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Research Paper

An investigation of the effect of numerous plate aspect ratios on the buckling analysis of laminated composites in clamped-free environment

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Abstract: *The impact of plate aspect ratio on buckling behavior has been statistically investigated for this sixteen-ply quasi-isotropic graphite/epoxy symmetrically laminated composite plate [0°/+45°/-45°/90°]2s incorporating square and rectangular cuts. By the finite element method (FEM), the plate experienced a sequence of linearly changing in-plane compressive stresses. This work investigates, considering the influence of boundary conditions, the plate length/thickness ratio (a/t), and the size of square or rectangular cuts, the buckling behavior of symmetrically laminated rectangular composite plates exposed to linearly increasing in-plane compressive pressures. The results show that increasing the ratio of the aspect to thickness and length helps to reduce the buckling loads of rectangular composite plates with rectangular or square cutouts, independent of the dimensions, configuration, or boundary conditions of the cutout, under different linear in-plane loads. Boundary conditions, aspect ratio (a/b), length-to---thickness ratio (a/t), and other linearly varying in-plane stresses significantly affect the buckling strength of a rectangular composite plate having a square or rectangular cutout.*
Keywords: *Plate Aspect Ratio, Buckling Analysis, FEM, Clamped-Free Conditions.*

I. Introduction

When composite laminated plates are under compressive loads from an outside source, buckling occurs. A composite is a substance made of two or more components that, used together, provide characteristics impossible to achieve with one component employed by itself. These ingredients make up composites. The fibers carry a great share of the weight of these components. Apart from offering flexible structural performance, low modulus matrices with high elongation shield fibers from environmental pressures and guarantee their alignment and correct position. While maintaining a high strength-to---weight ratio, the composition of the two or more component parts of composite materials may significantly reduce the weight of building. This is so since composite materials consist of numerous components. Usually found in the building sector, laminas are thin sheets. Often in this regard are fiber-reinforced composites. Laminae are the particular kind of material macrounit most often found in the materials. Changes to the sequence in which the layers are layered as well as the orientation of the fibers contained within each lamina might help to get the required degree of strength and stiffness for a certain application. The result of a single combination of properties brought about by the composition, distribution, and orientation of the composite's component elements is those which distinguish a composite material from other materials. Cutouts are required for a range of purposes, including the reduction of component weight, the improvement of air circulation, and the creation of linkages between closely spaced-off components. Carbon-fiber reinforced plastic is the composite material produced by combining several types of carbon fibers with thermosetting resins. Often known as CFRP, carbon fiber reinforced plastic is a nonconductive polymer enhanced with fibers from carbon fiber that is lightweight. a chemical with rather long-lasting action. Stacking several fiber sheets in a variety of ways might greatly enhance the strength and stiffness of the material. This helps one to get the intended result. Parth Bhavsar and colleagues used the finite element method to examine the buckling behavior of glass fiber reinforced polymer (GFRP) under linearly increasing loads.

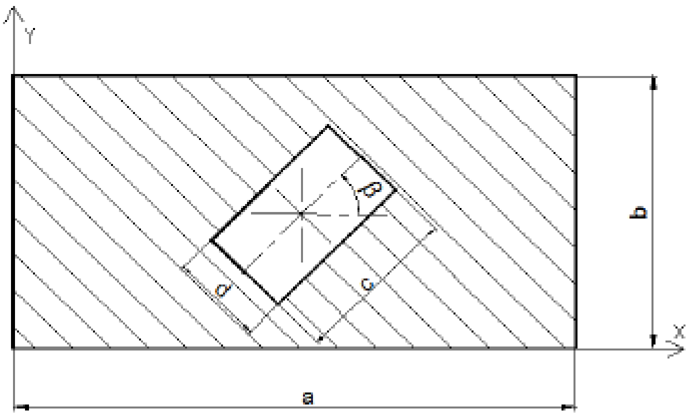

Figure 1: Geometry of the model.

The buckling stress of rectangular plates with an aspect ratio of one has been examined, focusing on a variety of characteristics to understand their impact on the stress. To ascertain the buckling stress per unit length of a rectangular plate featuring circular cuts under biaxial compression, Joshi and his team conducted a two-dimensional finite element analysis. To evaluate the buckling factors, two methods can be employed: modifying the length-to-thickness ratio and adjusting the placement of the holes. The buckling behavior of laminated rectangular plates was examined by Nagendra Singh Gaira and his team under conditions where no clamp was applied to the edges. The presence of cutouts leads to a decrease in the buckling load, which is an encouraging finding. A rise in the aspect ratio will result in a reduction of the buckling load factor, aligning with the intended goal. The study conducted by Hamidreza Allahbakhsh and Ali Dadrasi focused on a laminated composite cylindrical panel, aiming to explore how an axial load influences the buckling load of the panel. During the study, various sizes and positions of an elliptical cutout were observed. Throughout his investigation, Container Okutan Baba examines how various cut-out geometries, length-to-thickness ratios, and ply orientations affect the buckling stress produced in rectangular plates. Theoretical and experimental methods were employed to ascertain the influence of these factors on the buckling behavior of E-glass/epoxy composite plates subjected to in-plane compression stress. During their investigation into the finite element buckling of composite laminate skew plates under uniaxial compressive loads, Hsuan-Teh Hu and his team found that the failure criteria and nonlinear in-plane shear notably influenced the ultimate loads experienced by the skew plates. The distinction between this and the linearized buckling loads is considerable, with the latter exerting a lesser influence.

II. Finite Element Model

An uncomplicated approach to meet the requirements set forth for the structure of the research paper. This investigation employs finite element analysis to ascertain the buckling load factors of carbon fiber composite plates, specifically those with square or cylindrical geometries. The utilized version of APDL is ANSYS Version 14.5. Three distinct boundary conditions are considered when evaluating the dimensions of the plate. The scenarios under consideration include fixed, clamped, and unclamped conditions. The first scenario consists of two levels, whereas the second scenario includes three levels in total. This may be attributed to the stacking sequences employed, specifically [0°/+45°/-45°/90°]2s, respectively. To conduct the study, it is essential to perforate the plate with a considerable number of center holes that are uniformly sized. Various configurations, including square, triangular, circular, and star arrangements, can be utilized for the positioning of the center holes. An investigation is currently underway regarding the properties of the buckling load factor. This study employs the finite element method (FEM) to examine how the plate aspect ratio (a/b), length/thickness ratio (a/t), and boundary conditions affect the buckling response of quasi-isotropic graphite/epoxy composite plates featuring square or rectangular cuts, under linearly increasing in-plane compressive loads. The lamina is constructed using graphite fibers as reinforcement and epoxy as the matrix material. The study carried out by Hsuan Teh Hu and Bor Horng Lin (1995) presents the material properties of graphite/epoxy, as detailed in Table 1. The first axis of the material is oriented along the global x axis, while the second axis is aligned with the global y axis consistently during the process. The compressive loads applied to the plate align with the global x-axis. The orientation of the compressive load aligns with the direction of the 0° fiber.

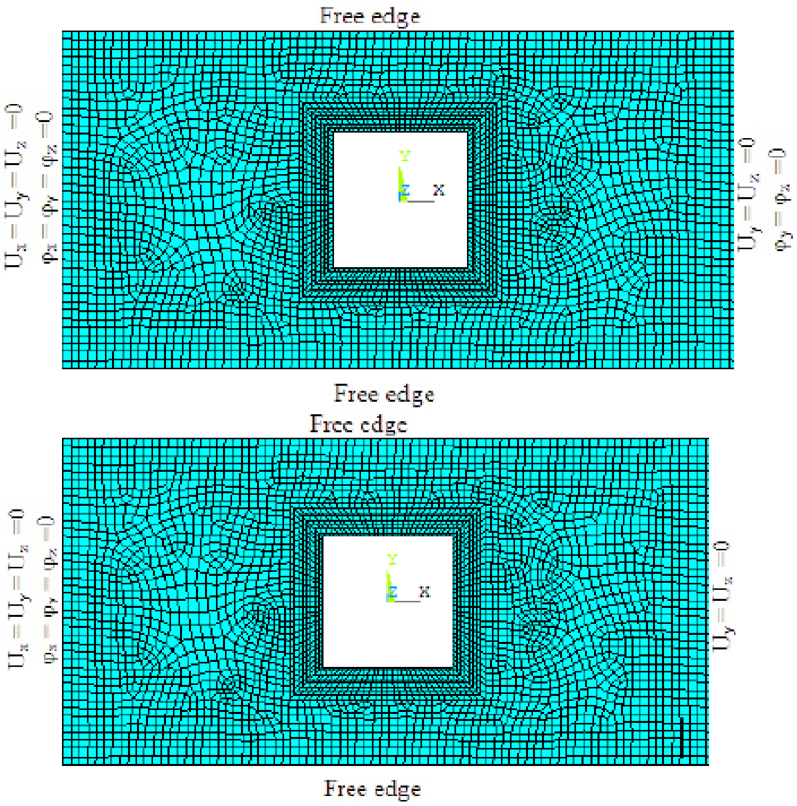

Figure 2: FE model with mesh

III. Description Of Element

The SHELL281 element type is utilized for this project. This shell element facilitates the analysis of shells that vary in thickness, whether they are extremely thin or relatively thick. Furthermore, because of its versatility in application, it serves as an ideal material for modeling layered composite coatings and sandwich structures. This material is ideally suited for applications that exhibit significant strain nonlinearity, linearity, or rotation, making them excellent candidates for its successful use. The element consists of eight nodes, each possessing six degrees of freedom. The various degrees of freedom allow for rotation around the three axes and translation along the x, y, and z axes contained within the element. The nonlinear element S8R5 is utilized in projects involving the examination of cylindrical plates. This element consists of eight nodes, each possessing five degrees of freedom. The presence of this element can be identified through its existence.

IV. Geometric Modelling And Material Property

Figure 1 illustrates the geometry as outlined. Plate 'a' has a length of 200 millimeters, whereas plate 'b' has a width of 100 millimeters. This laminate consists of sixteen layers, with each layer measuring 0.125mm in thickness. The symbol "t" represents the thickness of the plate, while the symbol "β" indicates the orientation angle of the cutout shape. The orientation angle of the cutout is considered to be 0 degrees for the objectives of this study. The composition features a rectangular cutout strategically placed at the center of a rectangular plate. c represents the length of the cutout, while d denotes the breadth. The rectangular hole transforms into a square hole when the ratios c and d are equivalent. Furthermore, the impact of square holes is examined under the same conditions as previously established. In the buckling analysis, the consideration of both square and rectangular holes is essential.

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 investigate how varying ply orientations of the plate influence its behavior when subjected to identical boundary conditions. All of these events will occur on the same day. This situation at the border exemplifies a fixed condition that is currently under consideration. This section employs various ply orientations. The orientations are outlined as follows: [0°/+45°/-45°/90°]2s to 90°. Kindly consult the list provided below for additional information. Both subjects are examined, and an inquiry is conducted to determine the outcomes that will arise from the situation. Both are analyzed, and the resulting implications are considered. The subsequent figures illustrate the impact of the plate aspect ratio (a/b), the length/thickness ratio (a/t), boundary conditions, and linearly increasing in-plane compressive stress on the buckling loads of a rectangular composite plate featuring a rectangular/square cutout.

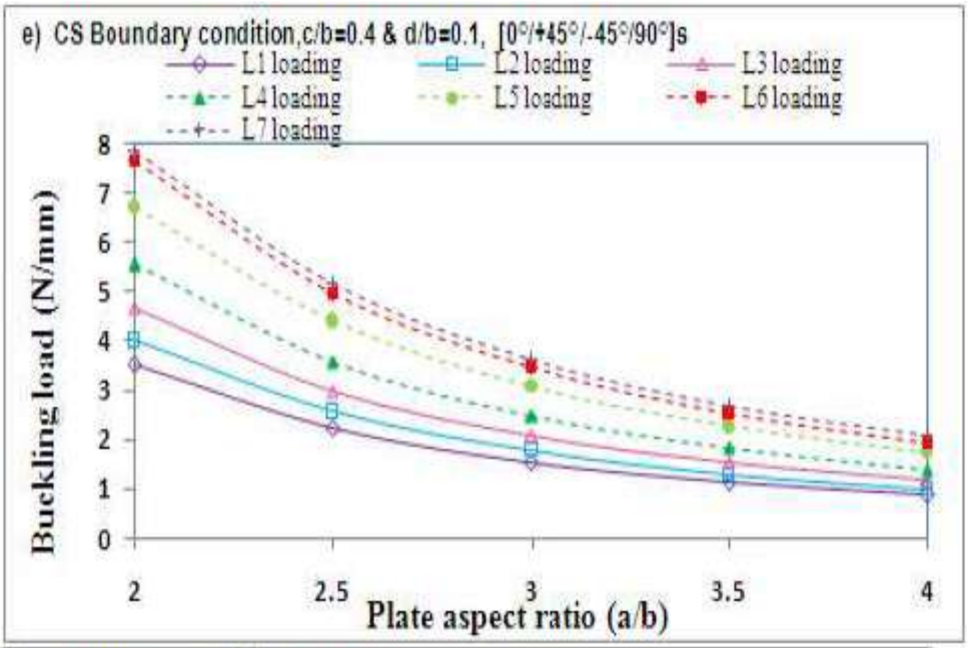

Figure 3 : Effect of plate aspect ratio with holes with unsymmetrical (S) layup under CS condition

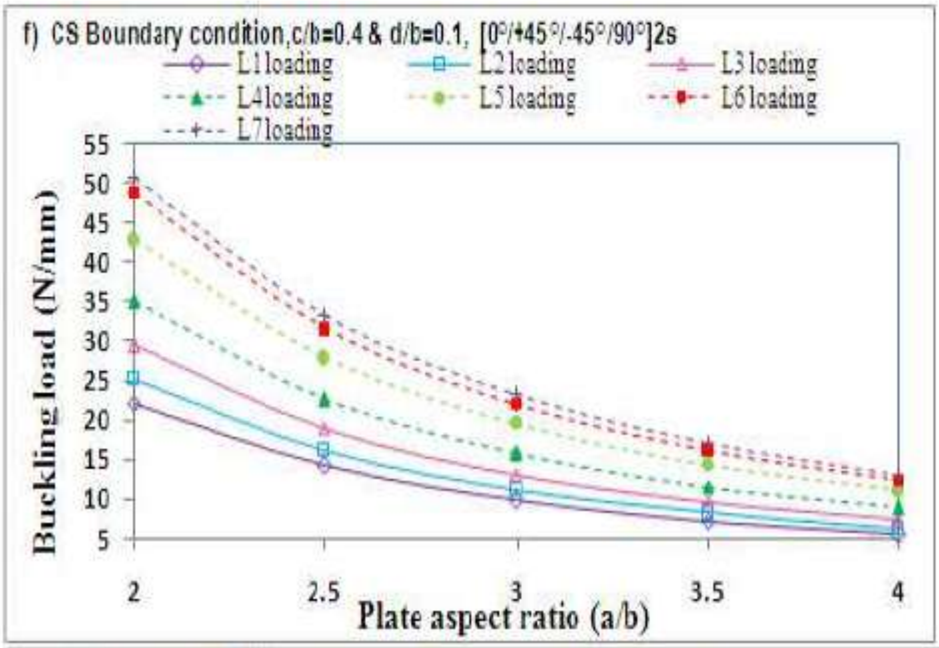

Figure 4 : Effect of plate aspect ratio with holes with unsymmetrical (2S) layup under CS condition

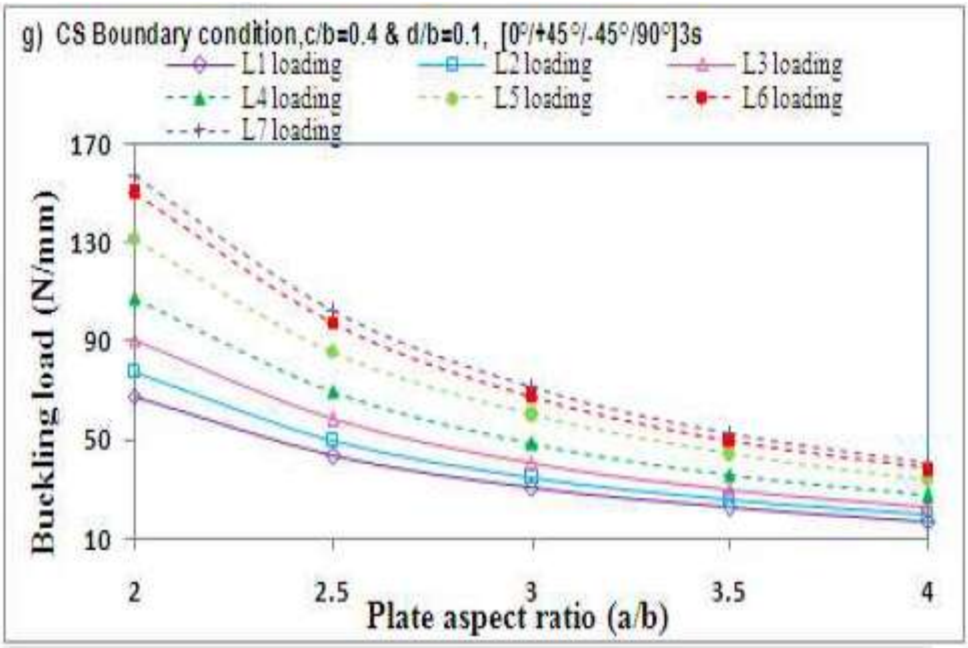

Figure 5 : Effect of plate aspect ratio with holes with unsymmetrical (3S) layup under CS condition

The subsequent figures illustrate the influence of the plate aspect ratio (a/b), the length/thickness ratio (a/t), boundary conditions, and linearly increasing in-plane compressive stress on the buckling loads of a rectangular composite plate featuring rectangular/square cuts. The figures illustrate that the buckling loads of a rectangular composite plate featuring a square/rectangular cutout exhibit variations of 35.8%, 30.4%, 26.44%, and 23.4% for the ranges a/b=2-2.5, a/b=2.5-3, a/b=3-3.5, and a/b=3.5-4, respectively. This holds true irrespective of the length/thickness ratios (a/t), boundary conditions, and the linearly varying in-plane compressive loading. In comparison to plates with aspect ratios of 2.5, 3, 3.5, and 4, 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 a plate with an aspect ratio of a/b=2. Regardless of the length-to-thickness ratios (a/t), boundary conditions, or the linearly increasing in-plane compressive force, this remains consistently true. The buckling load of a rectangular composite plate featuring a square or rectangular cutout experiences a reduction of 74% as the plate aspect ratio is elevated from 2 to 4. This reduction takes place regardless of the length/thickness ratios (a/t), boundary conditions, and the linearly varying in-plane compressive pressures.

VI. Conclusions

This study examines the effects of plate aspect ratio, length/thickness ratio, boundary conditions, and linearly varying in-plane compressive loading conditions on 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 buckling load of the rectangular composite plate with a/b=2 exceeds that of plates with a/b ratios of 2.5, 3.5, and 4, regardless of boundary conditions, linearly varying in-plane compressive loading, or length/thickness ratios (a/t). The buckling load of a rectangular composite plate featuring square or rectangular cutaways experiences a significant reduction of 97% as the length-to-thickness ratio escalates from 50 to 200, regardless of the plate aspect ratios (a/b) or boundary conditions, as well as the linearly varying in-plane compressive loading. The buckling load of a rectangular composite plate featuring square or rectangular cutouts experiences a reduction of 97% when the length-to-thickness ratio of the plate is increased from 50 to 200. This trend is consistent across various plate aspect ratios (a/b), boundary conditions, and under linearly varying in-plane compressive loading conditions.

References

[1]. 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.
[2]. Jain,P., Ashwin,K.. Post buckling response of square laminates with a central/elliptical cutout. Compos Struct. 75, (2004).
[3]. 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.
[4]. 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.
[5]. 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).

[6]. 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.
[7]. Y. Zhang, C. Yang, Recent developments in finite element analysis for laminated composite plates, Composite Structures 88(1) (2009) 147-157.
[8]. 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.
[9]. R. Mania, Buckling analysis of trapezoidal composite sandwich plate subjected to in-plane compression, Composite Structures 69(4) (2005) 482-490.
[10]. B.O. Baba, Buckling behavior of laminated composite plates, Journal of Reinforced Plastics and Composites (2007).
[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.