



Materiálové a průřezové charakteristiky

BOA001

Prezentuje



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- IDEA StatiCa – Product Owner
- VUT FAST – Odborný asistent

Výzkum:

- Přípoje ocelových konstrukcí
- Metoda konečných prvků

[Scopus Author ID: 56188615700](#)

Člen komisí:

- CEN/TC 250/SC 3/WG 8
"Evolution of EN 1993-1-8 -
Joints and connections"
- ECCS TC10 "Structural
Connections"



Calculate yesterday's estimates



Web:

<https://www.fce.vutbr.cz/KDK/vild.m/>

email: vild.m@fce.vutbr.cz

Kancelář: C203

Konzultace:

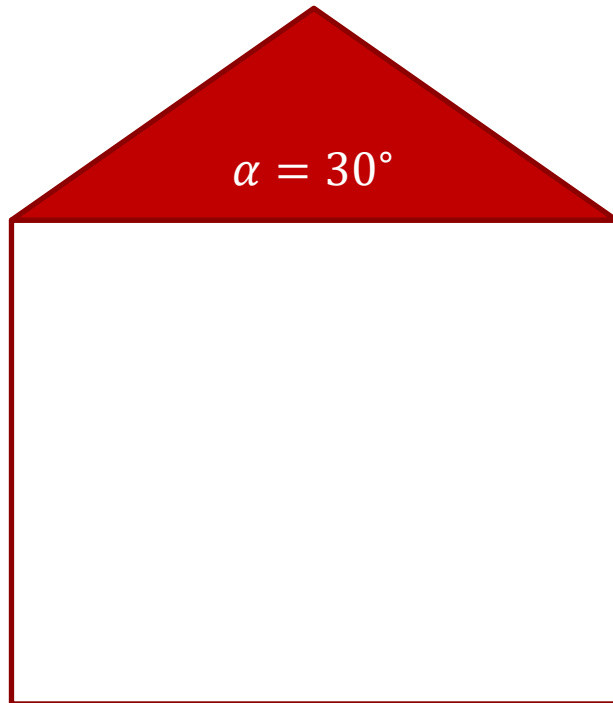
Úterý 14–15

Čtvrtek 14–16

Obsah

- Opakování, matka moudrosti
 - Zatížení sněhem “+” Zatížení větrem “+” Stálé zatížení
- Materiál
 - Ocel
 - Dřevo
- Přípoje
 - Šrouby
 - Svary
- Návrh prutů
 - Tah a tlak
 - Ohyb
 - Smyk
 - Kroucení

Kombinace zatížení



$$s_k = 1.2 \text{ kN/m}^2$$

$$W_{k,suction} = -2.0 \text{ kN/m}^2$$

$$W_{k,pressure} = 1.0 \text{ kN/m}^2$$

$$g_k = 0.5 \text{ kN/m}^2$$

$$\gamma_g = 1.35$$

$$\gamma_q = 1.5$$

$$\text{Sníh } H \leq 1000 \text{ m}$$

$$\psi_0 = 0.5$$

$$\psi_1 = 0.2$$

$$\psi_2 = 0.0$$

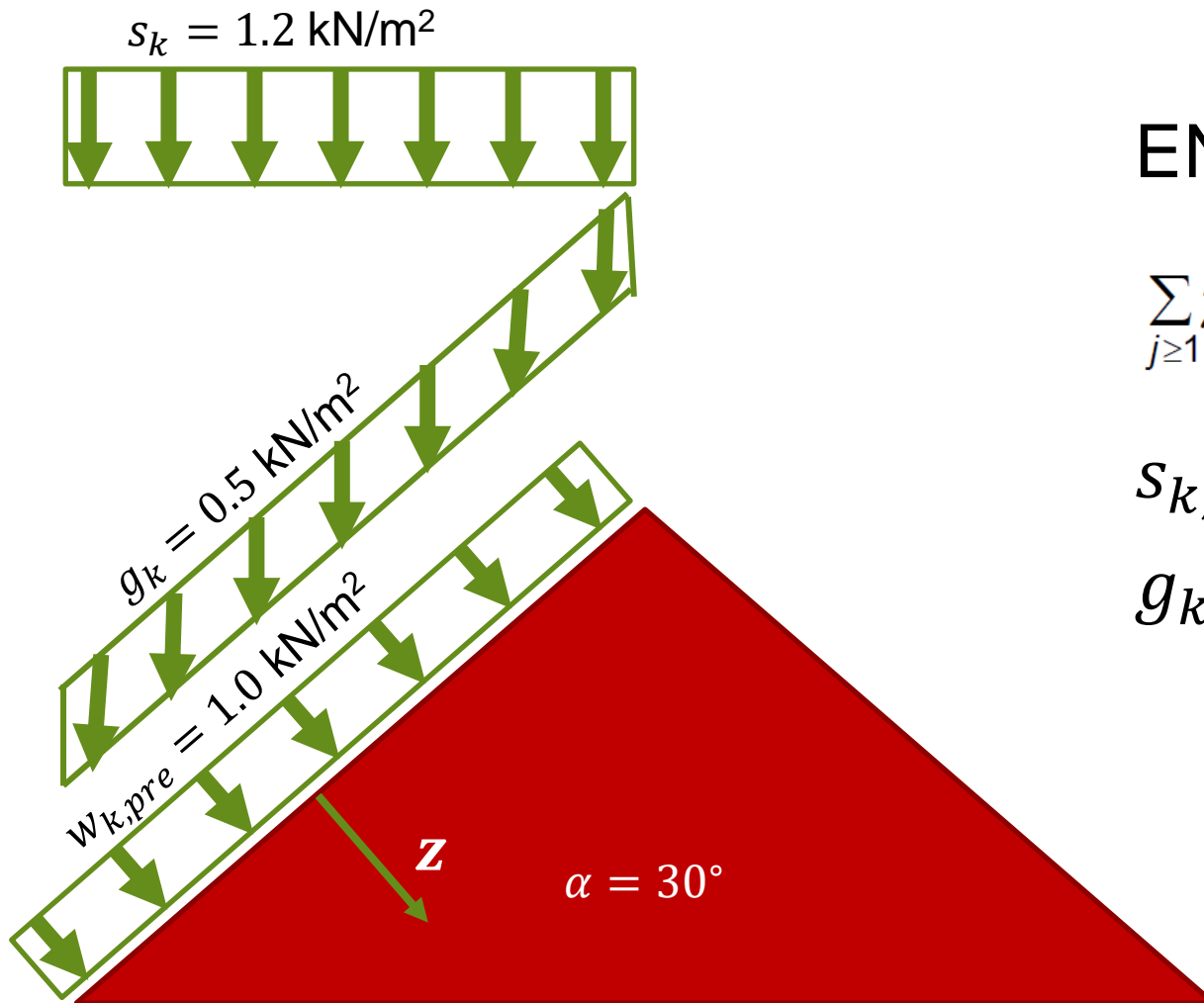
Vítr

$$\psi_0 = 0.6$$

$$\psi_1 = 0.2$$

$$\psi_2 = 0.0$$

Kombinace zatížení



EN 1990, comb. 6.10

$$\sum_{j \geq 1} \gamma_{G,j} G_{k,j} + \gamma_P P + \gamma_{Q,1} Q_{k,1} + \sum_{i > 1} \gamma_{Q,i} \psi_{0,i} Q_{k,i}$$

$$s_{k,z} = 1.2 \cdot \cos^2 \alpha = 0,9 \text{ kN/m}^2$$

$$g_{k,z} = 0.5 \cdot \cos \alpha = 0,433 \text{ kN/m}^2$$

Kombinace zatížení

Tlak:

$$q_d = \gamma_{G,sup} \cdot g_k + \gamma_Q \cdot w_{k,pressure} + \psi_0 \cdot \gamma_Q \cdot s_k$$
$$q_d = 1.35 \cdot 0.433 + 1.5 \cdot 1.0 + 0.5 \cdot 1.5 \cdot 0.9 = 2.760 \text{ kN/m}^2$$

$$q_d = \gamma_{G,sup} \cdot g_k + \gamma_Q \cdot s_k + \psi_0 \cdot \gamma_Q \cdot w_{k,pressure}$$
$$q_d = 1.35 \cdot 0.433 + 1.5 \cdot 0.9 + 0.6 \cdot 1.5 \cdot 1.0 = 2.835 \text{ kN/m}^2$$

Sání:

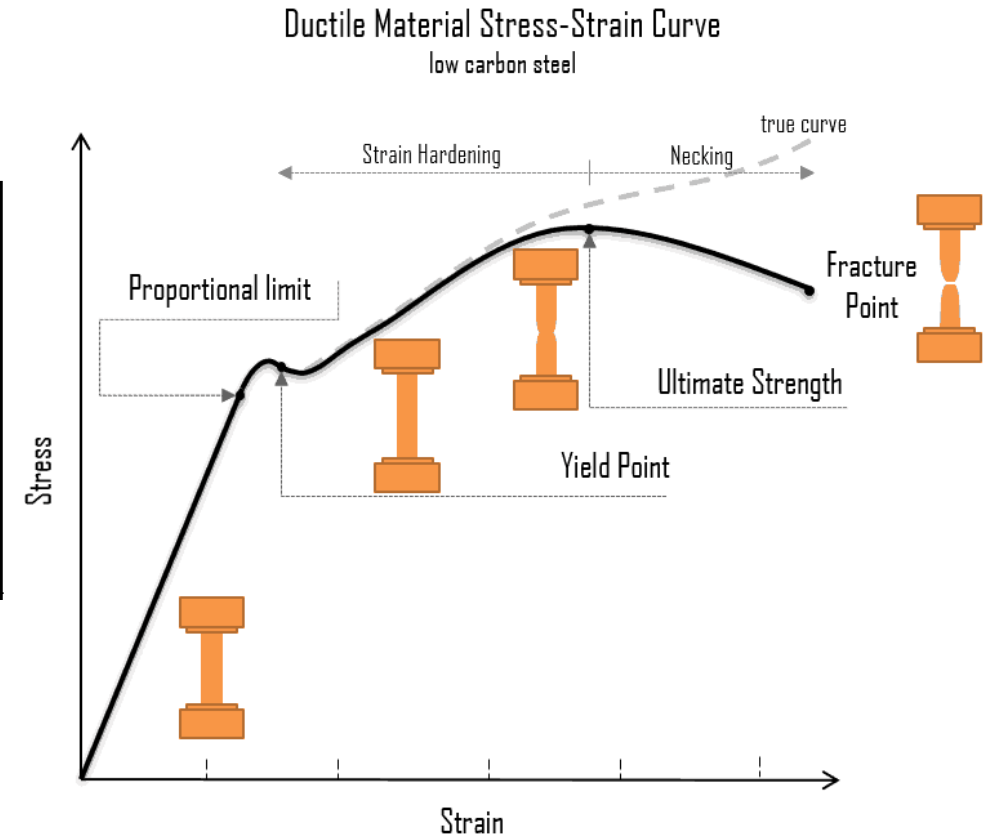
$$q_d = \gamma_{G,inf} \cdot g_k + \gamma_Q \cdot w_{k,suction}$$
$$q_d = 1.0 \cdot 0.433 + 1.5 \cdot (-2.0) = -2.567 \text{ kN/m}^2$$

Material – ocel

EN 1993

Table 3.1: Nominal values of yield strength f_y and ultimate tensile strength f_u for hot rolled structural steel

Standard and steel grade	Nominal thickness of the element t [mm]			
	$t \leq 40$ mm		$40 \text{ mm} < t \leq 80$ mm	
	f_y [N/mm ²]	f_u [N/mm ²]	f_y [N/mm ²]	f_u [N/mm ²]
EN 10025-2				
S 235	235	360	215	360
S 275	275	430	255	410
S 355	355	510	335	470
S 450	440	550	410	550

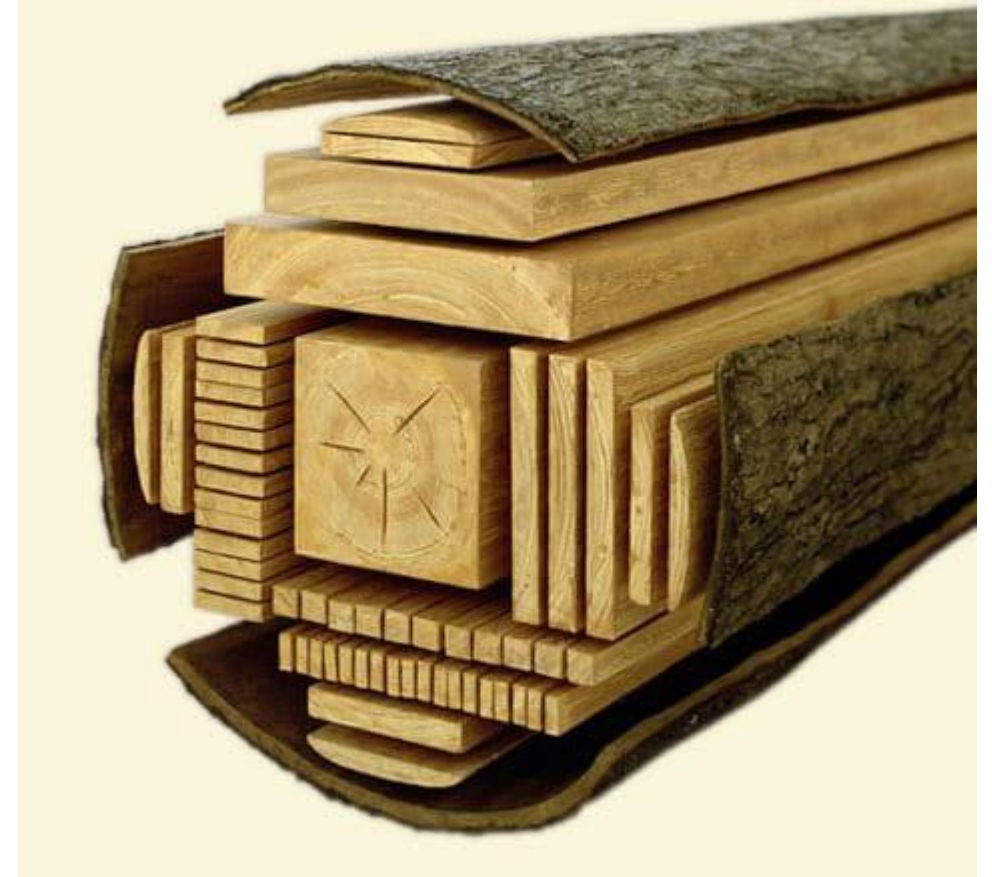


<https://material-properties.org/what-is-ultimate-tensile-strength-uts-definition/>

Materiál – dřevo

EN 1995

- Ortotropický
- Mnoho druhů:
 - Rostlé dřevo
 - Lepené lamelové dřevo
 - LVL, překližka, OSB
 - Dřevotřísková deska, MDF



Materiálové charakteristiky

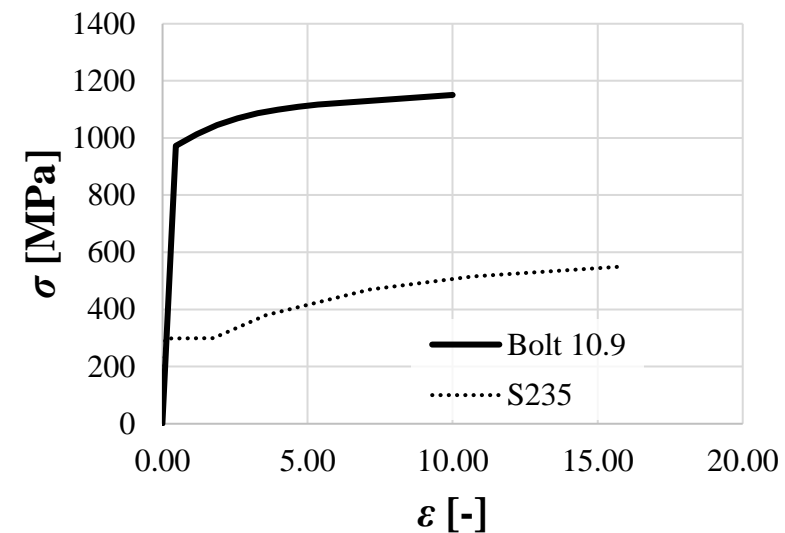
	Ocel S355	Dřevo C24	Beton C20/25
Objemová hmotnost $\rho = m/V$	7850 kg/m ³	420 kg/m ³	2400 kg/m ³
Poissonův součinitel ν	0.3	~0.3	0.2
Modul pružnosti E	210 000 MPa	11 000 MPa	30 000 MPa
Modul pružnosti ve smyku $G = \frac{E}{2 \cdot (1 + \nu)}$	80 769 MPa	690 MPa	12 500 MPa
Součinitel spolehlivosti γ_M	1.0	1.3	1.5
Characteristická pevnost f_k	355 MPa	24 MPa	20 MPa
Návrhová pevnost f_d	355 MPa	11.1 MPa	13.3 MPa

Přípoje – šrouby

Pevnosti: ISO 898-1

Rozměry: ISO 4014

Pevnostní třída	f_y [MPa]	f_u [MPa]
4.6	240	400
4.8	320	400
5.6	300	500
5.8	400	500
6.8	480	600
8.8	640	800
10.9	900	1000



<https://www.orbitalfasteners.co.uk/>



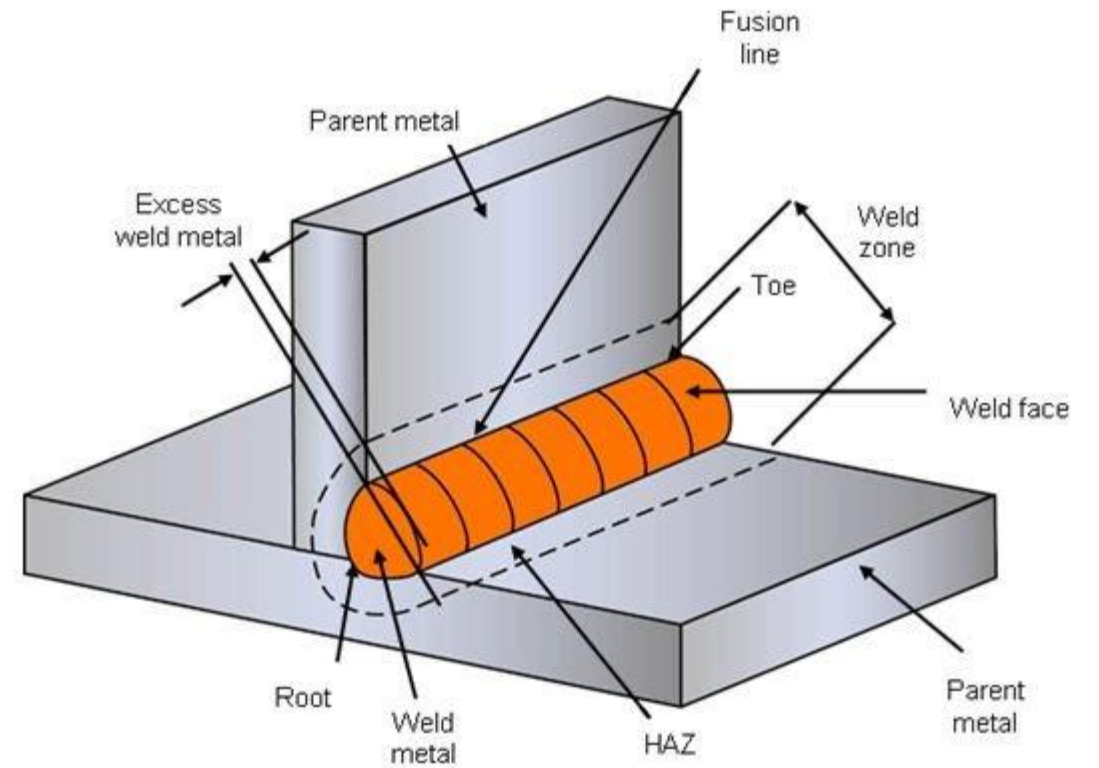
Kovozoo, Staré Město



Přípoje – svary

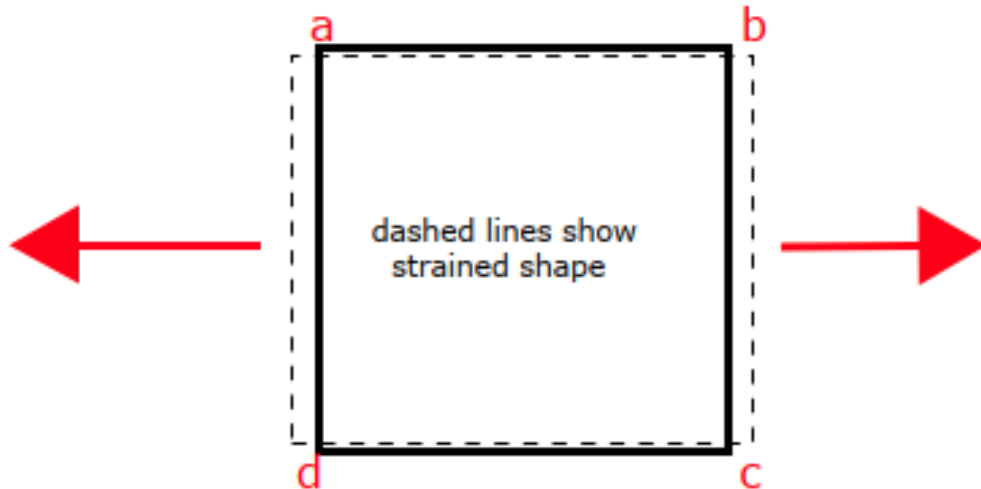


<https://northern-weldarc.com/types-welding-processes/>



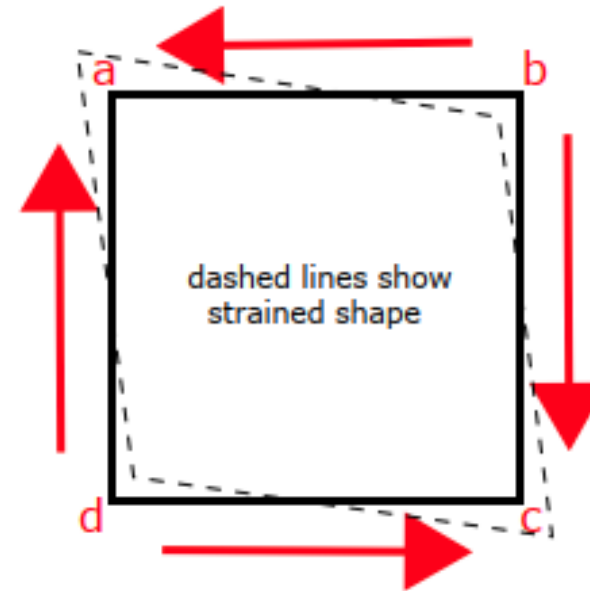
<https://www.twi-global.com/technical-knowledge/faqs/what-is-welding>

Napětí



NORMAL STRESS

Stress is normal (perpendicular) to faces ad and bc . Tension is shown, but compression is also a normal stress.

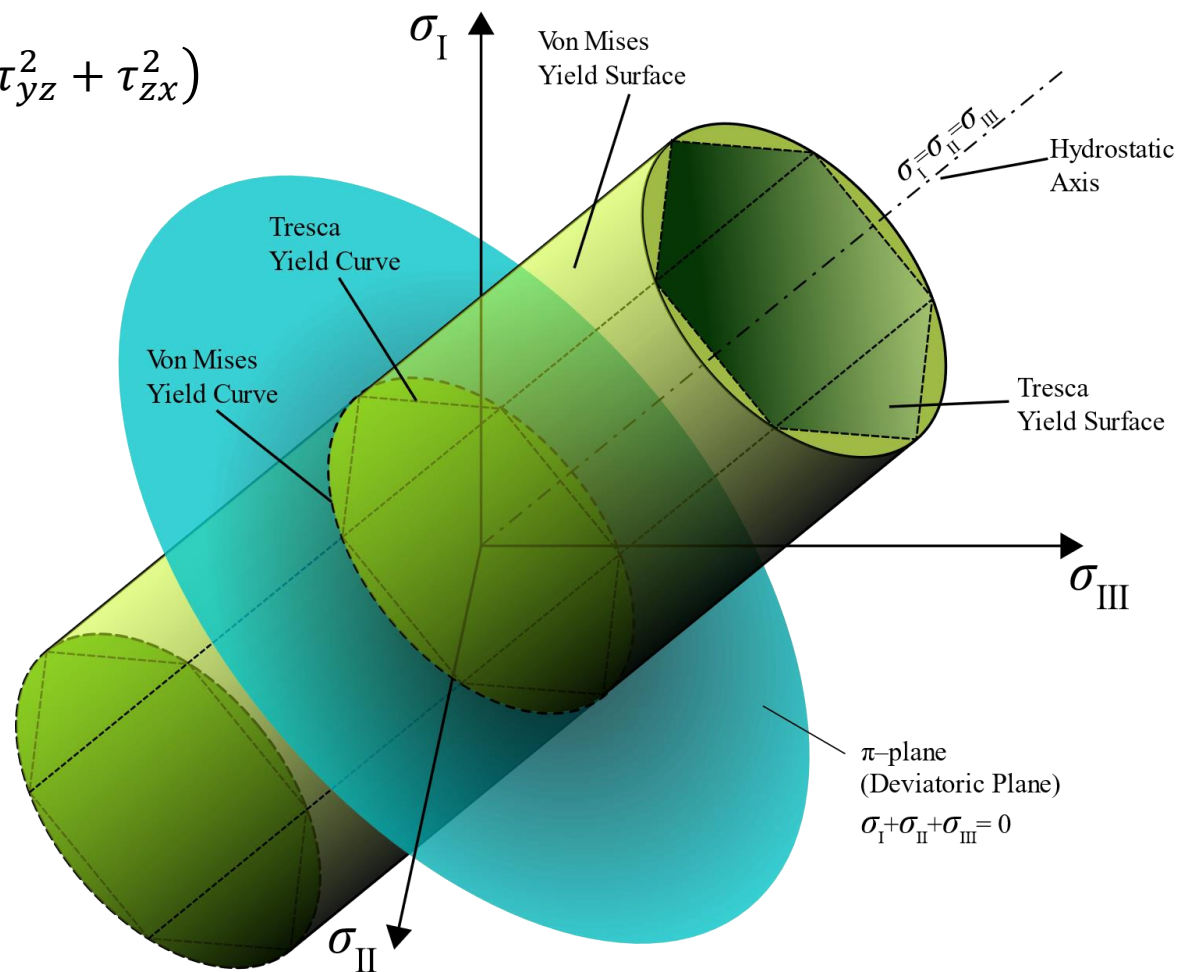
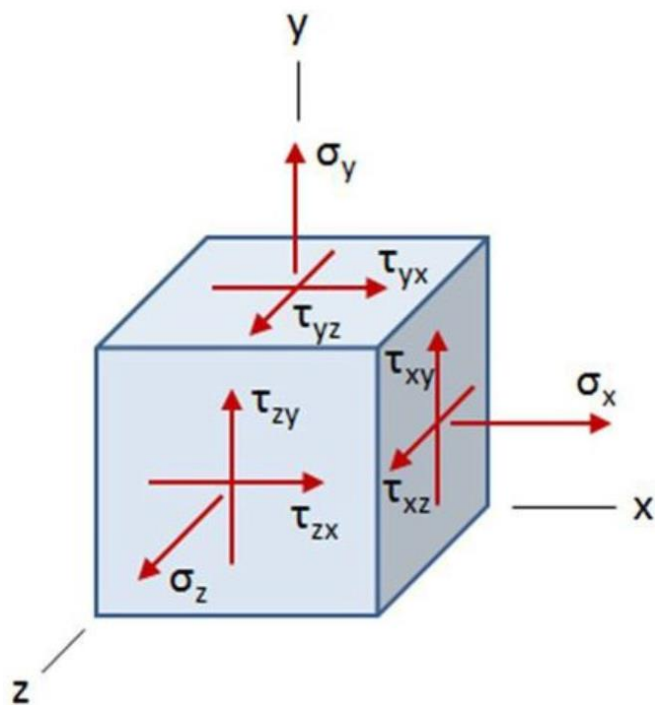


SHEAR STRESS

Shear stress on rectangular element $abcd$ tends to skew it to a parallelogram.

von Misesovo napětí

$$\sigma_v = \sqrt{\frac{1}{2} \left[(\sigma_x - \sigma_y)^2 + (\sigma_y - \sigma_z)^2 + (\sigma_z - \sigma_x)^2 \right] + 3(\tau_{xy}^2 + \tau_{yz}^2 + \tau_{zx}^2)}$$



https://en.wikipedia.org/wiki/Von_Mises_yield_criterion

von Misesovo napětí

Vliv na návrh:

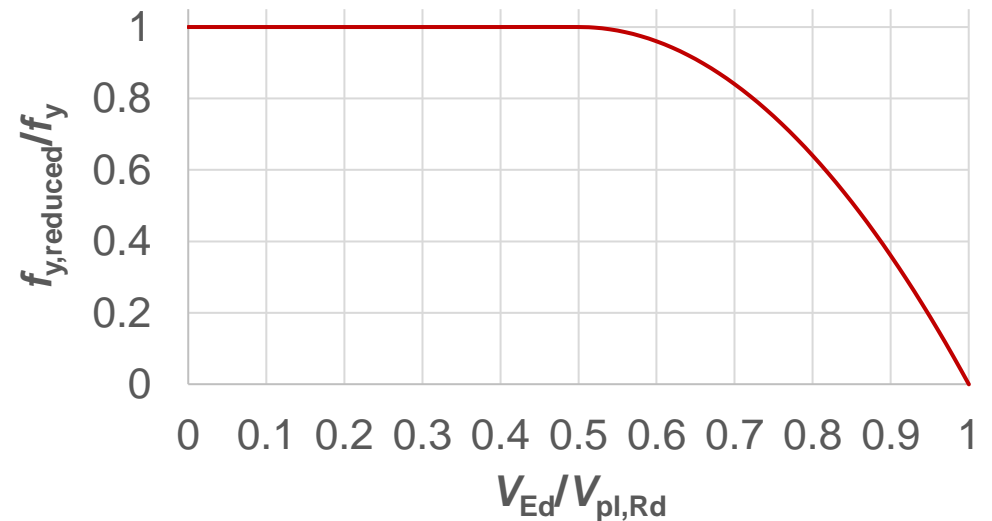
- Normálové napětí
 - Tah & tlak: $N_{Rd} = A \cdot f_y$
 - Ohyb: $M_{y,el,Rd} = W_{y,el} \cdot f_y$
- Smyk
 - $V_{z,Rd} = A_V \cdot f_y / \sqrt{3}$

Kombinace:

pro $V_{Ed} \geq 0.5V_{pl,Rd}$:

$$f_{y, reduced} = (1 - \rho) f_y$$

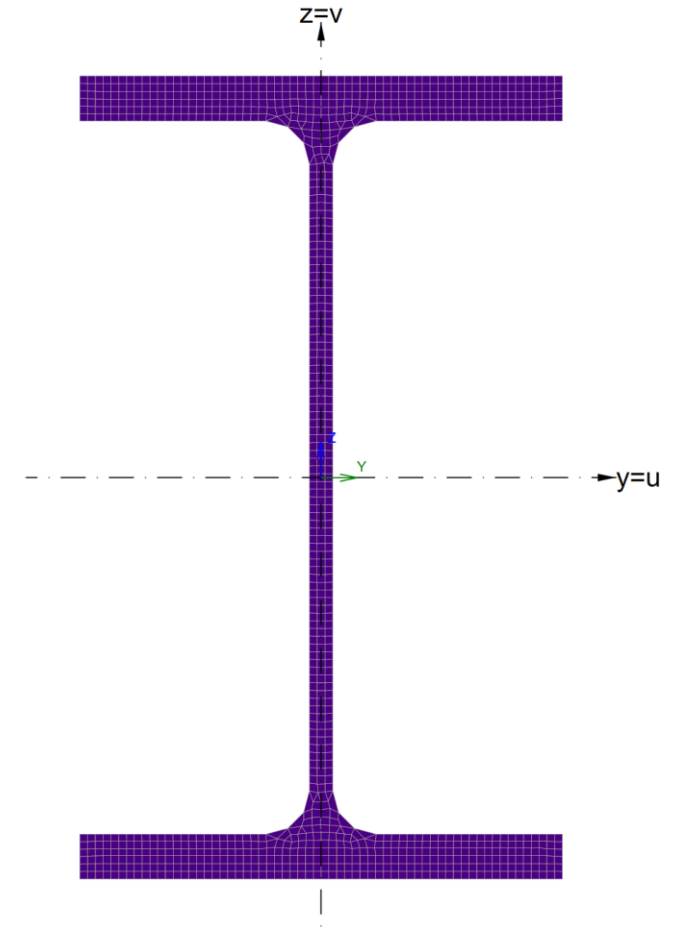
$$\rho = \left(\frac{2V_{Ed}}{V_{pl,Rd}} - 1 \right)^2$$



Tah & Tlak

Integrál $A = \int_A dA$

Diskrétní $A = \sum_{i=1}^n b_i \cdot t_i$



Příklad

A. Spočtete plochu průřezu HEB 500

B. Spočtete tahovou únosnost průřezu HEB 500

$$h = 500 \text{ mm}$$

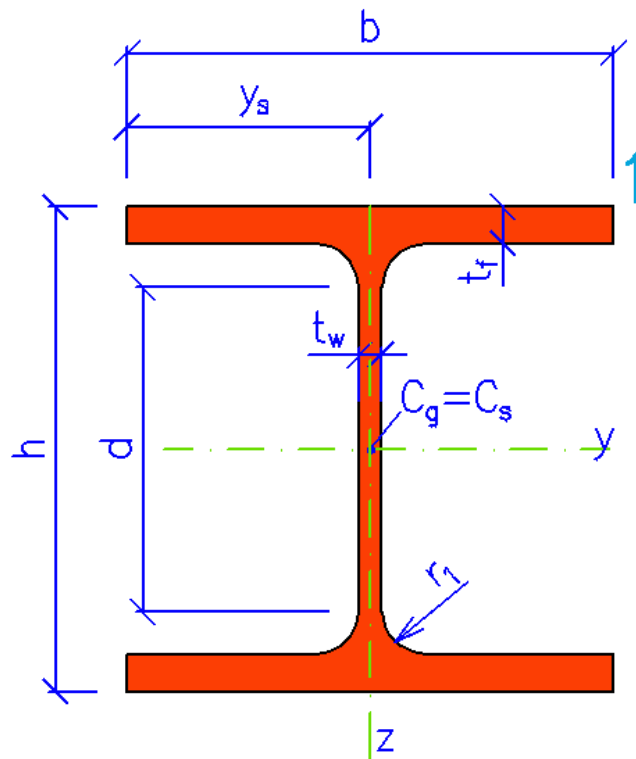
$$b = 300 \text{ mm}$$

$$t_f = 28 \text{ mm}$$

$$t_w = 14.5 \text{ mm}$$

$$r_1 = 27 \text{ mm}$$

$$d = 390 \text{ mm}$$



1. Přibližně (5 minut)

2. Přesně (komu zbyde čas)

$$F_{Rd} = A \cdot \frac{f_{yk}}{\gamma_{M0}}$$
$$f_{yk} = 355 \text{ MPa}$$
$$\gamma_{M0} = 1.0$$

<http://www.statictools.eu/cs/profile-heb/HE500B/mm/show>

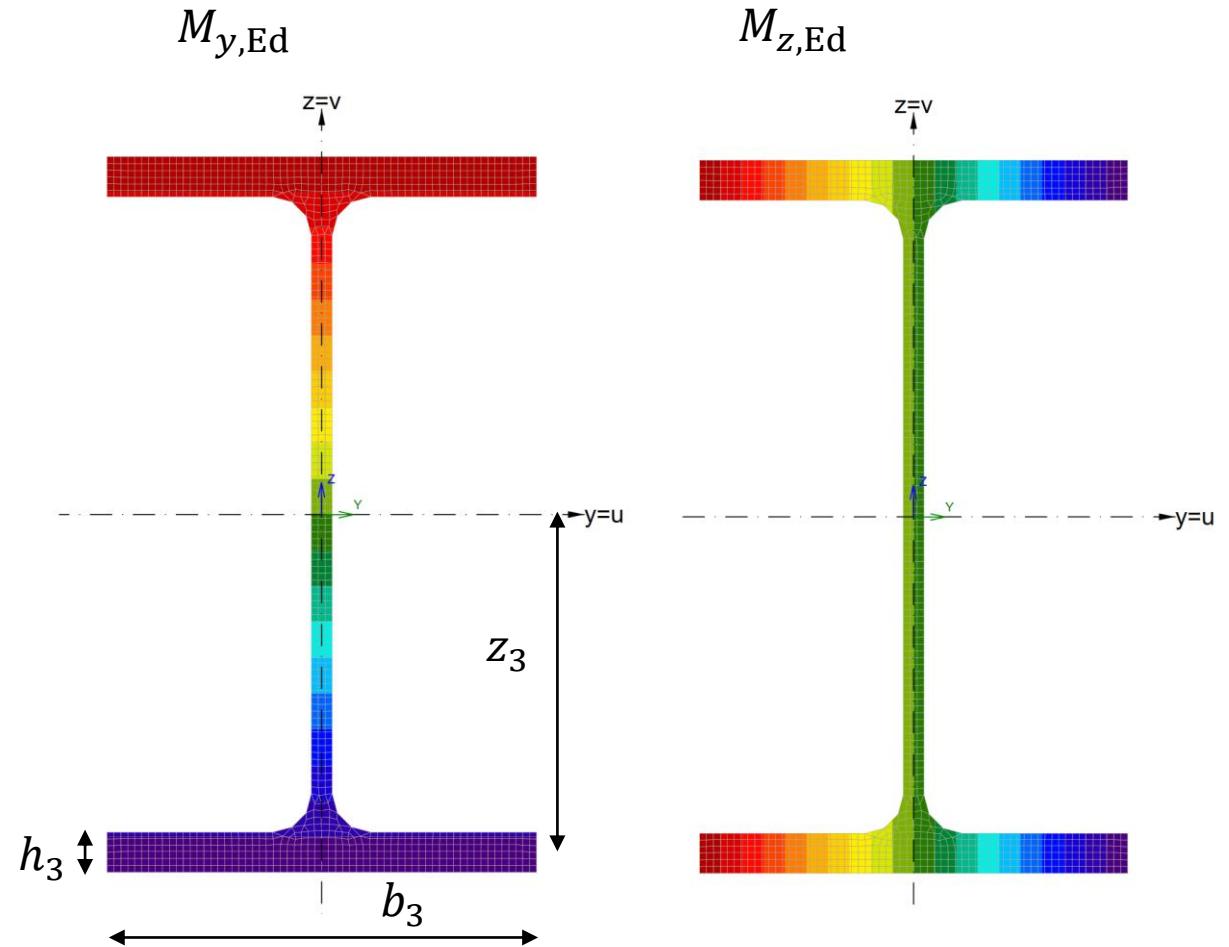
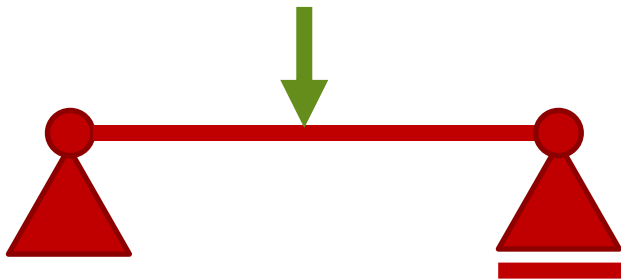
Ohyb – tuhost

$$I_y = \int_A z^2 dA$$

$$I_y = \sum_{i=1}^n \frac{1}{12} b_i \cdot h_i^3 + b_i \cdot h_i \cdot z_i^2$$

$$I_z = \int_A y^2 dA$$

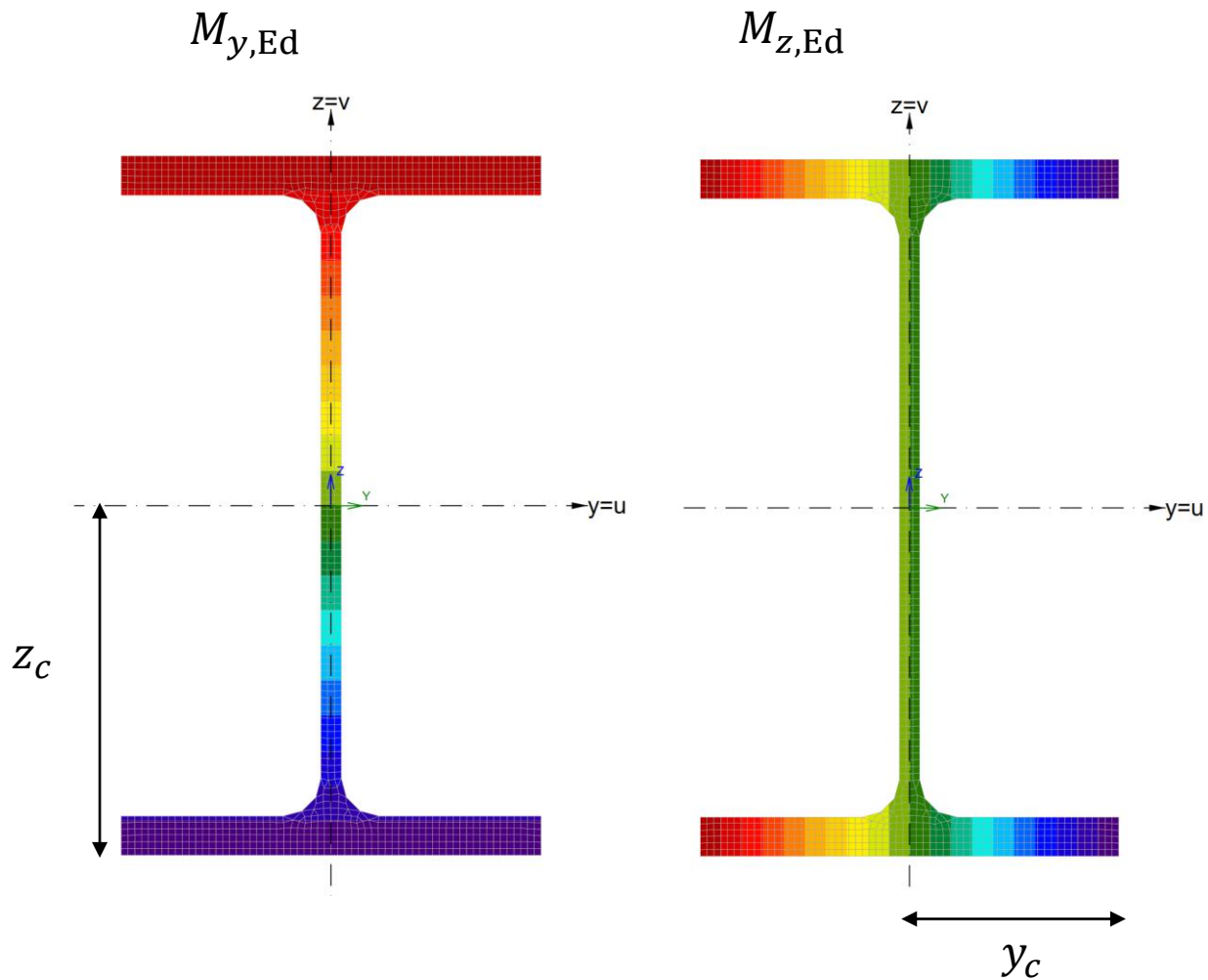
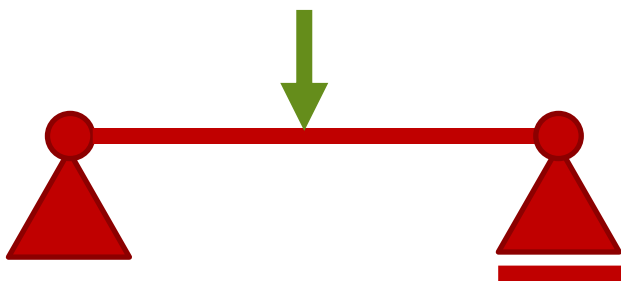
$$I_z = \sum_{i=1}^n \frac{1}{12} h_i \cdot b_i^3 + b_i \cdot h_i \cdot y_i^2$$



Ohyb – únosnost

$$W_{el,y} = I_y / z_c$$

$$W_{el,z} = I_z / y_c$$

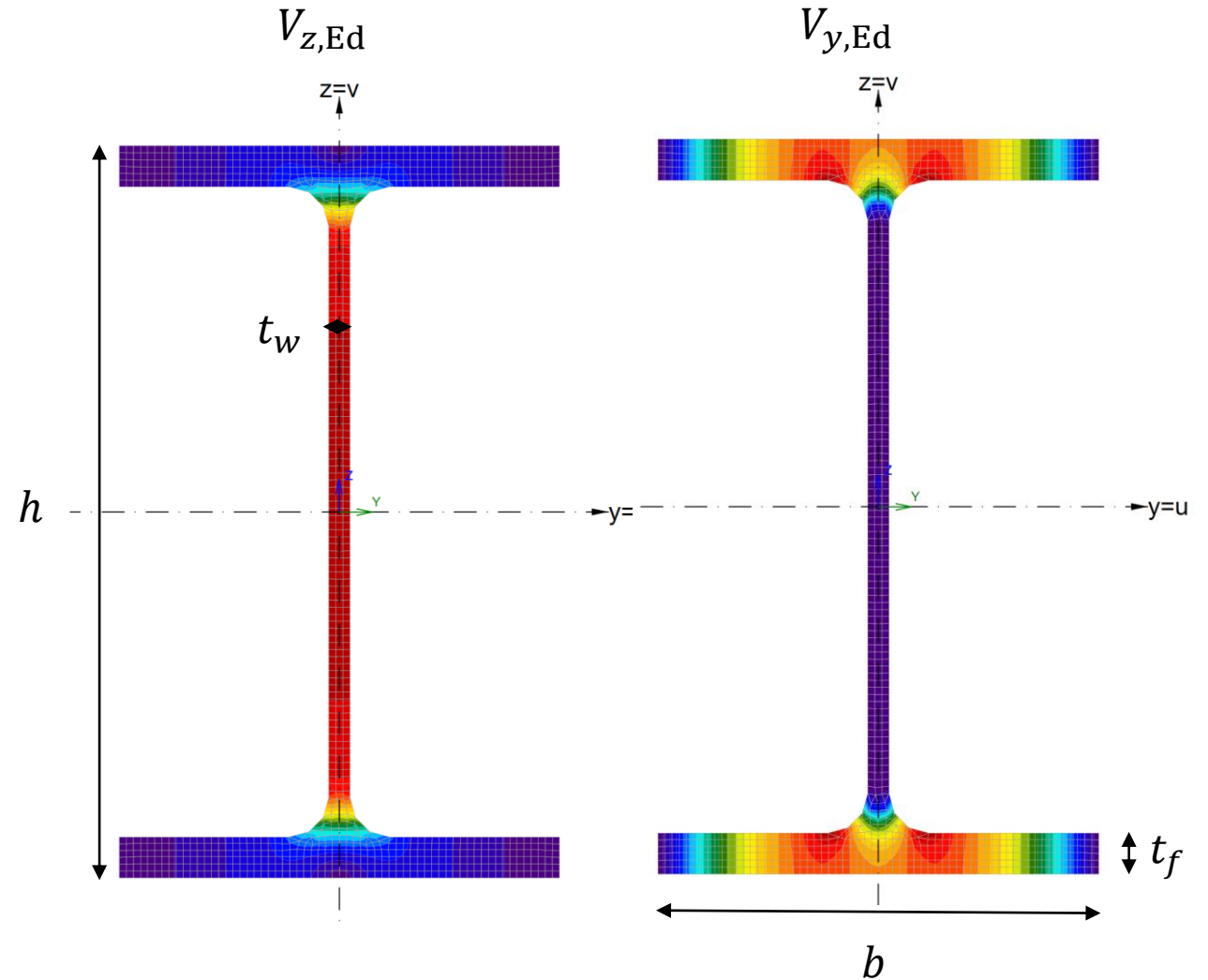
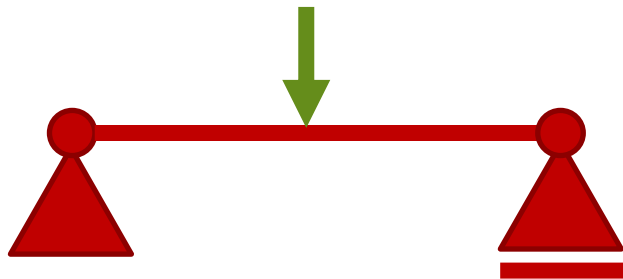


Smyk

Zjednodušeně:

$$A_{Vz} = t_w \cdot h$$

$$A_{Vy} = t_f \cdot b$$



(3) The shear area A_v may be taken as follows:

a) rolled I and H sections, load parallel to web $A - 2bt_f + (t_w + 2r)t_f$ but not less than $\eta h_w t_w$

b) rolled channel sections, load parallel to web $A - 2bt_f + (t_w + r)t_f$

c) rolled T-section, load parallel to web $0,9 (A - bt_f)$

d) welded I, H and box sections, load parallel to web $\eta \sum (h_w t_w)$

e) welded I, H, channel and box sections, load parallel to flanges $A - \sum (h_w t_w)$

f) rolled rectangular hollow sections of uniform thickness:

load parallel to depth $Ah/(b+h)$

load parallel to width $Ab/(b+h)$

g) circular hollow sections and tubes of uniform thickness $2A/\pi$

where A is the crosssectional area;

b is the overall breadth;

h is the overall depth;

h_w is the depth of the web;

r is the root radius;

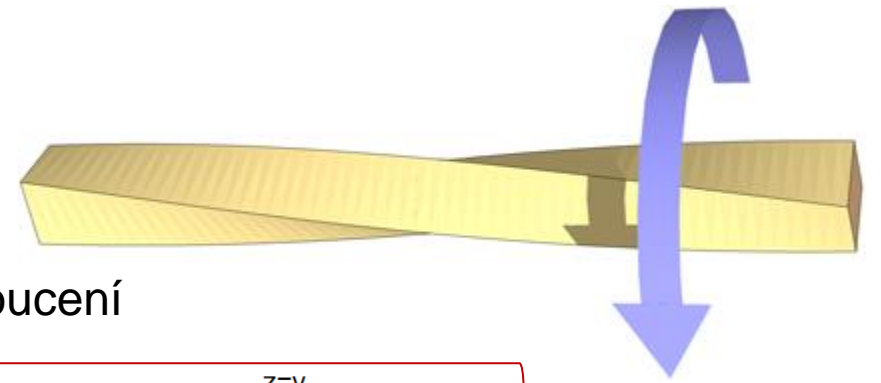
t_f is the flange thickness;

t_w is the web thickness (If the web thickness is not constant, t_w should be taken as the minimum thickness.).

η see EN 1993-1-5.

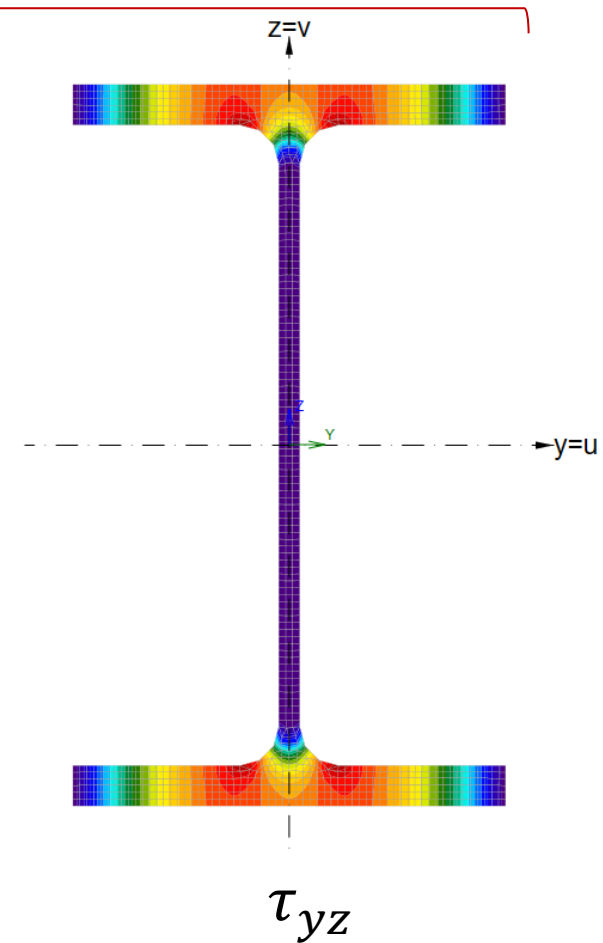
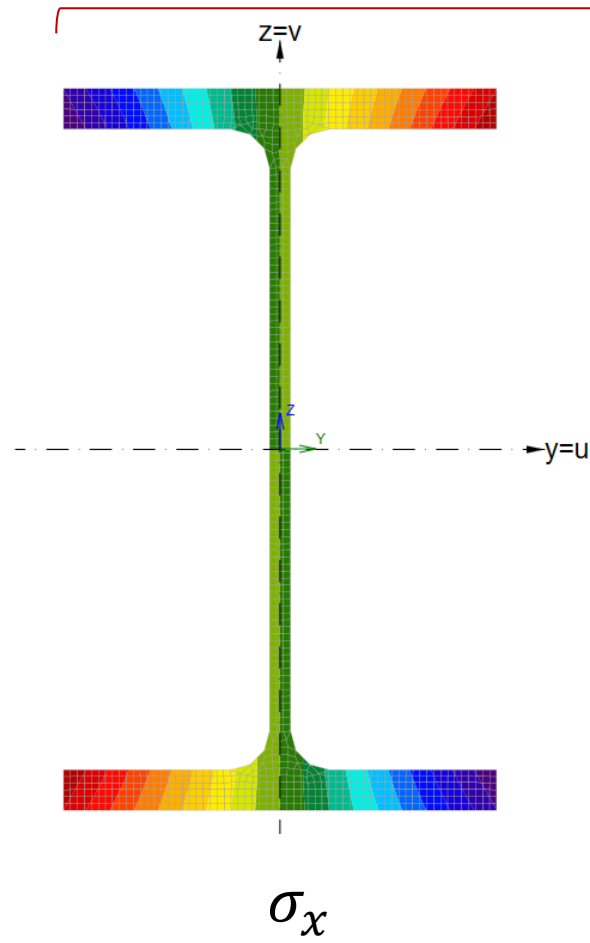
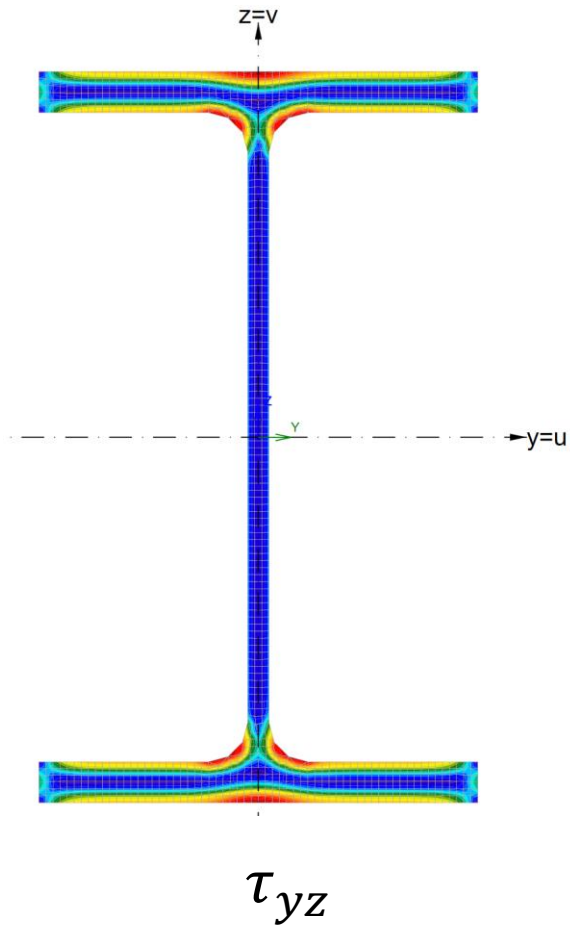
NOTE η may be conservatively taken equal 1,0.

Kroucení



Prosté kroucení

Vázané kroucení



Průřezové charakteristiky – tabulky

HE500B			
Geometrie		Průřezové charakteristiky	
h = 500 mm		Osa y	Osa z
b = 300 mm		$I_y = 1.07E+9 \text{ mm}^4$	$I_z = 1.26E+8 \text{ mm}^4$
$t_f = 28 \text{ mm}$		$W_{y1} = 4.29E+6 \text{ mm}^3$	$W_{z1} = 8.41E+5 \text{ mm}^3$
$t_w = 14.5 \text{ mm}$		$W_{y,pl} = 4.82E+6 \text{ mm}^3$	$W_{z,pl} = 1.28E+6 \text{ mm}^3$
$r_1 = 27 \text{ mm}$		$i_y = 212.0 \text{ mm}$	$i_z = 72.70 \text{ mm}$
$y_s = 150 \text{ mm}$		$S_y = 2.41E+6 \text{ mm}^3$	$S_z = 6.40E+5 \text{ mm}^3$
$d = 390 \text{ mm}$		Kroucení a klopení	
$A = 23900 \text{ mm}^2$		$I_w = 7.02E+12 \text{ mm}^6$	$I_t = 5.48E+6 \text{ mm}^4$
$A_L = 2.12 \text{ m}^2 \cdot \text{m}^{-1}$		$G = 187 \text{ kg} \cdot \text{m}^{-1}$	$i_w = 76.50 \text{ mm}$

<http://www.staticstools.eu/cs/>

Těžiště

$$S_y = \int_A z dA$$

$$S_y = \sum_{i=1}^n b_i \cdot t_i \cdot z$$

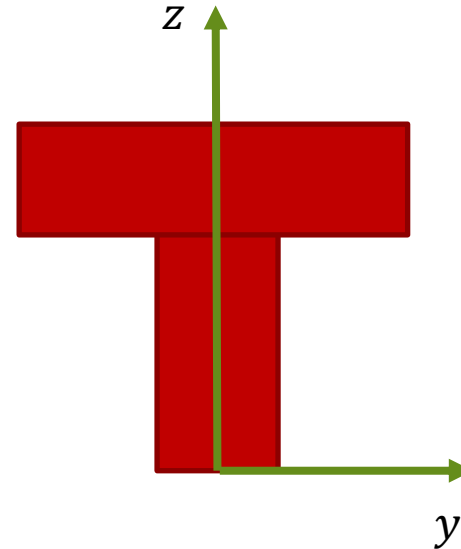
$$S_z = \int_A y dA$$

$$S_z = \sum_{i=1}^n b_i \cdot t_i \cdot y$$

$$C_{g,y} = \frac{S_z}{A}$$

$$C_{g,z} = \frac{S_y}{A}$$

$$C_g [C_{g,y}; C_{g,z}]$$



Příklad

Spočtete:

- Plocha: $A = \sum b_i \cdot t_i$ [mm²]
- Tahová únosnost: $F_{Rd} = A \cdot f_{t,0,d}$ [N]
- Poloha těžiště
- Moment setrvačnosti: $I_y = \sum_{i=1}^n \frac{1}{12} b_i \cdot h_i^3 + b_i \cdot h_i \cdot z_i^2$
- Průhyb nosníku: $w = \frac{5q_k L^4}{384EI_y} \leq w_{lim} = L/200$
- Modul průřezu: $W_{el,y} = I_y/z_c$
- Momentová únosnost: $M_{y,Rd} = W_{y,el} \cdot f_{t,0,d} \geq M_{Ed} = 1/8q_d L^2$

$$f_{t,0,d} = 11.1 \text{ MPa}, E = 11\,000 \text{ MPa}$$

