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Analysis of Laminated Composite Beams Using FEMAP Nx Nastran

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Abstract

A laminated composite beam consists of more than one lamina bonded together through their thickness. Laminate layers are stacked at different angles to withstand different loading and stiffness requirements. This paper deals with the analysis of laminated composite beam using FEMAP Nx Nastran and the results for transverse displacement are obtained. The results from FEMAP software are validated with standard research paper of Khdeir and Reddy [1]. The beam size used for the analysis is of 0.1m x 0.1m in cross-section and 1m in length. Both symmetric [0/90/0] and antisymmetric [0/90] layered beams are analysed and validated. Parametric study is also done on the symmetric laminated composite beam [0/90/0] by varying the L/h ratio, boundary conditions, and E1/E2 ratios and the results are tabulated and conclusions are made.

Keywords: *Laminated composite beam, FEMAP, Hinged-Hinged (H-H), Hinged-Clamped (H-C), Clamped-Clamped (C-C) Boundary conditions*

1. INTRODUCTION

Laminated composite materials are increasingly being used in a large variety of structures including civil infrastructure, aerospace, and marine structures. Laminated composite materials offer great advantages over the conventional materials; therefore they are increasingly being used nowadays.

Laminated composites offer high strength/stiffness for lower weight; high corrosion resistant and superior material properties of the composite. With the switch lay-up and fiber introductions composite material can be adjusted to meet the specific prerequisites of stiffness and quality.

1.1 Objective of present work

The objective of the present work is to analyse the laminated composite beam using finite element software FEMAP Nx Nastran and the results are compared from the software with standard research paper. Parametric study is also done by varying the (L/h) ratios, (x/L) ratio, boundary conditions and modular ratios.

1.2 Methodology

1) The Finite Element model is prepared in FEMAP Nx Nastran by applying the various properties, dimensions and boundary condition to the beam for analysis.
2) The laminated composite beam is assumed to be of orthotropic in nature.
3) The study on transverse displacement parameter is done by comparing the values obtained from FEMAP Nx Nastran for various lengths to thickness ratios, and different ply orientation and varying number of laminas for static loading condition.
4) Tables and graphs are plotted with the above parametric study.
5) Based on the above results and graphs, conclusions are drawn.

2. ANALYSIS OF LAMINATED BEAM

For the data validation and analysis work, the material adopted has following properties.

The transverse deflections values from the FEMAP results are non-dimensionalized as

$$W = \frac{100\, w\, A\, E_2\, h^2}{q_0\, L^4}$$

Where L - Length of the beam

A - Cross-sectional area and

h - Total thickness.

Material Properties:

Table 2.1 Material Properties

Properties	**Values**	**Units**
E1 =	25	Gpa
E2 =	1	Gpa
E3 =	1	Gpa
G12 =	0.5	Gpa
G13 =	0.5	Gpa
G23 =	0.2	Gpa
μ12 =	0.25	-
μ23 =	0.25	-
μ13 =	0.25	-
qo =	1	N/sqm
Supports	Simply	supported

The load acting on the beam is assumed to be uniformly distributed with an intensity q_0 .

Orthotropic beam with three layers having fibre orientation as [0/90/0] symmetric and [0/90] antisymmetric were considered for validation.

Table2.2 Non-Dimensional transverse Displacement for symmetric laminated Hinged –Hinged (H-H) Beam

Fiber orientation	**L/h**	**Khdeir and Reddy [1]**	**FEMAP**	**% error**
0/90/0	5	2.41	2.72	-12.9
0/90/0	10	1.1	1.16	-5.5
0/90/0	50	0.67	0.69	-3.0

Table2.3 Non-Dimensional transverse Displacement for symmetric Clamped-Hinged (C-H) Beam

Fiber orientation	L/h	Khdeir and Reddy [1]	FEMAP	% error
0/90/0	5	1.95	2.09	-7.2
0/90/0	10	0.74	0.78	-5.4
0/90/0	50	0.28	0.29	-3.6

Table2.4 Non-Dimensional transverse Displacement symmetric for Clamped-Clamped (C-C) Beam

Fiber orientation	L/h	Khdeir and Reddy [1]	FEMAP	% error
0/90/0	5	1.54	1.7	-10.4
0/90/0	10	0.53	0.57	-7.5
0/90/0	50	0.15	0.16	-6.7

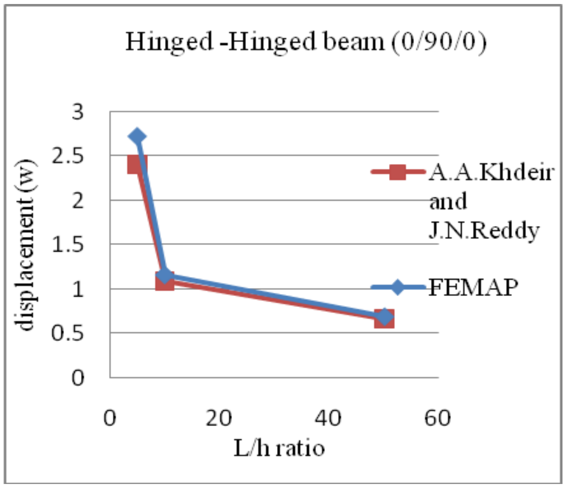

Fig. 2.1 Plot for symmetric Hinged – Hinged (H-H) beam

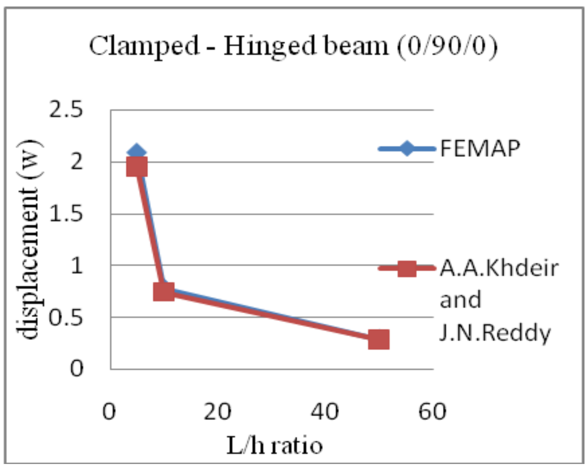

Fig. 2.2 Plot for symmetric Clamped– Hinged (C-H) beam

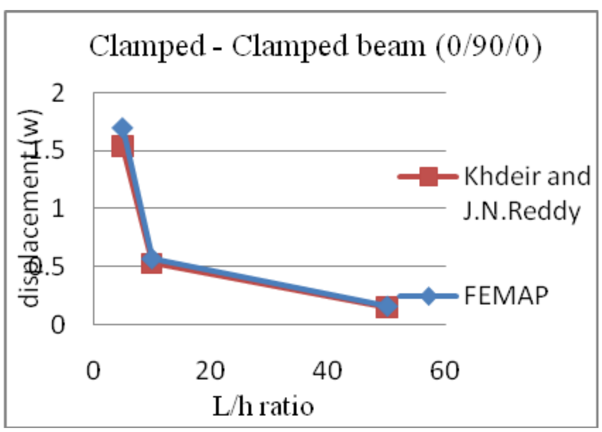

Fig. 2.3 Plot for symmetric Clamped – Clamped (C-C) beam

Table2.5 Non-Dimensional transverse displacement for antisymmetric Hinged - Hinged (H-H) Beam

Fiber orientation	L/h	Khdeir and Reddy [1]	FEMAP	% error
0/90	5	4.78	5.13	-7.3
0/90	10	3.69	3.91	-6.0
0/90	50	3.35	3.45	-3.0

Table2.6 Non-Dimensional transverse Displacement for antisymmetric Clamped-Hinged (C-H) Beam

Fiber orientation	L/h	Khdeir and Reddy [1]	FEMAP	% error
0/90	5	2.86	3.04	-6.3
0/90	10	1.74	1.81	-4.0
0/90	50	1.35	1.40	-3.7

Table 2.7 Non-Dimensional transverse Displacement for antisymmetric Clamped-Clamped (C-C) Beam

Fiber orientation	L/h	Khdeir and Reddy [1]	FEMAP	% error
0/90	5	1.92	2.11	-9.9
0/90	10	1.00	1.07	-7.0
0/90	50	0.68	0.71	-4.4

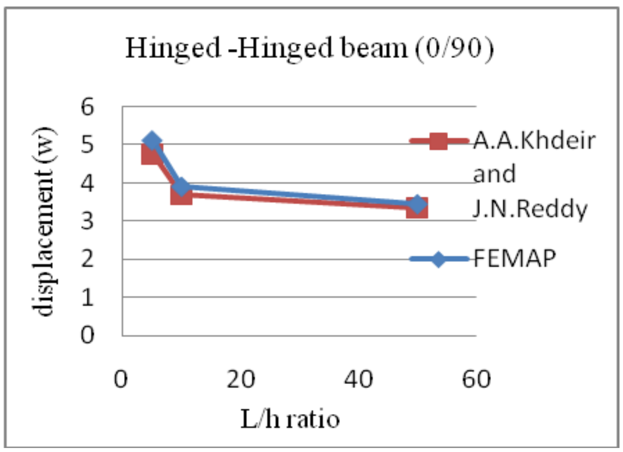

Fig. 2.4 Plot for antisymmetric Hinged – Hinged (H-H) beam

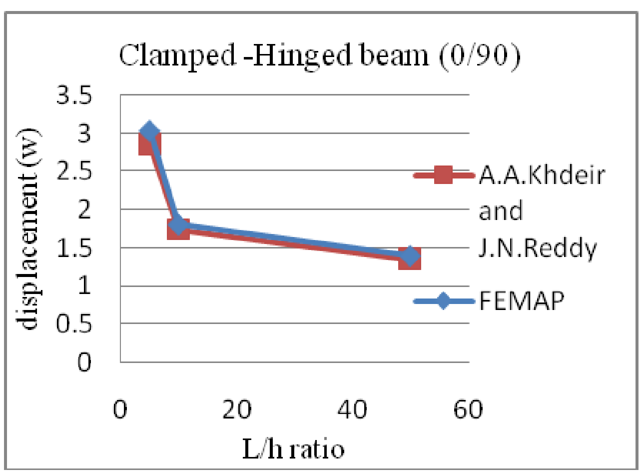

Fig. 2.5 Plot for antisymmetric Clamped - Hinged(C-H) beam

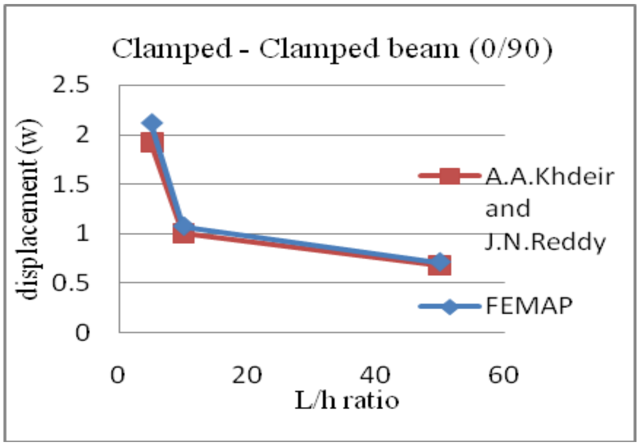

Fig. 2.6 Plot for antisymmetric Clamped – Clamped (C-C) beam

OBSERVATIONS:

From the above tables and graphs, it is observed that in laminated composite beams, the displacement (w) values tends to decrease with the increase in the length to thickness ratio (L/h) ratio and increase with the decrease in (L/h) ratio.

The percentage of error also reduces with the increase in (L/h) ratio when the results obtained from the FEMAP Nx Nastran is compared with Khdeir and Reddy research paper

Table 3.1 Transverse Deflection of a symmetric Beam (0/90/0) for various boundary conditions

L/h	Hinged -Hinged	Clamped - Hinged	Clamped - Clamped
5	2.96	2.34	1.98
10	1.22	0.78	0.63
20	0.75	0.54	0.390
30	0.73	0.48	0.32
40	0.71	0.35	0.28
50	0.68	0.19	0.16

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3. RESULTS AND DISCUSSIONS

3.1. Parametric study for orthotropic beam:

Parametric study is also done by varying the (L/h) ratio, boundary conditions, (x/L) ratio and with different modular ratios. Laminated beam considering 2, 3, 4, &10 are analysed by varying the x/L ratios with hinged – hinged and clamped – clamped boundary conditions, and the results are tabulated. Study is also done by varying the E1/E2 on different boundary conditions is also done.

See Table 3.1

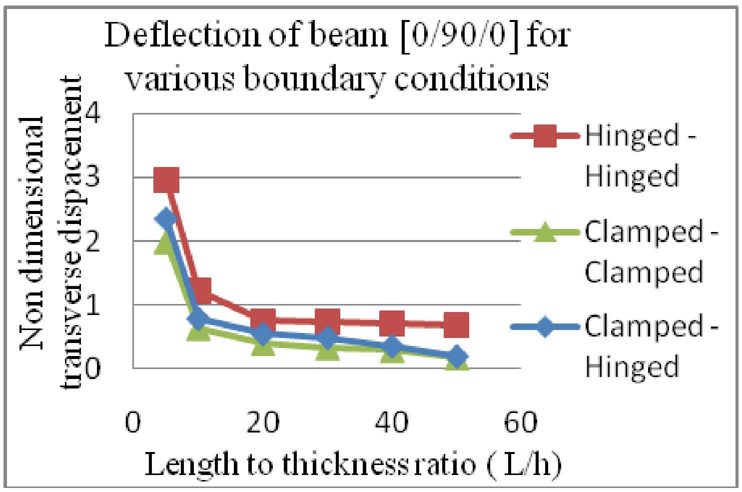

Fig.3.1 Transverse displacement for various boundary conditions

Table 3.2: Transverse deflection of Hinged - Hinged Beam for Different layers of beam

x/L	deflection			
	2 layers	**3 layers**	**4 layers**	**10 layers**
0	0	0	0	0
0.1	0.324	0.193	0.259	0.231
0.2	0.915	0.432	0.635	0.603
0.3	1.61	0.784	1.25	0.994
0.4	2.103	1.304	1.509	1.411

0.5	2.698	1.549	1.921	1.769
0.6	2.1	1.31	1.513	1.423
0.7	1.64	0.78	1.25	0.989
0.8	0.93	0.435	0.637	0.61
0.9	0.38	0.198	0.265	0.229
1	0	0	0	0

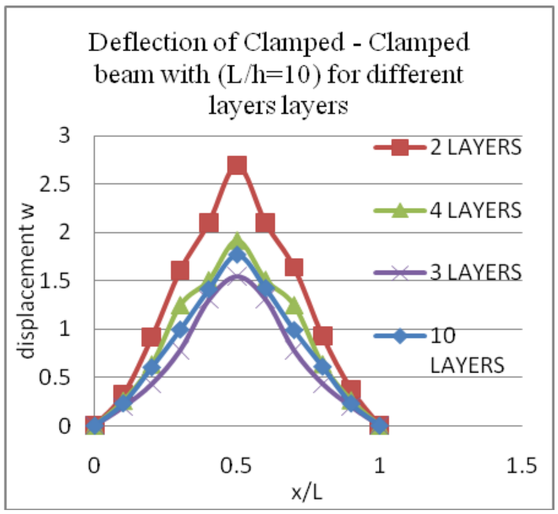

Fig.3.2 Transverse displacements of hinged-hinged beam for different layers

Table 3.3: Transverse deflection for Clamped - Clamped Beam for Different layers of beam

x/L	**deflection**			
	2 layers	**3 layers**	**4 layers**	**10 layers**
0	0	0	0	0
0.1	0.21	0.073	0.113	0.091
0.2	0.602	0.287	0.41	0.315
0.3	0.945	0.369	0.589	0.468
0.4	1.41	0.635	0.937	0.705

0.5	1.724	0.791	1.032	0.851
0.6	1.41	0.635	0.937	0.705
0.7	0.945	0.369	0.589	0.468
0.8	0.602	0.287	0.41	0.315
0.9	0.21	0.073	0.113	0.091
1	0	0	0	0

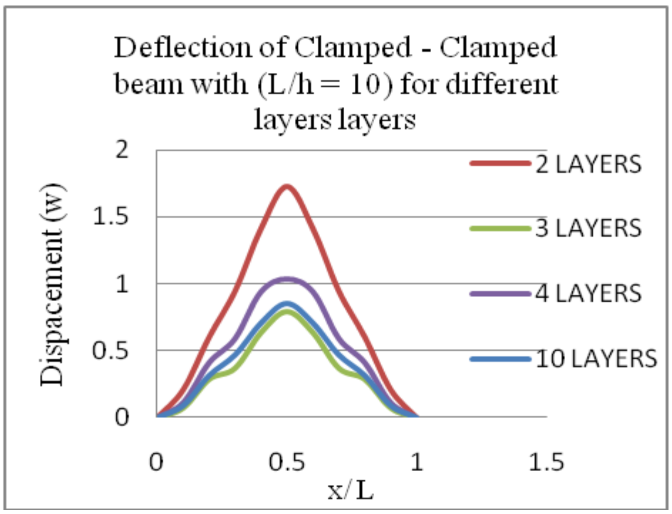

Fig.3.3 Transverse displacements of clamped-clamped beam for different layers

Table 3.4 Transverse displacements for different modular ratios

E_1/E_2	Hinged - Hinged	Clamped - Hinged	Clamped - Clamped
10	2.359	1.745	0.958
20	1.389	1.109	0.923
30	1.164	0.904	0.874
40	0.967	0.839	0.831
50	0.873	0.747	0.675

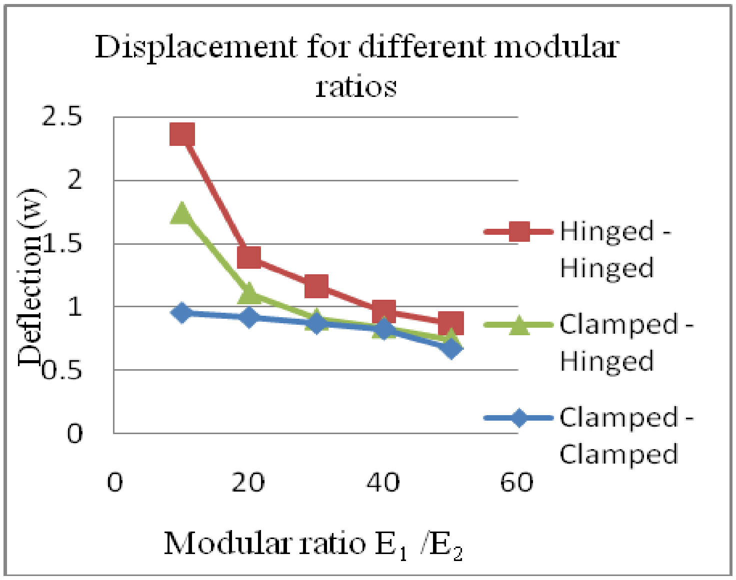

Fig.3.4 Effect of modular ratio in displacements

OBSERVATIONS

From the above table and graph, we observe that the increase in E1/E2 value reduces the non dimensional transverse displacement of the beam and the decrease in the E1/E2increases the displacements.

Also, from the graph it is seen that the hinged-hinged boundary condition beam gives a more displacement that the clamped-clamped and a clamped-hinged beam

CONCLUSIONS

Analysis of laminated composite beam is done using finite element method by FEMAP Nx Nastran.

Results obtained from FEMAP software are validated for symmetric and antisymmetric beams with results from research papers of Khdeir & Reddy.

Parametric study is done for various length-to-thickness ratios, and different ply orientation for different end support conditions.

The following conclusions are made:-

- Results from the FEMAP Nx Nastran are validated with the Khdeir& Reddy research paper, the percentage of error is varying from 13% to 3% depending on the length to thickness ratio and the various boundary conditions.

- The percentage of error reduced with increase in (L/h) ratio for symmetric and antisymmetric laminated beams.

- It is seen that the symmetric stacking sequence of the laminae gives a smaller response to transverse deflection than those of anti-symmetric.

- With the increase in the modular ratio E1/E2, the displacement reduces and vice-versa.

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