



INSTITUT GRAĐEVINARSTVA HRVATSKE d.d.
CIVIL ENGINEERING INSTITUTE OF CROATIA ZAVOD ZA
BETONSKE I ZIDANE KONSTRUKCIJE
CONCRETE AND MASONRY STRUCTURES DEPARTMENT
ODJEL ZA KONSTRUKCIJE
STRUCTURAL DIVISION
CROATIA, 10 000 ZAGREB, J. RAKUŠE 1, Fax +385 1 / 61 25 100

Statički proračun opečnog nadvoja tip D Wienerberger Ilovac, d.d., Karlovac

6. rujna 2006.

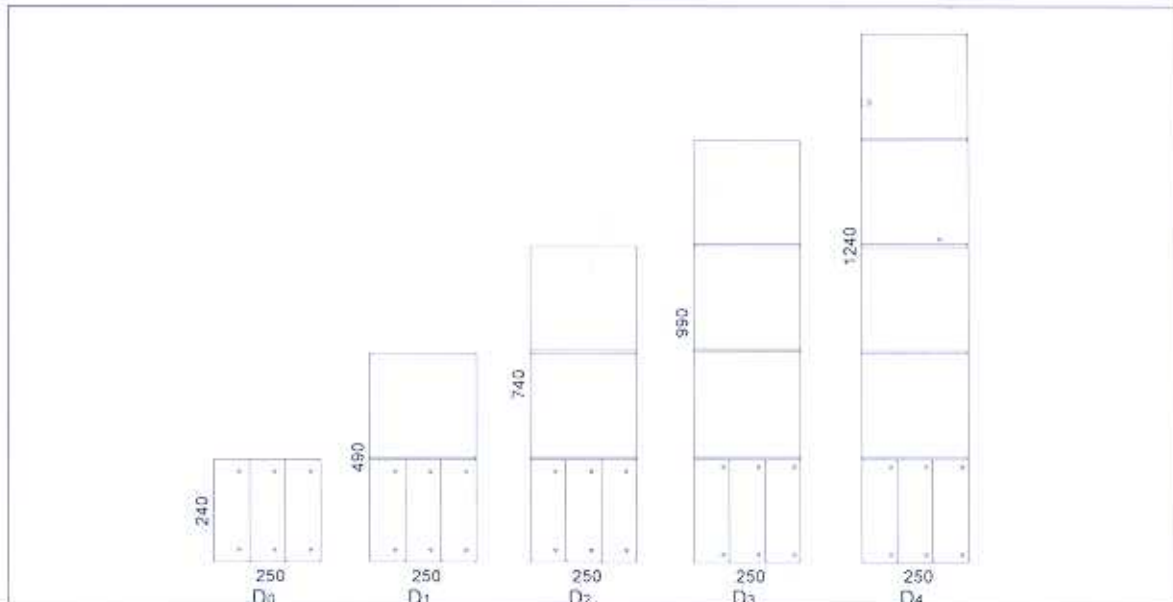


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GRAĐEVINA:	Opečni nadvoj tip D
NARUČITELJ:	Wienerberger Ilovac, d.d., 47000 Karlovac Donje Pokupje 2
BROJ NARUDŽBE: RADNI NALOG:	21008807
Statički proračun opečnog nadvoja tip D Wienerberger Ilovac, d.d., Karlovac	
IZVRŠITELJ:	ODJEL ZA KONSTRUKCIJE ZAVOD ZA BETONSKE I ZIDANE KONSTRUKCIJE INSTITUT GRAĐEVINARSTVA HRVATSKE
BROJ IZVJEŠTAJA:	21-2645/06
BROJ UNUTARNJE EVIDENCIJE:	2111-383/06
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DATUM:	6. rujna 2006.



Statički proračun opečnih nadvoja - tip D



1 Podaci o materijalima

1.1 Nadvoj

Opečni armirani predgotovljeni nadvoj iz proizvodnje Wienerberger Koeszeg, Madarska

Poprečni presjek gredice $b/h = 80/239$ mm

Uzdužna armatura $\varnothing 14$ mm u gornjoj zoni i $\varnothing 14$ mm u donjoj zoni; čelik BSt 600 (N/mm^2); površina $\varnothing 14$ mm žice jednog nadvoja $A_{s/1} = 154$ mm².

Poprečna armatura $\varnothing 7$ mm BSt 420

Vlastita težina gredice $g_1 = 41$ kg/m¹

1.2 Zidni element POROTHERM 25 S P+E

Izmjere: širina 250 mm duljina 375 mm visina 238 mm

Težina 16,7 kg/kom

Karakteristična tlačna čvrstoća u vertikalnom smjeru $f_{bk,v} = 10$ N/mm²

Karakteristična tlačna čvrstoća u horizontalnom smjeru $f_{bk,h} = 3$ N/mm²

1.3 Mort u sljubnicama

Karakteristična tlačna čvrstoća $f_{mk} = 5$ N/mm²

Karakteristična vlačna / posmična čvrstoća $f_{mkt} = 0,3$ N/mm²

Obujamska masa morta $\gamma_m = 18$ kN/m³

1.4 Žbuka

Cementno-vapnena žbuka, dvoslojna, ukupne debljine 20 mm

Obujamska masa $\gamma_2 = 18$ kN/m³

1.5 Beton gredice

$$f_{ck} = 40 \text{ N/mm}^2 \text{ (C25/30)}$$

$$f_{ctk,0.05} = 1,8 \text{ N/mm}^2$$

$$\tau_{Rd} = 0,30 \text{ N/mm}^2$$

1.6 Čelik

Uzdužna armatura Bst 600

$$\text{Proračunska vrijednost granice popuštanja } f_{sk,d} = f_{s,k}/1,15 = 600/1,15 = 520 \text{ N/mm}^2$$

Poprečna armatura Bst 420

$$\text{Proračunska vrijednost granice popuštanja } f_{sk,d} = f_{s,k}/1,15 = 420/1,15 = 365 \text{ N/mm}^2$$

1.7 Parcijalni koeficijenti sigurnosti za materijale

Beton	$\gamma_c = 1,5$
Čelik za prednapinjanje	$\gamma_s = 1,15$
Zide	$\gamma_w = 2,2$

2 Podaci o djelovanjima

2.1 Težina gredice sa žbukom

$$\begin{aligned} \text{Jedna gredica (neožbukana)} & 41,0 \text{ kg/m}^1 \\ \text{Žbuka (1x0,240 + 0,080+0,240/4). 0,02 . 18} & = 0,137 \text{ kN/m}^1 = 13,7 \text{ kg/m}^1 \end{aligned}$$

$$\text{Tri ožbukane gredice} \quad g_2 = 3 \cdot (41,0 + 13,7) = 164,1 \text{ kg/m}^1$$

2.2 Težina jednog reda zidnih elemenata sa žbukom

vlastita težina zidnih elemenata	$0,167 \cdot 100/37,5$	$0,445 \text{ kN/m}^1$
mort u horizontalnoj sljubnici	$0,012 \cdot 0,250 \cdot 18$	$0,054 \text{ kN/m}^1$
mort u vertikalnoj sljubnici	$0,250 \cdot 0,250 \cdot 0,012 \cdot 18 \cdot 100/37,5$	$0,036 \text{ kN/m}^1$
žbuka	$2 \cdot 0,250 \cdot 0,02 \cdot 18$	$0,180 \text{ kN/m}^1$
Ukupno		$g_3 = 0,715 \text{ kN/m}^1$

2.3 Težine pojedinih tipova nadvoja

Tip D0 (tri gredice bez zidnih elemenata)	$G_0 = 164,1 \text{ kg/m}^1$
Tip D1 (tri gredice + jedan red zidnih elemenata)	$G_1 = 235,6 \text{ kg/m}^1$
Tip D2 (tri gredice + dva reda zidnih elemenata)	$G_2 = 307,1 \text{ kg/m}^1$
Tip D3 (tri gredice + tri reda zidnih elemenata)	$G_3 = 378,6 \text{ kg/m}^1$
Tip D4 (tri gredice + četiri reda zidnih elemenata)	$G_4 = 450,1 \text{ kg/m}^1$

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2.4 Parcijalni koeficijent sigurnosti za djelovanja

Stalno djelovanje $\gamma_G = 1,35$

Promjenjivo djelovanje $\gamma_Q = 0$ (nadvoj je predviđen samo za nošenje vlastite težine)

3 Geometrijske značajke nadvoja

3.1 Tip D0

Za tip D0 približno vrijedi $S/(I*b) = 1,5/(d*b) = 1,5 / (240-52)*250 = 3,19*10^{-5} (1/mm^2)$

3.2 Tip D1

(Podaci potrebni za proračun posmičnog naprezanja u sljubnici gredica - zidni element)

$$I = 250*490^3/12 = 2451*10^6 \text{ mm}^4$$

$$A_1 = 250*240 = 60000 \text{ mm}^2$$

$$y = 390/2 - 240/2 = 75 \text{ mm}$$

$$S = A_1*y = 60000*75 = 4,5*10^6 \text{ mm}^3$$

$$b = 250 \text{ mm}$$

$$S/(b*I) = 4,5*10^6 / (250*2451*10^6) = 7,34*10^{-6} (1/mm^2)$$

3.3 Tip D2

$$I = 250*740^3/12 = 8442*10^6 \text{ mm}^4$$

$$A_1 = 250*240 = 60000 \text{ mm}^2$$

$$y = 740/2 - 240/2 = 250 \text{ mm}$$

$$S = A_1*y = 60000 * 250 = 15 * 10^6 \text{ mm}^3$$

$$b = 250 \text{ mm}$$

$$S/(b*I) = 15*10^6 / (250*8442*10^6) = 7,11*10^{-6} (1/mm^2)$$

3.4 Tip D3

$$I = 250*990^3/12 = 20214*10^6 \text{ mm}^4$$

$$A_1 = 250*240 = 60000 \text{ mm}^2$$

$$y = 990/2 - 240/2 = 375 \text{ mm}$$

$$S = A_1*y = 60000 * 375 = 22,5*10^6 \text{ mm}^3$$

$$b = 250 \text{ mm}$$

$$S/(b*I) = 22,5*10^6 / (250*20214*10^6) = 4,45*10^{-6} (1/mm^2)$$

3.5 Tip D4

$$I = 250*1240^3/12 = 39721*10^6 \text{ mm}^4$$

$$A_1 = 250*240 = 60000 \text{ mm}^2$$

$$y = 1240/2 - 240/2 = 500 \text{ mm}$$

$$S = A_1*y = 60000*500 = 30*10^6 \text{ mm}^3$$

$$b = 250 \text{ mm}$$

$$S/(b.I) = 30*10^6 / (250*39721*10^6) = 3,02*10^{-6} (1/mm^2)$$

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4 Duljine - svijetli otvori – rasponi - armatura

Proizvodne duljine (cm) L	100	125	150	175	200	225	250	275	300	325	350
Svijetli otvori (cm) $L_0 = L - 2 \cdot 12,5$	75	100	125	150	175	200	225	250	275	300	325
Proračunski rasponi (cm) $L_r = L_0 + (1/3) \cdot 12,5 \cdot 2 = L - 17$	83	108	133	158	183	208	233	258	283	308	333
Gornja zona armatura Φ (mm)	6	6	8	10	12	12	14	14	14	14	14
Poprečna armatura Φ (mm)	5	5	5	6	7	7	7	7	7	7	7
Donja zona armature Φ (mm)	6	6	8	10	12	12	14	14	14	14	14

5 Proračun unutarnjih sila

Pretpostavke proračuna: slobodno oslonjeni nosač. Zanemaruje se upetost koja se ostvaruje zbog kontinuirane izvedbe zida lijevo i desno od otvora nadvoja zbog čega nadvoj ima povećanu sigurnost. Proračun se provodi samo za najveći raspon $L_r=3,08$ m i vrijedi za sve manje raspone.

Momenti savijanja

$M_{Sd} = \gamma_G \cdot G \cdot L_r^2 / 8 = 1,35 \cdot G \cdot 3,33^2 / 8 = 1,87 G$ (kNm) – maksimalni raspon za Φ 14 (333 cm)

$M_{Sd} = \gamma_G \cdot G \cdot L_r^2 / 8 = 1,35 \cdot G \cdot 2,08^2 / 8 = 0,73 G$ (kNm) – maksimalni raspon za Φ 12 (208 cm)

$M_{Sd} = \gamma_G \cdot G \cdot L_r^2 / 8 = 1,35 \cdot G \cdot 1,58^2 / 8 = 0,42 G$ (kNm) – maksimalni raspon za Φ 10 (158 cm)

$M_{Sd} = \gamma_G \cdot G \cdot L_r^2 / 8 = 1,35 \cdot G \cdot 1,33^2 / 8 = 0,30 G$ (kNm) – maksimalni raspon za Φ 8 (133 cm)

$M_{Sd} = \gamma_G \cdot G \cdot L_r^2 / 8 = 1,35 \cdot G \cdot 1,08^2 / 8 = 0,20 G$ (kNm) – maksimalni raspon za Φ 6 (108 cm)

Tip	D ₀₋₁₄	D ₁₋₁₄	D ₂₋₁₄	D ₃₋₁₄	D ₄₋₁₄
M_{Sd} (kNm)	3,07	4,41	5,74	7,08	8,42

Tip	D ₀₋₁₂	D ₁₋₁₂	D ₂₋₁₂	D ₃₋₁₂	D ₄₋₁₂
M_{Sd} (kNm)	1,20	1,72	2,24	2,76	3,29

Tip	D ₀₋₁₀	D ₁₋₁₀	D ₂₋₁₀	D ₃₋₁₀	D ₄₋₁₀
M_{Sd} (kNm)	0,69	0,99	1,29	1,59	1,89

Tip	D ₀₋₈	D ₁₋₈	D ₂₋₈	D ₃₋₈	D ₄₋₈
M_{Sd} (kNm)	0,49	0,71	0,92	1,14	1,35

Tip	D ₀₋₆	D ₁₋₆	D ₂₋₆	D ₃₋₆	D ₄₋₆
M_{Sd} (kNm)	0,33	0,47	0,61	0,76	0,90

Poprečne sile

$$V_{Sd} = \gamma_G \cdot G \cdot L_r / 2 = 1,35 \cdot G \cdot 3,33 / 2 = 2,25 G \text{ (kN)}$$

$$V_{Sd} = \gamma_G \cdot G \cdot L_r / 2 = 1,35 \cdot G \cdot 2,08 / 2 = 1,40 G \text{ (kN)}$$

$$V_{Sd} = \gamma_G \cdot G \cdot L_r / 2 = 1,35 \cdot G \cdot 1,58 / 2 = 1,07 G \text{ (kN)}$$

$$V_{Sd} = \gamma_G \cdot G \cdot L_r / 2 = 1,35 \cdot G \cdot 1,33 / 2 = 0,90 G \text{ (kN)}$$

$$V_{Sd} = \gamma_G \cdot G \cdot L_r / 2 = 1,35 \cdot G \cdot 1,08 / 2 = 0,73 G \text{ (kN)}$$

Tip	D ₀₋₁₄	D ₁₋₁₄	D ₂₋₁₄	D ₃₋₁₄	D ₄₋₁₄
V _{Sd} (kN)	3,69	5,30	6,91	8,52	10,13

Tip	D ₀₋₁₂	D ₁₋₁₂	D ₂₋₁₂	D ₃₋₁₂	D ₄₋₁₂
V _{Sd} (kN)	2,30	3,30	4,30	5,30	6,30

Tip	D ₀₋₁₀	D ₁₋₁₀	D ₂₋₁₀	D ₃₋₁₀	D ₄₋₁₀
V _{Sd} (kN)	1,76	2,52	3,29	4,05	4,82

Tip	D ₀₋₈	D ₁₋₈	D ₂₋₈	D ₃₋₈	D ₄₋₈
V _{Sd} (kN)	1,48	2,12	2,76	3,41	4,05

Tip	D ₀₋₆	D ₁₋₆	D ₂₋₆	D ₃₋₆	D ₄₋₆
V _{Sd} (kN)	1,20	1,72	2,24	2,76	3,29

Posmično naprezanje

U horizontalnoj sljubnici na spoju gredice i prvog reda zidnih elemenata:

$$\tau_{Sd} = V_{Sd} S / (b \cdot I) \text{ (N/mm}^2\text{)}$$

Tip	D ₀₋₁₄	D ₁₋₁₄	D ₂₋₁₄	D ₃₋₁₄	D ₄₋₁₄
τ_{SdI} (N/mm ²)	---	0,039	0,049	0,038	0,031

Tip	D ₀₋₁₂	D ₁₋₁₂	D ₂₋₁₂	D ₃₋₁₂	D ₄₋₁₂
τ_{SdI} (N/mm ²)	---	0,024	0,031	0,024	0,019

Tip	D ₀₋₁₀	D ₁₋₁₀	D ₂₋₁₀	D ₃₋₁₀	D ₄₋₁₀
τ_{SdI} (N/mm ²)	---	0,019	0,023	0,018	0,015

Tip	D ₀₋₈	D ₁₋₈	D ₂₋₈	D ₃₋₈	D ₄₋₈
τ_{Sd1} (N/mm ²)	---	0,016	0,020	0,015	0,012

Tip	D ₀₋₆	D ₁₋₆	D ₂₋₆	D ₃₋₆	D ₄₋₆
τ_{Sd1} (N/mm ²)	---	0,013	0,016	0,012	0,010

U horizontalnoj sljubnici u polovini visine nadvoja:

$$\tau_{Sd} = 1,5 V_{Sd} / b \cdot h \quad (\text{N/mm}^2)$$

Tip	D ₀₋₁₄	D ₁₋₁₄	D ₂₋₁₄	D ₃₋₁₄	D ₄₋₁₄
τ_{Sd2} (N/mm ²)	0,092	0,065	0,056	0,052	0,049

Tip	D ₀₋₁₂	D ₁₋₁₂	D ₂₋₁₂	D ₃₋₁₂	D ₄₋₁₂
τ_{Sd2} (N/mm ²)	0,058	0,040	0,035	0,032	0,030

Tip	D ₀₋₁₀	D ₁₋₁₀	D ₂₋₁₀	D ₃₋₁₀	D ₄₋₁₀
τ_{Sd2} (N/mm ²)	0,044	0,031	0,027	0,025	0,023

Tip	D ₀₋₈	D ₁₋₈	D ₂₋₈	D ₃₋₈	D ₄₋₈
τ_{Sd2} (N/mm ²)	0,037	0,026	0,022	0,021	0,020

Tip	D ₀₋₆	D ₁₋₆	D ₂₋₆	D ₃₋₆	D ₄₋₆
τ_{Sd2} (N/mm ²)	0,030	0,021	0,018	0,017	0,016

6 Proračun otpornosti

Proračun se provodi kao za armiranobetonski presjek uz ograničenje deformacija za $\epsilon_b = 0,0020$ (opeka), $\epsilon_s = 0,0050$ (čelik) i $\epsilon_c = 0,0035$ (beton). Za presjek koji se sastoji od opeke u tlačnom području i armature za prednapinjanje u vlačnom području pretpostavljen je pravokutni tlačni "blok naprezanja" visine $b \cdot x$.

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6.1 Nosivost (otpornost) pri djelovanju momenta savijanja

6.1.1 Tip D0

Podtip D0-14

$$b = 250 \text{ mm (tri gredice)}$$

$$h = 240 \text{ mm}$$

$$d = 188 \text{ mm}$$

$$\varepsilon_c = 0,0035 \text{ (beton)}$$

$$\varepsilon_c = 0,0020 \text{ (opeka)}$$

$$\varepsilon_s = 0,0050$$

$$x = d \cdot \varepsilon_b / (\varepsilon_b + \varepsilon_s) = 188 \cdot 0,0020 / (0,0020 + 0,0050) = 53,7 \text{ mm}$$

$$x_c = d \cdot \varepsilon_c / (\varepsilon_c + \varepsilon_s) = 188 \cdot 0,0035 / (0,0035 + 0,0050) = 77,4 \text{ mm}$$

$$z = d - x/2 = 188 - 27 = 161 \text{ mm}$$

$$z_c = d - x/2 = 188 - 38,7 = 149 \text{ mm}$$

$$\gamma_c = 1,5$$

$$f_{cd} = 25/1,5 = 16,7 \text{ N/mm}^2$$

$$F_c = 0,85 f_{cd} b x = 0,85 \cdot 16,7 \cdot 250 \cdot 77,4 = 275,0 \text{ kN}$$

$$\gamma_b = 2,2$$

$$f_{bd} = 10/2,2 = 4,50 \text{ N/mm}^2$$

$$F_b = f_{bd} b x = 4,50 \cdot 250 \cdot 53,7 = 60,4 \text{ kN}$$

$$\gamma_s = 1,15$$

$$f_{pd} = f_{pk,d}/1,15 = 600/1,15 = 520 \text{ N/mm}^2$$

$$F_s = 1 \cdot A_s \cdot f_{pd} = 1 \cdot 154 \cdot 520 = 80,8 \text{ kN}$$

$$M_{Rd} = F_s \cdot z = 80,8 \cdot 149 = 12,04 \text{ kNm (za tri gredice)-slom preko armature}$$

$$M_{Rd} = F_b \cdot z = 60,4 \cdot 161 = 9,72 \text{ kNm (za tri gredice)-slom preko opeke}$$

$$\mu_{sd} = M_{sd} / (b d^2 f_{cd}) = 3,07 \cdot 10^6 / (250 \cdot 188^2 \cdot 16,7) = 0,021$$

$$\varepsilon_c/\varepsilon_s = -0,6/5,0$$

$$\xi = x/d = 0,107$$

$$\omega = 0,025$$

$$\text{potr} A_{s1} = \omega b d f_{cd} / f_{pd} = 0,025 \cdot 250 \cdot 188 \cdot 16,7 / 520 = 37,8 \text{ mm}^2 < A_{s1} = 154 \text{ mm}^2$$

Podtip D0-12

$$b = 250 \text{ mm (tri gredice)}$$

$$h = 240 \text{ mm}$$

$$d = 188 \text{ mm}$$

$$\varepsilon_c = 0,0035 \text{ (beton)}$$

$$\varepsilon_c = 0,0020 \text{ (opeka)}$$

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$$\varepsilon_s = 0,0050$$

$$x = d \cdot \varepsilon_b / (\varepsilon_b + \varepsilon_s) = 188 \cdot 0,0020 / (0,0020 + 0,0050) = 53,7 \text{ mm}$$

$$x_c = d \cdot \varepsilon_c / (\varepsilon_c + \varepsilon_s) = 188 \cdot 0,0035 / (0,0035 + 0,0050) = 77,4 \text{ mm}$$

$$z = d - x/2 = 188 - 27 = 161 \text{ mm}$$

$$z_c = d - x/2 = 188 - 38,7 = 149 \text{ mm}$$

$$\gamma_c = 1,5$$

$$f_{cd} = 25/1,5 = 16,7 \text{ N/mm}^2$$

$$F_c = 0,85 f_{cd} b x = 0,85 \cdot 16,7 \cdot 250 \cdot 77,4 = 275,0 \text{ kN}$$

$$\gamma_b = 2,2$$

$$f_{bd} = 10/2,2 = 4,50 \text{ N/mm}^2$$

$$F_b = f_{bd} b x = 4,50 \cdot 250 \cdot 53,7 = 60,4 \text{ kN}$$

$$\gamma_s = 1,15$$

$$f_{pd} = f_{pk,d}/1,15 = 600/1,15 = 520 \text{ N/mm}^2$$

$$F_s = 1 \cdot \Lambda_s \cdot f_{p,d} = 1 \cdot 113 \cdot 520 = 58,76 \text{ kN}$$

$$M_{Rd} = F_s \cdot z = 58,76 \cdot 149 = 8,76 \text{ kNm (za tri gredice)-sлом preko armature}$$

$$M_{Rd} = F_b \cdot z = 60,4 \cdot 161 = 9,72 \text{ kNm (za tri gredice)-sлом preko opeke}$$

$$\mu_{sd} = M_{sd} / (b d^2 f_{cd}) = 1,20 \cdot 10^6 / (250 \cdot 188^2 \cdot 16,7) = 0,008$$

$$\varepsilon_c / \varepsilon_s = -0,4/5,0$$

$$\xi = x/d = 0,074$$

$$\omega = 0,012$$

$$\text{potr} \Lambda_{s1} = \omega b d f_{cd} / f_{pd} = 0,012 \cdot 250 \cdot 188 \cdot 16,7 / 520 = 18,2 \text{ mm}^2 < \Lambda_{s1} = 131 \text{ mm}^2$$

Podtip D0-10

$$b = 250 \text{ mm (tri gredice)}$$

$$h = 240 \text{ mm}$$

$$d = 188 \text{ mm}$$

$$\varepsilon_c = 0,0035 \text{ (beton)}$$

$$\varepsilon_c = 0,0020 \text{ (opeka)}$$

$$\varepsilon_s = 0,0050$$

$$x = d \cdot \varepsilon_b / (\varepsilon_b + \varepsilon_s) = 188 \cdot 0,0020 / (0,0020 + 0,0050) = 53,7 \text{ mm}$$

$$x_c = d \cdot \varepsilon_c / (\varepsilon_c + \varepsilon_s) = 188 \cdot 0,0035 / (0,0035 + 0,0050) = 77,4 \text{ mm}$$

$$z = d - x/2 = 188 - 27 = 161 \text{ mm}$$

$$z_c = d - x/2 = 188 - 38,7 = 149 \text{ mm}$$

$$\gamma_c = 1,5$$

$$f_{cd} = 25/1,5 = 16,7 \text{ N/mm}^2$$

$$F_c = 0,85 f_{cd} b x = 0,85 \cdot 16,7 \cdot 250 \cdot 77,4 = 275,0 \text{ kN}$$



$$\gamma_b = 2,2$$

$$f_{bd} = 10/2,2 = 4,50 \text{ N/mm}^2$$

$$F_b = f_{bd} b x = 4,50 * 250 * 53,7 = 60,4 \text{ kN}$$

$$\gamma_s = 1,15$$

$$f_{pd} = f_{pk,d}/1,15 = 600/1,15 = 520 \text{ N/mm}^2$$

$$F_s = 1 * A_s * f_{p,d} = 1 * 79 * 520 = 41,08 \text{ kN}$$

$$M_{Rd} = F_s \cdot z = 41,08 * 149 = 6,12 \text{ kNm (za tri gredice)-sлом preko armature}$$

$$M_{Rd} = F_b \cdot z = 60,4 * 161 = 9,72 \text{ kNm (za tri gredice)-sлом preko opeke}$$

$$\mu_{sd} = M_{sd} / (b d^2 f_{cd}) = 0,69 * 10^6 / (250 * 188^2 * 16,7) = 0,005$$

$$\varepsilon_c / \varepsilon_s = -0,2/5,0$$

$$\xi = x/d = 0,038$$

$$\omega = 0,003$$

$$\rho_{tr} A_{sl} = \omega b d f_{cd} / f_{pd} = 0,003 * 250 * 188 * 16,7 / 520 = 4,5 \text{ mm}^2 < A_{sl} = 79 \text{ mm}^2$$

Podtip D0-8

$$b = 250 \text{ mm (tri gredice)}$$

$$h = 240 \text{ mm}$$

$$d = 188 \text{ mm}$$

$$\varepsilon_c = 0,0035 \text{ (beton)}$$

$$\varepsilon_c = 0,0020 \text{ (opeka)}$$

$$\varepsilon_s = 0,0050$$

$$x = d \cdot \varepsilon_b / (\varepsilon_b + \varepsilon_s) = 188 * 0,0020 / (0,0020 + 0,0050) = 53,7 \text{ mm}$$

$$x_c = d \cdot \varepsilon_c / (\varepsilon_c + \varepsilon_s) = 188 * 0,0035 / (0,0035 + 0,0050) = 77,4 \text{ mm}$$

$$z = d - x/2 = 188 - 27 = 161 \text{ mm}$$

$$z_c = d - x/2 = 188 - 38,7 = 149 \text{ mm}$$

$$\gamma_c = 1,5$$

$$f_{cd} = 25/1,5 = 16,7 \text{ N/mm}^2$$

$$F_c = 0,85 f_{cd} b x = 0,85 * 16,7 * 250 * 77,4 = 275,0 \text{ kN}$$

$$\gamma_b = 2,2$$

$$f_{bd} = 10/2,2 = 4,50 \text{ N/mm}^2$$

$$F_b = f_{bd} b x = 4,50 * 250 * 53,7 = 60,4 \text{ kN}$$

$$\gamma_s = 1,15$$

$$f_{pd} = f_{pk,d}/1,15 = 600/1,15 = 520 \text{ N/mm}^2$$

$$F_s = 1 * A_s * f_{p,d} = 1 * 50 * 520 = 26,00 \text{ kN}$$

$$M_{Rd} = F_s \cdot z = 26,0 * 149 = 3,90 \text{ kNm (za tri gredice)-sлом preko armature}$$

$$M_{Rd} = F_b \cdot z = 60,4 * 161 = 9,72 \text{ kNm (za tri gredice)-sлом preko opeke}$$



$$\mu_{Sd} = M_{Sd} / (b d^2 f_{cd}) = 0,49 \cdot 10^6 / (250 \cdot 188^2 \cdot 16,7) = 0,003$$

$$\varepsilon_c / \varepsilon_s = -0,2/5,0$$

$$\xi = x/d = 0,038$$

$$\omega = 0,003$$

$$\text{potr} A_{s1} = \omega b d f_{cd} / f_{pd} = 0,003 \cdot 250 \cdot 188 \cdot 16,7 / 520 = 4,5 \text{ mm}^2 < A_{s1} = 50 \text{ mm}^2$$

Podtip D0-6

$$b = 250 \text{ mm (tri gredice)}$$

$$h = 240 \text{ mm}$$

$$d = 188 \text{ mm}$$

$$\varepsilon_c = 0,0035 \text{ (beton)}$$

$$\varepsilon_c = 0,0020 \text{ (opeka)}$$

$$\varepsilon_s = 0,0050$$

$$x = d \cdot \varepsilon_b / (\varepsilon_b + \varepsilon_s) = 188 \cdot 0,0020 / (0,0020 + 0,0050) = 53,7 \text{ mm}$$

$$x_c = d \cdot \varepsilon_c / (\varepsilon_c + \varepsilon_s) = 188 \cdot 0,0035 / (0,0035 + 0,0050) = 77,4 \text{ mm}$$

$$z = d - x/2 = 188 - 27 = 161 \text{ mm}$$

$$z_c = d - x/2 = 188 - 38,7 = 149 \text{ mm}$$

$$\gamma_c = 1,5$$

$$f_{cd} = 25/1,5 = 16,7 \text{ N/mm}^2$$

$$F_c = 0,85 f_{cd} b x = 0,85 \cdot 16,7 \cdot 250 \cdot 77,4 = 275,0 \text{ kN}$$

$$\gamma_b = 2,2$$

$$f_{bd} = 10/2,2 = 4,50 \text{ N/mm}^2$$

$$F_b = f_{bd} b x = 4,50 \cdot 250 \cdot 53,7 = 60,4 \text{ kN}$$

$$\gamma_s = 1,15$$

$$f_{pd} = f_{pk,d} / 1,15 = 600 / 1,15 = 520 \text{ N/mm}^2$$

$$F_s = 1 \cdot A_s \cdot f_{pd} = 1 \cdot 28 \cdot 520 = 14,60 \text{ kN}$$

$$M_{Rd} = F_s \cdot z = 14,60 \cdot 149 = 2,17 \text{ kNm (za tri gredice)-slom preko armature}$$

$$M_{Rd} = F_b \cdot z = 60,4 \cdot 161 = 9,72 \text{ kNm (za tri gredice)-slom preko opeke}$$

$$\mu_{Sd} = M_{Sd} / (b d^2 f_{cd}) = 0,33 \cdot 10^6 / (250 \cdot 188^2 \cdot 16,7) = 0,002$$

$$\varepsilon_c / \varepsilon_s = -0,2/5,0$$

$$\xi = x/d = 0,038$$

$$\omega = 0,003$$

$$\text{potr} A_{s1} = \omega b d f_{cd} / f_{pd} = 0,003 \cdot 250 \cdot 188 \cdot 16,7 / 520 = 4,5 \text{ mm}^2 < A_{s1} = 28 \text{ mm}^2$$



6.1.2 Tip D1

Podtip D1-14

$b = 250$ mm (tri gredice)

$h = 490$ mm

$d = 438$ mm (za donju šipku)

$d = 370$ mm (za obje šipke)

$\varepsilon_b = 0,0020$ (opeka)

$\varepsilon_s = 0,0050$

$x = d \cdot \varepsilon_b / (\varepsilon_b + \varepsilon_s) = 370 \cdot 0,0020 / (0,0020 + 0,0050) = 105,7$ mm

$z = d - x/2 = 438 - 53 = 385$ mm (za samo donju šipku)

$z = d - x/2 = 370 - 53 = 317$ mm (za obje šipke)

$\gamma_w = 2,2$

$f_{bd} = 3/2,2 = 1,36$ N/mm²

$F_{b,d} = b \cdot x \cdot f_{bd} = 250 \cdot 105,7 \cdot 1,36 = 35,9$ kN

$\gamma_s = 1,15$

$f_{pd} = f_{pk,d}/1,15 = 600/1,15 = 520$ N/mm²

$F_{s,d} = 2 \cdot A_s \cdot f_{pd} = 2 \cdot 154 \cdot 520 = 2 \cdot 80,08$ kN = 160,16 kN

$M_{Rd} = F_{s,d} \cdot z = 160,16 \cdot 0,317 = 50,77$ kNm (za obje šipke)

$M_{Rd} = F_{s,d} \cdot z = 80,08 \cdot 0,438 = 35,07$ kNm (za samo donju šipku)

$M_{Rd} = F_{b,d} \cdot z = 35,90 \cdot 0,317 = 11,38$ kNm

$\mu_{Sd} = M_{Sd} / (b \cdot d^2 \cdot f_{bd}) = 4,41 \cdot 10^6 / (250 \cdot 317^2 \cdot 1,36) = 0,129$

$\varepsilon_b/\varepsilon_s = -1,9/5,0$

$\xi = x/d = 0,275$

$\omega = 0,152$

$\rho_{tr} A_{st} = \omega \cdot b \cdot d \cdot f_{bd} / f_{pd} = 0,152 \cdot 250 \cdot 317 \cdot 1,36 / 520 = 31,50$ mm² < $A_{st} = 308$ mm²

Podtip D1-12

$b = 250$ mm (tri gredice)

$h = 490$ mm

$d = 438$ mm (za donju šipku)

$d = 370$ mm (za obje šipke)

$\varepsilon_b = 0,0020$ (opeka)

$\varepsilon_s = 0,0050$

$x = d \cdot \varepsilon_b / (\varepsilon_b + \varepsilon_s) = 370 \cdot 0,0020 / (0,0020 + 0,0050) = 105,7$ mm

$z = d - x/2 = 438 - 53 = 385$ mm (za samo donju šipku)

$z = d - x/2 = 370 - 53 = 317$ mm (za obje šipke)

$\gamma_w = 2,2$



$$f_{bd} = 3/2,2 = 1,36 \text{ N/mm}^2$$

$$F_{b,d} = b \cdot x \cdot f_{bd} = 250 \cdot 105,7 \cdot 1,36 = 35,9 \text{ kN}$$

$$\gamma_s = 1,15$$

$$f_{pd} = f_{pk,d}/1,15 = 600/1,15 = 520 \text{ N/mm}^2$$

$$F_{s,d} = 2 \cdot A_s \cdot f_{pd} = 2 \cdot 113 \cdot 520 = 2 \cdot 58,80 \text{ kN} = 117,50 \text{ kN}$$

$$M_{Rd} = F_{s,d} \cdot z = 117,50 \cdot 0,317 = 37,25 \text{ kNm (za obje šipke)}$$

$$M_{Rd} = F_{s,d} \cdot z = 58,80 \cdot 0,438 = 25,75 \text{ kNm (za samo donju šipku)}$$

$$M_{Rd} = F_{b,d} \cdot z = 35,90 \cdot 0,317 = 11,38 \text{ kNm}$$

$$\mu_{sd} = M_{sd} / (b \cdot d^2 \cdot f_{bd}) = 1,72 \cdot 10^6 / (250 \cdot 317^2 \cdot 1,36) = 0,050$$

$$\varepsilon_b/\varepsilon_s = -1,0/5,0$$

$$\xi = x/d = 0,167$$

$$\omega = 0,059$$

$$\rho_{tr} A_{s1} = \omega \cdot b \cdot d \cdot f_{bd} / f_{pd} = 0,59 \cdot 250 \cdot 317 \cdot 1,36 / 520 = 12,22 \text{ mm}^2 < A_{s1} = 262 \text{ mm}^2$$

Podtip D1-10

$$b = 250 \text{ mm (tri gredice)}$$

$$h = 490 \text{ mm}$$

$$d = 438 \text{ mm (za donju šipku)}$$

$$d = 370 \text{ mm (za obje šipke)}$$

$$\varepsilon_b = 0,0020 \text{ (opeka)}$$

$$\varepsilon_s = 0,0050$$

$$x = d \cdot \varepsilon_b / (\varepsilon_b + \varepsilon_s) = 370 \cdot 0,0020 / (0,0020 + 0,0050) = 105,7 \text{ mm}$$

$$z = d - x/2 = 438 - 53 = 385 \text{ mm (za samo donju šipku)}$$

$$z = d - x/2 = 370 - 53 = 317 \text{ mm (za obje šipke)}$$

$$\gamma_w = 2,2$$

$$f_{bd} = 3/2,2 = 1,36 \text{ N/mm}^2$$

$$F_{b,d} = b \cdot x \cdot f_{bd} = 250 \cdot 105,7 \cdot 1,36 = 35,9 \text{ kN}$$

$$\gamma_s = 1,15$$

$$f_{pd} = f_{pk,d}/1,15 = 600/1,15 = 520 \text{ N/mm}^2$$

$$F_{s,d} = 2 \cdot A_s \cdot f_{pd} = 2 \cdot 79 \cdot 520 = 2 \cdot 41,08 \text{ kN} = 82,16 \text{ kN}$$

$$M_{Rd} = F_{s,d} \cdot z = 82,16 \cdot 0,317 = 26,05 \text{ kNm (za obje šipke)}$$

$$M_{Rd} = F_{s,d} \cdot z = 41,08 \cdot 0,438 = 17,99 \text{ kNm (za samo donju šipku)}$$

$$M_{Rd} = F_{b,d} \cdot z = 35,90 \cdot 0,317 = 11,38 \text{ kNm}$$

$$\mu_{sd} = M_{sd} / (b \cdot d^2 \cdot f_{bd}) = 0,99 \cdot 10^6 / (250 \cdot 317^2 \cdot 1,36) = 0,029$$

$$\varepsilon_b/\varepsilon_s = -0,7/5,0$$

$$\xi = x/d = 0,123$$

$$\omega = 0,032$$

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$$\omega_{\text{potr}} A_{s1} = \omega b d f_{bd} / f_{pd} = 0,32 * 250 * 317 * 1,36 / 520 = 6,63 \text{ mm}^2 < A_{s1} = 158 \text{ mm}^2$$

Podtip D1-8

b = 250 mm (tri gredice)

h = 490 mm

d = 438 mm (za donju šipku)

d = 370 mm (za obje šipke)

$\epsilon_b = 0,0020$ (opeka)

$\epsilon_s = 0,0050$

$x = d \cdot \epsilon_b / (\epsilon_b + \epsilon_s) = 370 * 0,0020 / (0,0020 + 0,0050) = 105,7 \text{ mm}$

$z = d - x/2 = 438 - 53 = 385 \text{ mm}$ (za samo donju šipku)

$z = d - x/2 = 370 - 53 = 317 \text{ mm}$ (za obje šipke)

$\gamma_w = 2,2$

$f_{bd} = 3/2,2 = 1,36 \text{ N/mm}^2$

$F_{b,d} = b * x * f_{bd} = 250 * 105,7 * 1,36 = 35,9 \text{ kN}$

$\gamma_s = 1,15$

$f_{pd} = f_{pk,d} / 1,15 = 600 / 1,15 = 520 \text{ N/mm}^2$

$F_{s,d} = 2 * A_s * f_{pd} = 2 * 50 * 520 = 2 * 26,00 \text{ kN} = 52,00 \text{ kN}$

$M_{Rd} = F_{s,d} \cdot z = 52,00 * 0,317 = 16,484 \text{ kNm}$ (za obje šipke)

$M_{Rd} = F_{s,d} \cdot z = 26,00 * 0,438 = 11,388 \text{ kNm}$ (za samo donju šipku)

$M_{Rd} = F_{b,d} \cdot z = 35,90 * 0,317 = 11,38 \text{ kNm}$

$\mu_{sd} = M_{sd} / (b d^2 f_{bd}) = 0,71 * 10^6 / (250 * 317^2 * 1,36) = 0,021$

$\epsilon_b / \epsilon_s = -0,6/5,0$

$\xi = x/d = 0,107$

$\omega = 0,025$

$\omega_{\text{potr}} A_{s1} = \omega b d f_{bd} / f_{pd} = 0,32 * 250 * 317 * 1,36 / 520 = 5,20 \text{ mm}^2 < A_{s1} = 100 \text{ mm}^2$

Podtip D1-6

b = 250 mm (tri gredice)

h = 490 mm

d = 438 mm (za donju šipku)

d = 370 mm (za obje šipke)

$\epsilon_b = 0,0020$ (opeka)

$\epsilon_s = 0,0050$

$x = d \cdot \epsilon_b / (\epsilon_b + \epsilon_s) = 370 * 0,0020 / (0,0020 + 0,0050) = 105,7 \text{ mm}$

$z = d - x/2 = 438 - 53 = 385 \text{ mm}$ (za samo donju šipku)

$z = d - x/2 = 370 - 53 = 317 \text{ mm}$ (za obje šipke)

$\gamma_w = 2,2$

$f_{bd} = 3/2,2 = 1,36 \text{ N/mm}^2$

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$$F_{b,d} = b \cdot x \cdot f_{bd} = 250 \cdot 105,7 \cdot 1,36 = 35,9 \text{ kN}$$

$$\gamma_s = 1,15$$

$$f_{pd} = f_{pk,d} / 1,15 = 600 / 1,15 = 520 \text{ N/mm}^2$$

$$F_{s,d} = 2 \cdot A_s \cdot f_{pd} = 2 \cdot 28 \cdot 520 = 2 \cdot 7,00 \text{ kN} = 14,00 \text{ kN}$$

$$M_{Rd} = F_{s,d} \cdot z = 14,00 \cdot 0,317 = 4,438 \text{ kNm (za obje šipke)}$$

$$M_{Rd} = F_{s,d} \cdot z = 7,50 \cdot 0,438 = 3,285 \text{ kNm (za samo donju šipku)}$$

$$M_{Rd} = F_{b,d} \cdot z = 35,90 \cdot 0,317 = 11,38 \text{ kNm}$$

$$\mu_{sd} = M_{sd} / (b \cdot d^2 \cdot f_{bd}) = 0,47 \cdot 10^6 / (250 \cdot 317^2 \cdot 1,36) = 0,014$$

$$\epsilon_b / \epsilon_s = -0,5 / 5,0$$

$$\xi = x/d = 0,091$$

$$\omega = 0,018$$

$$\text{potr} A_{s1} = \omega \cdot b \cdot d \cdot f_{bd} / f_{pd} = 0,32 \cdot 250 \cdot 317 \cdot 1,36 / 520 = 3,70 \text{ mm}^2 < A_{s1} = 56 \text{ mm}^2$$

6.1.3 Tip D2

Podtip D2-14

$$b = 250 \text{ mm (tri gredice)}$$

$$h = 740 \text{ mm}$$

$$d = 620 \text{ mm}$$

$$\epsilon_b = 0,0020 \text{ (opeka)}$$

$$\epsilon_s = 0,0050$$

$$x = d \cdot \epsilon_b / (\epsilon_b + \epsilon_s) = 620 \cdot 0,0020 / (0,0020 + 0,0050) = 177 \text{ mm}$$

$$z = d - x/2 = 620 - 88,5 = 531,5 \text{ mm}$$

$$\gamma_w = 2,2$$

$$f_{bd} = 3/2,2 = 1,36 \text{ N/mm}^2$$

$$F_{b,d} = b \cdot x \cdot f_{bd} = 250 \cdot 177 \cdot 1,36 = 60,2 \text{ kN}$$

$$\gamma_s = 1,15$$

$$f_{pd} = f_{pk,d} / 1,15 = 600 / 1,15 = 520 \text{ N/mm}^2$$

$$F_{s,d} = 2 \cdot A_s \cdot f_{pd} = 2 \cdot 154 \cdot 520 = 160,16 \text{ kN}$$

$$M_{Rd} = F_{b,d} \cdot z = 60,2 \cdot 0,5315 = 32,0 \text{ kNm}$$

$$\mu_{sd} = M_{sd} / (b \cdot d^2 \cdot f_{bd}) = 5,74 \cdot 10^6 / (250 \cdot 531^2 \cdot 1,36) = 0,059$$

$$\epsilon_b / \epsilon_s = -1,1 / 5,0$$

$$\xi = x/d = 0,180$$

$$\omega = 0,069$$

$$\text{potr} A_{s1} = \omega \cdot b \cdot d \cdot f_{bd} / f_{pd} = 0,069 \cdot 250 \cdot 531 \cdot 1,36 / 520 = 24,00 \text{ mm}^2 < A_{s1} = 308 \text{ mm}^2$$



Podtip D2-12

$b = 250 \text{ mm}$ (tri gredice)

$h = 740 \text{ mm}$

$d = 620 \text{ mm}$

$\epsilon_b = 0,0020$ (opeka)

$\epsilon_s = 0,0050$

$x = d \cdot \epsilon_b / (\epsilon_b + \epsilon_s) = 620 \cdot 0,0020 / (0,0020 + 0,0050) = 177 \text{ mm}$

$z = d - x/2 = 620 - 88,5 = 531,5 \text{ mm}$

$\gamma_w = 2,2$

$f_{bd} = 3/2,2 = 1,36 \text{ N/mm}^2$

$F_{b,d} = b \cdot x \cdot f_{bd} = 250 \cdot 177 \cdot 1,36 = 60,2 \text{ kN}$

$\gamma_s = 1,15$

$f_{pd} = f_{pk,d}/1,15 = 600/1,15 = 520 \text{ N/mm}^2$

$F_{s,d} = 2 \cdot A_s \cdot f_{pd} = 2 \cdot 113 \cdot 520 = 117,52 \text{ kN}$

$M_{Rd} = F_{b,d} \cdot z = 60,2 \cdot 0,5315 = 32,0 \text{ kNm}$

$\mu_{sd} = M_{sd} / (b \cdot d^2 \cdot f_{bd}) = 2,24 \cdot 10^6 / (250 \cdot 531^2 \cdot 1,36) = 0,024$

$\epsilon_b/\epsilon_s = -0,6/5,0$

$\xi = x/d = 0,107$

$\omega = 0,025$

$\text{potr} A_{s1} = \omega \cdot b \cdot d \cdot f_{bd} / f_{pd} = 0,025 \cdot 250 \cdot 531 \cdot 1,36 / 520 = 8,70 \text{ mm}^2 < A_{s1} = 226 \text{ mm}^2$

Podtip D2-10

$b = 250 \text{ mm}$ (tri gredice)

$h = 740 \text{ mm}$

$d = 620 \text{ mm}$

$\epsilon_b = 0,0020$ (opeka)

$\epsilon_s = 0,0050$

$x = d \cdot \epsilon_b / (\epsilon_b + \epsilon_s) = 620 \cdot 0,0020 / (0,0020 + 0,0050) = 177 \text{ mm}$

$z = d - x/2 = 620 - 88,5 = 531,5 \text{ mm}$

$\gamma_w = 2,2$

$f_{bd} = 3/2,2 = 1,36 \text{ N/mm}^2$

$F_{b,d} = b \cdot x \cdot f_{bd} = 250 \cdot 177 \cdot 1,36 = 60,2 \text{ kN}$

$\gamma_s = 1,15$

$f_{pd} = f_{pk,d}/1,15 = 600/1,15 = 520 \text{ N/mm}^2$

$F_{s,d} = 2 \cdot A_s \cdot f_{pd} = 2 \cdot 79 \cdot 520 = 82,16 \text{ kN}$

$M_{Rd} = F_{b,d} \cdot z = 60,2 \cdot 0,5315 = 32,0 \text{ kNm}$

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$$\mu_{Sd} = M_{Sd} / (b d^2 f_{bd}) = 1,29 \cdot 10^6 / (250 \cdot 531^2 \cdot 1,36) = 0,013$$

$$\varepsilon_b / \varepsilon_s = -0,5/5,0$$

$$\xi = x/d = 0,091$$

$$\omega = 0,018$$

$$\text{potr} A_{s1} = \omega b d f_{bd} / f_{pd} = 0,018 \cdot 250 \cdot 531 \cdot 1,36 / 520 = 6,24 \text{ mm}^2 < A_{s1} = 158 \text{ mm}^2$$

Podtip D2-8

$$b = 250 \text{ mm (tri gredice)}$$

$$h = 740 \text{ mm}$$

$$d = 620 \text{ mm}$$

$$\varepsilon_b = 0,0020 \text{ (opeka)}$$

$$\varepsilon_s = 0,0050$$

$$x = d \cdot \varepsilon_b / (\varepsilon_b + \varepsilon_s) = 620 \cdot 0,0020 / (0,0020 + 0,0050) = 177 \text{ mm}$$

$$z = d - x/2 = 620 - 88,5 = 531,5 \text{ mm}$$

$$\gamma_w = 2,2$$

$$f_{bd} = 3/2,2 = 1,36 \text{ N/mm}^2$$

$$F_{b,d} = b \cdot x \cdot f_{bd} = 250 \cdot 177 \cdot 1,36 = 60,2 \text{ kN}$$

$$\gamma_s = 1,15$$

$$f_{pd} = f_{pk,d} / 1,15 = 600 / 1,15 = 520 \text{ N/mm}^2$$

$$F_{s,d} = 2 \cdot A_s \cdot f_{pd} = 2 \cdot 50 \cdot 520 = 52,00 \text{ kN}$$

$$M_{Rd} = F_{s,d} \cdot z = 52,0 \cdot 0,5315 = 27,6 \text{ kNm}$$

$$\mu_{Sd} = M_{Sd} / (b d^2 f_{bd}) = 0,92 \cdot 10^6 / (250 \cdot 531^2 \cdot 1,36) = 0,010$$

$$\varepsilon_b / \varepsilon_s = -0,4/5,0$$

$$\xi = x/d = 0,074$$

$$\omega = 0,012$$

$$\text{potr} A_{s1} = \omega b d f_{bd} / f_{pd} = 0,012 \cdot 250 \cdot 531 \cdot 1,36 / 520 = 4,20 \text{ mm}^2 < A_{s1} = 158 \text{ mm}^2$$

Podtip D2-6

$$b = 250 \text{ mm (tri gredice)}$$

$$h = 740 \text{ mm}$$

$$d = 620 \text{ mm}$$

$$\varepsilon_b = 0,0020 \text{ (opeka)}$$

$$\varepsilon_s = 0,0050$$

$$x = d \cdot \varepsilon_b / (\varepsilon_b + \varepsilon_s) = 620 \cdot 0,0020 / (0,0020 + 0,0050) = 177 \text{ mm}$$

$$z = d - x/2 = 620 - 88,5 = 531,5 \text{ mm}$$

$$\gamma_w = 2,2$$

$$f_{bd} = 3/2,2 = 1,36 \text{ N/mm}^2$$

$$F_{b,d} = b \cdot x \cdot f_{bd} = 250 \cdot 177 \cdot 1,36 = 60,2 \text{ kN}$$

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$$\gamma_s = 1,15$$

$$f_{pd} = f_{pk,d} / 1,15 = 600 / 1,15 = 520 \text{ N/mm}^2$$

$$F_{s,d} = 2 * A_s * f_{p,d} = 2 * 28 * 520 = 29,10 \text{ kN}$$

$$M_{Rd} = F_{s,d} * z = 29,1 * 0,5315 = 15,5 \text{ kNm}$$

$$\mu_{Sd} = M_{Sd} / (b d^2 f_{bd}) = 0,61 * 10^6 / (250 * 531^2 * 1,36) = 0,007$$

$$\epsilon_b / \epsilon_s = -0,3 / 5,0$$

$$\xi = x / d = 0,057$$

$$\omega = 0,007$$

$$\text{potr } A_{s1} = \omega b d f_{bd} / f_{pd} = 0,007 * 250 * 531 * 1,36 / 520 = 2,43 \text{ mm}^2 < A_{s1} = 158 \text{ mm}^2$$

6.1.4 Tip D3

Podtip D3-14

$$b = 250 \text{ mm (tri gredice)}$$

$$h = 990 \text{ mm}$$

$$d = 870 \text{ mm}$$

$$\epsilon_b = 0,0020 \text{ (opeka)}$$

$$\epsilon_s = 0,0050$$

$$x = d * \epsilon_b / (\epsilon_b + \epsilon_s) = 870 * 0,0020 / (0,0020 + 0,0050) = 248,5 \text{ mm}$$

$$z = d - x / 2 = 870 - 124,3 = 745,7 \text{ mm}$$

$$\gamma_w = 2,2$$

$$f_{bd} = 3 / 2,2 = 1,36 \text{ N/mm}^2$$

$$F_{b,d} = b * x * f_{bd} = 250 * 248,5 * 1,36 = 84,5 \text{ kN}$$

$$\gamma_s = 1,15$$

$$f_{pd} = f_{pk,d} / 1,15 = 600 / 1,15 = 520 \text{ N/mm}^2$$

$$F_{s,d} = 2 * A_s * f_{p,d} = 2 * 154 * 520 = 160,16 \text{ kN}$$

$$M_{Rd} = F_{b,d} * z = 84,5 * 0,7457 = 63,00 \text{ kNm}$$

$$\mu_{Sd} = M_{Sd} / (b d^2 f_{bd}) = 7,08 * 10^6 / (250 * 870^2 * 1,36) = 0,028$$

$$\epsilon_b / \epsilon_s = -0,7 / 5,0$$

$$\xi = x / d = 0,123$$

$$\omega = 0,032$$

$$\text{potr } A_{s1} = \omega b d f_{bd} / f_{pd} = 0,032 * 250 * 870 * 1,36 / 520 = 18,20 \text{ mm}^2 < A_{s1} = 308 \text{ mm}^2$$

Podtip D3-12

$$b = 250 \text{ mm (tri gredice)}$$

$$h = 990 \text{ mm}$$

$$d = 870 \text{ mm}$$

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$$\varepsilon_b = 0,0020 \text{ (opeka)}$$

$$\varepsilon_s = 0,0050$$

$$x = d \cdot \varepsilon_b / (\varepsilon_b + \varepsilon_s) = 870 \cdot 0,0020 / (0,0020 + 0,0050) = 248,5 \text{ mm}$$

$$z = d - x/2 = 870 - 124,3 = 745,7 \text{ mm}$$

$$\gamma_w = 2,2$$

$$f_{bd} = 3/2,2 = 1,36 \text{ N/mm}^2$$

$$F_{b,d} = b \cdot x \cdot f_{bd} = 250 \cdot 248,5 \cdot 1,36 = 84,5 \text{ kN}$$

$$\gamma_s = 1,15$$

$$f_{pd} = f_{pk,d} / 1,15 = 600 / 1,15 = 520 \text{ N/mm}^2$$

$$F_{s,d} = 2 \cdot A_s \cdot f_{pd} = 2 \cdot 113 \cdot 520 = 117,52 \text{ kN}$$

$$M_{Rd} = F_{b,d} \cdot z = 84,5 \cdot 0,7457 = 63,00 \text{ kNm}$$

$$\mu_{Sd} = M_{Sd} / (b \cdot d^2 \cdot f_{bd}) = 2,76 \cdot 10^6 / (250 \cdot 870^2 \cdot 1,36) = 0,011$$

$$\varepsilon_b / \varepsilon_s = -0,4/5,0$$

$$\xi = x/d = 0,074$$

$$\omega = 0,012$$

$$\text{potr} A_{s1} = \omega \cdot b \cdot d \cdot f_{bd} / f_{pd} = 0,012 \cdot 250 \cdot 870 \cdot 1,36 / 520 = 6,83 \text{ mm}^2 < A_{s1} = 226 \text{ mm}^2$$

Podtip D3-10

$$b = 250 \text{ mm (tri gredice)}$$

$$h = 990 \text{ mm}$$

$$d = 870 \text{ mm}$$

$$\varepsilon_b = 0,0020 \text{ (opeka)}$$

$$\varepsilon_s = 0,0050$$

$$x = d \cdot \varepsilon_b / (\varepsilon_b + \varepsilon_s) = 870 \cdot 0,0020 / (0,0020 + 0,0050) = 248,5 \text{ mm}$$

$$z = d - x/2 = 870 - 124,3 = 745,7 \text{ mm}$$

$$\gamma_w = 2,2$$

$$f_{bd} = 3/2,2 = 1,36 \text{ N/mm}^2$$

$$F_{b,d} = b \cdot x \cdot f_{bd} = 250 \cdot 248,5 \cdot 1,36 = 84,5 \text{ kN}$$

$$\gamma_s = 1,15$$

$$f_{pd} = f_{pk,d} / 1,15 = 600 / 1,15 = 520 \text{ N/mm}^2$$

$$F_{s,d} = 2 \cdot A_s \cdot f_{pd} = 2 \cdot 78 \cdot 520 = 81,12 \text{ kN}$$

$$M_{Rd} = F_{b,d} \cdot z = 84,5 \cdot 0,7457 = 63,00 \text{ kNm}$$

$$\mu_{Sd} = M_{Sd} / (b \cdot d^2 \cdot f_{bd}) = 1,59 \cdot 10^6 / (250 \cdot 870^2 \cdot 1,36) = 0,006$$

$$\varepsilon_b / \varepsilon_s = -0,3/5,0$$

$$\xi = x/d = 0,057$$

$$\omega = 0,007$$

$$\text{potr} A_{s1} = \omega \cdot b \cdot d \cdot f_{bd} / f_{pd} = 0,007 \cdot 250 \cdot 870 \cdot 1,36 / 520 = 3,98 \text{ mm}^2 < A_{s1} = 156 \text{ mm}^2$$



Podtip D3-8

$b = 250 \text{ mm}$ (tri gredice)

$h = 990 \text{ mm}$

$d = 870 \text{ mm}$

$\varepsilon_b = 0,0020$ (opeka)

$\varepsilon_s = 0,0050$

$x = d \cdot \varepsilon_b / (\varepsilon_b + \varepsilon_s) = 870 \cdot 0,0020 / (0,0020 + 0,0050) = 248,5 \text{ mm}$

$z = d - x/2 = 870 - 124,3 = 745,7 \text{ mm}$

$\gamma_w = 2,2$

$f_{bd} = 3/2,2 = 1,36 \text{ N/mm}^2$

$F_{b,d} = b \cdot x \cdot f_{bd} = 250 \cdot 248,5 \cdot 1,36 = 84,5 \text{ kN}$

$\gamma_s = 1,15$

$f_{pd} = f_{pk,d}/1,15 = 600/1,15 = 520 \text{ N/mm}^2$

$F_{s,d} = 2 \cdot A_s \cdot f_{pd} = 2 \cdot 50 \cdot 520 = 52,00 \text{ kN}$

$M_{Rd} = F_{s,d} \cdot z = 52,00 \cdot 0,7457 = 38,78 \text{ kNm}$

$\mu_{Sd} = M_{Sd} / (b \cdot d^2 \cdot f_{bd}) = 1,14 \cdot 10^6 / (250 \cdot 870^2 \cdot 1,36) = 0,004$

$\varepsilon_b/\varepsilon_s = -0,3/5,0$

$\xi = x/d = 0,057$

$\omega = 0,007$

$\rho_{tr} A_{s1} = \omega \cdot b \cdot d \cdot f_{bd} / f_{pd} = 0,007 \cdot 250 \cdot 870 \cdot 1,36 / 520 = 3,98 \text{ mm}^2 < A_{s1} = 100 \text{ mm}^2$

Podtip D3-6

$b = 250 \text{ mm}$ (tri gredice)

$h = 990 \text{ mm}$

$d = 870 \text{ mm}$

$\varepsilon_b = 0,0020$ (opeka)

$\varepsilon_s = 0,0050$

$x = d \cdot \varepsilon_b / (\varepsilon_b + \varepsilon_s) = 870 \cdot 0,0020 / (0,0020 + 0,0050) = 248,5 \text{ mm}$

$z = d - x/2 = 870 - 124,3 = 745,7 \text{ mm}$

$\gamma_w = 2,2$

$f_{bd} = 3/2,2 = 1,36 \text{ N/mm}^2$

$F_{b,d} = b \cdot x \cdot f_{bd} = 250 \cdot 248,5 \cdot 1,36 = 84,5 \text{ kN}$

$\gamma_s = 1,15$

$f_{pd} = f_{pk,d}/1,15 = 600/1,15 = 520 \text{ N/mm}^2$

$F_{s,d} = 2 \cdot A_s \cdot f_{pd} = 2 \cdot 28 \cdot 520 = 29,12 \text{ kN}$

$M_{Rd} = F_{s,d} \cdot z = 29,12 \cdot 0,7457 = 21,71 \text{ kNm}$

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$$\mu_{Sd} = M_{Sd} / (b d^2 f_{bd}) = 0,76 \cdot 10^6 / (250 \cdot 870^2 \cdot 1,36) = 0,003$$

$$\varepsilon_b / \varepsilon_s = -0,3/5,0$$

$$\xi = x/d = 0,057$$

$$\omega = 0,007$$

$$\rho_{tr} A_{st} = \omega b d f_{bd} / f_{pd} = 0,007 \cdot 250 \cdot 870 \cdot 1,36 / 520 = 3,98 \text{ mm}^2 < A_{st} = 56 \text{ mm}^2$$

6.1.5 Tip D4

Podtip D4-14

$$b = 250 \text{ mm (dvije gredice)}$$

$$h = 1240 \text{ mm}$$

$$d = 1120 \text{ mm}$$

$$\varepsilon_b = 0,0020 \text{ (opeka)}$$

$$\varepsilon_s = 0,0050$$

$$x = d \cdot \varepsilon_b / (\varepsilon_b + \varepsilon_s) = 1120 \cdot 0,0020 / (0,0020 + 0,0050) = 320 \text{ mm}$$

$$z = d - x/2 = 1120 - 160 = 960 \text{ mm}$$

$$\gamma_w = 2,2$$

$$f_{bd} = 3/2,2 = 1,36 \text{ N/mm}^2$$

$$F_{b,d} = b \cdot x \cdot f_{bd} = 250 \cdot 320 \cdot 1,36 = 108,8 \text{ kN}$$

$$\gamma_s = 1,15$$

$$f_{pd} = f_{pk,d} / 1,15 = 600 / 1,15 = 520 \text{ N/mm}^2$$

$$F_{s,d} = 2 \cdot A_s \cdot f_{pd} = 2 \cdot 154 \cdot 520 = 160,2 \text{ kN}$$

$$M_{Rd} = F_{s,d} \cdot z = 160,2 \cdot 0,960 = 153,8 \text{ kNm}$$

$$\mu_{Sd} = M_{Sd} / (b d^2 f_{bd}) = 8,42 \cdot 10^6 / (250 \cdot 1120^2 \cdot 1,36) = 0,020$$

$$\varepsilon_b / \varepsilon_s = -0,6/5,0$$

$$\xi = x/d = 0,107$$

$$\omega = 0,025$$

$$\rho_{tr} A_{st} = \omega b d f_{bd} / f_{pd} = 0,025 \cdot 250 \cdot 1120 \cdot 1,36 / 520 = 18,31 \text{ mm}^2 < A_{st} = 308 \text{ mm}^2$$

Podtip D4-12

$$b = 250 \text{ mm (dvije gredice)}$$

$$h = 1240 \text{ mm}$$

$$d = 1120 \text{ mm}$$

$$\varepsilon_b = 0,0020 \text{ (opeka)}$$

$$\varepsilon_s = 0,0050$$

$$x = d \cdot \varepsilon_b / (\varepsilon_b + \varepsilon_s) = 1120 \cdot 0,0020 / (0,0020 + 0,0050) = 320 \text{ mm}$$

$$z = d - x/2 = 1120 - 160 = 960 \text{ mm}$$

$$\gamma_w = 2,2$$

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$$f_{bd} = 3/2,2 = 1,36 \text{ N/mm}^2$$

$$F_{b,d} = b \cdot x \cdot f_{bd} = 250 \cdot 320 \cdot 1,36 = 108,8 \text{ kN}$$

$$\gamma_s = 1,15$$

$$f_{pd} = f_{pk,d} / 1,15 = 600 / 1,15 = 520 \text{ N/mm}^2$$

$$F_{s,d} = 2 \cdot A_s \cdot f_{pd} = 2 \cdot 113 \cdot 520 = 117,52 \text{ kN}$$

$$M_{Rd} = F_{s,d} \cdot z = 108,8 \cdot 0,960 = 104,4 \text{ kNm}$$

$$\mu_{Sd} = M_{Sd} / (b \cdot d^2 \cdot f_{bd}) = 3,29 \cdot 10^6 / (250 \cdot 1120^2 \cdot 1,36) = 0,008$$

$$\epsilon_b / \epsilon_s = -0,4/5,0$$

$$\xi = x/d = 0,074$$

$$\omega = 0,012$$

$$\text{potr} A_{s1} = \omega \cdot b \cdot d \cdot f_{bd} / f_{pd} = 0,012 \cdot 250 \cdot 1120 \cdot 1,36 / 520 = 8,9 \text{ mm}^2 < A_{s1} = 226 \text{ mm}^2$$

Podtip D4-10

$$b = 250 \text{ mm (dvije gredice)}$$

$$h = 1240 \text{ mm}$$

$$d = 1120 \text{ mm}$$

$$\epsilon_b = 0,0020 \text{ (opeka)}$$

$$\epsilon_s = 0,0050$$

$$x = d \cdot \epsilon_b / (\epsilon_b + \epsilon_s) = 1120 \cdot 0,0020 / (0,0020 + 0,0050) = 320 \text{ mm}$$

$$z = d - x/2 = 1120 - 160 = 960 \text{ mm}$$

$$\gamma_w = 2,2$$

$$f_{bd} = 3/2,2 = 1,36 \text{ N/mm}^2$$

$$F_{b,d} = b \cdot x \cdot f_{bd} = 250 \cdot 320 \cdot 1,36 = 108,8 \text{ kN}$$

$$\gamma_s = 1,15$$

$$f_{pd} = f_{pk,d} / 1,15 = 600 / 1,15 = 520 \text{ N/mm}^2$$

$$F_{s,d} = 2 \cdot A_s \cdot f_{pd} = 2 \cdot 78 \cdot 520 = 81,12 \text{ kN}$$

$$M_{Rd} = F_{s,d} \cdot z = 81,12 \cdot 0,960 = 77,9 \text{ kNm}$$

$$\mu_{Sd} = M_{Sd} / (b \cdot d^2 \cdot f_{bd}) = 1,89 \cdot 10^6 / (250 \cdot 1120^2 \cdot 1,36) = 0,004$$

$$\epsilon_b / \epsilon_s = -0,4/5,0$$

$$\xi = x/d = 0,074$$

$$\omega = 0,012$$

$$\text{potr} A_{s1} = \omega \cdot b \cdot d \cdot f_{bd} / f_{pd} = 0,012 \cdot 250 \cdot 1120 \cdot 1,36 / 520 = 8,9 \text{ mm}^2 < A_{s1} = 156 \text{ mm}^2$$

Podtip D4-8

$$b = 250 \text{ mm (dvije gredice)}$$

$$h = 1240 \text{ mm}$$

$$d = 1120 \text{ mm}$$

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$$\varepsilon_b = 0,0020 \text{ (opeka)}$$

$$\varepsilon_s = 0,0050$$

$$x = d \cdot \varepsilon_b / (\varepsilon_b + \varepsilon_s) = 1120 \cdot 0,0020 / (0,0020 + 0,0050) = 320 \text{ mm}$$

$$z = d - x/2 = 1120 - 160 = 960 \text{ mm}$$

$$\gamma_w = 2,2$$

$$f_{bd} = 3/2,2 = 1,36 \text{ N/mm}^2$$

$$F_{b,d} = b \cdot x \cdot f_{bd} = 250 \cdot 320 \cdot 1,36 = 108,8 \text{ kN}$$

$$\gamma_s = 1,15$$

$$f_{pd} = f_{pk,d} / 1,15 = 600 / 1,15 = 520 \text{ N/mm}^2$$

$$F_{s,d} = 2 \cdot A_s \cdot f_{p,d} = 2 \cdot 50 \cdot 520 = 52,00 \text{ kN}$$

$$M_{Rd} = F_{s,d} \cdot z = 52,00 \cdot 0,960 = 49,9 \text{ kNm}$$

$$\mu_{Sd} = M_{Sd} / (b \cdot d^2 \cdot f_{bd}) = 1,35 \cdot 10^6 / (250 \cdot 1120^2 \cdot 1,36) = 0,0032$$

$$\varepsilon_b / \varepsilon_s = -0,4/5,0$$

$$\xi = x/d = 0,074$$

$$\omega = 0,012$$

$$\text{potr} A_{s1} = \omega \cdot b \cdot d \cdot f_{bd} / f_{pd} = 0,012 \cdot 250 \cdot 1120 \cdot 1,36 / 520 = 8,9 \text{ mm}^2 < A_{s1} = 100 \text{ mm}^2$$

Podtip D4-6

$$b = 250 \text{ mm (dvije gredice)}$$

$$h = 1240 \text{ mm}$$

$$d = 1120 \text{ mm}$$

$$\varepsilon_b = 0,0020 \text{ (opeka)}$$

$$\varepsilon_s = 0,0050$$

$$x = d \cdot \varepsilon_b / (\varepsilon_b + \varepsilon_s) = 1120 \cdot 0,0020 / (0,0020 + 0,0050) = 320 \text{ mm}$$

$$z = d - x/2 = 1120 - 160 = 960 \text{ mm}$$

$$\gamma_w = 2,2$$

$$f_{bd} = 3/2,2 = 1,36 \text{ N/mm}^2$$

$$F_{b,d} = b \cdot x \cdot f_{bd} = 250 \cdot 320 \cdot 1,36 = 108,8 \text{ kN}$$

$$\gamma_s = 1,15$$

$$f_{pd} = f_{pk,d} / 1,15 = 600 / 1,15 = 520 \text{ N/mm}^2$$

$$F_{s,d} = 2 \cdot A_s \cdot f_{p,d} = 2 \cdot 28 \cdot 520 = 29,10 \text{ kN}$$

$$M_{Rd} = F_{s,d} \cdot z = 29,10 \cdot 0,960 = 27,95 \text{ kNm}$$

$$\mu_{Sd} = M_{Sd} / (b \cdot d^2 \cdot f_{bd}) = 0,90 \cdot 10^6 / (250 \cdot 1120^2 \cdot 1,36) = 0,002$$

$$\varepsilon_b / \varepsilon_s = -0,3/5,0$$

$$\xi = x/d = 0,057$$

$$\omega = 0,007$$

$$\text{potr} A_{s1} = \omega \cdot b \cdot d \cdot f_{bd} / f_{pd} = 0,007 \cdot 250 \cdot 1120 \cdot 1,36 / 520 = 5,13 \text{ mm}^2 < A_{s1} = 56 \text{ mm}^2$$



6.2 Nosivost pri djelovanju poprečne sile

Za proračunsku vrijednost poprečne sile uzeta je reakcija na ležaju. Zanemaren je povoljan utjecaj izravnog prijenosa poprečne sile u ležaj kojim se smanjuje proračunska poprečna sila kao i stvaranje rasteretnog luka (odnosno opteretnog trokuta), što sve daje povećanu sigurnost nadvoja.

Otpornost poprečnog presjeka jednog nadvoja bez armature na poprečnu silu:

$$V_{Rd1} = [\tau_{Rd} * k(1,2 + 40\rho_1)] * b_w * d = 0,03 * (1,6 - 0,188) * (1,2 + 40 * 0,003) * 4,6 * 18,8 = 4,84 \text{ kN}$$

Za tri nadvoja : $V_{Rd1} = 14,51 \text{ kN}$

Posmična proračunska otpornost u horizontalnoj sljubnici na spoju gredica - zidni elementi:

$$\tau_{Rd} = f_{mkt} = f_{mkt} / \gamma_w = 0,3 / 2,2 = 0,136 \text{ N/mm}^2$$

7 Usporedba djelovanja i nosivosti

7.1 Moment savijanja

Tip	D ₀₋₁₄	D ₁₋₁₄	D ₂₋₁₄	D ₃₋₁₄	D ₄₋₁₄
M _{Sd} (kNm)	3,07	4,41	5,74	7,08	8,42
M _{Rd} (kNm)	9,72	11,38	32	63	104,4

Tip	D ₀₋₁₂	D ₁₋₁₂	D ₂₋₁₂	D ₃₋₁₂	D ₄₋₁₂
M _{Sd} (kNm)	1,2	1,72	2,24	2,76	3,29
M _{Rd} (kNm)	8,76	11,38	27,64	63	104,4

Tip	D ₀₋₁₀	D ₁₋₁₀	D ₂₋₁₀	D ₃₋₁₀	D ₄₋₁₀
M _{Sd} (kNm)	0,69	0,99	1,29	1,59	1,89
M _{Rd} (kNm)	6,12	11,3	32	63	77,9



Tip	D ₀₋₈	D ₁₋₈	D ₂₋₈	D ₃₋₈	D ₄₋₈
M _{Sd} (kNm)	0,49	0,71	0,92	1,14	1,35
M _{Rd} (kNm)	3,9	7,93	27,6	38,78	49,9

Tip	D ₀₋₆	D ₁₋₆	D ₂₋₆	D ₃₋₆	D ₄₋₆
M _{Sd} (kNm)	0,33	0,47	0,61	0,76	0,9
M _{Rd} (kNm)	2,17	4,44	15,5	29,12	27,95

7.2 Poprečna sila

Tip	D ₀₋₁₄	D ₁₋₁₄	D ₂₋₁₄	D ₃₋₁₄	D ₄₋₁₄
V _{Sd} (kN)	3,69	5,30	6,91	8,52	10,13
V _{Rd1} (kN)	14,51	14,51	14,51	14,51	14,51

Tip	D ₀₋₁₂	D ₁₋₁₂	D ₂₋₁₂	D ₃₋₁₂	D ₄₋₁₂
V _{Sd} (kN)	2,30	3,30	4,30	5,30	6,30
V _{Rd1} (kN)	14,51	14,51	14,51	14,51	14,51

Tip	D ₀₋₁₀	D ₁₋₁₀	D ₂₋₁₀	D ₃₋₁₀	D ₄₋₁₀
V _{Sd} (kN)	1,76	2,52	3,29	4,05	4,82
V _{Rd1} (kN)	14,51	14,51	14,51	14,51	14,51

Tip	D ₀₋₈	D ₁₋₈	D ₂₋₈	D ₃₋₈	D ₄₋₈
V _{Sd} (kN)	1,48	2,12	2,76	3,41	4,05
V _{Rd1} (kN)	14,51	14,51	14,51	14,51	14,51

Tip	D ₀₋₆	D ₁₋₆	D ₂₋₆	D ₃₋₆	D ₄₋₆
V _{Sd} (kN)	1,20	1,72	2,24	2,76	3,29
V _{Rd1} (kN)	14,51	14,51	14,51	14,51	14,51

7.3 Poprečna sila - posmično naprezanje

Tip	D ₀₋₁₄	D ₁₋₁₄	D ₂₋₁₄	D ₃₋₁₄	D ₄₋₁₄
τ _{Sd1} (N/mm ²)	---	0,039	0,049	0,038	0,031
τ _{Sd2} (N/mm ²)	0,092	0,065	0,056	0,052	0,049
τ _{Rd} (N/mm ²)	0,136	0,136	0,136	0,136	0,136



Tip	D ₀₋₁₂	D ₁₋₁₂	D ₂₋₁₂	D ₃₋₁₂	D ₄₋₁₂
τ_{sd1} (N/mm ²)	---	0,024	0,031	0,024	0,019
τ_{sd2} (N/mm ²)	0,058	0,040	0,035	0,032	0,030
τ_{Rd} (N/mm ²)	0,136	0,136	0,136	0,136	0,136

Tip	D ₀₋₁₀	D ₁₋₁₀	D ₂₋₁₀	D ₃₋₁₀	D ₄₋₁₀
τ_{sd1} (N/mm ²)	---	0,019	0,023	0,018	0,015
τ_{sd2} (N/mm ²)	0,044	0,031	0,027	0,025	0,023
τ_{Rd} (N/mm ²)	0,136	0,136	0,136	0,136	0,136

Tip	D ₀₋₈	D ₁₋₈	D ₂₋₈	D ₃₋₈	D ₄₋₈
τ_{sd1} (N/mm ²)	---	0,016	0,020	0,015	0,012
τ_{sd2} (N/mm ²)	0,037	0,026	0,022	0,021	0,020
τ_{Rd} (N/mm ²)	0,136	0,136	0,136	0,136	0,136

Tip	D ₀₋₆	D ₁₋₆	D ₂₋₆	D ₃₋₆	D ₄₋₆
τ_{sd1} (N/mm ²)	---	0,013	0,016	0,012	0,010
τ_{sd2} (N/mm ²)	0,030	0,021	0,018	0,017	0,016
τ_{Rd} (N/mm ²)	0,136	0,136	0,136	0,136	0,136

gdje je:

τ_{sd1} posmično naprezanje u sljubnici gornji rub gredice - donji rub prvog reda zidnih elemenata

τ_{sd2} posmično naprezanje u polovini visine presjeka.

Kako je za sve tipove nadvoja i za najveće proračunske raspone za pojedine tipove $M_{Rd} > M_{sd}$, $\tau_{Rd} > \tau_{sd}$ i $V_{Rd} > V_{sd}$ nosivost za proračunska djelovanja dokazana je i za sve manje raspone.

8 Provjera naprezanja

Provjera vlačnog naprezanja u sljubnici gornji rub gredice - donji rub prvog reda zidnih elemenata



$$\sigma = (M_{sd}/I) * (h/2 - h_1)$$

$$h_1 = 240 \text{ mm}$$

Tip D1

$$\sigma = (4,41 / 2451) * (490/2 - 240) = 0,090 \text{ N/mm}^2$$

Tip D2

$$\sigma = (5,74 / 8442) * (740/2 - 240) = 0,089 \text{ N/mm}^2$$

Tip D3

$$\sigma = (7,08 / 20214) * (990/2 - 240) = 0,090 \text{ N/mm}^2$$

Tip D4

$$\sigma = (8,42 / 39721) * (1240/2 - 240) = 0,082 \text{ N/mm}^2$$

9 Zaključak

Nadvoji tip D0, D1, D2, D3 i D4 imaju zahtijevanu nosivost za svijetle otvore od 1,00 m do 3,50 m za opterećenje vlastitom težinom uz uporabu zidnih elemenata tipa POROTHERM 25S P + E. Sve prema prikazanoj tablici.

Proizvodne duljine (cm) L	100	125	150	175	200	225	250	275	300	325	350
Svijetli otvori (cm) $L_0 = L - 2 \cdot 12,5$	75	100	125	150	175	200	225	250	275	300	325
Proračunski rasponi (cm) $L_r = L_0 + (1/3) \cdot 12,5 \cdot 2 = L - 17$	83	108	133	158	183	208	233	258	283	308	333
Gornja zona armatura Φ (mm)	6	6	8	10	12	12	14	14	14	14	14
Poprečna armatura Φ (mm)	5	5	5	6	7	7	7	7	7	7	7
Donja zona armature Φ (mm)	6	6	8	10	12	12	14	14	14	14	14