Physical and Mechanical Properties of Composite Panels Made From Kenaf Plant Fibers and Plastics

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ABSTRACT

The objective of this on-going research is to develop and advance technologies for new agricultural products. This project has been to demonstrate the viability of using kenaf fiber and plastics in producing thermoplastic composites. Kenaf (Hibiscus cannabinus IL.) Has been identified as a viable non-wood fiber source for industrial fiber use. It is an annual plant and is grown in row spacing using standard farm equipment and yield 6 to 10 tons of dry fiber per acre in Southern and Central Illinois in the United States. The crop requires about 150 days growing season for maturation. Therefore, kenaf plant can be an alternative agricultural fiber crop in the state which could increase farm income. The success of this study may mean tremendous economic advantage to Illinois community constituents.

This report presents the progress of this research to concentrate on optimizing the manufacturing techniques and testing of both air-laid non-woven, and melt-blended kenaf/plastic composite panels from kenaf bark fiber, whole stem of kenaf plant fiber, the virgin plastic and the recycled plastics. These composite panels could be used in building and farm construction panels, interior automobiles parts, and plastic floor tiles that are water resistant and easy to clean. A coupling chemical agent was used to improve the bonds between the recycled plastic molecules and the kenaf bark or whole stem fibers.

To form the panels, two methods of mat-forming were used: a) air-laid non-woven mats; and b) melt-blend technology formed mats using pre-formulated and pelletized stocks. Each series of experiment was to be combined with specific amount of copolymer chemical agent, the virgin or recycled post-industrial polypropylene powder, and kenaf bark fiber or whole stem of kenaf plant fibers. The physical properties including the dimensional stability performance and the mechanical properties, such as the maximum bending stress, modulus of elasticity, tensile stress, and internal bonding strength of the experimental composite panels were determined.

Key Words: Kenaf fiber, polypropylene fiber, composite panel, coupling agent, maleated polypropylene, melt-blend technology, extrusion, mechanical properties, physical properties,
Introduction:

In the Midwest of the United States, farmers are searching alternative cash crops that can be grown on set aside acres. These alternative crops must meet the criteria of produce income, fit existing crop rotations, and farm equipment complements. Alternatives crops should not tie land into a long term commitment which interrupts normal cropping systems.

Kenaf (Hibiscus cannabinus L) is an annual, non-wood fiber plant native to east-central Africa. It was introduced into the United States in the 1940's as a substitute for jute to produce cordage. Research work to use kenaf for paper, forage, animal bedding, and other products began in the 1960's and continues today. Business ventures are already under way in California, Delaware, Louisiana, Mississippi, and Texas.

Kenaf appears to be a viable candidate for fiber production, and meets all base requirements. The introduction of kenaf into the Illinois farm production enterprise would provide farmers an alternative crop which could increase farm income.

Wood and plastic fibers can be assembled into a mat using air forming or non-woven web technology. The fibers are initially held together by mechanical interlocking. The mat can then be fused into composite panels or into a variety of shapes. A synthetic adhesive can also be used in the mat to provide additional bonding of the fibers.

One of the shortcomings of non-woven mat composite is that poor attractions and low interfacial bonding between the hydrophilic wood and hydrophobic plastic limit the reinforcement imparted to the plastic matric by the wood component. One approach to developing greater compatibility is to use a coupling aging that possesses a duel functionality, enabling it to interact or react with both components. These wood/plastic composite panels have been used in building and farm construction panels, interior automobile parts, and other areas.

No information is available on the physical and mechanical properties of kenaf fiber/plastic-fiber composite panels made from the air-formed non-woven mats, and the melt-blend extruded technology. The purpose of this study was to provide baseline date information for tailoring mat-forming techniques, and performance standards to industrial products.

Materials:

The kenaf stalks were harvested from the experimental plots at University of Illinois, Central Illinois. There were two kinds of kenaf materials used in this study. Only kenaf bark fibers were used in the non-woven web-mat forming process to produce the composite panels. In making the melt-blend composite panels, the whole kenaf stalks, including the core fibers were utilized in compounding with the kenaf fiber/plastic composite panels.

Polypropylene fibers obtained from Hercules Inc. were about 3.0 denier, 37 mm long and crimped for non-woven web forming with kenaf bark fibers. To make the melt-blend extrusion panels using whole kenaf stalk fibers, virgin polypropylene (VPP) was used. The VPP is Fortilene HB 3907, an injection molding grade homopolymer with a melt flow index of 44g/10 min. A recycled post-industrial polypropylene powder (RPP) and recycled polyester (Rpet) fibers were also obtained. The maleated polypropylene (MAPP) coupling
agent was an anionic solid contain of 52 percent, and a pH of 9.5 to 10.0.

Process:

To form the panels, two methods of mat forming were used.

1. Air-laid non-woven mats

The kenaf bark fibers were hammermilled to separate the fiber bundle using a screen with a 10 mm diameter hold pattern when phenolic adhesive was used. The kenaf bark fiber saw sprayed to give a 5 percent (dry-weight basis) resin content based on the oven-dry weight of kenaf fibers. Three percent of MAPP coupling agent was introduced into fibers when it was needed in some experimental composite panels. The forming machine produces a 355 mm wide continuous mat. Following the mat forming process is a needler which consolidates the mat, improves the mat integrity. For panel production, the multiple mats were required to be stacked together to attain a certain basis weight. A multi-layered mattress mat which was cut into 355 mm single mat was hot-pressed into a composite panel at a thickness of 6.4 mm and an average specific gravity of 1.00.

Five types of composite panels were made from air-laid mats using a non-woven forming machine. They were:

1. 100% kenaf bark fiber (KB)/5% PF resin;
2. 90% kenaf bark fiber/5% PF resin/10% virgin polypropylene fiber (VPP)
3. 90% kenaf bark fiber/5% PF resin/10% recycled polyester fiber (Rpet);
4. 50% kenaf bark fiber/50% VPP/0% coupling agent (MAPP); and
5. 50% kenaf bark fiber/50% VPP/3% coupling agent.

2. Melt-blended process

Hammermilled whole stem of kenaf plant fiber and recycled polypropylene powder (RPP) were compounded at the U.S. Forest Products Laboratory using a Davis Standard 32 mm twin screw extruder. The compounded materials were then pelletized in long strips to form a desired mat dimension of 356 mm x 356 mm. The mats were hot-pressed to 6.4 mm thick in a steam heated platen press at a pressure of about 5 Mpa at 177°C.

Three types of composite panels were extruded using melt-blend process:

1. 50% kenaf whole stalk/50% RPP/0% MAPP coupling agent
2. 50% kenaf whole stalk/50% RPP/3% MAPP coupling agent
3. 50% kenaf whole stalk/50% RPP 3% coupling agent

Testing:

Six replicate panels were made for each types of kenaf/Plastic composites at a constant factors of thickness at 6.4 mm and a specific gravity at 1.00, resulting in a total of forty-eight panels. All experimental panels were tested for mechanical and physical properties.

Prior to the test, all specimens were conditioned at 65% relative humidily (RH) and
Three-point static bending modules of rupture (MOR) and modules of elasticity (MOE), and tensile parallel to face-stress (T) and tensile perpendicular to face or internal bond (IB) were mechanically tested using a universal testing machine. For physical properties evaluation, specimens were tested for 24-hour water soak 2-hour water boil, and exposure to 90% relative humidity (RH) from 50% RH condition. Values of thickness swell, water absorption and linear expansion were determined to determine the dimensional stability of composite panel specimens made from different combinations of kenaf fibers, plastic fibers, and coupling agent or PF adhesive. All tests were conducted in accordance with methods described in American Society for Testing and Materials (ASTM) D-1037. The Canadian 0188.0-M78 Standard was followed to conduct the 2-hour water boil test.

**Results and Summary:**

Table 1 shows the test results of the mechanical property of the kenaf/plastic composite panels. The physical property of the composite panels is presented in Table 2.

It can be concluded as the following:

1. **Mechanical Properties:** Air-laid panel properties exceeded melt-blend extruded panel properties.
2. **Physical Properties:** Extruded (melt-blend) panels were much better than those of air-laid panels.
3. **Coupling agent:** It generally improved both mechanical and physical properties.

**Table 1. Mechanical Property of Composite Panels**

<table>
<thead>
<tr>
<th>Panel Formulation</th>
<th>Static Bending</th>
<th>Tensile Stress</th>
<th>Internal bond</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MOR (Mpa)</td>
<td>MOE (Gpa)</td>
<td>(Mpa)</td>
</tr>
<tr>
<td><strong>Air-Laid Web-Mat</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K100-VPPO-R5</td>
<td>31.6</td>
<td>4.09</td>
<td>21.4</td>
</tr>
<tr>
<td>K90-VPP10-R5</td>
<td>20.4</td>
<td>2.83</td>
<td>19.5</td>
</tr>
<tr>
<td>K90-RPET10-R5</td>
<td>10.1</td>
<td>1.25</td>
<td>4.9</td>
</tr>
<tr>
<td>K50-VPP50-CA0</td>
<td>58.6</td>
<td>3.87</td>
<td>30.1</td>
</tr>
<tr>
<td>K50-VPP50-CA3</td>
<td>66.5</td>
<td>4.91</td>
<td>37.9</td>
</tr>
<tr>
<td><strong>Melt-Blend Extrusion</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K50-RPP50-CA0</td>
<td>23.9</td>
<td>2.02</td>
<td>10.0</td>
</tr>
<tr>
<td>K50-RPP50-CA3</td>
<td>39.7</td>
<td>2.94</td>
<td>15.1</td>
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<tr>
<td>K-50-RPP50-CA3</td>
<td>35.4</td>
<td>2.93</td>
<td>13.3</td>
</tr>
</tbody>
</table>

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K-kenaf; VPP-virgin polypropylene; R-Phenolic resin; RPET-recycled polyester; RPP-recycled polypropylene; CA-copolymer (MAPP).  
The numerical value following each caption shows the content (%) of each material.

Table 2. Physical Property of Composite Panels

<table>
<thead>
<tr>
<th>Panel Formulation</th>
<th>24-Hour Soak</th>
<th>2-Hour Boil</th>
<th>Linear Expansion 50% - 90% RH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Thickness swell (%)</td>
<td>Water Absorption (%)</td>
<td>Thickness swell (%)</td>
</tr>
<tr>
<td>Air-LaidWeb-Mat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K100-VPPO-R5</td>
<td>173</td>
<td>172</td>
<td>184</td>
</tr>
<tr>
<td>K90-VPP10-R5</td>
<td>151</td>
<td>168</td>
<td>182</td>
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<tr>
<td>K90-RPET10-R5</td>
<td>233</td>
<td>263</td>
<td>245</td>
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<tr>
<td>K50-VPP50-CA0</td>
<td>7</td>
<td>4</td>
<td>9</td>
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<tr>
<td>K50-VPP50-CA3</td>
<td>3</td>
<td>3</td>
<td>6</td>
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<tr>
<td>Melt-Blend Extrusion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K50-RPP50-CA0</td>
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<td>K50-RPP50-CA3</td>
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<td>1</td>
<td>1</td>
</tr>
<tr>
<td>K-50-RPP50-CA3</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

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The numerical value following each caption shows the content (%) of each material.
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