NAFEMS Benchmark Challenge

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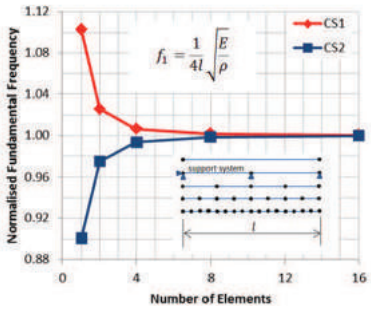
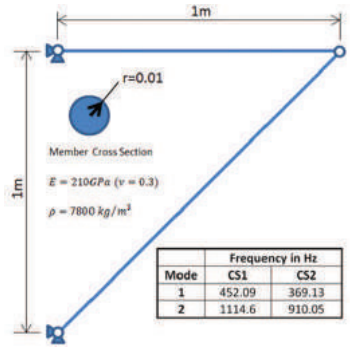
Challenge Problem 5
Dynamic Characteristics of a Truss Structure

In the final year of his engineering degree course a student was introduced to finite element analysis and conducted an assessment of a simple, planar, pin-jointed truss structure. This included a modal analysis to establish the natural frequencies of the structure. Being a cautious student he thought he'd better conduct some verification tests on the axial element used to model the truss structure. He found an analytical solution for a bar, fixed at one end and with uniform cross section and material properties. He conducted a convergence study on this test structure in two commercial finite element systems (CS1 and CS2) starting with a single element and then performing uniform mesh refinement until he reach a mesh with 16 elements. In his model he supported all nodes in the vertical direction and for the node at the left-hand end he also supported is against horizontal displacement. His results for the fundamental frequency are shown in figure 1. The frequencies have been normalised (divided) by the theoretical value which was obtained from the equation inset into the figure and he used the same elastic and inertial properties as for his truss structure.

The results worried him since, although he saw that the finite element programmes provided results that converge with mesh refinement to the theoretical solution, he also saw that a single element could be in excess of 10% in error and he realised that using different software would provide different approximations with CS1 giving an upper-bound and CS2 a lower-bound to the theoretical value. As his truss structure analysis had used single elements for each of the members he was concerned that the natural frequencies for the structure might be rather inaccurate.



(a) Test structure



(b) Truss structure

Figure 1: Student's structures and results

The Challenge

The challenge is to work with this student to understand why different finite element systems provide different approximations for coarse meshes and to provide some guidance on how he might obtain accurate frequencies for his truss structure.

Responses should be sent to challenge@nafems.org

The response and solution for the fourth NAFEMS Benchmark Challenge, as published in the January 2016 edition of benchmark, is now available on the Challenge Blog of the NAFEMS website: **nafems.org/blog/contributors/angus_ramsay**

The publication of this solution represents a complete year of the Challenge, and provides a good opportunity to reflect on the initiative. During this period, the following four Benchmark Challenges were presented, together with their solutions:

NBC01: Stress at the Centre of a Square Plate with Linear Boundary Tractions

NBC02: Assessment of a Simply Supported Plate with Uniformly Distributed Load

NBC03: Understanding and Explaining the Nature of the Plane Strain Approximation

NBC04: Poisson's Ratio for a Steel Plate

These challenges and their solutions will be published in a NAFEMS book entitled 'The NAFEMS Benchmark Challenge 2015/16', in the coming months. The book will include the original challenges and solutions, as well additional details not presented in the original responses. It is hoped that members will find this to be a useful educational and training resource.

There were many excellent responses submitted by NAFEMS members. In particular, **Jack Reijmers**, a Specialist Engineer at Nevesbu in The Netherlands, submitted four excellent solutions, and has therefore been selected as the winner of this year's challenge prize of an iPad mini.

An unexpected by-product of the challenge has been the development of a collaborative research project between the editor (Angus Ramsay of Ramsay Maunder Associates) and three of the respondants with a common interest in achieving accurate elastic and plastic solutions for plate problems. This work was prompted by the findings made in NBC02, where published solutions were found to be rather inaccurate when compared to the sort of results that can be generated using modern finite element tools. A series of five articles are planned covering the design/assessment of plate members, and it is hoped that these might be published by one of the engineering institutions in the UK. Publishers McGraw Hill, have also asked the editors to update the data in Roark's 'Formulas for Stress & Strain' for the next edition, and these articles will form a useful source of peer reviewed reference for this task.

The Future

The success of the Benchmark Challenge initiative, as judged by interest from readers of the magazine and others further afield, means that it will be continued for a further year. The fifth challenge involves the 'Dynamic Characteristics of a Truss Structure' and is published opposite. As usual, readers are encouraged to take part and to submit their responses to NAFEMS for an appraisal, and if successful, receive a certificate and NAFEMS business card holder.