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Substitution of Wood by Polymer Composites with Jute Fibre-A Case Study

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Abstract

Conservation of the natural resources of our planet has become an issue of prime importance all over the world. Indiscriminate felling of trees has come in for severe criticism and all developed countries have been exploring the possibilities of developing alternatives for wood products. Modern building planners, Architects and Builders are leaning towards environment friendly products by considering minimum use of wood in construction. The Central Public Works Department (CPWD) has now banned the use of wood in building constructions with effect from April 1993. Even so, about 4 million cubic metre of timber is annually used in our country for housing purposes and there is an additional annual demand of about 1.5 million cubic metres. It is, therefore, high time that wood alternatives are brought into use. Conventional wood-based materials are known for their susceptibility to fire damage, impact damage, high temperature damage, aggressive chemicals and high voltage areas. To overcome all these problems it has been made possible to use jute fibre as reinforcing filler fibre hybridizing with glass fibre to produce high strength synthetic wood substituted products. It is essential to prepare Sheet Moulding Compound (SMC) and Dough Moulding Compound (DMC) for the production of synthetic wood substituted composite materials. The basic technological aspects along with commercial applications and business possibilities of this unique and innovative, high strength synthetic wood substituted products have been highlighted in this paper.

Keywords: *sheet moulding compound (SMC), dough moulding compound (DMC), jute–glass fibre hybrid composite (JDMC), filler fibre, hybrid composite*

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INTRODUCTION

Cost of conventional sheet moulding compound (SMC) or dough moulding compound (DMC)-based composite is very high for the replacement of wood-based products due to incorporation of high cost glass fibre and low aspect ratio filler such as calcium carbonate. In the conventional SMC or DMC preparation, calcium carbonate is basically used as cheap particulate filler and these particles are extremely inefficient as reinforcing agent because of their low aspect ratio[1]. On the other hand, if part of this filler can be replaced by jute fibre, which can also act as a cheap substitute of filler, it will provide the extra advantage of improving the strength because jute fibre can act as a reinforcing agent because of its high aspect ratio[2]. This in turn will allow the reduction of glass fibre percentage in the conventional SMC or DMC, thereby reducing the cost and density of the jute–glass fibre hybrid SMC or DMC-based composite[3]. This type of hybrid composite will have a density lower than

the conventional only glass fibre-based composite and can be ideally used for the replacement of wood-based products[4–12].

Justification for the Use of Hybrid Composite

The justification for considering the jute–glass hybrid SMC or DMC-based composite as an alternative for wood-based products is cited below:

1. High volume production of various items will help the environment by preventing further deforestation.
2. By advocating the widespread use of this alternative material and disseminating information that would facilitate its commercial production.
3. By inclusion of jute fibre with high-energy related glass fibre as a partial replacement of reinforcement media will reduce the cost of the composite.
4. Versatility of this technology for building industries by producing doors, window frames, ventilators, partitions, false ceiling, furniture, electrical switch boxes and insulating sheets for housing.
5. High strength to weight ratio in comparison to wood and other synthetic composite materials and thermoplastic materials.
6. Weather resistant and durable for a long time.
7. Corrosion resistant.
8. Termite, fungus, rot and rodent resistant.
9. Fire retardant.
10. Cheaper than fibreglass reinforced plastics (FRP)[13–16].

MATERIALS AND METHOD

In the preparation of jute–glass hybrid SMC (JGSMC), jute fibre is used in the form of felt or stitched mat and the glass fibre is used in the form of surface mat, woven roving, chopped strand mat and combination mat. The matrix resin is selected as general purpose polyester, isophthalic polyester or water base phenolic (Resole). The fillers used are precipitated calcium carbonate, talcum powder or foamed silica. The flame retardant additives used are chlorinated paraffin wax, antimony trioxide and alumina trihydrate. The shrinkage controlling additives used are polyvinyl acetate, low density polyethylene or polystyrene. It is necessary to develop polar group over the surface of the jute fibre by applying organometallic silicon compound compatible with the resin matrix as surface active agent. This treatment enhances the coupling effect between the fibre and the matrix resin and ultimately increases the strength properties of the composite for higher fibre to resin ratio.

In the preparation of JGDMC, jute fibre was used in the form of chopped fibre of 12–18 mm length and glass fibre was used in the form of chopped strand of 12–25 mm length. All other ingredients were same as used in the preparation of JGSMC.

The SMC or DMC thus prepared were then used in the closed metal mould and produced the desired size by employing hot hydraulic press at a temperature of 140ºC and at a pressure of 500 psi.

RESULTS AND DISCUSSION

Jute fibre in general, requires high percentage of resin to wet with polymeric matrices due to weak interfacial bonding between the fibre and the resin and due to hygroscopic nature of the jute fibres. The alpha cellulose content of jute fibre possesses three hydroxyl groups for each glucose residue and the hemicellulose content of jute fibre possesses two hydroxyl groups for each pentose residue. The hydroxyl groups are the active centres to attract water molecules. Hydrogen bonds are formed between the hydroxyl groups and the water molecules. First the direct attachment of water molecules through the active sites (i.e., hydroxyl group) occur and then the indirect

attachment through directly attached water molecules take place. To overcome this major problem, sizing treatment with organometallic silicon compound is done similar to the process sequences followed in case of glass fibre. In our present study, we have made both SMC and DMC based on jute–glass hybrid as reinforcement and polyester resin or phenolic resin as matrix materials. The results obtained were then compared with conventional SMC and DMC based on only glass fibre as reinforcement. Table 1 shows typical composition of glass fibre-based DMC and JGDMC for making composites. Table 2 shows the comparative mechanical properties of only glass-based DMC and JGDMC. Table 3 shows the properties of JGSMC based composite. Jute fibre (density, 1.3 g/cc) being lighter than glass fibre (density, 2.54 g/cc) offers additional advantages. In DMC, calcium carbonate is basically used as cheap particulate filler and these particles are extremely inefficient as reinforcing agent. On the other hand, jute fibre can act as cheap filler and it can also act as a reinforcing agent because of its high aspect ratio. The authors have formulated JGDMC and JGSMC for making various wood substituted products at the Institute. In our investigation, we have observed that replacement of filler (calcium carbonate) by 25% by weight with jute fibre in DMC formulation increased the mechanical properties of the composite at a greater level. Such judicious selection of jute fibre for making hybrid composite with glass fibre brings down the cost of the products by almost 28%. Therefore, when we compared the strength and modulus values of the two types of composites (DMC & JGDMC), the JGDMC hybrid composite showed higher strength and modulus values than that of DMC-based composite (Table 2). Thus jute fibre can be considered as an extremely effective and economic type filler fibre for the production of composite products having better properties than that of DMC-based composite.

Table 1: *Comparison of Dough Moulding Compound (DMC) Based Composite and Jute–Glass Fibre Hybrid Composite (JDMC).*

Type of composite	Glass fibre (%)	Jute fibre (%)	Polyester resin (%)	Calcium carbonate (%)	Tertiary butyl perbenzoate(%)	Zinc stearate (%)
DMC	30	-	30	38	0.5	1.5
JDMC	6	33	31	28	0.5	1.5

Table 2: *Comparative Mechanical Properties ofDough Moulding Compound (DMC) Based Composite and Jute–Glass Fibre Hybrid Composite (JDMC).*

Type of composite & resin	Tensile strength (MPa)	Tensile modulus (GPa)	Flexural strength (MPa)	Flexural modulus (GPa)
DMC	60–80	8–14	70–100	5–8
JDMC	110–150	10–16	110–180	10–14
Polyester resin	35–60	3–4	50–70	3–4

Table 3: *Properties of Jute–Glass Fibre Hybrid SMC Composite (JGSMC).*

Sl. No.	Properties	Mean value of five samples
1	Tensile strength (MPa)	70–80
2	Tensile modulus (GPa)	5–7
3	Flexural strength (MPa)	150–170
4	Flexural modulus (GPa)	8–10
5	Izod impact strength (J/m)	450–500
6	Barcol hardness	45–50
7	Density (g/cc)	1.4–1.5
8	Water absorption (%) in 24 h at 28ºC	1

Cost Economics of Jute–Glass Fibre Hybrid SMC Based Composite

In the construction/building industry in India, JGSMC composite can be used as a wood substitute or as a PVC substitute for door panels or partitions. The relatively lower labour cost in manufacture of JGSMC composite sheets is a definite advantage in a country like India. In addition JGSMC composite sheets have better weathering resistance in tropical Indian conditions compared to PVC sheets and wooden board. Such type of composite may also be used in other countries because of its advantageous properties.

The techno-economic considerations that enabled JGSMC composite sheets to score over PVC or particle board can be highlighted in the following study. The flexural strength of PVC (68–83 MPa) is much lower than that of JGSMC composite sheets (147–168 MPa). Hence for equal flexural load bearing capability, the thickness of PVC sheet required would be more than that of hybrid composite sheets. Following equation can be used for thickness calculation:

T-pvc = (Flexural strength of composite ÷ Flexural strength of PVC)×T-composite
= (168 ÷83) × T-composite
= 1.42× T-composite

Where, T-pvc = Thickness of PVC sheet, and T-composite=Thickness of composite.

Similarly, for the particle board, we can calculate the thickness required for equal load bearing capability when compared with hybrid composite sheets.

T-particle board = (Flexural strength of composite ÷ Flexural strength of particle board) × T-composite
= (168 ÷22) × T-composite
= 2.76×Tcomposite
Where, T-particle board = Thickness of particle board.

In case of plywood also, we can calculate the thickness required for equal load bearing capability when compared with hybrid composite sheets.
T-plywood = (Flexural strength of composite ÷ Flexural strength of plywood) × T-composite
= (168 ÷ 75) ×T-composite
= 1.49 × T-composite

Where, T-plywood = Thickness of plywood.

Hence, for equal flexural load bearing capability, the thickness required for particle board and boiling water resistance (BWR) grade plywood would be 2.76 times and 1.49 times that of JGSMC composite sheet, respectively.

On the basis of the above calculation, the cost of JGSMC composite sheets will be lower than that of PVC, particle board and BWR grade plywood. Further, weathering characteristics of JGSMC composite sheets are far superior to thermoplastic

PVC sheets, particle board and BWR grade plywood sheets especially in a tropical country like India.

PRESENT SCENARIO

There is a growing demand for products such as composite doors & panels. So, while the country's forest cover is limited, the potential for composite doors & panels is unlimited. The cost of conventional SMC-based composite is very high for making doors & panels due to incorporation of high cost glass fibre and low aspect ratio filler such as calcium carbonate. In the conventional SMC preparation, calcium carbonate is basically used as a cheap particulate filler and these particles are extremely inefficient as reinforcing agent because of their low aspect ratio. On the other hand, if part of this filler can be replaced by jute fibre which can also act as a cheap substitute of filler it will provide the extra advantage of improving the strength because jute fibre can act as a reinforcing agent because of its high aspect ratio. This in turn will allow the reduction of glass fibre percentage in the conventional SMC, thereby reducing the cost and density of the JGSMC composite. The hybrid composite will have a density lower than the conventional only glass fibre-based composite.

EVALUATION OF THE PROPERTIES OF JUTE–GLASS FIBRE HYBRID SMC COMPOSITES

The test specimens from the JGSMC sheets are to be tested as per the methods of test indicated against each test laid down in Table 4.

Table 4: *Methods of Testing the Properties of Jute–Glass Hybrid Composite Sheets.*

No.	Properties	Mean value	Methods of test
1	Density	1.50–1.55	ASTM D 792
2	Barcol hardness	50–60	ASTM 2583-67
3	Tensile strength (MPa)	80–100	ASTM D 3039
4	Flexural strength (MPa)	168–200	ASTM D 790
5	Izod impact strength (J/M)	550–580	ASTM D 256
6	Water absorption (%)		
	after 24 h in water	0.6–1.0	ASTM D 570

CONCLUSIONS

1. The jute fibre can be considered as an extremely effective and economic type filler fibre because of its high aspect ratio for the production of JGSMC sheets & DMC moulded products.
2. The mechanical properties of the JGSMC sheets & DMC moulded products are well comparable to the conventional glass fibre-based SMC sheets & DMC moulded products.
3. The density of JGSMC sheets & DMC moulded products is 20–25 % lower than the conventional glass fibre-based SMC sheets & DMC moulded products.
4. The cost of JGSMC sheets & DMC moulded products are 15% lower than the conventional glass fibre-based SMC sheets & DMC moulded products.
5. The strength properties of JGSMC sheets & DMC moulded products are quite satisfactory and conform to the requirements of the consumer industries for producing various components.
6. The cost of JGSMC composite sheets will be lower than that of PVC,

particle board and BWR grade plywood.

LIST OF PLANT & EQUIPMENTS

(1) SMC machine,
(2) Z-blade type Sigma machine for DMC preparation,
(3) High speed mixer machine,
(4) Digital weighing machine,
(5) Pultrusion machine,
(6) Hydraulic hot press,
(7) Laboratory oven & other apparatus.

The sketch of SMC machine is shown in Figure 1.

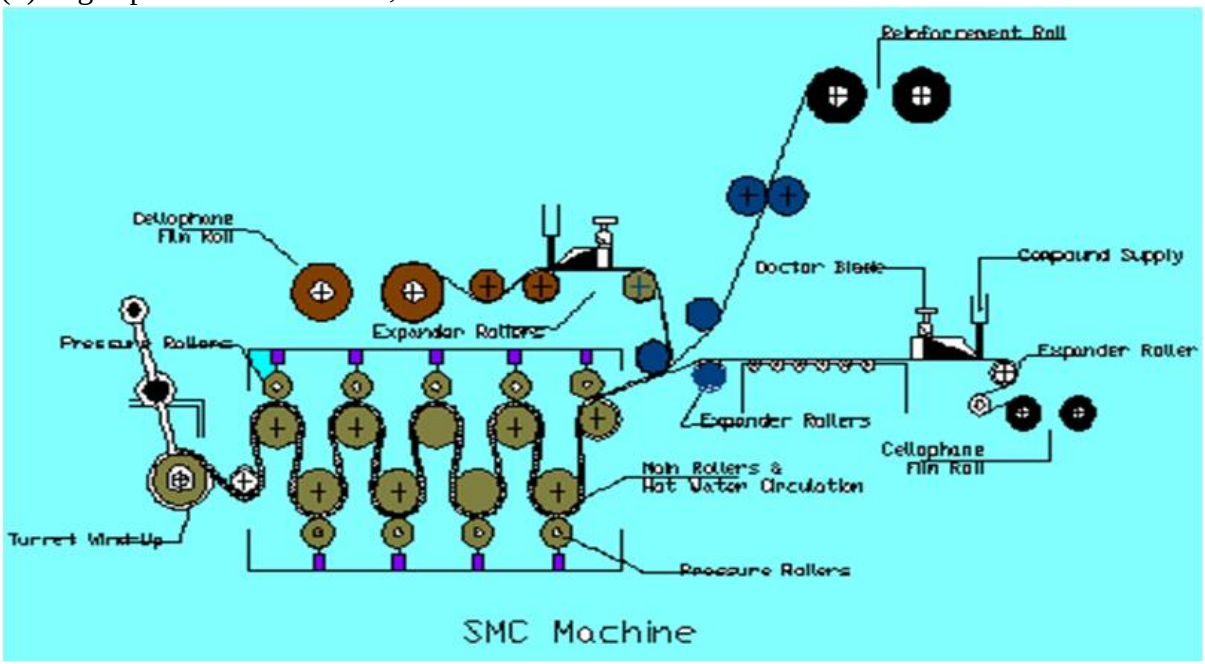

Fig. 1: *SMC Machine.*

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