Investigating the Effect of Different Plate Aspect Ratios on Clamped-Free Buckling Analysis of Laminated Composites

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ABSTRACT :

Statistical analysis was done on this sixteen-ply equally laminated composite plate $[0°/+45°/-45°/90°]_{2s}$, which has both square and rectangular cuts, to see how the plate aspect ratio affects how it buckles. The plate went through a number of in-plane compressive pressures that changed linearly. This was done using the finite element method (FEM). This study looks at how equally laminated rectangular composite plates buckle when in-plane compressive loads increase linearly. It does this by looking at the effects of boundary conditions, the plate length/thickness ratio (a/t), and the sizes of square or rectangular cuts. The results show that increasing the ratio of the plate's aspect to its thickness and length can lower the buckling loads of rectangular composite plates with rectangular or square cutouts when they are subjected to changing linear in-plane loads. This is true no matter what the cutout's size, shape, or boundary conditions are. The bending strength of a rectangular composite plate with a square or rectangular hole is greatly affected by the border conditions, the aspect ratio (a/b), the length-to-thickness ratio (a/t), and other in-plane loads that change linearly.

Keywords: FEM, Plate Aspect Ratio, Clamped-Free Conditions, Buckling Analysis.

1. INTRODUCTION

Pressure from outside causes composite layered plates to buckle when they are put under compression loads. There are two or more parts that make up a composite. When put together, they give the material traits that are hard to get from just one part. These things are what composites are made of. A big chunk of these materials' weight is held by their threads. Matrixes with a low stiffness and a high extension not only make structures flexible, but they also protect fibers from external pressures and keep them straight and in the right place. Composite materials are made up of two or more parts that can be put together in different ways to make the whole thing lighter while still keeping its high strength-to-weight ratio. This is because composite elements are made up of more than one part. Laminas are thin sheets that are often used in the building business. Fiber-reinforced materials are often used for this purpose. Most of the time, laminae are the type of material macrounit that can be found in the material. It is possible to change the way in which the layers are stacked as well as the direction of the fibers inside each lamina in order to get the right amount of strength and stiffness for a given application. The unique properties of a composite material come from the way its parts are mixed, arranged, and oriented. Cutouts are needed for many reasons, such as lowering the weight of parts, improving air flow, and connecting parts that are close to each other. One type of composite material called carbon-fiber reinforced plastic is made by mixing several types of carbon fibers with thermosetting resins. CFRP, which stands for carbon fiber reinforced plastic, is a type of polymer that is nonconductive, light, and strengthened with threads made from carbon fiber. A drug whose effects last a very long time. The strength and stiffness of the material can be greatly increased by stacking a lot of fiber sheets in different ways. It is possible to do this to get the result you want. Parth Bhavsar and his colleagues used the finite element method to study how glass fiber reinforced polymer (GFRP) bends when the pressures increase in a straight line.

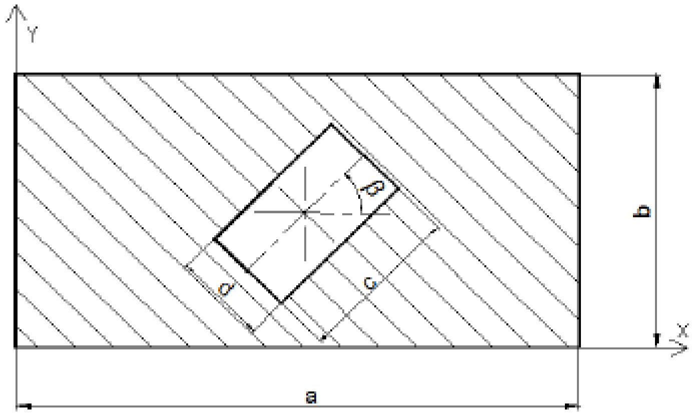

Figure 1: Geometry of the model.

Researchers have looked into the bending stress of rectangular plates with an aspect ratio of one. They have looked at a lot of different factors to see how they affect the stress. Joshi and his colleagues used two-dimensional finite element analysis to find the bending stress per unit length of a rectangle plate with circle cuts that was being compressed in two directions. If you want to figure out the bending factors, you can do one of two things: change the ratio of length to width or move the holes around. Nagendra Singh Gaira and his colleagues looked into how laminated rectangular plates buckled when there was no clamp on the edge. The bending load goes down when there are holes, which is a good thing. The bending load factor will go down as the aspect ratio goes up, which is what we want to happen. Two researchers, Hamidreza Allahbakhsh and Ali Dadrasi, studied bending in a layered composite cylinder panel. Their goal was to find out what happens when an axial load is put on the panel. Sometime during the study, an oval hole showed up in a number of different sizes and places. As part of his study, Container Okutan Baba looks into how different cut-out shapes, length-to-thickness ratios, and board angles affect the bending stress that is put on rectangle plates. So the researchers could find out how these things affected the bending of E-glass/epoxy composite plates that were put under in-plane compression stress, they used both theory and experimental methods. The research that Hsuan-Teh Hu and his colleagues did on finite element buckling on composite laminate skew plates that were put under uniaxial compressive loads showed that the failure criteria and nonlinear in-plane shear had a big effect on the ultimate loads that were put on the skew plates. Another big difference is between this and the linearized bending loads, which have a smaller effect.

2. FINITE ELEMENT MODEL

A simple way to meet the requirements set for the style of the meeting paper. The goal of this study is to find the bending load factors of carbon fiber composite plates that are either square or circular using finite element analysis. ANSA Version 14.5 is the version of APDL that is used. When the size of the plate is checked, three different border conditions are looked at. This is what the set, clamped, and unclamped possibilities look like. The first situation has two levels, and the second scenario has three levels for each case. This might be because of the stacking patterns that were used, which were [0°/+45°/-45°/90°]2s. In order for the study to be possible, the plate needs to have a lot of center holes that are all the same size. There are a number of other ways that the center holes can be placed, including in a square, triangular, circular, or star shape. It is being looked into right now what the qualities of the bending load factor are. We use the finite element method (FEM) to look into how the plate aspect ratio (a/b), length/thickness ratio (a/t), and boundary conditions affect the buckling behavior of quasi-isotropic graphite/epoxy composite plates with square or rectangular cuts when they are put under in-plane compressive loads that rise in a straight line. Graphite threads are used as support, and glue is used as the core material to build the lamina. Based on the work of Hsuan Teh Hu and Bor Horng Lin (1995), Table 1 shows the material qualities of graphite and resin. The material's axis 1 is aligned with the global x axis, and its axis 2 is aligned with the global y axis. This is done from start to finish. There is a match between the world x-axis and the compression loads that are put on the plate. The direction of the 0° fiber and the direction of the compression load are the same.

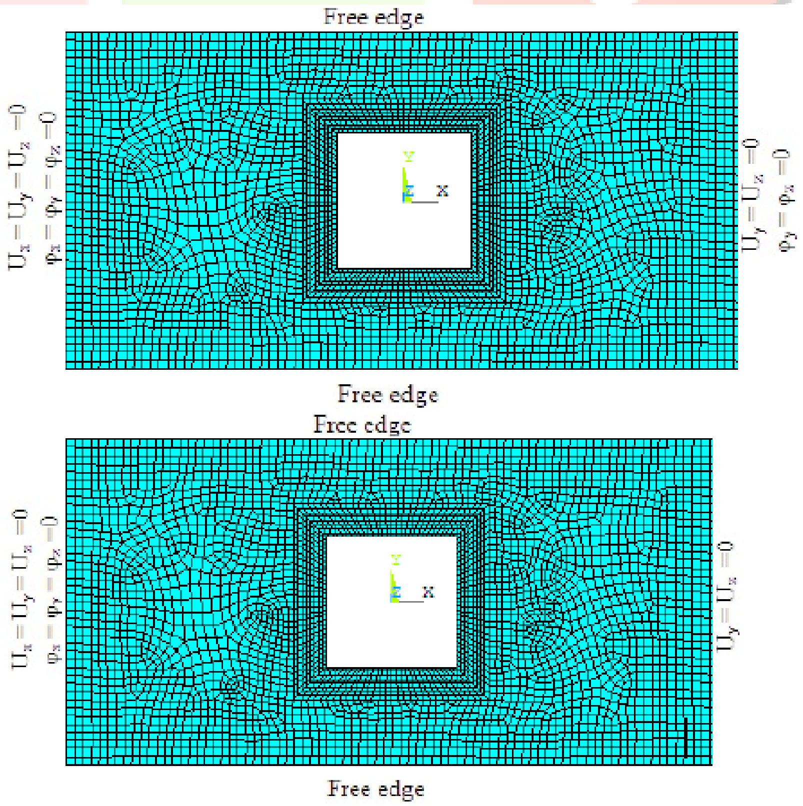

Figure 2: FE model with mesh

3. DESCRIPTION OF ELEMENT USED

In this work, the SHELL281 element type is being used. It is easy to study shells that are either very thin or pretty thick when this shell part is present. It is also great for creating stacked compound layers and sandwich structures because it can be used in so many ways. This material works best when used in situations where there is a lot of pressure nonlinearity, symmetry, or rotation. The element is made up of eight nodes, and each one has six degrees of freedom. Because of these degrees of freedom, the element can move along the x, y, and z directions and spin around the three axes. The S8R5 nonlinear element is used in projects that use cylinder-shaped plates to study things. There are eight nodes in this element, and each one can move in five different ways. This element can be found just by being there.

4. GEOMETRIC MODELLING AND MATERIAL PROPERTY

It is possible to see that the geometry is exactly as specified in Figure 1. In terms of dimensions, plate 'a' is 200 millimeters in length, while plate 'b' is 100 millimeters in width. This laminate is composed of sixteen layers, and each layer has a thickness of 0.125 millimeters. Specifically, the letter "t" represents the thickness of the plate, whereas the letter "β" determines the form of the cutout orientation angle. With regard to the objectives of this investigation, it is assumed that the cutout orientation angle is 0 degrees. The item is supported by a cutout that is rectangular in shape and is positioned in the center of a plate that is also rectangular. The length of the cutout is denoted by c, while the width is denoted by d. Once the ratios c and d are equal to one another, the rectangular hole transforms into a square hole rather than remaining rectangular. In addition, the impact of square holes is investigated by using the identical settings as in the previous examples. When doing the buckling analysis, it is important to take into account both square and rectangular holes.

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

5. RESULTS AND DISCUSSION

When the plate is subjected to the same boundary condition, the purpose of this section is to investigate the influence that various ply orientations of the plate have on the plate while it is being subjected to the same constraints. It is expected that all of these events will take place on the same day. This is an example of a fixed condition that is already being taken into account at the border, where it is now being considered. This section makes use of a variety of distinct ply orientations in its construction. The following is a list of the orientations: Up to 90 degrees, [0°/+45°/-45°/90°]2s. In the event that you need any more information, kindly consult the list that is shown below. Both of them are subjected to an investigation, and study is carried out, with the goal of determining the outcomes that will be brought about by the situation. Both are investigated, and the repercussions that will be brought about as a result of the investigation are taken into consideration. The buckling loads of a rectangular composite plate with a rectangular/square cutout are shown to be impacted by the plate aspect ratio (a/b), the length/thickness ratio (a/t), boundary conditions, and linearly increasing in-plane compressive stress. The effects of these factors are shown in the following pictures.

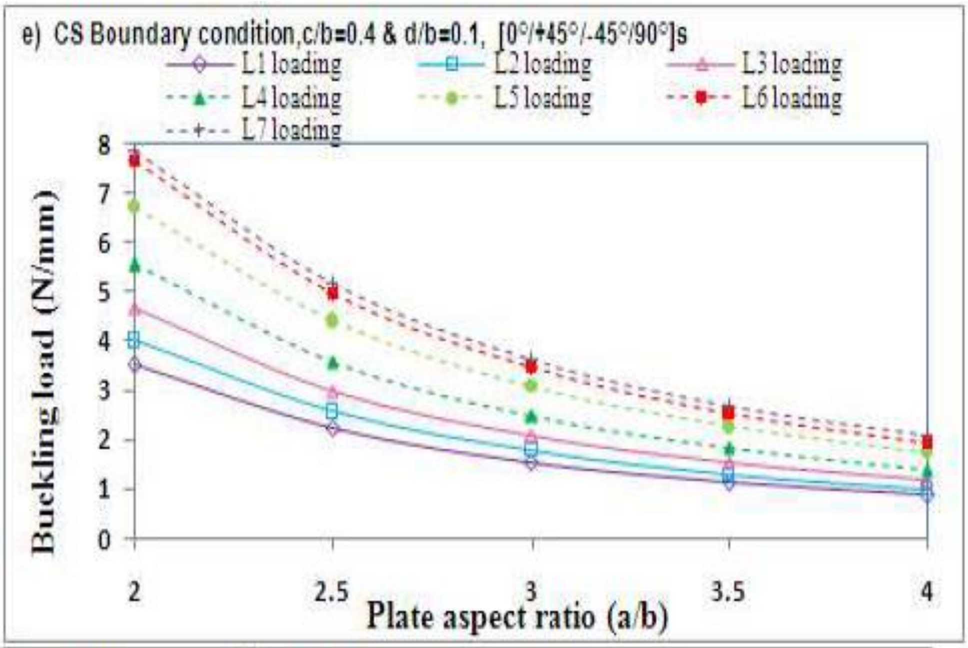

Figure 3 : Effect of plate aspect ratio with holes with unsymmetrical (S) layup under CS condition

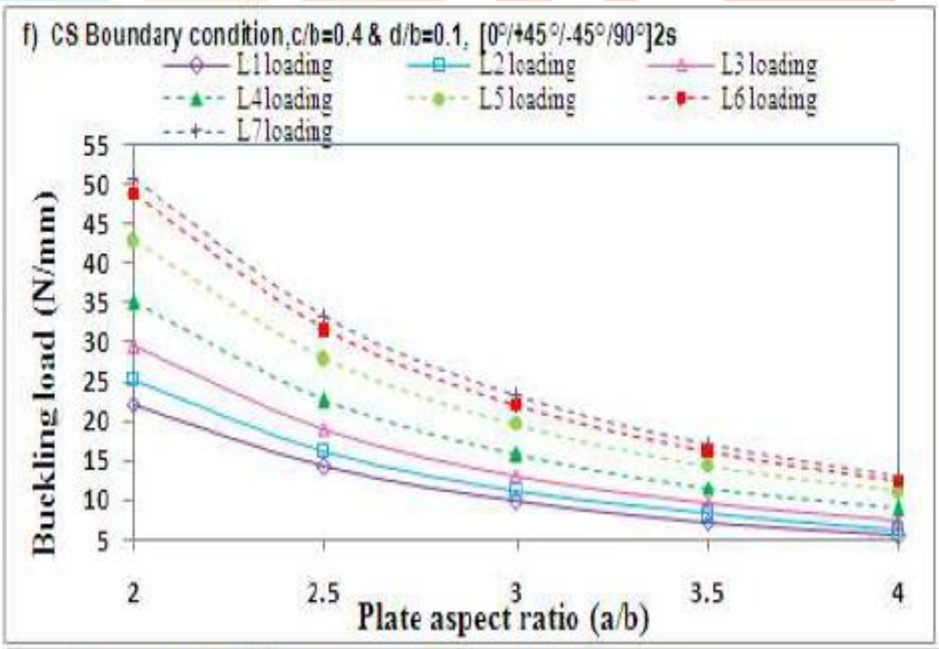

Figure 4 : Effect of plate aspect ratio with holes with unsymmetrical (2S) layup under CS condition

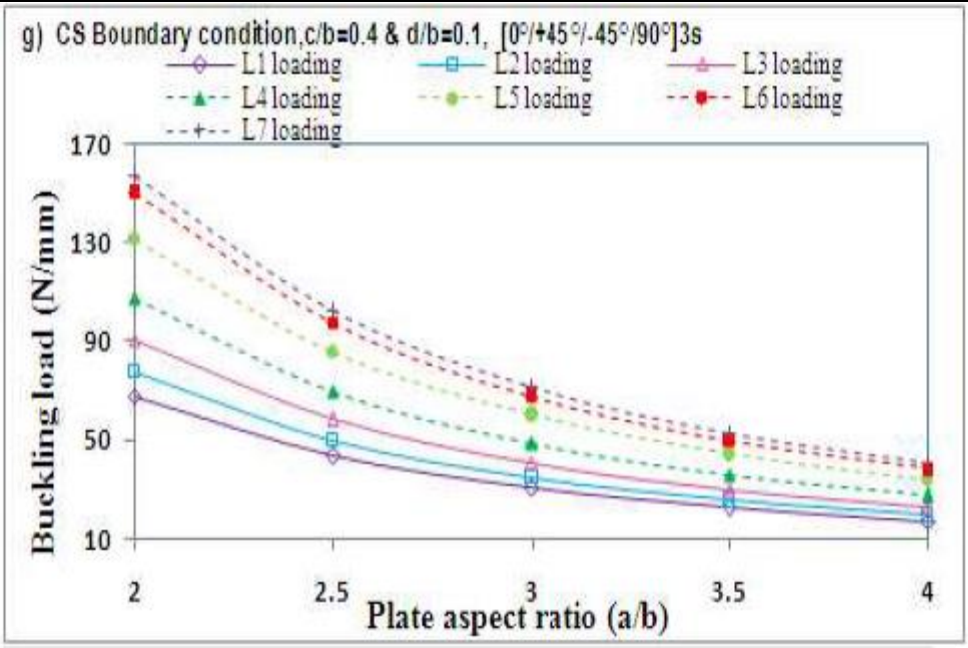

Figure 5 : Effect of plate aspect ratio with holes with unsymmetrical (3S) layup under CS condition

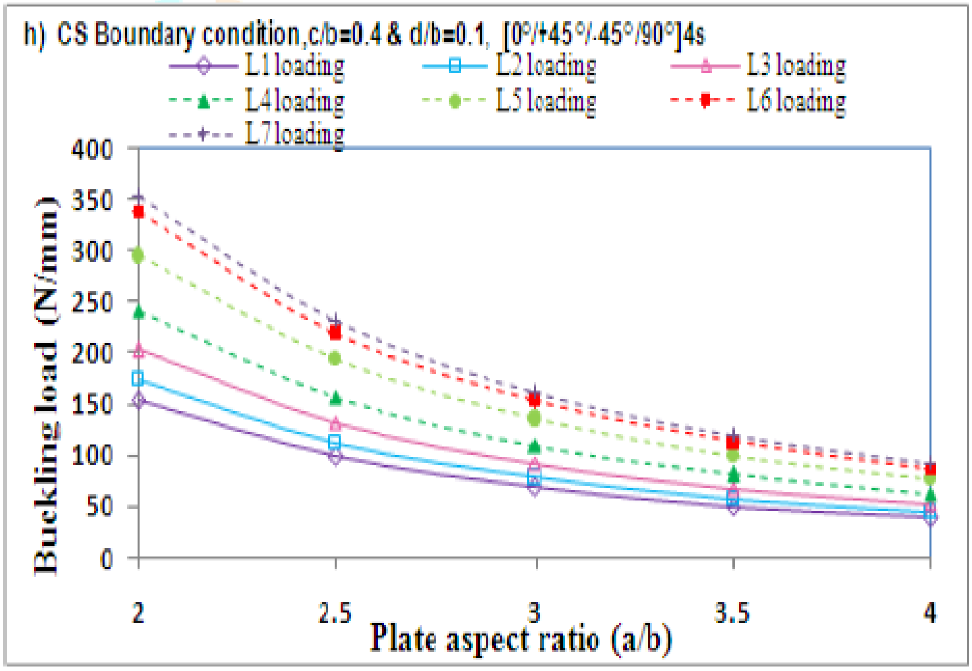

Figure 6 : Effect of plate aspect ratio with holes with unsymmetrical (4S) layup under CS condition

Each of the following illustrations illustrates how the buckling loads of a rectangular composite plate with rectangular/square cuts are impacted by the aspect ratio of the plate (a/b), the ratio of the length to the thickness (a/t), boundary conditions, and linearly increasing in-plane compressive stress. The figures illustrate that the buckling loads of a rectangular composite plate with a square/rectangular cutout vary 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. These values are displayed in the figures. Regardless of the length-to-thickness ratios (a/t), boundary conditions, and linearly increasing inplane compressive force, this is going to be the case. While 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 more than the buckling load attained by a plate with a plate aspect ratio of a/b=2, the buckling load of a plate with an aspect ratio of a/b=2 is 1.5 times, 2 times, 3 times, and 4 times greater than the buckling load of a plate with an aspect ratio of a/b=2. It is always the case that this is the case, regardless of the length-to-thickness ratios (a/t), boundary conditions, or linearly rising inplane compressive force. In a rectangular composite plate with a square/rectangular cutout, increasing the plate aspect ratio from 2 to 4 results in a 74% reduction in the buckling stress of the plate. It is not reliant on the length-to-thickness ratios (a/t), boundary conditions, or linearly varying inplane compressive forces for this decrease to take place.

6. CONCLUSIONS

This investigation investigates the influence 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 $[0°/+45°/-45°/90°]_{2s}$ with square/rectangular cutout.

The buckling load of the rectangular composite plate with a/b=2 is greater than that of plates with a/b=2.5, 2.5, 3.5, and 4, irrespective of boundary conditions, linearly varying inplane compressive loading, or length/thickness ratios (a/t). No matter the plate aspect ratios (a/b), boundary conditions, or linearly varying inplane compressive loading, the buckling load of a rectangular composite plate with square/rectangular cutaway decreases by 97% as the plate length/thickness ratio increases from 50 to 200.

The buckling load of a rectangular composite plate with square/rectangular cutout decreases by 97% as the plate length/thickness ratio increases from 50 to 200, regardless of the plate aspect ratios (a/b), boundary conditions, and linearly varying inplane compressive loading.

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