Assignment 1

Pre-design

Preliminary design of some common structures

This assignment is about preliminary design of some common structural design solutions for construction works. The purpose of the assignment is that you should practise to do rough estimations of action effects and preliminary dimensions of different structural members, by using hand calculations. The capacity of the sections should be within 15 % of the action effect (e.g. the bending moment), e.g. for a bending moment action effect the following requirement shall be fulfilled: MEd ≤ Mrd ≤ 1.15MEd, where Mrd is the bending moment capacity of the cross section and MEd is the bending moment caused by the load acting on the structural element. For the serviceability (SLS) verifications, i.e. the estimated deflection due to external loading, u_est, needs to fulfill the required deflection limit, u_requ, and thus u_est ≤ u_requ.

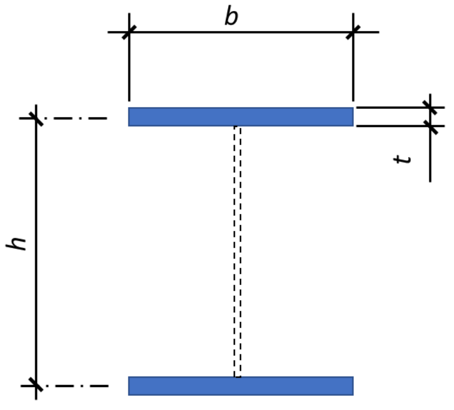
The length, L, in the tasks should be 12 (m) + the number of the month of your birth date times 0.2. (e.g. **12 + 5 · 0.2 = 13 (m) for the month of May**)

Estimate the dimensions of a steel section, a reinforced concrete section and a timber section in order to balance the bending moment in the tasks below. Use the following assumptions for the different sections:

Steel section:

Neglect the influence from the web on the bending moment capacity. The design strength of the steel is f_{yd} = 355 MPa. The Young's modulus is E= 210000 MPa.

Choose appropriate values of the height ***h***, width ***b*** and the thickness ***t*** to balance the bending moment that affect the beam.
The relation between the dimensions should be:
$t \leq b/6$ and $b \leq h/2$.



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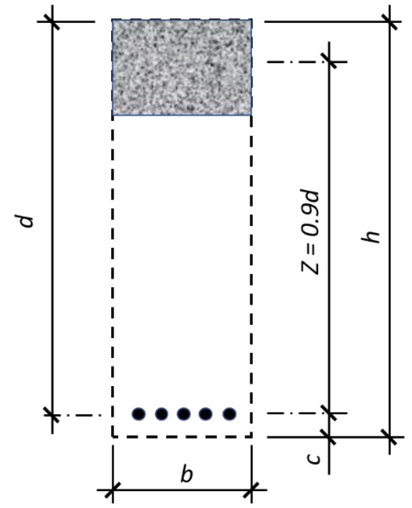
Concrete section:

The design strength, f_{yd}, of the reinforcement bars is 430 MPa. The number of bars (integer, *i.d.* 1, 2, 3 etc.) is *b*/70 (with *b* in mm) and the dimension ϕ of the bars is 20 mm. The Young's modulus of concrete is *E*= 30000 MPa.

Choose appropriate values of the height ***h***, width ***b*** to balance the bending moment that affect the beam.
The relation between the dimensions should be: $b \leq h/2.5$.
The distance c is 60 mm.

Assume the reinforced concrete beam to be cracked under ULS and SLS loading. A reduction of the bending stiffness, *EI*, to 35% of the uncracked bending stiffness can be assumed.

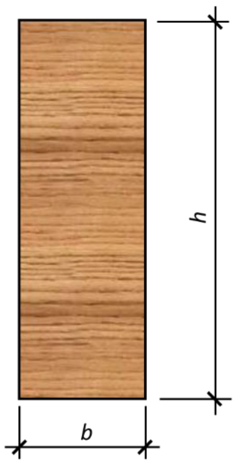


Timber section:

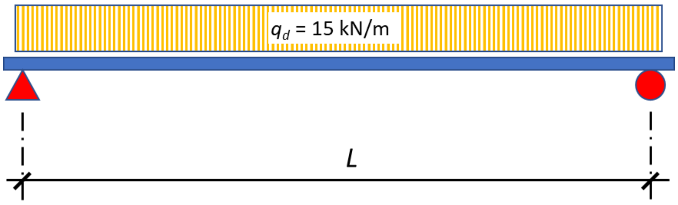
The design bending strength, f_d, of the timber is 20 MPa. The Young's modulus is *E*= 13000 MPa. The design bending moment capacity of the beam section is:

$$M_{Rd} = f_d \cdot \frac{b \cdot h^2}{6}$$

Chose appropriate values of the height ***h*** and width ***b*** to balance the bending moment that affect the beam.
The relation between the dimensions should be: $b \leq h/5$.



Task 1a: Estimate the necessary dimensions, for the ultimate loading case (ULS), for the three different materials for a simply supported beam according to the figure below.



Task 1b: Check if the deflection criteria (SLS, assumption short-term loading) at the mid span of the simply supported beam as illustrated in Task 1a, is fulfilled for the chosen cross-sections in Task 1a, for the three different materials, with:

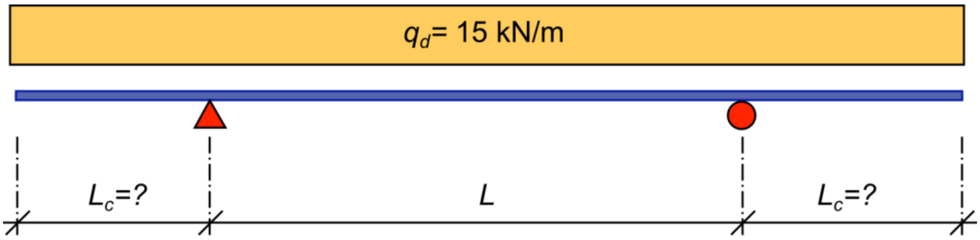
$$u_{requ} = \frac{L}{300},$$

$$u_{est} = \frac{5}{384} \frac{q_{d,SLS} \cdot L^4}{E \cdot I}$$

The SLS design load can be assumed to 60% of the ULS load, i.e. $q_{d,SLS}$= 0.6*q_d
Estimate the necessary cross-section dimensions, if the deflection criteria is not fulfilled.

Task 2a: Choose the length of the cantilever, L_c, in order to have the same absolute value for:

- the negative hogging moment above the supports, M_h, and
- the positive sagging moment, M_s.



Task 2b: Estimate the necessary dimensions for the three different materials for the beam given in Task 2a. The design distributed load (ULS) is q_d = 15 kN/m.

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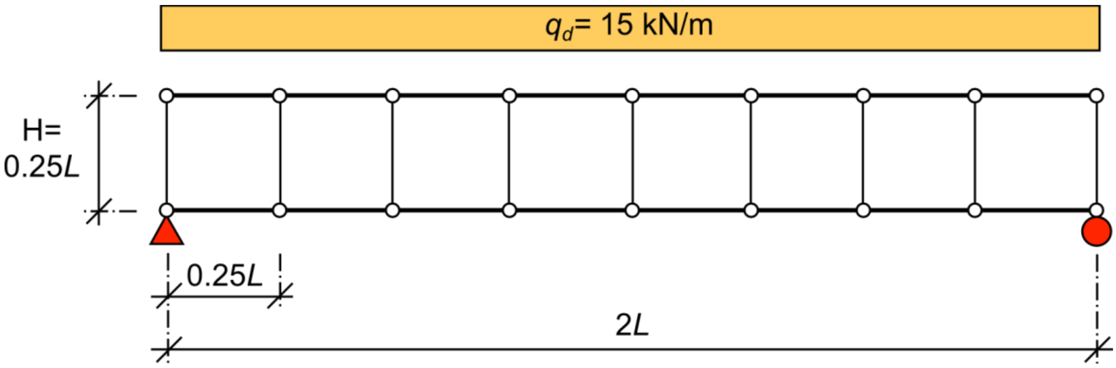
Task 3: Estimate the necessary dimensions for the upper and lower chord, and the diagonals of the truss given in the figure below. The design distributed load (ULS) is q_d = 15 kN/m, and acts only in the nodes of the chord.

The upper and lower chord are of timber with quadratic cross-section. The design compression/tensile strength is *fc/t,d*= 13 MPa.

The diagonals are of circular steel bars (take only tension). The design yield strength is *fy,d*= 460 MPa.



<u>Tasks:</u>

- Add to the above sketched truss, diagonals to provide a stable system, in which the diagonals are loaded in tension only.
- Estimate the cross-section dimensions for the upper and lower chord.
- Estimate the cross-section dimensions for the diagonals.

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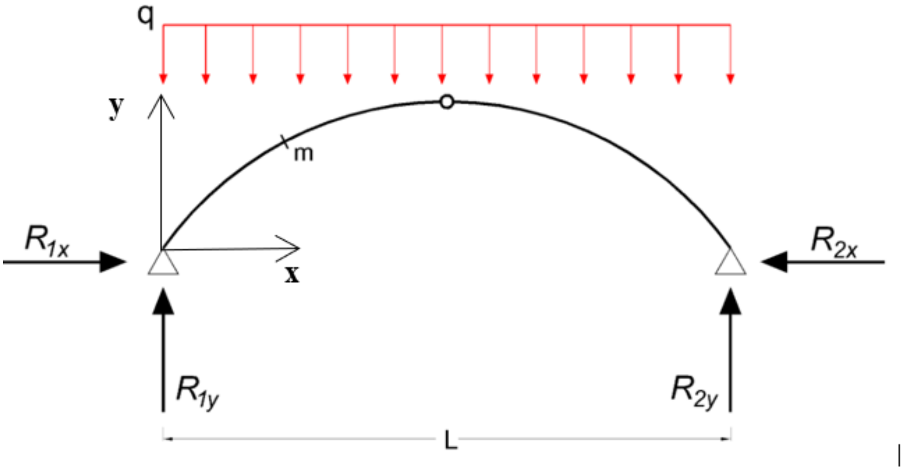
Task 4: Estimate the necessary dimensions for the three different materials for the bending moment M_m in the three-hinged arch according to the figure below (the arch is hinged at the supports). The length L is 40 + the number of the month of your birth date, (*e.g. 40 + 5 = 45 (m) for the month of May*). The design distributed load, q_d, is 24 kN/m. The height of the arch (y_c) is $L/4$, and the shape may be assumed to be circular, with radius r.
The maximum bending moment M_m can be assumed to be at $x_m = L/8$.



The bending moment is calculated according to the formula below.

Bending Moment	Support Reactions
$M_m = (q\,L^2 / 8)\,(4\,(x_m / L - (x_m / L)^2) - y_m / y_c)$ *where* M_m = *moment at m (Nm,)* q = *continuous load (N/m,)* x_m = *x-coordinate for m (m,)* y_m = *y-coordinate for m (m,)* y_c = *y-coordinate for center hinge (m,)* L = *horizontal distance between the supports (m,)*	$R_{1y} = R_{2y}$ $= q\,L / 2$ *where* R = *support force (N,)* $R_{1x} = R_{2x}$ $= q\,L^2 / (8\,y_c)$

The radius r of the arch is defined as:

$$r = \frac{4y_c^2 + L^2}{8y_c}$$