



FORMULE I TABELE ZA ISPIT IZ OTPORNOSTI MATERIJALA

Formule i tabele za ispit iz Otpornosti materijala

Naponi i deformacije

$$\sigma_{n\text{sr}} = \frac{F_n}{A} < \sigma_{\text{doz}}$$

$$\tau_{s\text{sr}} = \frac{F_s}{A} < \tau_{\text{doz}}$$

$$\sigma_{\text{doz}} = \frac{R_{eH}(\sigma)}{S} \quad \left(\tau_{\text{doz}} = \frac{R_{eH}(\tau)}{S} \right)$$

$$\sigma_{\text{doz}} = \frac{R_m(\sigma)}{S} \quad \left(\tau_{\text{doz}} = \frac{R_m(\tau)}{S} \right)$$

$$\nu = -\frac{\epsilon_{\text{pop}}}{\epsilon_{\text{uzd}}}$$

$$\sigma = \epsilon E$$

$$\tau = \gamma G$$

$$\epsilon = \frac{\Delta L}{L}$$

Aksijalno naprezanje

$$\sigma_n = \frac{F}{A} < \sigma_{\text{doz}}$$

$$\delta = \frac{FL}{EA} < \delta_{\text{max}}$$

$$\delta = \sum_i \delta_i = \sum_i \frac{F_i L_i}{E_i A_i} < \delta_{\text{max}}$$

$$\delta = \int_0^L \frac{F(x)}{E(x)A(x)} dx < \delta_{\text{max}}$$

$$\delta = \frac{F}{k} < \delta_{\text{max}} \quad k = \frac{EA}{L}$$

$$\delta_T = \alpha \Delta T L$$

Naponi u kosom presjeku

$$\sigma_\theta = \frac{\sigma_x}{2}(1 + \cos 2\theta)$$

$$\tau_\theta = -\frac{\sigma_x}{2} \sin 2\theta$$

Uvijanje

Kružni poprečni presjek

$$\tau_{u\text{max}} = \frac{Tr_{\text{max}}}{I_o} = \frac{T}{W_o} < \tau_{\text{doz}}$$

$$\tau_u = \frac{T}{I_o} \rho$$

$$W_o = \frac{I_o}{d_{\text{max}}/2}$$

$$\phi = \frac{TL}{GI_o} < \phi_{\text{max}}$$

$$\phi = \sum_i \phi_i = \sum_i \frac{T_i L_i}{G_i I_{oi}} < \phi_{\text{max}}$$

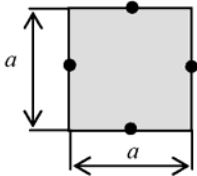
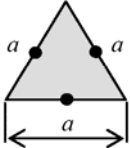
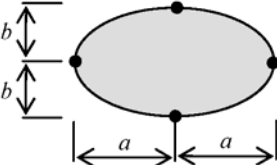
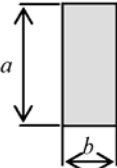
$$\phi = \int_0^\alpha \frac{T(x)}{G(x)I_o(x)} dx < \phi_{\text{max}}$$

$$\theta = \frac{\phi}{L} < \theta_{\text{max}}$$

$$G = \frac{E}{2(1 + \nu)}$$

Formule i tabele za ispit iz Otpornosti materijala

Neokrugli poprečni presjek

	$\tau_{\max}$	ϕ																																	
	$\frac{4.81T}{a^3}$	$\frac{7.10TL}{a^4G}$																																	
	$\frac{20T}{a^3}$	$\frac{46TL}{a^4G}$																																	
	$\frac{2T}{\pi ab^2}$	$\frac{(a^2 + b^2)TL}{\pi a^3 b^3 G}$																																	
 <table border="1"> <thead> <tr> <th>a/b</th><th>c_1</th><th>c_2</th></tr> </thead> <tbody> <tr><td>1.0</td><td>0.208</td><td>0.1406</td></tr> <tr><td>1.2</td><td>0.219</td><td>0.1661</td></tr> <tr><td>1.5</td><td>0.231</td><td>0.1958</td></tr> <tr><td>2.0</td><td>0.246</td><td>0.229</td></tr> <tr><td>2.5</td><td>0.258</td><td>0.249</td></tr> <tr><td>3.0</td><td>0.267</td><td>0.263</td></tr> <tr><td>4.0</td><td>0.282</td><td>0.281</td></tr> <tr><td>5.0</td><td>0.291</td><td>0.291</td></tr> <tr><td>10.0</td><td>0.312</td><td>0.312</td></tr> <tr><td>∞</td><td>0.333</td><td>0.333</td></tr> </tbody> </table> $a/b \geq 5$ $c_1 = c_2 = \frac{1}{3} \left(1 - 0.63 \frac{b}{a} \right)$	a/b	c_1	c_2	1.0	0.208	0.1406	1.2	0.219	0.1661	1.5	0.231	0.1958	2.0	0.246	0.229	2.5	0.258	0.249	3.0	0.267	0.263	4.0	0.282	0.281	5.0	0.291	0.291	10.0	0.312	0.312	∞	0.333	0.333	$\frac{T}{c_1 ab^2}$	$\frac{TL}{c_2 ab^3 G}$
a/b	c_1	c_2																																	
1.0	0.208	0.1406																																	
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Tankostjeni zatvoreni elementi

$$T = 2\tau_{sr}tA_m$$

$$\phi = \frac{TL}{4A_m^2 G} \oint \frac{ds}{t}$$

Savijanje

Normalni napon

$$\sigma = \frac{M}{I}y < \sigma_{doz}$$

Smičući napon

$$\tau_s = \frac{VQ}{Ib} < \tau_{doz}$$

– Pravougaoni poprečni presjek

$$Q = \frac{b}{2} \left(\frac{h^2}{4} - y_1^2 \right)$$

$$\tau_{\max} = \frac{3V}{2A}$$

– Kružni poprečni presjek

$$\tau_{\max} = \frac{4V}{3A}$$

Formule i tabele za ispit iz Otpornosti materijala

– Kružni prsten

$$\tau_{\max} = \frac{4V}{3A} \left(\frac{r_2^2 + r_1 r_2 + r_1^2}{r_1^2 + r_2^2} \right) = \frac{4V}{3A} \left(\frac{1 + \psi + \psi^2}{1 + \psi^2} \right) \quad \psi = \frac{d_1}{d_2}$$

Jednačina elastične linije

$$EIy'' = -M(x)$$

Ravno stanje napona

$$\sigma_{x_1} = \frac{\sigma_x + \sigma_y}{2} + \frac{\sigma_x - \sigma_y}{2} \cos 2\theta + \tau_{xy} \sin 2\theta$$

$$\tau_{xy} = -\frac{\sigma_x - \sigma_y}{2} \sin 2\theta + \tau_{xy} \cos 2\theta$$

$$\sigma_{1,2} = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2} \right)^2 + \tau_{xy}^2}$$

$$\operatorname{tg} 2\theta_p = \frac{2\tau_{xy}}{\sigma_x - \sigma_y}$$

$$\tau_{\max} = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2} \right)^2 + \tau_{xy}^2} = \frac{\sigma_1 - \sigma_2}{2}$$

$$\operatorname{tg} 2\theta_s = -\frac{\sigma_x - \sigma_y}{2\tau_{xy}}$$

$$\text{sferični sud pod pritiskom: } \sigma = \frac{pr}{2t} \quad \tau_{\max} = \frac{pr}{4t}$$

$$\text{cilindrični sud pod pritiskom: } \sigma_1 = \frac{pr}{t} \quad \sigma_2 = \frac{pr}{2t} \quad \tau_{\max} = \frac{pr}{2t}$$

$$\epsilon_x = \frac{1}{E}(\sigma_x - \nu\sigma_y)\langle +\alpha\Delta T \rangle$$

$$\epsilon_y = \frac{1}{E}(\sigma_y - \nu\sigma_x)\langle +\alpha\Delta T \rangle$$

$$\epsilon_z = -\frac{\nu}{E}(\sigma_x + \sigma_y)\langle +\alpha\Delta T \rangle$$

$$\sigma_x = \frac{E}{1 - \nu^2}(\epsilon_x + \nu\epsilon_y)\langle -\frac{E\alpha}{1 - \nu}\Delta T \rangle$$

$$\sigma_y = \frac{E}{1 - \nu^2}(\epsilon_y + \nu\epsilon_x)\langle -\frac{E\alpha}{1 - \nu}\Delta T \rangle$$

$$\sigma_z = 0$$

Troosno naponsko stanje

$$\epsilon_x = \frac{1}{E}[\sigma_x - \nu(\sigma_y + \sigma_z)]\langle +\alpha\Delta T \rangle$$

$$\epsilon_y = \frac{1}{E}[\sigma_y - \nu(\sigma_x + \sigma_z)]\langle +\alpha\Delta T \rangle$$

$$\epsilon_z = \frac{1}{E}[\sigma_z - \nu(\sigma_x + \sigma_y)]\langle +\alpha\Delta T \rangle$$

$$\sigma_x = \frac{E}{(1 + \nu)(1 - 2\nu)}[(1 - \nu)\epsilon_x + \nu(\epsilon_y + \epsilon_z)]\langle -\frac{E\alpha}{1 - \nu}\Delta T \rangle$$

$$\sigma_y = \frac{E}{(1 + \nu)(1 - 2\nu)}[(1 - \nu)\epsilon_y + \nu(\epsilon_x + \epsilon_z)]\langle -\frac{E\alpha}{1 - \nu}\Delta T \rangle$$

$$\sigma_z = \frac{E}{(1 + \nu)(1 - 2\nu)}[(1 - \nu)\epsilon_z + \nu(\epsilon_x + \epsilon_y)]\langle -\frac{E\alpha}{1 - \nu}\Delta T \rangle$$

$$\Delta V = V_0(\epsilon_x + \epsilon_y + \epsilon_z) = \frac{1 - 2\nu}{E}(\sigma_x + \sigma_y + \sigma_z)$$

Formule i tabele za ispit iz Otpornosti materijala

Hipoteze o razaranju materijala

$$\sigma_{ekv} = \begin{cases} \max(|\sigma_1|, |\sigma_2|), \sigma_1 \text{ i } \sigma_2 \text{ istog znaka} \\ |\sigma_1 - \sigma_2|, \sigma_1 \text{ i } \sigma_2 \text{ različitog znaka} \end{cases} < \frac{R_{eH}}{S}$$

$$\sigma_{ekv} = \sqrt{\sigma_1^2 - \sigma_1\sigma_2 + \sigma_2^2} < \frac{R_{eH}}{S}$$

$$\sigma_{ekv} = \max(|\sigma_1|, |\sigma_2|) < \frac{R_m}{S}$$

$$\sigma_{ekv} = \begin{cases} \sigma_1, \text{ za } \sigma_1, \sigma_2 > 0 \\ \sigma_1 - \alpha_\sigma \sigma_2, \sigma_1 \text{ i } \sigma_2 \text{ različitog znaka} \end{cases} < \frac{R_{mz}}{S}$$

$$\sigma_{ekv} = |\sigma_2| < \frac{R_{mp}}{S}, \text{ za } \sigma_1, \sigma_2 < 0$$

$$\alpha_\sigma = \frac{R_{mz}}{R_{mp}}$$

Izvijanje

$$F_{kr} = \frac{\pi^2 EI_{\min}}{(kl)^2}$$

gdje je $k = 2, 1, 0.7, 0.5$ za konzolu, prostu gredu, gredu s uklještenjem i gredu s dva uklještenja, respektivno.

Ekscentrično izvijanje

$$\sigma_{\max} = \frac{P}{A} + \frac{Mc}{I} = \frac{P}{A} \left[1 + \frac{ec}{r^2} \sec \left(k \frac{L}{2r} \right) \right]$$

$$r = \sqrt{\frac{I}{A}}$$

Neelastično izvijanje

$$\sigma_{kr} = \frac{\pi^2 E_t}{\left(\frac{KL}{r} \right)^2}$$

Formule i tabele za ispit iz Otpornosti materijala

Karakteristike poprečnih presjeka

$$I_{x_1} = \frac{I_x + I_y}{2} + \frac{I_x - I_y}{2} \cos 2\theta - I_{xy} \sin 2\theta$$

$$I_{x_1 y_1} = -\frac{I_x - I_y}{2} \sin 2\theta + I_{xy} \cos 2\theta$$

$$I_{1,2} = \frac{I_x + I_y}{2} \pm \sqrt{\left(\frac{I_x - I_y}{2}\right)^2 + I_{xy}^2}$$

$$\operatorname{tg} 2\theta = -\frac{2I_{xy}}{I_x - I_y}$$

$$I_x + I_y = I_{x_1} + I_{y_1} = I_1 + I_2 = \text{const.}$$

$$I_{x_1} I_{y_1} - I_{x_1 y_1}^2 = I_x I_y - I_{xy}^2 = I_1 I_2 = \text{const.}$$

$$I_x = I_{x_C} + y_C^2 A$$

$$I_y = I_{y_C} + x_C^2 A$$

$$I_{xy} = I_{x_C y_C} + x_C y_C A$$

$$I_o = I_x + I_y$$

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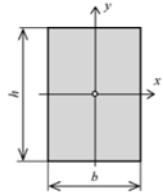
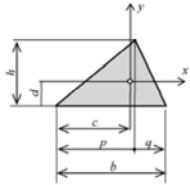
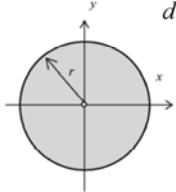
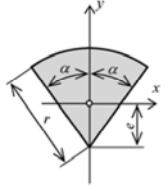
Tabela I Približne karakteristike nekih inženjerskih materijala

Materijal		Specifična gustina, ρ ×1000 kg/m ³	Modul elastičnosti, E GPa	Napon tečenja, R_{eH} MPa	Čvrstoća, R_m MPa			Poisson-ov koeficijent, ν -	Koeficijent termalnog širenja, α ×10 ⁻⁶ 1/°C
Al i legure		2.5-2.9	72-89	30-330	65-610			0.32-0.36	22-24
Bakar i Cu legure		8.9	112-148	30-350	100-400			0.34-0.35	16.9-18
Beton		2.3-2.6	14-31 ⁱ⁾	-	14-50 ⁱ⁾ 1-1.5 ⁱⁱⁱ⁾			0.15-0.2	6-13
Bronza		8.5-9	70-105	100-500	210-730			0.34-0.35	17-19
Drvo (uzduž vlakana)	Bor (pinus spp.)	0.44-0.54	7.6-9.3 ⁱⁱ⁾	-		35.1-42.9 ⁱ⁾	64.5-78.9 ⁱⁱⁱ⁾	-	-
					⊥	4.53 ⁱ⁾	3.2-3.9 ⁱⁱ⁾		
	Hrast (Quercus falcata)	0.69-0.84	14.1-17.3 ⁱⁱ⁾	-		54.2-66.3 ⁱ⁾	112-137 ⁱⁱⁱ⁾	0.35-0.4	2-11 ^{iv)}
					⊥	5.2-6.4 ⁱ⁾	5.2-6.4 ⁱⁱ⁾		
	Jela (abies procera)	0.39-0.48	10.7-13 ⁱⁱ⁾	-		37.9-46.3 ⁱ⁾	66.4-81.2 ⁱ⁾	-	-
					⊥	3.23-3.94 ⁱ⁾	1.4-1.7 ⁱⁱ⁾		
Čelik	ugljenični	7.8-7.9	205-217	400-1500	550-1760			0.285-0.295	10.5-13.5
	legirani (nerđajući)	7.6-8.1	189-210	170-1000	400-2240			0.265-0.275	13-20
Guma (prirodna)		0.92-0.93	0.0015-0.0025	20-30	22-32			0.499-0.50	150-450
Mesing		7.9-8.55	90-110	95-500	310-550			0.34-0.35	17-20.7
Magnezij i Mg legure		1.75-1.87	42-47	70-215	119-283			0.29-0.31	24.6-28
Olovo i Pb legure		8.85-11	13-17	90-360	21-46			0.435-0.445	23-29
Plastični materijali	Najlon (Tip 66)	1.13-1.15	1.73-3.79	55.2-82.7	90-99.2 ⁱⁱⁱ⁾			0.4-0.42	110-150
	Polietilen (PE-HD)	0.952-0.965	1.07-1.09	26.2-31	22.1-31 ⁱⁱⁱ⁾			0.41-0.427	106-198
Sivi liv		7.05-7.25	80-138	140-420 ⁱⁱⁱ⁾	500-1100 ⁱ⁾ 140-440 ⁱⁱⁱ⁾			0.26-0.28	11-12.5
Staklo (silika)		2.17-2.22	72-74	-	45.7-50.4 ⁱⁱⁱ⁾ 1050-1160 ⁱ⁾			0.15-0.16	0.48-0.52
Stijene	Granit, mermer, kvarc	2.6-2.9	40-100	-	500-280 ⁱ⁾			0.2-0.3	5-9
	Krečnjak, pješčenjak	2.0-2.9	20-70	-	20-200 ⁱ⁾				
Pluto		0.12-0.24	0.013-0.05 ⁱ⁾	-	0.54-2 ⁱ⁾			0.05-0.45	130-230

ⁱ⁾pritisak ⁱⁱ⁾savijanje ⁱⁱⁱ⁾zatezanje ^{iv)}procijenjene vrijednosti ⊥-okomito na vlakna ||-paralelno vlaknima

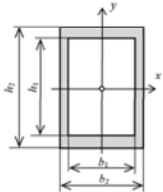
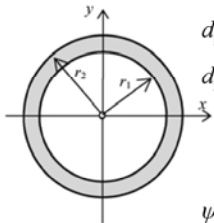
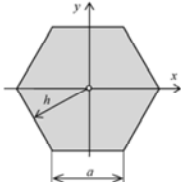
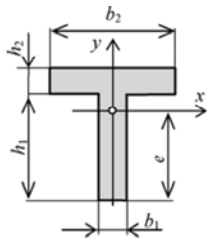
Formule i tabele za ispit iz Otpornosti materijala

Tabela II Karakteristike poprečnih presjeka

Presjek	Položaj težišta	Površina A	Moment inercije				
			I_x	I_y	W_x	W_y	$S_x (Q_x)$
	-	bh	$\frac{bh^3}{12} = \frac{Ah^2}{12}$	$\frac{hb^3}{12} = \frac{Ab^2}{12}$	$\frac{bh^2}{6} = \frac{Ah}{6}$	$\frac{hb^2}{6} = \frac{Ab}{6}$	$\frac{bh^2}{8}$
	$c = \frac{b+p}{3}$ $d = \frac{h}{3}$	$\frac{bh}{2}$	$\frac{bh^3}{36} = \frac{Ah^2}{18}$	$\frac{1}{12}(p^3 + q^3)$	$\frac{bh^2}{24} = \frac{Ah}{12}$	$\frac{I_y}{p}$ za $p > q$	$\frac{4}{81}bh^2$
	-	$r^2\pi = \frac{d^2\pi}{4}$	$\frac{r^4\pi}{4} = \frac{d^4\pi}{64}$	$\frac{r^4\pi}{4} = \frac{d^4\pi}{64}$	$\frac{r^3\pi}{4} = \frac{d^3\pi}{32}$	$\frac{r^3\pi}{4} = \frac{d^3\pi}{32}$	$\frac{2r^3}{3} = \frac{d^3}{12}$
	$e = \frac{r \sin \alpha}{3\alpha}$	$r^2\alpha$	$\frac{r^4}{72\alpha}(18\alpha^2 + 9\alpha \sin 2\alpha - \sin^2 \alpha)$	$\frac{r^4}{8}(2\alpha - \sin 2\alpha)$	$\frac{I_x}{e}$	$\frac{I_y}{r \sin \alpha}$	$\frac{4r^3 \sin \alpha}{3}$

Formule i tabele za ispit iz Otpornosti materijala

Tabela II Karakteristike poprečnih presjeka – nastavak

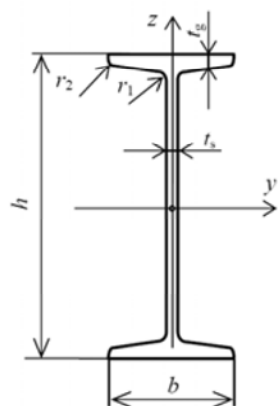
Presjek	Položaj težišta	Površina A	Moment inercije				
			I_x	I_y	W_x	W_y	$S_x (Q_x)$
	-	$b_2 h_2 - b_1 h_1$	$\frac{b_2 h_2^3 - b_1 h_1^3}{12}$	$\frac{h_2 b_2^3 - h_1 b_1^3}{12}$	$\frac{2I_x}{h_2}$	$\frac{2I_y}{b_2}$	$\frac{b_2 h_2^2 - b_1 h_1^2}{8}$
 $d_1 = 2r_1$ $d_2 = 2r_2$ $\psi = d_1 / d_2$	-	$(r_2^2 - r_1^2)\pi =$ $(d_2^2 - d_1^2)\frac{\pi}{4}$	$(r_2^4 - r_1^4)\frac{\pi}{4} =$ $(d_2^4 - d_1^4)\frac{\pi}{64}$	$(r_2^4 - r_1^4)\frac{\pi}{4} =$ $(d_2^4 - d_1^4)\frac{\pi}{64}$	$\frac{(d_2^4 - d_1^4)\pi}{32d_2} =$ $\frac{(r_2^4 - r_1^4)\pi}{4r_2} =$ $(1 - \psi^4)\frac{d_2^3\pi}{32}$	$\frac{(d_2^4 - d_1^4)\pi}{32d_2} =$ $\frac{(r_2^4 - r_1^4)\pi}{4r_2} =$ $(1 - \psi^4)\frac{d_2^3\pi}{32}$	$\frac{2(r_2^3 - r_1^3)}{3} =$ $\frac{d_2^3 - d_1^3}{12} =$ $(1 - \psi^3)\frac{d_2^3}{12}$
	-	$\frac{3\sqrt{3}a^2}{2} =$ $2\sqrt{3}a^2$	$\frac{5\sqrt{3}a^4}{16}$	$\frac{5\sqrt{3}a^4}{16}$	$\frac{5a^3}{8}$	$\frac{5\sqrt{3}a^3}{16}$	$\frac{a^3}{2}$
	$e = \frac{h_1^2 b_1 + h_2^2 b_2 + 2h_1 h_2}{2(h_1 b_1 + h_2 b_2)}$	$h_1 b_1 + h_2 b_2$	$\frac{b_1 h_1^3}{12} + b_1 h_1 \left(e - \frac{h_1}{2} \right)^2 + \frac{b_2 h_2^3}{12} + b_2 h_2 \left(h_1 + \frac{h_2}{2} - e \right)^2$	$\frac{h_1 b_1^3}{12} + \frac{h_2 b_2^3}{12}$	$\frac{I_x}{e}$	$\frac{2I_y}{b_2}$	$\frac{b_1 e^2}{2}$

Formule i tabele za ispit iz Otpornosti materijala

Tabela II Karakteristike nekih čeličnih profila

I-profil

(DIN 1025)



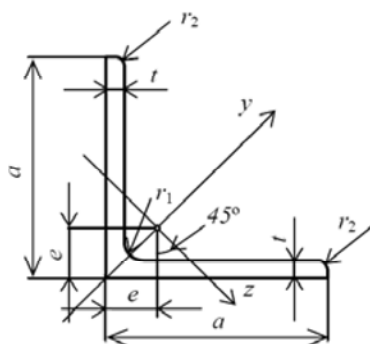
Oznaka	Osnovne mjere						Površina A	y-osa			z-osa		
	h	b	t_s	t_g	r_1	r_2		I_y	i_y	W_y	I_z	i_z	W_z
	mm	mm	mm	mm	mm	mm	cm ²	cm ⁴	mm	cm ³	cm ⁴	mm	cm ³
80	80.00	42.00	3.90	5.90	3.90	2.30	7.57	77.80	32.00	19.50	6.29	9.10	3.00
100	100.00	50.00	4.50	6.80	4.50	2.70	10.60	171.00	40.10	34.20	12.20	10.70	4.88
120	120.00	58.00	5.10	7.70	5.10	3.10	14.20	328.00	48.10	54.70	21.50	12.30	7.41
140	140.00	66.00	5.70	8.60	5.70	3.40	18.20	573.00	56.10	81.90	35.20	14.00	10.70
160	160.00	74.00	6.30	9.50	6.30	3.80	22.80	935.00	64.00	117.00	54.70	15.50	14.80
180	180.00	82.00	6.90	10.40	6.90	4.10	27.90	1450.00	72.00	161.00	81.30	17.10	19.80
200	200.00	90.00	7.50	11.30	7.50	4.50	33.40	2140.00	80.00	214.00	117.00	18.70	26.00
220	220.00	98.00	8.10	12.20	8.10	4.90	39.50	3060.00	88.00	278.00	162.00	20.20	33.10
240	240.00	106.00	8.70	13.10	8.70	5.20	46.10	4250.00	95.90	354.00	221.00	22.00	41.70
260	260.00	113.00	9.40	14.10	9.40	5.60	53.30	5740.00	104.00	442.00	288.00	23.20	51.00
280	280.00	119.00	10.10	15.20	10.10	6.10	61.00	7590.00	111.00	542.00	364.00	24.50	61.20
300	300.00	125.00	10.80	16.20	10.80	6.50	69.00	9800.00	119.00	653.00	451.00	25.60	72.20
320	320.00	131.00	11.50	17.30	11.50	6.90	77.70	12510.00	127.00	782.00	555.00	26.70	84.70
340	340.00	137.00	12.20	18.30	12.20	7.30	86.70	15700.00	135.00	923.00	674.00	28.00	98.40
360	360.00	143.00	13.00	19.50	13.00	7.80	97.00	19610.00	142.00	1090.00	818.00	29.00	114.00
380	380.00	149.00	13.70	20.50	13.70	8.20	107.00	24010.00	150.00	1260.00	975.00	30.20	131.00
400	400.00	155.00	14.40	21.60	14.40	8.60	118.00	29210.00	157.00	1460.00	1160.00	31.30	149.00
425	425.00	163.00	15.30	23.00	15.30	9.20	132.00	36970.00	167.00	1740.00	1440.00	33.00	176.00
450	450.00	170.00	16.20	24.30	16.20	9.70	147.00	45850.00	177.00	2040.00	1730.00	34.30	203.00
475	475.00	178.00	17.10	25.60	17.10	10.30	163.00	56480.00	186.00	2380.00	2090.00	36.00	235.00
500	500.00	185.00	18.00	27.00	18.00	10.80	179.00	68740.00	196.00	2750.00	2480.00	37.20	268.00
550	550.00	200.00	19.00	30.00	19.00	11.90	212.00	99180.00	216.00	3610.00	3490.00	40.20	349.00
600	600.00	215.00	21.60	32.40	21.60	13.00	254.00	139000.00	234.00	4630.00	4670.00	43.00	434.00

Formule i tabele za ispit iz Otpornosti materijala

Tabela II Karakteristike nekih čeličnih profila – nastavak

Ravnokraki L-profil

(DIN EN 10056-1)



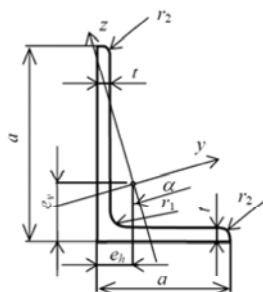
Oznaka	Osnovne mjere				Površina A	y-osa			z-osa		
	$a \times t$	r_1	r_2	e		I_y	i_y	W_y	I_z	i_z	W_z
L	mm	mm	mm	mm	cm ²	cm ⁴	mm	cm ³	cm ⁴	mm	cm ³
20x3	20x3	3.50	1.75	0.60	1.12	0.62	7.40	0.44	0.15	3.70	0.18
25x3	25x3	3.50	1.75	0.73	1.42	1.27	9.50	0.72	0.31	4.70	0.30
25x4	25x4	3.50	1.75	0.76	1.85	1.61	9.30	0.91	0.40	4.70	0.37
30x3	30x3	5.00	2.50	0.84	1.74	2.24	11.40	1.06	0.57	5.70	0.48
30x4	30x4	5.00	2.50	0.89	2.27	2.85	11.20	1.34	0.76	5.80	0.60
35x4	35x4	5.00	2.50	1.00	2.67	4.68	13.30	1.89	1.24	6.80	0.88
40x4	40x4	6.00	3.00	1.12	3.08	7.09	15.20	2.51	1.86	7.80	1.17
40x5	40x5	6.00	3.00	1.16	3.79	8.64	15.10	3.05	2.22	7.70	1.35
45x4	45x4	7.00	3.50	1.23	3.49	10.20	17.10	3.21	2.68	8.80	1.54
45x5	45x5	7.00	3.50	1.28	3.49	10.20	17.10	3.21	2.68	8.80	1.54
50x5	50x5	7.00	3.50	1.40	4.80	17.40	19.00	4.92	4.59	9.80	2.32
50x6	50x6	7.00	3.50	1.45	5.69	20.40	18.90	5.77	5.24	9.60	2.56
60x5	60x5	8.00	4.00	1.64	5.82	30.70	23.00	7.24	8.03	11.70	3.46
60x6	60x6	8.00	4.00	1.69	6.91	36.10	22.90	8.51	9.43	11.70	3.95
60x8	60x8	8.00	4.00	1.77	9.03	46.10	22.60	10.87	12.10	11.60	4.83
65x7	65x7	9.00	4.50	1.85	8.70	53.00	24.70	11.53	13.80	12.60	5.27
70x6	70x6	9.00	4.50	1.93	8.13	58.50	26.80	11.82	15.30	13.70	5.61
70x7	70x7	9.00	4.50	1.97	9.40	67.10	26.70	13.56	17.60	13.70	6.32
75x8	75x8	9.00	4.50	2.13	11.50	93.30	28.50	17.59	24.40	14.60	8.10
80x8	80x8	10.00	5.00	2.26	12.30	115.00	30.60	20.33	29.60	15.50	9.26
80x10	80x10	10.00	5.00	2.34	15.10	139.00	30.30	24.57	35.90	15.40	10.80
90x7	90x7	11.00	5.50	2.45	12.20	147.00	34.60	23.10	38.30	17.70	11.05
90x9	90x9	11.00	5.50	2.54	15.50	184.00	34.50	28.91	47.80	17.60	13.31
100x8	100x8	12.00	6.00	2.74	15.50	230.00	38.50	32.53	59.90	19.60	15.46
100x10	100x10	12.00	6.00	2.82	19.20	280.00	38.20	39.60	73.30	19.50	18.38
100x12	100x12	12.00	6.00	2.90	22.70	328.00	38.00	46.39	86.20	19.50	21.02
120x10	120x10	13.00	6.50	3.31	23.30	479.00	46.30	56.45	129.00	23.60	27.56
120x12	120x12	13.00	6.50	3.40	27.50	584.00	46.00	68.83	152.00	23.50	31.61
130x12	130x12	14.00	7.00	3.64	30.00	750.00	50.00	81.59	194.00	25.40	37.69
150x12	150x12	16.00	8.00	4.12	34.80	1170.00	58.00	110.31	303.00	29.50	52.00
150x15	150x15	16.00	8.00	4.25	43.00	1430.00	57.60	134.82	370.00	29.30	61.56
160x15	160x15	17.00	8.50	4.49	46.10	1750.00	61.50	154.68	453.00	31.40	71.34
180x16	180x16	18.00	9.00	5.02	55.40	2690.00	69.60	211.35	679.00	35.00	95.64
180x18	180x18	18.00	9.00	5.10	61.90	2970.00	69.30	233.35	757.00	34.90	104.96
200x16	200x16	18.00	9.00	5.52	61.80	3722.00	77.60	263.19	960.00	39.40	122.98
200x18	200x18	18.00	9.00	5.60	69.10	4132.00	77.30	292.18	1067.00	39.30	134.73
200x20	200x20	18.00	9.00	5.68	76.30	4529.00	77.00	320.25	1172.00	39.20	145.90
200x24	200x24	18.00	9.00	5.84	90.60	5284.00	76.40	373.64	1378.00	39.00	166.85

Formule i tabele za ispit iz Otpornosti materijala

Tabela II Karakteristike nekih čeličnih profila – nastavak

Raznokraki L-profil

(DIN EN 10056-1)



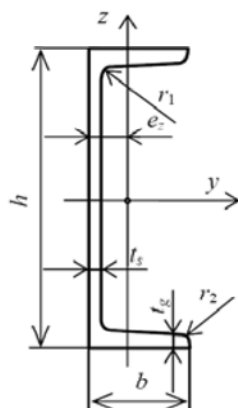
Oznaka	Osnovne mjere						Površina A	y-osa			z-osa		
	$a \times b \times t$	r_1	r_2	e_b	e_v	α		I_y	i_y	W_y	I_z	i_z	W_z
L	mm	mm	mm	cm	cm	rad	cm ²	cm ⁴	mm	cm ³	cm ⁴	mm	cm ³
30x20x3	30x20x3	4.00	2.00	0.502	0.99	0.404	1.42	1.43	10.00	0.70	0.25	4.20	0.24
30x20x4	30x20x4	4.00	2.00	0.541	1.03	0.399	1.85	1.81	9.90	0.89	0.33	4.20	0.32
40x20x4	40x20x4	4.00	2.00	0.481	1.47	0.247	2.25	3.79	13.00	1.47	0.39	4.20	0.34
40x25x4	40x25x4	4.00	2.00	0.623	1.36	0.364	2.40	4.35	13.30	1.62	0.70	5.30	0.52
45x30x4	45x30x4	4.50	2.25	0.739	1.48	0.408	2.87	6.65	15.20	2.17	1.18	6.40	0.76
50x30x5	50x30x5	5.00	2.50	0.741	1.73	0.339	3.78	10.40	16.60	3.12	1.56	6.40	0.95
60x30x5	60x30x5	6.00	3.00	0.684	2.17	0.252	4.29	16.50	19.60	4.23	1.69	6.30	0.95
60x40x5	60x40x5	6.00	3.00	0.972	1.96	0.409	4.79	19.80	20.30	4.84	3.50	8.60	1.67
60x40x6	60x40x6	6.00	3.00	1.01	2.00	0.407	5.68	23.10	20.20	5.67	4.12	8.50	1.99
65x50x5	65x50x5	6.50	3.50	1.25	1.99	0.523	5.54	28.80	22.80	6.36	6.21	10.60	2.63
70x50x6	70x50x6	6.00	3.00	1.25	2.23	0.460	6.88	39.90	24.10	8.28	7.94	10.70	3.18
75x50x6	75x50x6	7.00	3.50	1.21	2.44	0.410	7.19	46.62	25.46	9.10	8.36	10.78	3.17
75x50x8	75x50x8	7.00	3.50	1.29	2.52	0.406	9.41	59.65	25.17	11.74	10.76	10.69	4.10
80x40x6	80x40x6	7.00	3.50	0.884	2.85	0.253	6.89	47.60	26.30	9.14	4.90	8.40	2.06
80x40x8	80x40x8	7.00	3.50	0.963	2.94	0.248	9.01	60.90	26.00	11.85	6.41	8.40	2.75
80x60x7	80x60x7	8.00	4.00	1.52	2.51	0.500	9.38	72.00	27.70	12.98	15.40	12.80	5.32
100x50x6	100x50x6	9.00	4.50	1.05	3.51	0.256	8.73	95.20	33.00	14.51	9.78	10.60	3.24
100x50x8	100x50x8	9.00	4.50	1.13	3.60	0.252	11.50	123.00	32.80	18.96	12.60	10.50	4.27
100x65x7	100x65x7	10.00	5.00	1.51	3.23	0.393	11.20	128.00	33.90	18.75	21.60	13.90	6.19
100x65x8	100x65x8	10.00	5.00	1.55	3.27	0.392	12.67	144.20	33.74	21.18	24.80	13.99	7.14
100x65x10	100x65x10	10.00	5.00	1.63	3.36	0.389	15.61	174.90	33.47	25.86	30.15	13.90	8.72
100x75x8	100x75x8	10.00	5.00	1.87	3.10	0.500	13.47	162.50	34.74	23.38	34.64	16.04	9.48
100x75x9	100x75x9	10.00	5.00	1.91	3.15	0.500	15.10	181.00	34.70	26.14	37.80	15.90	10.50
100x75x10	100x75x10	10.00	5.00	1.95	3.19	0.498	16.61	197.20	34.46	28.51	42.17	15.94	11.56
100x75x11	100x75x11	10.00	5.00	1.99	3.23	0.497	18.20	214.00	34.40	31.03	45.40	15.80	12.77
100x75x12	100x75x12	10.00	5.00	2.03	3.27	0.495	19.67	229.60	34.16	33.32	49.47	15.86	13.55
120x80x8	120x80x8	11.00	5.50	1.87	3.83	0.412	15.50	261.00	41.00	31.71	45.80	17.20	10.84
120x80x10	120x80x10	11.00	5.50	1.95	3.92	0.410	19.10	318.00	40.70	38.86	56.10	17.10	13.45
120x80x12	120x80x12	11.00	5.50	2.03	4.00	0.407	22.70	371.00	40.40	45.53	66.10	17.10	15.86
125x75x8	125x75x8	11.00	5.50	1.68	4.14	0.345	15.49	274.00	42.06	32.47	40.93	16.26	9.75
125x75x10	125x75x10	11.00	5.50	1.76	4.23	0.343	19.13	334.20	41.80	39.86	49.86	16.14	11.96
125x75x12	125x75x12	11.00	5.50	1.84	4.31	0.340	22.69	391.00	41.51	46.92	58.47	16.05	14.10
135x65x8	135x65x8	11.00	5.50	1.34	4.78	0.240	15.49	307.10	44.53	34.95	29.45	13.79	7.45
135x65x10	135x65x10	11.00	5.50	1.42	4.88	0.238	19.13	374.70	44.26	42.99	35.86	13.69	9.18
150x75x9	150x75x9	12.00	6.00	1.57	5.26	0.256	19.59	482.90	49.64	49.17	50.00	16.01	11.15
150x75x10	150x75x10	12.00	6.00	1.61	5.31	0.255	21.65	530.80	49.51	54.25	55.13	15.96	12.30
150x75x12	150x75x12	12.00	6.00	1.69	5.40	0.252	25.71	623.20	49.23	64.11	64.69	15.86	14.55
150x75x15	150x75x15	12.00	6.00	1.81	5.52	0.248	31.65	753.50	48.79	78.23	78.59	15.76	17.86
150x90x10	150x90x10	12.00	6.00	2.04	5.00	0.346	23.15	590.90	50.52	58.50	88.28	19.53	17.55
150x90x12	150x90x12	12.00	6.00	2.12	5.08	0.344	27.51	694.50	50.24	69.10	103.7	19.41	20.72
160x90x15	160x90x15	12.00	6.00	2.23	5.21	0.340	33.90	840.60	49.79	84.24	126.0	19.28	25.30
150x100x1	150x100x1	12.00	6.00	2.34	4.81	0.413	24.15	637.00	51.35	61.99	114.2	21.74	21.57
150x100x1	150x100x1	12.00	6.00	2.42	4.90	0.412	28.71	749.00	51.07	73.22	134.2	21.62	25.44
200x100x1	200x100x1	15.00	7.50	2.01	6.93	0.257	29.24	1294.00	66.60	98.88	135.2	21.50	22.36
200x100x1	200x100x1	15.00	7.50	2.10	7.03	0.256	34.80	1528.00	66.30	117.0	159.2	21.39	26.52
200x100x1	200x100x1	15.00	7.50	2.22	7.16	0.254	42.99	1864.00	65.84	143.6	193.7	21.23	32.58
200x150x1	200x150x1	15.00	7.50	3.61	6.08	0.505	40.80	2025.00	70.45	145.4	430.2	32.47	58.62
200x150x1	200x150x1	15.00	7.50	3.73	6.21	0.503	50.49	2476.00	70.03	178.4	525.7	32.27	71.73

Formule i tabele za ispit iz Otpornosti materijala

Tabela II Karakteristike nekih čeličnih profila – nastavak

U-profil

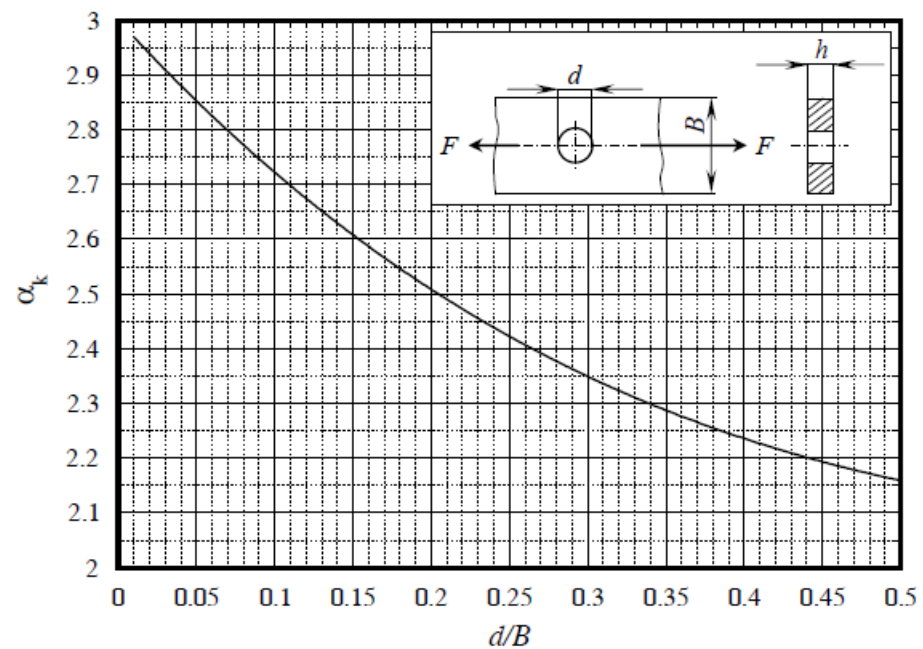
(DIN 1026-1)



Oznaka	Osnovne mjere							Površina A	y-osa			z-osa		
	h	b	t_s	t_g	r_1	r_2	e_z		I_y	i_y	W_y	I_z	i_z	W_z
U	mm	mm	mm	mm	mm	mm	mm	cm ²	cm ⁴	mm	cm ³	cm ⁴	mm	cm ³
30x15	30.00	15.00	4.00	4.50	4.50	2.00	5.20	2.21	2.53	10.70	1.69	0.38	4.20	0.39
30	30.00	33.00	5.00	7.00	7.00	3.50	13.10	5.44	6.39	10.80	4.26	5.33	9.90	2.68
40	40.00	35.00	5.00	7.00	7.00	3.50	13.30	6.21	14.10	15.00	7.05	6.68	10.40	3.08
40x20	40.00	20.00	5.00	5.50	5.00	2.50	6.70	3.66	7.58	14.40	3.79	1.14	5.60	0.86
50	50.00	38.00	5.00	7.00	7.00	3.50	13.70	7.12	26.40	19.20	10.56	9.12	11.30	3.75
50x25	50.00	25.00	5.00	6.00	6.00	3.00	8.10	4.92	16.80	18.50	6.72	2.49	7.10	1.47
60	60.00	30.00	6.00	6.00	6.00	3.00	9.10	6.46	31.60	22.10	10.53	4.51	8.40	2.16
65	65.00	42.00	5.50	7.50	7.50	4.00	14.20	9.03	57.50	25.20	17.69	14.10	12.50	5.07
80	80.00	45.00	6.00	8.00	8.00	4.00	14.50	11.00	106.00	31.00	26.50	19.40	13.30	6.36
100	100.00	50.00	6.00	8.50	8.50	4.50	15.50	13.50	206.00	39.10	41.20	29.30	14.70	8.49
120	120.00	55.00	7.00	9.00	9.00	4.50	16.00	17.00	364.00	46.20	60.67	43.20	15.90	11.08
140	140.00	60.00	7.00	10.00	10.00	5.00	17.50	20.40	605.00	54.50	86.43	62.70	17.50	14.75
160	160.00	65.00	7.50	10.50	10.50	5.50	18.40	24.00	925.00	62.10	115.63	85.30	18.90	18.30
180	180.00	70.00	8.00	11.00	11.00	5.50	19.20	28.00	1350.00	69.50	150.00	114.00	20.20	22.44
200	200.00	75.00	8.50	11.50	11.50	6.00	20.10	32.20	1910.00	77.00	191.00	148.00	21.40	26.96
220	220.00	80.00	9.00	12.50	12.50	6.50	21.40	37.40	2690.00	84.80	244.55	197.00	23.00	33.62
240	240.00	85.00	9.50	13.00	13.00	6.50	22.30	42.30	3600.00	92.20	300.00	248.00	24.20	39.55
260	260.00	90.00	10.00	14.00	14.00	7.00	23.60	48.30	4820.00	99.90	370.77	317.00	25.60	47.74
280	280.00	95.00	10.00	15.00	15.00	7.50	25.30	53.30	6280.00	109.00	448.57	399.00	27.40	57.25
300	300.00	100.00	10.00	16.00	16.00	8.00	27.00	58.80	8030.00	117.00	535.33	495.00	29.00	67.81
320	320.00	100.00	14.00	17.50	17.50	8.80	26.00	75.80	10870.00	121.00	679.38	597.00	28.10	80.68
350	350.00	100.00	14.00	16.00	16.00	8.00	24.00	77.30	12840.00	129.00	733.71	570.00	27.20	75.00
380	380.00	102.00	13.50	16.00	16.00	8.00	23.80	80.40	15760.00	140.00	829.47	615.00	27.70	78.64
400	400.00	110.00	14.00	18.00	18.00	9.00	26.50	91.50	20350.00	149.00	1017.50	846.00	30.40	101.32

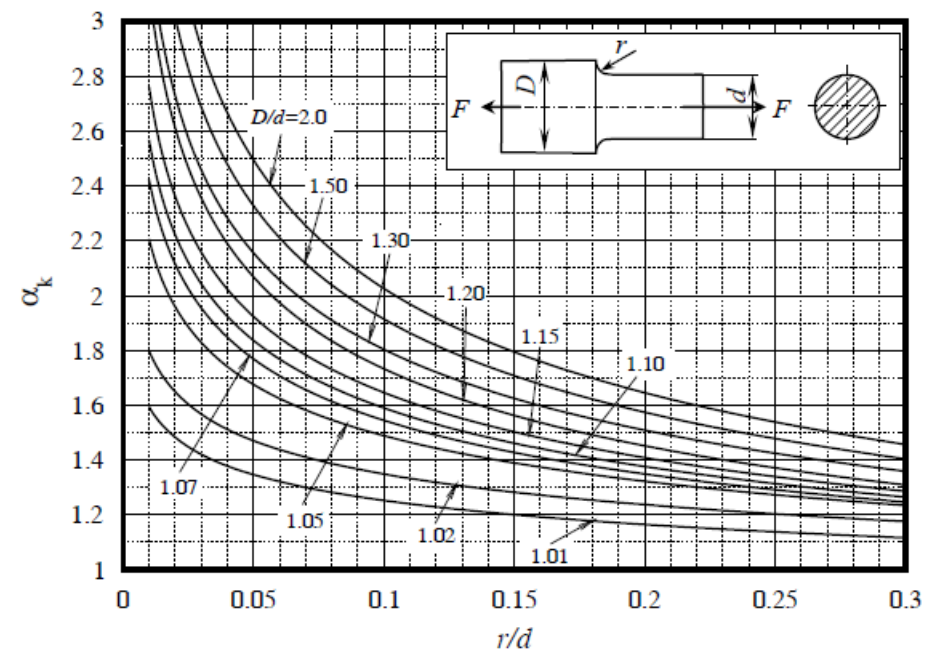
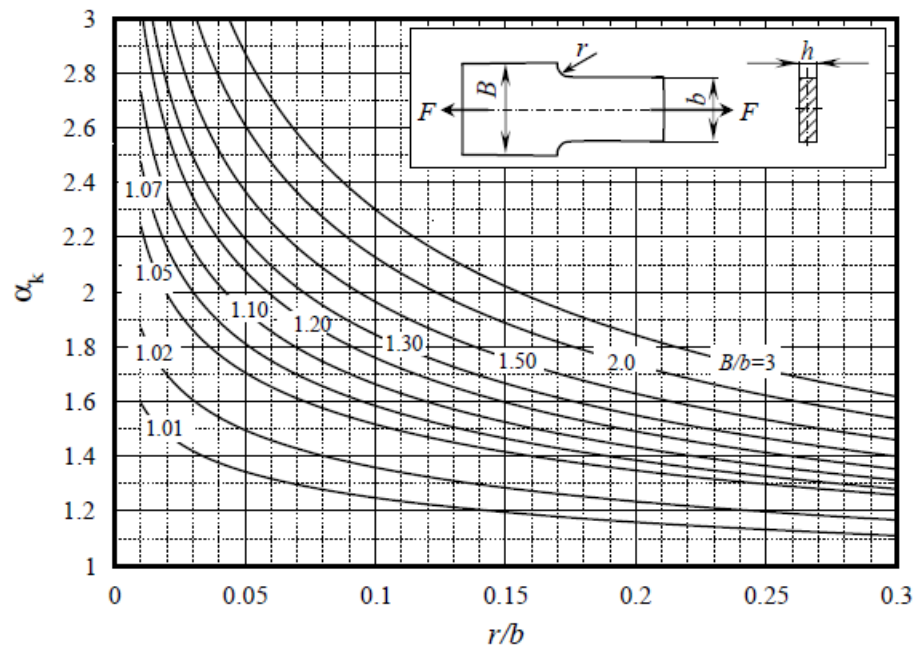
Formule i tabele za ispit iz Otpornosti materijala

Tabela IIIa Koncentracija napona – aksijalno opterećenje elemenata s otvorom



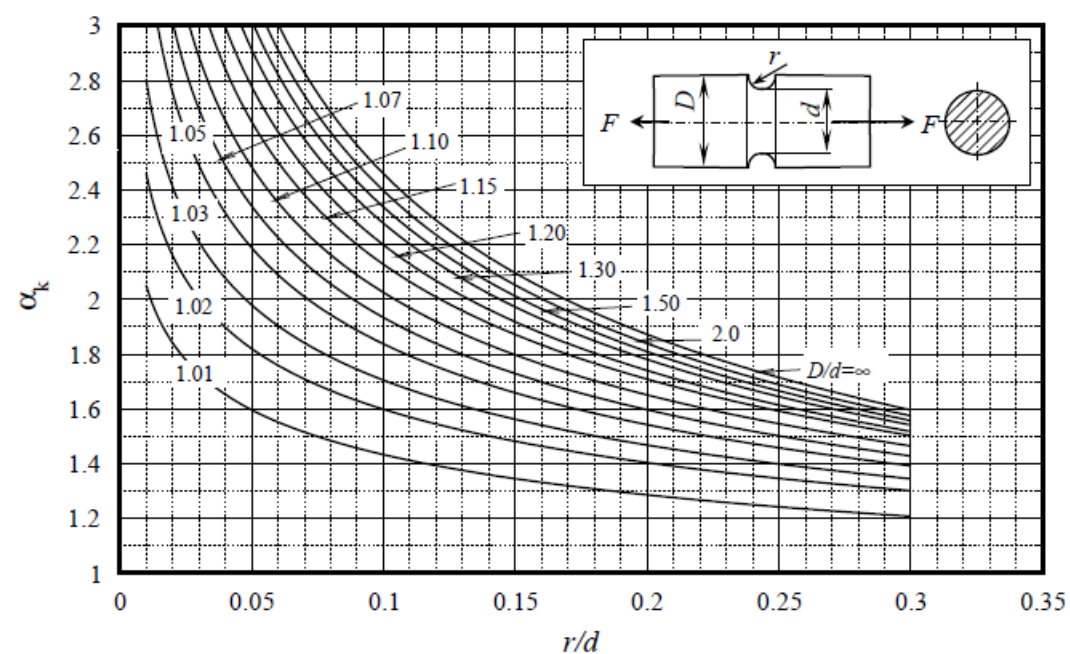
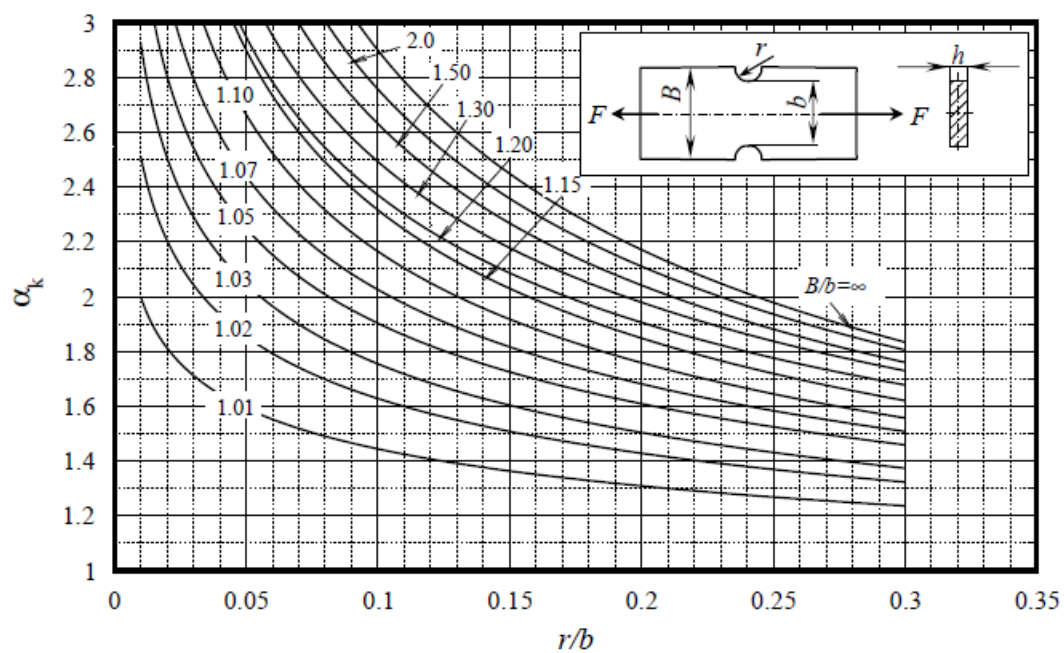
Formule i tabele za ispit iz Otpornosti materijala

Tabela IIIb Koncentracija napona – aksijalno opterećenje elemenata s prelazom



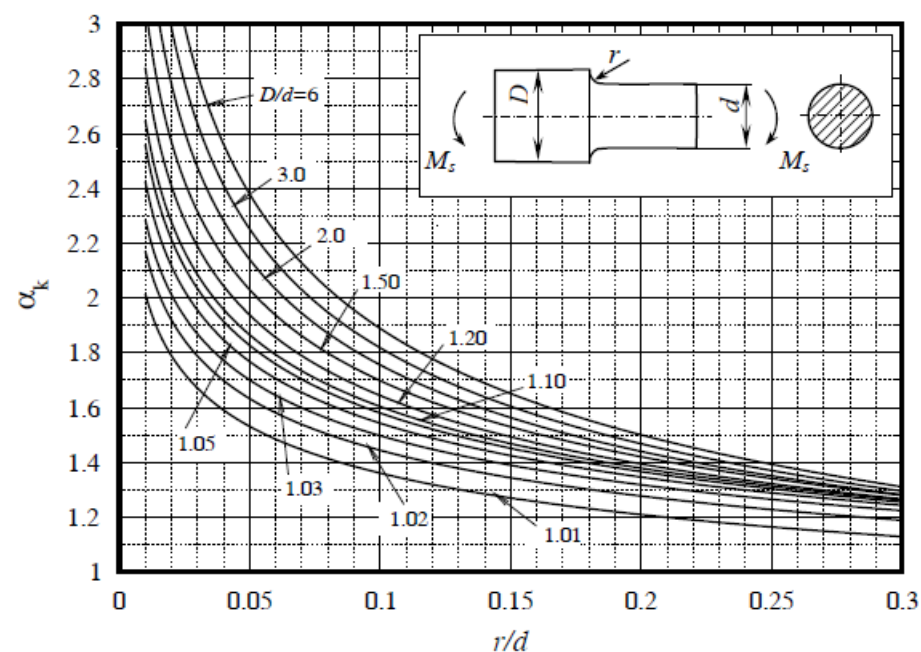
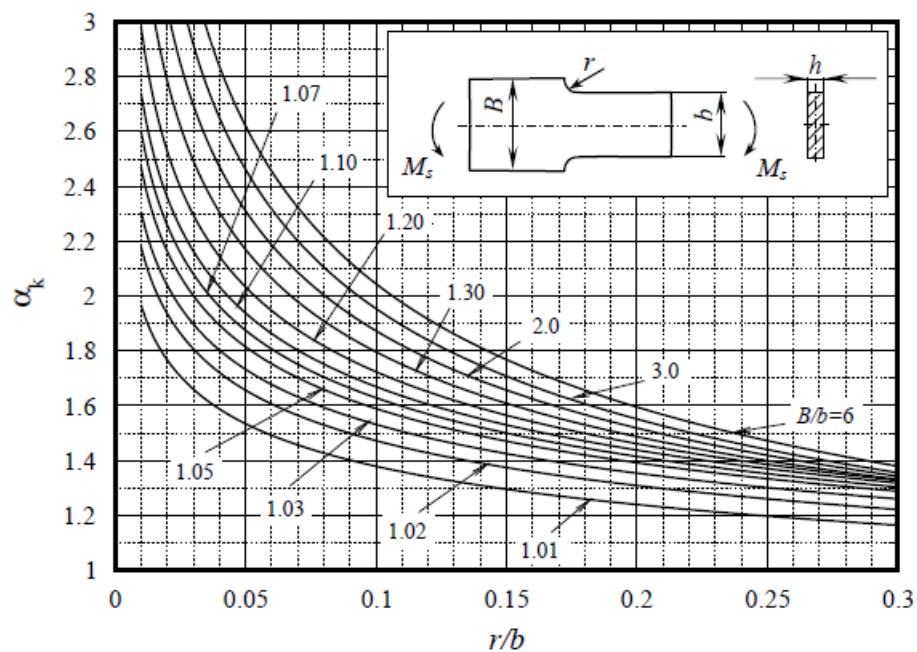
Formule i tabele za ispit iz Otpornosti materijala

Tabela IIIc Koncentracija napona – aksijalno opterećenje elemenata sa žlijebom



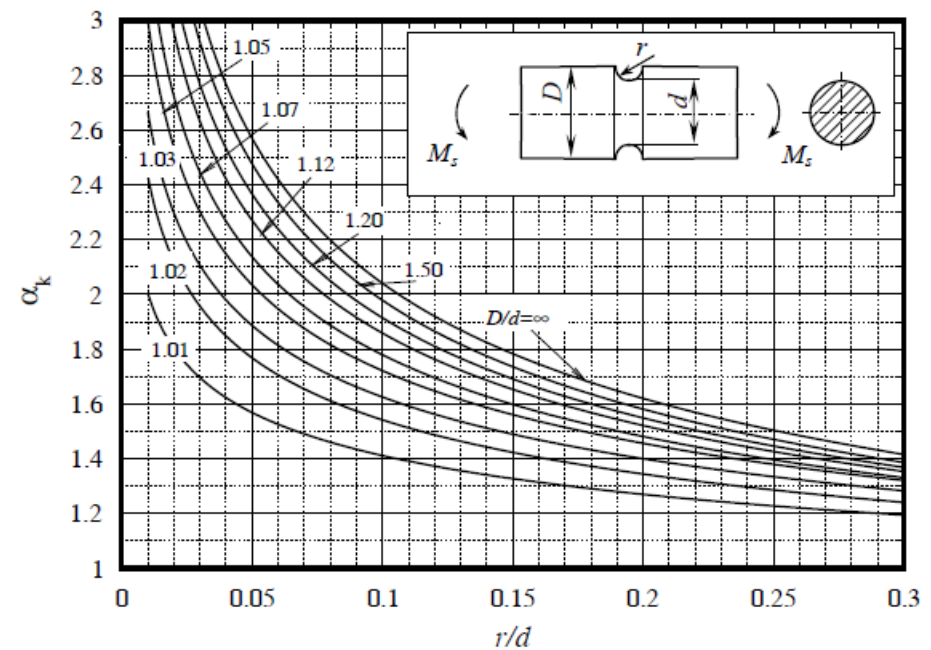
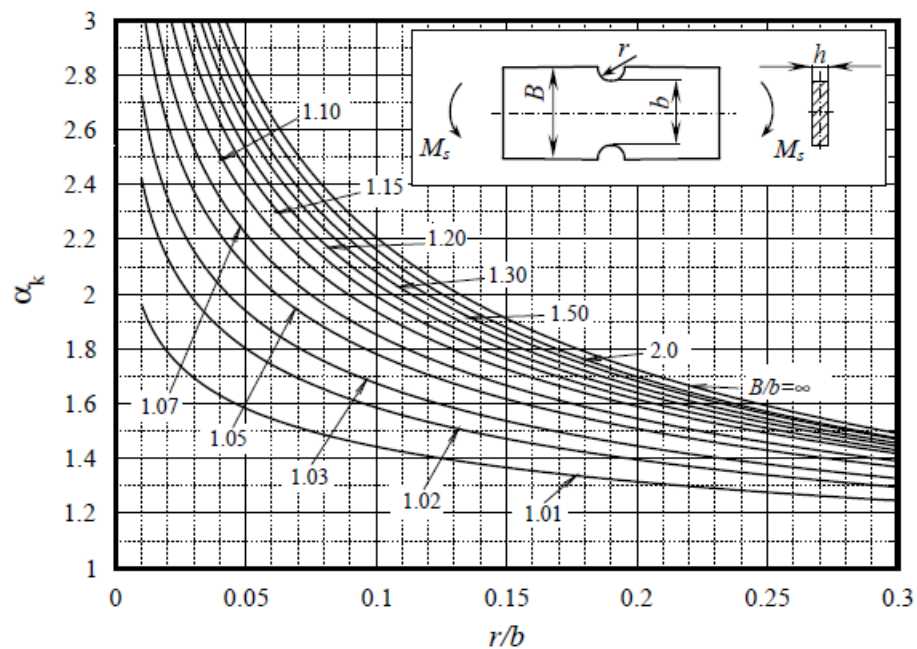
Formule i tabele za ispit iz Otpornosti materijala

Tabela IIId Koncentracija napona – savijanje elemenata s prelazom



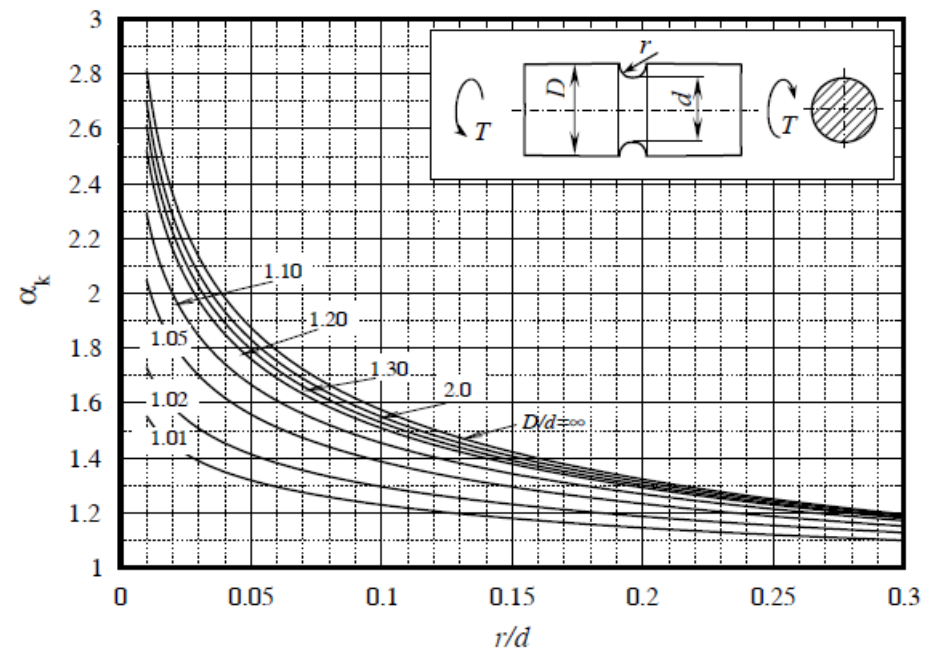
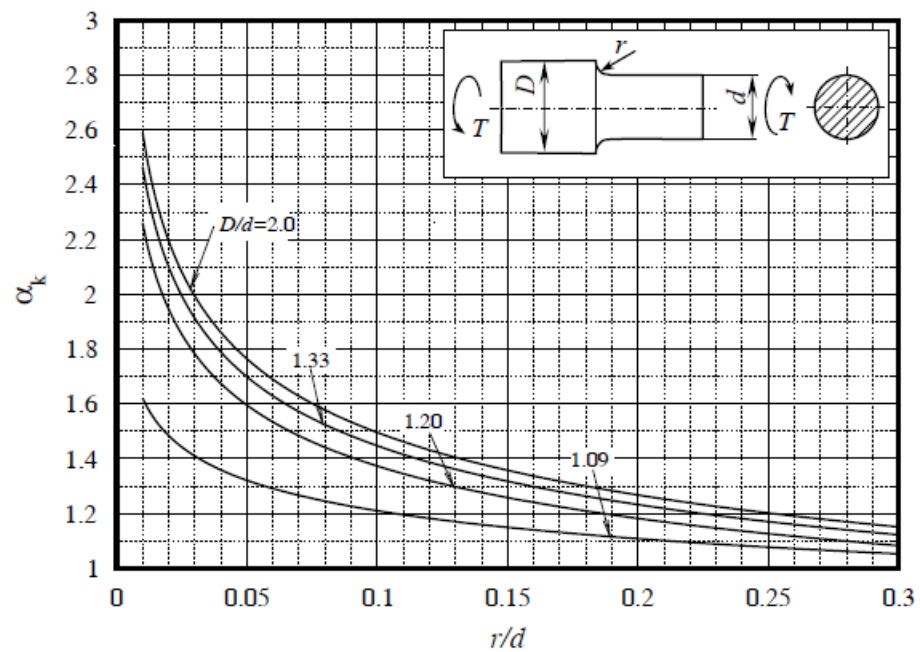
Formule i tabele za ispit iz Otpornosti materijala

Tabela IIIe Koncentracija napona – savijanje elemenata sa žlijebom



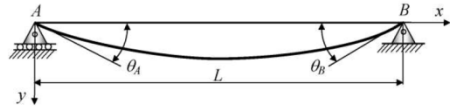
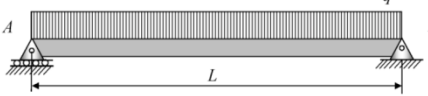
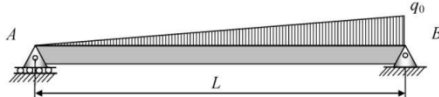
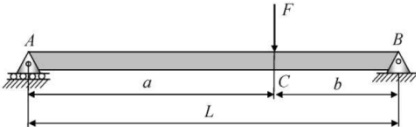
Formule i tabele za ispit iz Otpornosti materijala

Tabela IIIf Koncentracija napona – uvijanje elemenata s prelazom/žlijebom



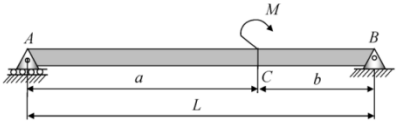
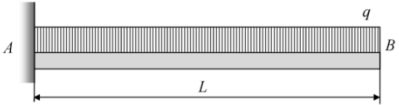
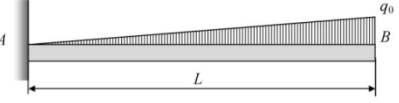
Formule i tabele za ispit iz Otpornosti materijala

Tabela IV Elastične linije osnovnih grednih nosača

I Prosta greda		
A		$y = \frac{qxL^3}{24EI} \left[1 - 2\left(\frac{x}{L}\right)^2 + \left(\frac{x}{L}\right)^3 \right]$ $y_{\max} = \frac{5qL^4}{384EI} \quad \text{za} \quad x = \frac{L}{2}$ $\theta_A = \theta_B = \frac{qL^3}{24EI}$
B		$y = \frac{q_0xL^3}{360EI} \left[7 - 10\left(\frac{x}{L}\right)^2 + 3\left(\frac{x}{L}\right)^3 \right]$ $y_{\max} \approx 0.00652 \frac{q_0L^4}{EI} \quad \text{za} \quad x \approx 0.5193L$ $\theta_A = \frac{7q_0L^3}{360EI} \quad \theta_B = \frac{8q_0L^3}{360EI}$
C		$y = \frac{FbxL}{6EI} \left[1 - 10\left(\frac{x}{L}\right)^2 - \left(\frac{b}{L}\right)^2 \right] \quad \text{za} \quad 0 \leq x \leq a$ $y_{\max} = \frac{FbL^2}{3EI} \left\{ \frac{1}{3} \left[1 - \left(\frac{b}{L}\right)^2 \right] \right\}^{3/2} \quad \text{za} \quad x = \sqrt{\frac{L^2 - b^2}{3}}$ $\theta_A = \frac{Fab}{6EI} \left(1 + \frac{b}{L} \right) \quad \theta_B = \frac{Fab}{6EI} \left(1 + \frac{a}{L} \right)$

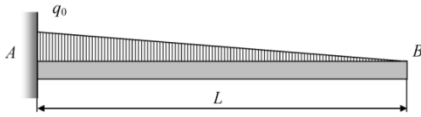
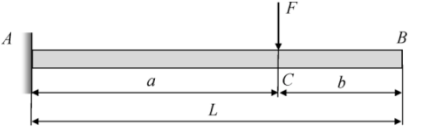
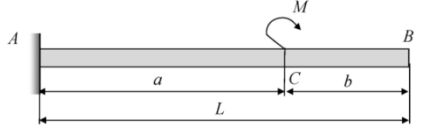
Formule i tabele za ispit iz Otpornosti materijala

Tabela IV Elastične linije osnovnih grednih nosača - nastavak

D	 $y = \frac{MxL}{6EI} \left[-2 - \left(\frac{x}{L}\right)^2 - 3\left(\frac{a}{L}\right)^2 + 6\left(\frac{a}{L}\right)^2 \right] \quad \text{za} \quad 0 \leq x \leq a$ $y_{\max} = \frac{ML^2}{3EI} \left[\frac{1}{3} - \left(\frac{b}{L}\right)^2 \right]^{3/2} \quad \text{za} \quad x = \sqrt{\frac{L^2 - 3b^2}{3}}$ $\theta_A = -\frac{ML}{6EI} \left[1 - 3\left(\frac{b}{L}\right)^2 \right] \quad \theta_B = -\frac{ML}{6EI} \left[1 - 3\left(\frac{a}{L}\right)^2 \right]$
II Konzola	
A	 $y = \frac{qx^2L^2}{24EI} \left[6 - 4\left(\frac{x}{L}\right) + \left(\frac{x}{L}\right)^2 \right]$ $y_{\max} = y_B = \frac{qL^4}{8EI} \quad \text{za} \quad x = L$ $\theta_B = \frac{qL^3}{6EI}$
B	 $y = \frac{q_0x^2L^2}{120EI} \left[20 - 10\left(\frac{x}{L}\right) + \left(\frac{x}{L}\right)^3 \right]$ $y_{\max} = y_B = \frac{11q_0L^4}{120EI} \quad \text{za} \quad x = L$ $\theta_B = \frac{q_0L^3}{8EI}$

Formule i tabele za ispit iz Otpornosti materijala

Tabela IV Elastične linije osnovnih grednih nosača - nastavak

C	 $y = \frac{q_0 x^2 L^2}{120EI} \left[10 - 10 \left(\frac{x}{L} \right) + 5 \left(\frac{x}{L} \right)^2 - \left(\frac{x}{L} \right)^3 \right]$ $y_{\max} = y_B = \frac{q_0 L^4}{30EI} \quad \text{za} \quad x = L$ $\theta_B = \frac{q_0 L^3}{24EI}$
D	 $y = \frac{F x^2 L}{6EI} \left(3 - \frac{x}{L} \right) \quad \text{za} \quad 0 \leq x \leq a$ $y_{\max} = y_B = \frac{F a^2}{6EI} (3L - a) \quad \text{za} \quad x = L$ $\theta_B = \frac{F a^2}{2EI}$
E	 $y = \frac{M x^2}{2EI} \quad \text{za} \quad 0 \leq x \leq a$ $y_B = \frac{M a}{2EI} (2L - a)$ $\theta_B = \frac{M a}{EI}$