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Mechanical Properties of Urea Formaldehyde Resin Composites Reinforced with Bamboo, Coconut and Glass Fibers

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Abstract— ***Composite materials, plastics and ceramics have been the dominant emerging materials from last thirty years. Polymeric materials reinforced with natural and synthetic fibres such as coconut, bamboo, jute glass, carbon and aramid provide advantages of high stiffness, good thermal, acoustic insulating properties, excellent formability and strength to weight ratio as compared to conventional construction materials, i.e. wood, concrete, iron and steel. The increase interest in using natural fibres as reinforcement in plastics is to substitute the conventional synthetic fibres in some structural applications and it has become one of the main concerns to study the potential of using natural fibres as reinforcement for polymers. In this research paper, seven different fiber reinforcement polymer composite were fabricated by wet hand-lay-up method using short coconut, short bamboo and short glass fibers binded with amino resin like urea formaldehyde. The urea formaldehyde was selected due to its low cost, less weight, easier to field fabricate, long durability and high temperature withstand ability. The different mechanical properties like density, tensile strength, hardness, flexural strength and percentage elongation of specimens were calculated and were compared with the pure urea formaldehyde.***

Key word: Composite, Polymeric materials, coconut, bamboo, glass fibers, urea formaldehyde.

I. INTRODUCTION

Increased environmental awareness and consciousness throughout the world, the fiber reinforcement polymer composites are being used in almost every type of applications in our daily life. The manufacture, use and removal of traditional composites structure made of glass, and carbon fibers, steel, wood and iron etc. Because of rising environment awareness the natural fibers are considered as serious alternative to synthetic fibers for use in a variety of fields. Coconut fiber and bamboo fiber is recyclable and environmental friendly materials and has been recognize as an important source of fiber for composites. The benefits of natural fibers over habitual reinforcement material are their specific strength properties easy availability, non corrosive nature, low density, low cost, good thermal properties, light weight and biodegradability. During earlier period many industries such as building, packaging and automobile industries have exposed massive interest in new bio-composites materials.

II. BACKGROUND

A number of investigations have been carried out to assess the potential of natural fibers as reinforcement in polymers [10-19]. Natural fiber exists in the form of vegetable fiber, animal fiber or mineral fiber. Vegetable fiber finds extensive applications due to its easy availability and inexpensive nature. Cellulose, hemi cellulose, lignin and pectin [20] form a major component in the vegetable fibers. Cellulose is a linear macromolecule consisting of D-anhydroglucose repeating units joined by β-1,4 glycosidic linkages. It is the main component, which provides strength, stiffness, and structural stability. Hemicelluloses are the branched polymers containing five-and six-carbon sugars of varied chemical structure, Lignin is an amorphous, cross-linked polymer network consisting of an irregular array of variously bonded hydroxy-and methoxy-substituted phenyl propane units [21]. Lignin is less polar than the cellulose and acts as a chemical adhesive within and between the fibers. Pectin's are complex polysaccharides, the main chains of which consist of a customized polymer of glucuronic acid and residues of rhamnose. Their side chains are prosperous in rhamnose, galactose, and arabinose sugars. The chains are often cross-linked by calcium ions, improving structural integrity in pectin-rich areas. Lignin, hemicelluloses and pectin collectively function as matrix and adhesive to hold together the cellulosic framework structure of the natural fiber composite

Urea formaldehyde resins are the most common thermosetting resins usually referred to as amino resins. it is commonly used as adhesive by the forest product industries due to number of advantages, including low cost, ease to use under wide verity of curing condition, low cure temperature, water solubility, resistance to micro organisms and to abrasion hardness, excellent thermal properties etc. Keeping in view the easy availability of bamboo and coconut fiber a comprehensive research work has been initiated in our laboratory on synthesis and study of properties of bamboo and coconut fibers reinforced urea formaldehyde resins matrix base bio-composites.

III. MATERIALS AND METHOD

The material used for the study were Urea formaldehyde resins (UF), Short Glass fibers, Short coconut fiber, short bamboo fibers,

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Silicone spray and is described as below :-

1. MATRIX POLYMER.

A urea formaldehyde resin (manufactured by Ciba Geigy India Ltd.) was used as matrix polymer. **Fig. 1** shows the photograph of urea formaldehyde in liquid form.

Fig. 1. Urea formaldehyde in liquid form.

2. REINFORCING MATERIAL

Short Glass fibers, Short coconut fiber and short bamboo fibers with different wt% as shown in **Table 1** was used as reinforcing materials.

A. *Short chips of bamboo fiber.*

The short chips of bamboo fibers were prepared by cutting the bamboo strip in 3-4 mm size. The bamboo strips were purchased from person who used to made bamboo buckets.

B. *Short coconut fiber.*

The coconut fiber was collected from the coconut waste material. The coconut fibers were cut into short fibers of 1-2 cm length.

C. *Short glass fiber.*

The short glass fiber of 1-2 cm length was purchased from the local market. NH_4CL and Silicone spray were use as hardened and releasing agent. **Fig. 2** shows the photograph of the (a) chips of bamboo fiber, (b) short coconut fiber and (c) short glass fiber used in the study.

(a)

(b)

(c)

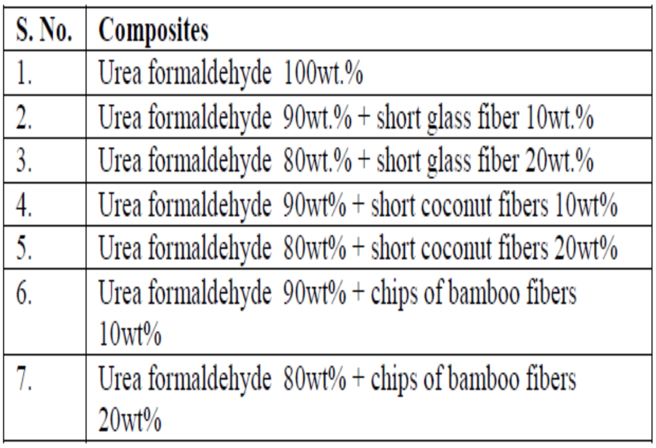
Fig. 2 showing (a) chips of bamboo fiber, (b) short coconut fiber and (c) short glass fiber

IV. EXPERIMANTAL PROCEDURE

1. FABRICATION OF COMPOSITES.

Without using any fiber reinforcement material, the composite materials are prepared by using pure urea formaldehyde resin. Further in the urea formaldehyde resin, the short glass fibers, short fibers of coconut and chips of bamboo reinforced composites are mixed in different wt (%). The detailed composition of urea formaldehyde resin composites with addition of short glass fiber, coconut fibres and bamboo fibres is given in **Table 1.** The fabrication of the composite slabs was done by conventional hand-lay-up technique followed by light compression moulding technique. The matrix body was thoroughly mixed with the suitable hardener before mixing the respective short fibers. The low temperature curing resins and corresponding hardeners were mixed in a ratio of 10:1 by weight as recommended. The wood moulding having dimensions $200\times200\times20\ mm^3$ were used in the study. Further, releasing agent (silicone spray) was used to facilitate easy removal of the composite from the mould after curing. The cast of each composite was cured under a load of about 10 kg for 24 hours before it was removed from the mould. Then, this cast was post cured in the air for another 24 hours after removing out of the mould. The specimens of suitable dimension were cut using a diamond cutter for physical/mechanical characterization testing. Utmost care was been taken to maintain uniformity and homogeneity of the composites.

Table1. Detail composition of urea formaldehyde resin composites



S. No.	Composites
1.	Urea formaldehyde 100wt.%
2.	Urea formaldehyde 90wt.% + short glass fiber 10wt.%
3.	Urea formaldehyde 80wt.% + short glass fiber 20wt.%
4.	Urea formaldehyde 90wt% + short coconut fibers 10wt%
5.	Urea formaldehyde 80wt% + short coconut fibers 20wt%
6.	Urea formaldehyde 90wt% + chips of bamboo fibers 10wt%
7.	Urea formaldehyde 80wt% + chips of bamboo fibers 20wt%

V. TESTING OF MATERIAL

1. DENSITY

The theoretical density (ρ_{ct}) of composite materials in terms of weight fractions of different constituents was obtained as per the formula given by Agarwal and Broutman [50]

$$\rho_{ct} = \frac{1}{(W_f/\rho_f)+(W_m/\rho_m)}$$

Where, W and ρ represent the weight fraction and density respectively. The suffixes f and m stand for the fiber and matrix, respectively. The actual density (ρ_{ce}) of the composite, however, can be determined experimentally by simple water immersion technique. The volume fraction of voids (V_v) in the composites was calculated using the following formula.

$$V_v = \frac{\rho_{ct} - \rho_{ce}}{\rho_{ct}}$$

2. SHORE D HARDNESS

Shore hardness is a measure of the resistance of a material to penetration of a spring loaded needle-like indenter. Hardness of Polymers (rubbers, plastics) is usually measured by Shore scales. Shore A scale is used for testing soft Elastomers (rubbers) and other soft polymers. Hardness of hard elastomers and most other polymer materials (Thermoplastics, Thermosets) is measured by Shore D scale. Shore hardness was tested with an instrument called Durometer. Durometer utilizes an indenter loaded by a calibrated spring as shown in **Fig. 3.** The measured hardness was determined by the penetration depth of the indenter under the load. Two different indenter shapes as shown in Fig. 3 and two different spring loads were used for two Shore scales (A and D). The description of the shore A and shore D is as below:-

The loading forces of Shore A: 1.812 lb (822 g), Shore D: 10 lb (4536 g). Shore hardness value may vary in the range from 0 to 100. Maximum penetration for each scale is 0.097-0.1 inch (2.5-2.54 mm). This value corresponds to minimum Shore hardness: 0. Maximum hardness value 100 corresponds to zero penetration.

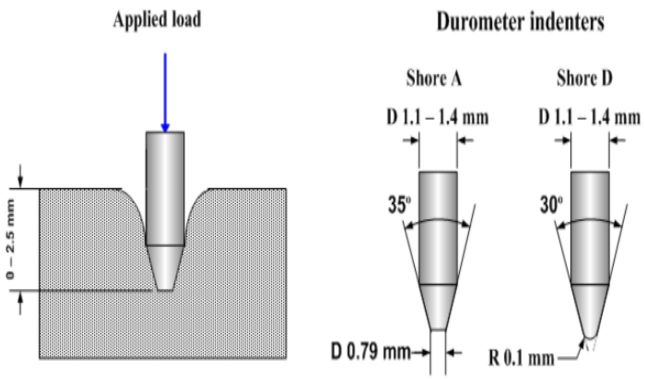


Fig. 3 Durometer hardness test

3. TENSILE AND FLEXURAL STRENGTH

The tensile test is generally performed on flat specimens. The commonly used specimens for tensile test are the dog-bone type and the straight side type with end tabs. During the test a uni-axial load was applied through both the ends of the specimen. The length of the test section used in the study was 200 mm. The tensile test was performed in the universal testing machine (UTM) and results were analysed to calculate the tensile strength of composite samples. The short beam shear (SBS) tests were performed on the composite samples at room temperature to evaluate the value of flexural strength (FS). A 3-point bend test, which generally promotes failure by inter-laminar shear, was performed. The SBS test was conducted as per ASTM standard using the same UTM. A span length of 40 mm and the cross head speed of 1 mm/min were maintained throughout the test. The flexural strength (F.S.) of any composite specimen is determined using the following equation.

$$F.S = \frac{3PL}{2bt^2}$$

(a)

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(b)

Fig. 4 (a) Universal Testing Machine (Instron 1195 make), (b) Loading arrangement used for flexural test.

4. PERCENTAGE ELONGATION

The percent elongation reported in a tensile test is defined as the maximum elongation of the gage length divided by the original gage length. The elongation (%) was used as indicators of ductility and the ability of a material to be elongated in tension. Because, the elongation is not uniform over the entire gage length and higher at the centre of the neck, hence the percent elongation is not an absolute measure of ductility. Thus, the reduction of area was measured at the minimum diameter of the neck.

Ductility is more commonly defined as the ability of a material to deform easily upon the application of a tensile force, or as the ability of a material to withstand plastic deformation without rupture. Ductility may also be thought of in terms of bend ability and crushability and shows large deformation before the fracture. The lack of ductility is often termed brittleness.

$$\text{Percent elongation} = \frac{\text{final gage length} - \text{initial gage length}}{\text{initial gage length}}$$

$$= \frac{L_x - L_o}{L_o} = \text{inches per inch x 100}$$

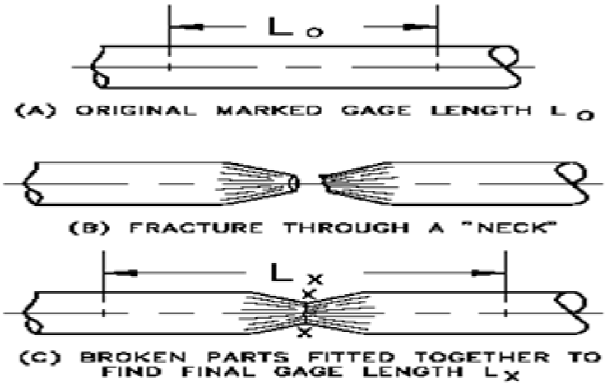

Fig.5 Measuring Elongation after Fracture

VI. RESULT AND DISCUSSIONS

1. DENSITY AND VOID FRACTION

The **Table 2** shows the experimental density compared with theoretical density for the Urea formaldehyde resins (UF) mixed with bamboo, coconut and glass fibers in various wt (%).

Table 2 revels that the volume fraction voids (%) was highest with the 20wt% of coconut mixed with 80wt% urea formaldehyde composite. The increase in the volume fraction void (%) has been attributed due to the presence of pores and voids in the composite structure. It has significantly affected the mechanical properties and even the performance of the composites. The higher voids content attributes lower fatigue resistance, greater susceptibility to water penetration and weathering. However, the presence of void is unavoidable in composite as hand lay-up method induces air void inside the composite. **Table 2** further reveals that the void fraction (%) was least in the composite formed by mixing 10wt% glass fiber with 90wt%. The least void fraction (%) has been attributed to the fact that the glass fibers are thinner than the coconut and bamboo fibres which leads to the reduction of voids.

Table 2. Theoretical and experimentally densities along with the void fractions of the UF composites mixed with different fiber percentage.

Composition	Experimental density (gm/cc)	Theoretical density (gm/cc)	Volume fraction voids %
10wt% Bamboo + 90wt% UF	1.104	1.169	0.056
20wt% bamboo + 80wt% UF	1.012	1.122	0.098
10wt% coconut + 90wt% UF	1.088	1.212	0.102
20wt% coconut + 80wt% UF	0.991	1.203	0.176
10wt% glass fiber + 90wt% UF	1.244	1.286	0.033
20wt% glass fiber + 80wt% UF	1.153	1.360	0.152

2. SHOE 'D' HARDNESS

The **Fig. 6** shows the variation of hardness of composite for the Urea formaldehyde resins (UF) mixed with bamboo, coconet and glass fibers in various wt(%). **Fig. 6** reveals that with inclusion of bamboo, coconut, glass fibers, there is decrease in the hardness of composite. For example, a value of 52 shore D hardness of pure UF decreases to a value of 46 shore D with the inclusion of 20wt% of bamboo fiber in UF. A similar pattern of decrease in shore D hardness was also observed for the inclusion coconut and glass fiber. It is related to the fact that while mixing the fibres in Urea formaldehyde resins, the fibres generally comes on the outer surface which reduces the hardness of the composite.

A close examination of **Fig. 6** reveals that the decrease in the shore D hardness was lowest for the inclusion of 20wt% of bamboo, coconut and glass fibers in comparison to 10wt% inclusion of bamboo, coconut and glass fibers. The decrease in hardness in the fiber composites from the pure composites has been attributed to the fiber-matrix interfacial bond formed in the composites, which causes a decrease in the chemical bond of the composites. This improves the mechanical properties of fiber composites by making more flexible and shock resistance.

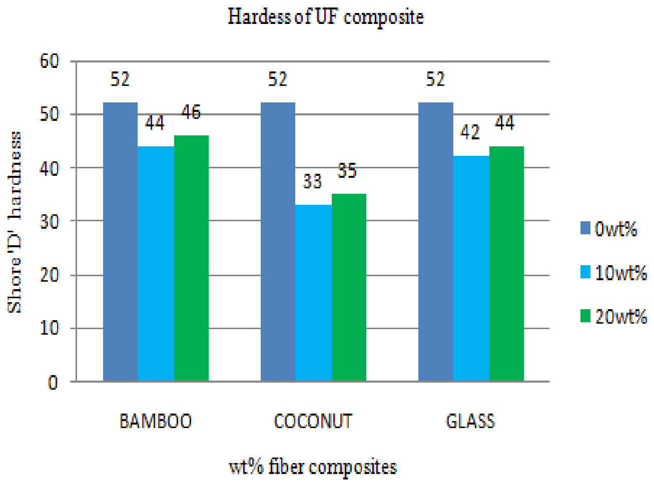

Fig. 6. Graphical representation of shore 'D' hardness of UF composites.

3. TENSILE PROPERTIES

The **Fig.7** shows the variation of Tensile strength for the Urea formaldehyde resins (UF) mixed with bamboo, coconut and glass fibers in various wt(%). **Fig. 7** reveals that with the inclusion of various glass fibers wt% in urea formaldehyde resin the tensile strength was on higher side. John and Anandjiwala (2008) has given the values for the various fibers and is shown in **Table 3** [13]. A study of **Table 3** reveals that tensile strength of glass fibres is higher than the bamboo and coconut fibers.

Table 3 Natural Tensile Strength of Fiber

Fibers	Tensile strength (MPA)
Glass fiber	2000-3400
Bamboo fiber	140-230
Coconut fiber	131-175

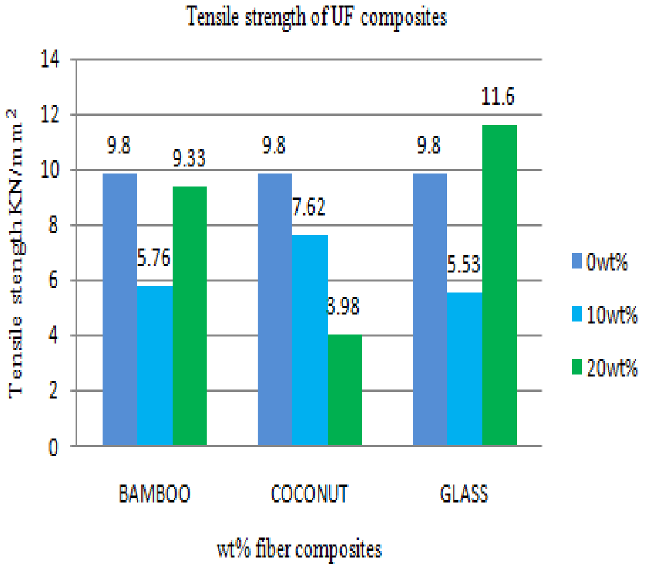

Fig. 7 Tensile strength of UF composite

4. FLEXURAL STRENGTH

The **Fig.8** shows the variation of flexural strength for the Urea formaldehyde resins (UF) mixed with bamboo, coconut and glass fibers in various wt. (%). An examination of Fig. 8 reveals that with the inclusion of fibres in Urea formaldehyde resins (UF), there is decrease in the flexural strength. The decrease in flexural strength is attributed to the fact that inclusion of fibres induces more void fraction and pores in the composites.

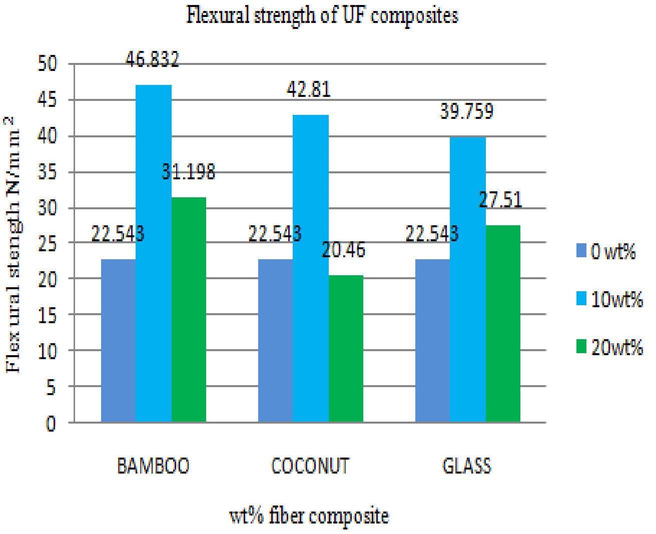

Fig. 8 Flexural strength of UF composite.

5. PERCENTAGE ELONGATION

The **Fig.9** shows the variation of percentage elongation for the Urea formaldehyde resins (UF) mixed with bamboo, coconut and glass fibers in various wt (%). This study reveals the ductile behaviour of various composites has been increased with the inclusion of 20% bamboo, coconut and glass fibers. However, the highest elongation percentage was observed with the inclusion of 20% coconut fibres.

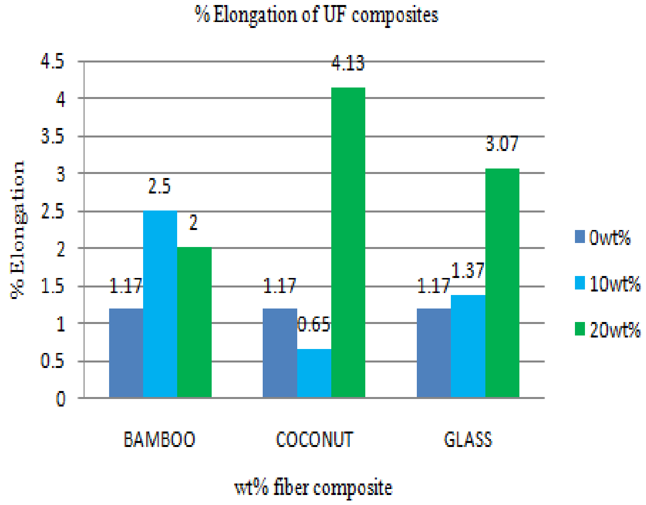

Figure 9. Graphical representation of % elongation of UF composites

VII. CONCLUSION

The mechanical property of natural fibers reinforced composites was reviewed. In this research work, epoxy resins were replaced with amino resins like urea formaldehyde. The amino resins were chosen as they are easily available in both liquid as well as in the solid form and can be easily fabricated by simple hand layup fabricated. The natural fibers like coconut and bamboo were used in the study.

The following conclusions have been derived from the study:-

1) The volume fraction voids (%) was highest with the 20wt% of coconut mixed with 80wt% urea formaldehyde composite. The increase in the volume fraction void (%) has been attributed due to the presence of pores and voids in the composite structure. It has significantly affected the mechanical properties and even the performance of the composites. The higher voids content attributes lower fatigue resistance, greater susceptibility to water penetration and weathering. However, the presence of void is unavoidable in composite as hand lay-up method induces air void inside the composite.
2) With the inclusion of bamboo, coconut, glass fibers in urea formaldehyde, there is decrease in the hardness of composite. The decrease in the shore D hardness was lowest for the inclusion of 20wt% of bamboo, coconut and glass fibers in comparison to 10wt% inclusion of bamboo, coconut and glass fibers. The decrease in hardness in the fiber composites from the pure composites has been attributed to the fiber-matrix interfacial bond formed in the composites, which causes a decrease in the chemical bond of the composites. This improves the mechanical properties of fiber composites by making more flexible and shock resistance.
3) The higher value of tensile strength was observed with the inclusion of glass fibers wt% in urea formaldehyde resin. The increase in the tensile strength in the composite due to mixing of glass fibres has been attributed due to the increased tensile strength of glass fibres in comparison to bamboo and coconut fibers.
4) With the inclusion of fibres in Urea formaldehyde resins (UF), there is decrease in the flexural strength. The decrease in flexural strength is attributed to the fact that inclusion of fibres induces voids fraction and pores in the composites.
5) Study had revealed the increase in the ductile behaviour of various composites with the inclusion of 20% bamboo, coconut and glass fibers. The elongation percentage was highest with the inclusion of 20% coconut fibres.

Since no composite mixed with fibres have satisfied all the parameters, thus authors are of view that particular composite as per the requirement of application has be selected. Since, the waste materials have been used in the study; hence their use will be cost effective and will prevent the environment from the polluting effect from these fibers. Beside this, it will also reduce the problems pertaining to their disposal. Authors are of view that tests like wear test, shear strength, fibre orientation, loading pattern, XRD and SEM tests has to be performed for further analysis of composite to be used for applications like electric appliances and plywood components etc.

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