Experimental Investigation of Aluminium Metal Matrix Composite Reinforced with Aloe Vera Powder

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Abstract: ***In this project investigation is carried out on aluminium reinforced with aloe vera powder and aluminium reinforced with fly ash. Aluminium, Aloe vera and fly ash commercially available in required manner to design a specimen. These materials heated up to critical temperature to obtain molten state. Further solidify the molten metal to desired geometrical shape by using stir casting process. Each specimen will be subjected to analyze vibration parameters namely natural frequency and mode shapes using FFT and ANSYS. Presently limited numbers of scientific researches are done on aluminium reinforced with aloe vera powder which provides wider area to study. Aloe vera gave better result than fly ash as reinforcement. The final stage of this work is to investigate natural frequency of concern specimen to minimize the vibration.***

Keywords: Aloe vera powder, fly ash, vibration

1. Introduction

The widespread use of composite structures in aerospace applications has stimulated many researches to study various aspects of their structural behavior. These materials are particularly widely used in situations where a large strength to weight ratio is required. Similarly to isotropic materials composite materials are subjected to various types of damage, mostly cracks and delamination. These result in local changes of the stiffness of elements for such materials and consequently their dynamic characteristics are altered. This problem is well understood in case of constructing elements made of isotropic materials, while data concerning the influence of fatigue cracks on the dynamics of composite elements are scarce in the available literature.

1.1 Research Context

The beam is manufactured from aluminium reinforced with flyash and aloe vera. Aluminium beams combine the benefits of strength, lightness and the ease of handling with consistency, versatility and exceptional durability. As technology progresses the cost involved in manufacturing and designing composite material will reduce, thus bringing added cost benefits also.

The vibration analyses in composite beams have been a problem for structural designer for years and have increased recently. Though, all elements have natural frequencies with the potential to suffer excessive vibrations under dynamic load. This is done by using modal analysis, which allows one to determine the natural frequencies of the structure, associated mode shapes and damping and once natural frequencies are known, thus making suitable for the task designed for.

This is mainly due to the human feeling of vibration while crossing a footbridge with a frequency close to the first (fundamental) natural frequency of the bridge, although the vibration caused by the pedestrians are far from harmful to the bridge. Therefore vibration analysis of such structure can be considered to be a serviceability issue. Modal parameters of a structure are frequency, mode shape and damping. Frequency is directly proportional to structure’s stiffness and inverse of mass. Nevertheless, modal parameters are functions of physical properties of the structures. Thus, changes in physical properties such as, beginning of local cracks and/or loosening of a connection will cause detectable changes in the modal properties by reducing the structure’s stiffness.

In this research, finite element models for different boundary conditions are constructed using the commercial finite element software package ANSYS to support and verify the dynamic measurements. Initial composite beams were created. Furthermore, the FEM results of the beams are compared to the experimental solution for understanding of the relationship between the FE results. The natural frequencies and mode shapes of the composite beam are obtained after performing modal analysis which the author contribution to this area of research.

1.2 Purpose and objectives of study

The main objective of this thesis is to study and compare the numerical and experimental result of free vibration analysis of composite beam. The present investigation mainly focuses on the study of vibration of aluminium reinforced fly ash and with aloe vera composites. The influence of boundary conditions on free vibration of composite beams are investigated experimentally also examined numerically.

1.3 Introduction to Composite materials

Composites are materials in which two phases are combined, usually with strong interfaces between them. They usually consist a continuous phase called the matrix and discontinuous phase in the form of fibers, whiskers or particles called the reinforcement. Considerable interest in composites has been generated in the past because many of their properties can be described by a combination of the individual properties of the constituent phases and the volume fraction in the mixture.

Composite materials are gaining wide spread acceptance due to their characteristics of behaviour with their high strength to weight ratio. The interest in metal matrix composites (MMCs) is due the relation of structure to properties such as specific stiffness, density and thermal and electrical properties can be tailored. Composites materials are high stiffness and high strength, low density, high temperature stability, high electrical and thermal conductivity, adjustable coefficient of thermal expansion, corrosion resistance, improved wear resistance etc. The matrix holds the reinforcement to form the desired shape while the reinforcement improves the overall mechanical properties of the matrix. When designed properly, the new combined material exhibits better strength than would each individual material.

1.3.1 Types of Composites

Particulate composites consist of particles immersed in matrices such as alloys and ceramics. They are usually isotropic since the particles are added randomly particulate composites have advantages such as improved strength, increased operating temperature and oxidation resistance etc. typical examples include use of aluminium particles in rubber, silicon carbide particles in aluminium. Flake composites provide advantages such as high out of plane flexural modulus, higher strength, and low cost.

Natural composites

Several natural materials can be grouped under natural composites. E.g. bones, wood, shell pearlite (steel which is a mixture of a phase FeC).

Man-made composites

Man-made composites are produced by combining two or more materials in definite properties under controlled conditions. E.g. mud mixed straw t0 produced stronger mud mortar and bricks, plywood, chipboards and Decorative laminate.

Classification

1) Based on the type of matrix material, composites are classified into:
   - Metal matrix composites (MMCs)
   - Polymer matrix composites (PMCs)
   - Ceramic matrix composites (CMCs)
2) Based on the geometry of reinforcement:
   - Particulate reinforced composites.
   - Whisker/ Flakes reinforced composites.

1.4 Metal Matrix Composite

Metal matrix composites (MMCs) generally consist of lightweight metal alloys of aluminium, magnesium or titanium, reinforced with ceramic particulate, whiskers or fibers. The reinforcement is very important because it determines the mechanical properties, cost and performance of a given composite. Composites reinforced with particulate (discontinuous types of reinforcement) can have costs comparable to unreinforced metals, with significantly better hardness, and somewhat better stiffness and strength. Continuous reinforcement (long fiber or wire reinforcement) can result in dramatic improvements in MMC properties, but costs remain high. Continuously and discontinuously reinforced MMCs have very different applications, and will be treated separately. MMCs can be designed to fulfil requirements that no other materials, including other advanced materials, can achieve. There are number of applications in aerospace structures and electronics that capitalize on this advantage.

1.5 Introduction to Vibration Measurement

Vibration measurement is complex because of its many components- displacement, velocity, acceleration, and frequencies. Also, each of these components can be measured in different ways – peak-to-peak, peak, average, RMS; each of which can be measured in the time domain (real-time, instantaneous measurements with an oscilloscope or data acquisition system) or frequency domain (vibration magnitude at different frequencies across a frequency spectrum), or just a single number for “total vibration”. Vibratory response of a system can be expressed through a number of parameters.

Frequency
Displacement
Acceleration
Induced strain / stress

1.5.1 Types of Vibration

Random Vibrations

Random vibration is motion which is non-deterministic, meaning that future behaviour cannot be precisely predicted. The randomness is a characteristic of the excitation or input, not the mode shapes or natural frequencies. Some common examples include an automobile riding on rough road, the load induced on an airplane wing during flight. Structural response to random vibration is usually treated using statistical or probabilistic approaches. Mathematically, random vibration is characterized as an ergodic and stationary process.

A measurement of the acceleration spectral density (ASD) is usual way to specify random vibration. The root mean square acceleration (Grms) is the square root of the area under the ASD curve in the frequency domain. The Grms value is typically used to express the overall energy of a particular random vibration event and is a statistical value used in mechanical engineering for structural design and analysis purposes. While the term power spectral density (PSD) is commonly used to specify a random vibration event, ASD is more appropriate when acceleration is being measured and used in structural analysis and testing.

Periodic Vibrations

Periodic vibrations stay as a steady repeating phenomenon and have a specific period over which it repeats itself. It is always response to an alternating force. Such vibration displays a periodic time function, which follows well defined mathematical rules, like a sine wave of the sum of many sine wave. It can thus be reasonably predicted. Thus the concepts of frequency and its inverse, the time-period are associated with periodic vibrations. Periodic vibration readings (also called in route) are made with portable equipment, these equipment according to their analysis capabilities can be grouped as:

- Overall value vibrometers: analog or digital.
- Frequency analyzers: Analog band- adjustment and FFT digital real-time.

2. Result and Discussion

2.1 Numerical Results

Numerical (FEM) and experimental results of frequencies of vibration for aluminium composite beams are obtained for fixed-free boundary condition. The boundary conditions considered for the present numerical analysis as well as experimental work is cantilever beam.

2.1.1 Effect of Reinforcement

By the simulation modal analysis, critical frequencies are found for different composition of AV and fly ash in below table

Table 2.1.1.2: Natural frequencies for different composites

Mode No.	Al-10%AV	Al-15%AV	Al-10% flyash	Al-15% flyash
1	777.91	802.28	739.34	756.51
2	8263.5	8522.4	7853.7	8036.1
3	13477	13900	12809	13106
4	50843.0	52435	48321	49444

The table shows the natural frequency in Hz predicted theory and ANSYS.

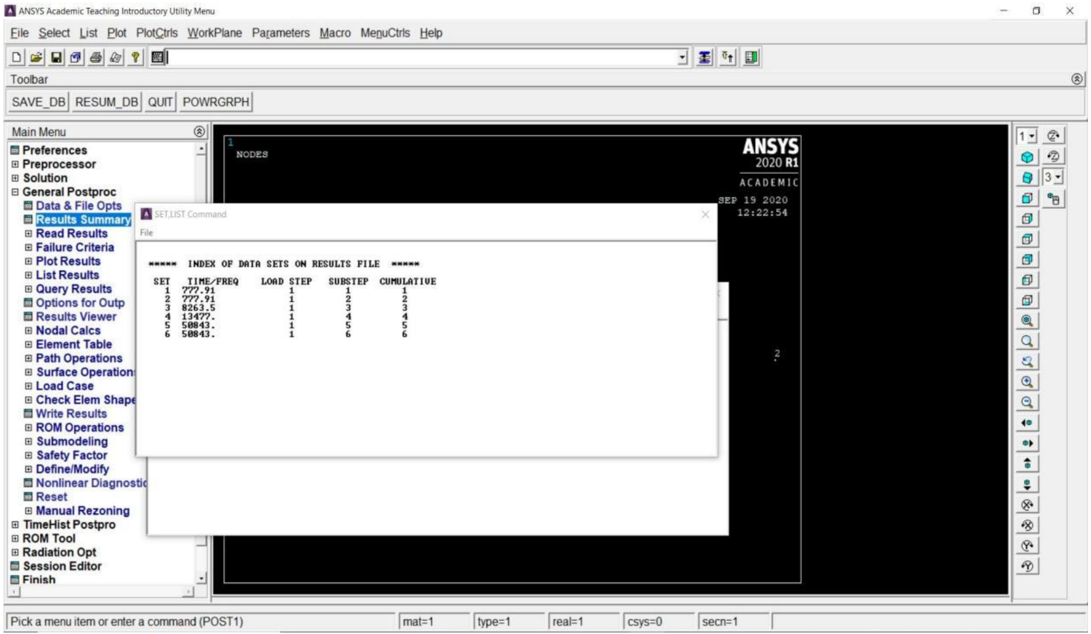
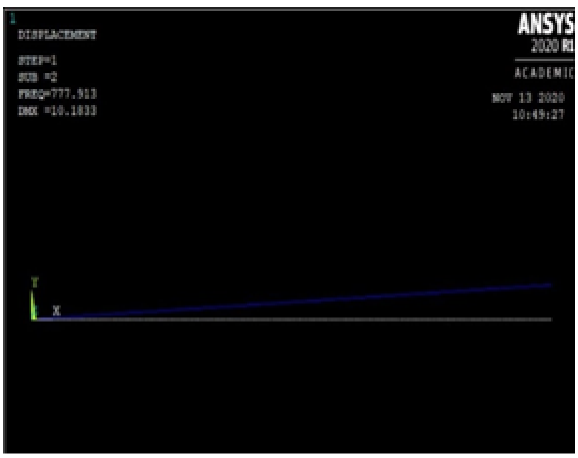


Figure 2.1.1.5: Modal analysis of Al-10%AV composite beam



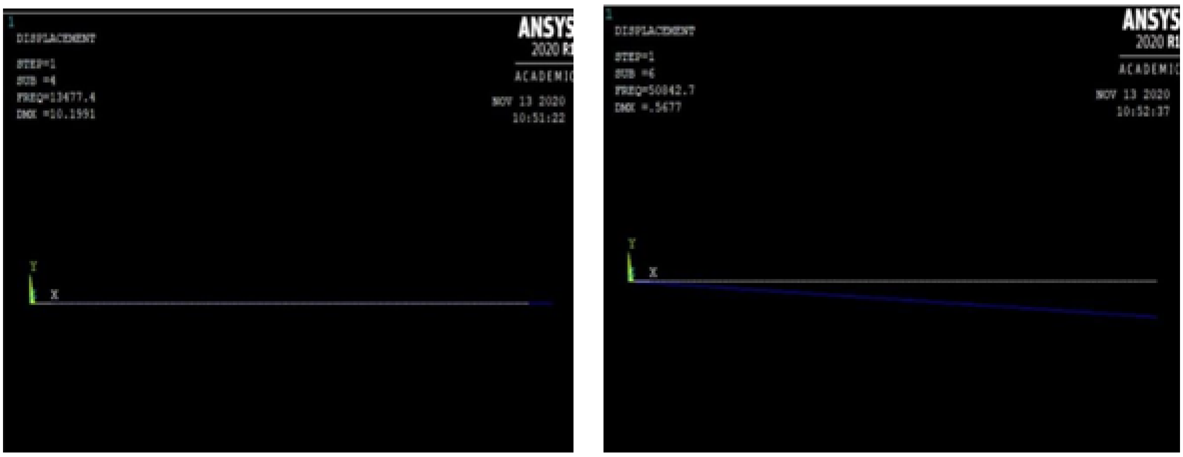


Figure 2.1.1.6: Four natural frequency mode shapes of Al-10%AV composite beam

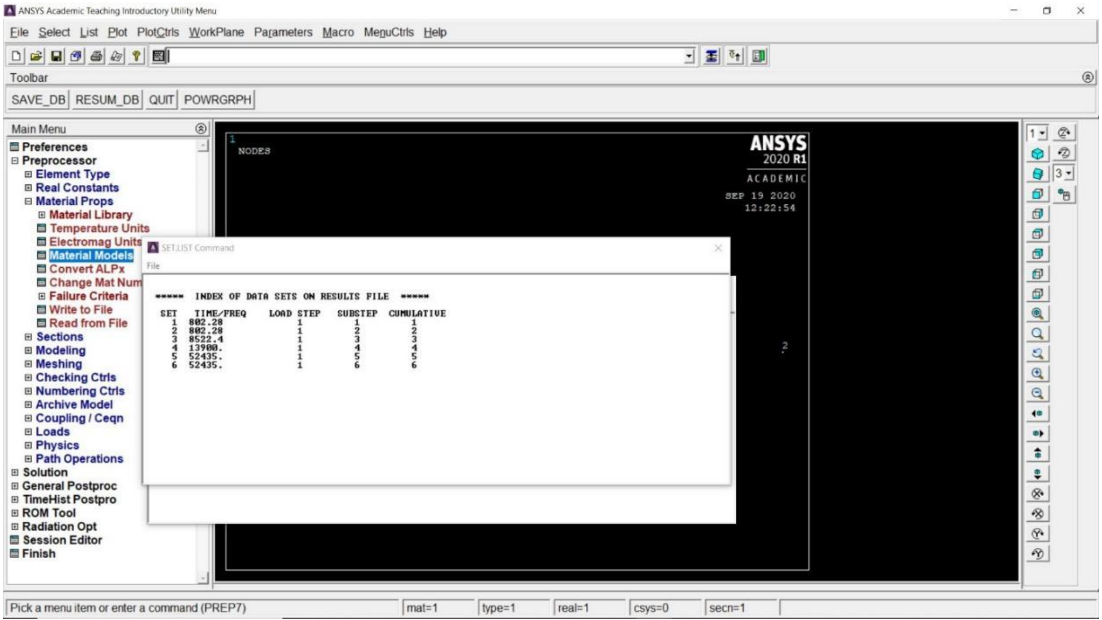
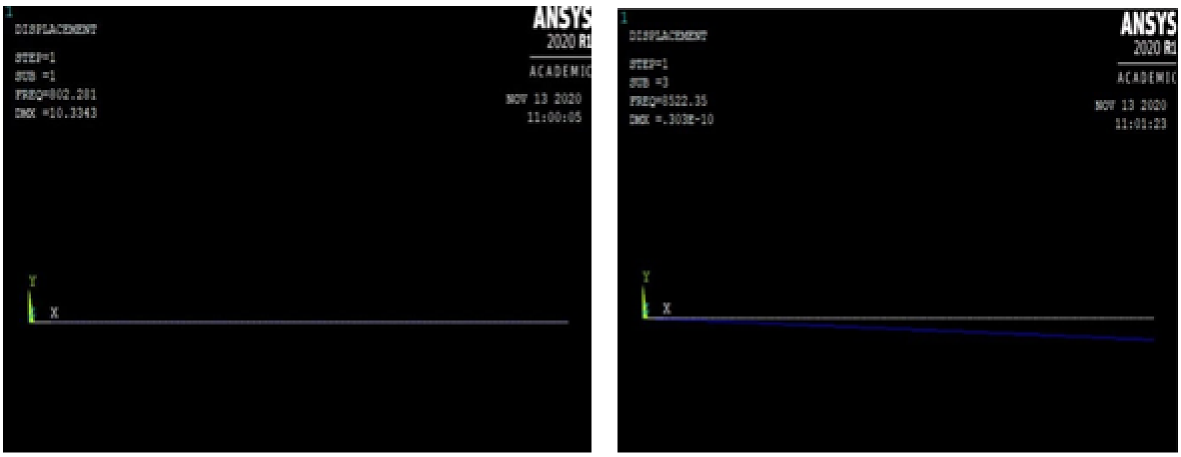


Figure 2.1.1.7: Modal analysis of Al-15%AV composite beam



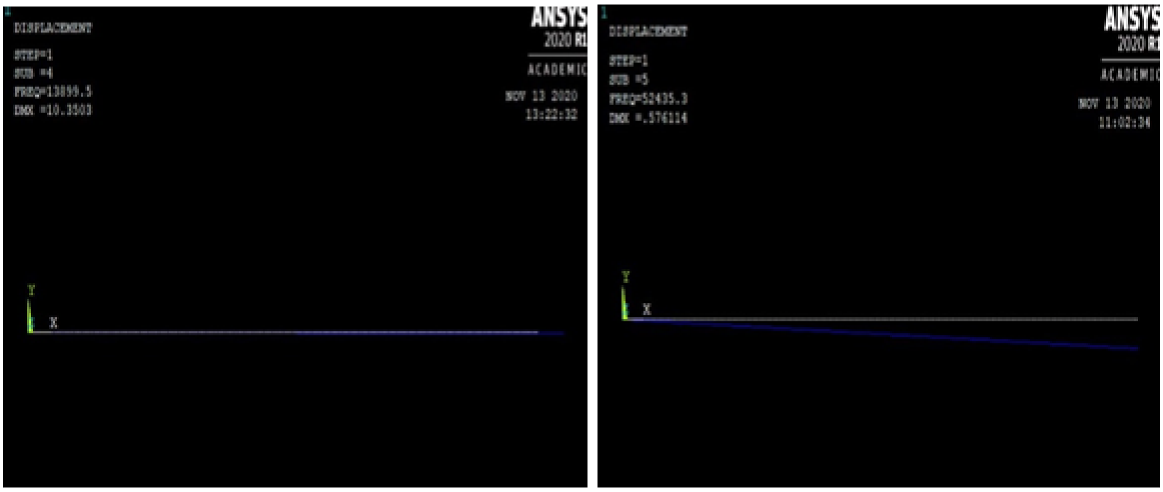


Figure 2.1.1.8: Four natural frequency mode shapes of Al-15%AV composite beam

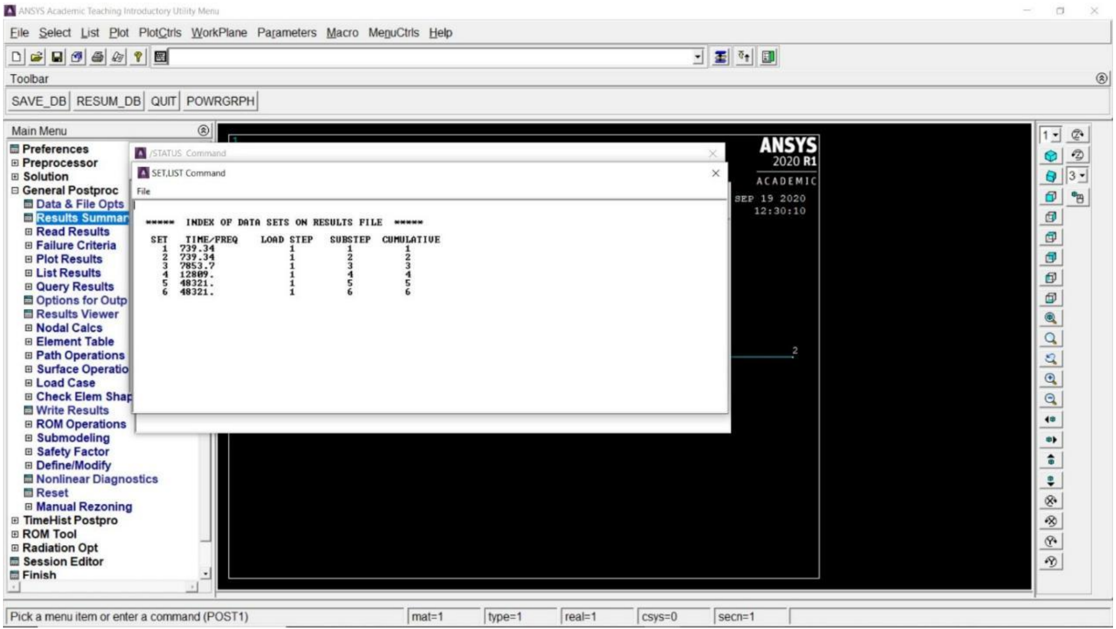
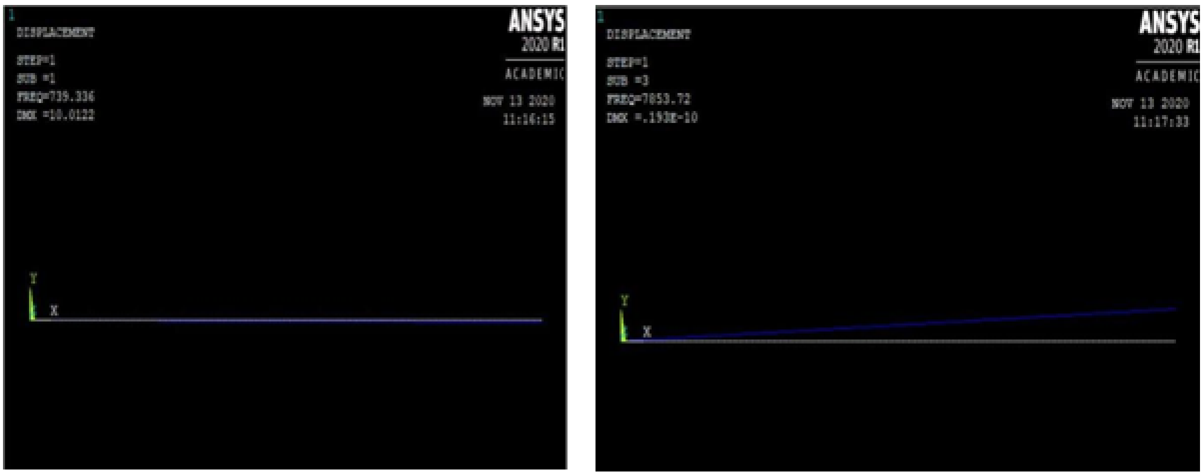


Figure 2.1.1.9: Modal analysis of Al-10% fly ash composite beam



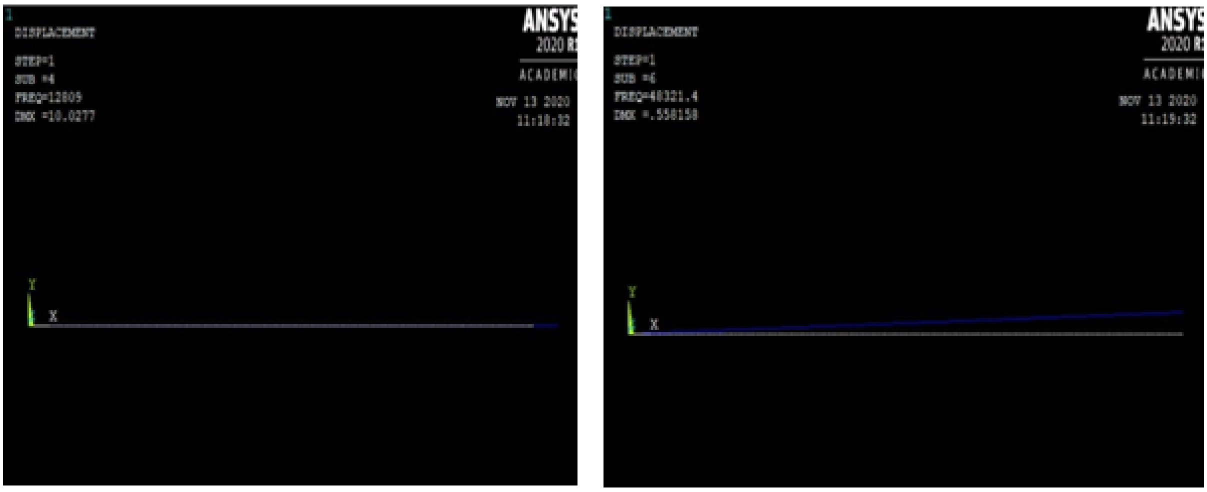


Figure 2.1.1.10: Four natural frequency mode shapes of Al-10% Fly ash composite beam

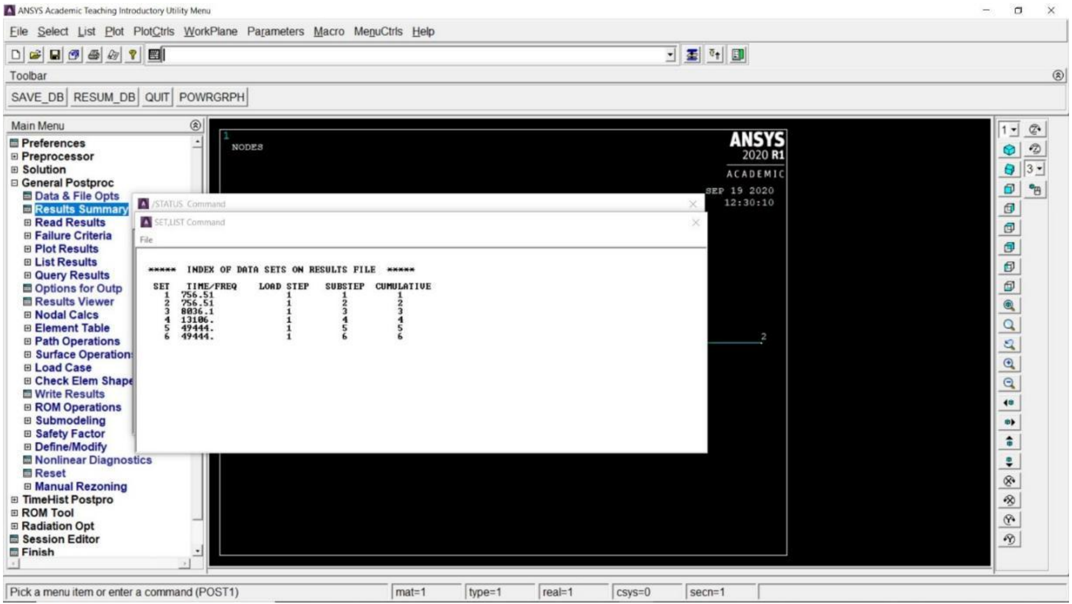
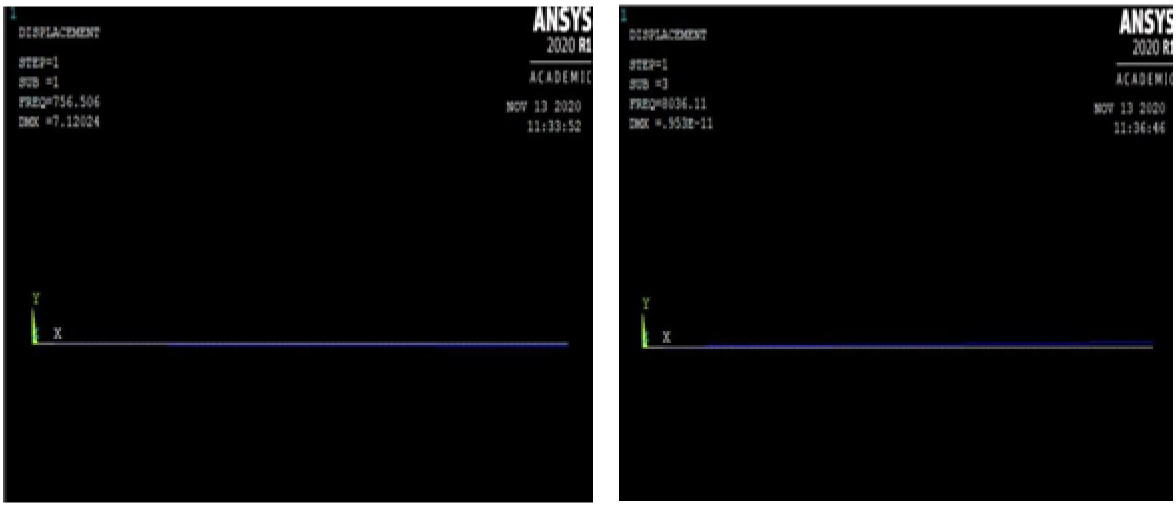


Figure 2.1.1.11: Modal analysis of Al-15% fly ash composite beam



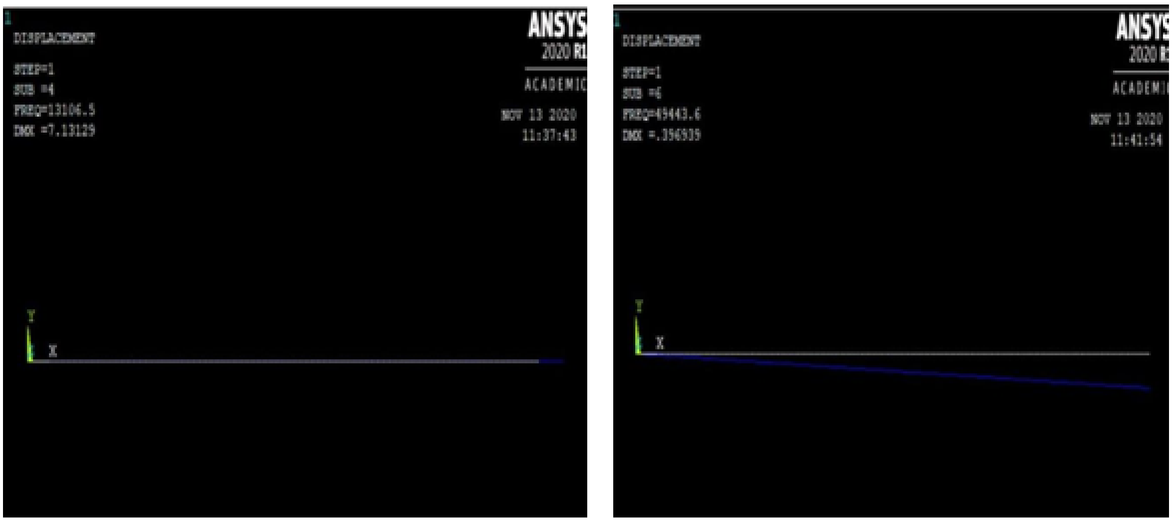


Figure 2.1.1.12: Four natural frequency mode shapes of Al-15%fly ash composite beam

2.1.2 Effect of Length

Table 2.1.2.1: Natural frequencies of Al-10% AV for different length of beam

Mode	Experimental	ANSYS			
	L=100mm	L=100mm	L=200mm	L=300mm	L=400mm
1	675	777.91	196.11	87.24	49.089
2	-	8263.5	4145.3	2763.5	2072.6
3	-	13477	6760.7	4507.2	3380.4
4	-	50843	26904	18129	13648

Table 2.1.2.2 : Natural frequencies of Al-15% AV for different length of beam

Mode	Experimental	ANSYS			
	L=100mm	L=100mm	L=200mm	L=300mm	L=40mm
1	828.75	802.28	201.59	89.679	50.461
2	-	8522.4	4261.2	2840.8	2130.6
3	-	13900	6949.8	4633.2	3474.9
4	-	52435	27656	18635	140303

Table 2.1.2.3: Natural frequencies of Al-10% fly ash for different length of beam

Mode	Experimental	ANSYS			
	L=100mm	L=100mm	L=200mm	L=300mm	L=400mm
1	672.5	739.34	185.77	82.643	46.502
2	-	7853.7	3926.9	2617.9	1963.4
3	-	12809	6404.5	4269.7	3202.3
4	-	48321	25486	17173	12929

Table 2.1.2.4: Natural frequencies of Al-15% fly ash for different length of beam

Mode	Experimental	ANSYS			
	L=100mm	L=100mm	L=200mm	L=300mm	L=400mm
1	715	756.51	190.09	84.563	47.582
2	-	8036.1	4018.1	2678.7	2009
3	-	13106	6553.2	4368.8	3276.6
4	-	49444	26078	17572	13229

3. Conclusion

The following conclusions can be made from the present investigation of composite beam. The dynamic investigation of a composite beam was carried out in this work. The modal analysis was performed to extract natural frequencies and mode shapes.

The fundamental frequency was estimated in numeric all way. Both Natural frequencies and mode shapes were successfully estimated in Numerical way by using ANSYS software.

- The fundamental frequencies of different composition of composite beam have been reported.
- Density of composite is low when the reinforcement is aloe vera.
- The minimum natural frequency is obtained with minimum fly ash content.
- Mode shapes was plotted for different composition of beams with the help of ANSYS to get exact idea of mode shape. Vibration analysis of composite beam was also done on ANSYS to get natural frequency and same trend of natural frequency was found to be repeated.
- It is found the natural frequency decreases with increase in beam length.

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