iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 12 Issue: V Month of publication: May 2024

DOI: https://doi.org/10.22214/ijraset.2024.61532

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue V May 2024- Available at www.ijraset.com

Finite Element Analysis of Sandwich Plates with Different Percentages of Delamination

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Abstract: The present study pinpoints the effect of delamination in multilayer glass fiber-reinforced composite slabs. The unit cell method of homogenization has been used to find the effect of air inclusion in the glass fiber-reinforced polymer composite. The natural frequency has been obtained up to different modes on every condition. The modal analysis module of ANSYS has been used to obtain the natural frequency for different boundary conditions
The present study considered 0% to 10 % of total volume as delamination in four steps (0.5, 1.0, 5.0, and 10%). Two types of boundary were considered in the present study, in the first condition the plate is fixed from all four sides, the second two sides are assumed to be free, and the remaining two sides are fixed.
Keywords: Sandwich Plate, Delamination, Natural Frequency, Finite Element Analysis, ANSYS.

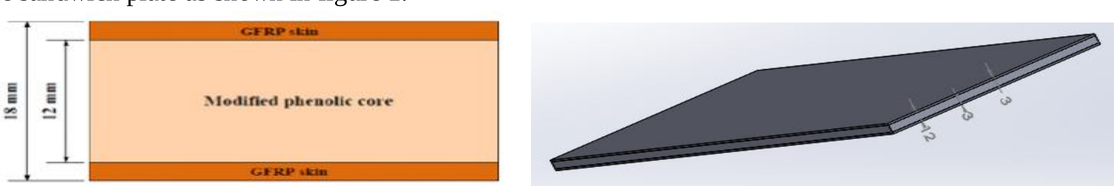
I. INTRODUCTION

The traditional materials used in the past have several important properties such as strength, stiffness, etc. The present modern era requires several distinct properties to be incorporated in one single material for application in areas such as aerospace, defence, submarine, and nuclear fields. For this functionally graded material (FGM) is one choice, FGM is a material whose properties will vary in the transversal direction and thus behaves differently compared to that of conventional material. In this regard, several reports are available in the open domain published by various researchers [1-4]. The layered structures such as laminates or sandwich structures also have varying properties in the transversal direction and thus come in the category of FGM. Nguyen et al. utilized the first-order deformation theory for vibration analysis of the FGM sandwich plate [5-6]. The third-order shear deformation theory, together with the sinusoidal shear deformation theory was used by Zenkour in their study to determine the deflection, stresses, and free vibration of functionally graded sandwiched plated (FGSP) [7-8]. Vinh et al. investigated the effect of nanoparticle inclusion on the free vibration of the FGM plate. In this study, the author presented a comparative report on static bending and free vibration of FGM plate without Nano infusion and FGM plate with nanoparticles infusion [9-10]. A rigorous study on the effect of thermo-mechanical bending on the behavior of FGM sandwiched plated was presented by Li. et al. using the four-variable refined plate theory [11]. Wang et al. in their study presented free vibration analysis of through width isotopic delaminated beam with coupling effect. [12]. In the latest publication, Vinh and Hay presented a compressive study on the effect of porosity on the free vibration and buckling effect of FGM sandwich plates. They reported that the level of porosity will increase the bending and critical deflection of the FGM sandwich plates [13].

It is clear from the literature presented that there is a lack of literature in the open domain about the free vibration analysis on the phenolic core with a GFRP multiple-layer sandwich plate. The analysis presented in this paper considers the effect of delamination on the free vibration of the FGM sandwich plate together with the effect of air inclusion on the free vibration of the sandwich FGM plate. Two end conditions were considered in the study. All four sides are fixed in one condition. Two sides are fixed and the other two are free in the second condition.

II. GEOMETRICAL MODELLING

A square sandwich plate of size 1000 mm x 1000 mm is considered for the analysis. GFRP skin and modified phenolic core are used to construct the sandwich plate as shown in figure 1.



(a) (b)

Fig. 1 (a) GFRP sandwich slabs cross sections (b) Isometric View of Slab [14]

Four different sizes of deboning are considered to examine the dynamic behavior as shown in Table 1 and Figure 2 shows the geometry of the plate with four different delamination areas

TABLE 1
DIMENSIONS OF SQUARE PLATE

S. No	Dimension of plate	% delamination	Dimension of delamination
1	1000 mm x 1000 mm	0.5	70.71 mm x 70.71 mm
2	1000 mm x 1000 mm	1.0	100 mm x 100 mm
3	1000 mm x 1000 mm	5.0	223.60 mm x 223.60 mm
4	1000 mm x 1000 mm	10.0	316.22 mm x 316.22 mm

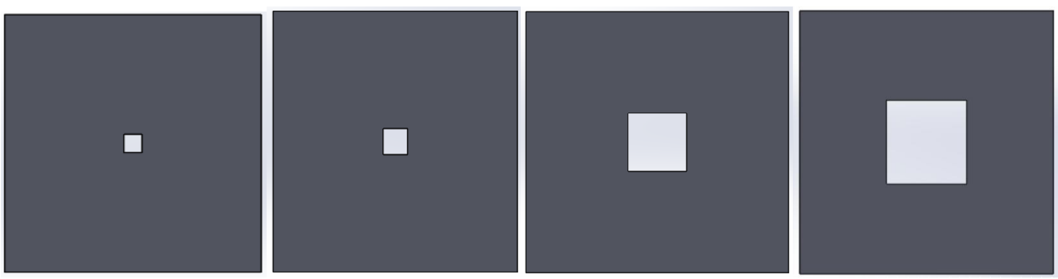


Fig. 2 Delamination area as 0.5%, 1%, 5%, and 10% of total area

III.MATERIAL PROPERTY OF THE PLATE

The effective mechanical properties of the fiber composite skin and the core material have been used for the present analysis of the sandwich panel taken from the published paper by Jayatilake et al. [14] and the relevant properties are listed in Table 2

TABLE 2
MECHANICAL PROPERTIES OF FIBER COMPOSITE SKIN AND CORE [14]

Property	**Skin**	**Core**
Young’s modulus along the long direction (MPa)	12360	1350
Young’s modulus in transverse direction (MPa)	10920	1350
Poisson’s ratio	0.3	0.2
Density (kg/m3)	1425	950

IV. MODEL VALIDATION

Validation of the mesh of the model was conducted by varying the size of the element from 100 mm to 10 mm. The graphical representation is shown in Figure 3, containing the data of first and second mode frequency with the variation of element size. From the figure 3, it is clear that the element size of 10 mm is suitable for the analysis.

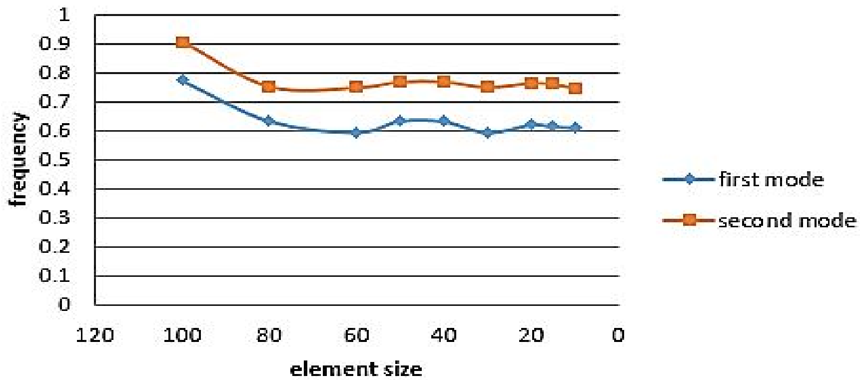


Fig. 3 Convergence Graph

The validation of the model results is done by comparing the result with the previously published result [3]. Table 3 shows the compiled data of the error. From the table, it can be said that the error is within the limit and further analysis can be done on the present model.

TABLE 3
MODEL VALIDATION

Model of vibration for 1000*1000 mm^2	STRAND 7, Jayatilake et al. [14]	Present analysis	% Error
Mode l	34	31.61	4.69%
Mode 2	45	45.74	1.61%

V. RESULT AND DISCUSSION

The effect of delamination is obtained for 1000 mm*1000 mm plates with two end conditions first two side fixed and second four side fixed cases. The analysis is conducted on the student version of the commercial FEA package ANSYS.

A. Effect of Boundary Condition on Natural Frequency and Deflection

The analyses are conducted for Fully Bonded Plates to show the effect of two boundary conditions on natural frequency and deflection as shown in the table. The natural frequency and deflection are found higher for the plate fixed from all sides than fixed from two opposite sides.

Table 4
Natural Frequency And Deflection For Fully Bonded Plate

Boundary Condition	Fully Bonded Plate Frequency Hz	Deflection
Fixed from two opposite sides	31.610	0.35407
Fixed from all sides	62.013	0.47796

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The nodal solution for deflection is shown in figures 4 and 5.

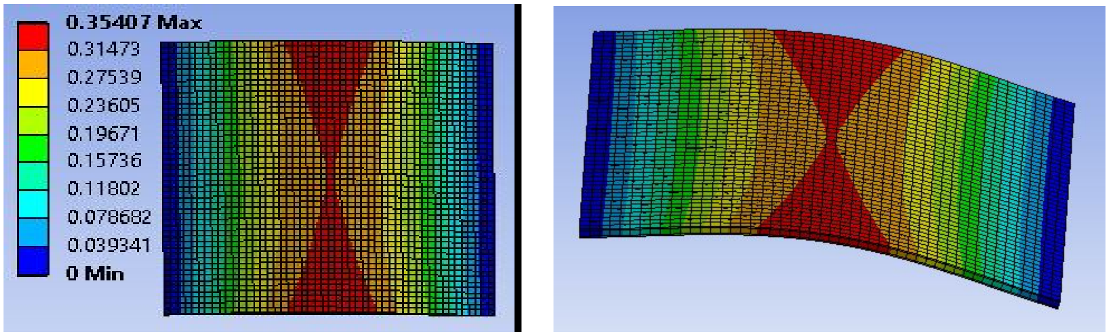

Fig. 4 Deflection for plate fixed from two opposite sides

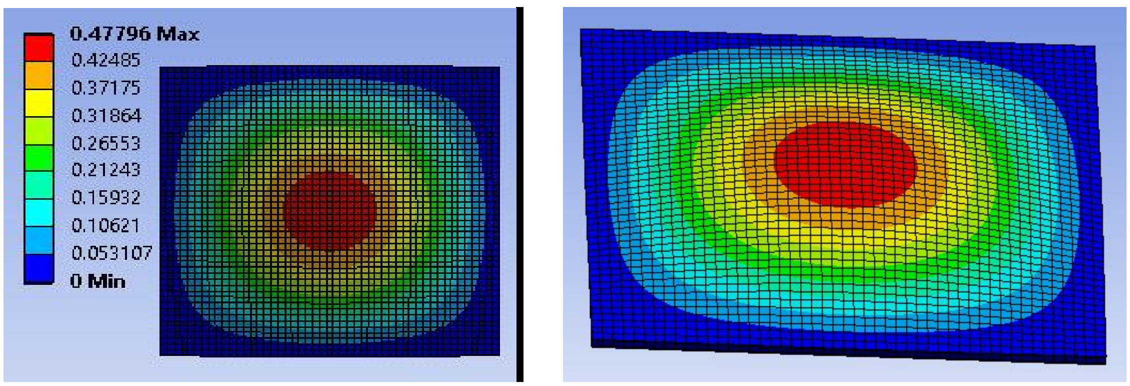

Fig. 5 Deflection for plate fixed from all sides

B. Effect of Delamination on Natural Frequency for Different Boundary Conditions

The frequency values for different cases of delamination are shown in a compiled form in Table 4 by varying the delamination percentage from 0.5 to 10%.

Table 4
Frequency Values Of The Sandwich Plate At Different Delamination Areas

Boundary Condition	Percentage Debonding Area	Fully Bonded Plate Frequency Hz	Debonded Plate Frequency Hz	Percentage Reduction
Fixed from two opposite sides	0.5	31.610	31.581	0.0917
	1.0	31.610	31.581	0.0917
	5.0	31.610	31.574	0.1138
	10.0	31.610	31.523	0.2752
Fixed from all sides	0.5	62.013	61.874	0.2241
	1.0	62.013	61.875	0.2225
	5.0	62.013	61.788	0.3628
	10.0	62.013	61.206	1.3013

From the table, it has been found that as the percentage of delamination increases, the percentage reduction in natural frequency is also increasing. On comparing the boundary condition, we can observe that the reduction in frequency is more for plates fixed at all sides than fixed at two opposite sides. The maximum percentage reduction on natural frequency is 1.3013 for 10%

VI. CONCLUSIONS

The change in natural frequency due to delamination has been successfully found using ANSYS software. The following conclusions are obtained from the analysis:

1) For a fully bonded plate, the natural frequency and deflection are found to be higher for the plate fixed from all sides than fixed from two opposite sides.
2) In both boundary conditions, the natural frequency decreases in all delaminated plate cases.
3) The maximum decrease in natural frequency is occurring for 10% delamination for both boundary conditions.
4) On comparing the case of fixed from two sides and all sides we find that the decrease in frequency is more in the case of fixed on all sides.

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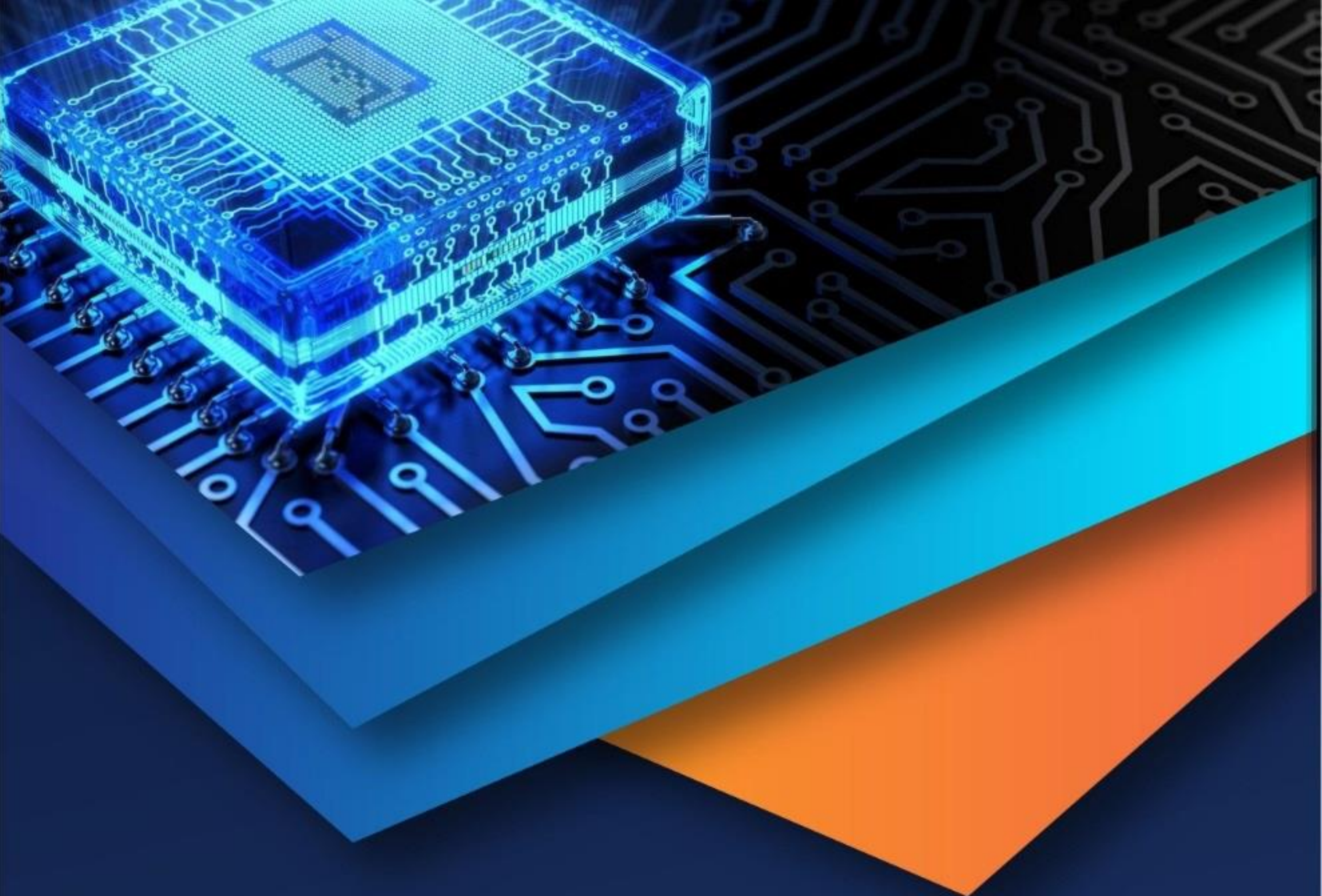

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