Development of a new engineered wood product for structural applications made from trembling aspen and paper birch

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Engineered Wood Product

Utilization of existing installations

Use of under-utilized species

Oriented Strand Lumber

- A structural composite lumber that combines parallel aligned wood strands with structural adhesive to form lumber-like structural products
- Can be produced in OSB mills
- Using paper birch and trembling aspen
Four Problems

Step 1

1. Conventional hot platen pressing results in a pronounced vertical density profile.

2. OSB production parameters are adapted to low density species.

Step 2

3. Adequate bending strength to compete with engineered wood products on the market must be achieved.

Step 3

Step 1: Develop a Pressing Procedure and Evaluate the Effect of Species

- Background -

- Problem: Conventional hot platen pressing results in a pronounced vertical density profile (VDP).

- Step-closure pressing significantly changes the traditional shape of the VDP (Wang et al. 2000).
Step 1: Develop a Pressing Procedure and Evaluate the Effect of Species

- Background –

- Problem: OSB production parameters are adapted to low density species.

- Panels produced from higher density species tend to have inferior bending properties compared to aspen panels (Blankenhorn et al. 1989, Brunette 1992).


- Specific surface:

\[ S_s = \frac{\text{Particle Surface}}{\text{Particle Mass}} \approx \frac{2}{e \cdot \rho} \]

Thin, slender particles

\( e = \text{strand thickness} \)

\( \rho = \text{oven-dry wood density} \)
Step 1: Developing a Pressing Procedure and Evaluating the Effect of Species

- Materials and Methods -

• Trembling aspen (benchmark) and paper birch
• Similar specific surfaces for both species
• Three adhesive contents (3.5%, 5%, 7%)
• Unidirectional strand alignment
• Three-step-closing pressing procedure
# Step 1: Production Parameters

<table>
<thead>
<tr>
<th></th>
<th>Oven-Dry Wood Density $\rho$ [kg/m$^3$]</th>
<th>Strand Thickness $e$ [mm]</th>
<th>Strand Length $\ell$ [mm]</th>
<th>Target Panel Density $\rho_{target}$ [m$^3$/kg]</th>
<th>Specific Surface $S_s$ [m$^2$/kg]</th>
<th>Adhesive Content$^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Powder PF</td>
</tr>
<tr>
<td>Aspen</td>
<td>451</td>
<td>0.69</td>
<td>105</td>
<td>650</td>
<td>6.4</td>
<td>1.0%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.43%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.0%</td>
</tr>
<tr>
<td>Birch</td>
<td>617</td>
<td>0.51</td>
<td>105</td>
<td>650</td>
<td>6.4</td>
<td>1.0%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.43%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.0%</td>
</tr>
</tbody>
</table>

$^1 S_s = \frac{2}{e \cdot \rho}$

$^2$ Percent per oven-dry wood weight

PF = Phenol formaldehyde
Vertical Density Profiles

- Results -
**Internal Bond**

**Results**

Internal bond (IB):
- Adhesive content: significant effect
- Species: no significant effect

<table>
<thead>
<tr>
<th>Species</th>
<th>N</th>
<th>IB (MPa)</th>
<th>Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspen</td>
<td>21</td>
<td>0.47</td>
<td>(14.1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.55</td>
<td>(19.0)</td>
</tr>
<tr>
<td>Birch</td>
<td>16</td>
<td>0.45</td>
<td>(21.8)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.67</td>
<td>(33.1)</td>
</tr>
</tbody>
</table>

Adhesive Content

OSB O-2 (CSA-O437): 0.345 MPa
Flatwise Bending Results

- **Modulus of Rupture (MOR):**
  - Adhesive content: no significant effect
  - Species: no significant effect

- **Modulus of Elasticity (MOE):**
  - Adhesive content: no significant effect
  - Species: significant effect

<table>
<thead>
<tr>
<th>Species</th>
<th>MOR (MPa)</th>
<th>COV (%)</th>
<th>Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspen</td>
<td>72.2</td>
<td>(12.6)</td>
<td>11.8</td>
</tr>
<tr>
<td>Birch</td>
<td>64.4</td>
<td>(13.1)</td>
<td>12.6</td>
</tr>
</tbody>
</table>

- Results -
  - Modulus of Rupture:
    - Means adjusted for short term loading; COV of 15%; thicknesses up to 89 mm; marketed in Canada
  - TimberStrand® LSL: 40.2 MPa
  - Modulus of Elasticity:
    - TimberStrand® LSL: 9 700 MPa

- Species: significant effect
Edgewise Bending

- Results -
Step 2: Evaluate Interaction Between Slenderness Ratio, Specific Surface, Species, and Performance

- Background -

- Problem: Adequate bending strength to compete with engineered wood products on the market.

- Particle geometry:
  - Strand length ↑ → bending properties ↑
    
    (Barnes 2001, and others).
  
  - Slenderness ratio (length-to-thickness ratio) ↑
    → bending properties ↑

    (Post 1958, Barnes 1988, and others).
Step 2: Evaluate Interaction Between Slenderness Ratio, Specific Surface, Species, and Performance

- Materials and Methods -

- Trembling aspen and paper birch
- Three strand lengths
- Two strand thicknesses
- 7% adhesive content
- Unidirectional strand alignment
- Three-step-closing pressing procedure
## Step 2: Production Parameters

<table>
<thead>
<tr>
<th>Oven-Dry Wood Density $\rho$ [kg/m$^3$]</th>
<th>Strand Thickness $e$ [mm]</th>
<th>Strand Length $\ell$ [mm]</th>
<th>Specific Surface $S_S$ [m$^2$/kg]</th>
<th>Slenderness Ratio $S_R^{\dagger}$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trembling Aspen</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.49</td>
<td>77.6</td>
<td>8.8</td>
<td>158</td>
</tr>
<tr>
<td></td>
<td>0.53</td>
<td>105.0</td>
<td>8.3</td>
<td>200</td>
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<td></td>
<td>0.45</td>
<td>142.1</td>
<td>9.8</td>
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</tr>
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<td></td>
<td>0.75</td>
<td>77.6</td>
<td>5.8</td>
<td>103</td>
</tr>
<tr>
<td></td>
<td>0.71</td>
<td>105.0</td>
<td>6.2</td>
<td>149</td>
</tr>
<tr>
<td></td>
<td>0.66</td>
<td>142.1</td>
<td>6.6</td>
<td>217</td>
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<tr>
<td><strong>Paper Birch</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>0.46</td>
<td>77.6</td>
<td>7.0</td>
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<tr>
<td></td>
<td>0.47</td>
<td>105.0</td>
<td>6.8</td>
<td>223</td>
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<td>0.43</td>
<td>142.1</td>
<td>7.4</td>
<td>330</td>
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<td>0.75</td>
<td>77.6</td>
<td>4.3</td>
<td>104</td>
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<td>0.71</td>
<td>105.0</td>
<td>4.5</td>
<td>149</td>
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<tr>
<td></td>
<td>0.71</td>
<td>142.1</td>
<td>4.5</td>
<td>199</td>
</tr>
</tbody>
</table>

\[ S_R^{\dagger} = \frac{\ell}{e} \]
Internal Bond

- **Results** -

Internal Bond (IB):
- **Species:**
  - no significant effect
- **Strand thickness:**
  - no significant effect
- **Strand length:**
  - no significant effect

OSB O-2 (CSA-O437): 0.345 MPa

- **Aspen**
  - \( N = 91 \)
  - \( 0.68 \)
  - (21.0)
  - \( A \)

- **Birch**
  - \( N = 116 \)
  - \( 0.76 \)
  - (26.2)
  - \( A \)
Flatwise Bending
Flatwise Bending
- Results -

- Species, thickness, and length: significant effect
- Slenderness ratio: significant effect
- Specific surface: significant effect

Modulus of Rupture

<table>
<thead>
<tr>
<th></th>
<th>S</th>
<th>M</th>
<th>L</th>
<th>S</th>
<th>M</th>
<th>L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspen</td>
<td>66.0 (15.3)</td>
<td>77.6 (15.9)</td>
<td>99.2 (19.5)</td>
<td>53.5 (26.8)</td>
<td>65.4 (24.3)</td>
<td>90.1 (16.4)</td>
</tr>
<tr>
<td>Birch</td>
<td>48.9 (19.3)</td>
<td>65.5 (15.7)</td>
<td>85.1 (20.2)</td>
<td>40.3 (19.3)</td>
<td>54.5 (21.1)</td>
<td>62.0 (26.2)</td>
</tr>
</tbody>
</table>

Modulus of Elasticity

<table>
<thead>
<tr>
<th></th>
<th>S</th>
<th>M</th>
<th>L</th>
<th>S</th>
<th>M</th>
<th>L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspen</td>
<td>8943 (7.1)</td>
<td>11642 (9.4)</td>
<td>13581 (14.9)</td>
<td>8189 (7.9)</td>
<td>10391 (11.7)</td>
<td>12624 (13.4)</td>
</tr>
<tr>
<td>Birch</td>
<td>7766 (18.6)</td>
<td>9647 (11.9)</td>
<td>12107 (7.0)</td>
<td>6395 (15.1)</td>
<td>8218 (11.5)</td>
<td>10002 (11.0)</td>
</tr>
</tbody>
</table>

TimberStrand®
- Modulus of Rupture: 40.2 MPa
- Modulus of Elasticity: 9700 MPa

TimberStrand® LSL

S = short
M = medium
L = long
Edgewise Bending

- Results -

<table>
<thead>
<tr>
<th>Species</th>
<th>Thickness</th>
<th>Length</th>
<th>MOR (MPa)</th>
<th>MOE (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspen</td>
<td>Thin</td>
<td>Short</td>
<td>42.7</td>
<td>35.0</td>
</tr>
<tr>
<td>Birche</td>
<td>Thick</td>
<td>Short</td>
<td>51.4</td>
<td>45.3</td>
</tr>
<tr>
<td></td>
<td>Thin</td>
<td>Medium</td>
<td>28.8</td>
<td>29.1</td>
</tr>
<tr>
<td></td>
<td>Thick</td>
<td>Medium</td>
<td>41.8</td>
<td>40.3</td>
</tr>
<tr>
<td></td>
<td>Thin</td>
<td>Long</td>
<td>66.3</td>
<td>65.7</td>
</tr>
<tr>
<td></td>
<td>Thick</td>
<td>Long</td>
<td>55.4</td>
<td>40.0</td>
</tr>
</tbody>
</table>

M = Medium
L = Long

- Modulus of Rupture:

- Modulus of Elasticity:

- Results -

- TimberStrand® LSL 40.2 to 55.1 MPa
- SolidStart® LSL 43.6 to 59.4 MPa
Edgewise Bending - Regression

Aspen:
MOE = $-1803 + 9.6 \text{ Density} + 27.4 \text{ SR}$
$R^2 = 0.81$

Birch:
MOE = $-10403 + 20.4 \text{ Density} + 24.4 \text{ SR}$
$R^2 = 0.88$
Compression

- Results -

S = short
M = medium
L = long
Step 3: Evaluate a Laminated OSL Prototype

- Background -

- Problem: Panel thickness limited by press opening in OSB mills.

- Face-lamination of thin panels allows to achieve adequate thickness.
Step 3: Evaluate a Laminated OSL Prototype

- Materials and Methods -

- Trembling aspen and paper birch panels
  - 0.55 mm thick, 142 mm long strands; 7% PF content
- Industrial webstock OSB
- Phenol-resorcinol adhesive
- Small scale testing
- Larger scale testing
Edgewise Bending – Small Scale

- Birch, aspen OSL
- OSB

<table>
<thead>
<tr>
<th>Material</th>
<th>MOE (GPa)</th>
<th>MOR (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspen Birch OSB</td>
<td>52.0 (4.7)</td>
<td>30.0 (6.1)</td>
</tr>
<tr>
<td></td>
<td>58.4 (11.4)</td>
<td>40.2 (6.4)</td>
</tr>
<tr>
<td></td>
<td>26.4 (6.1)</td>
<td>26.4 (6.1)</td>
</tr>
</tbody>
</table>

- Results:
- Modulus of Rupture:
  - TimberStrand® LSL: 40.2 to 55.1 MPa
  - SolidStart® LSL: 43.6 to 59.4 MPa

- Modulus of Elasticity:
  - TimberStrand® LSL: 9,000 to 10,700 MPa
  - SolidStart® LSL: 9,300 to 10,700 MPa

- MOR: 40 to 60 MPa
- MOE: 9,000 to 10,700 MPa
Edgewise Bending – Larger Scale

[Diagram showing a beam with dimensions labeled in millimeters (mm).]
Edgewise Bending – Larger Scale

- Results -

- Modulus of Rupture:
  - Means adjusted for short term loading and 120 mm depth; COV of 15%; marketed in Canada
  - Timberstrand® LSL: 39.2 to 53.5 MPa
  - SolidStart® LSL: 41.8 to 57.0 MPa

- Modulus of Elasticity:
  - Timberstrand® LSL: 9 000 to 10 700 MPa
  - SolidStart® LSL: 9 300 to 10 700 MPa

¹ No size effect indicated in literature → ignored.
Conclusions

- **Step 1: Develop a Pressing Procedure and Evaluate the Effect of Species**
  - Using a three-step closing schedule, a near-homogenous VDP was achieved.
  - Respecting similar specific surface for both species, comparable internal bond and bending properties were achieved.

- **Step 2: Evaluate Interaction Between Slenderness Ratio, Specific Surface, Species, and Performance**
  - Not only strand geometry and species had an effect on bending properties; the slenderness ratio and specific surface also played a role.
  - Strand length is a compromise between bending and compression performance.
Conclusions (2)

- **Step 3: Evaluate a Laminated OSL Prototype**
  - Average MOR and MOE values make laminated aspen and birch OSL competitive with similar EWPs.
Three Advantages

Laminated Oriented Strand Lumber

Engineered Wood Product
The properties of these laminated OSL products offer an affordable, viable alternative to similar products on the market.

Utilization of existing installations
These laminated OSL products can be manufactured in existing OSB mills, allowing them to react to market demand by alternating between OSB and OSL.

Use of underutilized species
Paper birch, currently an underutilized species, can be given added value.
In the Future...

- Other species
- Mill trials
- Full size testing
- Panel combinations
- Panel jointing
- Connections