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Relative performance of antisymmetric angle-ply laminated stiffened hypar shell roofs with cutout in terms of static behavior

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Abstract: A review of literature reveals that bending analysis of laminated composite stiffened hypar shells with cutout have not received due attention. Being a doubly ruled surface, a skewed hypar shell fulfils aesthetic as well as ease of casting requirements. Further, this shell allows entry of north light making it suitable as civil engineering roofing units. Hypar shell with cutout subjected to uniformly distributed load exhibits improved performances with stiffeners. Hence relative performances of antisymmetric angle-ply laminated composite stiffened hypar shells in terms of displacements and stress resultants are studied in this paper under static loading. A curved quadratic isoparametric eight noded element and three noded beam elements are used to model the shell surface and the stiffeners respectively. Results obtained from the present study are compared with established ones to check the correctness of the present approach. A number of additional problems of antisymmetric angle-ply laminated composite stiffened hypar shells are solved for various fibre orientations, number of layers and boundary conditions. Results are interpreted from practical application standpoints and findings important for a designer to decide on the shell combination among a number of possible options are highlighted.

Keywords: stiffened hypar shell; cutout; antisymmetric angle ply composite; finite element method

1 Introduction

Hypar shells are used in civil engineering industry to cover large column free areas such as in stadiums, airports and shopping malls. Being a doubly curved and doubly ruled surface, it satisfies aesthetic as well as ease of casting requirements of the industry. Moreover, hypar shell allows entry of daylight and natural air which is preferred in food processing and medicine units. Cutout is sometimes necessary in roof structure to allow entry of light, to provide accessibility of other parts of the structure, for venting and at times to alter the resonant frequency. Shell structure that are normally thin walled, when provided with cutout, exhibits improved performances with stiffeners. To use these doubly curved, doubly ruled surfaces efficiently, the behavior of these forms under bending are required to be understood comprehensively. The use of laminated composites to fabricate shells is preferred to civil engineers from second half of the last century. The reasons are high strength/stiffness to weight ratio, low cost of fabrication and better durability. Moreover, the stiffness of laminated composites can be altered by varying the fiber orientations and lamina thicknesses which gives designer flexibility. As a result, laminated shells are found more cost effective compared to the isotropic ones as application of laminated composites to fabricate shells reduces their mass induced seismic forces and foundation costs.

A thorough scrutiny of available literature on the bending behavior of laminated composite hypar shells with a cutout reveals that no study has been reported so far on this aspect. Sanders Jr. [1] and Ghosh and Bandyopadhyay [2] have considered the bending of isotropic shells with a cutout. The static behavior of a cylindrical composite panel in presence of cutouts has been reported using a geometrically non-linear theory [3] while the free vibration of cylindrical panel with square cutout has been studied based on finite element method [4]. The axisymmetric free vibration of isotropic shallow spherical shell with circular cutout has also been analyzed [5]. Madenci and Barut [6] studied buckling of composite panels in presence of cutouts. Non-linear post-buckling analysis of composite cylindrical panels with central circular cutouts but having no stiffeners was studied by Noor et al. [7] to consider the effect of edge shortening as well as uniform temperature change. Later Sai Ram and Babu [8, 9] investigated the bending behavior of axisymmetric composite spherical shell both punctured and un-punctured using the finite element method based on a higher order theory. Qatu

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