LMAPR2020: Second homework on influence of shape in material selection

Practical details for report :

Questions are to be answered per team.

Report should be maximum around 5 pages.

Accepted formats : PDF or clean and readable scan of handwritten report compiled in a single PDF.

Upload the file to the corresponding homework on Gradescope by 21/04 (before 12 pm)

1. **Impact of shape** - *Stiffness-limited design*

   Derive the shape efficiency factor for each of the shapes given below for a stiffness-limited design of a beam loaded in bending. To do so:

   a. Explicitly derive the expression for the second moment of inertia I for each shape about the axis shown as a dotted line. *Hints: To simplify the calculations, you can make use of the parallel axis theorem and associated results (not explained in Ashby's book). Moreover, the inertia of a hollowed structured is equal to the inertia of the full section minus the inertia of the hollowed section.*
   For the hollowed square, prove that the 2 techniques lead to the same result. (Note: assume that the thickness t is much smaller than the other dimensions).

   b. Derive each shape efficiency factor for ϕ_B^e and compute its value.

   c. Compare the different cases.

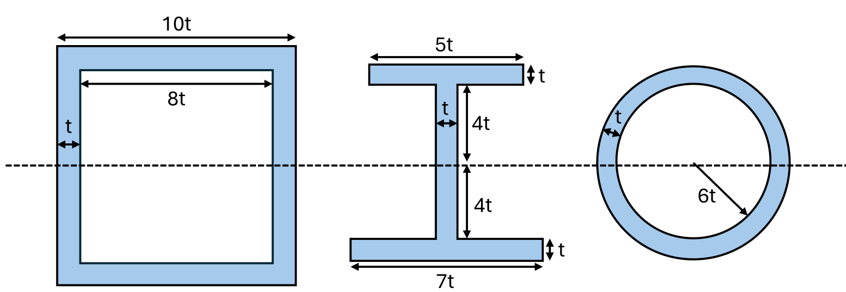


Figure 1: Shapes of the beam loaded in bending.

2. **4-quadrant chart**

   a. Use the 4-quadrant chart for stiffness-limited design shown in Figure 2 to compare the mass per unit length m/L of a section with $EI = 10^4 Nm^2$ (where I is the second moment of inertia) made from

      - steel with a shape factor Φ_B^e of 1, Young's modulus $E = 200\ GPa$, and density $\rho = 7900\ kg/m^3$

- aluminum alloy with a shape factor Φ_B^e of 1, Young's modulus $E = 70\ GPa$, and density $\rho = 2700\ kg/m^3$
- hard wood with a shape factor Φ_B^e of 10, Young's modulus $E = 23\ GPa$, and density $\rho = 900\ kg/m^3$

b. Show that the linear density can be computed using the values given above for the 3 materials. Verify the consistency of these values with those obtained using the 4-quadrant technique.

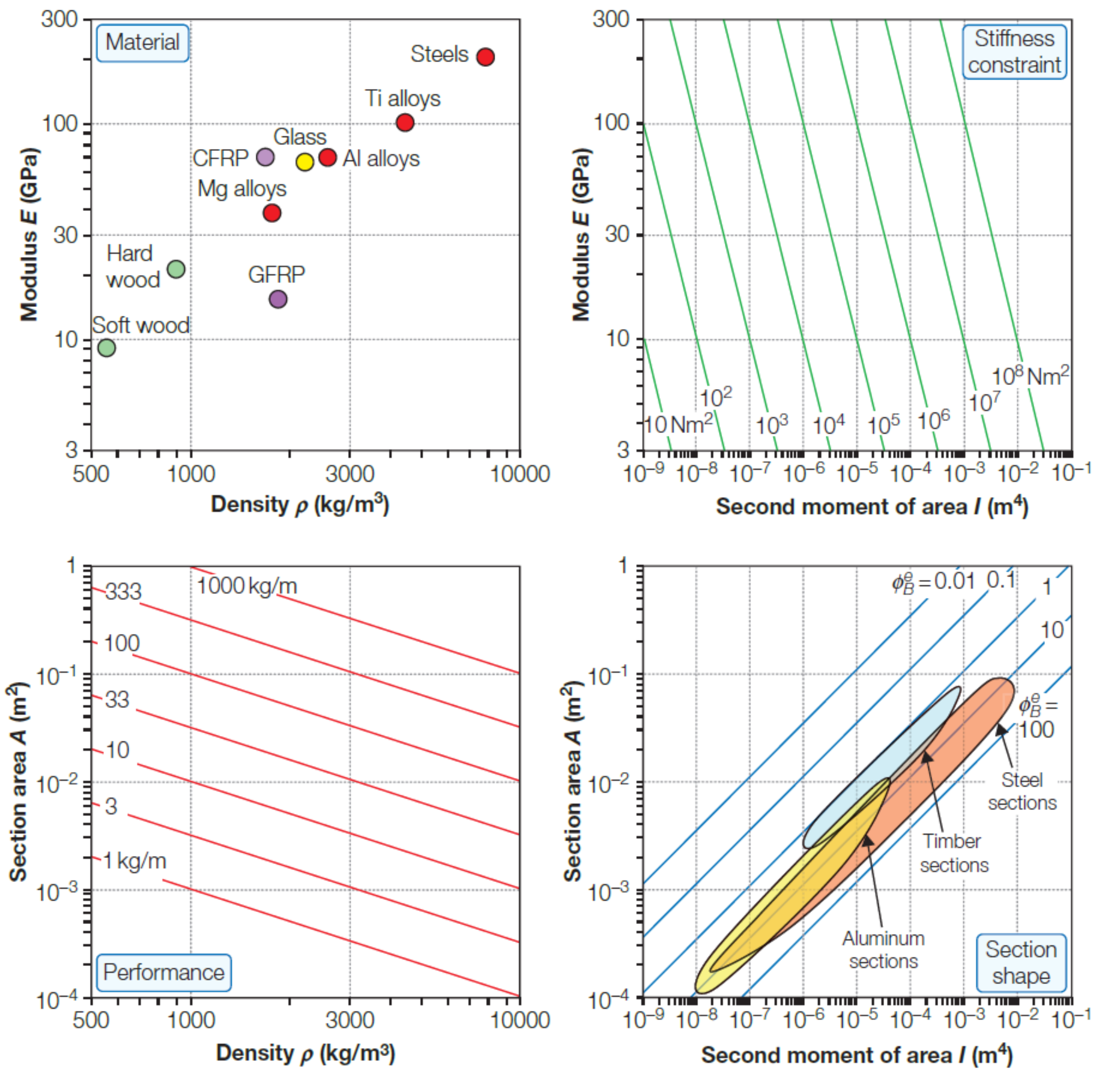


Figure 2: Illustration for exercise 2

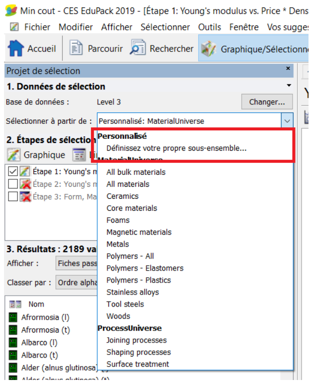
3. **Deriving indices with shape factor** - *A cheap and stiff beam*

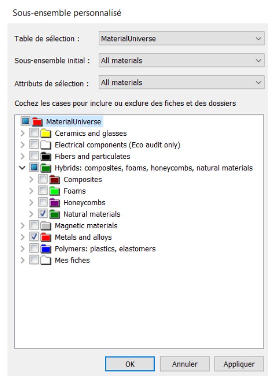
A beam of length L must be as light as possible. The stiffness constraint requires the beam to meet a specified bending stiffness S*. Section shape is a variable.

a. Write down the specifications. *(no extra text needed)*

b. Derive the material index considering shape factor. *(no extra text needed)*

c. *In CES Edupack, work with natural materials and Metals & alloys families. (See figures below).* Select the best material without shape. *(Use a 2 axes graph with the line of material index and highlight the selected material)*





d. Create 2 pseudo-materials in CES Edupack (level 3) (one from each family), whose properties take into account the shape factor. Select the best (pseudo-)materials. *(Text is needed: explain your calculations, hypotheses, ...)*

e. Quantify the cost reduction considering the best material without shape (found at point c), and the best pseudo-material (found at point d). *(Text is needed: explain your calculations, discuss the results,...)*

f. Based on your previous answers and on your general knowledge, discuss the following pictures. **Highlight & discuss** <u>at least</u> 4 points *Note: Many parameters may be considered here, among those don't forget to discuss also historical considerations*

Sources:`https://www.pinterest.fr/pin/516014069790120878/` and `https://www.cornwall-erecting.co.uk`