Static and Free Vibration Behavior of Laminated Composite Panels

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Abstract

In today's scenario, the light weight structures are most promising in many engineering sectors like aerospace, automobile, defence etc. This requirement can be convinced by the use of composite materials which exhibits comparatively higher strength to weight ratio than the conventional materials. In this work, the static and the free vibration behaviour of laminated composite panels have been examined, numerically. Simulation model is developed using ANSYS Parametric design language (APDL) code in ANSYS environment. An eight node quadrilateral shell element (SHELL281) is used for the discretization purpose of the present model. The convergence behaviour of present finite element results is checked and comprehensiveness of the model is revealed by comparing the results with those available published literature. The influences of different geometrical and material parameters such as lamination schemes, geometrical parameters, support conditions and material properties on the deflection and frequency responses of laminated composite panels will be examined through a wide variety of numerical illustrations.

Keywords— Laminated composites, Finite element method, Bending

I. Introduction

Composite materials are engineered materials made from two or more constituent materials that remain separate and distinct while forming a single component. Generally, one material forms a continuous matrix while the other provides the reinforcement. The two materials must be chemically inert with respect to each other so no interaction occurs upon heating until one of the components melts, an exception to this condition is a small degree of inter-diffusion at the reinforcement-matrix interface to increase bonding.

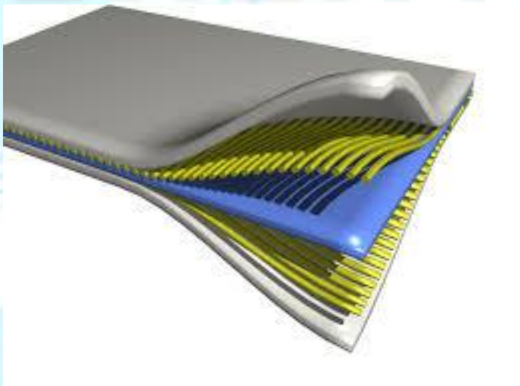

Fig 1: Composite material

II. FINITE ELEMENT MODELING

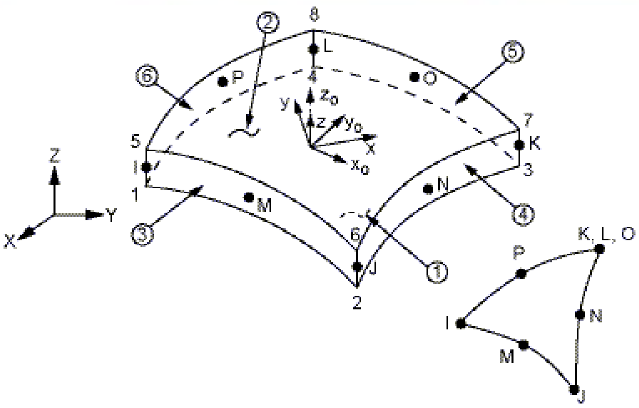

Fig 2:- Geometry of shell 281 element.

A. BOUNDARY CONDITIONS

SSSS: $v = w = \theta_y = \theta_z = 0$, at $x = 0, a$
$u = w = \theta_x = \theta_z = 0$, at $y = 0, b$
CCCC: $u = v = w = \theta_x = \theta_y = \theta_z = 0$, at $x = 0, a$
$u = v = w = \theta_x = \theta_y = \theta_z = 0$, at $y = 0, b$
SCSC: $v = w = \theta_y = \theta_z = 0$, at $x = 0, a$
$u = v = w = \theta_x = \theta_y = \theta_z = 0$, at $y = 0, b$

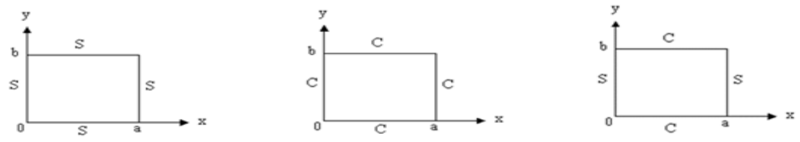

Fig. 3:- Representation of different support condition for the analysis.

III.STATIC ANALYSIS

A. CONVERGENCE STUDY

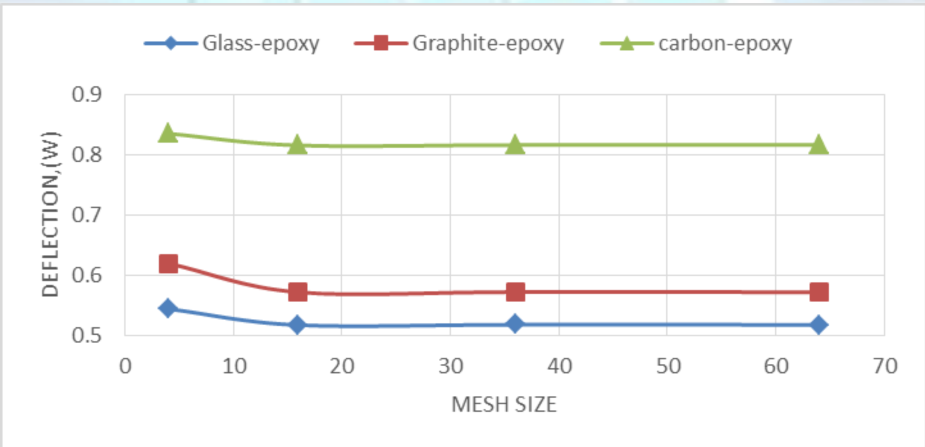

Fig 4:- Convergence study of laminated composite plate for different material models (a/h = 10, a/b=1).

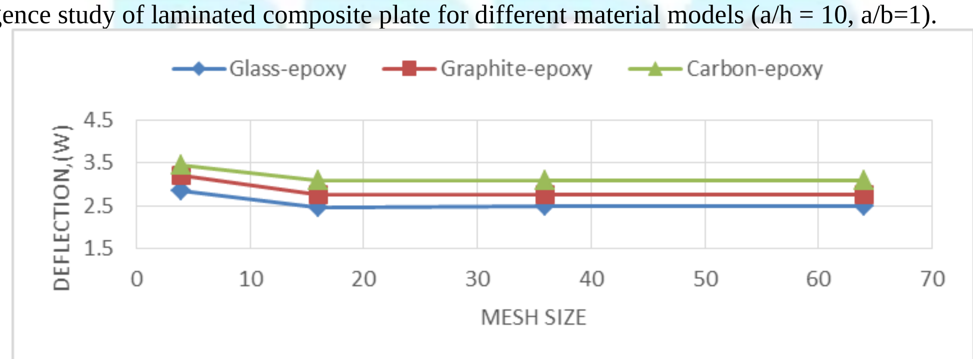

Fig 5:- Convergence study of laminated composite plate for different material models (a/h = 20, a/b=1).

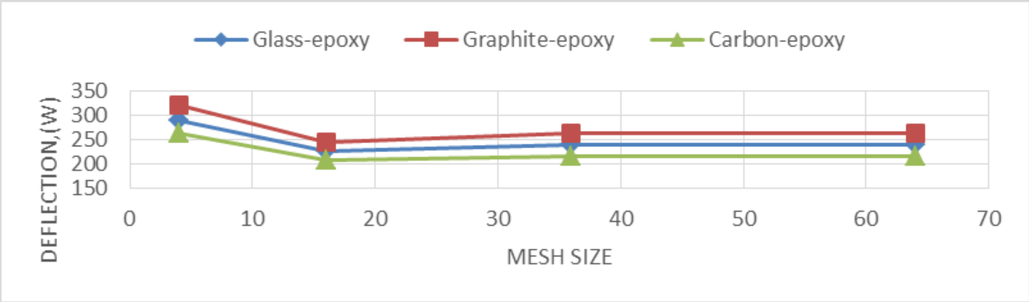

Fig 6:- Convergence study of laminated composite plate for different material models (a/h = 100, a/b=1).

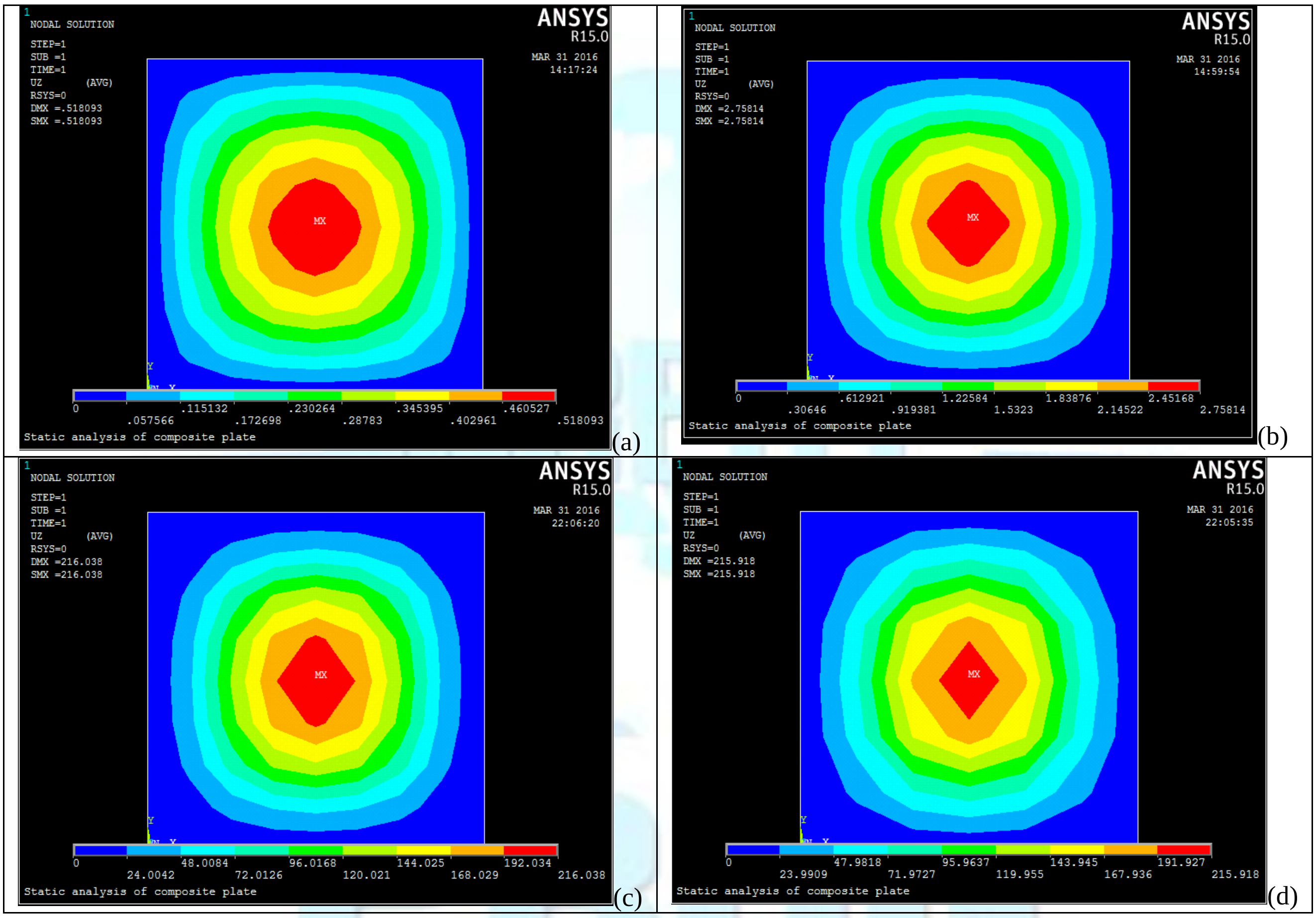

Fig 7:- Deflection shapes of laminated composite plates for different thickness.

(a) The deflection of Glass epoxy plate having thickness (h) = 0.1 and mesh 8x8.
(b) The deflection of Graphite epoxy plate having thickness (h) = 0.05 and mesh 8x8.
(c) The deflection of Carbon epoxy plate having thickness (h) =0.01 and mesh 8x8.
(d) The deflection of Carbon epoxy plate having thickness (h) = 0.01 and mesh 6x6.

B. VALIDATION STUDY

Fig. 8: Central deflection of a clamped cross-ply laminated plate under uniformly distributed load.

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C. EFFECT OF THICKNESS RATIO (a/h)

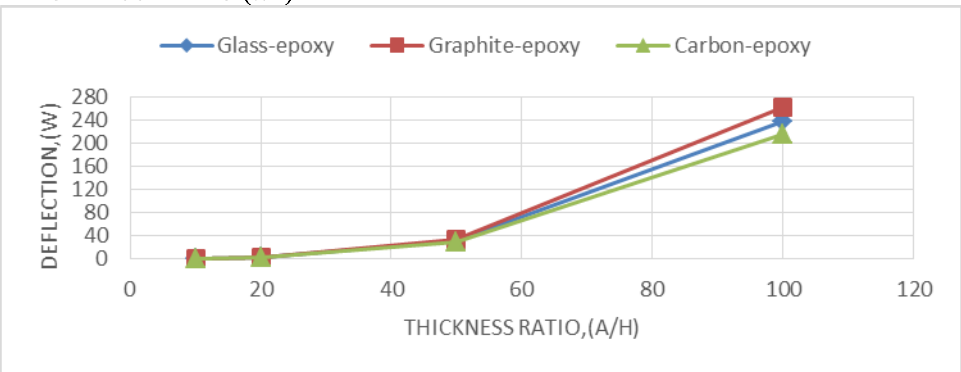

Fig 9:- Effect of thickness ratio on laminated composite plate for different material models.

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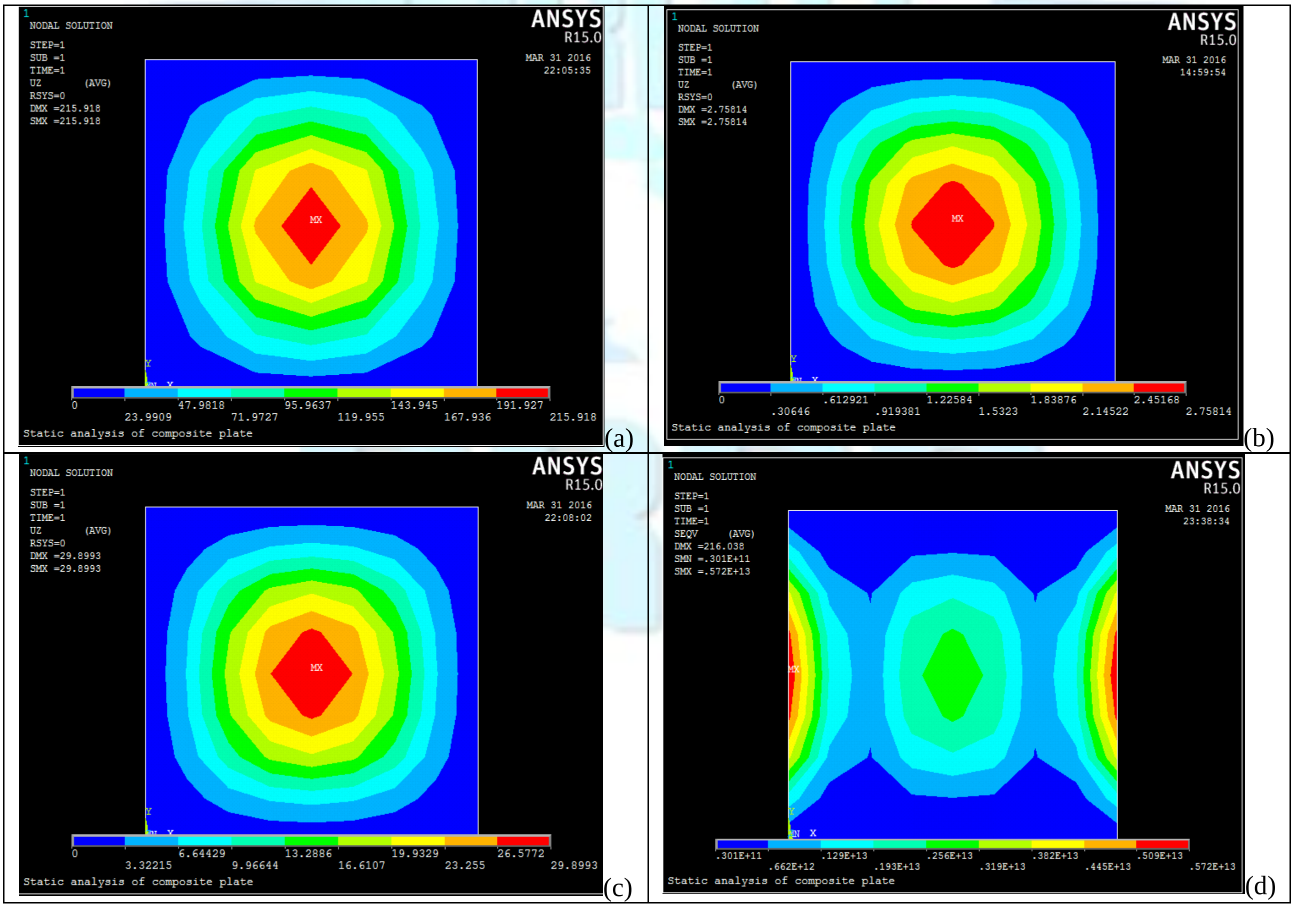


Fig 10:- Deflection shapes of laminated composite plates for different thickness ratios.

(a) The deflection of Glass epoxy plate having thickness ratio (a/h) = 10.

(b) The deflection of Graphite epoxy plate having thickness ratio (a/h) = 20.

(c) The deflection of Carbon epoxy plate having thickness ratio (a/h) = 100.

(d) The von mises stress of Carbon epoxy plate having thickness ratio (a/h) = 100.

D. EFFECT OF ASPECT RATIO

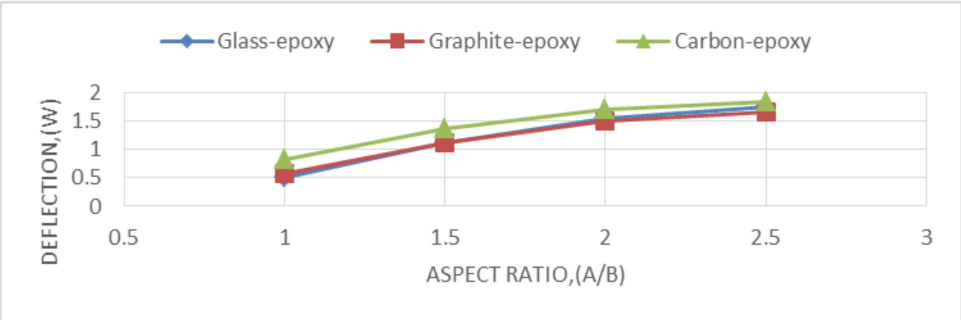
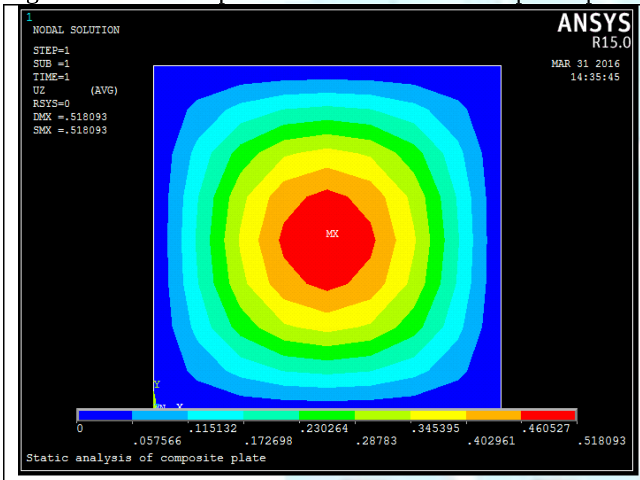
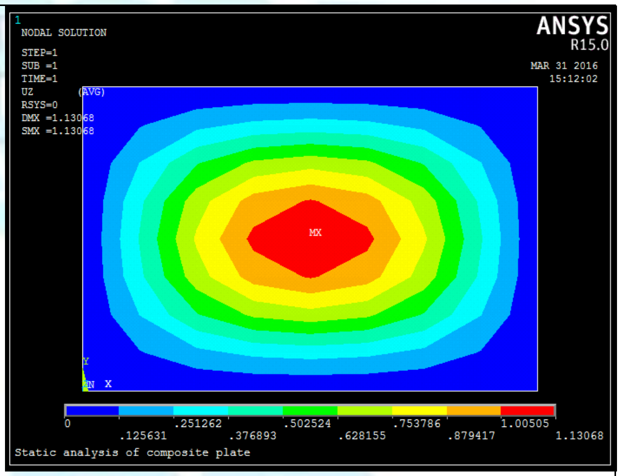


Fig 11:- Effect of aspect ratio on laminated composite plate for different material models.



(a)



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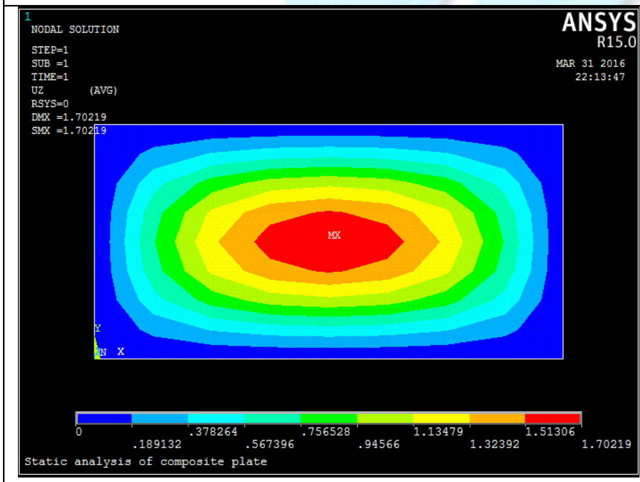

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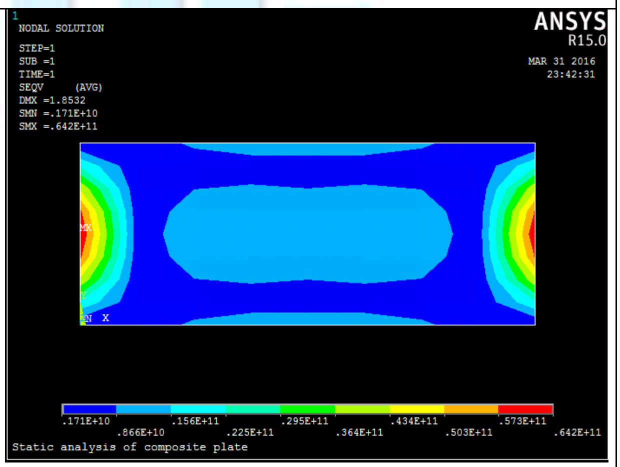


(d)

Fig 12:- Deflection shapes of laminated composite plates for different Aspect ratios.

(a) The deflection of Glass epoxy plate having Aspect ratio (a/b) = 1.

(b) The deflection of Graphite epoxy plate having Aspect ratio (a/b) = 1.5.

(c) The deflection of Carbon epoxy plate having Aspect ratio (a/b) = 2.

(d) The von mises stress of Carbon epoxy plate having Aspect ratio (a/b) = 2.5.

E. EFFECT OF BOUNDARY CONDITIONS

Table 1:- Deflection values of laminated composite plates for different Boundary conditions

material	Deflection values for Boundary conditions		
	SSSS	CCCC	SCSC
Glass epoxy	0.5180	0.5175	0.5179
Graphite epoxy	0.5723	0.5712	0.5721
Carbon epoxy	0.8166	0.8159	0.8165

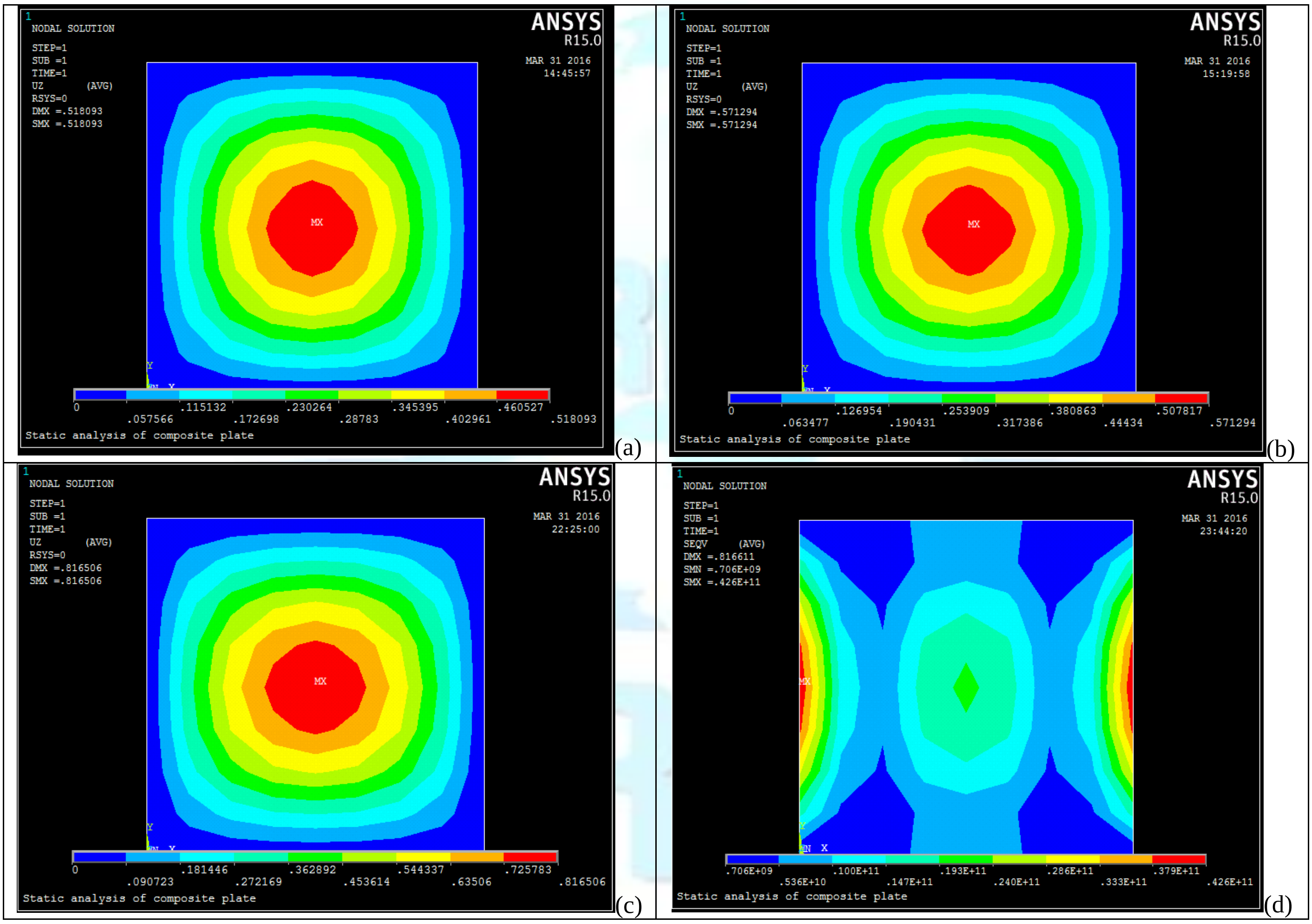


Fig 13:- Deflection shapes of laminated composite plates for different boundary conditions.

(a) The deflection of Glass epoxy plate under SSSS boundary condition.

(b) The deflection of Graphite epoxy plate under CCCC boundary condition.

(c) The deflection of Carbon epoxy plate under SCSC boundary condition.

(d) The von mises stress of Carbon epoxy plate under SSSS boundary condition.

F. EFFECT OF LOADING

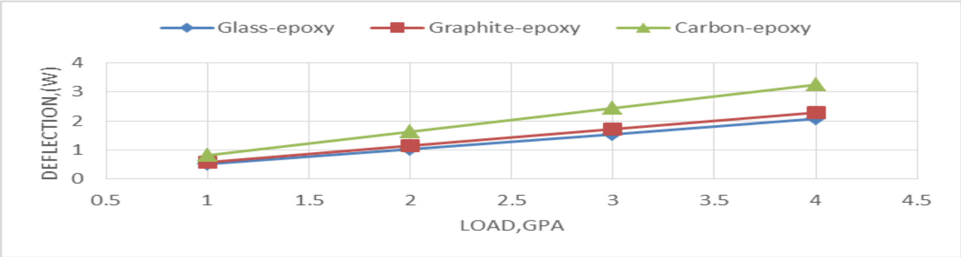


Fig 14:- Effect of loading on laminated composite plate for different material models.

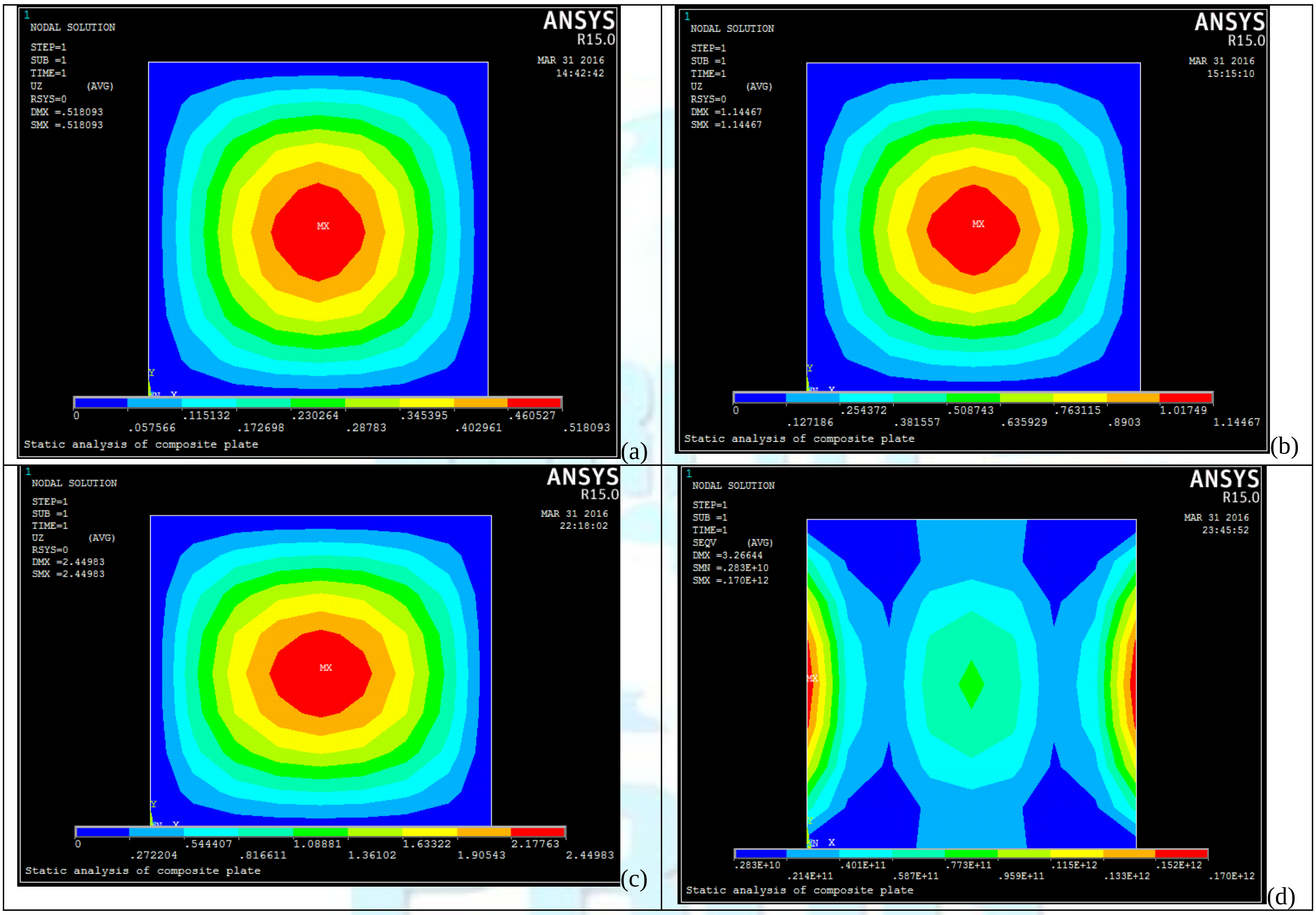


Fig 15:- Deflection shapes of laminated composite plates for different pressures.

(a) The deflection of Glass epoxy plate due to pressure 1GPa.
(b) The deflection of Graphite epoxy plate due to pressure 2GPa.
(c) The deflection of Carbon epoxy plate due to pressure 3GPa.
(d) The von mises stress of Carbon epoxy plate due to pressure 4GPa.

G. EFFECT OF LAMINATED SCHEME

Table 2:- Deflection values of laminated composite plates for different laminated schemes.

Material	**Deflection values for Laminated schemes**			
	0/90/0/90	**0/90/90/0**	**45/-45**	**0/90/0**
Glass epoxy	0.5478	0.5180	7.3336	0.9984
Graphite epoxy	0.5842	0.5723	7.5951	1.0664
Carbon epoxy	0.8341	0.8166	1.4399	13.140

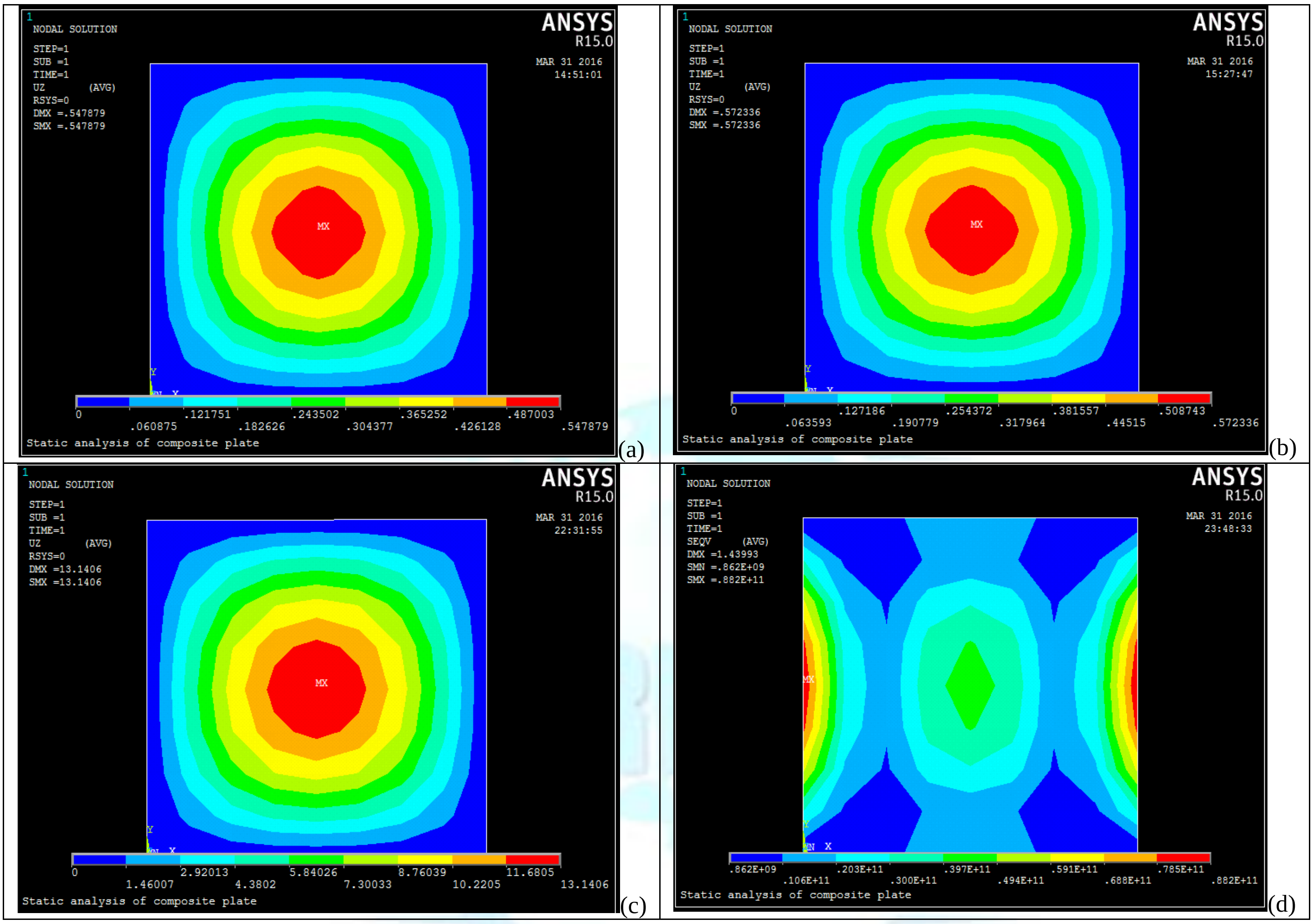


Fig 16:- Deflection shapes of laminated composite plates for different laminated schemes.

(a) The deflection of Glass epoxy plate with laminated scheme (0/90/0/90).

(b) The deflection of Graphite epoxy plate with laminated scheme (0/90/90/0).

(c) The deflection of Carbon epoxy plate with laminated scheme (45/-45).

(d) The von mises stress of Carbon epoxy plate with laminated scheme (0/90/0).

IV. MODAL ANALYSIS

A. CONVERGENCE STUDY

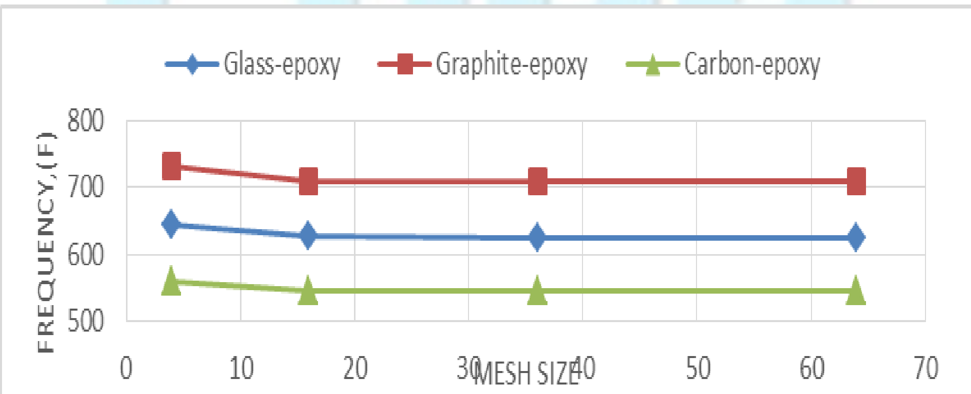


Fig 17:- Convergence study of laminated composite plate for different material models (a/h = 10, a/b=1).

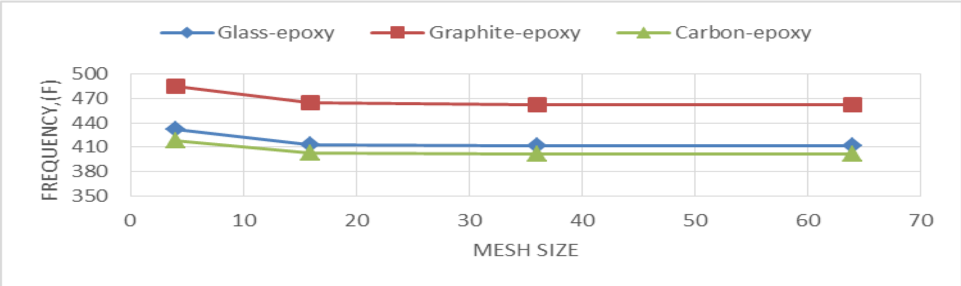


Fig 18:- Convergence study of laminated composite plate for different material models (a/h = 20, a/b=1)

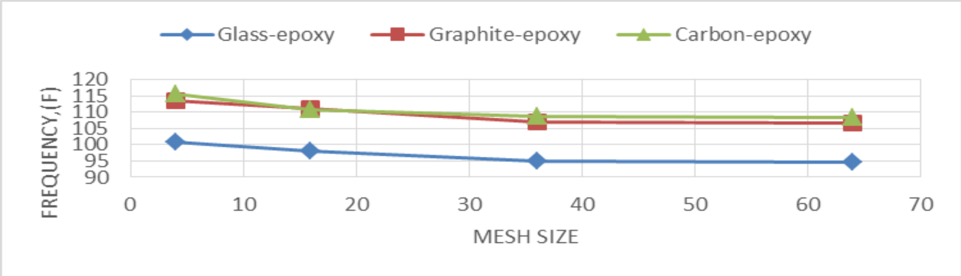


Fig 19:- Convergence study of laminated composite plate for different material models (a/h = 100, a/b=1).

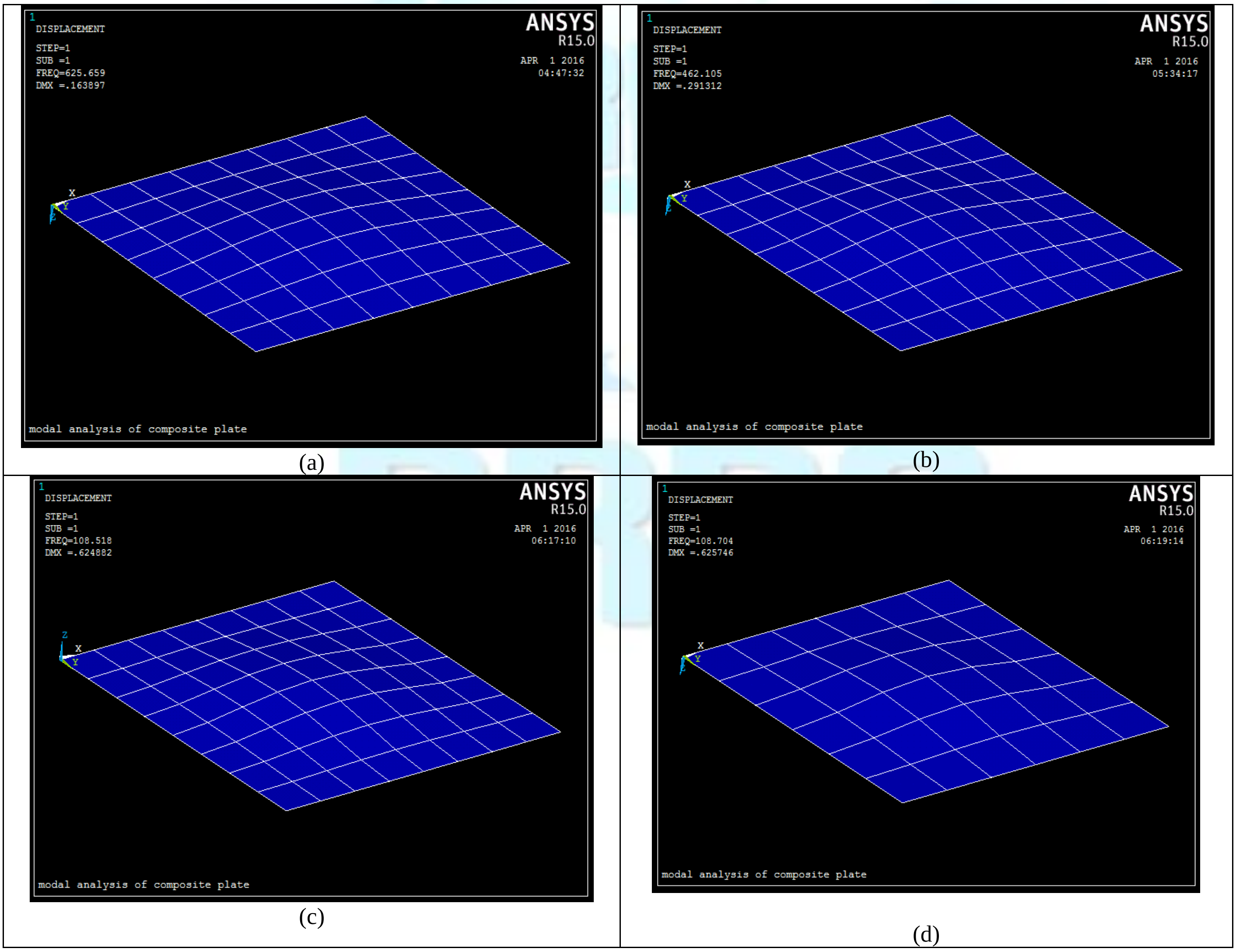


Fig 20:- Mode shapes of laminated composite plates for different thickness.

(a) The mode shape of Glass epoxy plate having thickness (h) = 0.1 and mesh 8x8.

(b) The mode shape of Graphite epoxy plate having thickness (h) = 0.05 and mesh 8x8.
(c) The mode shape of Carbon epoxy plate having thickness (h) =0.01 and mesh 8x8.
(d) The mode shape of Carbon epoxy plate having thickness (h) = 0.01 and mesh 6x6.

B. VALIDATION STUDY

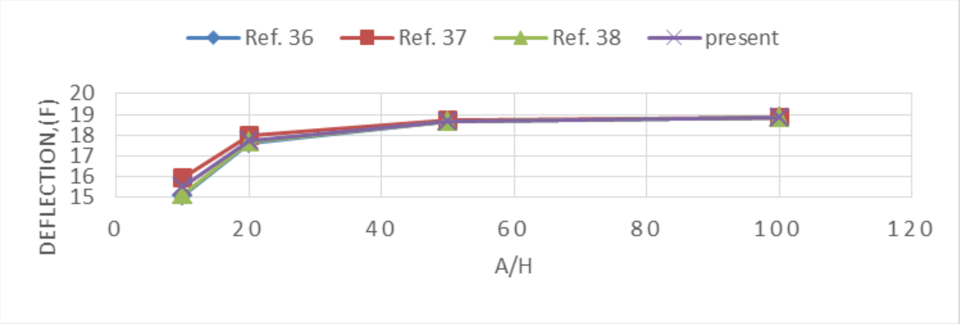


Fig 21: Frequency responses of a simply supported square laminated composite [0/90/90/0] plate for different thickness ratios.

C. EFFECT OF THICKNESS RATIO (a/h)

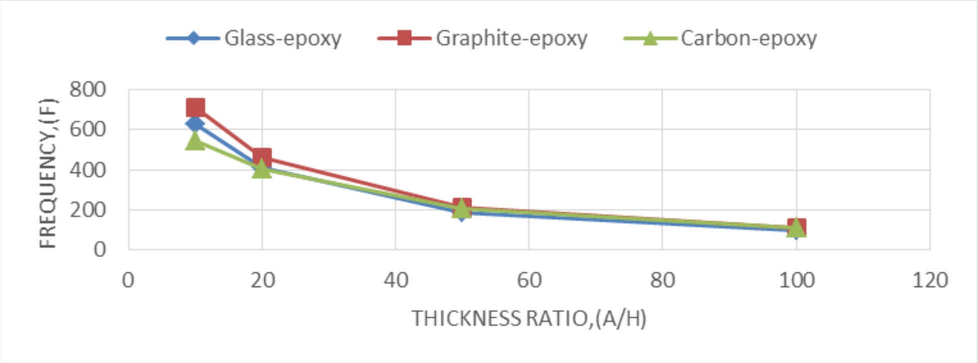
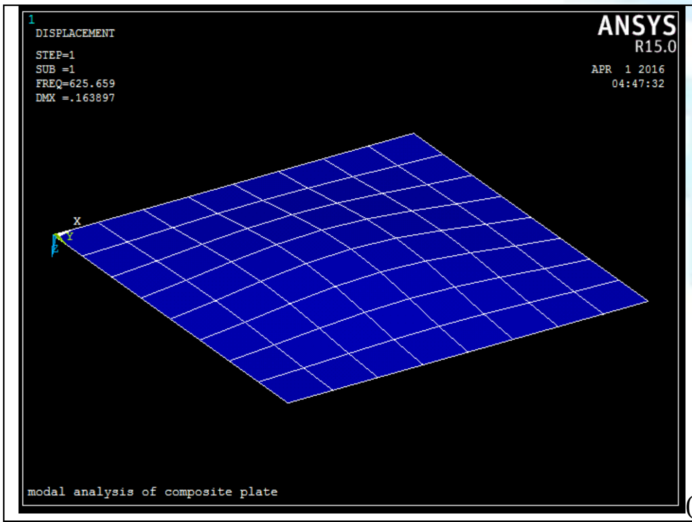


Fig 22:- Effect of thickness ratio on laminated composite plate for different material models.



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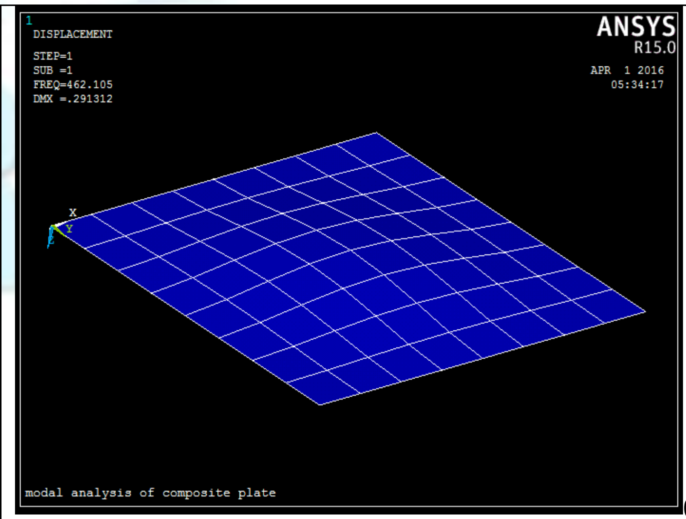

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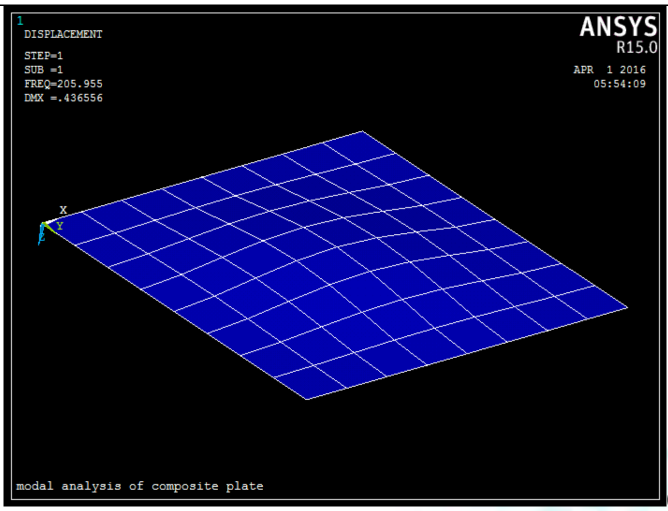

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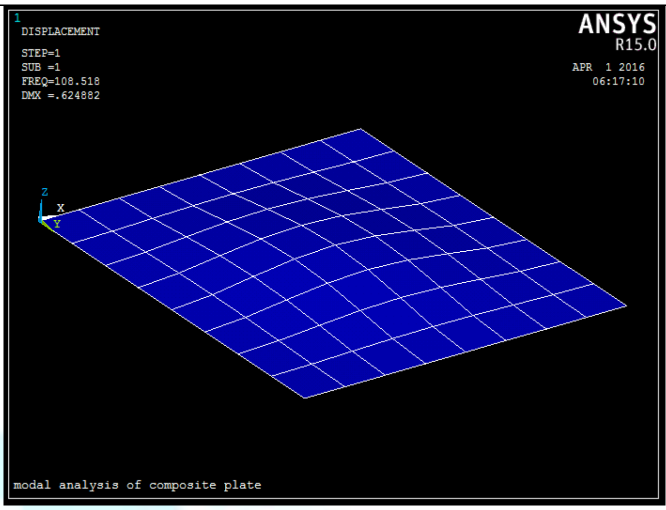


(d)

Fig 23:- Mode shapes of laminated composite plates for different thickness ratios.

(a) The mode shape of Glass epoxy plate having thickness ratio (a/h) = 10.

(b) The mode shape of Graphite epoxy plate having thickness ratio (a/h) = 20.

(c) The mode shape of Carbon epoxy plate having thickness ratio (a/h) = 50.

(d) The mode shape of Carbon epoxy plate having thickness ratio (a/h) = 100.

D. EFFECT OF ASPECT RATIO (a/b)

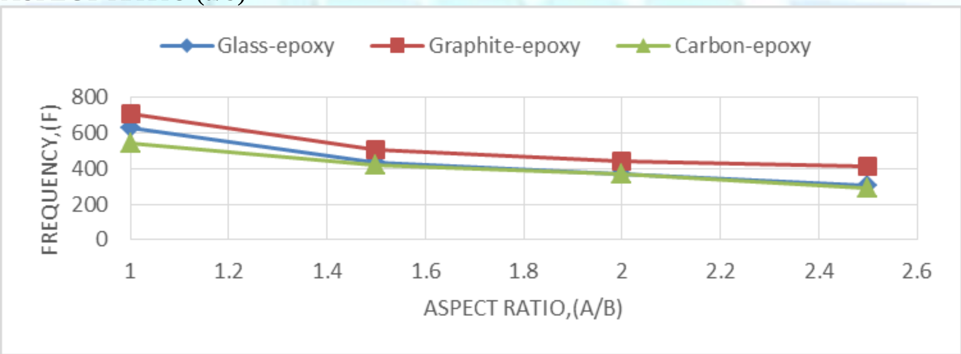
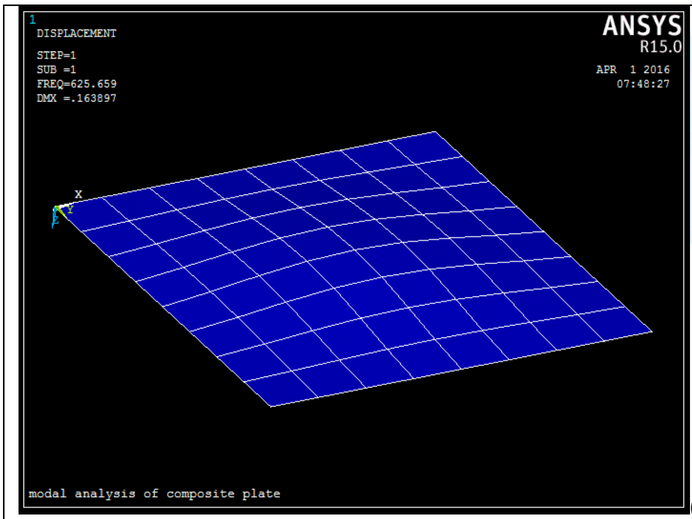
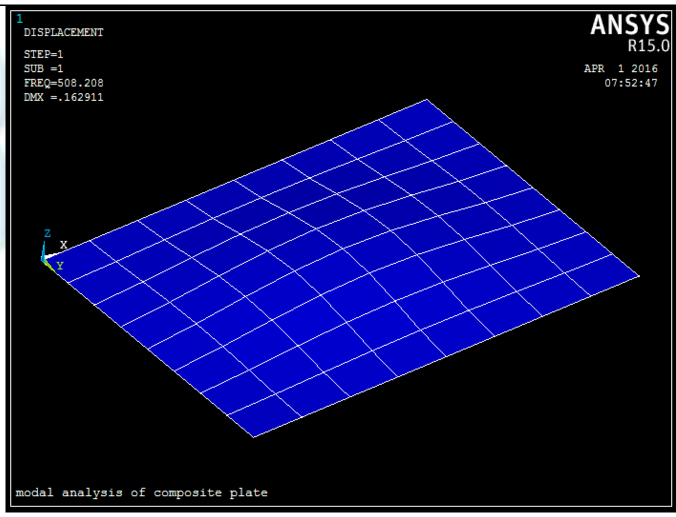


Fig 24:- Effect of aspect ratio on laminated composite plate for different material models.



(a)



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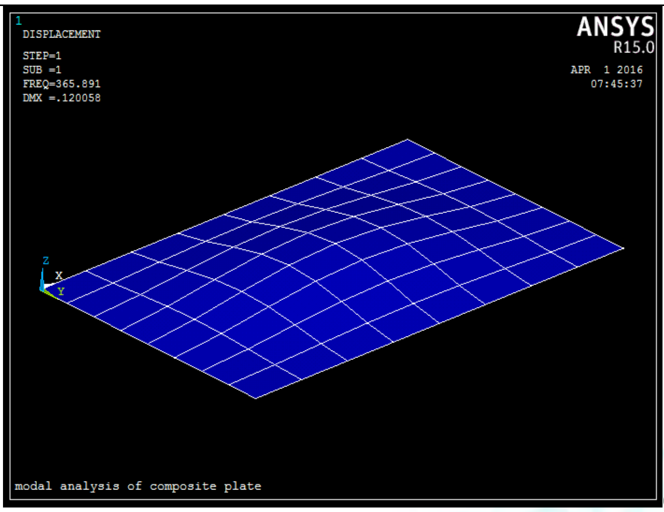

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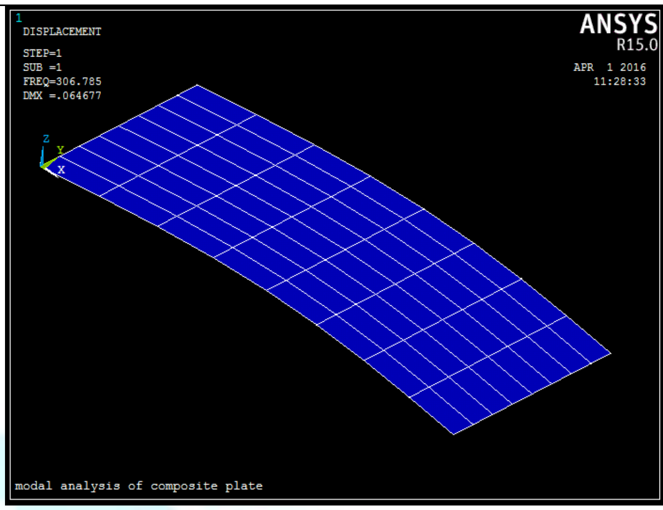


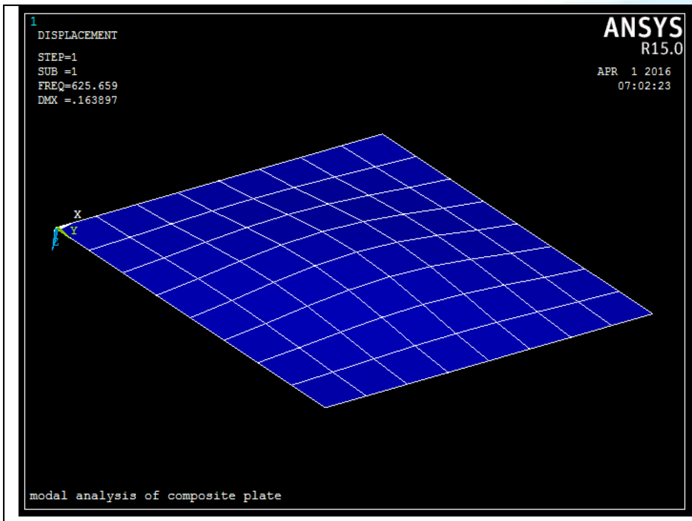
(d)

Fig 25:- Mode shapes of laminated composite plates for different Aspect ratios.
(a) The mode shape of Glass epoxy plate having Aspect ratio (a/b) = 1.
(b) The mode shape of Graphite epoxy plate having Aspect ratio (a/b) = 1.5.
(c) The mode shape of Carbon epoxy plate having Aspect ratio (a/b) = 2.
(d) The mode shape of Carbon epoxy plate having Aspect ratio (a/b) = 2.5.

E. EFFECT OF BOUNDARY CONDITIONS

Table 3:- Frequency values of laminated composite plates for different Boundary conditions

Material	Frequency values for boundary conditions		
	SSSS	CCCC	SCSC
Glass epoxy	625.66	626.02	625.73
Graphite epoxy	708.13	708.85	708.29
Carbon epoxy	544.63	544.90	544.67



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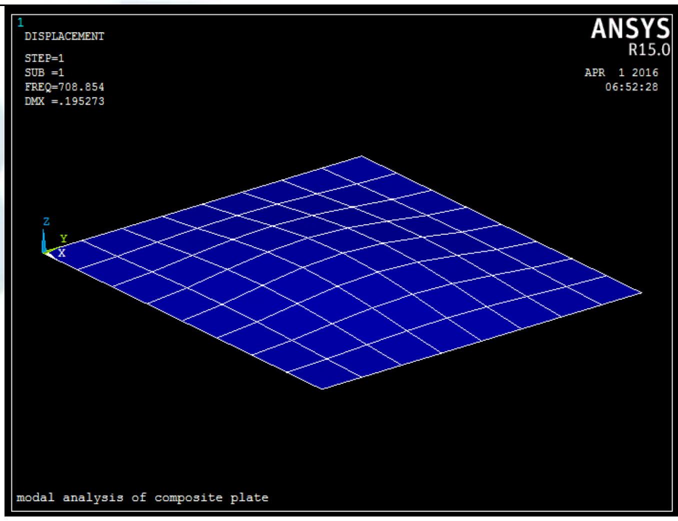

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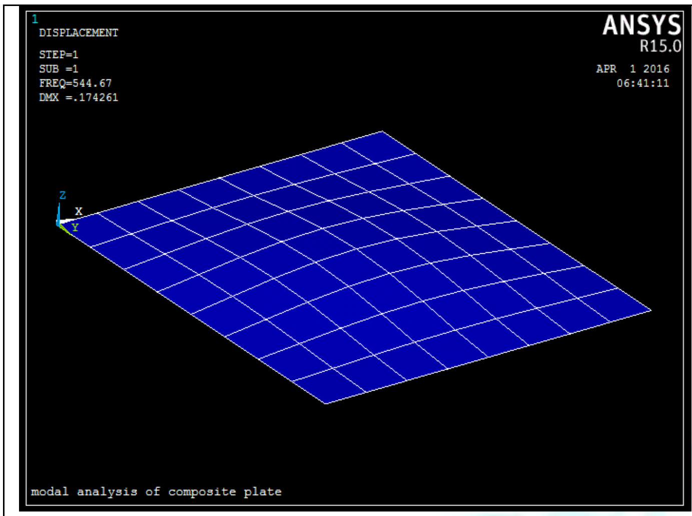

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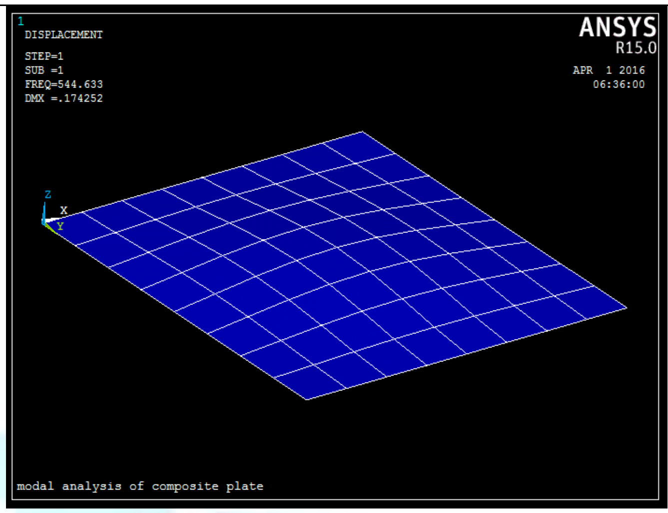


(d)

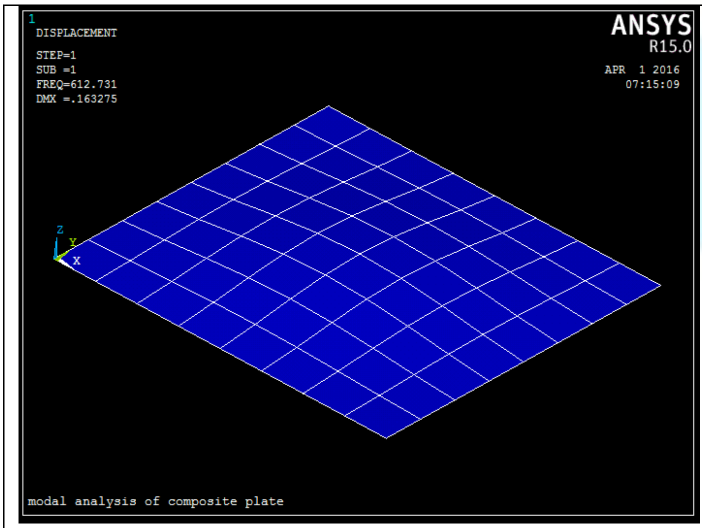
Fig 26:- Mode shapes of laminated composite plates for different boundary conditions.

(a) The mode shape of Glass epoxy plate under SSSS boundary condition.
(b) The mode shape of Graphite epoxy plate under CCCC boundary condition.
(c) The mode shape of Carbon epoxy plate under SCSC boundary condition.
(d) The mode shape of Carbon epoxy plate under SSSS boundary condition.

F. EFFECT OF LAMINATED SCHEME

Table 4:- Frequency values of laminated composite plates for different laminated schemes.

Material	Frequency values for laminated schemes			
	0/90/0/90	0/90/90/0	45/-45	0/90/0
Glass epoxy	612.73	625.66	237.45	521.57
Graphite epoxy	701.78	708.13	276.19	598.12
Carbon epoxy	536.57	544.63	191.89	473.64



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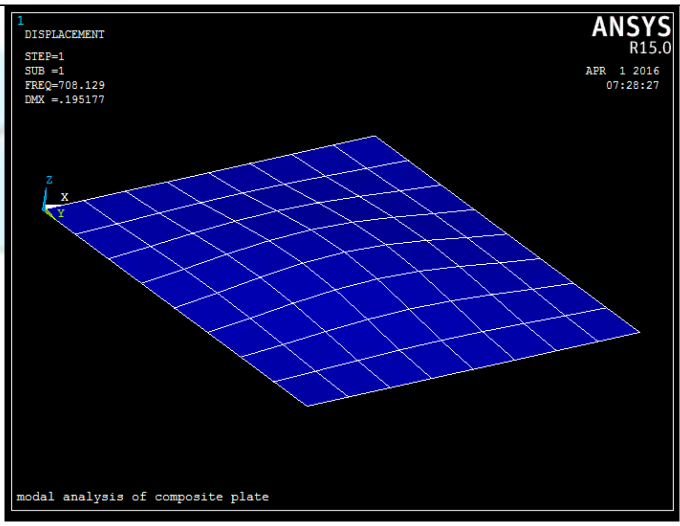

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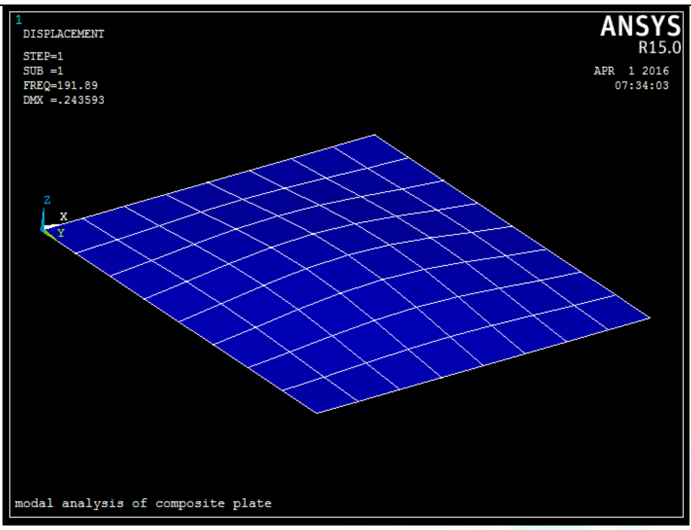

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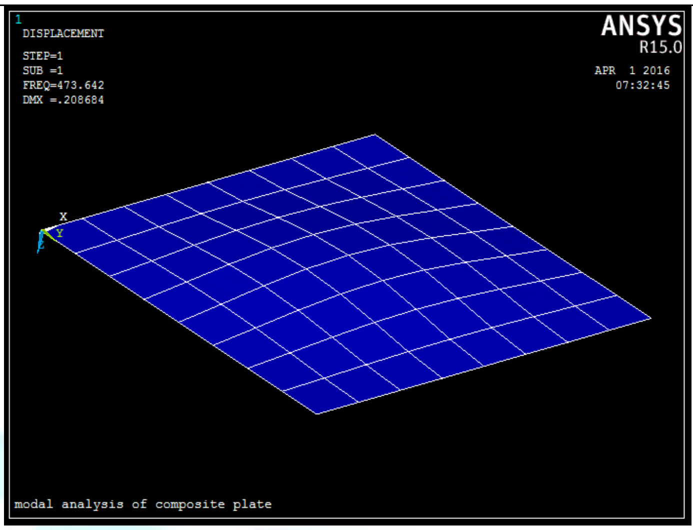

(d)

Fig 26:- Mode shapes of laminated composite plates for different laminated schemes.
(a) The mode shape of Glass epoxy plate with laminated scheme (0/90/0/90).
(b) The mode shape of Graphite epoxy plate with laminated scheme (0/90/90/0).
(c) The mode shape of Carbon epoxy plate with laminated scheme (45/-45).
(d) The mode shape of Carbon epoxy plate with laminated scheme (0/90/0).

V. CONCLUSION

A convergence and validation study of the static and free vibration analysis of laminated composite plate has been obtained. It is seen that the present model converging well with mesh refinement and the differences are within acceptable range.The deflection values increase and the frequency values decrease with the increase in thickness ratios for all material models.The deflection values increase and the frequency values decrease with the increase in aspect ratios for all material models.For all the conditions, Graphite epoxy has more deflection when compared to Glass epoxy and Carbon epoxy. Whereas, Graphite epoxy has more frequency when compare to Glass epoxy and Carbon epoxy.The deflection values increase with the increase in pressures for all material models.When compared to cross ply laminated schemes, angle laminated scheme has more deflection and less frequency. In symmetric laminated scheme, Compared to 4 lamina plate, 3 lamina plate has more deflection and less frequency.

VI. REFERENCES

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