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MECHANICAL CHARACTERIZATION OF CSP AND GGBS FILLED GLASS - EPOXY COMPOSITES

Dr. G. Mallesh[*1] & Mr.Pradeep Kumar V G[2]
[*1]Associate Professor, Department of Mechanical Engineering, S.J.C.E- Mysuru-06, India
[2]Assistant Professor, Department of Mechanical Engineering, S.J.C.E- Mysuru-06, India

ABSTRACT

Composites are the amalgamation of two or more materials which are different in form and chemical constituents. These are gradually gaining more significance as structural materials in the preset day engineering design and development activity; this is because they tender very attractive properties such as high strength to weight ratio, higher thermal, corrosive and wear resistance. Hence these materials have the potential to replace the conventional materials. The development of natural fiber reinforced polymer composites has gained popularity in many applications due to their environment friendly characteristics over the synthetic fiber based polymer composites.

In this work, the composites were fabricated by hand lay-up technique and the mechanical properties such as tensile strength, flexural strength, inter laminar shear strength (ILSS), tensile modulus, impact strength and hardness were carried out on glass-epoxy composites filled with varying volume fractions of industrial blast furnace slag and coconut shell powder. From the results it was found that the mechanical properties of the composites fabricated were increased with the increase in filler content.

Keywords- *CSP (coconut shell powder) GGBS (ground granulated blast furnace slag, mechanical behavior*

I. INTRODUCTION

Fibers are various forms which are intrinsically much stiff and stronger than the same materials in the massive form. The reinforcing fibers are the most important load-transferring agents. In general they are strong and stiff. The geometry of fibers was somehow crucial to evaluate their strength and must be considered in structural applications. In these composites fibers are the main basis for strength, the matrix collectively '**glues**' all the fibers to transfer stress within the reinforcing fibers.

Aramid, Carbon, Glass and Kevlar are some of the popular fibers which are widely used for load bearing applications. “The glass fiber is most popular due to low price and suitable for engineering applications.”

The task of matrix in the composite is to hold reinforcement together, further the matrix include toughness to the composites. There are many matrix materials being used to obtain the desired properties. Commonly used matrix materials are epoxy resins, phenolic resins, unsaturated polyester and polyurethane, etc, are used in combination with glass fibers.

Fillers or modifiers are added to reduce cost, improve the desired properties and enhance manufacturing process capabilities.

Major problem associated with urbanization and industrialization is pollution but industrialization is necessity to boost the economy of the developing countries. Urbanization leads to the environmental pollution due the generation of huge amount of solid wastes. Therefore, over recent decades, intensive research efforts are made to utilize unwanted wastes by their conversion into materials for various applications.

From world resource review, 1994 it is noticed that huge quantity of solid waste was formed by blast furnace slag and coconut shell which are not utilized properly leads to environmental pollution.

In the present scenario due growing interest on the natural fibers, attempts are made to use these filler in the development of composite materials for industrial applications and fundamental research.

Hence, in this paper attempts are made to develop new composite material using glass fiber, epoxy resign and filled with different weight fractions of slag and coconut shell powder to estimate mechanical properties.

II. LITERATURE REVIEW

A literature survey is the sources of background information which are relevant to a particular area of research. It provides a methodologies, description and critical assessment of each work. Present research mainly focused on the development, estimation of mechanical properties of slag and coconut shell powder filled glass fiber reinforced epoxy composites.

Bernd Wetzela.et.al, [1] were studied the behaviors of micro- and Nano-scale particles of $CaSiO_3$ and Al_2O_3 as a fillers used as reinforcements in glass epoxy resin. It is found that mechanical properties and synergistic effects were improved. **Kazuya Okubo.et.al,** [2] developed eco-friendly composites using bamboo fibers to study their mechanical property. A comparative result indicates that the bamboo fibers has strength equivalent to that of conventional glass fibers. Due decrease of voids and well impregnation of fibers the tensile strength of steam exploded fibers increases about 15 -30% as compared to that of mechanically extracted fibers**. M. Lai.et.al, [3]** thermal and mechanical properties of rubber micro-fillers and SiO_2 nano particles filled epoxy composite were estimated to know the effect of fillers in the composite. The results indicate that the inclusion of SiO_2 nano particles tensile modulus enhances and reduces with the addition of rubber content. During the investigations on variation of temperature, addition of particles content has no effect on the coefficient of thermal expansion. The effect of the rubber content that introduces a strong relief during processing when residual strains are generated, where as silica content tends to increase their level. **Sandhyarani Biswas.et.al, [4]** fabricated bamboo fiber reinforced epoxy composites with Al_2O_3 , SiC and industrial wastes such as copper slag and red mud fillers are used to study the synergistic effects. Result showed that the tensile strength of particulate filled bamboo epoxy composites are found to be declining in most of the cases because these composite systems contains voids, it also is noticed minimum void fraction was found in redmud filled composites as compared to SiC. **Dr.G. Ramachandra Reddy.et.al, [5]** determine the mechanical performance for the different weight fractions of filler with Epoxy composites filled with Sansevieria cylindrical (SC) was hybridized with betel nut short fiber with using the hot press molding and extrusion process. It is observed that 90%Epoxy resin: 10% Betel nut composites established the better performance compared with other composites. **Goulart.et.al, [6]** mechanical properties of natural fiber and glass fiber composites were studied and observed that certain drawbacks in natural fibers such as formation aggregates, incompatibility during processing of polymer matrix and weak resistance to moisture, to improve fibers and matrix compatibility various treatments and modifications are being used, such as acetylating, bleaching and use coupling agent and so on due to these reasons use of natural fibers in composite reduced. In this study effect of various treatments are studied to the possible use of natural fibers. **Ch.Ramesh.et.al, [7]** fabricated epoxy matrix composites filled with different weight fractions of slag particulate by hand layup method and to evaluate the mechanical properties it is noticed from the results that flexural and tensile properties enhanced by 20% beyond that Impact properties gradually reduces. If slag and cement are used as filler the mechanical behavior were improved. **R.Satheesh Raja.et.al, [8]** Fly ash filled epoxy polymer composites are manufactured with different fly ash particle sizes to investigate the physical and mechanical properties. It is observed that properties were enhanced with increase in the size of particles and overall strength of the composite decrease with increase in particle size. **Sudeep Deshpande.et,al, [9]** 15% volume fraction of bone and coconut shell powder filled E-glass /jute fiber reinforced epoxy composites were fabricated to investigate the mechanical properties in comparison with HFRP composites. With the addition of CSP flexural, inter laminar shear and tensile modulus were enhanced. There was increase in hardness and impact strength due the addition of bone powder.

From the literature survey it is found that very limited work has been done on mechanical characteristics of slag and coconut shell powder reinforced composite. Hence it is decided to study the mechanical properties of slag and coconut shell reinforced composite materials as per ASTM standards.

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III. MATERIALS AND METHODS

Fibers are the major elements in FRP composites; the reinforcing fiber is most important load-transferring agents and occupies the largest volume fraction in a composite laminate. Different types of glass fibers used to manufacture fiber-reinforced plastics (FRP) are S-glass and E-glass in industry. Many components for air craft and missile components are developed using S-glass fibers because of its highest tensile strength among all fibers in use. It is noticed that E-glass has the least expensive fibers among all commercially available fibers, because of this reason they are widely used in the FRP industries.

In general, Ceramics, thermoset and thermoplastic are used as common matrix materials. Epoxy resins are extensively used in the manufacture of fiber reinforced composites because of their flexibility, low contraction and exceptional adhesive properties with minimum cost.

Fillers are induced into a polymer matrix to minimize cost, enhance modulus, diminish mold shrinkage, controls the viscosity and to produce good surface roughness. The most common filler used in FRP composites are clay, mica, and glass microspheres, in this paper different weight fractions of slag and coconut shell powder are used as fillers.

A composite sheet of 400 mm X 400 mm X 3 mm thick is fabricated using hand layup and bag molding process for different weight fractions of slag and coconut shell powder reinforced with glass fiber, epoxy resin. Mass of glass fiber, epoxy resin and mass of the fillers were calculated as per their volume and density. Calculated quantity of glass fiber, epoxy resin along with the hardener and fillers are used manufacture composite plates of required dimensions.

The process flow chart to prepare composite material and its characteristics is as shown in **Figure 1.**
Initially number of layers of the glass fibers is marked and cut as per the required dimensions from the glass mat strands with the help of marker and scissors, number of layers are chosen based on the thickness of the laminate.
In the next step calculated amount of matrix resin along with hardener is mixed with the filler. First layer of the glass fiber is placed on a flat surface which is cleaned with the help of acetone. First layer is coated with a layer of resin either through a spray gun, or through a brush. Similar procedure will be followed till to get the required thickness of a laminate.

In order to remove the excess mixture, perforated sheet and breather sheet are placed on to the surface of the glass fiber. Vacuum pressure is created in the composite system about 1hr 30min in order to remove the air bubbles and excess resin in between the layers. Curing of the composite system is carried out for an hour at 100^0C. Similar procedure is carried out for different weight fractions of fillers keeping glass fiber volume fraction constant.

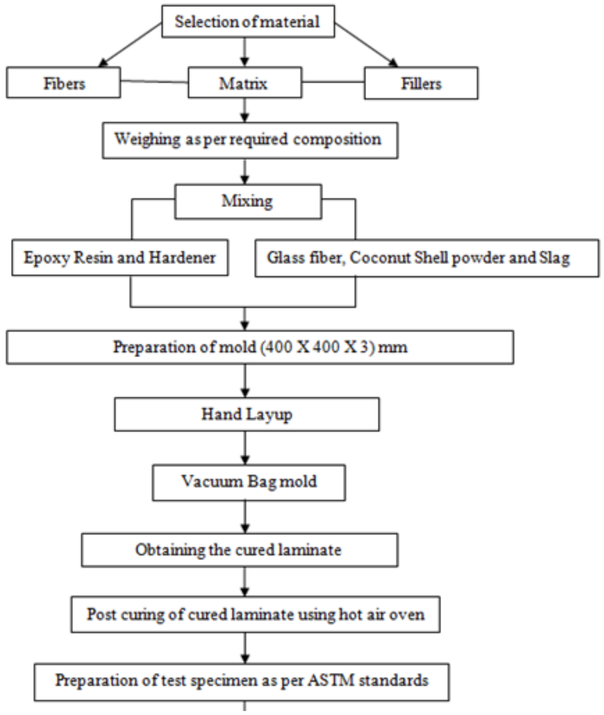


Figure 1: Process flow chart

Finally the slag and coconut shell reinforced composite plates were cut using band knife cutting machine as per different ASTM standard to carryout mechaical tests.

IV. TEST PROCEDURE

Tensile strength

Tensile strength indicates the ability of a composite material to withstand forces that pull it apart as well as the capability of the material to stretch prior to failure. The commonly used specimen for tensile test is the dog-bone type which is as shown in figure 2. During the test a uni-axial load is applied through both the ends of the specimen. The tensile test was conducted according to the ASTM 790 standard on computerized universal testing machine INSTRON H10KS.

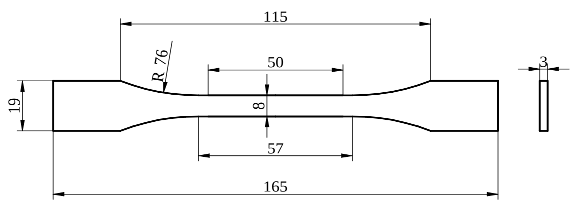


Figure.2: ASTM Tensile Test Specimen

Flexural Strength

Flexural strength is the ability of the composite material to withstand bending forces applied perpendicular to its longitudinal axis. The inter-laminar shear strength is the maximum shear stress existing between layers of laminated material. Flexural test were performed using 3-point bending test method according to ASTM D790-03 as shown in figure.3 on a computerized universal testing machine at a crosshead speed of 0.5 mm/min.

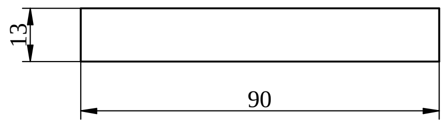


Figure.3: Flexural Test Specimen

Impact Strength

One of the most common tests, of the physical characteristics of plastic materials is the notched Izod impact test as specified by ASTM D 256 standard test method for determining the Izod pendulum impact resistance of plastics. The energy absorbed by the specimen in the breaking process is known as the breaking energy. The breaking energy can be converted into an indication of a materials impact resistance.

Hardness Strength

The hardness of plastics is most commonly measured by the Shore- Durometer (shore-D) test or Rockwell hardness test. Both methods measure the resistance of plastics toward indentation and provide an empirical hardness value that doesn't necessarily correlate well to other properties or fundamental characteristics. ASTM D2240 standard is used to measure the hardness.

Micro Structure Analysis

The scanning electron microscope (SEM) uses a focused beam of high-energy electrons to generate a variety of signals at the surface of solid specimens. The signals that derive from electron-sample interactions reveal information about the sample including external morphology (texture), chemical composition, and crystalline structure and orientation of materials. In most applications, data are collected over a selected area of the sample, and 2-dimensional images are generated to display the spatial resolution of 50 to 100 µm to identify their properties to analyze crystalline structure.

V. RESULTS AND DISCUSSIONS

Tensile strength

A series of tensile tests were conducted as per the section 4.1 using ASTM 790 standard on computerized universal testing machine to evaluate the ultimate tensile strength, deflection and Young's modulus of slag and coconut shell powder reinforced glass epoxy composite materials for different weight fractions via 3%, 6%, 9% and 12%. Similarly, the tensile strength of unfilled composite material was also carried out to evaluate the effect of the reinforcement.

Stress-starin behavoir of unfilled glass- epoxy composite material is as shown in figure 4 and noticed that a uniform elongation upto ultimate point it indictaes that there is a uniform composite was fabricated by handlayup and bag molding techinques. Also noticed that unfilled composite carries a maximum load of 868.8 kg with an ultimate modulus of 16207 MPa having 4.25% elonagation.

Due to uniform distribution of fillers in the composite 12.47% and 9.17% decrese in the percentage elongation occurred for 12% addtion coconut shell powder and blast furnace slag respectively.

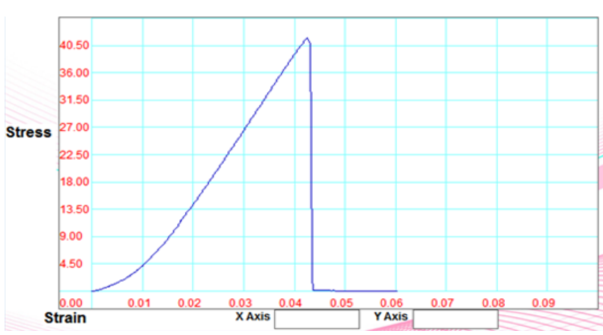


Figure:4 Stress –strain curve for unfilled glass and epoxy composite material.

It is examined that load carrying capacity increases with increase in the percentage of reinforcement of both slag as well as coconut shell powder up to 9%. Further load carrying capacity increases with addition of the coconut shell powder because from the XRD results it was noticed that percentage of carbon content is more when compared to slag hence coconut shell powered reinforced composite becomes hard it may with stand more load. The densities of composites further increase with incorporation of slag and subsequently rise in the volume fraction of voids.

Tensile modulus of the coconut shell powder is minimum compared with the slag this is due to the brittle phase formation because of the carbon content. From the XRD reults it was observed that slag contains different fillers like SiO_2, SiC, Al_2O_3, $MgCo_3$, $CaCo_3$, CaCl, etc., all these fillers leads to better interface bonding between fiber and the matrix hence tensile strength was improved with the addition of slag.

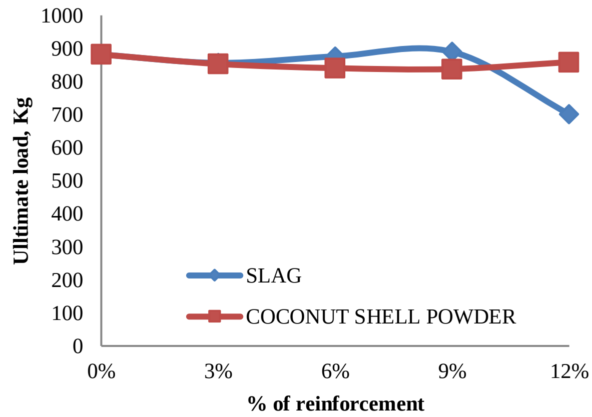


Figure: 5 Maximum load carrying capacity of different reinforcements.

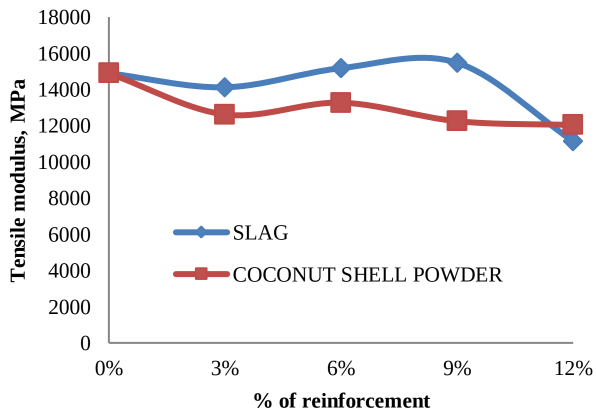


Figure: 6 . Tensile modulus for slag and cococnut shell powder filled Glass epoxy composite.

Flexural Strength

Flexural tests on different weight fractions of slag and coconut shell powder reinforced glass epoxy composite materials were conducted as per the section 4.2 using ASTM D790-03 standard to evaluate the effect of reinforcement.

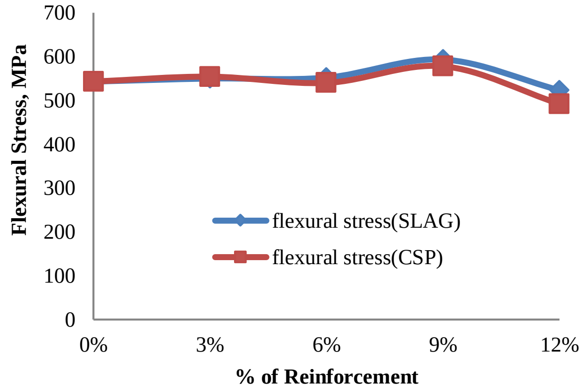


Figure: 7 Flexural stress for slag and coconut shell powder reinforced composite.

Figure 7 shows comparison of flexural strength for different weight fraction of slag and coconut shell powder. The results revealed that as the percentage of reinforcement increases flexural strength also increasers. The flexural strength tends to increases up to 9% of reinforcement beyond 9% the material tends to exhibit brittleness and adding more slag and coconut shell powder resulting poor dispersion and more possibility of existence of voids in composites.

Impact Strength

Impact strength of different weight fractions of slag and CSP filled composite were carried out to estimate the toughness as per ASTM D 256 standard.

Increase in filler content leads to higher impact strength due to the interfacial reaction and provide effective barrier for pinning and bifurcation of advancing cracks.

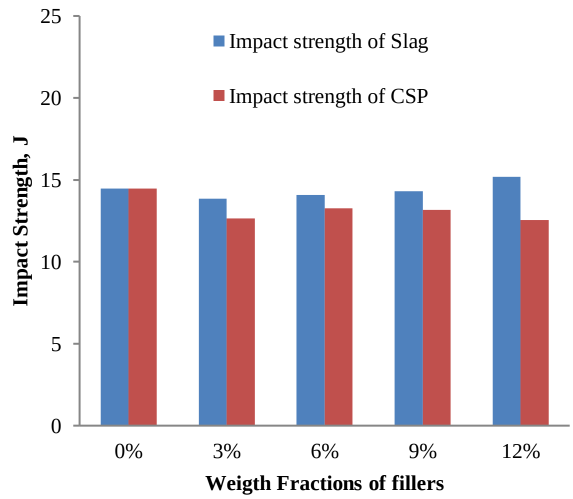


Figure: 8. Impact strength of slag and CSP filled glass epoxy composite.

Composite material exhibits slight variations in impact strength when compared to unfilled material. This clearly shows that better bonding strength was established when reinforcing material was added to the composite system. The addition of slag exhibits higher impact strength when compared with coconut shell powder.

Hardness Strength

The hardness of plastics was measured using Shore- Durometer (shore-D) test. It measures the resistance of plastics toward indentation and provides an empirical hardness value.

Several experiments were conducted for different weight fractions of slag and CSP at different locations and hardness number of each trial for slag and coconut shell powder were as shown in figure.9.

Micro Structure Analysis

It is observed from the SEM images ***(Figure: 10.)*** that due to the application of tensile load fracture take place in the fiber and also observed that fiber pull out from the specimen and noticed that some dislocations in the fibers as compared to the addition of the fillers.

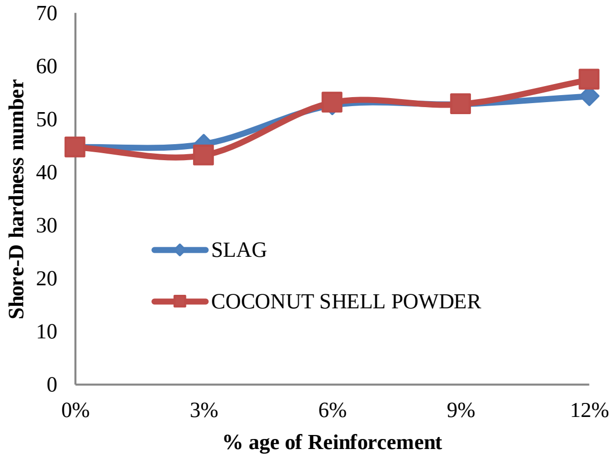
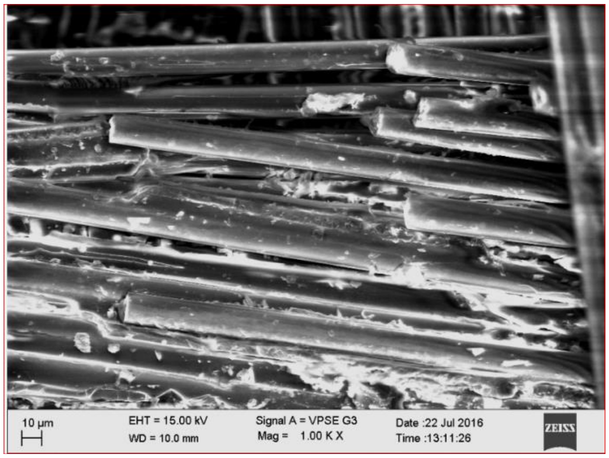
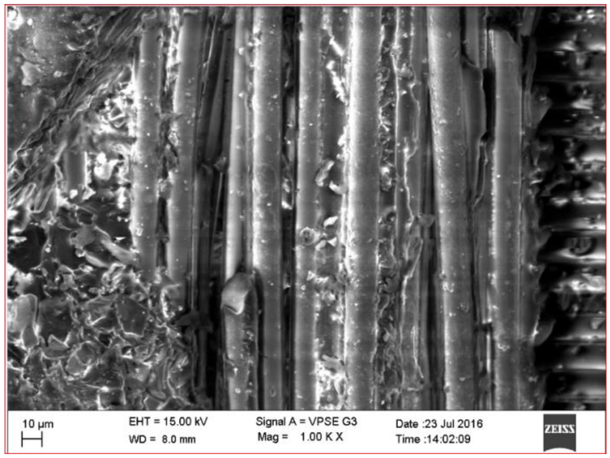


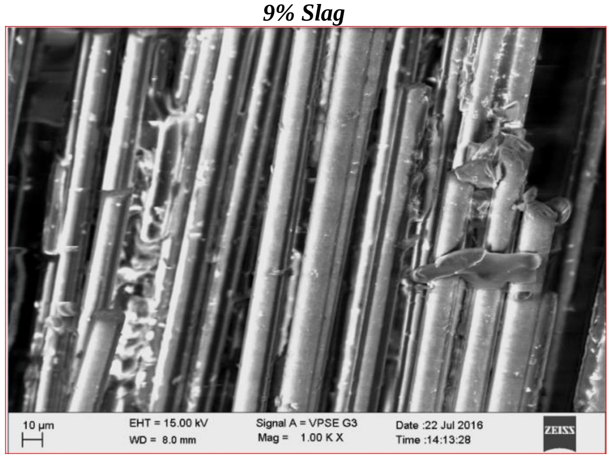
Figure: 9. Comparison of Shore-D hardness number for slag and CSP.



Glass-Epoxy



9% Slag



9% Coconut Shell Powder

Figure: 10. SEM Images of Epoxy, Slag and Coconut Shell Powder filled glass fiber reinforced composites (Tensile Test).

VI. CONCLUSIONS

In the present study different weight fractions of blast furnace slag and coconut shell powders filled glass and epoxy fiber reinforced composite material was developed using hand layup techniques to conduct mechanical behavior and following conclusions were drawn

- Tensile modulus of slag and coconut shell powder filled composite materials indictes increases tensile modulus as the percentage of filler increases. Tensile modulus decreases beyond 9% of slag addtion indiactes the poor adhesion between the fibers, filler and matrix interfaces.
- It is observed that flexural stress increased by 8.47% and 6.04% for 9% fillers addition due to better bonding and uniform distribution of fillers in the composite. Further, increases in filler content in the composite leads weak bonding hence flexural stress reduced to 3.65% and 9.38% in Slag and CSP respectively.
- It is evident that as the percentage of filler increases with slight decrease in impact strength. Beyond 9% slight increase in impact strength was noticed because the material becomes more brittle and hard hence its ability to absorb impact energy increases because of interfacial reaction and effective barrier for pinning and separation of induced cracks and moreover addition of slag exhibits higher impact strength when compared with coconut shell powder.

Hardness results indicates that 17-18% increase in hardness of slag filled composites and 22% increase in hardness of coconut shell powder filled composites this may be due to uniform dispersion, carbon content and decrease in particle distance in the matrix.

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