



VEŽBANJE 10

Pečurkaste ploče – kontrola probijanja stuba kroz ploču (član 218÷222)

čl. 218

Pečurkaste ploče su ploče koje se neposredno oslanjaju na stubove sa ojačanom glavom stuba (kapitelom) ili bez ojačanja glave stuba i koje su sa stubovima kruto ili zglobno povezane.

Napon smicanja τ u kritičnom preseku izračunava se prema izrazu:

$$\tau = \frac{T_{\max}}{O_{kr} \cdot h_s}$$

gde je:

- T_{\max} - transversalna sila pri eksploatacionom opterećenju
- O_{kr} - obim preseka oko stuba ili ojačanja sa prečnikom d_{kp}
- h_s - srednja statička visina ploče za dva usvojena pravca armature

$$O_{kp} = d_{kp} \cdot \pi$$

$$d_{kp} = d_s + h_s$$

$$d_s = 1.13 \cdot \sqrt{b \cdot d}$$

- d_s - prečnik kružnog oslonca
- b - manja dimenzija pravougaonog stuba
- d - veća dimenzija pravougaonog stuba (u izrazu se može uzeti najviše $d = 1.50 \cdot b$ bez obzira na stvarni odnos)

U zavisnosti od položaja stuba za obim O_{kp} kritičnog preseka treba uzimati:

- za srednji stub $1.0 \cdot O_{kp}$
- za krajnji stub $0.60 \cdot O_{kp}$
- za ugaoni stub $0.30 \cdot O_{kp}$

Ako je ispunjen sledeći uslov nije potrebna računaska armatura za prijem zatežućih sila usled dejstva transverzalne sile T_{max} :

$$\tau \leq \frac{2}{3} \cdot \gamma_1 \cdot \tau$$

U slučaju da se τ nalazi u granicama:

$$\frac{2}{3} \cdot \gamma_1 \cdot \tau_a < \tau$$

presek se mora armirati posebnom poprečnom armaturom koja se sračunava iz sledećeg izraza:

$$A_{ak} = 1.35 \cdot \frac{T_{max}}{\sigma_v}$$

Propisi ne dozvoljavaju sledeći slučaj:

$$\tau > \gamma_2 \cdot \tau_b$$

Koeficijenti γ_1 i γ_2 se sračunavaju iz izraza:

$$\gamma_1 = 1.30 \cdot \alpha_a \cdot \sqrt{\mu}$$

$$\gamma_2 = 0.45 \cdot \alpha_a \cdot \sqrt{\mu}$$

Koeficijenti α_a su:

$$\alpha_a = 1.00 \quad (\text{GA } 240/360)$$

$$\alpha_a = 1.30 \quad (\text{RA } 400/500)$$

$$\alpha_a = 1.40 \quad (\text{MA } 500/560)$$

Srednja vrednost procenta armiranja μ mora zadovoljiti uslov:

$$0.50\% \leq \mu \leq 25 \cdot \frac{f_{bk}}{\sigma_v} \leq 1.50\%$$

TABELA 21. Vrednosti dopuštenih napona zatezanja τ_a i τ_b :

	MB15	MB20	MB30	MB40	MB50	MB60
τ_a (MPa)	0.50	0.60	0.80	1.0	1.10	1.20
τ_b (MPa)	1.50	1.80	2.20	2.60	3.0	3.40

PRIMER 1

Kontrolisati probijanje stuba kroz AB ploču prema sledećim podacima:

MB30

MAG500 / 560

b/d=25.0/25.0 cm

d_p=16.0 cm

T_g = 46.64 kN

T_p = 22.10 kN

A_a = 3.35 cm² (Q335)

DIMENZIONISANJE

Statička visina poprečnog preseka u x-pravcu:

$$h_x = 16.0 - 1.50 - \frac{0.80}{2} = 14.10 \text{ cm}$$

Statička visina poprečnog preseka u y-pravcu:

$$h_y = 16.0 - 1.50 - 0.80 - \frac{0.80}{2} = 13.30 \text{ cm}$$

Srednja statička visina poprečnog preseka:

$$h_s = 0.50 \cdot (14.10 + 13.30) = 13.70 \text{ cm}$$

Prečnik zamenjujućeg kružnog stuba:

$$d_s = 1.13 \cdot \sqrt{b \cdot d} = 1.13 \cdot \sqrt{25.0 \cdot 25.0} = 28.25 \text{ cm}$$

Prečnik kritičnog kružnog preseka ploče:

$$d_{kp} = d_s + h_s = 28.25 + 13.70 = 41.95 \text{ cm}$$

Obim kritičnog kružnog preseka ploče:

$$O_{kp} = d_{kp} \cdot \pi = 41.95 \cdot 3.14 = 131.72 \text{ cm}$$

Maksimalni računski smičući napon:

$$\tau = \frac{T_{\max}}{O_{kp} \cdot h_s} = \frac{68.74}{131.72 \cdot 13.70} = 0.038 \frac{\text{kN}}{\text{cm}^2} = 0.38 \text{ MPa}$$

Sračunavanje srednje vrednosti procenta armiranja preseka ploče zategnutom armaturom iz dva upravna pravca na širini oslonačke trake $0.40 \cdot l_x$ i $0.40 \cdot l_y$:

$$\mu_x = \frac{A_a}{A_b} = \frac{3.35}{100.0 \cdot 14.10} \cdot 100 = 0.244\%$$

$$\mu_y = \frac{A_a}{A_b} = \frac{3.35}{100.0 \cdot 13.30} \cdot 100 = 0.268\%$$

$$\mu = 0.50 \cdot (0.244 + 0.268) = 0.256\%$$

$$\alpha_a = 1.40 \quad (\text{MA})$$

$$\gamma_1 = 1.30 \cdot \alpha_a \cdot \sqrt{\mu} = 1.30 \cdot 1.40 \cdot \sqrt{0.256} = 0.92$$

$$\text{Za } \mu = 0.50\%$$

$$\gamma_1 = 1.30 \cdot \alpha_a \cdot \sqrt{\mu} = 1.30 \cdot 1.40 \cdot \sqrt{0.50} = 1.29$$

$$\tau \leq \frac{2}{3} \cdot \gamma_1 \cdot \tau_a$$

$$0.38 \leq \frac{2}{3} \cdot 1.29 \cdot 0.80$$

$$0.38 \text{ MPa} < 0.688 \text{ MPa}$$

KOMENTAR:

Nije potrebna posebna armatura za prijem zatežućih sila.

PRIMER 2

Kontrolisati probijanje stuba kroz AB ploču prema sledećim podacima:

MB30

MAG500 / 560

$b/d = 25.0/25.0$ cm

$d_p = 16.0$ cm

$T_g = 100.0$ kN

$T_p = 70.0$ kN

$A_a = 3.35$ cm² (Q335)

DIMENZIONISANJE

$$h_x = 16.0 - 1.50 - \frac{0.80}{2} = 14.10 \text{ cm}$$

$$h_y = 16.0 - 1.50 - 0.80 - \frac{0.80}{2} = 13.30 \text{ cm}$$

$$h_s = 0.50 \cdot (14.10 + 13.30) = 13.70 \text{ cm}$$

$$d_s = 1.13 \cdot \sqrt{b \cdot d} = 1.13 \cdot \sqrt{25.0 \cdot 25.0} = 28.25 \text{ cm}$$

$$d_{kp} = d_s + h_s = 28.25 + 13.70 = 41.95 \text{ cm}$$

$$O_{kp} = d_{kp} \cdot \pi = 41.95 \cdot 3.14 = 131.72 \text{ cm}$$

$$\tau = \frac{T_{\max}}{O_{kp} \cdot h_s} = \frac{170.0}{131.72 \cdot 13.70} = 0.094 \frac{\text{kN}}{\text{cm}^2} = 0.94 \text{ MPa}$$

$$\mu_x = \frac{A_a}{A_b} = \frac{3.35}{100.0 \cdot 14.10} \cdot 100 = 0.244\%$$

$$\mu_y = \frac{A_a}{A_b} = \frac{3.35}{100.0 \cdot 13.30} \cdot 100 = 0.268\%$$

$$\mu = 0.50 \cdot (0.244 + 0.268) = 0.256\%$$

$$\alpha_a = 1.40 \quad (\text{MA})$$

$$\gamma_1 = 1.30 \cdot \alpha_a \cdot \sqrt{\mu} = 1.30 \cdot 1.40 \cdot \sqrt{0.256} = 0.92$$

$$Z_a \quad \mu = 0.50\%$$

$$\gamma_1 = 1.30 \cdot \alpha_a \cdot \sqrt{\mu} = 1.30 \cdot 1.40 \cdot \sqrt{0.50} = 1.29$$

$$\gamma_2 = 0.45 \cdot \alpha_a \cdot \sqrt{\mu} = 0.45 \cdot 1.40 \cdot \sqrt{0.50} = 0.445$$

$$\frac{2}{3} \cdot \gamma_1 \cdot \tau_a = \frac{2}{3} \cdot 1.29 \cdot 0.80 = 0.688 \text{ MPa}$$

$$\gamma_2 \cdot \tau_b = 0.445 \cdot 2.20 = 0.979 \text{ MPa}$$

$$\frac{2}{3} \cdot \gamma_1 \cdot \tau_a < \tau < \gamma_2 \cdot \tau_b$$

$$0.688 \text{ MPa} < 0.94 \text{ MPa} < 0.979 \text{ MPa}$$

$$A_{ak} = 1.35 \cdot \frac{T_{max}}{\sigma_v} = 1.35 \cdot \frac{170.0}{240.0 \cdot 10^{-1}} = 9.56 \text{ cm}^2$$

Usvojeno: 20 Ø6 ($A_a = 11.20 \text{ cm}^2$)

PRIMER 3

Višespratni skeletni okvir je fundiran na temeljnoj ploči debljine $d_p = 60.0$ cm. Izvršiti proračun ploče u odnosu na napone probijanja prema sledećim podacima:

MB30
RA400 / 500 – 2
 $b/d = 40.0/40.0$ cm
 $d_p = 60.0$ cm

$$T_{q,max} = 1599.18 \text{ kN}$$

$$A_{a,x} = 38.01 \text{ cm}^2 \quad (\text{R } \varnothing 22/10 \text{ cm}) \quad \text{x-pravac}$$

$$A_{a,y} = 49.09 \text{ cm}^2 \quad (\text{R } \varnothing 25/10 \text{ cm}) \quad \text{y-pravac}$$

DIMENZIONISANJE

$$h_x = 60.0 - 3.0 - \frac{2.20}{2} = 55.90 \text{ cm}$$

$$h_y = 16.0 - 3.0 - 2.20 - \frac{2.50}{2} = 53.55 \text{ cm}$$

$$h_s = 0.50 \cdot (55.90 + 53.55) = 54.72 \text{ cm}$$

$$d_s = 1.13 \cdot \sqrt{b \cdot d} = 1.13 \cdot \sqrt{40.0 \cdot 40.0} = 45.20 \text{ cm}$$

$$d_{kp} = d_s + h_s = 45.20 + 54.72 = 99.92 \text{ cm}$$

$$O_{kp} = d_{kp} \cdot \pi = 99.92 \cdot 3.14 = 313.91 \text{ cm}$$

$$\tau = \frac{T_{max}}{O_{kp} \cdot h_s} = \frac{1599.18}{313.91 \cdot 54.72} = 0.093 \frac{\text{kN}}{\text{cm}^2} = 0.93 \text{ MPa}$$

$$\mu_x = \frac{A_{a,x}}{A_b} = \frac{38.10}{100.0 \cdot 55.90} \cdot 100 = 0.68\%$$

$$\mu_y = \frac{A_{a,y}}{A_b} = \frac{49.09}{100.0 \cdot 53.55} \cdot 100 = 0.92\%$$

$$\mu = 0.50 \cdot (0.68 + 0.92) = 0.80\%$$

$$\alpha_a = 1.30 \quad (\text{RA400 / 500 – 2})$$

$$\gamma_1 = 1.30 \cdot \alpha_a \cdot \sqrt{\mu} = 1.30 \cdot 1.30 \cdot \sqrt{0.80} = 1.51$$

$$\gamma_2 = 0.45 \cdot \alpha_a \cdot \sqrt{\mu} = 0.45 \cdot 1.30 \cdot \sqrt{0.80} = 0.52$$

$$\frac{2}{3} \cdot \gamma_1 \cdot \tau_a = \frac{2}{3} \cdot 1.51 \cdot 0.80 = 0.806$$

$$\gamma_2 \cdot \tau_b = 0.52 \cdot 2.20 = 1.15$$

U slučaju da se presek armira rebrastom armaturom (RA400/500-2):

$$A_{ak} = 1.35 \cdot \frac{T_{max}}{\sigma_v} = 1.35 \cdot \frac{1599.18}{400.0 \cdot 10^{-1}} = 53.97 \text{ cm}^2$$

Usvojeno: 48 RØ12 ($A_a = 54.24 \text{ cm}^2$)

Za slučaj da se presek armira glatkom armaturom (GA240/360):

$$A_{ak} = 1.35 \cdot \frac{T_{max}}{\sigma_v} = 1.35 \cdot \frac{1599.18}{240.0 \cdot 10^{-1}} = 89.95 \text{ cm}^2$$

Usvojeno: 80 Ø12 ($A_a = 90.40 \text{ cm}^2$)

Ukoliko se dimenzije stuba povećaju na $b/d=60.0/60.0 \text{ cm}$:

$$d_s = 1.13 \cdot \sqrt{b \cdot d} = 1.13 \cdot \sqrt{60.0 \cdot 60.0} = 67.80 \text{ cm}$$

$$d_{kp} = d_s + h_s = 67.80 + 54.72 = 122.52 \text{ cm}$$

$$O_{kp} = d_{kp} \cdot \pi = 122.52 \cdot 3.14 = 384.91 \text{ cm}$$

$$\tau = \frac{T_{max}}{O_{kp} \cdot h_s} = \frac{1599.18}{384.91 \cdot 54.72} = 0.0759 \frac{\text{kN}}{\text{cm}^2} = 0.759 \text{ MPa}$$

$$\mu_x = \frac{A_{a,x}}{A_b} = \frac{38.10}{100.0 \cdot 55.90} \cdot 100 = 0.68\%$$

$$\mu_y = \frac{A_{a,y}}{A_b} = \frac{49.09}{100.0 \cdot 53.55} \cdot 100 = 0.92\%$$

$$\mu = 0.50 \cdot (0.68 + 0.92) = 0.80\%$$

$$\alpha_a = 1.30 \quad (\text{RA400 / 500} - 2)$$

$$\gamma_1 = 1.30 \cdot \alpha_a \cdot \sqrt{\mu} = 1.30 \cdot 1.30 \cdot \sqrt{0.80} = 1.51$$

$$\frac{2}{3} \cdot \gamma_1 \cdot \tau_a = \frac{2}{3} \cdot 1.51 \cdot 0.80 = 0.806$$

$$\tau = 0.759 \text{ MPa} < \frac{2}{3} \cdot \gamma_1 \cdot \tau_a = 0.806 \text{ MPa}$$

KOMENTAR:

Za stub dimenzija b/d=60.0/60.0 cm nije potrebna posebna armatura za prijem zatežućih sila.

PRIMER 4

Oblikovati kapitel prema sledećim podacima:

MB30

MAG500 / 560

$b/d = 25.0/25.0$ cm

$d_p = 16.0$ cm

$T_{q,max} = 350.0$ kN

$A_a = 3.35$ cm² (Q335)

DIMENZIONISANJE

$$h_x = 16.0 - 1.50 - \frac{0.80}{2} = 14.10 \text{ cm}$$

$$h_y = 16.0 - 1.50 - 0.80 - \frac{0.80}{2} = 13.30 \text{ cm}$$

$$h_s = 0.50 \cdot (14.10 + 13.30) = 13.70 \text{ cm}$$

$$d_s = 1.13 \cdot \sqrt{b \cdot d} = 1.13 \cdot \sqrt{25.0 \cdot 25.0} = 28.25 \text{ cm}$$

$$d_{kp} = d_s + h_s = 28.25 + 13.70 = 41.95 \text{ cm}$$

$$O_{kp} = d_{kp} \cdot \pi = 41.95 \cdot 3.14 = 131.72 \text{ cm}$$

$$\tau = \frac{T_{max}}{O_{kp} \cdot h_s} = \frac{350.0}{131.72 \cdot 13.70} = 0.1939 \frac{\text{kN}}{\text{cm}^2} = 1.939 \text{ MPa}$$

$$\mu_x = \frac{A_a}{A_p} = \frac{3.35}{100.0 \cdot 14.10} \cdot 100 = 0.244\%$$

$$\mu_y = \frac{A_a}{A_p} = \frac{3.35}{100.0 \cdot 13.30} \cdot 100 = 0.268\%$$

$$\mu = 0.50 \cdot (0.244 + 0.268) = 0.256\%$$

$$\alpha_a = 1.40 \quad (\text{MA})$$

$$\gamma_1 = 1.30 \cdot \alpha_a \cdot \sqrt{\mu} = 1.30 \cdot 1.40 \cdot \sqrt{0.256} = 0.92$$

$$\text{Za } \mu = 0.50\%$$

$$\gamma_1 = 1.30 \cdot \alpha_a \cdot \sqrt{\mu} = 1.30 \cdot 1.40 \cdot \sqrt{0.50} = 1.29$$

$$\gamma_2 = 0.45 \cdot \alpha_a \cdot \sqrt{\mu} = 0.45 \cdot 1.40 \cdot \sqrt{0.50} = 0.445$$

$$\frac{2}{3} \cdot \gamma_1 \cdot \tau_a = \frac{2}{3} \cdot 1.29 \cdot 0.80 = 0.688 \text{ MPa}$$

$$\gamma_2 \cdot \tau_b = 0.445 \cdot 2.20 = 0.979 \text{ MPa}$$

$$\tau = 1.939 \text{ MPa} > \gamma_2 \cdot \tau_b = 0.979 \text{ MPa}$$

KOMENTAR:

Pošto propisi ne dozvoljavaju ovaj slučaj potrebno je pristupiti usvajanju i konstrukciji kapitela.

Konstrukcija hiperbole probijanja

$$G + P = 2 \cdot \pi \cdot x \cdot y \cdot \tau_{\text{doz}}$$

$2 \cdot \pi \cdot x \cdot y$ - površina omotača cilindra po kome se vrši probijanje

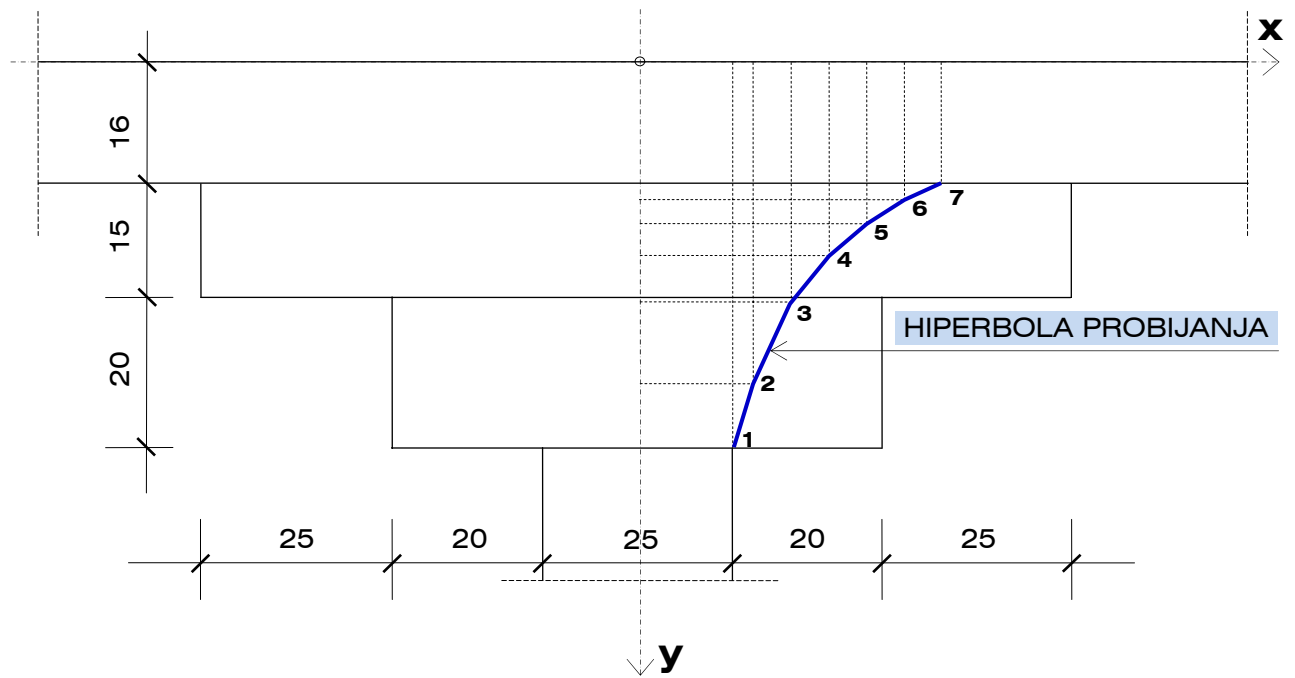
$$x \cdot y = \frac{G + P}{2 \cdot \pi \cdot \tau_{\text{doz}}}$$

Za kvadratni stub :

$$G + P = 2 \cdot x \cdot 4 \cdot y \cdot \tau_{\text{doz}} = 8 \cdot x \cdot y \cdot \tau_{\text{doz}}$$

$$x \cdot y = \frac{G + P}{8 \cdot \tau_{\text{doz}}} = \frac{350.0}{8 \cdot 0.0688} = 637.78$$

	1	2	3	4	5	6	7
x [cm]	12.50	15.00	20.00	25.00	30.00	35.00	39.86
y [cm]	51.02	42.52	31.89	25.51	21.26	18.22	16.00



Obzirom da kapitel obuhvata hiperbolu probijanja (za $\mu_{\min} = 0.50\%$) nije potrebna kontrola napona probijanja u okviru kapitela. Kontrola se zato vrši samo u ploči.

$$h_x = 16.0 - 1.50 - \frac{0.80}{2} = 14.10 \text{ cm}$$

$$h_y = 16.0 - 1.50 - 0.80 - \frac{0.80}{2} = 13.30 \text{ cm}$$

$$h_s = 0.50 \cdot (14.10 + 13.30) = 13.70 \text{ cm}$$

$$d_s = 1.13 \cdot \sqrt{b \cdot d} = 1.13 \cdot \sqrt{115.0 \cdot 115.0} = 129.95 \text{ cm}$$

$$d_{kp} = d_s + h_s = 129.95 + 13.70 = 143.65 \text{ cm}$$

$$O_{kp} = d_{kp} \cdot \pi = 143.65 \cdot 3.14 = 451.29 \text{ cm}$$

$$\tau = \frac{T_{\max}}{O_{kp} \cdot h_s} = \frac{200.0}{451.25 \cdot 13.70} = 0.0323 \frac{\text{kN}}{\text{cm}^2} = 0.323 \text{ MPa}$$

$$\tau \leq \frac{2}{3} \cdot \gamma_1 \cdot \tau_a$$

$$0.323 \leq \frac{2}{3} \cdot 1.29 \cdot 0.80$$

$$0.323 \text{ MPa} < 0.688 \text{ MPa}$$