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Robustness of Multi-Storey Timber Buildings

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Abstract

This paper investigates the probability of disproportionate collapse for a nine-storey mass-timber building designed for gravity and lateral loads. This is a static analysis which accounts for both geometric and material nonlinearities. Considering 32 different scenarios, the proposed building is subjected to removal of ground floor columns, one or two at a time, to compute the reliability index. As limit state functions, the results take into account the residual capacity of the building, in terms of bending moment resistance and shear stress within Cross-laminated timber panels, as well as the resulting deformations. Results indicate that failure is dictated by the imposed deflections rather than the capacity of the timber elements. The investigation shows that the proposed building does not have sufficient robustness to redistribute the load to the undamaged part of the building after the considered removal scenarios.

Keywords: Disproportionate Collapse; Progressive Collapse; Flat-Plates System; Extreme Events; Mid-Rise Timber Buildings; Structural Integrity.

1 Introduction

The use of Engineering Wood Products (EWPs) such as Cross-laminated timber (CLT) along with innovative structural systems and connectors are among the reasons behind the resurgence of wood as a structural material for mid-rise buildings [1]. Albeit the rapid growth in the number of multi-storey timber buildings, further studies to aid in the understanding of their structural behaviour are required. Since the magnitude of both gravity and lateral loads is proportional to building height, the need for structural performances that avoid abrupt collapse becomes imminent.

The occupancy level and the intended building use are baselines for collapse tolerances. Design codes such as the National Building Code of Canada (NBCC) [2] use the importance category to make for analysis and design. Although it is not realistic to have structures with 100% level of safety, it is unacceptable when an initial damage triggers chain failures of adjacent structural components and subsequently a large part of the structure. In Eurocodes EN1991 (Part 1-7 section A.1) [3], an incident is classified as disproportionate collapse when the final collapse affects more than 15% of the floor area of the affected storey or 100m^2, whichever is less, and does extend further than the immediate adjacent storeys. Prominent examples of disproportionate collapse are the

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