Jute-reinforced polyester sheet and its performance

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Abstract: The use of jute fibre in the manufacture of polyester plastic roofing sheet has been strongly favoured to promote the use of indigenous materials in the developing countries. Jute is a cellulosic material and is likely to decay on aging. Outdoor exposure tests of the fibre-reinforced sheets were carried out. Mechanical and physical properties were determined at the end of three and half years of weathering. It was found that sheets suffered greatly from the loss of tensile and flexural strength on aging. The losses were more pronounced in wet conditions. In addition, the sheets exhibited a high shrinkage stress which caused surface crazing and debonding of the resin from the jute-fibre matrix.

1 Introduction

Polyester resins are thermosetting resins which set hard at room temperature when mixed with a catalyst and accelerator in suitable proportions. Compared to other thermosetting resins, these resins are cheap and easy to mould. The set resin is, however, brittle and relatively weak. Fibre reinforcement in various forms is used to change and improve certain properties. The most commonly used reinforcement is glass fibre. Other reinforcing materials include asbestos, sisal, jute and synthetic fibres. The advantages of fibre-reinforced plastic are high strength-to-weight ratio, low fabrication cost and reduced maintenance.

Jute is a fibre derived from the inner bark of the jute plant, which is extensively cultivated in West Bengal. It is a soft and highly lignified fibre varying in colour from grey to brown. Nearly one million tonnes of fibre are produced in India every year. The use of jute fibre and jute cloth in the manufacture of polyester plastic products has been strongly advocated purely on the grounds of its low cost.[1,2] It is similar to GRP and can be readily fabricated into large and complex shapes. It has been extensively used in Bangladesh in the construction of cheap primary-school buildings under the auspices of CARE.

Applications and durability of glass-reinforced sheets have been adequately studied in India and elsewhere.[3,4] Loss of glass-to-resin attachment and erosion of the resin were identified as the two major failures of these sheets. It has been realised that the durability of glass-reinforced polyester sheets can be improved by the use of suitable coupling agents and by ensuring a resin-rich surface covering on the fibre and the sheet. Jute fibre is a cellulosic material and offers a poler surface for bonding to polyester resin. It is susceptible to volume changes and decay under prolonged hot and humid conditions. Its use as a reinforcing and filler material may have serious adverse effects after long-term exposure. Information on its durability is, therefore, of great importance to builders and engineers.

2 Method of preparation

A plain weave jute cloth is used for the preparation of the sheet. It makes a bidirectional laminate. Generally a hand lay-up process is employed in the preparation of jute polyester plastic. A normal polyester resin is mixed with the correct amount of catalyst and accelerator. It is thinned with styrene monomer to obtain the desired consistency. All plies of jute cloth of the desired size are saturated one at a time with the above resin. A gel coat consisting of an unthinned normal polyester resin with or without pigment and thixotropic filler is then applied on the mould so as to obtain a resin-rich surface. Layers of resin-wet jute cloth are next laid on a clean flat platform to build up to the design thickness. Normally three to four plies of jute cloth are required to form a sheet 3 mm thick. To avoid air entrapment in between the plies, the saturated cloth is pressed by a roller and worked up until the wrinkles and air pockets are eliminated. Finally, the whole assembly is covered with a glass plate.

3 Outdoor exposure and observations

Samples of jute-reinforced polyester (JRP) sheets of 3 mm thickness were obtained through CARE, Dacca, Bangladesh in addition to those made at this Institute. These samples were cut to 15 x 6 cm size and exposed vertically facing south on the terrace of the Institute in November 1975. A few opaque glass-fibre-reinforced polyester (GRP) sheets, obtained from Bakelite Hylam Ltd., Hyderabad, were also exposed in an outdoor durability test in March 1972. The test panels were removed from the exposure rack in May 1979 for laboratory examinations.

JRP panels showed slight warping, twisting and blackening behind the gel coat. Surface crazing and pitting of gel coat close to the edges of the test panels were noticed. Isolated white spots were also observed in some of the panels. The commercial GRP panels suffered excessively from erosion, fibre prominence and adhesive failure between the fibre and the resin. Unlike JRP panels, these sheets remained free from warping and twisting.

Test pieces were cut from the weathered and unweathered panels and data on their water absorption, flexural strength and tensile strength were obtained (see Table 1).

4 Discussion

The weathering of a fibre composite involves the breakdown of the polymer matrix of the fibre/polymer adhesion and the fibre reinforcement. Yellowing and erosion of resin depend mainly on the composition of the resin and the extent of UV radition. However, fibre prominance and surface crazing are invariably affected by the mechanical properties of the interface between the reinforcing fibre and the matrix. Normally a thick coat of polyester is formed over the jute-reinforced polyester sheet, and, therefore, UV degration is expected to affect only the surface layer. Other weathering factors become more important in determining its durability.

Jute fibre differs from glass fibre in its bulk density, porosity, tensile strength, water absorption and surface characteristics.

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Table 1. Physical properties of jute-fibre-* and glass-fibre-reinforced sheet

	Unweathered sheet		Weathered sheet	
	jute-fibre reinforced	glass-fibre reinforced	jute-fibre reinforced	glass-fibre reinforced
1 bulk density, kg/cm³	1150	1300	1025	1260
2 fibre content, %	12–15	28–32	–	30–35
3 water absorption at 28°C, %				
(a) 24 h	2·34	1·03	3·23	1·28
(b) 3 days	2·88	1·17	4·16	1·69
(c) 7 days	3·87	1·27	5·07	1·97
4 water absorption at 100°C, 1 h, %	3·08	1·05	3·90	1·34
5 flexural strength, kg/cm²				
(a) Dry	230·8	1073·8	116·0	1032·9
(b) 24 h water soaking	321·0	1231·9	262·0	991·8
(c) 3 days soaking	428·7	1362·2	196·0	987·6
(d) 7 days soaking	340·6	740·6	190·6	648·8
6 tensile strength kg/cm²	242	760	90–206	630

*Sheets obtained through CARB

The coefficient of thermal expansion for resin (90–110 x 10^{-6}/°C for E-glass (5·0 x 10^{-6}/°C) and for wood fibre (3·06 to 4·5 x 10^{-6}/°C) are different. Change in temperature produces internal stresses which may cause debonding and other type of failures. The length and the amount of the reinforcing fibre are also important factors in determining the degree to which stress is transferred. The flexural strength of dry unweathered JRP is approximately a quarter that of GRP and that of weathered JRP is about one ninth the flexural strength of GRP. Similarly, the tensile strength of dry unweathered JRP is about one third that of GRP and the flexural strength of weathered JRP is about one third to one sixth that of GRP. The low strength of JRP appears to be due to the poor tensile strength and the short fibre length of jute fibre as compared to glass fibre. It seems to work as a filler and constitutes a weak point in the composite system. Increasing the fibre/resin ratio to obtain a high flexural strength for JRP is not possible because of its open texture and high absorption of the resin. Even its bidirectional reinforcement properties do not improve its flexural or tensile strength.

It is observed that there is an initial improvement in the flexural strength of unweathered sheet on water soaking. However, the strength decreases significantly on prolonged water soaking. The water appears reaching the interface and reducing secondary bond forces between the fibre and the resin.[5] The dry strength remains more or less the same but the wet strength is very much affected by weathering. It is interesting to note that although the GRP sheet fails excessively in fibre prominence and erosion, but there is not much loss in its flexural or tensile strength on weathering. The same is, however, not true for JRP sheet. These observations reflect more on the deterioration of the reinforcement and its adhesion with the resin than the breakdown of the resin matrix.

Jute fibre is a cellulosic material and contains free hydroxyl groups. Because it is polar in character, it is likely to initially develop a strong bond with the polyester resin. It may, however, suffer from severe hydrolytic degradation during exposure for the reasons given above. The observed white spots on the surface and surface crazing and pitting of the gel coats may be due to hydrolytic degradation and mechanical stresses. The water absorption figures for JRP sheets are always higher as against GRP sheets even though the fibre content in JRP sheets is less than half of the GRP sheet. It is expected to absorb water through a wicking action also which may result into opening the laminate. Water absorption is increased by weathering for both GRP and JRP, but more so for JRP sheets. In warm moist conditions jute fibre is likely to support mould and algal growth and decay. In addition, moist conditions may catalyse the action of UV radiation and accelerate the process of degradation of the composite. It follows from the discussions given above that if a composite reinforcement consisting of glass-fibre mat with a backing of jute-fibre cloth is employed, the flexural strength as well as its durability may be greatly improved.

4.1 Costs

Polyester resin content by weight in JRP sheet is 85–88% and that in GRP is 68–72%. The cost of jute-fibre mat is one sixth that of glass-fibre mat. However, for a 3 mm sheet, the cost of the resin it requires is approximately 1·6 times that of GRP. As a result, it is found that the cost of both JRP and GRP is almost the same. There is therefore no advantage in the use of jute-fibre mat as a reinforcing material in fibre-reinforced polyester sheet.

5 Conclusions

Jute-reinforced polyester sheet (JRP) suffers greatly from the loss of tensile and flexural strength on weathering. The losses are more pronounced in wet conditions. Compared to GRP these sheets absorb more water and the degree of water absorption increases further on ageing. Adsorption and desorption of water produces high shrinkage stress and causes surface crazing and debonding of resin and jute-fibre.

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