

Betonske konstrukcije 2

Prof. dr. sc. Damir Varevac

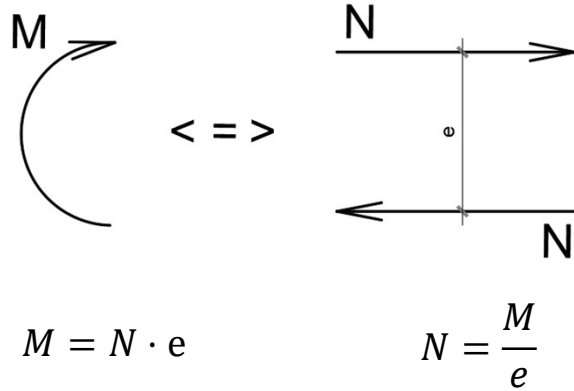
dvarevac@gfos.hr

DIMENZIONIRANJE ELEMENATA EKSCENTRIČNO OPTEREĆENIH UZDUŽNOM SILOM

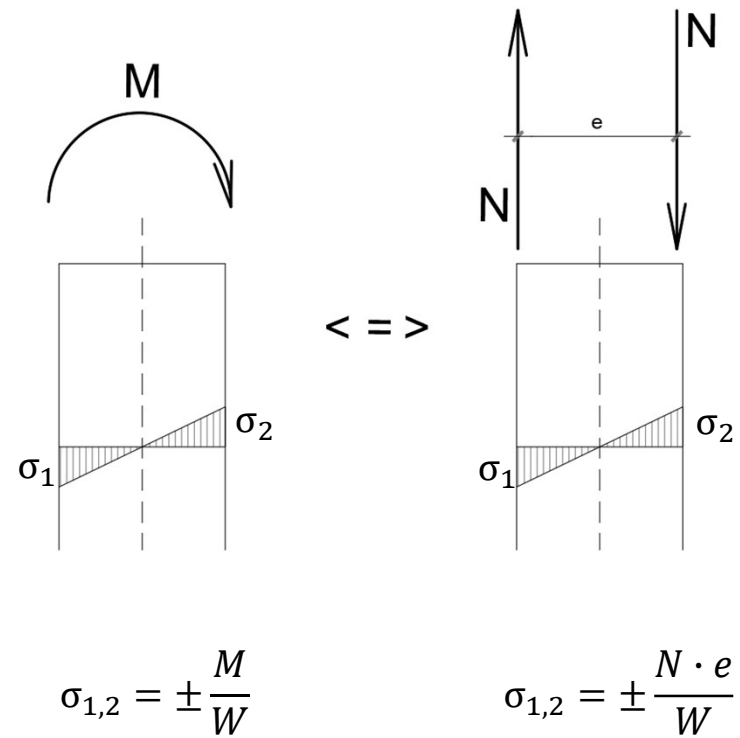
Z. Sorić, T. Kišiček: Betonske konstrukcije 1

Str. 245 - 273

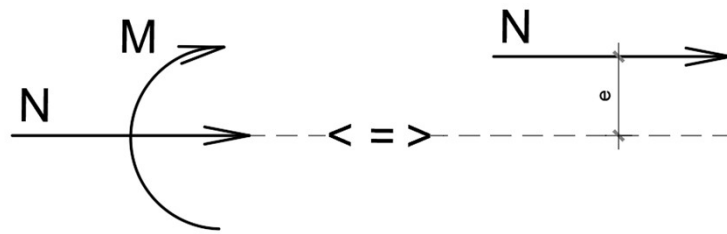
Osnovni stavci mehanike krutog tijela



$$e = \frac{M}{N}$$



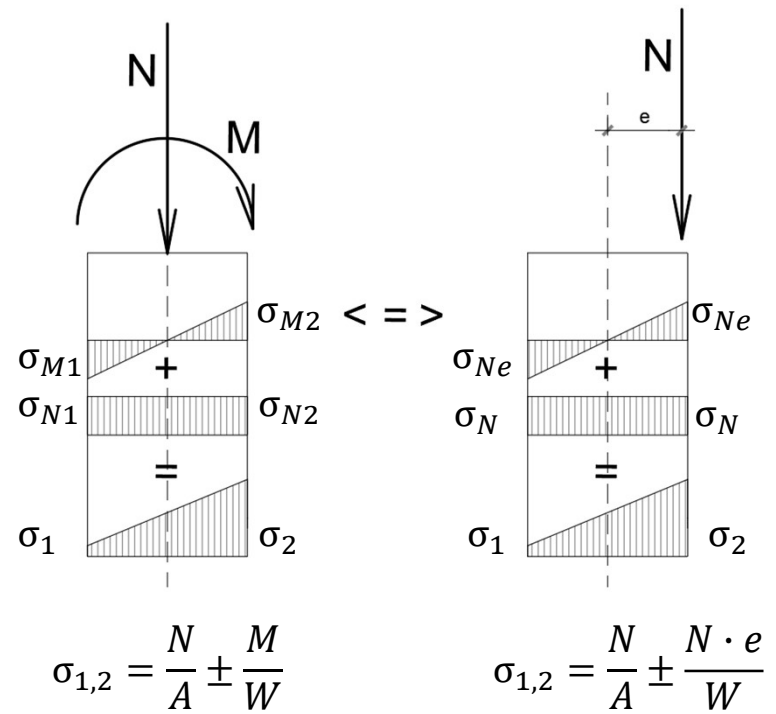
Osnovni stavci mehanike krutog tijela



$$M = N \cdot e$$

$$N = \frac{M}{e}$$

$$e = \frac{M}{N}$$

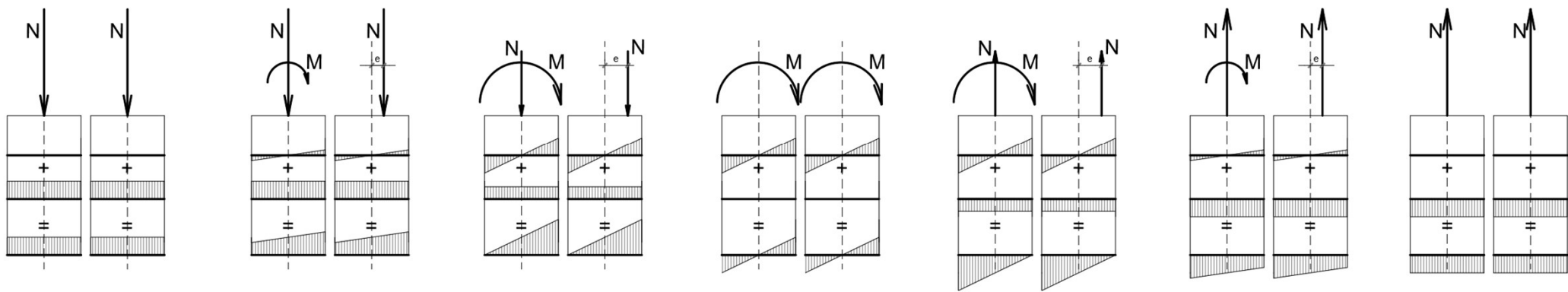


$$\sigma_{1,2} = \frac{N}{A} \pm \frac{M}{W}$$

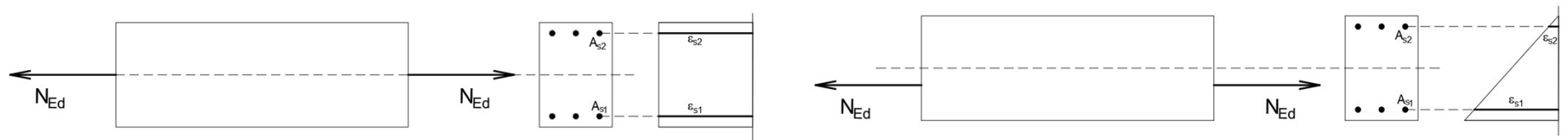
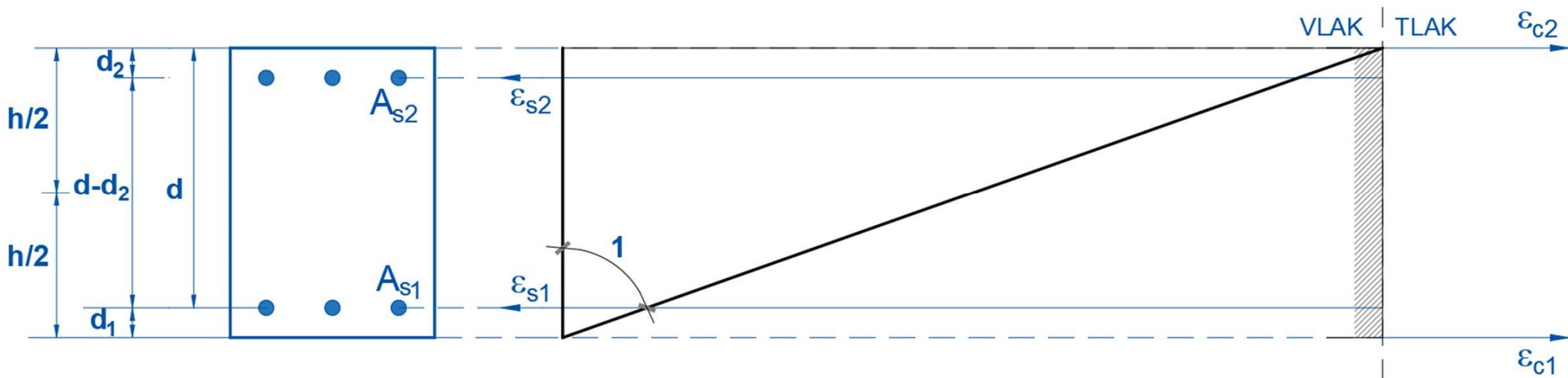
$$\sigma_{1,2} = \frac{N}{A} \pm \frac{N \cdot e}{W}$$

Osnovni stavci mehanike krutog tijela

Mogući dijagrami naprezanja/deformacija po visini presjeka u ovisnosti o omjeru sile i momenta

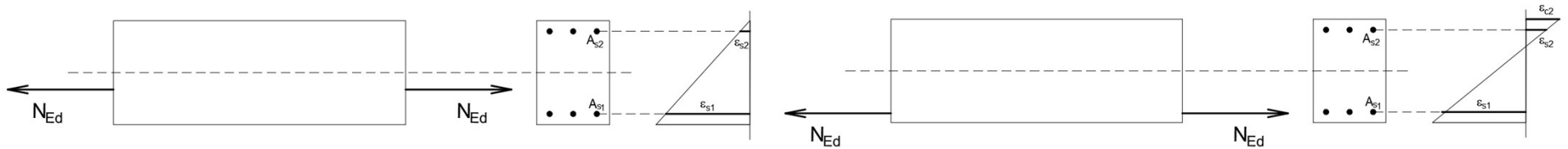
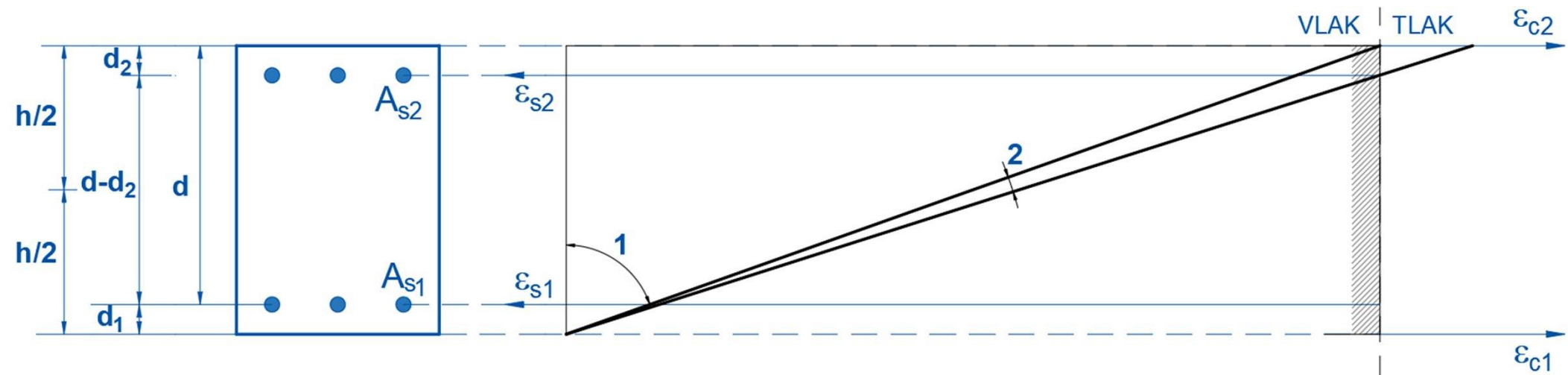


Područja deformacija područje 1



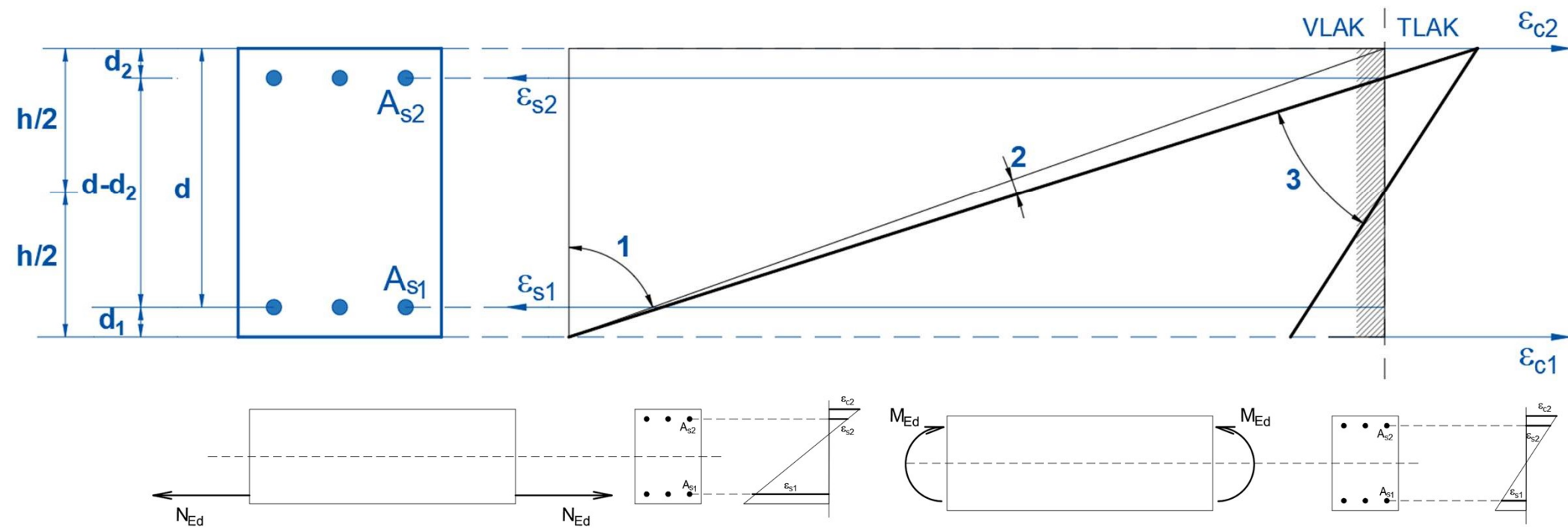
Granični slučajevi – centrična vlačna sila i vlačna sila s malim ekscentricitetom

Područja deformacija područje 2



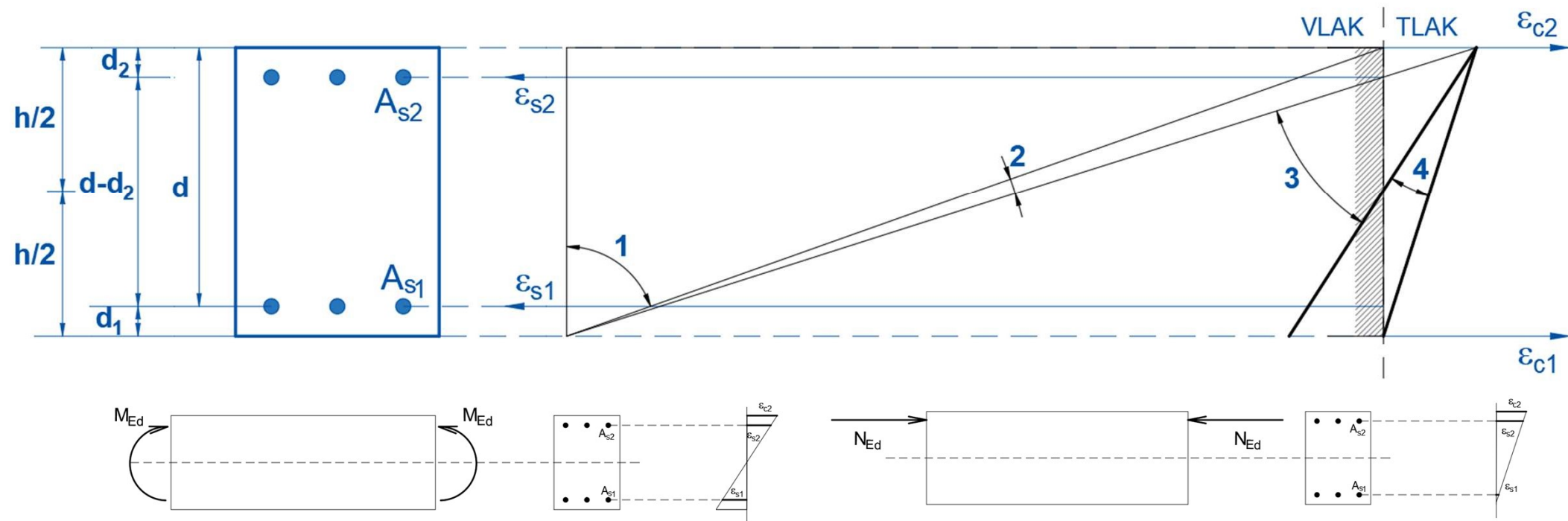
Granični slučajevi –vlačna sila s malim ekscentricitetom i vlačna sila s velikim ekscentricitetom

Područja deformacija područje 3



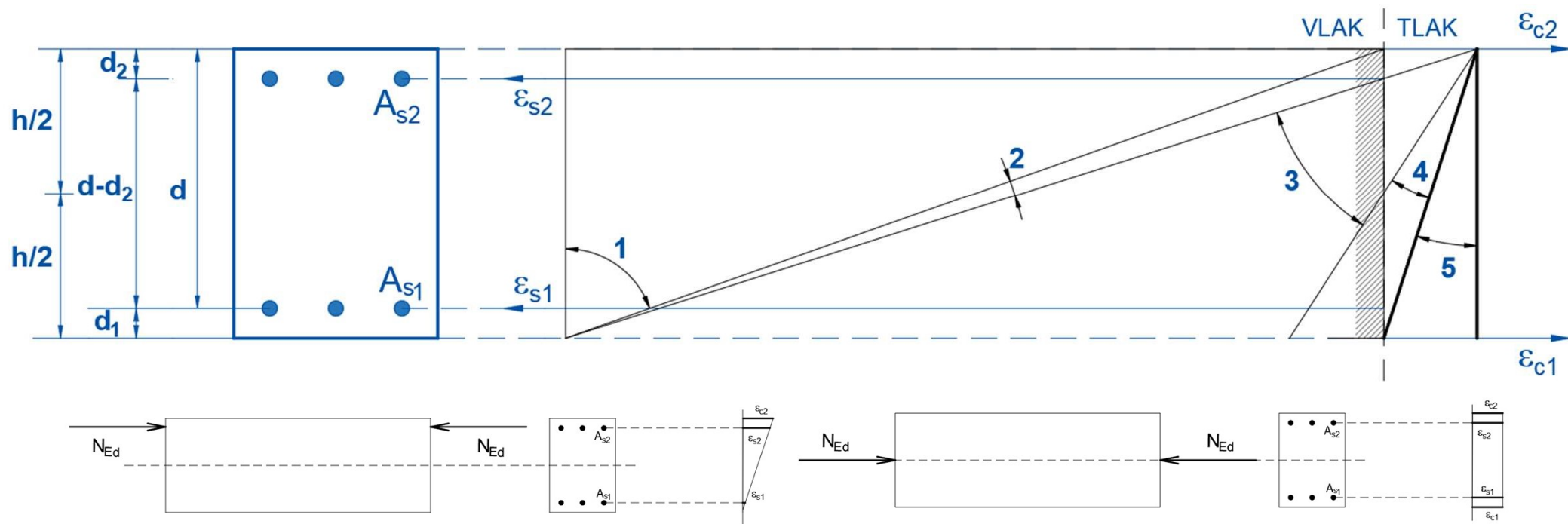
Granični slučajevi –vlačna sila s velikim ekscentricitetom i čisto savijanje

Područja deformacija područje 4



Granični slučajevi –čisto savijanje i tlačna sila s velikim ekscentricitetom

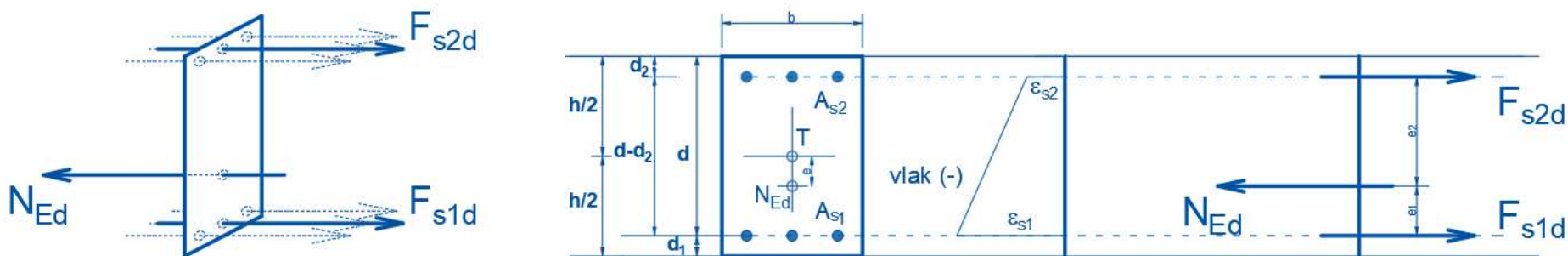
Područja deformacija područje 5



Granični slučajevi – tlačna sila s velikim ekscentricitetom i centrična tlačna sila

Interakcija uzdužne sile i momenta savijanja

Područje 1: vlačna sila s malim ekscentricitetom



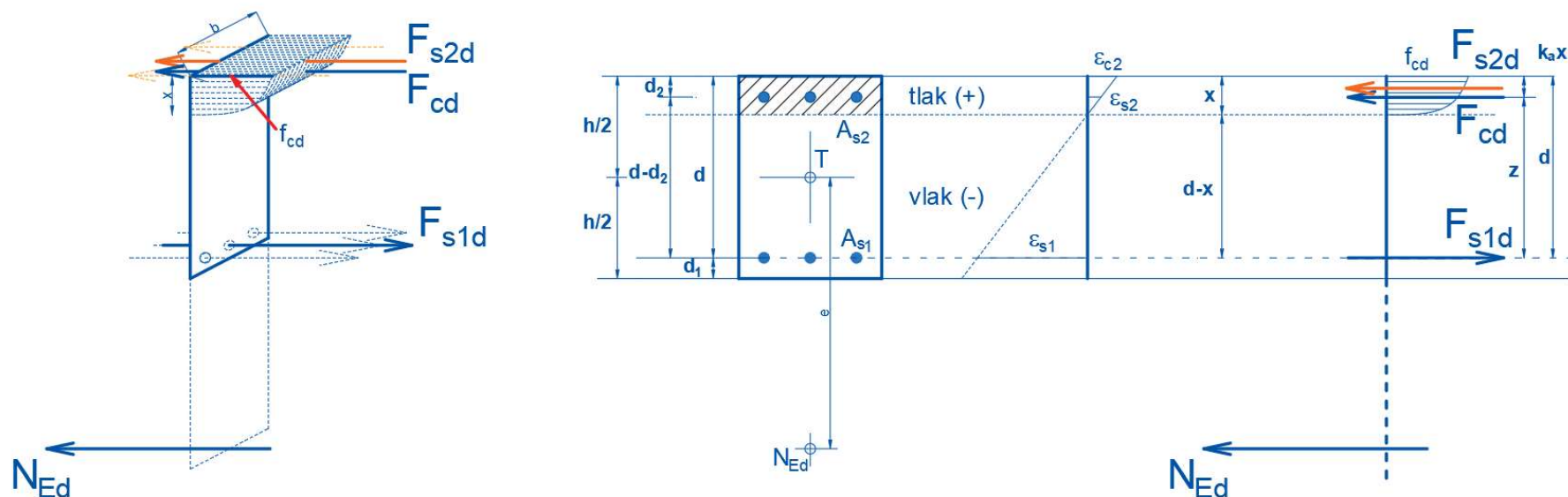
Nosivost presjeka (uvjeti ravnoteže):

$$N_{Rd} = F_{s1d} + F_{s2d} = A_{s1} \cdot \sigma_{s1} + A_{s2} \cdot \sigma_{s2}$$

$$\begin{aligned} M_{Rd} &= F_{s1d} \cdot \left(\frac{h}{2} - d_1 \right) - F_{s2d} \cdot \left(\frac{h}{2} - d_2 \right) \\ &= A_{s1} \cdot \sigma_{s1} \cdot \left(\frac{h}{2} - d_1 \right) + A_{s2} \cdot \sigma_{s2} \cdot \left(\frac{h}{2} - d_2 \right) \end{aligned}$$

Interakcija uzdužne sile i momenta savijanja

Područje 2: vlačna sila s velikim ekscentricitetom



Nosivost presjeka (uvjeti ravnoteže):

$$N_{Rd} = F_{s1d} - F_{s2d} - F_{cd}$$

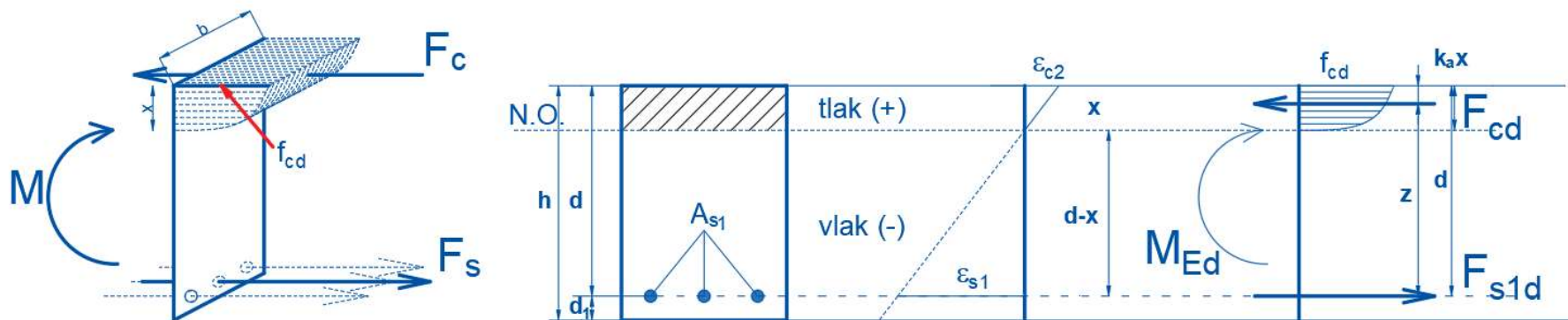
$$= A_{s1} \cdot \sigma_{s1} - A_{s2} \cdot \sigma_{s2} - f_{cd} \cdot \alpha_v \cdot \xi \cdot d \cdot b$$

$$M_{Rd} = F_{cd} \cdot \left(\frac{h}{2} - k_a \cdot x \right) + F_{s2d} \cdot \left(\frac{h}{2} - d_2 \right) + F_{s1d} \cdot \left(\frac{h}{2} - d_1 \right)$$

$$= f_{cd} \cdot \alpha_v \cdot \xi \cdot d \cdot b \cdot \left(\frac{h}{2} - k_a \cdot x \right) + A_{s2} \cdot \sigma_{s2} \cdot \left(\frac{h}{2} - d_2 \right) + A_{s1} \cdot \sigma_{s1} \cdot \left(\frac{h}{2} - d_1 \right)$$

Interakcija uzdužne sile i momenta savijanja

Područje 3: čisto savijanje bez uzdužne sile



Nosivost presjeka (uvjeti ravnoteže):

$$M_{Rd} = F_{cd} \cdot \left(\frac{h}{2} - k_a \cdot x \right) + F_{s1d} \cdot \left(\frac{h}{2} - d_1 \right)$$

$$= f_{cd} \cdot \alpha_v \cdot \xi \cdot d \cdot b \cdot \left(\frac{h}{2} - k_a \cdot x \right) + A_{s1} \cdot \sigma_{s1} \cdot \left(\frac{h}{2} - d_1 \right)$$

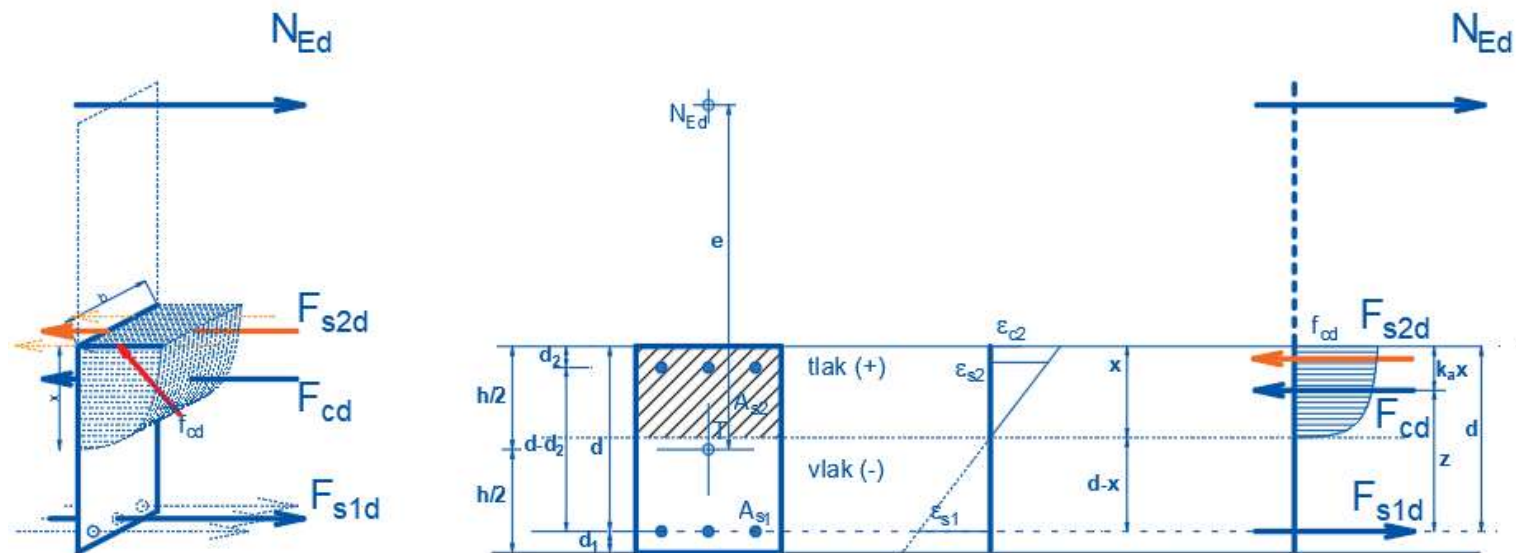
$$\text{ili } M_{Rd} = F_{cd} \cdot z = f_{cd} \cdot \alpha_v \cdot \xi \cdot d \cdot b \cdot \zeta \cdot d$$

$$= f_{cd} \cdot \alpha_v \cdot \xi \cdot \zeta \cdot d^2 \cdot b$$

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

Interakcija uzdužne sile i momenta savijanja

Područje 4: tlačna sila s velikim ekscentricitetom



Nosivost presjeka (uvjeti ravnoteže):

$$N_{Rd} = F_{s2d} + F_{cd} - F_{s1}$$

$$= A_{s2} \cdot \sigma_{s2} + f_{cd} \cdot \alpha_v \cdot \xi \cdot d \cdot b - A_{s1}$$

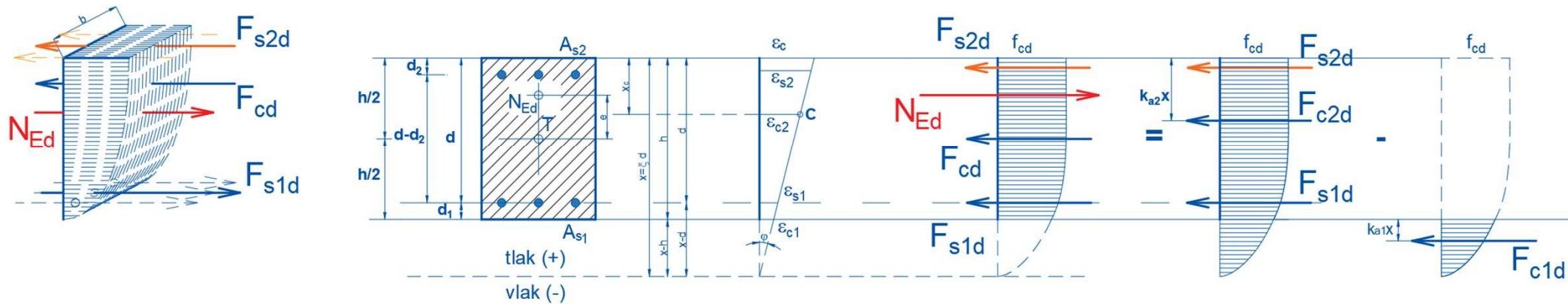
Usporediti s područjem 2!

$$M_{Rd} = F_{s1d} \cdot \left(\frac{h}{2} - d_1 \right) + F_{cd} \cdot \left(\frac{h}{2} - k_a \cdot x \right) + F_{s2d} \cdot \left(\frac{h}{2} - d_2 \right)$$

$$= A_{s1} \cdot \sigma_{s1} \cdot \left(\frac{h}{2} - d_1 \right) + f_{cd} \cdot \alpha_v \cdot \xi \cdot d \cdot b \cdot \left(\frac{h}{2} - k_a \cdot x \right) + A_{s2} \cdot \sigma_{s2} \cdot \left(\frac{h}{2} - d_2 \right)$$

Interakcija uzdužne sile i momenta savijanja

Područje 5: tlačna sila s malim ekscentricitetom

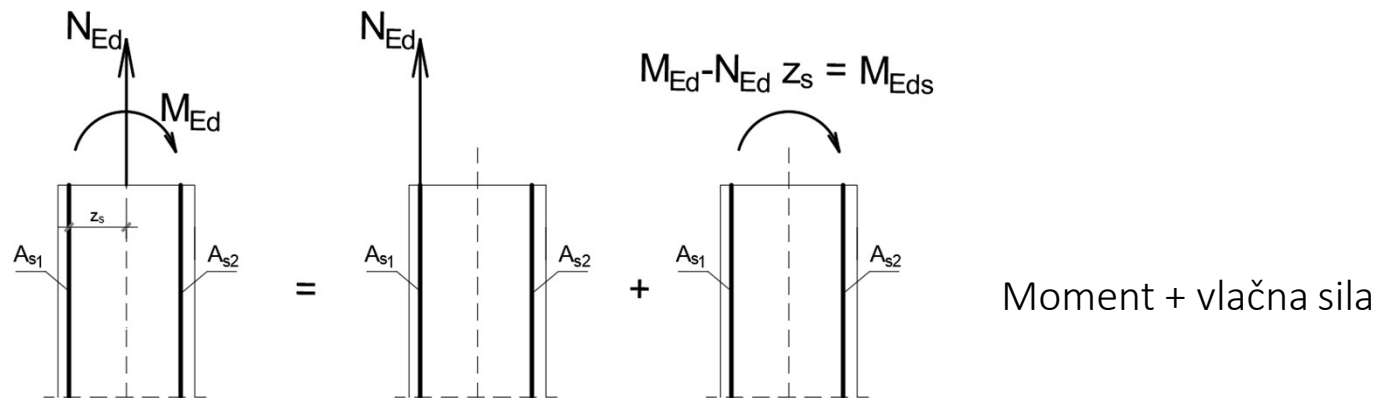
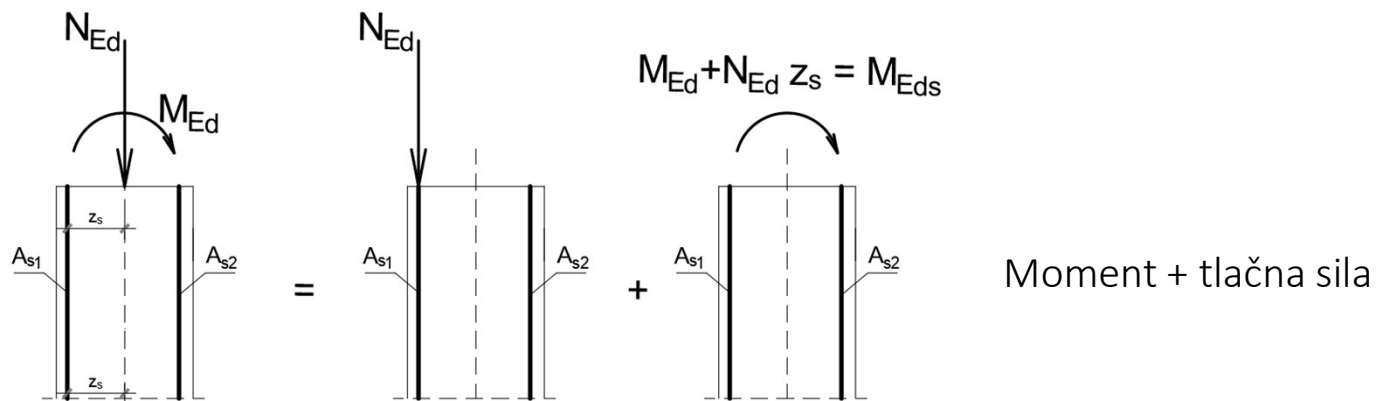


Nosivost presjeka (uvjeti ravnoteže):

$$\begin{aligned}
 N_{Rd} &= F_{c2d} - F_{c1d} + F_{s2d} + F_{s1d} \\
 &= f_{cd} \cdot \alpha_{v2} \cdot \xi \cdot d \cdot b - f_{cd} \cdot \alpha_{v1} \cdot (\xi \cdot d - h) \cdot b + A_{s2} \cdot \sigma_{s2} + A_{s1} \cdot \sigma_{s1} \\
 M_{Rd} &= F_{c2d} \cdot \left(\frac{h}{2} - k_{a2} \cdot \xi \cdot d \right) - \left(-F_{c1d} \cdot \left(\frac{h}{2} + k_{a1} \cdot (\xi \cdot d - h) \right) \right) + F_{s2d} \cdot \left(\frac{h}{2} - d_2 \right) - F_{s1d} \cdot \left(\frac{h}{2} - d_1 \right) \\
 &= f_{cd} \cdot \alpha_{v2} \cdot \xi \cdot d \cdot b \cdot \left(\frac{h}{2} - k_{a2} \cdot \xi \cdot d \right) + f_{cd} \cdot \alpha_{v1} \cdot (\xi \cdot d - h) \cdot b \cdot \left(\frac{h}{2} + k_{a1} \cdot (\xi \cdot d - h) \right) \\
 &\quad + A_{s2} \cdot \sigma_{s2} \cdot \left(\frac{h}{2} - d_2 \right) - A_{s1} \cdot \sigma_{s1} \cdot \left(\frac{h}{2} - d_1 \right)
 \end{aligned}$$

Interakcija uzdužne sile i momenta savijanja

Metoda Wuczkovski



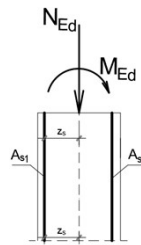
Interakcija uzdužne sile i momenta savijanja

Metoda Wuczkovski

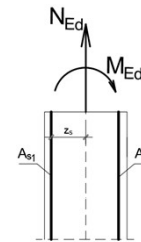
Uvjeti primjene metode:

$$v_{Ed} = \frac{N_{Ed}}{b \cdot d \cdot f_{cd}} \leq 0.3 \qquad e = \frac{M_{Ed}}{N_{Ed}} \geq \left(\frac{h}{2} - d_1 \right)$$

$$\mu_{Eds} = \frac{M_{Eds}}{b \cdot d \cdot f_{cd}} = \begin{cases} \frac{M_{Ed} + N_{Ed} \cdot z_s}{b \cdot d \cdot f_{cd}} \\ \frac{M_{Ed} - N_{Ed} \cdot z_s}{b \cdot d \cdot f_{cd}} \end{cases}$$



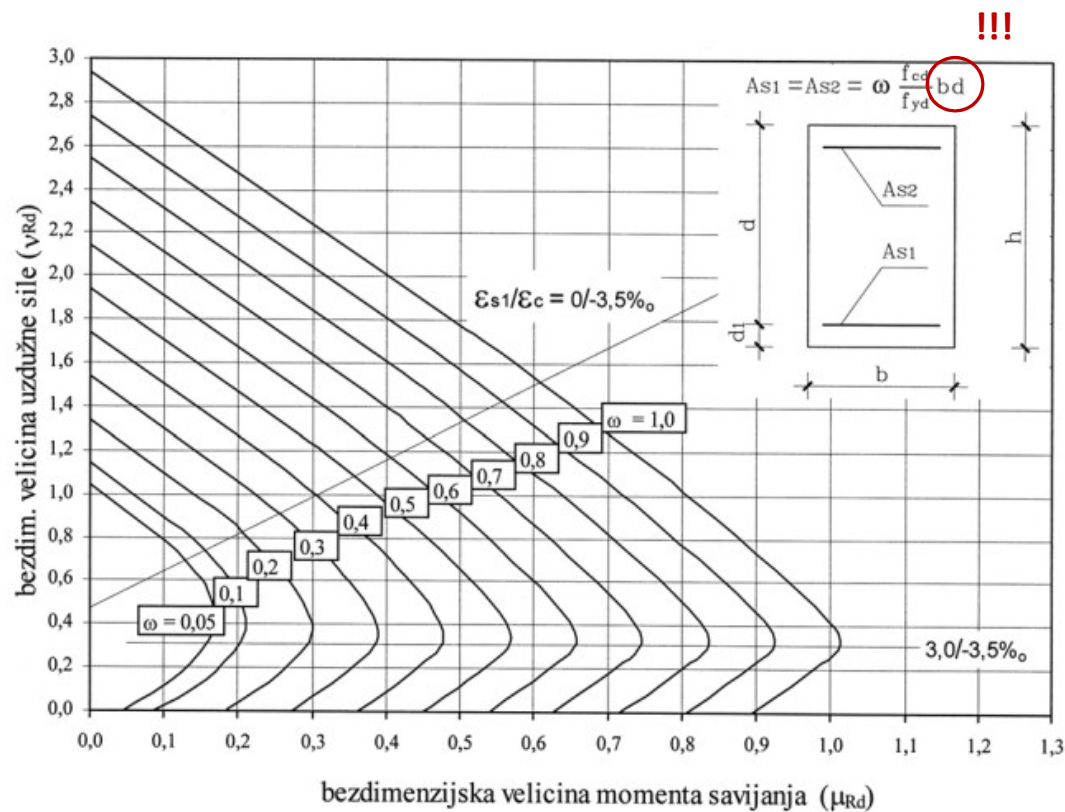
$$A_{s1} = \frac{M_{Eds}}{\zeta \cdot d \cdot f_{yd}} - \frac{N_{Ed}}{f_{yd}}$$



$$A_{s1} = \frac{M_{Eds}}{\zeta \cdot d \cdot f_{yd}} + \frac{N_{Ed}}{f_{yd}}$$

Interakcija uzdužne sile i momenta savijanja

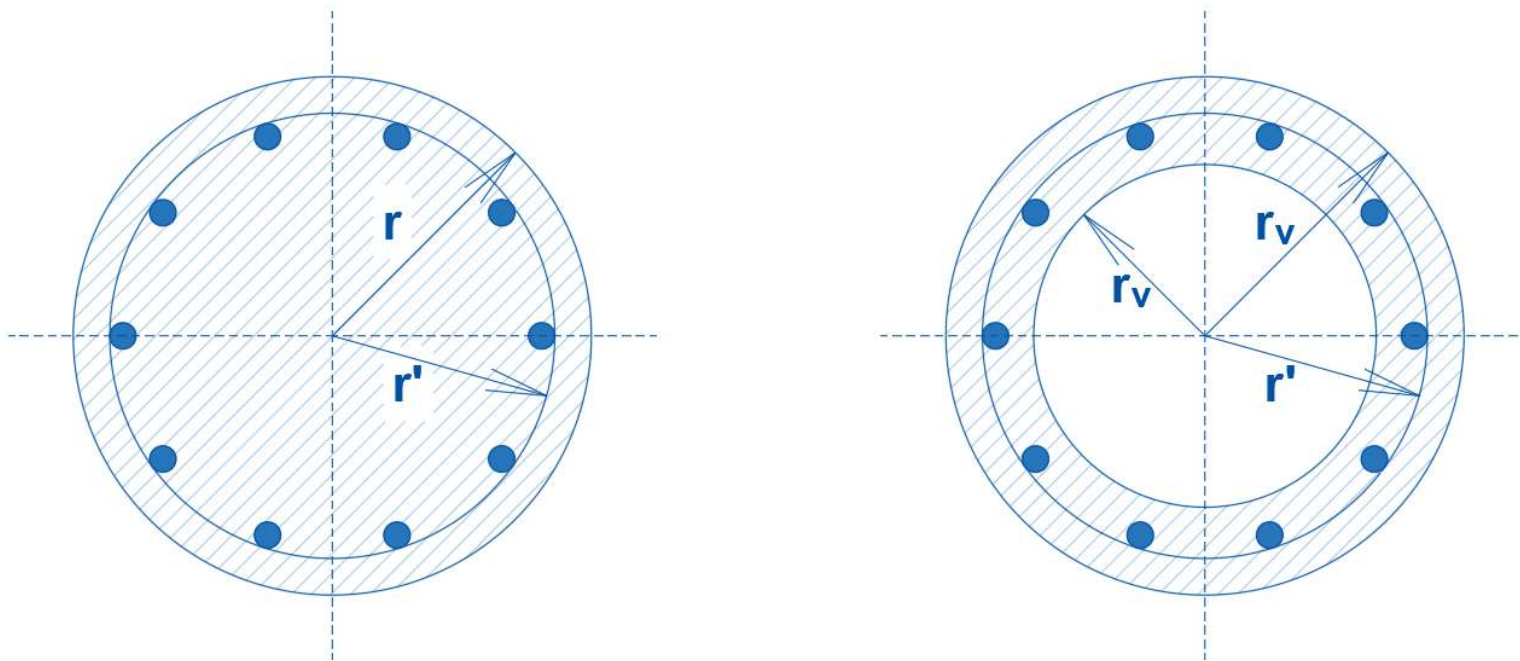
Dijagrami inetrakcije



Izvor: Zorislav Sorić, Ana Mandić: Dijagrami interakcije za proračun armature stupova; Građevinar 53, 453 - 464

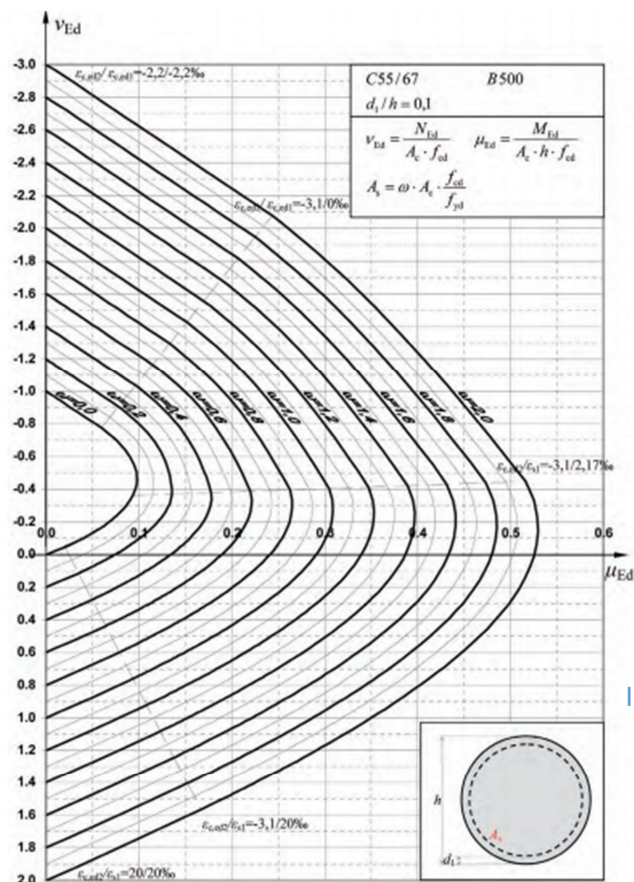
Interakcija uzdužne sile i momenta savijanja

Kružni poprečni presjeci



Interakcija uzdužne sile i momenta savijanja

Kružni poprečni presjeci



Slika 7. Dijagrami interakcije za kružni poprečni presjek (C55/67, B500, $d_1/h=0,1$)

Izvor: Željko Smolčić, Davor Grandić: Dijagrami interakcije za AB kružni presjek, Građevinar 2/2012