NAFEMS Benchmark Challenge

NBC06: The Sleipner Incident - A Computer-Aided Catastrophe Revisted

In a recent article ('NAFEMS: the Early Days', January 2016), Peter Bartholomew describes how John Robinson, one of the founders of NAFEMS, noted in the early 1970s "… that both coding and modelling errors were commonplace and only time separated the community from computer-aided catastrophe (CAC)". In the early 1990s just such an incident of CAC occurred when the reinforced concrete Sleipner Platform A sank in a Norwegian Fijord. No one was injured, but the incident cost some $700M (US). The subsequent inquiry found that the FE modelling local to the failure had been inadequate, under-predicting the shear forces by some 45%, and that the reinforcement detailing in the region was not adequate to support the loading. This incident, now some 25 years ago, is a significant reminder of the importance of good simulation governance and, as there are useful lessons to learn from it, this challenge revisits the Sleipner Incident.

The platform comprised a honeycomb of shafts and tri-cells. The tri-cells were subject to hydrostatic pressure from the fijord causing a pressure differential across the walls of the tri-cells. A basic FE model, which approximates the actual geometry, comprising a symmetric sixth of a tri-cell is provided, figure 1, and uniform mesh refinement should be used to improve the solution.

The Challenge

Often the first step in the design of reinforced concrete structures is to use a linear-elastic model to establish the internal stresses due to the applied load. These are then used to size the reinforcement required to support the load and this is generally done by looking at stress resultants (shear force, axial force and moment in this case) across critical sections deemed to be of structural interest. Commercial FE systems generally use conforming finite elements which are based on assumed continuous displacement fields which ensure strain/displacement compatibility. Stresses are related to the strains through the appropriate constitutive relations - Hooke's law in the case of linear elasticity. The remaining condition for the solution to be the theoretically exact one is that of equilibrium of the stresses with the applied load. Equilibrium is generally only weakly satisfied with conforming elements and this can be a problem for the engineering designer. The engineer deals with this issue by performing mesh refinement to reduce the lack of equilibrium in the finite element stresses.

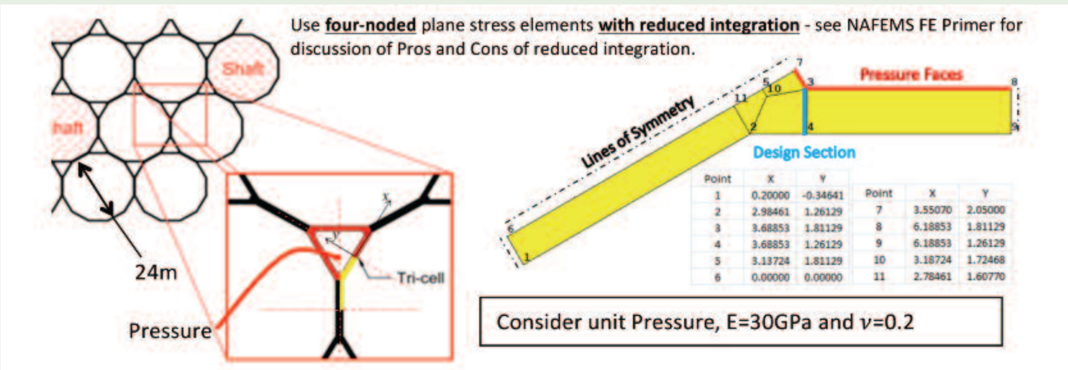

Figure 1: Shaft and tri-cell honeycomb and a basic finite element model

In this challenge you are asked to consider how best to achieve a set of equilibrating stress resultants on the design section identified in figure 1 and the following techniques should be considered:

- Stress Linearisation – see http://www.ramsay-maunder.co.uk/benchmark-challenge/stress-linearisation/
- Nodal Forces – these are in equilibrium with the applied load.
- Hand Calculations - based on static and kinematic requirements.
- Gauss point stresses – see the following references:

https://failures.wikispaces.com/Sleipner+A+-+North+Sea+Oil+Platform+Collapse

http://www.e-periodica.ch/digbib/view?var=true&pid=bse-cr-002:1996:15::127#1083

The reader is asked to provide a brief report detailing the studies they undertook and the results they achieved and it should conclude with a list of practical conclusions for the practising engineer.