HOLLOW MASSIVE TIMBER PANELS: A HIGH-PERFORMANCE, LONG-SPAN ALTERNATIVE TO CROSS LAMINATED TIMBER

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ABSTRACT: Solid Cross Laminated Timber floor panels do not take full advantage of the strength and stiffness of the wood used to produce it. It is controlled by vibration in most designs and has been found to be inefficient for long spans. Therefore, hollow wood panels were investigated in order to deepen the cross-section to make a more structurally efficient panel while taking advantage of many other benefits. An analytical study was done in order to found which cross-section could produce the most efficient cross-section in regards to strength, stiffness and fire. It was found that Southern Pine #2 lumber has excellent mechanical qualities for this type panel. Also, it was found that by using a thinner flange that has a deeper section, the gap between vibration controlling over strength can be decreases. On the other hand, through fire calculations it is seen that a certain wood flange thickness and geometry is required to meet 1 and 2 hour ratings. A parametric study was then done using SAP2000 in order to find how much certain variables affect the performance of the hollow panel. It was found that the strength and stiffness of the web to flange connection was very critical. To find the best solution to this critical connection, testing was done on different possible connections in shear in order to find the strength and stiffness which was entered into the SAP2000 model in order to predict overall panel behaviour.

KEYWORDS: Massive Timber, Hollow Floor Panels, Cross Laminated Timber, Southern Pine, Long Span

1 INTRODUCTION

The development of Cross Laminated Timber (CLT) has led to many new opportunities in wood construction, which include the potential for wood skyscrapers. With the recent advancement and push for tall timber building construction, there is also a need for a long-span massive timber floor system. Unfortunately, CLT falls short and may not be efficient for spanning long distances. While CLT can be made as thick as desired, and can technically obtain whatever span length is required, it is often economically infeasible to span more than 25 feet with solid CLT panels. With many architects desiring more than 30-foot span lengths, especially in commercial buildings, this leaves a research gap for a much needed long-span solution. An economical long-span solution could greatly aid in the ability to penetrate the commercial building market with massive timber construction including the push for wood skyscrapers. This paper presents the concept and development of a new composite hollow massive timber (HMT) system designed for long-span applications. The HMT composite system, which is adapted and derived from conventional CLT, is assembled together using mechanical fasteners and/or adhesive.

2 HOLLOW MASSIVE TIMBER

Figure 1 shows the schematic view of the HMT system. As can be seen, the cross-section is similar to that of a steel I-beam or voided concrete slab system. The top and bottom flanges of the HMT system can be made from either conventional CLT panels or modified massive timber panels. Solid sawn lumber or engineered wood products such as glued laminated timber (glulam) can be used as the web. Mechanical connectors in conjunction with adhesive were utilized in the HMT system to attach the flanges to the web.

Figure 1: Hollow massive timber (HMT) long-span system.

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Several cross-sectional profiles were investigated and tested in this study. *Figure 2* shows an example HMT cross-sectional profile. The preliminary section that was chosen for the cross-section of a HMT panel consisted of a top and bottom 3-ply flange. Along with this, dimensional lumber placed on their edge or glulam was used for the web members. For the flanges, it was decided that an unbalanced layup would be used where a double layer of Grade #2 Southern Pine lumber was used for the outside layer and an inner crosswise layer of Southern Pine Grade #3 lumber was used. This particular flange configuration was chosen because (1) it produces a higher moment of inertia, and (2) a greater fire rating can be achieved in comparison to a normal CLT panel configuration that has a crosswise layer in the middle of the panel.

### 3 PARAMETRIC STUDY

The goal of the parametric study is to find the level or importance of all the variables that affect the performance of CLT panels and hollow wood panels. A SAP2000 model was developed based on the Mechanically Jointed Method also known as the K method [1]. This takes into account the shear deformation in the web member, crosswise member and at the connection. From preliminary results the shear deformation results in a 10 - 15 % stiffness decrease. Spans from 25-35 feet can be accomplished based off preliminary modelling. The analytical study gave an idea of how what specimen sizes should be.

### 4 FLANGE TO WEB CONNECTION

From the results of parametric study, it was determined that the flange-to-web connection stiffness and strength heavily influences the performance of the HMT panel. An experimental study was conducted to determine the strength and stiffness of different possible web-to-flange connections (screw, glue or screw and glue). *Figure 4* shows the setup for web-to-flange connection test. The connection properties obtained from web-to-flange connection tests can be used in a numerical model to predict the stiffness and strength of the overall HMT panel.

*Figure 4: Typical web-to-flange connection test setup.*

*Figure 5* shows example load-slip curves of web-to-flange connected with mechanical connectors only at different placement angles. As can be seen, placement of screw at a 30-deg angle produces the stiffest connection.

*Figure 5: Typical load-slip curves of screws placed at different angles.*

### 5 CONCLUSION AND CLOSURE

This paper only presents the preliminary investigation of the feasibility of a HMT panel. Based on the results from preliminary analysis and connection tests, it is recommended to use #2 Southern Pine for longitudinal layers for the HMT panels. In addition, using double layers for the outer parallel to span layers is very beneficial for floors which primarily act as a one-way slab system. During the preparation of this article, this is still an ongoing research project. Full-scale testing of HMT panels are scheduled for late 2014 and early 2015. The full-scale test results will be utilized to confirm, modify or rectify the assumptions made in this research. Here are the specific topics that need to be investigated in the future in order for HMT panels to advance and become accepted by the timber construction and engineered wood industries.

### REFERENCES


Perpendicular to Span

Perpendicular to Span

Parallel to Span

*Figure 2: HMT cross-section.*

*Figure 3: SAP2000 model.*