Expert Tips

Standards and Testing: Ensuring Adhesive Performance in Mass Timber Buildings

A summary of code-referenced evaluations, tests and QA/QC required for adhesives in mass timber products

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Have you ever wondered what measures are in place to ensure the durability of adhesives used cross-laminated timber (CLT) and glue-laminated timber (glulam)? This article answers this question in detail, explaining how these materials are evaluated for moisture and fire conditions and why compliance with U.S. standards makes heat-induced delamination a non-issue.

The ability of mass timber buildings to remain structurally sound for decades of in-service use relies in large part on the performance of adhesives used to manufacture the wood elements. As with any manufactured building product, CLT and glulam are subject to performance tests and evaluations as part of the manufacturing and certification process, as dictated by the applicable manufacturing standard, referenced in the controlling building code.

For CLT, this refers to ANSI/APA PRG 320: Standard for Performance-Rated Cross-Laminated Timber. For glulam, it is ANSI A190.1 Product Standard for Structural Glued Laminated Timber. Any CLT and glulam product used in commercial or multi-family applications in the U.S. must be certified according to its relevant standard per sections 2303.1.4 (CLT) and 2303.1.3 (glulam) of the International Building Code (IBC). Within each standard are methods of ensuring the performance of adhesives when subject to moisture and fire conditions.

Evaluating the Moisture Performance of Adhesives

Ensuring that adhesives will stand up to moisture is achieved through evaluations that reflect the requirements of the material's end-use conditions. Section 1 of PRG 320 notes that:

CLT panels shall be used in dry service conditions, such as in most covered structures, where the average equilibrium moisture content of solid wood is less than 16 percent in the U.S., and is 15 percent or less over a year and does not exceed 19 percent in Canada. CLT panels qualified in accordance with the provisions of this standard are intended to resist the effects of moisture on structural performance as may occur due to construction delays or other conditions of similar severity.

For more information on the equilibrium moisture content of wood as a function of surrounding environments, see the WoodWorks publication, *Accommodating Shrinkage in Multi-Story Wood-Frame Structures*.

Another standard referenced in the IBC for wood-based design is the American Wood Council's National Design Specification® (NDS®) for Wood Construction. Section 10.1.5 notes similar requirements for CLT's in-use moisture conditions:

10.1.5 Service Conditions

Reference design values reflect dry service conditions, where the moisture content in service is less than 16%, as in most covered structures. Cross-laminated timber shall not be used in higher moisture service conditions unless specifically permitted by the cross-laminated timber manufacturer.

PRG 320 Section 6.3.1 cites several ASTM and ANSI testing standards for evaluating the adhesive moisture performance for CLT members:

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6.3.1 Requirements in the U.S.

Adhesives used in CLT shall meet the requirements of ANSI 405 with the following exceptions:

a. *Section 2.1.6 of ANSI 405 is not required, and*
b. *The CSA 0177 small-scale flame test (Sections 2.1.7 and 3.7 of ANSI 405) shall be conducted using CLT specimens of the same size and geometry as the structural glued laminated timber specimens (see Note 6).*

ANSI 405: Standard for Adhesives for Use in Structural Glued Laminated Timber further requires the evaluation of adhesives used in glulam (and CLT through PRG 320) according to the following test standards, which include moisture and bond durability tests.

- ASTM D2559: Standard Specification for Adhesives for Bonded Structural Wood Products for Use Under Exterior Exposure Conditions
- ASTM D1151: Standard Practice for Effect of Moisture and Temperature on Adhesive Bonds
- ASTM D7247: Standard Test Method for Evaluating the Shear Strength of Adhesive Bonds in Laminated Wood Products at Elevated Temperatures
- ASTM D1183: Standard Practices for Resistance of Adhesives to Cyclic Laboratory Aging Conditions

While some of these tests evaluate the adhesives in exterior exposure applications, this is a conservative approach since, as noted, CLT's use is limited to dry in-service applications. All CLT and glulam used in commercial and multi-family applications in the U.S. is required to have undergone these tests.

Evaluating the Fire Performance of Adhesives

A common topic when addressing questions related to the fire performance of adhesives used in mass timber—particularly in CLT—is heat-induced delamination. Several years ago, the National Fire Protection Association's (NFPA's) Fire Protection Research Foundation (FPRF) began working on a project titled, *Fire Safety Challenges of Tall Wood Buildings*. As part of this program, researchers undertook a series of compartment tests of design fires to evaluate the performance of protected and unprotected CLT compartments. These tests were not directly affiliated or connected with the compartment fire testing program that was developed by the International Code Council's Ad Hoc Committee on Tall Wood Buildings. In the FPRF series, compartment tests were performed with CLT fully protected with noncombustible protection. These tests resulted in compartment fires that essentially self-extinguished without contribution from the protected mass timber. Compartment tests were also performed with significant exposed CLT in which no sprinklers were used to control the fire. In certain configurations, the compartment fires did not decay and self-extinguish after burn-out of the contents. In these configurations, heat-induced delamination of CLT occurred. This delamination resulted in failure of the glue line as the char front approached. Thin pieces of the laminations fell to the floor, exposing the surface of uncharred wood on a new lamination, which contributed to fire regrowth.

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As containment of the fire within the compartment of origin is an important performance goal for high-rise fire protection, further studies were led by the NFPA FPRF and the American Wood Council to define testing methods to discern when heat-induced delamination can occur. PRG 320 was then revised to incorporate a new mandatory test for adhesives used in CLT production. This test evaluates the elevated temperature performance of adhesives, and is intended to exclude use of adhesives that permit CLT heat-induced delamination, as noted in PRG 320 Section 6.3.3:

6.3.3 Elevated temperature performance requirements in the U.S. and Canada

Adhesives shall be evaluated and comply with the requirements for elevated temperature performance in accordance with Annex B.

Note 7. The intent of the elevated temperature performance evaluation is to identify and exclude use of adhesives that permit CLT char layer fall-off resulting in fire regrowth during the cooling phase of a fully developed fire.

Passing this test is required for adhesives used in all CLT certified to the 2018 and 2019 editions of PRG 320. This valuable change helps provide assurance that CLT manufactured to the standard meets the performance requirements of high-rise buildings. However, while the test was initially focused on CLT used in tall mass timber construction types, all North American and European CLT manufacturers with PRG 320 certification have been certified to the 2018 or 2019 version, meaning that heat-induced delamination leading to fire regrowth is a non-issue for PRG 320-compliant CLT used in any construction type and building size.

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