Studijski program: **Građevinarstvo**
Modul: Konstrukcije
Godina/Semestar: **III godina / V semestar**

Naziv predmeta (šifra): **Teorija betonskih konstrukcija 1 (b2κ3b1)**

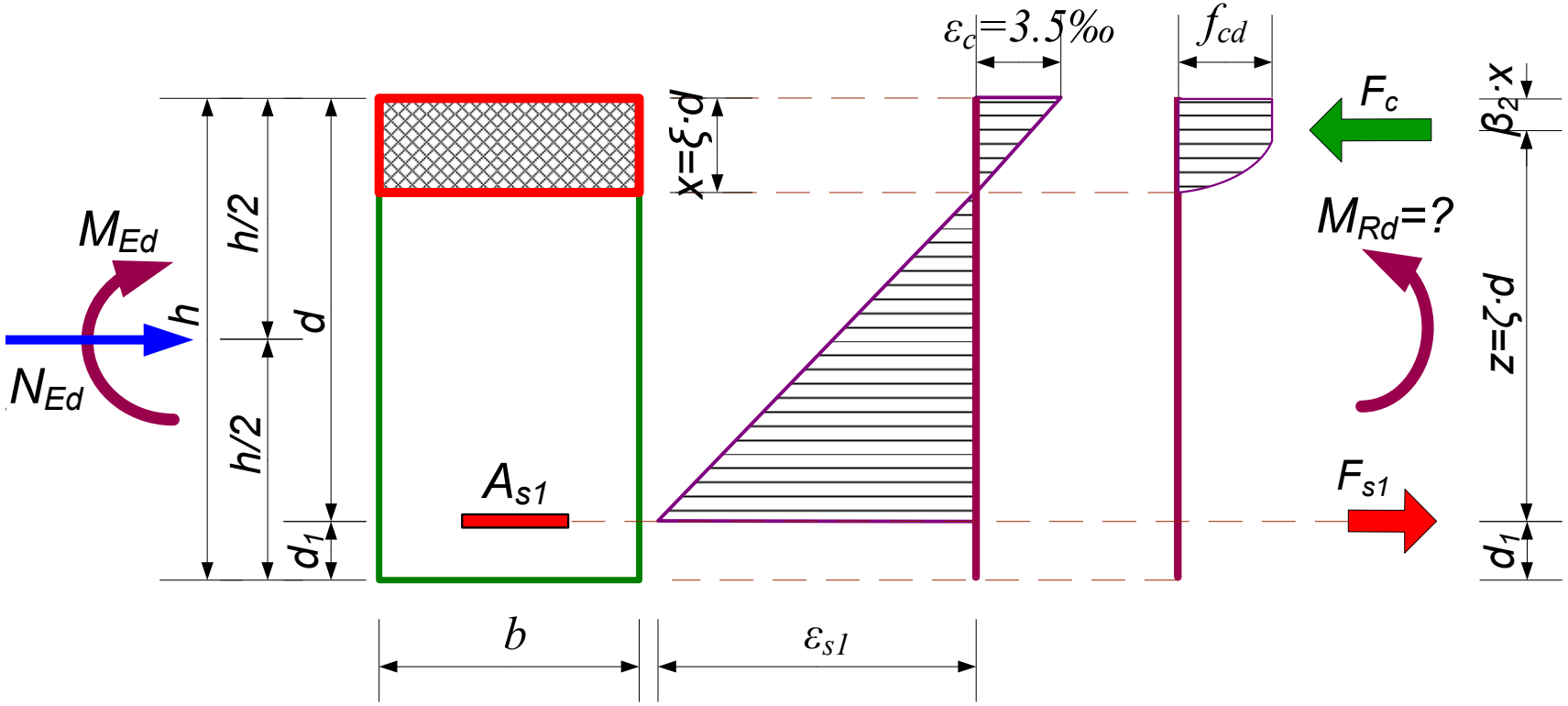
Nastavnik: **Ivan Ignjatović**

Naslov vežbi: **Moment nosivosti preseka**

Datum : 01.11.2022.

Određivanje MOMENTA NOSIVOSTI PRESEKA

Određivanje M_{Rd} - bez uzimanja u obzir nosivosti A_{s2}



$$\sum N = 0 \quad \Rightarrow \quad F_c - F_{s1} = N_{Ed}$$

$$\sum M_s = 0 \quad \Rightarrow \quad M_{Rds} = F_c z = M_{Eds} = M_{Ed} + N_{Ed} \cdot \left(\frac{h}{2} - d_1 \right)$$

Određivanje M_{Rd} - bez uzimanja u obzir nosivosti A_{s2}

$\sum N = 0$

$$A_{s1} = \beta_1 \xi \frac{f_{cd}}{f_{yd}} bd - \frac{N_{Ed}}{f_{yd}} = 0.810 \xi \frac{f_{cd}}{f_{yd}} bd - \frac{N_{Ed}}{f_{yd}} = \omega_1 \frac{f_{cd}}{f_{yd}} bd - \frac{N_{Ed}}{f_{yd}}$$

$$\omega_1 = 0.810 \xi = \frac{A_{s1} \cdot f_{yd} + N_{Ed}}{b \cdot d \cdot f_{cd}}$$

TABLICE → **K**

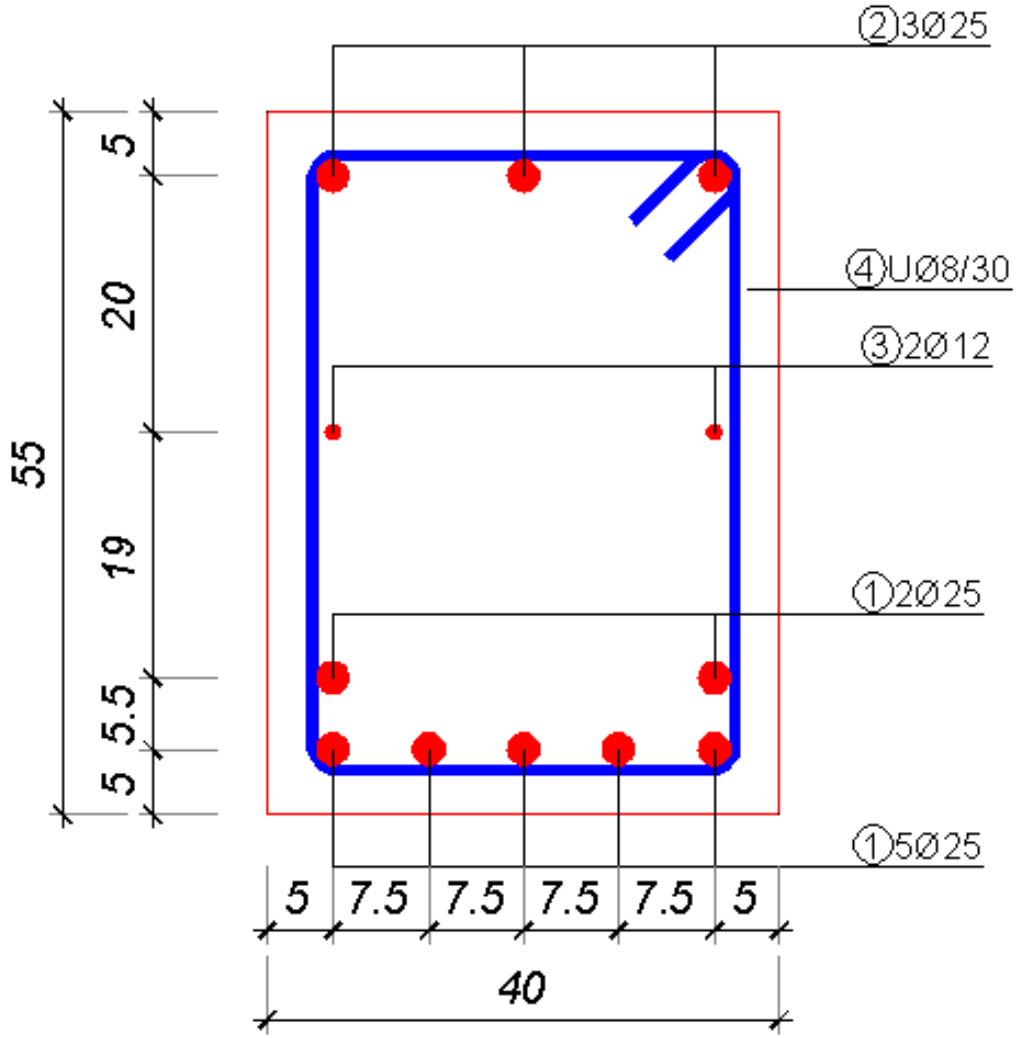
$\sum M_s = 0$

$$k = \frac{d}{\sqrt{\frac{M_{Eds}}{b f_{cd}}}}$$

$$M_{Rds} = M_{Eds} = \left(\frac{d}{k} \right)^2 \cdot b \cdot f_{cd}$$

$$M_{Rd} = M_{Rds} - N_{Ed} \cdot \left(\frac{h}{2} - d_1 \right)$$

Zadatak 14a – Moment nosivosti preseka bez A_{s2}



C30/37

B500B

N_{Ed} = -360 kN

d^{I} = 5.0 cm

d^{II} = 10.5 cm

$d_1 = (5 \times 5.5 + 2 \times 10.5)/7$

d_1 = 6.93 cm

d = 55 - 6.93 = 48.07 cm

A_{s1} = 34.37 cm^2 (7RØ25)

Zadatak 14a – Moment nosivosti preseka bez A_{s2}

C30/37 f_{cd} = 0,85·30/1.5= 17MPa = 1.7 kN/cm^2

B500 B f_{yd} = 500/1.15 = 435 Mpa = 43.5 kN/cm^2

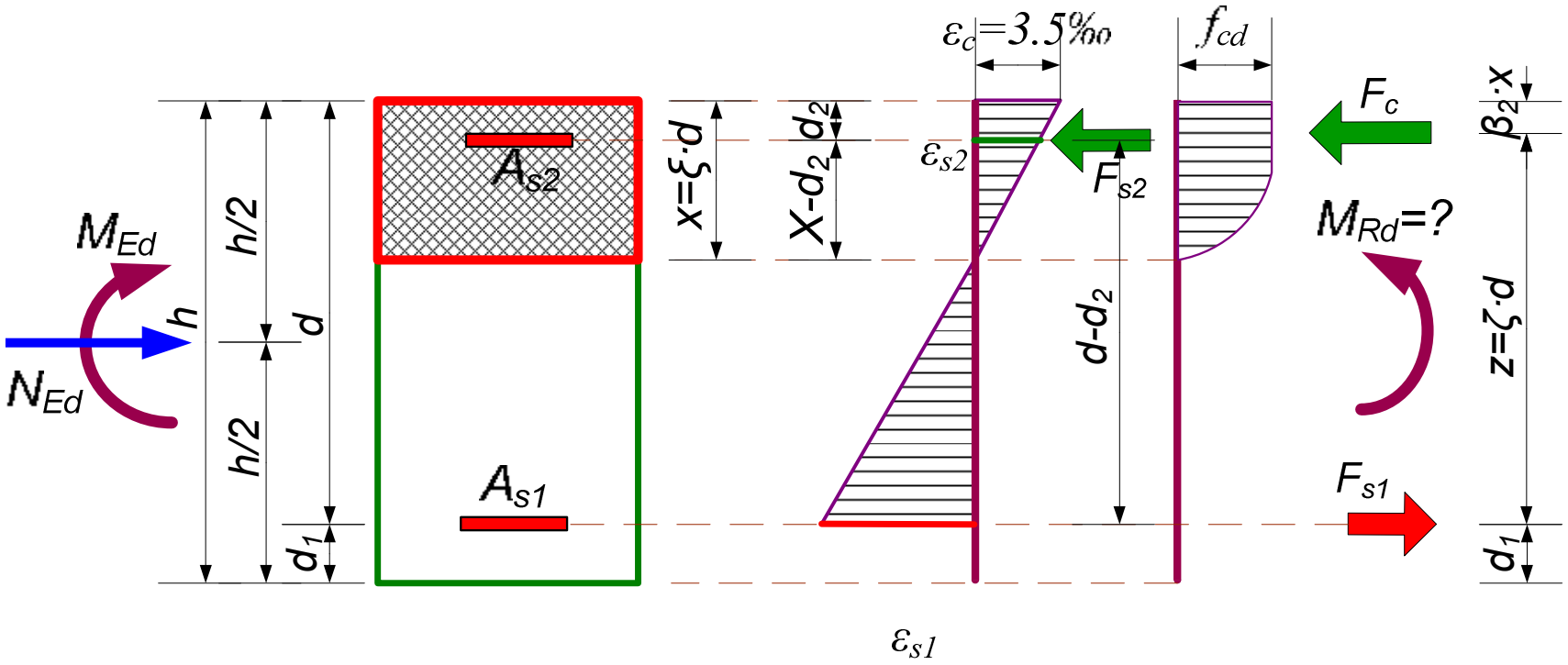
$$\omega_1 = \frac{A_{s1}\cdot f_{yd} + N_{Ed}}{b\cdot d\cdot f_{cd}} = \frac{34.37\cdot 43.5 + (-360)}{40\cdot 48.07\cdot 1.7} = 0.347 = 37.725\%$$

ε_c (‰)	ε_{s1} (‰)	ξ	ζ	ω_1 (%)	k	μ
3.50	4.70	0.427	0.822	34.553	1.876	0.284

$$M_{Rds} = M_{Eds} = \left(\frac{d}{k}\right)^2 \cdot b\cdot f_{cd} = \left(\frac{48.07}{1.876}\right)^2 \cdot 40\cdot 1.7 = 44647 kNcm = 446.47 kNm$$

$$M_{Rd} = M_{Rds} - (-N_{Ed})\cdot\left(\frac{h}{2} - d_1\right) = 446.47 + 360\left(\frac{0.55}{2} - 0.0693\right) = 520.5 kNm$$

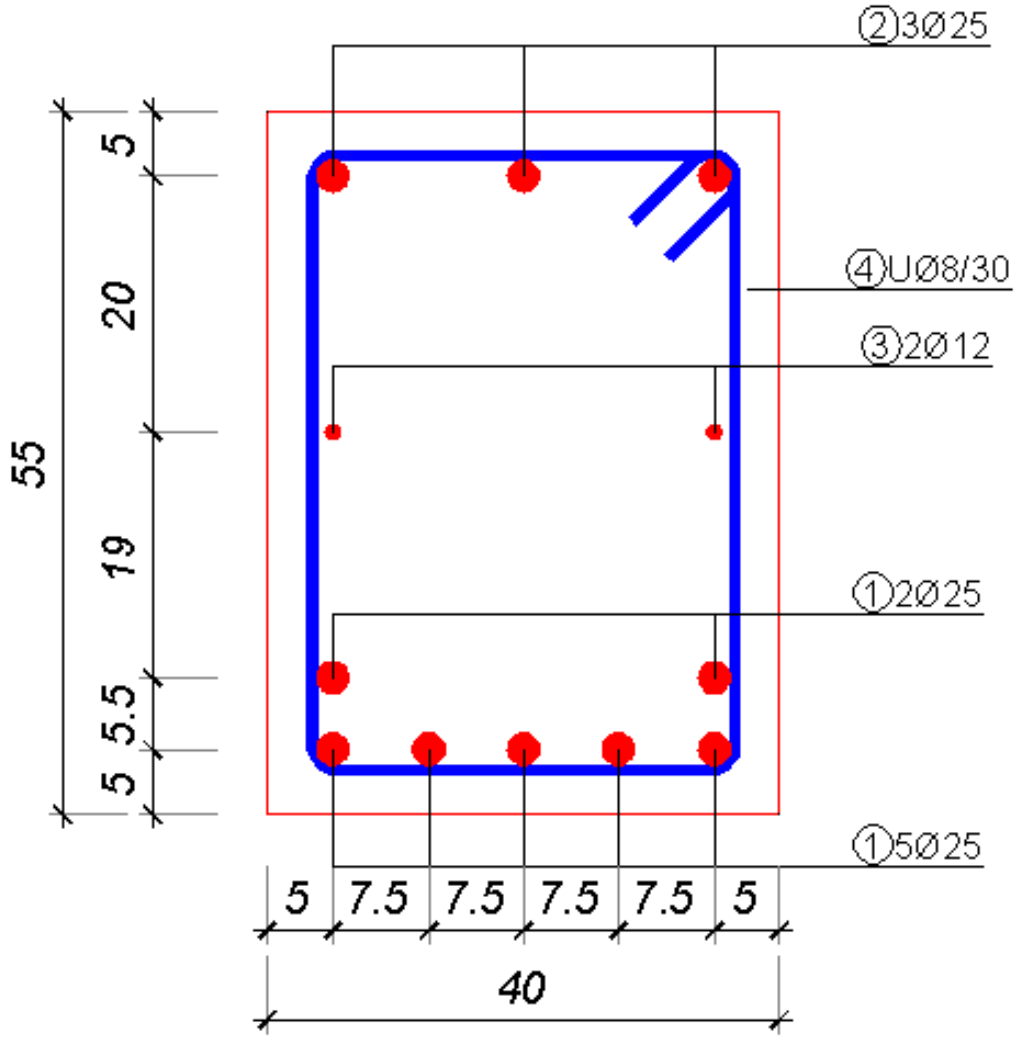
Određivanje M_{Rd} - uzimanje u obzir nosivosti A_{s2}



$$\sum N = 0 \quad \Rightarrow \quad F_c + F_{s1} - F_{s2} = N_{Ed} \quad \Rightarrow \quad \xi$$

$$\sum M_s = 0 \quad \Rightarrow \quad M_{Rds} = F_c \cdot z + F_{s2} \cdot (d - d_2) = M_{Eds} = M_{Ed} + N_{Ed} \cdot \left(\frac{h}{2} - d_1 \right)$$

Zadatak 14b – Moment nosivosti preseka sa A_{s2}



C30/37

B500B

N_{Ed} = -360 kN

d^{I} = 5.0 cm

d^{II} = 10.5 cm

$d_1 = (5 \times 5.5 + 2 \times 10.5)/7$

d_1 = 6.93 cm

d = 55 - 6.93 = 48.07 cm

A_{s1} = 34.37 cm^2 (7RØ25)

A_{s2} = 14.73 cm^2 (3RØ25)

Određivanje M_{Rd} - uzimanje u obzir nosivosti A_{s2}

1. ITERACIJA

1. Pretpostavka: **ξ=0,259**

ε_c (‰)	ε_{s1} (‰)	ξ	ζ	ω_1 (%)	k	μ
3.50	*10.00*	*0.259*	*0.892*	*20.988*	*2.311*	*0.187*

2. Sračunavanje unutrašnjih sila u preseku:

$$F_c = 0.810\xi dbf_{cd} = 0.81 \cdot 0.259 \cdot 48.07 \cdot 40 \cdot 1.7 = 685.75kN$$

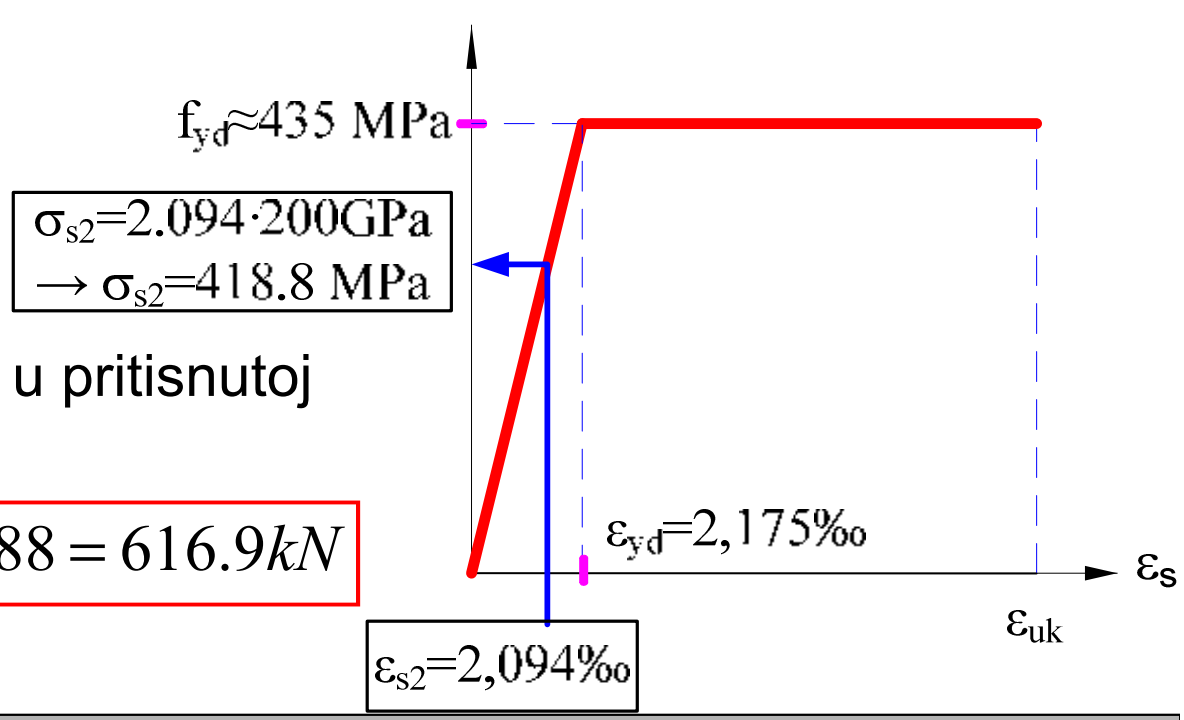
$$F_{s1} = A_{s1} \cdot \sigma_{s1} = 34.36 \cdot 43.5 = 1495kN$$

Određivanje M_{Rd} - uzimanje u obzir nosivosti A_{s2}

1. ITERACIJA

3. Sračunavanje dilatacije u pritisnutoj armaturi:

$$\varepsilon_{s2} = \frac{\xi - \frac{d_2}{d}}{\xi}\varepsilon_{cu2} = \frac{0.259 - \frac{5}{48.07}}{0.259}\cdot 3.5 = 2.094‰ < 2.175‰$$



4. Sračunavanje sile u pritisnutoj armaturi:

$$F_{s2} = A_{s2}\cdot\sigma_{s2} = 14.73\cdot 41.88 = 616.9kN$$

Određivanje M_{Rd} - uzimanje u obzir nosivosti A_{s2}

1. ITERACIJA

5. Suma sila:

$$685.8+616.9-1495-(-360)=167.7kN$$

Smanjiti silu u pritisnutom betonu, tj. podići neutralnu liniju, tj. smanjiti ξ !!!

2. ITERACIJA

1. Pretpostavka: **ξ=0,226**

ε_c (‰)	ε_{s1} (‰)	ξ	ζ	ω_1 (%)	k	μ
3.50	12.00	0.226	0.906	18.280	2.457	0.166

2. Sračunavanje unutrašnjih sila u preseku:

$$F_c = 0.810\xi dbf_{cd} = 0.81\cdot 0.226\cdot 48.07\cdot 40\cdot 1.7 = 598.4kN$$

$$F_{s1} = A_{s1}\cdot\sigma_{s1} = 34.36\cdot 43.5 = 1495kN$$

Određivanje M_{Rd} - uzimanje u obzir nosivosti A_{s2}

2. ITERACIJA

3. Sračunavanje dilatacije u pritisnutoj armaturi:

$$\varepsilon_{s2} = \frac{\xi^{II} - \frac{d_2}{d}}{\xi^{II}} \varepsilon_{cu2} = \frac{0.226 - \frac{5}{48.07}}{0.226} \cdot 3.5 = 1.889‰ < 2.175‰$$

$$\sigma_{s2} = \varepsilon_{s2} \cdot E_s = 1.889 \cdot 200 GPa = 377.8 MPa$$

4. Sračunavanje sile u pritisnutoj armaturi:

$$F_{s2} = A_{s2} \cdot \sigma_{s2} = 14.73 \cdot 37.78 = 556.5 kN$$

5. Suma sila:

$$598.4 + 556.5 - 1495 - (-360) = 19.9 kN$$

smanjiti ξ !

Određivanje M_{Rd} - uzimanje u obzir nosivosti A_{s2}

3. ITERACIJA

1. Pretpostavka: **ξ=0,219**

ε_c (‰)	ε_{s1} (‰)	ξ	ζ	ω_1 (%)	k	μ
3.50	12.50	0.219	0.909	17.708	2.492	0.161
3.50	12.00	0.226	0.906	18.280	2.457	0.166

2. Sračunavanje unutrašnjih sila u preseku:

$$F_c = 0.810\xi dbf_{cd} = 0.81 \cdot 0.219 \cdot 48.07 \cdot 40 \cdot 1.7 = 579.8kN$$

$$F_{s1} = A_{s1} \cdot \sigma_{s1} = 34.36 \cdot 43.5 = 1495kN$$

3. Sračunavanje dilatacije u pritisnutoj armaturi:

$$\varepsilon_{s2} = \frac{\xi^{III} - \frac{d_2}{d}}{\xi^{III}} \varepsilon_{cu2} = \frac{0.219 - \frac{5}{48.07}}{0.219} \cdot 3.5 = 1.838‰ < 2.175‰$$

Određivanje M_{Rd} - uzimanje u obzir nosivosti A_{s2}

3. ITERACIJA

$$\sigma_{s2} = \varepsilon_{s2} \cdot E_s = 1.838 \cdot 200 GPa = 367.7 MPa$$

4. Sračunavanje sile u pritisnutoj armaturi:

$$F_{s2} = A_{s2} \cdot \sigma_{s2} = 14.73 \cdot 36.76 = 541.5 kN$$

5. Suma sila:

$$579.8 + 541.5 - 1495 - (-360) = -13.7 kN$$

Za dve uzastopne vrednosti ξ iz tabele suma N sila menja znak !
PREKIDA SE SA ITERACIJAMA (može li da se nastavi ?)

tačna vrednost **ξ** je između 0,226 i 0,219, tačna vrednost dilatacije 12,0‰ < ε_{s1} <12.5‰

Određivanje M_{Rd} - uzimanje u obzir nosivosti A_{s2}

6. Sračunavanje sume momenata unutrašnjih sila u preseku oko težišta zategnute armature:

$$M_{Rds} = F_c \cdot z + F_{s2} \cdot (d - d_2) =$$
$$= 579.8 \cdot 0.909 \cdot 48.07 + 541.5 \cdot (48.07 - 5) = 486.57 kNm$$

7. Sračunavanje momenta nosivosti preseka za zadatu normalnu silu u preseku:

$$M_{Ed} = M_{Rds} - N_{Ed} \cdot \left(\frac{h}{2} - d_1 \right) =$$
$$= 486.57 - (-360) \cdot \left(\frac{0.55}{2} - 0.0693 \right) = 560.6 kNm$$

Određivanje M_{Rd} - uzimanje u obzir nosivosti A_{s2}

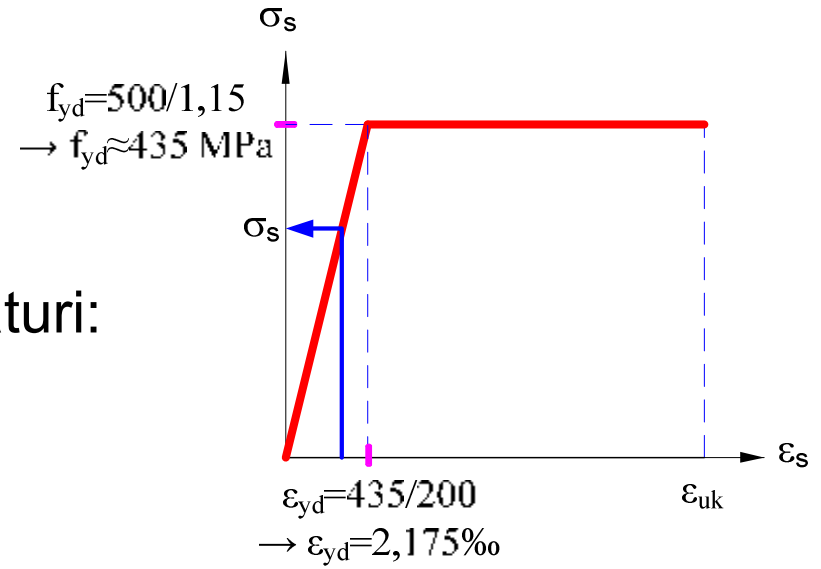
1. Pretpostavka položaja neutralne linije, **ξ**

2. Sračunavanje unutrašnjih sila u preseku:

$$F_c = 0.810\xi dbf_{cd} \qquad F_{s1} = A_{s1} \cdot \sigma_{s1}$$

3. Sračunavanje dilatacije u pritisnutoj armaturi:

$$\varepsilon_{s2} = \frac{\xi - \frac{d_2}{d}}{\xi}\varepsilon_{cu2}$$



4. Sračunavanje sila u pritisnutoj armaturi:

$$F_{s2} = A_{s2} \cdot \sigma_{s2}$$

Određivanje M_{Rd} - uzimanje u obzir nosivosti A_{s2}

5. Variranje položaja neutralne linije, **ξ,** dok se ne zadovolji uslov ravnoteže:

$$F_c + F_{s1} - F_{s2} = N_{Ed}$$

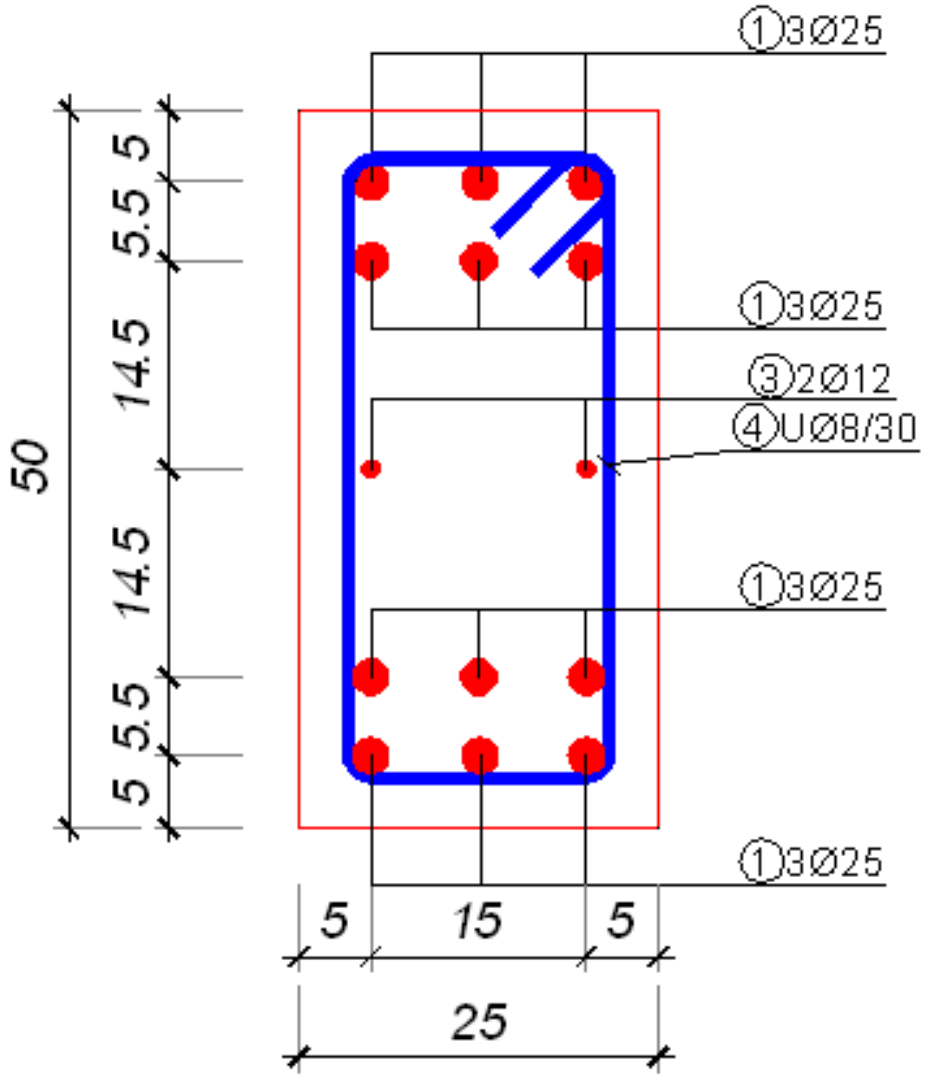
6. Sračunavanje sume momenata unutrašnjih sila u preseku oko težišta zategnute armature:

$$M_{Rds} = F_c \cdot z + F_{s2} \cdot (d - d_2)$$

7. Sračunavanje momenta nosivosti preseka za zadatu normalnu silu u preseku:

$$M_{Ed} = M_{Rds} - N_{Ed} \cdot \left(\frac{h}{2} - d_1 \right)$$

Zadatak 15a – Moment nosivosti preseka bez A_{s2}



C40/50

B500B

N_{Ed} = 325 kN

d^{I} = 5.0 cm

d^{II} = 10.5 cm

$d_1 = (3\times5 + 3\times10.5)/6$

d_1 = 7.75 cm

d = 50 – 7.75 = 42.25 cm

A_{s1} = 29.45 cm^2 (6Ø25)

Zadatak 15a – Moment nosivosti preseka bez A_{s2}

C40/50 f_{cd} = 0,85·40/1.5= 22.67 MPa = 2.27 kN/cm^2

B500 B f_{yd} = 500/1.15 = 435 MPa = 43.5 kN/cm^2

$$\omega_1 = \frac{A_{s1} \cdot f_{yd} + N_{Ed}}{b \cdot d \cdot f_{cd}} = \frac{29.45 \cdot 43.5 + 325}{25 \cdot 42.25 \cdot 2.27} = 0.6698 = 66.984\%$$

ε_c (‰)	μ	ω_1 (%)	ξ	ζ	ε_{s1} (‰)	κ
3.50	0.440	67.214	0.830	0.655	0.715	1.508

σ_{s1}=0.715·200GPa=143 MPa

Postupak je iterativan, menja se napon u armaturi

2. ITERACIJA

$$\omega_1 = \frac{A_{s1} \cdot f_{yd} + N_{Ed}}{b \cdot d \cdot f_{cd}} = \frac{29.45 \cdot 14.3 + 325}{25 \cdot 42.25 \cdot 2.27} = 0.31119 = 31.119\%$$

Zadatak 15a – Moment nosivosti preseka bez A_{s2}

$$\omega_1 = \frac{A_{s1} \cdot f_{yd} + N_{Ed}}{b \cdot d \cdot f_{cd}} = \frac{29.45 \cdot 14.3 + 325}{25 \cdot 42.25 \cdot 2.27} = 0.31119 = 31.119\%$$

ε_c (‰)	μ	ω_1 (%)	ξ	ζ	ε_{s1} (‰)	κ
3.50	0.260	30.909	0.382	0.841	5.667	1.961

$\varepsilon_{s1} > 2.5$ ‰ , tj. $\sigma_{s1} = f_{yd}$

- Izraz za ω_1 postaje isti kao u 1. iteraciji, beskonačan ciklus
- Problem rešavamo postavljanjem uslova ravnoteže, $\sum N = 0$

ε_{c2} (‰)	ε_{s1} (‰)	ξ	σ_{s1} (kN/cm^2)	F_c (kN)	F_{s1} (kN)	N_{Ed} (kN)	ΣN_u (kN)
3.5	2.500	0.583	43.50	1132.0	1281.1	325	474.1
3.5	1.750	0.667	35.00	1310.7	1030.8	325	45.0
3.5	1.642	0.681	32.84	1338.2	967.1	325	-46.1

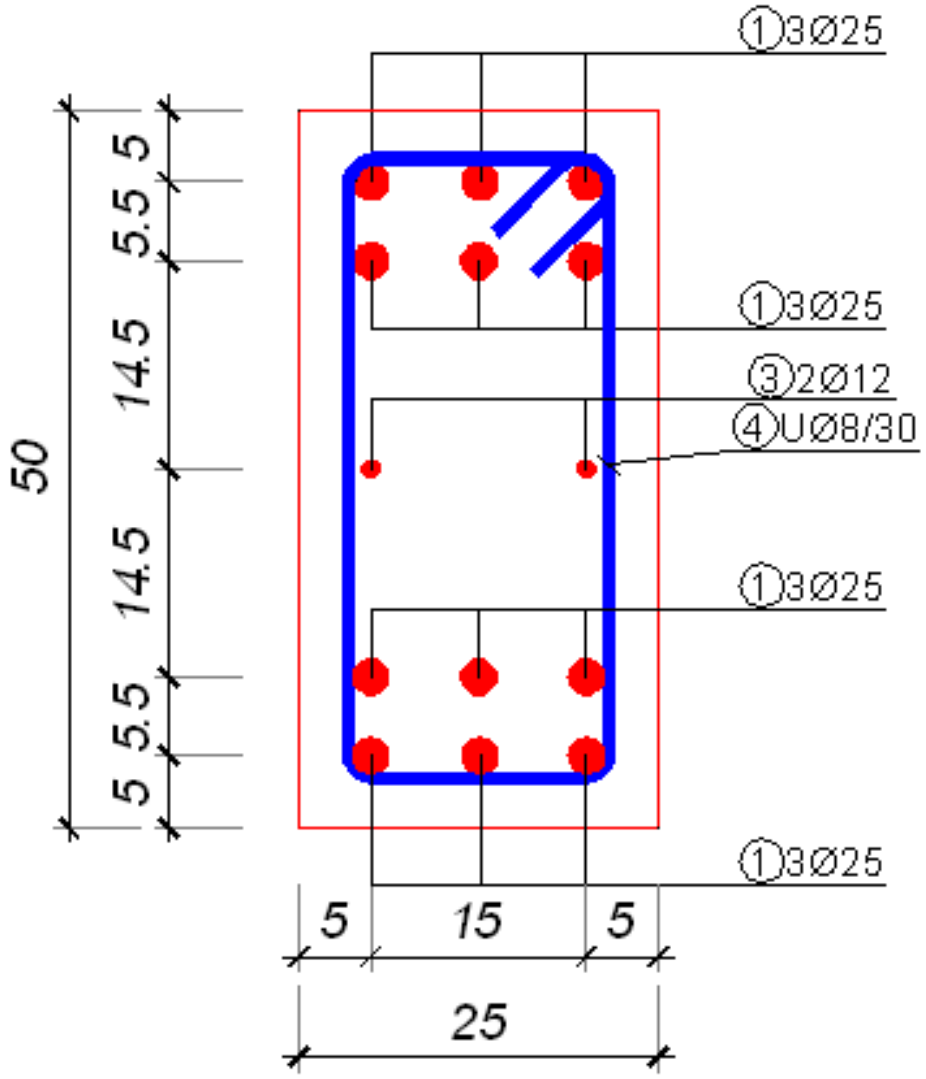
Zadatak 15a – Moment nosivosti preseka bez A_{s2}

ε_c (‰)	μ	ω_1 (%)	ξ	ζ	ε_{s1} (‰)	κ
3.50	0.390	53.963	0.667	0.723	1.750	1.601

$$M_{Rds} = M_{Eds} = \left(\frac{d}{k}\right)^2 \cdot b \cdot f_{cd} = \left(\frac{42.25}{1.601}\right)^2 \cdot 25 \cdot 2.27 = 395.22 kNm$$

$$M_{Rd} = M_{Rds} - N_{Ed} \cdot \left(\frac{h}{2} - d_1\right) = 395.22 - 325\left(\frac{0.5}{2} - 0.0725\right) = 337.5 kNm$$

Zadatak 15b – Moment nosivosti preseka sa A_{s2}



C40/50

B500B

N_{Ed} = 325 kN

d^{I} = 5.0 cm

d^{II} = 10.5 cm

$d_1 = (3\times5 + 3\times10.5)/6$

d_1 = 7.75 cm

d = 50 – 7.75 = 42.25 cm

A_{s1} = 29.45 cm^2 (6Ø25)

A_{s2} = 29.45 cm^2 (6Ø25)

Zadatak 15b – Moment nosivosti preseka sa A_{s2}

1. ITERACIJA

1. Pretpostavka: **ξ=0,259**

ε_c (‰)	ε_{s1} (‰)	ξ	ζ	ω_1 (%)	k	μ
3.50	10.00	0.259	0.892	20.988	2.311	0.187

2. Sračunavanje unutrašnjih sila u preseku:

$$F_c = 0.810\xi dbf_{cd} = 0.81 \cdot 0.259 \cdot 42.25 \cdot 25 \cdot 2.27 = 503kN$$

$$F_{s1} = A_{s1} \cdot \sigma_{s1} = 29.45 \cdot 43.5 = 1281.1kN$$

3. Sračunavanje dilatacije u pritisnutoj armaturi:

$$\varepsilon_{s2} = \frac{\xi^{III} - \frac{d_2}{d}}{\xi^{III}} \varepsilon_{cu2} = \frac{0.259 - \frac{7.75}{42.25}}{0.259} \cdot 3.5 = 1.021‰ < 2.175‰$$

4. Sila u pritisnutoj armaturi: $F_{s2} = 29.45 \cdot 1.021 \cdot 200/10 = 601kN$

Zadatak 15b – Moment nosivosti preseka sa A_{s2}

1. ITERACIJA

5. Suma sila:

$$503 + 601 - 1281.1 - 325 = -502kN$$

Povećati silu u pritisnutom betonu, tj. spustiti neutralnu liniju, tj. povećati ξ !!!

ITERATIVNI POSTUPAK:

ε_{c2} (‰)	ε_{s1} (‰)	ξ	σ_{s1} (kN/cm^2)	ε_{s2} (‰)	σ_{s2} (kN/cm^2)	F_c (kN)	F_{s1} (kN)	F_{s2} (kN)	N_{Ed} (kN)	ΣN_u (kN)
3.5	10.00	0.259	43.50	1.021	204.2	503.0	1281.1	601	325	-501.6
3.5	5.00	0.412	43.50	1.942	388.3	800.2	1281.1	1144	325	337.8
3.5	7.00	0.333	43.50	1.572	314.4	646.7	1281.1	926	325	-33.4
3.5	6.80	0.340	43.50	1.612	322.3	660.3	1281.1	949	325	3.6

Zadatak 15b – Moment nosivosti preseka sa A_{s2}

6. Sračunavanje sume momenata unutrašnjih sila u preseku oko težišta zategnute armature:

$$M_{Rds} = F_c \cdot z + F_{s2} \cdot (d - d_2) =$$

$$= 660.3 \cdot 0.859 \cdot 42.25 + 949 \cdot (42.25 - 7.75) = 567 kNm$$

7. Sračunavanje momenta nosivosti preseka za zadatu normalnu silu u preseku:

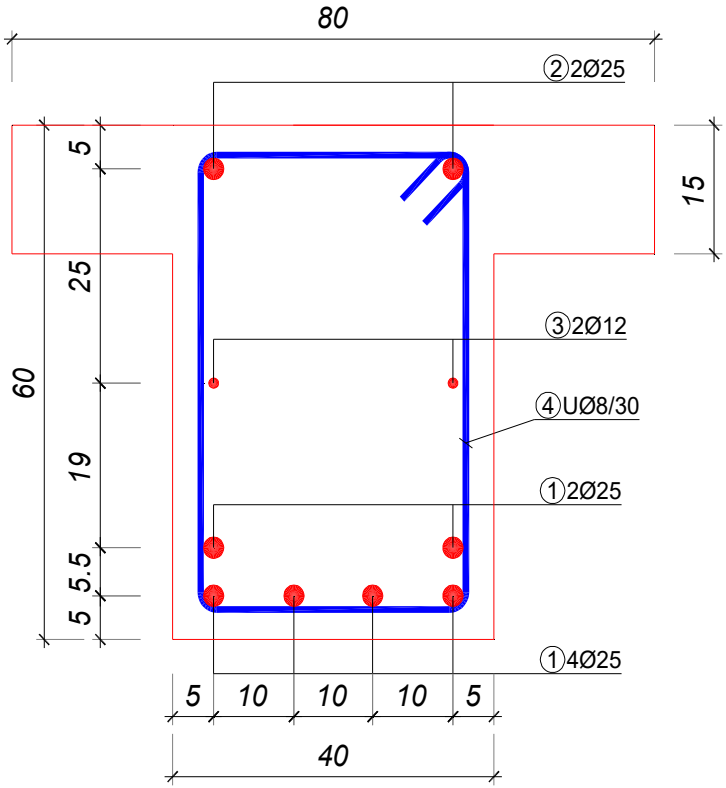
$$M_{Ed} = M_{Rds} - N_{Ed} \cdot \left(\frac{h}{2} - d_1 \right) =$$

$$= 567 - 325 \cdot \left(\frac{0.5}{2} - 0.075 \right) = \boxed{510.2 kNm}$$

Zadatak 16a – Moment nosivosti **"T" preseka**

Odrediti moment nosivosti preseka prikazanog na skici, koji je osim momenta savijanja opterećen i silom pritiska N_{Ed} = 1000 kN. Proračun sprovesti uz zanemarenje nosivosti pritisnute armature.

C30/37	B500 B

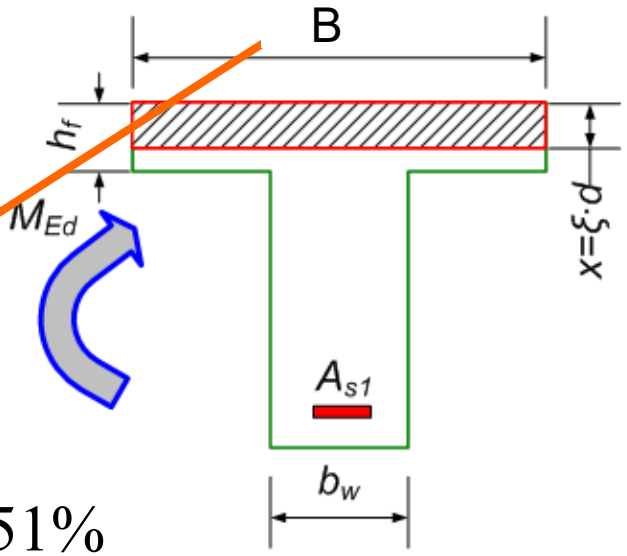


Zadatak 16a – Moment nosivosti **"T" preseka**

C30/37 $f_{cd} = 0{,}85 \cdot 30/1.5 = 17\text{MPa} = 1.7\ \text{kN/cm}^2$

B500 B $f_{yd} = 500/1.15 = 435\ \text{Mpa} = 43.5\ \text{kN/cm}^2$

Pretpostavka: neutralna linija je u ploči, tj. $x < h_f$



$$\omega_1 = \frac{A_{s1} \cdot f_{yd} + N_{Ed}}{B \cdot d \cdot f_{cd}} = \frac{29.46 \cdot 43.5 + 1000}{80 \cdot 53.17 \cdot 1.7} = 31.551\%$$

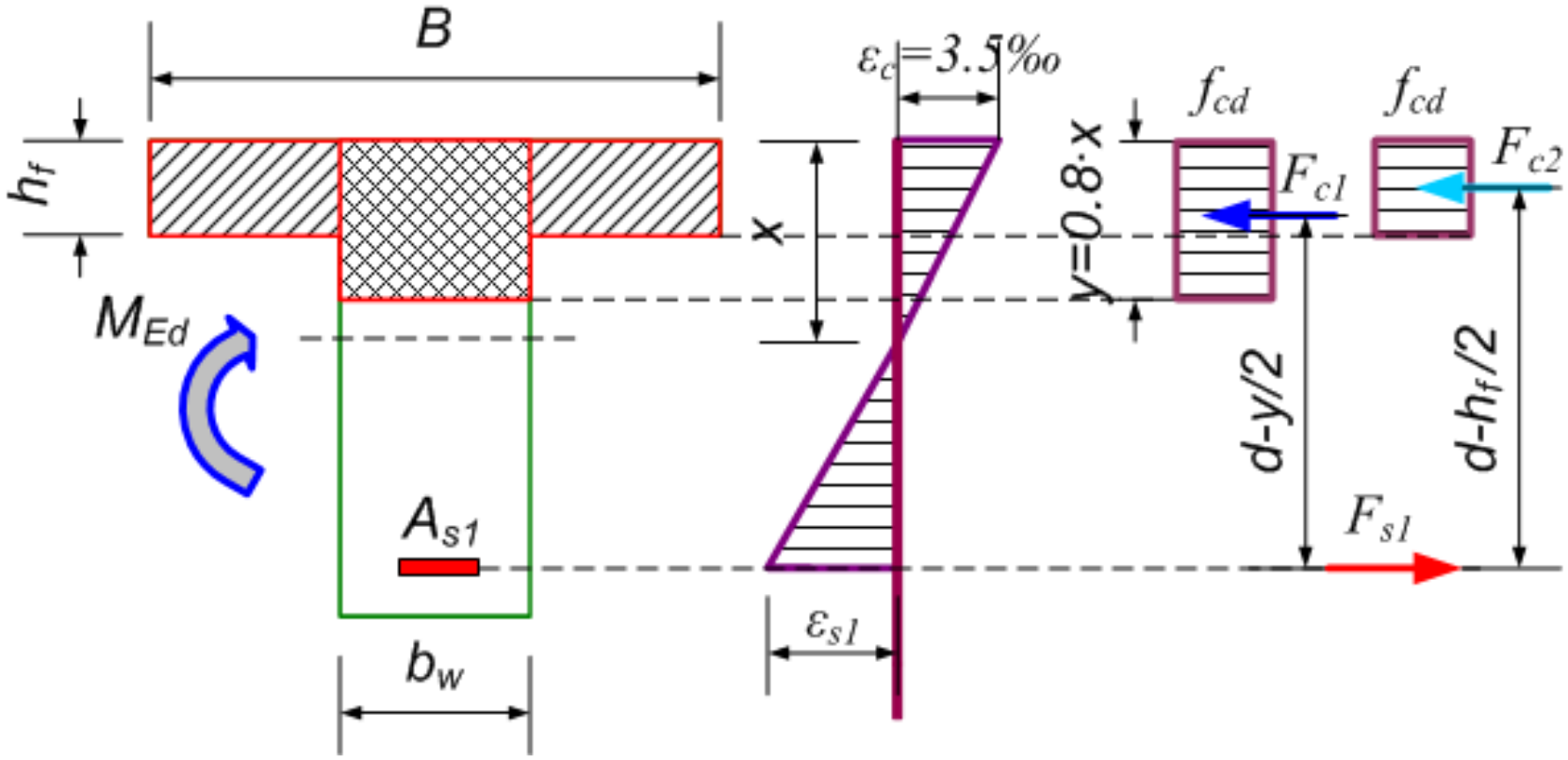
ε_c (‰)	μ	ω_1 (%)	ξ	ζ	ε_{s1} (‰)	κ
3.50	0.265	31.646	0.391	0.837	5.453	1.943

Zadatak 16a – Moment nosivosti **"T" preseka**

Provera položaja neutralne linije:

$x=\xi \cdot d=0.391 \cdot 53.17=20.8$ cm > 15 cm=h_f

Pretpostavka nije dobra, n-n linija je u rebru!



Zadatak 16a – Moment nosivosti **"T" preseka**

$$F_{c1} = b_w \cdot y \cdot f_{cd} = 40 \cdot y \cdot 1.7 = 68y$$
$$F_{c2} = (B - b_w) \cdot h_f \cdot f_{cd} = (80 - 40) \cdot 15 \cdot 1.7 = 1020kN$$
$$F_{s1} = A_{s1} \cdot f_{yd} = 29.46 \cdot 43.5 = 1281.5kN$$
$$N_{Ed} = 1000kN$$

Uslov ravnoteže: $\sum N = 0$

$$68y + 1020 - 1281.5 - 1000 = 0 \rightarrow y = 18.55cm$$

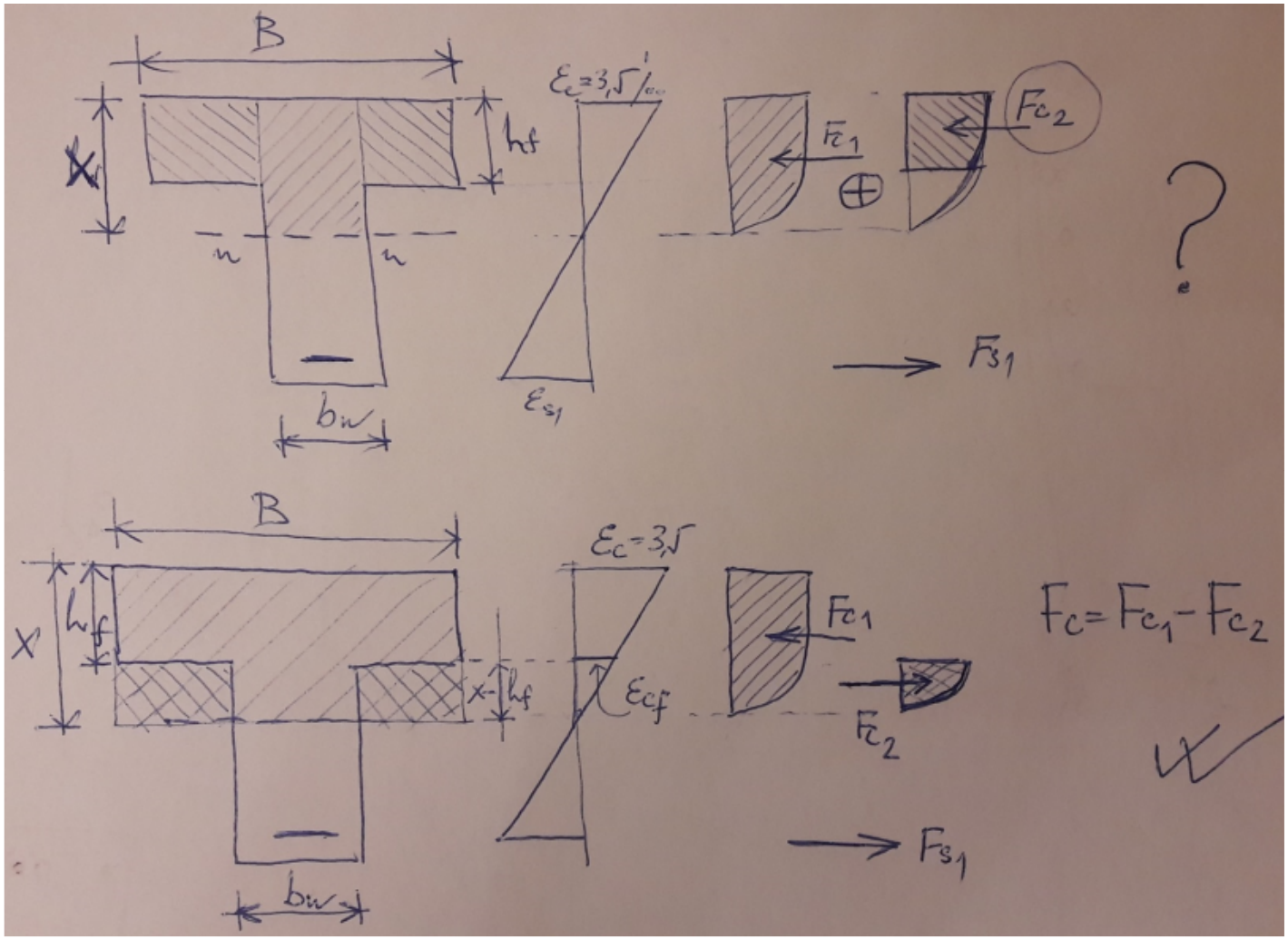
Kontrolisati ε_{s1}!!!

Uslov ravnoteže: $\sum M_s = 0$

$$M_{Rds} = f_{cd}\left[b_w y\left(d - \frac{y}{2}\right) + (B - b_w)h_f\left(d - \frac{h_f}{2}\right)\right] = M_{Eds} = 1019.5kNm$$

$$M_{Ed} = M_{Rds} - N_{Ed} \cdot \left(\frac{h}{2} - d_1\right) = 787.8kNm$$

Zadatak 16b – Moment nosivosti **"T" preseka (dijagram napona "parabola-prava")**



Zadatak 16b – Moment nosivosti **"T" preseka (dijagram napona "parabola-prava")**

$F_{c1} = \beta_{1,1} \cdot x \cdot f_{cd} \cdot B$ ..., $\beta_{1,1} = \beta_1(3{,}5‰) = 0{,}81$

$F_{c2} = \beta_{1,2} \cdot (x - h_f) \cdot f_{cd} \cdot (B - b_w)$, $\beta_{1,2} = \beta_1(\varepsilon_{cf})$

$\beta_1 = \frac{\varepsilon_c}{12} \cdot (6 - \varepsilon_c), \varepsilon_c \leq 2‰$; $\beta_1 = \frac{3\varepsilon_c - 2}{3\varepsilon_c}$, $2 \leq \varepsilon_c \leq 3{,}5‰$

контрола дилатације у арматури:

$\frac{3{,}5}{20{,}8} = \frac{3{,}5 + \varepsilon_{s1}}{53{,}17} \Rightarrow \varepsilon_{s1} = 5{,}45‰ > 2{,}5‰$

$\Rightarrow \sigma_{s1} = f_{yd}$

1. итерација

$\frac{3{,}5}{20{,}8} = \frac{\varepsilon_{cf}}{20{,}8 - 15} \Rightarrow \varepsilon_{cf} = 0{,}976‰ \Rightarrow \beta_1 = 0{,}317$

$\beta_1 = 0{,}409$

$F_{c1} = 0{,}81 \cdot 20{,}8 \cdot 1{,}7 \cdot 80 = 2291{,}3\,kN$

$F_{c2} = 0{,}317 \cdot (20{,}8 - 15) \cdot 1{,}7 \cdot (80 - 40) = 125\,kN$

Zadatak 16b – Moment nosivosti **"T" preseka (dijagram napona "parabola-prava")**

$F_{s_1} = 1281{,}5\ kN$; $F_{c_1} = 0{,}81 \cdot 20{,}8 \cdot 1{,}7 \cdot 80 = 2291{,}3\ kN$

$N_{ed} = 1000\ kN$; $F_{c_2} = 0{,}409 \cdot (20{,}8 - 15) \cdot 17 \cdot (80 - 40) = 161{,}3\ kN$

$\Sigma N = 0$: $(2291{,}3 - 161{,}3) - 1281{,}5 - 1000 = -159{,}0\ kN \neq 0$

$\Rightarrow$ usvojiti neutralnu liniju

2. iteracija

$x = 22\ cm$ $\quad \frac{3{,}5}{22} = \frac{\varepsilon_{cf}}{22 - 15} \Rightarrow \varepsilon_{cf} = 1{,}114\ ‰$

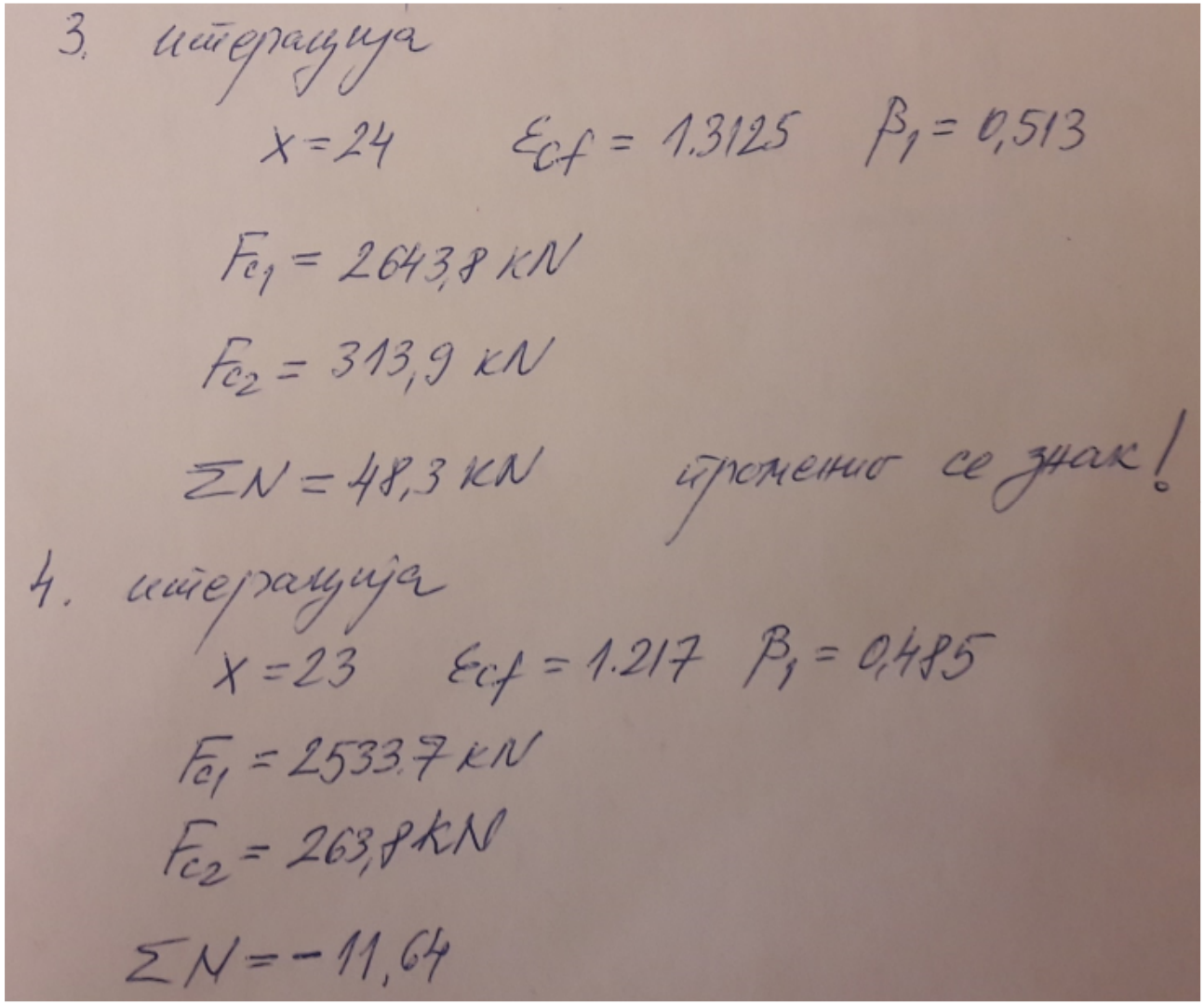
$\beta_1 = 0{,}454$

$F_{c_1} = 0{,}81 \cdot 22 \cdot 1{,}7 \cdot 80 = 2423{,}5\ kN$

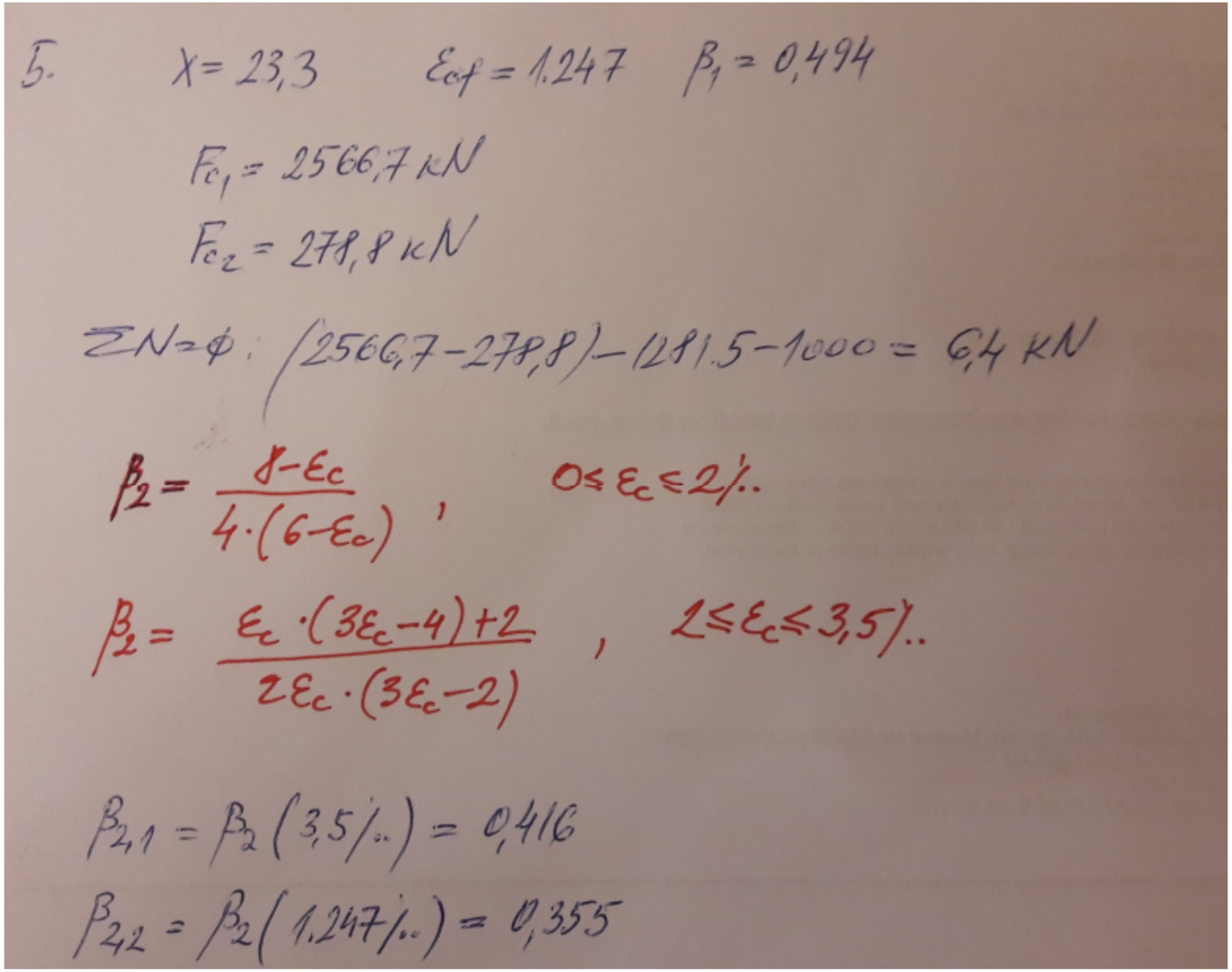
$F_{c_2} = 0{,}454 \cdot (22 - 15) \cdot 1{,}7 \cdot (80 - 40) = 216\ kN$

$\Sigma N = 0$: $(2423{,}5 - 216) - 1281{,}5 - 1000 = -74{,}1\ kN$

Zadatak 16b – Moment nosivosti **"T" preseka (dijagram napona "parabola-prava")**



Zadatak 16b – Moment nosivosti **"T" preseka (dijagram napona "parabola-prava")**



Zadatak 16b – Moment nosivosti **"T" preseka (dijagram napona "parabola-prava")**

$$M_{Rds} = F_{c1} \cdot \left(d - \beta_{21} x\right) - F_{c2} \cdot \left(d - h_f - \beta_{22} \cdot (x - h_f)\right)$$

$$M_{Rds} = 2566{,}7\left(53{,}17 - 0{,}416 \cdot 23{,}3\right) - 278{,}8\left(53{,}17 - 15 - 0{,}355 \cdot (23{,}3 - 15)\right)$$

$$M_{Rds} = 1017{,}7 \text{ kNm}$$

$$M_{Ed} = M_{Rds} - V_{ed}\left(\frac{h}{2} - d_1\right) = 1017{,}7 - 1000 \cdot \left(\frac{0{,}6}{2} - 0{,}0683\right)$$

$$\boxed{M_{Ed} = 786 \text{ kNm}}$$