Studijski program:	**Građevinarstvo**
Modul:	Konstrukcije
Godina/Semestar:	**III godina / V semestar**
Naziv predmeta (šifra):	**Teorija betonskih konstrukcija 1 (БЗО3Б1)**
Nastavnik:	**Jelena Carević / Stefan Ž. Mitrović / Milica Vidović**
Naslov vežbi:	Jednostruko armiranje-vezano dimenzionisanje. Parametarska analiza. Dvostruko armiranje. Slobodno dimenzionisanje.
Datum:	16.10.2024.

Zadatak 3 - **VEZANO** dimenzionisanje

Odrediti potrebnu površinu armature za presek poznatih dimenzija, pravougaonog oblika, opterećen graničnim momentom savijanja M_{Ed}. Podaci za proračun:

M_{Ed} = **500** kNm

b = 40 cm

h = 60 cm

C25/30

B500 B

C25/30 ⇒ $f_{cd} = 0.85 \cdot 25/1.5 = 14.2 MPa = 1.42\ kN/cm^2$

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

Zadatak 3 - **VEZANO** dimenzionisanje

1. M_{Ed}=500 kNm
2. pretp. d_1 = 7 cm

   $d = h - d_1 = 60 - 7 = 53$ cm

3. Računa se:

$$k = \frac{d}{\sqrt{\frac{M_{Ed}}{b \cdot f_{cd}}}} = \frac{53}{\sqrt{\frac{500 \cdot 10^2}{40 \cdot 1.42}}} = 1.786$$

ε_c (‰)	ε_{s1} (‰)	ξ	ζ	ω_1 (%)	κ	μ
3.50	3.75	0.483	0.799	39.080	1.789	0.312
3.50	3.70	0.486	0.798	39.352	1.785	0.314
3.50	3.65	0.490	0.796	39.627	1.780	0.316

$\varepsilon_{s1} \geq 2.5‰$

Zadatak 3 - **VEZANO** dimenzionisanje

ε_c (‰)	ε_{s1} (‰)	ξ	ζ	ω_1 (%)	κ	μ
3.50	3.70	0.486	0.798	39.352	1.785	0.314

4. Računa se:

$$A_{s1} = \omega_1 \times \frac{b \times d}{100} \times \frac{f_{cd}}{f_{yd}}$$

$$A_{s1} = 39.352 \times \frac{40 \times 53}{100} \times \frac{1.42}{43.5} = 27.23 cm^2$$

ILI

ε_c (‰)	ε_{s1} (‰)	ξ	ζ	ω_1 (%)	κ	μ
3.50	3.70	0.486	0.798	39.352	1.785	0.314

$$A_{s1} = \frac{M_{Ed}}{\zeta \times d \times f_{yd}} = \frac{500 \cdot 10^2}{0.798 \times 53 \times 43.5} = 27.18 cm^2$$

Zadatak 3 - **VEZANO** dimenzionisanje

5. Usvaja se: 9Ø20 (28.26 cm^2)

6. **Računanje težišta armature**

$d^{I} = 3.5 + 0.8 + 2.0/2 = 5.3$ cm

$d^{II} = 5.3 + 3.0 + 2\times2.0/2 = 10.3$ cm

$d_1 = (5\times5.3 + 4\times10.3)/9 = 7.52$ cm

$d_{1,stv} > d_{1,prp}$ nije na strani sigurnosti jer je $d_{stv} < d_{prp}$, ali:

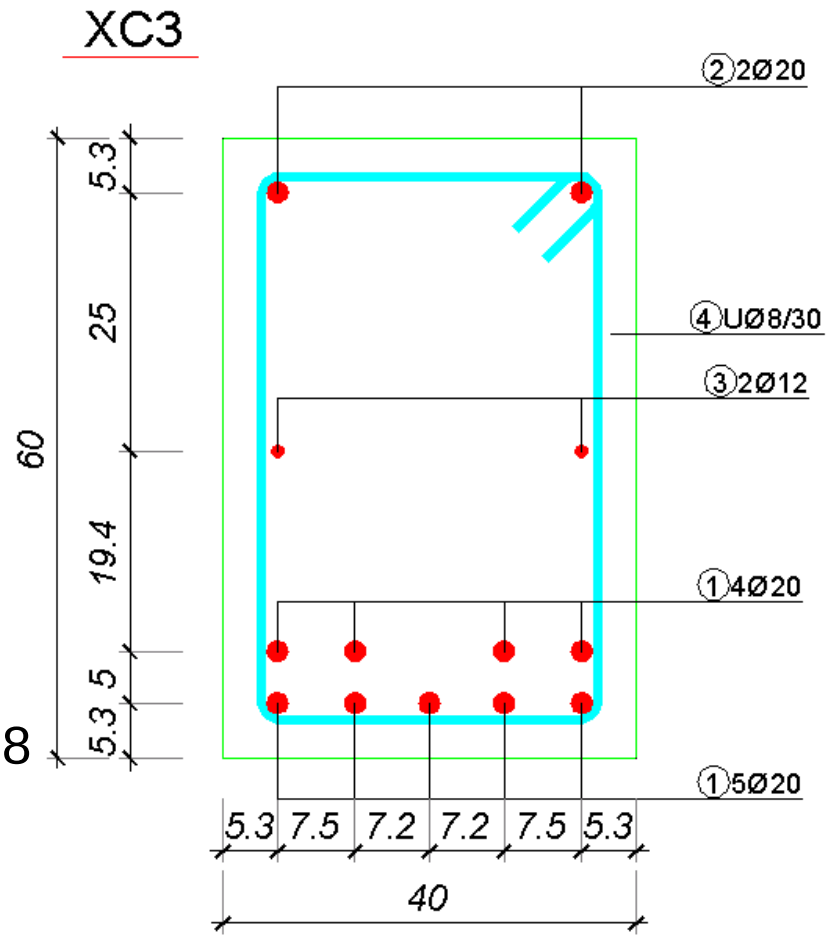
$z_{stv} \cdot A_{s1,stv} > z_{prp} \cdot A_{s1,pot}$

$\approx 0.798\cdot(60-7.52)\cdot28.26 > 0.798\cdot(60-7)\cdot27.18$

$M_{Rd,stv} \approx 514.8$ kNm > $M_{Rd,pot} = 500.1$ kNm

$M_{Rd} \approx 514.8$ kNm > $M_{Ed} = 500$ kNm

7. **Konstruisanje preseka**



Zadatak 3 - **VEZANO** dimenzionisanje (komentar)

ε_c (‰)	ε_{s1} (‰)	ξ	ζ	ω_1 (%)	κ	μ
3.50	*3.70*	*0.486*	*0.798*	*39.352*	*1.785*	*0.314*

$F_c = 0.810 \times \xi \times b \times d \times f_{cd}$

$F_c = 0.810 \times 0.486 \times 40 \times 53 \times 1.42 = 1185.1$ kN

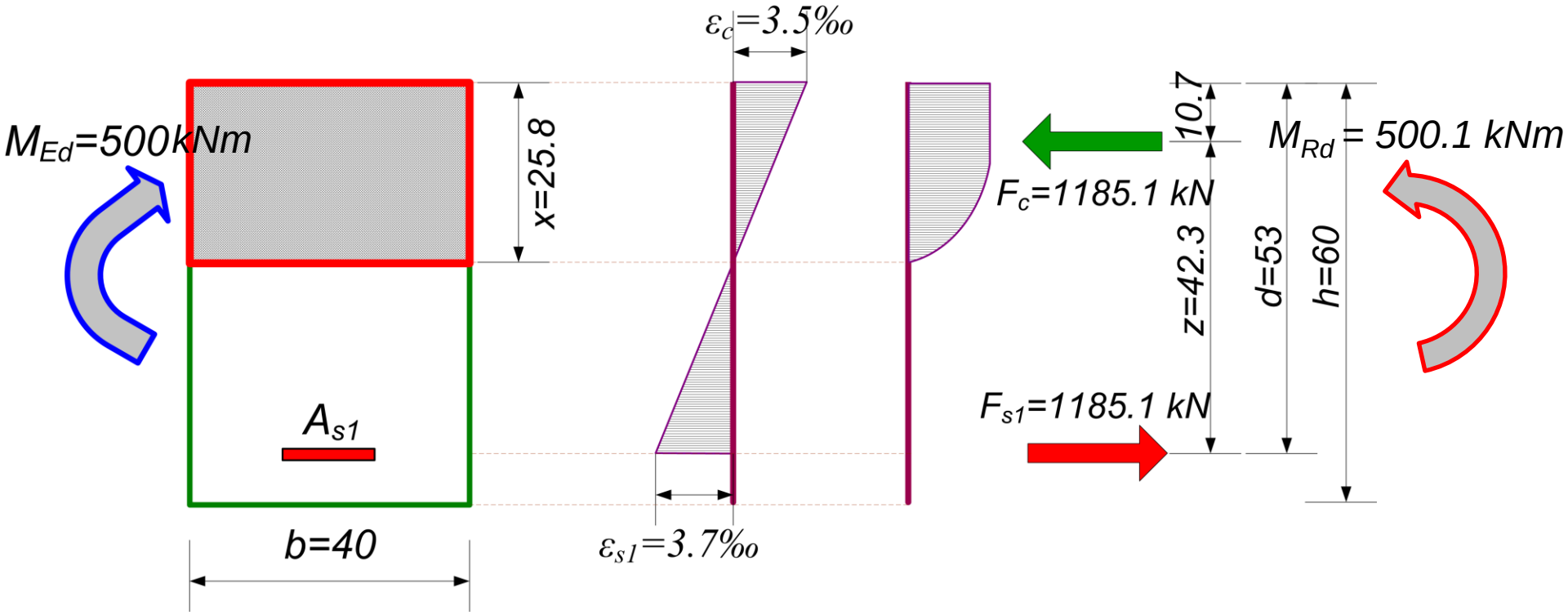
$F_{s1} = A_{s1} \times \sigma_{s1} = A_{s1} \times f_{yd}$

$F_{s1} = 27.18 \times 43.5 = 1182.3$ kN $= F_c$

x $= \xi \times d = 0.486 \times 53 = 25.8$ cm

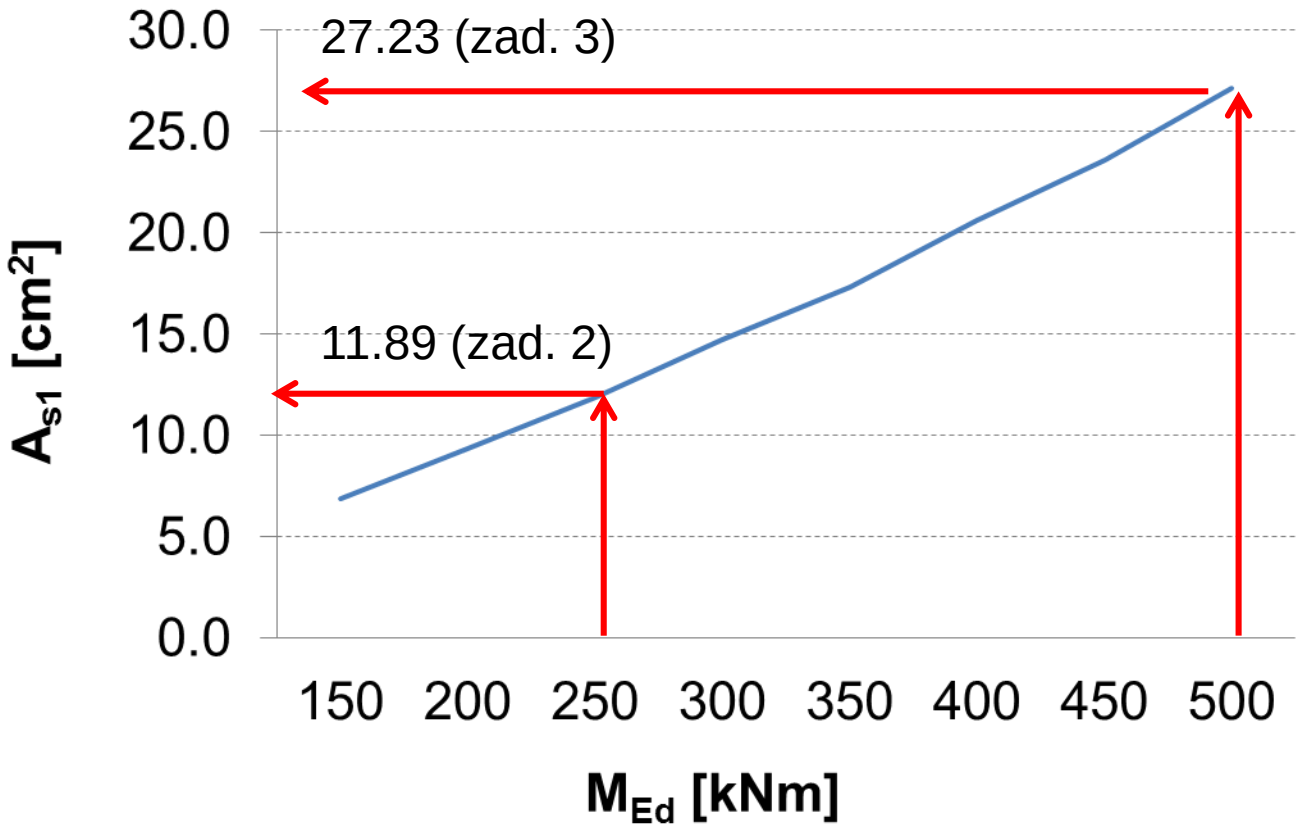
z $= \zeta \times d = 0.798 \times 53 = 42.3$ cm

Zadatak 3 - **VEZANO** dimenzionisanje (komentar)

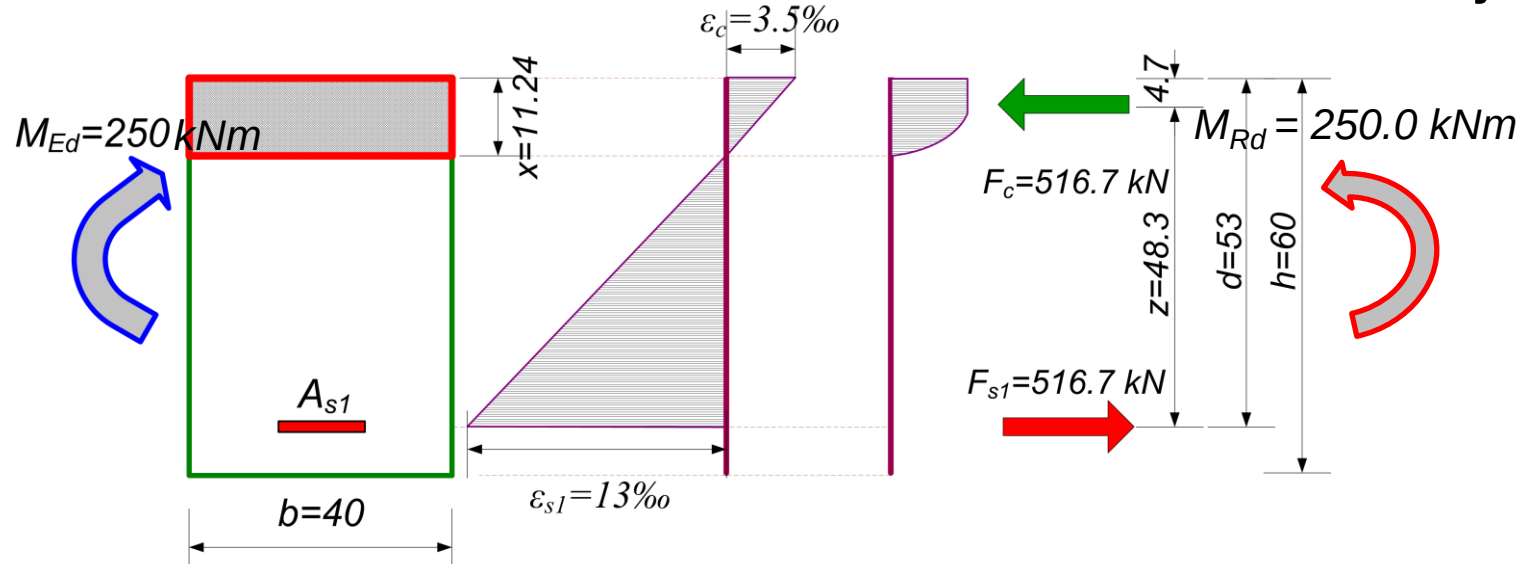


Za pretpostavljeno d_1 i potrebnu armaturu $A_{s1,pot}$

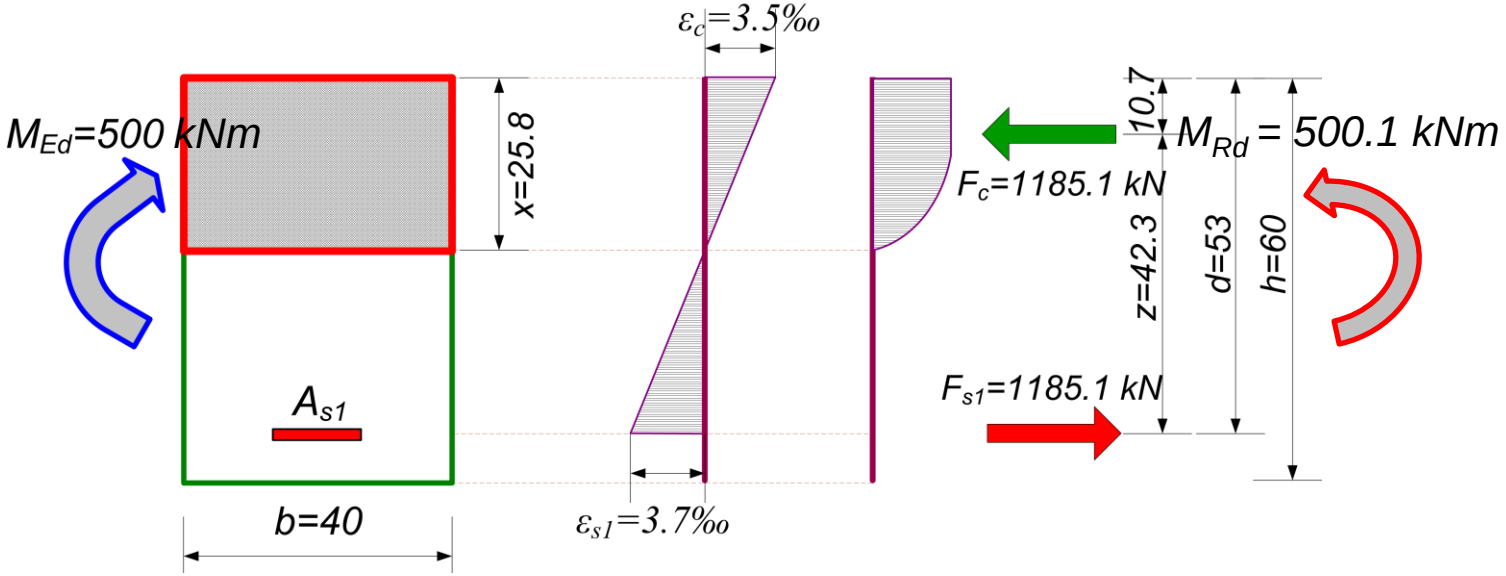
Zavisnost A_{s1} od promene M



Zadatak 3 - **VEZANO** dimenzionisanje



Zadatak 2



Zadatak 3

Zadatak 4 - **VEZANO** dimenzionisanje

Odrediti potrebnu površinu armature za presek poznatih dimenzija, pravougaonog oblika, opterećen graničnim momentom savijanja M_{Ed}. Podaci za proračun:

M_{Ed} = **250** kNm **b = 20 cm** C25/30

h = 60 cm B500 B

C25/30 ⇒ $f_{cd} = 0.85 \cdot 25/1.5 = 14.2 MPa = 1.42\ kN/cm^2$

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

Zadatak 4- **VEZANO** dimenzionisanje

1. M_{Ed}=250 kNm
2. pretp. d_1 = 7 cm

   d = h – d_1 = 60 – 7 = 53 cm

3. Računa se:

$$k = \frac{d}{\sqrt{\frac{M_{Ed}}{b \cdot f_{cd}}}} = \frac{53}{\sqrt{\frac{250 \cdot 10^2}{20 \cdot 1.42}}} = 1.784$$

ε_c (‰)	ε_{s1} (‰)	ξ	ζ	ω_1 (%)	κ	μ
3.50	3.70	0.486	0.798	39.352	1.785	0.314
3.50	3.65	0.490	0.796	39.627	1.780	0.316

$\varepsilon_{s1} \geq 2.5‰$

Zadatak 4 - **VEZANO** dimenzionisanje

ε_c (‰)	ε_{s1} (‰)	ξ	ζ	ω_1 (%)	κ	μ
3.50	3.70	0.486	0.798	39.352	1.785	0.314

4. Računa se:

$$A_{s1} = \omega_1 \times \frac{b \times d}{100} \times \frac{f_{cd}}{f_{yd}}$$

$$A_{s1} = 39.352 \times \frac{20 \times 53}{100} \times \frac{1.42}{43.5} = 13.62 cm^2$$

ILI

$$A_{s1} = \frac{M_{Ed}}{\zeta \times d \times f_{yd}} = \frac{250 \cdot 10^2}{0.798 \times 53 \times 43.5} = 13.59 cm^2$$

Zadatak 4 - **VEZANO** dimenzionisanje

5. Usvaja se: 5Ø20 (15.70 cm^2)

6. **Računanje težišta armature**

$d^{I} = 3.5 + 0.8 + 1.6/2 = 5.1$ cm

$d^{II} = 5.1 + 3.0 + 2\times1.6/2 = 9.7$ cm

$d_1 = (3\times5.1 + 2\times9.7)/7 = 6.94$ cm

$d_{1,stv} \approx d_{1,prp}$

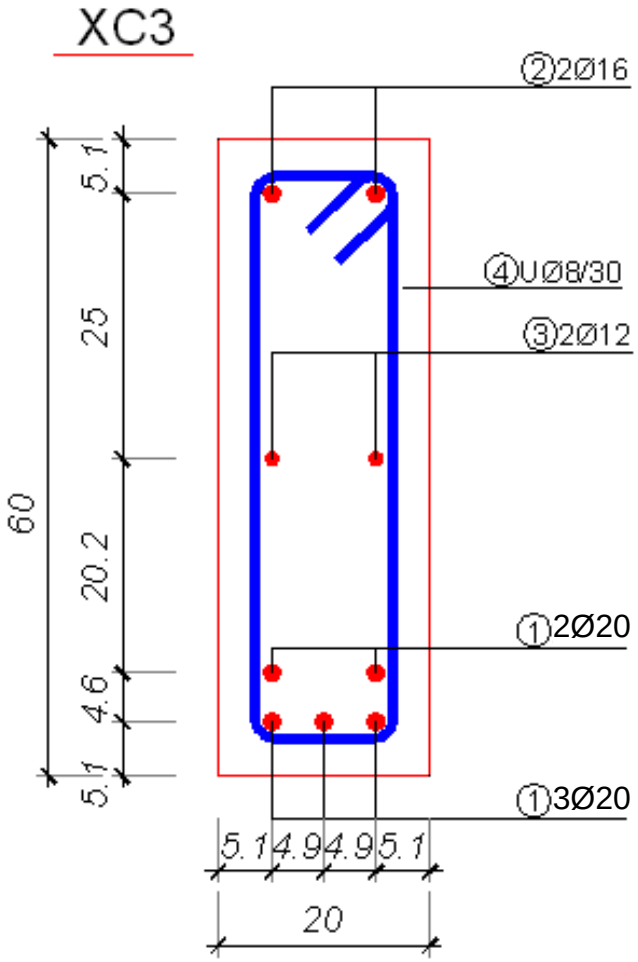
$z_{stv} \cdot A_{s1,stv} > z_{prp} \cdot A_{s1,pot}$

$\approx 0.798\cdot(60-6.94)\cdot15.7 > 0.798\cdot(60-7)\cdot13.59$

$M_{Rd,stv} \approx 289.2$ kNm > $M_{Rd,pot} = 250.0$ kNm

$M_{Rd} \approx 289.2$ kNm > $M_{Ed} = 250$ kNm

7. **Konstruisanje preseka**



Zadatak 4 - **VEZANO** dimenzionisanje

ε_c (‰)	ε_{s1} (‰)	ξ	ζ	ω_1 (%)	κ	μ
3.50	*3.70*	*0.486*	*0.798*	*39.352*	*1.785*	*0.314*

$F_c = 0.810 \times \xi \times b \times d \times f_{cd}$

$F_c = 0.810 \times 0.486 \times 20 \times 53 \times 1.42 = 592.5$ kN

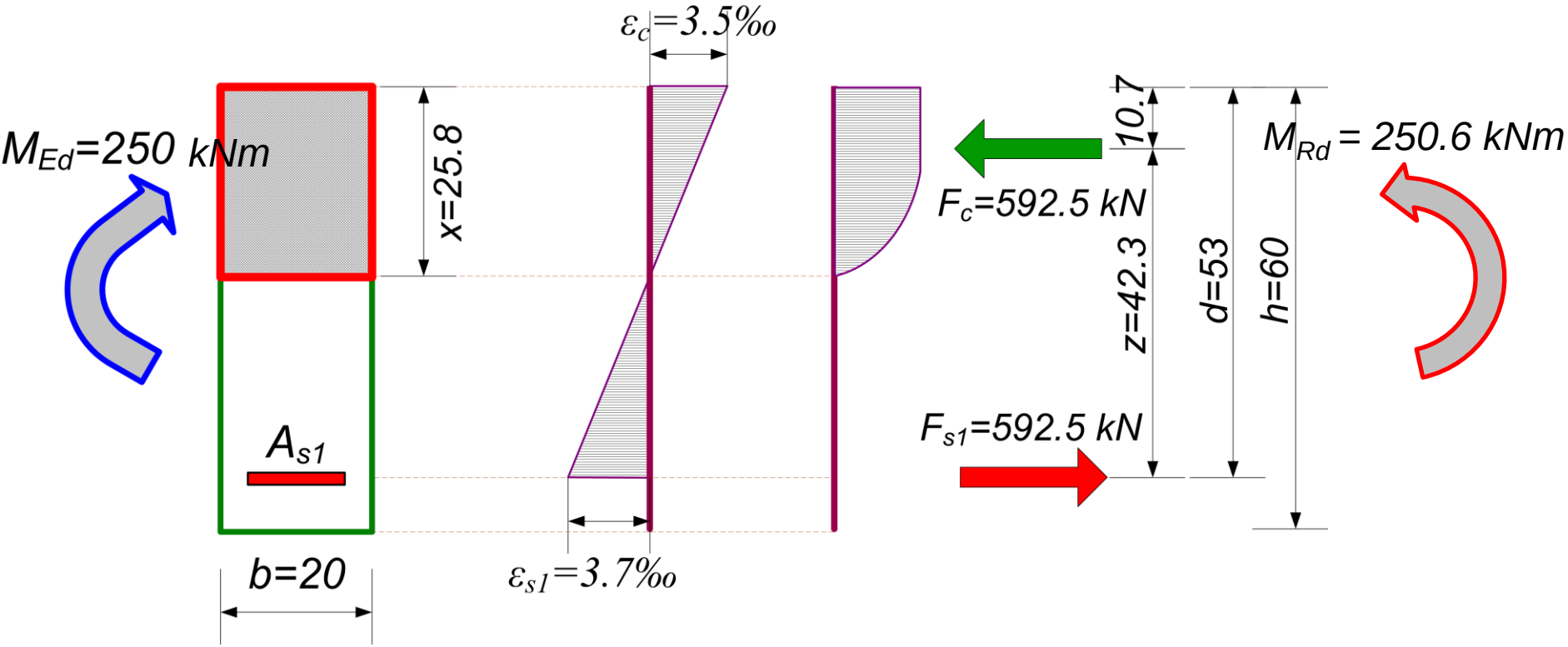
$F_{s1} = A_{s1} \times \sigma_{s1} = A_{s1} \times f_{yd}$

$F_{s1} = 13.62 \times 43.5 = 592.5$ kN $= F_c$

x $= \xi \times d = 0.486 \times 53 = 25.76$ cm

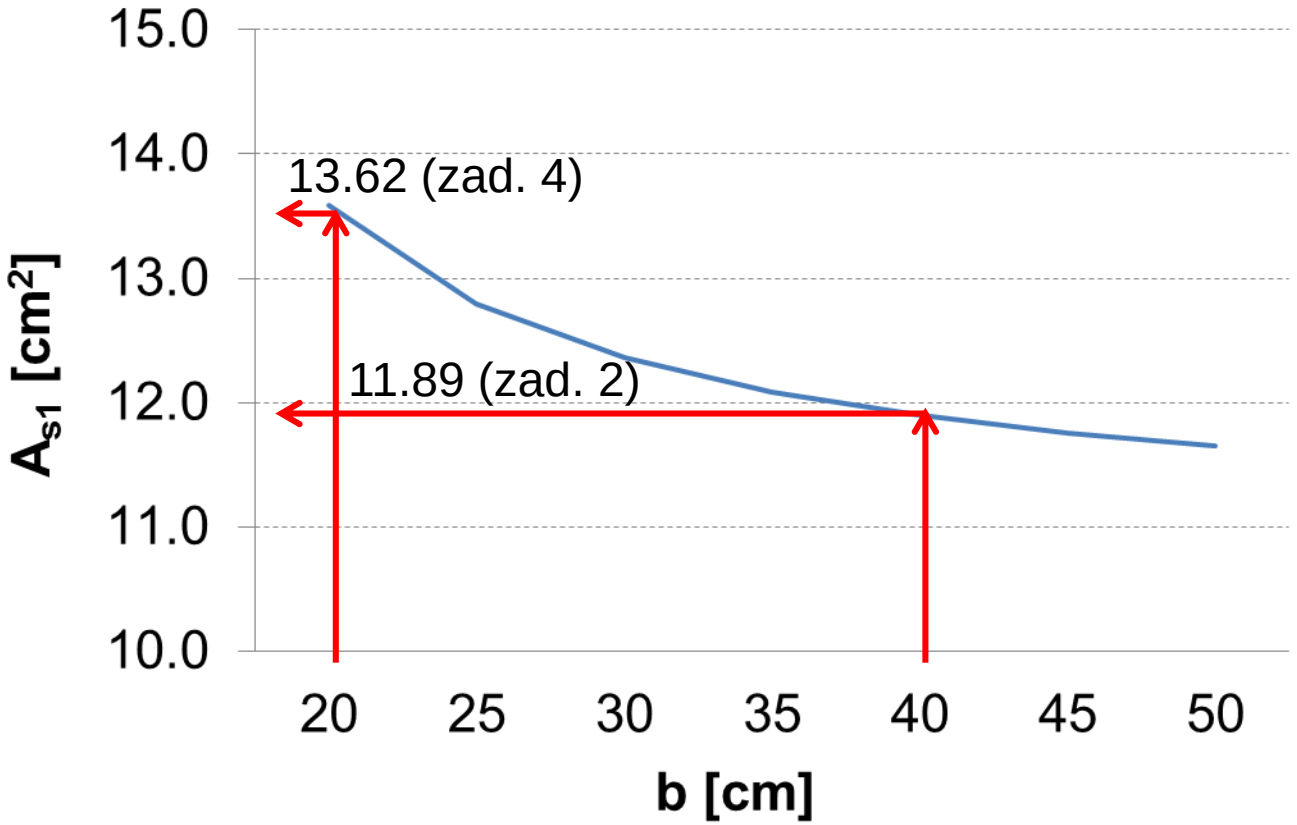
z $= \zeta \times d = 0.798 \times 53 = 42.29$ cm

Zadatak 4 - **VEZANO** dimenzionisanje

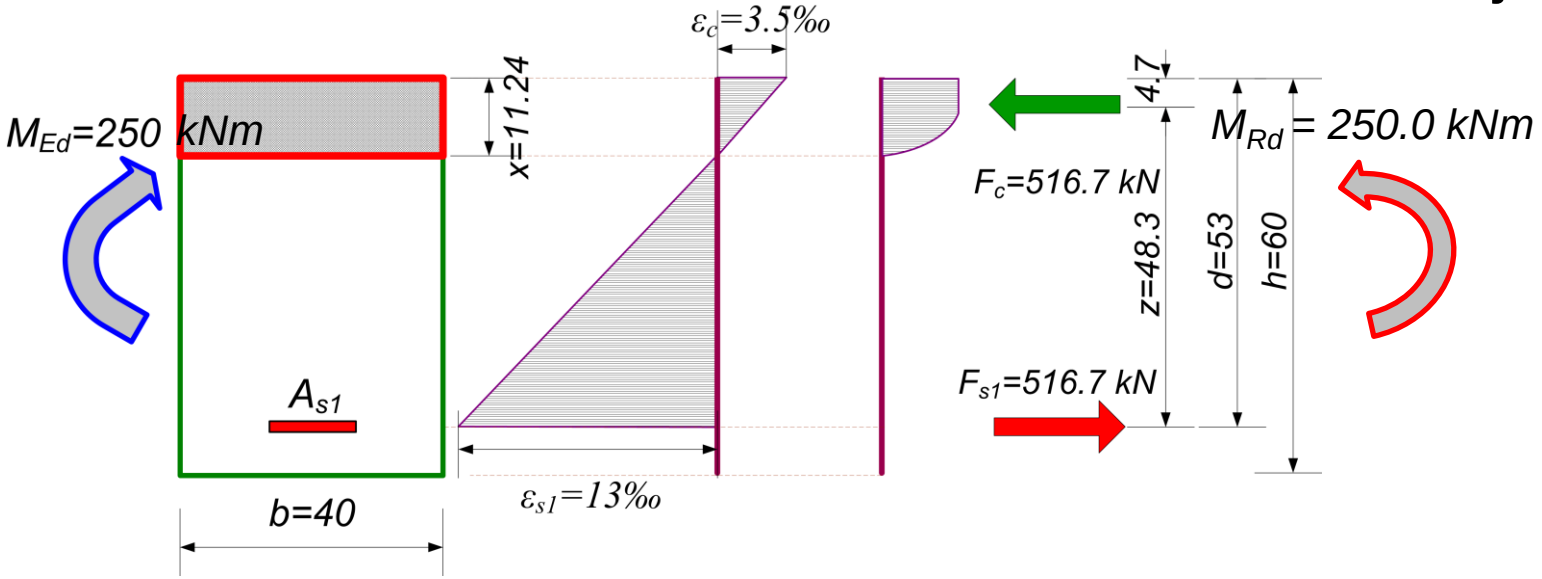


Za pretpostavljeno d_1 i potrebnu armaturu $A_{s1,pot}$

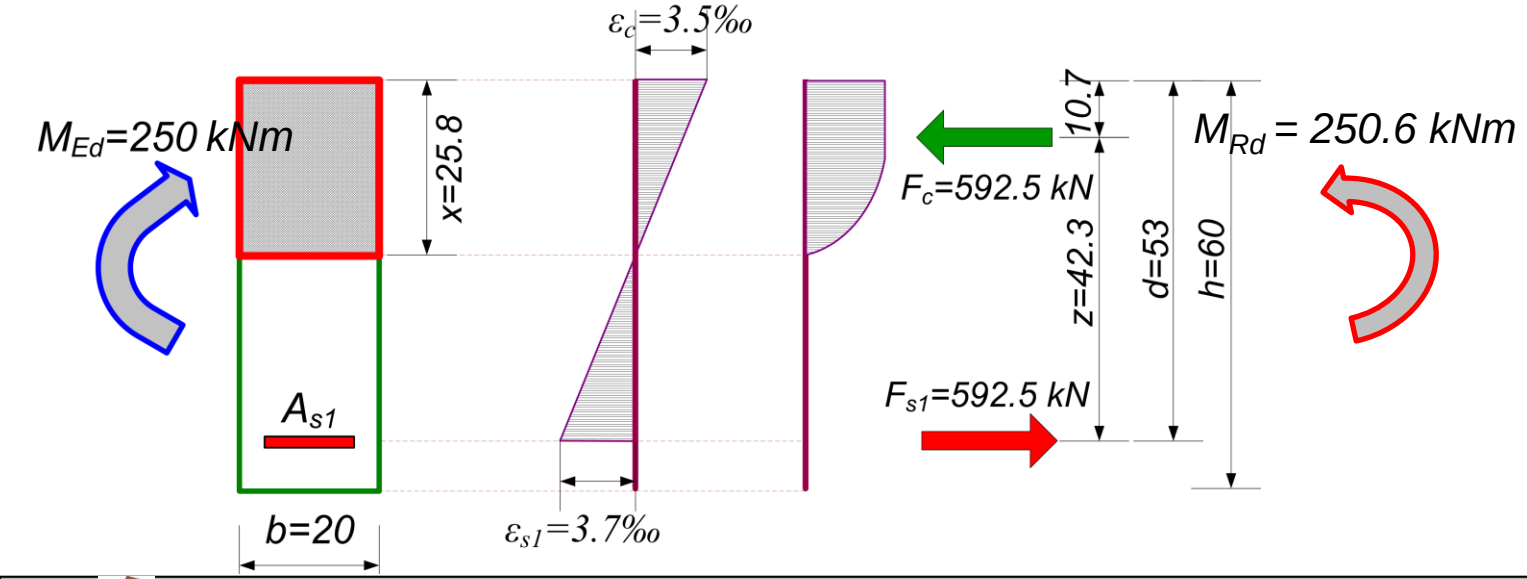
Zavisnost A_{s1} od promene b



Zadatak 4 - **VEZANO** dimenzionisanje



Zadatak 2



Zadatak 4

Zadatak 5 - **VEZANO** dimenzionisanje

Odrediti potrebnu površinu armature za presek poznatih dimenzija, pravougaonog oblika, opterećen graničnim momentom savijanja M_{Ed}. Podaci za proračun:

M_{Ed} =250 kNm	b = 40 cm	**C50/60**
	h = 60 cm	B500 B

C50/60 ⇒ $f_{cd} = 0.85 \cdot 50/1.5 = 28.3 MPa = 2.83\ kN/cm^2$

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

Zadatak 5 - **VEZANO** dimenzionisanje

1. M_{Ed}=250 kNm
2. pretp. d_1 = 7 cm

   $d = h - d_1 = 60 - 7 = 53$ cm

3. Računa se:

$$k = \frac{d}{\sqrt{\frac{M_{Ed}}{b \cdot f_{cd}}}} = \frac{53}{\sqrt{\frac{250 \cdot 10^2}{40 \cdot 2.83}}} = 3.566$$

ε_c (‰)	ε_{s1} (‰)	ξ	ζ	ω_1 (%)	κ	μ
3.50	35.00	0.091	0.962	7.359	3.758	0.071
3.50	30.00	0.104	0.957	8.458	3.516	0.081

Zadatak 5 - **VEZANO** dimenzionisanje

ε_c (‰)	ε_{s1} (‰)	ξ	ζ	ω_1 (%)	κ	μ
3.50	30.00	0.104	0.957	8.458	3.516	0.081

4. Računa se:

$$A_{s1} = \omega_1 \times \frac{b \times d}{100} \times \frac{f_{cd}}{f_{yd}}$$

$$A_{s1} = 8.458 \times \frac{40 \times 53}{100} \times \frac{2.83}{43.5} = 11.66 cm^2$$

ILI

ε_c (‰)	ε_{s1} (‰)	ξ	ζ	ω_1 (%)	κ	μ
3.50	30.00	0.104	0.957	8.458	3.516	0.081

$$A_{s1} = \frac{M_{Ed}}{\zeta \times d \times f_{yd}} = \frac{250 \cdot 10^2}{0.957 \times 53 \times 43.5} = 11.33 cm^2$$

Zadatak 5 - **VEZANO** dimenzionisanje

5. Usvaja se: 6Ø16 (12.06 cm^2)

6. **Računanje težišta armature**

$d^{I} = 3.5 + 0.8 + 1.6/2 = 5.1$ cm

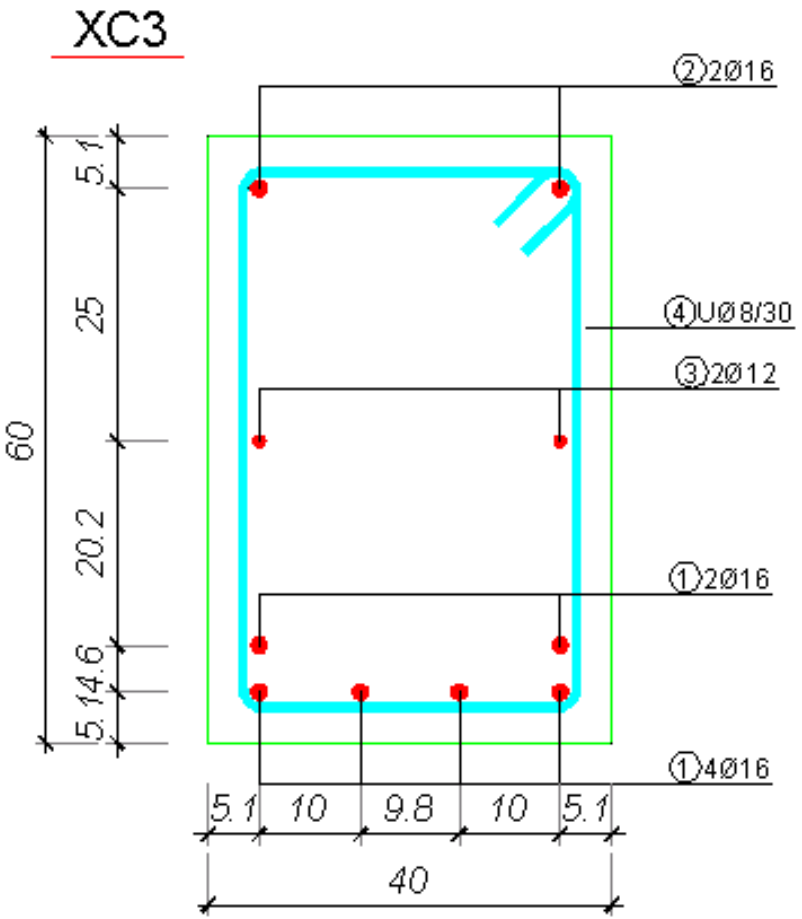
$d^{II} = 5.1 + 3.0 + 2\times1.6/2 = 9.7$ cm

$d_1 = (4\times5.1 + 2\times9.7)/5 = 6.63$ cm

$d_{1,stv} < d_{1,prp}$, na strani sigurnosti jer je

$d_{stv} > d_{prp}$

7. **Konstruisanje preseka**



Zadatak 5 - **VEZANO** dimenzionisanje

ε_c (‰)	ε_{s1} (‰)	ξ	ζ	ω_1 (%)	κ	μ
3.50	*30.00*	*0.104*	*0.957*	*8.458*	*3.516*	*0.081*

$F_c = 0.810 \times \xi \times b \times d \times f_{cd}$

$F_c = 0.810 \times 0.104 \times 40 \times 53 \times 2.83 = 505.4$ kN

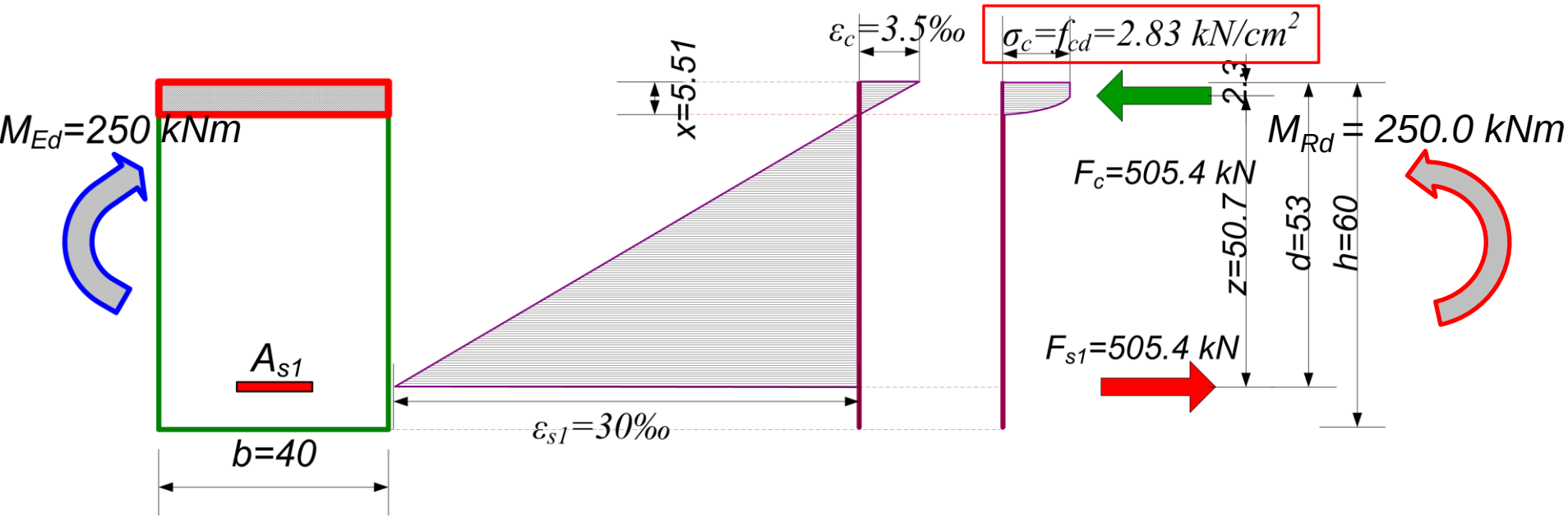
$F_{s1} = A_{s1} \times \sigma_{s1} = A_{s1} \times f_{yd}$

$F_{s1} = 11.66 \times 43.5 = 507.2$ kN $= F_c$

x $= \xi \times d = 0.104 \times 53 = 5.51$ cm

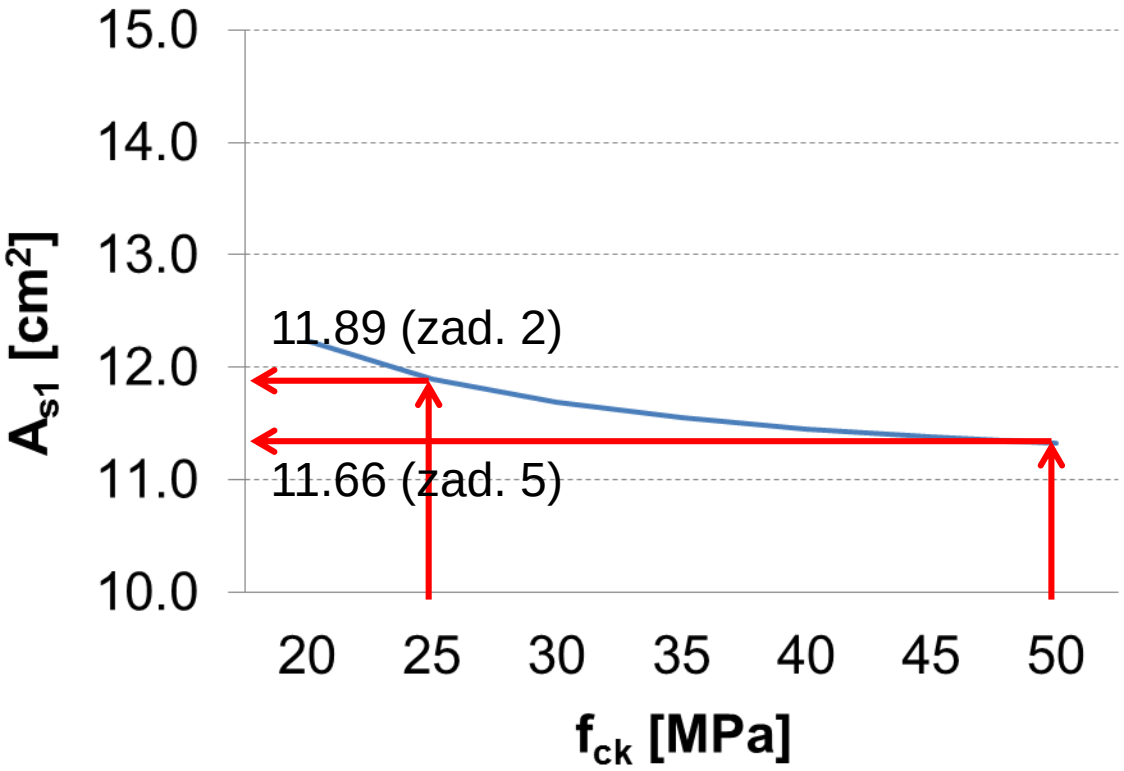
z $= \zeta \times d = 0.957 \times 53 = 50.72$ cm

Zadatak 5 - **VEZANO** dimenzionisanje

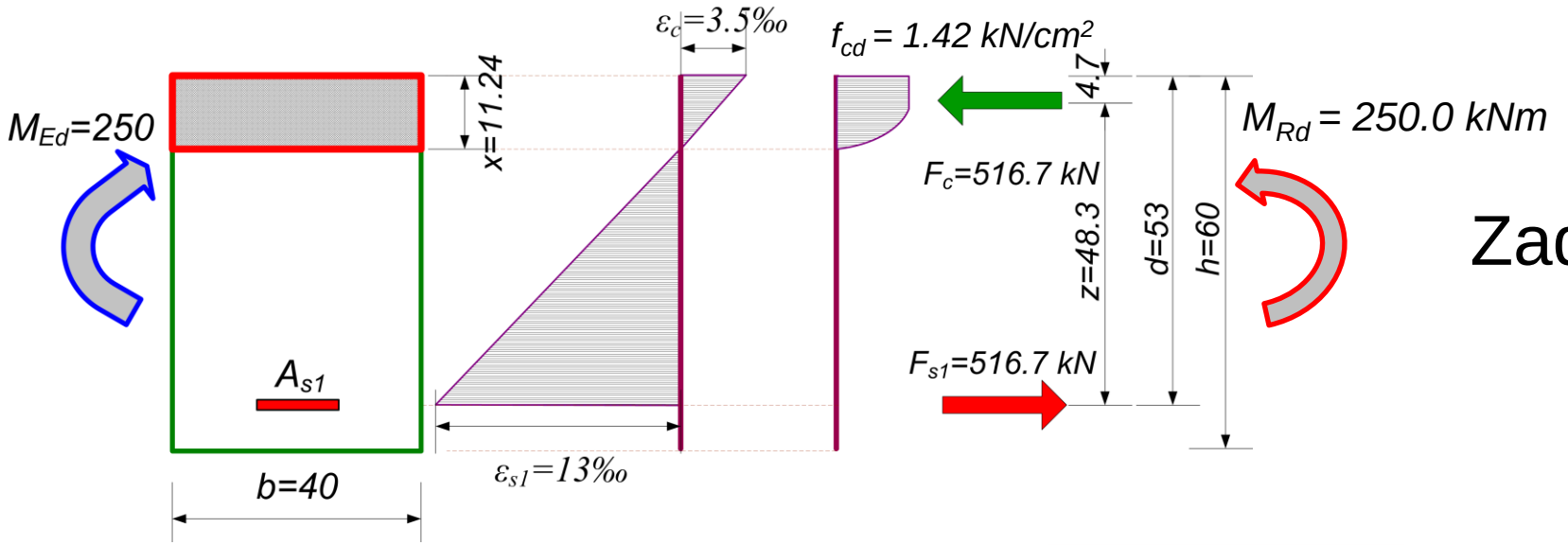


Za pretpostavljeno d_1 i potrebnu armaturu $A_{s1,pot}$

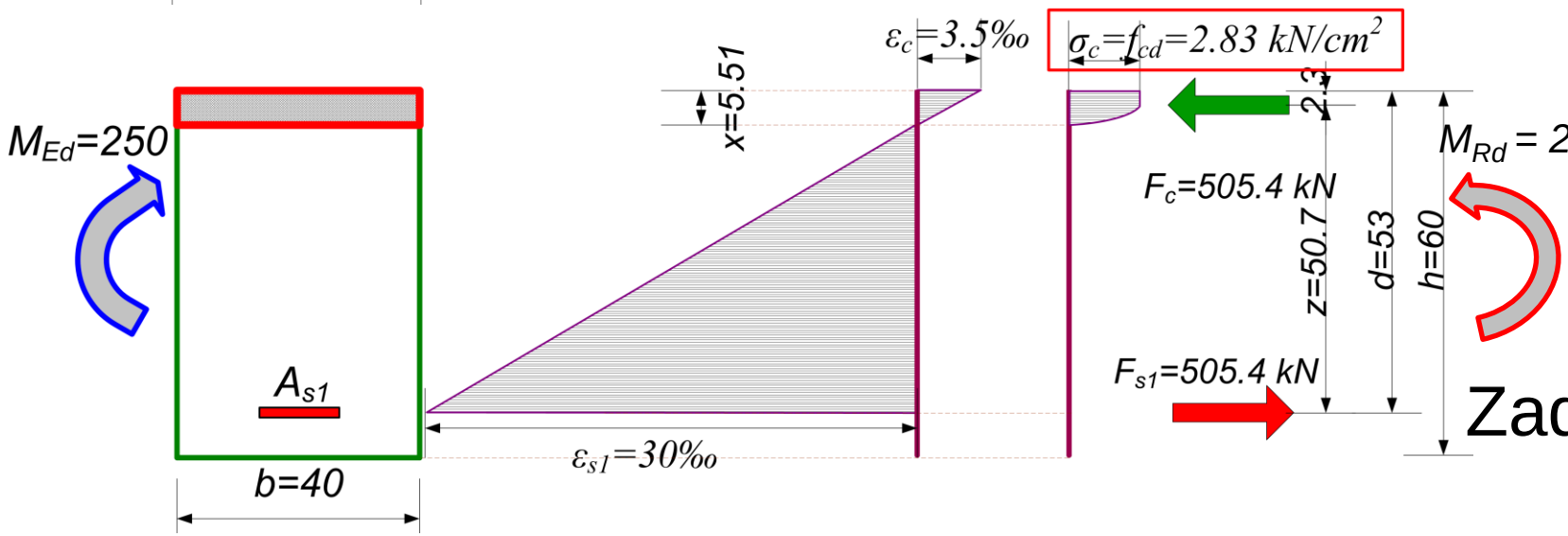
Zavisnost A_{s1} od promene klase betona



Zadatak 5 - **VEZANO** dimenzionisanje



Zadatak 2



Zadatak 5

Zadatak 6a - **SLOBODNO** dimenzionisanje

Odrediti visinu i potrebnu površinu armature za presek pravougaonog oblika, opterećen momentima savijanja usled stalnog (M_G) i povremenog (M_Q) opterećenja. Podaci za proračun:

M_G = 60 kNm	b = 25 cm	C25/30
M_Q = 80 kNm		B500 B

C25/30 ⇒ $f_{cd} = 0.85 \cdot 25/1.5 = 14.2 MPa = 1.42\ kN/cm^2$

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

Zadatak 6a - **SLOBODNO** dimenzionisanje

1. $M_{Ed} = 1.35 \times 60 + 1.5 \times 80 = 201$ kNm

2. usv. $\varepsilon_c/\varepsilon_{s1} = 3.5/10‰$

$2{,}5‰ \leq \boldsymbol{\varepsilon_{s1}} \leq 45‰$

Za B500 **B** !!

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

$k = 2.311$; $\omega_1 = 20.988\%$; $\zeta = 0.892$

3. Računamo: $$d = k\sqrt{\frac{M_{Ed}}{b \cdot f_{cd}}} = 2.311 \times \sqrt{\frac{201 \times 10^2}{25 \times 1{,}42}} = 55\,cm$$

Zadatak 6a - **SLOBODNO** dimenzionisanje

4. Računamo:

$$A_{s1} = \omega_1 \times \frac{b \times d}{100} \times \frac{f_{cd}}{f_{yd}} = 20.988 \times \frac{25 \times 55}{100} \times \frac{1.42}{43.5} = 9.42\,cm^2$$

ILI

$$A_{s1} = \frac{M_{Ed}}{z \times f_{yd}} = \frac{M_{Ed}}{\zeta \times d \times f_{yd}} = \frac{201 \times 10^2}{0.892 \times 55 \times 43.5} = 9.42\,cm^2$$

5. Usvojeno: 5Ø16 (10,05 cm^2)

Zadatak 6a - **SLOBODNO** dimenzionisanje

6. **Računanje težišta armature**

$d^{I} = 3.5 + 0.8 + 1.6/2 = 5.1$ cm

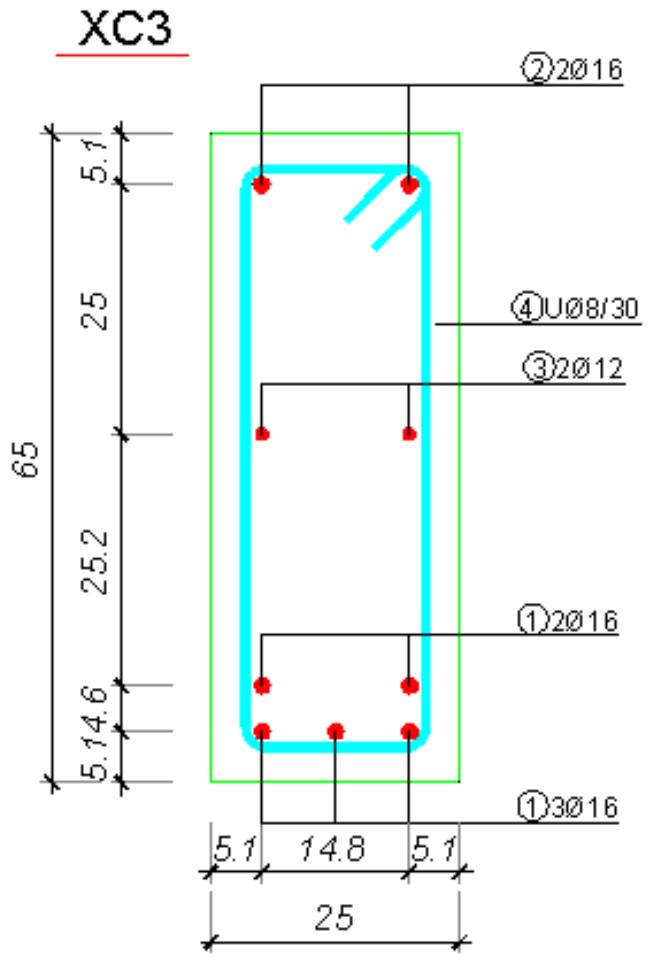
$d^{II} = 5.1 + 3.0 + 2\times1.6/2 = 9.7$ cm

$d_1 = (3\times5.1 + 2\times9.7)/5 = 6.94$ cm

$h = 55 + 6.94 = 61.94$ cm

usv. $h = 65$ cm

7. **Konstruisanje preseka**



Zadatak 6b - **SLOBODNO** dimenzionisanje

1. $M_{Ed} = 1.35 \times 60 + 1.5 \times 80 = 201$ kNm

2. usv. $\varepsilon_c / \varepsilon_{s1} = 3.5/20‰$

$$2.5‰ \leq \varepsilon_{s1} \leq 45‰$$

ε_c (‰)	ε_{s1} (‰)	ξ	ζ	ω_1 (%)	k	μ
3.50	*20.00*	*0.149*	*0.938*	*12.057*	*2.974*	*0.113*

3. Računamo:

$$d = k\sqrt{\frac{M_{Ed}}{b \cdot f_{cd}}} = 2.974 \times \sqrt{\frac{201 \times 10^2}{25 \times 1,42}} = 70.8\,cm$$

Zadatak 6b - **SLOBODNO** dimenzionisanje

4. Računamo:

$$A_{s1} = \omega_1 \times \frac{b \times d}{100} \times \frac{f_{cd}}{f_{yd}} = 12.057 \times \frac{25 \times 70.8}{100} \times \frac{1.42}{43.5} = 6.97\, cm^2$$

5. Usvojeno: 5Ø14 (7.70 cm^2)

„puno“ sitnih profila, neki predlog?

Zadatak 6b - **SLOBODNO** dimenzionisanje

6. **Računanje težišta armature**

$d^{I} = 3.5 + 0.8 + 1.4/2 = 5.0$ cm

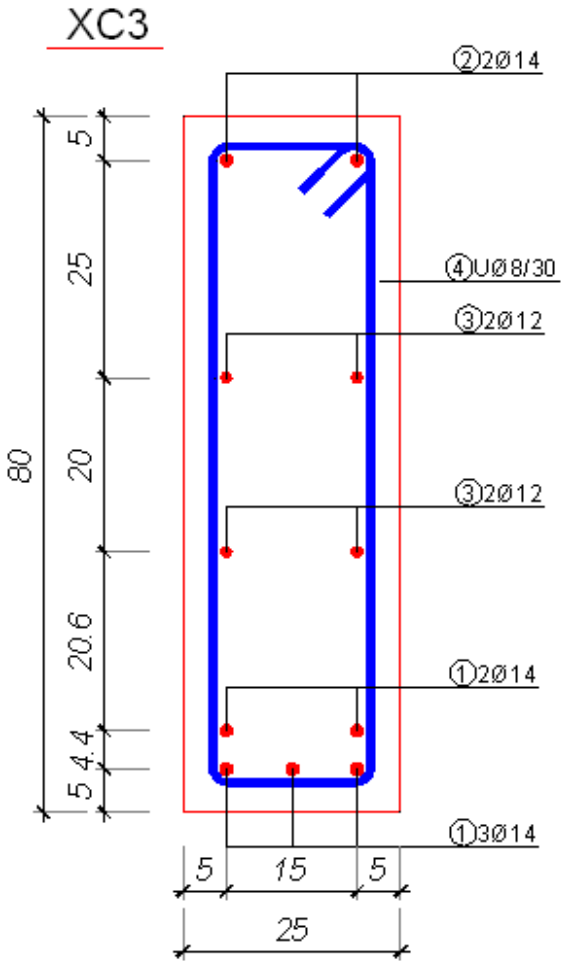
$d^{II} = 5.0 + 3.0 + 2 \times 1.4/2 = 9.4$ cm

$d_1 = (3 \times 5.0 + 2 \times 9.4)/5 = 6.76$ cm

$h = 70.8 + 6.76 = 77.56$ cm

usv. $h = 80$ cm

7. **Konstruisanje preseka**



Zadatak 6c - **SLOBODNO** dimenzionisanje

1. $M_{Ed} = 1.35 \times 60 + 1.5 \times 80 = 201$ kNm

2. usv. $\varepsilon_c/\varepsilon_{s1} = 3.5/3‰$

$$2{,}5‰ \le \varepsilon_{s1} \le 45\ ‰$$

ε_c (‰)	ε_{s1} (‰)	ξ	ζ	ω_1 (%)	k	μ
3.50	3.00	0.538	0.776	43.590	1.719	0.338

3. Računamo:

$$d = k\sqrt{\frac{M_{Ed}}{b \cdot f_{cd}}} = 1.719 \times \sqrt{\frac{201 \times 10^2}{25 \times 1{,}42}} = 40.9\,cm$$

Zadatak 6c - **SLOBODNO** dimenzionisanje

4. Računamo:

$$A_{s1} = \omega_1 \times \frac{b \times d}{100} \times \frac{f_{cd}}{f_{yd}} = 43.590 \times \frac{25 \times 40.9}{100} \times \frac{1.42}{43.5} = 14.55\,cm^2$$

5. Usvojeno: 5Ø20 (15.7 cm^2)

Zadatak 6c - **SLOBODNO** dimenzionisanje

6. **Računanje težišta armature**

$d^{I} = 3.5 + 0.8 + 2.0/2 = 5.3$ cm

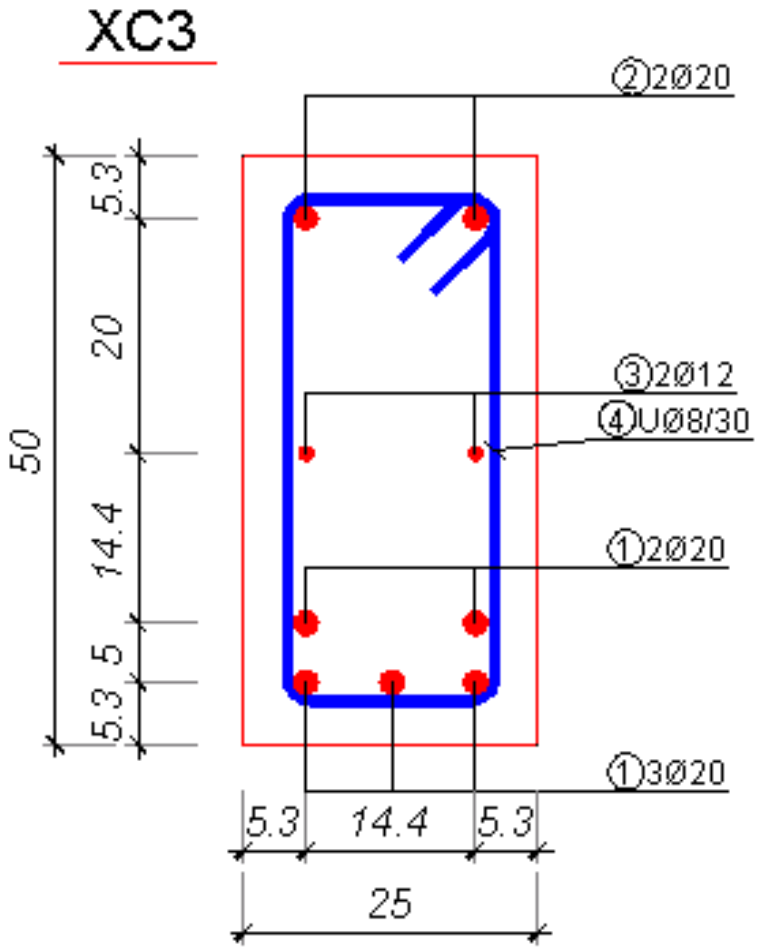
$d^{II} = 5.3 + 3.0 + 2\times2.0/2 = 10.3$ cm

$d_1 = (3\times5.3 + 2\times10.3)/5 = 7.3$ cm

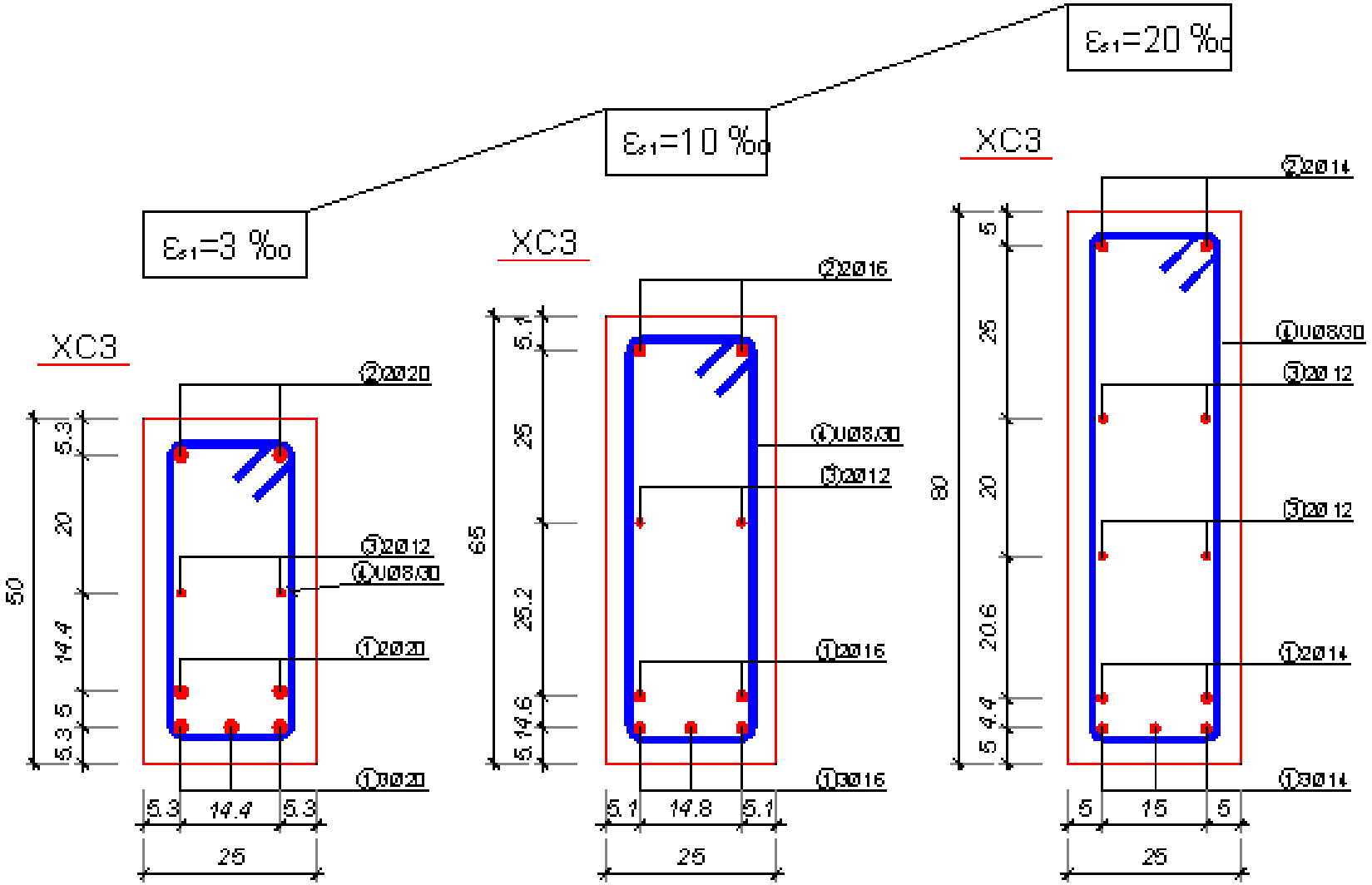
$h = 40.9 + 7.3 = 48.2$ cm

usv. $h = 50$ cm

7. **Konstruisanje preseka**



Uporedna analiza zadataka 6a, 6b, 6c



REZIME

Čisto savijanje – **SLOBODNO** dimenzionisanje

1. Sračunavaju se granični računski statički uticaji za odgovarajuće **proračunske situacije**

Stalne i prolazne proračunske situacije

$$\sum_{j\geq 1}\gamma_{G,j}G_{k,j}+\gamma_P P+\gamma_{Q,1}Q_{k,1}+\sum_{i>1}\gamma_{Q,i}\psi_{0,i}Q_{k,i}$$

$$M_{Ed}=\gamma_G\cdot M_{G,k}+\gamma_{Q,1}\cdot M_{Qk,1}+\sum_{i>1}\gamma_{Q,i}\psi_{0,i}\cdot M_{Qk,i}$$

Dejstvo	*Stalno (γ_G)*	*Promenljivo (γ_Q)*
Nepovoljno	***1.35***	***1.50***
Povoljno	*1.00*	*0.00*

Dejstvo	ψ_0
Korisno opterećenje (SRPS EN 1991-1-1)	
Kategorija A: Prostorije za domaćinstvo i stanovanje	0.7
Kategorija B: Kancelarijske prostorije	0.7
Kategorija C: Prostorije za okupljanje ljudi	0.7
Kategorija D: Trgovačke prostorije	0.7
Kategorija E: Skladišne prostorije	1.0
Kategorija F: Saobraćajne površine, vozilo ≤ 30 kN	0.7
Kategorija G: Saobraćajne površine, 30kN<vozilo ≤ 160 kN	0.7
Kategorija H: Krovovi	0
Opterećenja od snega (SRPS EN 1991-1-3)	
Finska, Švedska, Norveška, Island	0.7
Ostale članice CEN, lokacije visine H>1000m nadmorske visine	0.7
Ostale članice CEN, Lokacije visine H≤1000m nadmorske visine	0.5
Opterećenja od vetra (SRPS EN 1991-1-4)	0.6
Temperatura (ne požar) (SRPS EN 1991-1-5)	0.6

Čisto savijanje – **SLOBODNO** dimenzionisanje

2. Usvajaju se ε_c i $\varepsilon_{s1,}$ pri čemu je:

ε_c=3,5‰ i $\varepsilon_{s1,\lim} \le \varepsilon_{s1} \le \varepsilon_{ud}$

$$\varepsilon_{s1,\lim} = \max \begin{cases} 0,0025 \\ \dfrac{f_{yd}}{E_s} \end{cases}$$

$0.9 \cdot \varepsilon_{uk}$=45‰

Za usvojene vrednosti dilatacija iz tabela se očitavaju koeficijenti k ili μ (položaj neutralne linije) , odnosno ω_1 (mehanički procenat armiranja).

Čisto savijanje – **SLOBODNO** dimenzionisanje

3. Sračunava se **statička visina, *d***:

$$\varepsilon_c / \varepsilon_{s1} \xrightarrow{TABL.} k \Rightarrow d = k\sqrt{\frac{M_{Ed}}{b \cdot f_{cd}}}$$

4. Sračunava se **potrebna površina armature, A_{s1}**:

$$A_{s1} = \omega_1 \times \frac{b \times d}{100} \times \frac{f_{cd}}{f_{yd}} \qquad \text{ili} \qquad A_{s1} = \frac{M_{Ed}}{z \times f_{yd}} = \frac{M_{Ed}}{\zeta \times d \times f_{yd}}$$

Čisto savijanje – **SLOBODNO** dimenzionisanje

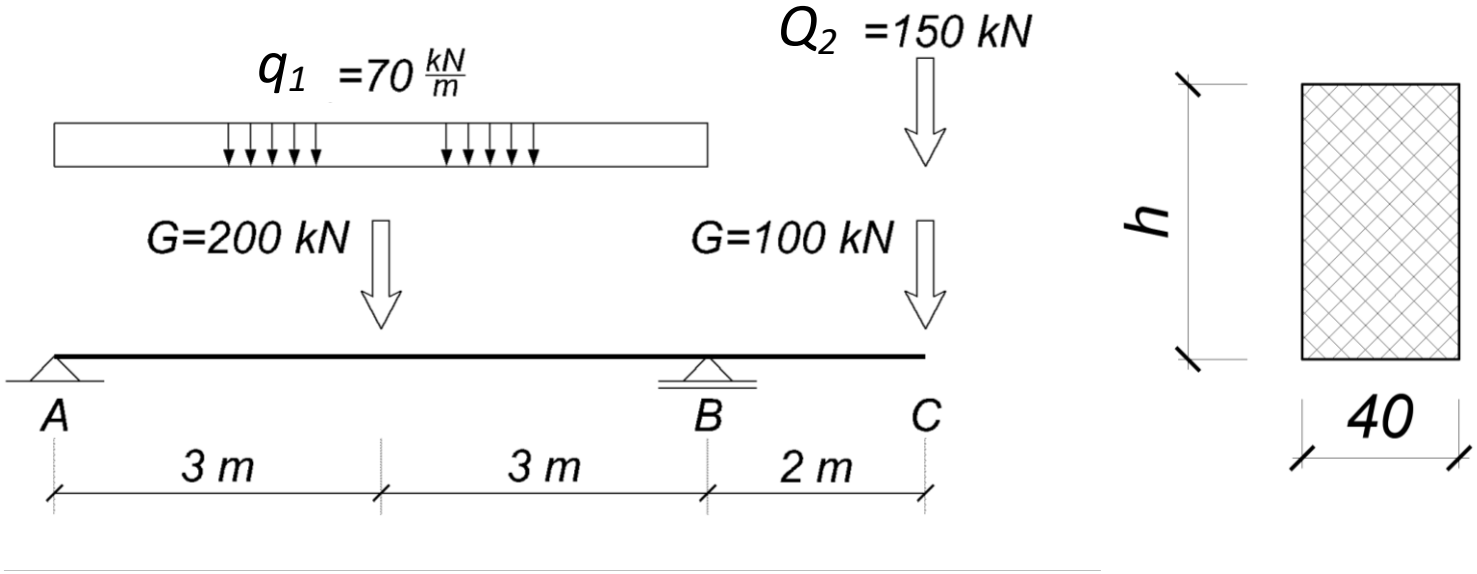
5. Usvaja se broj i prečnik šipki armature. Usvojena armatura se raspoređuje u preseku (*vidi vežbe 1V_TBK1*)
6. Sračunava se položaj težišta d_1 usvojene armature i usvaja visina preseka h:

$$h = d + d_1$$

7. Konačno se konstruiše poprečni presek i prikazuje u odgovarajućoj razmeri (1:10) sa svim potrebnim kotama i oznakama.

Primer ispitnog zadatka

1. *Gredu konstantnog poprečnog preseka, opterećenu stalnim opterećenjem **G** i povremenim opterećenjima **q_1** i **Q_2** (mogu delovati nezavisno) prema skici dole, dimenzionisati u karakterističnim presecima prema momentima savijanja.* ***Obezbediti da u svim dimenzionisanim presecima granična dilatacija u armaturi bude najmanje 5‰.***



Zadatak 7 - **OBOSTRANO ARMIRANJE**

Odrediti potrebnu površinu armature za presek poznatih dimenzija, pravougaonog oblika, opterećen graničnim momentom savijanja M_{Ed}. Podaci za proračun:

M_{Ed} =**750** kNm b = 40 cm C25/30

h = 60 cm B500 B

C25/30 → f_{cd} = 0,85·25/1,5= 14,2MPa = 1,42 kN/cm^2

B500 B → f_{yd} = 500/1,15 = 435 MPa = 43,5 kN/cm^2

Zadatak 7 - **OBOSTRANO ARMIRANJE**

1. M_{Ed}=750 kNm
2. pretp. d_1 = 7 cm

   d = h – d_1 = 60 – 7 = 53 cm

3. Računa se:

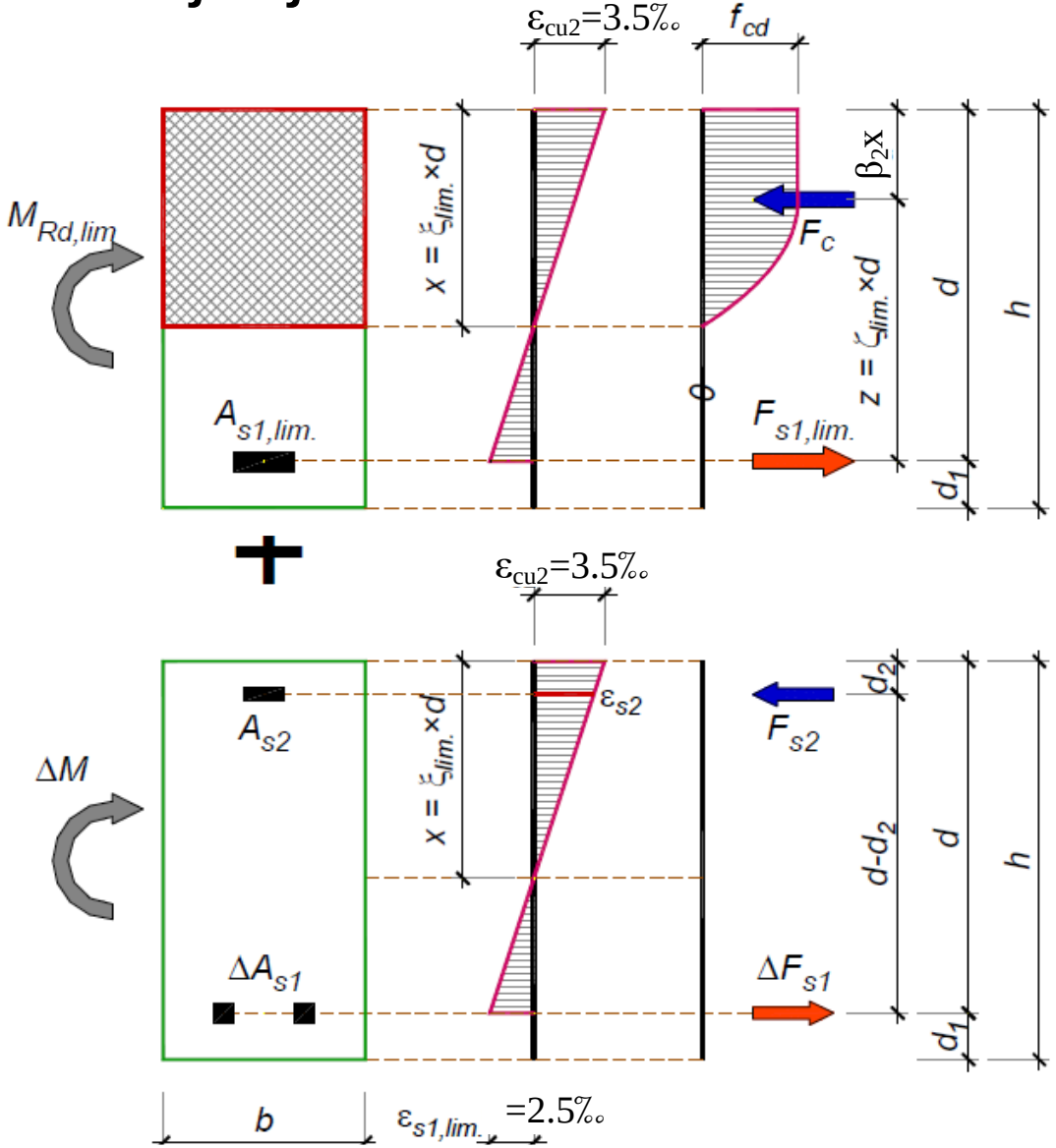
$$k = \frac{d}{\sqrt{\frac{M_{Ed}}{b \cdot f_{cd}}}} = \frac{53}{\sqrt{\frac{750 \cdot 10^2}{40 \cdot 1.42}}} = 1.458$$

"Poslednji " red u tablici za dimenzionisanje:

ε_c (‰)	ε_{s1} (‰)	ξ	ζ	ω_1 (%)	κ	μ
3.500	1.900	0.648	0.730	52.469	1.615	0.383

→ ε_{s1} < 2.5‰ !!!

ČISTO savijanje - OBOSTRANO ARMIRANJE



Zadatak 7 - **OBOSTRANO ARMIRANJE**

ε_c (‰)	ε_{s1} (‰)	ξ	ζ	ω_1 (%)	κ	μ
3.50	**2.50**	0.583	0.757	47.222	1.672	0.358

4. Računa se:

$$M_{Rd,\lim} = \left(\frac{53}{1.672}\right)^2 \cdot 40 \cdot 1.42 = 570.7$$

$$\Delta M = M_{Ed} - M_{Rd,\lim} = 750 - 570.7 = 179.3 kNm$$

Zadatak 7 - OBOSTRANO ARMIRANJE

ε_c (‰)	ε_{s1} (‰)	ξ	ζ	ω_1 (%)	κ	μ
3.50	**2.50**	0.583	0.757	47.222	1.672	0.358

5. Računa se:

$$A_{s2} = \frac{F_{s2}}{\sigma_{s2}} = \frac{\Delta M}{(d-d_2)\sigma_{s2}} = \frac{179.3 \cdot 10^2}{(53-5.5)\cdot 43.5} = 8.68 cm^2$$

$$\varepsilon_{s2} = \frac{\xi_{\lim} - \frac{d_2}{d}}{\xi_{\lim}} \varepsilon_{cu2} = \frac{0.584 - \frac{5.5}{53}}{0.584} \cdot 3.5 = 2.878 > 2.175 = \frac{435}{200}\left(= \frac{f_{yd}}{E_s}\right) \Rightarrow \sigma_{s2} = f_{yd} = 43.5 kN/cm^2$$

$$\Delta A_{s1} = \frac{\Delta F_{s1}}{\sigma_{s1}} = \frac{\Delta M}{(d-d_2) f_{yd}} = A_{s2} = 8.68 cm^2$$

$$\sigma_{s1} = f_{yd} = 43.5 kN/cm^2$$

$$A_{s1,\lim} = \omega_{1,\lim} bd \frac{f_{cd}}{f_{yd}} = 47.222 \cdot \frac{40 \cdot 53}{100} \cdot \frac{1.42}{43.5} = 32.8 cm^2$$

$$A_{s1} = A_{s1,\lim} + \Delta A_{s1} = 32.8 + 8.68 = 41.48 cm^2$$

Zadatak 7 - OBOSTRANO ARMIRANJE

6. Usvojeno: 9Ø25 (44.19 cm^2)

7. **Računanje težišta armature**

$d^{I} = 3.5 + 0.8 + 2.5/2 = 5.6$ cm

$d^{II} = 5.6 + 3.0 + 2 \times 2.5/2 = 11.1$ cm

$d_1 = (5 \times 5.6 + 4 \times 11.1)/5 = 8.04$ cm

$d_{1,stv} > d_{1,prp}$ nije na strani sigurnosti jer je $d_{stv} < d_{prp}$, ali:

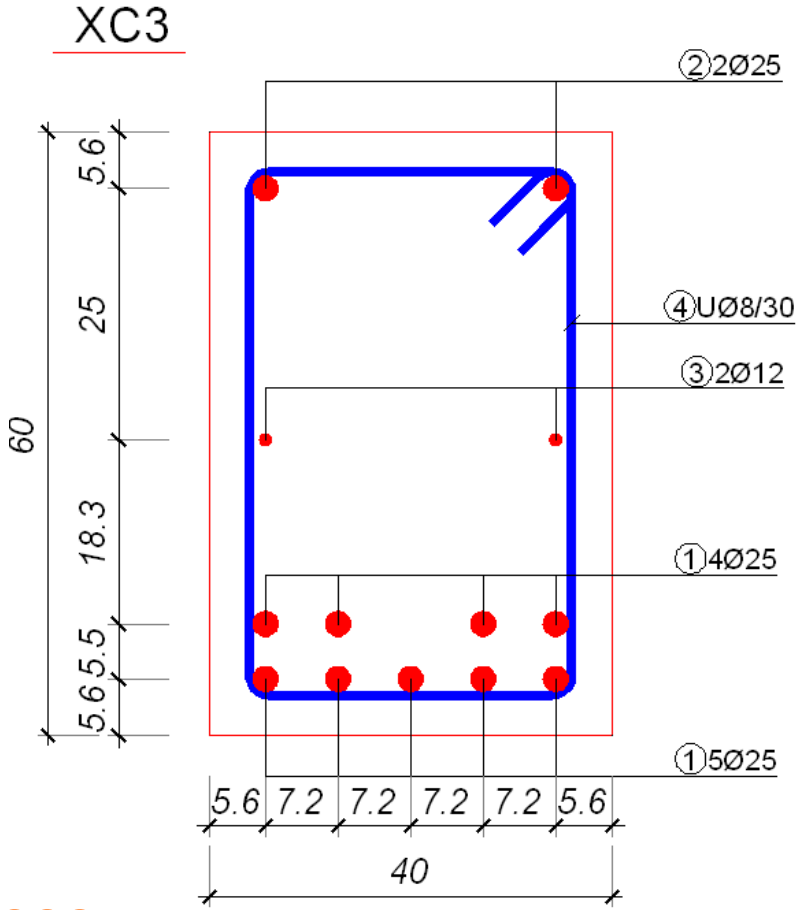
$z_{stv} \cdot A_{s1,stv} > z_{prp} \cdot A_{s1,pot}$

$0.757 \cdot (60\text{-}8.04) \cdot 44.19 > 0.757 \cdot (60\text{-}7) \cdot 41.48$

$M_{Rd,stv} \approx 756.1$ kNm > $M_{Rd,pot} \approx 723.9$ kNm ???

$M_{Rd} \approx 756.1$ kNm > $M_{Ed} = 750$ kNm

8. **Konstruisanje preseka**



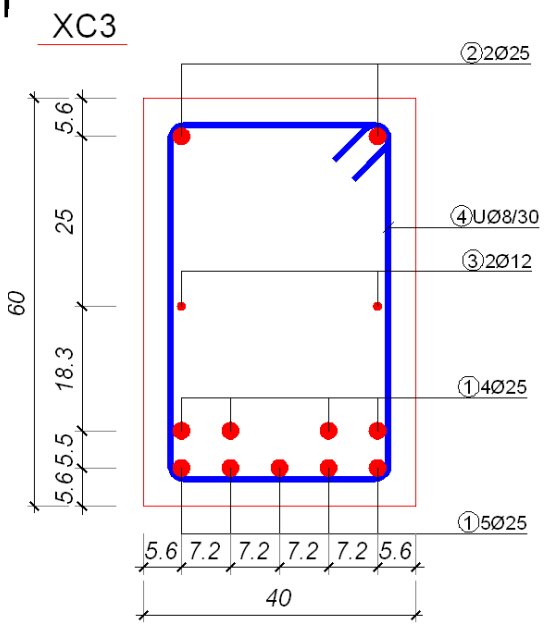
Zadatak 7 - OBOSTRANO ARMIRANJE

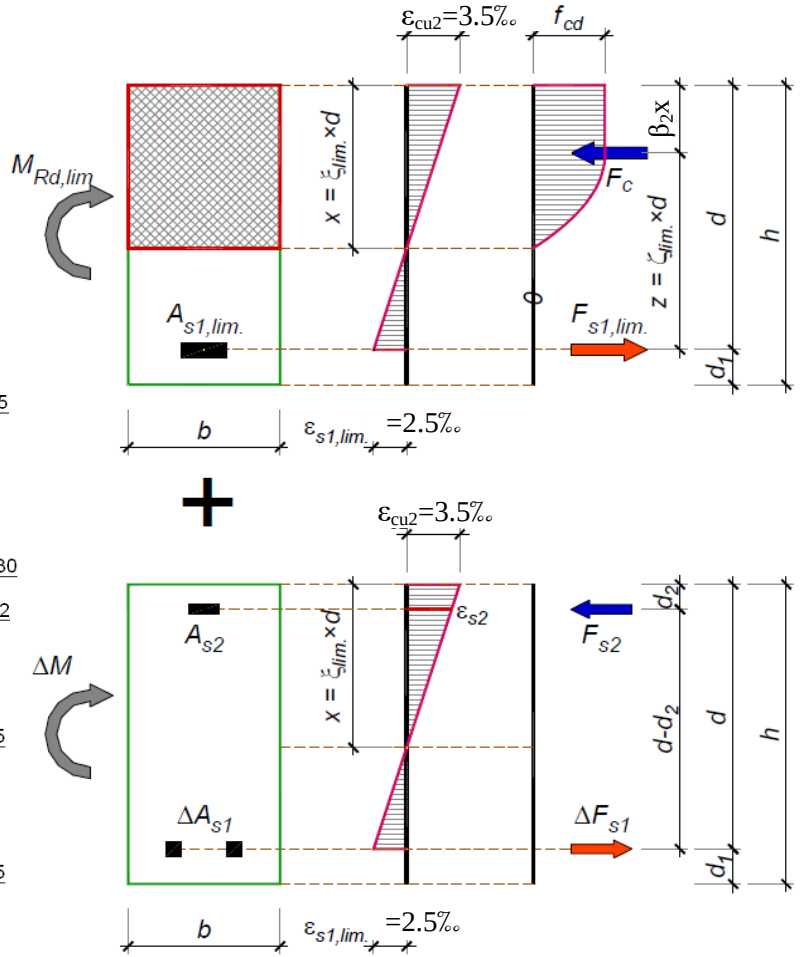
$M_{Rd,stv}$ = 0.757·(60-8.04)·32.8·43.5/100 +
(60-8.04-5.6)·9.82·43.5/100

$M_{Rd,stv}$ = 759.2 kNm

$M_{Rd,pot}$ = 0.757·(60-7)·32.8·43.5/100 +
(60-8.04-5.5)·8.68·43.5/100

$M_{Rd,pot}$ = 751.8 kNm





REZIME

ČISTO savijanje - OBOSTRANO ARMIRANJE

1. Sračunavaju se granični računski statički uticaji za odgovarajuće **proračunske situacije**

   Stalne i prolazne proračunske situacije

$$M_{Ed} = \gamma_G \cdot M_{G,k} + \gamma_{Q,1} \cdot M_{Qk,1} + \sum_{i>1} \gamma_{Q,i} \psi_{0,i} \cdot M_{Qk,i}$$

2. Pretpostavlja se položaj težišta zategnute armature $\mathbf{d_1}$ i na osnovu toga sračunava statička visina $d = h - d_1$

3. Sračunava se koeficijent k: $k = \dfrac{d}{\sqrt{\dfrac{M_{Ed}}{b \cdot f_{cd}}}}$ ⇒ dilatacije ε_c, ε_{s1}.

Ako je $\varepsilon_{s1} < 2.5‰$ (ili f_{yd}/E_s), presek se **OBOSTRANO** armira

ČISTO savijanje - **OBOSTRANO ARMIRANJE**

4. Određuje se MOMENT NOSIVOSTI JEDNOSTRANO ARMIRANOG PRESEKA, sa procentom armiranja $\omega_{Rd,lim}$ i koeficijentom k_{lim} koji odgovaraju dilataciji armature od $\varepsilon_{s1,lim} = 2.5‰$)

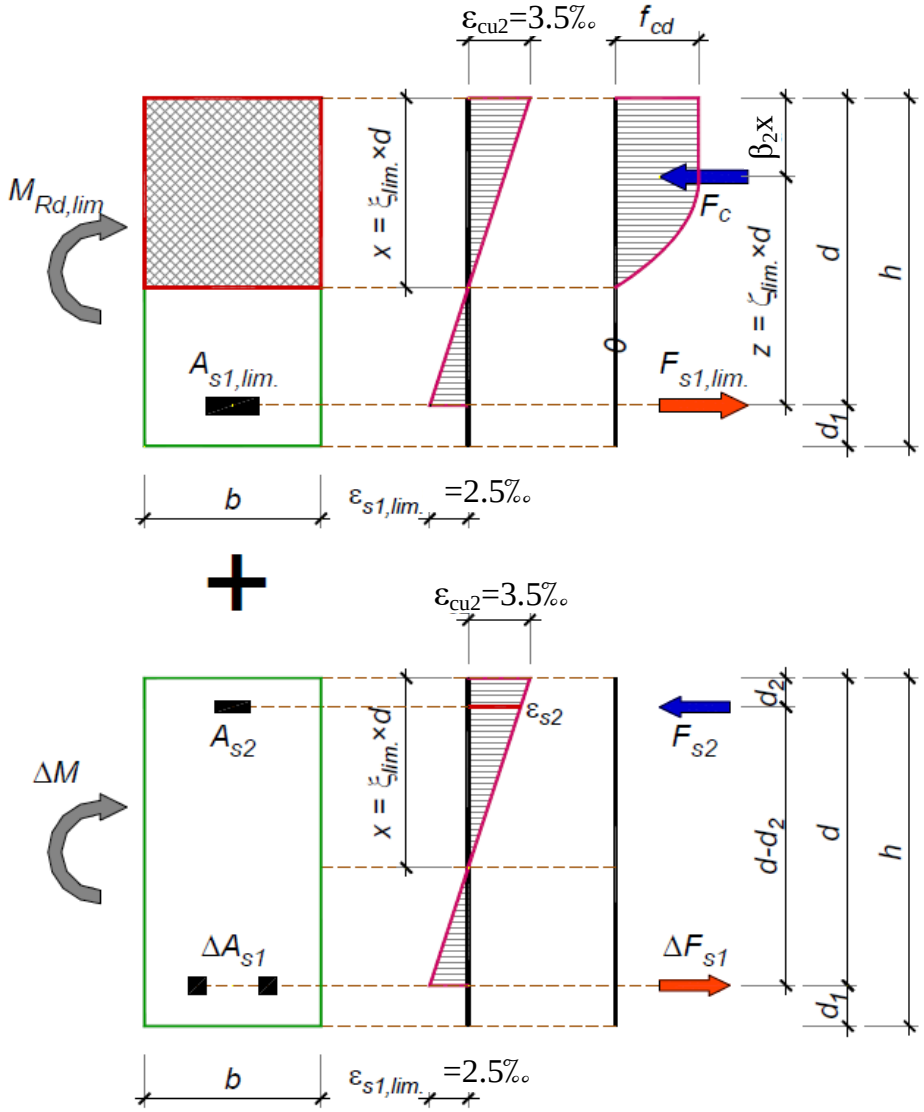
$$M_{Rd,\lim} = \left(\frac{d}{k_{\lim}}\right)^2 bf_{cd}$$

Preostali deo spoljašnjeg momenta savijanja:

$$\Delta M = M_{Ed} - M_{Rd,\lim}$$

prihvata se dodatnom zategnutom i pritisnutom armaturom.

ČISTO savijanje - OBOSTRANO ARMIRANJE



5. Pretpostavlja se položaj težišta pritisnute armature $\mathbf{d_2}$ i određuju se površine zategnute i pritisnute armature u preseku, iz izraza:

$$A_{s2} = \frac{F_{s2}}{\sigma_{s2}} = \frac{\Delta M}{(d - d_2)\sigma_{s2}}$$

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

$$\Rightarrow \quad \sigma_{s2} = E_s \varepsilon_{s2} \le f_{yd}$$

$$\Delta A_{s1} = \frac{\Delta F_{s1}}{\sigma_{s1}} = \frac{\Delta M}{(d - d_2) f_{yd}}$$

$$A_{s1} = A_{s1,\lim} + \Delta A_{s1} = \omega_{1,\lim} bd \frac{f_{cd}}{f_{yd}} + \frac{\Delta M}{(d - d_2) f_{yd}}$$

ČISTO savijanje - **OBOSTRANO ARMIRANJE**

6. Usvaja se broj i prečnik šipki armature. Usvojena armatura se raspoređuje u preseku (a, čisto rastojanje između šipki)

7. Sračunava se položaj težišta $\mathbf{d_1}$ usvojene armature i statička visina d i upoređuje sa pretpostavljenom.
   – U slučaju znatnijih odstupanja, proračun se ponavlja sa korigovanom vrednošću $\mathbf{d_1}$.

8. Konačno se konstruiše poprečni presek i prikazuje u odgovarajućoj razmeri (1:10) sa svim potrebnim kotama i oznakama.