ABSTRACT

In civil engineering, plates and shells are used as cladding units and research on these structural units has found a good place in the volume of published literature. The focus of research started from bending analysis of isotropic plates and shells and in course of time, more advanced and complicated aspects started getting attention from researchers. Engineers went on trying fabricating these structural units with innovative options of advanced materials with high specific strength and stiffness properties like the laminated composites. Parallel development in the area of analysis with the introduction of finite element method and advent of high speed computers made it possible to analyze complicated shapes of plates and shells which are aesthetically appealing and may be subjected to complicated load functions. Non-conventional boundary conditions which suit to specific practical situation became possible to be modeled by finite element approach. Numerical models of plates and shells had continuously been compared with experimental results and advanced theories of shear deformation, geometric and material nonlinearity were introduced to take care of mismatches between theoretical and experimental results. Successful applications of plates and shells with advanced materials like laminated composites required appropriate characterization in terms of different performance parameters including failure characteristics – both at initiation and during progress up to ultimate load. A study of literature shows that failure of skewed plates and skewed hypar shells has not received due attention.

The finite element method is employed here to study the first ply and progressive failure behaviour of laminated composite skew plates and skewed hypar shells considering Sanders' geometrically linear strains and von-Kármán's approach of nonlinear strains. An eight noded curved quadratic Serendipity element having five degrees of freedom at each node

is used to model the surface. The Newton – Raphson iteration is utilized to solve the nonlinear equation of static equilibrium. Different well-established failure criteria like maximum stress, maximum strain and those proposed by Hoffman, Tsai-Hill, Tsai-Wu, Hashin and Puck are used to obtain the linear and nonlinear first ply and ultimate ply failure load values.

The finite element code developed is validated through comparison of present results with published theoretical and experimental ones before applying the code to generate new results. The first ply and ultimate ply failure strength of thin skewed plate and skewed hypar shell geometry under uniformly distributed load for different boundary conditions and laminations are computed. Failure locations (such as failed element, failed Gauss point etc.) and failure mode or tendencies are also reported. The author further studies the first ply failure (FPF) and associated frequency reduction of composite skew plates considering practical parametric variations. The effects of skew angle on the first ply failure load are summarized in the form of charts and working equations. The engineers and researchers may use the charts and equations directly to predict the first ply failure load provided the geometry of the plate is known. Apart from reporting the failure load values, the failure zones and nature of damage progress on the skew plate surfaces are also presented which are expected to be valuable inputs for non-destructive health monitoring. Numerical experimentation with parametric variations of skewed hypar laminated composite shells are carried out and the results are post processed and interpreted to extract meaningful engineering conclusions. Further this investigation is aimed towards proposing design guidelines regarding failure characteristics of skewed hypar laminated composite shells with partially free boundaries considering both the aspects of collapse and serviceability using well-established failure criteria.

The literature review, mathematical formulation, details of investigations are presented chapterwise in the thesis. Scope of future research work is also discussed about at the end of this thesis.