EXPERIMENTAL WINDBORNE DEBRIS IMPACT TESTING OF CROSS-LAMINATED TIMBER PANELS

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Windborne debris produced in tornadoes has long been known to be a significant cause of damage to structures especially when the building envelope is compromised. While many traditional building materials have been experimentally tested to determine the response to debris impacts, new materials are always being used and their capabilities need to be explored. Cross-Laminated Timber (CLT) is a relatively new engineered wood product which is made by gluing orthogonal layers of dimensioned lumber in order to build panels between three and nine layers thick. The nature of the alternating layers gives the panels strength in both directions as well as significant rigidity. Because CLT is naturally produced it has beneficial environmental properties as well and makes an attractive building material for mid-rise structures. It could also be effective at reducing the damage in residential structures from hazards such as tornadoes. In order to determine this benefit, experimental debris impact testing was performed on 3-ply CLT.

Standards that inform the design of storm shelters and safe rooms require the testing of different wall assemblies with a 2 by 4 missile travelling at speeds between 35.8 and 44.7 m/s (80 to 100 mph) for vertical assemblies, i.e. walls and between 23.7 and 30.0 m/s (53 to 67 mph) for horizontal assemblies, i.e. floors or roofs (FEMA P-361, 2015). These standards are meant to capture the debris that is reasonably representative based on post-storm assessments. In order to determine the response of CLT panels to debris impact loads and attempt to quantify the variability in the panels, a variety of 2 by 4 missile masses and velocity were tested at three different locations: center of panel, edge of panel, and corner of panel.

Experimental testing of 3-ply CLT showed the potential to resist many of the impact loads expected during tornado hazards. The missile speed, missile indentation, and permanent backside deflection of the panel were measured during each debris impact test. In order to relate the momentum and kinetic energy of the missile with the damage on the panel, power models were fit to the experimental data. These relationships were used as inputs in a Monte Carlo simulation that aimed to estimate the probability of failure for a given missile mass and velocity. The results of these simulations and the experimental tests show that 3-ply CLT has a 20-25% chance of failure from an EF-2 level missile and a 75-80% chance of failure from an EF-5 level missile. The results of these tests indicate a significant improvement over other residential building materials and will be used in loss models to determine the benefit of building using CLT.