Basis of structural design

Basic notions and design code reccomendations
Applications

Civil Engineering

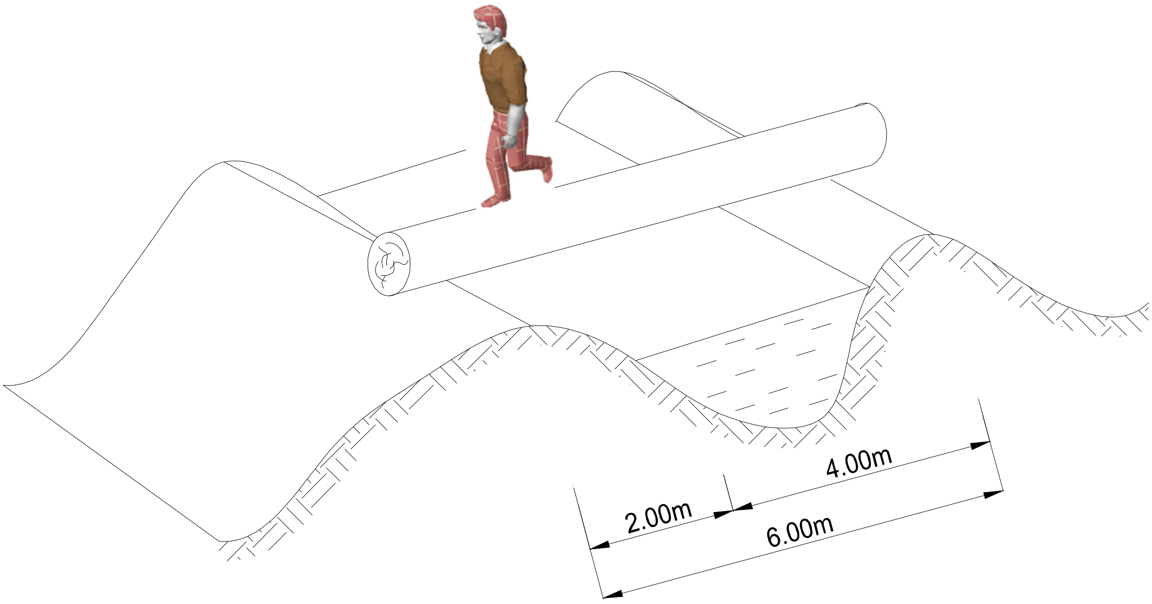
2nd Year

Ioan Both

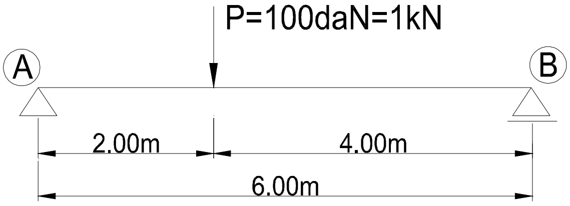
Load transmission

Simplest structure : simple supported beam

Consider a man of 100kgf crossing the log.



The static scheme can be represented by the following figure.

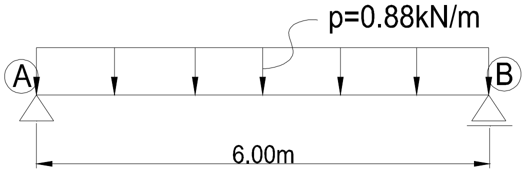


Beside the man loading there has to be considered the self-weight of the log.

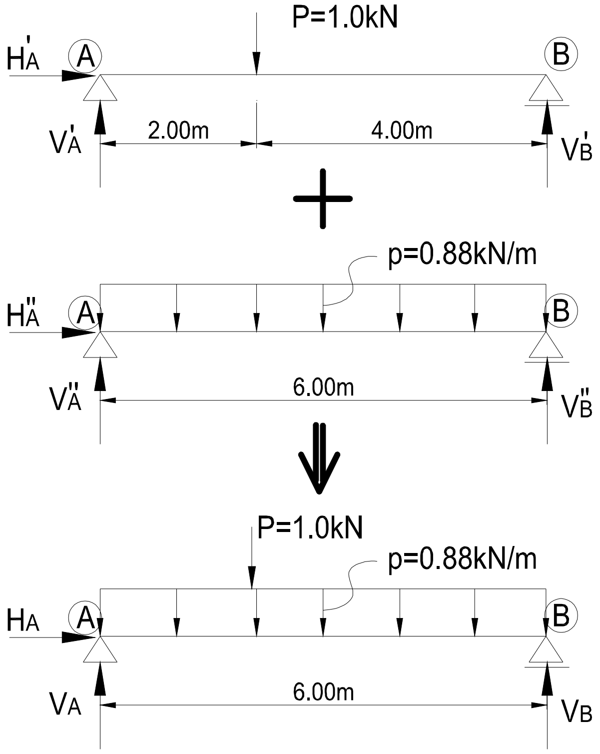
Considering the density of wood $\rho = 700\,\frac{daN}{m^3}$, the selfweight for the linear element has to be taken into acount as a linear uniform distributed force. Thus, multiplying with the area of cross section (m^2) it will result a uniform distributed force (daN/m)

$$A = \pi R^2 = \pi (0.2m)^2 = 1256 \cdot 10^{-4} m^2$$

$$p = \rho \cdot A = 700\frac{daN}{m^3} \cdot 0.1256 m^2 = 87.92\frac{daN}{m} = 0.88\frac{kN}{m}$$



Adding the two loads, it will result the total reactions of the supports



$$\sum H = 0 \rightarrow H'_A = 0$$

$$\sum (M_A) = 0 \rightarrow P \cdot 2m - V'_B \cdot 6m = 0$$

V'_B =0.33kN

$$\sum (M_B) = 0 \rightarrow P \cdot 4m - V'_A \cdot 6m = 0$$

V'_A =0.67kN

$$\sum H = 0 \rightarrow H''_A = 0$$

$$\sum (M_A) = 0 \rightarrow p \cdot 6m \cdot 3m - V''_B \cdot 6m = 0$$

V''_B =2.64kN

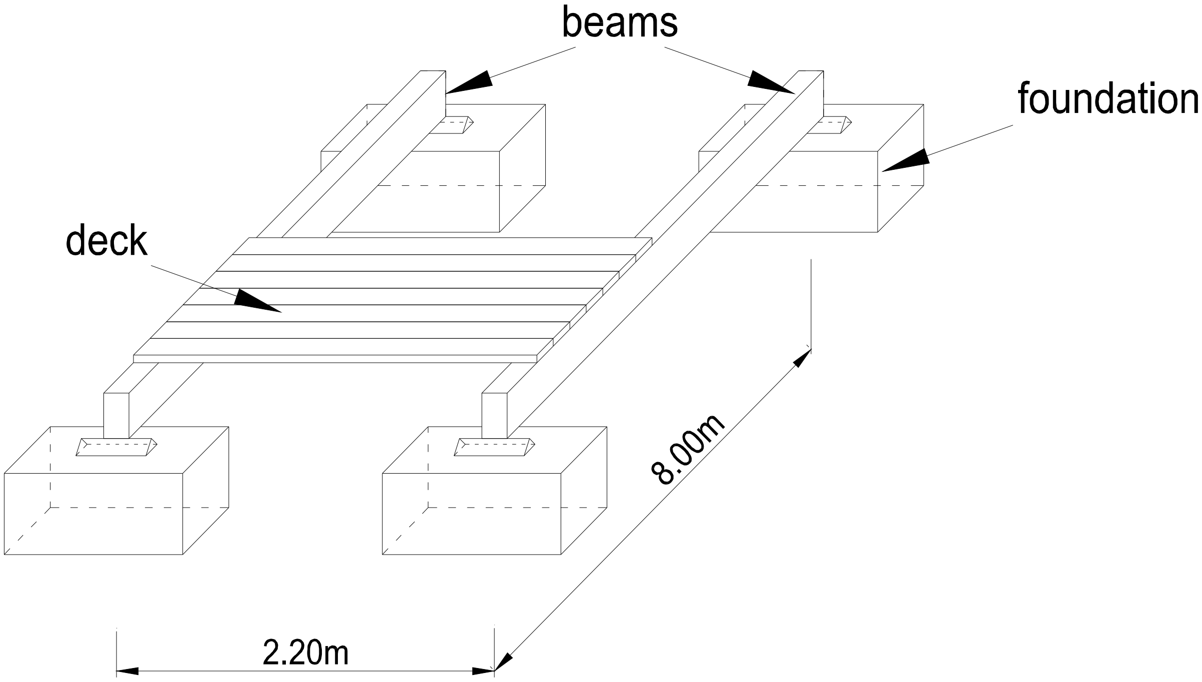
$$\sum (M_B) = 0 \rightarrow p \cdot 6 \cdot 3m - V''_A \cdot 6m = 0$$

$V''_A = 2.64$kN

$$V_A = V'_A + V''_A = 3.31kN$$

$$V_B = V'_B + V''_B = 2.97kN$$

The need for supporting or transportation larger loads lead to crossings or bridges.



The load is transmitted, for this simple structure, from the deck to the beams and from the beams to the foundations. The deck represents a surface loading

$$V_B = \frac{2 \cdot 100}{6} \qquad V_A = \frac{4 \cdot 100}{6}$$

Specific weight for wood: $\gamma_w = 700\ \frac{kg}{m^3}$

Circular section: $Area\ A = \frac{\Pi \cdot D^2}{4} = 1256\ cm^2$

The weight for one meter: $p = \gamma_w \cdot A = 700\ \frac{kg}{m^3} \cdot 1256 \cdot 10^{-4} m^2$

$$p = 87{,}92 \frac{kg}{m} = 0{,}88\ \frac{kN}{m}$$

The need for larger loads $\Longrightarrow$ bridges

The deck represents a surface loadinf: p_{deck}

$$p_{deck} = \gamma_w \cdot t_{plank} = 700 \frac{kg}{m^3} \cdot 0{,}024\, m = 16{,}8 \frac{kg}{m^2} = 16{,}8 \frac{daN}{m^2}$$

For a single plank to be calculated we use:

$$p_{deck} = \gamma_w \cdot t_{plank} \cdot b_{plank} = 700 \frac{kg}{m^3} \cdot 0{,}024m \cdot 0{,}2m = 3{,}36 \frac{kg}{m} = 3{,}36 \frac{daN}{m}$$

The weight for beams is obtained by adding weight of the deck and the self weight of the beam.

The weight of the deck for one beam is:

$$p_{d_{beam}} = p_{deck} \cdot \frac{2{,}45m}{2} = 16{,}8\frac{daN}{m^2} \cdot \frac{2{,}45m}{2} = 20{,}58\frac{daN}{m}$$

The self weight of a beam is:

$$p_{beam} = \gamma_w \cdot b_b \cdot h_b = 700\frac{daN}{m^3} \cdot 0{,}25m \cdot 0{,}4m = 70\frac{daN}{m}$$

The bending moment is larger hence the moment of inertia is:

$$I_{y_{beam}} = \frac{25cm \cdot (40cm)^3}{12} = 133333cm^4$$

$$I_{y_{plank}} = \frac{20cm \cdot (2{,}4cm)^3}{12} = 23{,}04cm^4$$

The load on foundation will be the reaction of the beam.

Example of a load distribution for a house

Horizontal plan view

SREN 1991-1-1. General actions. Densities, self weight, imposed loads

Let there be a multistory building with the height of a floor =28m.Being given the structural configuration of a floor, calculate the loads acting on an intermediate secondary beam, lateral secondary beam, current main beam, lateral main beam. A section through the floor is presented in the following figure. The roof of the building is flat and accessible (restaurant). The structure has curtain walls (1kN/m^2) on exterior and dividing walls on interior.

DESENE (3)

Floor

Imposed loads $\xrightarrow{\text{ch.6.3.1}}$ category: B $\longrightarrow$ national annex table NA 6.2 ⇨ 2,5kN/m^2

Roof

Imposed loads $\xrightarrow{\text{6.3.4}}$ category: I $\longrightarrow$ category: C $\longrightarrow$ NA ⇨ C$_1$ ⇨ C$_{1.3}$ ⇨ 3kN/m^2

Floor	**Roof**
Loads on secondary beam (intermediate) character value	Characteristic value
Loads on lateral secondary beam	
Loads on main beam	

1. Surface loads

1.1 Permanent loads

Current floor	thickness	specific weight (kN/m^3)	load (kN/m^2)
sandstone 12 mm	12 mm	27	0,324
adhesive (support layer)	6 mm	21	0,126
mortar layer	40 mm	22	0,88
thermal insulation - polystyrene	60 mm	0,25	0,015
reinforced concrete slab	100 mm	25	2,5
corrugated steel sheet	0,7 mm	-	0,0785
ceiling + installations	-	-	0,5
		Total	4,4235 kN/m^2

Roof	thickness	specific weight (kN/m^3)	load (kN/m^2)
granite	32 mm	30	0,96
membrane TPO 1.8	1,8 mm	-	0,0195
thermal insulation Rockwool	120 mm	1,82	0,2184
slope concrete (class LC 1,0)	150 mm	10	1,5
lightweight concrete (class LC 1,0)	60 mm	10	0,6
reinforced concrete	100 mm	25	2,5
corrugated steel sheet	0,7	-	0,0785
ceiling + installation	-	-	0,5
		Total	6,3754 kN/m^2

1.2 Walls

1.2.1. Interior walls (moveable) dividing walls

From characteristics chart results: $g'_{dw} = 0{,}6\frac{kN}{m^2}$

The height of one floor is 2,8 m results $g_{dw} = g'_{dw} \cdot 2{,}8m = 1{,}68\frac{kN}{m}$ results $q_{kdw} = 0{,}8\ \frac{kN}{m^2}$ results moveable, results imposed load

1.2.2. Exterior walls (courtain wall)

$g'_{cw} = 1\frac{kN}{m^2}$ results $g_{cw} = 1\frac{kN}{m^2} \cdot 2{,}8 = 2{,}8\ \frac{kN}{m}$ results not moveable, results permanent load

DESEN

1.3. Imposed loads

1.3.1. Current floor

SR EN 1991-1-1 $\xrightarrow[\text{cap 6.3 pag 15}]{}$ category: B $\Rightarrow$ table 6.2 $\Rightarrow$ SR EN 1991-1-1/NA $\Rightarrow$

table 6.1
Nota 2
pag 16

6.3.1.2
Nota

table
NA 6.2

$$q_{k_f} = 2{,}5\frac{kN}{m^2}$$

1.3.2. Roof

SR EN 199-1-1 $\longrightarrow$ category: I $\Rightarrow$ category: C $\Rightarrow$ C1.3 $\Rightarrow$ $q_{k_r} = 3{,}0\frac{kN}{m^2}$

cap 6.3.4
pag 22

2. Liniar loads

2.1. Intermediate secondary beam

Tributary area has the width $\frac{3m}{2} + \frac{3m}{2} = 3m = l_{t_1} = 2{,}5\frac{kN}{m^2} \cdot l_t + q_{dw} \cdot l_{t_1} = 4{,}4235\frac{kN}{m^2} \cdot l_t =$

2.2. Lateral secondary beam

Tributary area has the width $\frac{3}{2}m = 1{,}5m = l_{t_2}$

2.3. Current main beam

Tributary area has the width $\frac{6m}{2} + \frac{6m}{2} = 6m = l_{t_3}$

Homework: For the structure given in the figure, calculate the loads acting on a current purlin, lateral purlin, current beam and a lateral beam. The purlin is a steel profile IPE 160. The beam is IPE 330 and the closing of the structure is made by thermal resistant panels (sandwich) kingspan KS 1000 RW (120 mm). The roof is not accessible except for normal maintenance and repair. (Take into account the permanent load and the imposed load).

Snow

For the industrial hall presented in the figure bellow calculate the snow load acting on a current purlin, lateral purlin, current beam and lateral beam. The structure is built in Oradea being sheltered for its location.

$$c_e = \begin{cases} 0{,}8 \ - wind\ swept \\ 1{,}0 \ - normal \\ 1{,}2 - sheltered \end{cases}$$

Snow load is on horizontal plane.

$s_k = \mu_i \cdot c_e \cdot c_t \cdot s_{0k}$

$c_e = 1{,}2 \quad c_t = 1 \quad s_{0k} = 1{,}5\frac{kN}{m^2}$

$s_{k_1} = \mu_1 \cdot c_e \cdot c_t \cdot s_{ok} = 0{,}8 \cdot 1{,}2 \cdot 1 \cdot 1{,}5 = 1{,}44$

$\mu_2 = 0{,}8 + 0{,}8 \cdot \frac{15}{30} = 1{,}2$

$s_{k_2} = \mu_2 \cdot c_e \cdot c_t \cdot s_{ok} = 1{,}2 \cdot 1{,}2 \cdot 1 \cdot 1{,}5 = 2{,}16$

$s_{k_3} = 0{,}5\mu_1 \cdot c_e \cdot c_t \cdot s_{ok} = 0{,}72$

Undrifted snow

$tg\alpha = \frac{1{,}4}{5} = 0{,}28$

$\alpha = 15{,}64^{\circ}$

$\sin\alpha = 0{,}270$

$\cos\alpha = 0{,}963$

Length of the beam: $l_b \cdot \frac{5}{\cos\alpha} = 5{,}19$

Distance between purlins: $l_p = \frac{5{,}19}{3} = 1{,}73\ m$

Current purlin: $s_{pc} = s_{k_1} \cdot cos\alpha \cdot l_p$

Lateral purlin: $s_{pl} = s_{k_1} \cdot cos\alpha \cdot \frac{l_p}{2}$

Current beam

Distributed load

$s_{bc} = s_{k_1} \cdot cos\alpha \cdot 6m$

Drifted snow

Homework: Determine the snow loads acting on the rafter and the purlin of the following house roof. (Predeal, 1600m)

Test: Determine the loads (dead and imposed) on the secondary beam of the floor. The floor belongs to a retail shopping area. The height of the floor is 3m, the bay is 5m and the spam of the main frame is 6m. The secondary beam is an IPE300 having the self weight 42,2 kg/m.

NP 082-04-WIND ACTION

Let there be he structure described un following figure (seminar 9) The structure shall have 10 floors, being constructed in Cluj-Napoca, in an area with reduced density of constructions.
Plan view

Wind pressure on surfaces: page 4 $w(z) = q_{ref} \cdot c_e(z) \cdot c_p$

a) q_{ref} Chapter 6, page 6

$q_{ref} \longrightarrow 0{,}612\ U_{ref}^{2}$

rel(5) ⇨ $U_{ref}^{10min} = 0{,}84\ U_{ref}^{1min}$

Cluj ⇨ $U_{ref}^{1min} = 31 m/s$ ⇨ $U_{ref}^{10min} = 0{,}84 \bullet 31 = 26 m/s$

$$q_{\ ref} = 0{,}612 \cdot 26^2 = 413{,}7Pa = 0{,}414kPa$$

b) c_e = chapter 11

$c_e(z) = c_g(z) \cdot c_r(z)$

Establish z

height of the building $\left.\begin{matrix} h = 28m \\ b = 24 \end{matrix}\right\} \Rightarrow b < h < 2b \Rightarrow$ there will be 2 reference height:

$$z_e = h = 28m$$

$$z_e = b = 24m$$

Determine gust coefficient (c_g):

$c_g(28m) = 1 + g[2I(28)]$

$$I(z) = \frac{\sqrt{\beta}}{2{,}5ln\frac{z}{z_0}}$$

$$z = 28 \Rightarrow I(28) = \frac{2{,}5}{2{,}5ln\frac{28}{0{,}3}} = 0{,}207$$

g=peak factor (page 12, art. 10.2) $\Rightarrow g = 3{,}5$

$c_g(28m) = 1 + 3{,}5 \cdot 2 \cdot 0{,}207 = 2{,}45$

$c_g(24m) = 1 + g[2I(24)]$

$$I(24) = \frac{2{,}35}{2{,}5 \cdot ln\frac{24}{0{,}3}} = 0{,}215$$

$\Rightarrow c_g(24) = 1 + 3{,}5 \cdot 2 \cdot 0{,}215 = 2{,}51$

Determine roughness coefficient (c_r):

$$c_r(z) = k_r^2(z_0) \cdot \left(ln\frac{z}{z_0}\right)^2$$

From table 2, page 8: $k_r^2(z_0) = 0{,}22$

$$c_r(28) = 0{,}22^2 \cdot \left(ln\frac{28}{0{,}3}\right)^2 = 1$$

$$c_r(24) = 0{,}22^2 \cdot \left(ln\frac{24}{0{,}3}\right)^2 = 0{,}93$$

$\Rightarrow c_e(28) = c_g(28) \cdot c_r(28) = 2{,}45 \cdot 1 = 2{,}45$

$c_e(24) = c_g(24) \cdot c_r(24) = 2{,}51 \cdot 0{,}93 = 2{,}33$

c)c_p-pressure coefficient for walls and roof

Walls

$h = 28m$

$$\frac{d}{h} = \frac{18}{28} = 0{,}643$$

$e = \min(b; 2h) = \min(24; 2 \cdot 28) = 24$

$d < e \Rightarrow A\&B^*$

$$\frac{e}{5} = \frac{24}{5} = 4{,}8m$$

$c_{p_A} = -1;\ \ c_{p_{B^*}} = -0{,}8;\ \ c_{p_D} = 0{,}8;\ \ c_{p_E} = -0{,}3$

Roofs=>page 18 **flat roofs**

We will consider a parapet of 1 m.

$$\frac{h_p}{h} = \frac{1}{28} = 0{,}036$$

By interpolation we have:

$c_{p_F} = -1{,}5;\ \ c_{p_G} = -1;\ \ c_{p_H} = -0{,}7;\ \ c_{p_I} = \pm 0{,}2$

Wind pressure on walls:

- for $z < 24\,m$

$$W_A(24) = q_{ref} \cdot c_e(24) \cdot c_p = 0{,}414 \cdot 2{,}33 \cdot (-1) = -0{,}965 \frac{kN}{m^2}$$

$$W_{B^*}(24) = 0{,}414 \cdot 2{,}33 \cdot (-0{,}8) = -0{,}772 \frac{kN}{m^2}$$

$$W_D(24) = 0{,}414 \cdot 2{,}33 \cdot 0{,}8 = 0{,}772 \frac{kN}{m^2}$$

$$W_E(24) = 0{,}414 \cdot 2{,}33 \cdot (-0{,}3) = -0{,}289 \frac{kN}{m^2}$$

- for $24 < z < 28$

$$W_A(28) = q_{ref} \cdot c_e(28) \cdot c_p = 0{,}414 \cdot 2{,}45 \cdot (-1) = -1{,}01 \frac{kN}{m^2}$$

$$W_B(28) = 0{,}414 \cdot 2{,}45 \cdot (-0{,}8) = -0{,}811 \frac{kN}{m^2}$$

$$W_D(28) = 0{,}414 \cdot 2{,}45 \cdot 0{,}8 = 0{,}811 \frac{kN}{m^2}$$

$$W_E(28) = 0{,}414 \cdot 2{,}45 \cdot (-0{,}3) = -0{,}304 \frac{kN}{m^2}$$

Wind pressure on roof:

$$W_F(28) = 0{,}414 \cdot 2{,}45 \cdot (-1{,}5) = -1{,}52 \frac{kN}{m^2}$$

$$W_G(28) = 0{,}414 \cdot 2{,}45 \cdot (-1) = -1{,}01 \frac{kN}{m^2}$$

$$W_H(28) = 0{,}414 \cdot 2{,}45 \cdot (-0{,}7) = -0{,}71 \frac{kN}{m^2}$$

$$W_I'(28) = 0{,}414 \cdot 2{,}45 \cdot (-0{,}2) = -0{,}2 \frac{kN}{m^2}$$

$$W_I''(28) = 0{,}414 \cdot 2{,}45 \cdot 0{,}2 = 0{,}2 \frac{kN}{m^2}$$

Wind action on walls will be distributed on beams and from beams on columns

- $h < 24$

$$W_D(24) \cdot l_d = 0{,}77 \cdot 2{,}8 = 2{,}156 \frac{kN}{m^2}$$

- $24 < h < 2$

$$W_d(28) \cdot l_d = 0{,}81 \cdot 2{,}8 = 2{,}268 \frac{kN}{m^2}$$

Beams in zone F

Beams in zone G

Beams in zone H

Beams in zone I

Design according to limit state method CRO-2005

There are 2 limit states that must be considered:

- ultimate limit state → structural failure
- serviceability limit state →deformation vibration

According to CRO, chapter 4 , subchapter 4.2.4, page 27 $R_d = \frac{R_k}{\gamma_\mu}$, where:

R_k – character value

γ_μ – safety factor

According to ULS, chapter 4.3, page 27, $E_d<R_d$, where:

E_d – design value of action effect

R_d – design value of resistance

Action combination: $1{,}35\sum_{j=1}^{n} G_{kj} + 1{,}5Q_{k1} + \sum_{i=2}^{m} 1{,}5 \cdot \Psi_{0i} \cdot Q_{ki}$

Favorable effect: $0{,}9\sum_{j=1}^{n} G_{kj} + 1{,}5Q_{k1} + \sum_{i=2}^{m} 1{,}5 \cdot \Psi_{0i} \cdot Q_{ki}$

According to SLS : $f_{Ed} \leq f_{Rd}$

$v = \frac{P \cdot L^3}{3EI}$
$v = \frac{P \cdot L^4}{8EI}$
$v = \frac{5}{384} \cdot \frac{P \cdot L^4}{EI}$

Consider the roof structure in previous seminar. Stal=S235. The secondary beam is acted by:

- permanent load

$$G'_K = 6{,}375\ \frac{kN}{m^2}$$

$$G_K = G'_K \cdot l_t = 6{,}375 \frac{kN}{m^2} \cdot 3m = 19{,}125 \frac{kN}{m}$$

- imposed load

$$Q'_K = 4\frac{kN}{m^2}$$

$$Q_K = 4\frac{kN}{m^2}\cdot 3m = 12\frac{kN}{m}$$

- snow load

$$S'_K = \mu_i \cdot c_e \cdot c_t \cdot s_{0k} = 0{,}8\cdot 1\cdot 1\cdot 1{,}5\frac{kN}{m^2} = 1{,}2\frac{kN}{m^2}$$

$$S_K = S'_K \cdot 3m = 3{,}6\frac{kN}{m}$$

- wind load

Unfavorable: $W_I = 0{,}2\frac{kN}{m^2}\cdot 3m = 0{,}6\frac{kN}{m}$

Favorable: $W_F = -1{,}52\frac{kN}{m^2}\cdot 3m = -4{,}56\frac{kN}{m}$

ULS combination

$$1{,}35G_K + 1{,}5Q_K = 1{,}35\cdot 19{,}125 + 1{,}5\cdot 12 = 43{,}8\frac{kN}{m}$$

$$1{,}35G_K + 1{,}5S_K = 1{,}35\cdot 19{,}125 + 1{,}5\cdot 3{,}6 = 31{,}22\frac{kN}{m}$$

$$1{,}35G_K + 1{,}5S_K + 1{,}05W_K(+) = 1{,}35\cdot 19{,}125 + 1{,}5\cdot 3{,}6 + 1{,}05\cdot 0{,}6 = 31{,}85\frac{kN}{m}$$

$$1{,}35G_K + 1{,}5W_K(+) = 1{,}35\cdot 19{,}125 + 1{,}5\cdot 0{,}6 = 26{,}71\frac{kN}{m}$$

$$0{,}9G_K + 1{,}5W_K(-) = 0{,}9\cdot 19{,}125 + 1{,}5\cdot 4{,}56 = 24{,}05\frac{kN}{m}$$

Results that the maximum load is $43{,}8\frac{kN}{m}$

Design resistance of structural element: $R_d = W\cdot\frac{f_y}{\gamma_\mu}$ where:

f_y – yield strength , $f_y = 235\frac{N}{mm^2}$

W strength modulus for IPE 300 is $W_{I30} = 557cm^3$

Results that $R_d = 557\cdot 10^3 mm^3 \cdot \frac{235\frac{N}{mm^2}}{1{,}1} = 131\cdot 10^6 Nmm$

$E_d > R_d$ not OK, choose another section, IPE 400

$W_{I450} = 1156cm^3$

$$R_d = 1156\cdot 10^3 mm^3 \cdot \frac{235\frac{N}{mm^2}}{1{,}1} = 247\cdot 10^6 Nmm$$

$E_d < R_d$ OK

Secondary beam is IPE400.

Material resistance is $R_d = \frac{235\frac{N}{mm^2}}{1{,}1} = 210\frac{N}{mm^2}$

Unitary stress is $\sigma = \frac{\mu}{W} = \frac{197{,}1 \cdot 10^6 Nmm}{557 \cdot 10^3 mm^3} = 353 \frac{N}{mm^2}$

$W_{IPE300} = 557 \cdot 10^3 mm^3$

$\sigma = E_d$

$E_d > R_d$ not OK, results choose another section for beam.

SLS combination

$$G_K + Q_K = 19{,}125 + 12 = 31{,}125 \frac{kN}{m}$$

$$G_K + S_K = 19{,}125 + 3{,}6 = 22{,}725 \frac{kN}{m}$$

$$G_K + S_K + W_K(+) = 19{,}125 + 3{,}6 + 0{,}6 = 23{,}325 \frac{kN}{m}$$

$$G_K + S_K + W_K(-) = 19{,}125 + 3{,}6 + +4{,}56 = 27{,}285 \frac{kN}{m}$$

Maximum deflection for beam: $\begin{cases} \frac{L}{350} = 17{,}14 - main\ beam \\ \frac{L}{250} = 24 - secondary\ beam \end{cases}$

$$\Rightarrow v = \frac{5}{384} \cdot \frac{p \cdot L^4}{E \cdot I}$$

$I_{400} \Rightarrow I_y = 23130 \cdot 10^4 mm^4$

$$v = \frac{5}{384} \cdot \frac{31{,}125 \frac{N}{mm} \cdot 6000^4}{2{,}1 \cdot 10^6 \frac{N}{mm^2} \cdot 23130 \cdot 10^4 mm^4} = 10{,}81 mm = E_d$$

$f_{E_d} = 10{,}81\ m$

$f_{R_d} = \frac{L}{250} = 24\ m$

$f_{E_d} < f_{R_d}$ OK

Test 1

Let there be the structure in the following figure. It shall be constructed in an area with density of constructions in Cluj-Napoca. The roof can be considered with normal exposure. Beams' material is S235 an the maximum allowed deflection is L/250. The roof is not accessible except for normal maintenance and repair.

1. Calculate the permanent load acting on a current secondary beam.
2. Calculate the snow acting on a secondary beam.

3. Determine the wind pressures on walls and on roof taking into consideration transversal wind on higher wall.
4. Check the secondary beam at ULS.
5. Check the secondary beam at SLS.
6. Determine the characteristic loads acting on a lateral main beam.

$$f_g = 235 \frac{n}{mm^2}$$

Test 2

Let there be the configuration for the balcony of a multistory building. Check the elements ULS, SLS knowing that the beams' steal is S235 and the maximum deflection is L/300. The location is Timisoara, normal exposure. Permanent load is considered $g'' = 4 \frac{kN}{m^2}$

The tributary width for a secondary balcony beam is $l_t = 1m$.

Permanent load: $g_K' = 4 \frac{kN}{m^2}$

$$g_K = g_K' \cdot l_t = 4 \frac{kN}{m^2} \cdot 1m = 4 \frac{kN}{m}$$

The main beam will be acted by the secondary beam reactions.

$$2V = 24kN$$

Imposed load: SR EN 1991-1-1 NA table 6.2 Balconies 2,5 → $4 \frac{kN}{m}$

Footnote 3)

$$q_1' = 4 \frac{kN}{m^2} - \ strip\ of\ 0{,}8\ m$$

$$q_2' = 2{,}5 \frac{kN}{m^2} - \ area\ load$$

Case 1: Secondary beam

$$q_1 = 4 \frac{kN}{m^2} \cdot 0{,}8m = 3{,}2 \frac{kN}{m}$$

Case 2: Secondary beam

$$q_2 = 2{,}5 \frac{kN}{m^2} \cdot 1m = 2{,}5 \frac{kN}{m}$$

Main beam

Case 1: $2V_1 = 19{,}2 \qquad 2V_2 = 15$

Snow load CR1--1-3

Page 9, chapter 3.5 – Roofs close to taller building

$\mu_1 = 0{,}8$

$\mu_2 = \mu_s + \mu_W$

μ_s=0

$$\mu_W = \frac{b_1 + b_2}{2h} < \frac{\gamma \cdot h}{s^k}; \quad 0{,}8 < \mu_W < 4$$

$$\left.\begin{array}{r} b_1 = 18;\ \ b_2 = 2;\ \ h = 4 \implies \mu_W = \frac{18+2}{2\cdot 4} = 2{,}5 \\ \gamma = 2;\ \ s_{0k} = 1{,}5 \implies \mu_W = \dfrac{2 \cdot 4}{1{,}5} = 5{,}33 \end{array}\right\} \implies \mu_W = 2{,}5$$

$\implies \mu_2 = 0 + 2{,}5 = 2{,}5$

Page 10 $\implies l_s = 2h; \quad 5 \leq l_s \leq 15m \implies l_s = 8m$

Undrifted $\quad s_{k_1} = \mu_1 \cdot c_e \cdot c_t \cdot s_{0k} = 0{,}8 \cdot 1 \cdot 1 \cdot 1{,}5 = 1{,}2\frac{kN}{m^2}$

Secondary beam

$$s_{k_1} \cdot l_t = 1{,}2 \cdot 1 = 1{,}2\frac{kN}{m}$$

Main beam

s1) $2V_3 = 7{,}2kN$ undrifted

s2) $2V_4 = 18{,}27kN$ drifted