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Performance of two-storey CLT house subjected to lateral loads

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Date:	February 2014
Édition:	42984
Genre du document:	Research report
Description physique:	196 p.
Secteur:	Wood Products
Domaine:	Sustainable Construction
Champ de recherche:	Building Systems
Sujet:	Building construction
	Design
	Laminate product
	Timber
Série:	Transformative Technology TT 1.04
	W-3067
Langue:	English

Résumé:

Cross-laminated timber (CLT) is an innovative wood product that was first developed some 20 years ago in Austria and Germany and ever since has been gaining popularity in residential and non-residential applications in Europe. European experience shows that CLT construction system can be competitive, particularly in mid-rise and high-rise buildings. To evaluate the performance of CLT as a structural system, a series of quasi-static tests on connections and on various configurations of CLT wall panels were conducted at FPInnovations in 2010, and results were published in the Chapter 4 of the FPInnovations' Canadian CLT Handbook and US CLT Handbook. In addition, a survey of potentially available methods for development and assessment of R-factors for different structural systems was performed. Studies conducted in Europe on the assessment of the behaviour q-factor (European R-factor equivalent) for CLT structures and their findings are also discussed. Finally, based on all available information, estimates were made on the values of R-factors for CLT structures for implementation in the National Building Code of Canada, and capacity-based design procedures for CLT structures were drafted.

The work presented in this report is a continuation of the FPInnovations' research project on determining the performance of the CLT as a structural system under lateral loads. A two storey full-scale model of a CLT house was tested under quasi-static monotonic and cyclic lateral loading in two directions, one direction at a time. In total five tests were performed; one push-over and two cyclic tests were conducted in the longer symmetrical direction (E-W), and two cyclic tests were performed

longer symmetrical direction (E-W), and two cyclic tests were performed in the shorter asymmetrical direction (N-S). In addition, before and after each test, natural frequencies of the house in both directions were measured. The main objective of the tests was to investigate 3-D system behaviour of the CLT structure subjected to lateral loads. The CLT structure subjected to lateral loads performed according to the design objectives.

Failure mechanism of the house specimen was similar in all the tests, despite changing some parameters such as number of hold-downs, number of screws in perpendicular panel-panel connections and different directions of loading. The house failure occurred due to a shear failure of nails in the brackets in the first storey as a result of sliding and rocking of the wall panels. Even after the maximum force was reached, no global instabilities of the house were detected. Torsion effects did not compromise the integrity, stability or lateral resistance of the building.

The floor diaphragms were found to behave as rigid with minimal or almost no slip between the floor panels. Similarly, wall-to-floor panel connections were found to be rigid, which is beneficial for efficient transmission of forces from floor panels to lateral load resisting walls underneath. Vertically screwed step joints between parallel wall panels allowed for relative displacements between the wall elements in both storeys during their rocking while being loaded in their plane. On the other hand corner vertical connections acted as almost perfectly rigid. CLT wall elements were subjected to shear forces which caused some in-plane panel deformations. Wall panels with only window openings were rigid in their plane while wall panels with door and windows openings showed some in-plane flexibility. The building performed better in terms of deformability capacity in the N-S direction compared to E-W due to larger flexibility of the wall panels in the N-S direction, higher uplift-to-sliding deformation ratio in Test 04 and 05, aspect ratio of the building and the geometry of the panels.

Distribution of hold-downs and brackets, their number and number of nails in the connections were very similar in both directions, resulting in very similar lateral strengths in both directions. Reduction in the number of screws in perpendicular wall-to-wall panel screwed connections in Test 05 did not influence performance of the building in terms of resistance. Overall, the tests showed relatively good response of the building in terms of strength degradation capacity at repeated cyclic loading

Walls perpendicular to the loading direction contributed significantly to strength and stiffness of the building. The design models which included perpendicular walls in the design models predicted the governing failure condition correctly, while in case of design models without perpendicular walls, the prediction was incorrect.

The outcomes of the full-scale CLT house tests will be used for further analytical and numerical analyses which are needed for implementation of CLT structural system in the North American building codes and material standards.

Documents

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