# CIV102F Assignment # 5 – October 11-13, 2022

Due October 18-20, (before assigned tutorial) ,2022

## General Instructions

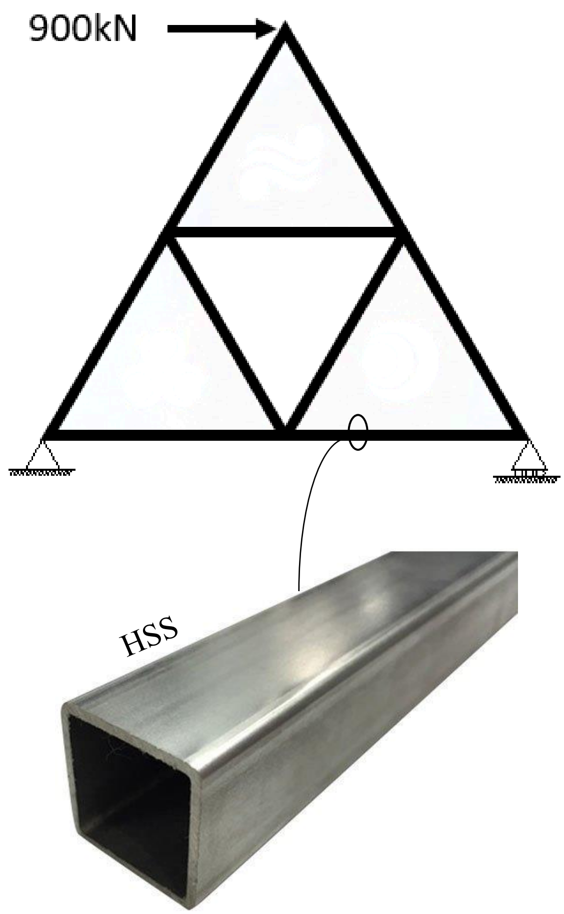
- There are five questions on this assignment. All questions must be attempted; however, only one question will be graded.
- Submissions which are incomplete and do not contain a serious attempt to solve each question will receive a grade of 0.
- Intermediate steps must be provided to explain how you arrived at your final answer. Receiving full marks requires both the correct process and answer.
- All final answers must be reported using slide-rule precision (ie, four significant figures if the first digit is a "1", three otherwise), and engineering notation for very large or very small quantities.
- Submissions must be prepared neatly and be formatted using the requirements discussed in the course syllabus. Marks will be deducted for poor presentation of work.

## Assignment-Specific Instructions

- Final answers **must** be provided in a neat sketch of each structure with the member forces written in. Tension members should be indicated as (+) and compression members should be indicated as (-)

**Truss Design**

**1.** In the truss structure shown below, all members have the length 4000 mm, $\sigma_{yield}$ = 350 MPa, E = 200,000 MPa.




**a)** Solve for member forces in all 9 members and identify the member with the largest tensile force and the largest compressive force.

**b)** Multiply the largest force from part a) by the $FOS_{yielding}$ = 2 and calculate the **required cross-sectional area (A)** such that yielding will not occur. Provide your answer for the *required cross-sectional area (A) in mm$^2$*.

**c)** Multiply the largest compressive force from part a) by the $FOS_{buckling}$ = 3 and calculate the **required second moment of area (I)** such that buckling will not occur. Recall that the force required to cause a member in compression to buckle is:

$$P_{cr} = \frac{\pi^2 EI}{L^2}$$

Provide your answer for the *required second moment of area (I) in 10$^6$ mm$^4$*.

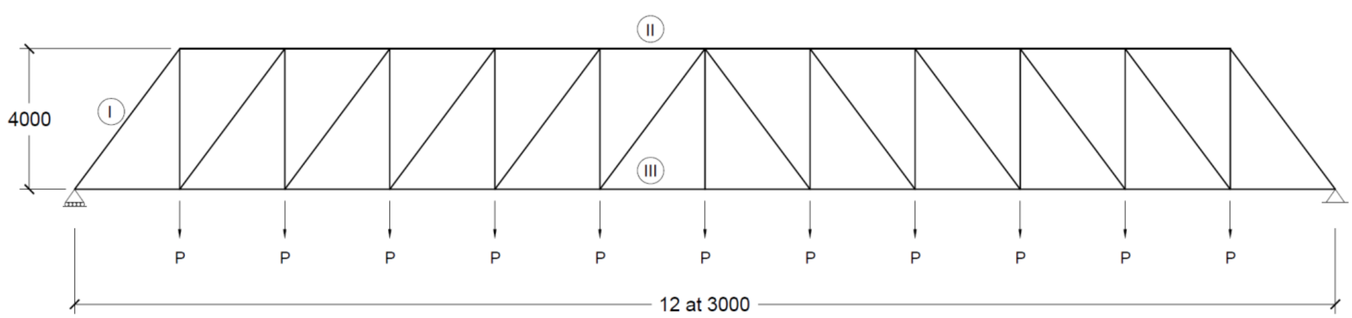
**d)** For the longest member in the structure, calculate the **required radius of gyration (r)** such that the minimum slenderness ratio is less than 200. Recall that the slenderness ratio is the ratio between the length the member and radius of gyration (L/r). Provide your answer for the *required radius of gyration (r) in mm.*

**e)** Using Appendix B from the course notes, pick the lightest square hollow structural section (HSS) designation such that the chosen HSS has a higher area (A), second moment of area (I), and radius of gyration (r), than those required in parts b) c) d).
(E.g., HSS 305×305×9.5 has an area A = 11 000 mm$^2$, a second moment of area I = 158 × 10$^6$ mm$^4$, and a radius of gyration r = 120 mm. This choice will likely satisfy all three requirements from parts b), c), d), but it is also likely not the lightest choice since it weighs 86.5 kg/m.)

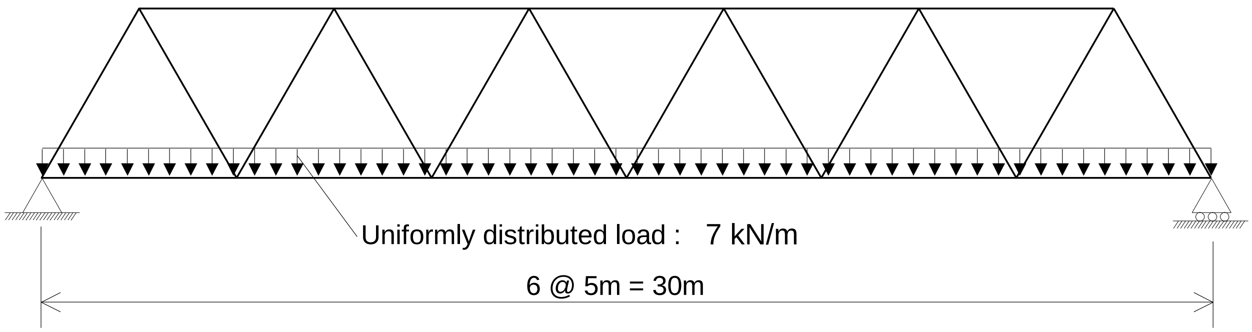
**2.** Consider the truss bridge shown below. The truss members identified as I, II and III have the largest member forces and will hence govern how much load the bridge can carry. All members are made of steel which have $\sigma_{yield}$ = 350 MPa, E = 200,000 MPa, A = 2000 mm$^2$ and I = 5.6×10$^6$ mm$^4$. All dimensions provided are in mm.

**a)** Solve for the forces in I, II and III using the method of joints (I) and method of sections (II and III) in terms of P.

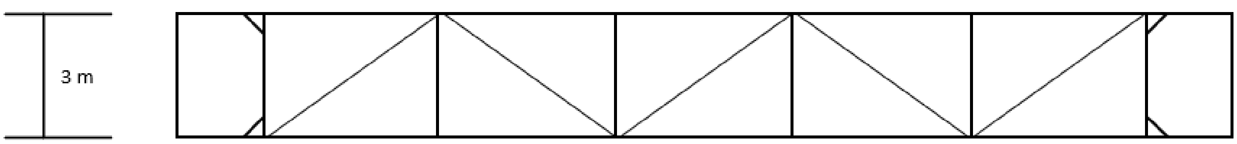
**b)** Calculate the value of P which would cause the bridge to fail. Failure may occur if the member stress exceeds the yield strength (in both tension or compression), or if a member in compression buckles. Factors of safety are ignored when the exact failure is to be determined.



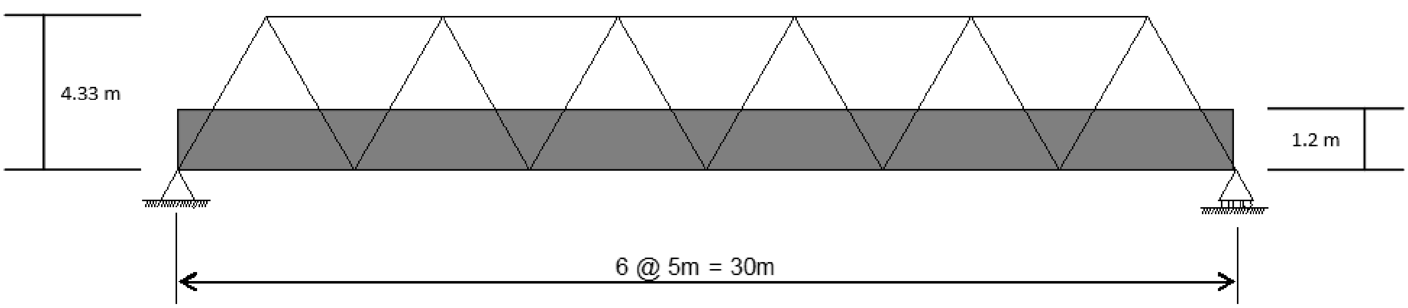
**3.** Consider the truss already analyzed in Q3 of Assignment 4:
**a)** Choose one HSS designation that can safely resist the forces and satisfy slenderness requirements (L/r < 200) for all truss members in the top chord (the 5 horizontal trusses at the top)
**b)** Choose one HSS designation for all truss members in the bottom chord (the 6 horizontal trusses at the bottom)
**c)** Choose one HSS designation for all diagonal truss members (12 total)



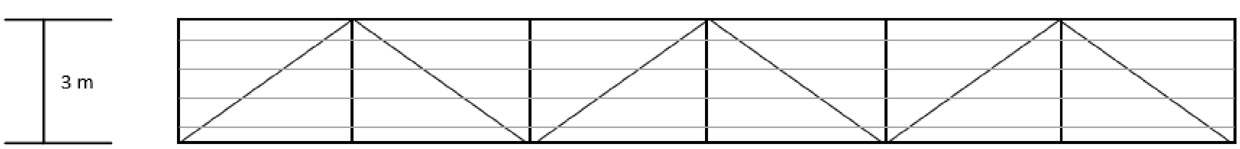

**Truss Analysis and Design for Lateral (Wind) Loading**
**4.** Consider the truss designed in Q3 and shown in more detail below:
**a)** Calculate the applied joint loads due to a wind load of 2 kPa at each joint of the elevation view. The truss bridge has a 1.2 m tall railing. Note: to calculate the applied joint loads, you will need the geometry of the HSS chosen in Q3.
**b)** Analyze the truss forces in the top braces and bottom braces. Present your final member forces on truss diagrams. Denote tension forces with (+) and compression with (−). Note: it is not necessary to solve for the forces in the horizontal members (when looking at the top / bottom view) caused by the wind.
**c)** Choose one HSS designation for both the top and bottom braces.




Top View (showing top braces)




Elevation View




Bottom View (showing bottom braces)

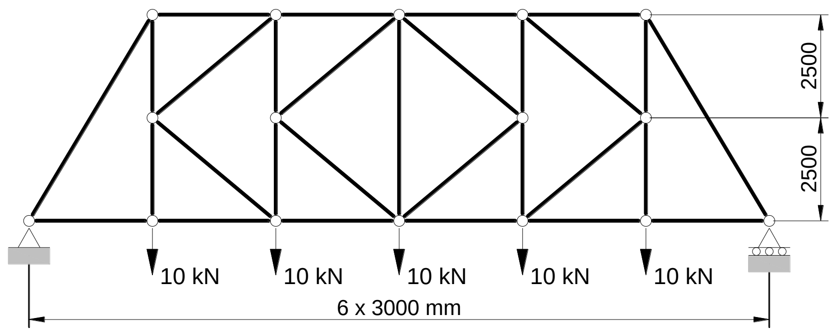
**Iterative Design Process**

**5.** Considering the HSS chosen in Q3 and Q4, calculate the weight of all truss members (there are two side trusses for a truss bridge). Divide this weight by the length of the bridge (L = 30 m) to calculate the load contribution of the truss members in kN/m.

The initial estimate of 7 kN/m (on each side truss) contained contributions from pedestrians, 5 kN/m, decking and railing material, 1.5 kN/m, and self-weight of truss members, 0.5 kN/m. Now that you've chosen the HSS for all truss members and calculated the self-weight, comment on whether your design is still safe. If not, how would you reiterate the design process?

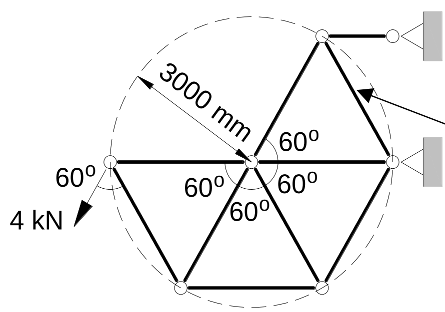
**Truss Analysis Sample Problems (OPTIONAL)**

**6.** Solve for the loads in all the members of the following trusses. Write the calculated member loads on a diagram of the truss. Use (+) for tension and (-) for compression.




**Ans:** The middle vertical truss has a tension force of 5 kN. The two middle horizontal trusses have compression forces of 24 kN.

**7.** Solve for the loads in all the members of the following trusses. Write the calculated member loads on a diagram of the truss. Use (+) for tension and (-) for compression.




**Ans:** 8 kN in compression