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Vibration Characteristics of Point Supported Composite Hypar Shell Roofs with Cutout

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Abstract: **A general finite element formulation for the stiffened hyperbolic paraboloidal shells bounded by straight edges (commonly called as hypar shells) is attempted using eight-noded curved quadratic isoparametric element for shell with a three noded beam element for stiffener. Numerical problems of earlier investigators are solved as benchmark problems to validate the approach. A number of problems are further solved by varying the size of the cutouts and their positions with respect to the shell centre for cross ply and angle ply shells. The results are presented in the form of figures and tables. The results are further analyzed to suggest guidelines to select optimum size and position of the cutout with respect to shell centre for cross ply and angle ply shells.**

Keywords: **Composite hypar shell; Finite element analysis; Point supported; Stiffened; Cutout.**

INTRODUCTION

Hyperbolic paraboloid shell bounded by straight edges is easy to fabricate doubly ruled surface and is preferred as roofing units in many practical situations. Cutout is sometimes necessary in roof structure for the passage of light, to provide accessibility to other parts of the structure, for venting and also sometimes for alteration of resonant frequency. In practice the margin of the cutouts must be stiffened to take account of stress concentration effects.

As early as in 1982 Reddy [1] carried out the finite element analysis of composite plate with cutout and presented the effects of parametric variations on linear and non-linear frequencies. Later in 1989, Malhotra et al. [2] presented the effect of fibre orientation and size of cutout on natural frequency on orthotropic square plates with square cutouts for dfferent boundary conditions using Rayleigh-Ritz method. Sivasubramonian et al. [3] reported free vibration of curved panels with cutout. They analysed the effect of cutouts on the natural frequencies of plates with some classical boundary conditions. Later Sivakumar et al. [4], Rossi [5], Huang and Sakiyama [6], Hota and Padhi [7] studied free vibration of plate with various cutout geometries. Chakravorty et al. [8] reported some results in order to study the effect of concentric cutout on natural frequency of different shell options. In 1999, Sivasubramonian et al. [9] studied the free vibration characteristics of longitudinally stiffened square panels with symmetrical square cutouts by using the finite element method. The size of the cutout (symmetrically located) as well as curvature of the panels is varied. Hota and Chakravorty [10] published useful information about free vibration of stiffened conoidal shell roofs with cutout. Later Nanda and Bandyopadhyay [11] investigated the effect of different parametric variation on nonlinear free vibration characteristics of cylindrical shell with cutout. The finite element model using an eight-noded C0 continuity, isoparametric quadrilateral element is used to study the dynamic behaviour. Chakravorty et al [8] worked on free and forced vibration of corner point supported composite hypar shell and also in the same paper reported fundamental frequencies of isotropic hypar shell. In a recent paper, Sahoo [12] reported some results on free vibration of composite stiffened hypar shell with cutout with different boundary constraints.

It is evident that though corner point supported hypar shell received some attention but corner point supported stiffened hypar shells with cutout are limitedly focused. Stiffened hypar shell on point supports with eccentric cutouts has not received any attention. The present aim is to study the vibration characteristics of point supported composite stiffened skewed hypar shells with concentric and eccentric cutout.

MATHEMATICAL FORMULATION

A laminated composite hypar shell of uniform thickness h (Figure 1) and twist radius of curvature R_{xy} is considered. Keeping the total thickness the same, the thickness may consist of any number of thin laminae each of which may be arbitrarily oriented at an angle θ with reference to the X-axis of the co-ordinate system. An eight-noded curved quadratic isoparametric finite element is used. The five degrees of freedom taken into consideration at each node include two in-plane and one transverse displacement and two rotations about the X and Y