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Research Paper

An Examination of the Influence of Various Plate Aspect Ratios on the Stability Analysis of Laminated Composites in Clamped Conditions

Chandrashekharaiah S B
Lecturer, Department of Mechanical engineering (MTT), S J (Govt.) Polytechnic Bangalore, Karnataka, India.

Abstract: *This sixteen-ply quasi-isotropic graphite/epoxy symmetrically laminated composite plate [0°/+45°/-45°/90°]2s, featuring square and rectangular cutouts, has undergone numerical analysis to assess how the aspect ratio of the plate influences its buckling behavior. The plate underwent a series of linearly varying in-plane compressive loads analyzed through the finite element method (FEM). This study discusses the buckling behavior of symmetrically laminated rectangular composite plates subjected to linearly increasing in-plane compressive loads, examining the effects of boundary conditions, the plate length/thickness ratio (a/t), and the dimensions of square or rectangular cutouts. The results indicate that, irrespective of the dimensions, configuration, or boundary conditions of the cutout, the buckling loads of rectangular composite plates featuring rectangular or square cutouts, when subjected to varying linear in-plane loads, can be diminished by enhancing the ratio of the plate's aspect to its thickness and length. The buckling strength of a rectangular composite plate featuring a square or rectangular cutout is greatly influenced by factors such as boundary conditions, aspect ratio (a/b), length/thickness (a/t), and various linearly variable in-plane loads.*
Keywords: *Aspect Ratio, Stability Analysis, FEM, Laminated Composites.*

I. Introduction

Composite laminated plates demonstrate buckling behavior when subjected to compressive loads. Composites consist of two or more materials that, when integrated, produce characteristics that are challenging to attain with a single material used independently. The fibers bear a significant portion of the load of these materials. Matrices characterized by a low modulus and high elongation exhibit flexible structural performance, effectively safeguarding fibers from environmental stressors while ensuring their alignment and proper positioning. Composite materials consist of two or more components and have the potential to greatly decrease construction weight while preserving a high strength-to-weight ratio due to the nature of their composition. In the construction sector, fiber-reinforced composites are frequently employed as laminas, which are thin sheets. Laminae represent the most common type of material macrounit found within the material. To achieve the required strength and stiffness for a particular application, modifications can be implemented in the layer stacking sequence and the orientation of fibers within each lamina. The unique characteristics of a composite material arise from a specific combination of traits influenced by the composition, distribution, and orientation of its components. Cutouts serve multiple purposes, such as reducing weight, enhancing air circulation, and facilitating connections between closely positioned components. A composite material known as carbon-fiber reinforced plastic is created by combining various types of carbon fibers with thermosetting resins. Carbon fiber reinforced plastic, commonly referred to as CFRP, is a lightweight and nonconductive polymer that is enhanced through the incorporation of fibers. This chemical exhibits remarkable longevity. By stacking numerous fiber sheets in various configurations, one can achieve a notable enhancement in the material's strength and stiffness. Parth Bhavsar and his team employed the finite element method to investigate the buckling characteristics of glass fiber reinforced polymer (GFRP) subjected to progressively increasing loads.

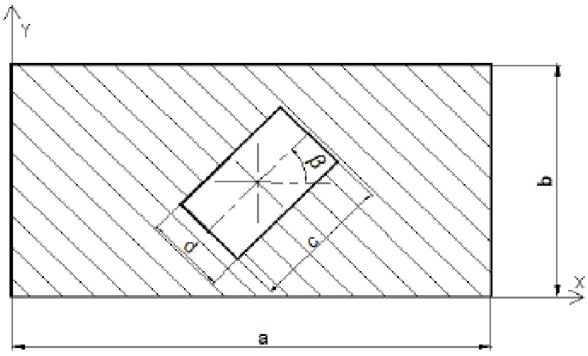

Figure 1: Geometry of the model

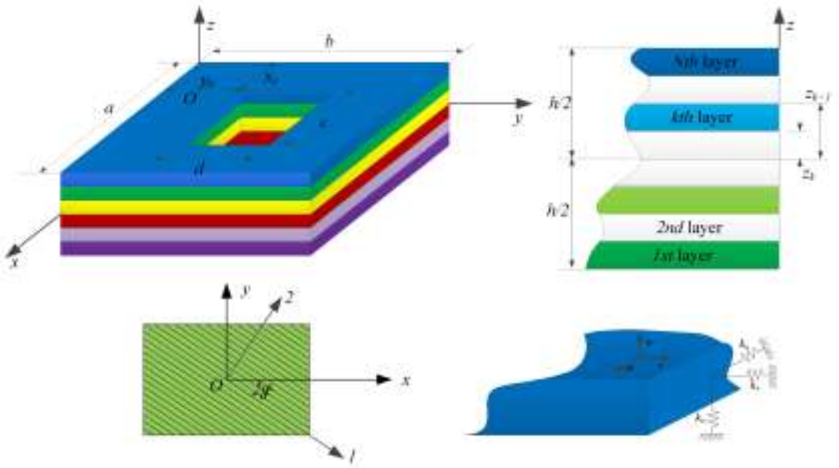

Figure 1: Laminated composite rectangular plate with cutout

Investigations have been conducted on various parameters to determine their influence on the buckling stress of rectangular plates with an aspect ratio of one. Joshi and colleagues employed two-dimensional finite element analysis to determine the buckling stress per unit length of a rectangular plate featuring circular cutouts subjected to biaxial compression. To evaluate the buckling variables, two approaches can be employed: altering the length-to-thickness ratio and positioning the holes. Nagendra Singh Gaira and colleagues investigated the buckling behavior of laminated rectangular plates in clamp-free boundary conditions. The presence of cutouts diminishes the buckling load, which is advantageous. Raising the aspect ratio will lead to a decrease in the buckling load factor, which aligns with the desired objective. Hamidreza Allahbakhsh and Ali Dadrasi performed a study on the buckling behavior of a laminated composite cylindrical panel, investigating how an axial load influences its buckling load. The study included an elliptical cut-out presented in various sizes and placements. The investigation conducted by Container Okutan Baba centers on the influence of different cut-out geometries, length-to-thickness ratios, and ply orientations on the buckling stress experienced by rectangular plates. To assess the impact of these variables on the buckling behavior of E-glass/epoxy composite plates under in-plane compression stress, a combination of theoretical and experimental methods was utilized. In their finite element buckling study of composite laminate skew plates subjected to uniaxial compressive loads, Hsuan-Teh Hu and colleagues demonstrated that the failure criteria and nonlinear in-plane shear significantly affected the ultimate loads of the skew plates. This stands in contrast to the linearized buckling loads, which exert a diminished influence.

II. Finite Element Model

A simple approach to adhere to the formatting guidelines for the research paper. This study aims to determine the buckling load factors of carbon fiber composite plates, whether they are square or cylindrical, through the application of finite element analysis. Version 14.5 of ANSYS is the APDL version. In the analysis of the plate's dimensions, three specific boundary conditions are considered: fixed, clamped, and unclamped scenarios. The initial scenario is comprised of two levels, whereas the subsequent scenario is segmented into three levels. The observed phenomenon could be attributed to the stacking sequences employed, which were [0°/+45°/-45°/90°]2s, respectively. For the purpose of the study, it is essential to perforate the plate with numerous center holes, ensuring each has an equal volume. The center holes can be arranged in various configurations, such as square, triangular, circular, and star formations. A study of the characteristics of the buckling load factor is currently in progress.

This investigation employs finite element methods to examine how the plate aspect ratio (a/b), length/thickness ratio (a/t), and boundary conditions influence the buckling behavior of quasi-isotropic graphite/epoxy composite plates featuring square or rectangular cutouts subjected to linearly varying in-plane compressive loads. The lamina consists of graphite fibers serving as reinforcement, with epoxy functioning as the matrix material. Table 1 presents the material parameters of graphite/epoxy, as referenced in the work of Hsuan*Teh Hu and Bor*Horng Lin (1995). The first material axis is oriented with the global x axis, while the second material axis is oriented with the global y axis. The compressive loads exerted on the plate are oriented along the global x-axis. The 0° fiber orientation is in alignment with the direction of the compressive load.

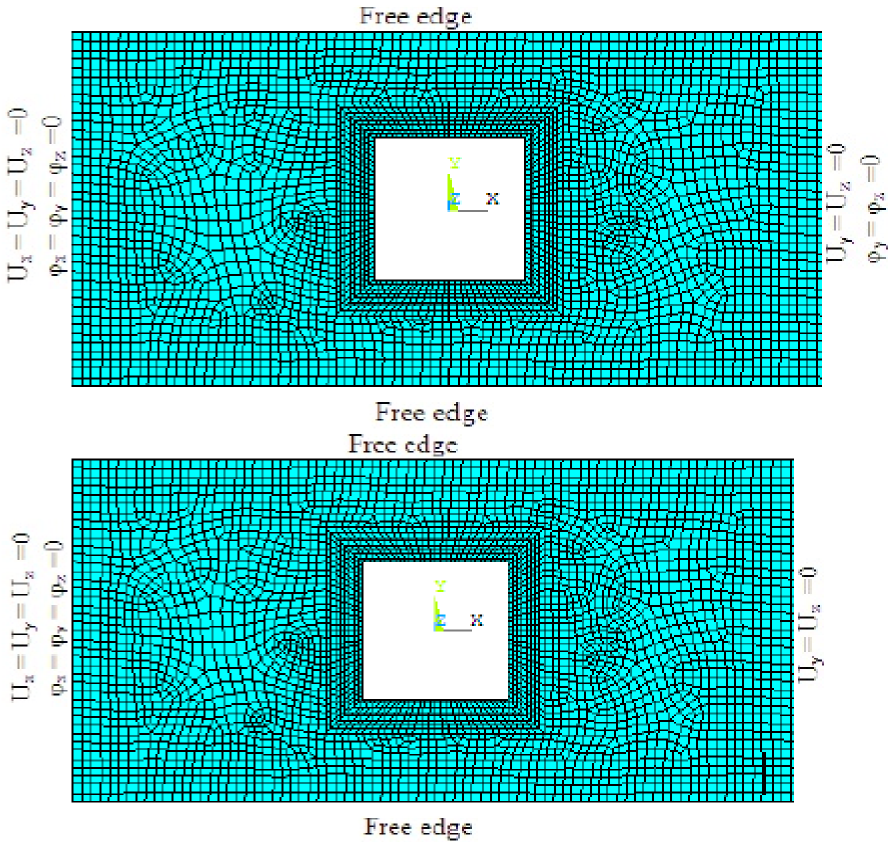

Figure 2: FE model with mesh

III. Description Of Element

This work utilizes the SHELL281 element type. This shell element enables the examination of very thin or moderately thick shells. Moreover, due to its versatility, it serves as an excellent material for modeling layered composite coatings and sandwich structures. Applications demonstrating considerable strain nonlinearity, linearity, or rotation represent prime opportunities for the effective use of this material. The structure comprises eight nodes, with each node exhibiting six degrees of freedom. The available degrees of freedom facilitate rotation about the three axes and allow for translations along the x, y, and z axes that are encompassed within the element. In the context of cylindrical plate studies, the nonlinear element S8R5 is employed. This element is characterized by the existence of eight nodes, each possessing five degrees of freedom.

IV. Geometric Modelling And Material Property

The geometry is represented as shown in Figure 1. Plate 'a' measures 200mm in length, while plate 'b' has a width of 100mm. This laminate consists of sixteen layers, each with a thickness of 0.125mm. In this context, "t" denotes the thickness of the plate, while "β" indicates the angle of the cutout orientation. This study assumes a cutout orientation angle of zero degrees. This study considers a rectangular cutout that is symmetrically positioned on a rectangular plate. The cutout measures a length of c and a width of d. When the ratios c and d are equal, the rectangular hole converts into a square hole. The influence of square holes is examined within the same parameters.

The analysis of buckling encompasses both square and rectangular openings.

Table 1 : Property of composite material

E_{11} (GPa)	E_{22} (GPa)	v_{12}	$G_{12} = G_{13}$ (GPa)	G_{23} (GPa)
128	11	0.25	4.48	1.53

V. Results And Discussion

This section aims to explore how different ply orientations of the plate influence its behavior under identical boundary conditions. All of this will occur simultaneously. This represents a specific situation at the border that is currently under evaluation. This section employs a diverse range of ply orientations. The orientations are specified as: [0°/+45°/-45°/90°]2s. For additional details, kindly refer to the list provided below. Both subjects are analyzed, and an investigation is conducted to ascertain the implications of the circumstances. Both are examined, and the ensuing implications are explored.

The figures demonstrate the influence of plate aspect ratio (a/b), length/thickness ratio (a/t), boundary conditions, and linearly increasing in-plane compressive loading on the buckling loads of a rectangular composite plate featuring rectangular or square cutouts.

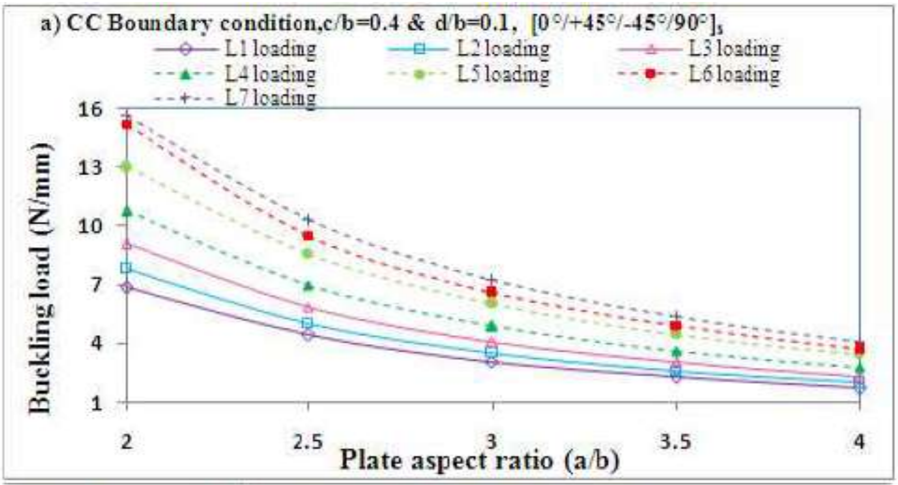

Figure 3 : Effect of plate aspect ratio with holes with unsymmetrical (S) layup

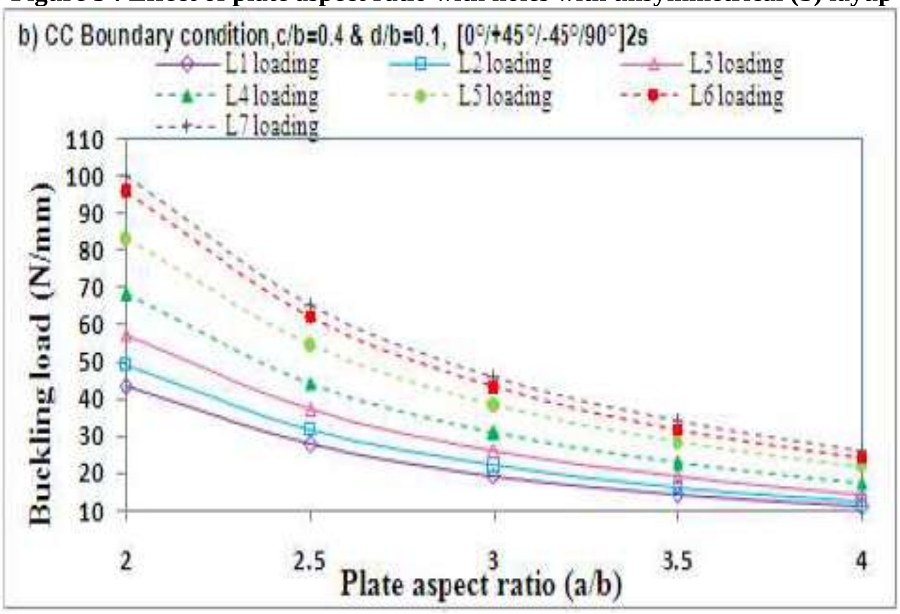

Figure 4 : Effect of plate aspect ratio with holes with symmetrical (2S) layup

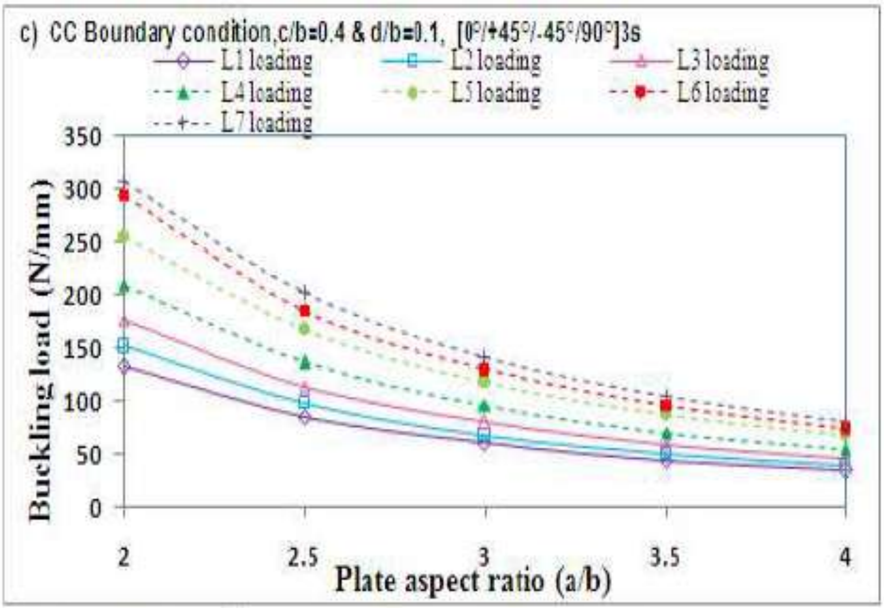

Figure 5 : Effect of plate aspect ratio with holes with symmetrical (3S) layup

The figures demonstrate the influence of plate aspect ratio (a/b), length/thickness ratio (a/t), boundary conditions, and linearly increasing in-plane compressive loading on the buckling loads of a rectangular composite plate featuring rectangular or square cutouts. The data indicates that the buckling loads of a rectangular composite plate featuring square or rectangular cutouts vary by 35.8%, 30.4%, 26.44%, and 23.4% for aspect ratios a/b of 2-2.5, 2.5-3, 3-3.5, and 3.5-4, respectively. This variation occurs independently of length to thickness ratios (a/t), boundary conditions, and the application of linearly varying in-plane compressive loading. The buckling load of a rectangular composite plate with an aspect ratio of a/b=2 is 1.5 times, 2 times, 3 times, and 4 times greater than that of plates with aspect ratios of 2.5, 3, 3.5, and 4, respectively. This is applicable irrespective of the length/thickness ratios (a/t), boundary conditions, or the presence of linearly varying in-plane compressive loading. The reduction in buckling load of a rectangular composite plate with a square/rectangular cutout is 74% when the plate aspect ratio is increased from 2 to 4, independent of length/thickness ratios (a/t), boundary conditions, and linearly variable in-plane compressive loads.

VI. Conclusions

This investigation explores how the plate aspect ratio, length/thickness ratio, boundary conditions, and linearly varying in-plane compressive loading conditions influence the buckling behavior of a sixteen-ply quasi-isotropic graphite/epoxy symmetrically laminated rectangular composite plate [0°/+45°/-45°/90°]2s featuring square/rectangular cutouts.

The rectangular composite plate with a/b=2 exhibits a greater buckling load compared to plates with a/b ratios of 2.5, 3.5, and 4, irrespective of the length/thickness ratios (a/t), boundary conditions, or the presence of linearly varying in-plane compressive loading. With an increase in the plate length/thickness ratio from 50 to 200, there is a notable decrease of 97% in the buckling load of a rectangular composite plate featuring square or rectangular cutouts. This trend is consistent across various plate aspect ratios (a/b), boundary conditions, and under linearly varying in-plane compressive loading.

References

[1]. Y. Zhang, C. Yang, Recent developments in finite element analysis for laminated composite plates, Composite Structures 88(1) (2009) 147-157.
[2]. Aydin Komur.M et al. (2010) Buckling analysis of laminated composite plates with an elliptical/circular cutout using FEM. Advances in Engineering Software 41: 161-164.
[3]. B.O. Baba, A. Baltaci, Buckling characteristics of symmetrically and antisymmetrically laminated composite plates with central cutout, Applied Composite Materials 14(4) (2007) 265-276.
[4]. Ghannadpour, S.A.M., Najafi,A., Mohammadi,B.: Buckling of Cross-ply laminate composite plates due to circular/elliptical cutouts. Compos.Struct.27 pp. 3-6 (2006).
[5]. Afsharmanesh, B., Ghaheri, A. and Taheri-Behrooz, F. (2014), "Buckling and vibration of laminated composite circular plate on winkler-type foundation", Steel and Composite Structures, 17(1), 1-19.
[6]. F. Millar, D. Mora, A finite element method for the buckling problem of simply supported Kirchhoff plates, Journal of Computational and Applied Mathematics 286 (2015) 68-78.
[7]. M. Dehghan, G.H. Baradaran, Buckling and free vibration analysis of thick rectangular plates resting on elastic foundation using mixed finite element and differential quadrature method, Applied Mathematics and Computation 218(6) (2011) 2772-2784.

[8]. R. Mania, Buckling analysis of trapezoidal composite sandwich plate subjected to in-plane compression, Composite Structures 69(4) (2005) 482-490.

[9]. B.O. Baba, Buckling behavior of laminated composite plates, Journal of Reinforced Plastics and Composites (2007).

[10]. Jain,P., Ashwin,K.. Post buckling response of square laminates with a central/elliptical cutout. Compos Struct. 75, (2004).

[11]. Khdeir AA. Free vibration and buckling of symmetric cross-ply laminated plates by an exact method. J Sound Vib 1988; 126:447–61.

[12]. Ganesh Soni, Ramesh Singh and Mira Mitra, Buckling behavior of composite laminates subjected to nonuniform In-plane loads, International Journal of Structural Stability and Dynamics 2013.

[13]. Topal U, Uzman U (2008) Maximization of buckling load of laminated composite plates with central circular holes using MFD method. Struct Multidisc optim35:131-139.