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Rooted in Research

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WOODWISE Fire Experiments Improve Mass Timber Safety: Phase I

Mass Timber

While buildings have been constructed of wood for centuries, mass timber has revolutionized wood as a building material by enabling construction of high-rise wood buildings, thereby rivaling concrete and steel. Using cross-laminated timber—a form of mass timber made by stacking and adhering dried lumber in alternating directions into solid panels—can increase construction speeds while sequestering carbon, reducing emissions, and providing a market for sustainable forest products.

As the number and complexity of structures made with cross-laminated timber continue to increase, critical fire research is necessary to ensure that these structures remain safe during fire. Understanding fire behavior in full-scale structures is difficult, however, due to the expense and limited laboratory facilities where such experiments can be conducted.

The WOODWISE Project

Enter: the WOODWISE project. WOODWISE—an abbreviation for Wood Optimization for Occupant Safety, Design, Wood Innovation, Smoldering, and Emissions—is a collaborative study among the U.S. Department of Agriculture, Forest Service (specifically the Forest Products Laboratory and Northern Research Station), Oregon State University, the U.S. Environmental Protection Agency, and ARUP (a private engineering firm) that, as part of the first phase of the study, tested fire behavior of room-sized cross-laminated timber compartments. The compartments were made with cross-laminated timber walls and ceilings and were fully equipped with sensors to measure fire behavior and impacts on the structure as the compartments were set ablaze under controlled conditions.

PUBLIC BENEFITS

Full-scale fire tests of mass timber, including those comparing encapsulated versus exposed mass timber and fuel loads composed of common household objects, are essential for understanding fire behavior and developing ways to improve the safety of mass timber buildings.

These experiments were designed to achieve the following outcomes:

- Fill critical knowledge gaps regarding fire performance of mass timber buildings for the full duration of a structure fire,
- Quantify the cross-laminated timber and modern furnishing interactions during fire to inform safe mass timber testing and design,
- Collect measurements of emissions from structure fires with modern furnishings, and
- Develop scaled fire testing approaches to improve the pace of research and development in this critical area.

Results and insights from these experiments lead to safer building practices when using mass timber.

Fire testing underway in one of the WOODWISE compartments. Forest Service photo by Kara Yedinak.

Encapsulate or Expose

The WOODWISE test compartments differed in the extent to which the cross-laminated timber was covered, or encapsulated, by noncombustible material (i.e., Type X gypsum boards) as well as the fuel type (modern household items or wood cribs).

For the first and fourth tests, the cross-laminated timber was fully encapsulated with three layers of fire-rated gypsum board. The cross-laminated timber in the second test was fully exposed. In the third test, cross-laminated timber was partially exposed: the ceiling, back wall, and glulam beams were exposed, but side walls were encapsulated. Within the second and third tests, researchers also tested the performance of exposed and concealed steel angle floor-to-wall connections that are commonly used to provide stability in mass timber buildings.

Encapsulation did not greatly affect the peak temperatures of the fire in these tests but did affect the total heat released by the structures, with less encapsulation producing more heat. Additionally, when evaluating the floor-to-wall connections, the encapsulated connections developed less char, which indicates the important role that encapsulation may play in reducing fire spread between building levels, better than exposed floor-to-wall connections.

Tests with Modern Fuel Loads

Each test was run with 798 megajoules per square meter of mobile fuels that were not a part of the structure, which is over 100 megajoules per square meter more than the previous maximum tested and represents an average contemporary residential dwelling.

Three tests were run using "modern mobile fuels," which consisted of a mix of common combustible and noncombustible household objects including furniture, electronics, and cleaning chemicals. A fourth test, performed in a fully encapsulated compartment, used a mobile fuel made entirely of wood cribs, which are perpendicularly stacked piles of wood with space between the pieces that are often used as a quasi-repeatable fuel source in fire tests.

Results show that the type of fuel had a greater influence over fire temperatures than encapsulation. Modern fuels were consumed more quickly than the wood cribs. The fire became fully developed in 15 minutes for the wood crib test, but only 4 minutes in the modern fuel test. As a result, the peak fire temperature occurred faster in the test with modern fuels.

Modern fuels inside one of the WOODWISE compartments. Researchers used a variety of household objects made from assorted materials. Forest Service photo by Kara Yedinak.

A look inside one of the compartments following the fire test. Forest Service photo by Laura Hasburgh.

Making Mass Timber Safer

Initial results from Phase I of the WOODWISE test series show that encapsulation may not affect fire temperature but does reduce the total heat release rate and reduce fire spread at the floor-to-wall connections. These results also underscore the importance of considering how the type of fuels present in mass timber buildings can change fire behavior.

More work remains for the WOODWISE team, including more analysis of Phase I as well as data collection and analysis for Phase II, to evaluate whether these types of tests can be scaled down. With a better understanding of how fire behaves in mass timber structures, safe building standards can be established to support increased use of mass timber in a way that will ensure the buildings are as safe as possible.

KEY FINDINGS

- Encapsulating mass timber did not necessarily reduce fire temperatures.
- Encapsulating floor-to-wall connections in mass timber structures reduced char propagation, improving fire resistance.
- Modern common household items, when compared to traditional wood cribs often used in fire experiments, significantly affected fire behavior.

PROJECT LEADS

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FURTHER READING

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For questions on Rooted in Research, please contact Jenna Zukswert. Technical editing by Carol Hollar-Zwick and Susan Barro. Design and layout by Jeremy Siegrist.

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