RESEARCH in Progress

Forest Products Laboratory

Blast-Resistant Testing for Loaded Mass Timber Structures

Based on live blast testing done with 2015 Wood Innovations Grant funding, we know that cross-laminated timber (CLT) can compete with light gauge metal, prestressed precast concrete panels, and masonry. However, testing previously completed was on structures carrying only their own weight. This project will provide necessary test data to characterize the response of CLT structures with superimposed dead/live loads under blast loading, establishing the inelastic and ultimate response limits, while also providing documentation needed for design guidance offering an alternative to concrete and steel in military structures.

Load tree testing of CLT panels at Tyndall Air Force Base.

Background

Opening new markets for the use of CLT that can capitalize on the strength and speed of construction allowed by the technology creates the best opportunity for wood product market growth. One such market is the Department of Defense (DoD), representing an estimated 148 million board feet of additional lumber production. Wood products have been significantly under-represented in the DoD construction market because of their perceived performance in blast conditions.

Objective

The objectives of this project are to develop a design methodology and to demonstrate performance for exterior bearing CLT walls used in buildings subject to force protection requirements. This methodology should be published by U.S. Army Corp of Engineers – Protective Design Center to be used by engineers for designing CLT elements to withstand blast loads as determined by code requirements and specific project conditions.

Approach

The testing program will include a series of quasi-static tests followed by a series of live blast tests. All testing will be done at Tyndall Air Force Base, where the project team has already constructed three CLT test structures.

The quasi-static testing will utilize a load tree apparatus housed on the Tyndall Air Force Base. A minimum of 27 tests will be conducted on 4-ft-wide CLT panel samples with various axial loads and possibly grade. Each test will apply an increasing uniform bending load while measuring panel resistance, deflection, and residual axial capacity after failure. Axial loads will be varied to determine ther effects on the out-of-plane bending capacity of the panel.

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Temporary moisture protection added to CLT blast testing structures.

Based on the results of this testing, the existing single degree of freedom (SDOF) analytical model created will be updated to include the effect of axial load. This revised analytical model will be used to design the test specimens for the live blast tests. The live blast tests are intended to demonstrate the effectiveness of axially loaded CLT to resist blast loads and validate the SDOF analysis methodology.

This proposal includes two series of live blast tests, each series consisting of two detonations, the first intended to test the structure to its design capacity and the second to take it to failure. The front panels on each of the three structures will be replaced twice; once before each series of blasts. The buildings will be loaded with sandbags prior to the tests to simulate real dead and live load scenarios. Each test will vary the axial load as a percentage of the exterior wall panel's capacity.

Building on supplementary testing, we will include one live blast test on a nail-laminated timber (NLT) wall. The NLT panel will be constructed from blue stain beetle-killed pine. The intent is to demonstrate the blast resistance of other mass timber systems that might be a viable outlet for timber stocks that present environmental hazards on public and private forest lands.

Expected Outcomes

The outcomes of the quasi-static testing will include

- establishing a resistance function to compare to the resistance function created from previous testing without axial load,
- potentially quantifying residual capacity after bending failure, and
- determining if a ductile failure mode exists when inducing a compression failure in the outer lamination.

Live blast testing outcomes will include

- proving the efficacy of CLT technology in real blast-resistant applications and
- establishing a basis for the design methods recommended for use.

Timeline

Quasi-static load tree testing began in July 2017. Temporary roof structures were put on the test structures and the drying process started in July 2017. Construction will take place in August 2017, and live blast testing is scheduled for September 2017.

Cooperators

USDA Forest Service, Forest Products Laboratory

WoodWorks™ – Wood Products Council

Softwood Lumber Board

Project Team

K&C Engineering, Jacobs Engineering & RTL at Tyndall Air Force Base, Lendlease

Material Suppliers

Smartlam, DRJohnson, Nordic Engineered Wood, MyTiCon Timber Connectors, Simpson Strong Tie, MiTek Industries, Hilti USA

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