VJEŽBA 9.

Centrično pritisnut stub kvadratnog poprečnog presjeka

Zadatak 1.

Armiranobetonski stub, slobodno oslonjen na obje strane, visine h= 3.0 m, kvadratnog poprečnog presjeka, centrično je pritisnut silom

N_g= 1000 kN N_p= 1200 kN

a) Dimenzionisati stub ne uzimajući u obzir vitkost (kratak stub);

b) Zadržavajući dimenzije stuba iz tačke a) odrediti potrebnu armaturu za slučajeve λ=60 i λ=90.

Kvalitet usvojenog materijala: MB 30 RA 400/500
Nacrtati plan armature poprečnog presjeka stuba u razmjeri R 1:10.

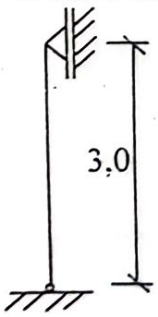
Rješenje:

a) Kratak stub (izvijanje se ne uzima u obzir)

a.1. Ulazni podaci

N_g= 1000 kN N_p= 1200 kN
MB 30 ⇨ f_b=20.5 MPa
RA 400/500 ⇨ σ_v= 400MPa

a.2. Statički sistem



a.3. Statički uticaji

N_u=1,9x N_g+2,1x N_p=1,9x1000+2,1x1200=4420 kN

a.4. Dimenzionisanje

Usvojeno $_{min}\mu$=0,6% $\overline{\mu} = \mu x \frac{\sigma_v}{f_b} = 0.6x\frac{400}{20.5}$=11,71%

$$A_b = \frac{N_u}{f_b x(1+\overline{\mu})} = \frac{4420}{2.05x\left(1+\frac{11.71}{100}\right)} = 1930.1 \text{ cm}^2$$

b=$\sqrt{A_b}$ =43,9 cm Usvojeno: b=45 cm

a.5. Kontrola vitkosti

h=l=3.0 m

$$i=\frac{b}{\sqrt{2}}=\frac{45}{\sqrt{2}}=13 \text{ cm}$$

$$\lambda=\frac{h}{i}=\frac{300}{13}=23{,}1<25$$

Ne vrši se provjera stabilnosti na uticaje izvijanja (član 105 PBAB'87 knjiga 2)

a.6. Određivanje armature

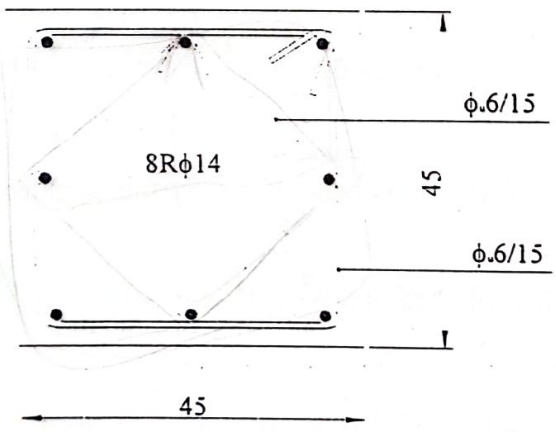
$$\overline{\mu}=\frac{N_u}{f_b x A_b}-1=\frac{4420}{2.05x45^2}-1=0.0647=6.47\%$$

$$\mu=\overline{\mu}x\frac{\sigma_v}{f_b}=6.47x\frac{2.05}{40}=0.33\%$$

$$\min\mu=0.3x\left(1+\frac{\sigma_b}{f_b}\right)=0.3x\left(1+\frac{\frac{4420}{45x45}}{2.05}\right)=0.619\%>0.33\%$$

$$A_a=\frac{0.619}{100}x45x45=12.54 \text{ cm}^2$$

Usvaja se : 8Rϕ14 (12.32 cm^2)



b) Vitki stubovi

b.1. Umjereno vitak stub ($25 \le \lambda_i \le 75$)

λ=60 i h=7.8 m

$e=e_0+e_1+e_\varphi+e_2$

e – ukupna ekcentričnost

e_0 – ekcentričnost usljed udstupanja od vertikale pri izvođenju

e_1 - $e_1=\frac{M}{N}$

e_φ - ekcentričnost usljed uticaja tečenja

e_2 – ekcentičnost koju izaziva sila pritiska usled deformacija stuba, uticaji drugog reda

b.1.2. Metoda dopunske ekcentričnosti za $25 \le \lambda_i \le 75$, važi za λ=60

e_0 $e_0=\frac{h_i}{300}=\frac{780}{300}$=2,6 cm, treba da važi 2 cm $\le e_0 \le$ 10 cm

e_1 M=0, pa je e_1=0

e_φ Efekti tečenja mogu biti zanemareni ako je ispunjen jedan od sljedećih uslova

$\lambda_i \le 50$	λ_i=60	nije
$e_1/d > 2$	e_1/d=0	nije
$N_g \le 0.2N_q$	1000>0.2x(1000+1200)=440	nije

} tečenje se ne može zanemariti

N_g=stalno
N_q=ukupna

$$e_\varphi=\left(e_{1g}+e_0\right)x\left(e^{\frac{\alpha_E}{1-\alpha_E}\varphi}-1\right), \quad \alpha_E=\frac{N_g}{N_E},$$

$N_E=\frac{E_b I_b \pi^2}{h_i^2}$ Ojlerova sila izvijanja

$$N_E=\frac{3150x\frac{45^4}{12}x\pi^2}{780^2}=17462 \text{ kN}; \quad N_g=1000 \text{ kN}; \quad \alpha_E=\frac{1000}{17462}=0,057$$

Za MB 30 E_b=31500 MPa PBAB'87, član 52, tabela 8.
φ_∞=2,5 PBAB'87, član 59, tabela 11.

$$e_\varphi=2,6x\left(e^{\frac{0.057}{1-0.057}x2.5}-1\right)=0,42 \text{ cm}$$

e_2 Postupak dopunske ekcentričnosti za $\lambda_i \le 75$

$$\frac{e_2}{d}=\frac{\lambda_i-25}{100}x\sqrt{0.10+\frac{e_1}{d}} \ge 0 \text{ kada je } 0 \le \frac{e_1}{d} \le 0.30$$

$$\frac{e_2}{d}=\frac{\lambda_i-25}{160} \ge 0 \text{ kada je } 0.3 \le \frac{e_1}{d} < 2.5$$

$$\frac{e_2}{d}=\frac{\lambda_i-25}{160}x\left(3.5-\frac{e_1}{d}\right) \text{ kada je } 2,5 \le \frac{e_1}{d} < 3.5$$

e_1=0, pa je $e_2=\frac{\lambda_i-25}{100}x\sqrt{0.10}xd=\frac{60-25}{100}x\sqrt{0.10}x45$=4.98

$e=e_0+e_1+e_\varphi+e_2$=2.6+0+0.42+4.98= 8 cm

b.1.3. Statički uticaji

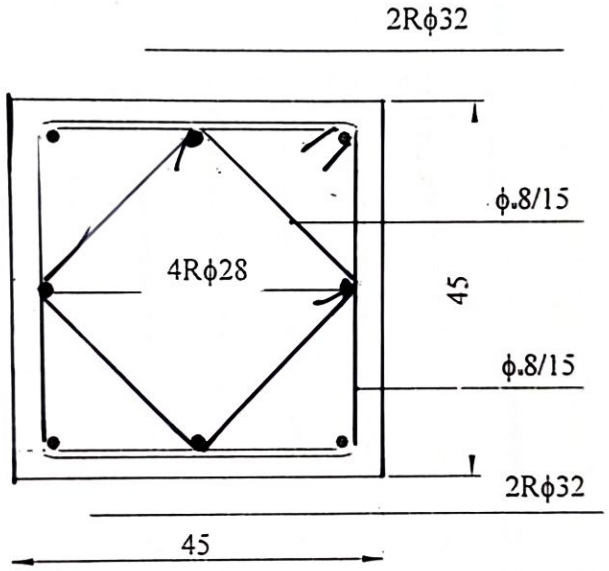
M_u=0,08x4420= 353,6 kNm i N_u=4420 kN

b.1.4. Dimenzionisanje

$$m_u=\frac{353.6x100}{45^3 x2.05}=0,189 \qquad n_u=\frac{4420}{45^2 x2.05}=1,065 \qquad \Big\} \quad \bar{\mu}_1=\bar{\mu}_2=0.26$$

$$A_{a1}=A_{a2}=\frac{0.26x45x45}{\frac{40}{2.05}}=26,98\ cm^2, \quad \text{te je} \quad A_a=53,98\ cm^2$$

Usvaja se: 4Rϕ28+4Rϕ32 (56,8 cm^2)



b.2. Vitak stub λ_i>75

λ_i=90 i h_i=11.7 m

b.2.1. Određivanje minimalnog procenta armiranja

$$\min \mu \frac{\lambda_i}{50}-0.4=\frac{90}{50}-0.4=1.4\% \qquad \text{član 188. PBAB'87}$$

$$\min \bar{\mu}=\min \mu x\frac{\sigma_v}{f_b}=1.4x\frac{40}{2.05}=27.32\%$$

b.2.2. Određivanje ekcentriciteta

e_0 $e_0=\frac{l_i}{300}=\frac{1170}{300}$=309 cm, iperfekcija

e_1 e_1=0, početni ekcentricitet M=0

e_φ $e_\varphi=\left(e_{1g}+e_0\right)x\left(e^{\frac{\alpha_E}{1-\alpha_E}\varphi}-1\right), \quad \alpha_E=\frac{N_g}{N_E},$

$$N_E=\frac{3150x\frac{45^4}{12}x\pi^2}{1170^2}=7760,8\ kN; \qquad N_g=1000\ kN; \quad \alpha_E=\frac{1000}{7760.8}=0,129$$

$\bar{\mu} = Fa*Sigv/b*d*fB$

n	k	.00	.10	.15	.20	.25	.30	.35	.40	.45	.50	.60	.70	.80	.90	1.00	1,10	1.20
		$m*10^3 = 10^3*Mu/b*d*d*fB$																
1.10	.5	0	0	13	19	24	28	32	35	39	42	48	54	60	65	71	76	81
	1.0	0	0	18	34	45	54	62	69	76	82	95	107	119	130	141	151	162
	1.5	0	0	0	37	53	69	84	99	110	120	140	158	176	192	209	225	241
	2.0	0	0	0	0	56	73	90	107	123	140	172	204	229	251	272	293	312
	2.5	0	0	0	0	0	0	94	111	129	146	181	214	248	280	313	345	374
	3.0	0	0	0	0	0	0	0	0	133	151	186	221	255	289	323	356	390
	3.5	0	0	0	0	0	0	0	0	0	0	0	0	260	295	330	364	399
	max k	.0	.0	1.2	1.7	2.1	2.4	2.6	2.8	3.0	3.2	3.3	3.4	3.6	3.7	3.8	3.9	4.0
	max m	0	0	19	38	56	75	94	113	133	152	188	225	261	297	333	369	406
1.20	.5	0	0	0	0	17	22	27	31	35	38	45	51	57	63	69	74	79
	1.0	0	0	0	0	0	36	51	60	68	75	89	101	113	125	136	147	158
	1.5	0	0	0	0	0	0	56	72	88	104	130	149	167	185	202	219	235
	2.0	0	0	0	0	0	0	0	76	93	110	144	177	210	243	265	287	308
	2.5	0	0	0	0	0	0	0	0	0	114	149	185	219	254	287	320	353
	3.0	0	0	0	0	0	0	0	0	0	0	0	189	225	260	295	329	364
	3.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	300	336	371
	max k	.0	.0	.0	.0	1.0	1.5	1.8	2.1	2.4	2.6	3.0	3.2	3.3	3.5	3.6	3.7	3.8
	max m	0	0	0	0	19	38	57	76	95	114	153	191	228	264	301	337	374
1.30	.5	0	0	0	0	0	0	18	25	30	34	41	48	54	60	66	72	77
	1.0	0	0	0	0	0	0	0	38	54	66	81	95	108	120	132	143	154
	1.5	0	0	0	0	0	0	0	0	57	74	107	139	159	177	195	212	229
	2.0	0	0	0	0	0	0	0	0	0	0	113	147	181	215	248	279	301
	2.5	0	0	0	0	0	0	0	0	0	0	0	152	188	223	258	293	327
	3.0	0	0	0	0	0	0	0	0	0	0	0	0	192	228	264	300	335
	3.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	341
	max k	.0	.0	.0	.0	.0	.0	.8	1.3	1.7	1.9	2.4	2.8	3.1	3.2	3.3	3.5	3.6
	max m	0	0	0	0	0	0	19	39	58	77	115	154	192	230	267	304	341
1.40	.5	0	0	0	0	0	0	0	0	19	29	37	45	51	58	64	70	75
	1.0	0	0	0	0	0	0	0	0	0	38	72	88	102	115	127	138	150
	1.5	0	0	0	0	0	0	0	0	0	0	76	110	143	169	188	205	222
	2.0	0	0	0	0	0	0	0	0	0	0	0	115	150	185	219	253	286
	2.5	0	0	0	0	0	0	0	0	0	0	0	0	154	190	226	262	297
	3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	231	268	304
	max k	.0	.0	.0	.0	.0	.0	.0	.0	.7	1.1	1.8	2.2	2.6	2.9	3.1	3.3	3.4
	max m	0	0	0	0	0	0	0	0	20	39	77	116	154	193	232	270	307
1.50	.5	0	0	0	0	0	0	0	0	0	0	33	41	48	55	61	67	73
	1.0	0	0	0	0	0	0	0	0	0	0	39	74	95	109	121	134	145
	1.5	0	0	0	0	0	0	0	0	0	0	0	77	113	146	179	198	216
	2.0	0	0	0	0	0	0	0	0	0	0	0	0	116	152	188	222	257
	2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	192	229	265
	3.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	270
	max k	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	1.0	1.6	2.1	2.4	2.7	3.0	3.2
	max m	0	0	0	0	0	0	0	0	0	0	39	78	116	155	194	233	271

$$e_\varphi = 3{,}9x\left(2.718^{\frac{0.129}{1-0.129}x2.5}-1\right) = 1{,}75 \text{ cm}$$

Ukupan bezdimenzionalni ekcentricitet I reda je:

$e_I = e_0 + e_1 + e_\varphi = 3{,}9 + 1{,}75 = 5{,}65$ cm

$$\frac{e_I}{d} = \frac{5.65}{45} = 0{,}126$$

b.2.3. Dimenzionisanje

Usvojeno: simetrično armiran stub
a/h=0,1, h=45-0,1x45=40,5 cm

$$n = \frac{N_u}{bxdxf_b} = \frac{4420}{45x45x2.05} = 1{,}06$$ usvojeno $n_r = 1.1 > n = 1.06$

1. Aproksimacija

$k = æ \text{ x } h\ 10^3 = 2 \Rightarrow æ = \frac{2.0x10^3}{40.5} = 4.938\ 10^{-5}$ 1/cm

- ekcentricitet

$e_2 = 0.1 \text{ x } æ\ h_i^2 = 0.1x\ 4.92810^{-5} \text{ x } 11.7^2 10^4 = 6.76$ cm
$e/d = e_I/d + e_2/d = 0.126 + 6.76/45 = 0.276$ cm

- potreban moment unutrašnjih sila

$_{potr}m_r = n_r x \frac{e}{d} = 1{,}1x0{,}276 = 0{,}304$

- potrebna armatura $\overline{\mu}\,(m_r\ 10^3) = 1{,}1(293) - 1{,}2\ (312)$

$$_{potr}\overline{\mu}_r = 1{,}1 + \frac{1.2-1.1}{312-293}x(304-293) = 1{,}158 > 0.273 = {}_{min}\overline{\mu}$$

2. Aproksimacija

$k = 2.5 \Rightarrow æ = \frac{2.5x10^3}{40.5} = 6.17\ 10^{-5}$ 1/cm

- ekcentricitet

$e_2 = 0.1x\ 6.1710^{-5} \text{ x } 11.7^2 10^4 = 8.45$ cm
$e/d = e_I/d + e_2/d = 0.126 + 8.45/45 = 0.314$ cm

- potreban moment unutrašnjih sila

$_{potr}m_r = n_r x \frac{e}{d} = 1{,}1x0{,}314 = 0{,}345$

- potrebna armatura $\overline{\mu}\,(m_r\ 10^3)$ za $m_r = 0.345$

$_{potr}\overline{\mu}_r = 1.1\%$

3. Aproksimacija

$k = 3.0 \Rightarrow æ = \frac{3.0x10^3}{40.5} = 7.407\ 10^{-5}$ 1/cm

- ekcentricitet

$e_2 = 0.1x\ 7.40710^{-5} \text{ x } 11.7^2 10^4 = 10.139$ cm

$e/d=e_1/d \div e_2/d=0.126+10.139/45=0.351$ cm

- potreban moment unutrašnjih sila

$_{potr}m_r=n_r x \frac{e}{d}=1,1x0,351=0,386$

- potrebna armatura $\overline{\mu}(m_r\ 10^3)=1,1(356)-1,2\ (390)$

- $_{potr}\overline{\mu}_r=1,1+\frac{1.2-1.1}{390-356}x(386-356)=1,19$

Iz aproksimacija 1, 2 i 3 tražimo $_{min}\overline{\mu}_r \Longrightarrow \overline{\mu}_r=1,1\%$

$$A_a=\overline{\mu}_r x b x d x \frac{f_b}{\sigma_v}=1.1x45^2 x \frac{2.05}{40}=114,16\ cm^2$$

Usvaja se: 12Rϕ36 (122,16 cm^2)