

# Buckling Analysis of Laminated Composite Plates with Cut-Out

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**ABSTRACT:** Laminated composite plates have applications in aircraft, railway coaches, and bridges etc., due to their improved properties and low cost of fabrication. Cut-outs are often found in composite structure for ventilation, lighting, inspection, electric lines etc. This paper addresses the effect of cut-out on buckling behaviour of laminated composite plates. In this analysis, finite element method was applied to perform parametric studies on various plates based on stacking sequences, shape of cut-out, size of cut-out and aspect ratio of plate. Buckling behaviour of laminated composite plates under uniaxial and biaxial compression load is studied using ANSYS software.

**KEYWORDS:** Laminated composite plate, Buckling, Finite Element

## I. INTRODUCTION

Composite laminates have been used increasingly in a variety of industrial area due to their high stiffness and strength-to-weight ratios, long fatigue life, resistance to electrochemical corrosion, thermal stability and other superior material properties. This plate is mainly used in marine, offshore, nuclear, aerospace, automotive and civil engineering structure. The need of cut-out in subcomponents is typically required by weight optimization and practical concern. It is commonly used as access ports for mechanical and electrical system, damage inspection, and to serve as door and windows. Laminated composite used generally as thin plated and under axial compressive load, the load carrying capacity is investigated by most of the researchers. Hongzhi et al.[1] used first order shear deformation theory for analysis of symmetrical cross-ply composite plates under varying in plane loading, effect of load intensity and layup configuration on buckling load are investigated and result verified with computer code ABAQUS. Their studies concluded that there exist ultimate buckling resistance capacity with respect of increase of modulus ratio. M. Darvizeh et al.[2] presented comparative study of buckling behaviour of composite plate, mathematical modelling are developed based on generalised differential quadrature rule (GDQR) and Rayleigh-Ritz method.

M.R. Khalili et al.[3] developed new approach based on derivatives of double Fourier series and Stokes' transformation and predicted the static and dynamic behaviour of laminated composite plate having different boundary condition and different fibre orientation. And observed that boundary condition such as CCCC or SSSS are quite immune to fibre orientation, there is significant influence of CSCS boundary condition on fibre orientation. S. K. Sahu et al.[4] performed finite element analysis using eight noded isoperimetric shell element having five DOF per node based on first order shear deformation theory for curved panels plate with cut-out. Study reveals that panels with cut-out shows highest stiffness with addition of curvature. S.A.M. Ghannadpour et al.[5] M. Aydin Kumar[6] carried out a buckling analysis of laminated composite plate with a circular/elliptical hole, numerically, studied that increasing of hole positioned angle cause to decrease of buckling loads. Additionally, the cross-ply composite plate is stronger than all other analysed angle-ply laminated plates.

Hsuan-Teh Hu et al.[7] carried out buckling optimization of symmetrically laminated plates with various geometries and end conditions by using a sequential linear programming method together with a simple move-limit strategy. Basharia A.A. Yousef et al. [8] presented an experimental study of the behaviour of woven glass fibre/epoxy with ply orientation (+45°/-45°/+45°)s composite laminated panels under compression. Investigated the effects of varying the centrally located holes and notches cut-out which indicates that a cut-out can have a significant effect on buckling, fracture and energy absorption response of a compression-loaded panel. The results indicated that the plates without cut-out exhibited higher fracture load and energy absorption than plates with cut-out. A.V. Asha et al.[9]

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studied the vibration, buckling and parametric instability characteristics of general laminated cross-ply pre-twisted cantilever flat and curved panels using first order shear deformation theory and it is found that the instability behaviour of twisted cross-ply cantilever panels is greatly influenced by the geometry, material, angle of twist and lamination parameters.

In this paper the effects of different shapes of cut-outs on the buckling behaviour of composite plates laminates are taken into consideration. This study also contains the effect of size of cut-out with different plate aspect ratio on buckling behaviour of the laminated composite plate.

**II. MATERIAL AND GEOMETRIC PROPERTIES**

The laminae are not isotropic, the structural properties in transverse direction have different values as compared to its in-plane values table 1 shows young modulus E, modulus of rigidity G and Poisson ratio  $\nu$ . The lamina is in 1-2 plane and 3 is the transverse direction.

Table 1 material properties of lamina [5]

Mechanical Properties	Values
$E_1$	130 GPa
$E_2$	10 GPa
$E_3$	10 GPa
$G_{12} = G_{13}$	5 GPa
$\nu_{12} = \nu_{13}$	0.35
$\nu_{32} = \nu_{23}$	0.49

The plate used for analysis having geometric properties. Plate dimension is 120 × 120 mm, Thickness of plate 1.2 mm (thickness of each layer of this eight layer laminates is 0.15mm) and boundary condition is simply supported. The plate normal is aligned in z direction and plate area is located on xy plan. The simply supported boundary condition are applied on each four edges by fixing the translational displacement in z axis. The compression load is applied uniformly along the two opposite edges. In order to achieve the static equilibrium, four nodes at the middle point of each edge are fixed i.e. the displacement in y direction are fixed in loaded edges along with the displacement in x direction are fixed in transverse sides. The mechanical properties of lamina as shown in Table 1.

Finite element software ANSYS is preferred as numerical tool for present study. The element type used is SHELL 281 which is an 8 noded structural shell, suitable for analysing thin to moderately thick shell structures. The element has 8 nodes with 5 degrees of freedom at each node.

**III. EFFECT OF LAY-ORIENTATION**

To observe the buckling behaviour of composite laminate plate for ply orientation  $[0/90]_{2s}$ ,  $[30/-30]_{2s}$ , and  $[45/-45]_{2s}$  subjected to uniaxial and biaxial compressive loading. Result shows that the critical buckling load for  $[45/-45]_{2s}$  ply orientation is more than that for  $[45/-45]_{2s}$  and  $[0/90]_{2s}$  for simply supported square laminated composite plate for both uniaxial and biaxial loading. It also shows that critical buckling load obtained for same plate under biaxial loading condition is exactly half that of uniaxial loading condition.

Table 2 buckling load (N/mm) results with Ply orientation

Ply orientation	Present study(uniaxial loading)	Ref .[5](uniaxial loading)	Present study(biaxial loading)
$[0/90]_{2s}$	16.54	16.55	8.27
$[30/-30]_{2s}$	23.37	23.16	11.684
$[45/-45]_{2s}$	25.65	25.92	12.826

**IV. EFFECT OF SHAPE OF CUT-OUT**

Because of design requirements and philosophy different cut-out shape may be used. In this section the effect of different shapes of cut-outs are taken in to account. It is assumed that cut-out to be located at the centre line of the square plates with ply orientation  $[45/-45]_{2S}$  subjected to uniaxial loading. The direction of the loads and its boundary conditions are the same as previous section. The different shapes and there dimension are shown in Table 2. The area of cut-out is kept same for all shapes of cut-out.

Table 2 different cut-out shapes and their dimensions

Cut-out Shapes	Dimensions(mm)
Circle	Radius=12
Square	Side=21.26
Diamond	Same just rotate by 45°
Triangle	Base=32.31 Height=27.985
Horizontal Rectangle	Length=30.046 Width=15.038
Vertical Rectangle	Length=15.038 Width=30.046

Fig 1 shows the effect of shapes of cut-outs on buckling behaviour of plates. Buckling load shows higher value for vertical rectangular cut-out and lower value for circle shape cut shown in Fig 1. The buckling load for square and triangle shape cut having nearly closer value.

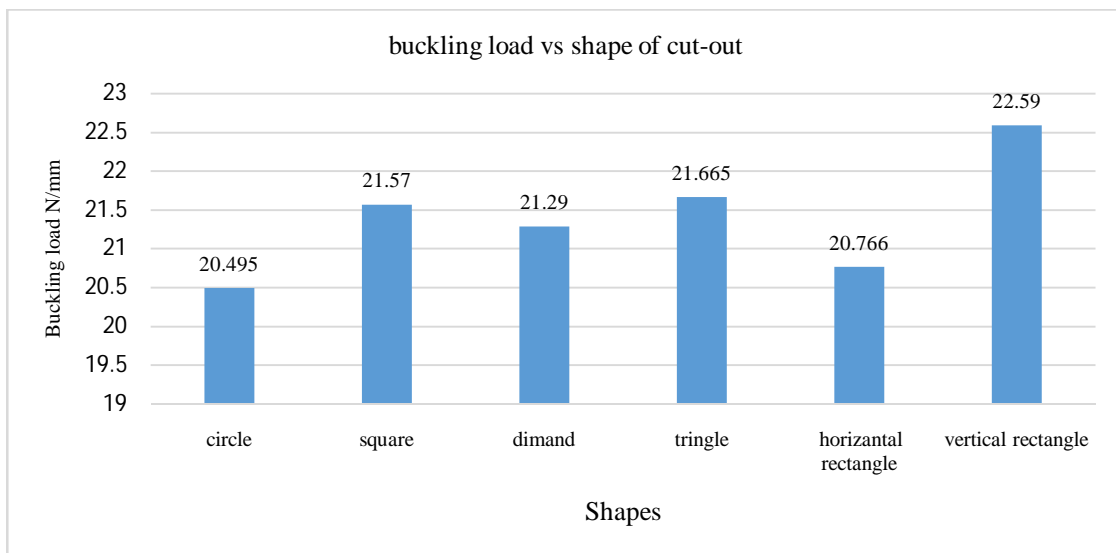


Fig 1 Effect of Different Cut-Out on Critical Buckling Load

**V. EFFECT OF SIZE OF CUT-OUT AND ASPECT RATIO**

This section deals with the buckling behaviour of perforated  $[45/-45]_{2S}$  laminated composite plate with different plate's aspect ratio i.e.  $a/b = 1, 2$  and  $3$  where 'a' is length and 'b' is width of plate. Simply supported boundary condition is applied on four edges. Plate is subjected to uniaxial compression along the width of the plate. The width of plate is same

for all plates which is 120mm and all cut-out is positioned in the centre of plate. Plates are provided with vertical rectangular shape hole having same aspect ratio of rectangle cut is  $c/d = 1/2$ , where  $c$  is length and  $d$  is width of rectangular cut. Buckling analysis is carried by increasing the area of cut-out.

The results of buckling load are depicted in Fig 2. This shows that aspect ratio of plate has negligible effects on buckling load of plates when plate is provided without cut-out. In case of square plate, there is decrease in maximum buckling load with addition of cut-out but for this vertical rectangular shape type cut-out with increase in area of cut there is increase and decrease of buckling load. Plate with aspect ratio 2 gives better result than that of other two with increase in area of cut. For plate with aspect ratio 2 provide greater value of buckling load for area of cut  $600\text{mm}^2$  and  $1200\text{mm}^2$  than that of same plate without cut.

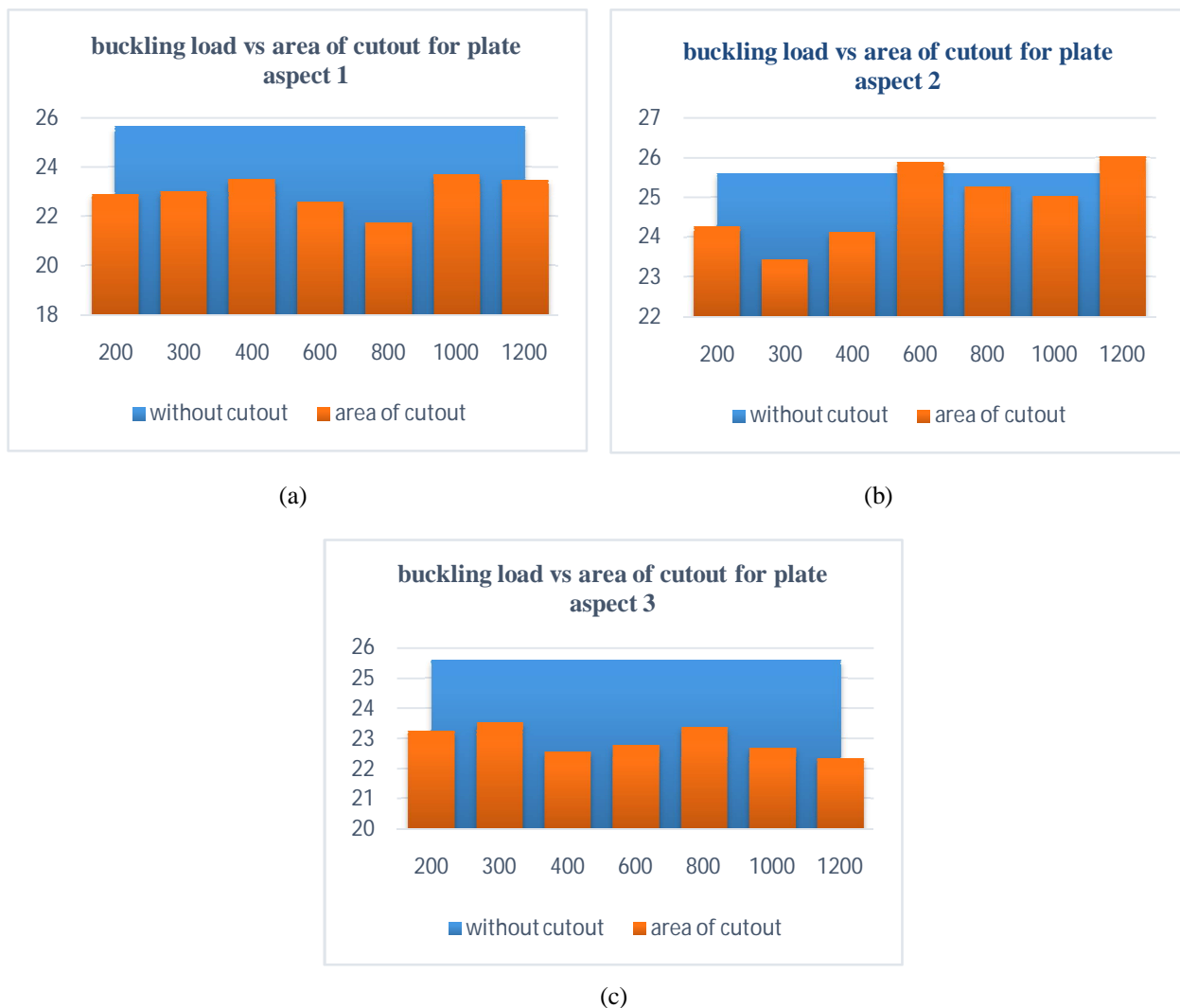


Fig 2. Effect of size of cut and aspect ratio of plate on buckling load for (a) plate aspect ratio 1

(b) Plate aspect ratio 2 (c) plate aspect ratio 3

## VI. CONCLUSIONS

On the basis of present study, which has been deal with the buckling behaviour of rectangular laminated composite plate under compression load, the following conclusion are made:

1. Buckling behaviour of laminated composite plate differ for different ply orientation (stacking sequence)
2. For simply supported square laminated composite plate subjected to axial loading as well as for biaxial loading, the laminated composite plate with  $[45/-45]_{2s}$  ply orientation gives maximum value of critical buckling load compare to  $[30/-30]_{2s}$  and  $[0/90]_{2s}$  ply orientation. Also in case of simply supported boundary for biaxial compressive loading condition buckling load is exact half that for axial loading conditions.
3. Laminated composite plate with simply supported boundary condition with ply orientation  $[45/-45]_{2s}$  subjected to uniaxial compression along the width of plateshows highest value of buckling load for vertical rectangular cut-out and lowest value for circle shape cut.
4. The aspect ratio of plate has negligible effects on buckling load of plates when plate is provided without cut-out. Plate with aspect ratio 2 gives better result than that of other two with increase in area of cut. For plate with aspect ratio 2 provide greater value of buckling load for area of cut  $600\text{mm}^2$  and  $1200\text{mm}^2$  than that of same plate without cut.

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