Project Report on

Investigation of Mechanical Properties of Coconut Shell Dust, Epoxy and Fly-Ash Composites.

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CERTIFICATE

This is to certify that the thesis entitled "**Investigations of Mechanical Properties of Coconut Shell- Fly Ash- Epoxy Composites**", submitted by Aruntapan Dash, Adyasha Samal , Jyotishman Mishra, Anurag Kujur in partial fulfilment of the requirements for the award of Bachelor in Technology in Mechanical Engineering at IGIT, Sarang under Biju Pattnaik Institute Of Technology, Rourkela is an authentic work carried out by them under my supervision and guidance.

To the best of my knowledge the matter embodied in the thesis has not been submitted to any other university/Institute for the award of any degree or diploma.

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ABSTRACT

A composite in the present context is a multiphase material that is artificially made as opposed to one that occurs naturally. The constituent phases must be chemically dissimilar and separated by a distinct interface. A lot of research has been undertaken with artificial fiber reinforced polymeric composites like glass/aramid/carbon etc. However due to higher cost and non-eco-friendly nature of such fibers, natural fiber reinforced composites are taking the place of artificial fiber reinforced composites. These composites are having low cost, easy availability or may be available in the form of waste. Therefore, waste utilization and application of these composites in engineering has significance in the present scenario. Under circumstances it has been thought proper to utilize coconut shells which are thrown away as waste in the form of dust and fly ash another industrial waste to fabricate composites of light weight and reasonable strength for engineering applications like in automotives, interior decorations, space technology and navigation etc. In this study a polymeric composite has been prepared by using epoxy resin as matrix and fly ash and coconut shell dust as filler and reinforcements. Fabrication of composite laminates has been done with different weight fractions of coconut shell dust and constant percentage of fly ash by hand lay up technique. The mechanical properties of the composite laminate so prepared with random distribution of reinforcements has been investigated such as micro structure, tensile strength, hardness, water absorption as per standards.From the tensile test it is observed that as the percentage of coconut shell dust increases the tensile strength of the samples is increases up to 15% & then decreases for 20%. The Vickers hardness test gave the values as 15.884VHN, 16.098VHN and 16.88VHN for 10%, 15% and 20% CSP reinforcement respectively. From the water absorption test as the gain in weight is less than 2% hence moisture absorption is negligible. It is also seen from the micro structure analysis that the shell dust is evenly distributed in the matrix. Because of this even distribution of filler in the epoxy matrix probably the hardness and strength values are quite optimum and the composite can be a promising material for future applications.

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Chapter-1

1.1 Introduction

A composite in the present context is a multiphase material that is artificially made as opposed to one that occurs naturally. The constituent phases must be chemically dissimilar and separated by a distinct interface. The most widely used meaning is the following one, which has been stated by Jartiz “Composites are multifunctional material systems that provide characteristics not obtainable from any discrete material. They are cohesive structures made by physically combining two or more compatible materials, different in composition and characteristics and sometimes in form”. The composites are compound materials which differ from alloys by the fact that the individual components retain their characteristics but are so incorporated into the composite as to take advantage only of their attributes and not of their short comings.

Over a past few decades’ composites, plastics, ceramics have been the dominant engineering materials. The areas of applications of composite materials have grown rapidly and have even found new markets. Modern day composite materials consist of many materials in day to day use and also being used in sophisticated applications while composites have already proven their worth as weight saving materials. The current challenge is to make them durable in tough conditions to replace other materials and also to make them cost effective. This has resulted in development of many new techniques currently being used in the industry. The composite industry has begun to recognise the various applications in industry mainly in the transportation sector.

In recent years, the continuous and increasing demand for environmentally friendly materials such as bio-composites from plant-derived fibres and from recycled fibre-based products has been on the increase due to their potential characteristics. India endowed with an abundant availability of natural fibre such as Jute, Coir, Sisal, Ramie, Bamboo, Banana, Bagasse etc. has focused on the development of natural fibre composites primarily to explore value-added application avenues.

While the use of composites is a clear choice in many applications but the selection of materials will depend on the factors such as working life, lifetime requirements, complexity of product shape, number of items to be produced , savings in terms of cost and the experience and skill of designer to trap the optimum skill of the composites.

1.2 Classification

On the basis of Matrix Material composite materials can be classified into three groups. They are:

a) Metal Matrix Composites (MMC)
b) Ceramic Matrix Composites (CMC)
c) Polymer Matrix Composites (PMC)

1.2.1 Metal Matrix Composites

Metal Matrix Composites have many advantages over monolithic metals like higher specific modulus, higher specific strength, better properties at elevated temperatures, and lower coefficient of thermal expansion. . High strength, fracture toughness and stiffness are offered by metal matrices than those offered by their polymer counterparts. Only light metals are responsive with their low density proving an advantage. Titanium, Aluminium and Magnesium are the popular matrix metals currently in vogue which are particularly useful for aircraft applications. If metallic matrix materials have to offer high strength, they require high modulus reinforcements.

The strength-to-weight ratios of resulting composites can be higher than most alloys. Because of these attributes metal matrix composites are under consideration for wide range of applications viz. combustion chamber nozzle (in rocket, space shuttle), housings, tubing, cables, heat exchangers, structural members etc.

1.2.2 Ceramic matrix Composites

One of the main objectives in producing ceramic matrix composites is to increase the toughness. Ceramics can be described as solid materials which exhibit very strong ionic bonding in general and in few cases covalent bonding. High melting points, good corrosion resistance, stability at elevated temperatures and high compressive strength, render ceramic-based matrix materials a favourite for applications requiring a structural material that doesn't give way at temperatures above 1500ºC. High modulus of elasticity and low tensile strength, which most ceramics possess, have combined to cause the failure. Attempts have been made to add reinforcements to obtain strength improvement. This is because at the stress levels at which ceramics rupture, there is insufficient elongation of the matrix which keeps composite from transferring an effective quantum of load to the reinforcement and the composite may fail unless the percentage of fibre volume is high enough. Naturally, ceramic matrices are the obvious choice for high temperature applications and it is hoped and indeed often found that there is a concomitant improvement in strength and stiffness of ceramic matrix composites.

1.2.3 Polymer Matrix Composites

Most commonly used matrix materials are polymeric. In particular their strength and stiffness are low compared to metals and ceramics. These difficulties are overcome by reinforcing other materials with polymers. Secondly the processing of polymer matrix composites need not involve high pressure and doesn't require high temperature. Also, equipment required for manufacturing polymer matrix composites are simpler. For this reason, polymer matrix composites developed rapidly and soon became popular for structural applications.
Composites have a greater modulus than the polymer component but aren't as brittle as ceramics.
On the basis of reinforcements two types of polymer composites are:
• Fibre reinforced polymer (FRP)
• Particle reinforced polymer (PRP)

Fibre Reinforced Polymer composites

Common fibre reinforced composites are composed of fibres and a matrix. Fibres are the reinforcement and the main source of strength while matrix glues all the fibres together in shape and transfers stresses between the reinforcing fibres. The fibres carry the loads along their longitudinal directions. Sometimes, filler might be added to smooth the manufacturing process, impact special properties to the composites, reduce the product cost. Common fibre reinforcing agents include asbestos, carbon / graphite fibres, beryllium, beryllium carbide, beryllium oxide, aluminium oxide, glass fibres, polyamide, natural fibres etc. Similarly, common matrix materials include epoxy, phenolic, polyester, polyurethane, polyetheretherketone (PEEK), vinyl ester etc. Among these resin materials, PEEK is most widely used. Epoxy, which has higher adhesion and less shrinkage than PEEK, comes in second for its high cost.

Particle Reinforced Polymer composites

Particles used for reinforcing include ceramics and glasses such as small mineral particles, metal particles such as aluminium and amorphous materials, including polymers and carbon black. Particles are used to increase the modules of the matrix and to decrease the ductility of the matrix and also to reduce the cost of the composites. Reinforcements and matrices can be common, inexpensive materials and are easily processed. Some of the useful properties of ceramics and glasses include high melting temp., low density, high strength, stiffness, wear resistance, and corrosion resistance, piezoelectric etc. Polymer composite materials have generated wide interest in various engineering fields, particularly in aerospace applications. Research is underway worldwide to develop newer composites with varied combinations of fibres and fillers so as to make them useable under different operational conditions.

1.3 Natural Fibre Reinforced Composites

The interest in natural fibre-reinforced polymer composite materials is rapidly growing both in terms of their industrial applications and fundamental research. They are renewable, cheap, completely or partially recyclable, and biodegradable. Plants, such as flax, cotton, hemp, jute, sisal, kenaf, pineapple, ramie, bamboo, banana, etc., as well as wood, used from time immemorial as a source of lignocellulosic fibres, are more and more often applied as the reinforcement of composites. Their availability, renewability, low density, and price as well as satisfactory mechanical properties make them an attractive ecological alternative to glass, carbon and man-made fibres used for the manufacturing of composites. The natural fibre-containing composites are more environmentally friendly, and are used in transportation (automobiles, railway coaches, aerospace), military applications, building and construction industries (ceiling panelling, partition boards), packaging, consumer products, etc. Classification of natural fibres has been demonstrated in Fig.1.1.

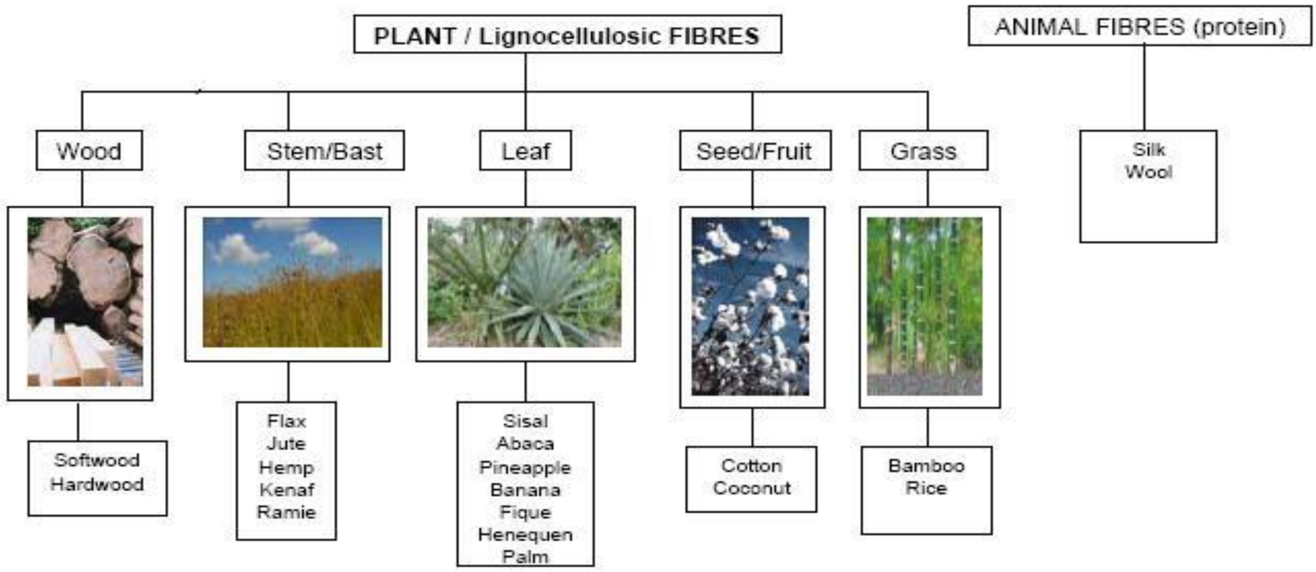

Fig.1.1 Classification of natural fibres

Over past two decades, natural fibre has received considerable attention as a substitute for synthetic fibre reinforcements like aramid and glass fibre due to their:

- Low density which may lead to a weight reduction of 10 to 30%
- Good thermal insulation and mechanical properties.
- Reduced tool wear.
- Unlimited availability, low price, and problem free disposal.
- Good calorific value and enhanced energy recovery
- Low specific gravity so high strength to weight ratio.
- Nonabrasive, non-toxic, biodegradable.
- Renewable and recyclable.

1.4 Utilities of fly ash and coconut shell dust

Fly ash is a coal combustion by product, which accumulates due to electrostatic precipitation of the flue gases in thermal power plant. When coal is burnt in thermal power plant the ash is carried forward in flue gases as fused particles, which solidifies as a spherical particle. Most of these spherical particles have a gas bubble at the centre. Fly ash depending upon the source of coal contain different proportions of silica, alumina, oxides of iron, calcium, magnesium etc. along with elements like carbon, Ti and Mg. So the fly ash has properties combined of spherical particles and that of metals and metal oxides. The demand for the lightweight materials such as for surfaces of ships had led to the development of fly–ash based thermosetting resins. In fibre epoxy composites the addition of fly ash led to a reduction of the density and increase in modulus of composites.

The incorporation of filler such as Coconut shell powder (CocosNucifera) into thermosetting materials is used to reduce the production costs of the moulded products. Coconut shell powder is widely available at very low cost, so it is an ideal filler material in this regard. Coconut shell powder is made from the most versatile part of the coconut which is from the shell where this shell is organic in nature. Increased in coconut shell content increases the tensile strength, Young's modulus and water absorption rate but reduces the elongation at break of coconut shell filled composites. Due to high lignin content in coconut shell particles the composites are more weather resistant and are also well suited in application of materials such as plywood, laminated board industry etc. Coconut shells are available in abundance in tropical countries as a waste product after consumption of coconut water and meat. Such abundance can fulfil the demand of filler based composites while reducing waste.

Therefore the present investigation is thought to utilize these waste materials to fabricate coconut shell dust reinforced epoxy matrix composite with fly-ash as filler for evaluation of mechanical properties (tensile strength, flexural strength, hardness, density etc). Besides the above all, the objective is to develop relatively low cost composites by incorporating cheaper reinforcing phases into a polymeric resin**.**

Chapter-2

2.1 Review of literature

Literature review is carried out to get the background information on the issues to be considered in the present research work and to focus the relevance of the present study. The purpose is also to present a thorough understanding of various aspects of fly ash and epoxy composite with varied concentrations of coconut shell dust that can be used as reinforcement filler in composite with a special attention to their mechanical properties and wear behaviour and future applications. The use of composite materials having light weight and high strength in aerospace, automotive, domestic appliances, navigation and rocketry is gaining importance. Under circumstances, utilization of waste for developing such materials having reasonable strength and other mechanical properties finds sincere attention of researchers worldwide. Therefore, it has been thought proper to have a review to know the direction of research particularly use of natural fibres for composite preparation. Their utility in the field of engineering with evaluation of mechanical properties becomes the prime factor for recommending for specific applications. An attempt has been made here to review the available literatures in this context.

Sapuan et al. [1] evaluated the mechanical properties of epoxy/ coconut shell filler particle composites. They presented the tensile and flexural properties of composite. The tensile and flexural tests of composites based on coconut shell filler particles at three different filler contents *viz*. 5%, 10%, and 15%, were carried out using universal tensile testing machine according to ASTM D 3039/D 3039 M-95a and ASTM D790-90 respectively. Experimental results showed that tensile and flexural properties of the composites increased with the increase of the filler particle content. Elastic moduli of the composites increased with an increase of the filler content

Singla and Chawla [2] evaluated the mechanical properties of epoxy resin – fly ash composite. Composite preparation was done by taking different weight percentage of fly ash and resin. Material was subjected to compression and impact test by taking different weight percentage of fly ash. It that with the addition of fly-ash in epoxy resin –fly-ash composite the compressive strength has been increased with increase in fly ash particles. This increase is attributed to hollowness of fly-ash particles & strong interfacial energy between resin & fly-ash. With increase in fly ash slight decrease in energy (Impact strength) has been observed due to decreased availability of epoxy material to bond all the fly ash particles in the matrix. In SEM analysis it has been found that fly ash particles are uniformly distributed in the matrix.

Husseinsyah and Mostapha [3] evaluated the effect of filler content on properties of coconut shell filled polyester composites. Polyester composite was prepared by incorporating coconut shell at different contents into polyester matrix. A catalyst, butanox M-60 was used to initiate the polymerization reaction. The effect of coconut shell content on the mechanical, water absorption and morphological properties were studied. The results revealed that increased in coconut shell content have increased the tensile strength, Young's modulus and the water absorption but reduced the elongation at break. Result from scanning electron microscopy (SEM) showed that increased in filler content have increased the tendency of filler-matrix interaction.

Bhaskar and Singh [4] investigated the physical and mechanical properties of coconut shell reinforced epoxy composite with varied weight % of coconut shell powder into the epoxy matrix**.** Experimental results showed that density, ultimate strength, modulus of elasticity and % elongation decrease with wt% of shell particle within the range of wt% 20-35 of reinforcement. Tensile strength of 25MPa and modulus of elasticity of 654 MPa were retained even after of 35% reinforcement. It was found that density decreases with increase of wt% of particle. The decrease in density can be related to the fact that the coconut particles are light in weight but occupy substantial amount of space.

Kumar and Kumar [5] evaluated the mechanical properties of coconut shell particle and coir fibre reinforced epoxy composite. Tensile, compression, wear and impact testing were carried out. Their work showed that Rockwell hardness number increases with increase of wt% of coconut shell particle and also that the Ultimate strength equal to 30 MPa and modulus of elasticity equal to 856 MPa are achieved for 20%wt shell particle reinforced composite. Density increases with addition of shell particle in case of coir and particle composite. Here fibre reduces density. The water absorption capacity was found to be maximum for 33 to 35 wt % of coconut shell particles.

Vijayaram [6] in his reported that the tensile and flexural strengths of the epoxy coconut filler composites were affected by the amount of filler in the composites. The tensile, flexural and compression tests of natural composites based on coconut shell filler particles at three different filler contents were carried out using universal tensile testing machine according to ASTM standard. The more the filler content, the higher the strength. In tensile testing, coconut filler particulate demonstrated linear behaviour with sharp fracture and exhibit higher tensile strength for higher filler particulate specimen. In flexural testing, filler composites demonstrated slightly nonlinear behaviour prior to sharp fracture.

Singh et al. [7] studied the mechanical properties and absorption behaviour of coconut shell powder-epoxy composites. The composite was prepared by using the coconut shell powder in different particle size and reinforcing in different volume and evaluated its tensile strength, flexural property and hydrophilic behaviour. The maximum flexural strength was obtained for the composite with 30% CSP, the maximum tensile strength was obtained for the composite prepared with 20% CSP volume fraction. It was also observed that an increase of CSP filler volume the corresponding tensile strength decreases. On increase of reinforcing volume, the water absorption goes on increasing.

Bashar et al. [8] in their work developed a composite for brake pad. The weights of the coconut shell powder and epoxy resin were varied while those of the abrasives, friction modifier, catalyst and accelerator were kept constant. The appropriate portion of epoxy resin was poured into a container followed by some small portions of the catalyst and accelerator and then thoroughly mixed. Series of tests were conducted that involved tensile, compressive, hardness, impact, wear and corrosion to ascertain composition with the best properties desired. The results showed that higher percentage of grounded coconut shell powder induces brittleness since compositions with lower percentage of it produced higher breaking strength and lower wear rate.

Girisha et al. [9] investigated the water absorption and mechanical property of sisal/coconut natural fibre reinforced epoxy composite. Fabrication was done by taking 10%, 20%, 30% and 40% weight fraction of fibre. Water absorption tests were done by immersing specimens in a water bath at 250^0 C and 1000^0C for different time durations. It was observed that the percentage of moisture uptake increased due to increase of the fibre volume fraction. It was found that the tensile and flexural properties of natural fibre reinforced epoxy composite specimens decreased due to the increase in the percentage of moisture content.

Olumuyiwa et al. [10] studied the mechanical behaviour of coconut shell reinforced polymer matrix composite. Coconut shell reinforced composite was prepared by compacting low density polyethylene matrix with 5% - 25% volume fraction of coconut shell particles and the effect of the particles on the mechanical properties of the composite produced was investigated. The results showed that the hardness of the composite increases with increase in coconut shell content though the tensile strength, modulus of elasticity, impact energy and ductility of the composite decreases with increase in the particle content. Scanning Electron Microscopy (SEM) of the composites (with 0% - 25% particles) surfaces indicates poor interfacial interaction between the coconut shell particle and the low-density polyethylene matrix.

Gummadi et al. [11] evaluated the flexural property of fly ash filled Polypropylene composites. Particulate composites have been developed from recycled polypropylene filled with fly ash. The study dealt with the effect of particle size and its concentration on the properties of fly ash filled polypropylene composites. Five different particle sizes of fly ash were used for sample preparation. Concentration of fly ash was also varied from 0, 10%, 15%, 20%, and 25% by weight in the polypropylene. The composite test specimens were prepared using injection moulding machine with hand layup technique as per ASTM D3641 standards. It was observed that as the addition of filler decreases the flexural strength because of particle agglomeration. It was also observed that smaller sized particles showed higher value of flexural strength. For smaller particles, as particle size decreases, interfacial area/unit volume is increased, and hence, flexural strength is increased. The percentage elongation at break also decreases on addition on
filler.

Karthikeyan and Balamurugun. [12] investigated the fibre length and sodium hydroxide treatment on impact behaviour of coir fibre reinforced epoxy composite. Composite fabrication was done by hand layup technique. Alkali treatment was done by taking 2,4,6,8,10% conc. of NAOH for 10 days and fibre length of each group of coir was taken as 10,20,30 mm.It was observed that alkali treated CFER composite gives better impact strength than the untreated coir fibre. Coir fiber of 30mm length gave better impact strength than the others.

Subham and Tiwari [13] have evaluated the effect of fly ash concentration and its surface modification on fibre reinforced epoxy composite. Investigation was done by varying fly ash concentration and modifying fly ash particles surface by a γ-aminopropyltriethoxysilane coupling agent. The DMA test result showed improvement in damping capability and thermal stability with lower concentration of fly ash. The tensile test result showed that with increase in fly ash concentration, the ultimate tensile strength and elongation at break was reduced; however, salinization of fly ash showed improvement in strength when compared to unmodified fly ash at same concentration. The impact test result showed that the toughness of FRP composite was reduced due to addition of fly ash, but salinization resulted in improved toughness. SEM analysis showed that surface modification of fly ash with coupling agent enhanced their bonding with polymer resin which resulted in lower damping capability and improved strength and toughness.

Singh [14] investigated the strength and stiffness response of fly ash reinforced with coir fibre. In the present investigation, samples of fly ash compacted to its maximum dry density at the optimum moisture content were prepared without and with randomly distributed coir fiber for triaxial compression tests. The coir fiber were taken as 0.25 %, 0.5 %, 0.75 % and 1 % by dry weight of fly ash and the shear strength parameters (c and ϕ) and stiffness modulus of reinforced fly ash for each fiber content was determined in the laboratory. Finally these strength parameters of reinforced fly ash were compared with that of unreinforced fly ash. Tests results indicate that on inclusion of coir fiber, the shear strength parameters and stiffness modulus of fly ash increase.

Raja et al. [15] evaluated the effect of fly ash filler size on mechanical properties of polymer matrix composites. Here four different sizes of fly ash (50 μm, 480 nm, 350 nm, 300 nm) with 10 wt % are impregnated with epoxy resin to process the polymer matrix composite by using simple mould arrangement. The size reduction is obtained by means of ball milling technique. Results showed that the addition of fly ash filler increases the hardness of composite material due to increase in the resistance strength of polymer to plastic deformation. The impact strength increased in the case of smaller particle size fly ash which confirmed that the void space available in the larger particle size fly ash material. Therefore the stress propagation was greater in the case of a larger fly ash particle size filled composites than that of a smaller fly ash particle size composites.

Bhaskar and Singh [16] evaluated the water absorption and compressive properties of coconut shell particle reinforced epoxy composites. Coconut particle reinforced composites were fabricated by reinforcing shell particle (size between 200-800μm) by wt% of 20, 25, 30 & 35 into epoxy matrix. Composites plates were made by casting in open mould. That is possible with very low cost and easy way. Experimental results showed that water absorption increases with the increase of wt% of particle but Composite with 30%wt of coconut shell particle shows very good ultimate strength and good modulus of elasticity in compressive zone in comparison to other wt% reinforcement of particles.

Salmah et al. [17] studied the effect of untreated and treated Coconut Shell (CS) reinforced Unsaturated Polyester (USP) composites. Coconut shell was treated with 1% sodium hydroxide (NaOH). The results showed that the addition of CS content have increased the tensile strength, modulus of elasticity, flexural strength, flexural modulus and thermal stability whereas elongation at break of USP/CS composites decreased. The treated USP/CS composites have higher tensile strength, modulus of elasticity, flexural strength, flexural modulus and thermal stability of treated USP/CS composites compared with untreated composites. The better filler dispersion and interaction between CS and USP with alkali treatments was proven by SEM study.

Thaker et al [18] studied the behaviour of alkali treated and untreated coconut shell powder reinforced polyster composites. Composites were prepared by incorporating treated and untreated coconut shell powder at different filler contents into Unsaturated Polyester matrix. An alkali treatment was used to enhance both the matrix filler wetting and the chemical surface modification in order to improve the physicochemical interactions at the filler–matrix interphase. A catalyst, Methyl Ethyl Ketone Peroxide (MEKP) was used to initiate the polymerization reaction. The results from Universal testing machine revealed that increased in coconut shell content have increased the tensile & flexural strength. Treated coconut shell filled composite showed slightly higher mechanical properties and lower water absorption than the untreated one. The chemical bonding between the filler and polymer matrix were characterized by using the Fourier Transformer Infrared Spectroscopy (FTIR). Result from scanning electron microscopy (SEM) showed that increased in filler content have increased the tendency of filler-matrix interaction.

Srivastava et al [19] investigated the compressive behaviour of walnut shell particle reinforced composites. Walnut particle reinforced epoxy composite was developed in an open mould with 10 – 40 weight percentage (wt%) of walnut particles and the effect of the reinforcement of particles on the water absorption capacity and compressive strength were evaluated. The water absorption capacity was found to increase with increasing percentage of walnut shell particle. Ultimate compressive strength and Percentage reduction in length in compression increases with increment of walnut particle wt% remarkably. There was a major increase in ultimate compressive strength between 20 to 30 wt % of walnut shell particle with the maximum value of 50 MPa at 30 wt% of walnut particles. Results showed that epoxy resin was a good solvent with improved chemical resistance over a wide range of temperature and so is effective as a matrix material.

Ozsoy et al [20] compared the mechanical properties of chopped bamboo and chopped coconut shell reinforced epoxy composites. Three different weight fractions (6%, 8%, 10%) were used as reinforcement for composites. Tensile tests were performed according to the ASTM D638 and three-point bending tests were performed according to the ASTM D790. The results were compared. As chopped coconut shell percentage increased, the tensile strength decreased. On the other hand, as chopped bamboo percentage increased the tensile strength increased. As the amount of the reinforcement increased density of the composites reduced but hardness increased.

Sudarshan et al. [21] investigated the mechanical behaviour of eggshell and coconut coir reinforced epoxy composite. Composites were fabricated by hand layup technique. Materials were subjected to tensile and compression test by taking different ratio of coconut coir and eggshell. They found that high compression strength was obtained for C5 composition due to the more quantity of eggshell and high tensile strength obtained for C1 composition due to more quantity of coconut fiber. It was concluded that tensile strength depends on coconut fiber and compression strength depends on eggshell concentrations.

Muthukumar and Lingadurai [22] investigated the mechanical properties of coconut shell dust and groundnut shell reinforced polymer matrix composite. The polymer matrix composite was developed using coconut shell powder (CSP) and groundnut shell powder (GSP) in different volume. Coconut shell particles and Groundnut shell particles reinforced polymer composite (CSP &GSPC) specimens were prepared by varying weight percentage of reinforcement material (i.e. 30, 40, 50, 60, 70 weight%) and matrix material. The tensile strength curve showed with an increase of filler volume the tensile strength goes on decreasing. The maximum flexural strength was obtained for the composite prepared with 50% CSP&GSP filled while the flexural strength was minimum for the composite prepared with 70% CSP&GSP.

Rudramurthy et al. [23] evaluated the properties of eco-friendly brake pad using coconut shell powder as a filler material. Keeping CSP constant (10-20 php) in brake pads as a filler composite material was fabricated using Phenol Formaldehyde (PF) and Epoxy Resin (ER – VP 401Grade) as matrices and varying proportions of Glass Fibre (GF) as reinforcement. Other constituent elements like coconut shell powder (CSP), Alumina (Al2O3), Calcium

Sulfate Dihydrate (CSD – Gypsum), Barium Sulphate (BS), Graphite and Antimony Sulphide (AS) were added to bring in other properties like thermal conductivity, thermal stability, strength etc. Experiments found that by using eco-friendly coconut shell powder the compressive strength, Wear rate, bonding and thermal resistivity increased.

Vignesh et al. [24] analysed the wear behaviour of coconut shell powder and coir fibre reinforced polymer composites. Pin-on-disc machine was used to investigate the abrasive wear property of the polymer matrix composites against 400μm grit size abrasive paper with the velocity of 2.0 m/s and the varying load conditions are applied like 5N, 10N, 15N, 20N and 25N. The result showed that the coefficient of friction increased with the increase of load in the coconut shell powder and coir fibre containing polymer matrix composites. It was observed that the wear rate increased with the increase in the applied load. The wear rate decreased with the addition of coconut shell powder and coir fibre.

Gopinath and Suresh [25] emphasized the utilization of industrial and agricultural waste to improve the performance and economics of composite to replace the wood and wood substitute. Composite was fabricated by taking fly ash, woven banana fibre reinforced in polyester resin. Experiments were done by design of export software taking different weight fraction of fly ash and polyester resin and 4 layer of woven fibre that was constant. Then composite specimens were subjected to tensile and flexural test. They found that maximum tensile strength of 20.10MPa and flexural strength of 69.60 MPa were obtained at 40 wt% fly ash. It was observed that the developed composite bears better properties than wood and wood substitutes.

Nagrajan et al. [26] experimented on partial replacement of cement with coconut shell ash in concrete. Coconut shells were collected and burnt in the open air (uncontrolled combustion) for three hours and that product is incinerated in muffle furnace at 800C for 6 hrs to produce coconut shell ash (CSA), which in turn was used as pozzolana in partial replacement of cement in concrete production. Concrete mortar cubes were produced using replacement levels of 0 and 5 percent of ordinary Portland cement with CSA. The Coconut Shell ash is used for the partial replacement of cement. Further, use of coconut shell ash reduced the consumption of cement. Reduction of cement usage reduced the production of cement which in turn cut the CO2 emissions. Further there was a reduction of compressive strength and density.

Durowaye et al. [27] investigated the mechanical properties of particulate coconut shell and palm fruit polyster composite. Coconut shell and palm fruit particles were separately and thoroughly blended with polyester resin. 1 gm of catalyst and 0.5g of accelerator were added to the mixture to achieve a good homogenous interfacial interaction. Particles of the reinforcement with different weight fractions (5, 10, 15, 20, 25 and 30) were added. The coconut shell particles reinforced polyester composite has the highest tensile strength value of 70MPa at 10wt % reinforcement and both the composites show increasing strain (ductility) as reinforcement concentration increases. Both flexural strength and modulus of the two composites increased with increase in reinforcement content at 10wt %. For coconut shell particulate polyester composite, the hardness value increases up to a maximum value of 208 BHN and the impact strength increases up to a maximum value of 4.76J at 10wt %. Beyond this reinforcement value, its impact strength decreases.

Akindapo et al. [28] evaluated the mechanical properties of coconut shell fibre as reinforcements in epoxy matrix. Coconut shell reinforced composite was prepared by compacting epoxy resin matrix with 10% - 30% volume fraction coconut shell fibres. The result shows that the hardness and tensile strength of the composite increase with increase in coconut shell fibre content while impact energy of the composite decreases with increase in the fibre content. Initially, the toughness was observed to increase as the ratios of fibre/epoxy and amine/epoxy increase but later dropped due to the presence of coconut shell powders which precipitate out of the solution and produce a weak composite. The prepared composite has an average hardness number of54.51 BHN. The average impact strength is 60Joules/mm^2. Scanning Electron Microscopy (SEM) of the composites indicated good interfacial interaction between the coconut shell fibre and the epoxy resin matrix.

Deshpande and Rangaswami et al. [29] evaluated the effect of Fillers on E-Glass/Jute Fibre Reinforced Epoxy Composites. The composites were prepared by keeping constant 50% volume fibres (40% glass fibre volume and 10% jute fibre volume). The filler material with varying concentrations of bone and coconut shell powder (0%, 10% and 15% volume) was added and fabrication was done at room temperature by hand lay-up technique. From the results it was found that the mechanical properties of the composites increased with the increase in filler content. Composites filled with 15% volume coconut shell powder exhibited maximum flexural strength, inter laminar shear strength, tensile modulus and hardness.

Choudhry et al. [30] in their work investigated the suitability of almond shell and coconut fibre as a renewable agricultural residue for manufacturing of bio composites t be used as a replacement for wood. Bio composite containing different weight percentage of almond shell particle and coconut fibre were mixed with epoxy resin and 0.5 weight % of Tricresyl phosphate. Thermal stability test and morphology (SEM) of the composite were determined. Results showed that increase in concentration of almond shell particles has contributed a marginal modification in the thermal stability of the biocomposite. Addition of cocconut fibre has contributed marginal control in the rate of decomposition. Addition of coconut fibre in the almond shell particle reinforced epoxy-based bio composite increased the thermal stability as compared to the pure almond shell particle based biocomposites.

Gelfuso et al [31] have investigated the vibration analysis of coconut shell reinforced polypropylene matrix composites. Polymers with coconut fibre composites were made by injection processing and mechanically characterized by tensile and dynamic testing. The fibre content ranged from 0 to 30wt%. The results of Young's modulus obtained from both methods decreased with fibre load and were nearly identical up to 15wt% of fibre, about 1.1GPa.Dynamic test performed to the composite based on coconut fibre-polypropylene shows that the increase in fibre content reduces the Loss Factor, Storage Factor and Loss Modulus. This behaviour can be attributed to lower elastic modulus of the fibre, as compared to the Polypropylene matrix. These materials can be applied to increase damping and reduce vibrations in structures.

Divya et al. [32] investigated the wear behaviour of coir reinforced treated and untreated hybrid composites. Three-body abrasive wear behaviour of different weight percentage (wt%) filled organo modified montmorillonite (oMMT) with constant wt% of treated and untreated coir sheath (CS) in unsaturated polyester (USP) resin were studied. Three-body abrasive wear of the hybrid composites were studied under different filler loading, treatment of the coir sheath and abrading distance. The results of the abrasive wear test revealed that the wear volume increases with increase in abrading distance and specific wear rate is high for the untreated composites (UTCs) compared to alkali treated composites (ATCs) and
Silane treated composites (STCs). STCs with 1 wt% oMMT-filled USP hybrid composite exhibited better abrasive wear resistance compared to UTCs and ATCs. Different wear

mechanisms were observed on the worn surfaces of the composites, including pitting, micro- and/or macro- cracks, as well as crack propagation of the matrix in the transverse direction.

Bongrade and Shinde [33] reviewed the manufacturing processes and mechanical properties of natural fibre reinforced composite. It was observed that with the use of natural fibre surface treatment of fibre has developed and implemented and also quantity of fibre matrix interface is improved.

Dinesh et al. [34] characterized the wear of sisal fiber reinforced epoxy composite material. Composite fabrication was done by taking 10,20 and 30% of sisal fiber as reinforcement using hand layup technique. Composites were subjected to wear test. They found that the wear resistance of the composite found to decrease with increased sisal fiber content. It was observed that 30% sisal fiber gave better wear resistance for orthopaedic implant.

Saleh et al. [35] in their work have evaluated the mechanical properties of epoxy resin with fly ash and silica fume as fillers. Composite polymeric material was prepared by using Epoxy resin as a major substance in work while the filler were the Fly ash and Silica fume. Composite panels were made by hand-made moulds has special dimensions according to the ASTM and adding each filler separately with different ratios as (10%, 20%, 30 %, 40% and 50%), then studying the mechanical properties of these material like tensile, hardness, compression, impact and bending properties. Their work showed that in fibre epoxy composites the addition of fly ash led to a reduction of the density and increase in modulus of composites.

Vignesh et al. [36] analysed the mechanical properties of alkaline treated coconut shell powder - polymer matrix composites. The coconut shell powder is treated with different levels of soaking time and concentration of alkali solutions. As a result of alkali treatment, modification is occurred in the surface of coconut shell powder. Coconut shell powder – Epoxy composite is fabricated by using hand layup process and the mechanical properties (Flexural, Impact strength, Hardness) were evaluated. These particles are having higher tensile strength, higher flexural strength good elasticity, and excellent resilience and in turn it would not induce a serious environmental problem like in plastics components.

Venkatesh [37] fabricated and tested coconut shell powder reinforced epoxy composites having different percentages weight fractions of coconut shell for different grain sizes using hand layup method. It was found that the density decreases as the weight percentage of fibre increases and with the increase of mesh size. As the reinforcement increases the hardness increases, the maximum value is obtained for composite prepared with the 30% shell dust of 240 mesh. Further the maximum tensile strength is obtained for the composite prepared with the 20wt % of 170 mesh coconut shell particulates.

Pattanaik et al. [38] studied effect of mixing time on mechanical properties of epoxy-fly ash composite. Different Samples were made with different mixing times i.e. 5, 10, 15, 20, 25 and 30 min. byultrasonic and magnetic process. They found that when mixing time increases strength of composite also increases. It was observed that the flexural strength in ultrasonic mixing condition was more than the magnetic mixing condition.

Srivastava and Maurya [39] characterized epoxy-based composite developed from biowaste material. Composites with 10, 20 and 30 wt % coconut shell powder epoxy composites were fabricated using hand layup technique. Tensile strength increases up to 20 wt % of filler reinforcement beyond that it decreases also the value of Young's modulus increased significantly. Composites show better resistance to abrasion and wear as hardness increases from 13 HV of epoxy to 35 HV in E-30CSP composite.

Kumar et al. [40] investigated on mechanical properties of CET (Coconut Shell, Egg shell powder, Teak wood flour) composite materials. It was concluded that when the CET composite materials of ratio (R2) i.e. the ratio of coconut shell powder: egg shell powder: teak wood powder in a specific proportion; exhibited best compression & impact Strength. CET composite materials are having good water resistance. When it is placed in Muff furnace and it is heated to 353^0C temperature it behaved like rubber.

Maheswaran et al. [41] characterized the natural fibre reinforced polymer composite. Composites were fabricated by using chemically untreated coconut and palm fibre with epoxy resin and chemically treated coconut and palm fibre with epoxy resin. The fibres are treated with 5% of sodium hydroxide (NaOH) for one hour and the specimens were fabricated by hand layup. The fibre content is kept constant to 30% of weight ratio. In the biomedical field, the use of natural fibre mixed with biodegradable and bio restorable polymer can produce joints and bone fixture to alleviate pain.

Kumar et al. [42] evaluated the mechanical properties on polyester typha fibre in composition of wood powder and coconut shell ash. Four filler concentrations (viz. 5 to 20 weight %) were fabricated, test results showed that tensile strength, elastic modulus, and micro-Hardness of the composite increases with increase in filler concentration, while percentage elongation and load at break decreases with increase in filler concentration from 5-20%**.**

2.2 Objectives

1. To prepare composites of coconut shell dust, fly ash and epoxy by hand layup technique using a suitable die developed in house
2. The weight fractions of the shell dust may be varied from 10, 15, and 20 % in the matrix of epoxy.
3. The weight fraction of fly ash will be kept constant at 5%.
4. Mechanical properties and water absorption behaviours are to be studied by preparing test specimens as per ASTM standards and results obtained will be discussed for examining the utility of these composites in engineering fields.

Chapter-3

3.1 Theoretical investigations

The composite is usually prepared based on calculation of weight fractions or Volume fractions of matrix or Filler material. Since random distribution of filler material has been considered various properties of the composite are found out following rule of mixtures as mentioned below.

WEIGHT FRACTION OF THE REINFORCEMENT:

$w_r = W_r / (W_r + W_m + W_f) *100$

WEIGHT FRACTION OF THE MATRIX:

$w_m = W_m / (W_r + W_m + W_f) *100$

Where,

W_r = Weight of reinforcement,

W_m = Weight of matrix and

W_f= Weight of filler.

Weight of the composite = $W_c = W_r + W_m + W_f$

Further as per rule of mixtures,

THE DENSITY OF THE COMPOSITE is obtained by

$\rho_c = \rho_m v_m + \rho_r v_r + \rho_f v_f$ Eqn.1

Where,

ρ_c = Density of the composite,

ρ_m = Density of the matrix,

ρ_r = Density of the reinforcement and

ρ_f= Density of the filler

v_m = Volume fraction of the matrix,

v_r = Volume fraction of the reinforcement and

v_f= Volume fraction of filler.

Here $v_m = V_m / (V_m + V_r + V_f + V_v) *100$,

$v_r = V_r / (V_m + V_r + V_f + V_v)*100$

VOLUME OF THE COMPOSITE

$V_c = V_m + V_r + V_f + V_v$

Where ,

V_m = Volume of the matrix,

V_r = Volume of the reinforcement,

V_f= Volume of filler and

V_v= Volume of void.

Assuming modulus reinforcing efficiency as unity and as per rule of mixtures:

MODULUS OF ELASTICITY OF THE COMPOSITE:

$E_c = E_m v_m + E_r v_r + E_f v_f$ Eqn.2

Where,
E_r= Modulus of elasticity of reinforcement,
E_m = Modulus of elasticity of Matrix and
E_f=Modulus of elasticity of filler.

STRENGTH OF THE COMPOSITE
$\sigma_c = \sigma_m v_m + \sigma_r v_r + \sigma_f v_f$ Eqn.3

Where,
σ_r = Strength of the reinforcement,
σ_m = Strength of the matrix and
σ_f=Strength of Filler.

Table 3.1 : Properties of epoxy

Properties	Value
Density (gm/cc)	1.2
Elastic modulus (GPa)	20
Tensile strength (MPa)	75

Table 3.2 : Properties of coconut shell dust

Properties	Value
Density (gm/cc)	0.6
Elastic modulus (GPa)	521
Tensile strength (MPa)	18.03

Table 3.3 : Properties of fly ash

Bulk density(gm/cc)	0.9-1.33
Specific gravity	1.6-2.6
Plasticity	Lower or non plastic
Compression index(C_C)	0.05-0.4
Compressive strength	43MPa

The properties of epoxy, coconut shell dust and fly ash are shown in Table 3.1, 3.2 and 3.3 respectively. The properties of the composite have been found out using above relations of rule of mixtures as indicated in Table 3.4.

Table 3.4 Properties of composites

Composites	Density (gm/cc)	Elastic modulus (GPa)	Tensile strength (MPa)
Specimen–A	1.125	69.1	63.403
Specimen-B	1.095	94.15	60.5545
Specimen-C	1.065	119.2	57.706

Specimen A – Composite with 10 % shell dust
Specimen- B – Composite with 15 % shell dust
Specimen-C - Composite with 20 % shell dust

4.1 Experimental investigations

Materials and methods:
The following materials have been collected from different sources for fabrication of the composite with varying coconut shell content (10, 15 and 20 %) and constant fly ash percentage (5%) by weight.

Fly ash
Sample Fly ash (Fig.4.1) was collected from NTPC and tested in R &D Laboratory of NTPC. The various constituents present are as in Table 4.1.

Fig.4.1 Sample of fly ash

Table 4.1 Constituents of fly ash

Sl.No.	Testing parameter	Test values (%)
1	Loss of ignition	1.2
2	Silica	56.5
3	Ferris oxide	11.0
4	Alumina(Al_2O_3)	17.7
5	Magnesia	5.4
6	Calcium oxide	3.2

Coconut shell dust
Coconut shell (Fig .4.2) obtained from Local market of Talcher, Odisha. It was crushed to desired grain size in Pulveriser at IMMT, BBSR. The shell dust (Fig.4.3) was used in random orientation in epoxy matrix with grain sizes between 200-500 µm.

Fig.4.2 Coconut shells

Fig.4.3Coconut shell dust

Table 4.2 Properties of coconut shell powder

Lignin	29.4%
Pentosans	27.7 %
Cellulose	26.6%
Moisture	8%
Solvent extractives	4.2%
Uronic anhydrides	3.5%
Ash	0.6%

Composite Preparation

A wooden mould of dimension (300 x 150 x30) mm^3as shown in Fig. 4.4 was used for casting the composite sheet.

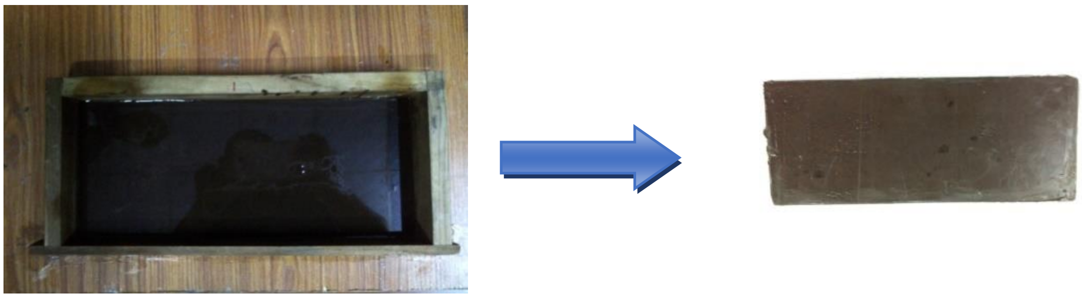

Fig. 4.4 Casting of the composites

The samples have been manufactured with different weight fractions of coconut shell dust i.e. 10, 15 and 20 % respectively. The size of coconut shell dust was measured by sieve shaker and found to be 212 µm. For constant weight fraction of Fly ash, (5%) resin and hardener were thoroughly mixed with gentle stirring to minimize air entrapment. The epoxy and hardener were mixed in 10:1 ratio. The coconut shell dust was then added to the slurry for different weight ratios and mixed thoroughly. The slurry was then poured in to the mould box till the required thickness is achieved. For quick and easy removal of composite sheets, silicon spray was applied at the inner surface of the mould. Care is taken to avoid formation of air bubbles. The mould was allowed to cure at room temperature for 24 hrs. After 24 hrs the samples were taken out of the mould, cut into different sizes for further experimentation as per standard.

Test samples

The samples are cut from the laminate according to reference standard of ASTM shown in Fig. 4.5 and Table 4.3.

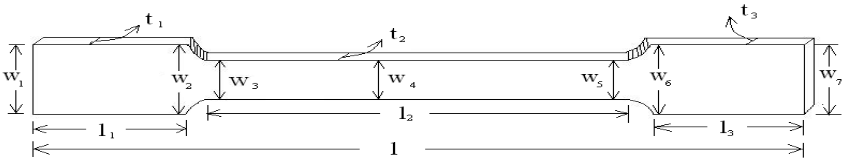

Fig. 4.5 ASTM standard specimen

Table 4.3 Dimensions of standard specimen

Specimen	l_1	l_2	l_3	l	w_1	w_2	w_3	w_4	w_5	w_6	w_7	t_1	t_2	t_3
Standard	**42**	**100**	**42**	**204**	**25**	**25**	**13**	**13**	**13**	**25**	**25**	**-**	**-**	**-**

After preparing the specimens manually the dimensions were measured and the results are interpreted in Table. 4.4.

(a) **(b)** **(c)**

Fig. 4.6 Actual specimens prepared. (a, b, c as 10, 15, 20% of CSP)

Table.4.4. Actual specimen dimensions

SPECIMEN	W_1 in mm	W_4 in mm	W_6 in mm	t_1 in mm	t_2 in mm	t_3 in mm	L_1 in mm	L_2 in mm	L_3 in mm
10% CSP 1	21.36	14.96	25.43	4.1003	4.4501	4.4312	43.126	103.016	50.134
10% CSP 2	23.24	14.62	25.89	4.1304	4.3612	4.3612	40.314	103.036	49.316
10% CSP 3	23.96	14.87	26.24	4.1187	4.3955	4.3263	43.125	102.104	49.831
15% CSP 1	27.63	14.32	28.36	5.1421	5.122	5.195	40.28	103.14	44.96
15% CSP 2	26.93	15.17	29.27	5.1786	5.1286	5.248	43.21	102.68	45.89
15% CSP 3	27.28	14.96	28.74	5.1692	5.1315	5.163	41.24	105.12	45.21
20% CSP 1	27.31	14.72	27.67	5.0036	5.002	4.9836	44.21	103.218	43.234
20% CSP 2	29.43	14.98	28.12	5.0071	5.2132	5.1249	47.82	106.824	45.682
20% CSP 3	28.68	14.52	27.97	5.0086	5.1426	5.0834	44.98	105.132	47.891

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TENSILE TESTING.

The tensile test has been carried out at CIPET, BBSR. Using Universal Testing Machine (Fig. 4.7) having specification:

Make: ADMET expert 2600 series

Model no.-2653, Load capacity-50KN, Maximum speed-508 mm/min, Minimum speed-.00005 mm/min, Maximum force at full speed-50 KN, Total cross head travel 1092 mm, Space between columns-558 mm, Height-2159 mm,Weidth-1041 mm , Depth-584 mm, Weight-730 Kgf

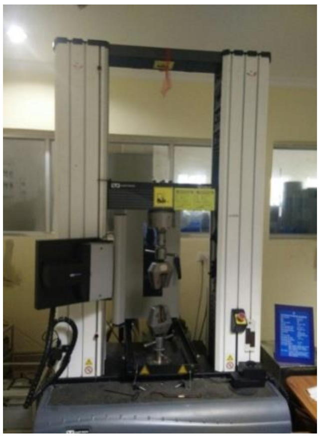

Fig.4.7 UTM for tensile test

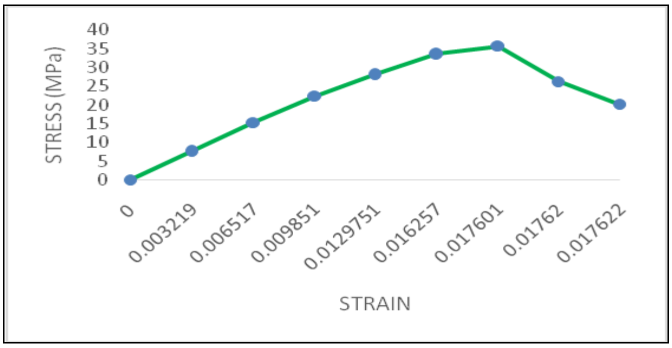

Fig.4.8 Stress-strain curve for composite with 10% CSP

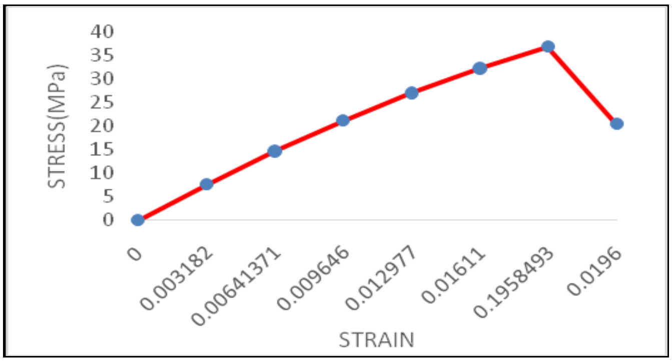

Fig. 4.9 Stress-strain curve for composite with 15% CSP

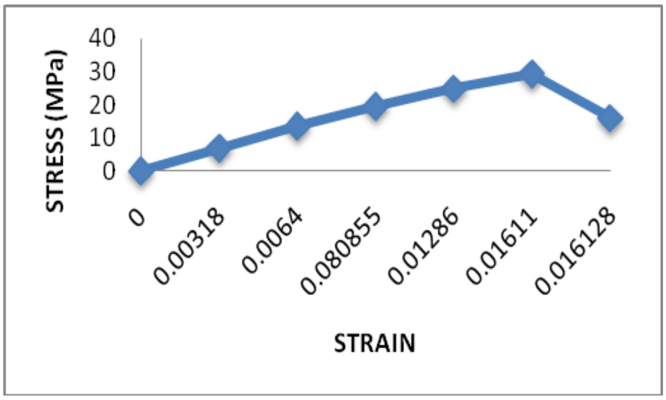

Fig.4.10 Stress-strain curve for composite with 20% CSP

Table 4.5 Tensile Strength of specimens

Samples	Tensile Strength in MPa
10% csp	35.63
15% csp	36.99
20% csp	29.35

The stress –strain curves for all the composites have been plotted in Fig. 4.8, 4.9 and 4.10. The tensile strength of each specimen with varying percentages of shell dust has been also indicated in Table 4.5.

WATER ABSORPTION TEST:

The water absorption test has been carried out by soaking the (2”x2”) circular samples (Fig.4.11) in water and taking percentage of weight gain after 24hrs and 48hrs respectively as per standard ASTMD 570-98 in the Table 4.6 and 4.7. The samples have been shown in Fig. 4.11 a, b, c. (10, 15 and 20% CSP respectively)

(a) **(b)** **(c)**

Fig.4.11. Water Absorption Test Samples.

Table 4.6 Water absorption test results after 24 hrs

SPECIMEN	Dry weight in gm. (W1)	Weight after 24 hr. of water absorption (W2)	Difference in gm. (W2- W1)	% gain in weight {(W2- W1)/ (W1)} x 100
SPECIMEN A (10%CSP)	9.8101	9.8724	0.0623	0.6350
SPECIMEN B (10%CSP)	12.1696	12.2324	0.0628	0.5160
SPECIMEN C (15%CSP)	9.4052	9.4567	0.1515	1.5044
SPECIMEN D (15%CSP)	10.0741	10.1324	0.0583	0.5787
SPECIMEN E (20%CSP)	13.2826	13.4016	0.1190	0.8959
SPECIMEN F (20%CSP)	10.4433	10.6079	0.1646	1.5761

Table 4.7 Water absorption test results after 48 hrs

SPECIMEN	Dry weight in gm. (W1)	Weight after 48 hr. of water absorption (W2)	Difference in gm. (W2- W1)	% gain in weight {(W2- W1)/ (W1)} x 100
SPECIMEN A (10%CSP)	9.8101	9.8934	0.0833	0.8491
SPECIMEN B (10%CSP)	12.1696	12.3467	0.1771	1.4552
SPECIMEN C (15%CSP)	9.4052	9.5167	0.1115	1.1855
SPECIMEN D (15%CSP)	10.0741	10.2341	0.1600	1.5882
SPECIMEN E (20%CSP)	13.2826	13.5217	0.2391	1.8010
SPECIMEN F (20%CSP)	10.4433	10.7879	0.3446	3.2997

MICRO HARDNESS TEST:

The micro hardness test has been carried out in the Vicker’s hardness testing machine (Fig. 4.12). Results show that hardness increases with increase in % of CSP as indicated in Table 4.8.

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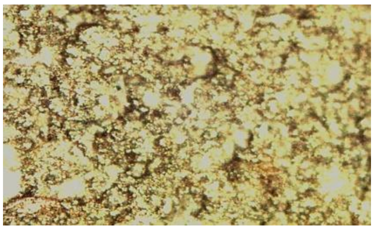
Fig.4.12. Vicker's Hardness Testing Machine.

Table 4.8 Hardness Test Results.

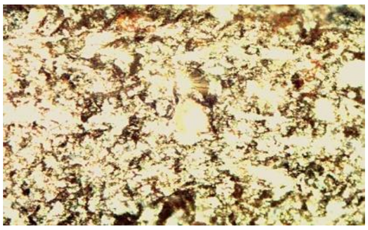
Specimens	First reading	Second reading	Third reading	Average(VHN)
Sp-1(10%CSP)	13.727	17.990	15.944	15.880
Sp-2(15%CSP)	16.471	17.715	14.108	16.098
Sp-3(20%CSP)	16.422	17.338	16.880	16.880

MICROSTRUCTURE OF SAMPLES:

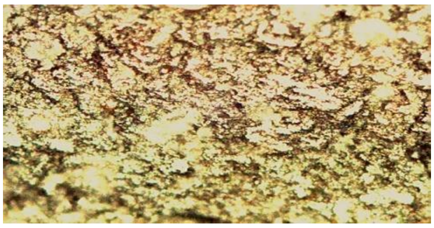
Microstructures of the specimens have been examined under optical microscope with 10x magnification. The structures have been shown in Fig. 4.13 a, b and c. The analysis showed better uniform distribution of reinforcement in sample with 15 % CSP compared to others.



(a)



(b)



(c)

Fig4.13 Microstructure analysis. a- 10%, b- 15%, c- 20 %

Discussion

Out of the results obtained as above it may be concluded that the tensile strength of the composites is increasing with increase in percentage of shell dust but further increase results in reduction of strength as in case of 20 % sample. As far as water absorption capacity is concerned all the composites have shown excellent properties as the gain in weight after 24 hrs is much less than recommended as per standard (Less than 2%). However while conducting the tests for 48 hrs it is seen that the water absorption capacity of one of the specimen with 20 % shell dust is little bit higher than recommended value. This might be due to higher content of shell dust. With increase in shell dust content the hardness is increasing for all the three test specimens meaning thereby the material is becoming more brittle.

Chapter-5

5.1 Conclusions

1. From the tensile test it is observed that as the percentage of coconut shell dust increases the tensile strength of the samples is increases up to 15% & then decreases for 20%
2. Further with increase in shell dust particles the hardness of the composites is increasing
3. From the water absorption test as the gain in weight is less than 2% hence moisture absorption is negligible.
4. It is also seen from the micro structure analysis that the shell dust is evenly distributed in the matrix. Fly ash presence is not significantly observable due to low magnification.
5. Because of this even distribution of filler in the epoxy matrix probably the hardness and strength values are quite optimum.
6. Out of all these samples, may be the sample with 15% of shell dust will be best suitable for mechanical applications.

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