# STUDY OF MECHANICAL PROPERTIES OF COCONUT SHELL PARTICLE AND COIR FIBRE REINFORCED EPOXY COMPOSITE

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## Abstract

Coconut coir fibre and shell particle reinforced epoxy based composite has proven a very promising material for structural application where wood and plastics were used. It has well mechanical property. Following has been concluded more specifically for this coir and particle reinforced composite. Density of this composite developed using only shell particle is low and order of 1.171g/cm$^3$ for 35wt% of shell particle changes from 28% to 35%. Here it is possible to comment that density decreases with increase of wt% of particle. 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 particle for composite of particle only. Water absorption increases with increase of coir wt% in coir and particle composite. Density of this does not increase appreciably with increase of particle content with coir. This does not increase up to mark for both only particle based and coir & particle Composites. Uniform dispersion of coconut shell particle and coir is found. So, mixing and adhesion among particles and coir fibre is proper. Disorder is negligible.

Tensile properties: Ultimate strength equal to 30 MPa and modulus of elasticity equal to 856 MPa is achieved for 20%wt shell particle reinforced composite. Ultimate strength of 48 MPa and modulus of elasticity of 920 MPa are achieved for 18%wt shell particle & 2%wt coir fibre and 17%wt shell particle & 3%wt coir fibre reinforced composite respectively. Elasticity decreases with increase of coir and ultimate strength decreases with increases with particle wt%. Ultimate strength and modulus of elasticity increase with addition of coir. Compressive Properties: Maximum ultimate strength and maximum modulus of elasticity is 88 MPa and 698 MPa for 30%wt particle reinforcement only. Maximum ultimate strength and maximum modulus of elasticity is 78 MPa and 658 MPa for 28%wt particle with 2%wt coir fibre reinforcement. So, compressive reduces with coir fibre. Flexural strength of 63.45 MPa is measured for 35%wt shell particle reinforcement. This strength decreases with the addition of coir fibre. Fracture toughness decreases with increase of wt% of particle for only shell particle reinforced composite. It increases minutely with increase of coir wt%. Rockwell hardness number increases with increase of wt% of coconut shell particle and reduces with increase of coir fibre content. Its value maximum on 30%wt of reinforcement with 2%wt of coir fibre.

**Keywords:** Coconut Shell Particles; Mechanical Properties; Composite; Morphology; coir fibre.

1.1 Introduction: India endowed with an abundant availability of natural fiber such as Jute, Coir, Sisal,Pineapple, Ramie, Bamboo, Banana, Bagasse etc. has focused on the development of natural fiber composites primarily to explore value-added application avenues. Such natural fiber composites are well suited as wood substitutes in the housing and construction sector. The development of natural fiber composites in India is based on two pronged strategy of preventing depletion of forest resources as well as ensuring good economic returns for the cultivation of natural fibers. Natural fillers and fibers reinforced thermoplastic composite have successfully proven their high qualities in various fields of technical application. Over past two decades, natural fibers have received considerable attention as a substitute for synthetic fiber reinforcements in plastics. As replacements for conventional synthetic fibers like aramid and glass fibers are increasingly used for reinforcement in the thermoplastic due to their

- low density,
- good thermal insulation and mechanical properties,
- reduced tool wear,
- Unlimited availability, low price, and problem free disposal.

Natural fibers offer economical and environmental advantages over traditional inorganic reinforcements and fillers. As a result of these advantages, natural fiber reinforced thermoplastic composite are gaining popularity in automotive components. They are used as a replacement for glass fiber in automotive components. They are used as trim parts in dashboards, door panels, parcel shelves, seat cushions, and backrest and cabin linings. Several types of natural fibers such as kenaf, jute,

sisal,flax, and hemp were studied as reinforcement for thermoplastic such as polypropylene(PP) and polyethylene. Among natural fibers, the coir fiber has remarkable interest in the automotive industry wing to its hard-wearing quality and high hardness(not fradile like glass fiber), good acoustic distance, moth-proof, not toxic, resistant to microbial and fungi degradation, and not easily combustible. The coir fibers are also more resistant to moisture than other natural fibers and withstand heat and salt water. Epoxy resins (ER) are one of the most important classes of thermosetting polymers which are widely used as matrices for fiber-reinforced composite materials and as structural adhesives. They are amorphous, highly cross linked polymers and this structure results in these materials possessing various desirable properties such as high tensile strength and modulus, uncomplicated processing, good thermal and chemical resistance, and dimensional stability. However, it leads to low toughness and poor crack resistance, which should be upgraded before they can be considered many end-use applications. One of the most successful methods of improving the toughness of epoxy resin is to incorporate a second phase of dispersed rubbery particles into the cross linked polymer. Because the addition of rubbery materials to epoxy resins has been shown to lower their glass transition temperature (Tg) and thermal and oxidative stability, high performance thermoplastic have been employed to toughen epoxy resin in recent years. Coconut fruit is very useful for our life. It not only gives us fruit to eat but left out of fruit is very useful for developing natural composites. Coconut shell is one of the most important natural fillers produced in tropical countries like Malaysia, Indonesia, Thailand, and Srilanka. Many works have been devoted to use of other natural fillers in composite in recent past and coconut shell filler and husk fiber are potential candidates for the development of new composites because of their high strength and modulus properties. The objective of this work is to study the mechanical behavior of epoxy composite based on coconut husk fiber and shell filler particles. Over the last thirty years composite materials, plastics and ceramics have been the dominant emerging materials. The volume and number of applications of composite materials have grown steadily, penetrating and conquering new markets relentlessly. Modern composite materials constitute a significant proportion of the engineered materials market ranging from everyday products to sophisticated niche applications. While composites have already proven their worth as weight-saving materials, the current challenge is to make them cost effective. The efforts to produce economically attractive composite components have resulted in several innovative manufacturing techniques currently being used in the composites industry. It is obvious, especially for composites, that the improvement in manufacturing technology alone is not enough to overcome the cost hurdle. It is essential that there be an integrated effort in design, material, process, tooling, quality assurance, manufacturing, and even program management for composites to become competitive with metals.

The most widely used meaning is the following one, which has been stated by Jartiz (1965) "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 weakness of this definition resided in the fact that it allows one to classify among the composites any mixture of materials without indicating either its specificity or the laws which should given it which distinguishes it from other very banal, meaningless mixtures.

Kelly (1967) very clearly stresses that the composites should not be regarded simple as a combination of two materials. In the broader significance; the combination has its own distinctive properties. In terms of strength to resistance to heat or some other desirable quality, it is better than either of the components alone or radically different from either of them.

Beghezan(1966) defines as "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", in order to obtain improved materials.

Van Suchetclan (1972) explains composite materials as heterogeneous materials consisting of two or more solid phases, which are in intimate contact with each other on a microscopic scale. They can be also considered as homogeneous materials on a microscopic scale in the sense that any portion of it will have the same physical property.

1.2 The preset investigation is aimed with the following objectives.

Objective of the present investigation

- Objective of the present investigation is to develop a natural composite material containing different percentage of coconut powder and coconut fiber in an epoxy resin matrix.
- To study the microscopic structure and dispersion of filler material by scanning electron microscopy analysis and to established structure properties correlation, if any.
- To determine the mechanical properties of composite material like hardness, tensile strength, compressive strength, impact strength, etc.

1.3 Approach

There are mainly three major areas used in the present investigation i.e. material science, material testing & microscopic investigation. Material science & testing is used to developed the composite material and determine the mechanical properties such as tensile strength, compressive strength, hardness, impact strength, dimensional stability and water absorption etc. Microscopic investigation is used to determine the microstructure of the developed composite material. It is

also used to see dispersion and interaction of the filler material within the matrix.

1.4 Composite preparation & Methodology

Its deals with the preparation of material and preparation of samples for number of tests required for properties. Following are the methods used for mechanical properties and others.

1.5 Material , Matrix Material , Epoxy Resin

Epoxy resin is widely used in industrial application because of their high strength and mechanical adhesiveness characteristic. Brush Bond makes epoxy resin SY-12(319) is a liquid solvent free epoxy resin. It has versatile applications in technical and industrial applications. Curing takes place at room temperature and atmospheric pressure after addition of hardener. Cure shrinkage is generally very less and may be still further reduced by the addition of fillers. The resin can be coloured easily. Fully cured mixture has excellent mechanical, thermal properties and atmospheric attack. The castings have good ageing characteristics. It is odourless, tasteless and completely non-toxic. Resin can be stored for at least a year if they are stored under cool, dry conditions in the original containers. It is also good solvent and has good chemical resistance over a wide range of temperature. In the present investigation SY-12(319) purchased from M/s RESINOVA CHEMIE Limited, Kanpur India has been used as matrix material. The epoxy used is colourless, odourless and completely nontoxic.

1.6 Hardener

Hardener SY31(B) is a yellowish-green liquid. Hardener SY31(B) purchased from M/s RESINOVA CHEMIE limited, Kanpur, India has been used as curing agent. In the present investigation 8 % wt/wt has been used in all material developed. The weight percentage of hardener used in the present investigation is as per recommendation of Singh V.K. (2002), figure 1.1.

1.6.1 Reinforcing Element:

Coconut shell is used as reinforcing material for present investigation.

1.6.2 Coconut shell particle and its preparation:

Shells were collected and crushed in to small pieces by manual hammering the shell then it was fed into crushing machine to convert it into powder form. This powder was dried to remove moisture.

Fig.1.1 Coconut shell

Fig.1.2 Coconut shell particle

1.6.3 Coconut fiber and its preparation:

Coconut fruit is covered inside coconut coir fiber. Fibers are very long and have good tensile properties. It is assumed that this fiber covering gives damping strength to the coconut fruit for protecting while falling from height. Fibers used were collected and milled to get fine form of coir fiber.

Fig.1.3 Coconut coir fiber

1.7 Optimization of weight percentage:

Hardener -As per the figure 1.2 Singh [2002] it is seen that % elongation, yield strength and young modulus value are maximum, when 8 %( by weight) hardener (HY-951) is mixed with resin (CY-230). It shows that 8 % to 9 % of hardener is optimum with respect to mechanical properties.

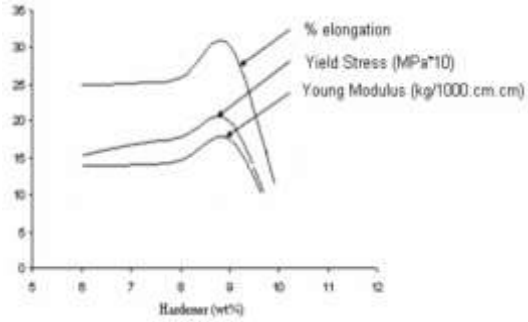


Fig.1.4 Effect of wt % of hardener (HY-951) on mechanical properties (Singh, 2009)

1.8 Method of casting:

The solution obtained by mixing silica and acrylic rubber in resin is kept in the furnace at a temperature of 90 ± 10 °C for two hours as per the recommendation of Singh V.K., 2003. The electric furnace (Temperature Range 0-6000C) used for this purpose. At each interval of 30 minutes the solution have been taken out from the furnace and remixed by mechanical stirrer at high speed. After two hours the whole solution is taken out and allowed to cool to a temperature of 45°C. When a temperature of 45°C has been attained the hardener HY-951 is mixed immediately. Due to addition of hardener high viscous solution has been obtained which is again mixed mechanically by high speed mechanical stirrer. The viscous solution so obtained is poured in to different moulds for sample preparation for tensile, compression, wear and impact testing.

1.9 Method of specimen preparation:

The viscous solution obtained from resin, hardener and filler materials is poured in to different moulds as shown in figure 1.6 for specimen preparation for tensile, compression, wear and impact testing. Flat plates as required for tensile test, hardness test and for scanning electron microscopy testing are prepared in mould shown in figure 1.5.Tensile test specimens were prepared on milling machine as per ISO 527-2(1996).

Fig.1.5 Oven for heating mixture

Fig.1.6(a) Mould for plate casting

Circular specimen used for wear and compression test, are prepared in mould. Rectangular specimens are required for Impact testing. For this purpose, material is casted in a rectangular box. The final dimensions of the impact testing specimen are prepared on shaper as per machine standard.

Fig1.7 (b) casted plates

Fig. 1.8(c) casted plates

1.9 Curing

Recommended curing conditions suitable for a mixture of 90-92 parts by weight of epoxy and 8-10 parts by weight of hardener. Slow curing or increasing curing temperature gives slightly better thermal stability and thus constant mechanical and electrical properties over a large range of temperatures.

| Curing temperature (°C) | Minimum curing time |
|---|---|
| 20 | 14-24 hr |
| 40 | 12-16 hr |
| 60 | 5-7 hr |
| 70 | 1-3 hr |
| 100 | 10-30 min |
| 130 | 5-10 min |

Table 1.1: Curing temperature and time for epoxy with hardener material

2.1 Tests Procedure

Though there are number of mechanical tests, which are necessary to determine the suitability of a metal, the following important tests have been performed in the present investigation.

1. Tensile test at different strain rate of 0.01, 0.1, 1.0, 10.0 and 100.0 mm/sec.
2. Compression test at different strain rate of 0.01, 0.1, 1.0, and 10.0 mm/min.
3. Hardness test
4. Bending strength test
5. Fracture toughness test

Different specimens for tensile, compression testing, fracture and hardness testing were made as per ISO standard and as per directed by different testing machine.

Tensile Test: In the present investigation all the tensile tests are conducted as per ISO test procedure.

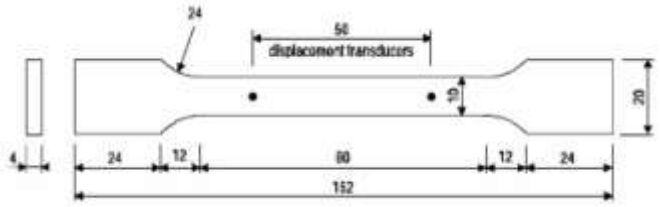


Fig1.9: Specimen geometry for tensile test according to ISO 527-2 (1996)

Compression test: The compression test is simply the opposite of the tension test with respect to the direction of loading. In some materials such as brittle and fibrous ones, the tensile strength is considerably different from compressive strength.

All the compression tests of casted hybrid composites are conducted on 100 kN servo hydraulic UTM machine (model 2008, ADMET make). Specimen configuration is shown in figure 1.9. All tests are conducted aspect ratio of 2.0. All tests are conducted under displacement mode of control. The displacement rates are 0.01mm/sec, 0.1mm/sec, 1mm/sec, 10mm/sec and 100mm/sec.

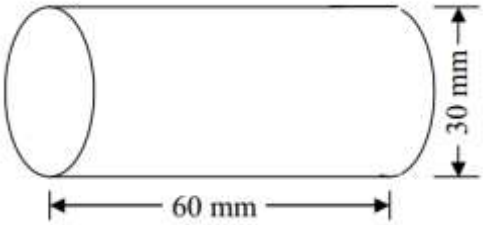


Fig2.1: Specimen geometry for compression test according to ISO-1708, 1960.

Three point bending test: Three point bending test is widely used for characterizing mechanical behavior of materials. A small of rectangular cross section is placed on two supports. A displacement is applied at the centre and the resulting force is recorded. This test is usually performed on a universal testing machine (UTM). For composite materials, the resulting load-deflection curve is dependent on the strain rate experienced by the specimen, as the strain rate increases, the modulus increases due to visco elastic effects. The load at yield also increases, it is therefore often necessary to include rate effects in material models for composite materials. To simulate impact situations, data at high strain rate is also needed. The UTM is usually too slow for this kind of test.2.2 Experimental set up

The experiments are performed on a composite material specimen. The span used is 20 mm. The stress-strain curves are calculated using a linear elastic approach.

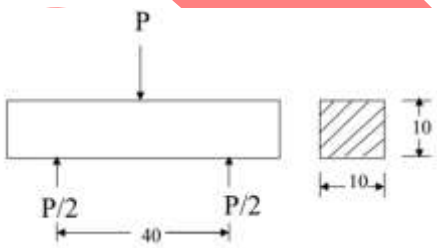


Fig.2.2: Three point bending test specimen

Because of application of load at three points it is known as three point bending test, as we can see in the above figure.

Sample size

Length=60 mm, depth=10 mm, width=10 mm, span length= 40 mm

Formulae used for calculation

Flexural stress = $3PL/2bd^2$

Where P=load at given point (N)

L=support

b=width (mm)

d=depth (mm)

Rockwell hardness test:

The Rockwell Hardness test also uses a machine to apply a specific load and then measure the depth of the resulting impression. The indenter may either be a steel ball of some specified diameter or a spherical diamond-tipped cone of 120° angle and 0.2 mm tip radius, called a brale. A minor load of 10 kg is first applied, which causes a small initial penetration to seat the indenter and remove the effects of any surface irregularities. T hen, the dial is set to zero and the major load is

applied. Upon removal of the major load, the depth reading is taken while the minor load is still on. The hardness number may then be read directly from the scale. The indenter and the test load used determine the hardness scale that is used (A, B, C, etc). For soft materials such as copper alloys, soft steel, and aluminium alloys a 1/16" diameter steel ball is used with a 10 kgf load and the hardness is read on the "B" scale. In testing harder materials, hard cast iron and many steel alloys, a 1 20 degrees diamond cone is used with up to a 15 kg load and the hardness is read on the "C" scale. There are several Rockwell scales other than the "B" & "C" scales, (which are called the common scales). A properly reported Rockwell value will have the hardness number followed by "HR" (Hardness Rockwell) and the scale letter. For example, 50 HRB indicates that the material has a hardness reading of 50 on the B scale.

A- Cemented carbides, thin steel and shallow case hardened steel

B -Copper alloys, soft steels, aluminium alloys, malleable iron, etc.

C -Steel, hard cast irons, paralytic malleable iron, titanium, deep case hardened steel and other materials harder than B 100

D -Thin steel and medium case hardened steel and paralytic malleable iron

E -Cast iron, aluminium and magnesium alloys, bearing metals

F -Annealed copper alloys, thin soft sheet metals

G -Phosphor bronze, beryllium copper, malleable irons

H -Aluminum, zinc, lead K, L, M, P, R, S, V -Bearing metals and other very soft or thin materials,including plastics.

Fracture Toughness test:

Linear-Elastic Plane-Strain Fracture Toughness KIC of Metallic Materials is most often tested according to ASTM E 399 specifications. The KIC test or KIC, or K1C, as it is also known, is used to determine the fracture toughness of metallic materials. Fracture toughness is an indication of the amount of stress required to propagate a pre-existing flaw. It is a very important material property since the occurrence of flaws is not completely avoidable in the processing, fabrication, or service of a material/component. Flaws may appear as cracks, voids, metallurgical inclusions, weld defects, design discontinuities, or some combination thereof. Since engineers can never be totally sure that a material is flaw free, it is common practice to assume that a flaw of some chosen size will be present in some number of components and use the linear elastic fracture mechanics (LEFM) approach to design critical components. This approach uses the flaw size and features, component geometry, loading conditions and the material property called fracture toughness to evaluate the ability of a component containing a flaw to resist fracture.A critical evaluation Plane Strain Fracture Toughness (KIc) quantifies the resistance of a metal to brittle fracture under various combinations of stress and critical flaw size. It is also a critical material property. A fracture toughness test characterizes the resistance of a material to fracture in a neutral environment and in the presence of a sharp crack.

2.3 Sample sizes for experiment

The test consists of fracturing a specimen of a specified geometry that has had a sharp defect or fatigue precrack already introduced into it.

Length=60mm

Width=10mm, Depth=10mm

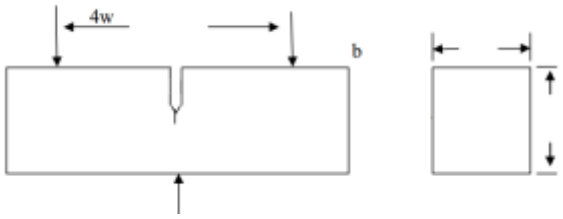


Fig.2.3: Specimen for fracture toughness test

Formula used to calculate fracture toughness KIc

$$K_Q = \frac{3PL\sqrt{a}}{2bw^2} f(a/w)$$

Where $f(a/w) = 1.93 - 3.07\left(\frac{a}{w}\right) + 14.53\left(\frac{a}{w}\right)^2 - 25.11\left(\frac{a}{w}\right)^3 + 25.80\left(\frac{a}{w}\right)^4$

P= load (N)

b= width (mm)

a= notch depth (mm)

L= span length (mm)

w= depth (mm)

Fig.2.4 samples in water for water absorption test

Procedure for measuring density:

First we weighted the mass of the specimen whose size was (15mm*10mm*10mm), and the volume of the specimen is known from the dimensions of the specimen.

Formula used- Density = weight/volume

Measurement water absorption capacity:

Weigh the specimen of sized (15mm*10mm*10mm) then after that dipped the specimen in to water for 48 hours, after 48 hrs we weighted the specimen again, the difference between weight of specimen before and after the absorption indicates the water absorption capacity of the casting.

2.4 Morphology

The morphology of composite material is determined by the way the organic and inorganic compounds are mixed. Since this mixing is on a nano scale, this can best be studied by scanning electron microscopy (SEM) or transmission electron microscopy (TEM). In general SEM shows features in the micrometer range where TEM visualized a nanometre range, but the sizes of structures visible with both methods depend also on the contrast in the samples. In SEM both surfaces and cross-sections of coatings can be studied. In general, though, the surface of the coating is not representative for the coating as a whole and therefore the study of cross-sections is preferred. Also with TEM cross-sections of the coatings were studied. Important for the preparation of samples for both techniques is not to damage the object to be studied: a thin coating layer supported by a thick substrate, during preparation.

2.4.1 SEM:

To obtain the topographical contrast of the morphology of the organic-inorganic samples they are etched. With this technique the 'weakest' compound is removed, while the 'strongest' compound remains at the surface, thus creating a topographical difference. The organic phase is etched away, without affecting inorganic particles present in the material. The inorganic phase is much better visible when etching is used. The scanning electron micrograph study generally performed by scanning electron microscope, which uses electron to form an image with high resolution or magnification. In the present investigation SEM studies has been done to see the dispersion of coconut shell particle and coir fibre. The images are obtained through microscopic investigation. To obtained the scanning electrons micrographs square samples are cut from the cast material and are gold coated to avoid the artifacts associated with sample charging and then placed inside a chamber in which an electron beam is fall on the material. The accelerated voltage was 20 kV. Different images are taken at various magnification ranges.

2.5 Results and discussion:

Appearance: Appearance of coconut particle reinforced composite for various wt % are found to be opaque and dark brown in colour. Coconut powder and husk fibre can be seen in cross sectional view as well as in transverse view. Very close view can be seen from SEM.

2.5.1 Density

Density is one of the most important mechanical properties of the particle board material. The density of coconut shell particle reinforced composite and coconut shell particle & coir fibre reinforced composite for various wt % of particle and coir fibre are presented in Table 1.2 figure No. 2.5, Table 1.3 and figure No. 2.6.

Table 1.2: Density of coconut shell particle reinforced composite

| S. No. | Coconut particle (20 wt %) ($gm/cm^3$) | Coconut particle (25 wt %) ($gm/cm^3$) | Coconut particle (30 wt %) ($gm/cm^3$) | Coconut particle (35 wt %) ($gm/cm^3$) |
|---|---|---|---|---|
| 1 | 1.293 | 1.287 | 1.285 | 1.170 |
| 2 | 1.287 | 1.283 | 1.280 | 1.171 |
| 3 | 1.285 | 1.278 | 1.277 | 1.173 |
| **Mean** | **1.288** | **1.283** | **1.280** | **1.171** |

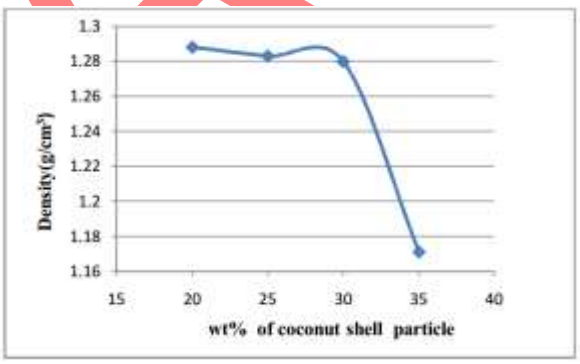


Fig.2.5: density variation w.r.t. wt% of coconut shell particle

In the present investigation density of Coconut particle filled composite are found be 1.288 $gm/cm^3$ for 20wt %, 1.283 $gm/cm^3$ for 25wt%, 1.280 $gm/cm^3$, for 30wt% and 1.171 $gm/cm^3$ for 35wt%.

Table 1.3: Density of coconut shell particle and coir fiber reinforced composite in g/cm$^3$

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| S.No. | 20 wt% of Reinforcement | | 20 wt% of reinforcement | | 30 wt% of reinforcement | | 30 wt% of Reinforcement | |
|---|---|---|---|---|---|---|---|---|
| | 18 wt% S | 2 wt% F | 17 wt% | 3 wt% F | 28 wt% S | 2 wt% F | 27 wt% S | 3 wt% F |
| 1 | 1.120 | | 1.081 | | 1.152 | | 1.090 | |
| 2 | 1.122 | | 1.085 | | 1.151 | | 1.093 | |
| 3 | 1.121 | | 1.083 | | 1.154 | | 1.091 | |
| **Mean** | **1.121** | | **1.083** | | **1.1523** | | **1.0913** | |

Table No 1.3 and figure No 2.6 reveals that increase in wt% of reinforced coconut particle from 18wt% to 28 wt% with 2wt% of coir fibre the density increases from 1.121 to 1.15 g/cm3. This is very noticeable increase in density. But density decreases with increase of wt% of coir fibre with same amount of 20wt% of total reinforcement. This behaviour of increasing the density with the increase of wt% coconut shell particle is contrary to the only reinforcement of coconut shell particle. This is also true for 30wt% of total reinforcement. An increase in density, with increasing the reinforcement from 20wt% to 30% total reinforcement with 3 wt% of coir fibre is not noticeable. It means that density decreases with increasing the wt% of coir fibre within range of 20% to 30%.

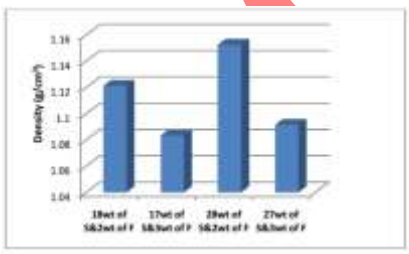

Fig2.6: density variation w.r.t. wt% of coconut shell particle and wt% of coir fibre

Hence, it can be concluded that proper combination of shell particle, coir fibre and epoxy wt% for composite material may have a varieties of industrial application when weight and strength would be the critical parameter in the design.

2.5.2Water absorption capacity:

Table 1.4: Water absorption of coconut particle reinforced composite in 24 hr

| S. No. | Coconut particle (20 wt %) | Coconut particle (25 wt %) | Coconut particle (30 wt %) | Coconut particle (35 wt %) |
|---|---|---|---|---|
| 1 | 0.431% | 0.483% | 0.512% | 0.518% |
| 2 | 0.432% | 0.482% | 0.513% | 0.520% |
| 3 | 0.430% | 0.481% | 0.511% | 0.516% |
| **Mean** | **0.431%** | **0.483%** | **0.513%** | **0.517%** |

The effect of water absorption is important in case the material that has been devel oped when used for applications comes in contact of water. The water absorption capacity was found to be maximum for 33 to 35 wt % of coconut shell particle.

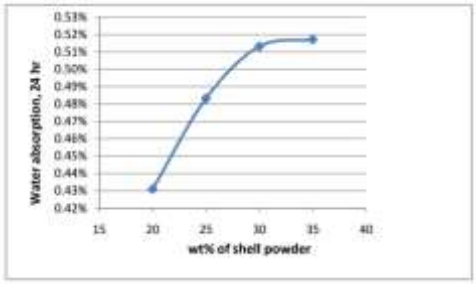

Fig2.7: Water absorption of coconut particle reinforced composite in 24 hr

Water absorption after 48 hr in coconut shell particle composite is observed reducing in rate as compared to after 24 hr. There is very small difference in water absorbed by composite with 20 %wt and 35 %wt of shell particle

Table No.1.5: water absorption with wt% of coconut shell particle after 48 hrs

| S. No. | Coconut particle (20 wt %) | Coconut particle (25 wt %) | Coconut particle (30 wt %) | Coconut particle (35 wt %) |
|---|---|---|---|---|
| 1 | 0.488% | 0.533% | 0.572% | 0.598% |
| 2 | 0.482% | 0.532% | 0.573% | 0.601% |
| 3 | 0.480% | 0.531% | 0.571% | 0.596% |
| **Mean** | **0.483%** | **0.532%** | **0.572%** | **0.597%** |

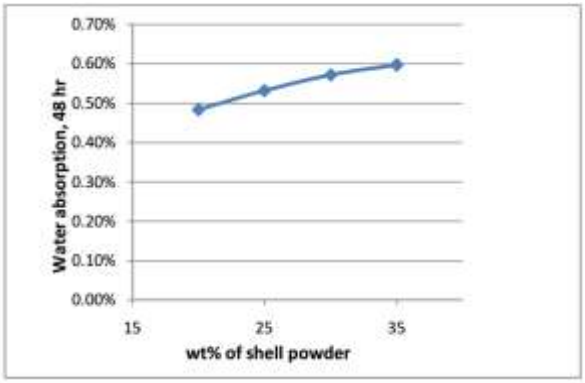


Fig2.8: water absorption with wt% of coconut shell particle after 48 hr

Table 1.6: Water Absorption of coconut shell particle and fiber reinforced composite in 24 hr

| S.No. | 20 wt% Reinforcement | | 20 wt% reinforcement | | 30 wt% reinforcement | | 30 wt% reinforcement | |
|---|---|---|---|---|---|---|---|---|
| | 18 wt% S | 2 wt% F | 17 wt% S | 3 wt% F | 28 wt% S | 2 wt% F | 27 wt% S | 3 wt% F |
| 1 | 1.45% | | 2.16% | | 1.15% | | 1.43% | |
| 2 | 1.47% | | 2.18% | | 1.16% | | 1.41% | |
| 3 | 1.40% | | 2.17% | | 1.18% | | 1.42% | |
| Mean | **1.46%** | | **2.16%** | | **1.16%** | | **1.42%** | |

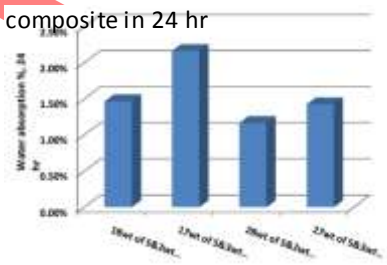

Fig2.9: Water absorption with wt% of coconut shell particle & coir fibre after 24 hr

Table 1.7: Water Absorption of coconut shell particle and fiber reinforced composite after 48 hr.

| S.No. | 20 wt% Reinforcement | | 20 wt% reinforcement | | 30 wt% reinforcement | | 30 wt% Reinforcement | |
|---|---|---|---|---|---|---|---|---|
| | 18 wt% S | 2 wt% F | 17 wt% S | 3 wt% F | 28 wt% S | 2 wt% F | 27 wt% S | 3 wt% F |
| 1 | 2.37% | | 2.82% | | 2.12% | | 2.07% | |
| 2 | 2.35% | | 2.83% | | 2.13% | | 2.06% | |
| 3 | 2.36% | | 2.84% | | 1.12% | | 1.08% | |
| Mean | **2.35%** | | **2.83%** | | **2.12%** | | **2.07%** | |

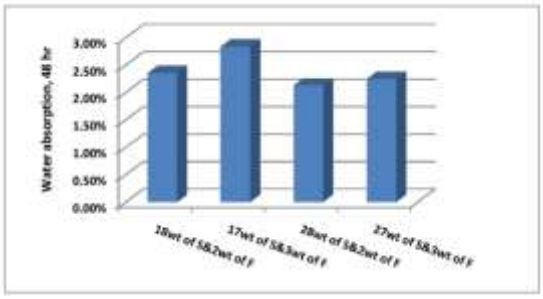


Figure No 3.1: Water absorption with wt% of coconut shell particle & coir fibre after 48 hr

2.6 Scanning Electron Microscope (SEM):

The state of dispersion of coconut shell particles into the resin matrix plays a significant role on the mechanical properties of the composite. Various methods such as SEM, TEM etc can be used to evaluate the particle dispersion in the composite.

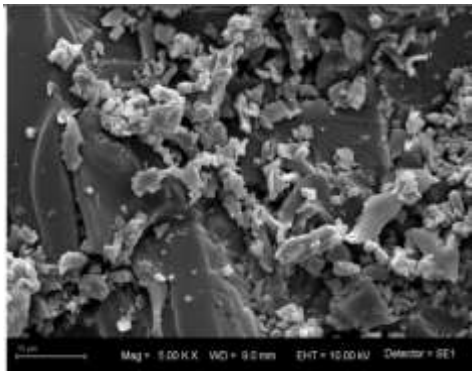

Fig3.2 .a: 5KX (20 %wt of shell particle)

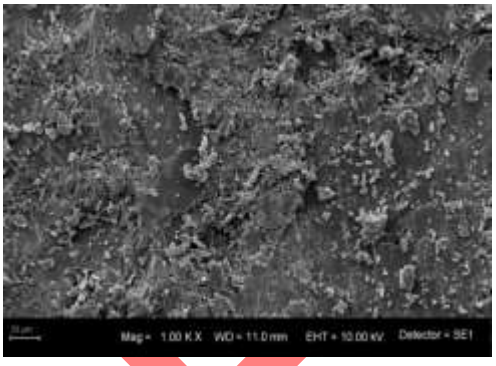

Fig3.3b:1.0 KX (18%wt shell particle &2%wt coir fiber)

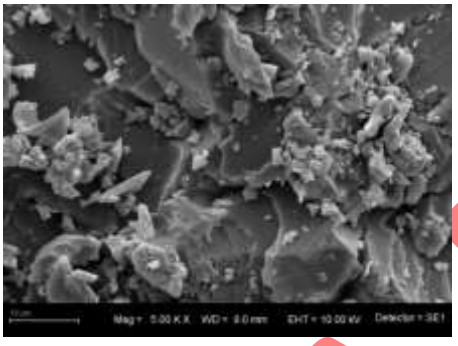

Fig3.4 c: 5KX (18%wtpowder&2% wt fiber)

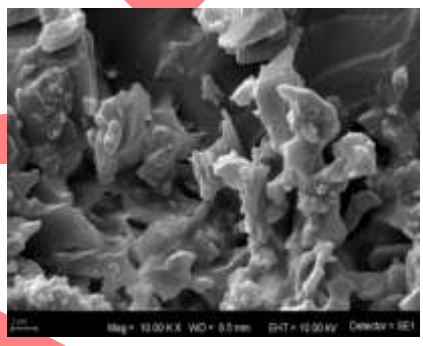

Fig3.5.d:10KX (27%wtpowder&3% wt fiber)

Tensile strength: The mechanical properties of the coconut particle filled epoxy resin composite materials were determined by universal testing machine at 0.1mm/min strain rate under displacement control mode.

Table No 1.8: Tensile Properties of coconut shell particle reinforced composite

| S.No. | 20 wt% S reinforcement | 25 wt% S reinforcement | 30 wt%S reinforcement | 35 wt%S reinforcement |
|---|---|---|---|---|
| Ultimate strength (MPa) | 30.60 | 29.40 | 28.80 | 25.20 |
| Modulus of elasticity (MPa) | 856.00 | 756.00 | 684.00 | 654.00 |
| % elongation | 25.44 | 25.436 | 25.06 | 21.00 |

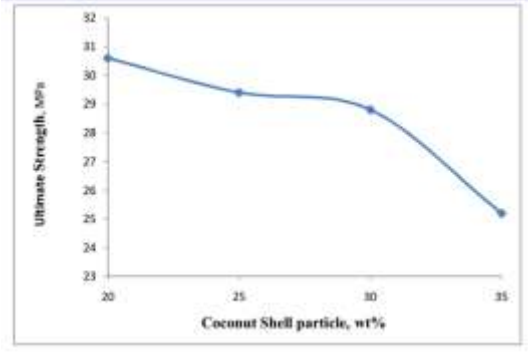


Fig3.6: Variation of ultimate strength with %wt of coconut shell particle

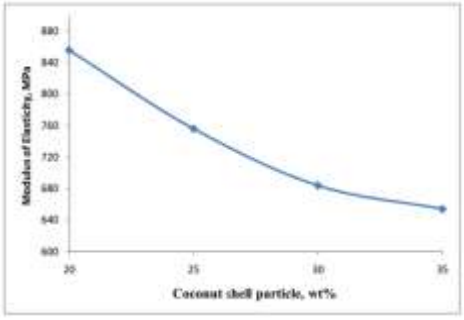


Fig3.7: Variation of modulus of elasticity with %wt

of coconut shell particle

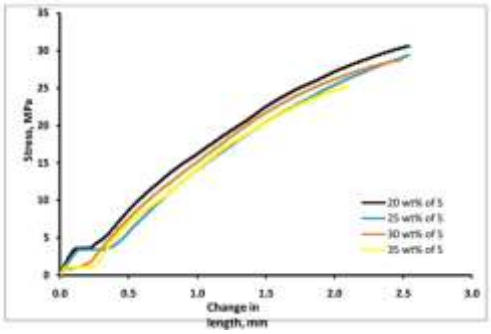


Fig3.8: Stress-Strain diagram for %wt of coconut shell particles.

Table No 1.9: Tensile Properties of coconut shell particle and coir fibre reinforced composite

| S.No. | 20 wt% Reinforcement | | 20 wt% reinforcement | | 30 wt% reinforcement | | 30 wt% reinforcement | |
|---|---|---|---|---|---|---|---|---|
| | 18 wt% S | 2 wt% F | 17 wt% S | 3 wt% F | 28 wt% S | 2 wt% F | 27 wt% S | 3 wt% F |
| Ultimate strength (MPa) | 44.59 | | 48.27 | | 30.20 | | 38.99 | |
| Modulus of elasticity (MPa) | 920.81 | | 848.53 | | 720.06 | | 684.93 | |
| % elongation | 12.09 | | 13.39 | | 9.90 | | 13.06 | |

It is observed from table no.4.8 that ultimate strength for 20% of total reinforcement increases with increase of wt% of fibre. It is also true for 30% wt reinforcement where increase wt% of of 2%wt is increased upto 3%.

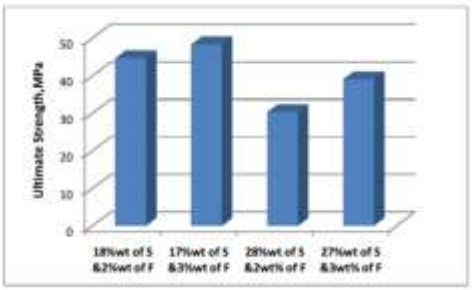


Fig3.9: Variation of ultimate strength with %wt of coconut shell particle and % coir fibre.

Modulus of elasticity decreases with increase in wt% of coir fibre and wt% of shell particle. But decrease in modulus of elasticity is more for increase in wt% of particle from 18% to 27%.

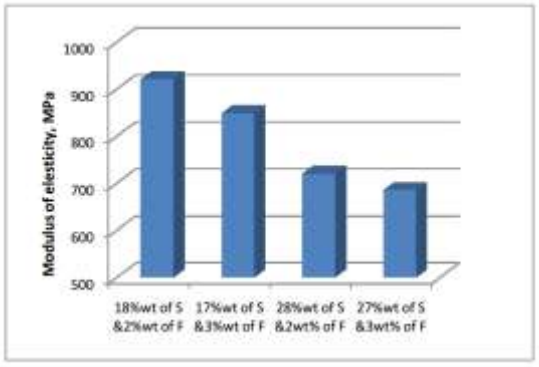


Fig4.1: Variation of modulus of elasticity with %wt of coconut shell particle and % coir fibre

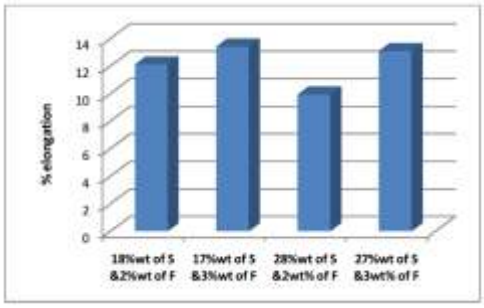


Fig4.2: Variation of % elongation with %wt of coconut shell particle and % coir fibre

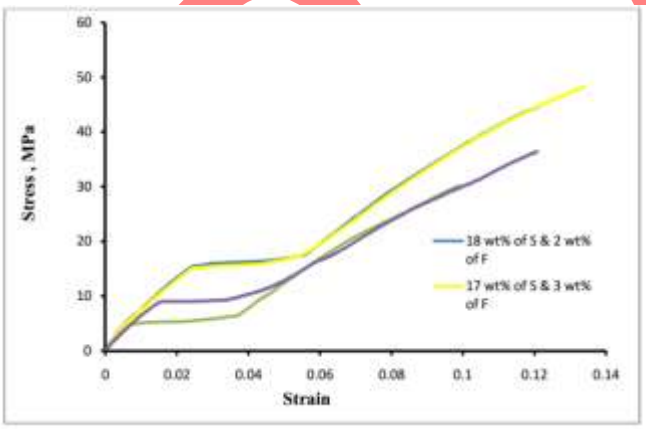


Fig4.3: Stress-Strain diagram for %wt of coconut shell particle and % coir fibre

Table No. 2.1 : Compressive strength of coconut particle reinforced composite.

| S.No. | 20 wt% S reinforcement | 25 wt% S reinforcement | 30 wt%S reinforcement | 35 wt%S reinforcement |
|---|---|---|---|---|
| Ultimate strength (MPa) | 59.333 | 61.33 | 88.00 | 60.666 |
| Modulus of elasticity (MPa) | 582.490 | 620.490 | 698.630 | 552.490 |
| % reduction | 4.4071 | 4.3773 | 3.9552 | 4.0752 |

Table No. 2.2 : Compressive strength of coconut particle and coir fibre reinforced composite.

| S.No. | 20 wt% Reinforcement | | 20 wt% reinforcement | | 30 wt% reinforcement | | 30 wt% reinforcement | |
|---|---|---|---|---|---|---|---|---|
| | 18 wt% S | 2 wt% F | 17 wt% S | 3 wt% F | 28 wt% S | 2 wt% F | 27 wt% S | 3 wt% F |
| Ultimate strength (MPa) | 53.30 | | 43.65 | | 78.92 | | 52.39 | |
| Modulus of elasticity (MPa) | 552.49 | | 508.53 | | 658.63 | | 512.57 | |
| % reduction | 50.24 | | 52.44 | | 44.46 | | 18.89 | |

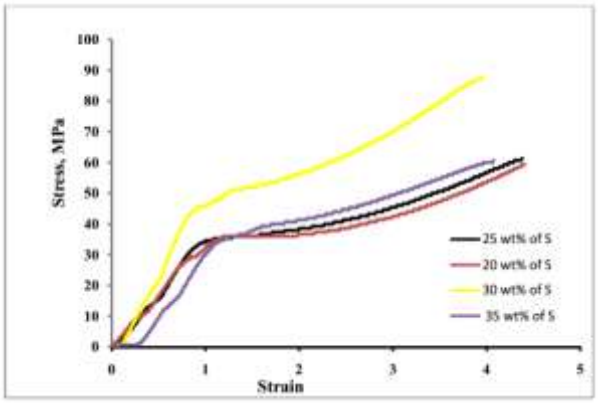


Fig4.4: Stress-strain curve for shell particle composite only in compression.

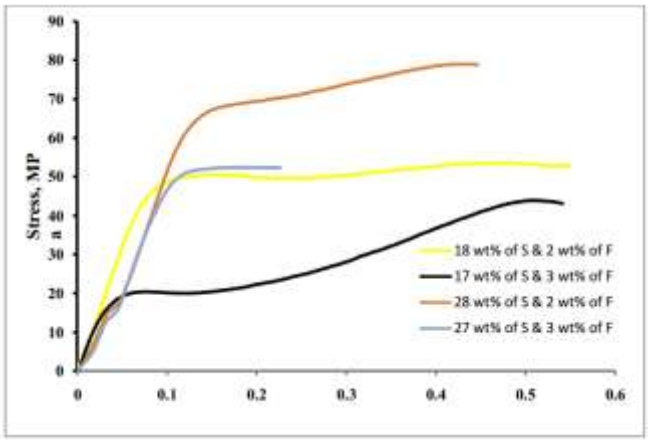


Fig4.5: Stress-strain curve for shell particle and coir fibre composite in compression.

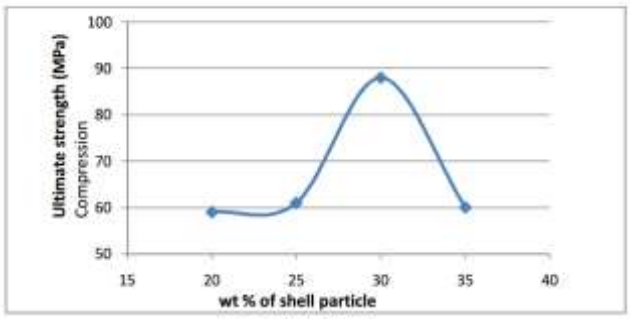

Fig4.6: Ultimate strength variation with wt% of shell particle in compression.

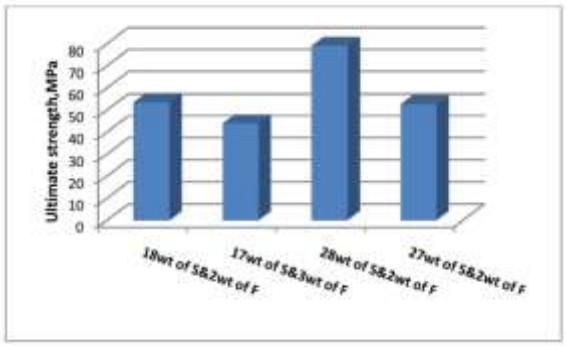


Fig4.7: Ultimate strength for composites shell particle and coir fibre.

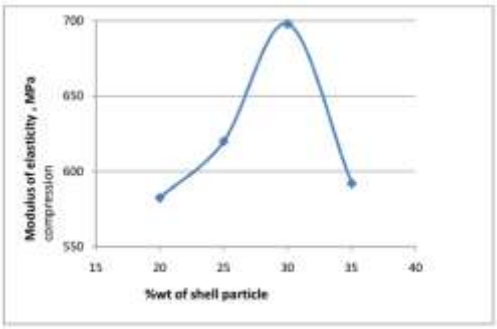


Fig4.8: Modulus of elasticity for shell particle composite.

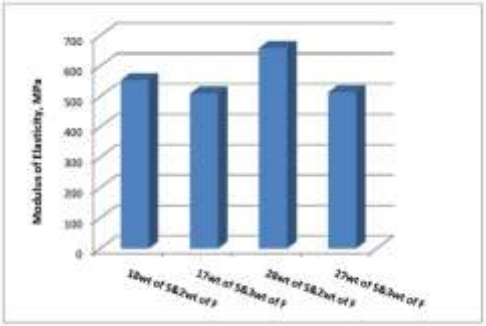


Fig4.9: Modulus of elasticity for shell particle and coir fibre composite.

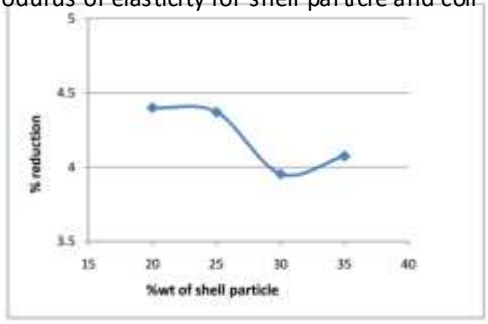


Fig5.1: % Reduction for shell particle and coir fibre composite

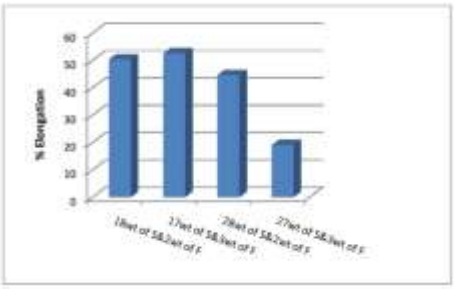


Fig5.2: % reduction for composites of shell particle and coir fibre.

Bending property of wood composite is very necessary for structural application to avoid failure.

Table No.2.3: Flexural strength of coconut shell particle composite.

| S.No. | 20 wt% S reinforcement | 25 wt% S reinforcement | 30 wt%S reinforcement | 35 wt%S reinforcement |
|---|---|---|---|---|
| Flexure Strength (MPa) | 61.482 | 61.87 | 62.52 | 63.45 |

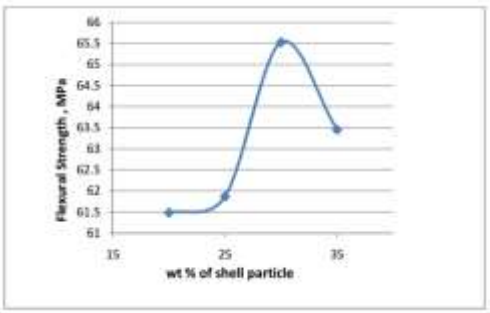


Fig5.3: variation of flexural strength for shell particle composite.

Table No.2.4: Flexural strength for composites of shell particle and coir fibre.

| S.No. | 20 wt% Reinforcement | | 20 wt% reinforcement | | 30 wt% reinforcement | | 30 wt% reinforcement | |
|---|---|---|---|---|---|---|---|---|
| | 18 wt% S | 2 wt% F | 17 wt% S | 3 wt% F | 28 wt% S | 2 wt% F | 27 wt% S | 3 wt% F |
| Flexure Strength(MPa) | 58.140 | | 51.048 | | 58.494 | | 44.910 | |

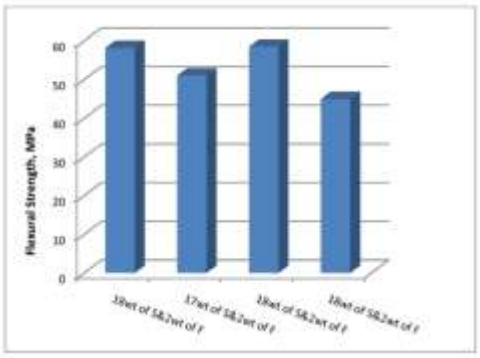


Fig5.4: Flexural strength of shell particle and coir fibre reinforced composite.

Table No2.5 : Fracture toughness of shell particle composites.

| S.No. | 20 wt% S reinforcement | 25 wt% S reinforcement | 30 wt%S reinforcement | 35 wt%S reinforcement |
|---|---|---|---|---|
| Fracture Toughness | 9.450 | 8.477 | 8.019 | 4.942 |

Table No.2.5 : Fracture toughness of shell particle and coir fibre reinforced composites.

| S.No. | 20 wt% Reinforcement | | 20 wt% reinforcement | | 30 wt% reinforcement | | 30 wt% reinforcement | |
|---|---|---|---|---|---|---|---|---|
| | 18 wt% S | 2 wt% F | 17 wt% S | 3 wt% F | 28 wt% S | 2 wt% F | 27 wt% S | 3 wt% F |
| Fracture Toughness | 10.376 | | 11.342 | | 8.345 | | 9.345 | |

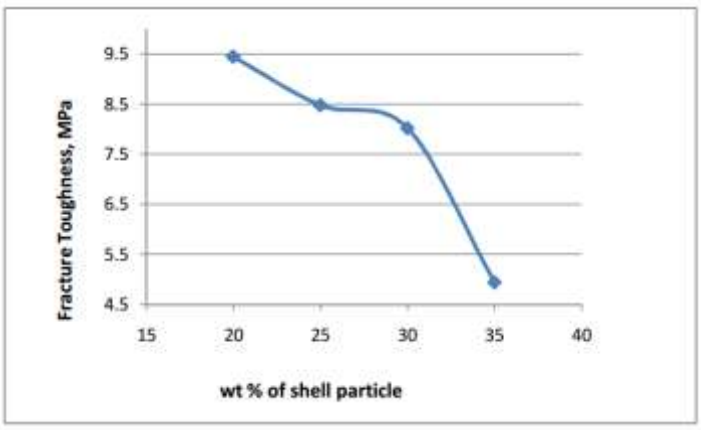


Fig5.5: Fracture toughness of shell particle composites.

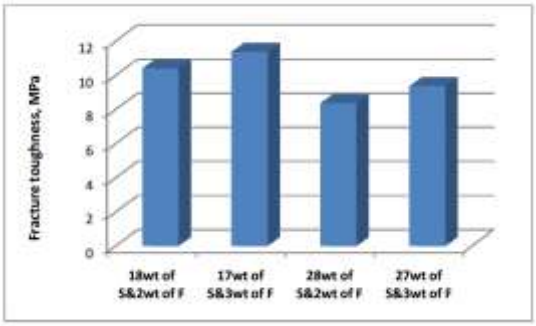


Fig5.6: Fracture toughness of shell particle and coir fibre reinforced composites.

Table No2.6: Rockwell Hardness on M- scale of shell particle reinforced composites

| S. No | (20 wt%) | (25wt%) | (30 wt%) | (35 wt%) |
|---|---|---|---|---|
| 1 | R-63 | R-65 | R--76 | R-89 |
| 2 | R-61 | R-66 | R-81 | R-88 |
| 3 | R-60 | R-67 | R-80 | R-87 |
| 4 | R-61 | R-66 | R-77 | R-86 |
| 5 | R-62 | R-65 | R-80 | R-87 |
| Mean | R-61.4 | R-65.8 | R78.8 | R-87.4 |

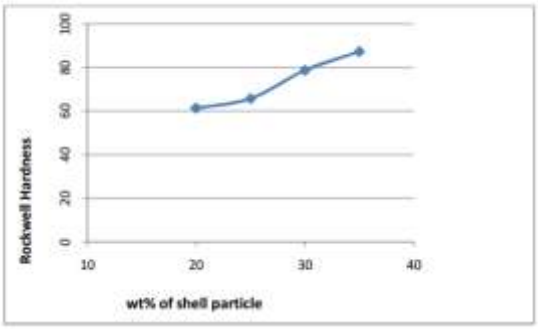


Fig5.7: Rockwell Hardness on M- scale of shell particle reinforced composites

Table No.2.7: Rockwell Hardness of shell particle and coir fibre reinforced composites

| S.N- | 20% reinforcement | | 20% reinforcement | | 30% reinforcement | | 30% reinforcement | |
|---|---|---|---|---|---|---|---|---|
| | 18 wt % S | 2 wt % F | 17 wt % S | 3 wt % F | 28 wt % S | 2 wt % F | 27 wt % S | 3 wt % F |
| 1. | R-61 | | R-56 | | R-77 | | R-74 | |
| 2. | R-62 | | R-57 | | R-75 | | R-73 | |
| 3. | R-60 | | R-55 | | R-76 | | R-75 | |
| 4. | R-59 | | R-58 | | R-77 | | R-73 | |
| 5 | R-62 | | R-56 | | R-79 | | R-72 | |
| mean | R-60.8 | | R-56.4 | | R-76.8 | | R-73.4 | |

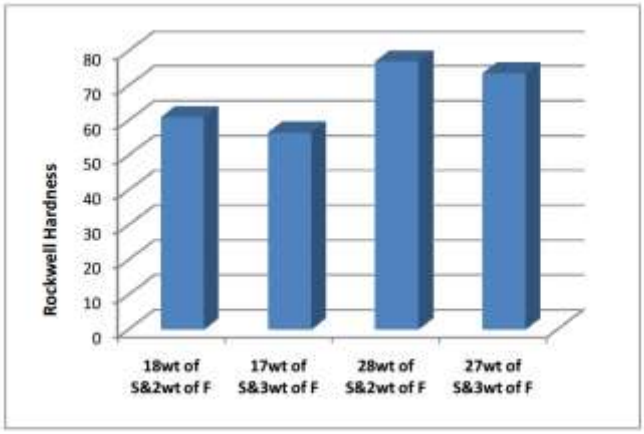


Fig5.8: Rockwell Hardness of shell particle and coir fibre reinforced composites

2.7 Conclusion:

Tensile properties:Ultimate strength equal to 30 MPa and modulus of elasticity equal to 856 MPa is achieved for 20%wt shell particle reinforced composite.Ultimate strength of 48 MPa and modulus of elasticity of 920 MPa are achieved for 18%wt shell particle & 2%wt coir fibre and 17%wt shell particle & 3%wt coir fibre reinforced composite respectively. Elasticity decreases with increase of coir and ultimate strength decreases with increases with particle wt%. Ultimate strength and modulus of elasticity increase with addition of coir.

2.7.1 Compressive Properties:

Maximum ultimate strength and maximum modulus of elasticity is 88 MPa and 698 MPa for 30%wt particle reinforcement only. Maximum ultimate strength and maximum modulus of elasticity is 78 MPa and 658 MPa for 28%wt particle with 2%wt coir fibre reinforcement. So, compressive reduces with coir fibre.

2.7.2 Bending Property:

Flexural strength of 63.45 MPa is measured for 35%wt shell particle reinforcement. This strength decreases with the addition of coir fibre.

2.7.3 Fracture Property:

Fracture toughness decreases with increase of wt% of particle for only shell particle reinforced composite. It increases minutely with increase of coir wt%.

2.7.4 Hardness:

Rockwell hardness number increases with increase of wt% of coconut shell particle and reduces with increase of coir fibre content. Its value maximum on 30%wt of reinforcement with 2%wt of coir fibre.

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