Original Research Article

EFFECT OF INITIATOR CONCENTRATION ON THE MECHANICAL AND DEGRADATION PROPERTIES OF BAMBOO FABRIC REINFORCED POLYESTER RESIN COMPOSITES

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ABSTRACT

This research work aims to fabricate bamboo fabric reinforced polyester composites (BFRPCs) and investigate the mechanical and degradation properties of BFRPCs. Composite samples were prepared using hand lay-up technique. Bamboo fabric was used as reinforcement material, unsaturated polyester resin (UPR) was used as matrix and Methyl ethyl ketone peroxide (MEKP) was used as initiator which was employed as 0.5, 1, 2, 3 and 4% concentration. The mechanical properties of the BFRPC samples such as tensile strength (TS), tensile modulus (TM), bending strength (BS), bending modulus (BM) and impact strength (IS) were conducted. The degradation behaviors of the composites in soil burial, immersed in alkaline water and saline water were also evaluated. The BFRPC sample with 2 (%) MEKP concentration showed better tensile properties with TS and TM values of 39 MPa and 744 MPa respectively. For the 1 (%) MEKP concentration, the maximum values of BS, BM and IS were found to be 62.8 MPa, 1229 MPa and 25.7 kJ/m² respectively. In the case of soil burial degradation the BFRPC sample with 1 (%) MEKP concentration shows better performance against loss of TS. No significant effect was found on the alkaline and saline water degradation properties of BFRPC for the variation of MEKP concentration. With the increase of all types of degradation time, decrease the tensile strength of all BFRPC samples.

Keywords: Composite, Bamboo Fabric, Unsaturated Polyester Resin, Methyl Ethyl Ketone Peroxide, Mechanical Properties.

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1. INTRODUCTION

Composite materials are made of a combination of two or more constituents to make one heterogeneous material. Due to some advantages such as low weight, corrosion resistance, high fatigue strength and faster assembly, composites are becoming an essential part of today’s materials [1-4]. In the last three decades in the development of composites, textile materials were used extensively as reinforcement material [5-7]. Use of textile material as reinforcement in composites has many unique advantages. These composites have found a number of applications in automobile [8-10], ballistic protection [11-13], aerospace industry [14-16], and lightweight tools [17, 18] etc. The textile material used in such reinforcement applications are mostly aramids, high-performance polyethylene, glass, carbon fiber etc. These materials are derived from synthetic sources and they are not biodegradable or recyclable one. The main reason for using these fibers is low fiber density and high tensile strength. There are a number of natural fibers such as jute, hemp, coir, flax, sisal, bamboo fiber which can replace these synthetic fibers for their strength [19, 20]. The undeniable benefits of natural fibers, such as low abrasion, multi functionality, low density, cost effective, limited availability and no problems with waste disposal promote applications on the composite [21-23]. Bamboo is a naturally occurring composite material which grows abundantly in most of the tropical countries. Because of their advantages over man-made fibers, bamboo has greater attention from researchers. It is sustainable, eco-friendly, non-toxic, inexpensive, non-abrasive and totally biodegradable [24]. Bamboo is considered a composite material because it contains cellulosic fibers implanted in a lignin matrix. Cellulose fibers are aligned along the length of the bamboo provide highest tensile, bending strength and rigidity in that direction [25]. The mechanical characteristics of bamboo are similar to wood and other natural fibers such as kenaf, jute and sisal [26, 27]. The specific young modulus (Specific E) of bamboo is close to that of the E-glass fiber [28].
Unsaturated polyester resin (UPR) is very common thermoset polymer which has a wide range of applications in the plastic materials fields. There are many beneficial properties of polyester resin, such as room temperature curing, good mechanical characteristics and transparency. A polymerization reaction was performed by curing which imparts crosslinking between individual linear polymer chains and the by-product is not produced compared to other thermosetting resins, as a result at low temperature and pressure it can be easily molded, cast and laminated. The reinforcement of polyester resin with cellulosic fibers, such as jute sisal, coir, pineapple leaf and hemp, has been extensively experimented [29-33]. Methyl ethyl ketone peroxide (MEKP) is one kind of organic peroxide, a high explosive, a colorless, oily liquid. MEKP is less sensitive to temperature and shock, high stable in storage and used as a curing agent in fiberglass and plastics industry [34].

The present study deals with the fabrication and mechanical analysis of bamboo fabric reinforced polyester composite (BFRPC). Here, bamboo fabric, unsaturated polyester resin (UPR) and methyl ethyl ketone peroxide (MEKP) were used as reinforcement material, matrix and imitator respectively. Five BFRPC samples were prepared with the variation MEKP concentration such as 0.5, 1, 2, 3 and 4%. The major purpose of this work was to study the effect MEKP concentration on the physicomechanical properties of the composites. After that, degradation behaviors of the composites in soil burial, immersed in alkaline water and saline water were also evaluated for MEKP concentration variation.

2. EXPERIMENTAL

2.1. Materials

In this research, the bamboo fabric was used as a reinforcing material which was collected from China. The specification of bamboo fabric is given below.

<table>
<thead>
<tr>
<th>Fiber</th>
<th>:100% Bamboo fiber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weave Structure</td>
<td>:2/2 ordinary twill</td>
</tr>
<tr>
<td>Ends per inch (EPI)</td>
<td>:80</td>
</tr>
<tr>
<td>Picks per inch (PPI)</td>
<td>:80</td>
</tr>
<tr>
<td>Warp count</td>
<td>:40</td>
</tr>
<tr>
<td>Wet count</td>
<td>:40</td>
</tr>
<tr>
<td>GSM</td>
<td>:100</td>
</tr>
<tr>
<td>Country of Origin</td>
<td>:China</td>
</tr>
</tbody>
</table>

Unsaturated Polyester Resin (PR) (Highpolymer Chemical Products Pte Ltd., Singapore), Methyl Ethyl Ketone Peroxide (MEKP) Pamukkale Company, Turkey), Alkali (NaOH) and NaCl all were laboratory grade and used as received.

2.2. Methods

2.2.1. Sample Preparation

The BFRPC samples were fabricated by hand lay-up technique according to the literature [20] with some modification. At first, 100% bamboo twill fabrics were cut with a dimension of 30 cm × 30 cm. The UPR and various concentrations of MEKP were mixed thoroughly before applying on the fabric. To avoid formation of bubbles, special care was taken. A glass plate with a dimension of 40 cm × 40 cm was kept on a suitable table. A mylot paper with the same dimension is placed on the glass plate. And then, mixture resin and MEKP was applied on the sheets. After that, one ply of fabric was put and proper rolling was done. The resin was again applied, next to it fabric ply put and rolled. The rest of the mixture was poured and spread on the bamboo fabric and covered by mylot paper and glass plate. Finally a light rolling was carried out. Deadweight of 20 kg was loaded on the glass plate for 6 hours. After removing the weight, the composite was kept in room temperature for 72 hours. Then the specimen was cut into the appropriate dimension for mechanical testing. Five BFRPC samples were prepared with different concentrations of MEKP such as 0.5, 1, 2, 3 and 4%. Here mention that, in this study, no specific treatment has been performed to improve the BFRPC.

2.2.2. Mechanical performance measurement of composites

The mechanical properties such as tensile strength (TS), tensile modulus (TM), bending strength (BS) and bending modulus (BM) of the prepared sample were evaluated by a universal testing machine (UTM) (Model: H50KS-0404, HOUNSFIELD Series S, UK) at Institute of Radiation & Polymer Technology (IRPT) Laboratory, Bangladesh atomic energy commission, Ganakbari, Savar, Dhaka-1344.

Specimens for tensile measurement were prepared according to the ASTM D638 standard. A Crosshead speed of 10 mm/min and a gauge length of 50 mm were maintained. The specimen dimension was 120 mm length, 15 mm width.

The specimen dimension was 60 mm length and 15 mm width for flexural measurement and was performed according to ISO 14125 method with a cross-head speed of 60 mm/sec at a span distance of 25 mm.

Impact strength (IS) was carried out by Universal Impact Tester (HUNG TA INSTRUMENT CO. LTD., Taiwan) hammer mass of 2.63kg, gravity distance of 30.68 mm and lift angle of 150º. The impact tests were conducted on unnotched mode composite specimens according to ASTM D 6110-97. IS of the samples is calculated using the following equation.

\[
\text{Impact strength} = \frac{\text{Impact energy (J)}}{\text{Area (m²)}}
\]  

(1)

2.2.4 Methods of Measuring Degradation Properties

Soil Degradation: Soil degradation tests of composites were carried out according to literature [35] with some modification. Composites samples were buried in soil (having at least 25% moisture) for 1 and 2 months. After every month, samples were withdrawn carefully, washed with distilled water and dried at 110ºC for 10 min and kept room temperature for 24 hours and then measured the tensile properties.

Alkaline Water Degradation: For determination of alkali degradation, a solution was prepared by adding 5 gm of NaOH with 100 ml of water. Composites samples were kept in 5% alkaline solution, pH approximately 13 for 2, 4 and 6 weeks. After certain time, BFRPC samples were withdrawn carefully, cleaned and washed with deionized water and kept at room temperature for overnight for drying and then finally evaluated the tensile properties.

Saline Water Degradation: For this test, a solution was prepared by adding 5 gm of salt with 100 ml of water. Composites samples were kept in 5% saline water, for 2, 4 and 6 weeks. After a certain time, BFRPCs were withdrawn carefully, washed and cleaned with deionized water and dried at 100ºC for 10 min and kept room temperature for overnight and then finally measured the tensile properties.

3. RESULTS & DISCUSSION

3.1. Effect of concentration of MEKP (%) on mechanical properties of BFRPCs

The mechanical properties such as tensile strength (TS), tensile modulus (TM), bending strength (BS) and bending modulus (BM) of are presented following table.
The above table indicates that, the concentration of MEKP (%) have great influences on tensile and bending properties of BFPRC. The highest value of TS and TM found be 39 and 790 MPa respectively at 2(%) concentration of MEKP and then the TS and TM of the composites decrease with the increased of MEKP% in the composites as shown in Table 1. On the other hand composite sample with 1(%) MEKP shows maximum value of bending strength 62.8 MPa and bending modulus 1239 MPa, after that with the increase of MEKP% bending properties are decreased. A longer time may be required for curing of BFPRCs at room temperature with a low concentration of MEKP (less than 1%). As a result, the tensile and bending properties of BFPRC samples were decreased. On the other hand, higher concentration of MEKP (more than 2%) may alter the chemical reaction and the mixture of UPR and MEKP as well as BRPRCs are not cured properly. As a result, tensile and bending properties also decrease at high concentration of MEKP. BFPRC samples prepared with 1-2% concentrations of MEKP show better tensile and bending properties which are also cost effective and environment friendly.

### Table 1. Effect of concentration of MEKP (%) on tensile and bending properties of BFPRCs

<table>
<thead>
<tr>
<th>Concentration of MEKP (%)</th>
<th>Tensile properties</th>
<th>Bending properties</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Strength (MPa)</td>
<td>Modulus (MPa)</td>
</tr>
<tr>
<td>0.5</td>
<td>34</td>
<td>730</td>
</tr>
<tr>
<td>1</td>
<td>36.5</td>
<td>744</td>
</tr>
<tr>
<td>2</td>
<td>39</td>
<td>790</td>
</tr>
<tr>
<td>3</td>
<td>32</td>
<td>628</td>
</tr>
<tr>
<td>4</td>
<td>29</td>
<td>580</td>
</tr>
</tbody>
</table>

From the above table it is seen that there is a great influence of concentration of MEKP (%) and soil burial time on loss of tensile strength of composite. With the increase of soil burial time, decrease the tensile strength of composite. Initially very rapid loss of tensile strength was observed for all the composite samples, but the rate loss of tensile strength decreased significantly with time. It is also seen that, with increase of concentration of MEKP (%), also increase the loss of tensile strength significantly. Composites with 1(%) and 4(%) concentration of MEKP samples show better and poor performance against loss of tensile strength respectively after 2 months soil burial. Maximum loss of TS is seen 22.8(%) for 4(%) MEKP concentration and minimum loss of TS is 13.7% for 1(%) MEKP concentration composite sample.

### Table 2. Effect of concentration of MEKP (%) on loss of tensile strength of composites during soil burial test

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>Concentration of MEKP (%)</th>
<th>Initial Tensile Strength (MPa)</th>
<th>Tensile Strength After 1 month (MPa)</th>
<th>Loss of TS (%)</th>
<th>Tensile Strength After 2 month (MPa)</th>
<th>Loss of TS (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.5</td>
<td>34</td>
<td>31.5</td>
<td>7.4</td>
<td>28</td>
<td>17.6</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>36.5</td>
<td>33</td>
<td>9.6</td>
<td>31.5</td>
<td>13.7</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>39</td>
<td>35</td>
<td>10.3</td>
<td>32</td>
<td>17.9</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>32</td>
<td>29.5</td>
<td>7.8</td>
<td>25</td>
<td>21.9</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>29</td>
<td>25.2</td>
<td>13.1</td>
<td>22.4</td>
<td>22.8</td>
</tr>
</tbody>
</table>

From the above table and figure it is seen that, there is very little effect of MEKP (%) on loss of tensile strength of composite but there is a great influence of alkali degradation time on degradation properties of composite. With the increase alkaline degradation time, decrease the tensile strength of composite. It is also observed that initially very rapid loss of tensile strength for all the composite samples, but the rate loss of tensile strength decreased significantly with time.

### Table 3. Effect of MEKP (%) on loss of tensile strength of composites during alkali degradation test

The impact strength (IS) of a composite material is the capability to absorb a sudden applied load and stress. The BFPRC samples of various MEKP concentrations of 0.5, 1, 2, 3 and 4% show impact strength of 22.8, 25.7, 19.9, 16.1 and 12.9 KJ/m² respectively. From Figure 2 it is observed that the maximum value of impact strength is 25.7 KJ/m² for 1(%) MEKP BFPRC sample. For a low concentration of MEKP (less than 1%), more time may be required for curing composite samples at room temperature. As a result, the impact strength of BFPRC samples were decreased. On the other hand, higher concentration of MEKP (more than 2%) may alter the chemical reaction and the mixture of UPR and MEKP as well as BRPRCs are not cured properly. As a result, impact strength also decrease at high concentration of MEKP as like as other mechanical properties of BFPRC Samples.

### 3.2. Effect of concentration of MEKP (%) on loss of tensile strength of composites during soil burial test

Table 2 which indicate the change of tensile strength with the change of concentration of MEKP (%) on BFPRC.

### 3.3. Effect of MEKP (%) on loss of tensile strength of composites during alkali degradation test

Loss of tensile strength of composites against alkali degradation time is presented in Table 3 which indicate the change of tensile strength with the change of MEKP (%) in composites.
3.4. Effect of MEKP% on loss of tensile strength of composites during to saline water degradation test

Loss of tensile strength of composites against saline water degradation time is presented in Table 4 which also indicate the change of tensile strength with the change of MEKP% in composites.

Table 4. Effect of MEKP (%) on loss of tensile strength of composites during to saline water degradation test

<table>
<thead>
<tr>
<th>Sample Type Concentration of MEKP (%)</th>
<th>Initial Tensile Strength (MPa)</th>
<th>After 2 weeks Tensile Strength (MPa)</th>
<th>Loss of TS (%)</th>
<th>After 4 weeks Tensile Strength (MPa)</th>
<th>Loss of TS (%)</th>
<th>After 6 weeks Tensile Strength (MPa)</th>
<th>Loss of TS (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>34</td>
<td>27.5</td>
<td>19.1</td>
<td>24</td>
<td>29.4</td>
<td>21</td>
<td>38.2</td>
</tr>
<tr>
<td>1</td>
<td>36.5</td>
<td>29.1</td>
<td>20.5</td>
<td>25</td>
<td>31.5</td>
<td>21</td>
<td>42.6</td>
</tr>
<tr>
<td>2</td>
<td>39</td>
<td>31</td>
<td>20.5</td>
<td>25</td>
<td>35.9</td>
<td>23.5</td>
<td>39.7</td>
</tr>
<tr>
<td>3</td>
<td>32</td>
<td>25.5</td>
<td>20.3</td>
<td>22.5</td>
<td>29.7</td>
<td>20</td>
<td>37.5</td>
</tr>
<tr>
<td>4</td>
<td>29</td>
<td>24</td>
<td>17.2</td>
<td>22.5</td>
<td>22.4</td>
<td>18</td>
<td>37.9</td>
</tr>
</tbody>
</table>

From the above table it is seen that there is very little influence of MEKP (%) on loss of tensile strength of composite but there is a great effect of saline water immersed time on degradation properties of BFPRCs. With the increase saline water immersed time, decrease the tensile strength of composite. Initially very rapid loss of tensile strength was observed for all the composite samples, but the rate loss tensile strength decreased significantly with saline water immersed time. BFPRC samples show better saline water degradation performance against loss of tensile strength as compared to alkaline water degradation. On the other hand BFPRC samples show lower performance than soil burial degradation.

4. Conclusion

BFPRC samples were prepared using unsaturated polyester resin and bamboo fabric by hand lay-up technique with the variation of MEKP concentration. The mechanical properties of and several degradation properties of BFPRCs were evaluated and studied. All tests were carried out according to the ASTM and ISO standards. Finally the following conclusion may be drawn from the result obtained from this work: The BFPRC sample with 2 (%) MEKP concentration showed better tensile properties and 1 (%) MEKP concentration sample exhibited the maximum bending properties and impact strength. BFPRC samples with 1 (%) MEKP concentration show better performance against loss of TS during soil burial test. There is a little effect found on the alkaline and saline water degradation properties of BFPRC for the variation of MEKP concentration. TS of all BFPRC samples were decreased, with the increase of degradation time.

Conflict of Interests

The authors declare that there is no conflict of interest related to the publication of this article.

Compliance with Ethics Requirements

This manuscript does not contain any studies with human or animal subjects performed by any of the authors.

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