VYSOKÉ UČENÍ TECHNICKÉ V BRNĚ

Fakulta stavební

BAKALÁŘSKÁ PRÁCE

Brno, 2022 Kamil Trunek

VYSOKÉ UČENÍ TECHNICKÉ V BRNĚ
BRNO UNIVERSITY OF TECHNOLOGY

FAKULTA STAVEBNÍ
FACULTY OF CIVIL ENGINEERING

ÚSTAV KOVOVÝCH A DŘEVĚNÝCH KONSTRUKCÍ
INSTITUTE OF METAL AND TIMBER STRUCTURES

SPORTOVNÍ HALA
THE SPORT HALL

BAKALÁŘSKÁ PRÁCE
BACHELOR'S THESIS

AUTOR PRÁCE — Kamil Trunek
AUTHOR

VEDOUCÍ PRÁCE — Ing. STANISLAV BUCHTA, Ph.D.
SUPERVISOR

BRNO 2022

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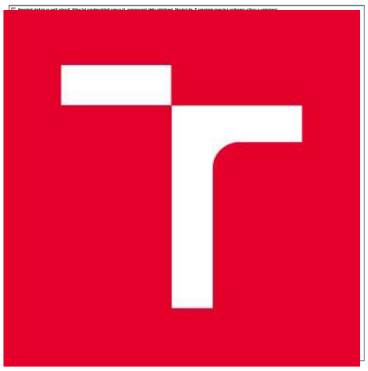

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FAKULTA STAVEBNÍ

Studijní program	B3607 Stavební inženýrství
Typ studijního programu	Bakalářský studijní program s prezenční formou studia
Studijní obor	3608R001 Pozemní stavby
Pracoviště	Ústav kovových a dřevěných konstrukcí

ZADÁNÍ BAKALÁŘSKÉ PRÁCE

Student	Kamil Trunek
Název	Sportovní hala
Vedoucí práce	Ing. Stanislav Buchta, Ph.D.
Datum zadání	30. 11. 2021
Datum odevzdání	27. 5. 2022

V Brně dne 30. 11. 2021

prof. Ing. Marcela Karmazínová, CSc.
Vedoucí ústavu

prof. Ing. Miroslav Bajer, CSc.
Děkan Fakulty stavební VUT

PODKLADY A LITERATURA

ČSN EN 1991 Zatížení staveb
ČSN EN 1993 Navrhování ocelových konstrukcí
Ocelové konstrukce pozemních staveb, Faltus
Kovové konstrukce - Konstrukce průmyslových budov, Melcher, Straka

ZÁSADY PRO VYPRACOVÁNÍ

Navrhněte a posuďte nosnou ocelovou konstrukci sportovní haly o půdorysných rozměrech 35x45m a světlé výšce střešní konstrukce 12m. Hala se nachází v lokalitě Brno.
Vypracujte:
Technickou zprávu s alternativami řešení.
Statický výpočet základních nosných prvků.
Výkresovou dokumentaci v rozsahu dispozičních výkresů včetně výkresu směrných detailů.

STRUKTURA BAKALÁŘSKÉ PRÁCE

VŠKP vypracujte a rozčleňte podle dále uvedené struktury:
1. Textová část závěrečné práce zpracovaná podle platné Směrnice VUT "Úprava, odevzdávání a zveřejňování závěrečných prací" a platné Směrnice děkana "Úprava, odevzdávání a zveřejňování závěrečných prací na FAST VUT" (povinná součást závěrečné práce).
2. Přílohy textové části závěrečné práce zpracované podle platné Směrnice VUT "Úprava, odevzdávání, a zveřejňování závěrečných prací" a platné Směrnice děkana "Úprava, odevzdávání a zveřejňování závěrečných prací na FAST VUT" (nepovinná součást závěrečné práce v případě, že přílohy nejsou součástí textové části závěrečné práce, ale textovou část doplňují).

Ing. Stanislav Buchta, Ph.D.
Vedoucí bakalářské práce

ABSTRAKT

Hlavným cieľom bakalárskej práce je vypracovanie statického návrhu nosnej oceľovej konštrukcie športovej haly.

Pôdorysné rozmery tejto haly sú 45x 35metrov, pričom výška konštrukcie nad terénom je 17,7metra.

Hlavná nosná časť je tvorená priečne oblúkovými väzbami, ktoré sú uložené pomocou čapov na betónových blokoch. Tieto oblúky sú navrhnuté ako priehradové s osovou vzdialenosťou 6metrov.Priestorovou tuhosť zaisťujú pozdĺžne, priečne stužidlá, a tiež väznice. Štítové steny sú tvorené priehradovými stĺpmi, ktoré sú kĺbovo uložené. Prvky sú z ocele triedy S235 JR. Stenové a strešné opláštenie je riešené zo sendvičových panelov. Športová hala je situovaná v lokalite Brno.

KLÍČOVÁ SLOVA

Športová hala , oceľová konštrukcia, statické posúdenie, priehradový oblúk, čapový spoj

ABSTRACT

The aim of bachleor thesis is design a static assessment of steel construction of sport hall.

The floor dimensions of the building are 45x35m and the height of the construction above the ground is 17,7m.

The main load- bearing construction is made of arched truss giders which are laid by pins on the concrete blocks. The range between these arched truss girders is 6m apart. The spatial rigidity of the construction is enshured with bracings and also with purlins. The front walls are formed by lattice columns that are articulated. The main elemenst of the construction are made of steel class S335 JR. Roof and front walls cladding is made of sandwich panels. Sport hall is situated in Brno.

KEYWORDS

Sport hall, steel construction, static assessment , arched truss girders, pin joint

BIBLIOGRAFICKÁ CITACE

Kamil Trunek *Sportovní hala.* Brno, 2022, 207 s. příl. Bakalářská práce. Vysoké učení technické v Brně, Fakulta stavební, Ústav kovových a dřevěných konstrukcí. Vedoucí práce Ing. Stanislav Buchta, Ph.D.

PROHLÁŠENÍ O SHODĚ LISTINNÉ A ELEKTRONICKÉ FORMY ZÁVĚREČNÉ PRÁCE

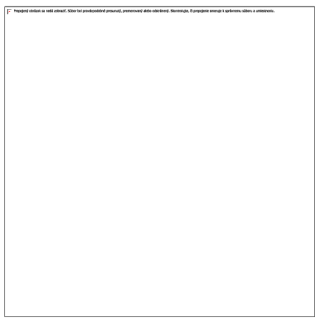
Prohlašuji, že elektronická forma odevzdané bakalářské práce s názvem *Sportovní hala* je shodná s odevzdanou listinnou formou.

V Brně dne 27. 5. 2022

Kamil Trunek
autor práce

POĎAKOVANIE

Chcel by som veľmi poďakovať môjmu vedúcemu bakalárskej práce, pánovi Ing. Stanislavovi Buchtovi, Ph.D. za jeho odborné rady, čas,pomoc a trpezlivosť pri vypracovaní mojej práce.



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1 ÚVOD

Pre oceľovú konštrukciu športovej haly je vypracovaný statický výpočet. Hala sa nachádza v lokalite Brno a má nasledovné rozmery 35,0 x 40,0m pričom výška konštrukcie nad terénom je 17,73m. Maximálna svetlá výska je 15,335m.

Konštrukcia je tvorená desiatimi oblúkovými priečnymi väzbami s osovou vzdialenosťou 5,0m pričom väzby tvoriace štítové steny budú vyhotovené ako plnostenné oblúkové väzníky typu IPE. Medziľahlé väzby tvorí oblúkový priehradový väzník. Väzníky sú uložené do betónových blokov pomocou čapu. Priečne väzby sú navzájom spojené väznicami typu HEA. Uloženie väzníc je uvažované kĺbovo (na hornú hranu väzníkov). Strešný plášť bude kladený na väznice. Stenový plášť štítových stien kotvený na paždíky, ktoré sú kĺbovo pripojené k stĺpom. Systém priečnych a pozdĺžnych stužidiel zaisťuje priestorovú tuhosť a stabilitu konštrukcie. Stĺpy aj stužidlá sú uložené kĺbovo.

2 GEOMETRIA

-dĺžka haly L = 45 m

- šírka väzníku b = 35 m

- väzby á = 5,0 m

- výška konštrukcie nad terénom H = 17,7m

2.1 SCHÉMA DISPOZÍCIA HALY

- rozmery ihrísk :

Tenisový kurt

- dĺžka l = 36,3 m

- šírka b = 18,3 m

- výška v strede hracej plochy hs=12,0m

- Minimálna odporúčaná výška 9m

Basketbal

- dĺžka l = 36,3 m

- šírka b = 18,3 m

- výška v strede hracej plochy hs = 12,0m

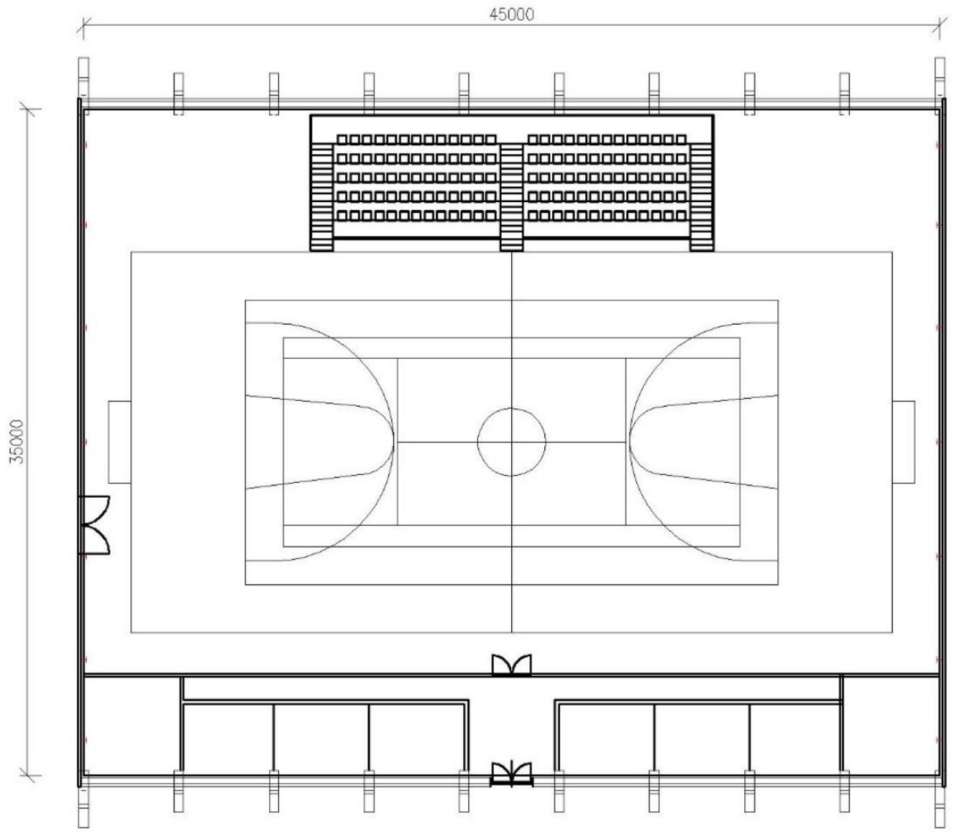
- odporúčaná výška svietidiel 15m

Hádzaná

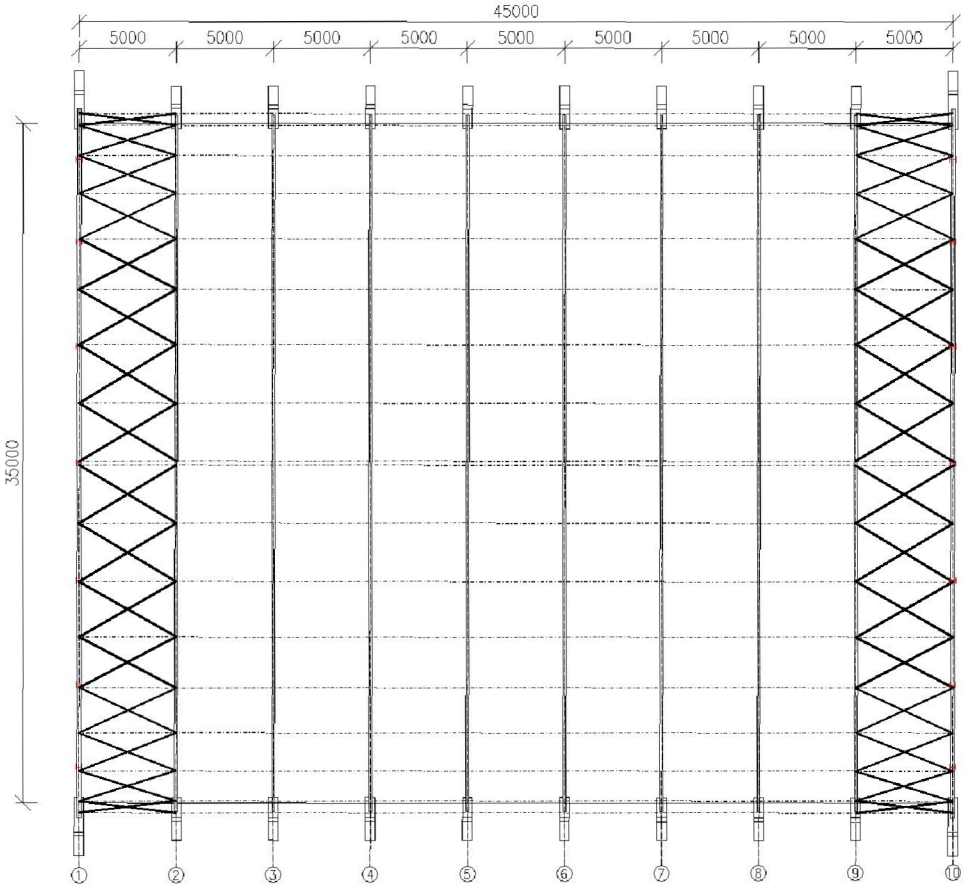
- dĺžka l = 36,3 m

- šírka b = 18,3 m

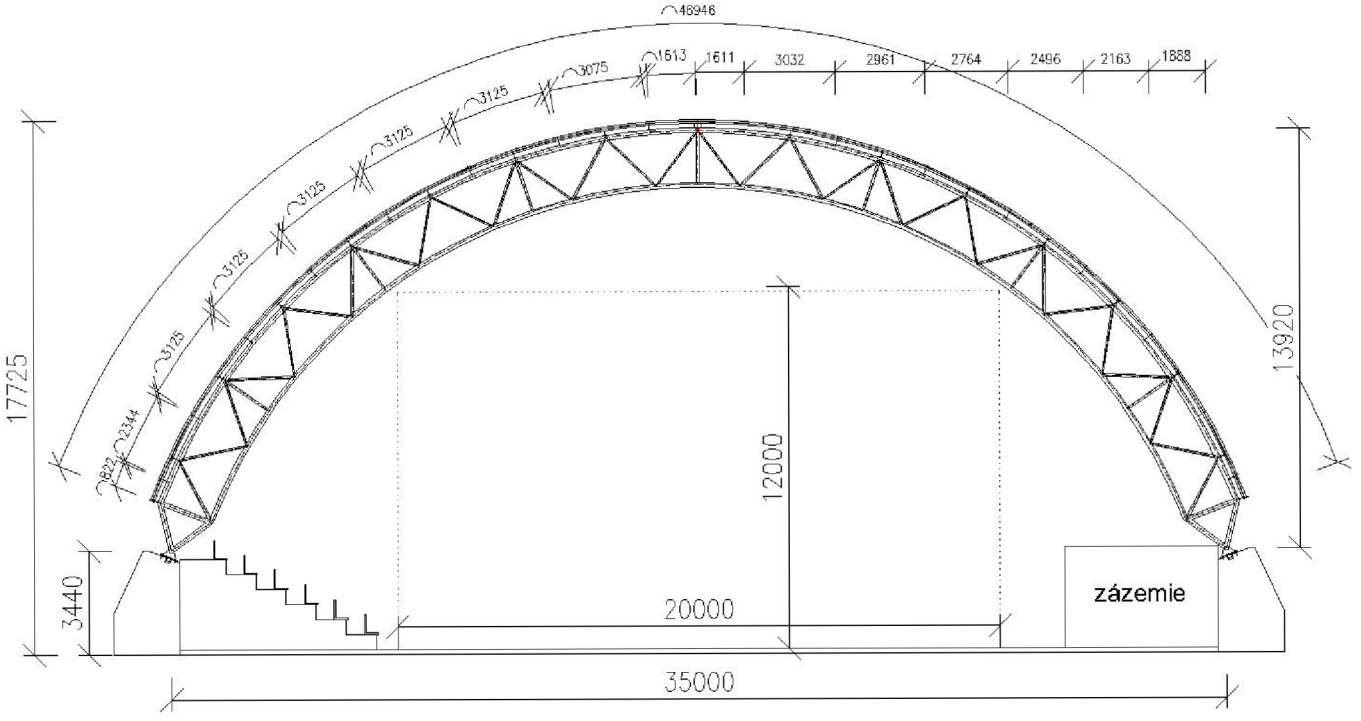
- výška v strede hracej plochy hs = 12,0m



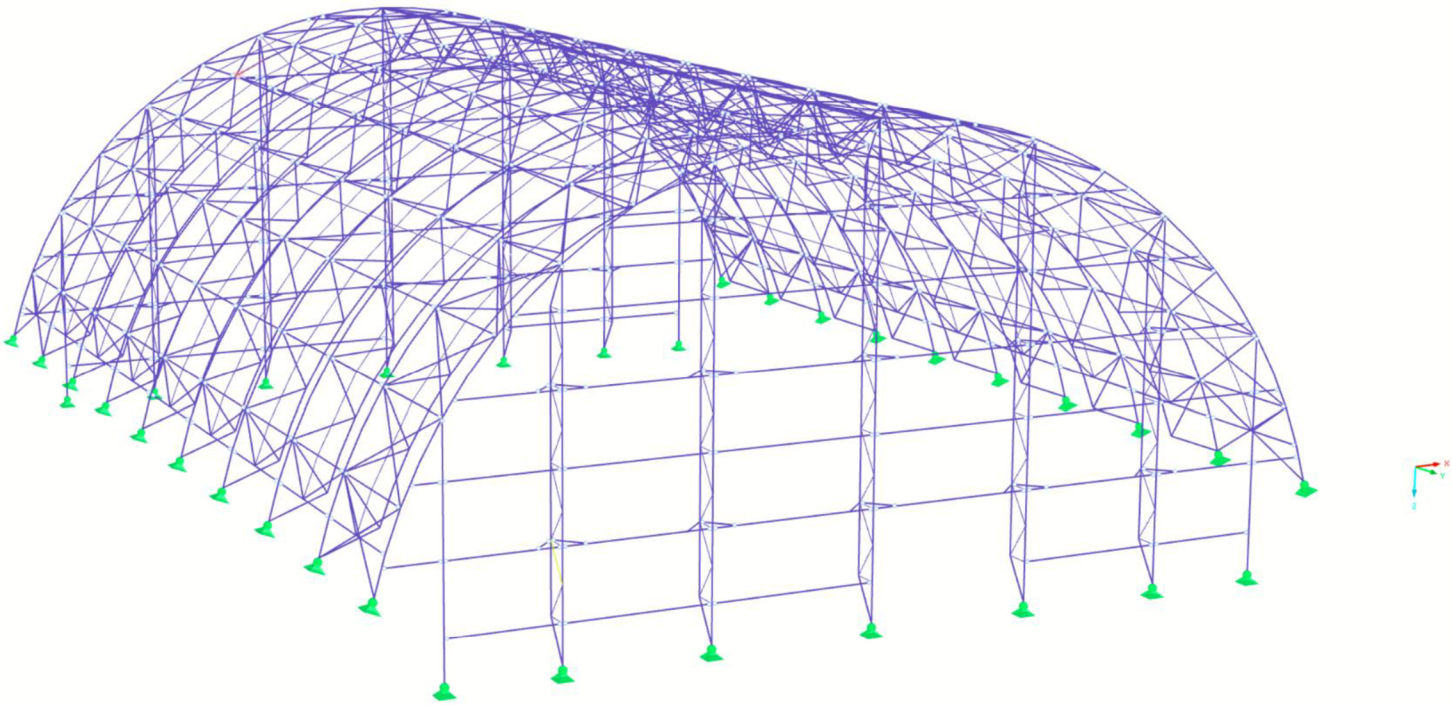
2.2 PÔDORYSNÁ SCHÉMA



2.3 SCHÉMA PRIEČNEJ VÄZBY



2.4 VÝPOČTOVÝ MODEL



3 ZAŤAŽENIE

3.1 ZAŤAŽENIE STÁLE

3.1.1 ZS1 VLASTNÁ TIAŽ

Vlastná tiaž konštrukcie bola spočítaná automaticky programom Dlubal RFEM.

3.1.2 ZS2 STREŠNÝ A STENOVÝ PLÁŠŤ

Strešný plášť je tvorený panelmi KINGSPAN TOP-DEK d (130 mm)

m= 12,35 kg/m² .Polomer horného pásu oblúku je 19,099 m

panely budú kladené v priečnom smere.

m = 12,35 kg/m² → Zaťaženie na väznice : gk= 0,1235 kN/m^2

Zaťaženie väzníc:

− väznica 1 a 18 $\mathrm{gk} = 0{,}1235 \,.\, 0{,}822 = 0{,}102\ \mathrm{kN/mb}$

− väznica 2 a 17 $\mathrm{gk} = 0{,}1235 \,.\, 2{,}344 = 0{,}289\ \mathrm{kN/mb}$

− väznica 3 − 7 $\mathrm{gk} = 0{,}1235 \,.\, 3{,}125 = 0{,}386\ \mathrm{kN/mb}$

− väznica 8 a 11 $\mathrm{gk} = 0{,}1235 \,.\, 3{,}075 = 0{,}380\ \mathrm{kN/mb}$

− väznica 9 − 10 $\mathrm{gk} = 0{,}1235 \,.\, 1{,}613 = 0{,}199\ \mathrm{kN/mb}$

Stenový plášť KINGSPAN 1150 NF (120mm) budú použite na štítové steny.

m = 13,28 kg/m² panely budú kladené zvislo.

m = 13,28 kg/m² → Zaťaženie na paždíky **gk = 0,1328 kN/m2**

Zaťaženie na paždíky:

− paždik $\mathrm{gk} = 0{,}1328 \,.\, 2{,}5 = 0{,}332\ \mathrm{kN/mb}$

3.1.3 ZS3 OSTATNÉ STÁLE ZAŤAŽENIE

Tiaž od vzduchotechniky, osvetlenia. Predpoklad hmotnosti 25kg/m2

− väznik 1 a 10 $\mathrm{gk} = 0{,}25 \,.\, 2{,}5 = 0{,}625\ \mathrm{kN/mb}$

− väznik 2 až 9 $\mathrm{gk} = 0{,}25 \,.\, 5 = 1{,}25\ \mathrm{kN/mb}$

3.2 PREMENNÉ ZATAŽENIE (KLIMATICKÉ) - SNEH

Lokalita : Brno

Snehová oblasť : II

Charakteristická hodnota zaťaženia snehom **s_k = 1,0 kN/m2**

Súčiniteľ expozície : c_e = 1,0

Tepelný súčiniteľ : c_t = 1,0

3.2.1 ZS4 – SNEH PLNÝ

Tvarový súčiniteľ (pre valcové strechy) : μ_i= 0,8

$S_1= \mu * C_e * C_{t*}s_k$ = 0,8. 1,0. 1,0, 1,0 = 0,8 kN/m^2

Zaťaženie na väznice : **s = 0,8 kN/m**

Tečný uhol beta β > 60° → l_s= 33,83 m

→ väznice 1,2,17,18 nebudú zaťažené snehom

− väznica 3 a 16 $\quad sk = 0{,}8\,.\ 1{,}888 = 1{,}510\ \mathrm{kN/mb}$

− väznica 4 a 15 $\quad sk = 0{,}8\,.\ 2{,}163 = 1{,}730\ \mathrm{kN/mb}$

− väznica 5 a 14 $\quad sk = 0{,}8\,.\ 2{,}496 = 1{,}997\ \mathrm{kN/mb}$

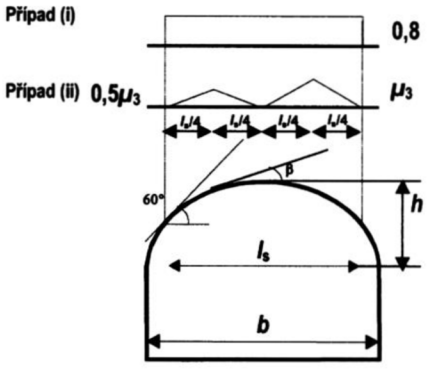
− väznica 6 a 13 $\quad sk = 0{,}8\,.\ 2{,}764 = 2{,}211\ \mathrm{kN/mb}$

− väznica 7 a 12 $\quad sk = 0{,}8\,.\ 2{,}961 = 2{,}369\ \mathrm{kN/mb}$

− väznica 8 a 11 $\quad sk = 0{,}8\,.\ 3{,}032 = 2{,}456\ \mathrm{kN/mb}$

− väznica 9 a 10 $\quad sk = 0{,}8\,.\ 1{,}611 = 1{,}289\ \mathrm{kN/mb}$

3.2.2 ZS5 – SNEH NAVIATÝ P (II A)



h = 13,92 m

b = 35 m

$\frac{h}{b} = \frac{13{,}92}{35{,}0} = 0{,}398 \geq 2{,}0 \rightarrow \mu 3 = 2{,}0$

Tečný uhol beta β > 60° → l_s= 33,83 m

Tečný uhol beta β > 60° → μ_3= 0

Tečný uhol beta β ≤ 60° → 0,5 μ_3 = 0,5.2 = 1

μ_3 = 2,0

$S_1 = \mu * C_e * C_{t*}s_k$ = 2,0. 1,0. 1,0. 1,0 = **2,0 kN/m2**

S_2= 0,5. $\mu * C_e * C_{t*}s_k$ = 0,5. 2,0. 1,0. 1,0, 1,0 = **1,0 kN/m2**

Zaťaženie na väznice :

→ väznice 1,2,17,18 nebudú zaťažené snehom

− väznica 3 $sk = 0{,}112 \,.\, 1{,}888 = 0{,}211$ kN/mb

− väznica 4 $sk = 0{,}351 \,.\, 2{,}163 = 0{,}759$ kN/mb

− väznica 5 $sk = 0{,}672 \,.\, 2{,}496 = 1{,}677$ kN/mb

− väznica 6a $sk = 0{,}887 \,.\, 1{,}911 = 1{,}695$ kN/mb

− väznica 6 b $sk = 0{,}950 \,.\, 0{,}854 = 0{,}811$ kN/mb

$sk = 6a + 6b = 1{,}695 + 0{,}811 = 2{,}506$ kN/mb

− väznica 7 $sk = 0{,}724 \,.\, 2{,}961 = 2{,}111$ kN/mb

− väznica 8 $sk = 0{,}370 \,.\, 3{,}032 = 1{,}122$ kN/mb

− väznica 9 $sk = 0{,}02 \,.\, 1{,}720 = 0{,}034$ kN/mb

− väznica 10 $sk = 0{,}190 \,.\, 1{,}611 = 0{,}306$ kN/mb

− väznica 11 $sk = 0{,}739 \,.\, 3{,}032 = 2{,}241$ kN/mb

− väznica 12 $sk = 1{,}448 \,.\, 2{,}961 = 4{,}288$ kN/mb

− väznica 13a $sk = 1{,}899 \,.\, 0{,}854 = 1{,}622$ kN/mb

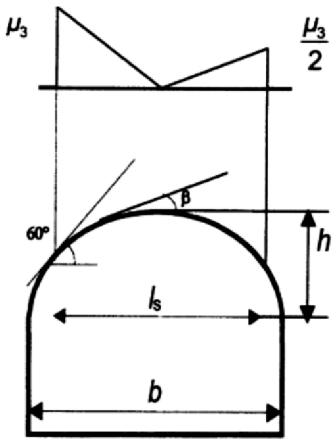
− väznica 13b $sk = 1{,}774 \,.\, 1{,}911 = 3{,}390$ kN/mb

$sk = 13a + 13b = 1{,}622 + 3{,}390 = 5{,}012$ kN/mb

− väznica 14 $sk = 1{,}253 \,.\, 2{,}496 = 3{,}749$ kN/mb

− väznica 15 $sk = 0{,}702 \,.\, 2{,}163 = 1{,}518$ kN/mb

− väznica 16 $sk = 0{,}223 \,.\, 1{,}888 = 0{,}421$ kN/mb



3.2.3 ZS6 – SNEH NAVIATÝ L (IIB)

Zaťaženie je symetrické so stavom ZS5

3.2.4 ZS7 – SNEH NAVIATÝ P (IIIA)

$\frac{h}{b} = \frac{13{,}92}{40} = 0{,}398 \geq 2{,}0 \rightarrow \mu 3 = 2{,}0$

$S_1 = \mu * C_e * C_{t*} s_k$ = 2,0. 1,0. 1,0. 1,0 = **2,0 kN/m2**

S_2= 0,5. $\mu * C_e * C_{t*} s_k$ =0,5. 2,0. 1,0. 1,0, 1,0 = **1,0 kN/m2**

Zaťaženie na väznice :

− väznica 3 $sk = 0{,}944 \,.\, 1{,}888 = 1{,}782$ kN/mb

− väznica 4 $sk = 0{,}824 \,.\, 2{,}163 = 1{,}783$ kN/mb

− väznica 5 $sk = 0{,}687 \,.\, 2{,}496 = 1{,}715$ kN/mb

− väznica 6 $sk = 0{,}531 \,.\, 2{,}764 = 1{,}468$ kN/mb

– väznica 7 $sk = 0{,}362 \,.\, 2{,}961 = 1{,}072\ \mathrm{kN/mb}$

– väznica 8 $sk = 0{,}185 \,.\, 3{,}032 = 0{,}561\ \mathrm{kN/mb}$

– väznica 9 $sk = 0{,}048 \,.\, 1{,}611 = 0{,}077\ \mathrm{kN/mb}$

– väznica 10 $sk = 0{,}095 \,.\, 1{,}611 = 0{,}153\ \mathrm{kN/mb}$

– väznica 11 $sk = 0{,}370 \,.\, 3{,}032 = 1{,}122\ \mathrm{kN/mb}$

– väznica 12 $sk = 0{,}724 \,.\, 2{,}961 = 2{,}144\ \mathrm{kN/mb}$

– väznica 13 $sk = 1{,}062 \,.\, 2{,}764 = 2{,}935\ \mathrm{kN/mb}$

– väznica 14 $sk = 1{,}373 \,.\, 2{,}496 = 4{,}070\ \mathrm{kN/mb}$

– väznica 15 $sk = 1{,}649 \,.\, 2{,}163 = 3{,}567\ \mathrm{kN/mb}$

– väznica 16 $sk = 1{,}888 \,.\, 1{,}888 = 3{,}565\ \mathrm{kN/mb}$

3.2.5 ZS8– SNEH NAVIATÝ L (IIIB)

Zaťaženie je symetrické so stavom ZS7.

3.3 PREMENNÉ ZATAŽENIE (KLIMATICKÉ)- VIETOR

Lokalita : Brno

Veterná oblasť : II

Kategória terénu : II

Parameter drsnosti terénu : z_0 = 0,05 m

Minimálna výška : z_{min} = 2,0 m

Základná rýchlosť vetra : $v_{b,0}$ = 25 m/s

Súčiniteľ smeru vetru c_{dir} = 1,0

Súčiniteľ ročného období : c_{season} = 1,0

Súčiniteľ ortografie terénu : $c_0(z)$ = 1,0

Výška objektu : z = 17,73 m (17,160)

Základná rýchlosť vetra 10 m nad terénom : $v_b = c_{dir}. C_{season}. V_{b,0}$ = 1,0. 1,0. 25 = 25 m/s

Súčiniteľ drsnosti terénu : $c_{r(z)} = k_r \,.\, \ln\left(\frac{z}{z_0}\right)$= 0,19. $\ln\left(\frac{17{,}73}{0{,}05}\right)$= 1,12 1,11

$k_r = 0{,}19\left(\frac{Z0}{Z0,II}\right)^{0{,}07} = 0{,}19\left(\frac{0{,}05}{0{,}05}\right)^{0{,}07}$ = 0,19

Stredná rýchlosť vetra : $v_m(z) = c_r(z)\cdot c0(z)\cdot v_b$ = 1,12·1,0·25 = 28m/s

Intenzita turbulencie: $I_v(z) = \frac{\sigma v}{vm(z)} = \frac{kI}{co(z).\ln\left(\frac{z}{zo}\right)} = \frac{1{,}0}{1{,}0.\ln\left(\frac{17{,}73}{0{,}05}\right)}$ = 0,170

Maximálny dynamický tlak: $q_p(z) = [1 + 7.\,Iv(z)] \,.\, \frac{1}{2} \,.\, \rho.\, vm(z)^2$

$q_p(z) = [1 + 7.\,0{,}170] \,.\, \frac{1}{2} \,.\, 1{,}25.\, 28^2$

$q_p(z)$ = 1073,1 Pa =**1,07 kN/m²**

3.3.1 ZS9– VIETOR PRIEČNÝ P

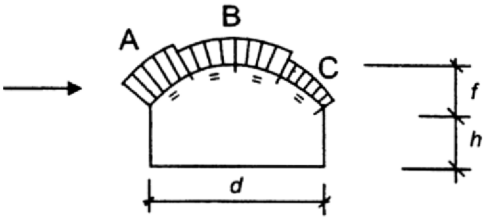
Účinky na strešný plášť

h = 5,14 m

d = 35,0 m

$$\frac{h}{d} = \frac{5,14}{35} = 0,15 \approx 0$$

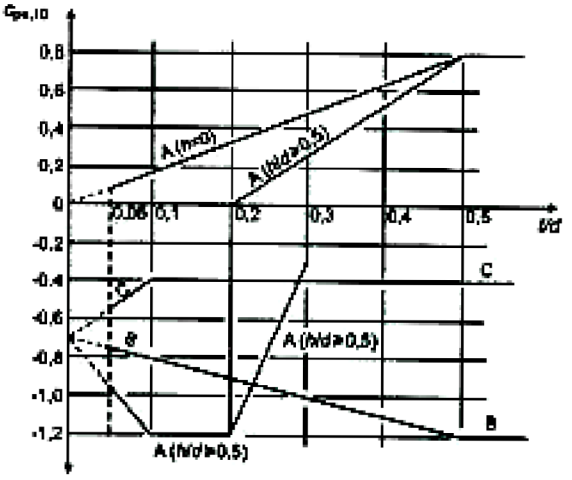
$$\frac{f}{d} = \frac{12,62}{35} = 0,361$$



$w_i = q_p(z) \cdot c_{p,10,i}$

Zdroj: norma ČSN EN 1991-1-4 Zatížení větrem

Zdroj: norma ČSN EN 1991-1-4 Zatížení větrem



Oblasť A:

$w_a = q_p(z) \cdot c_{p,10,a} = 1,07 \cdot 0,56 =$ **0,60 kN/m2**

Oblasť B

$w_b = q_p(z) \cdot c_{p,10,b} = 1,07 \cdot (-1,05) =$ **-1,12 kN/m2**

Zdroj: norma ČSN EN 1991-1-4 Zatížení větrem

Zaťaženie na väznice :

− väznica 1 $\quad sk = -1,12 \cdot 0,822 = -0,921\ \mathrm{kN/mb}$

− väznica 2 $\quad sk = -1,12 \cdot 2,344 = -2,625\ \mathrm{kN/mb}$

− väznica 3 $\quad sk = -1,12 \cdot 3,125 = -3,5\ \mathrm{kN/mb}$

− väznica 4 $\quad sk = -1,12 \cdot 3,125 = -3,5\ \mathrm{kN/mb}$

− väznica 5 $\quad sk = -1,12 \cdot 3,125 = -3,5\ \mathrm{kN/mb}$

− väznica 6 $\quad sk = -1,12 \cdot 3,125 = -3,5\ \mathrm{kN/mb}$

− väznica 7 $\quad sk = -1,12 \cdot 3,125 = -3,5\ \mathrm{kN/mb}$

− väznica 8 $\quad sk = -1,12 \cdot 3,075 = -3,444\ \mathrm{kN/mb}$

− väznica 9 $\quad sk = -1,12 \cdot 1,613 = -1,806\ \mathrm{kN/mb}$

− väznica 10 $\quad sk = -1,12 \cdot 1,613 = -1,806\ \mathrm{kN/mb}$

− väznica 11 $\quad sk = -1,12 \cdot 3,075 = -3,444\ \mathrm{kN/mb}$

− väznica 12 $\quad sk = -1,12 \cdot 3,125 = -3,5\ \mathrm{kN/mb}$

− väznica 13 $\quad sk = -1,12 \cdot 3,125 = -3,5\ \mathrm{kN/mb}$

− väznica 14 $\quad sk = 0,6 \cdot 3,125 = 1,875\ \mathrm{kN/mb}$

− väznica 15 $\quad sk = 0,6 \cdot 3,125 = 1,875\ \mathrm{kN/mb}$

$-$ väznica 16 $\quad sk = 0{,}6\,.\;3{,}125 = 1{,}875\ \mathrm{kN/mb}$

$-$ väznica 17 $\quad sk = 0{,}6\,.\;2{,}344 = 1{,}406\ \mathrm{kN/mb}$

$-$ väznica 18 $\quad sk = 0{,}6\,.\;0{,}822 = 0{,}493\ \mathrm{kN/mb}$

Účinky na štítové steny

b = 45,0 m

d = 35,0 m

h = 17,73 m

e = min{b; 2h} m = min $\{45{,}0;\ 2.17{,}73\}$ m = min $\{45{,}0;\ 35{,}46\}$ $\rightarrow$ e = 35,46 m

e $<$ d ...35,46m $<$ 35,0 m ... ✓

e $\geq$ d ...35,46m $\geq$ 35,0 m ... ✓ - iba oblasti A,B

Oblasť:

A = 7,092 m

B = 27,908 m

$$\frac{h}{d} = \frac{17{,}73}{35} = 0{,}507$$

$w_i = q_p(z)\ .\ c_{pe,10,i}$

Oblasť A: $c_{pe,10,(A)}$ = -1,2

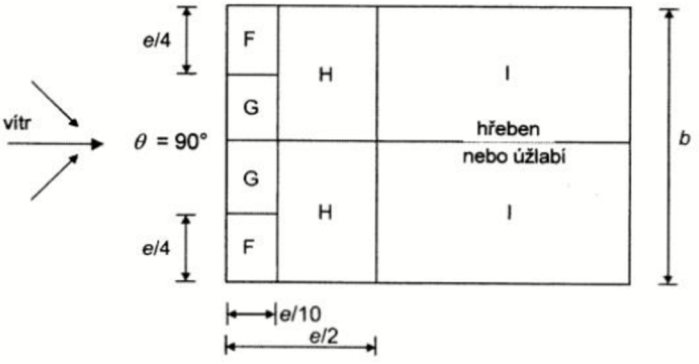
$w_{e,A} = q_p(z) \cdot c_{pe,10,(A)}$ = 1,07. (-1,2) = **-1,28 kN/m²**

Oblasť B: $c_{pe,10,(B)}$ = -1,0056 (interpolacia z tabulky 5.2)

$w_{e,B} = q_p(z) \cdot c_{pe,10,(B)}$ = 1,07 . (-1,0056) = **-1,076 kN/m²**

$-$ paždík $\quad = -1{,}28 \quad .\ 2{,}5 = -3{,}2 \quad \mathrm{kN/mb}$

$-$ paždík $\quad = -1{,}076\,.\ 2{,}5 = -2{,}69\ \mathrm{kN/mb}$



3.3.2 ZS10– VIETOR PRIEČNÝ P

Zaťaženie je symetrické so stavom ZS9.

3.3.3 ZS11 – VIETOR POZDĹŽNY PREDNY

Účinky na strešný plášť

e = 35,46 m

smer vetra θ = 90°

$$\frac{e}{4} = \frac{35{,}46}{4} = 8{,}865\ \mathrm{m}$$

$$\frac{e}{10} = \frac{35{,}46}{10} = 3{,}546\ \mathrm{m}$$

$\frac{e}{2} = \frac{35,46}{2} = 17,73$ m

$w_{e,C} = q_p(z) \cdot c_{pe,10,i} q_p(z)$ = **1,07 kN/m²**

- súčinitele $c_{pe,10,i}$ sú uvedené v nasledujúcej tabuľke

Väznica	cpe,10				We [kN/m2]			
	F	G	H	I	F	G	H	I
väznica 1,18	-1,10		-0,8	-0,50	-1,18	-	-0,86	-0,535
väznica 2,17	-1,10		-0,8	-0,50	-1,18	-	-0,86	-0,535
väznica 3,16	-1,10		-0,83	-0,50	-1,18	-	-0,89	-0,535
väznica 4,15	-1,10		-0,89	-0,50	-1,18	-	-0,95	-0,535
väznica 5,14	-1,10		-0,85	-0,50	-1,18	-	-0,91	-0,535
väznica 6,13	-1,13		-0,77	-0,50	-1,21	-	-0,82	-0,535
väznica 7,12	-	-1,32	-0,65	-0,50	-	-1,42	-0,70	-0,535
väznica 8,11	-	-1,30	-0,66	-0,50	-	-1,39	-0,71	-0,535
väznica 9,10	-	-1,30	-0,70	-0,50	-	-1,39	-0,75	-0,535

− väznica 1 a18 (f) $sk = -1,18 \ . \ 0,822 = -0,970$ kN/mb

− väznica 1 a18 (h) $sk = -0,86 \ . \ 0,822 = -0,707$ kN/mb

− väznica 1 a18 (i) $sk = -0,535 \ . \ 0,822 = -0,440$ kN/mb

− väznica 2 a17 (f) $sk = -1,18 \ . \ 2,344 = -4,407$ kN/mb

− väznica 2 a17 (h) $sk = -0,86 \ . \ 2,344 = -2,016$ kN/mb

− väznica 2 a17 (i) $sk = -0,535 \ . \ 2,344 = -1,254$ kN/mb

− väznica 3 a16 (f) $sk = -1,18 \ . \ 3,125 = -3,688$ kN/mb

− väznica 3 a16 (h) $sk = -0,89 \ . \ 3,125 = -2,781$ kN/mb

− väznica 3 a16 (i) $sk = -0,535 \ . \ 3,125 = -1,672$ kN/mb

− väznica 4 a15 (f) $sk = -1,18 \ . \ 3,125 = -3,688$ kN/mb

− väznica 4 a15 (h) $sk = -0,95 \ . \ 3,125 = -2,970$ kN/mb

− väznica 4 a15 (i) $sk = -0,535 \ . 3,125 = -1,672$ kN/mb

− väznica 5 a14 (f) $sk = -1,18 \ . \ 3,125 = -3,688$ kN/mb

− väznica 5 a14 (h) $sk = -0,91 \ . \ 3,125 = -2,844$ kN/mb

− väznica 5 a14 (i) $sk = -0,535 \ . \ 3,125 = -1,672$ kN/mb

− väznica 6 a13 (f) $sk = -1{,}21 \ . \ 1{,}990 = -2{,}408\ \mathrm{kN/mb}$

− väznica 6 a13 (g) $sk = -1{,}42 \ . \ 1{,}135 = -1{,}612\ \mathrm{kN/mb}$

− väznica 6 a13 (h) $sk = -0{,}82 \ . \ 3{,}125 = -2{,}563\ \mathrm{kN/mb}$

− väznica 6 a13 (i) $sk = -0{,}535 \ . \ 3{,}125 = -1{,}672\ \mathrm{kN/mb}$

− väznica 7 a12 (g) $sk = -1{,}42 \ . \ 3{,}125 = -4{,}428\ \mathrm{kN/mb}$

− väznica 7 a12 (h) $sk = -0{,}70 \ . \ 3{,}125 = -2{,}188\ \mathrm{kN/mb}$

− väznica 7 a12 (i) $sk = -0{,}535 \ . \ 3{,}125 = -1{,}672\ \mathrm{kN/mb}$

− väznica 8 a11 (g) $sk = -1{,}39 \ . \ 3{,}075 = -4{,}274\ \mathrm{kN/mb}$

− väznica 8 a11 (h) $sk = -0{,}71 \ . \ 3{,}075 = -2{,}183\ \mathrm{kN/mb}$

− väznica 8 a11 (i) $sk = -0{,}535 \ . \ 3{,}075 = -1{,}645\ \mathrm{kN/mb}$

− väznica 9 a10 (g) $sk = -1{,}39 \ . \ 1{,}613 = -2{,}242\ \mathrm{kN/mb}$

− väznica 9 a10 (h) $sk = -0{,}75 \ . \ 1{,}613 = -1{,}210\ \mathrm{kN/mb}$

− väznica 9 a10 (i) $sk = -0{,}535 \ . \ 1{,}613 = -0{,}863\ \mathrm{kN/mb}$

- Účinky trenia na strešný plášť

$q_p(Ze) = 1{,}07$ kN/m2

$c_{fr} = 0{,}01$ (pre hladký povrch)

$d_0 = \min\{2b; 4h\}\ m = \min\{2 \cdot 35{,}0; 4 \cdot 17{,}73\}\ m = \min\{70; 70{,}92\} m \rightarrow d_0 = 70$ m

$d_{fr} = d - d0 = 45 - 70 = -25$ m → nevznikajú trecie sily od vetra

- Účinky na štítové steny

$\frac{h}{d} = \frac{17{,}73}{35} = 0{,}506\mathrm{m} \rightarrow c_{pe,10}$

$w_i = q_p(z) \cdot c_{pe,10,i}$

Oblasť D: $c_{pe,10,(D)} = 0{,}734$

$w_{e,D} = q_p(z) \cdot c_{pe,10,(D)} = 1{,}07 . 0{,}734 =$ **0,785 kN/m²**

Oblasť E: $c_{pe,10,(E)} = -0{,}368$

$w_{e,E} = q_p(z) \cdot c_{pe,10,(E)} = 1{,}07 \ . (-0{,}368) =$ **- 0,394 kN/m²**

− paždík $= 0{,}785 \ . \ 2{,}5 = 1{,}963\ \mathrm{kN/mb}$

− paždík $= -0{,}394 \ . \ 2{,}5 = -0{,}985\ \mathrm{kN/mb}$

3.3.4 ZS12 – VIETOR POZDĹŽNY ZADNY

Zaťaženie je symetrické so stavom ZS10.

3.3.5 ZS13 – ÚŽITNÉ ZAŤAŽENIE – STRECHA

Predpoklad, že zaťaženie qk pôsobí na ploche $A = 10\ m^2$

Zaťaženie na väznicu: $qk = 0{,}75\ kN/m^2$

$qk = 0{,}75$ x zš $(3{,}125) = 2{,}344\ kN/m^2$

3.4 KOMBINÁCIE ZAŤAŽENIA

3.4.1 KOMBINÁCIE PRE MEDZNÝ STAV ÚNOSNOSTI

Kombinácie boli spočítané programom Dlubal RFEM podľa rovnice 6.10 ČSN EN 1990:

$$\sum_{j\geq 1} \gamma_{G,j} \cdot G_{k,j}\,'' + '' \gamma_p \cdot P\,'' + '' \gamma_{Q,1} \cdot Q_{k,1}\,'' + '' \sum_{i>1} \gamma_{Q,i} \cdot \Psi_{0.,i} \cdot Q_{k,i}$$

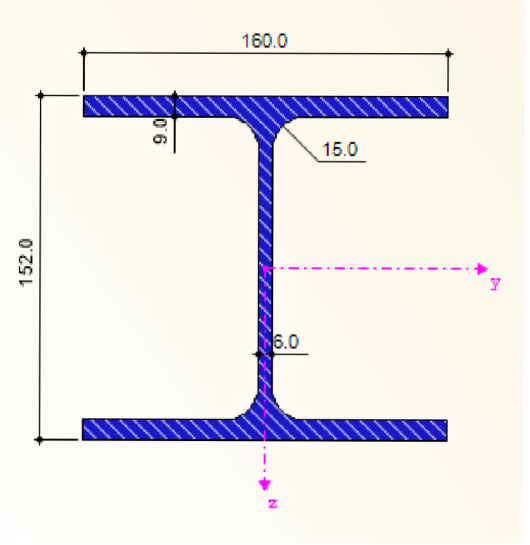
3.4.2 KOMBINÁCIE PRE MEDZNÝ STAV POUŽITELNOSTI

Kombinácie boli spočítané programom Dlubal RFEM podľa rovnice 6.14b, ČSN EN 1990:

$$\sum_{j\geq 1} G_{k,j}\,'' + '' P_k\,'' + '' Q_{k,1}\,'' + '' \sum_{i>1} \Psi_{0.,i} \cdot Q_{k,i}$$

4 POSÚDENIE NA MSÚ

4.1 VÄZNICA



Prierez: HEA 160

Prierezové charakteristiky:

A = 3,880 . 10^{-3} m^2

I_y = 1,673 . 10^{-5} m^4

I_z = 6,16 . 10^{-6} m^4

$W_{pl,y}$ = 2,46 . 10^{-4} m^3

$W_{pl,z}$ = 1,176 . 10^{-4} m^3

I_w = 3,14 . 10^{-8} m^6

I_t = 1,23 . 10^{-7} m^4

Materiálové charakteristiky:

S235 (f_y = 235 MPa, f_u = 360 MPa)

E = 210 GPa

G = 81 GPa

Trieda prierezu:

$$\varepsilon = \sqrt{\frac{235}{f_y}} = \sqrt{\frac{235}{235}} = 1{,}0$$

$$c_2 = \frac{160}{2} - \frac{6}{2} - 15 = 62\ mm$$

Pásnica:

$$\frac{c_2}{t} = \frac{62}{9} = 6{,}889 \leq 9\varepsilon = 9\,.\,1{,}0 = 9\ \ 1.třída$$

Stojina:

$$\frac{h_w}{tw} = \frac{134}{6} = 22{,}333\ \leq 72\varepsilon = 72\,.\,1 = 72\ 1.třída$$

4.1.1 POSÚDENIE NA OHYB OKOLO OSI Z BEZ KLOPENIA

Prút 1555 – KZ45

$M_{z,Ed}$ = 11,581 kNm

$$\frac{M_{z,Ed}}{M_{c,Rd}} \leq 1{,}0$$

$$M_{c,Rd} = M_{pl,Rd,z} = \frac{w_{pl,z}\,.\,f_y}{\gamma_{M0}} = \frac{1{,}176\,.\,10^{-4}\,.\ 235.10^3}{1{,}0} = 27{,}636\ \text{kN}$$

$$\frac{M_{z,Ed}}{M_{pl,Rd,z}} = \frac{11{,}581}{27{,}363} = 0{,}42 \leq 1{,}0$$

4.1.2 POSÚDENIE NA OHYB OKOLO OSI Y BEZ KLOPENIA

Prút 1188 – KZ49

$M_{y,Ed}$ = 33,739 kNm

$$\frac{M_{y,Ed}}{M_{c,Rd}} \leq 1,0$$

$$M_{c,Rd} = M_{pl,Rd,y} = \frac{w_{pl,y} \cdot f_y}{\gamma_{M0}} = \frac{2,46 \cdot 10^{-4} \cdot 235 \cdot 10^3}{1,0} = 57,81 \text{ kN}$$

$$\frac{M_{y,Ed}}{M_{pl,Rd,y}} = \frac{33,739}{57,81} = 0,58 \leq 1,0$$

0,58 ≤ 1,0 ... vyhovuje

4.1.3 POSÚDENIE NA ŠMYK:

Návrhová hodnota šmykovej sily:

Prút č. 1700 KZ50

$$V_{y,Ed} = 10,704kN$$

$$A_v = A - 2bt_f + (t_w + 2r)t_f = 3880 - 2 * 160 * 9 + (6 + 2 * 15) * 9 =$$

$$A_v = 1324\, mm^2$$

$$V_{y,pl,Rd} = \frac{A_v(f_y / \sqrt{3})}{\gamma_{M0}} = \frac{1324 * (235 / \sqrt{3})}{1,0} = 179,636kN$$

$$\frac{V_{y,Ed}}{V_{y,pl,Rd}} = \frac{10,704}{179,636} = 0,06 < 1,0$$

0,06 ≤ 1,0 ... vyhovuje

4.1.4 POSÚDENIE NA KOMBINÁCIU TLAKU A OHYBU

Prút č. 1730 – KZ 49

$N_{Ed} = -12,466$ kN

$M_{y,Ed} = 33,716$ kNm

$M_{z,Ed} = -5,313$ kNm

Vzper okolo osy Y

$$L_{cr,y} = 2,5m$$

$$\frac{h}{b} = \frac{152}{160} = 0,95 < 2 \Rightarrow krivka\ b \Rightarrow \alpha = 0,34 \quad tab\ 1.3$$

$$\lambda_y = \frac{L_{cr,y}}{i_y} = \frac{2500}{65,7} = 38,05$$

$$\frac{N_{Ed}}{N_{b,Rd}} \leq 1{,}0$$

$$N_{b,Rd} = \frac{\chi_y \,.\, A \,.\, f_y}{\gamma_{M1}} = \frac{0{,}924 \,.\, 3{,}88 \,.\, 10^{-3} \,.\, 235 \,.\, 10^3}{1{,}0} = 842{,}5 \text{ kN}$$

$$\chi_y = \frac{1}{\phi_y + \sqrt{\phi_y{}^2 - \bar{\lambda}_y{}^2}} = \frac{1}{0{,}617 + \sqrt{0{,}617^2 - 0{,}405^2}} = 0{,}924$$

$$\phi_y = 0{,}5 \,.\, \left[1 + \alpha_{LT}\left(\bar{\lambda}_{,y} - 0{,}2\right) + \bar{\lambda}_y{}^2\right] = 0{,}5 \,.\, \left[1 + 0{,}34 \,.\, (0{,}405 - 0{,}2) + 0{,}405^2\right] = 0{,}617$$

$$\bar{\lambda}_y = \sqrt{\frac{A \,.\, f_y}{N_{cr}}} = \sqrt{\frac{3{,}88 \,.\, 10^{-3} \,.\, 235 \,.\, 10^3}{5547{,}98}} = 0{,}405 \; > 0{,}2$$

Nemôžem zanedbať účinky vzperu

$$N_{cr,y} = \frac{\pi^2 \,.\, E \,.\, I_y}{Lcr, y^2} = \frac{\pi^2 \,.\, 210 \,.\, 10^6 \,.\, 1{,}673 \,.\, 10^{-5}}{2{,}5^2} = 5547{,}98\text{kN}$$

$$\frac{N_{Ed}}{N_{b,Rd}} = \frac{12{,}466}{842{,}5} = 0{,}02 \; \leq 1{,}0$$

0,02 ≤ 1,0 ... vyhovuje (program RFEM 0,04 ≤ 1,0)

Vzper okolo osy Z

$$\frac{h}{b} = \frac{152}{160} = 0{,}95 < 1{,}2 \; \Rightarrow krivka\ c \Rightarrow \; \alpha = 0{,}49 \quad tab\ 1.3$$

$$N_{b,Rd} = \frac{\chi_z \,.\, A \,.\, f_y}{\gamma_{M1}} = \frac{0{,}374 \,.\, 3{,}88 \,.\, 10^{-3} \,.\, 235 \,.\, 10^3}{1{,}0} = 341{,}01 \text{ kN}$$

$$\chi_z = \frac{1}{\phi_z + \sqrt{\phi_z{}^2 - \bar{\lambda}_z{}^2}} = \frac{1}{1{,}671 + \sqrt{1{,}671^2 - 1{,}336^2}} = 0{,}374$$

$$\phi_z = 0{,}5 \,.\, \left[1 + \alpha_{LT}\left(\bar{\lambda}_{zy} - 0{,}2\right) + \bar{\lambda}_z{}^2\right] = 0{,}5 \,.\, \left[1 + 0{,}49(1{,}336 - 0{,}2) + 1{,}336^2\right] = 1{,}671$$

$$\bar{\lambda}_z = \sqrt{\frac{A \,.\, f_y}{N_{cr}}} = \sqrt{\frac{3{,}88 \,.\, 10^{-3} \,.\, 235 \,.\, 10^3}{510{,}69}} = 1{,}336 \; > 0{,}2$$

Nemôžem zanedbať účinky vzperu

$$N_{cr,z} = \frac{\pi^2 \,.\, E \,.\, I_z}{Lcr, z^2} = \frac{\pi^2 \,.\, 210 \,.\, 10^6 \,.\, 6{,}16 \,.\, 10^{-6}}{5^2} = 510{,}69 \text{ kN}$$

$$\frac{N_{Ed}}{N_{b,Rd}} = \frac{12{,}466}{341{,}01} = 0{,}04 \; \leq 1{,}0$$

0,04≤ 1,0 ... vyhovuje

Parameter krútenia

$k_w = 1{,}0; L = 5{,}0\text{m}$

$$k_{wt} = \frac{\Pi}{k_w . L}\sqrt{\frac{E . I_w}{G . I_t}} = \frac{\Pi}{1{,}0 * 5}\sqrt{\frac{210 . 10^9 . 3{,}14 . 10^{-8}}{81 . 10^9 . 1{,}23 . 10^{-7}}} = 0{,}511$$

$$z_j = 0$$

$$\zeta_j = \frac{\pi z_j}{k_z L}\sqrt{\frac{EI_z}{GI_t}} = 0$$

$$z_g = 0{,}076\text{m}$$

$$\zeta_g = \frac{\pi . z_g}{k_z . L}\sqrt{\frac{EI_z}{GI_t}} = \frac{\pi . \ 0{,}076}{1 . 5}\sqrt{\frac{210 . 10^9 . 6{,}16 . 10^{-6}}{81 . 10^9 . 1{,}23 . 10^{-7}}} = 0{,}544$$

Bezrozmerný kriticky moment

$$C_1 = 1{,}13$$

$$C_2 = 0{,}46$$

$$C_3 = 0{,}53$$

$$\mu_{Cr} = \frac{C_1}{k_z}\left[\sqrt{1 + k_{wt}^2 + \left(C_2\zeta_g - C_3\zeta_j\right)^2} - \left(C_2\zeta_g - C_3\zeta_j\right)\right]$$

$$\mu_{Cr} = \frac{1{,}13}{1{,}0}\left[\sqrt{1 + 0{,}511^2 + (0{,}46 . \ 0{,}544 - 0{,}53 . \ 0\ )^2} - (0{,}46 . \ 0{,}544 - 0{,}53 . 0)\right]$$

$$\mu_{Cr} = 1{,}017$$

Pružný kritický moment pri klopení

$$M_{cr} = \mu_{cr}\frac{\pi\sqrt{E . I_z . G . I_t}}{L} = 1{,}017 * \frac{\pi\sqrt{210 . 10^9 . \ 6{,}16 . 10^{-6} . \ 81 . 10^9 . 1{,}23 . 10^{-7}}}{5}$$

$$M_{cr} = 72{,}543\ kNm$$

Pomerná štíhlosť

$$\bar{\lambda}_{LT} = \sqrt{\frac{W_{pl,y} . f_y}{M_{cr}}} = \sqrt{\frac{2{,}46 . 10^{-4} . 235 . 10^3}{72{,}543}} = 0{,}893$$

$$\frac{h}{b} = \frac{152}{160} = 0{,}95 < 2 \ \Rightarrow krivka\ klopenia\ \ a \Rightarrow \ \alpha_{LT} = 0{,}21 \quad tab\ 1.8$$

$$\phi_{LT} = 0{,}5\left(1 + \alpha_{LT}\left(\bar{\lambda}_{LT} - 0{,}2\right) + \bar{\lambda}_{LT}^2\right) = 0{,}5 . (1 + 0{,}21 . (0{,}893 - 0{,}2) + 0{,}893^2) = 0{,}971$$

$$\chi_{LT} = \frac{1}{\phi_{LT} + \sqrt{\phi_{LT}^2 - \bar{\lambda}_{LT}^2}} = \frac{1}{0{,}971 + \sqrt{0{,}971^2 - 0{,}893^2}} = 0{,}968$$

Návrhové hodnoty únosnosti:

$$M_{b,Rd} = \frac{\chi_{LT} . W_{pl,y} . f_y}{\gamma_{M0}} = \frac{0{,}739 . 2{,}46 . 10^{-4} . 235 . 10^3}{1{,}0} = 42{,}722 kNm$$

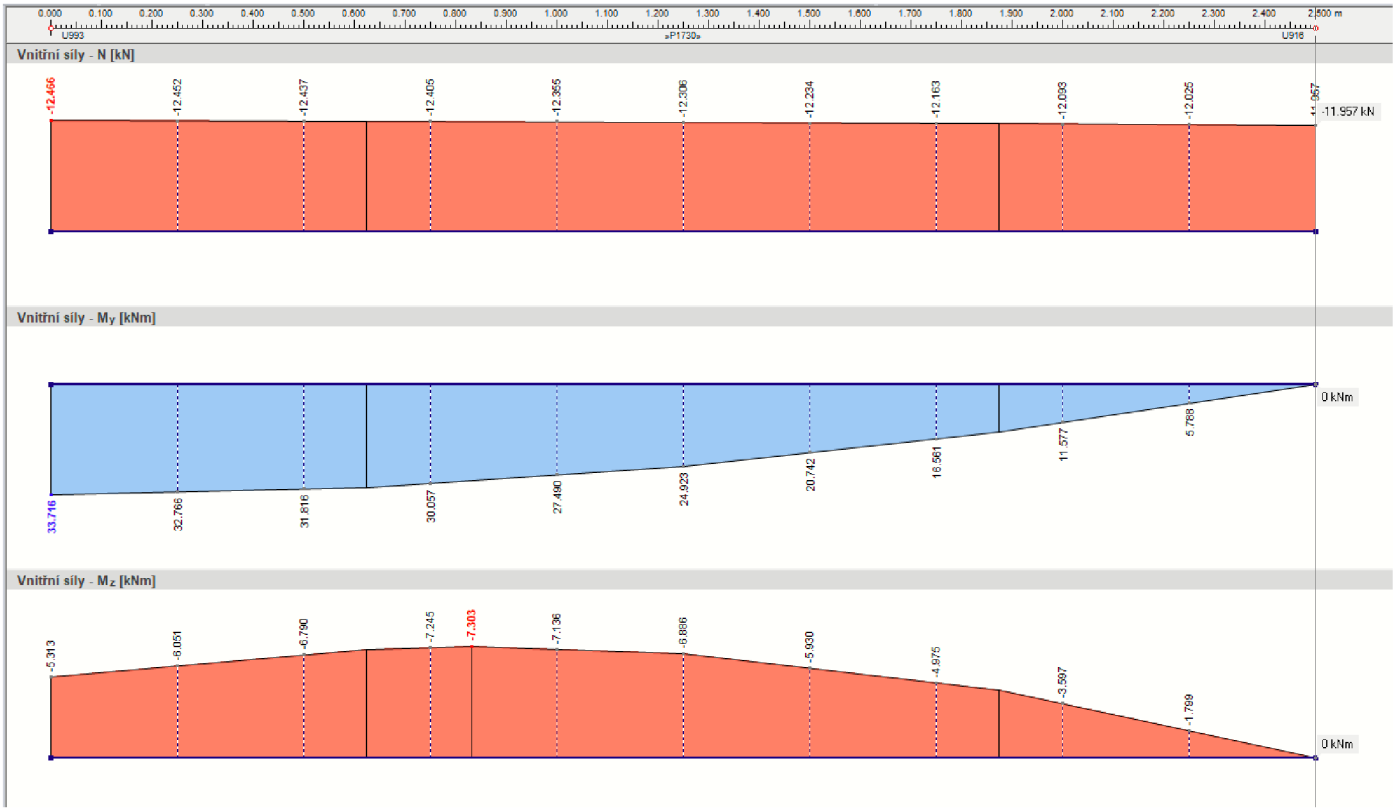
$$\frac{M_{y,Ed}}{M_{b,Rd}} = \frac{33,716}{42,722} = 0,78 < 1$$

Návrhové hodnoty únosnosti:

$$N_{Rd} = \frac{A \,.\, f_y}{\gamma_{M0}} = \frac{3,88 \,.\, 10^{-3} .\ 235 \,.\, 10^3}{1,0} = 911,8\ kN$$

$$M_{Y,Rd} = \frac{W_{pl,y} \,.\, f_y}{\gamma_{M0}} = \frac{2,46 \,.\, 10^{-4} \,.\, 235 \,.\, 10^3}{1,0} = 57,81\ kNm$$

$$M_{z,pl,Rd} = \frac{W_{pl,z} \,.\, f_y}{\gamma_{M0}} = \frac{1,176 .\ 10^{-4} .\ 235 \,.\, 10^3}{1,0} = 27,64\ kNm$$



$M_{h,y} = 33,716\ \text{kNm}$

$\Psi M_{h,y} = 0\ \text{kNm}$

$$\Psi = \frac{0}{33,716} = 0$$

$M_{s,y} = 24,923\ \text{kNm}$

$$\alpha_s = \frac{M_s}{M_h} = \frac{24,923}{33,716} = 0,739$$

$0 \le \alpha_s \le 1$

$0 \le 0,739 \le 1 \ldots \checkmark$

$0 \le \Psi \le 1$

$0 \le 0 \le 1 \ldots \checkmark$

$c_{my} = 0,2 + 0,8 \,.\, \alpha_s = 0,2 + 0,8 \,.\, 0,739 = 0,791 \ge 0,4 \ldots \checkmark$

$c_{my} = c_{mLT} = 0{,}791$

$$k_{yy} = c_{my} \cdot \left(1 + \left(\bar{\lambda}_y - 0{,}2\right) \cdot \frac{N_{Ed}}{\frac{\chi_y \cdot N_{Rk}}{\gamma_{M1}}}\right) \leq c_{my} \cdot \left(1 + 0{,}8 \cdot \frac{N_{Ed}}{\frac{\chi_y \cdot N_{Rk}}{\gamma_{M1}}}\right)$$

$$k_{yy} = 0{,}791 \cdot \left(1 + (0{,}405 - 0{,}2) \cdot \frac{12{,}466}{\frac{0{,}924 \cdot 911{,}8}{1{,}0}}\right) \leq 0{,}791 \cdot \left(1 + 0{,}8 \cdot \frac{12{,}466}{\frac{0{,}924 \cdot 911{,}8}{1{,}0}}\right)$$

$k_{yy} = 0{,}793 \leq 0{,}8 \ldots k_{yy} = 0{,}793$

Súčiniteľ C_{mz} ekvivalentného konštantného momentu

$M_{h,z} = -5{,}313\ \text{kNm}$

$\Psi M_{h,z} = 0\ \text{kNm}$

$\Psi = -\frac{0}{5{,}313} = 0$

$M_{s,z} = -6{,}886\ \text{kNm}$

$\alpha_h = \frac{M_h}{M_d} = \frac{-5{,}313}{-6{,}886} = 0{,}772$

$0 \leq a_h \leq 1$

$0 \leq 0{,}772 \leq 1 \ldots$ ✓

$-1 \leq \Psi \leq 1$

$-1 \leq 0 \leq 1 \ldots$ ✓

$c_{mz} = 0{,}95 + 0{,}05 \cdot \alpha_h = 0{,}95 + 0{,}05 \cdot 0{,}772 = 0{,}989 \geq 0{,}4 \ldots$ ✓

$$k_{zz} = c_{mz} \cdot \left(1 + \left(2 \cdot \bar{\lambda}_z - 0{,}6\right) \cdot \frac{N_{Ed}}{\frac{\chi_z \cdot N_{Rk}}{\gamma_{M1}}}\right) \leq c_{mz} \cdot \left(1 + 1{,}4 \cdot \frac{N_{Ed}}{\frac{\chi_z \cdot N_{Rk}}{\gamma_{M1}}}\right)$$

$$k_{zz} = 0{,}989 \cdot \left(1 + (2 \cdot 1{,}136 - 0{,}6) \cdot \frac{12{,}466}{\frac{0{,}374 \cdot 911{,}8}{1{,}0}}\right) \leq 0{,}989 \cdot \left(1 + 1{,}4 \cdot \frac{12{,}466}{\frac{0{,}374 \cdot 911{,}8}{1{,}0}}\right)$$

$k_{zz} = 1{,}049 \leq 1{,}039 \ldots k_{zz} = 1{,}039$

$k_{yz} = 0{,}6 \cdot k_{zz} = 0{,}6 \cdot 1{,}039 = 0{,}623$

$$k_{zy} = \left(1 - \frac{0{,}1 \cdot \bar{\lambda}_z}{C_{m,LT} - 0{,}25} \cdot \frac{N_{Ed}}{\frac{\chi_z \cdot N_{Rk}}{\gamma_{M1}}}\right) \geq \left(1 - \frac{0{,}1 \cdot}{C_{m,LT} - 0{,}25} \cdot \frac{N_{Ed}}{\frac{\chi_z \cdot N_{Rk}}{\gamma_{M1}}}\right)$$

$$k_{zy} = \left(1 - \frac{0{,}1 \cdot 1{,}336}{0{,}791 - 0{,}25} \cdot \frac{12{,}466}{\frac{0{,}374 \cdot 911{,}8}{1{,}0}}\right) \geq \left(1 - \frac{0{,}1}{0{,}791 - 0{,}25} \cdot \frac{12{,}466}{\frac{0{,}374 \cdot 911{,}8}{1{,}0}}\right)$$

$k_{zy} = 0{,}991 \geq 0{,}993 \ldots k_{zy} = 0{,}993$

$$\frac{N_{Ed}}{\frac{\chi_y \cdot N_{Rk}}{\gamma_{M1}}} + k_{yy} \cdot \frac{M_{y,Ed}}{\frac{\chi_{LT} \cdot M_{y,Rk}}{\gamma_{M1}}} + k_{yz} \cdot \frac{M_{z,Ed}}{\frac{\chi_{LT} \cdot M_{z,Rk}}{\gamma_{M1}}} \leq 1{,}0$$

$$\frac{12{,}466}{\frac{0{,}924 \cdot 911{,}8}{1{,}0}} + 0{,}793 \cdot \frac{33{,}716}{\frac{0{,}968 \cdot 57{,}81}{1{,}0}} + 0{,}623 \cdot \frac{5{,}313}{\frac{0{,}968 \cdot 27{,}64}{1{,}0}} \leq 1{,}0$$

$0{,}64 \leq 1{,}0$ (program $0{,}64 \leq 1{,}0$)

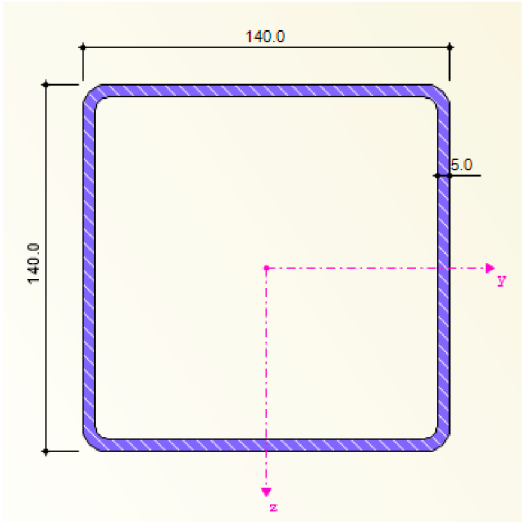
$$\frac{N_{Ed}}{\frac{\chi_z \cdot N_{Rk}}{\gamma_{M1}}} + k_{zy} \cdot \frac{M_{y,Ed}}{\frac{\chi_{LT} \cdot M_{y,Rk}}{\gamma_{M1}}} + k_{zz} \cdot \frac{M_{z,Ed}}{\frac{\chi_{LT} \cdot M_{z,Rk}}{\gamma_{M1}}} \leq 1{,}0$$

$$\frac{12{,}466}{\frac{0{,}374 \cdot 911{,}8}{1{,}0}} + 0{,}993 \cdot \frac{33{,}716}{\frac{0{,}968 \cdot 57{,}81}{1{,}0}} + 1{,}039 \cdot \frac{5{,}313}{\frac{0{,}968 \cdot 27{,}64}{1{,}0}} \leq 1{,}0$$

$0{,}84 \leq 1{,}0$ (program $0{,}88 \leq 1{,}0$)

4.2 PRIEHRADOVÝ VÄZNÍK

4.2.1 HORNÝ PÁS



Prierezové charakteristiky:

b = 140 mm

t = 5 mm

A = 2640 mm^2

I_y = 7910000 mm^4

i_y = 54,8 mm

$W_{pl,y}$ = 132000 mm^3

Materiálové charakteristiky:

S235 (f_y = 235MPa, f_u = 360 MPa)

E = 210 GPa

Trieda prierezu:

$$\varepsilon = \sqrt{\frac{235}{fy}} = \sqrt{\frac{235}{235}} = 1{,}0$$

Pre trubkové profily štvorcového tvaru platí

$$\frac{c}{t} = \frac{140 - 10}{5} = 26 \leq 33.\varepsilon = 33\,.1 = 33 \;\rightarrow\; 1.\check{t}\acute{r}\acute{i}da$$

4.2.2 POSÚDENIE NA ŤAH

Prút č 1116 kz 61

$$N_{Ed} \;=\; 178{,}759\text{kN}$$

$$\frac{N_{Ed}}{N_{t,Rd}} \leq 1{,}0$$

$$N_{t,Rd} = \frac{A\,.\,f_y}{\gamma_{M1}} = \frac{2640\,.10^{-6}\,.\;235.10^{3}}{1{,}0} = 620{,}4\text{ kN}$$

$$\frac{N_{Ed}}{N_{t,Rd}} \leq 1{,}0$$

$$\frac{178{,}759}{620{,}4} \leq 1{,}0$$

0,29 ≤ 1,0 ... vyhovuje program 0,29

4.2.3 POSÚDENIE NA VZPER

Prút č 1140 kz 89

$$N_{Ed} \;=\; -261{,}917\text{ kN}$$

$L_{cr,y} = L_{cr,z} = 3{,}022\ m$ (zaistené väznicami)

$\alpha = 0{,}49$ (duté prierezy tvarované za studena – krivka vzpernej pevnosti ´´c´´)

<u>Vybočenie kolmo k osy y:</u>

$$\lambda_y = \frac{L_{cr,y}}{i_y} = \frac{3022}{54{,}8} = 55{,}14$$

$$\frac{N_{Ed}}{N_{b,Rd}} \leq 1{,}0$$

$$N_{b,Rd} = \frac{\chi_y\,.\;A\,.\;f_y}{\gamma_{M1}} = \frac{0{,}79\,.2640\,.10^{-6}\,.\;235.10^{3}}{1{,}0} = 490{,}116\text{ kN}$$

$$\chi_y = \chi_z = \frac{1}{\phi_y + \sqrt{\phi_y{}^2 - \bar{\lambda}_y{}^2}} = \frac{1}{0{,}77 + \sqrt{0{,}77^2 - 0{,}59^2}} = 0{,}79$$

$$\phi_y = 0{,}5\,.\,\left[1 + \alpha_{LT}\left(\bar{\lambda}_{,y} - 0{,}2\right) + \bar{\lambda}_y{}^2\right] = 0{,}5\,.\,\left[1 + 0{,}49.(0{,}59 - 0{,}2) + 0{,}59^2\right] = 0{,}77$$

$$\bar{\lambda}_y = \bar{\lambda}_z = \sqrt{\frac{A\,.\,f_y}{N_{cr}}} = \sqrt{\frac{2640\,.\,10^{-6}.\,235\,.\,10^3}{1795{,}174}} = 0{,}59\ > 0{,}2$$

Nemôžem zanedbať účinky vzperu

$$N_{cr} = \frac{\pi^2.\ E\,.\,I_y}{Lcr, y^2} = \frac{\pi^2.\ 210\ .\ 10^6\ .\ 7910000.10^{-12}}{3{,}022^2} = 1795{,}174\text{kN}$$

$$\frac{\mathrm{N_{Ed}}}{\mathrm{N_{b,Rd}}} = \frac{261{,}917}{490{,}16} = 0{,}53\ \leq 1{,}0$$

0,53 ≤ 1,0 ... vyhovuje (program RFEM 0,27 ≤ 1,0)

4.2.4 POSÚDENIE NA KOMBINÁCIU OHYBU A TLAKU

Prút č 1140 kz 89

$\mathrm{N_{Ed}} = -261{,}917\ \mathrm{kN}$

$\mathrm{M_{y,Ed}} = 8{,}536\ \mathrm{kNm}$

$\mathrm{M_{z,Ed}} = 0{,}021\ \mathrm{kNm}$

$$\frac{\mathrm{N_{Ed}}}{\frac{\chi_y\,.\,\mathrm{N_{Rk}}}{\gamma_{M1}}} + \mathrm{k_{yy}}\,.\,\frac{\mathrm{M_{y,Ed}} + \Delta\mathrm{M_{y,Ed}}}{\frac{\chi_{LT}\,.\,\mathrm{M_{y,Rk}}}{\gamma_{M1}}} + \mathrm{k_{yz}}\,.\,\frac{\mathrm{M_{z,Ed}} + \Delta\mathrm{M_{z,Ed}}}{\frac{\chi_{LT}\,.\,\mathrm{M_{z,Rk}}}{\gamma_{M1}}} \leq 1{,}0$$

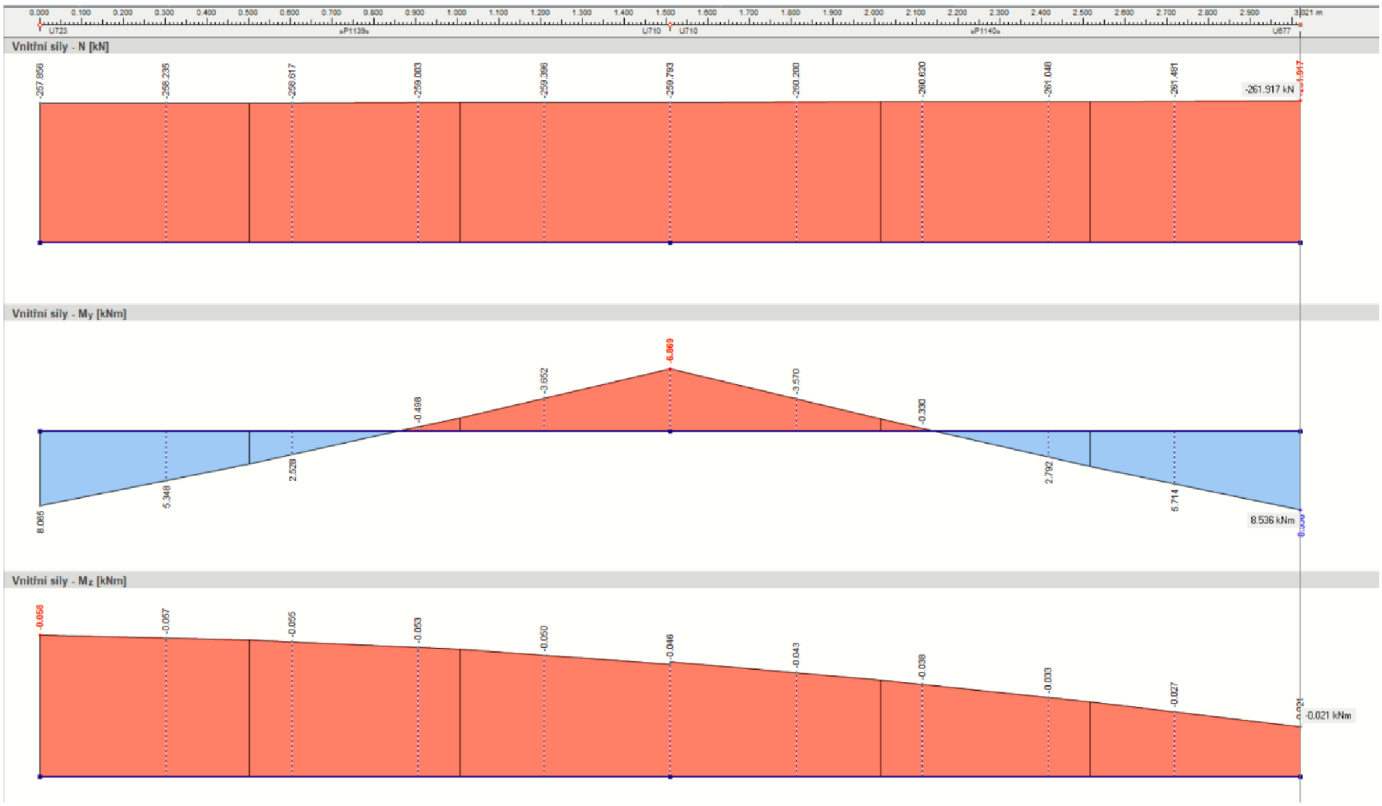
$$\frac{\mathrm{N_{Ed}}}{\frac{\chi_z\,.\,\mathrm{N_{Rk}}}{\gamma_{M1}}} + \mathrm{k_{zy}}\,.\,\frac{\mathrm{M_{y,Ed}} + \Delta\mathrm{M_{y,Ed}}}{\frac{\chi_{LT}\,.\,\mathrm{M_{y,Rk}}}{\gamma_{M1}}} + \mathrm{k_{zz}}\,.\,\frac{\mathrm{M_{z,Ed}} + \Delta\mathrm{M_{z,Ed}}}{\frac{\chi_{LT}\,.\,\mathrm{M_{z,Rk}}}{\gamma_{M1}}} \leq 1{,}0$$

Návrhové hodnoty únosnosti:

$$N_{Rd} = \frac{A\,.\,f_y}{\gamma_{M0}} = \frac{2640\,.\,10^{-6}.\ 235\,.\,10^3}{1{,}0} = 620{,}4\ kN$$

$$M_{y,Rd} = \frac{W_{pl,y}\,.\,f_y}{\gamma_{M0}} = \frac{132000\,.\,10^{-9}\,.\,235\,.\,10^3}{1{,}0} = 31{,}02\ kNm$$

$$M_{z,Rd} = \frac{W_{pl,z}\,.\,f_y}{\gamma_{M0}} = \frac{132000\,.\ 10^{-9}.\ 235\,.\,10^3}{1{,}0} = 31{,}02\ kNm$$



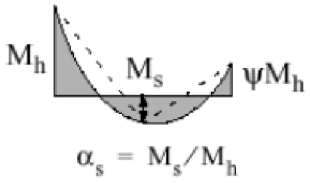
$M_{h,y} = 8{,}536\ \text{kNm}$

$\Psi M_{h,y} = 8{,}065\ \text{kNm}$

$$\Psi = \frac{8{,}065}{8{,}536} = 0{,}95$$

$M_{s,y} = -6{,}869\ \text{kNm}$

$$\alpha_s = \frac{M_s}{M_h} = \frac{-6{,}869}{8{,}536} = -0{,}8$$



$-1 \le a_s \le 0$

$-1 \le -0{,}8 \le 0 \ldots \checkmark$

$0 \le \Psi \le 1$

$0 \le 0{,}95 \le 1 \ldots \checkmark$

$c_{my} = 0{,}1 - 0{,}8 \,.\, \alpha_s = 0{,}1 - 0{,}8 \,.\, 0{,}8 = 0{,}54 \ge 0{,}4 \ldots \checkmark$

$$k_{yy} = c_{my} \,.\left(1 + \left(\bar{\lambda}_y - 0{,}2\right) \,.\, \frac{N_{Ed}}{\frac{\chi_y \,.\, N_{Rk}}{\gamma_{M1}}}\right) \le c_{my} \,.\left(1 + 0{,}8 \,.\, \frac{N_{Ed}}{\frac{\chi_y \,.\, N_{Rk}}{\gamma_{M1}}}\right)$$

$$k_{yy} = 0{,}54 \,.\left(1 + (0{,}59 - 0{,}2) \,.\, \frac{261{,}917}{\frac{0{,}79 \,.\, 620{,}48}{1{,}0}}\right) \le 0{,}54 \,.\left(1 + 0{,}8 \,.\, \frac{261{,}917}{\frac{0{,}79 \,.\, 620{,}48}{1{,}0}}\right)$$

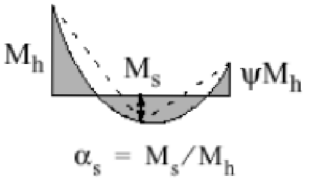
$k_{yy} = 0{,}65 \leq 0{,}77 \ldots k_{yy} = 0{,}65$

$k_{zy} = 0{,}6 \,.\, k_{yy} = 0{,}6 \,.\, 0{,}65 = 0{,}39$

$M_{h,z} = -0{,}058\ \text{kNm}$

$\Psi M_{h,z} = -0{,}021\ \text{kNm}$

$M_{s,z} = -0{,}046\ \text{kNm}$



$$\Psi = \frac{-0{,}021}{-0{,}058} = 0{,}36$$

$$\alpha_s = \frac{M_s}{M_h} = \frac{-0{,}046}{-0{,}058} = 0{,}79$$

$0 \leq a_s \leq 1$

$0 \leq 0{,}79 \leq 1 \ldots \checkmark$

$-1 \leq \Psi \leq 1$

$-1 \leq 0{,}36 \leq 1 \ldots \checkmark$

$c_{mz} = 0{,}2 + 0{,}8 \,.\, \alpha_s = 0{,}2 + 0{,}8 \,.\, 0{,}79 = 0{,}83 \geq 0{,}4 \ldots \checkmark$

$$k_{zz} = c_{mz} \,.\left(1 + \left(\bar{\lambda}_z - 0{,}2\right) \,.\, \frac{N_{Ed}}{\frac{\chi_z \,.\, N_{Rk}}{\gamma_{M1}}}\right) \leq c_{mz} \,.\left(1 + 0{,}8 \,.\, \frac{N_{Ed}}{\frac{\chi_z \,.\, N_{Rk}}{\gamma_{M1}}}\right)$$

$$k_{zz} = 0{,}83 \,.\left(1 + (0{,}59 - 0{,}2) \,.\, \frac{261{,}917}{\frac{0{,}79 \,.\, 620{,}48}{1{,}0}}\right) \leq 0{,}83 \,.\left(1 + 0{,}8 \,.\, \frac{261{,}917}{\frac{0{,}79 \,.\, 620{,}48}{1{,}0}}\right)$$

$k_{zz} = 1{,}003 \leq 1{,}18 \ldots k_{zz} = 1{,}003$

$k_{yz} = 0{,}6 \,.\, k_{zz} = 0{,}6 \,.\, 1{,}003 = 0{,}602$

$\chi_{LT} = 1{,}0$ (pri uzavretých prierezoch ku klopeniu nedochádza)

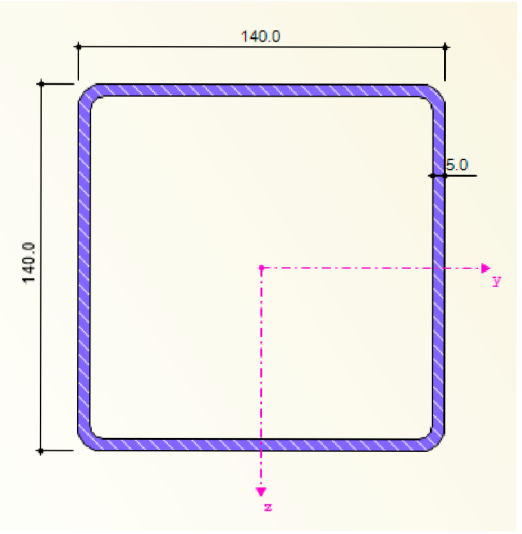
$$\frac{261{,}917}{\frac{0{,}79 \,.\, 620{,}4}{1{,}0}} + 0{,}65 \,.\, \frac{8{,}536 + 0}{\frac{1{,}0 \,.\, 31{,}02}{1{,}0}} + 0{,}39 \,.\, \frac{0{,}021 + 0}{\frac{1{,}0 \,.\, 31{,}02}{1{,}0}} \leq 1{,}0$$

0,71 ≤ 1,0 ... vyhovuje

$$\frac{261{,}917}{\frac{0{,}79 \,.\, 620{,}4}{1{,}0}} + 1{,}003 \,.\, \frac{8{,}536 + 0}{\frac{1{,}0 \,.\, 31{,}02}{1{,}0}} + 0{,}602 \,.\, \frac{0{,}021 + 0}{\frac{1{,}0 \,.\, 31{,}02}{1{,}0}} \leq 1{,}0$$

0,81 ≤ 1,0 ... vyhovuje

4.2.5 DOLNÝ PÁS



Prierezové charakteristiky:

b = 140 mm

t = 5 mm

A = 2640 mm^2

I_y = 7910000 mm^4

i_y = 54,8 mm

$W_{pl,y}$ = 132000 mm^3

Materiálové charakteristiky:

S235 (f_y = 235MPa, f_u = 360 MPa)

E = 210 GPa

Trieda prierezu:

$$\varepsilon = \sqrt{\frac{235}{\mathrm{fy}}} = \sqrt{\frac{235}{235}} = 1{,}0$$

Pre trubkové profily štvorcového tvaru platí

$$\frac{c}{t} = \frac{140 - 10}{5} = 26 \leq 33.\varepsilon = 33\,.1 = 33 \;\rightarrow\; 1.třída$$

4.2.6 POSÚDENIE NA ŤAH

Prút č 1170 kz 69

$$\mathrm{N_{Ed}} = 262{,}791\ \mathrm{kN}$$

$$\frac{\mathrm{N_{Ed}}}{\mathrm{N_{t,Rd}}} \leq 1{,}0$$

$$\mathrm{N_{t,Rd}} = \frac{\mathrm{A}.\ \mathrm{f_y}}{\gamma_{\mathrm{M1}}} = \frac{2640\,.10^{-6}\ .\ 235.10^{3}}{1{,}0} = 620{,}4\ \mathrm{kN}$$

$$\frac{\mathrm{N_{Ed}}}{\mathrm{N_{t,Rd}}} \leq 1{,}0$$

$$\frac{262{,}791}{620{,}4} \leq 1{,}0$$

0,42 ≤ 1,0 ... vyhovuje program 0,42

0,01 ≤ 1,0 ... vyhovuje

4.2.7 POSÚDENIE NA VZPER

Prút č 1150 kz 32

$$\mathrm{N_{Ed}} = -236{,}438\ \mathrm{kN}$$

$L_{cr,y} = 5{,}44m$ (zaistené styčníkmi)

$L_{cr,z} = 2{,}720m$ (zaistené stužidlami, väznicami)

$\alpha = 0{,}49$ (duté prierezy tvarované za studena – krivka vzpernej pevnosti ´´c´´)

Vybočenie kolmo k osy y:

$$\lambda_y = \frac{L_{cr,y}}{i_y} = \frac{5440}{54{,}8} = 99{,}27$$

$$\frac{N_{Ed}}{N_{b,Rd}} \leq 1{,}0$$

$$N_{b,Rd} = \frac{\chi_y \,.\, A \,.\, f_y}{\gamma_{M1}} = \frac{0{,}53 \,.\, 2640 \,.\, 10^{-6} \,.\, 235.10^3}{1{,}0} = 328{,}8\ \text{kN}$$

$$\chi_y = \frac{1}{\phi_y + \sqrt{{\phi_y}^2 - {\bar{\lambda}_y}^2}} = \frac{1}{1{,}22 + \sqrt{1{,}22^2 - 1{,}02^2}} = 0{,}53$$

$$\phi_y = 0{,}5 \,.\, \left[1 + \alpha_{LT}(\bar{\lambda}_{,y} - 0{,}2) + {\bar{\lambda}_y}^2\right] = 0{,}5 \,.\, [1 + 0{,}49 \,.\, (1{,}02 - 0{,}2) + 1{,}02^2] = 1{,}22$$

$$\bar{\lambda}_y = \sqrt{\frac{A \,.\, f_y}{N_{cr}}} = \sqrt{\frac{2460 \,.\, 10^{-6} . 235 \,.\, 10^3}{554}} = 1{,}02 > 0{,}2$$

Nemôžem zanedbať účinky vzperu

$$N_{cr,y} = \frac{\pi^2 .\ E \,.\, I_y}{Lcr, y^2} = \frac{\pi^2 .\ 210 \ .\ 10^6 \,.\, 7910000.10^{-12}}{5{,}44^2} = 554\text{kN}$$

$$\frac{N_{Ed}}{N_{b,Rd}} = \frac{236{,}438}{328{,}8} = 0{,}72 \leq 1{,}0$$

0,72 ≤ 1,0 ... vyhovuje (

Vybočenie kolmo k osy z:

$$\lambda_z = \frac{L_{cr,z}}{i_z} = \frac{2720}{54{,}8} = 49{,}64$$

$$\frac{N_{Ed}}{N_{b,Rd}} \leq 1{,}0$$

$$N_{b,Rd} = \frac{\chi_z \,.\, A \,.\, f_y}{\gamma_{M1}} = \frac{0{,}83 \,.\, 2640 \,.\, 10^{-6} \,.\, 235.10^3}{1{,}0} = 514{,}93\ \text{kN}$$

$$\chi_z = \frac{1}{\phi_z + \sqrt{{\phi_z}^2 - {\bar{\lambda}_z}^2}} = \frac{1}{0{,}71 + \sqrt{0{,}71^2 - 0{,}51^2}} = 0{,}83$$

$$\phi_z = 0{,}5 \,.\, \left[1 + \alpha_{LT}(\bar{\lambda}_{zy} - 0{,}2) + {\bar{\lambda}_z}^2\right] = 0{,}5 \,.\, [1 + 0{,}49(0{,}51 - 0{,}2) + 0{,}51^2] = 0{,}71$$

$$\bar{\lambda}_z = \sqrt{\frac{A \,.\, f_y}{N_{cr}}} = \sqrt{\frac{2460 \,.\, 10^{-6} . 235 \,.\, 10^3}{2215{,}94}} = 0{,}51 > 0{,}2$$

Nemôžem zanedbať účinky vzperu

$$N_{cr,z} = \frac{\pi^2 .\ E\ .I_z}{Lcr,z^2} = \frac{\pi^2 .\ 210\ .\ 10^6\ .\ 7910000.10^{-12}}{2{,}72^2} = 2215{,}94\ \text{kN}$$

$$\frac{\mathrm{N_{Ed}}}{\mathrm{N_{b,Rd}}} = \frac{236{,}438}{514{,}93} = 0{,}46\ \leq 1{,}0$$

0,46 ≤ 1,0 ... vyhovuje (program RFEM 0,09 ≤ 1,0)

4.2.8 POSÚDENIE NA KOMBINÁCIU OHYBU A TLAKU

Prút č 1150 kz 32

$\mathrm{N_{Ed}} = -236{,}438\ \text{kN}$

$\mathrm{M_{y,Ed}} = -9{,}333\ \text{kNm}$

$\mathrm{M_{z,Ed}} = 0{,}018\ \text{kNm}$

$$\frac{\mathrm{N_{Ed}}}{\frac{\chi_y\ .\ \mathrm{N_{Rk}}}{\gamma_{M1}}} + \mathrm{k_{yy}}\ .\ \frac{\mathrm{M_{y,Ed}} + \Delta\mathrm{M_{y,Ed}}}{\frac{\chi_{LT}\ .\ \mathrm{M_{y,Rk}}}{\gamma_{M1}}} + \mathrm{k_{yz}}\ .\ \frac{\mathrm{M_{z,Ed}} + \Delta\mathrm{M_{z,Ed}}}{\frac{\chi_{LT}\ .\ \mathrm{M_{z,Rk}}}{\gamma_{M1}}} \leq 1{,}0$$

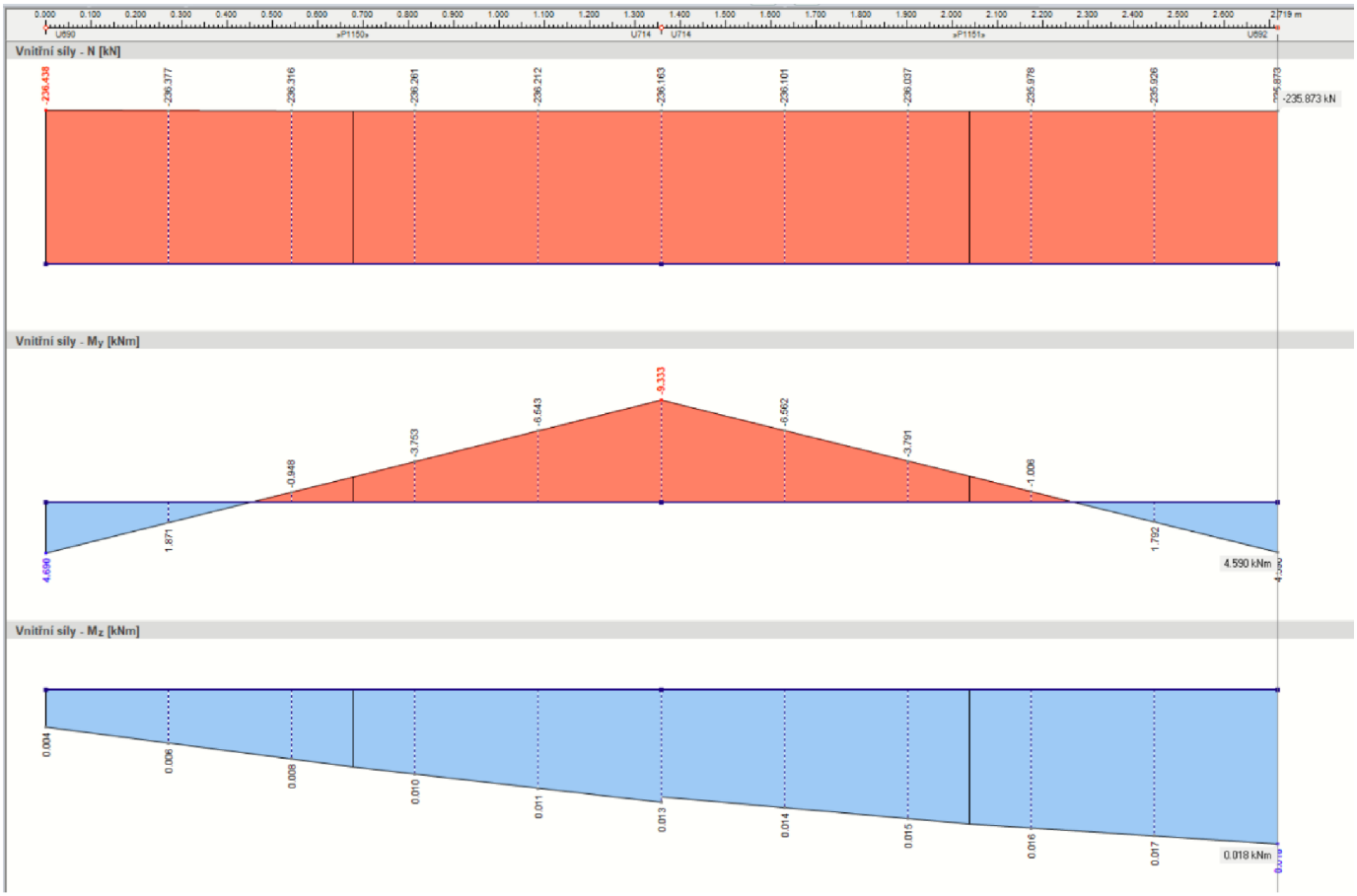
$$\frac{\mathrm{N_{Ed}}}{\frac{\chi_z\ .\ \mathrm{N_{Rk}}}{\gamma_{M1}}} + \mathrm{k_{zy}}\ .\ \frac{\mathrm{M_{y,Ed}} + \Delta\mathrm{M_{y,Ed}}}{\frac{\chi_{LT}\ .\ \mathrm{M_{y,Rk}}}{\gamma_{M1}}} + \mathrm{k_{zz}}\ .\ \frac{\mathrm{M_{z,Ed}} + \Delta\mathrm{M_{z,Ed}}}{\frac{\chi_{LT}\ .\ \mathrm{M_{z,Rk}}}{\gamma_{M1}}} \leq 1{,}0$$

Návrhové hodnoty únosnosti:

$$N_{Rd} = \frac{A\ .f_y}{\gamma_{M0}} = \frac{2640\ .10^{-6}.\ 235\ .10^3}{1{,}0} = 620{,}4\ kN$$

$$M_{y,Rd} = \frac{W_{pl,y}\ .f_y}{\gamma_{M0}} = \frac{132000\ .10^{-9}\ .235\ .10^3}{1{,}0} = 31{,}02\ kNm$$

$$M_{z,Rd} = \frac{W_{pl,z}\ .f_y}{\gamma_{M0}} = \frac{132000\ .\ 10^{-9}.\ 235\ .10^3}{1{,}0} = 31{,}02\ kNm$$



Podla tvaru priebehu momentov

linearny

$M_{h,y} = -9{,}333\ \text{kNm}$

$\Psi M_{h,y} = 4{,}590\ \text{kNm}$

$$\Psi = \frac{4{,}590}{-9{,}333} = -0{,}49$$

$-1 \leq \Psi \leq 1$

$-1 \leq -0{,}49 \leq 1 \ldots \checkmark$

$c_{my} = 0{,}6 + 0{,}4 \,.\, \Psi = 0{,}6 + 0{,}4 \,.\, 0{,}49 = 0{,}404 \geq 0{,}4 \ldots \checkmark$

$$k_{yy} = c_{my} \,.\left(1 + \left(\bar{\lambda}_y - 0{,}2\right) \,.\, \frac{N_{Ed}}{\frac{\chi_y \,.\, N_{Rk}}{\gamma_{M1}}}\right) \leq c_{my} \,.\left(1 + 0{,}8 \,.\, \frac{N_{Ed}}{\frac{\chi_y \,.\, N_{Rk}}{\gamma_{M1}}}\right)$$

$$k_{yy} = 0{,}404 \,.\left(1 + (1{,}02 - 0{,}2) \,.\, \frac{236{,}438}{\frac{0{,}53 \,.\, 620{,}4}{1{,}0}}\right) \leq 0{,}404 \,.\left(1 + 0{,}8 \,.\, \frac{236{,}438}{\frac{0{,}53 \,.\, 620{,}4}{1{,}0}}\right)$$

$k_{yy} = 0{,}646 \leq 0{,}64 \ldots k_{yy} = 0{,}646$

$k_{yz} = 0{,}6 \,.\, k_{yy} = 0{,}6 \,.\, 0{,}646 = 0{,}39$

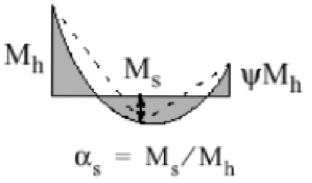
$M_{h,z} = 0{,}018\ \text{kNm}$

$\Psi M_{h,z} = 0{,}004\ \text{kNm}$

$M_{s,y} = 0{,}013\ \text{kNm}$

$\Psi = 0{,}22$

$\alpha_s = \frac{M_s}{M_h} = \frac{0{,}013}{0{,}018} = 0{,}72$



$0 \le a_s \le 1$

$0 \le 0{,}72 \le 1 \ldots \checkmark$

$-1 \le \Psi \le 1$

$-1 \le 0{,}22 \le 1 \ldots \checkmark$

$c_{mz} = 0{,}2 + 0{,}8 \,.\, \alpha_s = 0{,}2 + 0{,}8 \,.0{,}72 = 0{,}78 \ge 0{,}4 \ldots \checkmark$

$$k_{zz} = c_{mz} \,.\left(1 + \left(2.\bar{\lambda}_z - 0{,}6\right) \,.\, \frac{N_{Ed}}{\frac{\chi_z \,.\, N_{Rk}}{\gamma_{M1}}}\right) \le c_{mz} \,.\left(1 + 0{,}8 \,.\, \frac{N_{Ed}}{\frac{\chi_z \,.\, N_{Rk}}{\gamma_{M1}}}\right)$$

$$k_{zz} = 0{,}78 \,.\left(1 + (2 \,.\, 0{,}51 - 0{,}6) \,.\, \frac{236{,}438}{\frac{0{,}83 \,.\, 620{,}4}{1{,}0}}\right) \le 0{,}78 \,.\left(1 + 0{,}8 \,.\, \frac{236{,}438}{\frac{0{,}83 \,.\, 620{,}4}{1{,}0}}\right)$$

$k_{zz} = 0{,}93 \le 1{,}06 \ldots k_{zz} = 0{,}93$

$k_{yz} = 0{,}6 \,.\, k_{zz} = 0{,}6 \,.\, 0{,}93 = 0{,}56$

$\chi_{LT} = 1{,}0$ (pri uzavretých prierezoch ku klopeniu nedochádza)

$$\frac{236{,}438}{\frac{0{,}53 \,.\, 620{,}4}{1{,}0}} + 0{,}646 \,.\, \frac{9{,}333 + 0}{\frac{1{,}0 \,.\, 31{,}02}{1{,}0}} + 0{,}39 \,.\, \frac{0{,}018 + 0}{\frac{1{,}0 \,.\, 31{,}02}{1{,}0}} \le 1{,}0$$

0,91 ≤ 1,0 ... vyhovuje program 0,95

$$\frac{236{,}438}{\frac{0{,}83 \,.\, 620{,}4}{1{,}0}} + 0{,}93 \,.\, \frac{9{,}333 + 0}{\frac{1{,}0 \,.\, 31{,}02}{1{,}0}} + 0{,}56 \,.\, \frac{0{,}018 + 0}{\frac{1{,}0 \,.\, 31{,}02}{1{,}0}} \le 1{,}0$$

0,74 ≤ 1,0 ... vyhovuje program 0,58

4.2.9 DIAGONÁLY

Prierezové charakteristiky:

b = 70 mm

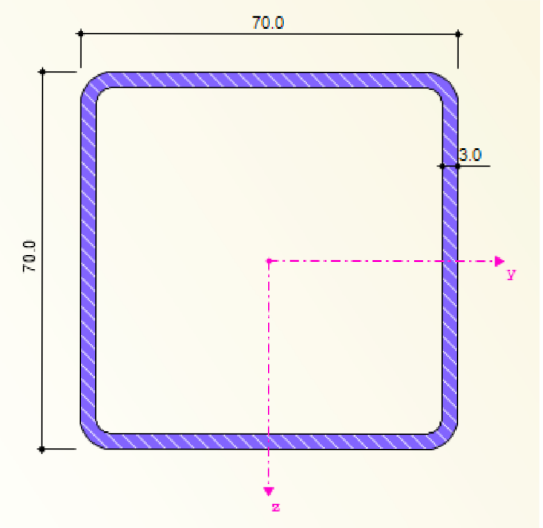
t = 3 mm

A = 781 mm^2

I_y = 575000 mm^4

i_y = 27,1 mm

$W_{pl,y}$ = 19400 mm^3



Materiálové charakteristiky:

S235 (f_y = 235MPa, f_u = 360 MPa)

E = 210 GPa

Trieda prierezu:

$$\varepsilon = \sqrt{\frac{235}{fy}} = \sqrt{\frac{235}{235}} = 1{,}0$$

Pre trubkové profily štvorcového tvaru platí

$$\frac{c}{t} = \frac{70-6}{3} = 21{,}33 \leq 33.\varepsilon = 33\,.\,1 = 33 \;\rightarrow\; 1.\,třída$$

4.2.10 ŤAHANÁ DIAGONÁLA

Prút č 1845 kz 69

$$N_{Ed} = 89{,}158\text{kN}$$

$$\frac{N_{Ed}}{N_{t,Rd}} \leq 1{,}0$$

$$N_{t,Rd} = \frac{A\,.\,f_y}{\gamma_{M1}} = \frac{781\,.10^{-6}\,.\;235.10^{3}}{1{,}0} = 183{,}5\text{ kN}$$

$$\frac{N_{Ed}}{N_{t,Rd}} \leq 1{,}0$$

$$\frac{89{,}158}{183{,}5} \leq 1{,}0$$

0,48 ≤ 1,0 ... vyhovuje (program RFEM 0,49 ≤ 1,0)

4.2.11 TLAČENÁ DIAGONÁLA POSUDENIE NA VZPER

Prút č 1844 kz 53

$$N_{Ed} = -86{,}915\text{ kN}$$

$$L_{cr,y} = L_{cr,z} = 2{,}3\ m$$

$\alpha = 0{,}49$ (duté prierezy tvarované za studena – krivka vzpernej pevnosti ´´c´´)

$$\lambda_y = \frac{L_{cr,y}}{i_y} = \frac{2300}{27{,}1} = 84{,}87$$

$$\frac{N_{Ed}}{N_{b,Rd}} \leq 1{,}0$$

$$N_{b,Rd} = \frac{\chi_y \,.\, A \,.\, f_y}{\gamma_{M1}} = \frac{0{,}597 \,.\, 781 \,.\, 10^{-6} \,.\, 235.10^3}{1{,}0} = 109{,}57\ \text{kN}$$

$$\chi_y = \chi_z = \frac{1}{\phi_y + \sqrt{\phi_y{}^2 - \bar{\lambda}_y{}^2}} = \frac{1}{1{,}08 + \sqrt{1{,}08^2 - 0{,}903^2}} = 0{,}597$$

$$\phi_y = 0{,}5 \,.\, \left[1 + \alpha_{LT}(\bar{\lambda}_{,y} - 0{,}2) + \bar{\lambda}_y{}^2\right] = 0{,}5 \,.\, [1 + 0{,}49 \,.\, (0{,}903 - 0{,}2) + 0{,}903^2] = 1{,}08$$

$$\bar{\lambda}_y = \bar{\lambda}_z = \sqrt{\frac{A \,.\, f_y}{N_{cr}}} = \sqrt{\frac{781 \,.\, 10^{-6} . 235 \,.\, 10^3}{225{,}28}} = 0{,}903 \ > 0{,}2$$

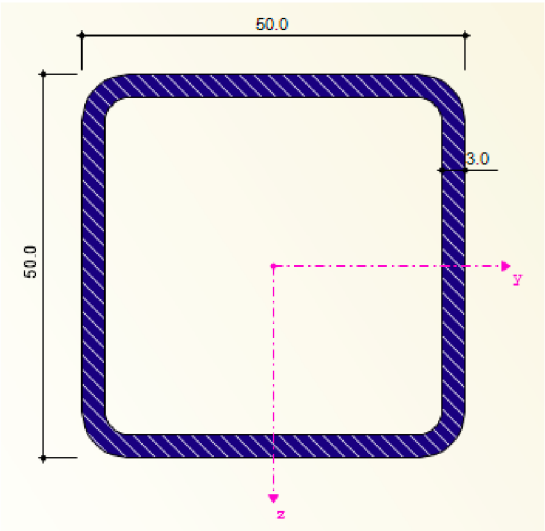
Nemôžem zanedbať účinky vzperu

$$N_{cr} = \frac{\pi^2 .\ E \,.\, I_y}{Lcr, y^2} = \frac{\pi^2 .\ 210 \ .\ 10^6 \,.\, 575000 \,.\, 10^{-12}}{2{,}3^2} = 225{,}28\text{kN}$$

$$\frac{N_{Ed}}{N_{b,Rd}} = \frac{86{,}915}{109{,}57} = 0{,}79 \ \leq 1{,}0$$

0,79 ≤ 1,0 ... vyhovuje (program RFEM 0,48 ≤ 1,0)

4.2.12 ZVISLICE



Prierezové charakteristiky:

b = 50 mm

t = 3 mm

A = 541 mm^2

I_y = 195000 mm^4

i_y = 19 mm

$W_{pl,y}$ = 9390 mm^3

Materiálové charakteristiky:

S235 (f_y = 235MPa, f_u = 360 MPa)

E = 210 GPa

Trieda prierezu:

$$\varepsilon = \sqrt{\frac{235}{\mathrm{fy}}} = \sqrt{\frac{235}{235}} = 1{,}0$$

Pre trubkové profily štvorcového tvaru platí

$$\frac{c}{t} = \frac{50-6}{3} = 16{,}67 \leq 33.\varepsilon = 33\,.\,1 = 33 \;\rightarrow\; 1.\,t\check{r}\acute{i}da$$

4.2.13 POSÚDENIE NA ŤAH

Prút č 2715 kz 95

$$\mathrm{N_{Ed}} \;=\; 16{,}188\,\mathrm{kN}$$

$$\frac{\mathrm{N_{Ed}}}{\mathrm{N_{t,Rd}}} \leq 1{,}0$$

$$\mathrm{N_{t,Rd}} = \frac{\mathrm{A}\,.\,\mathrm{f_y}}{\gamma_{\mathrm{M1}}} = \frac{541\,.\,10^{-6}\,.\;235.\,10^{3}}{1{,}0} = 127{,}135\ \mathrm{kN}$$

$$\frac{16{,}188}{127{,}135} \leq 1{,}0$$

0,013 ≤ 1,0 ... vyhovuje

4.2.14 POSUDENIE NA VZPER

Prút č 1032 kz 69

$$\mathrm{N_{Ed}} \;=\; 7{,}588\,\mathrm{kN}$$

$$L_{cr,y} = L_{cr,z} = 1{,}8\,m$$

$\alpha = 0{,}49$ (duté prierezy tvarované za studena – krivka vzpernej pevnosti ´´c´´)

$$\lambda_{\mathrm{y}} = \frac{\mathrm{L_{cr,y}}}{\mathrm{i_y}} = \frac{1800}{19} = 94{,}7$$

$$\frac{\mathrm{N_{Ed}}}{\mathrm{N_{b,Rd}}} \leq 1{,}0$$

$$\mathrm{N_{b,Rd}} = \frac{\chi_{\mathrm{y}}\,.\;\mathrm{A}\,.\;\mathrm{f_y}}{\gamma_{\mathrm{M1}}} = \frac{0{,}533\,.541\,.10^{-6}\,.\;\;235.10^{3}}{1{,}0} = 67{,}76\ \mathrm{kN}$$

$$\chi_y = \chi_z = \frac{1}{\phi_y + \sqrt{{\phi_y}^2 - {\bar{\lambda}_y}^2}} = \frac{1}{1{,}21 + \sqrt{1{,}21^2 - 1{,}01^2}} = 0{,}533$$

$$\phi_y = 0{,}5\,.\;\left[1 + \alpha_{LT}\left(\bar{\lambda}_{,y} - 0{,}2\right) + {\bar{\lambda}_y}^2\right] = 0{,}5\,.\;\left[1 + 0{,}49.(1{,}01 - 0{,}2) + 1{,}01^2\right] = 1{,}21$$

$$\bar{\lambda}_y = \bar{\lambda}_z = \sqrt{\frac{A\,.\,f_y}{N_{cr}}} = \sqrt{\frac{541.10^{-6}.235\,.10^{3}}{124{,}74}} = 1{,}01 \;> 0{,}2$$

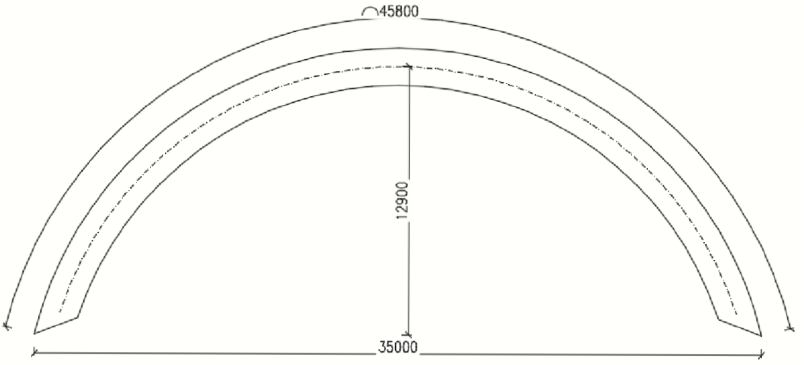
Nemôžem zanedbať účinky vzperu

$$N_{cr} = \frac{\pi^2.\;E\,.I_y}{Lcr,y^2} = \frac{\pi^2.\;210\;.\;10^{6}\,.\;195000\,.10^{-12}}{1{,}8^2} = 124{,}74\mathrm{kN}$$

$$\frac{N_{Ed}}{N_{b,Rd}} = \frac{7{,}588}{67{,}76} = 0{,}11 \leq 1{,}0$$

0,11 ≤ 1,0 ... vyhovuje (program RFEM 0,11 ≤ 1,0)

5 GLOBÁLNA STABILITA VÄZNÍKA



Horný pás

$A_1 = 2640\ mm^2$

I_1 = 7910000 mm^4

z_1 = 900 mm

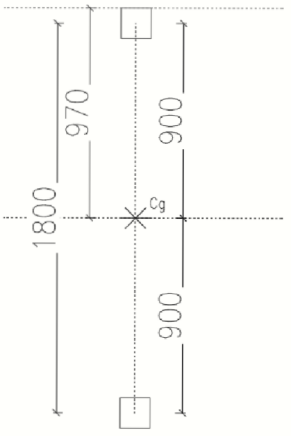
dolný pás

$A_2 = 2640\ mm^2$

I_2 = 7910000 mm^4

z_2 = 900 mm

$$t = \frac{\left(2640 \,.\, \frac{140}{2}\right) + \left(2640 \,.\, \left(1800 + \frac{140}{2}\right)\right)}{2640 + 2420} = 970\ mm$$



Idealizovaný prierez:

$A = A_1 + A_2 = 2640 + 2640 = 5280\ mm^2$

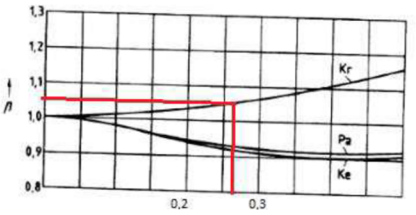
$I = I_1 + I_2 + A_1 . {z_1}^2 + A_2 . {z_2}^2 = (7910000 + 7910000 + 2640 . 900^2 + 2640 . 900^2) . 10^{-12} =$

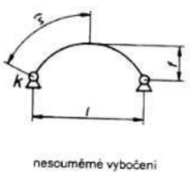
$= 4{,}29 . 10^{-3}\ m^4$

$L = 45{,}8$ m

β: $\frac{f}{l} = \frac{12900}{35000} = 0{,}36 \rightarrow \beta = 1{,}09$

K_r – kruhový tvar





$$L_{cr,y} = \beta \,.\, \bar{s} = \beta \,\frac{L}{2} = 1{,}09 \,.\, \frac{45{,}8}{2} = 24{,}96\text{m}$$

$$\frac{N_{Ed}}{N_{b,Rd}} \leq 1{,}0$$

$$N_{b,Rd} = \frac{\chi_y \,.\, A \,.\, f_y}{\gamma_{M1}} = \frac{0{,}962 \,.\, 5280 \,.\, 10^{-6} \,.\, 235 . 10^3}{1{,}0} = 1193{,}65\ \text{kN}$$

$$\chi_y = \chi_z = \frac{1}{\phi_y + \sqrt{{\phi_y}^2 - {\bar{\lambda}_y}^2}} = \frac{1}{0{,}56 + \sqrt{0{,}56^2 - 0{,}29^2}} = 0{,}962$$

$$\phi_y = 0{,}5\ .\ \left[1 + \alpha\ .\ (\bar{\lambda}_{,y} - 0{,}2) + \bar{\lambda}_y{}^2\right] = 0{,}5\ .\ [1 + 0{,}49\ .\ (0{,}29 - 0{,}2) + 0{,}29^2] = 0{,}56$$

$$\bar{\lambda}_y = \bar{\lambda}_z = \sqrt{\frac{A\ .\ f_y}{N_{cr}}} = \sqrt{\frac{5280\ .\ 10^{-6}.\ 235\ .\ 10^3}{14272}} = 0{,}29\ > 0{,}2$$

Nemôžem zanedbať účinky vzperu

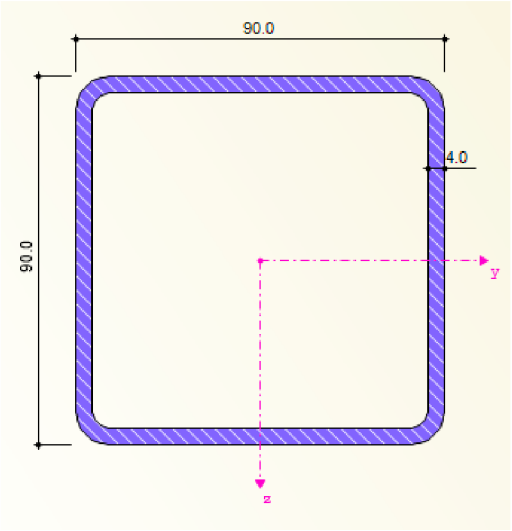
$$N_{cr} = \frac{\pi^2.\ E\ .\ I_y}{Lcr, y^2} = \frac{\pi^2.\ 210\ .\ 10^6\ .\ 4{,}29\ .\ 10^{-3}}{24{,}96^2} = 14272\text{kN}$$

$$\frac{\mathrm{N_{Ed}}}{\mathrm{N_{b,Rd}}} = \frac{\max N\ tlak}{1193{,}65} = 0{,}04\ \leq 1{,}0$$

0,04 ≤ 1,0 ... vyhovuje (program RFEM 0,04 ≤ 1,0)

5.1.1 PRIEČNE STUZIDLO V KRAJNÝCH POLIACH

Prierezové charakteristiky:



b = 90 mm

t = 4 mm

A = 1330 mm^2

I_y =1620000 mm^4

i_y = 34,8 mm

$W_{pl,y}$ = 42600 mm^3

Materiálové charakteristiky:

S235 (f_y = 235MPa, f_u = 360 MPa)

E = 210 GPa

Trieda prierezu:

$$\varepsilon = \sqrt{\frac{235}{\mathrm{fy}}} = \sqrt{\frac{235}{235}} = 1{,}0$$

Pre trubkové profily štvorcového tvaru platí

$$\frac{c}{t} = \frac{90 - 8}{4} = 20{,}5 \leq 33.\varepsilon = 33\ .\ 1 = 33\ \rightarrow\ \ 1.\ třída$$

5.1.2 POSÚDENIE NA VZPER

Prút č 2464 kz 87

$\mathrm{N_{Ed}}\ =\ 62{,}272\ \mathrm{kN}$

$L_{cr,y} = 2{,}92\ m$

$\alpha = 0{,}49$ (duté prierezy tvarované za studena – krivka vzpernej pevnosti ´´c´´)

$$\lambda_y = \frac{L_{cr,y}}{i_y} = \frac{2920}{34,8} = 83,9$$

$$\frac{N_{Ed}}{N_{b,Rd}} \leq 1,0$$

$$N_{b,Rd} = \frac{\chi_y \,.\, A \,.\, f_y}{\gamma_{M1}} = \frac{0,6 \,.\, 1330 \,.\, 10^{-6} \,.\, 235.10^3}{1,0} = 187,53 \text{ kN}$$

$$\chi_y = \frac{1}{\phi_y + \sqrt{\phi_y{}^2 - \bar{\lambda}_y{}^2}} = \frac{1}{1,07 + \sqrt{1,07^2 - 0,89^2}} = 0,6$$

$$\phi_y = 0,5 \,.\, \left[1 + \alpha_{LT}(\bar{\lambda}_{,y} - 0,2) + \bar{\lambda}_y{}^2\right] = 0,5 \,.\, [1 + 0,49 \,.\, (0,89 - 0,2) + 0,89^2] = 1,07$$

$$\bar{\lambda}_y = \sqrt{\frac{A \,.\, f_y}{N_{cr}}} = \sqrt{\frac{1330 \,.\, 10^{-6} . 235 \,.\, 10^3}{393,79}} = 0,89 > 0,2$$

Nemôžem zanedbať účinky vzperu

$$N_{cr} = \frac{\pi^2 .\ E \,.\, I_y}{Lcr, y^2} = \frac{\pi^2 .\ 210 \ .\ 10^6 \,.\, 1620000 \,.\, 10^{-12}}{2,92^2} = 393,79\text{kN}$$

$$\frac{N_{Ed}}{N_{b,Rd}} = \frac{62,272}{187,53} = 0,33 \leq 1,0$$

0,33 ≤ 1,0 ... vyhovuje

$L_{cr,z} = 5,84\ m$

α = 0,49 (duté prierezy tvarované za studena – krivka vzpernej pevnosti ´´c´´)

$$\lambda_z = \frac{L_{cr,z}}{i_z} = \frac{5840}{34,8} = 167,8$$

$$\frac{N_{Ed}}{N_{b,Rd}} \leq 1,0$$

$$N_{b,Rd} = \frac{\chi_z \,.\, A \,.\, f_y}{\gamma_{M1}} = \frac{0,24 \,.1330 \,.\, 10^{-6} \,.\, 235.10^3}{1,0} = 75,012 \text{ kN}$$

$$\chi_z = \frac{1}{\phi_z + \sqrt{\phi_z{}^2 - \bar{\lambda}_z{}^2}} = \frac{1}{2,47 + \sqrt{2,47^2 - 1,78^2}} = 0,24$$

$$\phi_z = 0,5 \,.\, \left[1 + \alpha_{LT}(\bar{\lambda}_{,z} - 0,2) + \bar{\lambda}_z{}^2\right] = 0,5 \,.\, [1 + 0,49 \,.\, (1,78 - 0,2) + 1,78^2] = 2,47$$

$$\bar{\lambda}_z = \sqrt{\frac{A \,.\, f_y}{N_{cr}}} = \sqrt{\frac{1330 \,.\, 10^{-6} . 235 \,.\, 10^3}{98,45}} = 1,78 > 0,2$$

Nemôžem zanedbať účinky vzperu

$$N_{cr} = \frac{\pi^2 .\ E \,.\, I_z}{Lcr, z^2} = \frac{\pi^2 .\ 210 \ .\ 10^6 \,.\, 1620000 \,.\, 10^{-12}}{5,84^2} = 98,45\text{kN}$$

$$\frac{N_{Ed}}{N_{b,Rd}} = \frac{62{,}272}{75{,}012} = 0{,}83 \leq 1{,}0$$

0,83 ≤ 1,0 ... vyhovuje (program RFEM 0,55 ≤ 1,0)

5.1.3 POSÚDENIE NA KOMBINÁCIU OHYBU A TLAKU

Prút č 53 kz 71

$N_{Ed} = -61{,}968\ \text{kN}$

$M_{y,Ed} = -0{,}042\ \text{kNm}$

$M_{z,Ed} = -0{,}508\ \text{kNm}$

$$\frac{N_{Ed}}{\frac{\chi_y \cdot N_{Rk}}{\gamma_{M1}}} + k_{yy} \cdot \frac{M_{y,Ed} + \Delta M_{y,Ed}}{\frac{\chi_{LT} \cdot M_{y,Rk}}{\gamma_{M1}}} + k_{yz} \cdot \frac{M_{z,Ed} + \Delta M_{z,Ed}}{\frac{\chi_{LT} \cdot M_{z,Rk}}{\gamma_{M1}}} \leq 1{,}0$$

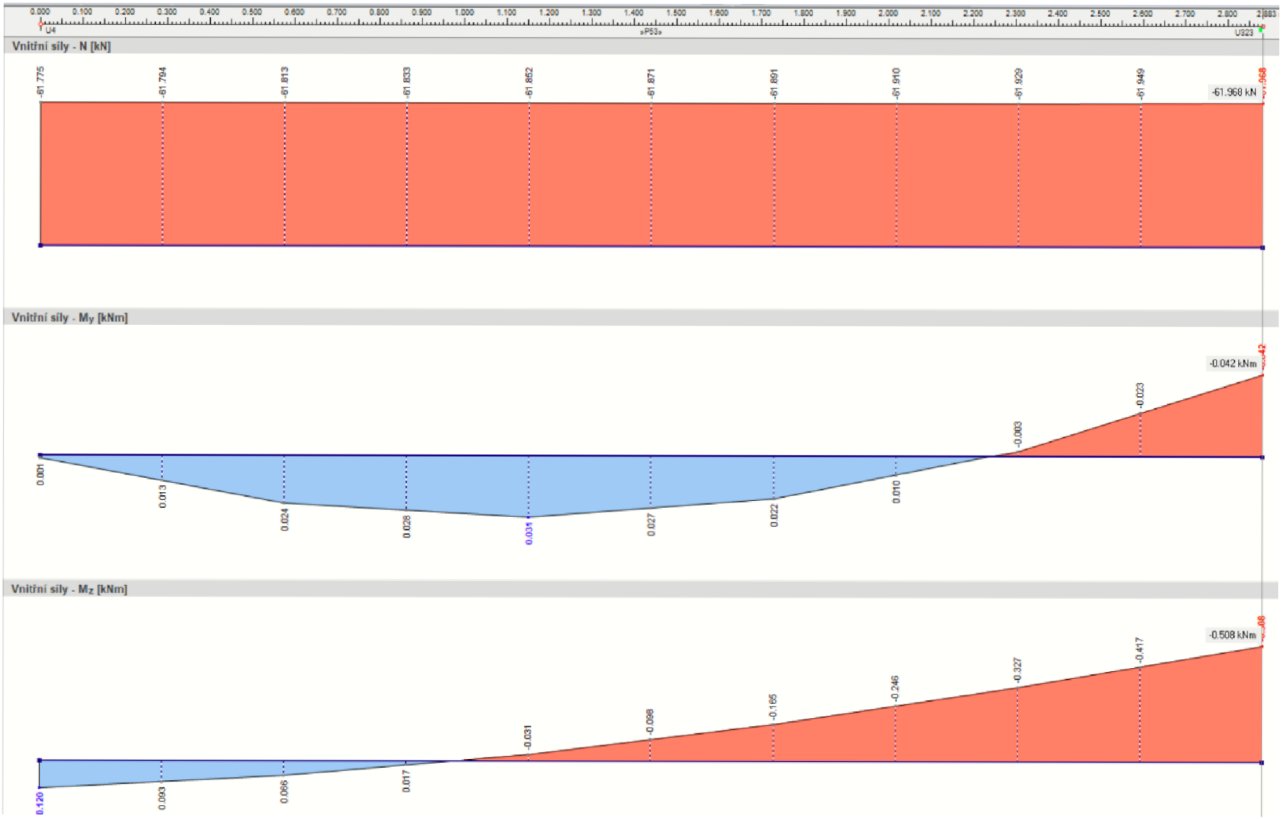
$$\frac{N_{Ed}}{\frac{\chi_z \cdot N_{Rk}}{\gamma_{M1}}} + k_{zy} \cdot \frac{M_{y,Ed} + \Delta M_{y,Ed}}{\frac{\chi_{LT} \cdot M_{y,Rk}}{\gamma_{M1}}} + k_{zz} \cdot \frac{M_{z,Ed} + \Delta M_{z,Ed}}{\frac{\chi_{LT} \cdot M_{z,Rk}}{\gamma_{M1}}} \leq 1{,}0$$

Návrhové hodnoty únosnosti:

$$N_{Rd} = \frac{A \cdot f_y}{\gamma_{M0}} = \frac{1330 \cdot 10^{-6} \cdot 235 \cdot 10^3}{1{,}0} = 312{,}55\ kN$$

$$M_{y,Rd} = \frac{W_{pl,y} \cdot f_y}{\gamma_{M0}} = \frac{42600 \cdot 10^{-9} \cdot 235 \cdot 10^3}{1{,}0} = 10{,}011\ kNm$$

$$M_{z,Rd} = \frac{W_{pl,z} \cdot f_y}{\gamma_{M0}} = \frac{42600 \cdot 10^{-9} \cdot 235 \cdot 10^3}{1{,}0} = 10{,}011\ kNm$$



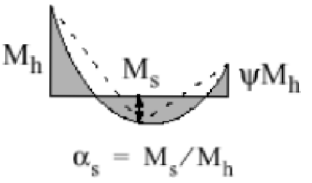
$M_{h,y} = -0{,}042\text{kNm}$

$\Psi M_{h,y} = 0{,}032\ \text{kNm}$

$M_{s,y} = 0{,}027\ \text{kNm}$

$\Psi = \frac{0{,}032}{-0{,}042} = -0{,}761$

$\alpha_s = \frac{M_s}{M_h} = \frac{0{,}027}{-0{,}042} = -0{,}642$



$-1 \le a_s \le 0$

$-1 \le -0{,}642 \le 0$ ... ✓

$-1 \le \Psi \le 0$

$-1 \le -0{,}761 \le 0$... ✓

$c_{my} = 0{,}1.(1-\Psi) - 0{,}8.\alpha_s = 0{,}1.(1+0{,}761) + 0{,}8.0{,}642 = 0{,}687 \ge 0{,}4$

$$k_{yy} = c_{my}.\left(1 + \left(\bar{\lambda}_y - 0{,}2\right).\frac{N_{Ed}}{\frac{\chi_y.N_{Rk}}{\gamma_{M1}}}\right) \le c_{my}.\left(1 + 0{,}8.\frac{N_{Ed}}{\frac{\chi_y.N_{Rk}}{\gamma_{M1}}}\right)$$

$$k_{yy} = 0{,}687.\left(1 + (0{,}89 - 0{,}2).\frac{62{,}272}{\frac{0{,}6.312{,}55}{1{,}0}}\right) \le 0{,}687.\left(1 + 0{,}8.\frac{62{,}272}{\frac{0{,}6.312{,}55}{1{,}0}}\right)$$

$k_{yy} = 0{,}844 \le 0{,}869 \ldots k_{yy} = 0{,}844$

$k_{yz} = 0{,}6.\ k_{yy} = 0{,}6.0{,}844 = 0{,}506$

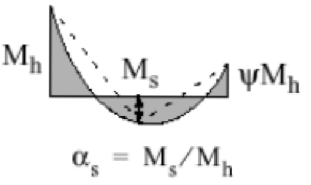
$M_{h,z} = -0{,}509\text{kNm}$

$\Psi M_{h,z} = 0{,}120\ \text{kNm}$

$M_{s,z} = -0{,}098\ \text{kNm}$

$\Psi = \frac{0{,}12}{-0{,}509} = -0{,}24$

$\alpha_s = \frac{M_s}{M_h} = \frac{-0{,}098}{-0{,}509} = +0{,}193$



$0 \le a_s \le 1$

$0 \le 0{,}193 \le 1$ ... ✓

$-1 \le \Psi \le 1$

$-1 \le -0{,}24 \le 1$... ✓

$$c_{mz} = 0{,}2 + 0{,}8 \cdot \alpha_s = 0{,}2 + 0{,}8 \cdot 0{,}193 = 0{,}354 \geq 0{,}4 \ldots x$$

$$c_{mz} = 0{,}4$$

$$k_{zz} = c_{mz} \cdot \left(1 + \left(2 \cdot \bar{\lambda}_z - 0{,}6\right) \cdot \frac{N_{Ed}}{\frac{\chi_z \cdot N_{Rk}}{\gamma_{M1}}} \right) \leq c_{mz} \cdot \left(1 + 0{,}8 \cdot \frac{N_{Ed}}{\frac{\chi_z \cdot N_{Rk}}{\gamma_{M1}}} \right)$$

$$k_{zz} = 0{,}4 \cdot \left(1 + (2 \cdot 1{,}78 - 0{,}6) \cdot \frac{62{,}272}{\frac{0{,}24 \cdot 312{,}55}{1{,}0}} \right) \leq 0{,}4 \cdot \left(1 + 0{,}8 \cdot \frac{62{,}272}{\frac{0{,}24 \cdot 312{,}55}{1{,}0}} \right)$$

$$k_{zz} = 1{,}38 \leq 0{,}665 \ldots k_{zz} = 0{,}665$$

$$k_{yz} = 0{,}6 \cdot k_{zz} = 0{,}6 \cdot 0{,}665 = 0{,}4$$

$\chi_{LT} = 1{,}0$ (pri uzavretých prierezoch ku klopeniu nedochádza)

$$\frac{62{,}272}{\frac{0{,}6 \cdot 312{,}55}{1{,}0}} + 0{,}844 \cdot \frac{0{,}042 + 0}{\frac{1{,}0 \cdot 10{,}011}{1{,}0}} + 0{,}506 \cdot \frac{0{,}018 + 0}{\frac{1{,}0 \cdot 10{,}011}{1{,}0}} \leq 1{,}0$$

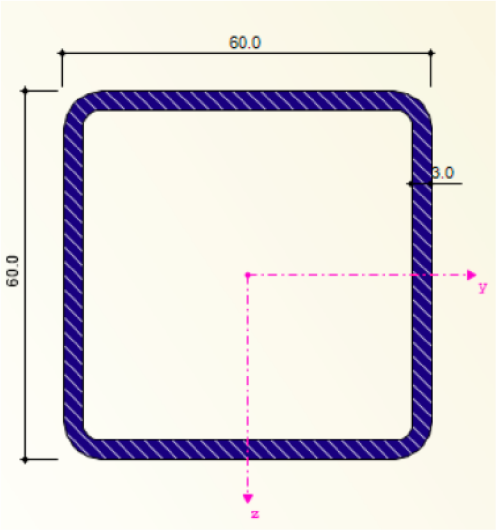
0,34 ≤ 1,0 ... vyhovuje program 0,35

$$\frac{62{,}272}{\frac{0{,}24 \cdot 312{,}55}{1{,}0}} + 0{,}665 \cdot \frac{0{,}042 + 0}{\frac{1{,}0 \cdot 10{,}011}{1{,}0}} + 0{,}4 \cdot \frac{0{,}508 + 0}{\frac{1{,}0 \cdot 10{,}011}{1{,}0}} \leq 1{,}0$$

0,84 ≤ 1,0 ... vyhovuje program 0,87

5.1.4 POZDĹŽNE STUŽIDLO VRCHOLOVÉ

5.1.5 DIAGONÁLY



Prierezové charakteristiky:

b = 60 mm

t = 3 mm

A = 661 mm^2

I_y =351000 mm^4

i_y = 23,1 mm

$W_{pl,y}$ = 14000 mm^3

Materiálové charakteristiky:

S235 (f_y = 235MPa, f_u = 360 MPa)

E = 210 GPa

Trieda prierezu:

$$\varepsilon = \sqrt{\frac{235}{fy}} = \sqrt{\frac{235}{235}} = 1{,}0$$

Pre trubkové profily štvorcového tvaru platí

$$\frac{c}{t} = \frac{60-6}{3} = 18 \leq 33.\varepsilon = 33\,.\,1 = 33 \;\rightarrow\; 1.\,t\check{r}\acute{i}da$$

5.1.6 POSÚDENIE NA VZPER

Prút č 2650 kz 60

$\mathrm{N_{Ed}} = 31{,}743\ \mathrm{kN}$

$L_{cr,y} = L_{cr,z} = 3{,}081\ m$ (zaistené väznicami)

$\alpha = 0{,}49$ (duté prierezy tvarované za studena – krivka vzpernej pevnosti ´´c´´)

$$\lambda_y = \frac{\mathrm{L_{cr,y}}}{\mathrm{i_y}} = \frac{3081}{23{,}1} = 133{,}37$$

$$\frac{\mathrm{N_{Ed}}}{\mathrm{N_{b,Rd}}} \leq 1{,}0$$

$$\mathrm{N_{b,Rd}} = \frac{\chi_y\,.\,\mathrm{A}\,.\,\mathrm{f_y}}{\gamma_{M1}} = \frac{0{,}34\,.661\,.10^{-6}\,.\;235.10^3}{1{,}0} = 52{,}81\ \mathrm{kN}$$

$$\chi_y = \chi_z = \frac{1}{\phi_y + \sqrt{{\phi_y}^2 - {\bar{\lambda}_y}^2}} = \frac{1}{1{,}807 + \sqrt{1{,}807^2 - 1{,}42^2}} = 0{,}34$$

$$\phi_y = 0{,}5\,.\,\left[1 + \alpha_{LT}\left(\bar{\lambda}_{,y} - 0{,}2\right) + {\bar{\lambda}_y}^2\right] = 0{,}5\,.\,\left[1 + 0{,}49.(1{,}42 - 0{,}2) + 1{,}42^2\right] = 1{,}807$$

$$\bar{\lambda}_y = \bar{\lambda}_z = \sqrt{\frac{A\,.\,f_y}{N_{cr}}} = \sqrt{\frac{661\,.10^{-6}.235\,.10^3}{76{,}638}} = 1{,}42 > 0{,}2$$

Nemôžem zanedbať účinky vzperu

$$N_{cr} = \frac{\pi^2.\;E\,.I_y}{Lcr,y^2} = \frac{\pi^2.\;210\;.\;10^6\,.\;351000\,.10^{-12}}{3{,}081^2} = 76{,}638\mathrm{kN}$$

$$\frac{\mathrm{N_{Ed}}}{\mathrm{N_{b,Rd}}} = \frac{31{,}743}{52{,}81} = 0{,}60 \;\leq 1{,}0$$

0,60 ≤ 1,0 ... vyhovuje (program RFEM 0,60 ≤ 1,0)

5.1.7 POSÚDENIE NA KOMBINÁCIU OHYBU A TLAKU

Prút č 1032 kz 69

$\mathrm{N_{Ed}} = 31{,}743\ \mathrm{kN}$

$\mathrm{M_{y,Ed}} = -0{,}022\ \mathrm{kNm}$

$\mathrm{M_{z,Ed}} = 0\ \mathrm{kNm}$

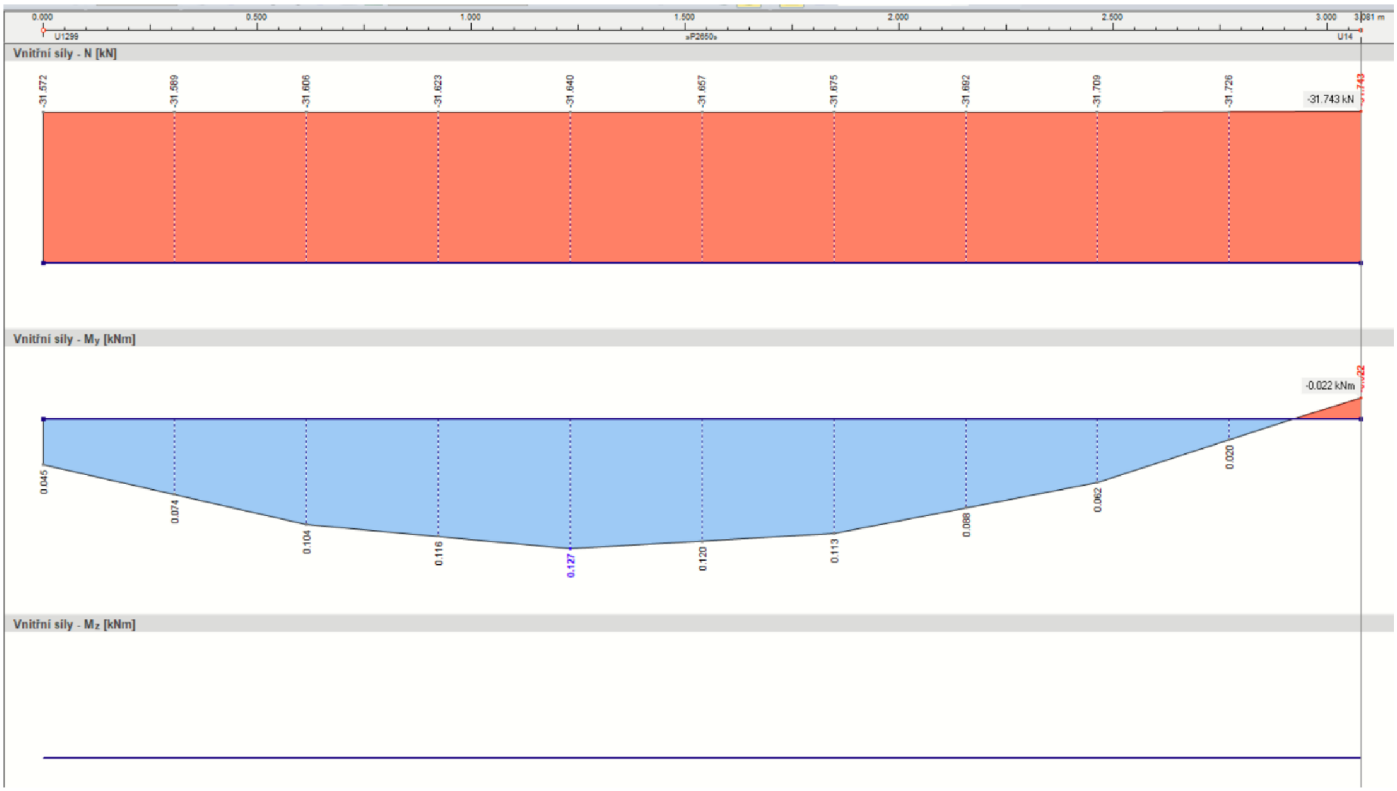
$$\frac{\mathrm{N_{Ed}}}{\frac{\chi_y\,.\,\mathrm{N_{Rk}}}{\gamma_{M1}}} + \mathrm{k_{yy}}\,.\,\frac{\mathrm{M_{y,Ed}} + \Delta\mathrm{M_{y,Ed}}}{\frac{\chi_{LT}\,.\,\mathrm{M_{y,Rk}}}{\gamma_{M1}}} \leq 1{,}0$$

$$\frac{N_{Ed}}{\frac{\chi_z \cdot N_{Rk}}{\gamma_{M1}}} + k_{zy} \cdot \frac{M_{y,Ed} + \Delta M_{y,Ed}}{\frac{\chi_{LT} \cdot M_{y,Rk}}{\gamma_{M1}}} \leq 1{,}0$$

Návrhové hodnoty únosnosti:

$$N_{Rd} = \frac{A \cdot f_y}{\gamma_{M0}} = \frac{661 \cdot 10^{-6} \cdot 235 \cdot 10^3}{1{,}0} = 155{,}335\ kN$$

$$M_{y,Rd} = \frac{W_{pl,y} \cdot f_y}{\gamma_{M0}} = \frac{14000 \cdot 10^{-9} \cdot 235 \cdot 10^3}{1{,}0} = 3{,}29\ kNm$$



$M_{h,y} = 0{,}045\ \text{kNm}$

$\Psi M_{h,y} = -0{,}022\ \text{kNm}$

$M_{s,y} = 0{,}127\ \text{kNm}$

$\alpha_h = M_h / M_s$

$$\Psi = \frac{-0{,}022}{0{,}045} = -0{,}488$$

$$\alpha_h = \frac{M_h}{M_s} = \frac{0{,}045}{0{,}127} = 0{,}354$$

$0 \leq a_h \leq 1$

$0 \leq 0{,}354 \leq 1 \ldots \checkmark$

$-1 \leq \Psi \leq 1$

$-1 \leq -0{,}488 \leq 1 \ldots \checkmark$

$c_{my} = 0{,}95 + 0{,}05 \cdot \alpha_h = 0{,}95 + 0{,}05 \cdot 0{,}354 = 0{,}968 \geq 0{,}4 \ldots \checkmark$

$$k_{yy} = c_{my} \cdot \left(1 + \left(\bar{\lambda}_y - 0{,}2\right) \cdot \frac{N_{Ed}}{\frac{\chi_y \cdot N_{Rk}}{\gamma_{M1}}}\right) \leq c_{my} \cdot \left(1 + 0{,}8 \cdot \frac{N_{Ed}}{\frac{\chi_y \cdot N_{Rk}}{\gamma_{M1}}}\right)$$

$$k_{yy} = 0{,}968 \cdot \left(1 + (1{,}42 - 0{,}2) \cdot \frac{31{,}743}{\frac{0{,}34 \cdot 155{,}335}{1{,}0}}\right) \leq 0{,}968 \cdot \left(1 + 0{,}8 \cdot \frac{31{,}743}{\frac{0{,}34 \cdot 155{,}335}{1{,}0}}\right)$$

$k_{yy} = 1{,}678 \leq 1{,}433 \ldots k_{yy} = 1{,}433$

$k_{zy} = 0{,}6 \cdot k_{yy} = 0{,}6 \cdot 1{,}433 = 0{,}86$

$\chi_{LT} = 1{,}0$ (pri uzavretých prierezoch ku klopeniu nedochádza)

$$\frac{31{,}743}{\frac{0{,}34 + 155{,}335}{1{,}0}} + 1{,}433 \cdot \frac{0{,}022 + 0}{\frac{1{,}0 \cdot 3{,}29}{1{,}0}} \leq 1{,}0$$

0,61 ≤ 1,0 ... vyhovuje

$$\frac{31{,}743}{\frac{0{,}34 + 155{,}335}{1{,}0}} + 0{,}86 \cdot \frac{0{,}022 + 0}{\frac{1{,}0 \cdot 3{,}29}{1{,}0}} \leq 1{,}0$$

0,61 ≤ 1,0 ... vyhovuje

5.1.8 DOLNÝ PÁS

Prierezové charakteristiky:

b = 70 mm

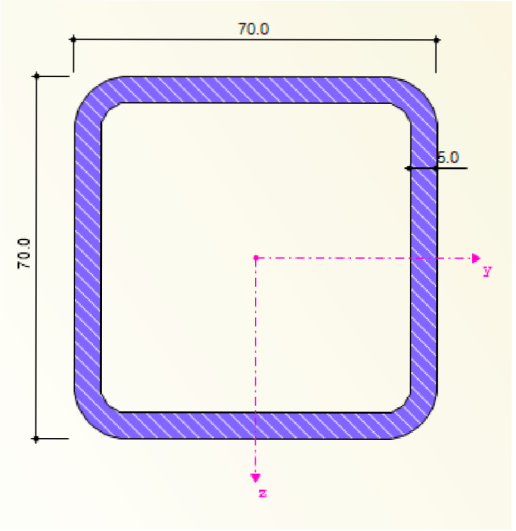
t = 5 mm

A = 1240 mm^2

I_y = 846000mm^4

i_y = 26,2 mm

$W_{pl,y}$ = 29600 mm^3



Materiálové charakteristiky:

S235 (f_y = 235MPa, f_u = 360 MPa)

E = 210 GPa

Trieda prierezu:

$$\varepsilon = \sqrt{\frac{235}{fy}} = \sqrt{\frac{235}{235}} = 1{,}0$$

Pre trubkové profily štvorcového tvaru platí

$$\frac{c}{t} = \frac{70 - 10}{5} = 12 \leq 33 . \varepsilon = 33 . 1 = 33 \rightarrow \ 1. \check{t}\acute{r}ida$$

5.1.9 POSÚDENIE NA TAH

Prút č 2648 kz 60

$N_{Ed} = 51{,}674\ \text{kN}$

$$\frac{N_{Ed}}{N_{t,Rd}} \leq 1{,}0$$

$$N_{t,Rd} = \frac{A.\ f_y}{\gamma_{M1}} = \frac{1240\,.10^{-6}\ .\ 235.10^3}{1{,}0} = 291{,}4\ \text{kN}$$

$$\frac{51{,}674}{291{,}4} \leq 1{,}0$$

0,18 ≤ 1,0 ... vyhovuje

5.1.10 POSÚDENIE NA VZPER

Prút č 1120 kz 100

$N_{Ed} = 38{,}4\ \text{kN}$

$L_{cr,y} = 5\ m$

$\alpha = 0{,}49$ (duté prierezy tvarované za studena – krivka vzpernej pevnosti ´´c´´)

$$\lambda_y = \frac{L_{cr,y}}{i_y} = \frac{5000}{26{,}2} = 190{,}84$$

$$\frac{N_{Ed}}{N_{b,Rd}} \leq 1{,}0$$

$$N_{b,Rd} = \frac{\chi_y\ .\ A.\ f_y}{\gamma_{M1}} = \frac{0{,}19\,.1240\,.10^{-6}\ .\ 235.10^3}{1{,}0} = 55{,}37\ \text{kN}$$

$$\chi_y = \frac{1}{\phi_y + \sqrt{{\phi_y}^2 - {\bar{\lambda}_y}^2}} = \frac{1}{3{,}03 + \sqrt{3{,}03^2 - 2{,}04^2}} = 0{,}19$$

$$\phi_y = 0{,}5\ .\ \left[1 + \alpha_{LT}\left(\bar{\lambda}_{,y} - 0{,}2\right) + {\bar{\lambda}_y}^2\right] = 0{,}5\ .\ \left[1 + 0{,}49\,.(2{,}04 - 0{,}2) + 2{,}04^2\right] = 3{,}03$$

$$\bar{\lambda}_y = \sqrt{\frac{A\,.f_y}{N_{cr}}} = \sqrt{\frac{1240\,.10^{-6}.235\,.10^3}{70{,}14}} = 2{,}04\ > 0{,}2$$

Nemôžem zanedbať účinky vzperu

$$N_{cr} = \frac{\pi^2.\ E\,.I_y}{Lcr,y^2} = \frac{\pi^2.\ 210\ .\ 10^6\ .\ 846000\,.10^{-12}}{5^2} = 70{,}14\text{kN}$$

$$\frac{N_{Ed}}{N_{b,Rd}} = \frac{38{,}4}{55{,}37} = 0{,}69\ \leq 1{,}0$$

0,69 ≤ 1,0 ... vyhovuje

$L_{cr,z} = 2{,}5\ m$

$\alpha = 0{,}49$ (duté prierezy tvarované za studena – krivka vzpernej pevnosti ´´c´´)

$$\lambda_z = \frac{L_{cr,z}}{i_z} = \frac{2500}{26{,}2} = 95{,}42$$

$$\frac{N_{Ed}}{N_{b,Rd}} \leq 1{,}0$$

$$N_{b,Rd} = \frac{\chi_z \,.\, A \,.\, f_y}{\gamma_{M1}} = \frac{0{,}53 \,.1240 \,.10^{-6} \,.\; 235.10^3}{1{,}0} = 154{,}44\text{kN}$$

$$\chi_z = \frac{1}{\phi_z + \sqrt{\phi_z{}^2 - \bar{\lambda}_z{}^2}} = \frac{1}{1{,}22 + \sqrt{1{,}22^2 - 1{,}02^2}} = 0{,}53$$

$$\phi_z = 0{,}5 \,.\, \left[1 + \alpha_{LT}\left(\bar{\lambda}_{,z} - 0{,}2\right) + \bar{\lambda}_z{}^2\right] = 0{,}5 \,.\, \left[1 + 0{,}49 \,.\, (1{,}02 - 0{,}2) + 1{,}02^2\right] = 1{,}22$$

$$\bar{\lambda}_z = \sqrt{\frac{A \,.\, f_y}{N_{cr}}} = \sqrt{\frac{1240 \,.10^{-6}.235 \,.10^3}{280{,}55}} = 1{,}02 \;> 0{,}2$$

Nemôžem zanedbať účinky vzperu

$$N_{cr} = \frac{\pi^2 .\; E \,.\, I_z}{Lcr, z^2} = \frac{\pi^2 .\; 210 \;.\; 10^6 \,.\; 846000 \,.10^{-12}}{2{,}5^2} = 280{,}55\text{kN}$$

$$\frac{N_{Ed}}{N_{b,Rd}} = \frac{38{,}4}{155{,}44} = 0{,}25 \;\leq 1{,}0$$

0,25 ≤ 1,0 ... vyhovuje

5.1.11 POSÚDENIE NA KOMBINÁCIU OHYBU A TLAKU

Prút č 1121 kz 100

$N_{Ed} \;= -37{,}662$ kN

$M_{y,Ed} = -0{,}388$ kNm

$M_{z,Ed} = \;\; 0$ kNm

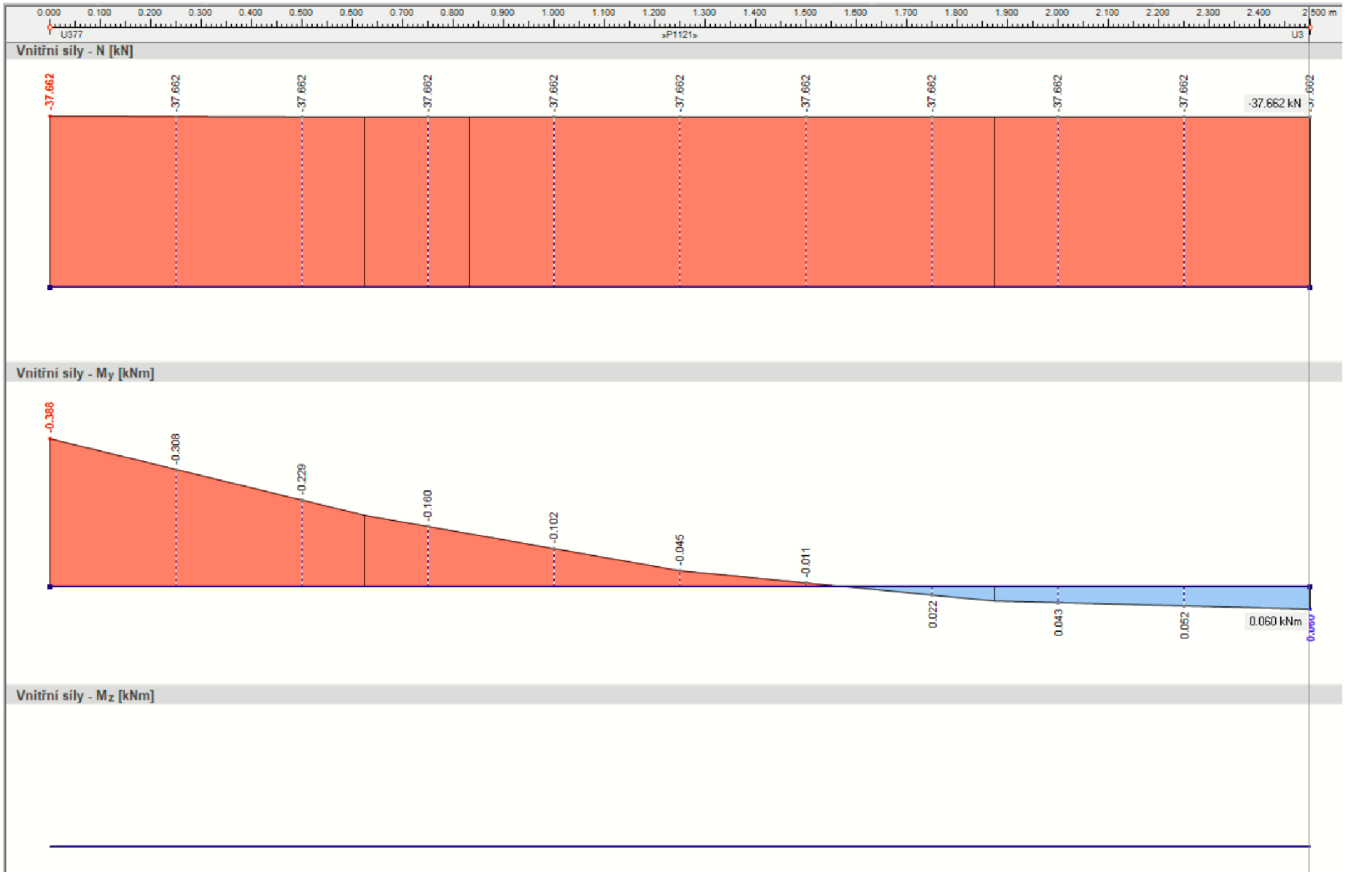
$$\frac{N_{Ed}}{\frac{\chi_y + N_{Rk}}{\gamma_{M1}}} + k_{yy} \,.\, \frac{M_{y,Ed} + \Delta M_{y,Ed}}{\frac{\chi_{LT} \,.\, M_{y,Rk}}{\gamma_{M1}}} \leq 1{,}0$$

$$\frac{N_{Ed}}{\frac{\chi_z + N_{Rk}}{\gamma_{M1}}} + k_{zy} \,.\, \frac{M_{y,Ed} + \Delta M_{y,Ed}}{\frac{\chi_{LT} \,.\, M_{y,Rk}}{\gamma_{M1}}} \leq 1{,}0$$

Návrhové hodnoty únosnosti:

$$N_{Rd} = \frac{A \,.\, f_y}{\gamma_{M0}} = \frac{1240 \,.10^{-6} .\; 235 \,.10^3}{1{,}0} = 291{,}4\; kN$$

$$M_{y,Rd} = \frac{W_{pl,y} \,.\, f_y}{\gamma_{M0}} = \frac{29600 \,.10^{-9} \,.235 \,.10^3}{1{,}0} = 6{,}96\; kNm$$



$M_{h,y} = -0{,}388\ \text{kNm}$

$\Psi M_{h,y} = 0{,}060\ \text{kNm}$

$M_{s,y} = -0{,}045\ \text{kNm}$

$$\Psi = \frac{-0{,}060}{0{,}388} = -0{,}155$$

$$\alpha_s = \frac{M_s}{M_h} = \frac{-0{,}045}{-0{,}388} = 0{,}116$$

$0 \leq a_s \leq 1$

$0 \leq 0{,}116 \leq 1 \ldots \checkmark$

$-1 \leq \Psi \leq 1$

$-1 \leq -0{,}115 \leq 1 \ldots \checkmark$

$c_{my} = 0{,}2 + 0{,}8 \,.\, \alpha_s = 0{,}2 + 0{,}8 \,.\, 0{,}116 = 0{,}29 \geq 0{,}4 \ldots x$

$c_{my} = 0{,}4$

$$k_{yy} = c_{my} \,.\left(1 + \left(\bar{\lambda}_y - 0{,}2\right) \,.\, \frac{N_{Ed}}{\frac{\chi_y \,.\, N_{Rk}}{\gamma_{M1}}}\right) \leq c_{my} \,.\left(1 + 0{,}8 \,.\, \frac{N_{Ed}}{\frac{\chi_y \,.\, N_{Rk}}{\gamma_{M1}}}\right)$$

$$k_{yy} = 0{,}4 . \left(1 + (2{,}04 - 0{,}2) . \frac{37{,}662}{\frac{0{,}19 . 291{,}4}{1{,}0}} \right) \leq 0{,}4 . \left(1 + 0{,}8 . \frac{37{,}662}{\frac{0{,}19 . 291{,}4}{1{,}0}} \right)$$

$k_{yy} = 0{,}901 \leq 0{,}618 \ldots k_{yy} = 0{,}618$

$k_{zy} = 0{,}6 . k_{yy} = 0{,}6 . 0{,}618 = 0{,}371$

$\chi_{LT} = 1{,}0$ (pri uzavretých prierezoch ku klopeniu nedochádza)

$$\frac{37{,}662}{\frac{0{,}19 + 291{,}4}{1{,}0}} + 0{,}618 . \frac{\frac{0{,}388 + 0}{1{,}0 . 6{,}96}}{1{,}0} \leq 1{,}0$$

0,71 ≤ 1,0 ... vyhovuje program 0,86

$$\frac{37{,}662}{\frac{0{,}53 + 291{,}4}{1{,}0}} + 0{,}371 . \frac{\frac{0{,}388 + 0}{1{,}0 . 6{,}96}}{1{,}0} \leq 1{,}0$$

0,26 ≤ 1,0 ... vyhovuje program 0,27

5.1.12 PRIEČNÉ STREŠNÉ STUŽIDLO VAZNÍC

Prierezové charakteristiky:

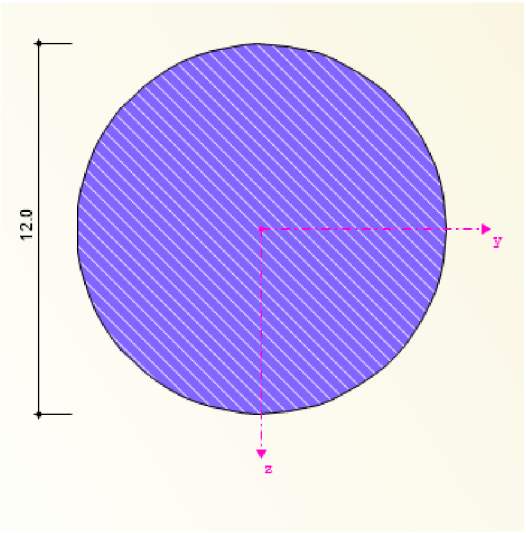
A = 113 mm^2

d = 12 mm

Materiálové charakteristiky:

S235 (f_y = 235MPa, f_u = 360 MPa)

E = 210 GPa



5.1.13 POSÚDENIE NA ŤAH

Prút č 1750 kz 44

$N_{Ed} = -21{,}97$ kN

$$\frac{N_{Ed}}{N_{t,Rd}} \leq 1{,}0$$

$$N_{t,Rd} = \frac{A . f_y}{\gamma_{M1}} = \frac{113 . 10^{-6} . 235 . 10^3}{1{,}0} = 26{,}561 \text{ kN}$$

$$\frac{21{,}97}{26{,}56} \leq 1{,}0$$

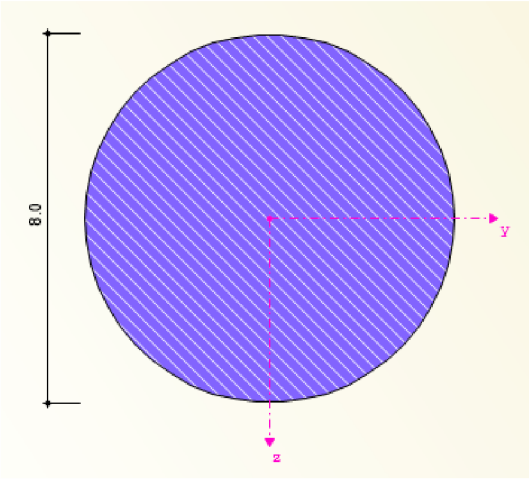
0,83 ≤ 1,0 ... vyhovuje

5.1.14 POZDĹŽNE STUŽIDLO DOLNEHO PÁSU VAZNÍKU

Prierezové charakteristiky:

A = 50,3 mm^2

d = 8 mm



Materiálové charakteristiky:

S235 (f_y = 235MPa, f_u = 360 MPa)

E = 210 GPa

5.1.15 POSÚDENIE NA TAH

Prút č 885 kz 89

$$N_{Ed} = 2{,}894\ \text{kN}$$

$$\frac{N_{Ed}}{N_{t,Rd}} \leq 1{,}0$$

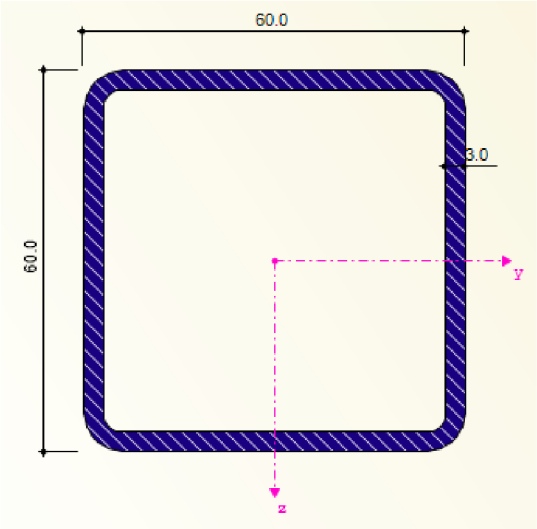
$$N_{t,Rd} = \frac{A.\ f_y}{\gamma_{M1}} = \frac{50{,}3\ .\ 10^{-6}\ .\ 235.10^3}{1{,}0} = 11{,}82\ \text{kN}$$

$$\frac{2{,}894}{11{,}82} \leq 1{,}0$$

0,25 ≤ 1,0 ... vyhovuje

5.1.16 POZDĹŽNE OKAPOVÉ STUZIDLO

Prierezové charakteristiky:



b = 60 mm

t = 3 mm

A = 661 mm^2

I_y = 351000 mm^4

i_y = 23,1 mm

$W_{pl,y}$ = 14000 mm^3

Materiálové charakteristiky:

S235 (f_y = 235MPa, f_u = 360 MPa)

E = 210 GPa

Trieda prierezu:

$$\varepsilon = \sqrt{\frac{235}{fy}} = \sqrt{\frac{235}{235}} = 1{,}0$$

Pre trubkové profily štvorcového tvaru platí

$$\frac{c}{t} = \frac{60-6}{3} = 18 \leq 33.\varepsilon = 33\,.\,1 = 33 \;\rightarrow\; 1.\,třída$$

5.1.17 POSÚDENIE NA ŤAH

Prút č 2666 kz 83

$$\mathrm{N_{Ed}} \;=\; 21{,}337\ \mathrm{kN}$$

$$\frac{\mathrm{N_{Ed}}}{\mathrm{N_{t,Rd}}} \leq 1{,}0$$

$$\mathrm{N_{t,Rd}} = \frac{\mathrm{A}\,.\,\mathrm{f_y}}{\gamma_{\mathrm{M1}}} = \frac{661\,.\,10^{-6}\,.\;235.\,10^{3}}{1{,}0} = 155{,}34\ \mathrm{kN}$$

$$\frac{21{,}337}{155{,}34} \leq 1{,}0$$

0,14 ≤ 1,0 ... vyhovuje

5.1.18 POSÚDENIE NA VZPER

Prút č 2693 kz 55

$$\mathrm{N_{Ed}} \;=\; -20{,}633\mathrm{kN}$$

$L_{cr,y} = L_{cr,z} = 2{,}921\ m$ (zaistené väznicami)

$\alpha = 0{,}49$ (duté prierezy tvarované za studena – krivka vzpernej pevnosti ´´c´´)

$$\lambda_{\mathrm{y}} = \frac{\mathrm{L_{cr,y}}}{\mathrm{i_y}} = \frac{2921}{23{,}1} = 126{,}45$$

$$\frac{\mathrm{N_{Ed}}}{\mathrm{N_{b,Rd}}} \leq 1{,}0$$

$$\mathrm{N_{b,Rd}} = \frac{\chi_{\mathrm{y}}\,.\;\mathrm{A}\,.\;\mathrm{f_y}}{\gamma_{\mathrm{M1}}} = \frac{0{,}37\,.\,661\,.\,10^{-6}\,.\;235.\,10^{3}}{1{,}0} = 57{,}47\ \mathrm{kN}$$

$$\chi_y = \chi_z = \frac{1}{\phi_y + \sqrt{{\phi_y}^2 - {\bar{\lambda}_y}^2}} = \frac{1}{1{,}69 + \sqrt{1{,}69^2 - 1{,}35^2}} = 0{,}37$$

$$\phi_y = 0{,}5\,.\;\left[1 + \alpha_{LT}\left(\bar{\lambda}_{,y} - 0{,}2\right) + {\bar{\lambda}_y}^2\right] = 0{,}5\,.\;\left[1 + 0{,}49\,.\,(1{,}35 - 0{,}2) + 1{,}35^2\right] = 1{,}69$$

$$\bar{\lambda}_y = \bar{\lambda}_z = \sqrt{\frac{A\,.\,f_y}{N_{cr}}} = \sqrt{\frac{661\,.\,10^{-6}.235\,.\,10^{3}}{85{,}26}} = 1{,}35 \;>\; 0{,}2$$

Nemôžem zanedbať účinky vzperu

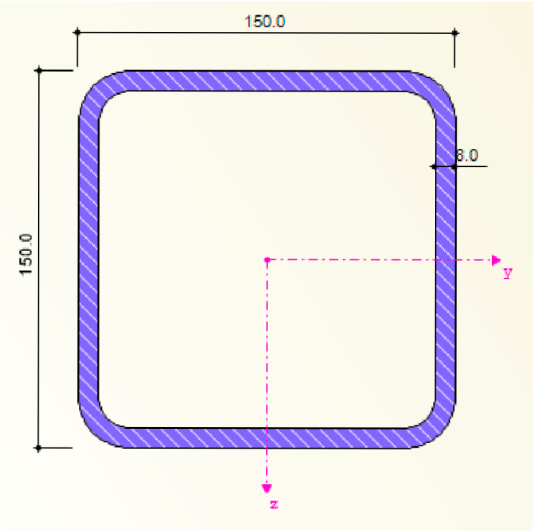
$$N_{cr} = \frac{\pi^2.\;E\,.\,I_y}{Lcr,y^2} = \frac{\pi^2.\;210\;.\;10^{6}\,.\;351000\,.\,10^{-12}}{2{,}921^2} = 85{,}26\mathrm{kN}$$

$$\frac{\mathrm{N_{Ed}}}{\mathrm{N_{b,Rd}}} = \frac{20{,}633}{57{,}47} = 0{,}36 \leq 1{,}0$$

0,36 ≤ 1,0 ... vyhovuje

5.2 PAŽDÍKY

Prierezové charakteristiky:



b = 150 mm

t = 8 mm

A = 4320 mm^2

I_y = 14120000 mm^4

i_y = 57,1mm

$W_{pl,y}$ = 226000 mm^3

Materiálové charakteristiky:

S235 (f_y = 235MPa, f_u = 360 MPa)

E = 210 GPa

Trieda prierezu:

$$\varepsilon = \sqrt{\frac{235}{\mathrm{fy}}} = \sqrt{\frac{235}{235}} = 1{,}0$$

Pre trubkové profily štvorcového tvaru platí

$$\frac{c}{t} = \frac{150 - 16}{8} = 16{,}75 \leq 33.\varepsilon = 33\,.\,1 = 33 \;\rightarrow\; 1.\check{t}\acute{r}ida$$

5.2.1 POSÚDENIE NA VZPER

Prút č 462 kz 54

$\mathrm{N_{Ed}} = -42{,}464\ \mathrm{kN}$

$L_{cr,y} = L_{cr,z} = 5{,}932\ m$

$\alpha = 0{,}49$ (duté prierezy tvarované za studena – krivka vzpernej pevnosti ´´c´´)

$$\lambda_y = \frac{\mathrm{L_{cr,y}}}{\mathrm{i_y}} = \frac{5932}{57{,}1} = 103{,}88$$

$$\frac{\mathrm{N_{Ed}}}{\mathrm{N_{b,Rd}}} \leq 1{,}0$$

$$\mathrm{N_{b,Rd}} = \frac{\chi_y\,.\,\mathrm{A}.\,\mathrm{f_y}}{\gamma_{\mathrm{M1}}} = \frac{0{,}49\,.4320\,.10^{-6}\,.\;235.10^3}{1{,}0} = 469{,}37\ \mathrm{kN}$$

$$\chi_y = \chi_z = \frac{1}{\phi_y + \sqrt{\phi_y{}^2 - \bar{\lambda}_y{}^2}} = \frac{1}{1{,}32 + \sqrt{1{,}32^2 - 1{,}1^2}} = 0{,}49$$

$$\phi_y = 0{,}5\,.\,\left[1 + \alpha_{LT}\left(\bar{\lambda}_{,y} - 0{,}2\right) + \bar{\lambda}_y{}^2\right] = 0{,}5\,.\,\left[1 + 0{,}49\,.\,(1{,}1 - 0{,}2) + 1{,}1^2\right] = 1{,}32$$

$$\bar{\lambda}_y = \bar{\lambda}_z = \sqrt{\frac{A\,.\,f_y}{N_{cr}}} = \sqrt{\frac{4320\,.\,10^{-6}.\,235\,.\,10^3}{831{,}67}} = 1{,}10\ > 0{,}2$$

Nemôžem zanedbať účinky vzperu

$$N_{cr} = \frac{\pi^2.\ E\,.\,I_y}{Lcr, y^2} = \frac{\pi^2.\ 210\ .\ 10^6\,.\ 14120000\,.\,10^{-12}}{5{,}932^2} = 831{,}67\text{kN}$$

$$\frac{\mathrm{N_{Ed}}}{\mathrm{N_{b,Rd}}} = \frac{42{,}464}{469{,}37} = 0{,}09 \leq 1{,}0$$

0,09 ≤ 1,0 ... vyhovuje

5.2.2 POSÚDENIE NA KOMBINÁCIU OHYBU A TLAKU

Prút č 466 kz 74

$\mathrm{N_{Ed}} = -19{,}772\ \mathrm{kN}$

$\mathrm{M_{y,Ed}} = 4{,}084\ \mathrm{kNm}$

$\mathrm{M_{z,Ed}} = -18{,}193\ \mathrm{kNm}$

$$\frac{\mathrm{N_{Ed}}}{\frac{\chi_y\,.\,\mathrm{N_{Rk}}}{\gamma_{M1}}} + \mathrm{k_{yy}}\,.\,\frac{\mathrm{M_{y,Ed}} + \Delta\mathrm{M_{y,Ed}}}{\frac{\chi_{LT}\,.\,\mathrm{M_{y,Rk}}}{\gamma_{M1}}} + \mathrm{k_{yz}}\,.\,\frac{\mathrm{M_{z,Ed}} + \Delta\mathrm{M_{z,Ed}}}{\frac{\chi_{LT}\,.\,\mathrm{M_{z,Rk}}}{\gamma_{M1}}} \leq 1{,}0$$

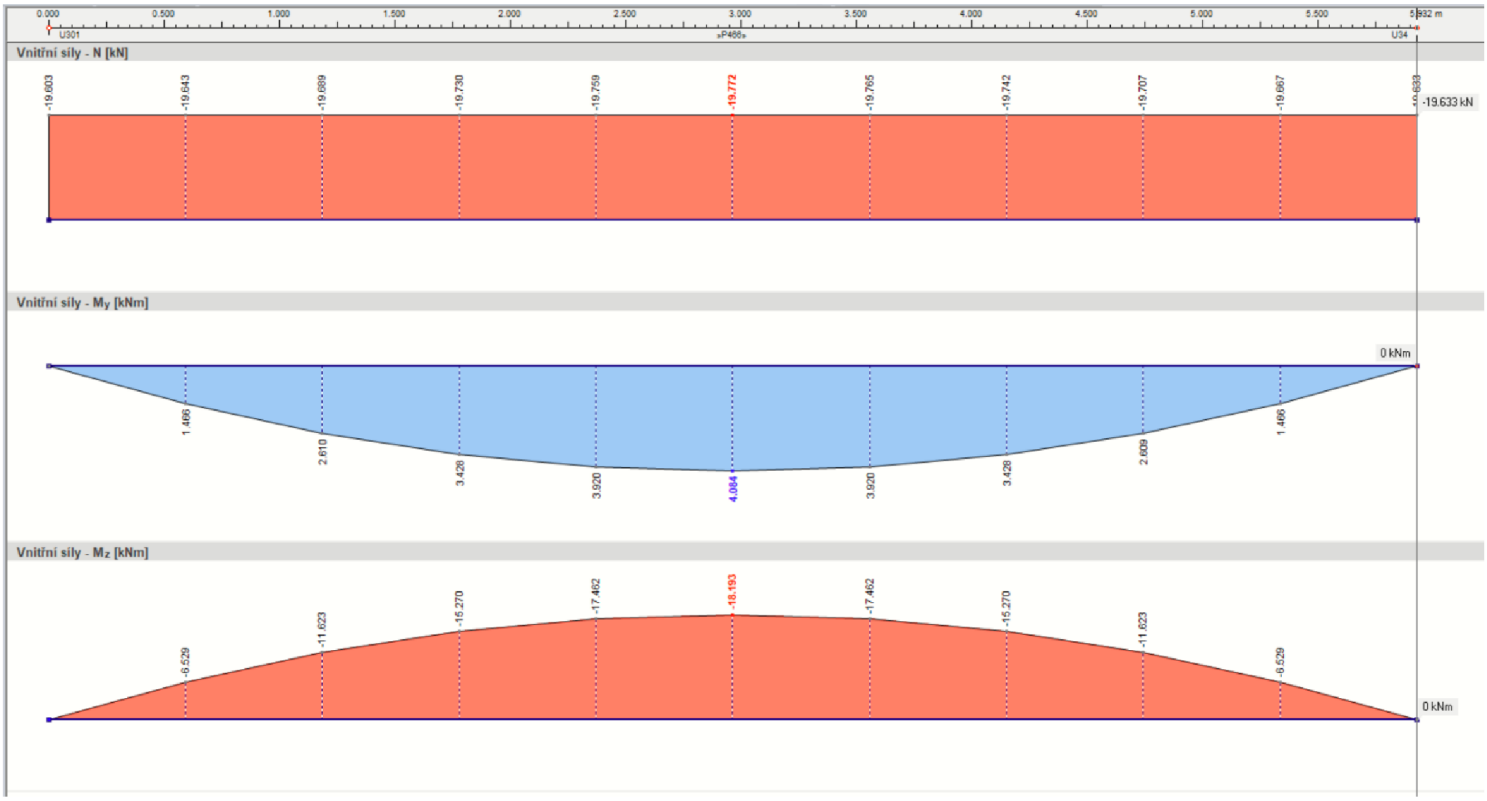
$$\frac{\mathrm{N_{Ed}}}{\frac{\chi_z\,.\,\mathrm{N_{Rk}}}{\gamma_{M1}}} + \mathrm{k_{zy}}\,.\,\frac{\mathrm{M_{y,Ed}} + \Delta\mathrm{M_{y,Ed}}}{\frac{\chi_{LT}\,.\,\mathrm{M_{y,Rk}}}{\gamma_{M1}}} + \mathrm{k_{zz}}\,.\,\frac{\mathrm{M_{z,Ed}} + \Delta\mathrm{M_{z,Ed}}}{\frac{\chi_{LT}\,.\,\mathrm{M_{z,Rk}}}{\gamma_{M1}}} \leq 1{,}0$$

Návrhové hodnoty únosnosti:

$$N_{Rd} = \frac{A\,.\,f_y}{\gamma_{M0}} = \frac{4320\,.\,10^{-6}.\ 235\,.\,10^3}{1{,}0} = 1015{,}2\ kN$$

$$M_{y,Rd} = \frac{W_{pl,y}\,.\,f_y}{\gamma_{M0}} = \frac{226000\,.\,10^{-9}\,.\,235\,.\,10^3}{1{,}0} = 53{,}11\ kNm$$

$$M_{z,Rd} = \frac{W_{pl,z}\,.\,f_y}{\gamma_{M0}} = \frac{1{,}176\,.\ 10^{-4}.\ 235\,.\,10^3}{1{,}0} = 53{,}11\ kNm$$



$M_{h,y} = 0\ \text{kNm}$

$\Psi M_{h,y} = 0\ \text{kNm}$

$M_{s,y} = 4{,}084\ \text{kNm}$

$\Psi = 0$

$$\alpha_h = \frac{M_h}{M_s} = 0$$

$\alpha_h = M_h / M_s$

$0 \le \alpha_h \le 1$

$0 \le 0 \le 1 \ldots \checkmark$

$-1 \le \Psi \le 1$

$-1 \le 0 \le 1 \ldots \checkmark$

$c_{my} = 0{,}95 + 0{,}05 \cdot \alpha_h = 0{,}95 + 0{,}05 \cdot 0 = 0{,}95 \ge 0{,}4 \ldots \checkmark$

$$k_{yy} = c_{my} \cdot \left(1 + \left(\bar{\lambda}_y - 0{,}2\right) \cdot \frac{N_{Ed}}{\frac{\chi_y \cdot N_{Rk}}{\gamma_{M1}}}\right) \le c_{my} \cdot \left(1 + 0{,}8 \cdot \frac{N_{Ed}}{\frac{\chi_y \cdot N_{Rk}}{\gamma_{M1}}}\right)$$

$$k_{yy} = 0{,}95 \cdot \left(1 + (1{,}1 - 0{,}2) \cdot \frac{19{,}772}{\frac{0{,}49 \cdot 1015{,}2}{1{,}0}}\right) \le 0{,}95 \cdot \left(1 + 0{,}8 \cdot \frac{19{,}772}{\frac{0{,}49 \cdot 911{,}8}{1{,}0}}\right)$$

$k_{yy} = 0{,}984 \leq 0{,}980 \ldots k_{yy} = 0{,}98$

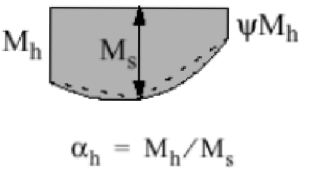
$k_{yz} = 0{,}6 \,.\, k_{yy} = 0{,}6 \,.\, 0{,}98 = 0{,}588$

$M_{h,z} = 0\ \text{kNm}$

$\Psi M_{h,z} = 0\ \text{kNm}$

$M_{s,z} = -18{,}193\ \text{kNm}$

$\Psi = 0$



$$\alpha_h = \frac{M_h}{M_s} = 0$$

$0 \leq a_h \leq 1$

$0 \leq 0 \leq 1 \ldots \checkmark$

$-1 \leq \Psi \leq 1$

$-1 \leq 0 \leq 1 \ldots \checkmark$

$c_{mz} = 0{,}95 + 0{,}05 \,.\, \alpha_h = 0{,}95 + 0{,}05 \,.\, 0 = 0{,}95 \geq 0{,}4 \ldots \checkmark$

$$k_{zz} = c_{mz} \,.\left(1 + \left(2.\bar{\lambda}_z - 0{,}6\right) . \frac{N_{Ed}}{\frac{\chi_z \,.\, N_{Rk}}{\gamma_{M1}}} \right) \leq c_{mz} \,.\left(1 + 0{,}8 \,.\, \frac{N_{Ed}}{\frac{\chi_z \,.\, N_{Rk}}{\gamma_{M1}}} \right)$$

$$k_{zz} = 0{,}95 \,.\left(1 + (2 \,.\, 1{,}1 - 0{,}6) \,.\, \frac{19{,}772}{\frac{0{,}49 \,.\, 1015{,}2}{1{,}0}} \right) \leq 0{,}95 \,.\left(1 + 0{,}8 \,.\, \frac{19{,}772}{\frac{0{,}49 \,.\, 1015{,}2}{1{,}0}} \right)$$

$k_{zz} = 1{,}011 \leq 0{,}980 \ldots k_{zz} = 0{,}980$

$k_{yz} = 0{,}6 \,.\, k_{zz} = 0{,}6 \,.\, 0{,}980 = 0{,}588$

$\chi_{LT} = 1{,}0$ (pri uzavretých prierezoch ku klopeniu nedochádza)

$$\frac{19{,}772}{\frac{0{,}49 + 1015{,}2}{1{,}0}} + 0{,}98 \,.\, \frac{4{,}084 + 0}{\frac{1{,}0 \,.\, 53{,}11}{1{,}0}} + 0{,}588 \,.\, \frac{18{,}193 + 0}{\frac{1{,}0 \,.\, 53{,}11}{1{,}0}} \leq 1{,}0$$

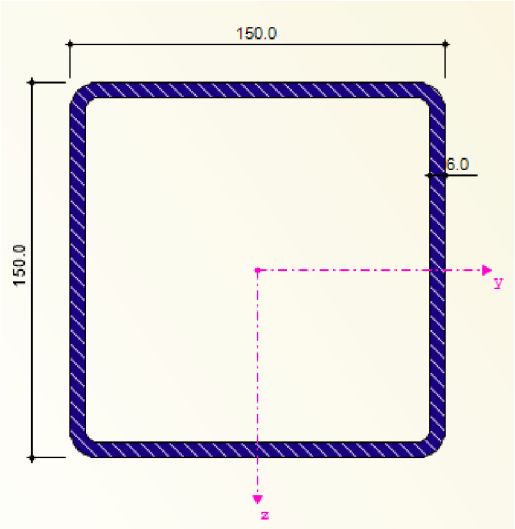
031≤ 1,0 ... vyhovuje

$$\frac{19{,}772}{\frac{0{,}49 + 1015{,}2}{1{,}0}} + 0{,}588 \,.\, \frac{4{,}084 + 0}{\frac{1{,}0 \,.\, 53{,}11}{1{,}0}} + 0{,}98 \,.\, \frac{18{,}193 + 0}{\frac{1{,}0 \,.\, 53{,}11}{1{,}0}} \leq 1{,}0$$

0,42 ≤ 1,0 ... vyhovuje

5.3 PRIEHRADOVÉ STĹPY

5.3.1 DOLNÝ PÁS



Prierezové charakteristiky:

b = 150 mm

t = 6 mm

A = 3360 mm^2

I_y = 11460000 mm^4

i_y = 58,4 mm

$W_{pl,y}$ = 180000 mm^3

Materiálové charakteristiky:

S235 (f_y = 235MPa, f_u = 360 MPa)

E = 210 GPa

Trieda prierezu:

$$\varepsilon = \sqrt{\frac{235}{fy}} = \sqrt{\frac{235}{235}} = 1{,}0$$

Pre trubkové profily štvorcového tvaru platí

$$\frac{c}{t} = \frac{150 - 12}{6} = 23 \leq 33.\varepsilon = 33\,.\,1 = 33 \;\rightarrow\; 1.\,třída$$

5.3.2 POSÚDENIE NA ŤAH

Prút č 332 kz 75

$$N_{Ed} = 246{,}353\ \text{kN}$$

$$\frac{N_{Ed}}{N_{t,Rd}} \leq 1{,}0$$

$$N_{t,Rd} = \frac{A\,.\,f_y}{\gamma_{M1}} = \frac{3360\,.10^{-6}\,.\;235.10^{3}}{1{,}0} = 789{,}6\ \text{kN}$$

$$\frac{246{,}353}{789{,}6} \leq 1{,}0$$

0,31 ≤ 1,0 ... vyhovuje program 0,31

5.3.3 POSÚDENIE NA VZPER

Prút č 1278 kz 31

$$N_{Ed} = -74{,}633\ \text{kN}$$

$$L_{cr,y} = 2{,}5m$$

$$L_{cr,z} = 5m$$

$\alpha = 0{,}49$ (duté prierezy tvarované za studena – krivka vzpernej pevnosti ´´c´´)

Vybočenie kolmo k osy y:

$$\lambda_y = \frac{L_{cr,y}}{i_y} = \frac{2500}{58,4} = 42,8$$

$$\frac{N_{Ed}}{N_{b,Rd}} \leq 1,0$$

$$N_{b,Rd} = \frac{\chi_y \,.\, A \,.\, f_y}{\gamma_{M1}} = \frac{0,87 \,.\, 3360 \,.\, 10^{-6} \,.\, 235.10^3}{1,0} = 686,95\ \text{kN}$$

$$\chi_y = \frac{1}{\phi_y + \sqrt{\phi_y{}^2 - \bar{\lambda}_y{}^2}} = \frac{1}{0,66 + \sqrt{0,66^2 - 0,45^2}} = 0,87$$

$$\phi_y = 0,5 \,.\, \left[1 + \alpha_{LT}(\bar{\lambda}_{,y} - 0,2) + \bar{\lambda}_y{}^2\right] = 0,5 \,.\, [1 + 0,49 \,.\, (0,45 - 0,2) + 0,45^2] = 0,66$$

$$\bar{\lambda}_y = \sqrt{\frac{A \,.\, f_y}{N_{cr}}} = \sqrt{\frac{3360 \,.\, 10^{-6} . 235 \,.\, 10^3}{3800}} = 0,45 > 0,2$$

Nemôžem zanedbať účinky vzperu

$$N_{cr,y} = \frac{\pi^2 .\ E \,.\, I_y}{Lcr, y^2} = \frac{\pi^2 .\ 210 \ .\ 10^6 .\ 11460000.10^{-12}}{2,5^2} = 3800\text{kN}$$

$$\frac{N_{Ed}}{N_{b,Rd}} = \frac{74,633}{686,96} = 0,11 \leq 1,0$$

0,11 ≤ 1,0 ... vyhovuje (program RFEM 0,11 ≤ 1,0)

Vybočenie kolmo k osy z:

$$\lambda_z = \frac{L_{cr,z}}{i_z} = \frac{5000}{58,4} = 85,62$$

$$\frac{N_{Ed}}{N_{b,Rd}} \leq 1,0$$

$$N_{b,Rd} = \frac{\chi_z \,.\, A \,.\, f_y}{\gamma_{M1}} = \frac{0,59 \,.\, 3360 \,.\, 10^{-6} \,.\, 235.10^3}{1,0} = 465,86\ \text{kN}$$

$$\chi_z = \frac{1}{\phi_z + \sqrt{\phi_z{}^2 - \bar{\lambda}_z{}^2}} = \frac{1}{1,088 + \sqrt{1,088^2 - 0,91^2}} = 0,59$$

$$\phi_z = 0,5 \,.\, \left[1 + \alpha_{LT}(\bar{\lambda}_{zy} - 0,2) + \bar{\lambda}_z{}^2\right] = 0,5 \,.\, [1 + 0,49(0,91 - 0,2) + 0,91^2] = 1,088$$

$$\bar{\lambda}_z = \sqrt{\frac{A \,.\, f_y}{N_{cr}}} = \sqrt{\frac{3360 \,.\, 10^{-6} . 235 \,.\, 10^3}{950,09}} = 0,91 > 0,2$$

Nemôžem zanedbať účinky vzperu

$$N_{cr,z} = \frac{\pi^2 .\ E \,.\, I_z}{Lcr, z^2} = \frac{\pi^2 .\ 210 \ .\ 10^6 .\ 11460000.10^{-12}}{5^2} = 950,09\ \text{kN}$$

$$\frac{N_{Ed}}{N_{b,Rd}} = \frac{74{,}633}{465{,}86} = 0{,}16 \leq 1{,}0$$

0,16 ≤ 1,0 ... vyhovuje (program RFEM 0,16 ≤ 1,0)

5.3.4 POSÚDENIE NA KOMBINÁCIU OHYBU A TLAKU

Prút č 332 kz 57

$N_{Ed} = -342{,}139\ \text{kN}$

$M_{y,Ed} = 0{,}297\ \text{kNm}$

$M_{z,Ed} = -1{,}910\ \text{kNm}$

$$\frac{N_{Ed}}{\frac{\chi_y \cdot N_{Rk}}{\gamma_{M1}}} + k_{yy} \cdot \frac{M_{y,Ed} + \Delta M_{y,Ed}}{\frac{\chi_{LT} \cdot M_{y,Rk}}{\gamma_{M1}}} + k_{yz} \cdot \frac{M_{z,Ed} + \Delta M_{z,Ed}}{\frac{\chi_{LT} \cdot M_{z,Rk}}{\gamma_{M1}}} \leq 1{,}0$$

$$\frac{N_{Ed}}{\frac{\chi_z \cdot N_{Rk}}{\gamma_{M1}}} + k_{zy} \cdot \frac{M_{y,Ed} + \Delta M_{y,Ed}}{\frac{\chi_{LT} \cdot M_{y,Rk}}{\gamma_{M1}}} + k_{zz} \cdot \frac{M_{z,Ed} + \Delta M_{z,Ed}}{\frac{\chi_{LT} \cdot M_{z,Rk}}{\gamma_{M1}}} \leq 1{,}0$$

Návrhové hodnoty únosnosti:

$$N_{Rd} = \frac{A \cdot f_y}{\gamma_{M0}} = \frac{3360 \cdot 10^{-6} \cdot 235 \cdot 10^3}{1{,}0} = 789{,}6\ kN$$

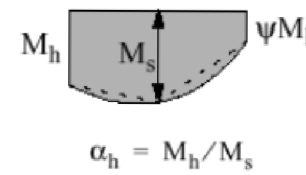
$$M_{y,Rd} = \frac{W_{pl,y} \cdot f_y}{\gamma_{M0}} = \frac{180000 \cdot 10^{-9} \cdot 235 \cdot 10^3}{1{,}0} = 42{,}3\ kNm$$

$$M_{z,Rd} = \frac{W_{pl,z} \cdot f_y}{\gamma_{M0}} = \frac{180000 \cdot 10^{-9} \cdot 235 \cdot 10^3}{1{,}0} = 42{,}3\ kNm$$

$M_{h,y} = 0{,}298\,\text{kNm}$

$\Psi M_{h,y} = 0{,}297\,\text{kNm}$

$M_{s,y} = 0{,}327\,\text{kNm}$



$$\Psi = \frac{0{,}297}{0{,}298} = 0{,}996$$

$$\alpha_h = \frac{0{,}298}{0{,}327} = 0{,}911$$

$0 \le a_h \le 1$

$0 \le 0{,}911 \le 1 \ldots \checkmark$

$-1 \le \Psi \le 1$

$-1 \le 0{,}996 \le 1 \ldots \checkmark$

$c_{my} = 0{,}95 + 0{,}05 \,.\, \alpha_h = 0{,}95 + 0{,}05\,.0{,}911 = 0{,}995 \ge 0{,}4 \ldots \checkmark$

$$k_{yy} = c_{my} \,.\left(1 + \left(\bar{\lambda}_y - 0{,}2\right) .\, \frac{N_{Ed}}{\frac{\chi_y \,.\, N_{Rk}}{\gamma_{M1}}}\right) \le c_{my} \,.\left(1 + 0{,}8 \,.\, \frac{N_{Ed}}{\frac{\chi_y \,.\, N_{Rk}}{\gamma_{M1}}}\right)$$

$$k_{yy} = 0{,}995 \,.\left(1 + (0{,}45 - 0{,}2) .\, \frac{342{,}139}{\frac{0{,}87\,.\,789{,}6}{1{,}0}}\right) \le 0{,}995 \,.\left(1 + 0{,}8 \,.\, \frac{342{,}139}{\frac{0{,}87\,.\,789{,}6}{1{,}0}}\right)$$

$k_{yy} = 1{,}119 \le 1{,}39 \ldots k_{yy} = 1{,}119$

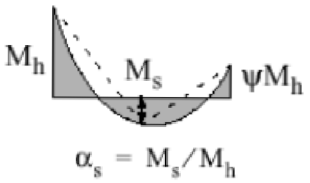
$k_{zy} = 0{,}6 \,.\, k_{yy} = 0{,}6 \,.\, 1{,}119 = 0{,}67$

$M_{h,z} = -3{,}113\,\text{kNm}$

$\Psi M_{h,z} = -1{,}910\,\text{kNm}$

$M_{s,z} = -2{,}756\,\text{kNm}$

$\Psi = 0{,}614$



$$\alpha_s = \frac{M_s}{M_h} = \frac{-2{,}756}{-3{,}113} = 0{,}885$$

$0 \le a_s \le 1$

$0 \le 0{,}885 \le 1 \ldots \checkmark$

$-1 \le \Psi \le 1$

$-1 \le 0{,}614 \le 1 \ldots \checkmark$

$c_{mz} = 0{,}2 + 0{,}8 \,.\, \alpha_s = 0{,}2 + 0{,}8\,.0{,}885 = 0{,}908 \ge 0{,}4 \ldots \checkmark$

$$k_{zz} = c_{mz} \cdot \left(1 + \left(2 \cdot \bar{\lambda}_z - 0{,}6 \right) \cdot \frac{N_{Ed}}{\frac{\chi_z \cdot N_{Rk}}{\gamma_{M1}}} \right) \leq c_{mz} \cdot \left(1 + 0{,}8 \cdot \frac{N_{Ed}}{\frac{\chi_z \cdot N_{Rk}}{\gamma_{M1}}} \right)$$

$$k_{zz} = 0{,}908 \cdot \left(1 + \left(2 \cdot 0{,}91 - 0{,}6 \right) \cdot \frac{342{,}139}{\frac{0{,}59 \cdot 789{,}6}{1{,}0}} \right) \leq 0{,}908 \cdot \left(1 + 0{,}8 \cdot \frac{342{,}139}{\frac{0{,}59 \cdot 789{,}6}{1{,}0}} \right)$$

$k_{zz} = 1{,}72 \leq 1{,}44 \ldots k_{zz} = 1{,}44$

$k_{yz} = 0{,}6 \cdot k_{zz} = 0{,}6 \cdot 1{,}44 = 0{,}864$

$\chi_{LT} = 1{,}0$ (pri uzavretých prierezoch ku klopeniu nedochádza)

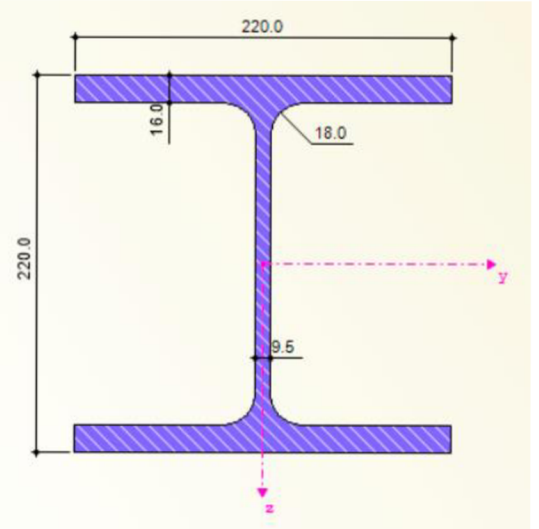
$$\frac{342{,}139}{\frac{0{,}87 \cdot 789{,}6}{1{,}0}} + 1{,}119 \cdot \frac{0{,}297 + 0}{\frac{1{,}0 \cdot 42{,}3}{1{,}0}} + 0{,}864 \cdot \frac{1{,}910 + 0}{\frac{1{,}0 \cdot 42{,}3}{1{,}0}} \leq 1{,}0$$

0,54 ≤ 1,0 ... vyhovuje program 0,56

$$\frac{342{,}139}{\frac{0{,}59 \cdot 789{,}6}{1{,}0}} + 0{,}67 \cdot \frac{0{,}297 + 0}{\frac{1{,}0 \cdot 42{,}3}{1{,}0}} + 1{,}44 \cdot \frac{1{,}910 + 0}{\frac{1{,}0 \cdot 42{,}3}{1{,}0}} \leq 1{,}0$$

0,80 ≤ 1,0 ... vyhovuje program 0,83

5.3.5 HORNÝ PÁS



Prierez: HEB 220

Prierezové charakteristiky:

h = 220 mm

b = 220 mm

t_w = 9,5 mm

t_f = 16 mm

r = 18 mm

A = 9100 mm^2

I_y = 80900000 mm^4

I_z = 28400000 mm^4

I_t = 768000 mm^4

I_w = 295400000000 mm^6

$I_w = 0{,}2954 \cdot 10^{12}$

i_y = 94,4 mm

i_z = 55,9 mm

$W_{pl,y}$ = 828000 mm^3

$W_{pl,z}$ = 393881 mm^3

Materiálové charakteristiky:

S235 (f_y = 235 MPa, f_u = 360 MPa)

E = 210 GPa

G = 81 GPa

Trieda prierezu:

$$\varepsilon = \sqrt{\frac{235}{f_y}} = \sqrt{\frac{235}{235}} = 1{,}0$$

Stojina:

$$c_w = h - 2\,.\,t_f - 2\,.\,r = 220 - 2\,.\,16 - 2\,.\,18 = 152\ mm$$

$$\frac{c_w}{t_w} = \frac{152}{16} = 9{,}5$$

$$9{,}5 \leq 72\varepsilon = 72.1 = 72 \ \rightarrow \ 1.\,třída$$

Pásnica:

$$c_f = \frac{b - 2.r - t_w}{2} = \frac{220 - 2.18 - 9{,}5}{2} = 87{,}25$$

$$\frac{c_f}{t_f} = \frac{87{,}25}{16} = 5{,}45$$

$$5{,}45 \leq 9\varepsilon = 9.1 = 9 \ \rightarrow \ 1.\,třída$$

5.3.6 POSÚDENIE NA VZPER

Prút 352 – KZ80

N_{Ed} = 271,383 kN

Vzper okolo osy Y

$L_{cr,y}$ = 1,25m

$$\frac{h}{b} = \frac{220}{220} = 1 < 1{,}2 \ \Rightarrow krivka\ b \Rightarrow \ \alpha = 0{,}34 \quad tab\ 1.9$$

$$\lambda_y = \frac{L_{cr,y}}{i_y} = \frac{1240}{94{,}4} = 13{,}13$$

$$\frac{N_{Ed}}{N_{b,Rd}} \leq 1{,}0$$

$$N_{b,Rd} = \frac{\chi_y\,.\,A.\,f_y}{\gamma_{M1}} = \frac{1{,}02\,.\,9100\,.\,10^{-6}\,.\ 235.10^3}{1{,}0} = 2181\ \text{kN}$$

$$\chi_y = \frac{1}{\phi_y + \sqrt{{\phi_y}^2 - {\bar{\lambda}_y}^2}} = \frac{1}{0{,}5 + \sqrt{0{,}5^2 - 0{,}14^2}} = 1{,}02$$

,

$$\phi_y = 0{,}5\,.\,\left[1 + \alpha_{LT}\left(\bar{\lambda}_{,y} - 0{,}2\right) + \bar{\lambda}_y{}^2\right] = 0{,}5\,.\,\left[1 + 0{,}34.(0{,}14 - 0{,}2) + 0{,}14^2\right] = 0{,}5$$

$$\bar{\lambda}_y = \sqrt{\frac{A\,.\,f_y}{N_{cr}}} = \sqrt{\frac{9100\,.\,10^{-6}.\,235\,.\,10^3}{107311}} = 0{,}14\ > 0{,}2$$

môžem zanedbať účinky vzperu

$$N_{cr,y} = \frac{\pi^2.\ E\,.\,I_y}{Lcr, y^2} = \frac{\pi^2.\ 210\ .\ 10^6\,.\ 80900000\,.\,10^{-12}}{1{,}25^2} = 107311\text{kN}$$

$$\frac{\mathrm{N_{Ed}}}{\mathrm{N_{b,Rd}}} = \frac{271{,}383}{2181} = 0{,}12\ \leq 1{,}0$$

0,12 ≤ 1,0 ... vyhovuje

Vzper okolo osy Z

$$\frac{h}{b} = \frac{220}{220} = 1 < 1{,}2\ \Rightarrow krivka\ c \Rightarrow\ \alpha = 0{,}49\quad tab\ 1.3$$

$$\mathrm{N_{b,Rd}} = \frac{\chi_z\,.\ \mathrm{A}\,.\ \mathrm{f_y}}{\gamma_{M1}} = \frac{0{,}86\ .9100\,.\,10^{-6}\ .\ \ 235.\,10^3}{1{,}0} = 1839\ \mathrm{kN}$$

$$\chi_Z = \frac{1}{\phi_z + \sqrt{\phi_z{}^2 - \bar{\lambda}_z{}^2}} = \frac{1}{0{,}676 + \sqrt{0{,}676^2 - \ 0{,}47^2}} = 0{,}86$$

$$\phi_z = 0{,}5\,.\,\left[1 + \alpha_{LT}\left(\bar{\lambda}_{zy} - 0{,}2\right) + \bar{\lambda}_z{}^2\right] = 0{,}5\,.\,\left[1 + 0{,}49.\ (0{,}47 - 0{,}2) + 0{,}47^2\right] = 0{,}676$$

$$\bar{\lambda}_z = \sqrt{\frac{A\,.\,f_y}{N_{cr}}} = \sqrt{\frac{9100\,.\,10^{-6}.\,235\,.\,10^3}{9417{,}97}} = 0{,}47\ > 0{,}2$$

Nemôžem zanedbať účinky vzperu

$$N_{cr,z} = \frac{\pi^2.\ E\,.\,I_z}{Lcr, z^2} = \frac{\pi^2.\ 210\ .\ 10^6\,.\ 28400000\,.\,10^{-12}}{2{,}5^2} = 9417{,}97\ \mathrm{kN}$$

$$\frac{\mathrm{N_{Ed}}}{\mathrm{N_{b,Rd}}} = \frac{271{,}383}{1839} = 0{,}15\ \leq 1{,}0$$

0,15 ≤ 1,0 ... vyhovuje (program RFEM 0,09 ≤ 1,0)

POSÚDENIE NA KOMBINÁCIU OHYBU A TLAKU

Prút č. 321 – KZ89

$\mathrm{N_{Ed}}\ =\ -262{,}429\ \mathrm{kN}$

$\mathrm{M_{y,Ed}} =\ 9{,}589\ \mathrm{kNm}$

$\mathrm{M_{z,Ed}} =\ \ \ 0{,}034\ \mathrm{kNm}$

Kombinacia osovej sily a momentu

VPLYV KLOPENIA

Parameter krútenia

$k_w = 1{,}0; L = 2{,}5\text{m}$

$$k_{wt} = \frac{\Pi}{k_w . L}\sqrt{\frac{E . I_w}{G . I_t}} = \frac{\Pi}{1{,}0 * 2{,}5}\sqrt{\frac{210 . 10^9 . 2{,}954 . 10^{-7}}{81 . 10^9 . 7{,}68 . 10^{-7}}} = 1{,}25$$

$z_j = 0$

$$\zeta_j = \frac{\pi z_j}{k_z L}\sqrt{\frac{EI_z}{GI_t}} = 0$$

$z_g = 0{,}110\text{m}$

$$\zeta_g = \frac{\pi . z_g}{k_z . L}\sqrt{\frac{EI_z}{GI_t}} = \frac{\pi . \ 0{,}110}{1 . 2{,}5}\sqrt{\frac{210 . 10^9 . 2{,}84 . 10^{-5}}{81 . 10^9 . \ 7{,}68 . 10^{-7}}} = 1{,}35$$

Bezrozmerný kriticky moment

$C_1 = 1{,}13$

$C_2 = 0{,}46$

$C_3 = 0{,}53$

$$\mu_{Cr} = \frac{C_1}{k_z}\left[\sqrt{1 + k_{wt}^2 + \left(C_2\zeta_g - C_3\zeta_j\right)^2} - \left(C_2\zeta_g - C_3\zeta_j\right)\right]$$

$$\mu_{Cr} = \frac{1{,}13}{1{,}0}\left[\sqrt{1 + 1{,}25^2 + (0{,}46 . \ 1{,}35 - 0{,}53 . \ 0\ )^2} - (0{,}46 . \ 1{,}35 - 0{,}53 . 0)\right]$$

$\mu_{Cr} = 1{,}238$

Pružný kritický moment pri klopení

$$M_{cr} = \mu_{cr}\frac{\pi\sqrt{E . I_z . G . I_t}}{L} = 1{,}238 * \frac{\pi\sqrt{210 . 10^9 . \ 2{,}87 . 10^{-5} . \ 81 . 10^9 . 7{,}68 . 10^{-7}}}{2{,}5}$$

$M_{cr} = 952{,}59\ kNm$

Pomerná štíhlosť

$$\bar{\lambda}_{LT} = \sqrt{\frac{W_{pl,y} . f_y}{M_{cr}}} = \sqrt{\frac{8{,}28 . 10^{-4} . 235 . 10^6}{952590}} = 0{,}45$$

$$\frac{h}{b} = \frac{152}{160} = 0{,}95 < 2 \Rightarrow krivka\ klpopenia\ \ a \Rightarrow \ \alpha_{LT} = 0{,}21 \quad tab\ 1.8$$

$$\phi_{LT} = 0{,}5\left(1 + \alpha_{LT}\left(\bar{\lambda}_{LT} - 0{,}2\right) + \bar{\lambda}_{LT}^2\right) = 0{,}5 . (1 + 0{,}21 . (0{,}45 - 0{,}2) + 0{,}45^2) = 0{,}628$$

$$\chi_{LT} = \frac{1}{\phi_{LT} + \sqrt{\phi_{LT}^2 - \bar{\lambda}_{LT}^2}} = \frac{1}{0{,}628 + \sqrt{0{,}628^2 - 0{,}45^2}} = 0{,}938$$

Návrhové hodnoty únosnosti:

$$M_{b,Rd} = \frac{\chi_{LT} . W_{pl,y} . f_y}{\gamma_{M0}} = \frac{0{,}938 . 8{,}28 . 10^{-4} . 235 . 10^3}{1{,}0} = 182{,}52\ kNm$$

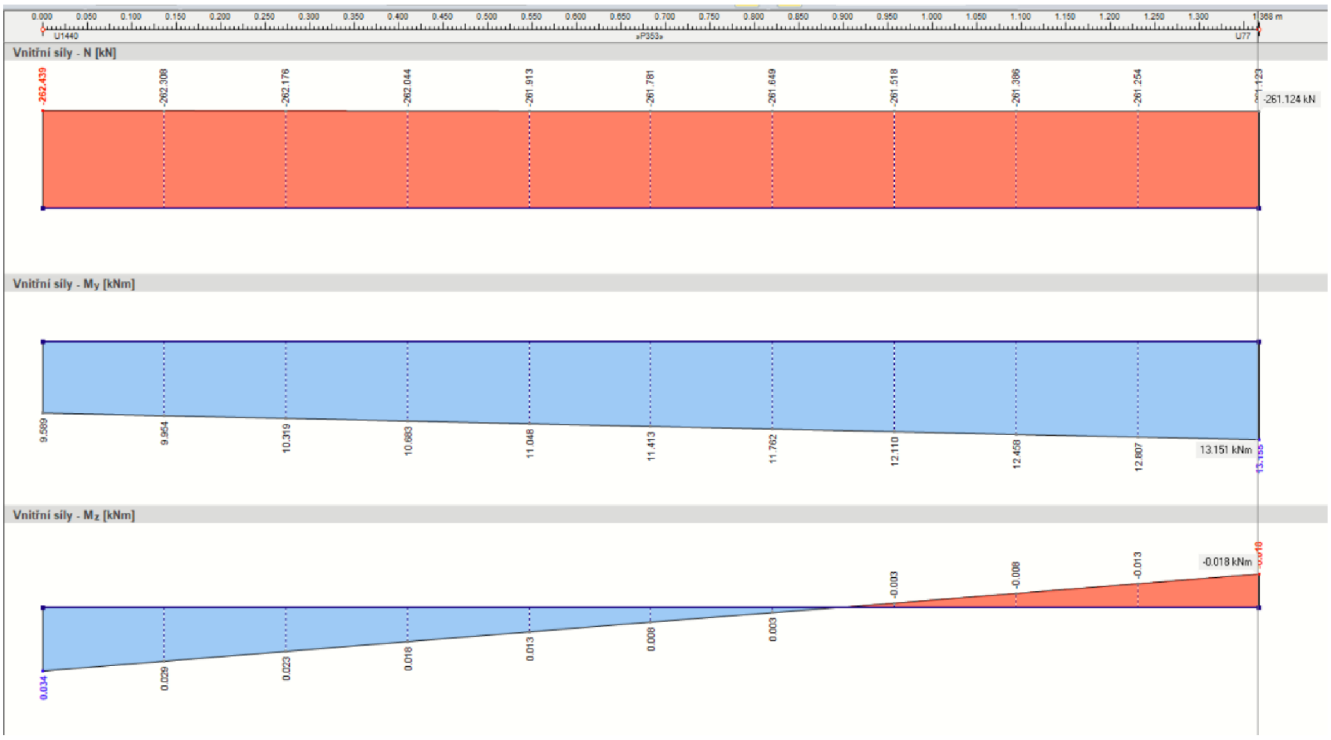
$$\frac{M_{y,Ed}}{M_{b,Rd}} = \frac{9{,}589}{182{,}52} = 0{,}0{,}5 < 1$$

Návrhové hodnoty únosnosti:

$$N_{Rd} = \frac{A . f_y}{\gamma_{M0}} = \frac{9{,}1 . 10^{-3} . 235 . 10^3}{1{,}0} = 2138{,}5\ kN$$

$$M_{Y,Rd} = \frac{W_{pl,y} . f_y}{\gamma_{M0}} = \frac{8{,}28 . 10^{-4} . 235 . 10^3}{1{,}0} = 194{,}58\ kNm$$

$$M_{z,pl,Rd} = \frac{W_{pl,z} . f_y}{\gamma_{M0}} = \frac{3{,}938 . 10^{-4} . 235 . 10^3}{1{,}0} = 92{,}54\ kNm$$



Súčiniteľ C_{my} ekvivalentného konštantného momentu

$M_{h,y} = 13{,}155$ kNm

$\Psi M_{h,y} = 9{,}589$ kNm

$$\Psi = \frac{9{,}589}{13{,}155} = 0{,}729$$

$-1 \leq \Psi \leq 1$

$-1 \leq 0{,}729 \leq 1 \ldots$ ✓

$c_{my} = 0{,}6 + 0{,}4 . \Psi = 0{,}6 + 0{,}4 . 0{,}729 = 0{,}892 \geq 0{,}4 \ldots$ ✓

$$k_{yy} = c_{my} \cdot \left(1 + \left(\bar{\lambda}_y - 0{,}2\right) \cdot \frac{N_{Ed}}{\frac{\chi_y \cdot N_{Rk}}{\gamma_{M1}}}\right) \leq c_{my} \cdot \left(1 + 0{,}8 \cdot \frac{N_{Ed}}{\frac{\chi_y \cdot N_{Rk}}{\gamma_{M1}}}\right)$$

$$k_{yy} = 0{,}892 \cdot \left(1 + (0{,}14 - 0{,}2) \cdot \frac{262{,}429}{\frac{1{,}02 \cdot 2138{,}58}{1{,}0}}\right) \leq 0{,}892 \cdot \left(1 + 0{,}8 \cdot \frac{262{,}429}{\frac{1{,}02 \cdot 2138{,}5}{1{,}0}}\right)$$

$$k_{yy} = 0{,}886 \leq 0{,}977 \ldots k_{yy} = 0{,}886$$

Súčiniteľ C_{mz} ekvivalentného konštantného momentu

$M_{h,z} = 0{,}034\ \text{kNm}$

$\Psi M_{h,z} = -0{,}018\ \text{kNm}$

$$\Psi = \frac{-0{,}018}{0{,}034} = -0{,}529$$

$-1 \leq \Psi \leq 1$

$-1 \leq -0{,}529 \leq 1 \ldots$ ✓

$c_{mz} = 0{,}6 + 0{,}4 \cdot \Psi = 0{,}6 - 0{,}4 \cdot 0{,}529 = 0{,}388 \geq 0{,}4 \ldots x$

$c_{mz} = 0{,}4$

$$k_{zz} = c_{mz} \cdot \left(1 + \left(2 \cdot \bar{\lambda}_z - 0{,}6\right) \cdot \frac{N_{Ed}}{\frac{\chi_z \cdot N_{Rk}}{\gamma_{M1}}}\right) \leq c_{mz} \cdot \left(1 + 1{,}4 \cdot \frac{N_{Ed}}{\frac{\chi_z \cdot N_{Rk}}{\gamma_{M1}}}\right)$$

$$k_{zz} = 0{,}4 \cdot \left(1 + (2 \cdot 0{,}47 - 0{,}6) \cdot \frac{262{,}429}{\frac{0{,}86 \cdot 2138{,}58}{1{,}0}}\right) \leq 0{,}4 \cdot \left(1 + 1{,}4 \cdot \frac{262{,}429}{\frac{0{,}86 \cdot 2138{,}58}{1{,}0}}\right)$$

$k_{zz} = 0{,}419 \leq 0{,}479 \ldots k_{zz} = 0{,}419$

$k_{yz} = 0{,}6 \cdot k_{zz} = 0{,}6 \cdot 0{,}419 = 0{,}251$

$$k_{zy} = \left(1 - \frac{0{,}1 \cdot \bar{\lambda}_z}{C_{m,LT} - 0{,}25} \cdot \frac{N_{Ed}}{\frac{\chi_z \cdot N_{Rk}}{\gamma_{M1}}}\right) \geq \left(1 - \frac{0{,}1}{C_{m,LT} - 0{,}25} \cdot \frac{N_{Ed}}{\frac{\chi_z \cdot N_{Rk}}{\gamma_{M1}}}\right)$$

$$k_{zy} = \left(1 - \frac{0{,}1 \cdot 0{,}47}{0{,}95 - 0{,}25} \cdot \frac{262{,}429}{\frac{0{,}86 \cdot 2138{,}58}{1{,}0}}\right) \geq \left(1 - \frac{0{,}1}{0{,}95 - 0{,}25} \cdot \frac{262{,}429}{\frac{0{,}86 \cdot 2138{,}58}{1{,}0}}\right)$$

$k_{zy} = 0{,}990 \geq 0{,}979 \ldots k_{zy} = 0{,}979$

$$\frac{N_{Ed}}{\frac{\chi_y \cdot N_{Rk}}{\gamma_{M1}}} + k_{yy} \cdot \frac{M_{y,Ed}}{\frac{\chi_{LT} \cdot M_{y,Rk}}{\gamma_{M1}}} + k_{yz} \cdot \frac{M_{z,Ed}}{\frac{\chi_{LT} \cdot M_{z,Rk}}{\gamma_{M1}}} \leq 1{,}0$$

$$\frac{262{,}429}{\frac{1{,}02 \cdot 2138{,}58}{1{,}0}} + 0886 \cdot \frac{9{,}589}{\frac{0{,}938 \cdot 194{,}58}{1{,}0}} + 0{,}251 \cdot \frac{0{,}034}{\frac{0{,}938 \cdot 92{,}54}{1{,}0}} \leq 1{,}0$$

$0{,}17 \leq 1{,}0$ (program $0{,}18 \leq 1{,}0$)

$$\frac{N_{Ed}}{\frac{\chi_z \cdot N_{Rk}}{\gamma_{M1}}} + k_{zy} \cdot \frac{M_{y,Ed}}{\frac{\chi_{LT} \cdot M_{y,Rk}}{\gamma_{M1}}} + k_{zz} \cdot \frac{M_{z,Ed}}{\frac{\chi_{LT} \cdot M_{z,Rk}}{\gamma_{M1}}} \leq 1{,}0$$

$$\frac{262{,}429}{\frac{0{,}86 \cdot 2138{,}58}{1{,}0}} + 0{,}979 \cdot \frac{9{,}589}{\frac{0{,}938 \cdot 194{,}58}{1{,}0}} + 0{,}419 \cdot \frac{0{,}034}{\frac{0{,}938 \cdot 92{,}54}{1{,}0}} \leq 1{,}0$$

$0{,}19 \leq 1{,}0$ (program $0{,}21 \leq 1{,}0$)

5.3.7 DIAGONÁLY

Prierezové charakteristiky:

b = 60 mm

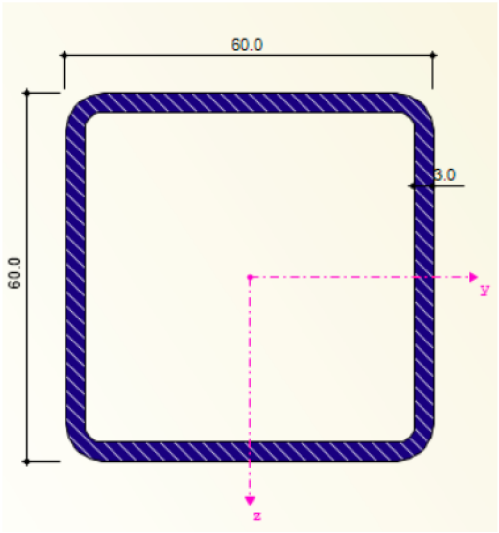
t = 3 mm

A = 661 mm^2

I_y =351000 mm^4

i_y = 23,1 mm

$W_{pl,y}$ = 14000 mm^3



Materiálové charakteristiky:

S235 (f_y = 235MPa, f_u = 360 MPa)

E = 210 GPa

Trieda prierezu:

$$\varepsilon = \sqrt{\frac{235}{fy}} = \sqrt{\frac{235}{235}} = 1{,}0$$

Pre trubkové profily štvorcového tvaru platí

$$\frac{c}{t} = \frac{60-6}{3} = 18 \leq 33.\varepsilon = 33\,.\,1 = 33 \;\rightarrow\; 1.\,t\check{r}\acute{i}da$$

5.3.8 POSÚDENIE NA ŤAH

Prút č 1287 kz 53

$$\mathrm{N_{Ed}} \;=\; 74{,}147\ \mathrm{kN}$$

$$\frac{\mathrm{N_{Ed}}}{\mathrm{N_{t,Rd}}} \leq 1{,}0$$

$$\mathrm{N_{t,Rd}} = \frac{\mathrm{A}\,.\,\mathrm{f_y}}{\gamma_{\mathrm{M1}}} = \frac{661\,.\,10^{-6}\,.\;235.\,10^{3}}{1{,}0} = 155{,}33\ \mathrm{kN}$$

$$\frac{74{,}147}{155{,}33} \leq 1{,}0$$

0,47≤ 1,0 ... vyhovuje

5.3.9 POSÚDENIE NA VZPER

Prút č 1286 kz 77

$$\mathrm{N_{Ed}} \;=\; -85{,}287\ \mathrm{kN}$$

$L_{cr,y} = L_{cr,z} = 1{,}54\ m$ (zaistené väznicami)

$\alpha = 0{,}49$ (duté prierezy tvarované za studena – krivka vzpernej pevnosti ´´c´´)

$$\lambda_{\mathrm{y}} = \frac{\mathrm{L_{cr,y}}}{\mathrm{i_y}} = \frac{1540}{23{,}1} = 66{,}67$$

$$\frac{\mathrm{N_{Ed}}}{\mathrm{N_{b,Rd}}} \leq 1{,}0$$

$$\mathrm{N_{b,Rd}} = \frac{\chi_{\mathrm{y}}\,.\;\mathrm{A}\,.\;\mathrm{f_y}}{\gamma_{\mathrm{M1}}} = \frac{0{,}72\,.661\,.\,10^{-6}\,.\;\;235.\,10^{3}}{1{,}0} = 111{,}84\ \mathrm{kN}$$

$$\chi_y = \chi_z = \frac{1}{\phi_y + \sqrt{{\phi_y}^2 - \bar{\lambda}_y{}^2}} = \frac{1}{0{,}877 + \sqrt{0{,}877^2 - 0{,}71^2}} = 0{,}72$$

$$\phi_y = 0{,}5\,.\;\left[1 + \alpha_{LT}\left(\bar{\lambda}_{,y} - 0{,}2\right) + \bar{\lambda}_y{}^2\right] = 0{,}5\,.\;\left[1 + 0{,}49.\,(0{,}71 - 0{,}2) + 0{,}71^2\right] = 0{,}877$$

$$\bar{\lambda}_y = \bar{\lambda}_z = \sqrt{\frac{A\,.\,f_y}{N_{cr}}} = \sqrt{\frac{661\,.\,10^{-6}.235\,.\,10^{3}}{306{,}75}} = 0{,}71 > 0{,}2$$

Nemôžem zanedbať účinky vzperu

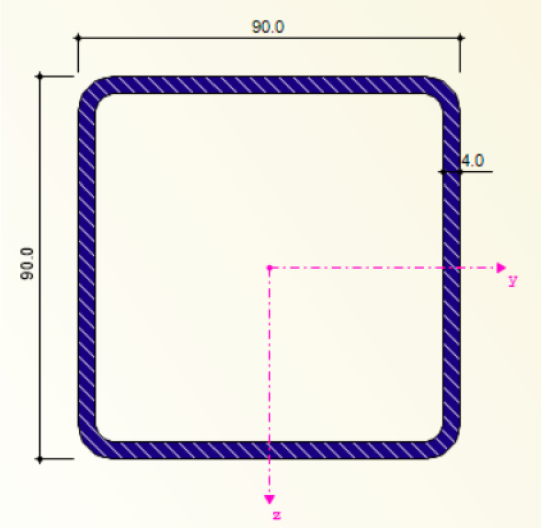
$$N_{cr} = \frac{\pi^2.\;E\,.I_y}{Lcr,y^2} = \frac{\pi^2.\;210\;.\;10^6\,.\;351000\,.10^{-12}}{1{,}54^2} = 306{,}75\mathrm{kN}$$

$$\frac{\mathrm{N_{Ed}}}{\mathrm{N_{b,Rd}}} = \frac{85{,}287}{111{,}84} = 0{,}52 \;\leq 1{,}0$$

0,52 ≤ 1,0 ... vyhovuje (program RFEM 0,77 ≤ 1,0)

5.4 VZPERKY

Prierezové charakteristiky:



b = 90 mm

t = 4 mm

A = 1330 mm^2

I_y = 1620000 mm^4

i_y = 34,8 mm

$W_{pl,y}$ = 42600 mm^3

Materiálové charakteristiky:

S235 (f_y = 235MPa, f_u = 360 MPa)

E = 210 GPa

Trieda prierezu:

$$\varepsilon = \sqrt{\frac{235}{\mathrm{fy}}} = \sqrt{\frac{235}{235}} = 1{,}0$$

Pre trubkové profily štvorcového tvaru platí

$$\frac{c}{t} = \frac{90-8}{4} = 20{,}5 \leq 33.\varepsilon = 33\,.\,1 = 33 \;\rightarrow\; 1.\check{t}\acute{r}\acute{i}da$$

5.4.1 ŤAHANÁ DIAGONÁLA

Prút č 1233 kz 94

$$\mathrm{N_{Ed}} \;=\; 28{,}636\mathrm{kN}$$

$$\frac{\mathrm{N_{Ed}}}{\mathrm{N_{t,Rd}}} \leq 1{,}0$$

$$\mathrm{N_{t,Rd}} = \frac{\mathrm{A}\,.\,\mathrm{f_y}}{\gamma_{\mathrm{M1}}} = \frac{1330\,.10^{-6}\,.\;235.10^{3}}{1{,}0} = 312{,}55\ \mathrm{kN}$$

$$\frac{\mathrm{N_{Ed}}}{\mathrm{N_{t,Rd}}} \leq 1{,}0$$

$$\frac{28{,}636}{312{,}55} \leq 1{,}0$$

0,09 ≤ 1,0 ... vyhovuje

5.4.2 TLAČENÁ DIAGONÁLA POSUDENIE NA VZPER

Prút č 1233 kz 74

$N_{Ed} = -17{,}574\ \text{kN}$

$L_{cr,y} = L_{cr,z} = 1{,}273\ m$

$\alpha = 0{,}49$ (duté prierezy tvarované za studena – krivka vzpernej pevnosti ´´c´´)

$$\lambda_y = \frac{L_{cr,y}}{i_y} = \frac{1273}{34{,}8} = 36{,}58$$

$$\frac{N_{Ed}}{N_{b,Rd}} \leq 1{,}0$$

$$N_{b,Rd} = \frac{\chi_y \,.\, A \,.\, f_y}{\gamma_{M1}} = \frac{0{,}68 \,.\, 1330 \,.\, 10^{-6} \,.\, 235.10^3}{1{,}0} = 212{,}53\ \text{kN}$$

$$\chi_y = \chi_z = \frac{1}{\phi_y + \sqrt{\phi_y{}^2 - \bar{\lambda}_y{}^2}} = \frac{1}{0{,}93 + \sqrt{0{,}93^2 - 0{,}76^2}} = 0{,}68$$

$$\phi_y = 0{,}5 \,.\, \left[1 + \alpha_{LT}\left(\bar{\lambda}_{,y} - 0{,}2\right) + \bar{\lambda}_y{}^2\right] = 0{,}5 \,.\, \left[1 + 0{,}49 \,.\, (0{,}76 - 0{,}2) + 0{,}76^2\right] = 0{,}93$$

$$\bar{\lambda}_y = \bar{\lambda}_z = \sqrt{\frac{A \,.\, f_y}{N_{cr}}} = \sqrt{\frac{1330 \,.\, 10^{-6}.235 \,.\, 10^3}{544{,}84}} = 0{,}76 > 0{,}2$$

Nemôžem zanedbať účinky vzperu

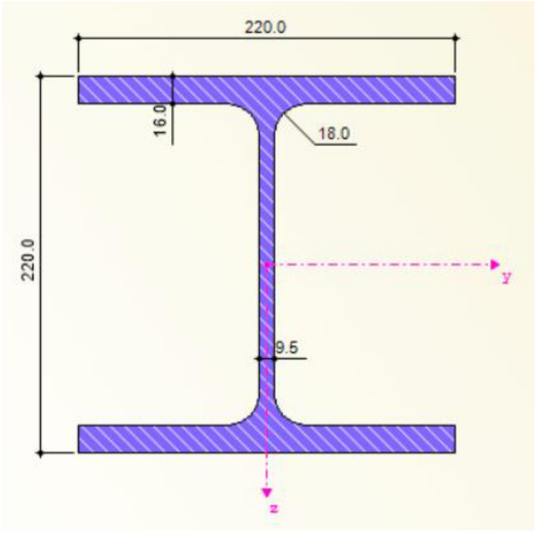
$$N_{cr} = \frac{\pi^2.\ E \,.\, I_y}{Lcr, y^2} = \frac{\pi^2.\ 210\ .\ 10^6 .\ 42600 \,.\, 10^{-12}}{1{,}273^2} = 544{,}84\text{kN}$$

$$\frac{N_{Ed}}{N_{b,Rd}} = \frac{17{,}574}{212{,}53} = 0{,}08 \leq 1{,}0$$

0,08 ≤ 1,0 ... vyhovuje (program RFEM 0,48 ≤ 1,0)

5.5 STĹP HEB220

Prierez: HEB 220



Prierezové charakteristiky:

h = 220 mm

b = 220 mm

t_w = 9,5 mm

t_f = 16 mm

r = 18 mm

A = 9100 mm^2

I_y = 80900000 mm^4

I_z = 28400000 mm^4

I_t = 768000 mm^4

I_w = 295400000000 mm^6

I_w = 0,2954 . 10^{12}

i_y = 94,4 mm

i_z = 55,9 mm

$W_{pl,y}$ = 828000 mm^3

$W_{pl,z}$ = 393881 mm^3

Materiálové charakteristiky:

S235 (f_y = 235 MPa, f_u = 360 MPa)

E = 210 GPa

G = 81 GPa

Trieda prierezu:

$$\varepsilon = \sqrt{\frac{235}{f_y}} = \sqrt{\frac{235}{235}} = 1{,}0$$

Stojina:

$$c_w = h - 2\,.\,t_f - 2\,.\,r = 220 - 2\,.\,16 - 2\,.\,18 = 152\ mm$$

$$\frac{c_w}{t_w} = \frac{152}{16} = 9{,}5$$

$$9{,}5 \leq 72\varepsilon = 72.1 = 72 \quad \rightarrow \quad 1.\,třída$$

Pásnica:

$$c_f = \frac{b - 2.r - t_w}{2} = \frac{220 - 2.18 - 9{,}5}{2} = 87{,}25$$

$$\frac{c_f}{t_f} = \frac{87{,}25}{16} = 5{,}45$$

$$5{,}45 \leq 9\varepsilon = 9.1 = 9 \;\rightarrow\; 1.\,třída$$

5.5.1 POSÚDENIE NA OHYB OKOLO OSY Y

Prút 373 – KZ72

$M_{y,Ed}$ = 22,234 kNm

$$M_{c,Rd} = \frac{W_{pl,y} \cdot f_y}{\gamma_{M0}} = \frac{8{,}28 \cdot 10^{-4} \cdot 235 \cdot 10^3}{1{,}0} = 194{,}58\ kNm$$

$$\frac{M_{y,Ed}}{M_{c,Rd}} \leq 1{,}0$$

$$\frac{22{,}234}{194{,}58} \leq 1{,}0$$

0,15 ≤ 1,0 ... vyhovuje (program RFEM 0,11 ≤ 1,0)

5.5.2 POSÚDENIE NA OHYB OKOLO OSY Z

Prút 373 – KZ72

$M_{y,Ed}$ = 22,234 kNm

$$M_{c,Rd} = \frac{W_{pl,y} \cdot f_y}{\gamma_{M0}} = \frac{8{,}28 \cdot 10^{-4} \cdot 235 \cdot 10^3}{1{,}0} = 194{,}58\ kNm$$

$$\frac{M_{y,Ed}}{M_{c,Rd}} \leq 1{,}0$$

$$\frac{22{,}234}{194{,}58} \leq 1{,}0$$

0,15 ≤ 1,0 ... vyhovuje (program RFEM 0,11 ≤ 1,0)

5.5.3 POSÚDENIE NA VZPER

Vzper okolo osy Y

$L_{cr,y}$ = 8,411m

$$\frac{h}{b} = \frac{220}{220} = 1 < 1{,}2 \;\Rightarrow krivka\ b \Rightarrow\ \alpha = 0{,}34 \quad tab\ 1.9$$

$$\lambda_y = \frac{L_{cr,y}}{i_y} = \frac{8411}{94{,}4} = 89{,}1$$

$$\frac{N_{Ed}}{N_{b,Rd}} \leq 1{,}0$$

$$N_{b,Rd} = \frac{\chi_y \,.\, A \,.\, f_y}{\gamma_{M1}} = \frac{0{,}627 \,.\, 9100 \,.\, 10^{-6} \,.\, 235.10^3}{1{,}0} = 1346{,}54\ \text{kN}$$

$$\chi_y = \frac{1}{\phi_y + \sqrt{\phi_y{}^2 - \bar{\lambda}_y{}^2}} = \frac{1}{1{,}08 + \sqrt{1{,}08^2 - 0{,}95^2}} = 0{,}627$$

,

$$\phi_y = 0{,}5 \,.\, \left[1 + \alpha_{LT}\left(\bar{\lambda}_{,y} - 0{,}2\right) + \bar{\lambda}_y{}^2\right] = 0{,}5 \,.\, [1 + 0{,}34.(0{,}95 - 0{,}2) + 0{,}95^2] = 1{,}08$$

$$\bar{\lambda}_y = \sqrt{\frac{A \,.\, f_y}{N_{cr}}} = \sqrt{\frac{9100 \,.\, 10^{-6}.235 \,.\, 10^3}{2370{,}13}} = 0{,}95 > 0{,}2$$

môžem zanedbať účinky vzperu

$$N_{cr,y} = \frac{\pi^2 .\ E \,.\, I_y}{Lcr, y^2} = \frac{\pi^2 .\ 210 \ .\ 10^6 .\ 80900000 \,.\, 10^{-12}}{8{,}411^2} = 2370{,}13\text{kN}$$

$$\frac{N_{Ed}}{N_{b,Rd}} = \frac{185{,}787}{1346{,}54} = 0{,}14 \ \leq 1{,}0$$

0,14 ≤ 1,0 ... vyhovuje

Vzper okolo osy Z

$$\frac{h}{b} = \frac{220}{220} = 1 < 1{,}2 \ \Rightarrow krivka\ c \Rightarrow \ \alpha = 0{,}49 \quad tab\ 1.3$$

$$N_{b,Rd} = \frac{\chi_z \,.\, A \,.\, f_y}{\gamma_{M1}} = \frac{0{,}28 \ .9100 \,.\, 10^{-6} \,.\, 235.10^3}{1{,}0} = 598{,}78\ \text{kN}$$

$$\chi_z = \frac{1}{\phi_z + \sqrt{\phi_z{}^2 - \bar{\lambda}_z{}^2}} = \frac{1}{2{,}12 + \sqrt{2{,}12^2 - 1{,}6^2}} = 0{,}28$$

$$\phi_z = 0{,}5 \,.\, \left[1 + \alpha_{LT}\left(\bar{\lambda}_{zy} - 0{,}2\right) + \bar{\lambda}_z{}^2\right] = 0{,}5 \,.\, [1 + 0{,}49.\ (1{,}6 - 0{,}2) + 1{,}6^2] = 2{,}12$$

$$\bar{\lambda}_z = \sqrt{\frac{A \,.\, f_y}{N_{cr}}} = \sqrt{\frac{9100 \,.\, 10^{-6}.235 \,.\, 10^3}{832}} = 1{,}60 \ > 0{,}2$$

Nemôžem zanedbať účinky vzperu

$$N_{cr,z} = \frac{\pi^2 .\ E \,.\, I_z}{Lcr, z^2} = \frac{\pi^2 .\ 210 \ .\ 10^6 .\ 28400000 \,.\, 10^{-12}}{8{,}411^2} = 832\ \text{kN}$$

$$\frac{N_{Ed}}{N_{b,Rd}} = \frac{271{,}383}{598{,}78} = 0{,}45 \leq 1{,}0$$

0,45 ≤ 1,0 ... vyhovuje

5.5.4 VPLYV KLOPENIA

$\mathrm{M_{y,Ed}} = -38{,}179\ \mathrm{kNm}$

Parameter krútenia

$k_w = 1{,}0; L = 8{,}411\mathrm{m}$

$$k_{wt} = \frac{\Pi}{k_w . L}\sqrt{\frac{E . I_w}{G . I_t}} = \frac{\Pi}{1{,}0 * 8{,}411}\sqrt{\frac{210 . 10^9 . 2{,}954 . 10^{-7}}{81 . 10^9 . 7{,}68 . 10^{-7}}} = 0{,}373$$

$z_j = 0$

$$\zeta_j = \frac{\pi z_j}{k_z L}\sqrt{\frac{E I_z}{G I_t}} = 0$$

$z_g = 0{,}110\mathrm{m}$

$$\zeta_g = \frac{\pi . z_g}{k_z . L}\sqrt{\frac{E I_z}{G I_t}} = \frac{\pi .\ 0{,}110}{1 . 8{,}411}\sqrt{\frac{210 . 10^9 . 2{,}84 . 10^{-5}}{81 . 10^9 .\ 7{,}68 . 10^{-7}}} = 0{,}403$$

Bezrozmerný kriticky moment

$C_1 = 1{,}13$

$C_2 = 0{,}46$

$C_3 = 0{,}53$

$$\mu_{Cr} = \frac{C_1}{k_z}\left[\sqrt{1 + k_{wt}^2 + \left(C_2\zeta_g - C_3\zeta_j\right)^2} - \left(C_2\zeta_g - C_3\zeta_j\right)\right]$$

$$\mu_{Cr} = \frac{1{,}13}{1{,}0}\left[\sqrt{1 + 0{,}373^2 + (0{,}46 .\ 0{,}403 - 0{,}53 .\ 0\ )^2} - (0{,}46 .\ 0{,}403 - 0{,}53 . 0)\right]$$

$\mu_{Cr} = 1{,}015$

Pružný kritický moment pri klopení

$$M_{cr} = \mu_{cr}\frac{\pi\sqrt{E . I_z . G . I_t}}{L} = 1{,}015 * \frac{\pi\sqrt{210 . 10^9 .\ 2{,}87 . 10^{-5} .\ 81 . 10^9 . 7{,}68 . 10^{-7}}}{8{,}411}$$

$M_{cr} = 232{,}135\ kNm$

Pomerná štíhlosť

$$\bar{\lambda}_{LT} = \sqrt{\frac{W_{pl,y} . f_y}{M_{cr}}} = \sqrt{\frac{8{,}28 . 10^{-4} . 235 . 10^6}{232{,}135}} = 0{,}916$$

$$\frac{h}{b} = \frac{220}{220} = 1 < 1{;}2 \Rightarrow krivka\ klopenia\ \ a \Rightarrow\ \alpha_{LT} = 0{,}21 \quad tab\ 1.8$$

$$\phi_{LT} = 0{,}5\left(1 + \alpha_{LT}\left(\bar{\lambda}_{LT} - 0{,}2\right) + \bar{\lambda}_{LT}^2\right) = 0{,}5 . (1 + 0{,}21 . (0{,}916 - 0{,}2) + 0{,}916^2) = 0{,}995$$

$$\chi_{LT} = \frac{1}{\phi_{LT} + \sqrt{\phi_{LT}^2 - \bar{\lambda}_{LT}^2}} = \frac{1}{0{,}995 + \sqrt{0{,}995^2 - 0{,}916^2}} = 0{,}723$$

Návrhové hodnoty únosnosti:

$$M_{b,Rd} = \frac{\chi_{LT} . W_{pl,y} . f_y}{\gamma_{M0}} = \frac{0{,}723 . 8{,}28 . 10^{-4} . 235 . 10^3}{1{,}0} = 195{,}1\ kNm$$

$$\frac{M_{y,Ed}}{M_{b,Rd}} = \frac{38{,}179}{195{,}1} = 0{,}20 < 1$$

5.5.5 POSÚDENIE NA KOMBINÁCIU OHYBU A TLAKU

Prút č. 321 – KZ89

$N_{Ed} = -177{,}570\ \text{kN}$

$M_{y,Ed} = -38{,}179\ \text{kNm}$

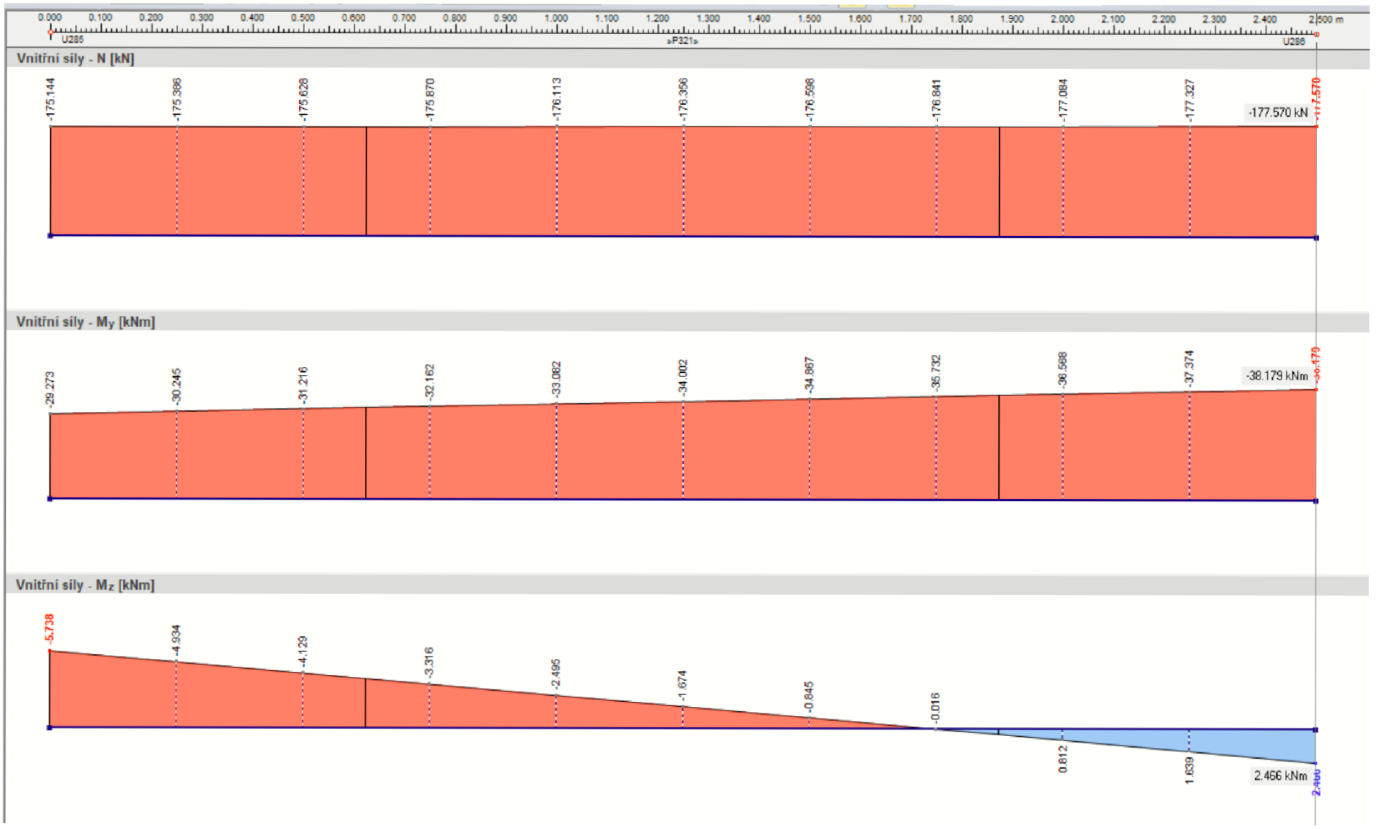
$M_{z,Ed} = 2{,}466\ \text{kNm}$

Návrhové hodnoty únosnosti:

$$N_{Rd} = \frac{A . f_y}{\gamma_{M0}} = \frac{9{,}1 . 10^{-3} . 235 . 10^3}{1{,}0} = 2138{,}5\ kN$$

$$M_{Y,Rd} = \frac{W_{pl,y} . f_y}{\gamma_{M0}} = \frac{8{,}28 . 10^{-4} . 235 . 10^3}{1{,}0} = 194{,}58\ kNm$$

$$M_{z,pl,Rd} = \frac{W_{pl,z} . f_y}{\gamma_{M0}} = \frac{3{,}938 . 10^{-4} . 235 . 10^3}{1{,}0} = 92{,}54\ kNm$$



lentného konštantného momentu

$M_{h,y} = -38{,}179\ \text{kNm}$

$\Psi M_{h,y} = -29{,}273\ \text{kNm}$

$\Psi = \frac{29{,}273}{38{,}179} = 0{,}767$

$-1 \leq \Psi \leq 1$

$-1 \leq 0{,}767 \leq 1 \ldots \checkmark$

$c_{my} = 0{,}6 + 0{,}4 \,.\, \Psi = 0{,}6 + 0{,}4 \,.\, 0{,}767 = 0{,}907 \geq 0{,}4 \ldots \checkmark$

$$k_{yy} = c_{my} \,.\left(1 + \left(\bar{\lambda}_y - 0{,}2\right) \,.\, \frac{N_{Ed}}{\frac{\chi_y \,.\, N_{Rk}}{\gamma_{M1}}}\right) \leq c_{my} \,.\left(1 + 0{,}8 \,.\, \frac{N_{Ed}}{\frac{\chi_y \,.\, N_{Rk}}{\gamma_{M1}}}\right)$$

$$k_{yy} = 0{,}907 \,.\left(1 + (0{,}95 - 0{,}2) \,.\, \frac{177{,}570}{\frac{0{,}627 \,.\, 2138{,}58}{1{,}0}}\right) \leq 0{,}907 \,.\left(1 + 0{,}8 \,.\, \frac{177{,}570}{\frac{0{,}627 \,.\, 2138{,}5}{1{,}0}}\right)$$

$k_{yy} = 0{,}997 \leq 1{,}003 \ldots k_{yy} = 0{,}997$

Súčiniteľ C_{mz} ekvivalentného konštantného momentu

$M_{h,z} = -5{,}738\ \text{kNm}$

$\Psi M_{h,z} = 2{,}466\ \text{kNm}$

$\Psi = \frac{2{,}466}{-5{,}738} = -0{,}429$

$-1 \leq \Psi \leq 1$

$-1 \leq -0{,}429 \leq 1 \ldots \checkmark$

$c_{mz} = 0{,}6 + 0{,}4 \,.\, \Psi = 0{,}6 - 0{,}4 \,.\, 0{,}429 = 0{,}428 \geq 0{,}4 \ldots \text{x}$

$$k_{zz} = c_{mz} \,.\left(1 + \left(2.\bar{\lambda}_z - 0{,}6\right) \,.\, \frac{N_{Ed}}{\frac{\chi_z \,.\, N_{Rk}}{\gamma_{M1}}}\right) \leq c_{mz} \,.\left(1 + 1{,}4 \,.\, \frac{N_{Ed}}{\frac{\chi_z \,.\, N_{Rk}}{\gamma_{M1}}}\right)$$

$$k_{zz} = 0{,}428 \,.\left(1 + (2 \,.\, 1{,}6 - 0{,}6) \,.\, \frac{177{,}570}{\frac{0{,}28 \,.\, 2138{,}58}{1{,}0}}\right) \leq 0{,}428 \,.\left(1 + 1{,}4 \,.\, \frac{177{,}570}{\frac{0{,}28 \,.\, 2138{,}58}{1{,}0}}\right)$$

$k_{zz} = 0{,}758 \leq 0{,}606 \ldots k_{zz} = 0{,}606$

$k_{yz} = 0{,}6 \,.\, k_{zz} = 0{,}6 \,.\, 0{,}606 = 0{,}364$

$$k_{zy} = \left(1 - \frac{0{,}1 \cdot \bar{\lambda}_z}{C_{m,LT} - 0{,}25} \cdot \frac{N_{Ed}}{\frac{\chi_z \cdot N_{Rk}}{\gamma_{M1}}}\right) \geq \left(1 - \frac{0{,}1}{C_{m,LT} - 0{,}25} \cdot \frac{N_{Ed}}{\frac{\chi_z \cdot N_{Rk}}{\gamma_{M1}}}\right)$$

$$k_{zy} = \left(1 - \frac{0{,}1 \cdot 1{,}6}{0{,}95 - 0{,}25} \cdot \frac{177{,}570}{\frac{0{,}28 \cdot 2138{,}58}{1{,}0}}\right) \geq \left(1 - \frac{0{,}1}{0{,}95 - 0{,}25} \cdot \frac{177{,}570}{\frac{0{,}28 \cdot 2138{,}58}{1{,}0}}\right)$$

$$k_{zy} = 0{,}932 \geq 0{,}958 \ldots k_{zy} = 0{,}932$$

$$\frac{N_{Ed}}{\frac{\chi_y \cdot N_{Rk}}{\gamma_{M1}}} + k_{yy} \cdot \frac{M_{y,Ed}}{\frac{\chi_{LT} \cdot M_{y,Rk}}{\gamma_{M1}}} + k_{yz} \cdot \frac{M_{z,Ed}}{\frac{\chi_{LT} \cdot M_{z,Rk}}{\gamma_{M1}}} \leq 1{,}0$$

$$\frac{177{,}570}{\frac{0{,}627 \cdot 2138{,}58}{1{,}0}} + 0{,}997 \cdot \frac{38{,}179}{\frac{0{,}723 \cdot 194{,}58}{1{,}0}} + 0{,}364 \cdot \frac{2{,}466}{\frac{0{,}723 \cdot 92{,}54}{1{,}0}} \leq 1{,}0$$

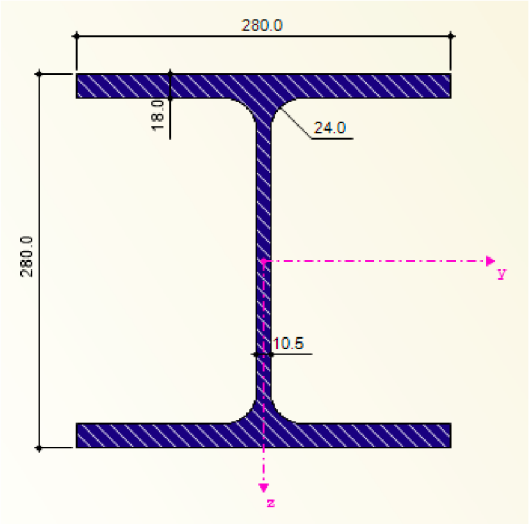
$0{,}41 \leq 1{,}0$ (program $0{,}34 \leq 1{,}0$)

$$\frac{N_{Ed}}{\frac{\chi_z \cdot N_{Rk}}{\gamma_{M1}}} + k_{zy} \cdot \frac{M_{y,Ed}}{\frac{\chi_{LT} \cdot M_{y,Rk}}{\gamma_{M1}}} + k_{zz} \cdot \frac{M_{z,Ed}}{\frac{\chi_{LT} \cdot M_{z,Rk}}{\gamma_{M1}}} \leq 1{,}0$$

$$\frac{177{,}570}{\frac{0{,}28 \cdot 2138{,}58}{1{,}0}} + 0{,}932 \cdot \frac{38{,}179}{\frac{0{,}723 \cdot 194{,}58}{1{,}0}} + 0{,}606 \cdot \frac{2{,}466}{\frac{0{,}723 \cdot 92{,}54}{1{,}0}} \leq 1{,}0$$

$0{,}57 \leq 1{,}0$ (program $0{,}42 \leq 1{,}0$)

5.6 VÄZNÍK HEB280



Prierez: HEB 280

Prierezové charakteristiky:

A = 13100 mm^2

I_y = 192700000 mm^4

I_z = 65900000 mm^4

I_t = 1440000 mm^4

I_w = 1130000000000 mm^6

$I_w = 0{,}2954 \cdot 10^{12}$

i_y = 121mm

i_z = 70,9 mm

$W_{pl,y}$ = 1534000 mm^3

$W_{pl,z}$ = 717572 mm^3

Materiálové charakteristiky:

S235 (f_y = 235 MPa, f_u = 360 MPa)

E = 210 GPa

G = 81 GPa

Trieda prierezu:

Stojina:

$$c_w = h - 2\,.\,t_f - 2\,.\,r = 280 - 2\,.\,18 - 2\,.\,24 = 196\ mm$$

$$\frac{c_w}{t_w} = \frac{196}{10{,}5} = 18{,}67$$

$$18{,}67 \leq 72\varepsilon = 72.1 = 72 \rightarrow 1.\,třída$$

Pásnica:

$$c_f = \frac{b - 2.r - t_w}{2} = \frac{280 - 2.24 - 10{,}5}{2} = 110{,}75$$

$$\frac{c_f}{t_f} = \frac{110{,}75}{18} = 6{,}15$$

$$6{,}15 \leq 9\varepsilon = 9.1 = 9 \rightarrow 1.\,třída$$

5.6.1 POSÚDENIE NA OHYB OKOLO OSI Z BEZ KLOPENIA

Prút 302 – KZ98

$M_{z,Ed}$ = -8,448 kNm

$$\frac{M_{z,Ed}}{M_{c,Rd}} \leq 1{,}0$$

$$M_{c,Rd} = M_{pl,Rd,z} = \frac{w_{pl,z}\,.\,f_y}{\gamma_{M0}} = \frac{1{,}534\,.\,10^{-3}\,.\ 235.10^{6}}{1{,}0} = 360{,}49\ \text{kN}$$

$$\frac{M_{z,Ed}}{M_{pl,Rd,z}} = \frac{8{,}448}{360{,}49} = 0{,}02 \leq 1{,}0$$

5.6.2 POSÚDENIE NA OHYB OKOLO OSI Y BEZ KLOPENIA

Prút 699 – KZ61

$M_{y,Ed}$ = 39,637 kNm

$$\frac{M_{y,Ed}}{M_{c,Rd}} \leq 1{,}0$$

$$M_{c,Rd} = M_{pl,Rd,y} = \frac{w_{pl,y}\,.\,f_y}{\gamma_{M0}} = \frac{7{,}17\,.\,10^{-4}\,.\ 235.10^{3}}{1{,}0} = 168{,}495\ \text{kN}$$

$$\frac{M_{y,Ed}}{M_{pl,Rd,y}} = \frac{39{,}637}{168{,}495} = 0{,}24 \leq 1{,}0$$

0,24≤ 1,0 ... vyhovuje

5.6.3 POSÚDENIE NA ŠMYK:

Návrhová hodnota šmykovej sily:

Prút č. 704 KZ69

$V_{y,Ed} = 34{,}729$

$A_v = A - 2bt_f + (t_w + 2r)t_f = 13100 - 2 * 280 * 18 + (10{,}5 + 2 * 24) * 18 = 4073$

$A_v = 4073\ mm^2$

$$V_{y,pl,Rd} = \frac{A_v\left(f_y / \sqrt{3}\right)}{\gamma_{M0}} = \frac{4073 * \left(235 / \sqrt{3}\right)}{1{,}0} = 552{,}613kN$$

$$\frac{V_{y,Ed}}{V_{y,pl,Rd}} = \frac{34{,}729}{552{,}613} = 0{,}06 < 1{,}0$$

0,06 ≤ 1,0 ... vyhovuje

5.6.4 POSÚDENIE NA PROSTÝ TLAK

Prút 181 – KZ69

$\mathrm{N_{Ed}} = -218{,}251\ \mathrm{kN}$

$$\frac{\mathrm{N_{Ed}}}{\mathrm{N_{c,Rd}}} \leq 1{,}0$$

$$\mathrm{N_{c,Rd}} = \frac{\mathrm{A}.\ \mathrm{f_y}}{\gamma_{\mathrm{M0}}} = \frac{13{,}1.10^{-3}\ .\ 235.10^{3}}{1{,}0} = 3078\ \mathrm{kN}$$

$$\frac{\mathrm{N_{Ed}}}{\mathrm{N_{c,Rd}}} = \frac{218{,}251}{3078} \leq 1{,}0$$

0,0,7 ≤ 1,0 ... vyhovuje

5.6.5 POSÚDENIE NA PROSTÝ ŤAH

Prút 181 – KZ69

$\mathrm{N_{Ed}} = 287{,}403\ \mathrm{kN}$

$$\frac{\mathrm{N_{Ed}}}{\mathrm{N_{c,Rd}}} \leq 1{,}0$$

$$\mathrm{N_{c,Rd}} = \frac{\mathrm{A}.\ \mathrm{f_y}}{\gamma_{\mathrm{M0}}} = \frac{13{,}1.10^{-3}\ .\ 235.10^{3}}{1{,}0} = 3078\ \mathrm{kN}$$

$$\frac{\mathrm{N_{Ed}}}{\mathrm{N_{c,Rd}}} = \frac{287{,}403}{3078} \leq 1{,}0$$

0,09 ≤ 1,0 ... vyhovuje

5.6.6 POSÚDENIE NA KOMBINÁCIU TLAKU A OHYBU

Prút č. 702 – KZ 81

$N_{Ed} = -214{,}182\text{kN}$

$M_{y,Ed} = -37{,}506\ \text{kNm}$

$M_{z,Ed} = -0{,}969\ \text{kNm}$

Vzper okolo osy Y

$L_{cr,y} = 3{,}022m$

$\frac{h}{b} = \frac{280}{280} = 1 < 1;2 \Rightarrow krivka\ b \Rightarrow \alpha = 0{,}34 \quad tab\ 1.3$

$\lambda_y = \frac{L_{cr,y}}{i_y} = \frac{3022}{121} = 24{,}97$

$\frac{N_{Ed}}{N_{b,Rd}} \leq 1{,}0$

$N_{b,Rd} = \frac{\chi_y \,.\, A \,.\, f_y}{\gamma_{M1}} = \frac{0{,}977\,.\,13{,}1\,.\,10^{-3}\,.\,\ 235.10^3}{1{,}0} = 3007\ \text{kN}$

$\chi_y = \frac{1}{\phi_y + \sqrt{\phi_y{}^2 - \bar{\lambda}_y{}^2}} = \frac{1}{0{,}546 + \sqrt{0{,}546^2 - \ 0{,}265^2}} = 0{,}977$

$\phi_y = 0{,}5\,.\ \left[1 + \alpha_{LT}\left(\bar{\lambda}_{,y} - 0{,}2\right) + \ \bar{\lambda}_y{}^2\right] = 0{,}5\,.\ [1 + 0{,}34\,.\,(0{,}265 - 0{,}2) + 0{,}265^2] = 0{,}546$

$\bar{\lambda}_y = \sqrt{\frac{A\,.\,f_y}{N_{cr}}} = \sqrt{\frac{13{,}1\,.\,10^{-3}.235\,.\,10^3}{43733}} = 0{,}265\ > 0{,}2$

Nemôžem zanedbať účinky vzperu

$N_{cr,y} = \frac{\pi^2.\ E\,.\,I_y}{Lcr,y^2} = \frac{\pi^2.\ 210\ .\ 10^9\,.\ 1{,}927\,.\,10^{-4}}{3{,}022^2} = 43733\text{kN}$

$\frac{N_{Ed}}{N_{b,Rd}} = \frac{214{,}182}{3007} = 0{,}07\ \leq 1{,}0$

0,07 ≤ 1,0 ... vyhovuje

Vzper okolo osy Z

$\frac{h}{b} = \frac{280}{280} = 1 < 1{,}2 \Rightarrow krivka\ c \Rightarrow \alpha = 0{,}49 \quad tab\ 1.3$

$N_{b,Rd} = \frac{\chi_z \,.\, A \,.\, f_y}{\gamma_{M1}} = \frac{0{,}6\ .13{,}1\,.\,10^{-3}\,.\ 235.10^6}{1{,}0} = 1847{,}1\ \text{kN}$

$$\chi_z = \frac{1}{\phi_z + \sqrt{{\phi_z}^2 - {\bar{\lambda}_z}^2}} = \frac{1}{1{,}08 + \sqrt{1{,}08^2 - 0{,}907^2}} = 0{,}6$$

$$\phi_z = 0{,}5\,.\,\left[1 + \alpha_{LT}\left(\bar{\lambda}_{zy} - 0{,}2\right) + {\bar{\lambda}_z}^2\right] = 0{,}5\,.\,\left[1 + 0{,}49(0{,}907 - 0{,}2) + 0{,}907^2\right] = 1{,}08$$

$$\bar{\lambda}_z = \sqrt{\frac{A\,.\,f_y}{N_{cr}}} = \sqrt{\frac{13{,}1\,.\,10^{-3}.235\,.\,10^6}{3739000}} = 0{,}907\ > 0{,}2$$

Nemôžem zanedbať účinky vzperu

$$N_{cr,z} = \frac{\pi^2.\ E\,.I_z}{Lcr,z^2} = \frac{\pi^2.\ 210\ .\ 10^9\,.\ 6{,}59\,.10^{-5}}{6{,}044^2} = 3739\ \text{kN}$$

$$\frac{\mathrm{N_{Ed}}}{\mathrm{N_{b,Rd}}} = \frac{214{,}182}{1847{,}1} = 0{,}12\ \leq 1{,}0$$

0,12≤ 1,0 ... vyhovuje

Parameter krútenia

$$k_w = 1{,}0; L = 3{,}022$$

$$k_{wt} = \frac{\Pi}{k_w.L}\sqrt{\frac{E.I_w}{G.I_t}} = \frac{\Pi}{1{,}0 * 3{,}022}\sqrt{\frac{210\,.10^9\,.1{,}13\,.10^{-6}}{81.10^9\,.1{,}44\,.10^{-6}}} = 1{,}48$$

$$z_j = 0$$

$$\zeta_j = \frac{\pi z_j}{k_z L}\sqrt{\frac{EI_z}{GI_t}} = 0$$

$$z_g = 0{,}140\text{m}$$

$$\zeta_g = \frac{\pi.z_g}{k_z.L}\sqrt{\frac{EI_z}{GI_t}} = \frac{\pi\,.\ 0{,}140}{1\,.3{,}022}\sqrt{\frac{210\,.10^9\,.6{,}59\,.10^{-5}}{81.10^9\,.1{,}44\,.10^{-6}}} = 1{,}595$$

Bezrozmerný kriticky moment

$$C_1 = 1{,}13$$

$$C_2 = 0{,}46$$

$$C_3 = 0{,}53$$

$$\mu_{Cr} = \frac{C_1}{k_z}\left[\sqrt{1 + k_{wt}^2 + \left(C_2\zeta_g - C_3\zeta_j\right)^2} - \left(C_2\zeta_g - C_3\zeta_j\right)\right]$$

$$\mu_{Cr} = \frac{1{,}13}{1{,}0}\left[\sqrt{1 + 1{,}48^2 + (0{,}46\,.\ 1{,}595 - 0{,}53\,.\ 0\,)^2} - (0{,}46\,.\ 1{,}595 - 0{,}53\,.0)\right]$$

$$\mu_{Cr} = 1{,}35$$

Pružný kritický moment pri klopení

$$M_{cr} = \mu_{cr}\frac{\pi\sqrt{E.I_z.G.I_t}}{L} = 1{,}35 * \frac{\pi\sqrt{210\,.10^9\,.\ 6{,}59\,.10^{-5}.\ 81\,.10^9\,.1{,}44\,.10^{-6}}}{3{,}022}$$

$$M_{cr} = 1783\ kNm$$

Pomerná štíhlosť

$$\bar{\lambda}_{LT} = \sqrt{\frac{W_{pl,y}.f_y}{M_{cr}}} = \sqrt{\frac{7{,}17\,.10^{-4}\,.235.10^6}{1783000}} = 0{,}307$$

$$\frac{h}{b} = \frac{280}{1280} = 1 < 1;2\ \Rightarrow krivka\ klpopenia\ \ a \Rightarrow\ \alpha_{LT} = 0{,}21 \quad tab\ 1.8$$

$$\phi_{LT} = 0{,}5\left(1 + \alpha_{LT}\left(\bar{\lambda}_{LT} - 0{,}2\right) + \bar{\lambda}_{LT}^2\right) = 0{,}5\,.(1 + 0{,}21\,.(0{,}307 - 0{,}2) + 0{,}307^2) = 0{,}558$$

$$\chi_{LT} = \frac{1}{\phi_{LT} + \sqrt{\phi_{LT}^2 - \bar{\lambda}_{LT}^2}} = \frac{1}{0{,}558 + \sqrt{0{,}558^2 - 0{,}307^2}} = 0{,}976$$

Návrhové hodnoty únosnosti:

$$M_{b,Rd} = \frac{\chi_{LT}\,.W_{pl,y}\,.f_y}{\gamma_{M0}} = \frac{0{,}976\,.7{,}17\,.10^{-4}\,.235\,.10^3}{1{,}0} = 164{,}45kNm$$

$$\frac{M_{y,Ed}}{M_{b,Rd}} = \frac{37{,}506}{164{,}45} = \ 0{,}23 < 1$$

Prút č. 702 – KZ 81

$\mathrm{N_{Ed}}\ = -214{,}182\mathrm{kN}$

$\mathrm{M_{y,Ed}} = -37{,}506\ \mathrm{kNm}$

$\mathrm{M_{z,Ed}} = \ -0{,}969\ \mathrm{kNm}$

Návrhové hodnoty únosnosti:

$$N_{Rd} = \frac{A\,.f_y}{\gamma_{M0}} = \frac{13{,}1\,.10^{-3}.\ 235\,.10^3}{1{,}0} = 3078{,}5\ kN$$

$$M_{Y,Rd} = \frac{W_{pl,y}\,.f_y}{\gamma_{M0}} = \frac{7{,}17\,.10^{-4}\,.235\,.10^3}{1{,}0} = 168{,}495\ kNm$$

$$M_{z,pl,Rd} = \frac{W_{pl,z}\,.f_y}{\gamma_{M0}} = \frac{1{,}5\,.\ 10^{-3}.\ 235\,.10^3}{1{,}0} = 352{,}5\ kNm$$

$M_{h,y} = -37{,}506\ \text{kNm}$

$\Psi M_{h,y} = -19{,}667\ \text{kNm}$

$\Psi = \frac{-19{,}667}{-37{,}506} = 0{,}524$

$-1 \leq \Psi \leq 1$

$-1 \leq 0{,}524 \leq 1 \ldots \checkmark$

$c_{my} = 0{,}6 + 0{,}4 \,.\, \Psi = 0{,}6 + 0{,}4 \,.\, 0{,}524 = 0{,}807 \geq 0{,}4 \ldots \checkmark$

$$k_{yy} = c_{my} \,.\left(1 + \left(\bar{\lambda}_y - 0{,}2\right) \,.\, \frac{N_{Ed}}{\frac{\chi_y \,.\, N_{Rk}}{\gamma_{M1}}}\right) \leq c_{my} \,.\left(1 + 0{,}8 \,.\, \frac{N_{Ed}}{\frac{\chi_y \,.\, N_{Rk}}{\gamma_{M1}}}\right)$$

$$k_{yy} = 0{,}807 \,.\left(1 + (0{,}265 - 0{,}2) \,.\, \frac{214{,}182}{\frac{0{,}977 \,.\, 3078{,}5}{1{,}0}}\right) \leq 0{,}807 \,.\left(1 + 0{,}8 \,.\, \frac{214{,}182}{\frac{0{,}977 \,.\, 3078{,}5}{1{,}0}}\right)$$

$k_{yy} = 0{,}811 \leq 0{,}53 \ldots k_{yy} = 0{,}811$

Súčiniteľ C_{mz} ekvivalentného konštantného momentu

$M_{h,z} = -2{,}691\ \text{kNm}$

$\Psi M_{h,z} = -0{,}969\ \text{kNm}$

$$\Psi = \frac{-0{,}969}{-2{,}691} = 0{,}360$$

$$-1 \leq \Psi \leq 1$$

$$-1 \leq 0{,}36 \leq 1 \ldots \checkmark$$

$$c_{mz} = 0{,}6 + 0{,}4 \,.\, \Psi = 0{,}6 + 0{,}4 \,.\, 0{,}36 = 0{,}744 \geq 0{,}4 \ldots \checkmark$$

$$k_{zz} = c_{mz} \,.\left(1 + \left(2.\bar{\lambda}_z - 0{,}6\right) . \frac{N_{Ed}}{\frac{\chi_z \,.\, N_{Rk}}{\gamma_{M1}}} \right) \leq c_{mz} \,.\left(1 + 1{,}4 \,.\, \frac{N_{Ed}}{\frac{\chi_z \,.\, N_{Rk}}{\gamma_{M1}}} \right)$$

$$k_{zz} = 0{,}744 \,.\left(1 + (2 \,.\, 0{,}907 - 0{,}6) \,.\, \frac{214{,}182}{\frac{0{,}6 \,.\, 3078{,}5}{1{,}0}} \right) \leq 0{,}744 \,.\left(1 + 1{,}4 \,.\, \frac{214{,}182}{\frac{0{,}6 \,.\, 3078{,}5}{1{,}0}} \right)$$

$$k_{zz} = 0{,}848 \leq 0{,}865 \ldots k_{zz} = 0{,}848$$

$$k_{yz} = 0{,}6 \,.\, k_{zz} = 0{,}6 \,.\, 0{,}848 = 0{,}509$$

$$k_{zy} = \left(1 - \frac{0{,}1 \,.\, \bar{\lambda}_z}{C_{m,LT} - 0{,}25} \cdot \frac{N_{Ed}}{\frac{\chi_z \,.\, N_{Rk}}{\gamma_{M1}}} \right) \geq \left(1 - \frac{0{,}1 \,.}{C_{m,LT} - 0{,}25} \cdot \frac{N_{Ed}}{\frac{\chi_z \,.\, N_{Rk}}{\gamma_{M1}}} \right)$$

$$k_{zy} = \left(1 - \frac{0{,}1 \,.\, 0{,}907}{0{,}95 - 0{,}25} \cdot \frac{214{,}182}{\frac{0{,}6 \,.\, 3078{,}5}{1{,}0}} \right) \geq \left(1 - \frac{0{,}1}{0{,}95 - 0{,}25} \cdot \frac{214{,}182}{\frac{0{,}6 \,.\, 3078{,}5}{1{,}0}} \right)$$

$$k_{zy} = 0{,}985 \geq 0{,}983 \ldots k_{zy} = 0{,}983$$

$$\frac{N_{Ed}}{\frac{\chi_y \,.\, N_{Rk}}{\gamma_{M1}}} + k_{yy} \,.\, \frac{M_{y,Ed}}{\frac{\chi_{LT} \,.\, M_{y,Rk}}{\gamma_{M1}}} + k_{yz} \,.\, \frac{M_{z,Ed}}{\frac{\chi_{LT} \,.\, M_{z,Rk}}{\gamma_{M1}}} \leq 1{,}0$$

$$\frac{214{,}182}{\frac{0{,}977 \,.\, 3078{,}5}{1{,}0}} + 0{,}811 \,.\, \frac{37{,}506}{\frac{0{,}976 \,.\, 168{,}495}{1{,}0}} + 0{,}509 \,.\, \frac{0{,}969}{\frac{0{,}976 \,.\, 352{,}5}{1{,}0}} \leq 1{,}0$$

$0{,}26 \leq 1{,}0$ (program $0{,}16 \leq 1{,}0$)

$$\frac{N_{Ed}}{\frac{\chi_z \,.\, N_{Rk}}{\gamma_{M1}}} + k_{zy} \,.\, \frac{M_{y,Ed}}{\frac{\chi_{LT} \,.\, M_{y,Rk}}{\gamma_{M1}}} + k_{zz} \,.\, \frac{M_{z,Ed}}{\frac{\chi_{LT} \,.\, M_{z,Rk}}{\gamma_{M1}}} \leq 1{,}0$$

$$\frac{214{,}182}{\frac{0{,}6 \,.\, 3078{,}5}{1{,}0}} + 0{,}983 \,.\, \frac{37{,}506}{\frac{0{,}976 \,.\, 168{,}495}{1{,}0}} + 0{,}848 \,.\, \frac{0{,}969}{\frac{0{,}976 \,.\, 352{,}5}{1{,}0}} \leq 1{,}0$$

$0{,}34 \leq 1{,}0$ (program $0{,}23 \leq 1{,}0$)

6 POSÚDENIE NA MPS

Maximálne hodnoty priehybov boli vypočítané programom RFEM

6.1 ZVISLÉ PRIEHYBY

6.1.1 VÄZNICA

$\sigma = 21{,}4\ \mathrm{mm}$ Hodnoty převzaté z programu Dlubal RFEM

$\sigma_{lim} = \frac{L}{200} = \frac{5000}{200} = 25mm$

$\sigma \leq \sigma_{lim}$

$21{,}4mm < 25mm$

6.1.2 OBLÚK

Horný pás σ_{HP} = 24,4mm

Dolný pás σ_{DP} = 23,4mm

$\sigma_{max} = \{\sigma_{HP};\sigma_{DP}\} = \max\{24{,}4; 23{,}4\}mm = 24{,}4\ mm$

$\sigma \leq \sigma_{lim}$

$\sigma_{max} = \frac{L}{250} = \frac{45800}{250} = 183{,}2mm$

$24{,}4mm < 183{,}2mm$

6.2 VODOROVNÉ PRIEHYBY

6.2.1 PAŽDÍK

$\sigma = 22{,}1\ \mathrm{mm}$ Hodnoty převzaté z programu Dlubal RFEM

$\sigma_{lim} = \frac{L}{250} = \frac{5932}{250} = 23{,}7mm$

$\sigma \leq \sigma_{lim}$

$22{,}1mm < 23{,}7mm$

6.3 STĹP

$\sigma = 26{,}9\ \mathrm{mm}$ Hodnoty převzaté z programu Dlubal RFEM

$\sigma_{lim} = \frac{L}{250} = \frac{16800}{250} = 67{,}2mm$

$\sigma \leq \sigma_{lim}$

$26{,}9mm < 67{,}2mm$

7 SPOJE

vybrané spoje boli posúdene ručne na základe vnútorných síl vypočítaných programom RFEM

7.1 PRIPOJ VÄZNICE K HORENÉMU PÁSU VÄZNÍKU DETAIL 1

Prút č 1032 KZ 69

$N_{c,Ed} = 50{,}427\ \text{kN}$

$V_{z,Ed} = 7{,}364\ \text{kN}$

$V_{y,Ed} = 0{,}726\ \text{kN}$

$$F_{ed} = \sqrt{{N_{c,Ed}}^2 + {V_{z,Ed}}^2} = \sqrt{50{,}427^2 + 7{,}363^2} = 50{,}96\ KN$$

$$F_{v,ed} = \frac{F_{ed}}{2} = \frac{50{,}96}{2} = 25{,}48\ kN$$

2x M16, 8.8

Nrk udavana výrobcom 68,7 kN

$f_{ub} = 800\ \text{MPa}$

$f_{yb} = 640\ \text{MPa}$

$d = 16\ \text{mm}$

$d_0 = 18\ \text{mm}$

$A_s = 157\ mm^2$

minimalne rozteče šróbov

$e_1 = 1{,}2\ .\ d_o = 1{,}2\ .\ 18 = 21{,}6mm \rightarrow$ 25mm

$e_2 = 1{,}2\ .\ d_o = 1{,}2\ .\ 18 = 21{,}6mm \rightarrow$ 25mm

$p_2 = 2{,}4\ .\ d_o = 2{,}4\ .\ 18 = 43{,}2mm \rightarrow$ 45 mm

Návrhová únosnosť v strihu

$$F_{v,Rd} = \frac{n.\ \alpha_v\ .\ f_{ub}\ .\ A_s}{\gamma_{M2}} = \frac{1\ .\ 0{,}6\ \ .\ 800\ .\ 157\ .\ 10^{-3}}{1{,}25} = 60{,}288\ \text{kN}$$

$$\frac{F_{v\,Ed}}{F_{v,Rd}} \leq 1{,}0$$

$$\frac{F_{v,Ed}}{F_{t,Rd}} = \frac{25{,}48}{60{,}288} = 0{,}42\ \leq 1{,}0$$

0,42 ≤ 1,0 ... vyhovuje

Návrhová únosnosť v otlačení

$$k_1 = min\left\{2{,}8\ .\ \frac{e_2}{d_o} - 1{,}7;\ 1{,}4\ .\ \frac{p_2}{d_o} - 1{,}7;\ 2{,}5\right\} = min\left\{2{,}8\ .\ \frac{25}{18} - 1{,}7;\ 1{,}4\ .\ \frac{45}{18} - 1{,}7;\ 2{,}5\right\}$$

$= \min\{2{,}18;\ 1{,}8\ ;\ 2{,}5\} = 1{,}8$

pozn.: pri splnení podmienok pre doporučené rozteče platí že $k_1 = 2{,}5$

$$\alpha_d = min\left\{\frac{e_1}{3\,.\,d_o}\ ;\frac{p_1}{3\,.\,d_o} - 0{,}25;\right\} = \min\left\{\frac{25}{3\,.\,18}\ ;\frac{45}{3\,.\,18} - 0{,}25;\right\} = \min\{0{,}46;\ 0{,}58\} = 0{,}46$$

súčinitel α_b

$$\alpha_b = min\left\{\ \alpha_d\ ;\frac{f_{ub}}{f_u};\ 1{,}0\right\} = \min\left\{0{,}46;\ \frac{800}{360};\ 1{,}0\right\} = \min\{0{,}46;\ 2{,}22;\ 1{,}0\} = 0{,}46$$

$$F_{b,Rd} = \frac{k_1\,.\ \alpha_b\,.\ fu\,.\ d\,.t}{\gamma m_2} = \frac{1{,}8\,.\,0{,}46\,.\,360\ .16\,.\ 8}{1{,}25}$$

$$F_{b,Rd} = 30{,}523KN$$

$$\frac{F_{v\,Ed}}{F_{b,Rd}} \leq 1{,}0$$

$$\frac{F_{v,Ed}}{F_{b,Rd}} = \frac{25{,}48}{30{,}523} = 0{,}83\ \leq 1{,}0$$

0,83 ≤ 1,0 ... vyhovuje

Posúdenie zvaru uholník na príložku

Návrh zvaru:

$a = \ 4\,mm$

$a_{min} = \ 3\ \text{mm}$

$a_{max} = 1{,}1\,.\,t_{min} = 1{,}1\,.\,8 = 8{,}8mm$

$a_{min} \leq a\ \leq a_{max}$

$3\ mm \leq 4\ mm\ \leq 8{,}8\ mm$

$L_W = \ 70 - 2.\,a = 70 - 2\,.\,8 = 54mm$

$\beta_W = \ 0{,}8$

$f_u = 360\ \text{MPa}$

$$\tau_{\parallel} = \frac{N_{Ed}}{2.\,a\,.\,L_W} = \frac{50{,}427\,.\,10^3}{2\ .\ 4\ .\ 54} = 116{,}73\ MPa$$

$$\sigma_c = \frac{V_{Ed}}{4.\,a\,.\,L_W} = \frac{7{,}364\,.\,10^3}{2\ .\ 4\ .\ 54} = 17{,}05\ MPa$$

$$\tau_{\perp} = \sigma_{\perp} = \frac{\sigma_c}{\sqrt{2}} = \frac{17{,}05}{\sqrt{2}} = 12{,}06MPa$$

$$\sigma_{\perp} = \frac{0{,}9\,.\,f_u}{\gamma_{M2}} = \frac{0{,}9\,.\,360}{1{,}25} = 259{,}2\ MPa$$

$12{,}06 \leq 259{,}2\ MPa$

Zrovnávacie napätie vo zvare

$$\sqrt{{\sigma_\perp}^2 + 3{\tau_\perp}^2 + 3{\tau_\parallel}^2} \leq \frac{fu}{\beta w * \gamma m_2}$$

$$\sqrt{12{,}06^2 + 3\,.\,12{,}06^{\,2} + 3\,.\;116{,}73^{\,2}} \leq \frac{360}{0{,}8\,.\;1{,}25}$$

$$203{,}61 \leq 360\ MPa$$

7.2 MONTÁŽNY SPOJ HORNÉHO PÁSU – DETAIL 2

Spoj montážnych dielov D1 a D2 (väzba č 6) prut 1886

Kz61

(spoj je použitý na všetky montážne spoje HP)

$\mathrm{N_{Ed}} = 179{,}866\ \mathrm{kN}$

$\mathrm{M_{y,Ed}} = 7{,}588\ \mathrm{kN}$

$\mathrm{V_{z,Ed}} = 9{,}945\ \mathrm{kN}$

Návrh šróbov 4x M20 - 4.6

návrhová pevnosť v ťahu 70,6 kN

$f_{ub} = 400\ \mathrm{MPa}$

$f_{yb} = 320\ \mathrm{MPa}$

$d = 20\ \mathrm{mm}$

$d_0 = 22\ \mathrm{mm}$

$A_s = 245\ mm^2$

Návrh plechov P10 S235

minimalne rozteče šróbov → skutočné

$e_1 = 1{,}2\,.\,d_o = 1{,}2\,.\,20 = 24mm$ → 30mm

$e_2 = 1{,}2\,.\;d_o = 1{,}2\,.\,20 = 24mm$ → 30mm

$p_1 = 2{,}4\,.\;d_o = 2{,}2\,.\,20 = 44mm$ → 200 mm

$p_2 = 2{,}4\,.\;d_o = 2{,}4\,.\,20 = 48mm$ → 200 mm

Posúdenie únosnosti v strihu

$$\mathrm{F_{v,Rd}} = \mathrm{n}\,.\;\frac{\alpha\,.\;\mathrm{f_{ub}}\,.\mathrm{A_s}}{\gamma_{\mathrm{M2}}} = \;\; 4.\;\frac{0{,}6\;.\;400\,.10^3\;.\;245\,.10^{-6}}{1{,}25} = 188{,}16\ \mathrm{kN}$$

$$\frac{\mathrm{F_{V,Ed}}}{\mathrm{F_{V,Rd}}} \leq 1{,}0$$

$$\frac{\mathrm{F_{V,Ed}}}{\mathrm{F_{V,Rd}}} = \frac{9{,}945}{188{,}16} = 0{,}05 \;\leq 1{,}0$$

0,05 ≤ 1,0 ... vyhovuje

Posúdenie únosnosti v otlačení

$$k_1 = min\left\{2{,}8 \,.\, \frac{e_2}{d_o} - 1{,}7;\, 1{,}4 \,.\, \frac{p_2}{d_o} - 1{,}7;\, 2{,}5\right\} = min\left\{2{,}8 \,.\, \frac{30}{22} - 1{,}7;\, 1{,}4 \,.\, \frac{200}{22} - 1{,}7;\, 2{,}5\right\}$$

$$= \min\{2{,}18;\ 11{,}02\ ;\ 2{,}5\} = 2{,}18$$

$pozn.: pri\ splnení\ podmienok\ pre\ doporučené\ rozteče\ platí$ že $k_1 = 2{,}5$

$$\alpha_d = min\left\{\frac{e_1}{3 \,.\, d_o}\ ;\frac{p_1}{3 \,.\, d_o} - 0{,}25;\right\} = \min\left\{\frac{30}{3 \,.\, 22}\ ;\frac{200}{3 \,.\, 22} - 0{,}25;\right\} = \min\{0{,}45;\, 2{,}78\} = 0{,}45$$

súčinitel α_b

$$\alpha_b = min\left\{\ \alpha_d\ ;\frac{f_{ub}}{f_u};\, 1{,}0\right\} = \min\left\{0{,}45;\ \frac{800}{360};\, 1{,}0\right\} = \min\{0{,}45;\, 2{,}22;\, 1{,}0\} = 0{,}45$$

$$F_{b,Rd} = 4 \,.\ \frac{k_1 \,.\ \alpha_b \,.\ fu \,.\ d \,.\, t}{\gamma m_2} = 4 \,.\, \frac{2{,}18 \,.\, 0{,}45 \,.\, 360\ \,.\, 20 \,.\ 10}{1{,}25}$$

$$F_{b,Rd} = 226{,}02\ KN$$

$$\frac{F_{v\,Ed}}{F_{b,Rd}} \leq 1{,}0$$

$$\frac{F_{v,Ed}}{F_{b,Rd}} = \frac{9{,}945}{226{,}02} = 0{,}04 \leq 1{,}0$$

0,04 ≤ 1,0 ... vyhovuje

Posúdenie únosnosti spoja v ťahu s vplyvom páčenia zjednodušený postup

(posúdenie s vplyvom páčenia podľa ČSN 73 14 01)

Najmenšia hrúbka dosky, pri ktorej nedôjde k páčeniu

$$te = 4{,}3 \,.\ \ 3\sqrt{\frac{b \,.\ d^2}{a}} = 4{,}3 \,.\ 3\sqrt{\frac{30 \,.\ 20^2}{30}} = 31{,}7mm$$

$t < te$

$10 < 31{,}7\ \rightarrow$ nastáva páčenie

Návrhová sila $F_{t,Rd}$ v šróbe sa zvyšuje súčiniteľom páčenia γ_p

$$\gamma_p = 1 + 0{,}005 \,.\ \frac{te^3 - t^3}{d^2} = 1 + 0{,}005 \,.\ \frac{31{,}7^3 - 10^3}{20^2}$$

$$\gamma_p = 1{,}39$$

$$\gamma_p \,.\ F_{t,Ed,1} = 1{,}39 \,.\ 179{,}866 = 250{,}01KN < 4.\ F_{t,Rd,1} =$$

$$250{,}01 < 4.\ 70{,}6$$

$$250{,}01 \leq 282{,}4KN$$

0,88 ≤ 1,0 ... vyhovuje

posúdenie zvaru medzi horným pásom a čelnou doskou

Návrh zvaru:

$a = 4\,mm$

$a_{min} = 3\ \text{mm}$

$a_{max} = 1{,}1\,.\,t_{min} = 1{,}1\,.\,5 = 5{,}5\,mm$

$a_{min} \leq a \leq a_{max}$

$3\,mm \leq 4\,mm \leq 5{,}5\,mm$

$L = 4\,.\,b = 4\,.\,140 = 560mm$

$A = L\,.\,a = 560\,.\,4 = 2240\,mm^2$

$$\tau_{\perp} = \sigma_{\perp} = \frac{N_{Ed}}{\sqrt{2}\ .\ A} = \frac{179{,}866\ .10^3}{\sqrt{2}\ .2240} = 56{,}78\,MPa$$

$$\tau_{\parallel} = \frac{V_{Ed}}{2\ .\ L} = \frac{9{,}945\,.10^3}{2\,.560} = 8{,}88\,MPa$$

Zrovnávacie napätie vo zvare

$$\sqrt{{\sigma_{\perp}}^2 + 3{\tau_{\perp}}^2 + 3{\tau_{\parallel}}^2} \leq \frac{fu}{\beta w * \gamma m_2}$$

$$\sqrt{56{,}78^2 + 3\,.\,56{,}78^{\,2} + 3\,.\ 8{,}88^{\,2}} \leq \frac{360}{0{,}8\,.\ 1{,}25}$$

$114{,}6 \leq 360\,MPa$

7.3 PRIPOJENIE DIAGONÁLY K DP – K – STYČNÍK DETAIL 3

uzol č. 1007 – KZ 65

$N_{0,Ed} = 263{,}792\ \text{kN}$

$N_{Ed,1} = 40{,}136\ \text{kN}$ (zodpovedajúca) max tah 93,728 tlak 91,45

$N_{Ed,2} = -49{,}391\ \text{kN}$

$M_{0,Ed} = -0{,}165\ \text{kN}$

$\theta_1 = \theta_2 = 51°$

Podmienky:

1)

$$0{,}2 \leq \frac{d_i}{d_0} \leq 1{,}0$$

$$0{,}2 \leq \frac{70}{140} \leq 1{,}0$$

$0{,}2 \leq 0{,}5 \leq 1{,}0$

2)

$$10 \leq \frac{d_o}{t_0} \leq 50$$

$$10 \leq \frac{140}{5} \leq 50$$

$$10 \leq 28 \leq 50$$

3)

$$10 \leq \frac{d_i}{t_i} \leq 50$$

$$10 \leq \frac{70}{3} \leq 50$$

$$10 \leq 23{,}3 \leq 50$$

4)

$$g \geq t_1 + t_2$$

$$29 \geq 3 + 3$$

$$29 \geq 6$$

Styčník vyhovuje všetkým kritériám – posudzujem len na vybrané prípady z tabulky

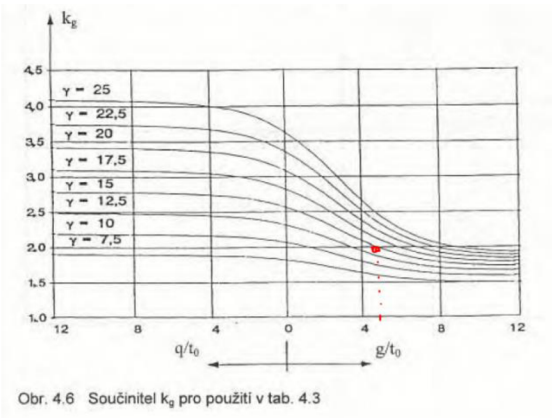
7.2 ČSN EN 1993-1-8

7.3.1 PORUŠENIE POVRCHU PÁSU

Porušenie povrchu pásu – styčníku K s medzerou nebo prekrytím

Tab. 4.3 Návrhové osové únosnosti zvarovaných styčníkov z trubiek

$$N_{1,Rd} = \frac{\frac{k_g \,.\, k_p \;.\; f_{y0} \;.\, {t_0}^2}{\sin\theta_1} \;.\; (1{,}8 + 10{,}2 \;.\; \frac{d_1}{d_0})}{\gamma_{Mj}} =$$



Obr. 4.6 Součinitel k_g pro použití v tab. 4.3

$$N_{2,Rd} = \frac{\sin\theta_1}{\sin\theta_2} . N_{1,Rd}$$

$$\frac{g}{t_0} = \frac{29}{5} = 5{,}8$$

$$\gamma = \frac{d_0}{2\,.\,t_0} = \frac{140}{2\,.\,5} = 14$$

$$k_g = 2{,}0$$

$$k_p = 1 - 0{,}3\,.\,n_p\,.\,\left(1 + n_p\right) = 1 - 0{,}3\,.\,0{,}29\,.\,(1 + 0{,}29) = 0{,}88 \leq 1{,}0$$

$$n_p = \frac{\frac{\sigma_{p,Ed}}{f_{y0}}}{\gamma_{Mj}} = \frac{\frac{69{,}6}{235}}{1{,}0} = 0{,}29$$

napatie v páse vo styčníku

$$\sigma_{p,Ed} = \frac{N_{p,Ed}}{A_0} + \frac{M_{0,Ed}}{W_{el,0}} = \frac{180{,}45.\ 10^{-3}}{2640.\ 10^{-6}} + \frac{0{,}165.\ 10^{-3}}{132000.\ 10^{-9}} = 69{,}6\ MPa$$

$$N_{p,Ed} = N_{0,Ed} - \Sigma\, N_{i,Ed}\,.\cos\theta_1 = 236{,}792 - ((40{,}136\,.\cos 51) + (49{,}391\,.\cos 51)) = 180{,}45\ kN$$

$$N_{1,Rd} = \frac{\frac{2{,}0\,.\,0{,}88\ .\ 235\ .5^2}{\sin 51}\ .\ (1{,}8 + 10{,}2\ .\ \frac{70}{140})}{\gamma_{Mj}}\ .\ 10^{-3} = 91{,}822\text{kN}$$

$$N_{2,Rd} = \frac{\sin\theta_1}{\sin\theta_2}.N_{1,Rd} = \frac{\sin 51}{\sin 51}\ .91{,}822 = 91{,}288\ \text{kN}$$

$$\frac{N_{Ed,1}}{N_{1,Rd}} \leq 1{,}0$$

$$\frac{N_{Ed,1}}{N_{1,Rd}} = \frac{40{,}136}{91{,}288} = 0{,}44\ \leq 1{,}0$$

0,44 ≤ 1,0 ... vyhovuje

$$\frac{N_{Ed,2}}{N_{2,Rd}} \leq 1{,}0$$

$$\frac{N_{Ed,2}}{N_{2,Rd}} = \frac{49{,}391}{91{,}288} = 0{,}54\ \leq 1{,}0$$

0,54 ≤ 1,0 ... vyhovuje

7.3.2 PORUŠENIE PRELOMENÍM ŠMYKOM

$$d_i\ \leq d_0 - 2\,.\,t_0$$

$$70\ \leq 140 - 2\,.\,5$$

$$70\ \leq 130$$

$$N_{i,Rd} = \frac{\frac{f_{y0}}{\sqrt{3}}\ .\,t_0\,.\,\pi\,.\,d_i\,.\frac{1+\sin\theta_1}{2\,.\,\sin{\theta_2}^2}}{\gamma_{Mj}}$$

$$N_{1,Rd} = N_{2,Rd} = \frac{\frac{235}{\sqrt{3}}\ .5\,.\,\pi\,.\,70\,.\frac{1+\sin 51}{2\,.\,\sin 51^2}}{1{,}00}\ .\ \ 10^{-3} = 219{,}49\text{kN}$$

$$\frac{N_{Ed,1}}{N_{1,Rd}} \leq 1{,}0$$

$$\frac{N_{Ed,1}}{N_{1,Rd}} = \frac{40{,}136}{219{,}49} = 0{,}18 \leq 1{,}0$$

0,18 ≤ 1,0 ... vyhovuje

$$\frac{N_{Ed,2}}{N_{2,Rd}} \leq 1{,}0$$

$$\frac{N_{Ed,2}}{N_{2,Rd}} = \frac{49{,}391}{219{,}49} = 0{,}23\ \leq 1{,}0$$

0,23 ≤ 1,0 ... vyhovuje

7.3.3 POSÚDENIE ZVARU DIAGONÁLA – DP

Návrh zvaru:

$a = 4\,mm$

$a_{min} = 3\ \text{mm}$

$a_{max} = 1{,}1\,.\,t_{min} = 1{,}1\,.\,5 = 5{,}5\,mm$

$a_{min} \leq a \leq a_{max}$

$3\,mm \leq 4\,mm \leq 5{,}5\,mm$

$L_W = 70 - 2.a = 70 - 2\,.\,4 = 62mm$

$\beta_W = 0{,}9$

$f_u = 360\ \text{MPa}$

$$\tau_{\parallel} = \frac{N_{Ed}\,.\cos\theta}{4.a\,.L_W} = \frac{49{,}391\,.\,10^3\,.\,cos51}{4\,.\,4\,.\,62} = 31{,}33\,MPa$$

$$\sigma_c = \frac{N_{Ed}\,.\sin\theta}{4.a\,.L_W} = \frac{49{,}391.\,10^3\,.\sin 51}{4\,.\,4\,.\,162} = 38{,}69\,MPa$$

$$\tau_{\perp} = \sigma_{\perp} = \frac{\sigma_c}{\sqrt{2}} = \frac{38{,}69}{\sqrt{2}} = 27{,}55MPa$$

$$\sigma_{\perp} = \frac{0{,}9\,.f_u}{\gamma_{M2}} = \frac{0{,}9\,.360}{1{,}25} = 259{,}2\,MPa$$

$27{,}55 \leq 259{,}2\,MPa$

Zrovnávacie napätie vo zvare

$$\sqrt{{\sigma_{\perp}}^2 + 3{\tau_{\perp}}^2 + 3{\tau_{\parallel}}^2} \leq \frac{fu}{\beta w * \gamma m_2}$$

$$\sqrt{27{,}55^2 + 3\,.\,27{,}55^{\,2} + 3\,.\,31{,}33^{\,2}} \leq \frac{360}{0{,}9\,.\,1{,}25}$$

$77{,}34 \leq 320\,MPa$

8 KOTVENIE

8.1 KOTVENIE K1 ČAPOVÝ SPOJ

Uzol 322 KZ 46

Tlak: Rx= -29,206 kN

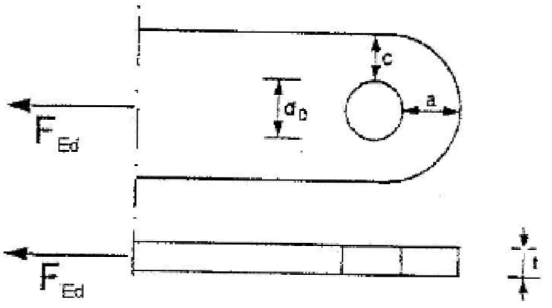
Ry = -43,078 kN

Rz = 261,01 kN

Tah: Rx= -51,486 kN

Ry = 20,572 kN

Rz = -198,881 kN



8.1.1 POSÚDENIE ČAPOVÉHO SPOJA

Návrh čapu

d = 50 mm

$A = \pi . r^2 = \pi . 25^2 = 1963\ mm^2$

S235 (f_y = 235 MPa, f_u = 360 MPa)

Geometrické požiadavky

$$t = 0{,}7.\sqrt{\frac{F_{Ed} \cdot \gamma_{M0}}{f_y}} = 0{,}7 . \sqrt{\frac{261{,}01 . 1{,}0}{235 . 10^3}} = 0{,}023 \Rightarrow návrh\ t = 30mm$$

$$d_o \leq 2{,}5 . t = 2{,}5 . 30 = 75\text{mm} \Rightarrow d_o = 52mm$$

$$a \geq \frac{F_{Ed} \cdot \gamma_{M0}}{f_y}$$

$$a \geq \frac{F_{Ed} \cdot \gamma_{M0}}{2 . t . f_y} + \frac{2 . d_0}{3} = \frac{261{,}01 . 10^3 . 1{,}0}{2 . 30 . 235} + \frac{2 . 52}{3} = 53{,}18 \Rightarrow návrh\ a = 55\ mm$$

$$c \geq \frac{F_{Ed} \cdot \gamma_{M0}}{2 . t . f_y} + \frac{d_0}{3} = \frac{261{,}01 . 10^3 . 1{,}0}{2 . 30 . 235} + \frac{52}{3} = 35{,}84 \Rightarrow návrh\ c = 66\ mm$$

8.1.2 ÚNOSNOSŤ ČAPU V STRIHU

$$F_{v,Rd} = \frac{\alpha . f_{ub} . A_s}{\gamma_{M2}} = \frac{0{,}6 . 360 . 10^3 . 1963 . 10^{-6}}{1{,}25} = 339{,}21\ \text{kN}$$

$$\frac{F_{V,Ed}}{F_{V,Rd}} \leq 1{,}0$$

$$\frac{F_{V,Ed}}{F_{V,Rd}} = \frac{261,01}{339,21} = 0,77 \leq 1,0$$

0,77 ≤ 1,0 ... vyhovuje

8.1.3 ÚNOSNOSŤ SAMOTNÉHO STYČNÍKOVÉHO PLECHU V OTLAČENÍ

$$F_{b,Rd} = \frac{1,5 \,.\, f_y \,.\, d \,.\, t}{\gamma_{M0}} = \frac{1,5 \;.\; 235.10^3 \;.\; 0,05 \,.\, 0,03}{1,0} = 528,75 \text{ kN}$$

$$\frac{F_{Ed}}{F_{b,Rd}} \leq 1,0$$

$$\frac{F_{Ed}}{F_{b,Rd}} = \frac{261,01}{528,75} = 0,49 \leq 1,0$$

0,49 ≤ 1,0 ... vyhovuje

8.1.4 ÚNOSNOSŤ DVOJICE STYČNÍKOVÝCH PLECHOV V OTLAČENÍ

$$F_{Ed1} = 0,5 \,.\, F_{Ed} = 0,5 \,.\, 261,01 = 130,51$$

$$F_{b,Rd1} = \frac{1,5 \,.\, f_y \,.\, d \,.\, t}{\gamma_{M0}} = \frac{1,5 \;.\; 235.10^3 \;.\; 0,05 \,.\, 0,02}{1,0} = 352,5\text{kN}$$

$$\frac{F_{Ed1}}{F_{b,Rd1}} \leq 1,0$$

$$\frac{F_{Ed1}}{F_{b,Rd1}} = \frac{130,51}{352,5} = 0,37 \leq 1,0$$

0,37 ≤ 1,0 ... vyhovuje

8.1.5 ÚNOSNOSŤ ČAPU V OHYBE

$$M_{Rd} = \frac{1,5 \,.\, f_{ub} \,.\, W_{el}}{\gamma_{M0}} = \frac{1,5 \;.\; 360.10^{-6} \,.\, \pi \,.\, \frac{d^3}{32}}{1,0} = \frac{1,5 \;.\; 360.10^{-6} \,.\, \pi \,.\, \frac{50^3}{32}}{1,0} = 6,63 \text{ kNm}$$

$$M_{Ed} = \frac{F_{Ed}}{8} \,.\, (t + 4 \,.\, t_0 + 2 \,.\, t_2 = \frac{261,01}{8} \,.\, (0,03 + 4 \,.\, 0,005 + 2 \,.\, 0,020) = 2,94 \text{ kNm}$$

$$\frac{M_{Ed}}{M_{Rd}} \leq 1,0$$

$$\frac{M_{Ed}}{M_{Rd}} = \frac{2,94}{6,63} = 0,44 \leq 1,0$$

0,44 ≤ 1,0 ... vyhovuje

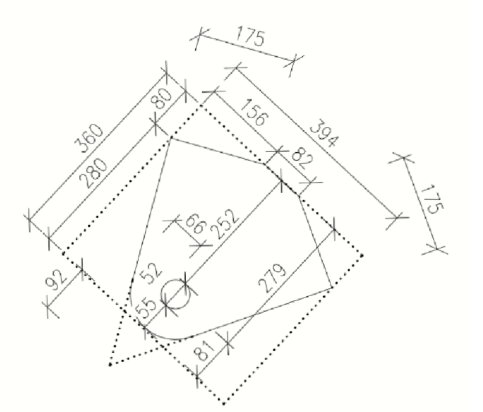
8.1.6 ÚNOSNOSŤ NA KOMBINÁCIU STRIHU A OHYBU

$$\left[\frac{M_{Ed}}{M_{Rd}}\right]^2 + \left[\frac{F_{V,Ed}}{F_{V,Rd}}\right]^2 \leq 1,0$$

$$\left[\frac{2{,}94}{6{,}63}\right]^2 + \left[\frac{261{,}01}{339{,}21}\right]^2 \leq 1{,}0$$

0,20 ≤ 1,0 ... vyhovuje

8.1.7 NÁVRH STYČNÍKOVÉHO PLECHU



P18 S235

$$A = 2 . t . c + d_0 . t = 2 . 20 . 66 + 52 . 20 = 3680\ mm^2$$

$$A_{net} = 2 . t . c = 2 . 20 . 66 = 2640\ mm^2$$

P30 S235

$$A = 2 . t . c + d_0 . t = 2 . 30 . 66 + 52 . 30 = 5520 mm^2$$

$$A_{net} = 2 . t . c = 2 . 230 . 66 = 3960\ mm^2$$

8.1.8 ÚNOSNOSŤ V ŤAHU

Plech P18:

$$N_{t,Rd} = \frac{0{,}9 . A_{net} . f_y}{\gamma_{M2}} = \frac{0{,}9 . 2640 . 10^{-6} . 235 . 10^3}{1{,}25} = 446{,}69\ \text{kN}$$

Plech P30:

$$N_{t,Rd} = \frac{0{,}9 . A_{net} . f_y}{\gamma_{M2}} = \frac{0{,}9 . 3960 . 10^{-6} . 235 . 10^3}{1{,}25} = 670{,}03\ \text{kN}$$

$$\frac{N_{Ed}}{N_{t,Rd}} \leq 1{,}0$$

$$\frac{N_{Ed}}{N_{t,Rd}} = \frac{198{,}881}{446{,}69} = 0{,}45 \leq 1{,}0$$

0,45 ≤ 1,0 ... vyhovuje

8.1.9 VZPERNÁ ÚNOSNOSŤ PLECHU P18

Predpokladám roznos sily na šírku b. posudzujem prúžok široký 1mm.

$$\sigma_{Ed} = \frac{N_{Ed}}{b . t} = \frac{261{,}01 . 10^3}{245 . 18} = 59{,}19\ \text{MPa}$$

$$L = 154\ \text{mm}$$

$$L_{cr,z} = \beta . L = 2 . 154 = 308\ \text{mm}$$

$$I_Z = \frac{1}{12} . t . b^3 = \frac{1}{12} . 1 . 18^3 = 486\ mm^4$$

$$i_Z = \sqrt{\frac{I_Z}{A}} = \sqrt{\frac{486}{1 . 18}} = 5{,}2\ \text{mm}$$

$$\lambda_z = \frac{L_{cr,z}}{i_z} = \frac{308}{5,2} = 59,23$$

$$\bar{\lambda}_y = \frac{\lambda_z}{\lambda_1} = \frac{\lambda_z}{\pi \cdot \sqrt{\frac{E}{f_y}}} = \frac{59,23}{\pi \cdot \sqrt{\frac{210 \cdot 10^9}{235 \cdot 10^6}}} = 0,63$$

$$\phi_z = 0,5 \cdot \left[1 + a \cdot (\bar{\lambda}_y - 0,2) + \bar{\lambda}_y{}^2\right] = 0,5 \cdot \left[1 + 0,49 \cdot (0,63 - 0,2) + 0,63^2\right] = 0,80$$

$$\chi_z = \frac{1}{\phi_z + \sqrt{\phi_z{}^2 - \bar{\lambda}_z{}^2}} = \frac{1}{0,80 + \sqrt{0,80^2 - 0,63^2}} = 0,77$$

$$\sigma_{Rd} = \frac{\chi_z \cdot f_y}{\gamma_{M1}} = \frac{0,77 \cdot 235.10^3}{1,0} = 181 \text{ MPa}$$

$$\frac{\sigma_{Ed}}{\sigma_{Rd}} \leq 1,0$$

$$\frac{\sigma_{Ed}}{\sigma_{Rd}} = \frac{59,19}{181} = 0,33 \leq 1,0$$

0,33 ≤ 1,0 ... vyhovuje

8.1.10 STYČNÍKOVÝ PLECH- V PÄTE VÄZNÍKU

Priestor medzi plechmi je 30mm. Nie je dostatočný priestor na prevedenie kútového zvaru.

navrhujem tupý plne prevarený zvar tvaru pol V

8.1.11 STYČNÍKOVÝ PLECH V PÄTE VÄZNÍKU HORNÝ PÁS

Prút 1072 KZ52

$N_{Ed} = -215,473$ KN 7,062KN

$V_{Ed} = -3,211$ KN

<u>Návrh zvaru:</u>

$a = 4\,mm$

$a_{min} = 3$ mm

$a_{max} = 1,1 \cdot t_{min} = 1,1 \cdot 5 = 5,5\,mm$

$a_{min} \leq a \leq a_{max}$

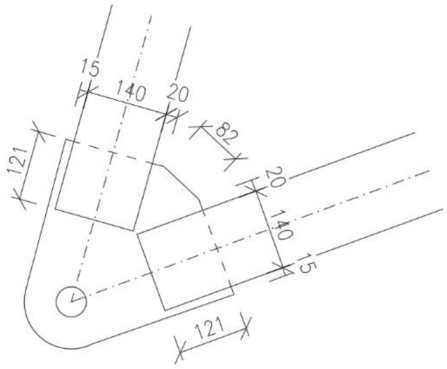
$3\,mm \leq 4\,mm \leq 5,5\,mm$

$L_W = 121 - 2.a = 121 - 2 \cdot 4 = 113mm$

$\beta_W = 0,9$

$f_u = 360$ MPa

$$\tau_{\parallel} = \frac{N_{Ed}}{4.a.L_W} = \frac{215,473 \cdot 10^3}{4 \cdot 4 \cdot 113} = 119,18\,MPa$$



$$\sigma_c = \frac{V_{Ed}}{4.a.L_W} = \frac{7{,}062.10^3}{4.\ 4.\ 113} = 3{,}906\ MPa$$

$$\tau_\perp = \sigma_\perp = \frac{\sigma_c}{\sqrt{2}} = \frac{3{,}096.10^3}{\sqrt{2}} = 2{,}762 MPa$$

$$\sigma_\perp = \frac{0{,}9.f_u}{\gamma_{M2}} = \frac{0{,}9.360}{1{,}25} = 259{,}2\ MPa$$

$3{,}906 \leq 259{,}2\ MPa$

Zrovnávacie napätie vo zvare

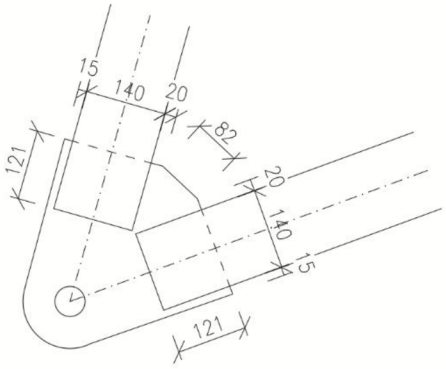
$$\sqrt{{\sigma_\perp}^2 + 3{\tau_\perp}^2 + 3{\tau_\parallel}^2} \leq \frac{fu}{\beta w * \gamma m_2}$$

$$\sqrt{2{,}762^2 + 3.2{,}762^{\,2} + 3.\ 119{,}18^{\,2}} \leq \frac{360}{0{,}9.\ 1{,}25}$$

$206{,}5 \leq 320\ MPa$

8.1.12 STYČNÍKOVÝ PLECH V PÄTE VÄZNÍKU DOLNÝ PÁS

Prút 1843 KZ32



$N_{Ed} = -106{,}027$ KN

$V_{Ed} = 3{,}773$KN

Návrh zvaru:

$a = 4\ mm$

$a_{min} = 3$ mm

$a_{max} = 1{,}1.t_{min} = 1{,}1.5 = 5{,}5\ mm$

$a_{min} \leq a \leq a_{max}$

$3\ mm \leq 4\ mm \leq 5{,}5\ mm$

$L_W = 121 - 2.a = 121 - 2.4 = 113 mm$

$\beta_W = 0{,}9$

$f_u = 360$ MPa

$$\tau_\parallel = \frac{N_{Ed}}{4.a.L_W} = \frac{106{,}027.10^3}{4.\ 4.\ 113} = 58{,}648 MPa$$

$$\sigma_c = \frac{V_{Ed}}{4.a.L_W} = \frac{3{,}773.10^3}{4.\ 4.\ 113} = 2{,}086\ MPa$$

$$\tau_\perp = \sigma_\perp = \frac{\sigma_c}{\sqrt{2}} = \frac{2{,}086}{\sqrt{2}} = 1{,}475 MPa$$

$$\sigma_\perp = \frac{0{,}9.f_u}{\gamma_{M2}} = \frac{0{,}9.360}{1{,}25} = 259{,}2\ MPa$$

$1{,}475 \leq 259{,}2\ MPa$

Zrovnávacie napätie vo zvare

$$\sqrt{{\sigma_\perp}^2 + 3{\tau_\perp}^2 + 3{\tau_\parallel}^2} \leq \frac{fu}{\beta w * \gamma m_2}$$

$$\sqrt{1{,}475^2 + 3\,.\,1{,}475^{\,2} + 3\,.\,58{,}648^{\,2}} \leq \frac{360}{0{,}9\,.\,1{,}25}$$

$$101{,}62 \leq 320\ MPa$$

8.2 KOTVENIE PRIEČNEJ VAZBY K1

Uzol 669 KZ 53

Tlak: Rx= -29,206 kN

Ry = -43,078 kN

Rz = 261,01 kN

Tah: Rx= -83,834 kN

Ry = 0,030 kN

Rz = -26,504kN

Kotevné bloky z betónu C20/25

$f_{cd} = 20\ \mathrm{MPa}$

$f_{ck} = 13{,}33\ \mathrm{MPa}$

Podliatie MC20 hrúbky 30mm

Plech S235

$b_1 = 540\ \mathrm{mm}$

$d_1 = 350\ \mathrm{mm}$

$t = 20\ \mathrm{mm}$

8.2.1 POSÚDENIE PATKOVÉHO PLECHU

$$b_1 = min\begin{pmatrix} b_1 + 2b_\mathrm{r} \\ 3b_1 \\ b_1 + h \end{pmatrix} = min\begin{pmatrix} 540 + 2\,.\,150 \\ 3\,.\,540 \\ 540 + 800 \end{pmatrix} = 840\ mm$$

$$d_2 = min\begin{pmatrix} d_1 + 2d_\mathrm{r} \\ 3d_1 \\ d_1 + h \end{pmatrix} = min\begin{pmatrix} 350 + 2\,.\,150 \\ 3\,.\,350 \\ 350 + 800 \end{pmatrix} = 650\ mm$$

$$K_j = \sqrt{\frac{b_2\,.\,d_2}{b_1\,.\,d_1}} = \sqrt{\frac{840\,.\,650}{540\,.\,350}} = 1{,}70$$

$$F_{jd} = \frac{\beta_j\,.\,K_j\,.\,f_{ck}}{\gamma_c} = \frac{\frac{2}{3}\,.1{,}70\,.20}{1{,}25} = 18{,}13\ MPa$$

$$c = t \,.\, \sqrt{\frac{f_y}{3\,.\;F_{jd}\,.\;\gamma_{M0}}} = 20\,.\,\sqrt{\frac{235}{3\,.\;18{,}13\,.1{,}0}} = 42\;mm$$

$$\mathrm{N_{Rd}} = \mathrm{A_{eff}}\,.F_{jd} \;=\; 80696\,.18{,}13\;10^{-3} = 1463\;\mathrm{KN}$$

$$\frac{\mathrm{N_{Ed}}}{\mathrm{N_{Rd}}} \leq 1{,}0$$

$$\frac{\mathrm{N_{Ed}}}{\mathrm{N_{Rd}}} = \frac{261{,}01}{1463} = 0{,}18 \;\leq 1{,}0$$

0,18 ≤ 1,0 ... vyhovuje

8.2.2 POSÚDENIE ŠMYKOVEJ ZARÁŽKY

Výška:

$$\sigma_c = \frac{V_{Ed}}{A_{knot}} \;\rightarrow\; h_{min} \;= \frac{V_{Ed}}{f_{cd}\;.\;b} = \frac{83{,}834\,.\,10^3}{13{,}33\;.\;100} = 63\mathrm{mm}$$

$$h = \;h_{min} + h_{tolerancia} = 63 + 20 = 83\;\mathrm{mm}\;\ldots.\;\mathrm{h} = 100\;\mathrm{mm}$$

$$h_{celk} = h + h_{podliatie} = \;100 + 30 = 130mm$$

HEB100

$$A_V = \;2\,.\,\mathrm{b}\,.\,t_f = 2\,.100\,.10 = 2000\;mm^2$$

$$V_{pl,Rd} = \frac{A_V\;.\;f_y}{\sqrt{3}\;.\;\gamma_{M0}} = \frac{2000\,.\,10^{-6}\;.\;235\,.\,10^3}{\sqrt{3}\;.\;1{,}0} = 271{,}35\;KN$$

$$\frac{\mathrm{V_{Ed}}}{\mathrm{V_{pl,Rd}}} \leq 1{,}0$$

$$\frac{\mathrm{V_{Ed}}}{\mathrm{V_{pl,Rd}}} = \frac{83{,}834}{271{,}35} = 0{,}31 \leq 1{,}0$$

0,31 ≤ 1,0 ... vyhovuje

8.2.3 POSÚDENIE ZARÁŽKY NA OHYB

$$\mathrm{M_{Ed}} = \mathrm{V_{Ed}}\,.\,\mathrm{e} \;= 83{,}834\,.\,(0{,}100/2 + 0{,}03) = 6{,}7\;\mathrm{kNm}$$

$$M_{pl,Rd} = \frac{W_{pl,y}\;.\;f_y}{\gamma_{M0}} = \frac{104000\,.\,10^{-9}\;.\;235\,.\,10^3}{1{,}0} = 24{,}44kNm$$

$$\frac{\mathrm{M_{Ed}}}{M_{pl,Rd}} \leq 1{,}0$$

$$\frac{\mathrm{M_{Ed}}}{M_{pl,Rd}} = \frac{6{,}7}{24{,}44} = 0{,}27 \leq 1{,}0$$

0,27 ≤ 1,0 ... vyhovuje

8.2.4 POSÚDENIE ZVARU ZARÁŽKY

Návrh zvaru:

$a = 4\,mm$

$a_{min} = 3\ \text{mm}$

$a_{max} = 1{,}1\,.\,t_{min} = 1{,}1\,.\,10 = 11\,mm$

$a_{min} \leq a \leq a_{max}$

$3\,mm \leq 4\,mm \leq 11\,mm$

$L_W = 100 - 2.10 = 100 - 2\,.\,10 = 800\,mm$

$\beta_W = 0{,}9$

$f_u = 360\ \text{MPa}$

$$\tau_{\parallel} = \frac{N_{Ed}}{2.a\,.\,L_W} = \frac{83{,}834\,.\,10^3}{2\,.\,4\,.\,80} = 131\,MPa$$

Moment zotrvačnosti zvarového obrazca

$$I_y = \left[100\,.\,4\,.\left(\frac{\left(-52 - (-52)\right)^2}{12}\right) + (-52)^2\right] + \left[100\,.\,4\,.\left(\frac{(52-52)^2}{12}\right) + 52^2\right] =$$

$$= 216{,}3\,.\,10^3 mm^4$$

$$W = \frac{\mathrm{I_W}}{z} = \frac{216{,}3\,.\,10^3}{50} = 43260\,mm^3$$

$$\tau_{\perp} = \sigma_{\perp} = \frac{\sigma_M}{\sqrt{2}} = \frac{154{,}88}{\sqrt{2}} = 109{,}52 MPa$$

$$\sigma_{\perp} = \frac{0{,}9\,.\,f_u}{\gamma_{M2}} = \frac{0{,}9\,.\,360}{1{,}25} = 259{,}2\,MPa$$

$$\sigma_M = \frac{M_{Ed}}{\mathrm{W}} = \frac{6{,}7.10^{-3}}{43260\,.\,10^{-9}} = 154{,}88\,MPa$$

$109{,}52 \leq 259{,}2\,MPa$

Zrovnávacie napätie vo zvare

$$\sqrt{{\sigma_{\perp}}^2 + 3{\tau_{\perp}}^2 + 3{\tau_{\parallel}}^2} \leq \frac{fu}{\beta w * \gamma m_2}$$

$$\sqrt{109{,}52^2 + 3\,.\,109{,}52^{\,2} + 3\,.\,131^{\,2}} \leq \frac{360}{0{,}9\,.\,1{,}25}$$

$315 \leq 320\,MPa$

8.2.5 POSÚDENIE TLAČENÉHO BETÓNU

$$\sigma_{Mc} = \frac{V_{Ed}}{\mathrm{h}\,.\,\mathrm{b}} \leq f_{cd}$$

$$\frac{83834}{100\,.\,100} \leq 13{,}33\,MPa$$

$8{,}338 \leq 13{,}33\,MPa$

8.2.6 POSÚDENIE KOTEVNÝCH ŠRÓBOV

4x M16, 8.8

Nrk udávaná výrobcom 68,7 kN

$f_{ub} = 800\ \text{MPa}$

$f_{yb} = 640\ \text{MPa}$

$k_2 = 0{,}9$

$d = 16\ \text{mm}$

$d_m = 25{,}9\text{mm}$

$A = 201\ mm^2$

$A_s = 157\ mm^2$

Pri návrhu uvažovaná len ťahová sila, šmykové sily budú prenesené zarážkou

POSÚDENIE NA ŤAH

$$\mathrm{F_{Ed,1}} = \frac{\mathrm{F_{Ed}}}{4} = \frac{198{,}881}{4} = 49{,}72\ \text{kN}$$

$$\mathrm{F_{t,Rd}} = \frac{\mathrm{K_2 \,.\, f_{ub} \,.\, A_s}}{\gamma_{M2}} = \frac{0{,}9\ .\ 800\ .\ 157\ .\ 10^{-3}}{1{,}25} = 90{,}43\ \text{kN}$$

$$\frac{\mathrm{F_{Ed,1}}}{\mathrm{F_{t,Rd}}} \leq 1{,}0$$

$$\frac{\mathrm{F_{Ed,1}}}{\mathrm{F_{t,Rd}}} = \frac{49{,}72}{90{,}43} = 0{,}55 \leq 1{,}0$$

0,55 ≤ 1,0 ... vyhovuje

8.3 KOTVENIE PRIEČNEJ VÄZBY K2

Uzol 418 KZ 81

Tlak: Rx= -10,723 kN

Ry = -0,359 kN

Rz = 218,722 kN

Uzol 417 KZ 53

Tah: Rx= -11,231 kN

Ry = 11,548 kN

Rz = -234,352kN

Uzol 1346 KZ95		Uzol 418 KZ88
Šmyk :	Rx= 15,991 kN	max Rx = 16,343 kN kz
max	Ry = -50,295 kN	Ry = 49,392kN
	Rz = 164,589 kN tlak	Rz = 165,882 kN tlak

Kotevné bloky z betónu C20/25

$f_{cd} = 20$ MPa

$f_{ck} = 13{,}33$ MPa

Podliatie MC20 hrúbky 30mm

Plech S235

$b_1 = 500$ mm

$d_1 = 500$ mm

$t = 20$ mm

8.3.1 POSÚDENIE PATKOVÉHO PLECHU

$$b_2 = min\begin{pmatrix} b_1 + 2b_r \\ 3b_1 \\ b_1 + h \end{pmatrix} = min\begin{pmatrix} 500 + 2\ .\ 150 \\ 3\ .\ 500 \\ 500 + 800 \end{pmatrix} = 800\ mm$$

$$d_2 = min\begin{pmatrix} d_1 + 2d_r \\ 3d_1 \\ d_1 + h \end{pmatrix} = min\begin{pmatrix} 500 + 2\ .\ 75 \\ 3\ .\ 500 \\ 500 + 800 \end{pmatrix} = 650\ mm$$

$$K_j = \sqrt{\frac{b_2\ .\ d_2}{b_1\ .\ d_1}} = \sqrt{\frac{800\ .\ 650}{500\ .\ 500}} = 1{,}44$$

$$F_{jd} = \frac{\beta_j\ .\ K_j\ .\ f_{ck}}{\gamma_c} = \frac{\frac{2}{3}\ .1{,}44\ .20}{1{,}25} = 15{,}36\ MPa$$

$$c = t\ .\ \sqrt{\frac{f_y}{3\ .\ F_{jd}\ .\ \gamma_{M0}}} = 20\ .\ \sqrt{\frac{235}{3\ .\ 15{,}36\ .1{,}0}} = 45\ mm$$

$$\mathrm{N_{Rd}} = \mathrm{A_{eff}}\ .F_{jd}\ =\ 95397\ .15{,}36\ 10^{-3} = 1465\mathrm{KN}$$

$$\frac{\mathrm{N_{Ed}}}{\mathrm{N_{Rd}}} \leq 1{,}0$$

$$\frac{\mathrm{N_{Ed}}}{\mathrm{N_{Rd}}} = \frac{218{,}722}{1465} = 0{,}15\ \leq 1{,}0$$

0,18 ≤ 1,0 ... vyhovuje

8.3.2 POSÚDENIE ZVARU - HEB 280 K PÄTNÝ PLECH P20

Návrh zvaru:

$a =\ 4\ mm$

$a_{min} =\ 3$ mm

$a_{max} = 1{,}1 \,.\, t_{min} = 1{,}1 \,.\, 10{,}5 = 11{,}55\ mm$

$a_{min} \leq a \ \leq a_{max}$

$3\ mm \leq 4\ mm \ \leq 11{,}55\ mm$

zvar po celom obvode $\rightarrow L_y = 1098mm\,, L_z = 524\ mm$

$\beta_W = \ 0{,}9$

$f_u = 360$ MPa

$smer\ y$:

$$\tau_{\parallel} = \ \frac{V_{Ed}}{a \,.\, L_W} = \frac{50{,}295 \,.\, 10^3}{4 \,.\ 1098} = 11{,}45\ MPa$$

$$\sigma_c = \ \frac{N_{Ed}}{a \,.\, L_W} = \frac{218{,}722 \,.\, 10^3}{4 \,.\ (1098 + 524)} = 33{,}71\ MPa$$

$$\tau_{\perp} = \sigma_{\perp} = \frac{\sigma_c}{\sqrt{2}} = \ \frac{33{,}71}{\sqrt{2}} = 23{,}84MPa$$

$$\sigma_{\perp} = \ \frac{0{,}9 \,.\, f_u}{\gamma_{M2}} = \frac{0{,}9 \,.\, 360}{1{,}25} = 259{,}2\ MPa$$

$23{,}84 \leq 259{,}2\ MPa$

Zrovnávacie napätie vo zvare

$$\sqrt{{\sigma_{\perp}}^2 + 3{\tau_{\perp}}^2 + 3{\tau_{\parallel}}^2} \leq \ \frac{fu}{\beta w * \gamma m_2}$$

$$\sqrt{23{,}84^2 + 3 \,.\, 23{,}84^{\,2} + 3 \,.\ 11{,}45^{\,2}} \leq \ \frac{360}{0{,}9 \,.\ 1{,}25}$$

$51{,}64 \leq 320\ MPa$

$smer\ z$:

$$\tau_{\parallel} = \ \frac{V_{Ed}}{a \,.\, L_W} = \frac{16{,}343 \,.\, 10^3}{4 \,.\ 524} = 7{,}8\ MPa$$

$$\sigma_c = \ \frac{N_{Ed}}{a \,.\, L_W} = \frac{218{,}722 \,.\, 10^3}{4 \,.\ (1098 + 524)} = 33{,}71\ MPa$$

$$\tau_{\perp} = \sigma_{\perp} = \frac{\sigma_c}{\sqrt{2}} = \ \frac{33{,}71}{\sqrt{2}} = 23{,}84MPa$$

$$\sigma_{\perp} = \ \frac{0{,}9 \,.\, f_u}{\gamma_{M2}} = \frac{0{,}9 \,.\, 360}{1{,}25} = 259{,}2\ MPa$$

$23{,}84 \leq 259{,}2\ MPa$

Zrovnávacie napätie vo zvare

$$\sqrt{{\sigma_{\perp}}^2 + 3{\tau_{\perp}}^2 + 3{\tau_{\parallel}}^2} \leq \ \frac{fu}{\beta w * \gamma m_2}$$

$$\sqrt{23{,}84^2 + 3 \,.\, 23{,}84^{\,2} + 3 \,.\ 7{,}8^{\,2}} \leq \ \frac{360}{0{,}9 \,.\ 1{,}25}$$

$49{,}56 \leq 320\ MPa$

8.3.3 POSÚDENIE ŠMYKOVEJ ZARÁŽKY

Výška:

$$\sigma_c = \frac{V_{Ed}}{A_{knot}} \rightarrow h_{min} = \frac{V_{Ed}}{f_{cd}\ .\ b} = \frac{50{,}295\ .\ 10^3}{13{,}33\ .\ 100} = 38\ \text{mm}$$

$h = h_{min} + h_{tolerancia} = 38 + 20 = 58\ \text{mm}$ .... h = 100 mm

$h_{celk} = h + h_{podliatie} = 100 + 30 = 130mm$

HEB100

$A_V = 2\ .\ \text{b}\ .\ t_f = 2\ .\ 100\ .\ 10 = 2000\ mm^2$

$$V_{pl,Rd} = \frac{A_V\ .\ f_y}{\sqrt{3}\ .\ \gamma_{M0}} = \frac{2000\ .\ 10^{-6}\ .\ 235\ .\ 10^3}{\sqrt{3}\ .\ 1{,}0} = 271{,}35\ KN$$

$$\frac{\text{V}_{\text{Ed}}}{\text{V}_{\text{pl,Rd}}} \leq 1{,}0$$

$$\frac{\text{V}_{\text{Ed}}}{\text{V}_{\text{pl,Rd}}} = \frac{50{,}295}{271{,}35} = 0{,}19 \leq 1{,}0$$

0,19 ≤ 1,0 ... vyhovuje

8.3.4 POSÚDENIE ZARÁŽKY NA OHYB

$\text{M}_{\text{Ed}} = \text{V}_{\text{Ed}}\ .\ \text{e} = 50{,}295\ .\ (0{,}100/2 + 0{,}03) = 4{,}02\ \text{kNm}$

$$M_{pl,Rd} = \frac{W_{pl,y}\ .\ f_y}{\gamma_{M0}} = \frac{104000\ .\ 10^{-9}\ .\ 235\ .\ 10^3}{1{,}0} = 24{,}44kNm$$

$$\frac{\text{M}_{\text{Ed}}}{M_{pl,Rd}} \leq 1{,}0$$

$$\frac{\text{M}_{\text{Ed}}}{M_{pl,Rd}} = \frac{4{,}02}{24{,}44} = 0{,}16 \leq 1{,}0$$

0,16 ≤ 1,0 ... vyhovuje

8.3.5 POSÚDENIE ZVARU ZARÁŽKY

<u>Návrh zvaru:</u>

$a = 4\ mm$

$a_{min} = 3\ \text{mm}$

$a_{max} = 1{,}1\ .\ t_{min} = 1{,}1\ .\ 10 = 11\ mm$

$a_{min} \leq a \leq a_{max}$

$3\ mm \leq 4\ mm \leq 11\ mm$

$L_W = 100 - 2.10 = 100 - 2\ .\ 10 = 80\ mm$

$\beta_W = 0{,}9$

$f_u = 360$ MPa

$$\tau_{\parallel} = \frac{N_{Ed}}{2.a.L_W} = \frac{50{,}295 \,.\, 10^3}{2\,.\,4\,.\,80} = 78{,}59\ MPa$$

Moment zotrvačnosti zvarového obrazca

$$I_y = \left[100\,.\,4\,.\left(\frac{\left(-52-(-52)\right)^2}{12}\right) + (-52)^2\right] + \left[100\,.\,4\,.\left(\frac{(52-52)^2}{12}\right) + 52^2\right] =$$

$$= 216{,}3 \,.\, 10^3 mm^4$$

$$W = \frac{\mathrm{I_W}}{z} = \frac{216{,}3 \,.\, 10^3}{50} = 43260\ mm^3$$

$$\tau_{\perp} = \sigma_{\perp} = \frac{\sigma_M}{\sqrt{2}} = \frac{92{,}93}{\sqrt{2}} = 65{,}71 MPa$$

$$\sigma_{\perp} = \frac{0{,}9\,.\,f_u}{\gamma_{M2}} = \frac{0{,}9\,.\,360}{1{,}25} = 259{,}2\ MPa$$

$$\sigma_M = \frac{M_{Ed}}{\mathrm{W}} = \frac{4{,}02.10^{-3}}{43260\,.\,10^{-9}} = 92{,}93\ MPa$$

$65{,}71 \leq 259{,}2\ MPa$

Zrovnávacie napätie vo zvare

$$\sqrt{{\sigma_{\perp}}^2 + 3{\tau_{\perp}}^2 + 3{\tau_{\parallel}}^2} \leq \frac{fu}{\beta w * \gamma m_2}$$

$$\sqrt{65{,}71^2 + 3\,.\,65{,}71^{\,2} + 3\,.\,78{,}59^{\,2}} \leq \frac{360}{0{,}9\,.\,1{,}25}$$

$183{,}74 \leq 320\ MPa$

8.3.6 POSÚDENIE TLAČENÉHO BETÓNU

$$\sigma_{Mc} = \frac{V_{Ed}}{\mathrm{h}\,.\,\mathrm{b}} \leq f_{cd}$$

$$\frac{50295}{100\,.\,100} \leq 13{,}33\ MPa$$

$5{,}02 \leq 13{,}33\ MPa$

8.3.7 POSÚDENIE KOTEVNÝCH ŠRÓBOV

4x M16, 8.8

Nrk udavana výrobcom 68,7 kN

$f_{ub} = 800$ MPa

$f_{yb} = 640$ MPa

$k_2 = 0{,}9$

$d = 16$ mm

$A_s = 157\ mm^2$

POSÚDENIE NA ŤAH

$$F_{Ed,1} = \frac{F_{Ed}}{4} = \frac{234{,}352}{4} = 58{,}59\ \text{kN}$$

$$F_{t,Rd} = \frac{K_2 \,.\, f_{ub} \,.\, A_s}{\gamma_{M2}} = \frac{0{,}9 \;.\; 800 \,.\; 157 \,.\, 10^{-3}}{1{,}25} = 90{,}43\ \text{kN}$$

$$\frac{F_{Ed,1}}{F_{t,Rd}} \leq 1{,}0$$

$$\frac{F_{Ed,1}}{F_{t,Rd}} = \frac{58{,}59}{90{,}43} = 0{,}65 \leq 1{,}0$$

0,65 ≤ 1,0 ... vyhovuje

8.4 KOTVENIE PRIEČNEJ VÄZBY K3

Uzol 386 KZ 89

Tlak: Rx= 0,416 kN

Ry = 14,251 kN

Rz = 187,249kN

Uzol 382 KZ 61

Tah: Rx= 0,140 kN

Ry = 12,016 kN

Rz = -143,414kN

Uzol 1315 KZ58		Uzol 338 KZ81
Šmyk :	Rx= 0,455 kN	max Rx = 1,208 kN kz
max	Ry = -66,837 kN	Ry = 55,914 kN
	Rz = 90,165 kN tlak	Rz = 111,816 kN tlak

Kotevné bloky z betónu C20/25

$f_{cd} = 20\ \text{MPa}$

$f_{ck} = 13{,}33\ \text{MPa}$

Podliatie MC20 hrúbky 30mm

Plech S235

$b_1 = 400\ \text{mm}$

$d_1 = 350\ \text{mm}$

$t = 10\ \text{mm}$

8.4.1 POSÚDENIE PATKOVÉHO PLECHU

$$b_2 = min\begin{pmatrix} b_1 + 2b_r \\ 3b_1 \\ b_1 + h \end{pmatrix} = min\begin{pmatrix} 400 + 2\ .\ 150 \\ 3\ .\ 400 \\ 400 + 800 \end{pmatrix} = 700\ mm$$

$$d_2 = min\begin{pmatrix} d_1 + 2d_r \\ 3d_1 \\ d_1 + h \end{pmatrix} = min\begin{pmatrix} 350 + 2\ .\ 150 \\ 3\ .\ 350 \\ 350 + 800 \end{pmatrix} = 650\ mm$$

$$K_j = \sqrt{\frac{b_2\ .\ d_2}{b_1\ .\ d_1}} = \sqrt{\frac{700\ .\ 650}{400\ .\ 350}} = 1{,}80$$

$$F_{jd} = \frac{\beta_j\ .\ K_j\ .\ f_{ck}}{\gamma_c} = \frac{\frac{2}{3}\ .1{,}80\ .10}{1{,}25} = 9{,}6\ MPa$$

$$c = t\ .\ \sqrt{\frac{f_y}{3\ .\ F_{jd}\ .\ \gamma_{M0}}} = 10\ .\ \sqrt{\frac{235}{3\ .\ 9{,}6\ .1{,}0}} = 29\ mm$$

$$\mathrm{N_{Rd}} = \mathrm{A_{eff}}\ .F_{jd}\ =\ 49921\ .9{,}6\ 10^{-3} = 479\ \mathrm{KN}$$

$$\frac{\mathrm{N_{Ed}}}{\mathrm{N_{Rd}}} \leq 1{,}0$$

$$\frac{\mathrm{N_{Ed}}}{\mathrm{N_{Rd}}} = \frac{187{,}249}{479} = 0{,}39\ \leq 1{,}0$$

0,39 ≤ 1,0 ... vyhovuje

8.4.2 POSÚDENIE ZVARU - HEB 220 K PÄTNÝ PLECH P10

Návrh zvaru:

$a =\ 4\ mm$

$a_{min} =\ 3\ \mathrm{mm}$

$a_{max} = 1{,}1\ .\ t_{min} = 1{,}1\ .\ 9{,}5 = 10{,}45\ mm$

$a_{min} \leq a\ \leq a_{max}$

$3\ mm \leq 4\ mm\ \leq 10{,}45\ mm$

zvar po celom obvode $\rightarrow L_y = 860\ mm\ , L_z = 408\ mm$

$\beta_W =\ 0{,}9$

$f_u = 360\ \mathrm{MPa}$

smer y:

$$\tau_{\parallel} =\ \frac{V_{Ed}}{a\ .\ L_W} = \frac{66{,}837.\ 10^3}{4\ .\ 860} = 19{,}43\ MPa$$

$$\sigma_c =\ \frac{N_{Ed}}{a\ .\ L_W} = \frac{187{,}249\ .10^3}{4\ .\ (860 + 408)} = 36{,}92\ MPa$$

$$\tau_\perp = \sigma_\perp = \frac{\sigma_c}{\sqrt{2}} = \frac{36{,}92}{\sqrt{2}} = 26{,}1 MPa$$

$$\sigma_\perp = \frac{0{,}9 \,.\, f_u}{\gamma_{M2}} = \frac{0{,}9 \,.\, 360}{1{,}25} = 259{,}2\ MPa$$

$$26{,}1 \leq 259{,}2\ MPa$$

Zrovnávacie napätie vo zvare

$$\sqrt{{\sigma_\perp}^2 + 3{\tau_\perp}^2 + 3{\tau_\parallel}^2} \leq \frac{fu}{\beta w * \gamma m_2}$$

$$\sqrt{26{,}1^2 + 3 \,.\, 26{,}1^{\,2} + 3 \,.\, 19{,}43^{\,2}} \leq \frac{360}{0{,}9 \,.\, 1{,}25}$$

$$62{,}1 \leq 320\ MPa$$

$smer\ z$:

$$\tau_\parallel = \frac{V_{Ed}}{a \,.\, L_W} = \frac{1{,}208 \,.\, 10^3}{4 \,.\, 408} = 0{,}74\ MPa$$

$$\sigma_c = \frac{N_{Ed}}{a \,.\, L_W} = \frac{187{,}249 \,.\, 10^3}{4 \,.\, (860 + 408)} = 36{,}92\ MPa$$

$$\tau_\perp = \sigma_\perp = \frac{\sigma_c}{\sqrt{2}} = \frac{36{,}92}{\sqrt{2}} = 26{,}1 MPa$$

$$\sigma_\perp = \frac{0{,}9 \,.\, f_u}{\gamma_{M2}} = \frac{0{,}9 \,.\, 360}{1{,}25} = 259{,}2\ MPa$$

$$26{,}1 \leq 259{,}2\ MPa$$

Zrovnávacie napätie vo zvare

$$\sqrt{{\sigma_\perp}^2 + 3{\tau_\perp}^2 + 3{\tau_\parallel}^2} \leq \frac{fu}{\beta w * \gamma m_2}$$

$$\sqrt{26{,}1^2 + 3 \,.\, 26{,}1^{\,2} + 3 \,.\, 0{,}74^{\,2}} \leq \frac{360}{0{,}9 \,.\, 1{,}25}$$

$$52{,}2 \leq 320\ MPa$$

8.4.3 POSÚDENIE ŠMYKOVEJ ZARÁŽKY

Výška:

$$\sigma_c = \frac{V_{Ed}}{A_{knot}} \rightarrow h_{min} = \frac{V_{Ed}}{f_{cd} \,.\, b} = \frac{66{,}837 \,.\, 10^3}{13{,}33 \,.\, 100} = 50\text{mm}$$

$$h = h_{min} + h_{tolerancia} = 50 + 20 = 70\text{mm} \ldots\ \text{h = 100 mm}$$

$$h_{celk} = h + h_{podliatie} = 100 + 30 = 130mm$$

HEB100

$$A_V = 2 . b . t_f = 2 . 100 . 10 = 2000\ mm^2$$

$$V_{pl,Rd} = \frac{A_V . f_y}{\sqrt{3} . \gamma_{M0}} = \frac{2000 . 10^{-6} . 235 . 10^3}{\sqrt{3} . 1,0} = 271,35\ KN$$

$$\frac{V_{Ed}}{V_{pl,Rd}} \leq 1,0$$

$$\frac{V_{Ed}}{V_{pl,Rd}} = \frac{66,837}{271,35} = 0,25 \leq 1,0$$

0,25 ≤ 1,0 ... vyhovuje

8.4.4 POSÚDENIE ZARÁŽKY NA OHYB

$$M_{Ed} = V_{Ed} . e = 66,837 . (0,100/2 + 0,03) = 5,35 kNm$$

$$M_{pl,Rd} = \frac{W_{pl,y} . f_y}{\gamma_{M0}} = \frac{104000 . 10^{-9} . 235 . 10^3}{1,0} = 24,44 kNm$$

$$\frac{M_{Ed}}{M_{pl,Rd}} \leq 1,0$$

$$\frac{M_{Ed}}{M_{pl,Rd}} = \frac{5,35}{24,44} = 0,22 \leq 1,0$$

0,16 ≤ 1,0 ... vyhovuje

8.4.5 POSÚDENIE ZVARU ZARÁŽKY

Návrh zvaru:

$a = 4\ mm$

$a_{min} = 3\ mm$

$a_{max} = 1,1 . t_{min} = 1,1 . 10 = 11\ mm$

$a_{min} \leq a \leq a_{max}$

$3\ mm \leq 4\ mm \leq 11\ mm$

$L_W = 100 - 2.10 = 100 - 2 . 10 = 80\ mm$

$\beta_W = 0,9$

$f_u = 360\ MPa$

$$\tau_{\parallel} = \frac{V_{Ed}}{2 . a . L_W} = \frac{60,837 . 10^3}{2 . 4 . 80} = 95,1\ MPa$$

Moment zotrvačnosti zvarového obrazca

$$I_y = \left[100 . 4 . \left(\frac{(-52 - (-52))^2}{12}\right) + (-52)^2\right] + \left[100 . 4 . \left(\frac{(52 - 52)^2}{12}\right) + 52^2\right] =$$

$$= 216,3 . 10^3 mm^4$$

$$W = \frac{I_W}{z} = \frac{216,3 . 10^3}{50} = 43260\ mm^3$$

$$\tau_{\perp} = \sigma_{\perp} = \frac{\sigma_M}{\sqrt{2}} = \frac{123{,}67}{\sqrt{2}} = 87{,}45 MPa$$

$$\sigma_{\perp} = \frac{0{,}9 \,.\, f_u}{\gamma_{M2}} = \frac{0{,}9 \,.\, 360}{1{,}25} = 259{,}2 \; MPa$$

$$\sigma_M = \frac{M_{Ed}}{\mathrm{W}} = \frac{5{,}35 . 10^{-3}}{43260 \,.\, 10^{-9}} = 123{,}67 \; MPa$$

$$87{,}45 \leq 259{,}2 \; MPa$$

Zrovnávacie napätie vo zvare

$$\sqrt{{\sigma_{\perp}}^2 + 3{\tau_{\perp}}^2 + 3{\tau_{\parallel}}^2} \leq \frac{fu}{\beta w * \gamma m_2}$$

$$\sqrt{65{,}71^2 + 3 \,.\, 65{,}71^{\,2} + 3 \,.\, 78{,}59^{\,2}} \leq \frac{360}{0{,}9 \,.\, 1{,}25}$$

$$183{,}74 \leq 320 \; MPa$$

8.4.6 POSÚDENIE TLAČENÉHO BETÓNU

$$\sigma_{Mc} = \frac{V_{Ed}}{\mathrm{h} \,.\, \mathrm{b}} \leq f_{cd}$$

$$\frac{66837}{100 \,.\, 100} \leq 13{,}33 \; MPa$$

$$6{,}7 \leq 13{,}33 \; MPa$$

8.4.7 POSÚDENIE KOTEVNÝCH ŠRÓBOV

2x M16, 8.8

Nrk udavana výrobcom 90,4 kN

$f_{ub} = 800$ MPa

$f_{yb} = 640$ MPa

$k_2 = 0{,}9$

$d = 16$ mm

$A_s = 157 \; mm^2$

POSÚDENIE NA ŤAH

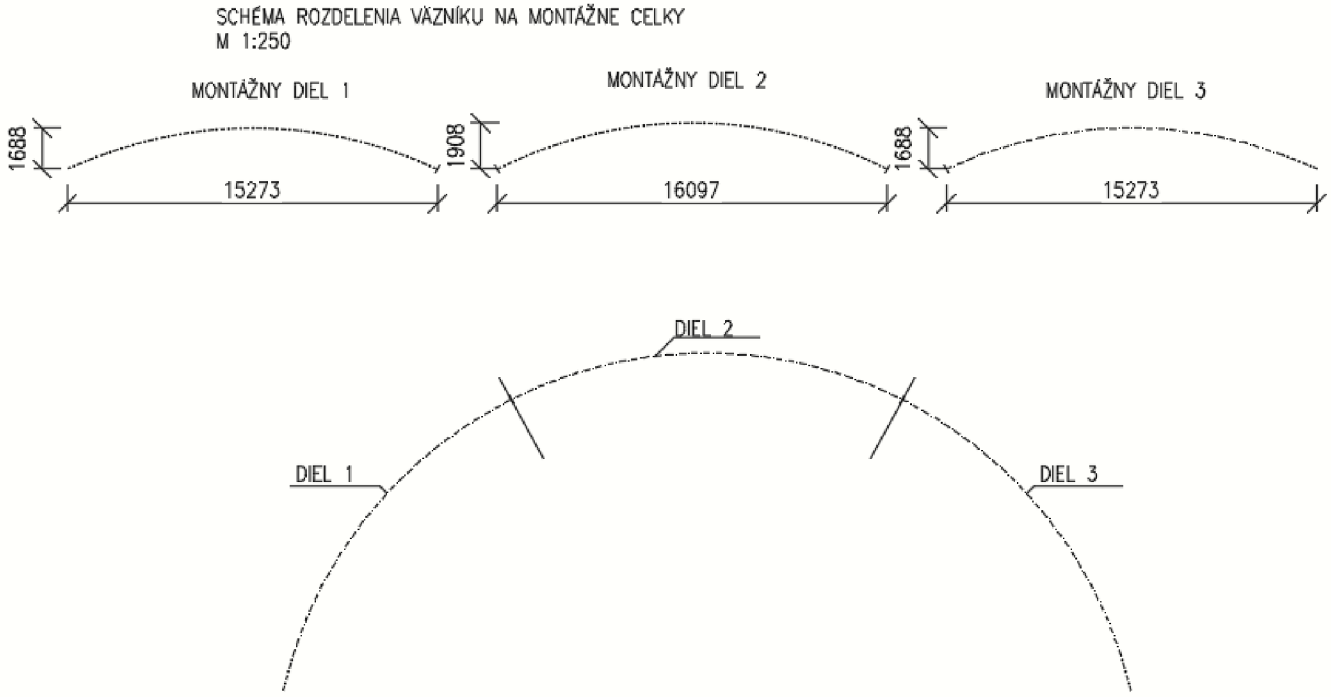
$$\mathrm{F_{Ed,1}} = \frac{\mathrm{F_{Ed}}}{2} = \frac{143{,}414}{2} = 71{,}7 \text{ kN}$$

$$\mathrm{F_{t,Rd}} = \frac{\mathrm{K_2} \,.\, \mathrm{f_{ub}} \,.\, \mathrm{A_s}}{\gamma_{M2}} = \frac{0{,}9 \;.\; 800 \,.\; 157 \,.\, 10^{-3}}{1{,}25} = 90{,}43 \text{ kN}$$

$$\frac{\mathrm{F_{Ed,1}}}{\mathrm{F_{t,Rd}}} \leq 1{,}0$$

$$\frac{\mathrm{F_{Ed,1}}}{\mathrm{F_{t,Rd}}} = \frac{71{,}7}{90{,}43} = 0{,}79 \leq 1{,}0$$

0,79 ≤ 1,0 ... vyhovuje

8.5 MONÁŽNE SPOJE VÄZNÍK HEB280

Štítový väzník je rozdelený na do troch montážnych dielov, ktoré budú spojene tupými zvarmi s plným prevarením tvaru ´´polV´´