Quality Control Considerations for Developing Structural Glued-laminated Timber (glulam) for U.S. Markets Using South American Wood Species

Presented By:
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11/10/08
Objectives of this presentation

• Understand the system of codes and standards for glued-laminated timber (glulam) in the United States.

• Review details of the standards and how they apply to U.S. wood species.

• Review details of how those same standards can be applied to South American wood species.
Use of Glulam in U.S. Buildings

- All wood products used as structural members in the United States must follow the 2006 International Building Code requirements.
• **2303.1.3 Structural glued-laminated timber.** Glued-laminated timbers shall be manufactured and identified as required in AITC A190.1 and ASTM D 3737.
• To establish nationally recognized requirements for...
  – Production
  – Inspection
  – Testing, and
  – Certification

...of structural glued laminated timber
• To established nationally recognized requirements for...
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...of structural glued laminated timber
• Production requirements
  – Sizes and tolerances
  – Lumber requirements
  – Laminating and Adhesive requirements
  – Manufacture

* If highlighted in red, this requires special consideration when using a species of wood not currently included in the U.S. standard.
• Production requirements
  – Lumber requirements
    • Species
    • Moisture Content
    • Grading (Visual, Mechanical, SCL)
• Production requirements
  – Laminating and Adhesive requirements
    • Surface quality for bonding
    • Adhesive strength
      – Surface Bonding: Test T107
      – End-Joint Bonding: Test T119;
      – Durability of adhesive: Test T110
• Production requirements
  – Sizes and tolerances
  – Lumber requirements
  – Laminating and Adhesive requirements
  – Manufacture
    • Lamination preparation
    • Adhesive Curing
    • The use of End Joints (finger, scarf)
    • Assembly (e.g. Spacing of End Joints)
• To established nationally recognized requirements for...
  – Production
  – Inspection
  – Testing, and
  – Certification

...of structural glued laminated timber
• Inspection requirements
  – Plant manuals (production, quality control)
  – Quality control records (5 years)
  – Inspection and test procedures
  – Plant qualification
  – Daily quality control
• Inspection requirements
  – Plant manuals (production, quality control)
  – Quality control records
  – Inspection and test procedures
  – Plant qualification
  – Daily quality control
### Table 1—SUMMARY OF QUALIFICATION TESTS

<table>
<thead>
<tr>
<th>Test Performed On</th>
<th>Minimum Number of Samples</th>
<th>Minimum Number of Specimens per Sample</th>
<th>AITC Test Number and Type of Test</th>
<th>Requirements or Limitations for Within this Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Face and Edge Joints</td>
<td>2 beams <strong>a</strong></td>
<td>10</td>
<td>T107 Shear</td>
<td>Strength and Wood Failure</td>
</tr>
<tr>
<td></td>
<td>2 beams <strong>a,b</strong></td>
<td>3</td>
<td>T110 Cyclic Delamination</td>
<td>Bond Line Openings</td>
</tr>
<tr>
<td>End Joints</td>
<td>1 *</td>
<td>30</td>
<td>T119 Tension</td>
<td>Strength and Wood Failure</td>
</tr>
<tr>
<td></td>
<td>1 *c</td>
<td>5</td>
<td>T110 Cyclic Delamination</td>
<td>Bond Line Openings</td>
</tr>
</tbody>
</table>

The following tests are required in addition to the above requirements when these processes and/or materials are used in the plant.

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<thead>
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</tr>
</thead>
<tbody>
<tr>
<td>Proof Loaded End Joints</td>
<td>2</td>
<td>30</td>
<td>T118 Bending -or- T121 Tension</td>
<td>Strength -or- Strength</td>
</tr>
<tr>
<td>End Joints for Repair</td>
<td>10 Repairs</td>
<td>2</td>
<td>T119 (Modified) Tension</td>
<td>Strength and Wood Failure</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>5</td>
<td>Beam Test</td>
<td></td>
</tr>
<tr>
<td>Manufactured Lumber</td>
<td>1</td>
<td>102</td>
<td>T123 Tensile Properties</td>
<td>Strength</td>
</tr>
<tr>
<td>SCL</td>
<td>Per Applicable Requirements in ASTM D5456 and AITC 402</td>
<td>Per Applicable Requirements in ASTM D5456 and AITC 402</td>
<td>T123 Tension Plus Referenced ASTM Tests T107, T110</td>
<td>Strength</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>T116 Long Span E</td>
<td></td>
</tr>
<tr>
<td>Radially Reinforced Curved Members</td>
<td>1</td>
<td>10</td>
<td>T116 Long Span E</td>
<td></td>
</tr>
<tr>
<td>Proof Graded Lumber</td>
<td>1</td>
<td>102</td>
<td>T123 Tensile Properties</td>
<td>Strength</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>T116 Long Span E</td>
<td></td>
</tr>
</tbody>
</table>
• Inspection requirements
  – Plant manuals (production, quality control)
  – Quality control records
  – Inspection and test procedures
  – Plant qualification
  – Daily quality control
• Plant qualification
  – End-joints
    • Must meet required strength levels
  – Adhesives
    • Must pass ASTM standard tests for durability
  – SCL and Manufactured Lumber
  – Wood species
    • U.S. glulam standards primarily cover North American species.
• Inspection requirements
  – Plant manuals (production, quality control)
  – Quality control records
  – Inspection and test procedures
  – Plant qualification
  – Daily quality control
• Daily Quality Control
  – In-Line Tests
    • moisture content
    • adhesive spread
    • Assembly parameters (pressure, temperature)
  – Physical Tests
    • Parallel to the plant qualification tests
    • To assure that the plant is maintaining performance
• **2303.1.3 Structural glued-laminated timber.**
  Glued-laminated timbers shall be manufactured and identified as required in AITC A190.1 and ASTM D 3737.
• Standard Practice for Establishing Allowable Properties for Structural Glued Laminated Timber (Glulam)

  – Analysis method
  – Lamination requirements and properties
  – Determining glulam properties when made from visually-graded lumber
  – Determining glulam properties when made from E-rated lumber
  – End-use adjustment factors
ASTM D3737

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• D3737 Analysis method
  – Developed in 1950s
  – Clear wood stress of lumber is reduced by the strength-reducing effect of knots in a glulam beam.
  – Referred to as the $I_k/I_g$ Method
    • $I_k$ is the moment of inertia of knots
    • Knots farther away from the neutral axis have larger effect
    • Requires properties of clear wood and properties of knot size

  – Many evolutions since the 1950s
ASTM D3737

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- Lamination requirements
  - Thickness requirements
  - Grade requirements
    - Visually- or E-rated lumber
    - Primarily, limitations on strength-reducing characteristics
  - Moisture content requirements
    - Cannot exceed 16% (bonding)
    - Cannot vary by more than 5% (residual stresses)
ASTM D3737

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- Glulam made with visually-graded lumber
  - Clear wood and knot size properties provided for
    - Douglas Fir-Larch
    - Southern Pine
    - Hem-Fir
  - For other visually-graded species, properties can be derived from ASTM D2555
    - Standard Practice for Establishing Clear Wood Strength Values
    - Primarily includes commercial species that grow in the United States and Canada.
    - Knot data is often proprietary information.
ASTM D3737

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• Glulam made with E-rated lumber
  – E-rated lumber assures
    • An average modulus of elasticity for the grade
    • Visual Quality Level (VQL)
      – Edge knot characteristic (1/6, 1/4, 1/3, 1/2)
  – Wood properties are determined based on E-rated grade level, not specifically for a species
    • Higher E is assigned higher clear wood stress properties
    • VQL determines the knot properties used for the analysis.
• Standard Practice for Establishing Allowable Properties for Structural Glued Laminated Timber (Glulam)
  
  – Analysis method
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  – End-use adjustment factors
• End-use adjustment factors
  – Moisture content
  – Duration of load
  – Volume effect (???)
  – Curvature
  – Treatment (chemical or incising)
  – Shear deflection
ASTM D3737

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Developing glulam for U.S. markets

• Developing glulam using South American species for acceptance in U.S. markets.
  – Must be manufactured according to ANSI A190.1
  – Must be analyzed using ASTM D3737,
  – Must be confirmed with testing
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Developing glulam for U.S. markets

- Analyzing South American glulam using ASTM D3737
  - E-rated lumber approach

Analysis of Glulam Timber Beams with Mechanically Graded (E-rated) Outer Laminations

Roland Hernandez and Russell C. Moody, USDA Forest Service, Forest Products Laboratory, Madison, WI USA

» http://www.fpl.fs.fed.us/
Developing glulam for U.S. markets

- Analyzing South American glulam using ASTM D3737
  - A study of 771 glulam beams made from E-Rated lumber, from various species, was conducted.
Analyzing South American glulam using ASTM D3737

- Balanced and Unbalanced glulam combinations were studied, and found to have similar performance.

- Increasing E-rated lumber grades in the tension lamination showed similar increases in final glulam performance.
Developing glulam for U.S. markets

• Analyzing South American glulam using ASTM D3737
  – The conclusion of the Hernandez & Moody (1996) study: “Species, species group, and country of origin of the lumber have a minimum effect on glulam beam strength properties”
  – Using E-rated lumber allows for non-North American species to be analyzed using ASTM D3737, and past research shows that these beams have predictable performance regardless of species.
Developing glulam for U.S. markets

- Developing glulam using South American species for acceptance in U.S. markets.
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Developing glulam for U.S. markets

- A study was conducted using North American Ponderosa pine forest thinnings (small-diameter trees).
  - Low properties
  - Visual graded data not available
  - Utilized E-rated lumber
  - Conducted D3737 analysis
  - Glulam beam testing
  - Glulam combination was adopted

- Good example of tests and procedures necessary for developing South American glulam for U.S. markets.
2006 International Building Code

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Thank you!

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