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Comparison of CLT Design Methods to Composite Beam Theory

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Abstract

Cross-laminated timber (CLT) is increasingly being used as a primary structural material. Since about 60-70% of structural material is associated with the floor system, sustainability gains are efficiently realized by use of CLT floor plates. Most floors can be modelled as 1-way slabs and idealized via beam theory; however, increasingly complicated composite beam and plate theories are being proposed for CLT design. This research compares methods from the US CLT Handbook to a composite beam design equation derived from elasticity theory. All deflection and stress results are compared to a benchmarked finite element model. Results show that CLT Handbook methods provide stresses and deflections within 5% of the FEA and composite beam theory. However, results indicate the shear analogy method over-estimates required laminate thickness for 4.6m span by up to 30% for deflection-governed design compared to the composite beam theory.

Keywords: Cross-laminated timber, composite, beam theory, elasticity, wood design, rolling shear

1 Introduction

Cross-laminated timber (CLT) is becoming an increasingly popular structural system due to desirable characteristics associated with aesthetics, sustainability and structural performance. Past research by Puettmann and Wilson[1] and Puettmann, et al.[2,3] has shown wood to be more sustainable than other structural materials because it requires less energy to produce than structural steel and reinforced concrete. Additionally, from a structural perspective, the density of CLT is typically around 5N/m^3 for most species which is approximately 20% of the density of concrete (ρ=19N/m^3) and 8% of steel (ρ=62N/m^3). This allows for faster construction times, leads to significant dead load reduction, smaller foundations and cost savings on sub-structure. Most importantly, wood is approximately 50% carbon by weight and is a natural carbon sink resulting from photosynthesis.

CLT is a laminated material consisting of alternating orthogonal layers of dimensional softwood lumber and structural glue that is built up to achieve composite panels as large as 305mm thick and 12.2m wide. These panels can be used as floor diaphragms and shear walls with structural sizes necessary to support tall wooden buildings up to 42 stories in height as demonstrated by Baker, et al.[4] Additionally, the orthogonal lay-up of CLT improves the dimensional stability.

Increasingly, key developments in mass-timber technology are overcoming strength and fire challenges associated with wood structures (Baker, et al.[4]). As a result, governing structural criteria are increasingly serviceability (i.e., deflection and vibration) and not strength (i.e., stress, post-fire strength, stability etc.) considerations.

Since CLT is such a relatively new structural material, there are several different design procedures commonly presented in codes and industry standards to determine deflections and stresses. The purpose of this paper is to evaluate the three design procedures from the US CLT Handbook[5] and compare results against a composite beam theory derived from first

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