MEC-E1070 Selection of Engineering Materials

Task 3: The effect of shape

Instructions: Check the following questions and exercises. Read chapters 9 and 10 in the 4th edition of the course textbook about the selection of material and shape.

Criterion: A good report on this task demonstrates a good understanding of:

- the meaning of shape factors, and consequently how to calculate them
- theoretical and practical considerations of how different shapes allow the use of materials efficiently
- how shape factors can be used to take the effect of shape into account in materials selection

Task 3.1.1: Calculate the shape factor for bending stiffness for Glass-reinforced plastic (GRP) bar, when the profile of the bar is:

a) solid square profile, width, and height 100 mm.
b) solid rectangle profile, width 500 mm, height 100 mm.
c) hollow square profile, outer width and height 100 mm, wall thickness 10 mm.
d) hollow round pipe, outer diameter 500 mm, wall thickness 10 mm.
e) a spar of the wind turbine blade, whose cross-section is either an I-beam with a width of 500 mm, height of 100 mm, flange thickness of 10 mm, and web thickness of 20 mm, or a box girder with a width of 500 mm, height 100 mm, wall thickness 10 mm

Note: Including the calculation procedure in your report is beneficial. In case you make mathematical mistakes at the end, there are still points for the correct solution steps.

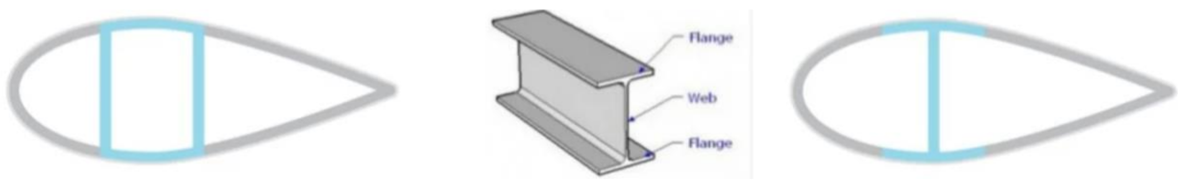

Figure 1 spar with a hollow rectangular and I-beam cross-section

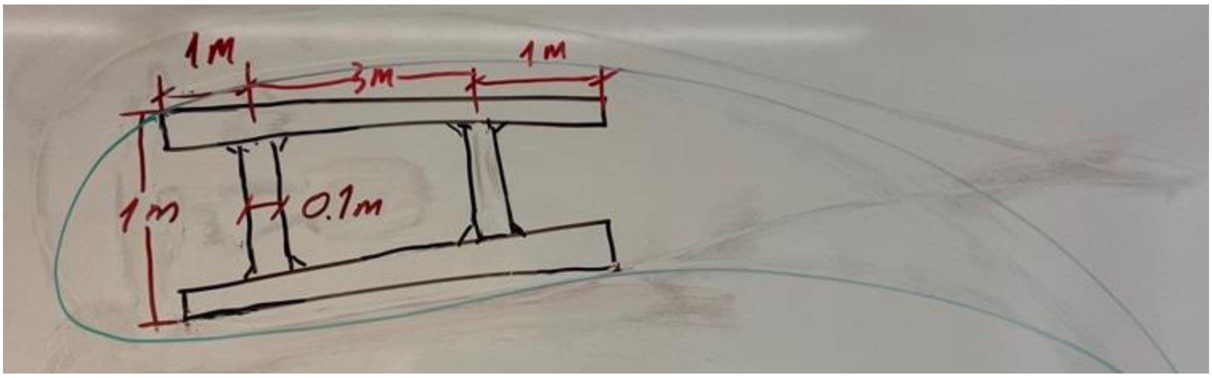

Figure 2 A box girder spar with dimensions

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Task 3.1.2: First, **apply all 5 profiles** to the "level 2" bending stiffness map for the **GRP bar**. Then, **select 2 profiles** with **2 different materials** (e.g., Carbon-fiber-reinforced polymers (CFRP) and 6061 T6 aluminum), and **add** these **4** records to the GRP bending stiffness map. **Compare** the overall **9** records among these **3** materials, and **discuss** your observations regarding the locus of these points on the selection chart, preferably with figures and tables.

Hint: Find the properties of each material, apply the calculated factors, and use the "Add records" tool (*Tools – Add records*) to construct the map.

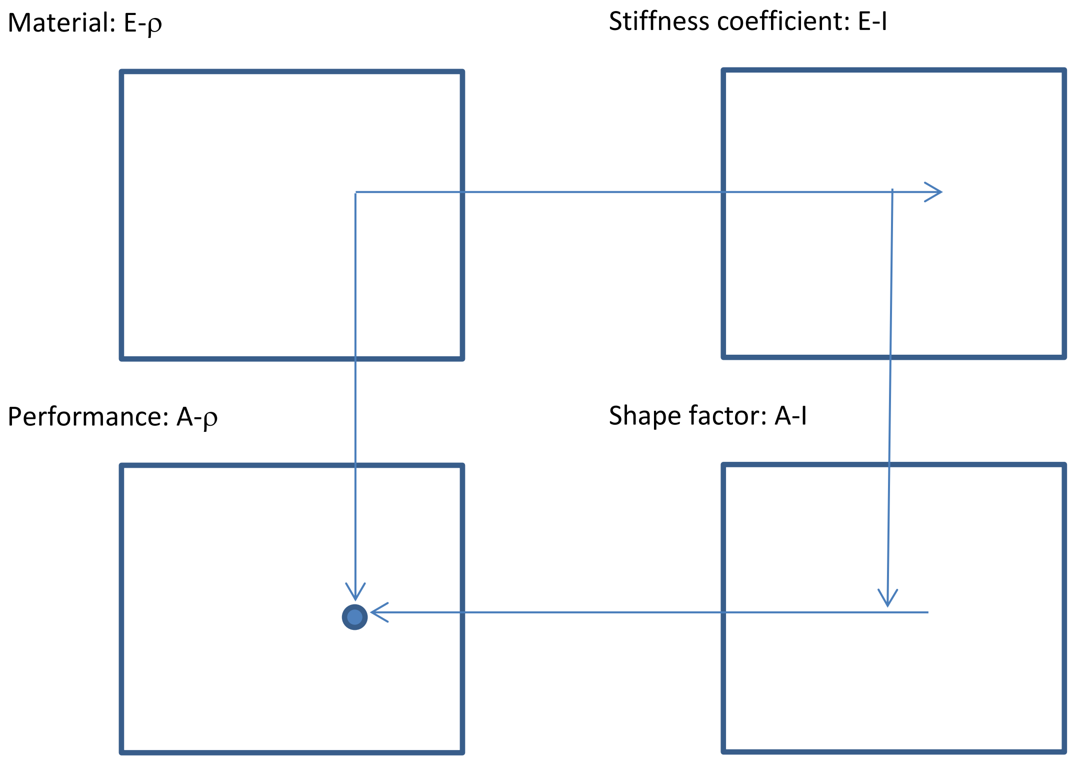
Task 3.2.1: **Calculate** the theoretical maximum shape factor for a low alloy steel, aluminum, CFRP, and wood, according to equation 9.15a from the textbook (4th edition): $(\varphi_B^e)_{max} \approx 2.3\left(\frac{E}{\sigma_f}\right)^{0.5}$.

Compare your results to the empirical maximum shape factors found in Table 9.4 of the textbook (4th edition) reproduced below. **Discuss** the extent to which theoretical and empirical results agree or differ.

Material	$(\varphi_B^e)_{max}$
Steel	65
6061 aluminum	44
CFRP	39
Polymer	12
Wood	5
Elastomers	<6

Task 3.2.2: Which of these materials, structural steel, aluminum, wood, or CFRP, would be the best choice for a bending beam? The beam must have a stiffness $S = EI_{max} > 10^7$ Nm^2 and the beam has to be as light as possible. Use the following shape factors in your solution: steel (I-beam) 15, aluminum (I-beam) 10, CFRP (tube) 10, and wood (beam) 2. Resolve the problem using the 4-field method, and present your answers together with the decision-making process with text and figures.

Hint: You do not need to draw the 4-field map by yourself, you can use the one from the book.



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