EINDHOVEN UNIVERSITY OF TECHNOLOGY

DEPARTMENT OF THE BUILT ENVIRONMENT
UNIT STRUCTURAL DESIGN

Intermediate test: Dimensioning of Structures (7PPX2)
Date: December 2, 2016
Time: 13.45 – 15.15 h

SURNAME:
INITIALS:
ID.NR.:

Part Applied Mechanics

Assignments and answer sheets

First read the following terms and conditions regarding writing and submitting the replies of the test!

- write your surname including initials and identity number of your study card clearly on the top of this front page
- page 7 and 8 are scrap paper, this will not be graded by the lecturer
- for open questions, only place the answers in the input fields and / or tables and / or figures, which should be done neatly and clearly readable; other notes on the answer sheets will not be graded
- for multiple-choice questions, clearly check a box only; other comments will not be taken into account
- graphs and sketches drawing to scale in the pre-printed characters
- only a single set of answer sheets per student is handed out, so think carefully first before writing down the answers
- **formulas see page 5**
- return the handed out assignment sheets with the answer sheets
- course book, notes, laptop, mobile phone, and similar are not permitted
- a non-graphical pocket calculator is permitted

Do not remove the staples
It is permitted to separate the scrap paper (page 7 and 8)

Assessment of the assignments of this applied mechanics part (25 points for Mechanics in total):
assignment 1: 2 + 2 + 1 + 2 + 2 points
assignment 2: 6 + 4 + 6 points

Assessment of the total intermediate test: total number of points (applied mechanics part and material part together) divided by five.
The total intermediate test contributes for 15% to the final mark.

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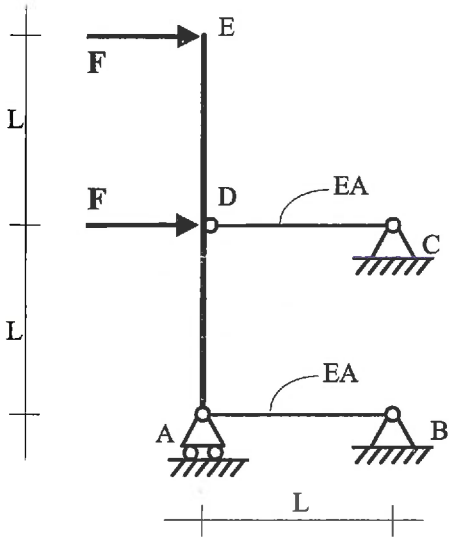
1. In the mechanical model below, the vertical beam ADE is continuous and infinitely stiff, so it cannot bend. Normal stiffness of bars AB and CD equals EA.



Furthermore for bars AB and CD :
$E = 2.1 \times 10^5$ N/mm^2
$A = 744$ mm^2
$L = 2.6$ m
$F = 12$ kN

1a) The forces in bar AB and CD have to be determined. For each of the statements below check the box whether they are correct or incorrect:

A The force in bar DC equals F as this force is on the left of bar DC and clearly works in the same direction.
1/2
☐ Correct ☒ Incorrect

B For finding the 5 unknown reaction components, at least 2 internal hinges have to be present. Then it doesn't matter which 2 are selected from A, B, C, or D for this.
1/2
☐ Correct ☒ Incorrect

C The 5 unknown reaction components can be calculated by using the 3 equilibrium equations $\sum H = 0, \sum V = 0, \sum M = 0$, and taking into account that in the internal hinges the bending moment equals zero.
1/2
☒ Correct ☐ Incorrect

D Taking into account that in the internal hinges the bending moment equals zero, in this particular case 2 equilibrium equations are enough to find the forces in bars AB and CD.
1/2
☒ Correct ☐ Incorrect

1b) Calculate the forces in rod AB and CD, and circle the correct answer for their values below (only a single answer is correct):

A $F_{AB}=2F$ (tension), $F_{CD}=3F$ (compression)
B $F_{AB}=F$ (compression), $F_{CD}=3F$ (compression)
C $F_{AB}=2F$ (tension), $F_{CD}=2F$ (compression)
2 **D** $F_{AB}=F$ (tension), $F_{CD}=3F$ (compression)
E $F_{AB}=F$ (compression), $F_{CD}=F$ (compression)

1c) Circle the character of the figure that qualitatively correctly presents the deformations of the mechanical model. Note that A_1, B_1, and C_1 are the final positions in the deformed model of the nodes A, B, and C of the undeformed model.

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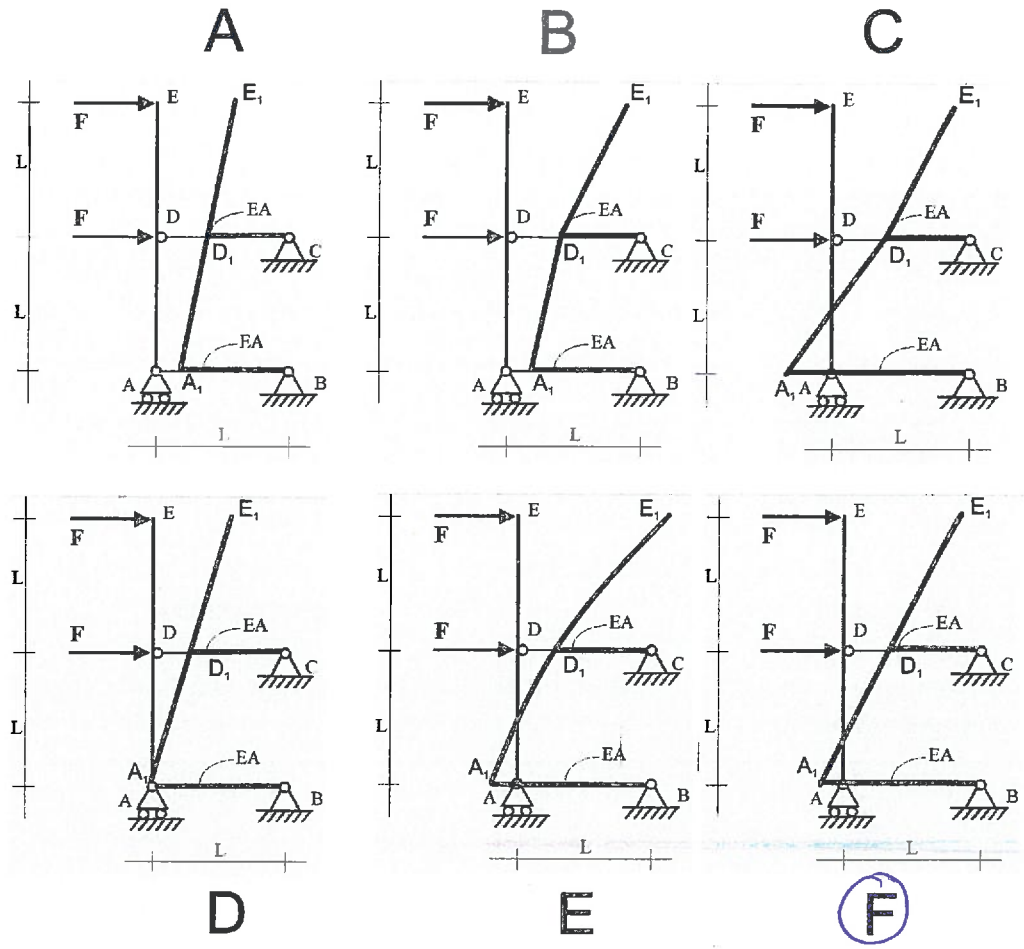

1

1d) **Assume** $F_{AB}=F$ **(tension) and** $F_{CD}=2F$ **(compression). Note that these values do not need to be the correct answers of question 1b. With this assumption calculate the changes of length of bar AB and CD and circle a single correct answer below:**

A $\Delta l_{AB} = 0.2$ mm $\Delta l_{CD} = 0.2$ mm

B $\Delta l_{AB} = 0.2$ mm $\Delta l_{CD} = 0.4$ mm

C $\Delta l_{AB} = 0.0002$ mm $\Delta l_{CD} = 0.0004$ mm

D $\Delta l_{AB} = 0.4$ mm $\Delta l_{CD} = 0.2$ mm

E $\Delta l_{AB} = 0.01$ mm $\Delta l_{CD} = 0.02$ mm

F $\Delta l_{AB} = 0.4$ mm $\Delta l_{CD} = 0.8$ mm

2

1e) **Assume** $\Delta l_{AB} = 0.1mm$ (tension) $\Delta l_{CD} = 0.3mm$ (compression) **Note that these values do not need to be the correct answers of question 1d. With this assumption calculate the displacement of node E and circle a single correct answer below:**

A $\bar{w}_{EH} = 0.40$ mm

B $\bar{w}_{EH} = 0.70$ mm

C $\bar{w}_{EH} = 0.10$ mm

D $\bar{w}_{EH} = 0.60$ mm

E $\bar{w}_{EH} = 0.61$ mm

2

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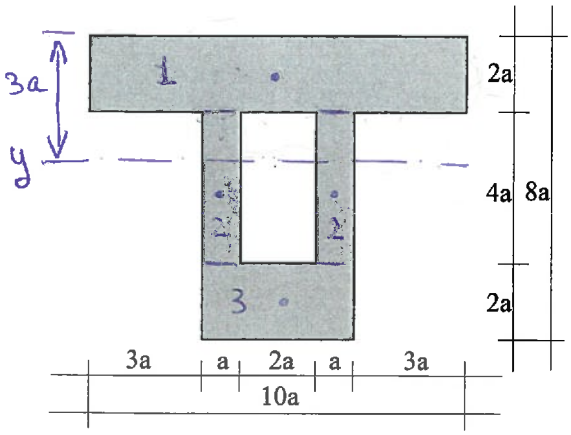
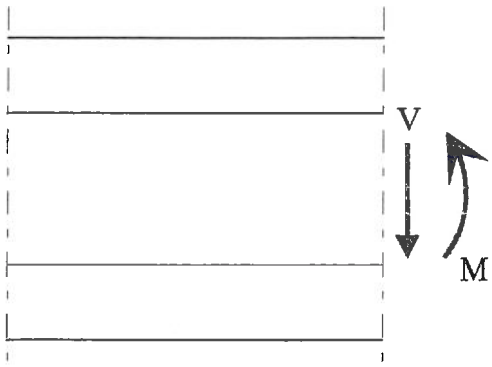
2. At the cross-section of the hollow-core beam below, a shear force V and a bending moment M act. The **horizontal line of gravity** is positioned at a distance $5a$ **from the bottom of the cross-section.**



cross section beam



side view beam

a. In the box below, derive the second moment of area I, relative to the horizontal line of gravity, to be equal to $236a^4$.

$$I_y = \frac{1}{12}\,10a\,(2a)^3 + 20a^2(2a)^2 + 2\cdot\frac{1}{12}\,a\,(4a)^3 + 2\cdot 4a^2\cdot a^2 +$$

$$\frac{1}{12}\,4a\,(2a)^3 + 8a^2(4a)^2 =$$

$$= a^4\left(\frac{20}{3} + 80 + \frac{32}{3} + 8 + \frac{8}{3} + 128\right) = 236a^4$$

b. In the box below, calculate the extreme bending stresses in the cross-section (expressed in M and a) and indicate clearly whether the stress is tension or compression.

TOP: $\sigma = \frac{M\cdot 3a}{236a^4} = \frac{3}{236}\frac{M}{a^3}$ COMPRESSION

LOWER EDGE: $\sigma = \frac{M\cdot 5a}{236a^4} = \frac{5}{236}\frac{M}{a^3}$ TENSION

c) Calculate the shear stress at the location of the transition from web to flange (so at distance $2a$ from the top of the cross-section) and calculate the maximum shear stress in the cross-section. Express all shear stresses in V and a. Make use of the box below.

2a FROM THE TOP: $\tau = \frac{V \cdot 10a \cdot 2a \cdot 2a}{2a \cdot 236a^4} = \frac{5}{59}\frac{V}{a^2}$ (1) (1/2) (1/2)

τ_{MAX} (GRAVITY LINE) (1)

$\tau_{MAX} = \frac{V(10a \cdot 2a \cdot 2a + 2 \cdot a \cdot a \cdot \frac{1}{2}a)}{2a \cdot 236a^4} = \frac{41}{472}\frac{V}{a^2}$ (1) (1) (1/2) (1/2)

OR

$\tau_{MAX} = \frac{V(4a \cdot 2a \cdot 4a + 2 \cdot a \cdot 3a \cdot \frac{3}{2}a)}{2a \cdot 236a^4} = \frac{41}{472}\frac{V}{a^2}$

Second moment of area rectangular cs. $I = \frac{1}{12}bh^3$, triangular cs. $I = \frac{1}{36}bh^3$, round cs. $I = \frac{1}{4}\pi(R_u^4 - R_i^4)$

Polar moment of area: $I_p = \frac{1}{2}\pi(R_u^4 - R_i^4)$

Formulae for stress: $\sigma = \frac{N}{A}$ $\sigma = \frac{Mz}{I}$ $\tau = \frac{VS}{bI}$ $\tau = \frac{Mr}{I_p}$

Formula for elongation: $\Delta\ell = \frac{N\ell}{EA}$

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