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Extended Abstract

Development of the Discrete Kirchhoff-Mindlin Quadrilateral (DKMQ) Element for Composite Folded Plate Analysis

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The discrete-Kirchhoff Mindlin quadrilateral (DKMQ) element was developed by Katili [1] based on the Reissner Mindlin plate theory. This element is free from shear locking, has no spurious zero-energy modes, and passes the patch tests. Recently, this element has been developed for analyses of composite laminated plates and shells. The aim of this research is to further develop the DKMQ element for analysis of composite laminated folded plates.

In this development, the folded plate element is formulated using a combination of the DKMQ element and the standard four-node plane stress quadrilateral (Q4) element to form an element as it is show in Fig. 1. To prevent singularity of the stiffness matrix, an artificial stiffness corresponding to the drilling degrees of freedom is added.

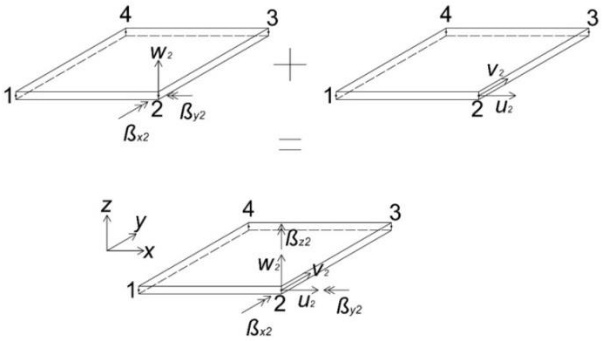
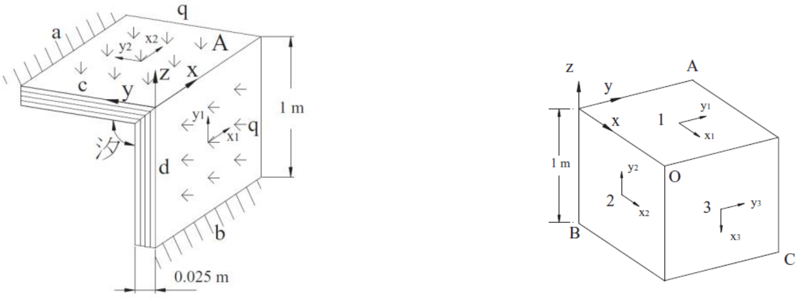


Figure 1. Folded plate element is formed from the DKMQ and Q4 elements

The developed folded plate element is tested using several problems. The first test is a series of patch tests, in which we test an inclined composite plate with meshes of regular elements and irregular elements. The results show that the element passes the tests for constant curvature patch tests, constant shear patch tests, and plane stress patch tests.

The next benchmark problems are taken from Ref. [2]. The problems are an L-shaped folded plate, Fig. 2a, and a half box folded plate, Fig. 2b. The L-shaped folded plate is tested both on the case of homogeneous, orthotropic, and composite laminated cases. The results for the cases of homogeneous and orthotropic results are compared to those obtained from SAP2000 commercial software. The results show a good accuracy and convergence, that is, the relative errors for the homogeneous and orthotropic cases are 4.755% and 3.043%, respectively. For the composite laminated case, the results is compared to Peng el al.'s ANSYS results [2]. The relative error is 5.9344%.



a. L-shaped folded plate

b. Half a box folded plate

Figure 2. Folded plate structures

A half box plate is tested with material arrangement in plate 1 is taken to be -45°/45°/45°/-45° and plate 2 and 3 to be 45°/-45°/-45°/45°. The deflection along line X = 0.5 m is shown in Fig. 3. It demonstrates a good accuracy of the results.

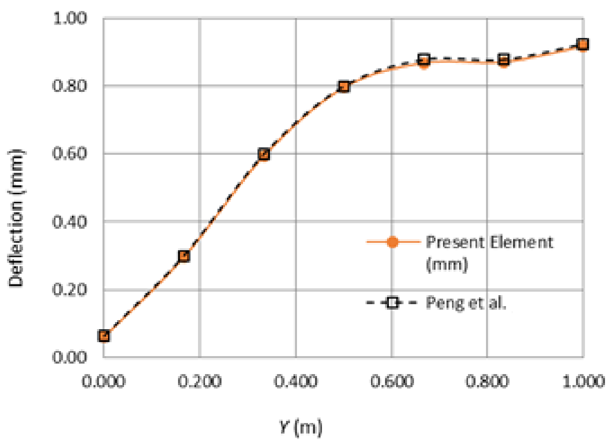


Figure 3. Deflection of plate 1 along line X = 0.5 m

In conclusion, the developed element give good results in the folded plate examples in terms of the accuracy and convergence. This element can be used in practical engineering analyses.

References

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