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DEVELOPMENT OF SUSTAINABLE AND LOW COST JUTE-POLYESTER COMPOSITE: APPLICABILITY ASSESSMENT IN HOUSING SECTOR

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ABSTRACT

In this study, the applicability of jute–polyester composite as housing material was evaluated. The effect of stacking sequence on mechanical behavior of jute reinforced polyester composite was investigated. Jute fiber was chosen as the reinforcing material because of its availability, low cost and excellent bonding properties. It has high tensile strength, low extensibility, and ensures better breathability of fabrics. Polyester Resin was used as matrix material. Polyester is easy to handle, cheap, stable dimensionally, and has good mechanical and electrical properties with good chemical-resistance. Simple hand layup method was used to fabricate the composite. The jute was cut into desired pieces and then dried inside a heating chamber at 80-90 ◦C approximately for an hour and a half. A wooden mold was used. The polymer solution was applied to the pieces of jute fabric and composites of different stacking sequence were fabricated. The mixture was pressed using available means for better adhesion. It was kept for 48 hours for better curing. Tensile strength (TS), Tensile modulus (TM), Bending strength (BS), Bending modulus (TM), Impact strength (IS) were measured. The TS, TM, BS, BM and IS for specimens with one jute layer (J1) to five jute layers (J5) were measured. In each case J5 showed better mechanical properties. The TS, TM, BS, BM and IS for specimens with five jute layer (J5) was 117.7 MPa, 3.78 GPa, 126.7MPa, 5.192 GPa, 20.97 kJ/m^2. The increase of TS, TM, BS, BM and IS for J5 were found to be 26.5%, 8.7%, 154.4%, 74.8% and 71.5% respectively. Water intake test revealed that the intake rate increased gradually at first but eventually steadied. On average the water intake was not more than 30%. The water intake increased with increased stacking sequence. As this composite is aimed to be used as a housing material, soil degradation properties were tested. In the soil degradation test, after 6 weeks, the mechanical properties such as TS, TM, BS and BM were decreased to 31.2, 24.6, 23.5 and 30.1% respectively. A facile approach to cost analysis was made for J5. The cost was approximately 73tk/ft^2. It was clear that the Jute-Polyester composite has superior mechanical properties than other locally available natural housing materials. Also, the cost was lower than other materials available in market. It is suitable to be made into parts like roof, floor covering, walls, tiles etc. Eco-friendly and hygienic toilets are possible to be made by this composite material.

Keywords: *Jute fiber, Polyester resin, Mechanical properties, Eco friendly, Low cost housing material.*

1. INTRODUCTION

Bangladesh is a country of 142 million people living in 32 million households. Only 2% of this huge population live in concrete houses, 46% live in corrugated-iron (CI) and galvanized-plain (GP) sheet-made households (Population & Housing Census 2011, Bangladesh Bureau of Statistics). The balance population live in houses built of housing materials like tree leaves (31%) and thatch (21%). These materials are not secured and also unstable. This ghastly scenario is a result of poverty of the marginalized people as indicated by the economists from the World Bank (World Bank Report on South Asian Real Estate Sector, October 2010). Because of lack of access to rudimentary housing, the socio-economic pyramid faces multiple consequences like reduced productivity and lack of income, mental trauma owing to the lack of security etc. (Friedman & Danny, 2010).

The intense level of poverty coupled with unaffordable housing materials walk hand in hand for which the housing problem of Bangladesh is far from being solved. A humble effort can be made by making high quality composite material with locally available natural reinforcements.

Synthetic fibres have hazardous effects to the surroundings. Natural fibre has some advantages like high strength and modulus, low extensibility, high abrasion resistance, good thermal stability, insulation against sound & heat, biodegradability, anti-static property, surface morphology, etc.

Products made of jute-reinforced composites have the additional advantages such as low density, acceptable specific strength, less wear during processing, low cost, renewability and biodegradability. Among all the natural fibres, jute fibre gain particular attention to the scientists due to its many unique properties like durable, biodegradable, renewable, rust proof, saline resistant, unbreakable, maintenance free, fire retardant and water resistant, less costly, heat resistant with low thermal conductivity, Eco-friendly (Khan, Hossain & Ali, 1999).

Bangladesh grows 1,349,000 Tonnes of jute per year (Wikipedia, Jute). The lives of 40 million Bangladeshi people depend on either jute or jute related business (Bangladesh Jute Research Institute [BJRI]. n. d) Jute is being used in this sub-continent since the beginning of the Mughal era. Clothes, ropes, twines etc are common uses of jute. But the use of jute has extended largely. A host of new products with high value addition such as home textiles, floor coverings, shopping /carry bags, soft luggage, brief-cases, footwear/shoes/espadrilles, home decorative, handicrafts, novelties, gift items, fashion accessories, fine and wrap yarn, particle boards, composites, technical textiles, chemical products, pulp and paper, etc. have been possible to be manufactured from jute.

2. METHODOLOGY

Jute fiber is bio-degradable. It can be recycled and so not harmful to the environment. It is a natural fiber with golden and silky shine and it's called The Golden Fiber. It is the cheapest Bast fiber. In terms of usage, global consumption, production, and availability, jute is the second most important plant fiber. It has high tensile strength and low extensibility. Therefore, jute is very suitable in bulk packaging. It helps to make best quality industrial yarn, fabric, net, and sacks. It is one of the most versatile natural fibers that have been used in raw materials for packaging, textiles, non-textile, construction, and agricultural sectors. Having said that, the crease resistance of Jute is very low and the drape Property is not good enough. (Asia Jute, n. d)

Polyester resins are low viscosity liquids based on unsaturated polyesters, which are dissolved in a reactive monomer, such as styrene. (Science Direct, n. d) Polyester is easy to handle, cheap and is stable dimensionally. It has good mechanical and electrical properties with good chemical-resistance. Polyester resins are the most optimum choice amongst all resin options as it is the least expensive with best qualities (Molded Fiber Glass Companies, n. d).

2.1 Materials

For producing the desired composite regular quality jute cloth were collected from available source. Unsaturated polyester resin, peroxide (hardener), anti-bubbling agents were collected from the local market.

2.2 Fabrication

The jute cloth was cut to desired sized pieces and then dried inside a heating compartment approximately for two hours. The heating chamber was made out of clay walls and the temperature inside the chamber was kept 80-90 ◦C. The polymeric solution was prepared by mixing unsaturated polyester resin, hardener, and anti-bubbling agent. The mixture was stirred well to get an even mixture. This mixture was then added to the fiber. Here, a simple hand lay-up method was used.

A wooden mold was used. Releasing agent was applied at the bottom and then the composite mixture was poured and evenly spread. Different stacking sequences were applied and five different compositions were manufactured. The mixture was pressed using available means for better adhesion. It was kept for 48 hours for better curing.

The jute content was kept 25% in all the composites from J1 to J5. This was done because in previous studies (Mohanty & Khan, 2000) it was found that 25% jute fiber in a composite show best mechanical property.

2.3 Testing of Mechanical Properties

2.3.1 Tensile Test

To test the tensile properties of the Jute-Polyester composite, specimen was prepared as the first step. The dimension of the specimen was 120mm×20mm. A Universal Testing Machine (Hounsfield series, model: INSTRON 1011, UK) with a cross-head speed of 10mm/min at a span distance of 50 mm was used and the tests were conducted according to ASTM Designation: D638-03.

2.3.2 Flexural Test

For measuring Flexural properties, the same UTM was used. Specimens had a dimension of 65mm×20mm. The tests were carried out according to ISO14125 methods. The cross-head speed of the UTM was 60mm/sec at a span distance of 25mm.

2.3.3 Impact Test

The Charpy impact test were conducted on composite specimens (un-notched) according to ASTM D 6110-97 using an Impact tester (MT-3016, Pendulum type, Germany).

2.3.4 Water Intake Test

Firstly, the specimens were prepared. They were cut into following dimensions (30cm×20cm). The thickness of the specimens varied with varying stacking sequence. Before immersing into water, the specimens were dried again inside a heating chamber at 105 °C for an hour. They were then taken out cooled in room temperature. Silica gel was added to absorb any excess moisture. All the specimens were weighed.

The specimens were then put into water tank at a temperature slightly higher than room average temperature (30 ˚C). The water intake test was conducted at a time span of 15 days. Fifteen sets of specimens were used. The first specimen was taken out of water after 24 hours and weighed. The increased weight was granted as the weight of absorbed water.

2.3.5 Soil Degradation Test

In pursuit of testing soil degradation, the composite specimens were cut into pieces of desired size (30cm×20cm). The specimens were dried at 100° C for an hour and then cooled at room temperature. They were also dried properly using desiccators (silica gel). The specimens were then buried under soil and kept for 6 weeks. The soil was natural and not lab treated in any ways.

3. RESULTS AND DISCUSSIONS

3.1 Thickness

Since different stacking sequence was used the thickness of the composite specimen were different. Following is a list of the thickness of the various stacking sequence:

Table 1: data of the average thickness of the composites

Stacking sequence	Thickness (mm)
J1(single layer)	0.60±.05
J2(two layer)	0.95±.05
J3(three layer)	1.09±.05
J4(four layer)	1.60±.05
J5(five layer)	2.00±.05

3.2 Tensile Properties

Testing the tensile properties of the composite revealed that the tensile strength increased with increasing layers of jute fiber. Following is a table that lists the tensile strength for each stacking sequence:

Table 2: Data of the Tensile strengths of the composites

Stacking sequence	Tensile Strength (MPa)
J1(single layer)	86.50
J2(two layer)	89.78
J3(three layer)	95.36
J4(four layer)	108.04
J5(five layer)	117.7

Figure 1 shows this data. It can be said that J5 shows superior properties as an indication of better adhesion of matrix and fiber.

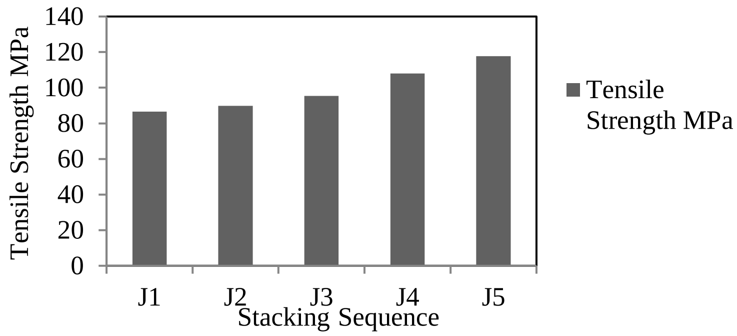

Figure 1: Variation of tensile strength with stacking sequence

The effectiveness of the interconnection of the matrix and the fibers and their ability to transfer stress across the interface is a key feature deciding the mechanical properties of the composite. It also depends on the strength and modulus of the fibers, chemical stability of the cured matrix (Saheb, 1999; Park, Seo, Ma & Lee, 2002)

3.3 Bending Properties

Bending Strength for J1, J2, J3, J4 and J5 is 76.52, 117.6, 120.09, 124.09, 126.7 MPa as per the reading of the testing machine. Better bending qualities are observed with increased stacking sequence. Figure 3 illustrates the increasing trend. The bending modulus (showed in figure 4) also increases with stacking sequence. It is clear that both the tensile and the bending strength increase with increasing layers of fiber in the composite.

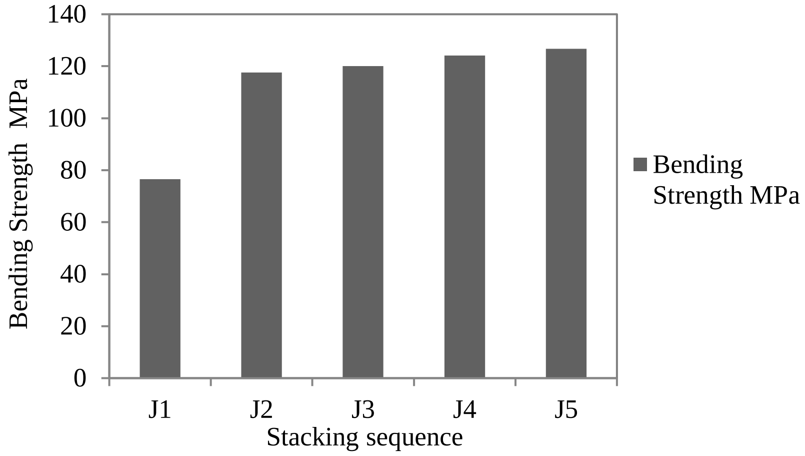

Figure 2: Variation of Bending strength (BS) with stacking sequence

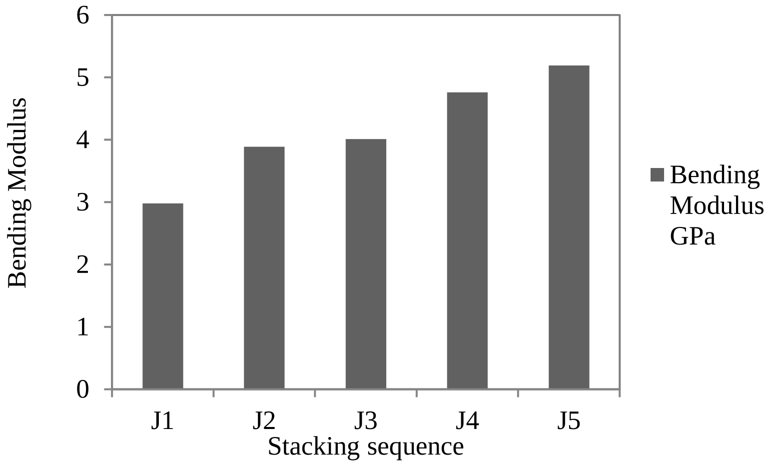

Figure 3: Variation of Bending Modulus with stacking sequence

3. 4 Impact Strength

The Impact strength of J1, J2, J3, J4 and J5 composites were found to be 14.01, 15.11, 17.44, 19.41 and 20.97 kJ/m² respectively . Unlike bending and tensile properties, the impact strength increases with increasing stacking sequences of jute fabric. Impact strength of the composite is influenced by the matrix and the fiber and their interfacial bond Strength. The fibers play an important role on the impact resistance of the composites as they interact with the crack formation in the matrix Figure 5 shows the increasing trend of Impact strength with increasing stacking sequence

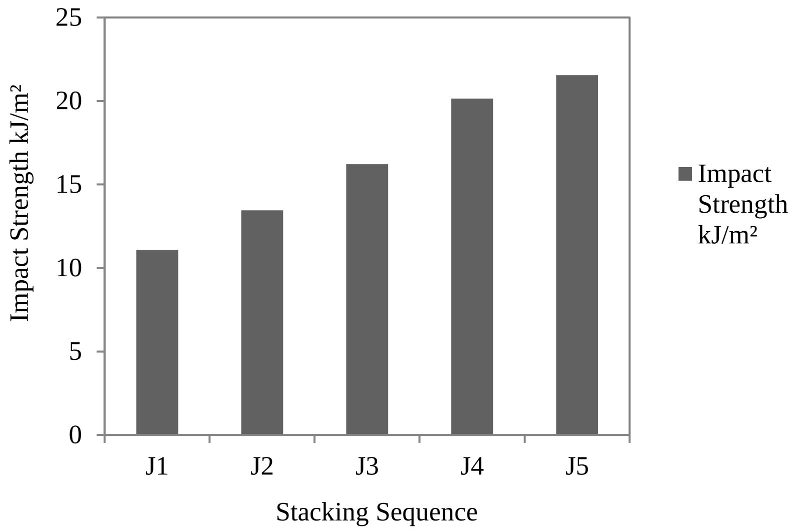

Figure 4: Impact strength with increasing stacking sequence

3.5 Water Intake Properties

It was observed that the absorption of water was very large at the begining but after a certain amount of time the intake rate stabilized. Figure 6 shows the increased water intake at the first 24 hours and then then the approximately stable state. It was clearly observed that on an average on the first 24 hours, the water intake increased rapidly in specimens of all stacking sequence (27.91% to 32.01%) After 1 day, the rate stabilized. After 15 days the water intake was lowest in one jute layered specimens (J1) and highest in five jute layered specimens (J5). The rates were 34.98 % for J1 and 38.90% for J5. This property is due to the very hydrophylic nature of jute which is mainly composed of cellulose.(S. Mishra, Mohanty, Drzal, M. Misra, Parija, Nayak, Tripathy). Another observation can be made that the tensile strength, bending strength, bending modulus and impact strength increase with increasing stacking sequence. These are desireable traits for the composite. But the increase of water intake is not desirable. Increasing Fiber content of the composite retains more water molecules and that is why water intake increase with the increase of fiber content.

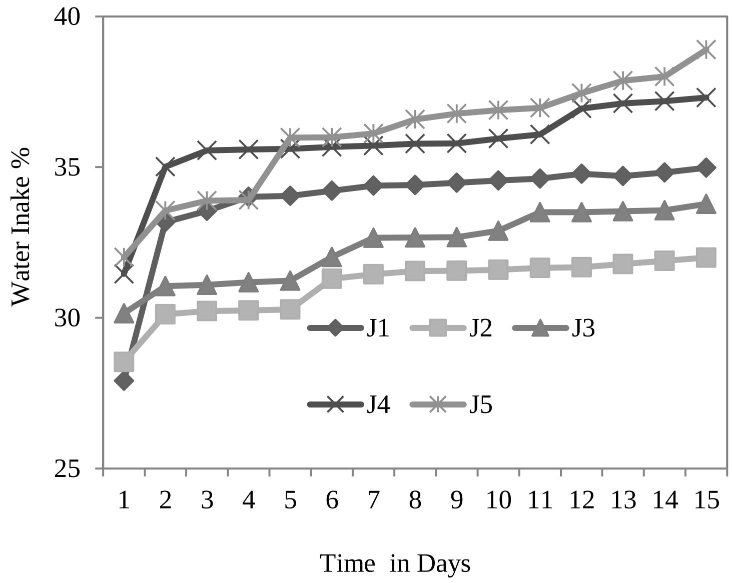

Figure 5 : Water intake increase with stacking sequence

3.6 Soil Degradation Test

After 6 weeks the specimens showed that the TS, TM, BS and BM were decreased to 31.2%, 24.6%, 23.5% and 30.1% respectively. The samples were kept for 6 weeks and the conditions were exactly natural. It is clear that the rate of reduction of TS, TM, BS and BM were slow. The results of Soil Degradation test are shown in Figure 6, Figure 7, Figure 8 and Figure 9.

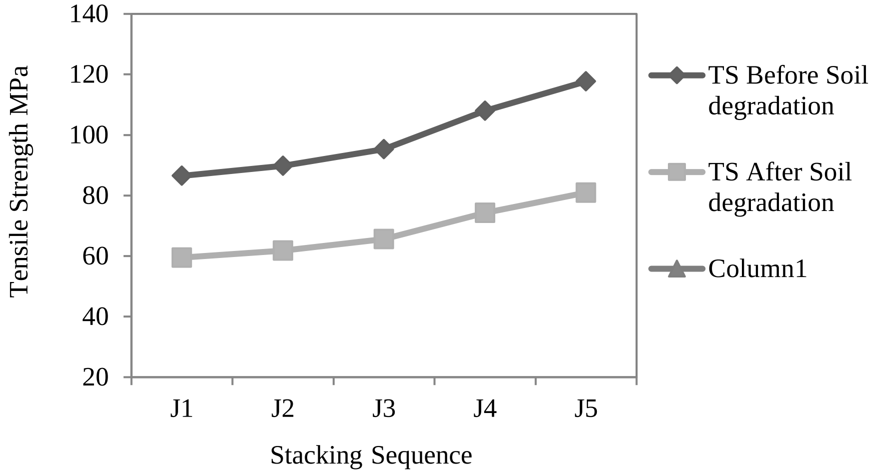

Figure 6: Reduction of tensile properties for Soil degradation

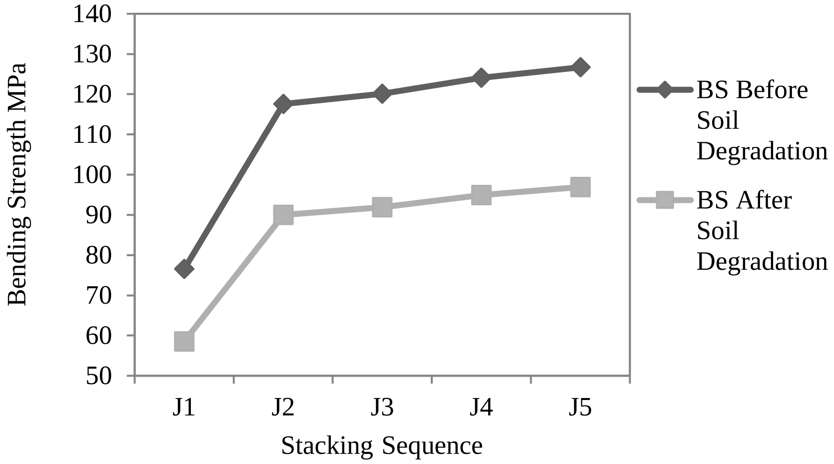

Figure 7: Reduction of tensile properties for Soil degradation

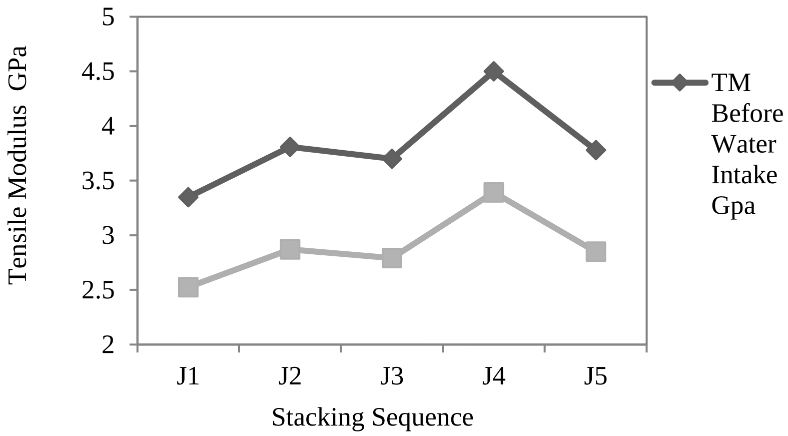

Figure 8: Reduction of Tensile Modulus for Soil degradation

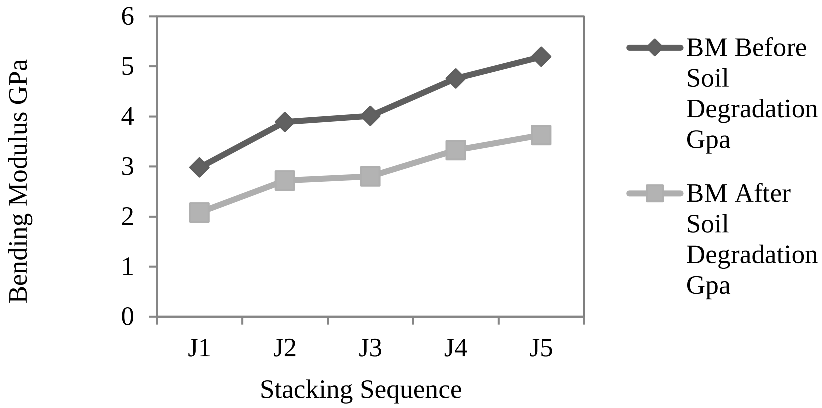

Figure 9: Reduction of Tensile Modulus for Soil degradation

4. COST ANALYSIS

A practical cost analysis was not easy since the whole process is still in an experimental stage. Still, a rough count was made for J5. Approximately 73tk/ft^2 was the estimated price of the J5 Jute-Polyester composite.

Item	Price (tk/ft^2)
Polyester	52
Jute	10
Utilities	1
Labour cost	10

The price of corrugated metal sheets was collected from local source and also compared with the price of online sources. (Prices of CI sheets, The Daily star, April 27, 2008), Appollo Ishpat Complex Ltd.

Figure 11 shows the compared price of jute-polyester composites with other common housing materials used in the rural areas of Bangladesh.

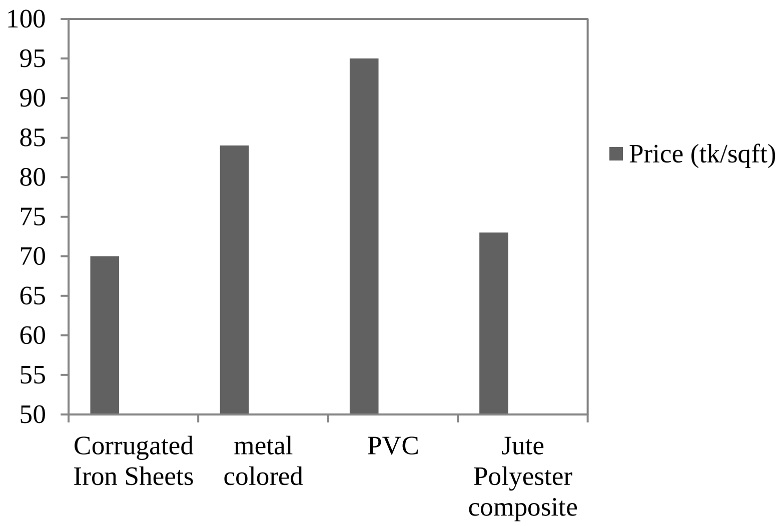

Figure 10: Price comparison of Jute-polyester composite

5. CONCLUSIONS

This study shows the potential of Jute-Polyester composite to be used as housing material. The mechanical properties were in many cases found superior to natural elements used from local sources whereas the price is lower than that of CI sheets or PVC. So, this composite can be used to build houses with superior quality than natural components in lower price. Also, the price of Jute-polyester composite will be even lower if manufactured on an industrial scale. Another important aspect is that also possible to manufacture in a small scale using no machinery or electricity. Local manpower if taught properly, can make this composite on their own. The use of jute will increase and the economy will mobilize. This composite will be durable as it has good mechanical properties but the water intake properties need to be improved for best results. Further research can be done in this regard.

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