CIV102F Assignment # 8 – November 1-3, 2022

Due Wednesday November 15-17, (before assigned tutorial), 2022

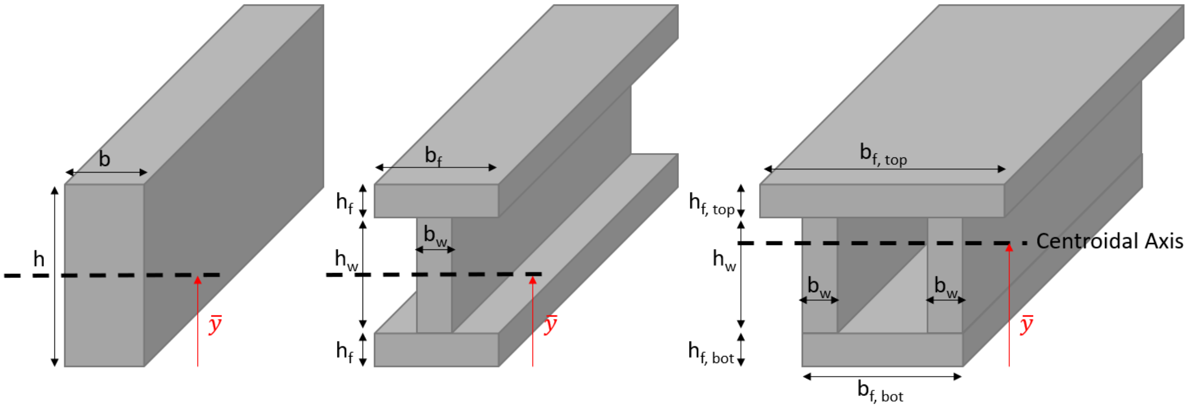
General Instructions

- There are FOUR 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

- For questions requiring the bending moment diagram and shear force diagram, key values must be labeled (i.e. local minima/maxima)
- In the second question in Q2, the change in I at point B will cause the curvature to abruptly change there as well. Don't forget that $\phi = M/EI$.

1. For the cross-sections of the three beams shown, calculate the location of their centroidal axis, $\bar{y}$, and their second moment of area, I, based on their dimensions. The cross-sectional areas, A, have been provided for reference. Your formulas for I can (should) contain $\bar{y}$ as a variable when needed. For the 3rd beam, $b_{f,top}$ and $b_{f,bot}$ can be abbreviated to b_t and b_b.

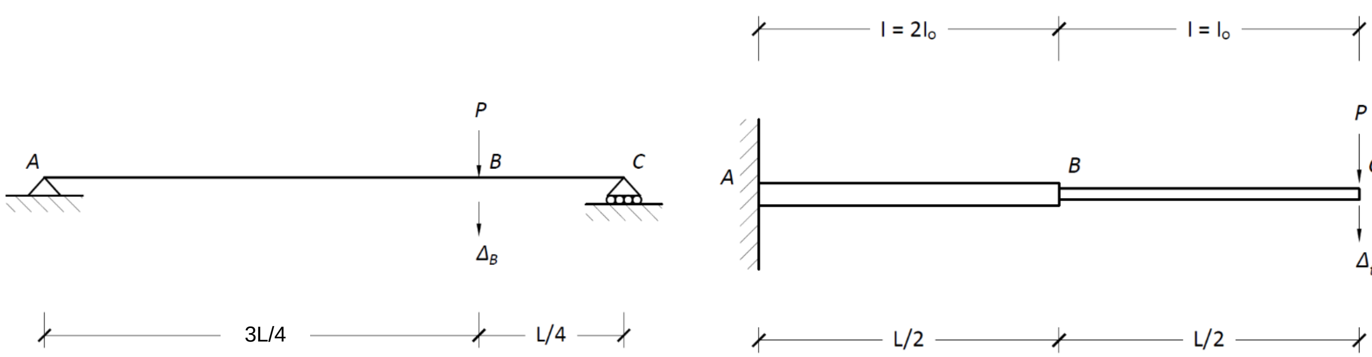


$A = bh$
$\bar{y} = ?$
$I = ?$

$A = 2b_f h_f + b_w h_w$
$\bar{y} = ?$
$I = ?$

$A = b_{f,top}h_{f,top} + 2b_w h_w + b_{f,bot}h_{f,bot}$
$\bar{y} = ?$
$I = ?$

2. For the two beams shown below, draw the shear force diagrams, bending moment diagrams and curvature diagrams. Calculate the unknown displacements shown on each figure. Express your results in terms of P, L, E and I (I_o for the cantilever on the right).



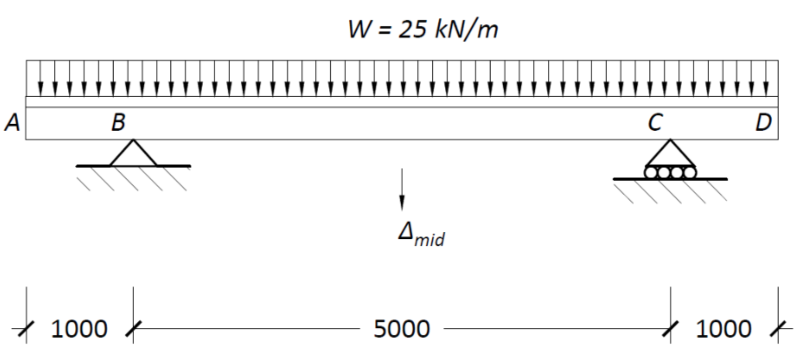
3. For the following beam, E = 30,000 MPa and ignore self-weight of the beam. All dimensions are in mm.

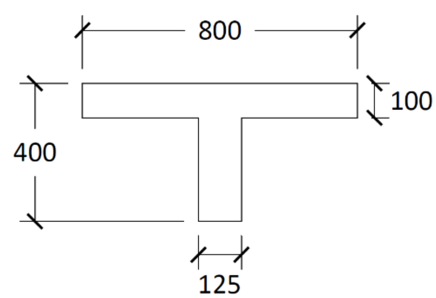
a) Draw the shear force diagram, bending moment diagram and curvature diagrams.

b) Calculate the location of the centroidal axis and the second moment of area.

c) Draw the flexural stress profile at mid-span and at support B.

d) Calculate the mid-span displacement and the slope of the beam at points B and C. Sketch out the displaced shape and also indicate the points of inflection.

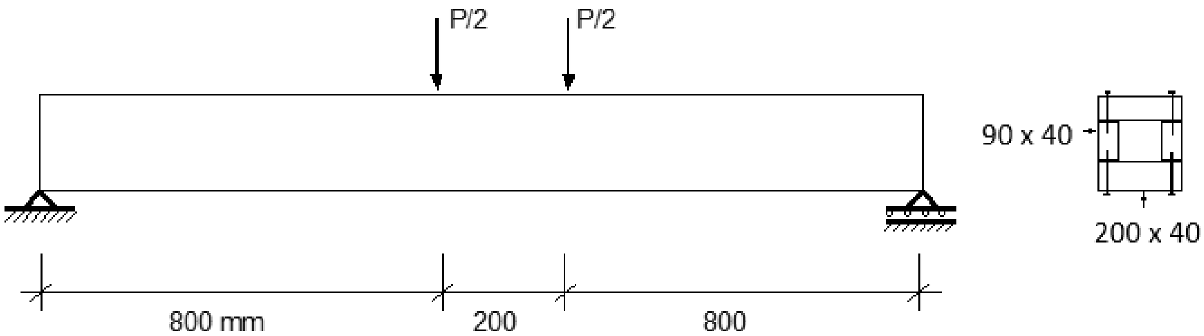


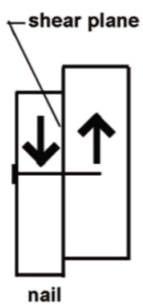


4. A 170 mm wide x 200 mm deep beam has been fabricated by nailing together four pieces of wood, as shown below. It will be used to support two concentrated loads, each having a magnitude of P/2. The allowable bending stress for the wood is 6 MPa, the allowable shear stress in the wood is 0.6 MPa, and the allowable force on each nail acting in shear is 725 N. Nails are spaced at 125 mm along the length.

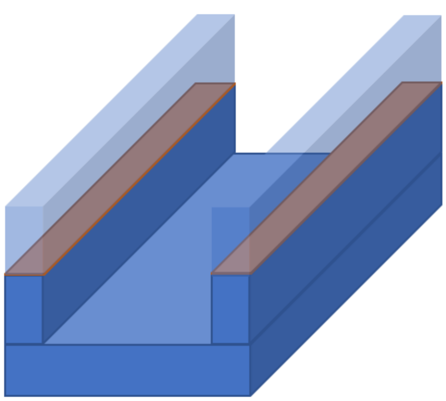
a) Determine the maximum value of P that can be safely carried by the beam before shear failure occurs in the wood or in the nails. Be sure to draw and label a profile of the shear stress distribution at the relevant sections.

b) If the nails were all removed and the pieces were glued together, what would be the allowable shear strength of the glue required to carry the load P determined in part A.

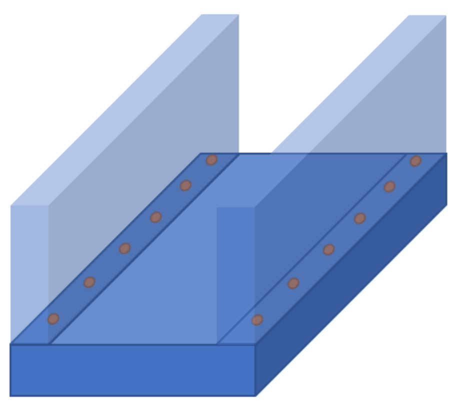




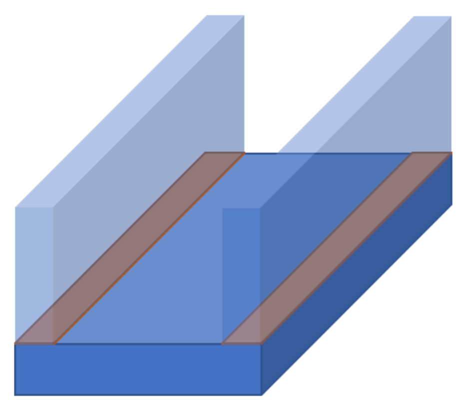
Sketch showing shear failure of a nail



Shear failure surface through wood. Q4 a). Top piece not shown for clarity

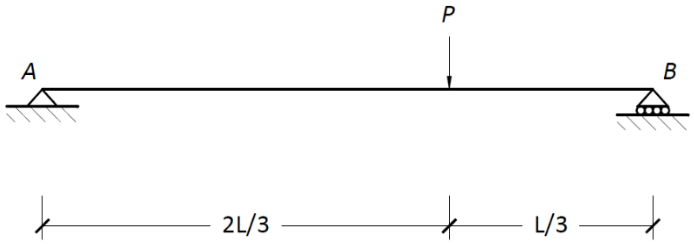


Shear failure surface through nails. Q4 a)

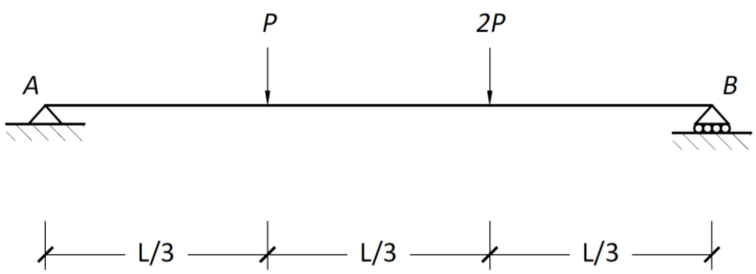


Shear failure surface through glue. Q4 b)

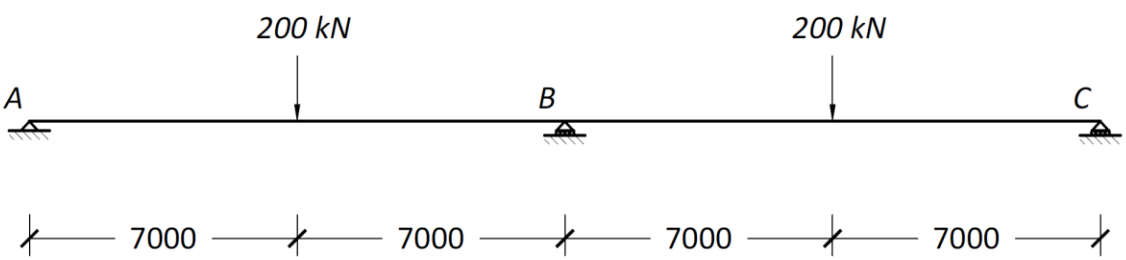
5 (OPTIONAL). Determine the location of maximum displacement in the following beam and calculate it. Calculate the slopes at points A and B. Express your answers in terms of P, E, I and L.



6 (OPTIONAL). Determine the location of maximum displacement in the following beam and calculate it. Calculate the slopes at points A and B. Express your answers in terms of P, E, I and L.

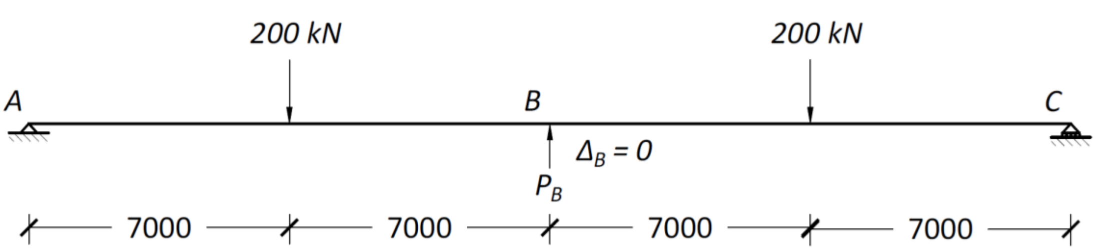


7 (OPTIONAL). Shown below in System 1 is a statically indeterminate beam – there are four unknown reaction forces, which cannot be solved by the three equilibrium equations alone. All dimensions are in mm.



System 1: Statically indeterminate beam

The statically indeterminate beam in System 1 is equivalent to System 2 shown below, which is a simply supported beam where the upwards force P_B causes the downwards displacement at point B to be zero.



System 2: Statically determinate beam with displacement constraint

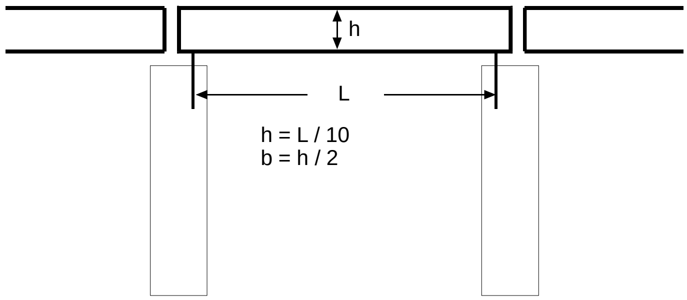
Solve for the following:

a. Find Δ_B in System 2 due to the two downwards point loads only. Remove the upwards force P_B.

b. In System 2, remove the two 200 kN point loads and solve for P_B which would cause an upwards displacement Δ_B equal to the downwards displacement found in part (a).
c. From your results in parts (a) and (b), draw the shear force and bending moment diagrams for system 1.

Perform your calculations assuming the E = 200,000 MPa and I = 1.00×10^9 mm^4.

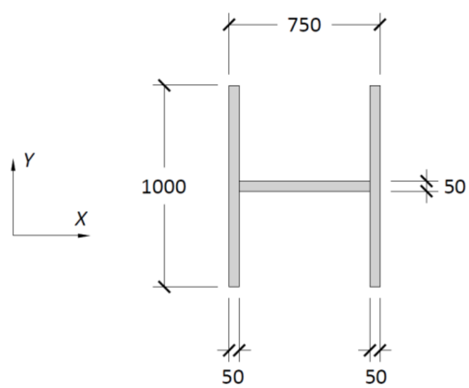
8 (OPTIONAL). You have been transported back to Athens in 500 BC where your engineering talents are appreciated. The city has commissioned you to design a spectacular monument, something like Stonehenge, to sit on top of a hill.



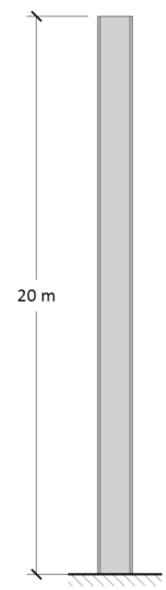
You have decided to use a series of simply supported, rectangular, granite beams. To achieve a pleasing appearance you choose to make the depth of the beams 10% of the span and the width of the beams 50% of the depth. The beam supports only its own weight. Using a factor of safety of 4 what is the longest span stone beam that can be designed?

9 (OPTIONAL). Shown to the right is a large I-shaped tower built of 3 oak pieces fastened together. A large wind applies a pressure of 2 kPa onto the tower, and this wind can blow in both the *x*- or *y*- directions.

a. In the x- direction calculate the load per metre of height along the tower and draw the shear force diagrams and bending moment diagrams. Calculate the highest tensile and compressive flexural stresses in the oak wood.
b. Repeat part a, but in the y-direction.
c. Based on your results from parts a and b, calculate the factor of safety against failure of the oak tower. Assume in this calculation that the wind can only blow in either the x- direction or y- direction, and not both.

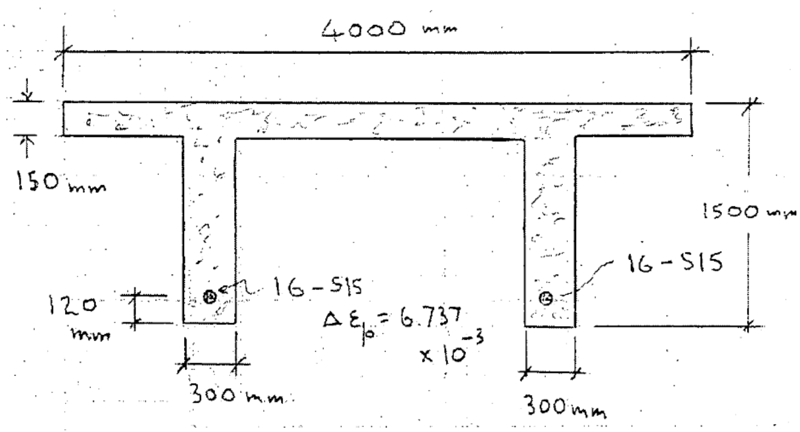


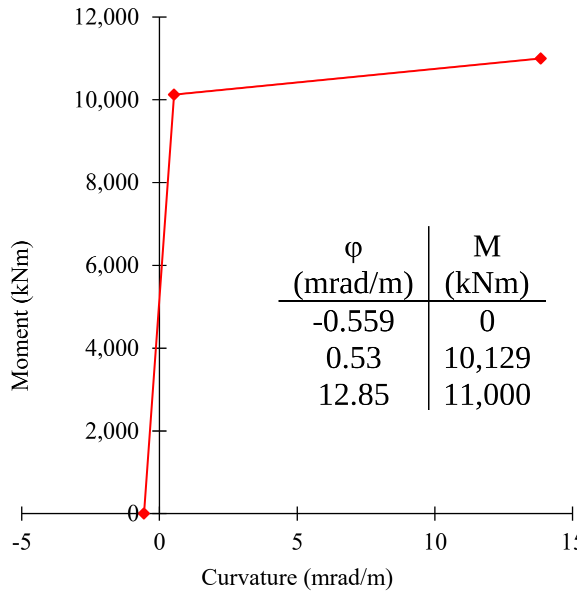
Cross Section View



Elevation View

10 (OPTIONAL). Shown below is the cross section of a prestressed concrete "double-tee" girder which is a simply supported 30 m long pedestrian bridge. Concrete structures crack under small tensile stresses, and although reinforcing them with steel permits them to carry loads following cracking, the bending stiffness EI is reduced as the structure is loaded to failure. Thus, it is common for structural engineers to compute the changing relationship between the moment and curvature. A plot showing this relationship is shown below, with the structure failing at a moment of 11,000 kNm (note the units of curvature are shown in mrad/m or rad/mm × 10^{-6}). Key points are shown in the table in the figure.





Using the information in the description above and in the provided moment-curvature plot, complete the following:

a. The self-weight of the bridge causes a distributed load of w_{self} = 33.8 kN/m. Calculate the additional distributed weight, w, which is required to cause the bridge to fail at midspan.

b. Under the loading causing failure, draw the bending moment diagram and curvature diagram. Use the provided M-ϕ plot to obtain the curvature diagram. Label values on these two diagrams at every 1.5 m along the 30 m length (only label values on half distance due to symmetry).

c. Estimate the midspan deflection at failure. Use the Appendix F of the course notes when estimating the areas and centroids under the curvature diagram.
Don't use the trapezoid rule as it will take too much time – instead approximate the area using simple shapes. Use your judgement!