Determination of the Capacities of a new Composite Timber-Steel Connector System

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Outline

System

Tests
- Tension
- Compression
- Shear
- Climate Cycles

Manufacturing
The Components

- Connector
  (Sandblasted Surface)
- Mortar: Upat UPM66®
- Drill
Manufacturing

Drill Ring Hole and Countersink

Inject Mortar
Insert Connector

Hardening 10 min.
Remove Excess Material
Test Program

- Axial Tensile Tests, Single Connector (Glulam and PSL)
- Axial Compression Tests, Single Connector (Glulam)
- Shear Tests, Single and Double Connector Joints, Varying Edge Distances (Glulam)
- Tensile Tests after Cyclic Climate Changes (3 Cycles, 6 Weeks each)
**Test Setup**

**Tension / Compression Tests:**
- EN 26 891
- 1 Load Cycle

**Shear Tests:**
- Ramp Load
Tensile Tests

- 20 Tests
- 80/80/500 mm, Glulam
- 2 Connectors per Specimen, 1 End Clamped
Tensile Tests

**Average**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>COV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Failure Load</td>
<td>54.10 kN</td>
<td>13.8 %</td>
</tr>
<tr>
<td>Failure Displacement</td>
<td>0.214 mm</td>
<td>29.6 %</td>
</tr>
<tr>
<td>Slip Modulus $k_s$</td>
<td>336.44 kN/mm</td>
<td>10.8 %</td>
</tr>
</tbody>
</table>
**Tensile Tests - PSL**

5 Tests

- Failure Load: 59.69 kN (+10%)
- Failure Displacement: 0.201 mm
- Slip Modulus $k_s$: 338.27 kN/mm

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Average</th>
<th>Difference</th>
<th>COV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Failure Load</td>
<td>59.69 kN</td>
<td>+10%</td>
<td>11.5%</td>
</tr>
<tr>
<td>Failure Displacement</td>
<td>0.201 mm</td>
<td></td>
<td>10.5%</td>
</tr>
<tr>
<td>Slip Modulus $k_s$</td>
<td>338.27 kN/mm</td>
<td></td>
<td>19.1%</td>
</tr>
</tbody>
</table>
Compression Tests

- 30 Tests
- 80/80/300 mm, Glulam
- 1 Connector per Specimen
Compression Tests

### Average Values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Failure Load</td>
<td>68.85 kN</td>
<td>8.5 %</td>
</tr>
<tr>
<td>Max. Load</td>
<td>106.15 kN</td>
<td>5.9 %</td>
</tr>
<tr>
<td>Failure Displacement</td>
<td>0.311 mm</td>
<td>14.5 %</td>
</tr>
<tr>
<td>Slip Modulus</td>
<td>229.22 kN/mm</td>
<td>9.6 %</td>
</tr>
</tbody>
</table>
Shear Tests

- 50 Tests
- Varying Cross-Sections
- Glulam
- 1 or 2 Connectors
Shear Tests

- **Failure**: Rotation of Connector and Debonding ➔ Split
- Double Failure Load for Double Connector Specimens
Shear Tests

Capacity - Edge Distance Relationship:

\[ y = 0.2057x + 7.6195 \]

\[ R^2 = 0.7358 \]
**Climate Cycles**

- **10 Specimens (5 Cycled, 5 Reference), Glulam**

- **3 Cycles (6 Weeks Each), then Tension-Test:**
  - 1st Cycle: 3°C / 90% R.H. (M.C. → 20%)
  - 2nd Cycle: 25°C / 28% R.H. (M.C. → 7%)
  - Normalization: 20°C / 65% R.H.

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<th></th>
<th>Average</th>
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<th>COV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Failure Load (Cycled)</td>
<td>45.55 kN</td>
<td>-15%</td>
<td>15.81 %</td>
</tr>
<tr>
<td>Failure Load (Ref.)</td>
<td>53.84 kN</td>
<td></td>
<td>10.82 %</td>
</tr>
<tr>
<td>Failure Load (Tension)</td>
<td>54.10 kN</td>
<td></td>
<td>13.8 %</td>
</tr>
</tbody>
</table>
Conclusions

- Low Variability of Results
- Ductile Failure in Compression
- Brittle Failure in Tension → Ductile Elements Required
- PSL Yields Higher Failure Levels
- Shear Load - Edge Distance Relationship Established
- Reduction in Load Observed after Climate Cycles
Outlook

**Improvements:**

- **Surface:** Grooved
  - Better Adhesion
- **Top Plate:** Thickness
  - Reduced to 8 mm
  - Ductility