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# The physio-mechanical property of particle board from coconut coir reinforced with municipal solid waste.

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**Abstract:** The objective of the paper is to evaluate the mechanical behaviour of coconut coir reinforced with municipal solid waste. The mechanical properties like tensile strength, tensile modulus, flexural strength, impact strength, hardness and water absorption were studied .The study revealed the sample of fibres without size reduction showed higher tensile strength, flexural strength and impact strength when compared with different fibre length of 10mm, 20mm and 30mm respectively. The fibre board from MSW and coir have shown less moisture content and better flexural strength.
**Keywords :** coir fibre, Polyester, Municipal solid waste.

## Introduction

Natural fibre reinforced polymer composites have emerged as a potential environmentally friendly and also as cost-effective option to synthetic fibre reinforced composites. The availability of natural fibres and ease of manufacturing have attracted researchers to try locally available inexpensive fibres and to study their feasibility of reinforcement purposes. The mechanical properties of a natural fiber-reinforced composite depend on various parameters, such as fiber strength, modulus, fiber length and orientation, in addition to the fiber-matrix interfacial bond strength. Ligno-cellulosic natural fibres like jute, sisal, coir etc. have substantially gained importance as reinforcing materials in different polymer matrix composites[1]. These fibers are characterized by low cost, high strength-to-weight ratio, low density, biodegradable nature and offer similar reinforcing effects within the polymer matrix which leads them to compete with their synthetic counterparts[1]. It is a seed-hair fiber obtained from the outer shell, or husk, of the coconut. It is resistant to abrasion and can be dyed. Because of its hard-wearing quality, durability and other advantages, it is used for making a wide variety of floor furnishing materials, yarn, rope etc[2].

There are various ways to prepare the composite test specimen. The test specimens were prepared by using the pouring matrix system (resin) into a mould where fibers were reinforced and air bubbles were removed carefully with a roller. The closed mould was kept under pressure for 24 hours at room temperature[3]. The specimens of sugarcane fibre reinforced polyester (SCRP) and glass fibre reinforced polyester (GRP) composite were prepared in a laboratory using hand-lay-up and open mould techniques[4].

The physical and mechanical characteristics can further be modified by adding a solid filler phase to the matrix body during the composite preparation. The new type wood based filler derived from oil palm wood flour (OPWF) for bio-based thermoplastics composites by thermo gravimetric analysis and the results were very promising[5]. The physical properties of natural fibers are mainly determined by the chemical & physical composition, such as structure of fibers, cellulose content, angle of fibrils, cross section and by the degree of polymerization. An unsaturated polyester resin (thermoset) was used as a polymer matrix in this study for making composites. It was convenient for hand lay-up applications and easy air release[4]. The particle board made from Urea formaldehyde (UF) and Phenol formaldehyde (PF) resin using coir pith as the filler was studied[6]. Coir pith with various particle sizes were employed to make the composite. Better mechanical properties were obtained for PF resins composite than the UF resin based composites. The surface treatment of the coir fiber and its mechanical properties were studied and the effects of mercerization (alkali treatment) on shrinkage and fiber weight losses were monitored at different temperature and alkali concentration. Higher fiber shrinkage was observed at low temperature[2]. The coir composite mechanical properties were analyzed and found to be much lower than those of glass fibers[7]. The stiffness of coir fibre was comparable to the glass fibers[8]. Properties of alkali treated coir fiber reinforced with polyester were studied[9]. The mechanical properties found decreasing nature after 48 hours of treatment. Scanning electron micrographs revealed that the cell wall thickening and fiber shrinkage was occurring by the alkali treatment[10]. Among all modifications, bleached (65°C) coir-polyester composites showed better flexural strength (61.6 MPa) whereas 2% alkali-treated coir/polyester composites showed significant improvement in tensile strength (26.80 MPa). Hybrid composites containing surface modified coir fibres show significant improvement in flexural strength[10].

The effect of NaOH treatment density on the mechanical properties of the Coir fiber and coir fiber- PP composites were studied and showed that as the concentration of the NaOH increases, the tensile strength properties of the raw coir fiber shown a decreasing trend[11]. But, in the case of Coir fiber-PP composite, it gave an increasing trend[11]. Treatment done to coir fiber green composites by washing in Boiling water and washing in cold water. From the two treatments, washing in Cold water gave much better properties than the boiling[11].

## Materials and methods

### Materials

The raw materials utilized for the process are Coir fiber, Vegetable waste (skins), Polyester Resin, Accelerator(Co-naphthanate), Catalyst (Methyl-ethyl ketone). The vegetable waste collected from VIT hostel was sun dried followed by estimation of the moisture content. The moisture content of vegetable waste was calculated and it was found to be 80% for cabbage and 88% for banana. This dried vegetable waste was powdered and sieved. The powder was sieved with different mesh size namely 600,150, 75 and 37(μ) is shown in Table 1. The coir fiber were collected from keelthampattu, near Vellore. The fibre length of 10, 20and 30mm were used respectively as shown in Table 2.

**Table 1: Designation of Composites with different particle sizes of MSW**

| Composites | C1 | C2 | C3 | C4 |
|---|---|---|---|---|
| Different mesh sizes(μ) | 600 | 150 | 75 | 37 |

**Table 2: Designation of composites with different fiber length**

| Composites | S | S1 | S2 | S3 |
|---|---|---|---|---|
| Different fiber length (mm) | No Size Reduction | 10 | 20 | 30 |

Various chemical treatments were done for the fibres to improve the strength and the bonding between matrix and fibres[12]. Mercerization, Acetylation, Benzoylation, Peroxide treatment followed by Permanganate treatment after these treatments fibers were dried.

### Composite production;

**(a) cabbage waste (b) Banana waste (c) Coir fibre**

**Figure. 1 Vegetable waste (a-cabbage, b- banana) and (c) Coir fibers**

The fabrication of composite materials was carried out by hand lay-up technique. Short and long coconut coir fibers along with Municipal solid waste powder (vegetable waste skins) were reinforced with polyester resin, as the matrix material were shown in the Fig.1(a),(b)and (c). Each composite were prepared in the ratio of 2:1:1 consisting of polyester resin, fibers and filler. Before lay-up, a release agent (silicon grease) was applied onto the mould. Reinforcement fibers were laid in the mould either as long fibers or short fibers and were arranged in random orientation. This was followed by filling the fibers with filler (vegetable powder) and uniform distribution of the filler were taken cared. Then the resin mixture was poured onto the fibers containing the filler. A roller was used to impregnate the fibers-filler mixture with the resin.

**Curing process;**

The mould was heated using hydraulic press and it was compressed for curing reaction to takes place. The cast of each composite was cured under a load of about 60 kg at a temperature of about 70 °C for 24 hours before being removed from the mould. Then same cast was post cured in air for another 24 hours. Specimens of suitable dimension were cut into 23.4cm ×33.4cm for mechanical testing.

**Testing of Characterization of composites**

The Particle board of different fibre lengths and different particle sizes of MSW were produced separately. The fabricated test specimens were subjected to various mechanical tests as per ASTM standards. For a fibre board, the mechanical properties and water absorption tests are more important since it decides the strength of the material and porosity for a particle board. The tensile tests were carried out by using Autograph Instron model 3382 tensile testing machine and three-point flexural tests of composites were carried out using Llyods Instron model 3382. Hardness measurement is done using a Rockwell hardness testing machine. The impact tests were carried out in Tinius olson charpy for measuring impact strength.

For water absorption, the test piece of about 1.9 cm was cut and immersed in distilled water in a glass vessel at room temperature 20-30°C for every 2 hours duration till constant weight was obtained. The scanning electron microscope (SEM Zeiss Evo Model 1360) was used to identify the tensile fractured morphology of composite samples. The samples were washed, cleaned thoroughly and vacuum dried. Then the samples were sputter-coated with gold and observed SEM at 15 kV and the photographs were taken using scanning electron microscope.

The results of various characterization tests are reported here. It includes the tensile strength, flexural strength, impact strength, hardness and water absorption study

**Effect of particle size of MSW and fiber length on tensile properties of composites**

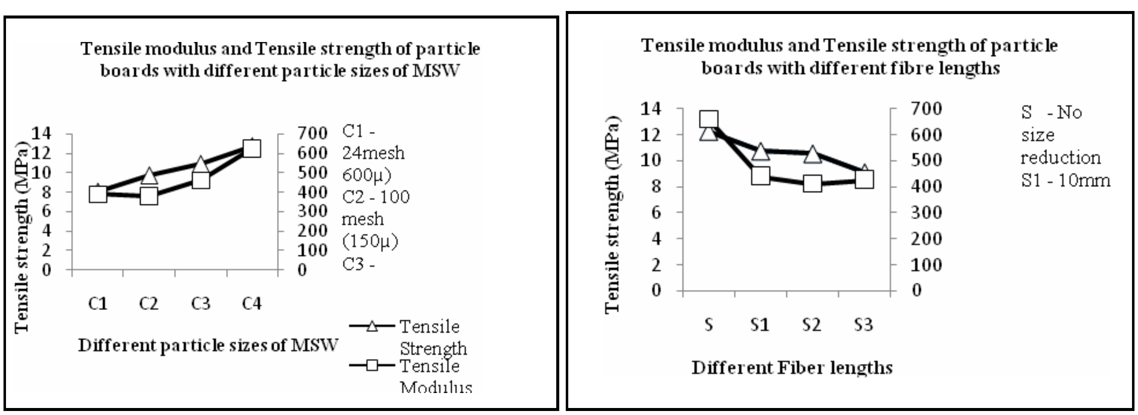



**Figure 2: Tensile strength and Tensile Modulus of particle boards with (a) different particle size and (b) different fibre lengths**

The test results for tensile strength and modulus for particle boards with different particle size of MSW and different fibre lengths are shown in Fig 2(a) and 2(b) respectively. In different particle sizes of MSW the tensile strength and modulus increases with decrease in particle size. The values of tensile modulus and tensile strength for particle boards with different particle size and fibre lengths and sample of fibres without size reduction are represented in Table 3 and 4. The particle boards with long unreduced fibres showed higher tensile strength and higher tensile modulus.

**Table 3: Tensile modulus and Tensile strength of particle boards with different particle sizes of MSW**

| Different particle sizes of MSW | Tensile strength(MPa) | Tensile modulus(MPa) |
|---|---|---|
| C1 | 8.10 | 388.34 |
| C2 | 9.77 | 379.13 |
| C3 | 10.95 | 461.5 |
| C4 | 12.75 | 626.16 |

**Table 4: Tensile modulus and Tensile strength of particle boards with different fibre lengths**

| Different Fibre lengths | Tensile strength(MPa) | Tensile modulus(MPa) |
|---|---|---|
| S | 12.26 | 659.69 |
| S1 | 10.75 | 441.11 |
| S2 | 10.55 | 412.74 |
| S3 | 9.11 | 427 |

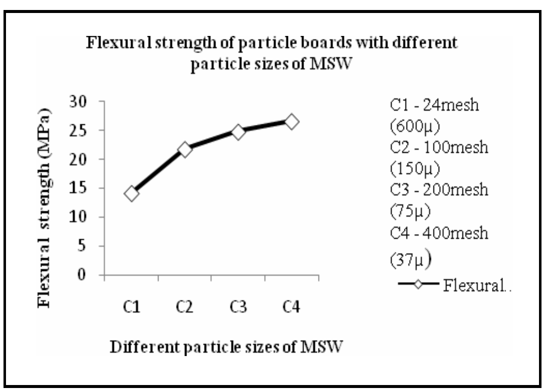
**Effect of particle size of MSW and fiber length on flexural strength of composites**

**Table 5 Flexural strength of particle boards with different particle sizes of MSW and different fibre length**

| Different particle sizes of MSW | Flexural strength (MPa) |
|---|---|
| C1 | 14.12 |
| C2 | 21.78 |
| C3 | 24.82 |
| C4 | 26.65 |

| Different Fibre lengths | Flexural strength (MPa) |
|---|---|
| S | 23.34 |
| S1 | 22.31 |
| S2 | 20.8 |
| S3 | 19.44 |

The test results for flexural strength of different particle sizes of MSW and different fiber length are tabulated in Table 5 and the graphs are shown in Fig. 3(a) and 3(b) respectively. Fig. 3(a) indicates the flexural strength of the composite increases with decrease in particle size of MSW. In Fig. 3(b) the particle boards with long unreduced fibres showed higher flexural strength.



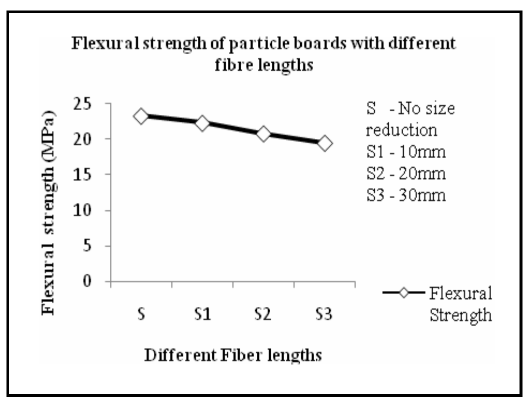




**Figure 3: Flexural strength of particle boards with (a) different particle sizes of MSW and (b) different fibre lengths**

**Effect of particle size of MSW and fibre length on Impact strength of composites**

The test results for impact strengths of particle boards with different particle sizes of MSW and different fibre lengths are tabulated in Table 6 and graphs are represented in Fig. 4(a) and 4(b) respectively. The impact strength of the composite increases with decrease in particle sizes of MSW in Fig. 4(a) and in Fig. 4(b)

It is seen that the particle boards with long unreduced fibres showed higher impact strength when compared with the short fibres

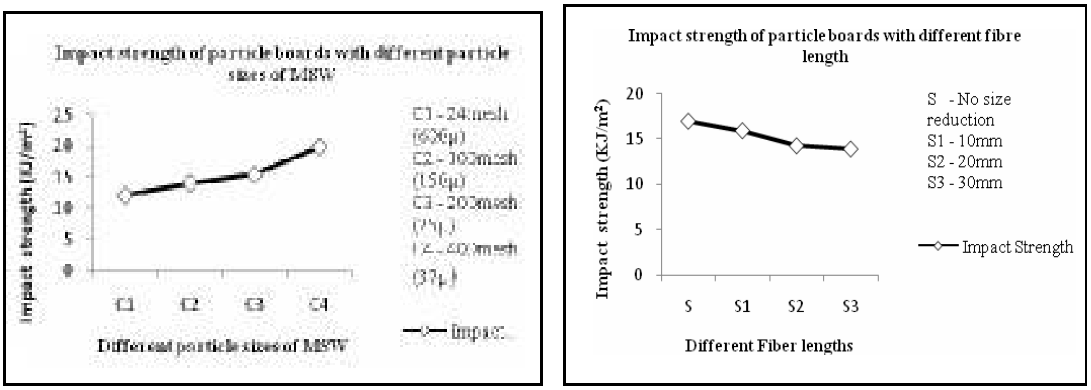



**Figure 4: Impact strength of particle boards with (a) different particle sizes of MSW and (b) different fibre lengths**

**Table 6: Impact strength of particle boards with different particle sizes of MSW**

| Different particle sizes of MSW | Impact strength(KJ/m$^2$) |
|---|---|
| C1 | 12.18 |
| C2 | 14.15 |
| C3 | 15.52 |
| C4 | 19.92 |

| Different Fibre lengths | Impact strength(KJ/m$^2$) |
|---|---|
| S | 17.03 |
| S1 | 15.99 |
| S2 | 14.33 |
| S3 | 13.98 |

**Effect of particle size of MSW and fibre length on hardness of composites**

The test results for Rockwell hardness number of different particle sizes of MSW and different fibre lengths are tabulated in Table 7 and represented graph in Fig. 5(a) and 5(b) respectively. From the graphs we find the hardness of the composite increases with decrease in particle size and also the particle boards with long unreduced fibres showed more hardness when compared to other fibre lengths.

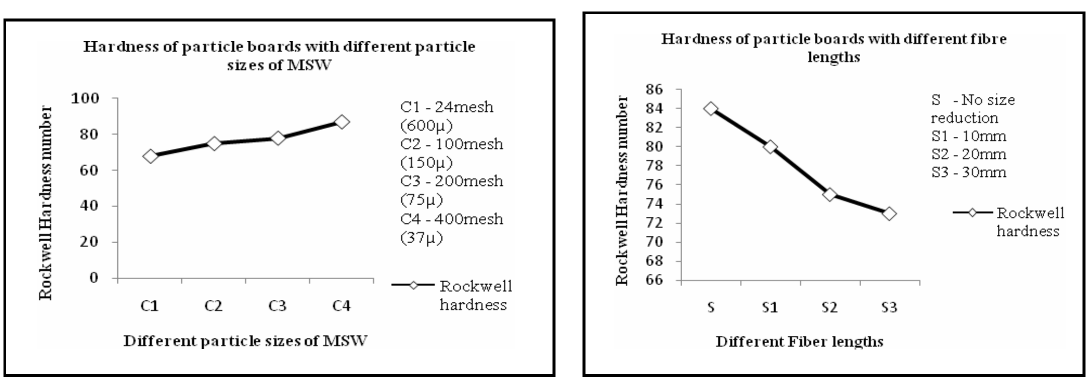



**Figure 5: Hardness of particle boards with (a) different particle sizes of MSW and (b) different fibre lengths**

**Table 7: Hardness of particle boards with different particle sizes of MSW**

| Different particle sizes of MSW | Rockwell Hardness no |
|---|---|
| C1 | 68 |
| C2 | 75 |
| C3 | 78 |
| C4 | 87 |

| Different Fibre lengths | Rockwell Hardness no |
|---|---|
| S | 84 |
| S1 | 80 |
| S2 | 75 |
| S3 | 73 |

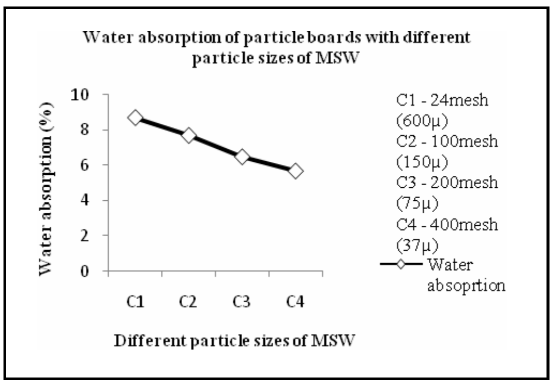
**Effect of particle size of MSW on Water absorption of composites**

**Table 8: Water absorption of particle boards with different particle sizes of MSW and Different fiber lengths**

| Different particle sizes of MSW | Water absorption (%) |
|---|---|
| C1 | 8.7 |
| C2 | 7.7 |
| C3 | 6.5 |
| C4 | 5.7 |

| Different Fibre lengths | Water absorption (%) |
|---|---|
| S | 5.0 |
| S1 | 5.8 |
| S2 | 7.0 |
| S3 | 8.0 |

The most mandatory test for any particle board is water absorption study have been studied and discussed here. The test results for water absorption of different particle sizes of MSW and different fiber lengths are tabulated in the Table 8 and represented as graph in Fig. 6 Constant weight was observed after 48 hours. Water absorption of the composite (containing 37µ particle size of MSW) was found to be around 5.7%. From Fig. 6 it was found that the water absorption decreased with decrease in the particle size of MSW. Water absorption of composite with long unreduced fibre was found to be less (around 5%) when compared with short fibres. It is within limit when compared with conventional particle boards which was found to be 5-15%.



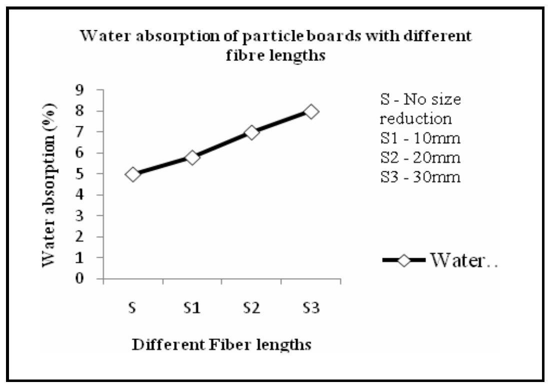
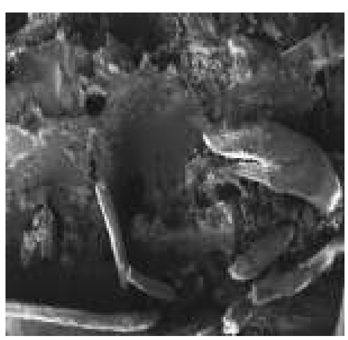




**Figure 6: Water absorption of particle boards with (a) different particle sizes of MSW and (b) different fibre lengths**

**4.4 SEM Analysis**



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

**Figure 7 (a) and (b): SEM photographs of the fractured surface of the composites with long unreduced fibre and short fibres along with filler.**

From the SEM analysis we can conclude that the long unreduced fibres can withstand maximum stress given and shows better strength compared to short fibres. The arrangement of fibres carried out in this study was random orientation. The short fibres were not uniformlly distributed in the specimen which resulted in lesser strength. Hence improvement in strength of the boards can be obtained by having different fibre orientations like longitudinal, transverse etc.,Various chemical treatments like merceriztion, acetylation, benzoylation,peroxide ,permanganate can also be done to increase the strength and bonding between matrix and fibres.The SEM analysis results of fractured surface of the composites with long unreduced fibres and short fibres are shown in the Fig 7 (a) and Fig 7(b).

**4.5 Surface finish**

After formation of particle board the surfaces can be made attractive by using sun mica laminates. Since the particle board is laminated with different lamination films, different finishes can be given like rosewood finish, teakwood finish, metallic finish etc. Some of the surface finishes are shown in the Fig. 8

**Figure 8: Different surface finished samples**

**4.6 Comparison and Application**

When comparing with the conventional particle boards, the strength of the boards made from coir and municipal solid waste showed improved results. Further improvement in strength of the composites can be done by chemical treatments, varying particle to resin ratio, with different fibre orientations. Some of the applications of the particle board made from coir and Municipal solid waste are shelves, furniture, laminating doors and cupboards. The comparison results with Indian and other international standards are shown in Table 9 and 10.

**Table 9: Comparison of different properties of board (from coir and MSW) with conventional particle Board ( Indian standards)**

| est Conducted | Conventional Particle board ( Indian standard) IS | Particle board from Coir and MSW |
|---|---|---|
| Density (g/cc) | 0.5 – 0.9 | 0.10 – 0.15 |
| Moisture content (%) | 5 – 15% | 5 -8% |
| Bending strength (N/mm$^2$) (Tested as per IS 2380 part IV 1977) | 12.5 - 15 | 14 – 25 |
| Water absorption test – 2hrs | 6 -10% | 4 – 8% |

**Table 10: Comparison of different properties of (coir: MSW) board with Australian and Newzealand standards particle boards of different thickness)**

| Tests conducted | Australian and Newzealand standards with thickness | | Particle board from coir and municipal solid waste |
|---|---|---|---|
| | 9mm | 12mm | |
| Density(g/cc) | 0.67 | 0.67 | 0.10-0.25 |
| Moisture content (%) | 5-8 | 5-8 | 5-8% |
| Bending strength (MPa) | 18 | 18 | 14-24 |

This experimental investigation shows that fabrication of polyester resin composites reinforced with coir fibers (of different length) and municipal solid waste (as filler) is possible by simple hand lay-up technique with ratio of 2:1:1. Along with this their mechanical properties is also studied with varying particle sizes of MSW and fibres length. It has been noticed that sample of fibres without size reduction shown higher tensile strength , flexural strength and impact strength when compared with different fibre lengths. The arrangement of fibres chosen was random. The uniform distribution of fibres could not be obtained properly. Hence the boards were of lesser strength. When comparing with conventional particle board, the fibre board from MSW and coir have shown less moisture content and better flexural strength. From this work we conclude that particle board will be a good and economically valuable product formed from wastes. This will be a good alternative to wood and it's by- products can be used for various applications as shelves, laminating doors, cupboards. This particle boards from coir fibres and vegetable waste using polyester resin as matrix which will be a good substitute and cost effective option instead of wood based particle boards.

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