NEWBuildS

# Technical Note 17

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# CONNECTIONS FOR CLT DIAPHRAGMS IN STEEL-FRAME BUILDINGS

**KEYWORDS: Cross laminated timber (CLT), diaphragms, self-tapping screws, structural steel**

## OVERVIEW OF PROJECT

An emerging trend is to use engineered wood products like cross laminated timber (CLT) that fully exploit their attributes and mechanical properties to create tall and large buildings multi-material hybrid building superstructures. Construction systems that are particularly attractive in this context are ones that exploit the relative lightness of CLT as slab material, because CLT slabs can have about one quarter to one third of the mass of mechanically equivalent normal weight reinforce concrete (RC) slabs. As past research at UNB identified, optimal uses of CLT slabs are situations where they form horizontal floor and roof diaphragms of high-rise multi-storey superstructures that also contain structural frameworks and massive RC building cores for the purposes of resisting effects of self-weight and imposed gravity loads and lateral wind and seismic loads on buildings (Figure 1). In such superstructures the horizontal diaphragms must have high in-plane rigidity, and be able to act compositely with steel framework and RC building core. This poses new technical problems in respect of connection methods for joining CLT plates together and joining CLT elements to other materials. The research work undertaken addressed:

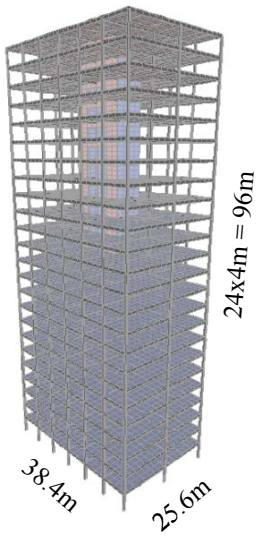


**Figure 1 -** High-rise superstructure with CLT diaphragms

1. CLT plate-to-CLT butt and spliced connection methods intended to transfer in-plane tension, compression and shear forces across joint planes; and

2. CLT plate-to-structural steel connection methods intended to transfer forces developed in the planes of CLT plates to building superstructure frameworks.

It was assumed that composite action between RC building core and other parts (steel framework and CLT diaphragm) is achieved via steel framework to RC connections, which avoids a number of practical difficulties associated with joining CLT to RC. Focus was restricted to using relatively slender self-tapping screws or lag screws to join CLT to CLT, or CLT to structural steel elements because prior research had indicated that using such fasteners is mechanically efficient and helps minimize the likelihood that driving or loading screws will split CLT plate materials. Various screw placement configurations were studied based on extrapolation of practice in Europe where there is greater experience of successful use of CLT as a high performance structural material. The research also built on experiences of Professor Marco Ballerini and other collaborating researchers from the University of Trento in Italy.

The primary research objectives were:

- To determine the influence of connection design variables and quantify mechanical properties of CLT plate-to-CLT plate connections made using metal self-tapping screws, with emphasis on

Researchers : Tom Joyce, Ian Smith
Affiliation : University of New Brunswick
Contact email address: ismith@unb.ca

transfer of in-plane thrust and shear forces that occur with diaphragms.

- To develop an efficient fabrication approach to creation of CLT-to-structural steel connections based on use of self-tapping screws or lag screws.
- To collect test data suitable for design of investigated types of connections.

The primary method of research was to investigate the behaviours of connection of various types experimentally (Figures 2 & 3). The scope of tests and design of specimens was based on numerical analyses of force flows within CLT diaphragms of hybrid superstructure systems as might occur in buildings of various geometries and sizes. Via that approach emphasis was only placed on types of connections likely to be strong and stiff enough to ensure that diaphragms consisting of a number of interconnected CLT plates would respond in a non-yielding manner if overloaded; and that composite action between CLT diaphragms and structural steel frameworks would be retained if design level event like the maximum credible earthquake for a geographic location were to occur. This is consistent with the design philosophy that large and tall buildings should sustain no more than superficial or easily repairable damage during design level loading events.

**Figure 2 -** CLT-to CLT connection test

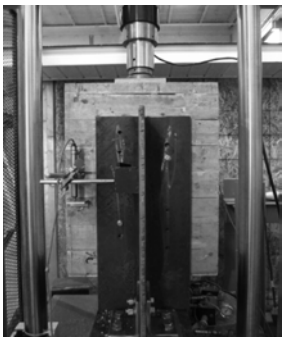

**Figure 3 -** CLT-to-steel connection test

## KEY RESULTS

The results support the selection of the panel-to-panel half-lap connection detail and inclined self-tapping screws connection for most situations where CLT plates are joined together. Double spline connections were found to respond consistently under loads in both primary panel directions (i.e. parallel and perpendicular to grain in face layers) and may perform well in cases requiring some out-of-plane moment transfer across joints. Results from tests on connections joining CLT panels to structural steel framing revealed that the best behaviour is achieved using lag screws, with resulting responses being characterized by high strength and stiffness and moderate-to-high ductility. Individual fastener responses were found to be independent of fastener spacing for centre-to-centre spacing distances exceeding 40 times the fastener diameter (40d), with connection stiffness being linearly proportional to the inverse of the fastener spacing. Therefore, when fasteners must be tightly packed than 40d apart to achieve desired stiffness and strength capabilities, maximization of connection efficiency and ensuring that their performance characteristics are not brittle depends on arranging fastener in staggered row arrangements (i.e. off-setting locations of fasteners in adjacent rows). The test data is part of the data base available for derivation of generic connection design capacities for Canadian manufactured CLT, with the expectation that such information will be incorporated in provisions of the national timber design code and/or publications produced by technical organization which promote use of engineered wood products.

## THESIS

Tom Joyce. 2013. Connections for CLT Diaphragms in Steel-Frame Buildings. MScFE Thesis, University of New Brunswick, Fredericton, NB.