene sve tri jednadžbe ravnoteže:

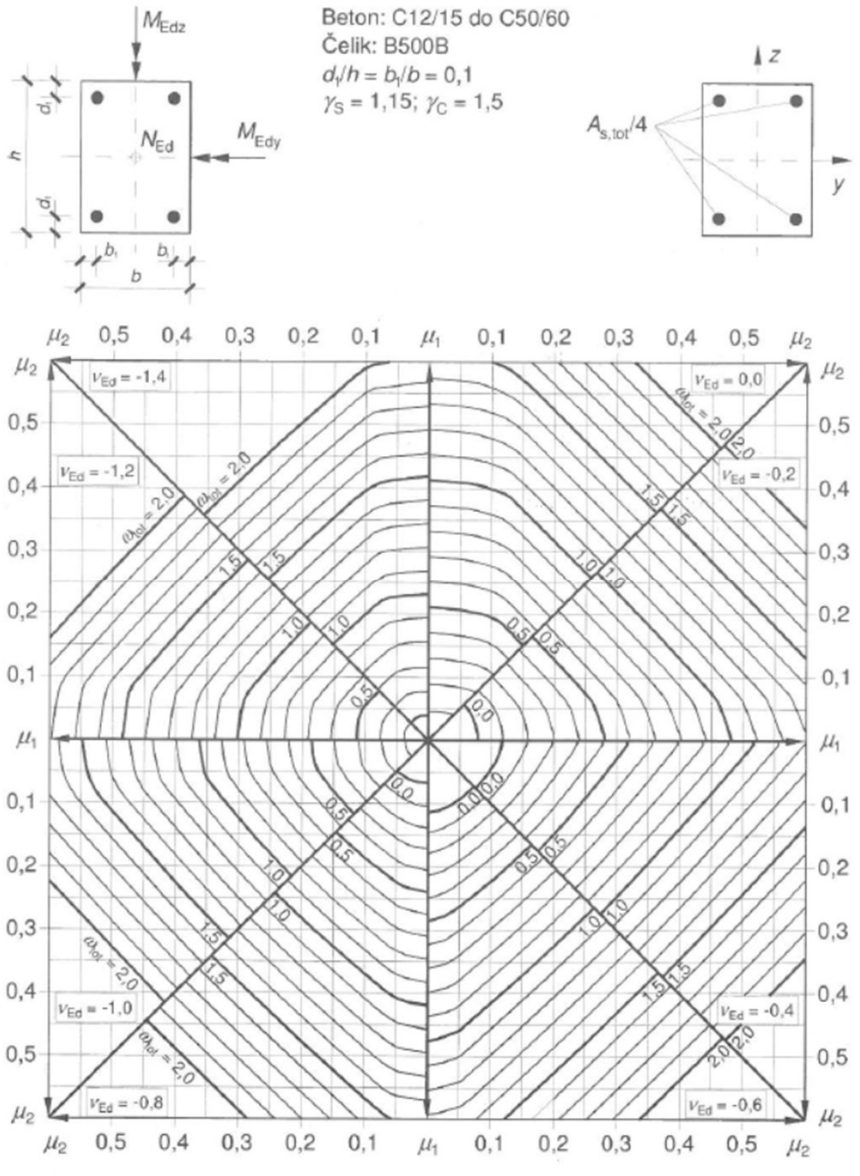
$$\Sigma N = 0$$
$$\Sigma M_y = 0$$
$$\Sigma M_z = 0$$

$$N_{Rd} = F_{cd} + F_{sd1} + F_{sd2} - F_{sd3} - F_{sd4}$$
$$= 0.95 \cdot f_{cd} \cdot \bar{x} \cdot b + f_{yd} \cdot (A_{sd1} + A_{sd2} - A_{sd3} - A_{sd4})$$

$$M_{Rdy} = N_{Rd} \cdot e_z$$
$$= F_{cd} \cdot \left(\frac{h}{2} - \overline{e_z}\right) + (F_{sd1} + F_{sd2}) \cdot \left(\frac{h}{2} - d_2\right) + (F_{sd3} + F_{sd4}) \cdot \left(\frac{h}{2} - d_1\right)$$
$$= 0.95 \cdot f_{cd} \cdot \bar{x} \cdot b \cdot \left(\frac{h}{2} - \overline{e_z}\right) + (A_{s1} \cdot \sigma_{s1} + A_{s2} \cdot \sigma_{s2}) \cdot \left(\frac{h}{2} - d_2\right) + (A_{s3} \cdot \sigma_{s3} + A_{s4} \cdot \sigma_{s4}) \cdot \left(\frac{h}{2} - d_1\right)$$

$$M_{Rdz} = N_{Rd} \cdot e_y$$
$$= F_{cd} \cdot \left(\frac{b}{2} - \overline{e_y}\right) + (F_{sd1} - F_{sd3}) \cdot \left(\frac{b}{2} - b_1\right) + (F_{sd4} - F_{sd2}) \cdot \left(\frac{b}{2} - b_1\right)$$
$$= 0.95 \cdot f_{cd} \cdot \bar{x} \cdot b \cdot \left(\frac{b}{2} - \overline{e_y}\right) + (A_{s1} \cdot \sigma_{s1} - A_{s3} \cdot \sigma_{s3}) \cdot \left(\frac{b}{2} - b_1\right) + (A_{s4} \cdot \sigma_{s4} - A_{s2} \cdot \sigma_{s2}) \cdot \left(\frac{b}{2} - b_1\right)$$


Beton: C12/15 do C50/60
Čelik: B500B
$d_1/h = b_1/b = 0{,}1$
$\gamma_S = 1{,}15$; $\gamma_C = 1{,}5$
M_{Edz}
M_{Edy}
N_{Ed}
$A_{s,tot}/4$
$\nu_{Ed} = -1{,}4$
$\nu_{Ed} = -1{,}2$
$\nu_{Ed} = -1{,}0$
$\nu_{Ed} = -0{,}8$
$\nu_{Ed} = 0{,}0$
$\nu_{Ed} = -0{,}2$
$\nu_{Ed} = -0{,}4$
$\nu_{Ed} = -0{,}6$
$\omega_{tot} = 2{,}0$


Beton: C12/15 do C50/60
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$d_1/h = b_1/b = 0{,}1$
$\gamma_S = 1{,}15$; $\gamma_C = 1{,}5$
M_{Edz}
M_{Edy}
N_{Ed}
$A_{s,tot}/4$
$\nu_{Ed} = -1{,}4$
$\nu_{Ed} = -1{,}2$
$\nu_{Ed} = -1{,}0$
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$\nu_{Ed} = 0{,}0$
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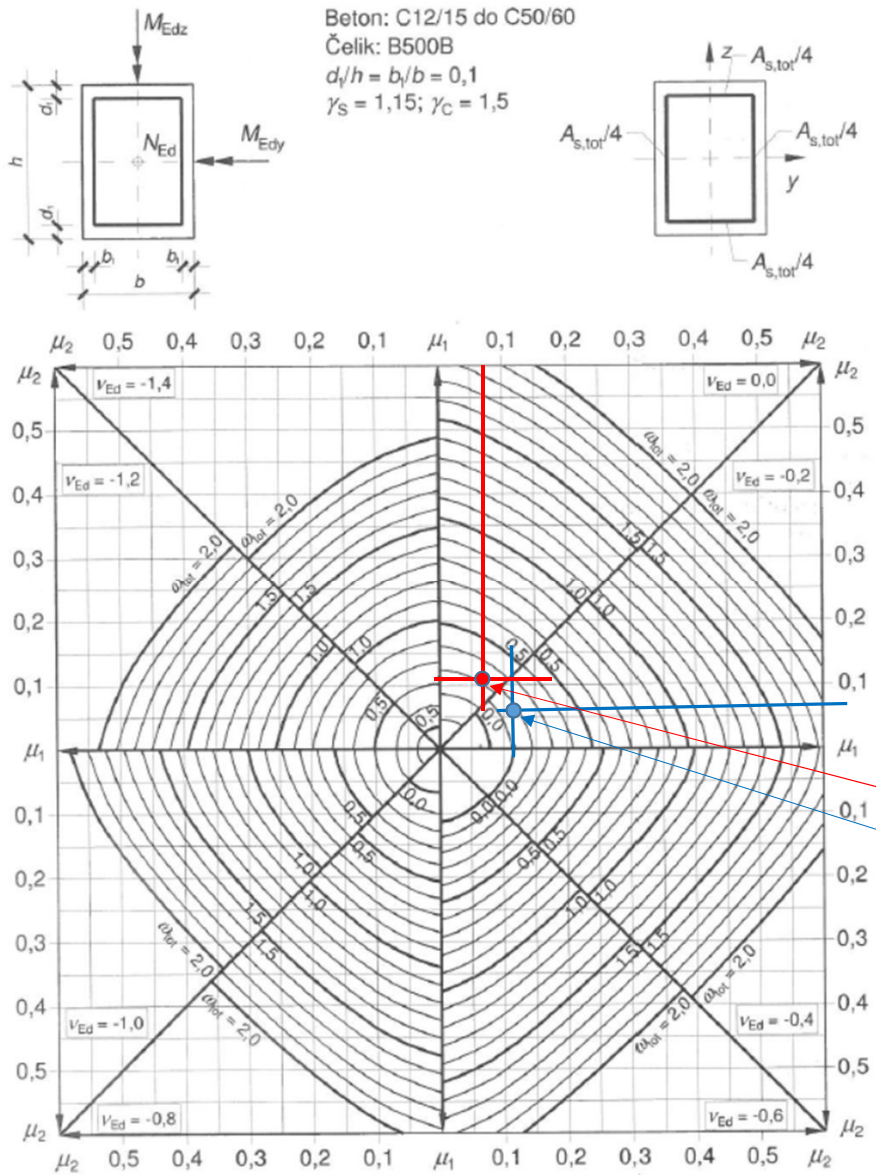
$\nu_{Ed} = -0{,}4$
$\nu_{Ed} = -0{,}6$
$\omega_{tot} = 2{,}0$



$$\mu_{Edy} = \frac{|M_{Edy}|}{b \cdot h^2 \cdot f_{cd}}$$

$$\mu_{Edz} = \frac{|M_{Edz}|}{b^2 \cdot h \cdot f_{cd}}$$

μ_1 je uvijek veći od ova dva

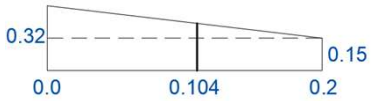
$$\nu_{Ed} = \frac{N_{Ed}}{b \cdot h \cdot f_{cd}}$$

Primjer:

$\mu_{Edy} = 0.112 = \mu_1$
$\mu_{Edz} = 0.066 = \mu_2$
$\nu_{Ed} = -0.104$

$U\ području\ \nu_{Ed} = 0.0 \Rightarrow \omega_{tot} = 0.32$
$U\ području\ \nu_{Ed} = 0.2 \Rightarrow \omega_{tot} = 0.15$

$\omega_{tot} = 0.236$



$$A_{s,tot} = \omega_{tot} \cdot b \cdot h \frac{f_{cd}}{f_{yd}}$$

Ukupna armatura za sve četiri stranice!

Odvojena provjera oko svake osi posebno

Odvojene provjere oko svake osi (kao jednoosno savijanje) smiju se provesti samo ako su ispunjena oba uvjeta:

$\frac{\lambda_y}{\lambda_z} \leq 2$ i $\frac{\lambda_z}{\lambda_y} \leq 2$

i jedan od sljedeća dva uvjeta:

$\frac{\frac{e_y}{b_{eq}}}{\frac{e_z}{h_{eq}}} \leq 2$ ili $\frac{\frac{e_z}{h_{eq}}}{\frac{e_y}{b_{eq}}} \leq 2$

gdje je:

$\lambda_y, \lambda_z = \frac{l_0}{i}$ duljine izvijanja

$e_z = \frac{M_{Edy}}{N_{Ed}}$

$e_y = \frac{M_{Edz}}{N_{Ed}}$

} ekscentriciteti

$b_{eq} = i_z \cdot \sqrt{12}$

$h_{eq} = i_y \cdot \sqrt{12}$

} Istovrijedna širina i visina poprečnog presjeka (b_{eq}=b i $h_{eq} = h$ za pravokutne presjeke)

Odvojena provjera oko svake osi posebno