Abstract

The present work is concerned with the development of finite element techniques for nonlinear analysis of anisotropic and reinforced concrete plates and shells. The computational models coded are capable of tracing the entire nonlinear response up to ultimate loads of various shell structures. Applications to a variety of structural problems under quasi-static short-term loading and thermal loads are included.

A general description of the degenerate shell concept is given and special reference is made to the quadratic isoparametric shell elements (8-node Serendipity, 9-node Lagrangian and Heterosis) employed in this work. The problems related to the application of these thick shell elements to thin structures are discussed. The incremental and iterative procedure adopted for the finite element nonlinear analysis of problems involving plasticity and large displacements is described. A nonlinear geometric model, based on a total Lagrangian approach accounting for large displacements in the von Karman sense, is developed to mainly deal with reinforced concrete shell structures.

Two different finite element formulations are developed for the solution of anisotropic material problems, with special emphasis on fibrous composite and laminated composite structures. The Semiloof shell element and a yield condition formulated in terms of stress resultants is employed in one of these formulations, which is in consequence restricted to thin shell applications. The other formulation for anisotropic problems employs degenerate shell elements and a layered approach for discretization through the thickness. Transverse shear effects are taken into account and correction shear factors are included to extend this latter formulation to the analysis of laminated composite structures. Material anisotropy is considered both for elastic and for plastic material response. An industrial application of an aerofoil wind turbine blade is considered.

The modelling of reinforced concrete behaviour for the global analysis of shell structures is considered. Quadratic degenerate shell elements and a layered model are employed; nonlinear geometric effects and thermal loads are accounted for. A dual criterion for yielding and crushing in terms of stresses and strains, implemented with a tension cut-off representation, is considered. Both a perfect and a strain hardening plasticity approach are employed to model the compressive behaviour of the concrete. A smeared approach for cracked concrete is considered and a reduced shear modulus is used in cracked zones; full bond is assumed at the reinforcement-concrete interface, but a tension stiffening diagram is adopted to simulate the gradual bond deterioration with progressive cracking. Various reinforced concrete beams, plates and shells are analysed and a full discussion of the results is presented.