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Research Paper

An Evaluation of the Influence of Varying Plate Aspect Ratios on the Stability Analysis of Laminated Composites in Clamped Conditions

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ABSTRACT: *The effect of plate aspect ratio on the buckling behavior has been investigated numerically for this sixteen-ply quasi-isotropic graphite/epoxy symmetrically laminated composite plate* $[0°/+45°/-45°/90°]_{2s}$*, which is equipped with square and rectangular cuts. The finite element technique (FEM) was used to apply a range of linearly variable in-plane compressive stresses to the plate. This study also discusses the effects of boundary conditions, plate length/thickness ratio (a/t), and the size of square or rectangular cutouts on the buckling behavior of symmetrically laminated rectangular composite plates exposed to linearly increasing in-plane compressive loads. The results show that increasing the ratio of the plate's aspect to its thickness and length can reduce the buckling loads of rectangular composite plates with rectangular or square cutouts subjected to various in-plane loads that vary linearly, irrespective of the cutout's size, shape, or boundary conditions. A number of linearly variable inplane loads, length/thickness (a/t), aspect ratio (a/b), and boundary conditions all have a substantial impact on the buckling strength of a rectangular composite plate with a square or rectangular cutout.*

KEYWORDS: *Aspect Ratio, Stability Analysis, FEM, Laminated Composites*.

I. INTRODUCTION

Composite laminated plates buckle when subjected to compressive stresses. Composites are composed of two or more materials that work together to provide qualities that are hard to get when using just one of the ingredients. The majority of these materials' weight is supported by their fibers. In addition to offering flexible structural performance, matrices with a low modulus and a high elongation shield fibers from external stresses and maintain their alignment and proper location. Because of the nature of the elements, composite materials—which are composed of two or more components—may considerably lower construction weight while preserving a high strength-to-weight ratio. Fiber-reinforced composites are often used as laminas, or thin sheets, in the building industry. The most common kind of material macrounit in the material is called a laminate. The orientation of the fibers inside each lamina and the layer stacking sequence may be altered to provide the required level of strength and stiffness for a particular application. The distinctive characteristics of a composite material are the outcome of a special combination of characteristics brought about by the orientation, distribution, and composition of the composite's constituent parts. Cutouts are necessary for many purposes, such as reducing weight, enhancing air circulation, and creating connections between components that are close to one another. A composite material called carbon-fiber reinforced plastic is created by combining several carbon fiber types with thermosetting resins. The lightweight, nonconductive polymer known as carbon fiber reinforced plastic, or CFRP, is reinforced with fibers. The compound has an extremely lengthy half-life. The strength and stiffness of the material may be greatly increased by stacking several fiber sheets in different configurations. Parth Bhavsar and his associates examined the buckling behavior of glass fiber reinforced polymer (GFRP) under loads that increased linearly using the finite element method.

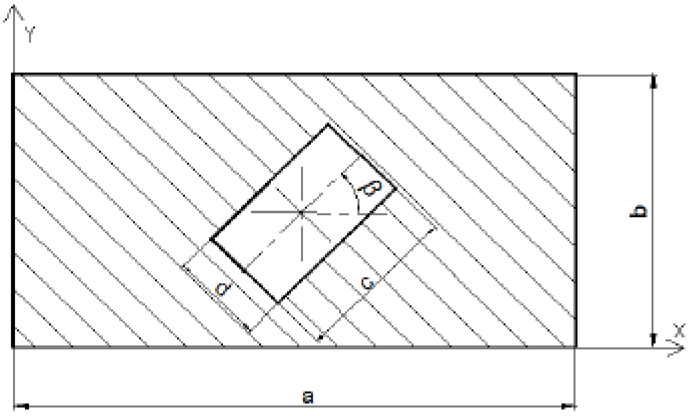

Figure 1: Geometry of the model.

Numerous factors have been examined to determine their effects on the buckling stress of rectangular plates having an aspect ratio of one. Joshi and associates determined the buckling stress per unit length of a rectangular plate with circular cuts under biaxial compression using two-dimensional finite element analysis. There are two methods to evaluate the buckling variables: adjusting the length-to-thickness ratio and positioning the holes. The buckling behavior of laminated rectangular plates under clamp-free boundary conditions was investigated by Nagendra Singh Gaira and associates. It is advantageous that cutouts exist since they lower the buckling stress. The desired effect of increasing the aspect ratio is to reduce the buckling load factor. To investigate how an axial load affects a laminated composite cylindrical panel's buckling load, Hamidreza Allahbakhsh and Ali Dadrasi performed a buckling research on the panel. An elliptical cutout of various sizes and positions was used in the study. In Container Okutan Baba's research, the buckling stress generated on rectangular plates is examined in relation to different cut-out geometries, length-to-thickness ratios, and ply orientations. The researchers used both theoretical and experimental methods to ascertain how these factors affected the buckling behavior of E-glass/epoxy composite plates under in-plane compression stress. According to Hsuan-Teh Hu and colleagues' finite element buckling investigation of composite laminate skew plates subjected to uniaxial compressive loads, the failure criteria and nonlinear in-plane shear significantly impacted the skew plates' final loads. In comparison, the linearized buckling loads have less of an impact.

1. **Finite Element Model**

This work uses finite element analysis to determine the buckling load factors of carbon fiber composite plates that have square or cylindrical geometries. The APDL version is ANSYS Version 14.5. Three different boundary conditions—fixed, clamped, and unclamped—are considered while analyzing the plate's dimensions. Two levels make up the first scenario, whilst three levels make up the second. The stacking sequences used, which were [0°/+45°/-45°/90°]2s, respectively, may be to blame for this. The plate must be perforated with several center holes of similar volume in order to do the investigation. There are many possible configurations for the center holes, including square, triangular, circular, and star patterns. The properties of the buckling load factor are presently being examined.

The buckling response of quasi-isotropic graphite/epoxy composite plates with square or rectangular cutouts under linearly increasing in-plane compressive loads is examined in this work using FEM to examine the effects of plate aspect ratio (a/b), length/thickness ratio (a/t), and boundary conditions. Epoxy serves as the matrix material and graphite fibers as reinforcement in the lamina. The graphite/epoxy material properties are shown in Table 1 and are taken from Hsuan*Teh Hu and Bor*Horng Lin (1995). The global x axis is aligned with material axis 1, while the global y axis is aligned with material axis 2. The global x*axis is aligned with the compressive loads applied to the plate. The direction of the compressive load coincides with the 0° fiber direction.

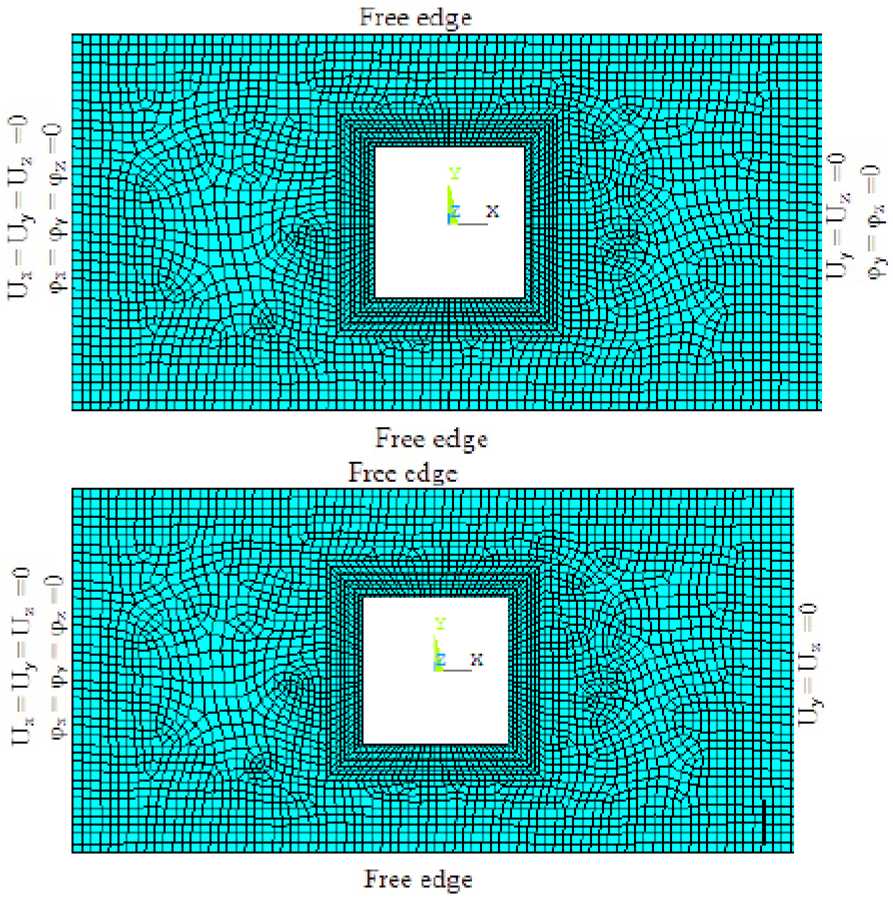

Figure 2: FE model with mesh

II. DESCRIPTION OF SHELL ELEMENT

The SHELL281 element type is used for this project. The study of very thin or slightly thick shells is made easier by the presence of this shell element. It is also the perfect material for modeling sandwich structures and layered composite coatings because of its wide range of applications. The effective use of this material is best suited for applications with considerable strain nonlinearity, linearity, or rotation. Eight nodes make up the element, and each one has six degrees of freedom. These degrees of freedom allow for translations along the x, y, and z axes that are included inside the element, as well as rotation around the three axes. The nonlinear element S8R5 is employed in studies with cylindrical plates. The existence of eight nodes, each with five degrees of freedom, identifies this element.

III. GEOMETRIC MODELLING AND MATERIAL PROPERTY

Figure 1 illustrates the geometry. Plates 'a' and 'b' are 200 mm long and 100 mm broad, respectively. Each layer of this sixteen-layer laminate is 0.125 mm thick, with "t" standing for plate thickness and "β" for cutout orientation angle. A cutout orientation angle of zero degrees is assumed in this study. A rectangular cutout centered on a rectangular plate is assumed in this piece. The cutout is c in length and d in breadth. The rectangular hole becomes a square hole when the ratios c and d are equal. Under the same conditions, the effect of square holes is also examined. Both square and rectangular holes are included in the buckling analysis.

Table 1 : Property of composite material

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

IV. RESULTS AND DISCUSSION

This section's goal is to examine the impact that different plate ply orientations have on the plate under certain boundary conditions. All of this will go place simultaneously. It is being viewed as an example of a fixed condition at the border. A range of ply orientations are used in this section. These are the orientations: [0°/+45°/-45°/90°]2s. Please refer to the list below for further details. Both of them are analyzed, and research is done to find out what the situation's effects are. Both are examined, along with the implications that follow.

Figures show how the buckling loads of a rectangular composite plate with a rectangular/square cutout are influenced by the plate aspect ratio (a/b), length/thickness ratio (a/t), boundary conditions, and linearly rising in-plane compressive stress.

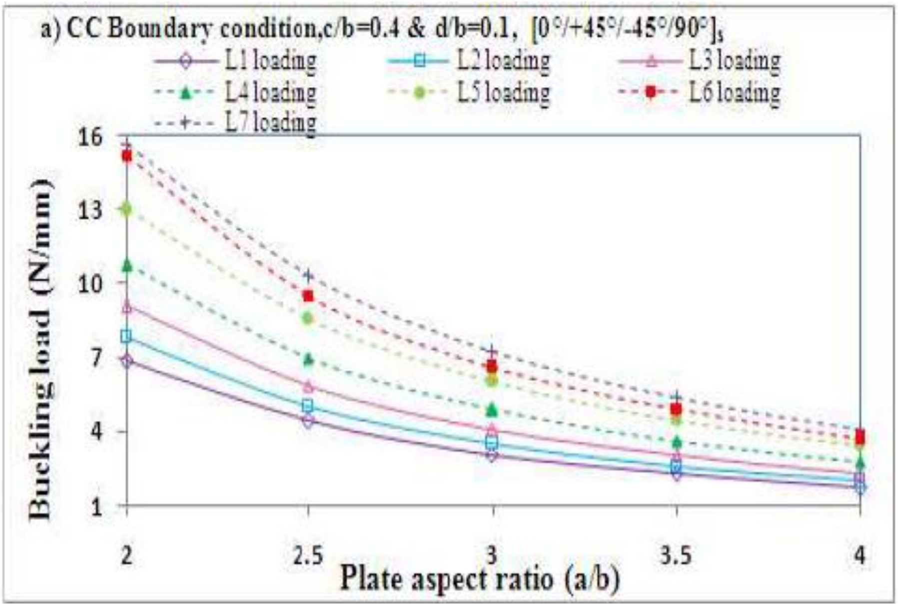

Figure 3 : Effect of plate aspect ratio with Clamped BC (S) layup Scheme

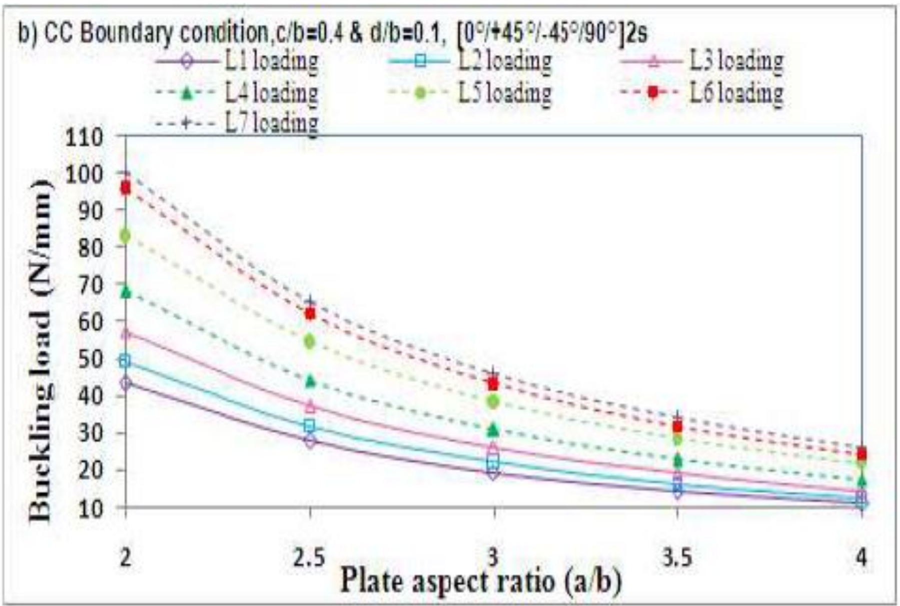

Figure 4 : Effect of plate aspect ratio with Clamped BC (2S) layup Scheme

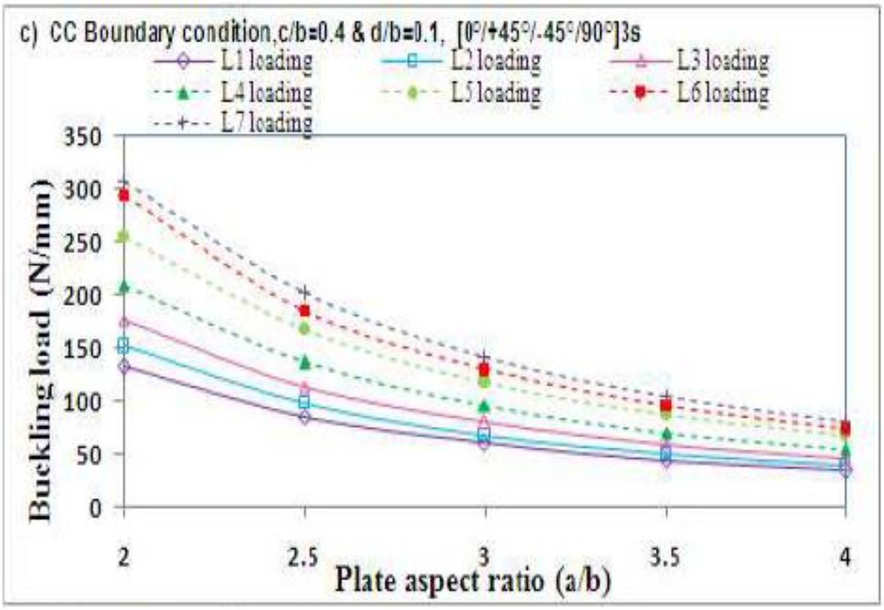

Figure 5 : Effect of plate aspect ratio with Clamped BC (3S) layup Scheme

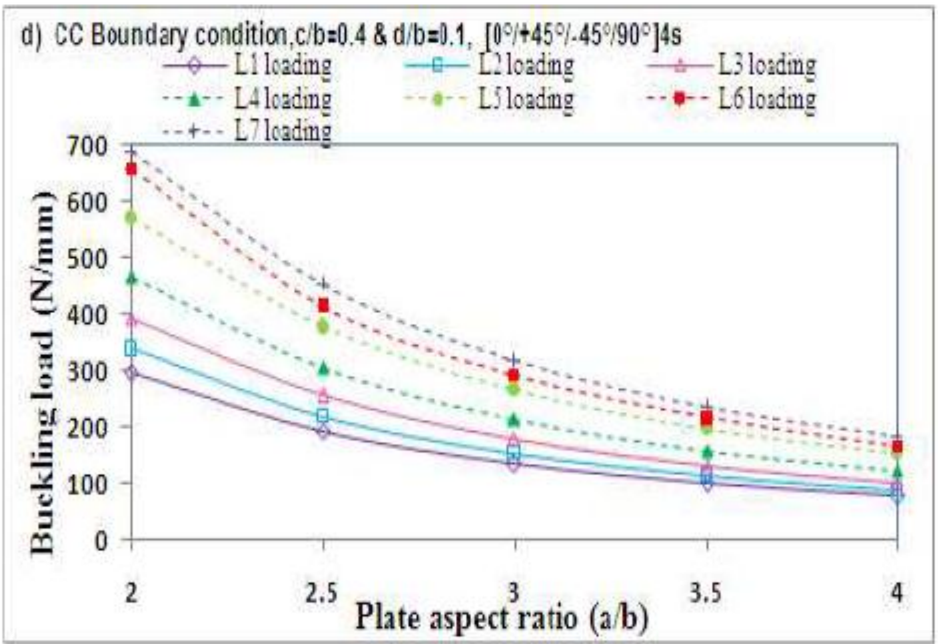

Figure 5 : Effect of plate aspect ratio with Clamped BC (4S) layup Scheme

Figures show how the buckling loads of a rectangular composite plate with rectangular/square cuts are affected by the plate aspect ratio (a/b), length/thickness ratio (a/t), boundary conditions, and linearly rising in-plane compressive stress. Figures demonstrate that, independent of length/thickness ratios (a/t), boundary conditions, and linearly varying inplane compressive loading, the buckling loads of a rectangular composite plate with square/rectangular cutout differ by 35.8%, 30.4%, 26.44%, and 23.4% for a/b=2-2.5, a/b=2.5-3, a/b=3-3.5, and a/b=3.5-4, respectively. In comparison to a plate with plate aspect ratios of 2.5, 3, 3.5, and 4, the buckling load of a rectangular composite plate with a plate aspect ratio of a/b=2 is 1.5 times, 2 times, 3 times, and 4 times greater. This is independent of boundary conditions, linearly variable inplane compressive stress, and length/thickness ratios (a/t). Regardless of length/thickness ratios (a/t), boundary conditions, and linearly changing inplane compressive loads, a rectangular composite plate with a square/rectangular cutout experiences a 74% reduction in buckling load when the plate aspect ratio is increased from 2 to 4.

V. CONCLUSIONS

This study investigates how the buckling behavior of a sixteen-ply quasi-isotropic graphite/epoxy symmetrically laminated rectangular composite plate [0°/+45°/-45°/90°]2s with square/rectangular cutout is affected by the plate aspect ratio, length/thickness ratio, boundary conditions, and linearly varying in-plane compressive loading conditions.

The rectangular composite plate with a/b=2 has a larger buckling load than plates with a/b=2.5, 2.5, 3.5, and 4. This is true independent of boundary conditions, linearly increasing inplane compressive loads, or length/thickness ratios (a/t). Regardless of plate aspect ratios (a/b), boundary conditions, and linearly increasing inplane compressive stress, the buckling load of a rectangular composite plate with square/rectangular cutout reduces by 97% as the plate length/thickness ratio grows from 50 to 200.

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