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# Linear Buckling Analysis on Thin FRP Cross Ply Rectangular Laminates with Square Cut-Outs of curved corners under Biaxial Compression

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### *Abstract*

*The main objective of the present study abstract is to determine the buckling load for cross ply(0°/90°/90°/0)rectangular plate with square cuts having curved corners under biaxial compression using 2-D finite element analysis ANSYS is the commercial software, which has been successfully executed and finite model is validated. the present problem is evaluated by changing the position of the square cut with curved corners, aspect ratio(a/b) and thickness ratio(b/t).the results show that the buckling load is more at the bottom positioned square hole, increases with increase in aspect ratio, decreases with increase in thickness ratio and increases with increase in number of layers (N).*

*Key words: FRP, FEM buckling analysis and biaxial load.*

## 1. Introduction

A composite material consists of two or more materials and offers a significant weight saving in structures in the view of its high strength to weight ratio and high stiffness to weight ratios. In fiber reinforced composites, the mechanical properties can be varied as required by suitably orienting the fibers. In such materials fibers are main load bearing members and matrix are supporting members to the fibers because of their low elastic modulus and high ductility.



## 2. Problem statement

The objective of present research is to find the buckling load of rectangular laminates with square cuts having curved corners subjected to biaxial compression by changing the position of the square holes in the plate, aspect ratio, thickness and number of layers.

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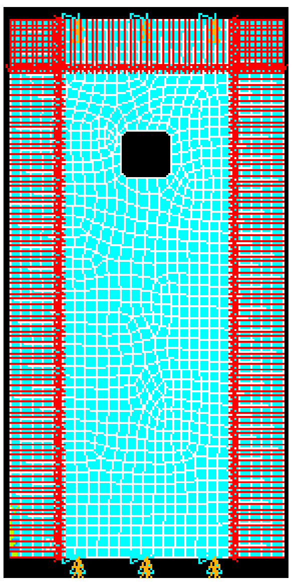
## 3. Geometric modeling

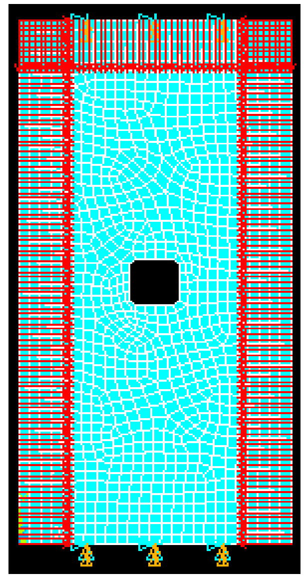
The width of the rectangular plate is varying from 50mm, 100mm, 150mm, 200mm in X-direction and span of the rectangular plate (b) is 100mm which is fixed in Y-direction. Then corresponding a/b ratios are 0.5, 1, 1.5 and 2. The thickness of the plate is determined from b/t ratios i.e. varied from 20 to 100 (20, 40, 60, 80 and 100). The numbers of layers (N) are varied from 4, 8, 12, 16 and 20. The area of the square hole with fillet corners is 79sqmm and the radius of the fillet is 1mm.

Fig.1 shows the geometrical modeling of rectangular plate with square cuts of curved corners of various positions of cuts as shown below.

top



middle



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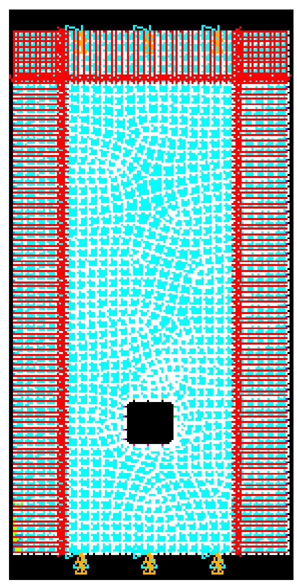


Fig.1 FE Model (Top, Middle and Bottomsquare hole)
(a/b=0.5, b/t=100, s-s Boundary and N=4)

## 4. Material Properties

The following material properties

are considered for the present analysis

Young's Moduli,
$E_1$=147E3MPa, $E_2$=10.3E3MPa, $E_3$=10.3E3MPa
Poission's ratio
$V_{12}=0.27$, $V_{23}=0,54$, $V_{31}=0.27$
Rigidity Moduli,
$G_{12}$=7E3MPa, $G_{23}$= 3.7E3MPa, $G_{13}$=7E3MPa

## 5. Validation of FE Model

The present work is validated from J. Leela Krishna and he has chosen that buckling of thin FRP rectangular plates with rectangular cuts of curved corners under biaxial compression.

Table. 1 Validation of present value with Leela Krishna's value

| Hole position | Leela krishna's Buckling load in KN/mm | Present value for Buckling load in KN/mm |
|---|---|---|
| TOP | 0.11684 | 0.12198 |

## 6.Results and Discussion

Fig 2 shows buckling load per unit length for different hole positions. buckling load is maximum for bottom hole position due to the fact that it gets more support compared to other hole positions. and subject to more constraints at this position

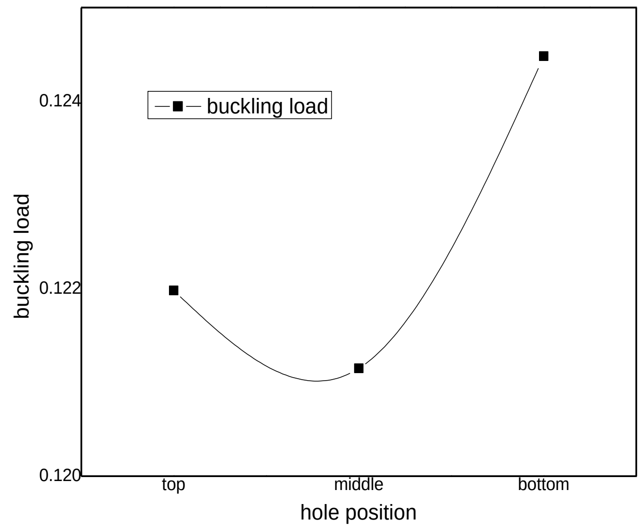



Fig. 2 Effect of Square Hole location at different position



Fig.3 shows that values of various buckling loads of first five modes for a/b ratios. It is observed that the buckling load increases as the mode number increases and also increases for different a/b ratios. The reason is due to the number of cycles increases when the mode number increases, so that the stiffness of the laminates is more.

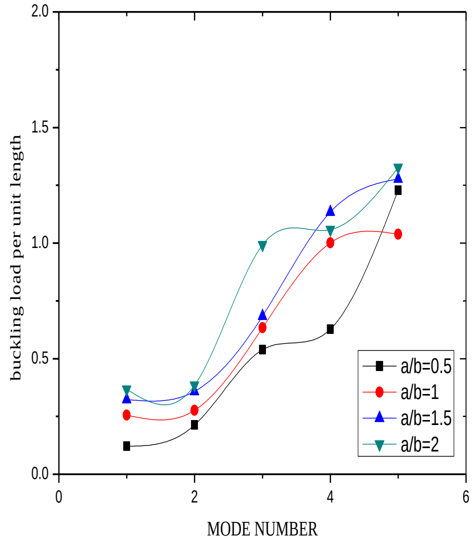



Fig.3 Effect of Aspect ratio on buckling load per unit length

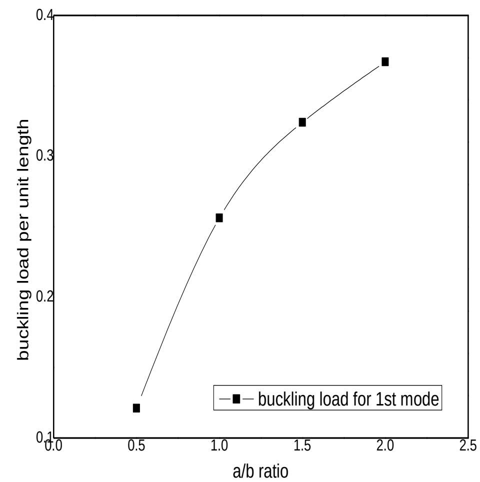
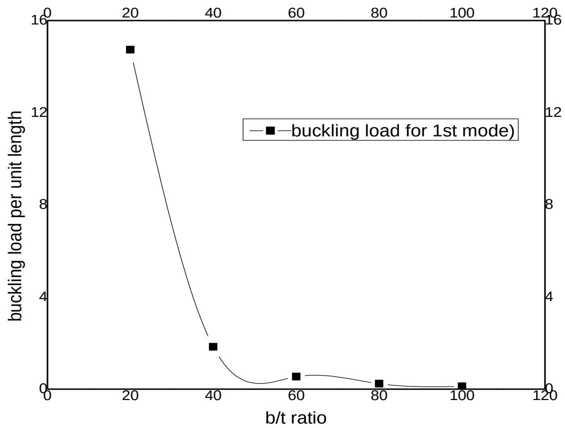



Fig. 4 Effect of Aspect ratio on 1st mode buckling load per unit length

Fig.4 shows the buckling load with respect to a/b ratio for first mode. It is found that the buckling load increases with increase in aspect ratio. It could be attributed to the fact that the width of the plate increases in X-direction, so it offers more resistance.

Fig.5 shows that the buckling load varies with respect to thickness ratio. It is observed that the buckling load decreases from b/t=20 to b/t=100. It could be attributed to the fact that the resistance of the plate decreases as the thickness of the plate decreases with increase in thickness ratio.




Fi g. 5 Effect of thickness ratio on 1st mode of buckling load per unit length

Fig.6 shows that the buckling load varies with respect to number of layers. It is observed that the buckling load increases with increase in number of layers for 1st five modes of different layers. It could be attributed to the fact that the plate offers more resistance with increase in number of layers.

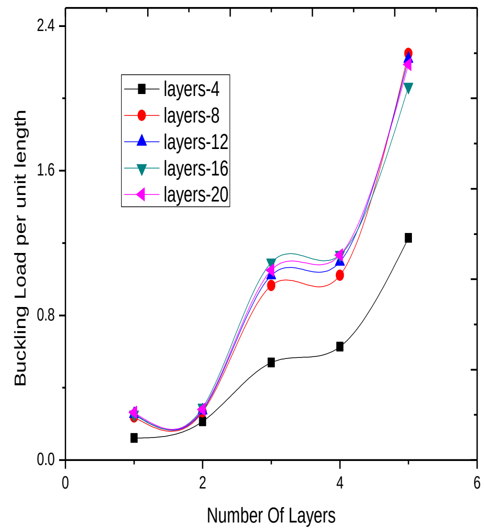
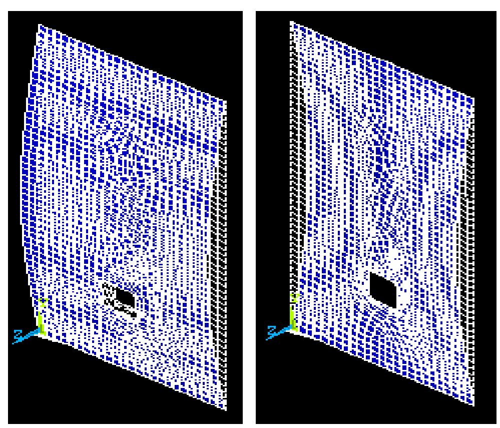


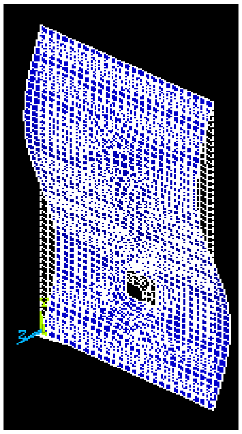

Fig. 6 Effect of Number of layers(N) on first five modes of buckling load per unit length

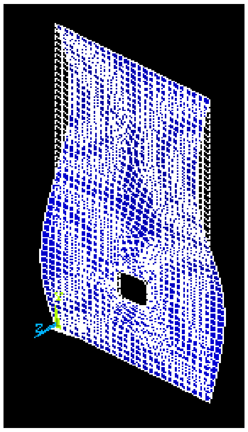
Fig.7shows 1st five modes of mode shapes

1. 2.



**3.** **4.**





**5.**

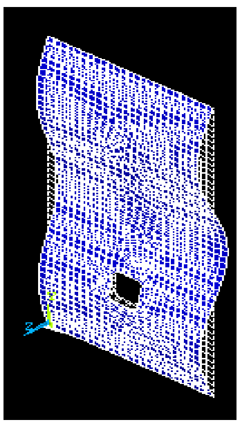


Fig.7 Buckling mode shapes -1, 2, 3, 4 & 5 (a/b=0.5, b/t=100, number of layers=4 and s-s Boundary)

## Conclusion

This study considers the buckling response of cross ply rectangular laminates with simply supported-simply supported boundary conditions along the top and bottom edges. The laminated composite plates rectangular in shape with square cutouts with curved corners at different locations, varying aspect ratio, thickness ratio and number of layers are discussed.

- Buckling load is maximum when the location of hole is at bottom.
- As a/b ratio increases, the buckling load increases.
- As b/t ratio increases, the buckling load decreases.
- As the number of layers increases, the buckling load increases.

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