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INFLUENCE OF CONNECTION SYSTEMS ON SERVICABILITY RESPONSE OF CLT TIMBER FLOORING

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KEYWORDS: Timber floors, cross laminated timber, serviceability limit design, finite element analysis

1 INTRODUCTION

Building with timber has many benefits in terms of sustainability and structural performance. It is versatile and renewable with net negative carbon emissions. Advances in timber technology allow for adaptable design and greater spans making it very suitable to modern architecture and high-rise development.

Cross laminated timber (CLT) has emerged as a preferred solid timber construction material in recent years. Studies are ongoing in many countries on the performance of CLT panels and CLT fixing systems particularly with regard to dynamic loads due to wind and seismic activity, causing shear, tensile, and bending stresses in the panels and the fixing systems. However, serviceability limit design (SLD) including static deflections and structural vibrations in floors, particularly due to footfall, continues to be a limiting factor in the selection of timber generally for floors in modern design.

Eurocode 5 (EC-5) [1] sets out equations to determine basic criteria on the serviceability limit state (SLS) of traditional timber floors, equations (1-5) below.

$$f_1 = \frac{\pi}{2l^2} \sqrt{\frac{(EI)_l}{m}} \quad (1)$$

$$v = \frac{4(0.4 + 0.6 n_{40})}{mbl + 200} \quad (2)$$

$$n_{40} = \left\{ \left(\left(\frac{40}{f_1} \right)^2 - 1 \right) \left(\frac{b}{l} \right)^4 \frac{(EI)_l}{(EI)_b} \right\}^{0.25} \quad (3)$$

f_1 = fundamental frequency < 8 Hz, m = mass, v = impulse velocity, l = long span, b = short span, $(EI)_l$ = bending stiffness, n_{40} = number of 1st order modes with natural frequencies below 40 Hz. Also

$$\frac{w}{F} < a \quad (4)$$

$$v < b(f_1(\xi-1)) \quad (5)$$

where w is the maximum instantaneous vertical deflection caused by a concentrated static force, F , of 1kN, and ξ is the damping coefficient. Limit values for parameters a and b are given in [1]. All equations relate to single span traditional timber floor construction. However, bearing in mind the influence on the deflection and vibration response of the rotational stiffness provided by the fixing system and that CLT floors can be supported on all sides, it is important to establish the influence of different connection configurations.

Current industry standards recommend connecting CLT floor and wall panels with different combinations of stainless or galvanised carbon steel tension and shear brackets or plates, with self-tapping screws, hold-down anchors and various separating membranes. Figure 1 shows a typical shear bracket connection of a mid-storey floor to wall connection.

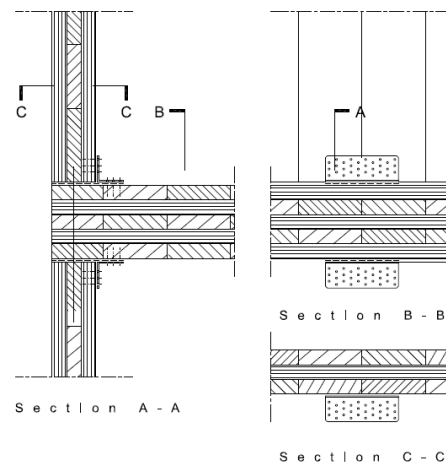


Figure 1: Typical shear angle bracket

The aim of the current research is to identify which proprietary fixing systems or component configurations,

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give optimum results with regard to SLD, consistent with the construction industries requirement for economical fixing systems with standardised components and simple assembly.

2 MATERIALS AND METHODS

A CLT floor system to carry loading consistent with a school building was designed in accordance with EC5 [1]. A five-layer panel with an overall depth of 0.2 m was found to be suitable to carry this loading over a 7 m span. The panel properties provided by the manufacturer are: density $\rho_k = 471 \text{ kg/m}^3$, and mean values of Young's and shear moduli for the outer lamella parallel to grain $E_{0, \text{mean}} = 12,000$, $G_{\text{mean}} = 250 \text{ MPa}$.

Finite element models of the floors were developed in Abaqus, using a 3-D shell element in order to investigate the deflection and vibration response. Orthotropic elastic material properties were defined. Different support configurations were investigated including: one and two-way spanning floors, with simply supported and fully fixed supports. For each case, the serviceability deflection is determined from a static small displacement analysis and the first three natural frequencies and mode shapes from a mode-frequency analysis.

3 RESULTS

The maximum displacement and frequency response is significantly impacted by the support conditions. Figures 2 and 3 show that by changing the rotational stiffness from zero (simply supported) to infinity (fixed) the fundamental frequency is increased by a factor about 2 for both one and two-way spanning floors. For the higher frequencies, the impact is not as pronounced. By supporting the floors on four sides instead of two, the fundamental frequency is increased by a factor of 5.

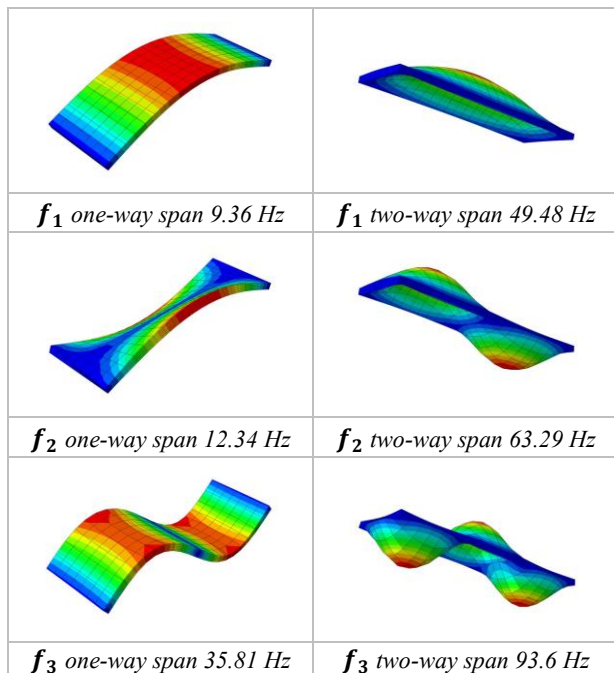


Figure 2: Modes shapes for simply supported floors

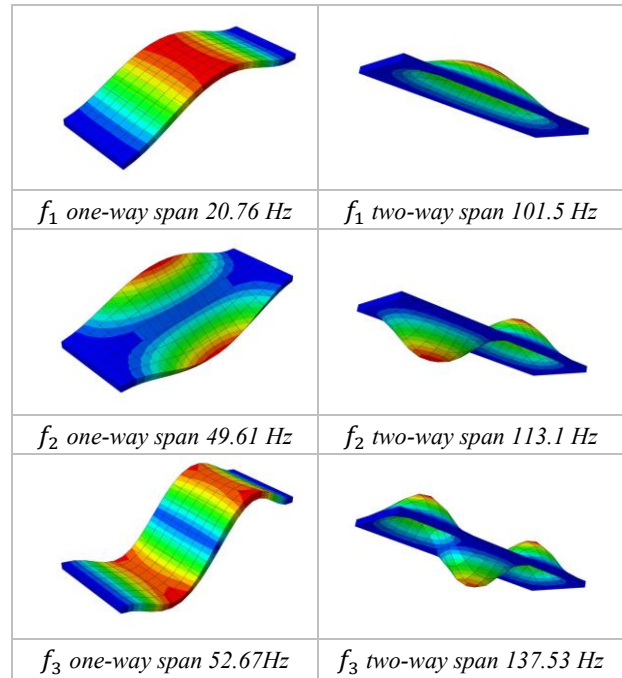


Figure 3: Mode shapes for fixed support conditions

4 CONCLUSIONS

Finite element modelling of a CLT floor with different support systems has shown that the deflections and frequency responses vary significantly with the support stiffness and the number of edges supported. The fundamental frequency varies from 9.36 Hz for a simply supported one-way spanning floor to 101.5 Hz for a two-way spanning floor with fixed supports.

Work is currently underway to determine experimentally the rotational stiffness of a number of proprietary fixing systems. These values will be incorporated into the FE models, which will in turn be compared with full-scale laboratory tests results. In further work, on the influence of concrete toppings, and other floor components, including acoustic and thermal insulation on deflection and structural vibration of CLT floors will be investigated.

ACKNOWLEDGEMENT

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