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A Study of Effect of Geometric Ratio and Fiber Orientation on Modal Characteristics of Composite Beam

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Abstract: *Now a day's laminated composite beams are preferred for various engineering applications on priority. These beams are subjected to different environments and loads during their operation. Sometimes these beams exhibit irregular behavior under certain working condition. The Dynamic analyses of composite components are hence essential to avoid the failure of the component, which can be analyzed by the natural frequency and mode shape. The complexity of the analysis of composite structures is faced as it often operates in complex environmental and boundary conditions and is frequently exposed to a variety of dynamic excitations. The use of the structures in different places according to the need of the applications decides the end conditions and geometry of the composite beam. The mechanical property like stiffness and rigidity of the composite material depends upon the orientation of fiber layer, boundary condition and thickness of the beam which in turns reflect on the natural frequency. In this paper the effect of variation of width or (geometric ratio) on the natural frequency of the composite is studied for the beams of different fiber orientations and boundary conditions using finite element analysis software. Bi directional woven fabric E-Glass polyester composite beam is considered for the purpose.*

Keywords: *Laminated composite, dynamic analysis, fiber orientations, E-glass, geometric ratio*

1. INTRODUCTION

The strength of a composite structure depends on its constituent fiber and matrix material. Also for same matrix and fiber combination, variation of volume fraction, presence of void and variation of geometry of the structure plays important role for the variation of mechanical properties. The orientation of fiber layer, thickness and boundary condition also controls the elastic modulus and strength of the composite material. The use of the composite specimen according to its necessity laid different boundary condition and geometry for it.

A number of researchers had carried out numerous numbers of methods for dynamic analysis of pate like composite beams. Yung et al. [1] presented transient dynamic finite element analysis of laminated composite under the influence of transverse load by the use of Newmark scheme and Newton-Raphson method. Liou et al. [2] made an investigation over the transient response of an E-glass epoxy laminated composite plate impacted by a steel circular cylinder by three-dimensional hybrid stress finite element program to determine the transverse deflection at centre. Matsunaga [3] determined the natural frequencies and buckling stresses of cross-ply laminated composite plates under the influence of shear deformation, thickness change and rotary inertia using the method of power series expansion of displacement components and Hamilton's principle for above. Koo [4] studied the effects of layer wise in-plane displacements on fundamental frequencies and specific damping capacity for composite laminated plates using FEA method and experimental method. Lee and Yhim [5] analyzed single and two-span continuous composite plate structures subjected to multi-moving loads using 7-DOF finite element model for computational analysis and third order shear deformation theory to validate. Lee et al. [6] investigated the dynamic behavior of multiply-folded composite laminates using higher order plate theory and the third order finite element program. The effects of folding angles and ply orientations on the transient responses for various loading and boundary conditions are studied. Morozov [7] has made a theoretical and experimental characterization of elastic properties of the textile composites. Khalili et al. [8] used Fourier series to investigate the dynamic response of laminated composite plate subjected to static and dynamic loading The result is validated by comparing with the result obtained from the FEM code NISA II. Attaran et al. [9] made a study over the effects of aspect ratio, sweep angle, and stacking sequence of laminated composites on aero dynamic properties like flutter speed using 2D finite element analysis in conjunction with Doublet lattice Method. Davallo et al. [10] studied the mechanical behavior of uni-directional glass-polyester composites in flexure and tensile testing. The effect of laminate thickness on the mechanical properties is studied using simple energy model. Mohammed et.al [11] had explained the effect of fiber orientations on the flexural natural frequencies by finite element (FEA) and experimental approach. Jweeg et al.[12] made experimental and theoretical study on modulus of elasticity of composite material due to the reinforcement of different types of fiber like short ,long woven, powder, and particulate shapes. Majid et.al. [13] had developed frequency response function and modal analysis for composite plate like wing and tested it as cantilever to get the dynamic properties and its dependency on ply orientation and thickness. Long et al. [14] presented a general formulation for free and transient vibration analyses of composite laminated beams for any boundary condition. To confirm the validity of the formulation, the result is compared with the result obtained from the analytical, experimental and FEA. Ratnaparkhi and Sarnobat [15] made the modal analysis to obtain the Natural frequencies in free-free boundary condition and validated the results obtained from the FEA using ANSYS in their work. Parida and Dash [16,17] developed generalized frequency equation taking bending and shearing in to consideration and studied the effect of fiber orientation, boundary condition and aspect ratio on modal characteristics of a plate like beam using finite element analysis software.

From the above study it is evident that the orientation of fiber layer and thickness controls the elastic modulus and strength of the composite material. In this paper the effect of variation of width and fiber orientation on natural frequency for different boundary conditions of the beam is to be studied. In section 2 mathematical modeling is proposed for free vibration analysis of Timoshenko composite beam. The problem for the analysis is defined and validation of FEA analysis is done in section 3. In section 4 effect of different fiber orientation and geometric ratio on natural frequency for different boundary condition are investigated in a detail.

2. THEORETICAL MODELING

In literature modal analysis of beam is conducted by many of researchers. In general beams the bending phenomenon is pre-dominant. The natural frequency for a beam subjected to bending action only is given by

$$(\omega_{zi}^{B})^2 = \frac{EI_{zz}}{2\pi\rho}\frac{\alpha_{Bi}^4}{L^4} \tag{1a}$$

For a beam undergoing shearing action, the free natural frequency for a beam subjected to shearing is given by

$$(\omega_{zi}^{s})^2 = \frac{S_{yy}}{\rho}\frac{\alpha_{si}^2}{L^4} \tag{1b}$$

In this paper, Timoshenko beam is referred. In this beam the shear deformation is considered for beam analysis. One of them is first order shear deformation theory (FSDT). According to first order shear deformation theory, it is assumed that the cross sections of beam subjected to bending remain plane but not perpendicular to the axis.

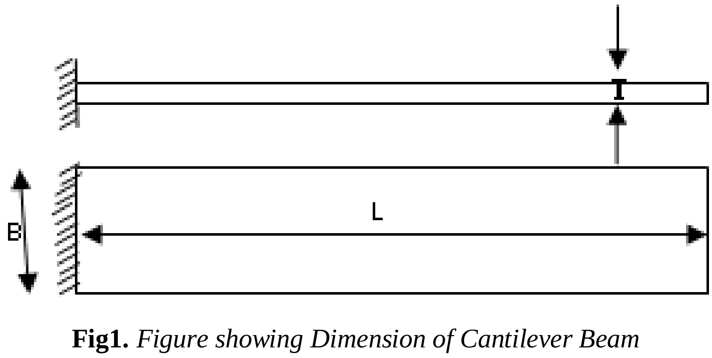


Fig1. *Figure showing Dimension of Cantilever Beam*

As the dimension of the beam taken is such that both bending and shearing comes to play. The natural frequencies in x-y plane for the orthotropic beams as shown in figure-1 subjected to bending and shearing deformation simultaneously by shear beam theory is given as

$$(\omega_{zi})^2 = \left[\frac{1}{(\omega_{zi}^B)^2} + \frac{1}{(\omega_{zi}^s)^2}\right]^{-1} \tag{1}$$

Where, $Syy = \frac{5}{6} b \int_{T/2}^{T/2} (q_{ss} dy)$, $EIzz = \frac{1}{a_{xx}} \frac{a^3}{12}$ in $N.m^2$

The super script s stands for shearing and B stands for bending.

Stiffness matrices for a laminated composite structure can be given by relating force and moment results considering the following structure of the laminate as shown in figure-2

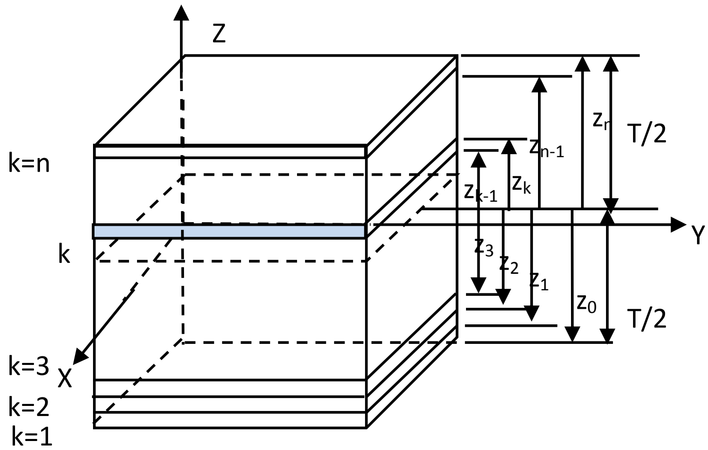


Fig2. *Multidirectional laminate with co-ordinate notation of individual plies*

$$\left.\begin{aligned}
V_f &= \frac{\text{volume of fibers}}{\text{total volume of composite}}\\
V_{\tilde{v}} &= 1 - \frac{\left(\frac{W_f}{\rho_f}\right) + \frac{W_c - W_f}{\rho m}}{\frac{W_c}{\rho_c}}\\
\rho_c &= \rho_f v_f + \rho_m (1 - v_f - v_{\tilde{v}})\\
E_x &= E_f V_f + E_m V_m\\
E_y &= \left[\frac{E_f \times E_m}{V_f E_m + V_m E_f}\right]\\
\gamma_{yz} &= \gamma_f V_f + \gamma_m (1 - V_f)\left[\frac{1 + \gamma_m - \frac{\gamma_{xy} E_m}{E_{xx}}}{1 - \gamma_m{}^2 + \frac{\gamma_m \gamma_{xy} E_m}{E_{xx}}}\right]\\
G_{xy} &= \frac{G_m G_f}{V_m G_f + V_f G_m} \text{ and } G_{yz} = \frac{E_{yy}}{2(1+\gamma_{yz})}
\end{aligned}\right\} \tag{6}$$

Where the subscript c, f , m & ṽ stands for composite, fiber ,matrix an void respectively. V,ρ, γ, E,G, stands for volume fraction, density, poison's ratio, elastic modulus and shear modulus respectively.

The fiber reinforced in the beam is in woven form. The elastic constants of the woven fabric composite material are estimated by relating them to the properties of uni-directional composite material as using following relations:

$$\left.\begin{aligned}
E_{wx} &= \frac{E_x}{2}\left(\frac{E_x + (E_x + 2E_y) + (1 + 2\gamma_{xy}^2)E_y^2}{E_x\left(E_x + (1 - \gamma_{xy}^2)E_y\right) - \gamma_{xy}^2 E_y^2}\right)\\
\gamma_{wxy} &= \frac{4Ew_x}{E_x}\left(\frac{\gamma_{xy} E_y (E_x - \gamma_{xy}^2 E_y)}{E_x(E_x + 2E_y) + (1 + 2\gamma_{xy}^2)E_y^2}\right)\\
\gamma_{wxz} &= \frac{Ew_x}{E_x}\left(\frac{E_x(\gamma_{xy} + \gamma_{yz} + \gamma_{xy}\gamma_{yz}) + \gamma_{xy}^2 E_y}{E_x + (1 + 2\gamma_{xy})E_y}\right)\\
Ew_z &= \frac{(1 - \gamma_{yz}^2)E_x^2 + (1 + 2\gamma_{xy} + 2\gamma_{xy}\gamma_{yz})E_x E_y - \gamma_{xy}^2 E_y^2}{E_x E_y\left(E_x + (1 + 2\gamma_{xy})E_y\right)}\\
Gw_{xy} &= G_{xy}\,,\; G_{wxz} = \frac{2G_{xy}E_y}{1 + \gamma_{yz}}
\end{aligned}\right\} \tag{7}$$

Where the subscript w stands for woven fabric composite

For the variation of fiber orientation the bending stiffness of the composite component also varies. Hence the natural frequency will change accordingly. In next section a numerical example is taken for the study based on this assumption.

E-glass-polyester composite plate like beams is taken for consideration. The mechanical properties of the beam specimens taken for the study are calculated by using the relations for woven fabric composite as given by the relations (7) and depicted in table-2 from the constituent material properties for matrix as presented in table-1.

Table1. *Mechanical Property of Constituent Materials*

Properties	**Material**	
	Glass fiber	Polyester resin
Elasticity modulus	80GPa	3.5GPa
Shear modulus	30.3GPa	1.26GPa
Density	2600 kg/m^3	1200kg/m^3
Poisson ratio	0.32	0.38

Table2. *Elastic Properties Of bi-directional woven Composite Lamina specimens*

Properties	**Polyester-Glass**
Elastic modulus along y-axis	20.41 Gpa
Elastic modulus along y-axis	20.41 Gpa
Elastic modulus through thickness or z-axis	6.57 Gpa
Shear modulus in plane x-y plane	2.74 Gpa
Shear modulus in plane x-z plane	2.25 Gpa
Shear modulus in plane y-z *plane*	2.25 Gpa
Poisson ratio in plane x-y plane	0.356
Poisson ratio in plane x-z plane	0.48
Poisson ratio in plane y-z plane	0.48
Density of composite	1750kg/m^3

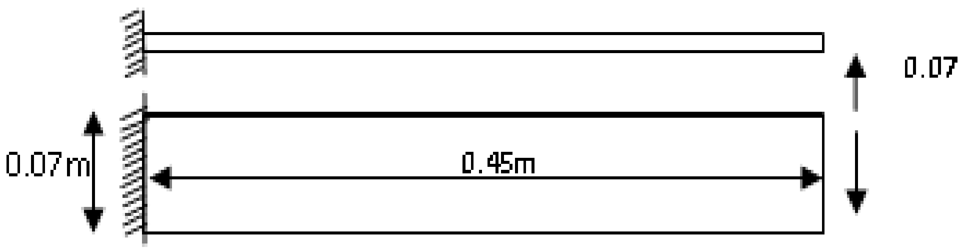


Fig3. *Dimensions of cantilever beam*

The geometric dimension of the beam for the study is taken as L=0.45m, T=0.007m and B is varied from 0.007m to 0.07m as shown in figure 3.Different type of end conditions like cantilever, clamped-clamped, clamped-simple supported and simple-simple supported beams are taken for the study. The beam is composed of six ply layers. The orientations of six plies are kept symmetric, that is the orientation of upper three layers are exactly opposite to the lower three layers. This type of arrangement of plies can be done with even number of ply layers and are called as symmetric orientation. Six combinations of plies orientations with 15˚,30˚and 45˚ along with 0°-15°-30° and 0°-30°-15° orientations are taken for the study and compared with the resultant frequency obtained keeping all the plies at 0°-0°-0°. The first five natural frequencies are obtained by using the commercial finite element analysis (FEA) software (ANSYS13.0). The beams were first descretized using solid brick 8 node 185 finite elements that's each node has six degrees of freedom. The meshing of the beam is refined by taking the node length of 5mm for better result. To check the validity of the procedure the numerical example as in Goda et al. [11] is taken for the study and the result is shown in table 3 for comparison.

Table3. *First two natural frequencies of cantilever (330×43×5.45mm)*

Fiber orientation	Natural frequency	Present	Reference[11]	
			ANSYS	Exp.
0˚	1	21.16	25.1	22.0
	2	162.52	157.0	146.5
15˚	1	19.16	22.7	20.0
	2	147.42	141.8	143.5
30˚	1	16.44	19.48	17.0
	2	125.91	121.7	121.0

The result obtained is very close to the experimental result obtained in reference and to the ANSYS result which certify the authenticity of the procedure.

3. RESULTS

The first five natural frequencies (NF) for the beam specimens are obtained from commercial finite element package ANSYS13.0 and presented through table4 to table 7. The variable parameters for the study are taken as outer fiber orientations, end conditions and geometric ratio. Eight combinations of outer fiber orientations such as ±(0˚-30˚-15˚), ±(30˚-45˚-15˚), ±(45˚-30˚-15˚),±(0˚-15˚-30˚),±(45˚-15˚-30˚),±(30˚-15˚-45˚), ±(15˚-45˚-30˚) and ±(15˚-30˚-45˚) are compared with the result obtained keeping all the plies at ±(0˚-0˚-0˚). In the study the thickness of the beam is kept fixed and the width is varied to vary the geometric ratio (GR=B/L) that is ratio of width of beam (B) to length of beam (L) and also its effect on natural frequencies is studied.

Table4. *First five natural frequencies of Cantilever beam*

Geometric ratio(GR)	Natural freq.(w_n)	±(0˚-0˚-0˚)	±(0˚-30˚-15˚)	±(30˚-45˚-15˚)	±(45˚-30˚-15˚)	±(0˚-15˚-30˚)	±(45˚-15˚-30˚)	±(30˚-15˚-45˚)	±(15˚-45˚-30˚)	±(15˚-30˚-45˚)
0.0156	ω_1	19.09	15.86	16.20	16.10	15.04	14.84	14.49	14.07	13.63
	ω_2	119.32	102.07	101.32	100.69	94.12	92.86	90.70	88.07	85.30
	ω_3	332.58	284.85	282.79	281.04	262.80	259.30	253.29	246.03	238.32
	ω_4	647.51	555.55	551.64	548.22	512.86	506.12	494.5	480.47	465.53
	ω_5	1061.6	912.98	906.71	901.14	843.45	832.54	813.57	790.89	766.46
0.0333	ω_1	19.10	16.32	16.29	16.17	15.13	14.91	14.6	14.14	13.73
	ω_2	119.37	102.1	101.89	101.29	94.65	93.27	91.37	88.52	85.91
	ω_3	332.73	285.15	284.39	282.32	264.29	260.48	255.22	247.31	240.07
	ω_4	647.83	556.32	554.63	550.98	515.82	508.50	498.42	483.15	469.14
	ω_5	1062.2	914.44	912.02	911.93	848.75	836.90	820.38	795.72	772.86
0.0666	ω_1	19.13	16.38	16.41	16.30	15.28	15.05	14.75	14.30	13.89
	ω_2	119.56	102.44	102.61	101.93	95.55	94.17	92.30	89.50	86.98
	ω_3	333.29	286.06	286.57	284.69	267.13	263.33	258.24	250.49	243.53
	ω_4	649.05	559.19	559.97	556.54	523.04	515.82	505.59	491.12	477.58
	ω_5	1064.5	918.44	920.87	914.38	861.54	850.0	834.70	811.28	789.97
0.111	ω_1	19.192	16.67	16.57	16.46	15.50	15.28	14.98	14.54	14.15
	ω_2	119.89	104.02	103.56	102.91	96.85	95.52	93.74	91.03	88.63
	ω_3	334.26	290.86	289.63	287.87	271.48	267.89	263.74	255.42	249.25
	ω_4	651.18	569.87	567.38	564.30	533.77	527.12	517.5	504.48	492.05
	ω_5	1068.6	943.00	938.37	934.53	889.00	879.69	862.49	858.29	819.41
0.155	ω_1	19.25	16.855	16.753	16.581	15.72	15.516	15.205	14.806	14.4191
	ω_2	120.22	104.69	104.38	103.67	97.97	96.709	95.070	92.513	90.239
	ω_3	335.22	293.23	292.40	290.52	275.36	272.02	267.60	260.92	254.88
	ω_4	653.35	575.58	568.83	566.88	543.34	537.37	528.85	517.22	506.00
	ω_5	1072.7	949.99	949.23	939.88	904.54	888.00	877.97	858.33	846.96

Table5. *First five natural frequencies of Clamped- clamped beam*

Geometric ratio(GR)	Natural freq.(w_n)	±(0°-0°-0°)	±(0°-30°-15°)	±(30°-45°-15°)	±(45°-30°-15°)	±(0°-15°-30°)	±(45°-15°-30°)	±(30°-15°-45°)	±(15°-45°-30°)	±(15°-30°-45°)
0.0156	ω_1	121.19	103.90	103.11	102.51	95.89	94.61	92.40	89.77	86.96
	ω_2	332.10	285.19	283.07	281.42	263.35	259.89	253.85	246.69	239.03
	ω_3	646.13	556.03	552.05	548.80	513.81	507.15	495.47	481.70	466.85
	ω_4	1058.2	912.97	906.59	901.34	844.36	833.62	814.64	792.25	768.18
	ω_5	1563.7	1353.1	1344	1336.2	1252.6	1237.0	1209.2	1176.9	1141.3
0.0333	ω_1	121.30	104.53	103.92	103.28	96.74	95.36	93.36	90.55	87.9
	ω_2	332.39	286.89	285.25	283.51	265.69	261.95	256.6	248.86	241.64
	ω_3	646.71	559.36	556.27	552.89	518.46	511.26	500.74	486.06	472.08
	ω_4	1059.2	918.40	913.59	908.01	852.19	840.60	823.55	799.88	777.14
	ω_5	1565.2	1361.5	1354.6	1346.4	1279.9	1248.0	1223.0	1188.7	1155.3
0.0666	ω_1	121.67	105.97	105.27	104.80	98.52	97.16	95.09	92.47	89.9
	ω_2	333.41	290.71	288.95	287.57	270.62	266.96	261.44	254.35	247.4
	ω_3	648.73	567.28	563.91	561.31	528.88	521.92	511.24	497.85	484.51
	ω_4	1062.7	933.66	927.93	924.24	873.61	863.50	842.55	820.13	800.23
	ω_5	1570.6	1378.8	1374.9	1366.9	1295.0	1279.5	1255.3	1225.3	1194.6
0.111	ω_1	122.32	108.09	107.23	107.01	101.19	99.92	97.71	95.47	92.99
	ω_2	335.08	295.70	293.66	292.89	277.58	274.25	268.79	262.66	256.22
	ω_3	651.98	577.91	574.45	572.63	543.88	542.57	527.08	515.95	503.74
	ω_4	1068.2	952.51	946.75	944.33	899.51	889.98	872.28	855.91	836.26
	ω_5	1579.4	1418.0	1409.4	1406.8	1344.6	1331.7	1304.2	1284.4	1255
0.155	ω_1	122.32	108.10	107.25	107.02	101.17	99.90	97.69	95.74	92.99
	ω_2	335.08	295.73	293.97	292.92	277.55	274.22	268.74	262.66	256.21
	ω_3	651.98	577.96	574.51	572.69	543.82	537.62	526.98	515.96	503.71
	ω_4	1068.2	952.60	946.85	944.42	899.41	889.88	872.12	855.93	836.22
	ω_5	1579.4	1418.2	1409.5	1406.9	1344.5	1331.6	1304.0	1284.5	1254.9

Table6. *First five natural frequencies of Clamped simple beam*

Geometric ratio(GR)	Natural freq.(w_n)	±(0°-0°-0°)	±(0°-30°-15°)	±(30°-45°-15°)	±(45°-30°-15°)	±(0°-15°-30°)	±(45°-15°-30°)	±(30°-15°-45°)	±(15°-45°-30°)	±(15°-30°-45°)
0.0156	ω_1	83.55	71.68	71.07	70.71	66.06	65.17	63.50	61.76	59.72
	ω_2	269.58	231.07	229.31	227.97	213.14	210.29	205.27	199.47	193.13
	ω_3	558.99	479.69	476.23	473.35	442.76	436.93	426.76	414.73	401.74
	ω_4	948.32	815.30	809.71	804.72	753.21	743.45	726.48	706.20	684.35
	ω_5	1433.2	1233.9	1226.5	1218.4	1141.9	1127.4	1102.4	1072.0	1039.4
0.0333	ω_1	83.58	72.15	71.58	71.27	66.57	65.68	63.99	62.19	60.17
	ω_2	269.71	231.99	230.67	229.20	214.5	211.40	206.85	200.81	199.29
	ω_3	559.27	481.59	479.07	475.89	445.60	439.26	430.16	417.16	404.87
	ω_4	948.84	817.67	814.19	808.27	757.74	747.17	732.54	710.46	690.05
	ω_5	1434.1	1245.5	1241.1	1233.5	1147.9	1132.6	1112.2	1085.0	1076.9
0.0666	ω_1	81.23	72.78	72.21	72.03	67.51	66.53	64.56	63.01	60.94
	ω_2	270.17	233.6	232.41	230.99	216.78	213.69	209.30	203.17	197.36
	ω_3	560.32	485.61	483.30	480.33	451.42	445.17	436.29	423.82	396.12
	ω_4	950.89	834.59	829.31	826.93	753.82	748.43	744.94	722.18	705.09
	ω_5	1437.7	1250.2	1248.3	1238.7	1171.5	1156.8	1135.9	1106.2	1080.4
0.111	ω_1	83.96	73.80	73.07	73.00	68.66	67.71	65.72	64.22	62.14
	ω_2	270.97	235.61	234.73	233.23	220.11	217.22	213.24	207.44	202.10
	ω_3	562.19	496.49	483.37	471.12	459.60	454.19	446.80	435.45	424.94
	ω_4	954.16	842.60	838.48	835.15	793.76	784.81	768.22	752.75	733.56
	ω_5	1444.3	1287.7	1280.1	1277.2	1220.6	1209.2	1179.5	1171.2	1168.8
0.155	ω_1	83.96	73.81	73.05	73.01	68.65	67.70	65.70	64.22	62.14
	ω_2	270.97	235.63	234.75	233.25	220.08	217.19	213.19	207.44	202.08
	ω_3	562.19	496.52	499.08	494.06	459.55	454.14	446.71	435.46	424.91
	ω_4	954.61	842.67	838.57	835.23	793.67	784.72	768.07	752.77	733.51
	ω_5	1444.3	1287.8	1280.2	1277.3	1220.5	1209.1	1179.3	1171.3	1168.9

Table7. *First five natural frequencies of Simple supported beam*

Geometric ratio(GR)	Natural freq.(w_n)	±(0˚-0˚-0˚)	±(0˚-30˚-15˚)	±(30˚-45˚-15˚)	±(45˚-30˚-15˚)	±(0˚-15˚-30˚)	±(45˚-15˚-30˚)	±(30˚-15˚-45˚)	±(15˚-45˚-30˚)	±(15˚-30˚-45˚)
0.0156	ω_1	53.47	46.45	46.82	46.1	43.45	42.82	40.53	39.74	38.10
	ω_2	213.29	182.17	180.88	181.17	166.69	164.69	161.81	157.08	152.12
	ω_3	477.62	409.34	406.19	405.34	377.84	370.84	363.13	353.01	341.53
	ω_4	843.51	722.2	719.55	718.2	665.66	655.66	643.14	624.58	605.24
	ω_5	1307.1	1123.3	1055.7	1044.3	1028.7	1018.7	1000.2	972.41	941.99
0.0333	ω_1	53.47	47.21	46.35	46.62	43.50	42.86	40.79	40.18	38.30
	ω_2	213.30	182.29	181.51	180.07	168.29	165.81	162.58	157.33	152.69
	ω_3	477.66	410.54	408.09	405.57	379.14	373.62	365.08	354.16	343.05
	ω_4	843.65	721.79	719.79	713.36	668.07	658.53	646.76	626.02	608.20
	ω_5	1307.4	1125.4	1083.8	1075.5	1041.8	1027.1	1006.7	976.16	947.54
0.0666	ω_1	53.48	47.65	46.63	47.08	44.0	43.35	40.94	40.48	38.44
	ω_2	213.36	182.36	181.86	180.25	168.67	166.14	163.25	157.82	153.38
	ω_3	477.94	412.07	409.86	407.37	381.66	376.06	367.73	356.90	346.07
	ω_4	844.46	728.88	729.85	718.10	664.14	656.40	653.47	630.77	616.37
	ω_5	1309.3	1127.2	1127	1083.2	1053.0	1039.1	1022.2	992.30	966.44
0.111	ω_1	53.49	47.87	46.79	47.31	44.29	43.63	41.08	40.7	38.59
	ω_2	213.51	182.37	182.28	180.4	169.43	166.98	164.59	159.12	155.02
	ω_3	478.64	414.52	412.86	410.22	386.49	381.26	373.64	363.39	353.43
	ω_4	844.17	742.94	738.37	735.93	697.80	689.64	669.03	659.03	638.36
	ω_5	1313.8	1167.6	1159.5	1158.2	1113.3	1106.7	1051.3	1013.3	1006.4
0.155	ω_1	53.49	47.88	46.80	47.32	44.28	43.63	41.07	40.70	38.58
	ω_2	213.51	182.39	182.30	180.42	169.41	166.96	164.55	159.12	155.01
	ω_3	478.64	414.56	412.91	410.26	386.43	381.21	373.55	363.40	353.40
	ω_4	846.52	743.01	738.45	736.00	714.54	689.55	670.88	659.36	656.95
	ω_5	1313.8	1167.7	1159.6	1158.3	1113.2	1106.6	1102.3	1013.3	1006.64

Figure-4(a) , figure-4(b), figure-4(c) and figure-4(d) represents the variation of natural frequencies for cantilever, clamped-clamped beam, clamped-simple supported beam and simple-simple supported beam of GR=0.111 respectively. The variation of natural frequencies with mode number is found to have simmilar for all of the cases i.e the natural frequenciy increases exponentially with increase in mode number for the beams of different fiber orientations, geometric ratios and end conditions as depicted through table4 to table7.

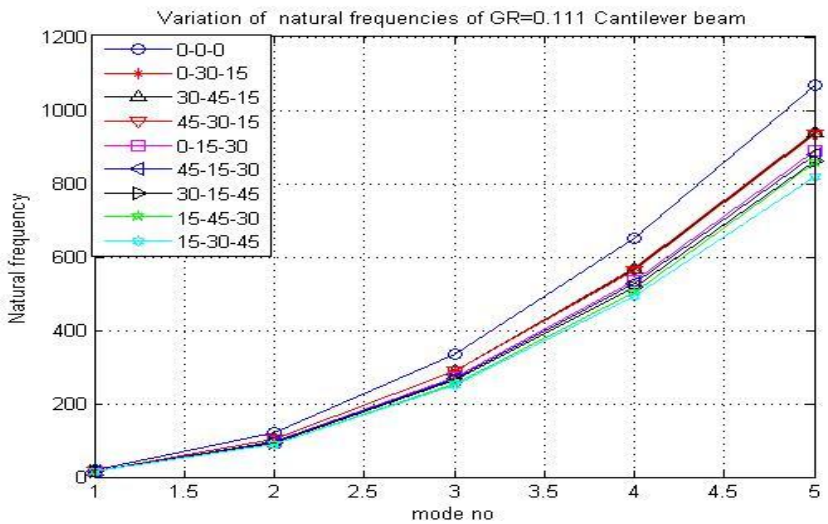


Fig4(a). *Nature of variation of NF with mode no. for cantilever beam of GR=0.111*

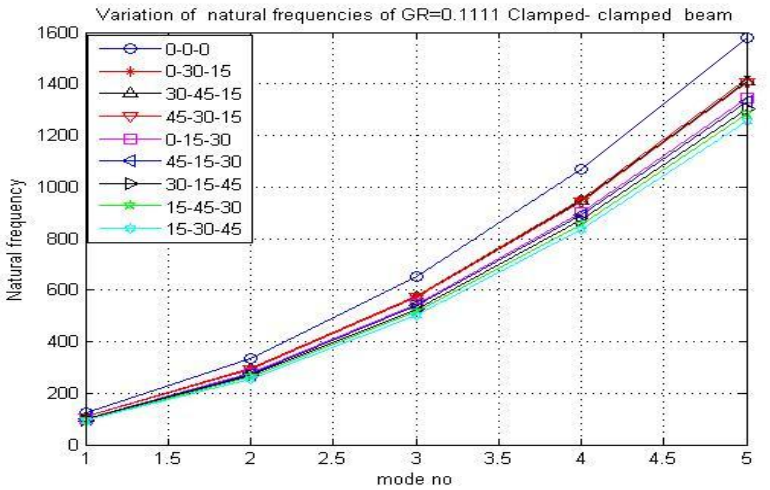


Fig4(b). *Nature of variation of NF with mode no. for clamped-clamped beam of GR=0.111*

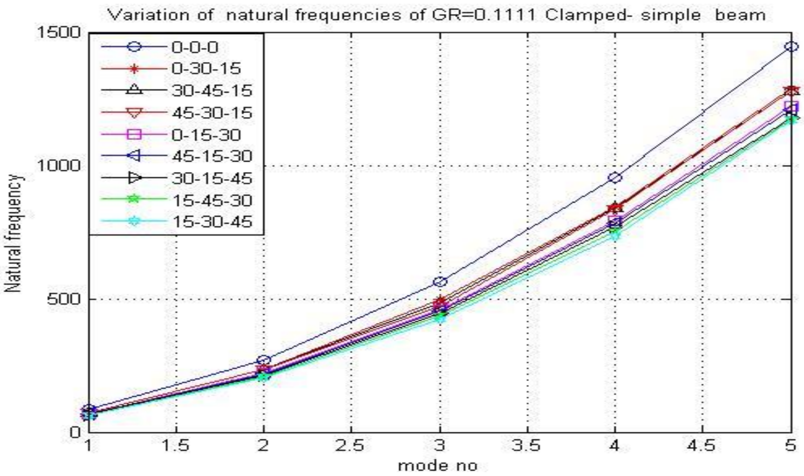


Fig4(c). *Nature of variation of NF with mode no. for clamped-simple supported beam of GR=0.111*

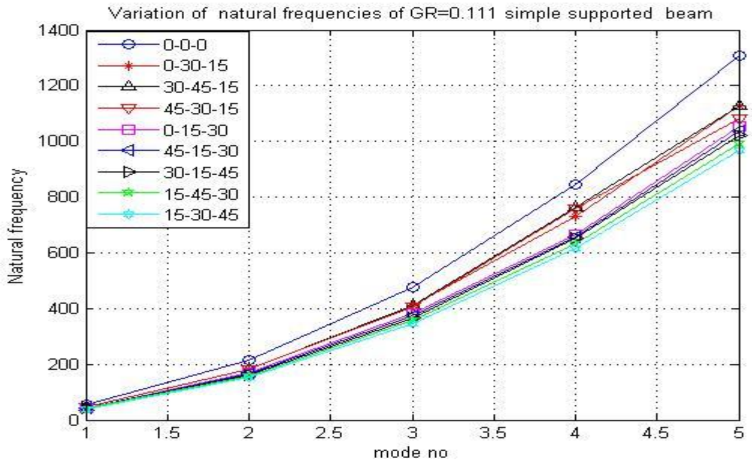


Fig4(d). *Nature of variation of NF with mode no. for simple- simple supported beam of GR=0.111*

The variation of first five natural frequencies with geometric ratios is studied and presented through Figure-5(a) to figure-5(e) for a cantilever beam. It is observed that the natural frequency increases slowly with increase in geometric ratio upto a limit of GR=0.111 and then tends to be constant irrespective of outer fiber orienations. It is assumed that with increase in width of the beam, the supporting area of the beam also increases which provides enough strength to carry the aditional mass for fixed length. Hence the stiffness of the the beams becomes almost constant for a beam of same material and density. The same nature of variation of natural frequencies is also obsreved for other three type of end conditions of beam irrespective of outer fiber orientations.

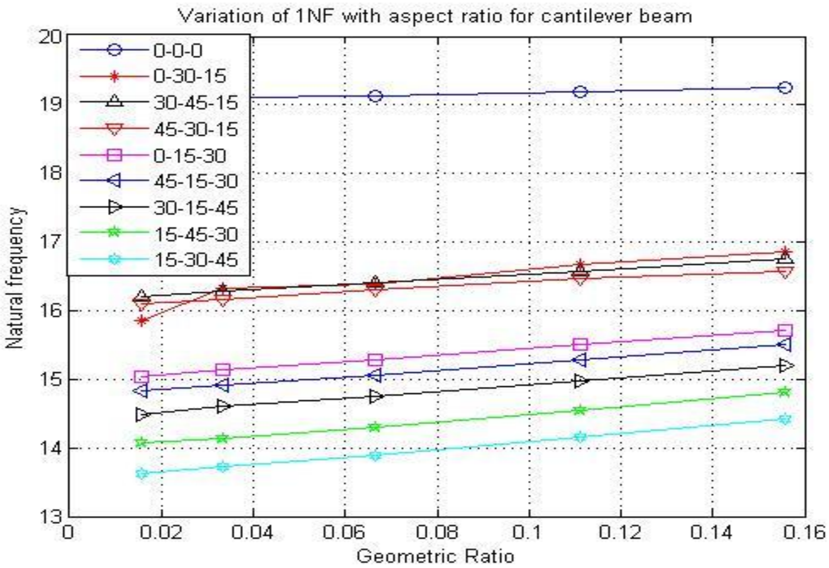


Fig5(a). *Variation of 1NF with GR for* cantilever

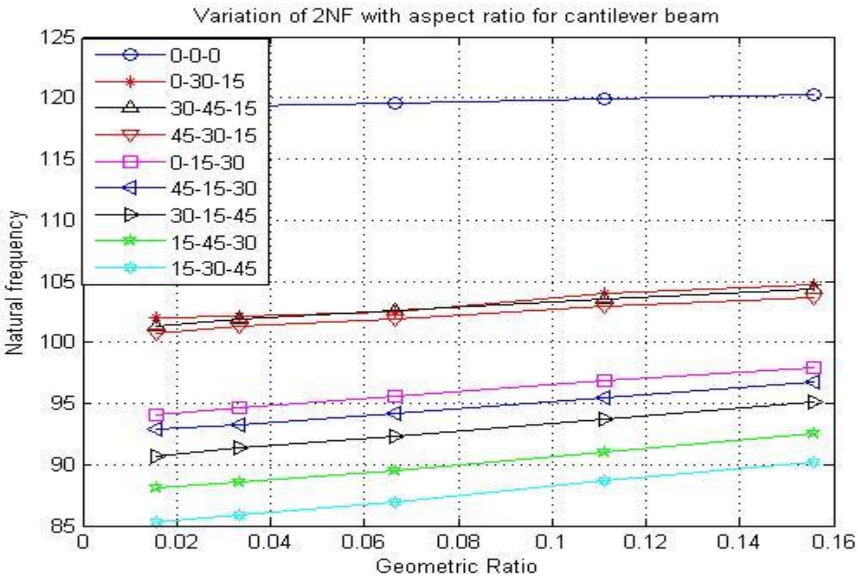


Fig5(b). *Variation of 2NF with GR for cantilever*

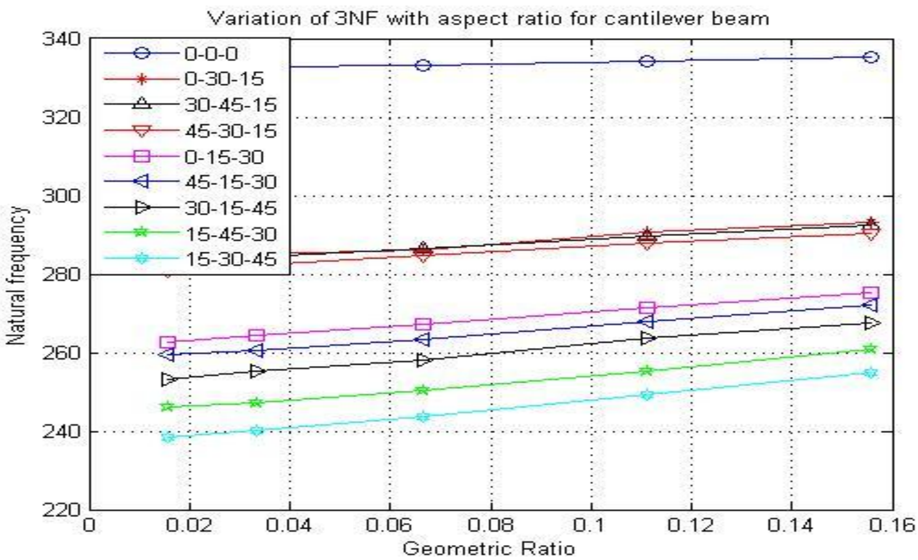


Fig5(c). *Variation of 3NF with GR for cantilever*

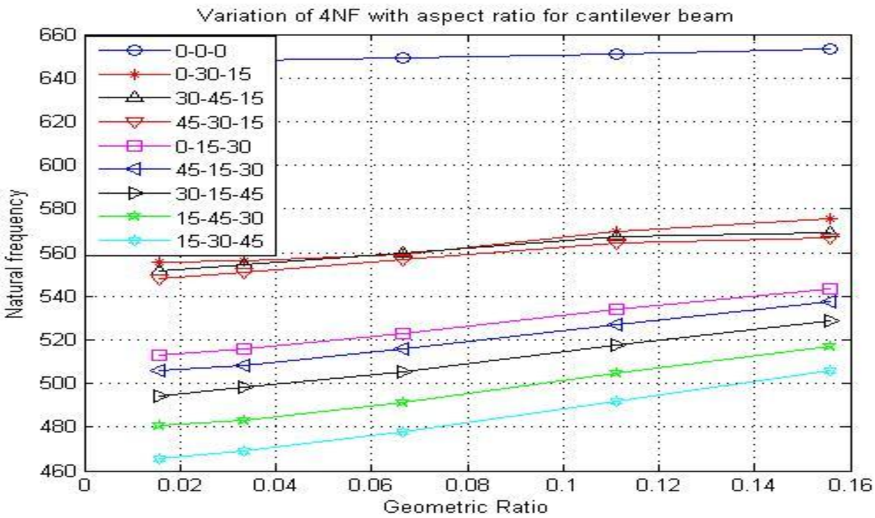


Fig5(d). *Variation of 4NF with GR for cantilever*

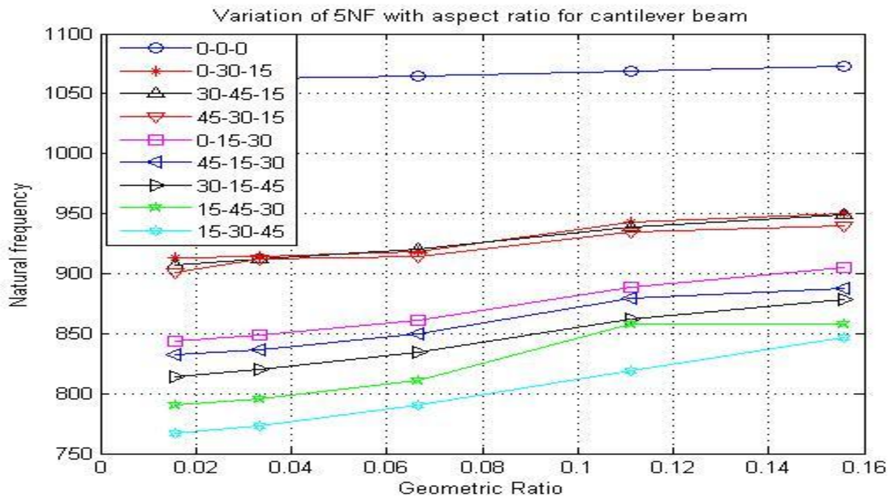


Fig5(e). *Variation of 5NF with GR for cantilever*

The effects of geometric ratios on natural frequencies for different end conditions are also studied. Figure-6 represents the variation of the first five natural frequencies for the beams of different end conditions with ± (15˚-30˚-45˚) outer fiber orientation. From the graph it is clear that the natural frequency is independent to geometric ratio. Also it can be seen that the clamped-clamped beam have higher natural frequency than other three end conditions. It is due to the higher stiffness of clamped-clamped beam than other type of beams.

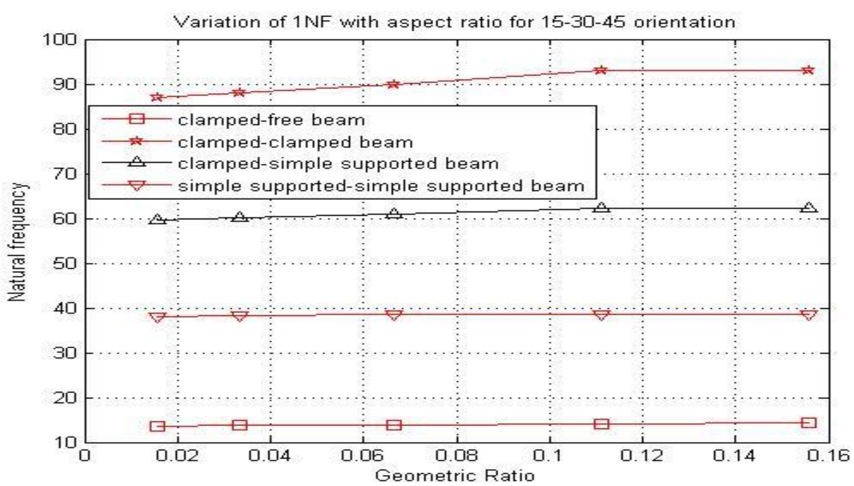


Fig6(a). *1NF Vs GR for ±(15˚-30˚-45˚)outer fiber orientation beams of different end conditions*

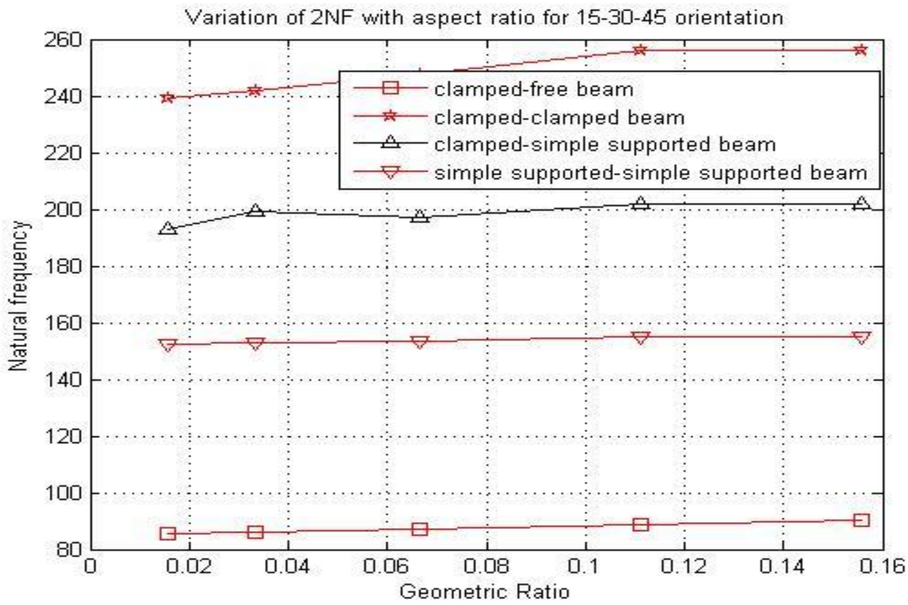


Fig6(b). *2NF Vs GR for ±(15˚-30˚-45˚)outer fiber orientation beams of different end conditions*

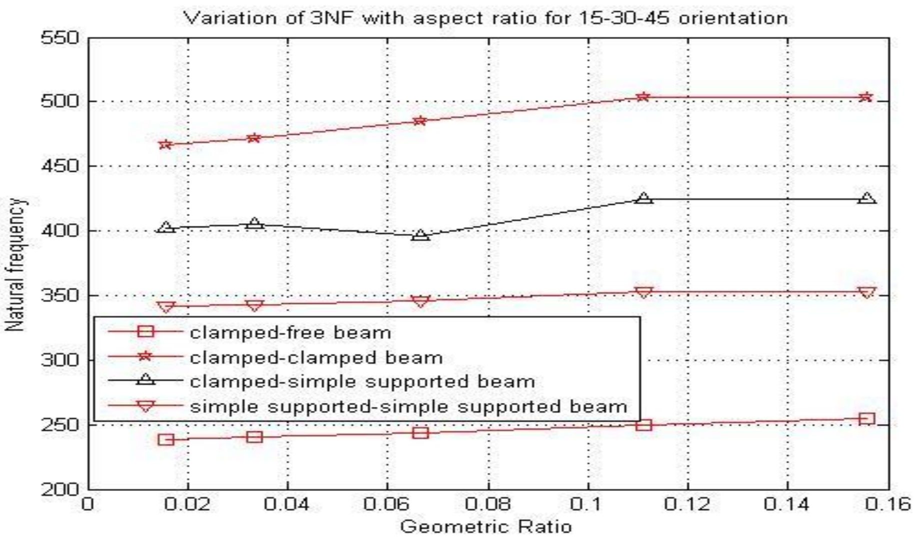


Fig6(c). *3NF Vs GR for ±(15˚-30˚-45˚)outer fiber orientation beams of different end conditions*

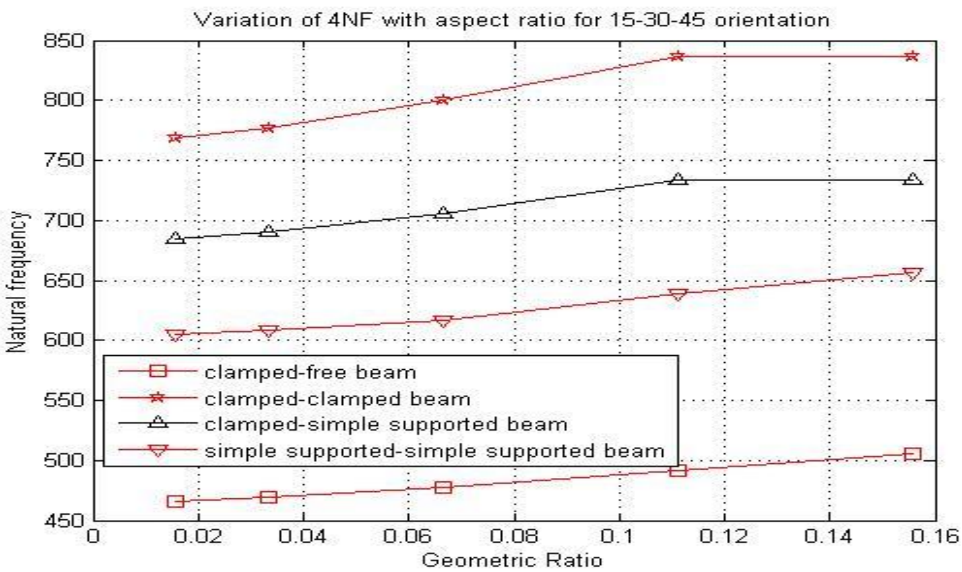


Fig6(d). *4NF Vs GR for ±(15˚-30˚-45˚)outer fiber orientation beams of different end conditions*

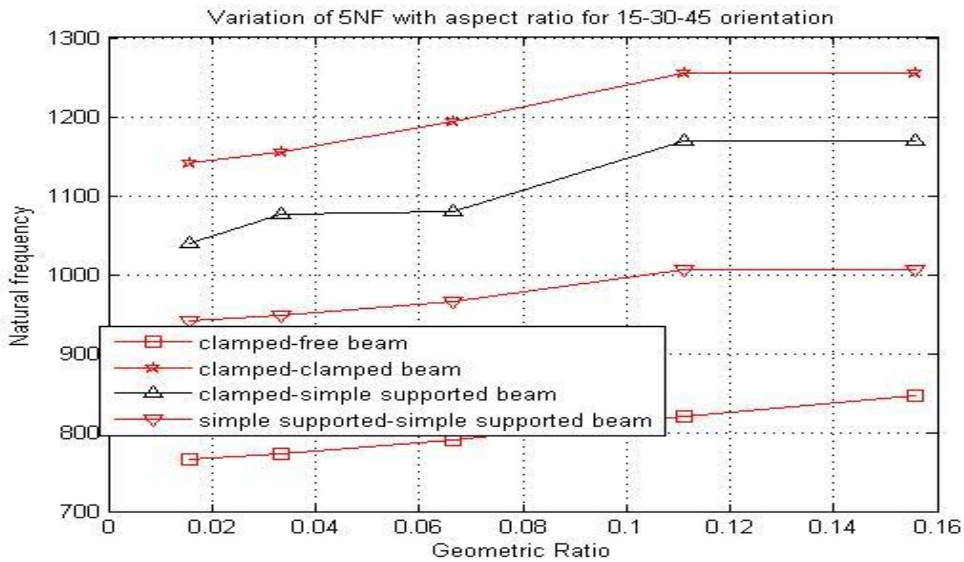
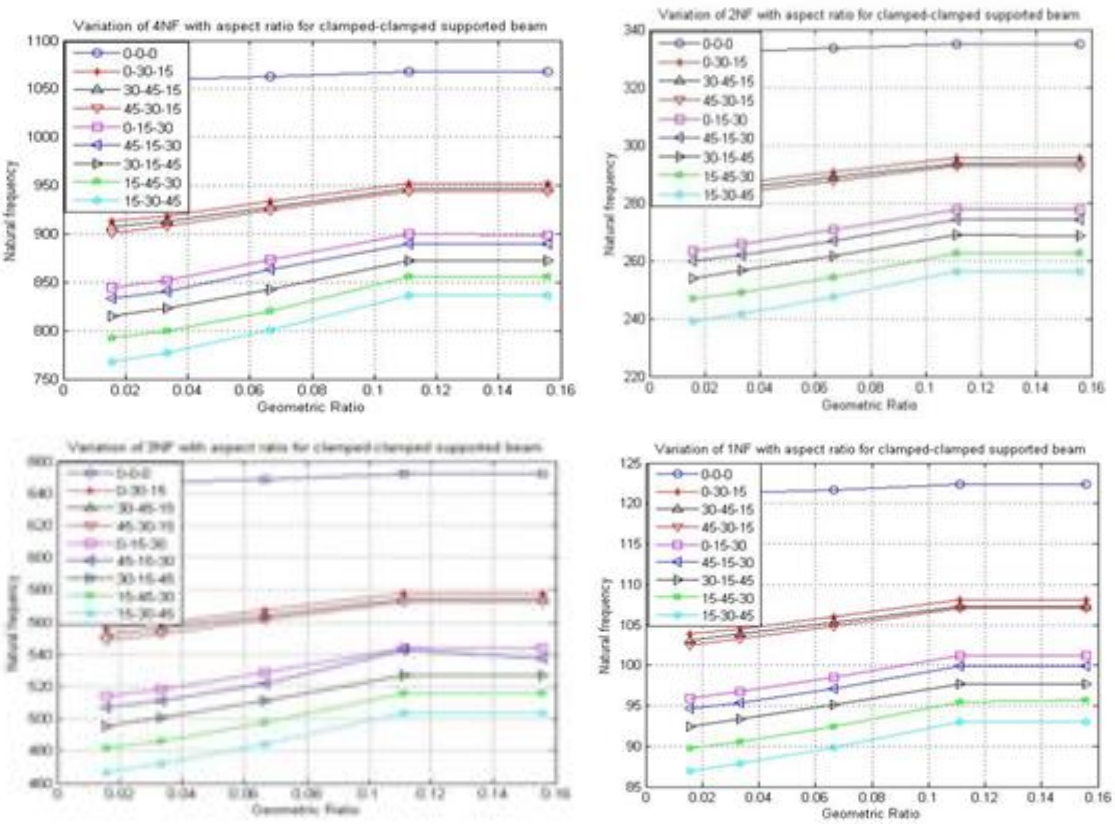
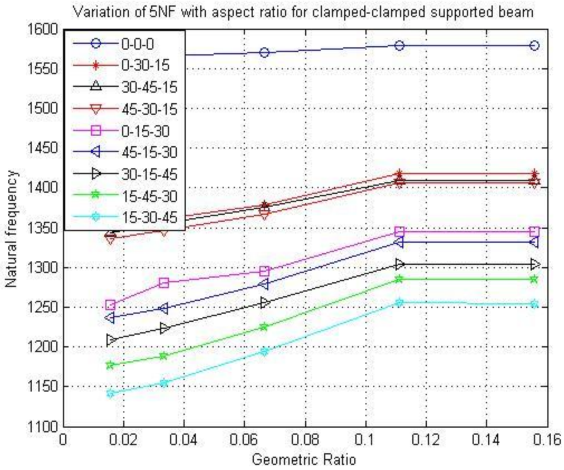


Fig6(e). *5NF Vs GR for ±(15˚-30˚-45˚)outer fiber orientation beams of different end conditions*

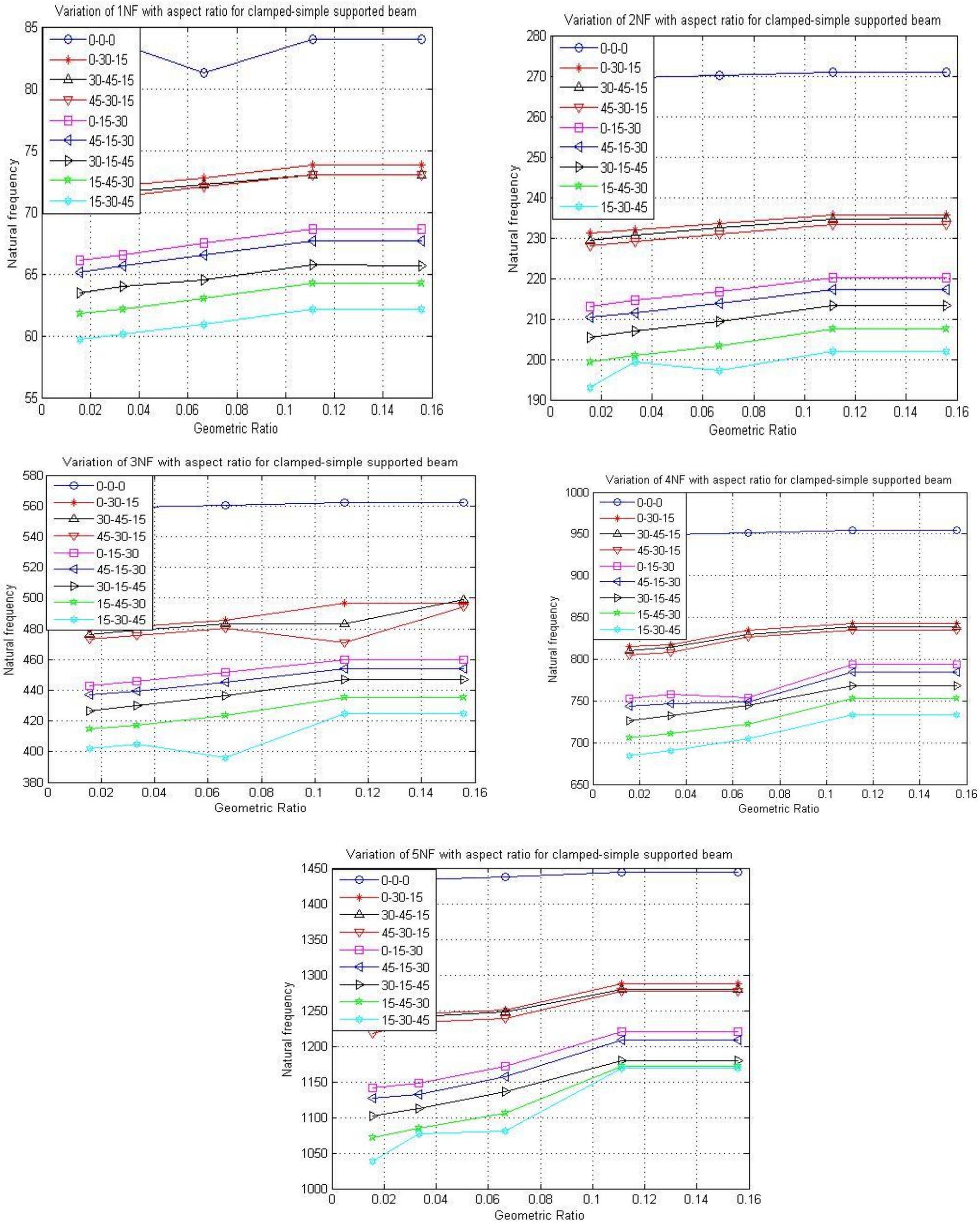
4. Conclusion

Composite materials have wide range of engineering applications in various fields. The mechanical properties of composite beams depend upon the properties of fiber and matrix. It is also true that the fiber orientation and aspect ratio affects the mechanical properties like strength and rigidity of the material which in turn affects the natural frequency for same geometry and boundary condition [16, 17]. The effect of geometric ratio on the natural frequency is studied and presented. It is found out that the natural frequency increases slowly with increase in geometric ratio upto a limit of GR=0.111 and then tends to become constant irrespective of outer fiber orienations and boundary conditions. Here Composite beams with ± (0˚-0˚-0˚) orientation is found to have highest value of natural frequency and ± (15˚-30˚-45˚) have lowest value of natural frequency for all of the configurations and boundary conditions as same as from the previous study [16, 17]. In future further study will be carried out in this field.

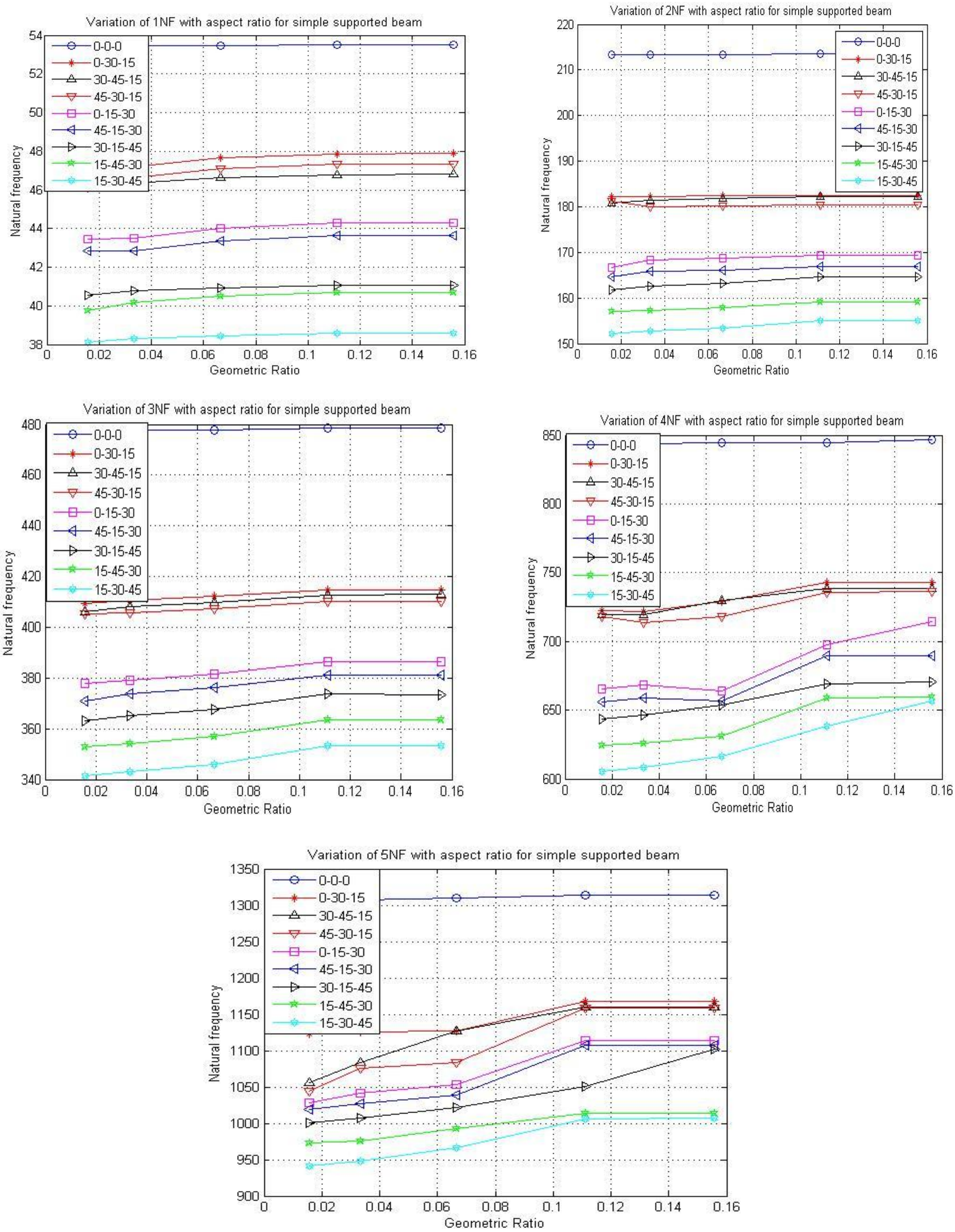




FigA1. *Variation of NF with GR for clamped-clamped beam*



FigA2. *Variation of NF with GR for clamped-simple supported beam*



FigA3. *Variation of NF with GR for simple-simple supported beam*

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