Shell exam, 28 June 2021, 13:30 – 16:30 hours

1a A reinforced concrete planetarium dome has a diameter of 34 m and a thickness of 95 mm. Is it thin? Explain your answer.

Yes, 17000 / 95 = 179 > 30

1b A nuclear power plant has a spherical containment hull. The hull diameter is 16 m and its thickness is 7 mm. An accident happens and the inside over pressure is 0.42 N/mm2. What is the stress in the hull? Explain your answer.

n = ½ p a = ½ x 0.42 x 8000 = 1680 N/mm, σ = 1680 / 7 = 240 N/mm2

2a A shell is pinned at an edge. In this shell edge, large stresses occur. How is this phenomenon called?

edge disturbance

2b A shell has the following curvature. kxx = 1/(5 m), kyy = -1/(17 m), kxy = 1/(39 m). What is the Gaussian curvature? Explain your answer.

$k_G = k_{xx} k_{yy} – k_{xy}^2 = 1/5 \times (–1/17) – (1/39)^2 = –0.0124/m2$

3a We use the Lame parameters when evaluating the shell membrane equations. How?

When differentiating to u we multiply with 1/αx, when differentiating to v we multiply with 1/αy.

3b A shell is loaded by a uniformly distributed wind pressure of 1.71 kN/m2. The surface slope varies between 30 o and 40 o with the horizontal plane. What are the load components px, py and pz?

Wind load is always perpendicular to a surface. px = 0, py = 0, pz = +/- 1.71 kN/m2

4a When we analyse a tubular beam with the shell membrane equations, not all boundary conditions are fulfilled. How can we solve this?

Use the Sanders-Koiter equations.

4b Suppose you calculated the deflection of a beam. Unfortunately, you made a mistake in the value of Poisson's ratio. Do you need to correct the calculation? Explain your answer.

No for a slender beam. Yes for a deep beam. This is true for simply supported tubes and probably also for other beams, other supports and other loads.

5a What are hairpins for?

To carry the concentrated shear force.

5b Do the Sanders-Koiter equations describe shear deformation? Explain your answer.

No. Shear is not in the constitutive equations.

6a A shell is fixed at a curved edge. The curvature is 1/(20 m). The shell thickness is 20 mm. What element size is recommended? Explain your answer. Is this size in the direction of the edge, perpendicular to the edge or in both directions?

li = 2.4 sqrt(20000 x 20) = 1520 mm, h = li / 6 = 1520 / 6 = 253 mm, in the perpendicular direction

6b A shell has a curvature of 1/(12 m) in the direction of a fixed edge. Perpendicular to the edge, the shell curvature is zero. The shell is 10 mm thick. At what distance from the edge are the effects of the edge disturbance negligible? Explain your answer.

li = 2.4 sqrt(12000 x 10) = 831 mm

7a How do we know that 8 node shell elements are better than 4 node shell elements?

They give more accuracy per node of a model.

7b Membrane forces in SCIA have an error of order h2, where h is the element size. We perform a finite element analysis and in some point nxx = 21.3 kN/m. We halve the mesh size and compute in this point nxx = 22.8 kN/m. What is the best estimate of the exact value of nxx?

22.8 – 21.3 = 1.5, 1.5 / 3 = 0.5, 22.8 + 0.5 = 23.3 kN/m

8a A finite element program analyses a reinforced concrete shell. In an element the linear elastic principal stress is 18 N/mm2 (partial safety factor included). The yield stress of the reinforcing bars is 480 N/mm2 (partial safety factor included). What local reinforcement ratio is required? Explain your answer.

18 / 480 = 3.7% in the principal direction

8b Why do we rotate the coordinate systems of finite elements?

If element coordinate systems are not aligned, many contour plots make no sense. In addition, for the concentrated shear force the element coordinate systems need to be in the edge direction and for designing reinforcement the element coordinate systems need to be in the reinforcement directions.

9a How does software compute the principal stresses of a elementary cube?

eigen values of the stress tensor computed with Jacobi's algorithm

9b Somebody proposed reinforcement for a concrete shell roof: nsx = 271, nsy = 271 kN/m. A finite element analysis computes the membrane forces: nxx = 203, nyy = 57, nxy = -101. nyx = -122 kN/m. Is this reinforcement sufficient? Explain your answer.

nxx <? nsx OK, nyy <? nsy OK,

nxy nyx <? (nsx – nxx)(nsy – nyy), 101 x 122 <? (271 – 203)(271 – 57), 12322 <? 14552 OK

10a Suppose that a shell carries load by bending and not by membrane forces. How is this called?

in-extensional deformation

10b Consider a perpendicular point load on a shell structure. The shell is properly supported so there is no in-extensional deformation. What is stiffer: positive Gaussian curvature or negative Gaussian curvature? What is the ratio between these stiffnesses?

Positive is stiffer. Positive is about twice as stiff as negative.

11a How is the arithmetic accuracy of a SCIA computation checked?

Equilibrium of loads and support reactions is checked.

11b Frame structures are sometimes designed such that the frequency of the load is no problem because it is in between two natural frequencies. Is this possible for shells too? Explain your answer.

No, in most shells there is little space between natural frequencies.

12a What is the difference between ncr and nult?

ncr Is computed in a linear buckling analysis. nult Is computed in a nonlinear analysis. The latter includes shape imperfections and their growth before collapse.

12b The Sanders-Koiter equations cannot accurately predict shell buckling. What is the problem?

We need to add equilibrium in the deformed state, shape imperfections and how imperfections grow before collapse.

13a What is the difference between a safety factor and a knockdown factor?

Safety factors account for uncertainty in load and material strengths. The knockdown factor accounts for imperfection sensitivity.

13b Why do we add shape imperfections to nonlinear analyses only?

In linear buckling analyses we do not because it does not include growth of the imperfections.

14a Does tension in a shell make the natural frequency larger, smaller or does it have no influence? Explain your answer.

Larger. This follows from the square panel equation.

14b Suppose we want to increase the natural frequency of a shell. Should we increase the mean curvature or increase the Gaussian curvature? Explain your answer.

Mean curvature. This follows from the square panel equation.

