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# A Study of the Flexure Behavior and Compressive Strength of Fly Ash Core Sandwiched Composite Materials

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## ABSTRACT

***This article's core material is comprised of a woven glass cloth and an epoxy matrix/adhesive component." Three different combinations were used to assess the flexural and compressive strength of epoxy and fly ash sandwiched composites. It's not uncommon to see composites with 65-35 percent fly ash with epoxy resin, 60-40 percent fly ash with resin, and 55-45 percent epoxy resin in use (fly ash and epoxy resin). The 60-40 percent composite specimen performed better than the 60-40 percent metal specimen in flexure and compression tests. This paper presents and discusses the investigation's results.***

***Some of the parameters used to assess this product are epoxy resin, compressive strength, and flexural strength.***

## Introduction

When two or more chemically different materials are macroscopically united, they form a functional entity known as a composite. Composite materials may have an interface between two or more separate materials. Composites' electrical, thermal, tribological, and environmental qualities must also be taken into account. Composites may be defined as materials that contain a continuous matrix element binding together and forming an array of stronger, stiffer reinforcing elements. Generally speaking, the fibre or particle phases of composites are stiffer and stronger than their matrix phases. Several types of reinforcement have a lower coefficient of thermal expansion (CTE) than the matrix, as well as high wear resistance. Two thin yet sturdy face sheets sandwich a lightweight, substantial core. The most essential attribute of these materials is their lightweight core, which reduces the sandwich structures that have been widely employed in aviation during the last several decades. There are numerous methods to characterise these materials. The material used to construct a structural sandwich has an impact on the final design. An integrated approach to material selection must be taken into account rather than depending just on geometric design.

As their flat surfaces may bear extraordinarily high compression stress without buckling, glass-fibre skins and eco-cores are often employed in aerospace sandwiches because to their high specific stiffness structures. As a general rule, control surfaces should maintain their smoothness even when exposed to high amounts of stress. Over the course of its service life, the sandwich structure will be subject to stress fluctuations regardless of the applied tensile or compressive force. The face-sheet of the sandwich construction is being tested to see how it responds to various loading situations. The major goal is to fulfil ASTM requirements in order to better understand the mechanical characteristics of glass fibre face sheet with an eco-core sandwich composite.

## A REVIEW OF THE BOOKS.

The influence of fly ash filler on HDPE mechanical properties was investigated by Ahmad and Mahanwar (2010). Fly ash was used in three different particle sizes. Up to 40% of the fly ash's weight was changed. Injection moulding was used to manufacture test specimens after the composites were made using a twin screw extruder. The qualities of tensile, flexural, and impact strength were examined. Fly ash was shown to boost the tensile and flexural strengths and moduli of the composite. Fly ash concentration more than 10% lowered tensile elongation significantly. Impact resistance decreased by 15% or more when fly ash content increased.

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After being multiplied a second time, the value didn't change significantly. Smaller fly ash particles resulted in the highest increases in strength and relative elongation in composites containing these particles. Two layers of 1808 E-glass fabric were sandwiched between 12.5mm thick core materials using vacuum-infusion and hand-layup laminates. It was possible to choose between two different densities of cross-linked PVC foams, two types of extruded PET foam, an extruded polypropylene honeycomb core, an extruded polyurethane honeycomb core, and an extruded polyurethane honeycomb core, as well as one density of SAN foam. Materials in the second and third categories had kerfs cut by knife or saw. Polyurethane foam cores were used in place of scrimping. The initial density of the core, the laminated weight per unit area, the average thickness, and flexural and "flat-wise" tensile strength and stiffness were all analysed. As a result of vacuum-infusion processing, the overall panel thickness and weight were significantly reduced, along with subtle differences in the flexural strength, significantly lower flexure stiffness, and slightly greater flatwise tensile strength and significantly greater flatwise tensile moduli. VARTM was utilised by Shivakumar to make a sandwich panel and two laminated panels (VARTM). Woven E-glass and vinyl-ester resin were utilised in one laminated panel while carbon and vinyl-ester resin were used in the other two. E-glass was woven with vinyl-ester resin and PVC foam to make the sandwich panel. Fibres make up 42% of the E-glass panel. The carbon fibre volume of the panel is estimated to be 50%. Compression, shear, and tension tests were used to assess the mechanical characteristics of composite panels. The tensile modulus is 23.03 Gpa; the ultimate tensile strength is 325 Mpa; and the Poisson's ratio is 0.111. The shear modulus of the E-glass panel was measured at 3.86 GPa. The carbon panel has a Poisson's ratio of 0.04 and a maximum strength of 436 MPa. The carbon panel has a shear modulus of 2.81 GPa. We tested sandwich beams made from sandwich panels for three- and four-point bending. Actual beam deflection measurements at four places were found to be pretty close based on face-sheet and core parameter projections.

**They weren't designed for three-point bends [3].**

An Enrico Papa (2001) lightweight composite sandwich with marine engineering applications underwent experimental testing of its mechanical characteristics. Glass microspheres and polymer matrix make form the core of a three-dimensional glass fiber/polymer matrix fabric with transverse pile binding the skins together. The exterior face of the filled fabric is strengthened using Glass Fiber Reinforced Plastics (GFRP). Experimental and computational methods will be used by researchers to better understand the mechanical characteristics of this composite sandwich [4]. Kunigal Shivakumar (2007) studied the Eco-mechanical Core's environmental and fire-resistant qualities, comparing it to Type X SHEETROCK, a commonly used commercial material. In this investigation, the average increase in Eco-compression, Core tension, and flexural strength was between four and eight times. The density has been reduced by 40%, yet the fire resistance has not changed. [5,] has all the information you need to know about this study. In order to investigate the effects of weathering on mechanical qualities such as flexural strength, S K Acharya, P Mishra, and SC Acharya employed a composite made of fly ash, jute, and epoxy resin. Scanning electron microscopy is used to evaluate the specimen's fracture surfaces. According to the analysis, fibre removal seems to be the most common failure mechanism. Interfacial bonding was increased because fly ash particles bonded to one other. Composites, according to the study, might be employed as structural materials in homes and automobiles, as well as low-cost construction materials. It's Kishore S.M. (2002) This research investigates the compressive characteristics of fly ash and fibre epoxy composite materials with different aspect ratios. Incorporating fly ash preserves the strength and modulus of a broader variety of fibre volume fractions. As the amount of fly ash in the composites increased, it became clear that they were suited for weight-specific applications. Samples containing fibres were shown to lose more strength than those containing just ash, according to the results. The decrease was attributed to the propensity of fibres to cluster. Increased strength and modulus may be attributed to the use of ash filler, which seems to minimise fibre clustering. Over the next weeks and months, further research will take place.

SEM (Scanning electron microscopy) was used to evaluate fibres and fillers in failed samples. In the case of glass reinforced polyamide 6,6, Thomsons J L. asserts that the diameter and strength of the fibres have an effect on the mechanical quality balance (2000). Fiber sizes in the 10-17 micron range have little effect on the elastic characteristics of injection-molded short glass-fiber-reinforced polyamide 6,6 resin. The quantity of S-2 glass® fibre and the diameter of the fibres had a significant effect on their characteristics (i.e., strength and Izod impact). All three tensile, flexural, and unnotched Izod impact properties were significantly reduced in the 10-17 micron diameter range of materials. Because Notched Izod had a greater overall impact, its effect was only marginally reduced in the same time frame. The composite's strength increased by 8% when 20 percent w/w S-2 glass® was added to the 17 micron E-glass. [8]. Glass reinforced polymeric (GRP) composites have been used by Shah Khan M.Z. in naval mine countermeasure surface ships since 2000. It has been examined how ship constructions react to the shock waves generated by sea mine explosions. So, a test was done to examine how GRP composites, which are the same as real structural materials, react to increasing strain rates. Hydraulic testing equipment was used to conduct compression strain rate tests of 10 to 101 per second and loading rate tests of 2 to 1000 kilogrammes per second per second. For their trials, the researchers employed solid cylindrical and cube samples that had dimensions of 10 mm by 10 mm to illustrate how strain rate affects the maximum strain, maximum strength, and elastic modulus of the material. A notched three-point bend specimen was used to measure the composites' fracture toughness in response to loading rate.

## THE METHODOLOGY.

The production process adheres to ASTM C271 guidelines.

Projects like this one need a lot of time and attention to detail. In the first step, a square frame made of mild steel with dimensions of is needed to be built (304x304x12.5mm).

Fig. 1 shows how the core is covered in aluminium foil for easy removal after curing.

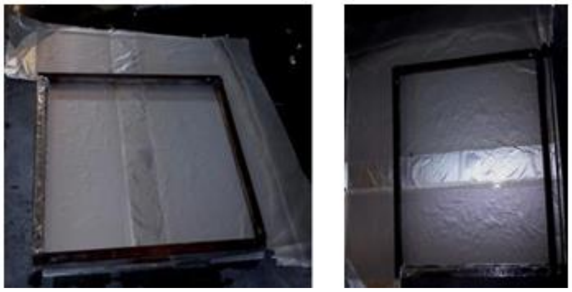

*Figure 1: Aluminum foil is wrapped around the frame.*

The quantity of fly ash that is needed is collected and measured.

Resin and hardener are also weighed to determine the exact amount needed.

As illustrated in Fig. 2, the measured fly ash is combined with the measured hardener and resin.

Mixing of Fly Ash, Resin, and Hardener in Figure 2

Fly ash, resin, and hardener are combined and then poured into the mould. Fig.3

Figure 3: Filling the Aluminum Frame with the Mixture

The next step is to cure the newly combined mixture for 8-12 hours before using it.

The final product is made after curing.

Fly ash and epoxy resins are used in a variety of ratios, including the following:

Either 65 percent or 35 percent fly ash or epoxy resin by weight

(For example, 1.027 kilogrammes of fly ash, 331.8 kilogrammes of resin, and 221.2 kilogrammes of hardener)

Epoxy resin and fly ash make about 60% of the mixture by weight.

A total of 1.050kg of Fly Ash, 330g Resin, and 220g Hardener were used in this process.

Fly ash makes up 55% of the weight, while epoxy resin makes up 45%.

The total weight of the materials is.891 kilogrammes of fly ash, 437.4 grammes of resin, and 291.6 grammes of hardener

Face Sheet to Core Bonding

The epoxy resin glue is used to adhere five layers of glass fibre to the core.

*Figure 4 depicts the process of attaching the Glass Fabric to the Core.*

Face sheet and bottom side of face sheet are layered around the core. The face sheet may be made up to five layers thick using the same processes. Sandwich panels are made heavier to provide a solid connection between the core and the glass fibres. The sandwich is left at room temperature for 24 hours before to serving in order to cure. When everything else fails, a specimen may be chopped down to the necessary size for analysis. Here, the core is attached to the glass fabric as seen in Figure 4.

## TESTS AND TRIAL AND TESTING.

The thickness of the sandwich material is measured in grammes per square metre.

The sandwich composite may be described by its density and other physical properties. Quality control, acceptance specification testing and research may all benefit from this way of assessing sandwich core and density.

There are 300mm long and 300mm wide examples with different thicknesses depending on the core and sandwich material used. For testing and research reasons, it is now possible to get simulated density data thanks to ASTM standard C 271. Procedure

## Determine the weight of the specimen.

Millimeters are the unit of measurement for specimens' plan dimensions.

Samples should be measured in millimetres in terms of thickness.

The following formula may be used to compute density:

**Calculation**

$$\rho = \frac{W_t \times 10^6}{V} \qquad (1)$$

In kilogrammes per cubic metre, grammes and millilitres are used to measure density, mass, and volume. Smart Compression testing of Sandwich Flat.

Sandwich panel construction relies on the flatwise compressive strength and modulus of sandwich cores. Using a complete load deformation curve and deformation data, the compressive stress at every load may be computed to determine the core's effective modulus (such as compressive stress at proportional limit load or maximum load).

Sandwich panel design and development may benefit from the ASTM C 365 standard test method, which assesses compressive strength and modulus on a flat surface.

A moving top fixture pulls in the same direction as the facing plane during flatwise compression tests, while a fixed bottom fixture remains stationary. The computer stores data on the weight and deflection of loads. Procedure

Vernier callipers were used to measure the specimen's dimensions, including its length, breadth, and thickness.

A self-aligning spherical loading block hung from the exterior and was used for loading. A specimen's loading surface is uniformly spread when this kind of block is used.

Consistent speed loading and movement of machine's cross-head are necessary for testing

The elastic modulus was calculated using the deflection curves of the loads.

**Calculation**

The formula for flat wise compressive strength:

$$\sigma_{Fc} = \frac{\rho_{max}}{A} \qquad (2)$$

Where $\sigma_{FC}$ is flat wise compressive strength in MPa, $\rho_{max}$ is ultimate load in N, and A is cross sectional area in mm$^2$ (whereA=LXW).

Flat wise compressive strain:

$$\epsilon_{Fc} = \frac{\Delta_t}{t} \qquad (3)$$

Where $\epsilon_{Fc}$ is compressive strain, t is original thickness in $mm$ and $\Delta_t$ is change in thickness in mm

Flat wise compressive modulus:

$$E_{Fc} = \frac{\Delta\sigma_{Fc}}{\Delta\epsilon_{Fc}} \qquad (4)$$

Where $E_{Fc}$ is the compressive modulus in MPa and $\frac{\Delta\sigma_{Fc}}{\Delta\epsilon_{Fc}}$ is the slope of initial linear portion of stress strain curve in N/mm².

Sandwich composites flexural testing.

In this test, the core shear strength and modulus of a flat sandwich structure may be determined.

The ASTM C 393 standard procedure simplifies the testing of sandwich flexure panels.

Procedure

Vernier callipers were used to measure length, breadth, thickness, and span length.

Second, mid-span load is continuously supplied.

The stiffness and core shear modulus of a sandwich may be determined using load-deflection curves.

**Calculation**

Core shear stress:

$$\tau_c = \frac{P_{max}}{(1+t_c)w} \qquad (5)$$

Where $\tau_c$ core shear stress in MPa is, $P_{max}$ is maximum load in N, t is sandwich thickness in *mm*.

Facing Bending Stress:

$$\sigma_{fb} = \frac{P_{max}L}{2t_f(t+t_c)w} \qquad (6)$$

Where, $\sigma_{fb}$ is facing bending stress on *MPa*, $t_f$ is facing thickness in *mm* and *L* is span length in *mm*.

Explanation of the findings and results of the study. Sandwich composites density research results

The density data in Table 1 and Table 2 may be used to show how the sandwich core influences overall density.

The sandwich and core densities are shown side by side in Figure 5.

Sandwich composite core density is shown in Table 1.

| Specimen | Dimensions (*mm*) | | | Weight kg | Volume mm³ | Density Kg/m³ |
|---|---|---|---|---|---|---|
| | t L | w | | | | |
| 65%-35% | 298 | 301 | 13 | 1.583 | 1166074 | 1357.54 |
| 60%-40% | 304 | 304 | 12.5 | 1.604 | 1155200 | 1388.5 |
| 55%-45% | 303 | 302 | 12.5 | 1.624 | 1143825 | 1419.8 |
| AVG | | | | 1.603 | | 1388.61 |

**Table 2. Density of the Whole of sandwich composite**

| Specimens | Dimensions (*mm*) | | | Weight *Kg* | Volume mm³ | Density Kg/m³ |
|---|---|---|---|---|---|---|
| | L | w | | | | |
| 65%-35% | 298 | 301 | 15 | 1.834 | 1345470 | 1363.1 |
| 60%-40% | 304 | 304 | 14.5 | 1.954 | 1340032 | 1458.6 |
| 55%-45% | 303 | 302 | 14.5 | 1.974 | 1326837 | 1487.74 |
| AVG | | | | 1.921 | | 1436.48 |

Where L-length of specimen, w-width of specimen, t-thickness of specimen

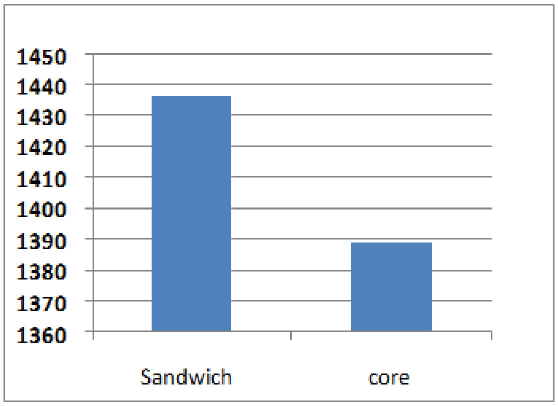

**Figure 5: Comparison result of core and sandwich composite results**

**Bending test**

**Experimental Results of bending test for composition 65%-35%**

Fig.6 Shows the load versus deflection graph of bending for composition 65%-

35%.Table 3 shows the bending test results for the composition 65%-35%

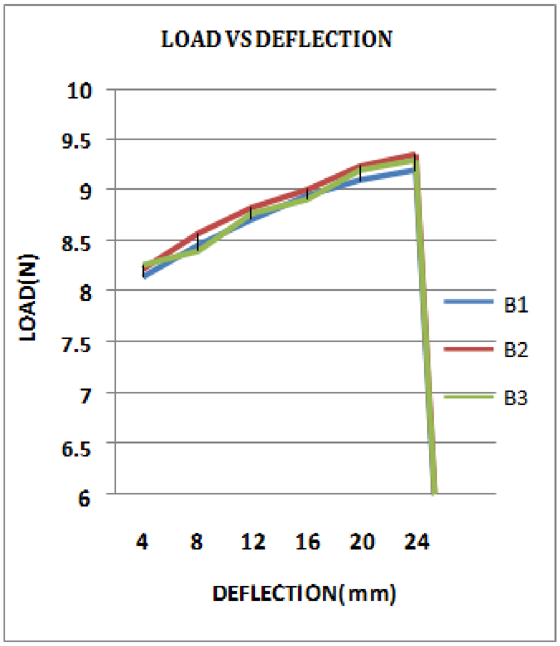

**Figure 6: Load vs Deflection graph of bending for composition 65%-35%**

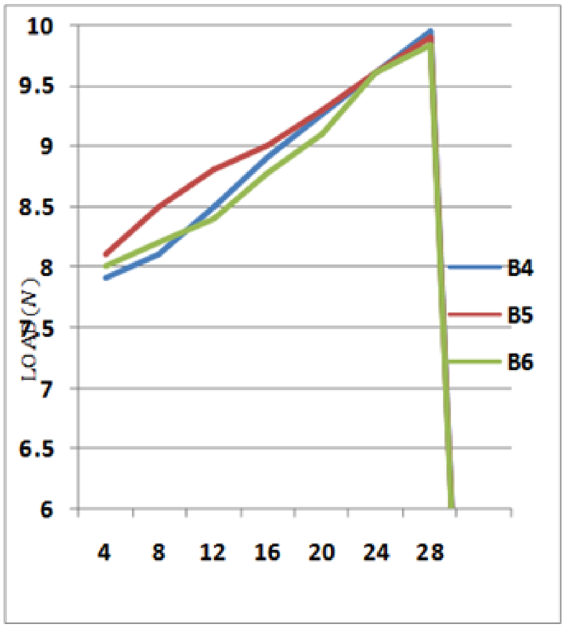

**Figure 7: Load vs Deflection graph of Three Point bending for composition 60%-40%**

**Table 3 Bending Results for composition 65%-35%**

| Specimen | Span length *(mm)* | Width w *(mm)* | Thickness t *(mm)* | Max Load (kN) | Facing Stress (MPa) | Core Shear Stress (MPa) |
|---|---|---|---|---|---|---|
| B1 | 200 | 40 | 15 | 9.2 | 410.71 | 8.214 |
| B2 | | | | 9.36 | 417.85 | 8.357 |
| B3 | | | | 9.3 | 415.17 | 8.304 |
| AVG | | | | 9.28 | 414.58 | 8.29 |

Experiments on the Bending test for the 60-40% composition

Bending load versus deflection is shown in Fig.7, with the composition 60%-40%.

Bending test results for the 60%-40% composition are shown in Table 4.

**Table 4 Bending Results for composition 60%-40%**

| Specimen | Span length *(mm)* | Width w *(mm)* | Thickness t *(mm)* | Max Load (kN) | Facing Stress (MPa) | Core Shear Stress (MPa) |
|---|---|---|---|---|---|---|
| B4 | 200 | 40 | 14.5 | 9.95 | 460.64 | 9.212 |
| B5 | | | | 9.9 | 458.33 | 9.166 |
| B6 | | | | 9.84 | 455.55 | 9.111 |
| AVG | | | | 9.9 | 458.17 | 9.163 |

Bending test results for a composition of 55% to 45%.

Bending load versus deflection is shown in Fig.8 for a composition of 55%–45%.

bending test results for the 55%-45% mixture are shown in Table 5.

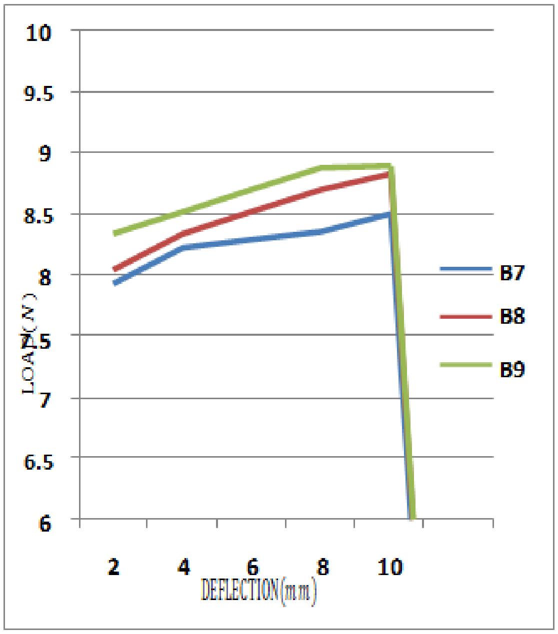

**Figure 8: Load vs Deflection graph of bending for composition 55%-45%**

**Table 5 Bending Results for composition 55%-45%**

| Specimen Code | Span length *(mm)* | Width w *(mm)* | Thickness t *(mm)* | Max Load (kN) | Facing Stress (MPa) | Core Shear Stress (MPa) |
|---|---|---|---|---|---|---|
| B4 | 200 | 40 | 14.5 | 8.5 | 393.51 | 7.870 |
| B5 | | | | 8.82 | 408.33 | 8.166 |
| B6 | | | | 8.9 | 412.03 | 8.240 |
| AVG | | | | 8.74 | 404.62 | 8.092 |

The following is a list of possible causes of failure during a bending test.

A precise centre load is applied during a bending test. After the first contact with the loading fixture, the face sheet delamination from the core occurs, and therefore the face sheet bears the majority of the load. At a core failure stress of 9.28kN for 65-35 percent compositions, 9.9kN for 60--40 percent compositions, and 8.74kN for 55-45 percent compositions, sandwich composites deflection occurs.

Using Flat Wise for Compression Experiments

Fig. 10 shows the relationship between the applied load and deflection; Fig. 9 shows the stress-strain relationship in a flat plane; and Fig. 10 shows the experimental data (Table 6).

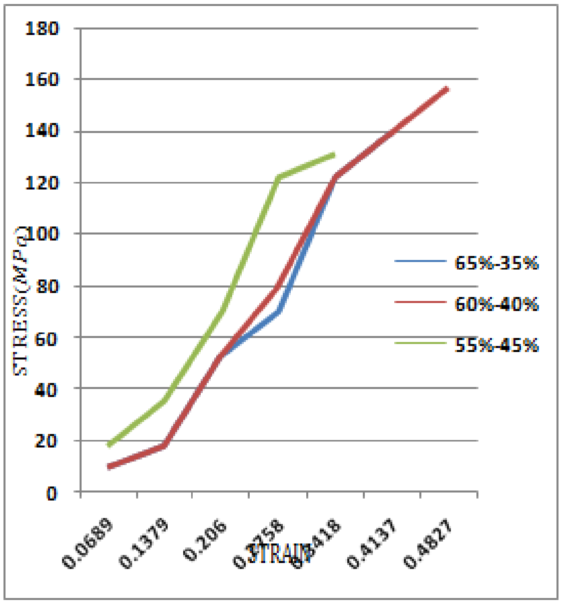

**Figure 9: Stress vs Strain graph of flat wise compression for all three compositions**

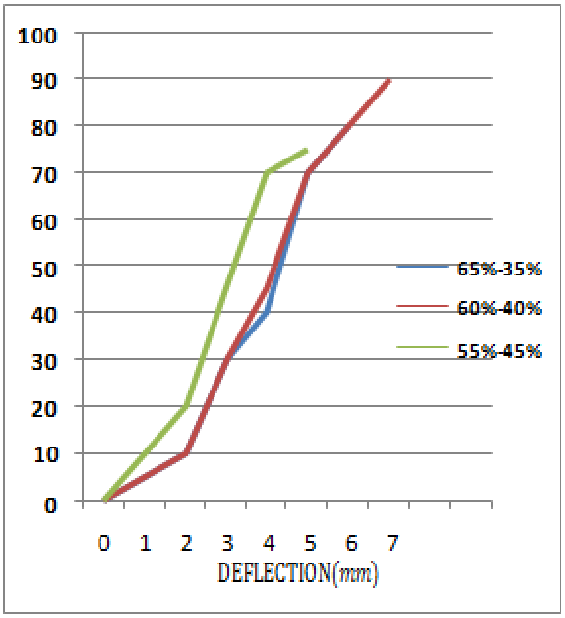

**Figure 10: Load vs Deflection graph of flat wise compression for all three compositions**

Table 6 Experimental Results Flat Wise Compression test

| Specimen | Dimension (mm) | | | Max Load (kN) | Max Stress (MPa) | Max Strain (%) | Modulus of Elasticity (MPa) |
|---|---|---|---|---|---|---|---|
| | L | w | t | | | | |
| 65%-35% | 75 | 75 | 15 | 784.8 | 139.52 | 40 | 399.12 |
| 60%-40% | 75 | 75 | 14.5 | 882.9 | 156.96 | 48.3 | 562.40 |
| 55%-45% | 75 | 75 | 14.5 | 735.75 | 130.8 | 34 | 580.55 |

A flatwise compression test resulted in failure.

During flatwise compression failure, the core's centre fracture propagates, crushing the core and creating bulges at the margins of the sandwich. These samples all fail to perform as expected. Sandwiches will become thinner as their weight increases. The highest average load that the sandwich composite can sustain under flatwise compression is 784.8 kN for 65 percent -35 percent, 60 percent -40 percent, and 55 percent -45 percent by weight of fly ash and epoxy resin; for 882.9 kN; and for 735.75 kN; the maximum average load is 784.8 kN.

## CONCLUSION

An epoxy resin and binder were mixed with fly ash, a waste product from thermal power plants, to create a core that was then wrapped in two sheets of glass fibre. As much as 65 to 35 percent by weight of the fly ash and epoxy resin sandwich composite specimens were subjected to testing, it was discovered. For 60 percent of specimens, the bending and compression results are better than for 40 percent of specimens, in this research. The compressive strength of epoxy resin increases when fly ash is added. We may credit the hollowness of fly-ash particles and the high interfacial energy between resin and fly-ash for this rise. The energy absorbed by the fibre pull out has resulted in an increase in both compressive and impact strength. Material has a high compressive strength and high impact strength, which may be used as a substitute for wood in places where compressive strength is required.

From software to flooring and even the ceilings, everything is taken care of.

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