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Experimental Study of Polymer Matrix Composites using Polyester, HEMP and Calcium Silicate

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Abstract

The present study deals with the preparation of polymer matrix composites with polyester resin as matrix and hemp as reinforced material and calcium silicate as filler particles'. The calcium silicate is available in powder form and it is known that, filler particle increases the mechanical properties of polymer matrix composites. In this project work the different percentage of calcium silicate is added in polyester resin to improve its hardness, strength and also mechanical properties of polyester resin. The objective of this project is to prepare PMCs using calcium silicate, hemp fibre and polyester resin using hand lay-up technique as per ASTM standards. In this project work, PMCs are prepared by varying three composition i.e. 2% $CaSiO_3$ + 5% hemp, and 93% polyester resin, 4% $CaSiO_3$, 10% hemp and 86% polyester resin and 6% $CaSiO_3$, 15% hemp and 79% polyester resin. The experimental test will be carried on prepared PMCs and find out the different mechanical characteristics such as tensile strength, compression strength, flexural strength and also to study the dynamic behaviour of PMCs by using damping test with experimental set up.

Keywords: *Hemp fibre, Polyester resin, Calcium silicate, Natural frequency, damping factor.*

1.0 Introduction

Nowadays, the scientists and engineers are working upon the use of plant fibres, as economically and effectively as possible to develop good quality of fibre reinforcement, polymer matrix composites are being used in automotive industry, aerospace industry, building, sporting goods and structural application. The fibres are used because high strength, good quality, light weight and high availability and have led to develop an alternative material, instead of conventional materials. Composite materials are engineering materials made up of two or more combination of material with expressively different chemical or physical properties, which remain separate and distinct in a macroscopic level within finished material. Natural fiber reinforced polymer matrix composites (PMCs) it can be found in structures from sporting goods, automotive, industrial, and residential to aerospace and aircraft applications. Typically, polymer matrix composites having good properties like superior stiffness light weight and high strength. Therefore these composites materials are replacing conventional metals and unreinforced polymers because of their lamination it is one of the major configurations in these PMCs.

The Young modulus of the natural fibers reinforce polymer composite is increased with increasing fiber loading. The change in angles of fibres in composite material, then reduces natural frequency of composites [10]. The inorganic filler particles enhance the mechanical properties of polymers. Calcium silicate with different percentage is added to the resin material in order to enhance the mechanical property [1]. The

PMCs specimens are prepared with different composition of calcium silicate with polyester resin and hemp fibre. The objectives of this present work is to determine the different mechanical properties such as tensile, compression, flexural test and also to determine the dynamic behaviour of PMCs plate and study the damping properties like, damping factor, natural frequency, and different mode shapes using Fast Fourier technique (FFT) based on spectrum analyzer.

2.0 Methodology

The polymer matrix composites specimens are prepared using hand lay-up technique. In this present work the PMCs are prepared by varying three composition i.e. 2% $CaSiO_3$ + 5% hemp, and 93% polyester resin, 4% $CaSiO_3$, 10% hemp and 86% polyester resin and 6% $CaSiO_3$, 15% hemp and 79% polyester resin with different rule of mixture. The specimens are prepared as per ASTM standards. The wax (releasing agent) is applied on mould surface then OHP sheets are cut according to the dimensions and are fixed in the mould to facilitate easy extracting of specimens and on top of OHP sheet another coat of wax releasing agent is applied. In this present work there are three specimens are prepared for each composition and average will be taken. The same process is continued for all moulds like tensile, compression, bending and damping.

3.0 Experimenation

A. Tensile Test

The tensile test specimens are prepared as per ASTM standard D3039. The dimension of rectangular specimens are length L=250mm, breadth b=25mm, and thickness t=3mm as shown in Fig.1

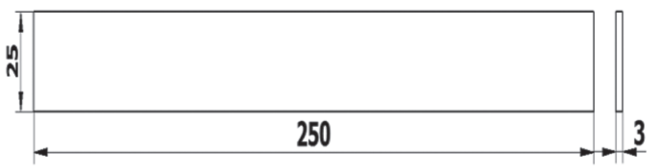


Figure 1: Diagram of tensile specimen. All dimensions are in mm

The PMCs specimen is subjected to tensile load in UTM as shown in Figure 2. The specimen is tested in UTM for determining its ultimate tensile strength.

In Fig.3(a) shows the PMCs tensile specimens are prepared using hand lay-up technique. The experimental tests are conducted on prepared specimens and determined tensile strength of PMCs. In Fig.3(a) shows tensile specimens before testing and in Fig.3(b) shows tensile specimens after testing.

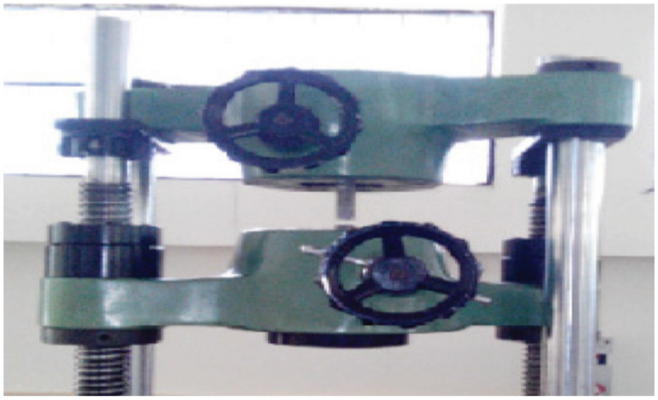


Figure 2: PMCs tensile strength testing in UTM

(a)

(b)

Figure 3: (a) PMCs tensile specimens before testing, (b) PMCs Tensile specimens after testing

B. Compression test

These test specimens are prepared as per ASTM standard D3410. The dimensions of PMCs rectangular specimens are L=140mm, b=25mm, and t=3mm. as shown in Fig.3.

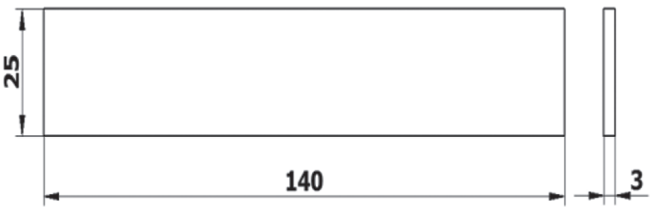


Figure 4: Diagram of compression specimen

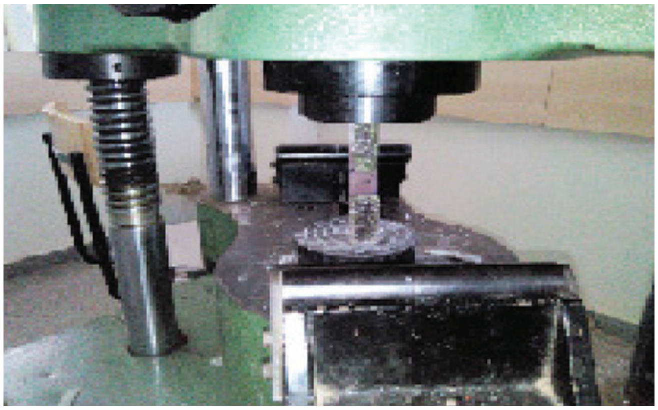


Figure 5: PMCs compression strength testing in UTM

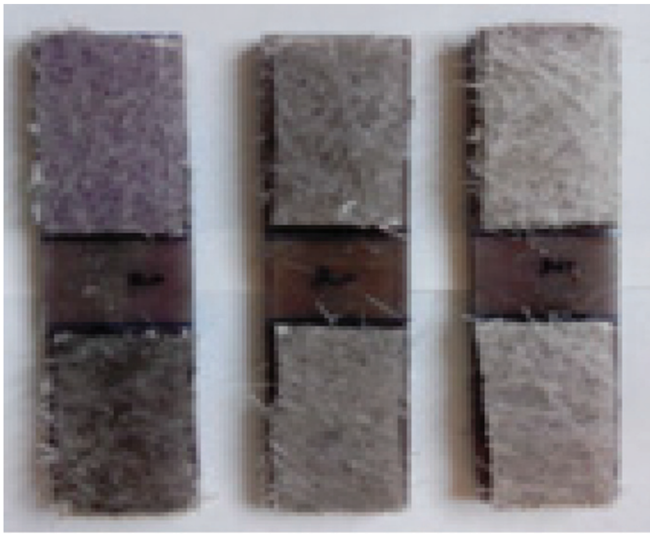
The polymer matrix composites specimen is subjected to compressive load as shown in Figure 5. An experimental test is conducted to determine the compressive strength.

In Fig.6.(a) shows the prepared PMCs using hand lay up technique. The Figure 6(a). shows PMCs specimen before testing and Figure 6(b) shows PMCs specimens after testing. These specimens are tested on UTM subjected to compressive load, and determined the compressive strength of polymer matrix composites.

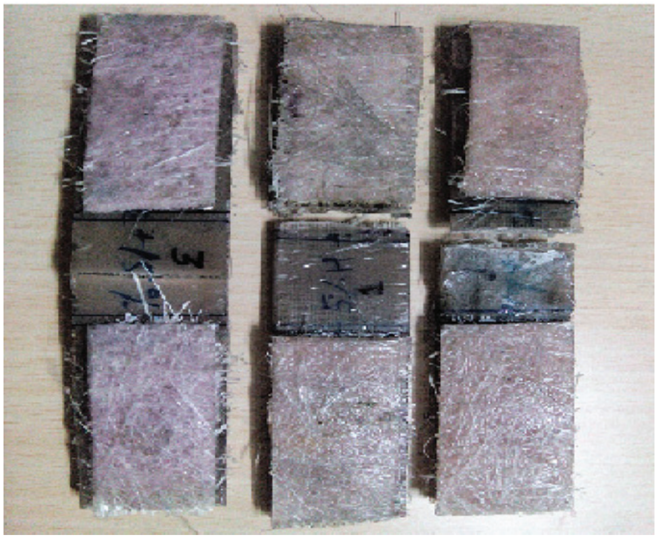
C. Flexural strength

The flexural test specimens are prepared as per ASTM standards D790. The dimensions of PMCc rectangular specimens are L=125mm, b=12.7mm and t=3mm as shown in Fig.7.

In Fig.8 shows the PMCs specimen is subjected to three point bending, the specimen is supported on two edge and load is applied on middle of specimens and finally determined flexural strength of PMCs.



(a)



(b)

Figure 6: (a) PMCs compression specimen before testing, (b) PMCs compression specimens after testing

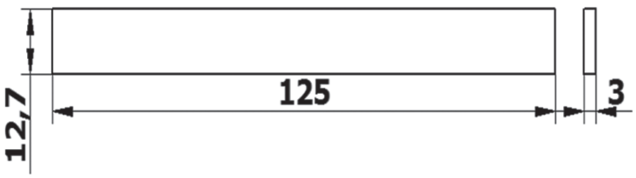


Figure 7: Diagram of flexural specimen. All dimensions are in mm

In Fig.9(a) shows the PMCs flexural specimen before testing and in Fig.9(b) shows the PMCs flexural specimen after testing and finally determined the flexural strength of PMCs.

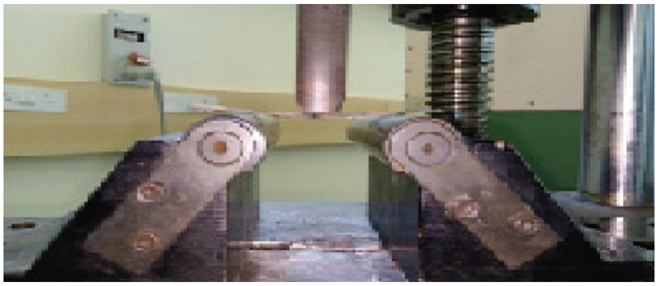
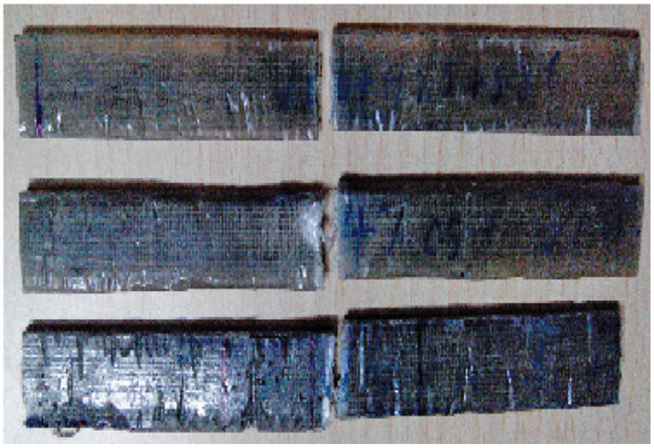


Figure 8: PMCs flexural strength testing in UTM

(a)



(b)

Figure 9: (a) PMCs flexural specimens before testing, (b) PMCs flexural specimens after testing

D. Damping test

Damping is the energy dissipation properties of a material or system under cyclic stress. Damping is an influence within or upon an oscillatory system that has the effect of reducing, restricting or preventing its oscillations. In physical systems, damping is produced by processes that dissipate the energy stored in the oscillation. The damping test are prepared using hand lay up technique, the dimension of rectangular specimens are L=300mm, b=300mm and t=5 mm. as shown in Fig.10.

Once the specimens are prepared then mark on its surface 7*6, 42 points then it is fixed on stand for experimental test shown in Fig.11 aprepared PMCs specimen.

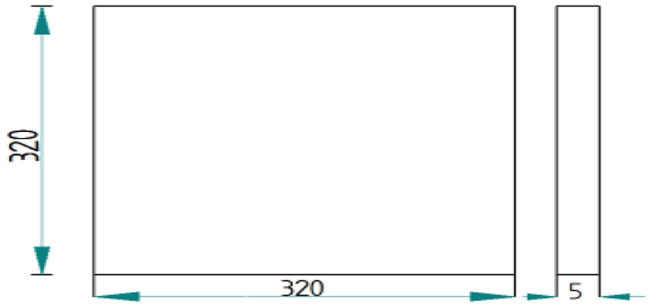
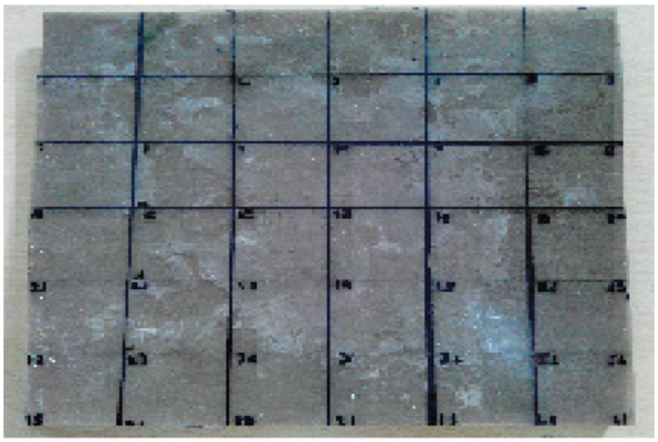
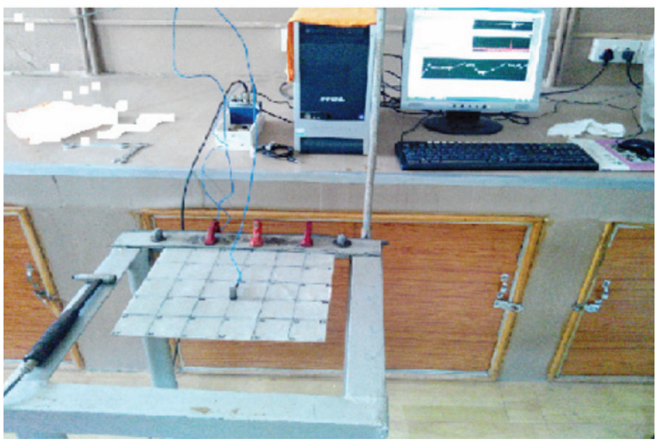


Figure 10: Diagram of damping specimen. All dimensions are in mm



(a)



(b)

Figure 11: (a) Prepared PMCs damping specimen (b) Experimental setup of damping test

The specimen is clamped on stand with nut and bolt arrangement once specimen is fixed, accelerometer will be placed on it as shown in above Figure 11(b). The main function accelerometer is to measure the frequency when system is excited or vibrates. The force is applied by impact hammer having a small tip, the system vibrates or excited then vibration is measured by accelerometer. The transducer is fixed in this hammer and it is connected to data acquisition system with wire cable and accelerometer also connected to DAS with cable.

The main function of transducer is to convert system response from one form to another form when system is vibrates. These signals are recorded in the form of voltage or current and amplify then these signals are passes to the analyzer where these signals converted in to frequency and time domain by Fast Fourier transform (FFT). Then it is display on displayed unit. The output data of all 42 points are measured and used as an input data for LABVIEW- 2009 package to identify response frequencies.

4.0 Results and Descussions

The different mechanical tests are carried on prepared PMCs specimens like tensile strength, compression, flexural strength and damping test and after testing discusses, which composition having more strength.

a. Tensile test

In Fig.12 the graph is plotted between load and composition of specimens. From Fig.12 it is observed that composition 6% $CaSiO_3$ + 15% Hemp + 79% polyester withstand maximum load compared to other composition and composition 2% $CaSiO_3$ + 5% Hemp + 93% polyester withstand minimum load.

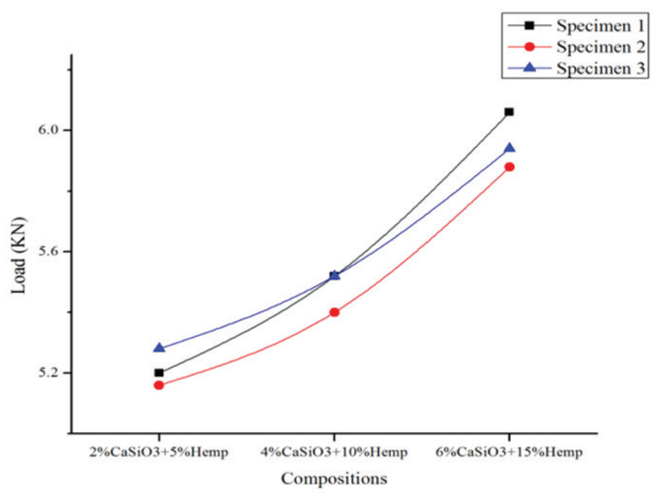


Figure 12: load in KN v/s composition

In Fig.13 the graph is plotted between tensile strength v/s compositions, it indicates that the composition of 6% $CaSiO_3$ + 15% Hemp + 79% polyester consisting of more tensile strength compared to other and 2% $CaSiO_3$ + 5% hemp + 93% polyester composition consisting low tensile strength. In this figure the compositions are taken average of three specimens then graph is plotted.

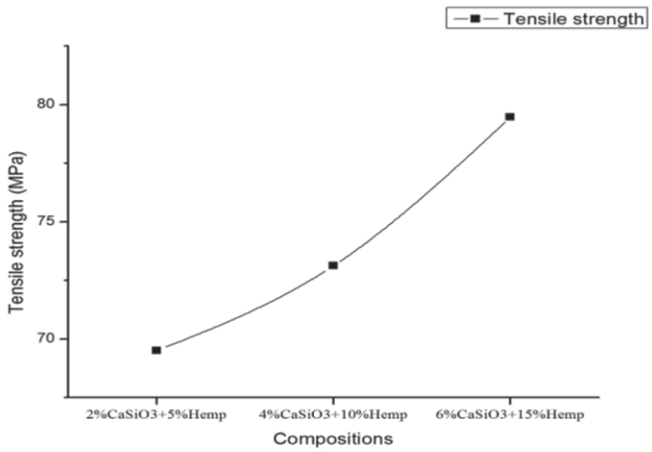


Figure 13: Tensile strength in MPa v/s compositions

b. Compression strength

From Fig.14 observed that the 2% $CaSiO_3$ + 5% hemp + 93% polyester resin composition withstands maximum load and 6% $CaSiO_3$ + 15% hemp + 79% polyester resin composition with stands minimum load.

2% $CaSiO_3$ + 5% Hemp + 93% polyester resin composition consists of the maximum compressive strength as compared to other and 6% $CaSiO_3$ + 15% hemp + 79% polyester resin

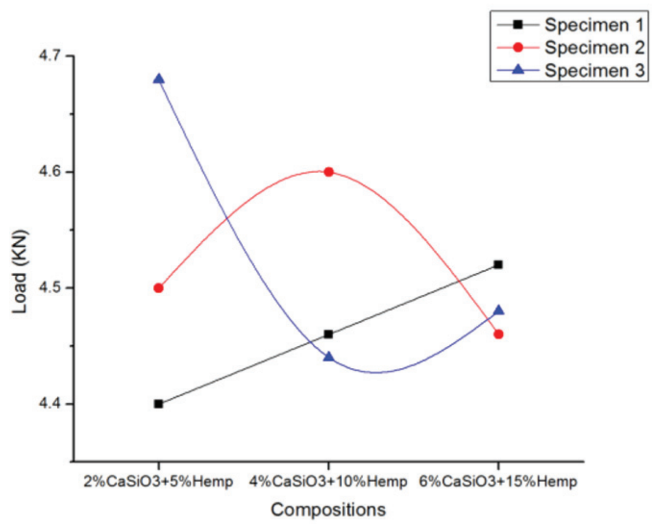


Figure 14: load in KNv/s compositions

composition consists of less compression strength as compared to other two compositions. The graph is plotted between compressive strength v/s compositions of each average specimen as shown in Fig.15.

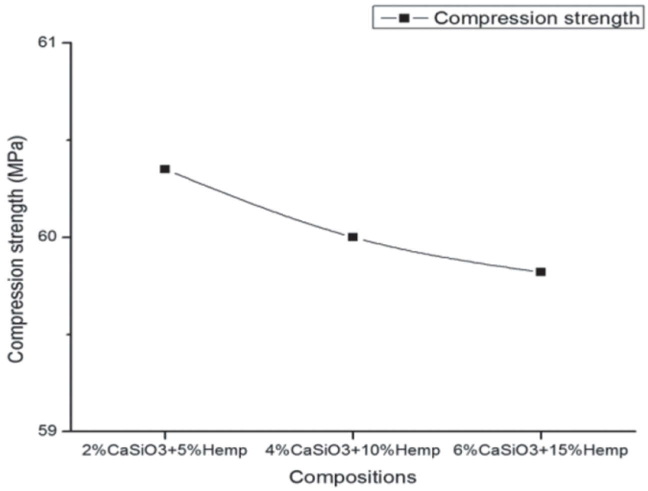


Figure 15: Compression strength in MPa v/s compositions

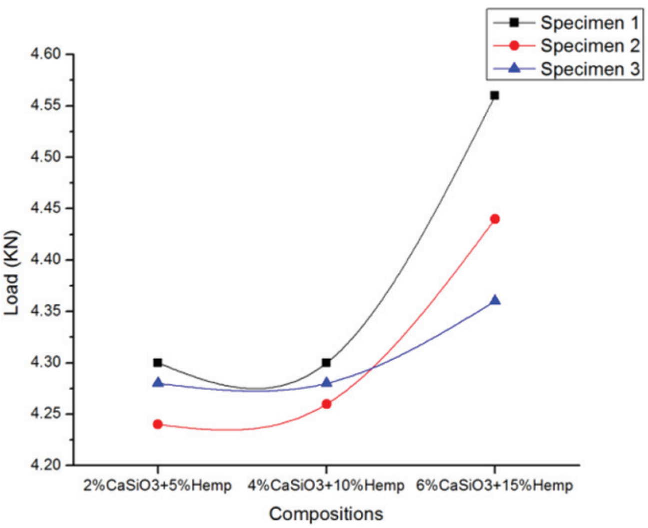


Figure 16: Load in KN v/s composition

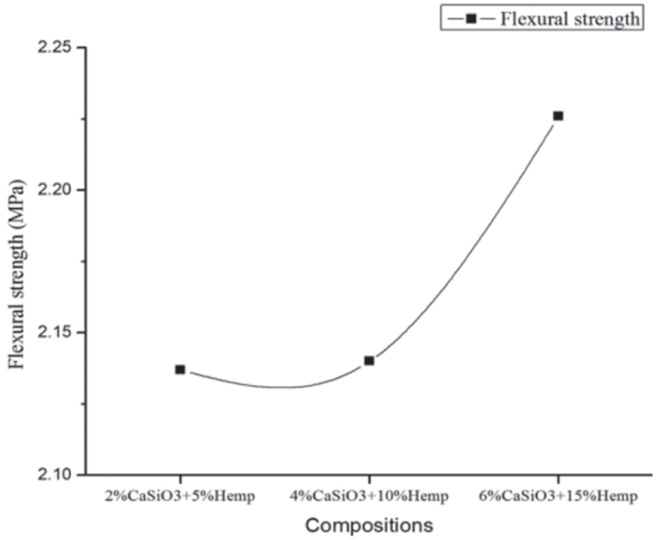


Figure 17: Flexural strength KN/mm^2 v/s compositions

c. Flexural strength

From the Fig.16 it is observed that the composition of 6% calcium silicate + 15% hemp mat + 79% polyester resin having more load carrying capacity as compared to 2% $CaSiO_3$ + 5% hemp + 93% polyester and 4% $CaSiO_3$ + 10% Hemp + 86% Polyester composition.

In Fig.17 graph is plotted between composition v/s flexural strength in kN/mm^2. In this graph, 2% $CaSiO_3$ + 5% hemp + 93% polyester and 4% $CaSiO_3$ + 10% hemp + 86% polyester composition have nearly equal flexural strength where as 6% $CaSiO_3$ + 15% Hemp + 79% polyester composition.

d. Damping test

Damping test is conducted for all three compositions among these three compositions the 6% $CaSiO_3$ + 15% hemp + 79% polyester resin have good damping characteristics are shown in Table 1.

A. Mode shapes of PMCs for 2% $CaSiO_3$ + 5% hemp + 93% polyester resin

Table 1: damping test results for 2% $CaSiO_3$ + 5% Hemp + 93% Polyester resin

Mode no's	Frequency (Hz)	Damping ratio %	Magnitude (m^2/s-N)	Phase angle in degree
1	15.291	6.985	0.0160	119.1
2	34.206	7.873	0.0070	151.2
3	114.122	7.584	0.5120	85.88
4	142.276	1.165	0.1433	138.9

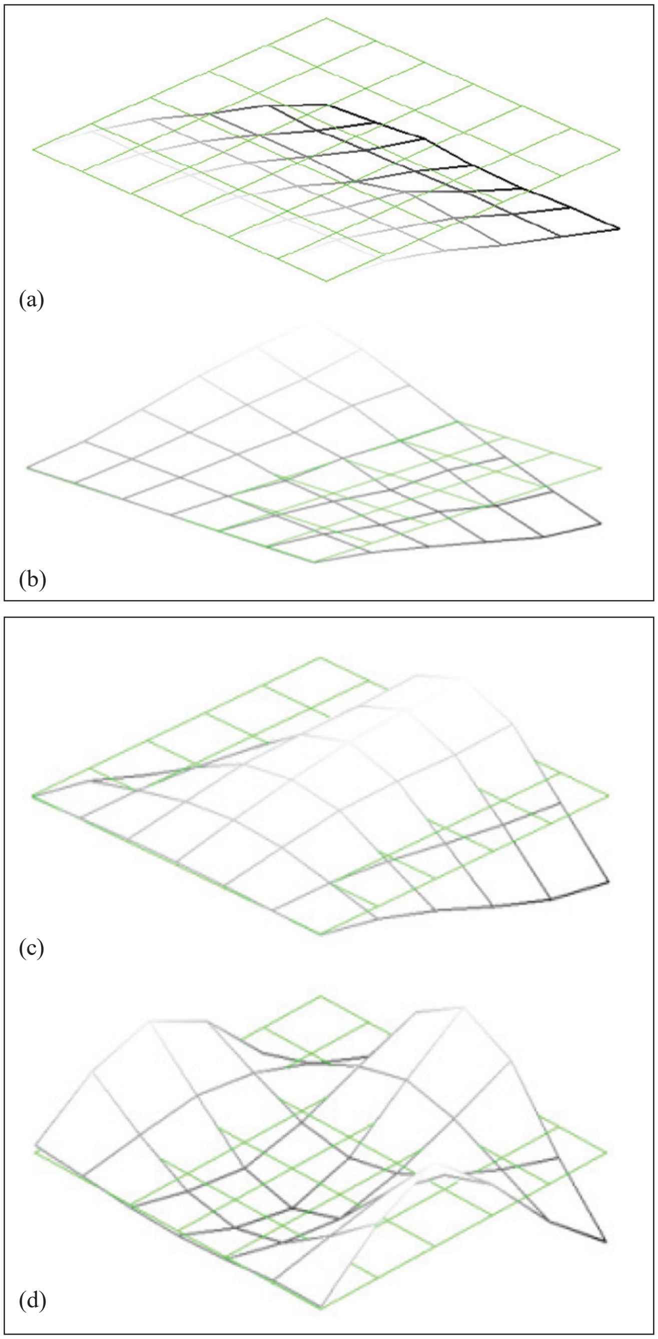


Figure 18: (a) Bending mode (b) Twisting mode
Mode-1: 1 Mode-1 : 2
Frequency : 15.291 Frequency : 34.206 Hz
Damping ratio : 6.985 Damping ratio : 7.873

(c) Combination of bending and twisting mode
(d) Complex mode.
Mode-1 : 3 Mode-1 : 4
Frequency : 114.122 Hz Frequency : 142.2 Hz
Damping ratio: 7.584 Damping ratio : 1.165

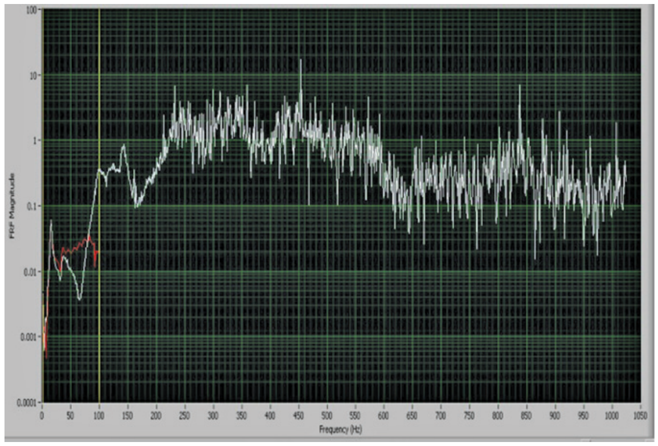


Figure 19: FRF magnitude v/s frequency in Hz.

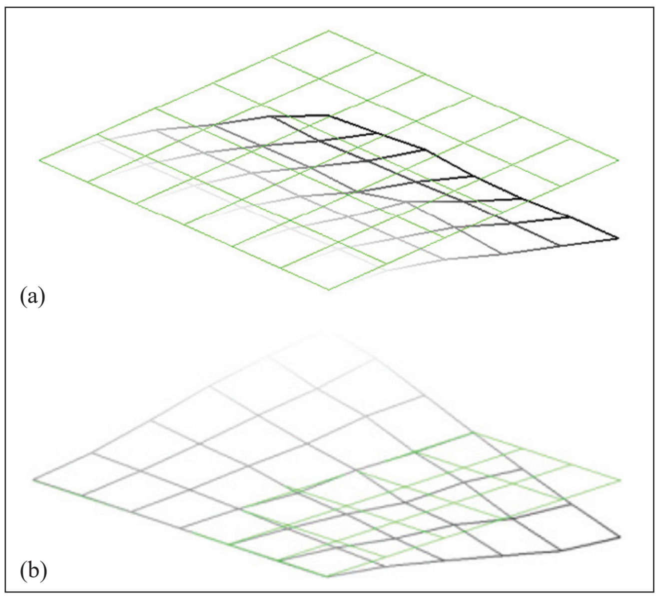
Fig. 18(a), (b), (c) and (d) represents the bending, twisting, combination of bending and twisting and complex made shapes.

In this composition mode shape-2 having greater damping ratio i.e. 7.873 as compared to other mode shapes and mode shape-4 having low damping ratio i.e. 1.165. as shown in Table 1. The graph is plotted between FRF magnitude v/s frequencies by using FFT analyzer as shown in Fig.19.

B. Mode shapes of PMCs for 4% $CaSiO_3$ + 10% hemp + 86% polyester resin

Fig. 20.(a), (b), (c) and (d) repsents the bending, twisting, combination of bending and twisting and complex made shapes.

In this composition mode shape-2 having greater damping ratio i.e. 5.478 as compared to other mode shapes and mode shape-4 having low damping ratio i.e. 4.163. as shown in



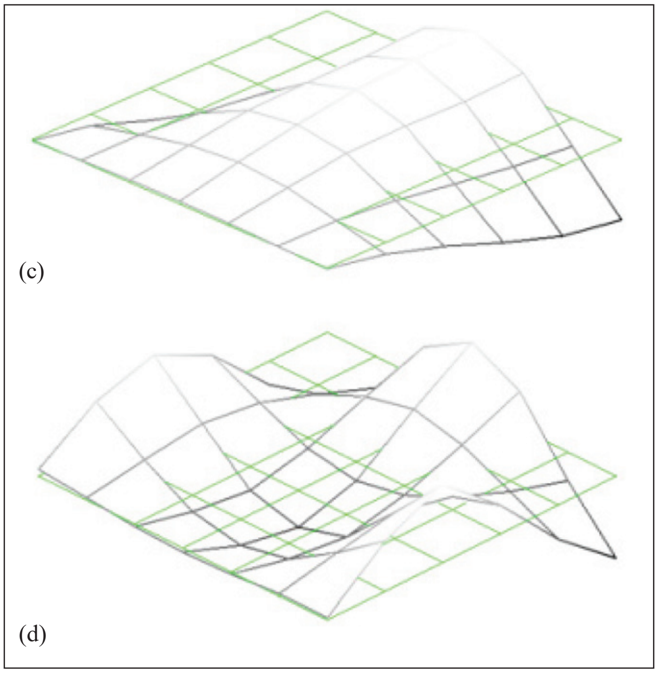


Figure 20: (a) Bending mode (b) Twisting mode
Mode-1 : 1 Mode-1 : 2
Frequency : 15.291 Frequency : 34.206 Hz
Damping ratio: 6.985 Damping ratio : 7.873
(c) Combination of bending and twisting mode
(d) Complex mode.
Mode-1 : 3 Mode-1 : 4
Frequency : 114.122 Hz Frequency : 142.2 Hz
Damping ratio: 7.584 Damping ratio : 1.165

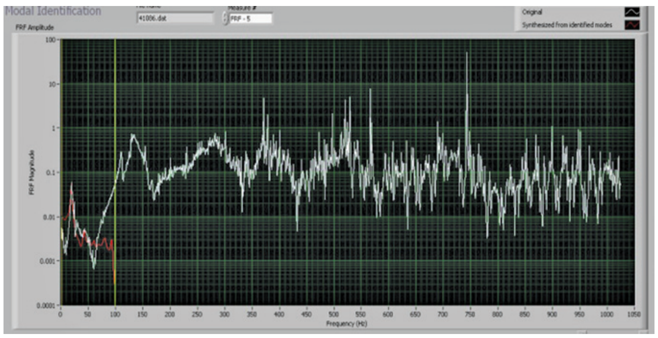


Figure 21: FRF magnitude v/s frequency in Hz.

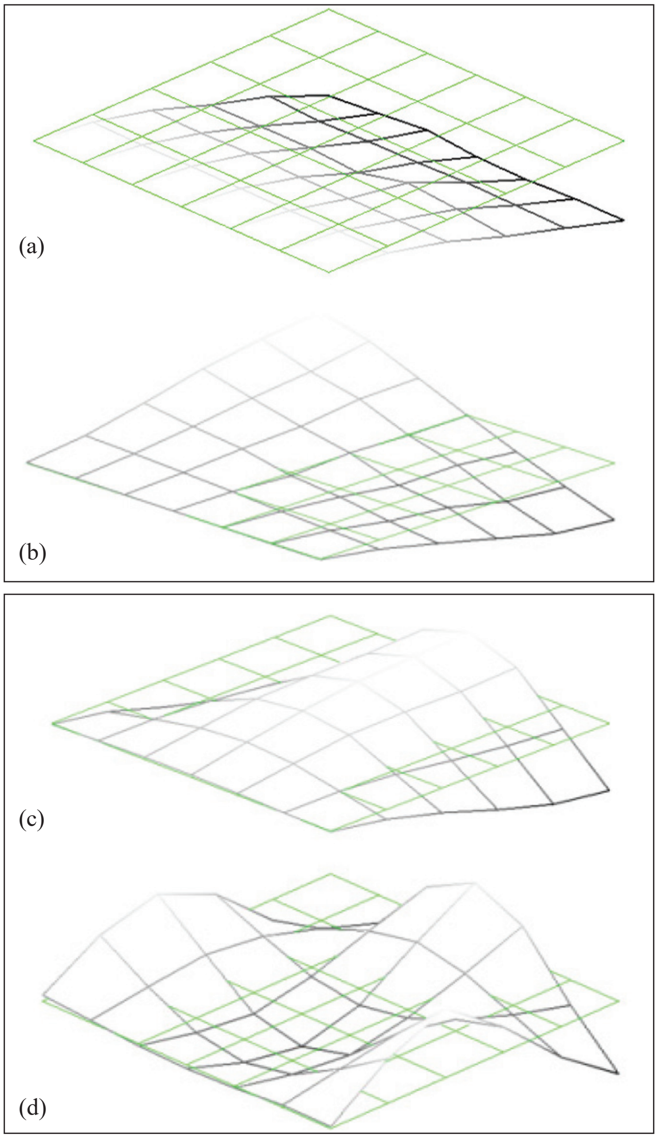


Figure 22: (a) Bending mode (b) Twisting mode
Mode-1 : 1 Mode-1 : 2
Frequency : 22.193 Hz Frequency : 34.799 Hz
Damping ratio: 2.775Damping ratio : 1.854
(c) Combination of bending and twisting mode
(d) Complex mode.
Mode-1 : 3 Mode-1 : 4
Frequency : 115.524 Hz Frequency : 146.555 Hz
Damping ratio: 2.414 Damping ratio : 2.711

Table 2: Damping test results for 4% $CaSiO_3$ + 10% Hemp + 86% Polyester resin

Mode no's	Frequency in Hz	Damping ratio %	Magnitude in m^2/s-N	Phase angle in degree
1	19.321	4.287	0.0470	123.2
2	42.704	5.478	0.0038	155.4
3	109.379	4.869	0.4586	54.05
4	131.788	4.163	1.8302	127.9

Table 3: Damping test results for 6% $CaSiO_3$ + 15% Hemp + 79% Polyester resin

Mode no's	Frequency in Hz	Damping ratio %	Magnitude in m^2/s-N	Phase angle in degree
1	22.193	2.775	0.0686	144.293
2	34.799	1.854	0.0116	172.76
3	115.524	2.414	0.1335	118.81
4	146.555	2.711	1.0472	110.50

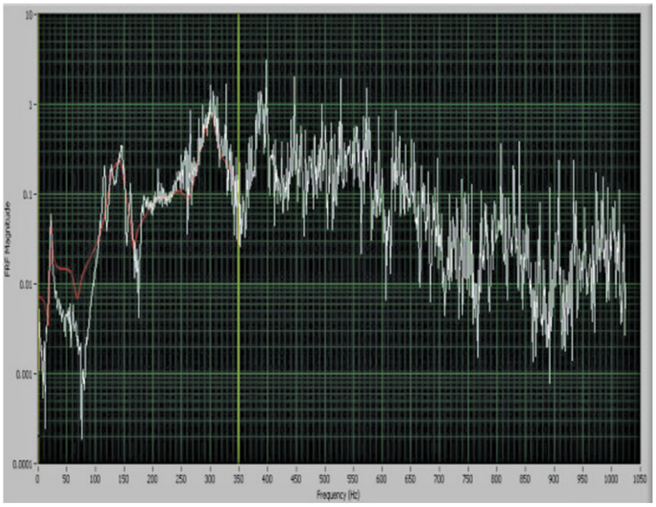


Figure 23: FRF magnitude v/s frequency in Hz.

Table 2. The graph is plotted between FRF magnitude vs frequency by using FFT analyzer as shown in Fig.21.

Fig. 22. (a), (b), (c) and (d) repsents the bending, twisting, combination of bending and twisting and complex made shapes.

In this composition mode shape-1 having greater damping ratio i.e. 2.775 as compared to other mode shapes and mode shape- 2 having low damping ratio i.e. 1.854. as shown in Tables 3 and (b) The graph is plotted between FRF magnitude vs frequency by using FFT analyzer as shown in Fig.23.

5.0 Conclusions

- From observation of the experiment it is concluded that the A3 composition i.e. 6% $CaSiO_3$ + 15% hemp + 79% polyester resin with stand the maximum tensile load, hence from the tensile point of view, A3 composition has more tendency of with stand the tensile strength compared to all other composition.
- Further observation of the experiment tells us that, A1 composition i.e. 2% $CaSiO_3$ + 5% hemp + 93% polyester resin withstands more compressive load, so the A1 composition has more compressive strength compared to other composition.
- In flexural test it is observed that, the A3 composition i.e. 6% $CaSiO_3$ + 15% hemp + 79% polyester resin with stand more load compared to other composition. This shows that from point of tensile and bending, the A3 composition has more flexural strength along with tensile strength.
- Further going ahead with dynamic analysis, the obtained results show that the compositions 2% $CaSiO_3$ + 5% hemp + 93% polyester resin and 4% $CaSiO_3$ + 10% hemp + 86% polyester resin have less natural frequency and damping ratio as compared to 6% $CaSiO_3$ + 15% hemp + 79% polyester resin composition.
- Overall project results indicate that, A3 composites are showing better mechanical properties and suggested to use as good vibration absorbing materials in certain applications like an automobile industries, for sound and noise absorbing construction roofing material and for other indoor applications etc.

Scope for Future Work

- Study of other properties on the same compositions such as impact, thermal, fatigue and tribological behaviour.
- Advanced studies such as SEM, XRD and FT-IR to know the presence of fracture and internal structure of composites.
- Usage of different natural fibres along with different orientations, and different fillers particles' such as nano-material fillers, comparison of properties with conventional and nano-fillers.
- For manufactured composites, various machining characteristics such as feed rate, cutting speed and material removal rate etc. can be carried out and machining properties can be studied.

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