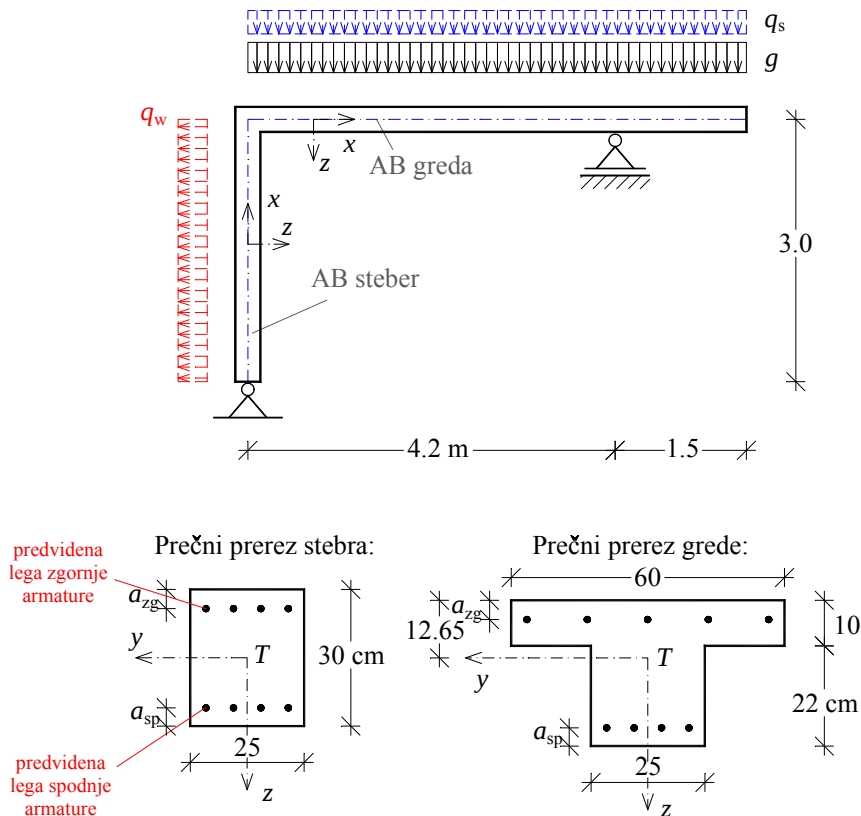


5. vaja: DIMENZIONIRANJE AB KONSTRUKCIJE NA KOMBINIRANO OBREMENITEV

1. NALOGA:

Dimenzionirajte na kritičnih mestih AB gredo in steber, prikazano na spodnji sliki. Uklon stebra je preprečen!

2. PODATKI O GEOMETRIJI IN OBTEŽBI:

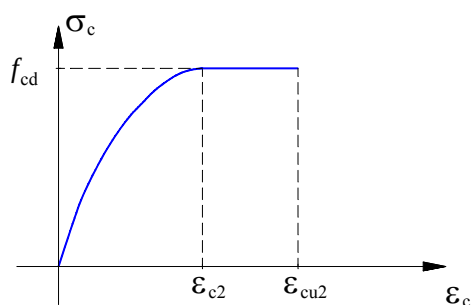


UPOŠTEVANA OBTEŽBA:

- lastna teža + stalna obtežba: $g = 25 \text{ kN/m}$
- obtežba snega: $q_s = 8 \text{ kN/m}$
- obtežba vetra: $q_w = 10 \text{ kN/m}$

UPORABLJENI MATERIALI:

- beton C25/30: $f_{ck} = 2.5 \text{ kN/cm}^2$, $f_{ctm} = 0.26 \text{ kN/cm}^2$



Delovni diagram betona v tlaku za MSN:

$$f_{cd} = \frac{f_{ck}}{\gamma_c} = 1.67 \text{ kN/cm}^2$$

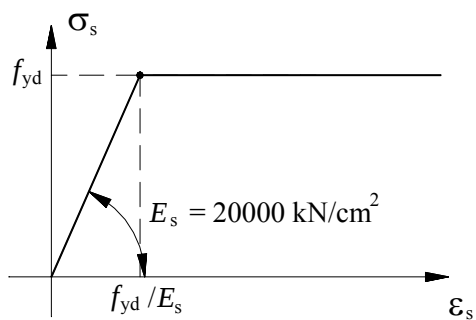
$$\epsilon_{c2} = 2.0 \text{ ‰}$$

$$\epsilon_{cu2} = 3.5 \text{ ‰}$$

- armatura S 500 B (rebraste arm. palice): $f_{yk} = 50 \text{ kN/cm}^2$, $E_s = 20000 \text{ kN/cm}^2$

Delovni diagram jekla za armiranje za MSN:

$$f_{yd} = \frac{f_{yk}}{\gamma_s} = 43.5 \text{ kN/cm}^2$$

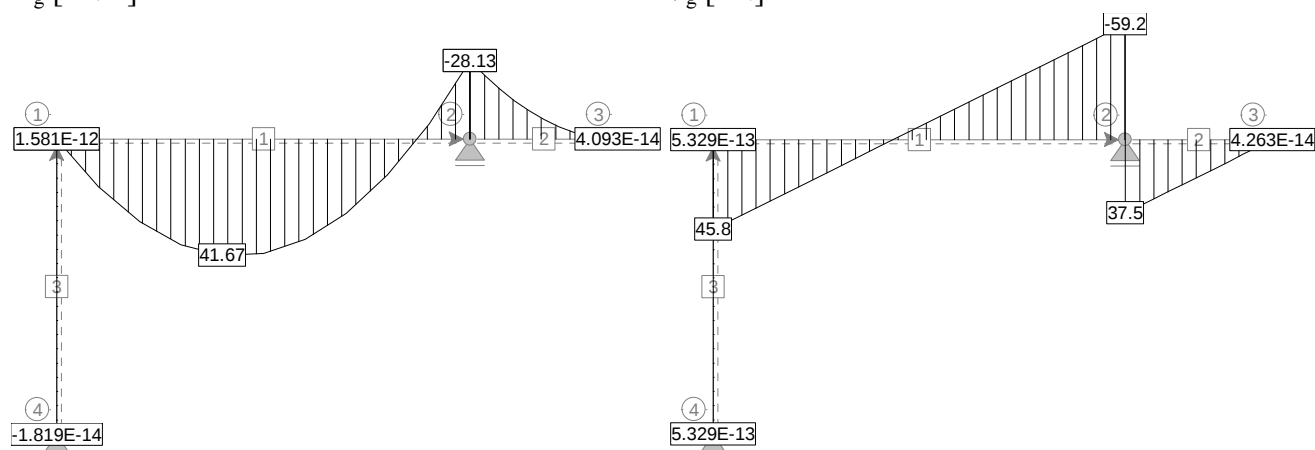


3. RAČUN NOTRANJE STATIČNIH KOLIČIN KONSTRUKCIJE

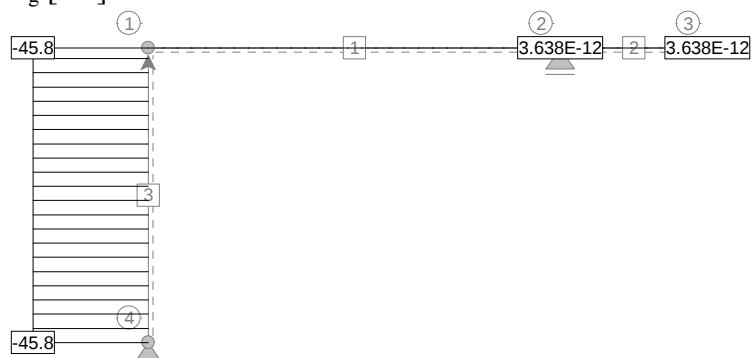
3.1. Notranje sile zaradi stalne obtežbe g

M_g [kNm]

V_g [kN]



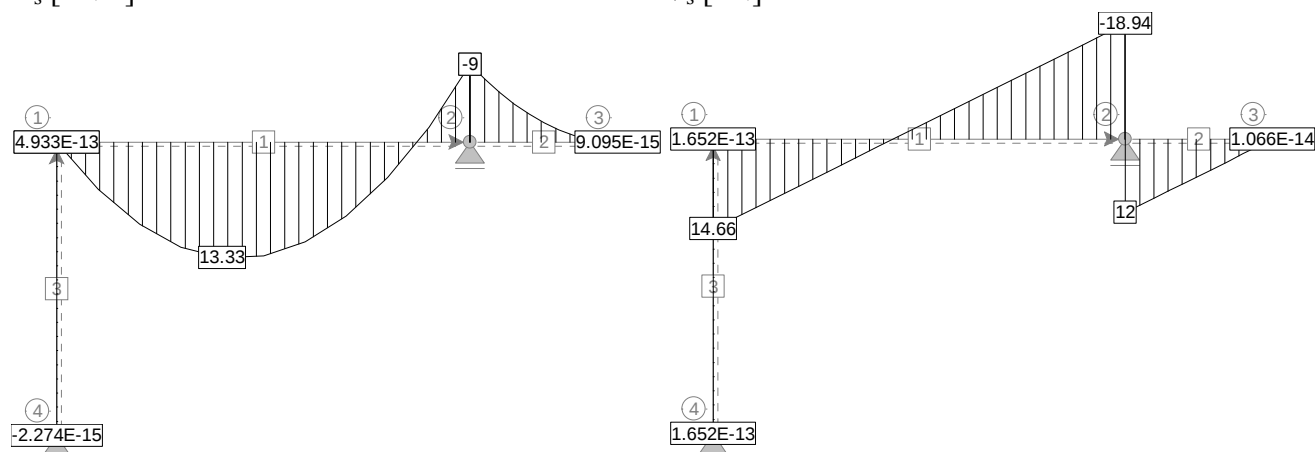
N_g [kN]



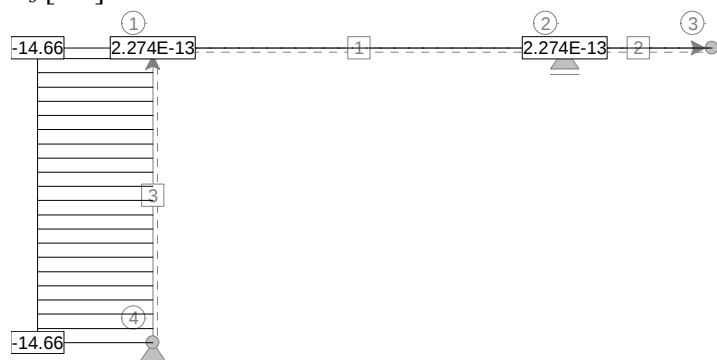
3.2. Notranje sile zaradi obtežbe snega q_s

M_s [kNm]

V_s [kN]

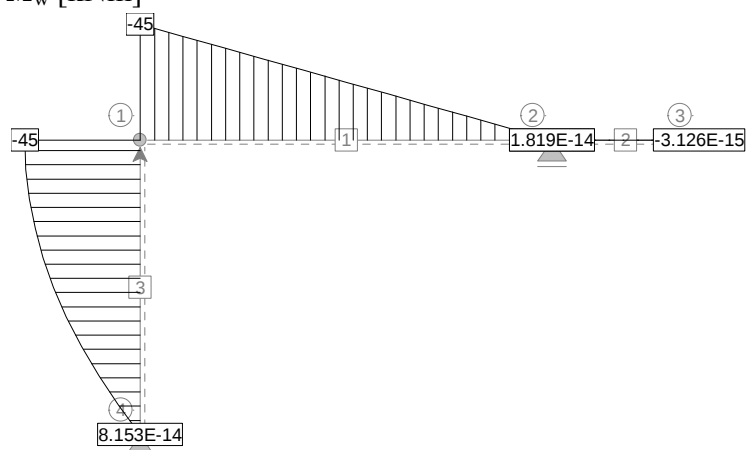


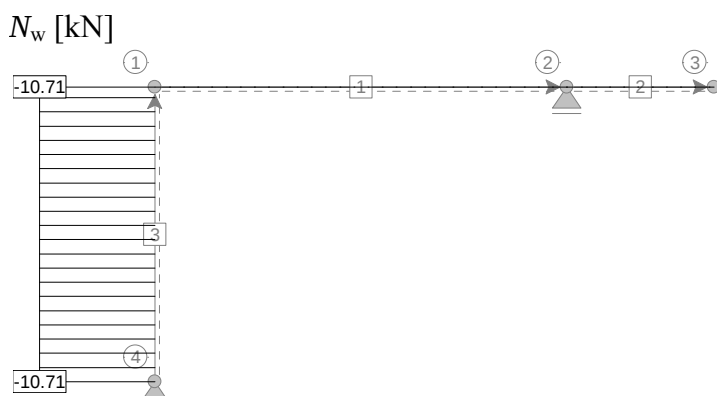
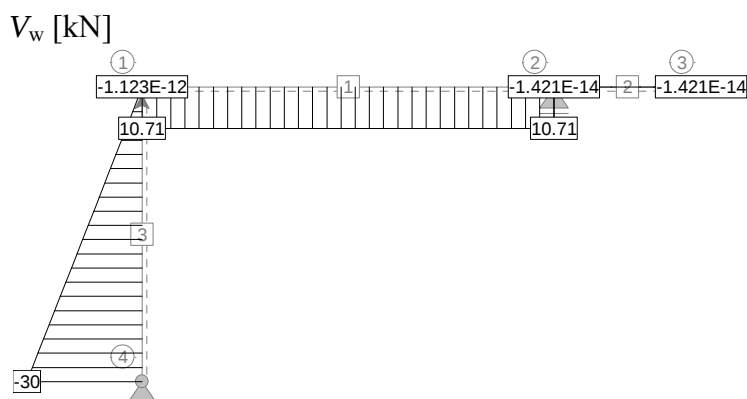
N_s [kN]



3.3. Notranje sile zaradi obtežbe vetra q_w

M_w [kNm]





3.4. Kombinacije vplivov

MSN - stalna projektna stanja (osnovne komb.): $\sum_{j \geq 1} \gamma_{G,j} G_{k,j} + \gamma_{Q,1} Q_{k,1} + \sum_{i > 1} \gamma_{Q,i} \Psi_{0,i} Q_{k,i}$

MSU - kombinacije vplivov: karakteristična: $\sum_{j \geq 1} G_{k,j} + P + Q_{k,1} + \sum_{i > 1} \Psi_{0,i} Q_{k,i}$

pogosta: $\sum_{j \geq 1} G_{k,j} + P + \Psi_{1,1} Q_{k,1} + \sum_{i > 1} \Psi_{2,i} Q_{k,i}$

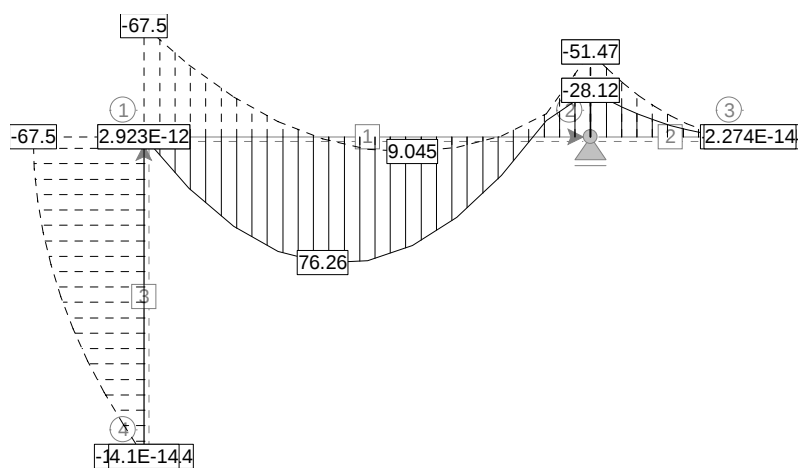
navidezno stalna: $\sum_{j \geq 1} G_{k,j} + P + \sum_{i \geq 1} \Psi_{2,i} Q_{k,i}$

		MSN					MSU	
obt.primer	kombinacija	K1	K2	K3	K4	K5	K6	K7
	g – lastna+stalna obtežba							
	q_s – sneg ($\Psi_0=0.5$)							
	q_w – veter ($\Psi_0=0.6$)							

3.5. Ovojnice obremenitev

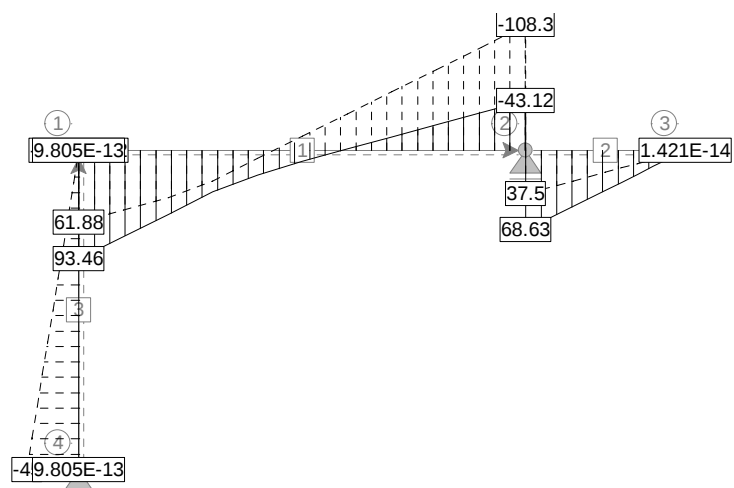
3.5.1. Upogibni momenti

$[M_{Ed}]$



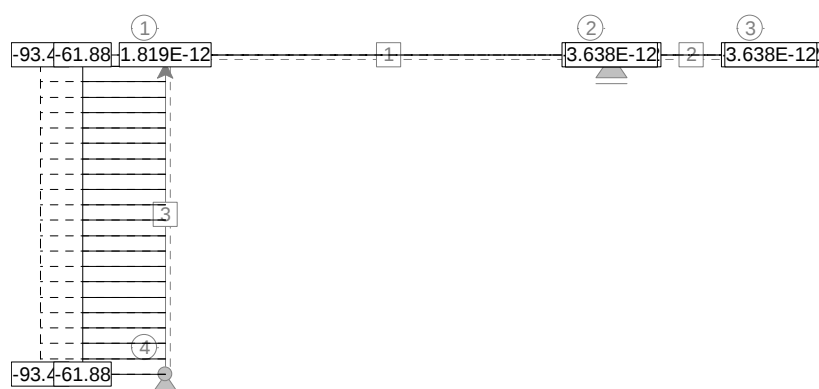
3.5.2. Prečne sile

$[V_{Ed}]$



3.5.3. Osne sile

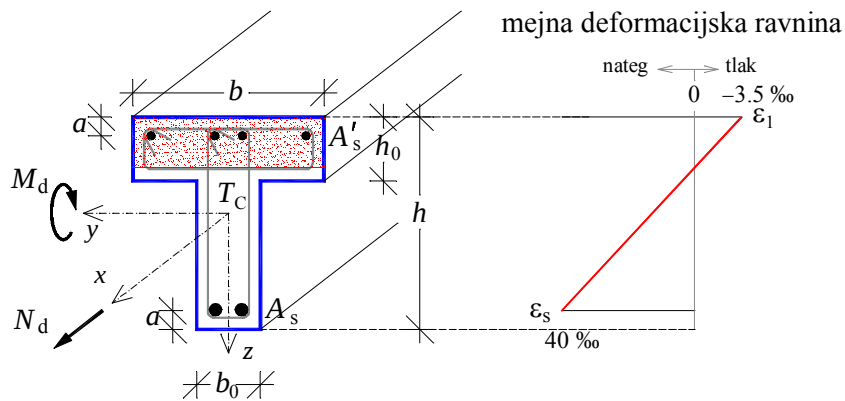
$[N_{Ed}]$



4. DIMENZIONIRANJE GREDE

4.1. Dimenzioniranje grede pri osno-upogibni obremenitvi

4.1.1. Dimenzioniranje grede v polju ($M_{Ed,max}$)



geometrijska parametra
prereza:

$$\frac{b_0}{b} =$$

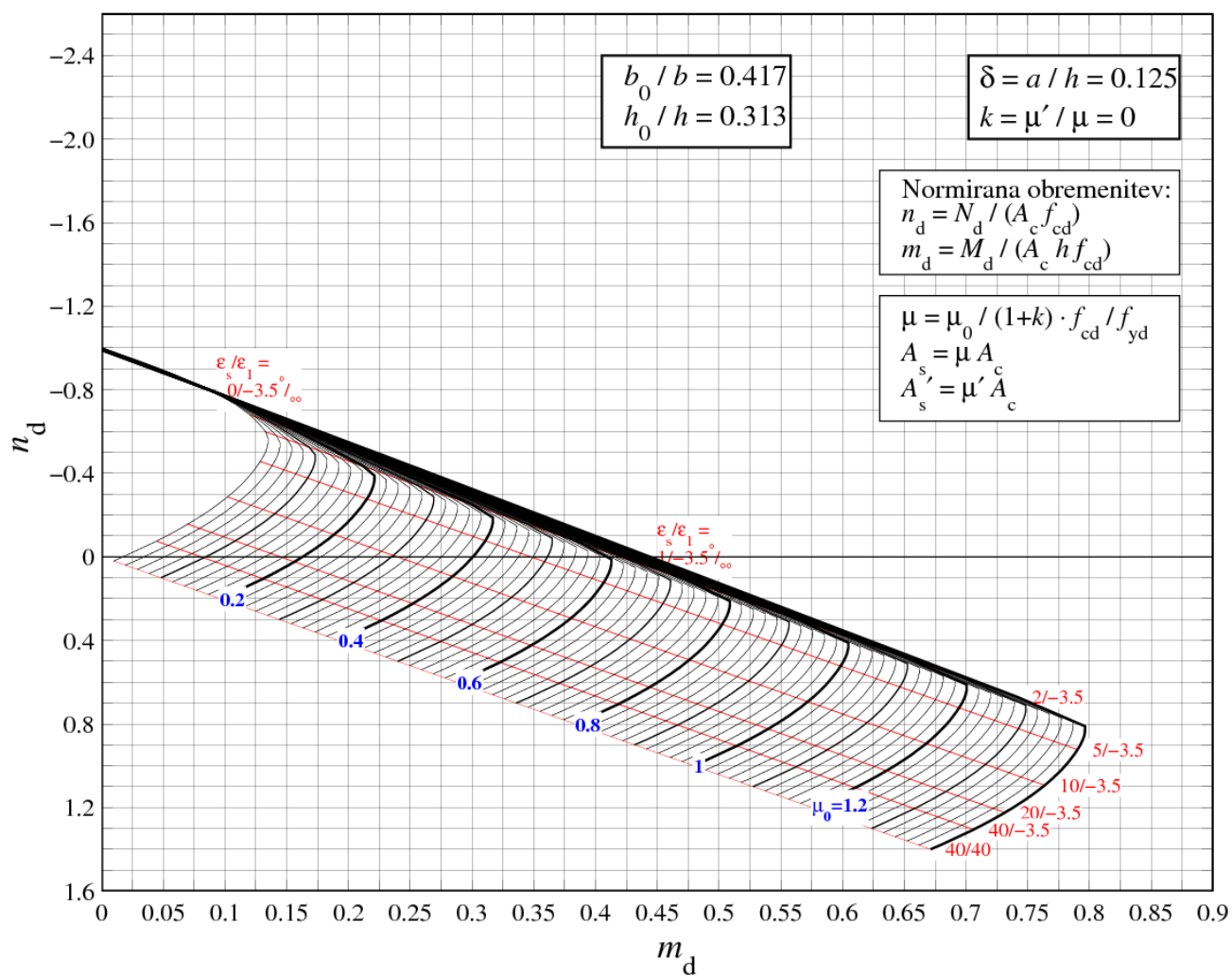
$$\frac{h_0}{h} =$$

interakcijski diagram mejne nosilnosti prečnega prereza v polju:

$$\left. \begin{aligned} n_d &= \frac{N_d}{f_{cd} A_c} = \\ m_d &= \frac{M_d}{f_{cd} A_c h} = \end{aligned} \right\} \rightarrow \mu_0 = \quad ; \quad A_s = \left(\frac{\mu_0}{1+k} \cdot \frac{f_{cd}}{f_{yd}} \right) \cdot A_c =$$

minimalna armatura:

$$A_{s,min} = 0.26 \frac{f_{ctm}}{f_{yk}} b_t d \geq 0.0013 b_t d, \quad \begin{aligned} b_t &\dots \text{ širina natezne cone prereza} \\ d &\dots \text{ statična višina prereza} \\ f_{ctm} &\dots \text{ povprečna natezna trdnost betona (C25/30: 0.26 kN/cm}^2\text{)} \end{aligned}$$



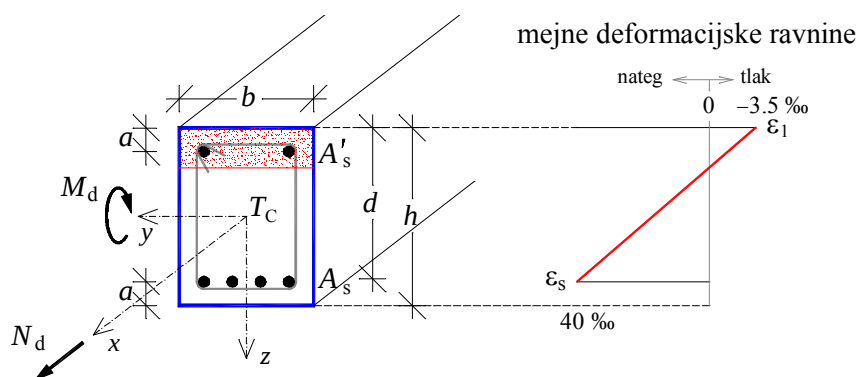
4.1.2. Dimenzioniranje grede ob podpori ($M_{Ed,min}$)

Tabela za projektiranje natezne armature pri pravokotnem prečnem prerezu, obremenjenem z upogibom in osno silo:

$$M_{us} = M_u - N_u \cdot z_s$$

$$k_h = \frac{M_{us}}{f_{cd} \cdot b \cdot h^2}$$

Enojna armatura:

$$A_s = k_s \cdot \frac{M_{us}}{h \cdot \sigma_s} + \frac{N_u}{\sigma_s}$$

Ekscentrični nateg $N > 0$

Ekscentrični tlak $N < 0$

Čisti upogib $N = 0$

Pravokotni prerez – enojna armatura

Tabela 2

$\epsilon_s [\text{‰}]$		1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25	3.50
						$-\epsilon_1 [\text{‰}]$						
1.5	k_x	.400	.455	.500	.538	.571	.600	.625	.647	.667	.684	.700
	k_s	1.163	1.193	1.220	1.247	1.273	1.298	1.323	1.347	1.370	1.391	1.411
	k_h	.143	.189	.230	.268	.299	.325	.346	.364	.379	.391	.402
3.0	k_x	.250	.294	.333	.368	.400	.429	.455	.478	.500	.520	.538
	k_s	1.096	1.117	1.137	1.157	1.176	1.196	1.216	1.235	1.254	1.272	1.289
	k_h	.095	.130	.165	.197	.227	.252	.274	.293	.310	.325	.338
4.0	k_x	.200	.238	.273	.304	.333	.360	.385	.407	.429	.448	.467
	k_s	1.075	1.092	1.109	1.126	1.143	1.160	1.177	1.194	1.210	1.226	1.241
	k_h	.078	.108	.138	.168	.194	.218	.240	.259	.276	.291	.304
5.0	k_x	.167	.200	.231	.259	.286	.310	.333	.355	.375	.394	.412
	k_s	1.062	1.076	1.091	1.105	1.120	1.135	1.150	1.165	1.179	1.193	1.207
	k_h	.065	.092	.119	.145	.170	.192	.213	.231	.247	.262	.276
6.0	k_x	.143	.172	.200	.226	.250	.273	.294	.314	.333	.351	.368
	k_s	1.053	1.065	1.078	1.091	1.103	1.117	1.130	1.143	1.156	1.169	1.181
	k_h	.057	.080	.104	.128	.151	.172	.191	.208	.224	.239	.253
7.0	k_x	.125	.152	.176	.200	.222	.243	.263	.282	.300	.317	.333
	k_s	1.046	1.057	1.068	1.079	1.091	1.103	1.115	1.127	1.138	1.150	1.161
	k_h	.050	.071	.093	.115	.136	.155	.173	.190	.205	.219	.232
8.0	k_x	.111	.135	.158	.179	.200	.220	.238	.256	.273	.289	.304
	k_s	1.040	1.050	1.060	1.071	1.081	1.092	1.103	1.113	1.124	1.135	1.145
	k_h	.044	.064	.084	.104	.123	.141	.158	.174	.189	.202	.215
9.0	k_x	.100	.122	.143	.163	.182	.200	.217	.234	.250	.265	.280
	k_s	1.036	1.045	1.054	1.064	1.073	1.083	1.093	1.103	1.113	1.122	1.132
	k_h	.040	.058	.076	.095	.113	.130	.146	.161	.175	.188	.200
10.0	k_x	.091	.111	.130	.149	.167	.184	.200	.216	.231	.245	.259
	k_s	1.033	1.041	1.049	1.058	1.067	1.076	1.085	1.094	1.103	1.112	1.121
	k_h	.037	.053	.070	.087	.104	.120	.135	.149	.163	.175	.187

4.2. Dimenzioniranje grede pri obremenitvi s prečno silo

4.2.1. Dimenzioniranje grede ob podpori ($|V_{Ed,min}|$)

V_{Ed} ... računska (projektna) prečna sila v obravnavanem prečnem prerezu, ki jo povzroča zunanja obtežba in prednapetje,

$V_{Rd,c}$... računska strižna odpornost betonskega elementa brez strižne armature v [N],

$V_{Rd,s}$... računska prečna sila, ki jo lahko prenese plastificirana strižna armatura,

$V_{Rd,max}$... največja računska prečna sila, ki jo lahko prenese element, omejena z drobljenjem tlačne diagonale formiranega loka pri strižnem mehanizmu.

- V območjih elementa, kjer velja $V_{Ed} \leq V_{Rd,c}$, računska **strižna armatura ni potrebna**. Kljub temu moramo zagotoviti (vgraditi) minimalno strižno armature ($\rho_w \geq \rho_{w,min}$). Minimalno strižno armature lahko opustimo v elementih kot so plošče in pri manj pomembnih elementih (npr. preklade z razpetino ≤ 2 m).

$$\rho_w = \frac{A_{sw}}{s b_w \sin \alpha} \geq \rho_{w,min} = \frac{0.08 \sqrt{f_{ck}} [\text{MPa}]}{f_{yk} [\text{MPa}]}, \quad s_{max} = 0.75 d (1 + \cot \alpha)$$

- V območjih, kjer velja $V_{Ed} > V_{Rd,c}$, mora biti **zagotovljena zadostna strižna armatura**, da velja $V_{Ed} \leq V_{Rd}$ in $V_{Rd} \leq V_{Rd,max}$. Vz dolžna natezna armatura mora biti sposobna prevzeti dodatno natežno silo, ΔF_{td} , ki jo povzroči strig.

Strižna odpornost elementa s strižno armaturo V_{Rd} je enaka: $V_{Rd} = V_{Rd,s} \left(\frac{V_{Ed}}{V_{Rd,c}} \right)$.
spremenljiva višina elementa

$$V_{Rd,c} = \left[C_{Rd,c} k (100 \rho_l f_{ck})^{1/3} + k_1 \sigma_{cp} \right] b_w d \geq (v_{min} + k_1 \sigma_{cp}) b_w d,$$

f_{ck} ... karakteristična tlačna trdnost betona v [MPa],

b_w ... najmanjša širina prereza v območju nategov v [mm],

d ... statična višina prereza,

$$C_{Rd,c} = 0.18 / \gamma_c,$$

$$k_1 = 0.15,$$

$$v_{min} = 0.035 k^{3/2} f_{ck}^{1/2},$$

$$k = 1 + \sqrt{\frac{200}{d [\text{mm}]}} \leq 2,$$

$$\rho_l = \frac{A_{sl}}{b_w d} \leq 0.02, \quad \sigma_{cp} = \frac{N_{Ed}}{A_c} < 0.2 f_{cd},$$

N_{Ed} ... osna sila v prerezu zaradi zunanje obtežbe oziroma prednapetja v [N] ($N_{Ed} > 0$ za tlak),

A_{sl} ... ploščina prereza natezne armature, ki se nadaljuje naprej od obravnavanega prereza,

A_c ... površina prečnega prereza v [mm²].

Pri elementih z **navpično strižno armaturo** je strižna odpornost V_{Rd} :

$$V_{Rd} = \min \left\{ \begin{array}{l} V_{Rd,s} = \frac{A_{sw}}{s} 0.9 d f_{ywd} \cot \theta \\ V_{Rd,max} = \alpha_{cw} b_w 0.9 d \nu_1 f_{cd} / (\cot \theta + \tan \theta) \end{array} \right\}$$

A_{sw} ... prečni prerez strižne armature,

s ... razmik med stremeni,

f_{ywd} ... računska meja elastičnosti strižne armature,

ν_1 ... redukcijski faktor trdnosti za strižno razpokani beton: $\nu_1 = \nu = 0.6 \left(1 - \frac{f_{ck} [\text{MPa}]}{250} \right)$,

θ ... kot med tlačno diagonalo formiranega loka pri strižnem mehanizmu in osjo nosilca, ki je pravokotna na prečno silo ($1 \leq \cot \theta \leq 2.5$),

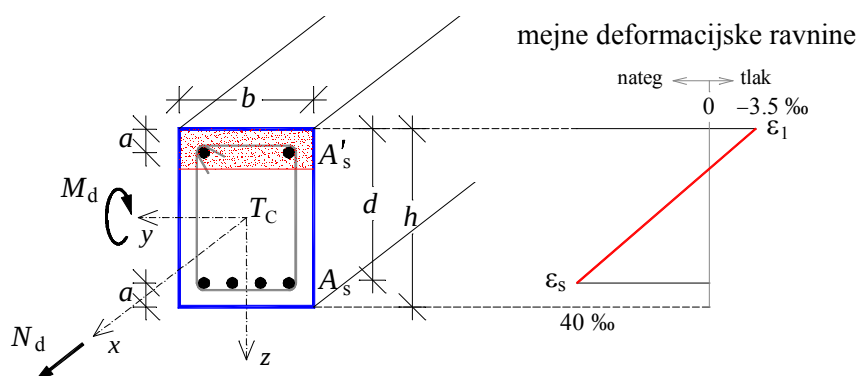
α_{cw} ... koeficient, ki upošteva vzajemno delovanje napetosti v tlačnem pasu in kakršnekoli nanešeneosne tlačne napetosti (za elemente, ki niso prednapeti, je $\alpha_{cw} = 1$),

Dodatno natezno silo, ΔF_{td} , ki jo v vzdolžni armaturi povzroča prečna sila V_{Ed} , lahko izračunamo z izrazom: $\Delta F_{td} = 0.5 V_{Ed} (\cot \theta - \cot \alpha)$. α je kot med strižno armaturo in osjo nosilca.

5. DIMENZIONIRANJE STEBRA

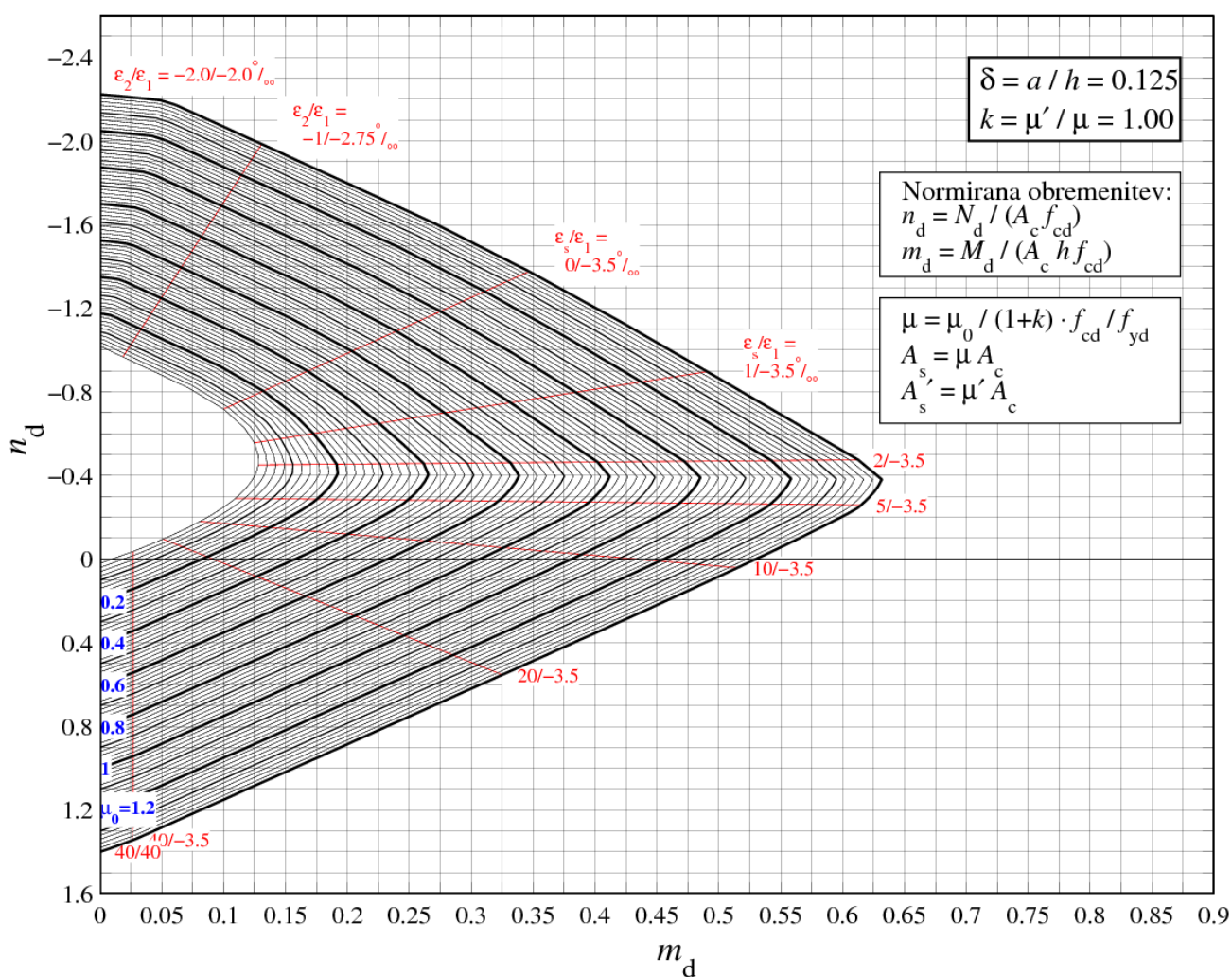
5.1. Dimenzioniranje stebra pri osno-upogibni obremenitvi

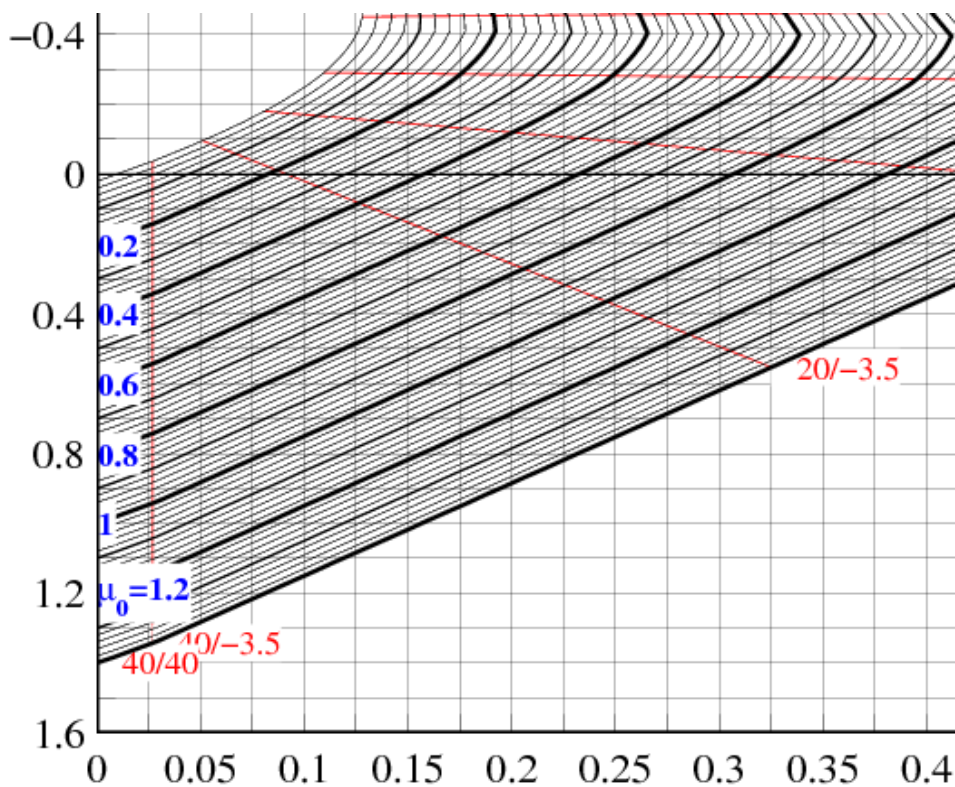
5.1.1. Dimenzioniranje ($M_{Ed,min}$; $N_{Ed,prp}$)



interakcijski diagram mejne nosilnosti prečnega prereza v polju:

$$\left. \begin{aligned} n_d &= \frac{N_d}{f_{cd} A_c} = \\ m_d &= \frac{M_d}{f_{cd} A_c h} = \end{aligned} \right\} \rightarrow \mu_0 = \quad ; A_s = \left(\frac{\mu_0}{1+k} \cdot \frac{f_{cd}}{f_{yd}} \right) \cdot A_c =$$





minimalna vzdolžna armatura stebrov:

$$A_{s,min} = \frac{0.15 N_{Ed}}{f_{yd}} \geq 0.003 A_c, \quad N_{Ed} \dots \text{računska tlačna sila v stebriu}$$

5.2. Dimenzioniranje stebra pri obremenitvi s prečno silo

Enak postopek kot pri točki 4.2.1