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# Comparison between the Quadratic and the Cubic Linked Interpolation on the Mindlin Plate Four-Node Quadrilateral Finite Elements

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**Abstract :** We employ the so-called problem-dependent linked interpolation concept to develop two cubic 4-node quadrilateral Mindlin plate finite elements with 12 external degrees of freedom. In the problem-independent linked interpolation, the interpolation functions are independent of any problem material parameters and the rotation fields are not expressed in terms of the nodal displacement parameters. On the contrary, in the problem-dependent linked interpolation, the interpolation functions depend on the material parameters and the rotation fields are expressed in terms of the nodal displacement parameters. Two cubic 4-node quadrilateral plate elements are presented, named Q4-U3 and Q4-U3R5. The first one is modelled with one displacement and two rotation degrees of freedom in every of the four element nodes and the second element has five additional internal degrees of freedom to get polynomial completeness of the cubic form and which can be statically condensed within the element. Both elements are able to pass the constant-bending patch test exactly as well as the non-zero constant-shear patch test on the oriented regular mesh geometry in the case of cylindrical bending. In any mesh shape, the elements have the correct rank and only the three eigenvalues, corresponding to the solid body motions are zero. There are no additional spurious zero modes responsible for instability of the finite element models. In comparison with the problem-independent cubic linked interpolation implemented in Q9-U3, the nine-node plate element, significantly less degrees of freedom are employed in the model while retaining the interpolation conformity between adjacent elements. The presented elements are also compared to the existing problem-independent quadratic linked-interpolation element Q4-U2 and to the other known elements that also use the quadratic or the cubic linked interpolation, by testing them on several benchmark examples. Simple functional upgrading from the quadratic to the cubic linked interpolation, implemented in Q4-U3 element, showed no significant improvement compared to the quadratic linked form of the Q4-U2 element. Only when the additional bubble terms are incorporated in the displacement and rotation function fields, which complete the full cubic linked interpolation form, qualitative improvement is fulfilled in the Q4-U3R5 element. Nevertheless, the locking problem exists even for the both presented elements, like in all pure displacement elements when applied to very thin plates modelled by coarse meshes. But good and even slightly better performance can be noticed for the Q4-U3R5 element when compared with elements from the literature, if the model meshes are moderately dense and the plate thickness not extremely thin. In some cases, it is comparable to or even better than Q9-U3 element which has as many as 12 more external degrees of freedom. A significant improvement can be noticed in particular when modeling very skew plates and models with singularities in the stress fields as well as circular plates with distorted meshes.

**Keywords :** Mindlin plate theory, problem-independent linked interpolation, problem-dependent interpolation, quadrilateral displacement-based plate finite elements
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