Usage of Polyester Textile Wastes in Composites

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A composite material is produced by using polyester textile wastes as reinforcement material and mainly urea formaldehyde as matrix material. This composite is used in banks, tables, shelves, and pots. The bending strength and absorption properties of the textile reinforced composite are investigated and compared with fibreboard and medium density fibreboard which are alternative materials for the same end-uses. The polyester wastes such as, yarns, woven, and knitted fabrics cut at random dimensions are used as reinforcement material. Matrix material is prepared by mixing urea formaldehyde resin, ammonium sulphate, and flour in a weight ratio of 100:5:10 consecutively. The bending strength of the textile reinforced composite is less than the fibreboard and the medium density fibreboard, but it absorbs less water. It seems that the properties of the textile reinforced composite can be improved by considering the test results obtained.

Introduction

Textile reinforced composites have various applications in engineering sciences in less expensive materials. Since 1970, textile reinforced composites grew attention which led to many global researches. As a result, in the past 30 y great attention has been given to textile reinforced composites. The main reasons for which being that they are light and rigid, performing well under complex thermo-mechanical loads, having high strength/weight ratio or modulus/weight ratio, having low expansion and good damping characteristics.

Three dimensional textile prepgreps and composites have been useful in developing new fibre and matrix production techniques. As a result of these developments textile reinforced composites have been an important alternative for the traditional engineered materials in aerospace and automotive industries.

In this study, a composite has been produced and tested by using polyester textile wastes such as yarns, woven and knitted fabrics. This textile reinforced composite is used in banks, tables, shelves, pots, etc. The absorption and strength properties of the composite have been investigated and compared with fibreboard and medium density fibreboard (MDF), which are alternative materials for the same end-uses.

Experimental Procedure

Materials

Urea formaldehyde resin, ammonium sulphate and flour have been used for the matrix material. Hundred per cent polyester (PET) textile wastes, such as yarns and woven and knitted fabrics, cut at random dimensions were used as reinforcement material. In samples B and D packing bands were used. Materials and their properties are given on Table 1. Fibreboard (Sample E) and medium density fibreboard (Sample F) were also tested for comparison.

Preparation of the Materials

Matrix material was prepared by mixing urea formaldehyde resin, ammonium sulphate and flour in a weight ratio of 100:5:10 consecutively. PET wastes were sunk in this mixture first and were immersed thoroughly by the matrix material. After excess resin was removed from textiles by squeezing, they were...
Table 1 — Material properties

<table>
<thead>
<tr>
<th>Material code</th>
<th>Textile reinforcement content</th>
<th>Textile reinforcement material ratio by weight (per cent)</th>
<th>Matrix material ratio by weight (per cent)</th>
<th>Density, ( \rho ) (g/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>PET woven fabric and yarn waste</td>
<td>30</td>
<td>70</td>
<td>0.97</td>
</tr>
<tr>
<td>B</td>
<td>PET woven fabric and yarn waste with package bands</td>
<td>30</td>
<td>70</td>
<td>0.97</td>
</tr>
<tr>
<td>C</td>
<td>PET knitted fabric waste</td>
<td>35</td>
<td>65</td>
<td>0.859</td>
</tr>
<tr>
<td>D</td>
<td>PET knitted fabric waste with package bands</td>
<td>35</td>
<td>65</td>
<td>0.94</td>
</tr>
<tr>
<td>E</td>
<td>Fiberboard</td>
<td>—</td>
<td>—</td>
<td>0.60</td>
</tr>
<tr>
<td>F</td>
<td>Medium density fiberboard</td>
<td>—</td>
<td>—</td>
<td>0.64</td>
</tr>
</tbody>
</table>

Table 2 — Dimensions of bending test samples

<table>
<thead>
<tr>
<th>Material code</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensions (mm)</td>
<td>279x23x24</td>
<td>275x20x24</td>
<td>276x20x21</td>
<td>278x21x23</td>
<td>281x36x19</td>
<td>279x39x18</td>
</tr>
</tbody>
</table>

Tests

Bending Tests

After production of composites the plates were machine-cut into five pieces through their 125 mm long edges. The dimensions of the samples are given in Table 2. Three samples were tested for each material type. Three-point-bending test was carried out, as shown in Figure 1. The tests were conducted in a DARTEC servo-hydraulic universal tensile test frame with a ramp rate of 0.1 mm/s and he diameter of the bending supports being 30 mm.

Water Absorption Test

The samples were weighed after being conditioned for 24 h. They were placed in a tank full of water. A weight that prevented them from floating was placed over them. The samples were weighed again after 1, 3, 6, and 24 h. Sample E and F were weighed only after 1 and 24 h.

Results and Discussion

Bending Strength Test Results

Bending strength \( \sigma \) was calculated by using the following formula:

\[
\sigma = \frac{M}{I} \cdot \frac{1}{h}.
\]

where \( M \) = bending moment \((M = F \cdot L)\), \( I \) = moment of inertia, \( h \) = maximum distance from neutral axis in sample cross-section, \( F \) = maximum load on the linear portion of load-deflection curve, and \( L \) = half span length. Bending strengths of the samples are listed in Table 3.

Using linear elastic analysis, modulus of elasticity values (Table 4) can be obtained as follows:
\[ E = \frac{(2L)^3}{32B^3} \left( \frac{dF}{d\delta} \right), \]

where \( L \) = half span length (\( L = 121 \text{ mm} \)), \( B \) = width of the specimen, \( h \) = height of the specimen, \( F \) = load applied in elastic region, \( \delta \) = load point deflection, \( dP/d\delta \) = slope of the linear portion of the load-deflection curve.

Toughness values were calculated as “Work to Proportional Limit per Unit Volume” from Load-Deflection curve as shown in Table 5.

Water Absorption Test Results

Water absorption percentages (WAP) by weight were calculated according to the formula given below:

Water absorption percentage = \[
\frac{\text{Last weight (after 1,3,6,24h)} - \text{Initial weight}}{\text{Initial weight}} \times 100
\]

The test results are listed in Table 6.

Discussion

When average bending strengths are taken into account, it can be seen that Sample E and F have higher values than the textile-reinforced composite samples (Figure 2 and 3).

Interestingly, Sample A, which is composed of woven fabric and yarn wastes, has got a higher bending strength than Sample B, which is composed of woven fabric and yarn wastes with package bands. Similarly, Sample C, which is composed of knitted fabric wastes, has higher bending strength than Sample D, which is composed of knitted fabric wastes with package bands. This can be attributed to the band's behaviour as a discontinuity that creates a defect when a bending moment is applied.

### Table 3—Three-point-bending test results

<table>
<thead>
<tr>
<th>Material code</th>
<th>Average bending strength, ( \sigma ) (MPa)</th>
<th>Specific bending strength, ( \sigma/\rho ) (MPa/g.cm(^2))</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>7.18</td>
<td>7.38</td>
</tr>
<tr>
<td>B</td>
<td>5.97</td>
<td>6.07</td>
</tr>
<tr>
<td>C</td>
<td>6.39</td>
<td>7.46</td>
</tr>
<tr>
<td>D</td>
<td>6.17</td>
<td>6.54</td>
</tr>
<tr>
<td>E</td>
<td>8.26</td>
<td>13.56</td>
</tr>
<tr>
<td>F</td>
<td>10.44</td>
<td>16.24</td>
</tr>
</tbody>
</table>

### Table 4—Modulus of Elasticity values

<table>
<thead>
<tr>
<th>Material code</th>
<th>Average modulus of elasticity, ( E ) (MPa)</th>
<th>Specific modulus, ( E/\rho ) (MPa/g.cm(^2))</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>573</td>
<td>587</td>
</tr>
<tr>
<td>B</td>
<td>624</td>
<td>635</td>
</tr>
<tr>
<td>C</td>
<td>433</td>
<td>504</td>
</tr>
<tr>
<td>D</td>
<td>614</td>
<td>652</td>
</tr>
<tr>
<td>E</td>
<td>1085</td>
<td>1779</td>
</tr>
<tr>
<td>F</td>
<td>2072</td>
<td>3224</td>
</tr>
</tbody>
</table>

### Table 5—Toughness values

<table>
<thead>
<tr>
<th>Material code</th>
<th>Average toughness, ( W ) (Nm/m(^2))</th>
<th>Specific toughness, ( W/\rho ) (Nm/m(^2)/g.cm(^2))</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>5053</td>
<td>699</td>
</tr>
<tr>
<td>B</td>
<td>3184</td>
<td>341</td>
</tr>
<tr>
<td>C</td>
<td>5360</td>
<td>651</td>
</tr>
<tr>
<td>D</td>
<td>3766</td>
<td>461</td>
</tr>
<tr>
<td>E</td>
<td>3502</td>
<td>989</td>
</tr>
<tr>
<td>F</td>
<td>2923</td>
<td>804</td>
</tr>
</tbody>
</table>

### Table 6—Weight of samples and water absorption percentages by weight

<table>
<thead>
<tr>
<th>Material code</th>
<th>Initial weight (g)</th>
<th>Weight 1 h (g)</th>
<th>Weight 3 h (g)</th>
<th>Weight 6 h (g)</th>
<th>Weight 24 h (g)</th>
<th>WAP 1 h (per cent)</th>
<th>WAP 3 h (per cent)</th>
<th>WAP 6 h (per cent)</th>
<th>WAP 24 h (per cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>115.03</td>
<td>123.95</td>
<td>123.93</td>
<td>128.62</td>
<td>132.53</td>
<td>7.75</td>
<td>10.35</td>
<td>11.81</td>
<td>15.21</td>
</tr>
<tr>
<td>B</td>
<td>126.17</td>
<td>136.10</td>
<td>137.89</td>
<td>138.60</td>
<td>141.40</td>
<td>7.87</td>
<td>9.29</td>
<td>9.85</td>
<td>12.07</td>
</tr>
<tr>
<td>C</td>
<td>114.68</td>
<td>127.60</td>
<td>128.90</td>
<td>129.67</td>
<td>130.68</td>
<td>11.27</td>
<td>12.4</td>
<td>13.07</td>
<td>13.08</td>
</tr>
<tr>
<td>D</td>
<td>126.94</td>
<td>134.35</td>
<td>135.05</td>
<td>136.13</td>
<td>136.21</td>
<td>5.83</td>
<td>6.39</td>
<td>7.24</td>
<td>7.30</td>
</tr>
<tr>
<td>E</td>
<td>28.54</td>
<td>45.18</td>
<td>—</td>
<td>—</td>
<td>48.04</td>
<td>58.3</td>
<td>68.33</td>
<td>82.36</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>20.80</td>
<td>23.27</td>
<td>—</td>
<td>—</td>
<td>27.62</td>
<td>11.88</td>
<td>32.79</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
If we compare the modulus of elasticity values (Table 4, Figure 4 and 5), Sample A and C are less rigid than Sample B and D, nevertheless Sample B and D have the same rigidity. It is obvious that the rigidity is gained by the reinforcement effect of the package bands. Package bands decrease the strength of the composite material, but at the same time increase the elasticity modulus. Elasticity modulus values of textile composites are less than fibreboard and MDF. If the toughness values are checked (Table 5, Figure 6), Sample A and C have higher toughness values. It can be said that the package bands decreased the toughness.

It is seen from water absorption results that Sample E absorbs maximum water (68.33 per cent) after 24 h (Table 6 and Figure 7). Sample F is the second highest absorbent material with a WAP of 32.79 per cent after 24 h. The textile reinforced composite samples have less WAP values than fibreboard and MDF.

Sample A and B have higher WAP values compared with Sample C and D. Sample A and B are composed of yarns and woven fabrics and Sample C and D are composed of knitted fabrics only. Because of the presence of the yarns in Sample A and B the
Table 7 — Comparison Index values for the tested materials

<table>
<thead>
<tr>
<th>Material code</th>
<th>Average bending strength, $\sigma$ (MPa)</th>
<th>Density, $\rho$ (g/cm$^3$)</th>
<th>Water absorption per cent in 24 h</th>
<th>Comparison Index, $CI$ (MPa/ g.cm$^-3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>7.18</td>
<td>0.97</td>
<td>0.1521</td>
<td>48.5</td>
</tr>
<tr>
<td>B</td>
<td>5.97</td>
<td>0.97</td>
<td>0.1207</td>
<td>50.3</td>
</tr>
<tr>
<td>C</td>
<td>6.39</td>
<td>0.85</td>
<td>0.1308</td>
<td>57.0</td>
</tr>
<tr>
<td>D</td>
<td>6.17</td>
<td>0.94</td>
<td>0.7300</td>
<td>89.6</td>
</tr>
<tr>
<td>E</td>
<td>8.26</td>
<td>0.60</td>
<td>0.6833</td>
<td>19.8</td>
</tr>
<tr>
<td>F</td>
<td>10.44</td>
<td>0.64</td>
<td>0.3279</td>
<td>49.5</td>
</tr>
</tbody>
</table>

The initial absorbency test for yarns, woven fabric, and knitted fabric before producing the composite should have been done.

If we compare Sample A with B and Sample C with D, it is seen that the composites with bands have lower WAP values. The bands cause less water absorption, because they are very rigid and non-absorbent materials. Sample A and B have similar densities, but Sample C has a lower density than D. The reason for the WAP value for Sample C to be much higher than Sample D (13.08 >> 7.3 - after 24 h) may be this density difference. Sample A has higher WAP value than B, but the difference is not as much as with Sample C and D (15.21 > 12.07, after 24 h).

For Sample A and B, at the end of 1 h, the samples absorb approximately half of the water that is absorbed at the end of 24 h. For C and D, at the end of 1 h, the samples absorb approximately 80 per cent of the water that is absorbed at the end of 24 h. This may be due to the absorbency of textile materials used, again.

As a result, WAP values for textile reinforced composites are lower than fibreboard and MDF up to great extent. This may be advantageous for their end-uses that expose to water. For example, banks, tables in the parks, pots, etc. The strength of the wet materials should also have been taken into account, but unfortunately the wetted materials have not been tested.

The material type

Figure 8— Comparison Index vs. material type

where $\sigma$ is bending strength in MPa, $\rho$ is density in g/cm$^3$ and $W_{24}$ is the water absorption per cent by weight of the composite in 24 h. High Comparison Index values indicates a better composite for chosen properties. According to the CI results, Sample D, which is the textile reinforced composite composed of knitted fabric wastes and package bands, gave the best result and Sample E the fibreboard, gave the worst result. Generally the textile reinforced composites have similar Comparison Index values with MDF (Table 7 and Figure 8).

Conclusions

The new textile-reinforced composite absorbs less water than fibreboard and MDF. The specific bending strength of the new composite is less than fibreboard and MDF. But the CI values are much better than fibreboard and similar to MDF. It seems that the properties of the new composite can be improved by considering the above results. The bending strength test after water absorption should be done and this value should be used as strength value in the CI calculations in the future works. Also some additive tests for evaluating its performance, such as thermal conductivity, flammability, resistance to sun
light, effect of textile materials (fibre, yarn, fabric properties) could prove to be useful.

References