Technical Feasibility of Flakeboard Production from Recycled CCA-Treated Wood

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OBJECTIVES

- To determine the effect of the ratio of recycled CCA-treated wood and untreated virgin wood on flakeboard panel properties.

- To determine copper, chromium, and arsenic retention levels of out-of-service CCA-treated highway guardrails and flakeboard panels.

- To evaluate the leaching performance of flakeboard panels made from five different ratios of recycled CCA-treated wood and untreated virgin wood.
MATERIALS AND METHODS
Guard Rails
Sawmill
Lumber
Flowchart of Experimental Plan

- Guard rails
  - CCA Retention
    - Mechanical and Physical Properties
    - Decay Resistance
  - Lumber
    - Flakes
    - Flakeboard panels
    - Leachability
Sample Groups

1. 100% CCA-treated flakes
2. 75% CCA-treated flakes : 25% untreated flakes
3. 50% CCA-treated flakes : 50% untreated flakes
4. 25% CCA-treated flakes : 75% untreated flakes
5. 100% untreated flakes
Panel Assembly

- PF resin 4.5 % by weight.
- Temperature: 370 °F (188 °C).
- Hot Press Schedule:
  - 1,225 psi ---- 3 minutes.
  - 307 psi ---- 0.5 minute.
  - 62 psi ---- 0.5 minute.
- Panel size: 14" x 14" x 0.5".
- Target density: 46 pcf.
- Flake orientation: random.
- Two replications.
Tests and Analyses

**Mechanical Properties:**
- Modulus of Rupture (MOR)
- Modulus of Elasticity (MOE)
- Internal Bond (IB)

**Physical Properties:**
- Thickness Swell (TS)
- Linear Expansion (LE)
- Water Absorption (WA)

**Chemical Properties:**
- CCA Retention
- Leachability

**Durability:**
- ODVPS
- Decay Resistance

**Statistical Analyses:**
- Analysis of Variance (ANOVA)
- Regression
- Group Comparison
- Variance proportion
RESULTS AND DISCUSSION
Mechanical Properties
MOE

Group MOE (1,000 PSI)

1. 672.633
2. 693.496
3. 721.171
4. 700.387
5. 773.052
MOR – ODVPS

Group 1: MOR (PSI) = 2,774.80
Group 2: MOR (PSI) = 2,609.30
Group 3: MOR (PSI) = 3,525.40
Group 4: MOR (PSI) = 3,467.60
Group 5: MOR (PSI) = 4,097.90

All groups are labeled as 'A'.

MOR (PSI) scale from 0 to 5,000.
MOE – ODVPS

![Bar graph showing MOE values for different groups.]

- Group 1: 330.053
- Group 2: 405.638
- Group 3: 477.016
- Group 4: 461.866
- Group 5: 468.972

All groups except Group 1 have an MOE of 461,866 or 468,972.
Contrast of MOR between Standard and ODVPS
Contrast of MOE between Standard and ODVPS
Bending Strength Reduction

![Bar chart showing bending strength reduction by group.](image)
Flakeboard with 100 % Untreated SYP (Group 5)
Internal Bond
Internal Bond – ODVPS

IB (PSI)

Group

<table>
<thead>
<tr>
<th>Group</th>
<th>IB (PSI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>48.57</td>
</tr>
<tr>
<td>2</td>
<td>34.85</td>
</tr>
<tr>
<td>3</td>
<td>44.36</td>
</tr>
<tr>
<td>4</td>
<td>32.97</td>
</tr>
<tr>
<td>5</td>
<td>55.74</td>
</tr>
</tbody>
</table>
Contrast of IB between Standard and ODVPS

The graph shows the IB (PSI) for different groups. The standard IB values are represented by light blue bars, while the ODVPS IB values are represented by dark purple bars. Group 1 has the highest IB for both standard and ODVPS, followed by Group 5. Group 2 and Group 4 have the lowest IB values for both categories.
Internal Bond Reduction

- Group 1: 42.71%
- Group 2: 46.45%
- Group 3: 40.40%
- Group 4: 54.31%
- Group 5: 37.57%
Physical Properties
# Physical Properties of Flakeboards

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Thickness (in.)</th>
<th>Density (pcf)</th>
<th>Moisture Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>0.47</td>
<td>47.70</td>
<td>7.8</td>
</tr>
<tr>
<td>Group 2</td>
<td>0.47</td>
<td>47.21</td>
<td>7.6</td>
</tr>
<tr>
<td>Group 3</td>
<td>0.48</td>
<td>47.20</td>
<td>7.6</td>
</tr>
<tr>
<td>Group 4</td>
<td>0.48</td>
<td>47.21</td>
<td>7.3</td>
</tr>
<tr>
<td>Group 5</td>
<td>0.48</td>
<td>49.48</td>
<td>7.1</td>
</tr>
</tbody>
</table>
Thickness Swell

<table>
<thead>
<tr>
<th>Group</th>
<th>Thickness swell (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A</td>
</tr>
<tr>
<td>2</td>
<td>A</td>
</tr>
<tr>
<td>3</td>
<td>AB</td>
</tr>
<tr>
<td>4</td>
<td>AB</td>
</tr>
<tr>
<td>5</td>
<td>B</td>
</tr>
</tbody>
</table>
Linear Expansion

![Linear Expansion Bar Chart]

- Group 1: 0.32
- Group 2: 0.31
- Group 3: 0.20
- Group 4: 0.26
- Group 5: 0.27

Linear expansion (%)
Water Absorption

<table>
<thead>
<tr>
<th>Group</th>
<th>Water Absorption (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>102.6</td>
</tr>
<tr>
<td>2</td>
<td>100.0</td>
</tr>
<tr>
<td>3</td>
<td>94.3</td>
</tr>
<tr>
<td>4</td>
<td>97.6</td>
</tr>
<tr>
<td>5</td>
<td>98.6</td>
</tr>
</tbody>
</table>
## Analysis of Variance (ANOVA)

<table>
<thead>
<tr>
<th>Sources</th>
<th>Numerator DF</th>
<th>Denominator DF</th>
<th>TYPE III MS</th>
<th>F value</th>
<th>Pr&gt;F</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOR</td>
<td>4</td>
<td>5</td>
<td>1052192</td>
<td>1.06</td>
<td>0.4254</td>
</tr>
<tr>
<td>MOE</td>
<td>4</td>
<td>5</td>
<td>583829</td>
<td>1.59</td>
<td>0.2518</td>
</tr>
<tr>
<td>MOR-ODVPS</td>
<td>4</td>
<td>5</td>
<td>1468313</td>
<td>1.27</td>
<td>0.3454</td>
</tr>
<tr>
<td>MOE-ODVPS</td>
<td>4</td>
<td>5</td>
<td>1531942</td>
<td>0.60</td>
<td>0.6739</td>
</tr>
<tr>
<td>IB</td>
<td>4</td>
<td>5</td>
<td>2299</td>
<td>8.94</td>
<td>&lt;0.0001**</td>
</tr>
<tr>
<td>IB-ODVPS</td>
<td>4</td>
<td>5</td>
<td>1361</td>
<td>9.47</td>
<td>&lt;0.0001**</td>
</tr>
<tr>
<td>Thickness swell</td>
<td>4</td>
<td>5</td>
<td>0.0033</td>
<td>4.46</td>
<td>0.0252*</td>
</tr>
<tr>
<td>Linear expansion</td>
<td>4</td>
<td>5</td>
<td>9.335E-7</td>
<td>1.05</td>
<td>0.4272</td>
</tr>
<tr>
<td>Water absorption</td>
<td>4</td>
<td>5</td>
<td>0.0038</td>
<td>1.10</td>
<td>0.4091</td>
</tr>
</tbody>
</table>
# Regression Analysis

- **Linear regression**

<table>
<thead>
<tr>
<th>Source</th>
<th>Regression model</th>
<th>P-value for slope</th>
<th>R-square</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness swell</td>
<td>$y = 0.335 - 0.00065 \times t$</td>
<td>0.0209*</td>
<td>0.5067</td>
</tr>
</tbody>
</table>
Thickness Swell Regression Plot

Model: $y = 0.335 - 0.00065 \times t$
R-square = 0.5067
Regression Analyses

- Quadratic regression

<table>
<thead>
<tr>
<th>Sources</th>
<th>Regression models</th>
<th>P-value for coefficients</th>
<th>R-square</th>
</tr>
</thead>
<tbody>
<tr>
<td>IB</td>
<td>$y = 89.21 - 0.77 \times t + 0.0071 \times t^2$</td>
<td>t: 0.0328*</td>
<td>0.5015</td>
</tr>
<tr>
<td></td>
<td></td>
<td>t²: 0.0388*</td>
<td></td>
</tr>
<tr>
<td>IB-ODVPS</td>
<td>$y = 53.08 - 0.64 \times t + 0.0059 \times t^2$</td>
<td>t: 0.0775</td>
<td>0.3792</td>
</tr>
<tr>
<td></td>
<td></td>
<td>t²: 0.0864</td>
<td></td>
</tr>
</tbody>
</table>
**IB Regression Plot**

Model: \( y = 89.21 - 0.77 \times t + 0.0071 \times t^2 \)

R-square = 0.5015
Decay Resistance
Soil Block Decay Test Methodology

- Tests performed in accordance with AWPA E10-91.
- Sample dimensions were \( \frac{1}{2} \text{ in.}^3 \).
- White rot (Trametes versicolor (ATCC isolate 42462)) and brown rot (Gloeophyllum trabeum (ATCC isolate 11539)).
- 8 weeks for brown rot and 16 weeks for white rot.
Soil Decay Tests

Five experimental group samples  Control group samples
Analysis of Variance (ANOVA)

<table>
<thead>
<tr>
<th>Sources</th>
<th>Numerator DF</th>
<th>Denominator DF</th>
<th>TYPE III MS</th>
<th>F value</th>
<th>Pr&gt;F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown rot</td>
<td>6</td>
<td>63</td>
<td>1949</td>
<td>74.46</td>
<td>&lt;0.0001**</td>
</tr>
<tr>
<td>White rot</td>
<td>6</td>
<td>63</td>
<td>40</td>
<td>19.78</td>
<td>&lt;0.0001**</td>
</tr>
</tbody>
</table>
Chemical Analyses

- CCA retention level of guard rails and flakeboards
- CCA leaching property of flakeboards
ICP Test
CCA Retention of Guard Rails

Retention (pcf)

Top
Middle
Bottom

Horizontal Distances from Poles Surface

Retention (pcf)

2-O 2-M 2-I 8-O 8-M 8-I 10-O 10-M 10-I
CCA Retention of Flakeboards

- Retention (pcf)

- Total
- Copper
- Chromium
- Arsenic

Group Retention (pcf) of CCA Retention of Flakeboards
Leaching Test
CCA Leaching Tests of Flakeboards

![Graph showing CCA content (ppm) over time for different groups. The x-axis represents the group numbers (1, 2, 3, 4) and the y-axis represents the CCA content in ppm. The graph indicates the CCA leaching over days 1, 7, 14, 21, and 28 for each group.](image-url)
Supplementary Experiments

- Microscopic analyses
- Wettability
- Hot water solubility
- Gel time and viscosity
SEM Pictures

CCA-treated flake of sapwood

CCA-treated flake of heartwood
SEM Picture

Untreated southern pine flake
Wettability Determination

- Contact angles determined with PF resin at ambient room conditions.
- Angle recorded within 5 seconds after introduction of resin to wood.
- Flake conditions: air dry and oven dry.
- Wood types: early wood and late wood.
## Contact Angles of Flakes with PF Resin

<table>
<thead>
<tr>
<th>Flake conditions</th>
<th>Wood types</th>
<th>Contact angle (°)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Untreated southern pine</td>
<td>CCA-treated recycled southern pine</td>
</tr>
<tr>
<td>Air dry</td>
<td>Earlywood</td>
<td>72.52 (10.09)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>93.50 (13.37)</td>
</tr>
<tr>
<td></td>
<td>Latewood</td>
<td>71.06 (10.23)</td>
<td>84.91 (10.39)</td>
</tr>
<tr>
<td>Oven dry</td>
<td>Earlywood</td>
<td>42.40 (7.24)</td>
<td>64.32 (21.34)</td>
</tr>
<tr>
<td></td>
<td>Latewood</td>
<td>43.48 (6.58)</td>
<td>65.59 (23.53)</td>
</tr>
</tbody>
</table>

<sup>a</sup> Values in parentheses are standard deviations.
Hot Water Solubility

- Tests performed in accordance with ASTM D 1110-84.
- Five groups with same mixture ratios and resin content as experimental flakeboards. Two control groups.
- Wood particles were between 40 – 60 micron.
- PF resin blended with wood particles cured at 130°C, 20 min.
## Hot Water Solubility

<table>
<thead>
<tr>
<th>Group</th>
<th>Hot water solubility</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.17 (1.53)(^a)</td>
</tr>
<tr>
<td>2</td>
<td>4.33 (1.26)</td>
</tr>
<tr>
<td>3</td>
<td>5.00 (0.50)</td>
</tr>
<tr>
<td>4</td>
<td>5.67 (0.58)</td>
</tr>
<tr>
<td>5</td>
<td>5.83 (1.61)</td>
</tr>
<tr>
<td>Untreated wood</td>
<td>5.00 (1.32)</td>
</tr>
<tr>
<td>CCA-treated wood</td>
<td>4.50 (0.50)</td>
</tr>
</tbody>
</table>

\(^a\) Values in parentheses are standard deviations.
Gel time of PF blended with wood particle

The graph shows the gel time (in minutes) of PF blended with wood particles at different percentages by weight, comparing untreated and CCA-treated samples. The gel time decreases as the percentage of wood particle increases, with CCA-treated samples generally having a longer gel time compared to the untreated samples.
Viscosities of PF blended with wood particle

- Untreated
- CCA-treated
## Contrast of Experimental Results and ANSI Standards

<table>
<thead>
<tr>
<th></th>
<th>MOR (psi)</th>
<th>MOE (psi)</th>
<th>IB (psi)</th>
<th>LE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade M-1</td>
<td>1,595</td>
<td>250,200</td>
<td>58</td>
<td>0.35</td>
</tr>
<tr>
<td>Grade M-2</td>
<td>2,103</td>
<td>326,300</td>
<td>65</td>
<td>0.35</td>
</tr>
<tr>
<td>Group 1</td>
<td>4,441</td>
<td>672,600</td>
<td>84.8</td>
<td>0.32</td>
</tr>
<tr>
<td>Group 2</td>
<td>4,894</td>
<td>693,500</td>
<td>65.1</td>
<td>0.31</td>
</tr>
<tr>
<td>Group 3</td>
<td>4,743</td>
<td>700,400</td>
<td>74.4</td>
<td>0.26</td>
</tr>
<tr>
<td>Group 4</td>
<td>5,137</td>
<td>721,200</td>
<td>72.2</td>
<td>0.20</td>
</tr>
<tr>
<td>Group 5</td>
<td>5,803</td>
<td>773,000</td>
<td>89.3</td>
<td>0.27</td>
</tr>
</tbody>
</table>
CONCLUSIONS

- As expected, most mechanical and physical properties improved as the percent of recycled treated wood in the furnish decreased.
- As expected, decay resistance increased as the percent of recycled treated wood in the furnish increased.
CONCLUSIONS

- Flakeboard made from recycled CCA-treated wood is technically feasible.
- Mechanical and physical properties do not substantially decrease with as much as 50 percent recycled treated material in the furnish of the panels.
ACKNOWLEDGEMENT

- Drs. Shupe, Hse, Marx, and Vlosky
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- Arch Wood Protection, Inc.
- Arnold Forest Products Co., Shreveport, LA
- Louisiana Dept. of Transportation and Development
Comments and Questions