

Univerza
v Ljubljani

Fakulteta
*za gradbeništvo
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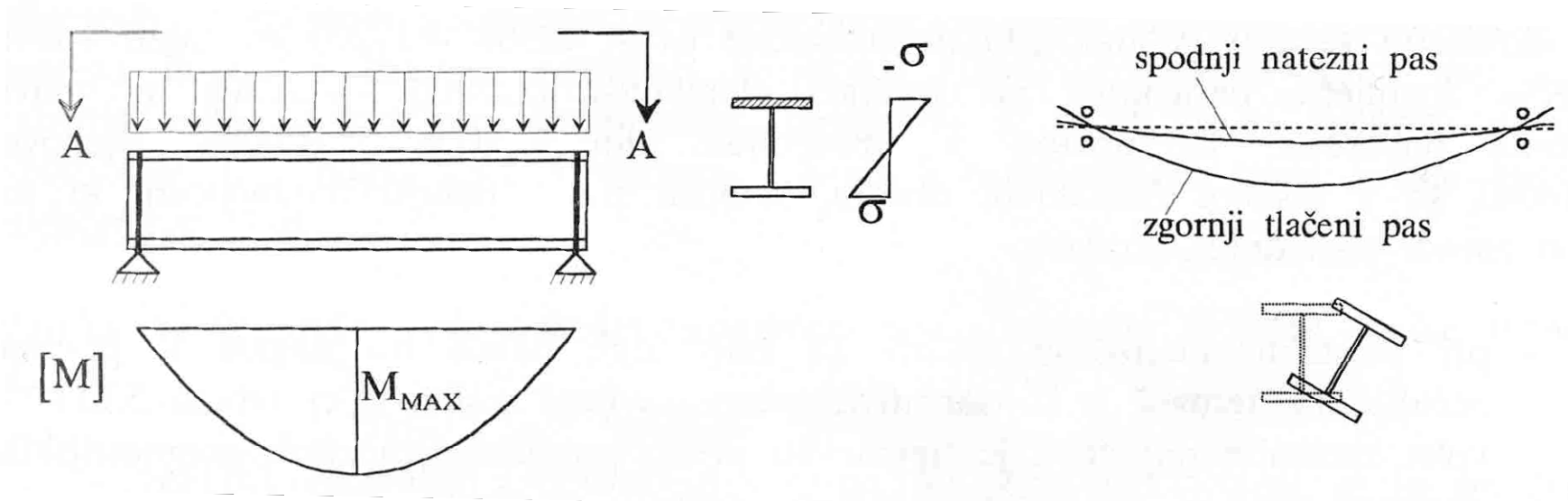
Katedra za metalne konstrukcije

JEKLENE KONSTRUKCIJE I

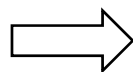
11.0 BOČNA ZVRNITEV UPOGIBNIH NOSILCEV

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Sodelavec: Blaž Čermelj

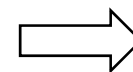
Fenomen bočne zvrnitve



upogib okoli močne osi



tlačen zgornji pas



uklon tlačnega pasu – bočna zvrnitev

Bočna zvrnitev - splošno

$$\frac{M_{Ed}}{M_{b,Rd}} \leq 1,0 \qquad M_{b,Rd} = \chi_{LT} W_y \frac{f_y}{\gamma_{M1}}$$

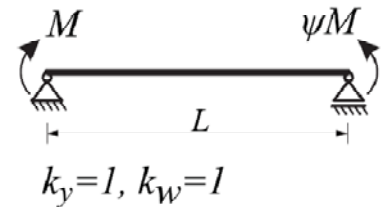










$$\begin{aligned} W_y &= W_{pl,y} && \text{za 1. in 2. razred kompaktnosti} \\ W_y &= W_{el,y} && \text{za 3. razred kompaktnosti} \\ W_y &= W_{eff,y} && \text{za 4. razred kompaktnosti} \end{aligned}$$


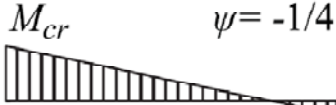
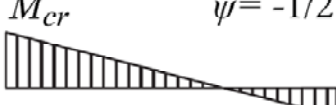
$$\bar{\lambda}_{LT} = \sqrt{\frac{W_y f_y}{M_{cr}}}$$

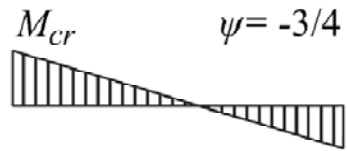

Ni nevarnosti bočne zvrnitve:

$$\bar{\lambda}_{LT} \leq \bar{\lambda}_{LT,0} = 0,4$$

Vrednost koeficienta C_1 – nosilec obremenjen z robnimi momenti

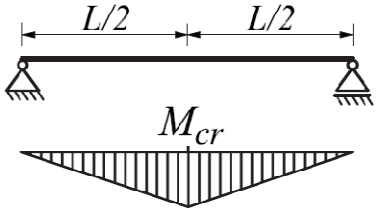
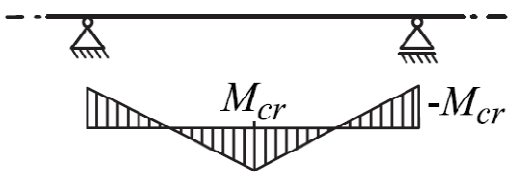
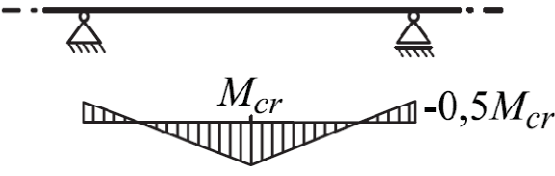
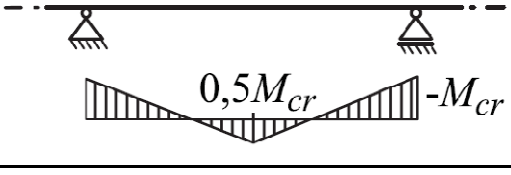
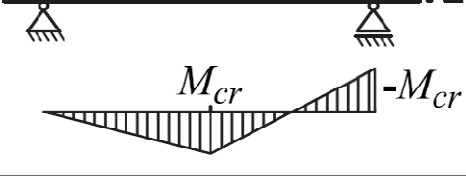
Obtežba in robni pogoji	Potek momentov	$k_z^{1)}$	C_1
 <p>$k_y=1, k_w=1$</p>	 <p>$M_{cr} \quad \psi=+1$</p>	1,0	1,000
		0,7L	1,016
		0,7R	1,016
		0,5	1,000
<p>$k_z=1$</p>  <p>0,7L</p> 	 <p>$M_{cr} \quad \psi=+3/4$</p>	1,0	1,139
		0,7L	1,210
		0,7R	1,109
<p>$k_z=0,5$</p>  <p>0,7R</p> 	 <p>$M_{cr} \quad \psi=+1/2$</p>	1,0	1,312
		0,7L	1,480
		0,7R	1,213
 <p>$k_z=0,5$</p> 	 <p>$M_{cr} \quad \psi=+1/4$</p>	1,0	1,522
		0,7L	1,853
		0,7R	1,329
		0,5	1,516

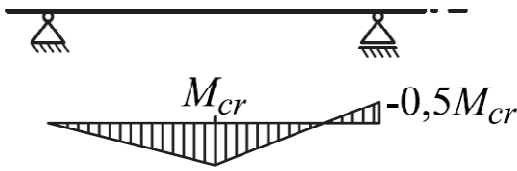
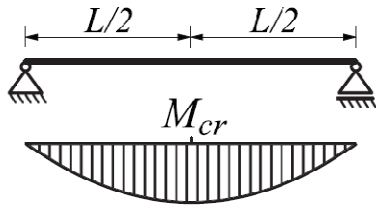

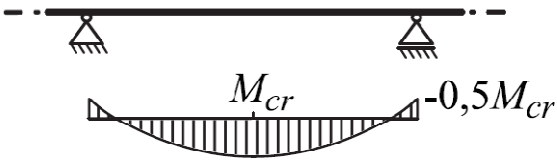
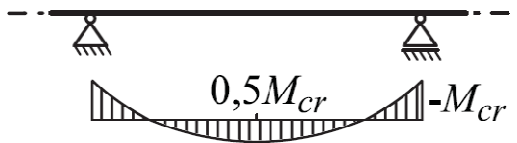
Obtežba in robni pogoji	Potek momentov	$k_z^{1)}$	C_1
	 <p>M_{cr} $\psi=0$</p>	1,0	1,770
		0,7L	2,331
		0,7R	1,453
		0,5	1,753
	 <p>M_{cr} $\psi= -1/4$</p>	1,0	2,047
		0,7L	2,827
		0,7R	1,582
0,5		2,004	
 <p>M_{cr} $\psi= -1/2$</p>	1,0	2,331	
	0,7L	3,078	
	0,7R	1,711	
	0,5	2,230	


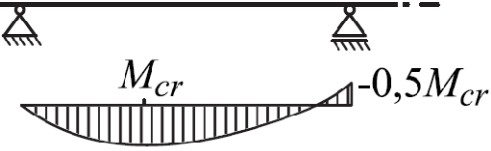


Obtežba in robni pogoji	Potek momentov	$k_z^{1)}$	C_1
		1,0	2,547
		0,7L	2,592
		0,7R	1,829
		0,5	2,352
		1,0	2,555
		0,7L	1,921
		0,7R	1,921
		0,5	2,223

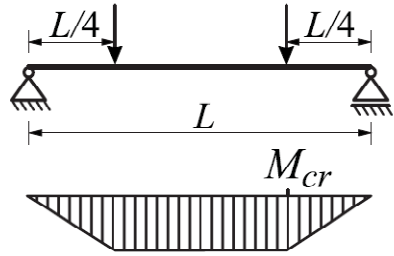
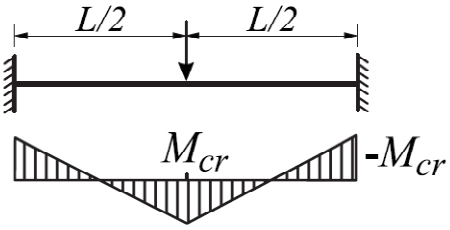
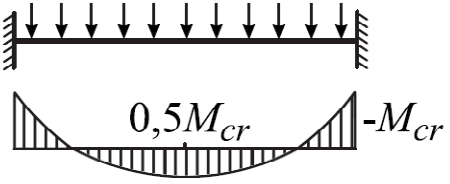
1) 0,7L = levi rob bočno podprt, 0,7R = desni rob bočno podprt

Vrednost koeficientov C_1 , C_2 – prečno obremenjen nosilec


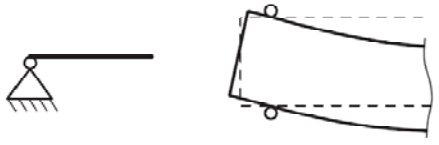
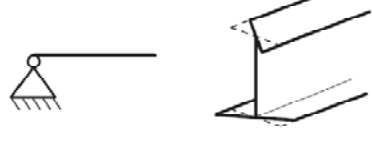
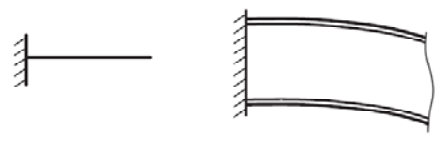
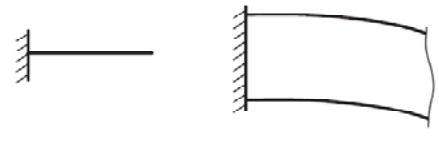
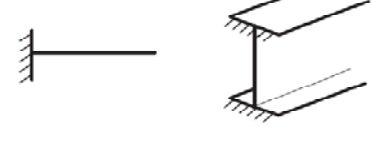
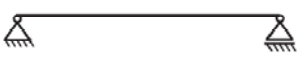
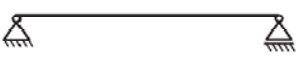
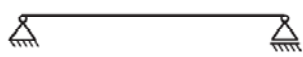
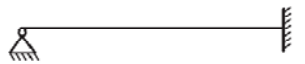
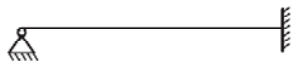
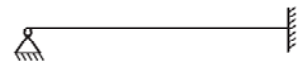



Potek momentov in robni pogoji	k_y	k_z	C_1	C_2
	1	1	1,35	0,55
	1	0,5	1,03	0,45
	1	1	1,70	0,50
	1	1	1,60	0,50
	1	1	2,50	0,50
	1	1	1,52	0,50

Potek momentov in robni pogoji	k_y	k_z	C_1	C_2
	1	1	1,48	0,50
	1	1	1,13	0,46
	1	0,5	0,95	0,41
	1	1	1,39	0,50
	1	1	1,27	0,50
	1	1	2,50	0,50

Potek momentov in robni pogoji	k_y	k_z	C_1	C_2
	1	1	1,29	0,50
	1	1	1,23	0,50
	1	1	2,50	0,50
	1	1	2,40	0,50

Potek momentov in robni pogoji	k_y	k_z	C_1	C_2
	1	1	1,04	0,43
	1	0,5	0,92	0,40
	0,5	1	1,86	1,39
	0,5	0,5	0,94	0,76
	0,5	1	2,58	1,56
	0,5	0,5	1,49	0,90

Uklonski koeficienti

k_y – uklon okoli močne osi		k_z – uklon okoli šibke osi		k_{ω} – uklon okoli močne osi	
					
					
	$k_y = 1,0$		$k_z = 1,0$		$k_{\omega} = 1,0$
	$k_y = 0,7$		$k_z = 0,7$		$k_{\omega} = 0,7$
	$k_y = 0,5$		$k_z = 0,5$		$k_{\omega} = 0,5$

Bočna zvrnitev - splošno

$$\chi_{LT} = \frac{1}{\Phi_{LT} + \sqrt{\Phi_{LT}^2 - \bar{\lambda}_{LT}^2}}, \text{ vendar } \chi_{LT} \leq 1,0$$

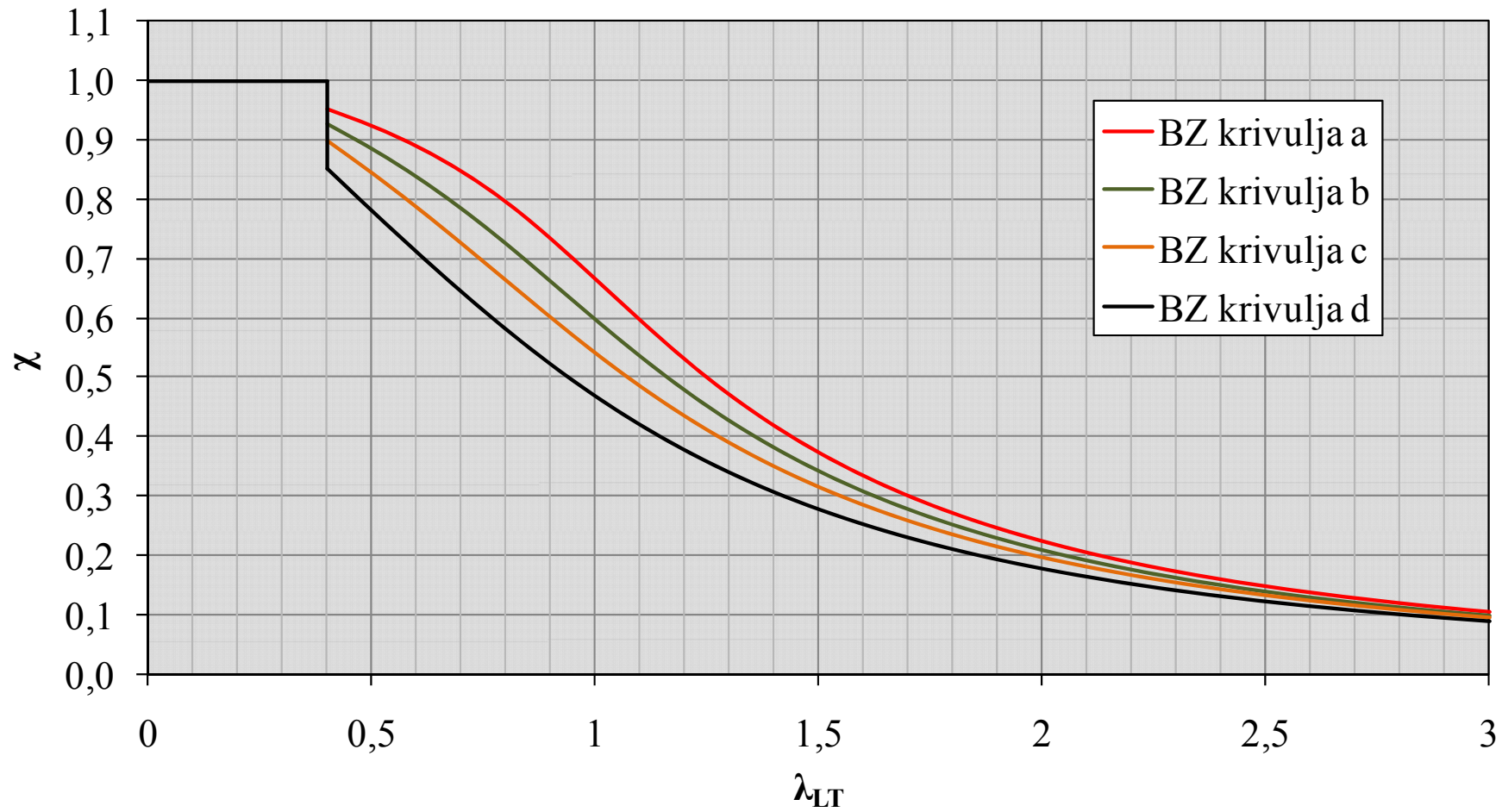
$$\Phi_{LT} = 0,5 \left[1 + \alpha_{LT} (\bar{\lambda}_{LT} - 0,2) + \bar{\lambda}_{LT}^2 \right]$$

α_{LT} faktor nepopolnosti

Uklonska krivulja	a	b	c	d
Faktor nepopolnosti α_{LT}	0,21	0,34	0,49	0,76

Prečni prerez	Omejitve	Uklonska krivulja
Vroče valjani I-prerezi	$h/b \leq 2$ $h/b > 2$	a b
Varjeni I-prerezi	$h/b \leq 2$ $h/b > 2$	c d
Ostali prečni prerezi	-	d

Bočna zvrnitev - splošno



Bočna zvrnitev – vroče valjani in podobni profili

$$\chi_{LT} = \frac{1}{\Phi_{LT} + \sqrt{\Phi_{LT}^2 - \beta \bar{\lambda}_{LT}^{-2}}}, \text{ vendar } \begin{cases} \chi_{LT} \leq 1,0 \\ \chi_{LT} \leq \frac{1}{\bar{\lambda}_{LT}^{-2}} \end{cases}$$

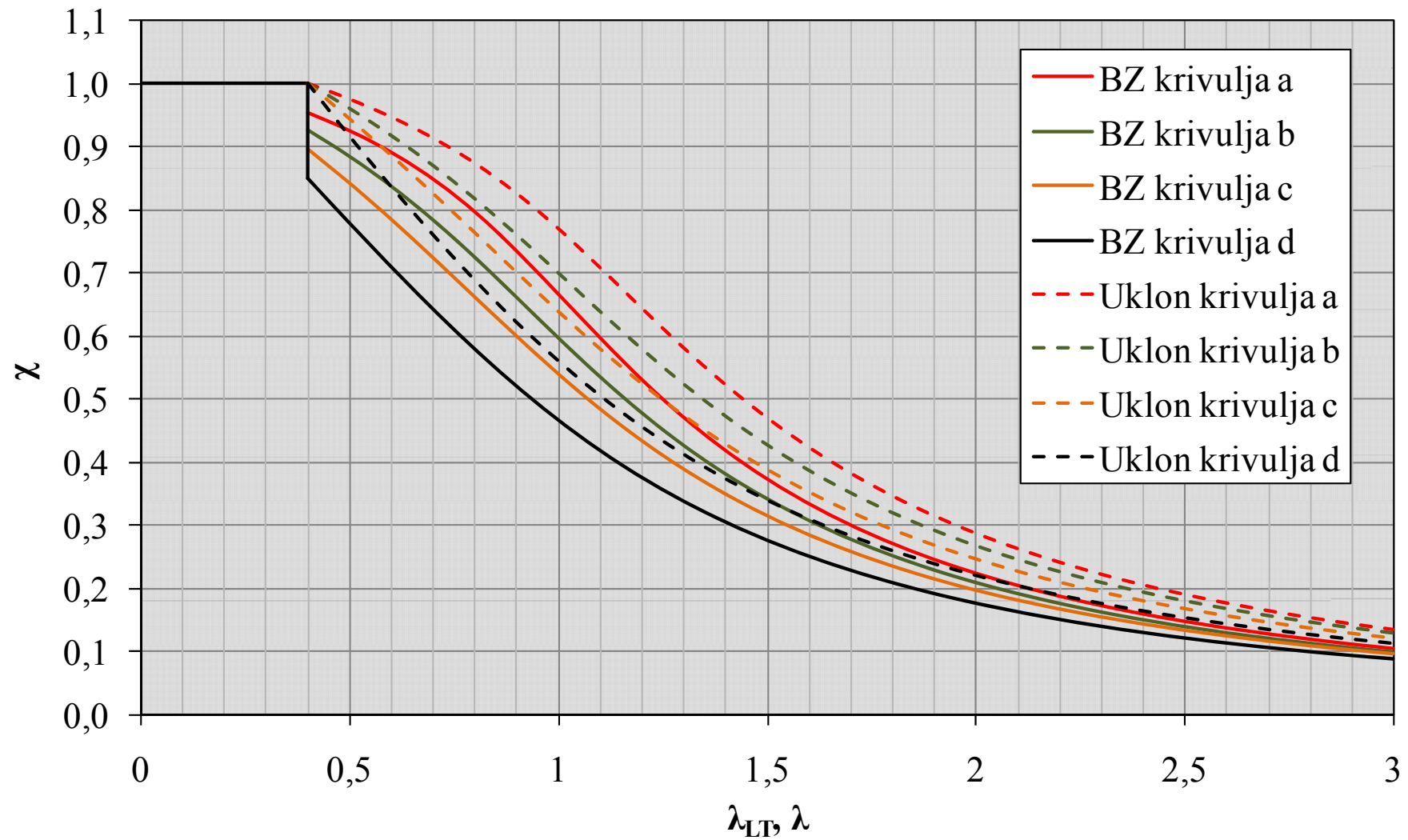
$$\Phi_{LT} = 0,5 \left[1 + \alpha_{LT} (\bar{\lambda}_{LT} - \bar{\lambda}_{LT,0}) + \beta \bar{\lambda}_{LT}^{-2} \right]$$

$$\bar{\lambda}_{LT,0} = 0,4$$

$$\beta = 0,75$$

Prečni prerez	Omejitve	Uklonske krivulje
Vroče valjani I-prerezi	$h/b \leq 2$ $h/b > 2$	b c
Varjeni I-prerezi	$h/b \leq 2$ $h/b > 2$	c d

Bočna zvrnitev – vroče valjani in podobni profili



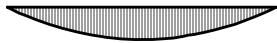







Bočna zvrnitev – vroče valjani in podobni profili

$$\chi_{LT,mod} = \frac{\chi_{LT}}{f}$$

vendar

$$\chi_{LT,mod} \leq 1$$

Razporeditev momentov	k_c
 $\psi = 1$	1,0
 $-1 \leq \psi \leq 1$	$\frac{1}{1,33 - 0,33\psi}$
	0,94
	0,90
	0,91
	0,86
	0,77
	0,82

$$f = 1 - 0,5(1 - k_c)[1 - 2,0(\bar{\lambda}_{LT} - 0,8)^2]$$

vendar $f \leq 1,0$

Metoda tlačene pasnice

Ni nevarnosti bočne zvrnitve:

$$\bar{\lambda}_f = \frac{k_c L_c}{i_{f,z} \lambda_1} \leq \bar{\lambda}_{c0} \frac{M_{c,Rd}}{M_{y,Ed}}$$

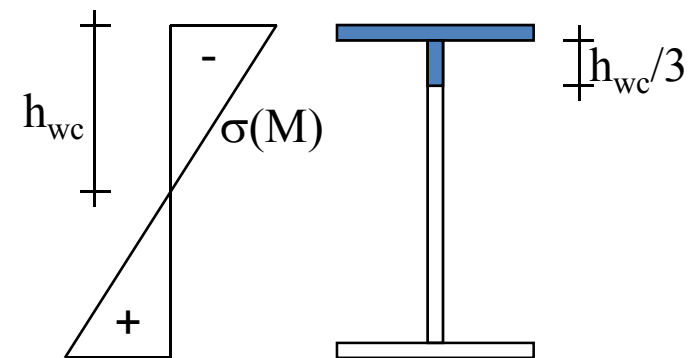
$$i_{f,z} = \sqrt{\frac{I_f}{A_f + \frac{1}{6} A_w}}$$

$$M_{c,Rd} = W_y \frac{f_y}{\gamma_{M1}}$$

$M_{y,Ed}$ največja projektna vrednost upogibnega momenta

L_c razdalja med bočnimi podporami

$$\bar{\lambda}_{c0} = \bar{\lambda}_{LT,0} + 0,1 = 0,5$$



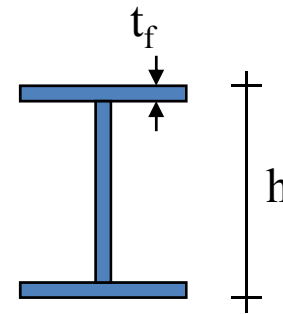
Metoda tlačene pasnice

$$M_{b,Rd} = 1,10 \chi M_{c,Rd}$$

vendar $M_{b,Rd} \leq M_{c,Rd}$

Krivulja d: varjeni prerezi s $h/t_f \leq 44\epsilon$

Krivulja c: ostali prerezi



Kontrola bočne zvrnitve nosilca z vmesnimi bočnimi podporami

