Exam CT3280 Shell Roofs
Minor Bend & Break, Delft University of Technology
2 February 2024, 9:00 – 12:00 hours dr.ir. P.C.J. Hoogenboom

A calculator is needed. It is allowed to use your report, notes, computer, tablet, software, internet and chatGPT during the exam. Obviously, it is not allowed disturb others or to communicate with others during the exam. It is not allowed to use a phone. It is not allowed to use software with which one can communicate with people.

1 We started the course by studying pine wood laths 4 mm x 8 mm, 500 mm long. Somebody will bend similar laths (dry and cold) to a curvature of 1/m. Will most break? Explain your answer.

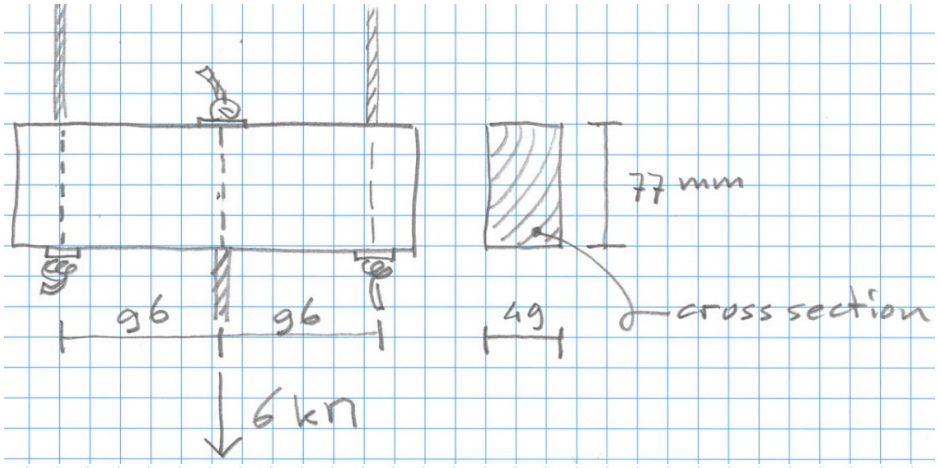
2 What is a spatkracht?

3 Which finite element analyses are useful to perform on a shell roof?

4 What is a knock down factor?

5 What was the self-weight of your shell model? (in grams or kg or N or N/m^2 or ...) How did you obtain this value? (Write down the calculation or refer to a page of your report.)

6 Check the calculation of a distribution wood (see figure below). The material is pine without knots. If there is a mistake, redo the calculation. Will this distribution wood break?

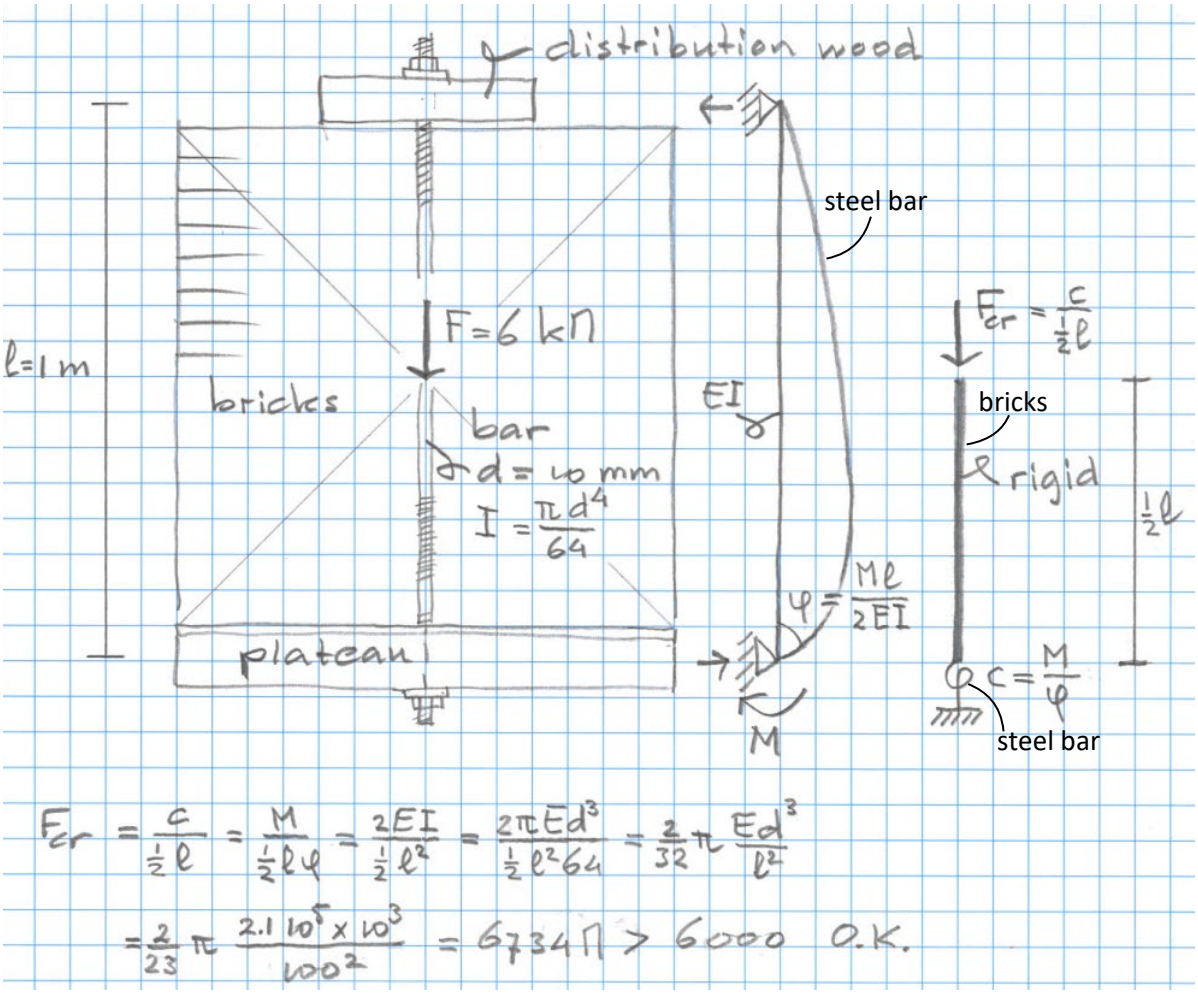


section modulus $W = \frac{1}{6} b h^2 = \frac{1}{6} 49 \times 96^2 = 75264\ mm^3$

moment $M = \frac{1}{4} F l = \frac{1}{4} 60000 \times 192 = 1895000\ Nmm$

bending stress $\sigma = \frac{M}{W} = \frac{1985000}{75264} = 26\ N/mm^2 < 50$ O.K.

7 Check the buckling calculation of the loading plateau (see figure below).
If there is a mistake, redo the calculation. Will this loading plateau buckle?



8 How did your shell model collapse? Did it buckle, crush or something else? How did you come to this conclusion? (Describe accurately what you observed. Refer to pages of your report.)

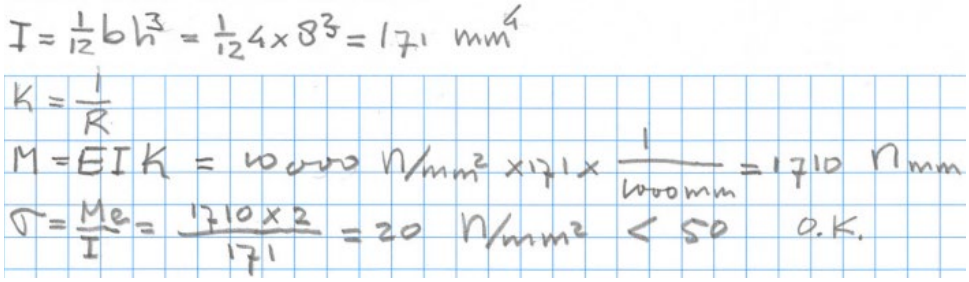
9 Suppose your large shell has been built. What will be the extra deflection due to 1 kN/m^2 snow load? Explain your answer. (Make calculations and refer to data on pages of your report.)

10 What is the largest size that your shell design can be built? (For example 12 times as large as the model.) Make a calculation. Include self-weight and 1 kN/m^2 snow load. Use a safety factor of 2 on the mean material strength or stiffness. Do not include wind load. Do not use a safety factor on self-weight or snow load.

Answers

1 No, none will break provided there are no knots: Trying out shows that many laths break at a sagitta of about 70 mm. The radius of curvature is s/2 + l^2/(8 x s) = 70/2 + 440^2/(8 x 70) = 381 mm, which is much smaller than 1 m.

Alternative answer: None will break because the stress is much smaller than the tensile strength.



2 The horizontal component of the force on a foundation exerted by an arch, truss or shell

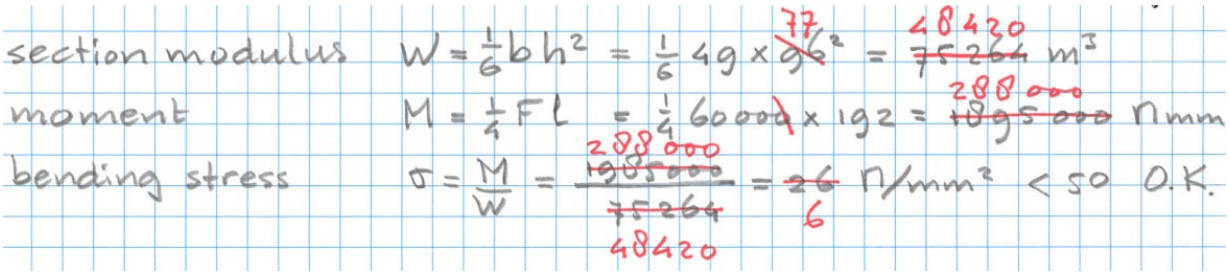
3 Linear elastic analysis, linear buckling analysis, non-linear analysis

4 A correction factor for including shape imperfections after calculating the buckling load of a perfect shell by the formula or by a linear buckling analysis

5 For example, the wood grid shell was approximately 300 gram. It can have been measured or calculated.

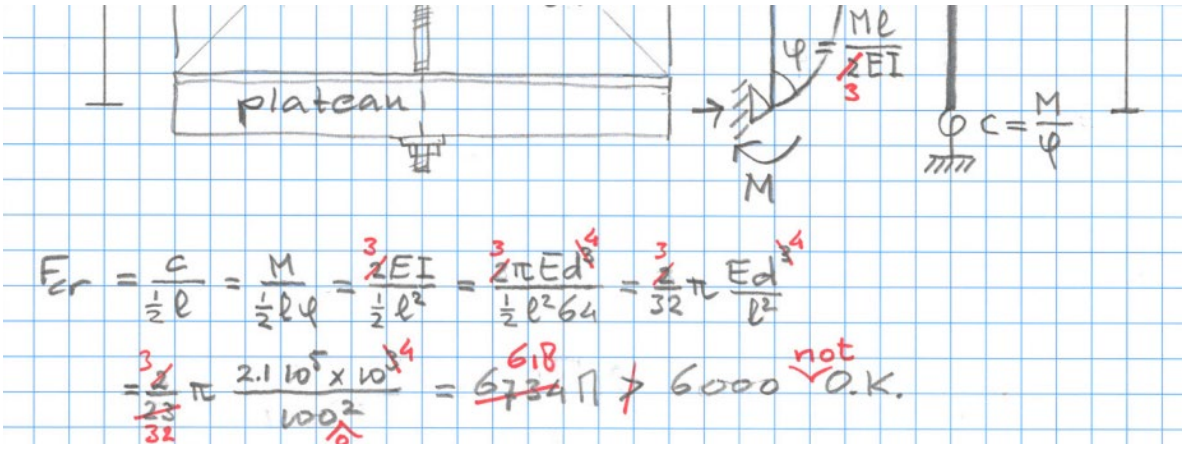
The calculation can go like this: Lath cross section 4 x 8 = 32 mm^2. The lath spacing is 80 mm. We consider a patch of 80 x 80 = 6400 mm^2. In this patch the material volume is 32 x 80 x 2 = 5120 mm^3. The length and width of the shell are 754 mm. The number of patches is 754 x 754 / 6400 = 89. A bit more because of curvature, say 100 patches. The total material volume is 100 x 5120 = 512 000 mm^3. Pine wood specific mass is 600 kg/m^3. The total mass is 0.000 512 m^3 x 600 = 0.307 kg.

6



It will not break.

7



It will buckle.

8 For example; part of the shell buckled and subsequently a row of laths broke in bending. We observed this in a movie made during the experiment (see photos page …).

9 For example; in the graph on page … the model deflects 3 mm at a distributed load of 1 kN/m^2. The real roof is 20 times as large. Therefore, the deflection of the real roof due to 1 kN/m^2 snow will be 20 x 3 = 60 mm.

10 See calculation example on the website: phoogenboom.nl/B&B_schaal_0.html

