Analysis of Effect of Polystyrene as a Binder on Properties of Sawdust Ceiling Tile

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ABSTRACT: In this research work, analysis of the effect of polystyrene as a binder on the properties of sawdust ceiling tile was carried out. The weight fraction of the polystyrene and sawdust were; 38.4% polystyrene, 61.6% sawdust particles; 32.7% polystyrene, 67.3% sawdust particles and 36.4% polystyrene, 63.6% Sawdust particles for sample 1, 2 and 3 respectively and were the variable factors at experimental design consisting of three composite samples. Metal mould of dimension (120 x 120 x 120, mm) was fabricated to produce the specimen and specifications were in accordance to American Society for Testing and Materials (ASTM) standard. The tensile strength, compression strength, and water absorption capacity were analysed. The suitability of sawdust particles as fillers for polystyrene has been tested using three composite samples with results of 12.2%, 35.9% and 42.4% water absorption strength for sample 1, 2 and 3 respectively. The compressive strength of the three samples tiles were obtained as 396.04MPa, 431.31MPa, and 469.89MPa. The tensile strength of 3.59MPa, 6.27MPa, and 14.57MPa were experimentally obtained for the composite samples. It is evident from these results that the mechanical properties depend on the variations of the wood fibres and the polystyrene. Also from this test results, the specimen made with 110ml polystyrene has the highest modulus of elasticity and lowest water resistance. This is not unconnected to the fact that polymer has a higher tensile strength and that wood fibre contains high hydrophilic content (cellulose and hemicelluloses) which is responsible for the improvement in its water absorption capacity.

Keywords: Wood dusts, Reinforcement, Polymers, Composites, Mechanical properties.

INTRODUCTION

Wood plastic composites (WPCs) are relatively new generation of composite materials and also the most promising sector in the field of both composite and plastic industries. In 1970s, the modern concept of WPC was developed in Italy and gradually got popularity in the other parts of the world (Akpens and Tyagher, 2006). Wood in the form of flour/particles/fibres are combined with the thermoplastic materials under specific heat and pressure for producing WPCs where additives are added for improving the quality. Many researchers have been working on WPCs by flat-pressed method at various wood-plastic ratios (Badejo, 2001; Najafi et al. 2007; Maul et al. 2007) which typically ranges between 50 to 80% of sawdust or fibre either as filler or reinforcements (Clemens, 2002). The higher strength and aspect ratio of natural fibres offers good reinforcing potential in composite matrix compared to the artificial fibres (Abdul Khalil et al. 2014). Composite materials are multiphasic materials that show superior properties than their individual phase, providing a synergetic effect (Bengtsson et al. 2005).
Composite tiles are of various types depending on the production process and the materials they are made of. Their acceptability will be governed by aesthetics, physical properties, cost and health related factors. The most common type; asbestos ceiling tile has been adjudged by the world Health Organization (WHO) as being carcinogenic (Moslemi, 1999). Hence, there is need to produce safer alternative. Wood composite are made from any fibrous or particulate wood material that is bonded together either using natural bonding (i.e., no resin) or using a thermoset resin or thermoplastic or inorganic binder (Nyiszli, 2011). This product mix ranges from fibreboard to laminated beams. Composites are used for a number of structural and non-structural applications in product lines ranging from panels for interior covering purposes to panels for exterior uses and in furniture and architectural trim materials in many times different types of buildings (Badejo and Ademiluyi, 1980). Lingo cellulosic fibres and particles other than wood (e.g., straw) can many times be readily substituted for wood to produce other bio composites with similar engineering properties. Wood composite material (and other bio composite) can be engineered to meet a range of specific properties (Green, 2006). When wood materials and processing variables are properly selected, the result can provide high performance and reliable service. With solid wood, properties are determined at the cellular level, and properties can be highly variable for pieces of solid wood both within and between wood species. With composite wood materials, properties are determined at the fibre, particle, flake, or veneer level, and properties are less variable (Williams, 2008).

**MATERIALS AND METHOD**

In the preparation of sawdust ceiling tile using polystyrene as binder, the following materials were used for the specimen preparation: Sawdust (Mahogany wood), Polystyrene, Gasoline and Teflon. The sawdust is readily available in south-west Nigeria. The dry sample of the sawdust was pulverized using ball mill and sieved with mesh of grain size 250ìm as displayed in Figure 1.

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The preparation consisted of pulverized sawdust, dispersed polystyrene particles, and gasoline. The polystyrene particle was dissolved in the gasoline to form an aqueous solution as shown in Figure 2. The sawdust was screened to remove impurities, pulverized and dried in the oven at 102°C after preheated to 60°C for a moisture content of 5%. The specimen preparations and specifications were according to the standard established by American Standard ASTM D-1037: 2010, following the procedure of all the relevant sections of the same designation. The aqueous solution of polystyrene and sawdust particles was stirred manually to ensure homogeneity and the following variables were added and mixed together manually: 60ml polystyrene, 100g sawdust particles and 50ml silicate; 70ml of polystyrene, 150g sawdust particles and 50ml of the silicate; 110ml polystyrene, 200g Sawdust particles and 50ml of silicate for sample 1, 2 and 3 respectively and four trials were carried out. The molten polystyrene was added to serve as a binder to the majority wood component. The silicate was also incorporated in the mixture to serve as curing catalyst, heat resistant agent and to make the product more attractive. Figure 3 displayed the composite preparation. The molten mixture was then transferred into the 120 mm ×120 mm ×20 mm metallic mould and allowed to cure for 7hours in an open and ventilated atmosphere under a press pressure of 2MPa. The Compressive, Tensile and Water
Absorption properties of the specimen produced was carried out (Three specimen for each sample were produced for the test). The tensile tests were carried out with three samples each on each specimen using Instron Universal Testing Machine. Compression test was conducted by loading the sample cube of each specimen between two plates, and then applying a force on the specimen by moving the crossheads together. During compression test, the specimen was compressed, and deformation versus the applied load was recorded. Figure 4 shows the tensile specimen samples used.

RESULTS AND DISCUSSION

Table 1 shows the mass of sawdust, Polystyrene, and weight fraction of Sawdust and Polystyrene. The density (ρ) of Polystyrene is 1.04g/cm³ (Badejo,1998). Table 2 shows the results of the water absorption tests obtained from various mixing ratios of polystyrene and sawdust composites.

Calculations:

\[
(W_a) = \frac{(SS_m) - (DS_m)}{(DS_m)}
\]

(Nasscuser, 2011)

\[
(\%W_a) = \frac{(SS_m) - (DS_m)}{(DS_m)} \times 100
\]

Therefore,

\[
(\%W_a) = \frac{10.597 - 9.445}{9.445} \times 100
\]

Therefore, (\%W_a) for sample 1 = 12.1967%

Where;

\[
(W_a) \text{ is Water absorption, } (\%W_a) \text{ is Percentage Water Absorption, } (DS_m) \text{ is Dry sample mass, } (SS_m) \text{ is Saturated sample mass.}
\]

The percentage water absorption of the remaining specimens was calculated by following the same steps of calculations. According to (klyosov, 2007) water absorption for wood plastic is 0.7-2% after 24hours, 1-5% after a week, and up to 18-35% after several months. For this test, the samples were soaked in water for Four months. This result could be explained by wood chemical composition itself which is because wood fibre contains high hydrophilic content (cellulose and hemicelluloses). They are mostly responsible for the high water absorption. Besides, poor adhesion between wood particles and the polystyrene matrix generates void spaces around the wood particles. These lead to higher water uptake in wood plastic composite.

Table 1: Experimental design of samples

<table>
<thead>
<tr>
<th>Specimen samples</th>
<th>Sawdust percentage by mass (g)</th>
<th>Polystyrene percentage by volume (ml)</th>
<th>Polystyrene percentage by mass (g)</th>
<th>Weight fraction of polystyrene (%)</th>
<th>Weight fraction of sawdust (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>60</td>
<td>62.4</td>
<td>38.4</td>
<td>61.6</td>
</tr>
<tr>
<td>2</td>
<td>150</td>
<td>70</td>
<td>72.8</td>
<td>32.7</td>
<td>67.3</td>
</tr>
<tr>
<td>3</td>
<td>200</td>
<td>110</td>
<td>114.4</td>
<td>36.4</td>
<td>63.6</td>
</tr>
</tbody>
</table>

Table 2: Water Absorption Test Result

<table>
<thead>
<tr>
<th>Specimen samples</th>
<th>Dry sample mass (g)</th>
<th>Wet/saturated sample mass (g)</th>
<th>Percentage water absorption (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9.4450</td>
<td>10.5970</td>
<td>12.1967</td>
</tr>
<tr>
<td>2</td>
<td>8.4920</td>
<td>11.5400</td>
<td>35.8952</td>
</tr>
<tr>
<td>3</td>
<td>8.9290</td>
<td>12.7181</td>
<td>42.4358</td>
</tr>
</tbody>
</table>
Tensile Test

Modulus of elasticity = \frac{\text{Tensile stress}}{\text{Tensile strain}} \quad (3)

(Kollman et al, 2005)

Tensile stress = \frac{\text{Load at break}}{\text{Area}} \quad (4)

(Kollman et al, 2005)

\text{Strain} = \frac{L - L_o}{L_o} \quad (5)

(Kollman et al, 2005)

Where,
L_o = \text{original length of the sample}, L = \text{new length of the sample}

From this result in Table 3, it is evident that the specimen made with 110ml polystyrene has the highest modulus of elasticity. This is not unconnected to the fact that polymer has a better and higher tensile strength.

Uniaxial Compression Test

Table 4 shows the results of the uniaxial compression tests conducted on various mixing ratios of polystyrene and sawdust composites.

<table>
<thead>
<tr>
<th>Samples</th>
<th>Area (mm$^2$)</th>
<th>Compressive load (N)</th>
<th>Compressive stress at yield (Mpa)</th>
<th>Ultimate compressive strength (Mpa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.3</td>
<td>514.8554</td>
<td>4.6862</td>
<td>396.0426</td>
</tr>
<tr>
<td>2</td>
<td>1.3</td>
<td>560.7147</td>
<td>5.00638</td>
<td>431.3190</td>
</tr>
<tr>
<td>3</td>
<td>1.3</td>
<td>610.8669</td>
<td>5.9333</td>
<td>469.8976</td>
</tr>
</tbody>
</table>

Calculation:

Ultimate compressive strength = \frac{\text{Maximum load applied}}{\text{Cross sectional area}} \quad (6)

(Badejo, 1995).

The compressive strength of a material is its capacity to withstand loads tending to reduce size (Badejo, 1990). Hence, the ultimate Compressive strength increases as the wood fibre increases.

Nailing of the Board

Carpenter hammer was used to drive a 3mm nail into the board. This was repeated for six more boards. After two blows the board shows no sign of crack or rupture visible to the eyes. The nail was fully pushed in and no noticed crack developed but the nail was held firmly in the board.
CONCLUSION

This research work has analysed the effect of polystyrene as binder on properties of sawdust ceiling tile. The effect of fibre size on water uptake is minimal. Increasing fibre load improves the strength of the composite but decreases elongation and energy to break. However, increase in polystyrene increases the tensile and slight improvement in compressive strength of the board. Water uptake increases with increasing fibre content. During this preparation it was discovered that, 150 g of polystyrene successfully dissolved in 80ml of gasoline. It was also discovered that, the composite made with 110ml polystyrene, 200g sawdust and 50ml silicate had the best combination in terms of strength.

REFERENCES


