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STATIC ANALYSIS OF THICK LAMINATED PLATES USING ENRICHED MACROELEMENTS

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Abstract. *An appropriate structural analysis of laminated plates must include the effects of coupling between the membrane, bending-torsion and shear modes. The laminated composites have low relative transverse shear stiffness and thus exhibit important transverse shear deformation, even for low thickness-length ratios. The development, computational implementation and application of polynomially-enriched plate macro-elements are presented in this work. This macro-element has been formulated by the authors for thin plates and in this work it has been incorporated the first-order theory, the material anisotropy and a process selection of approximation functions that avoid shear locking. The obtained formulation is applied to the static analysis of thick composite laminated quadrilateral plates. The enriched finite element is obtained using Gram-Schmidt orthogonal polynomials, which facilitate this enrichment. For taking into account plates of several geometrical shapes, an arbitrary quadrilateral laminate is mapped onto a square basic one, so that a unique macro-element is constructed for the whole element. Then, hierarchically enriched stiffness matrix, and loading vector of general laminated plate element are derived. The several different boundary conditions may be arranged in the analysis by specifying whether an element edge is simply supported, clamped, free, or whether an element corner is point supported. This procedure gives a matrix equation of static equilibrium to be solved with optimum efficiency, and moreover, enables a hierarchical new analysis to be carried out at the post-processing stage. Numerical results obtained by the present method for a variety of plate structures show good correlation with published results. An important conclusion of this work is that it is stable, computationally efficient and most economical to use the coarsest h-mesh to obtain the same approximation. Furthermore it is easy to perform parametric studies and also the optimization process can be carried out using a new proposed objective functions.*