Optimal seismic design of tall timber buildings with CLT panels

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Motivation

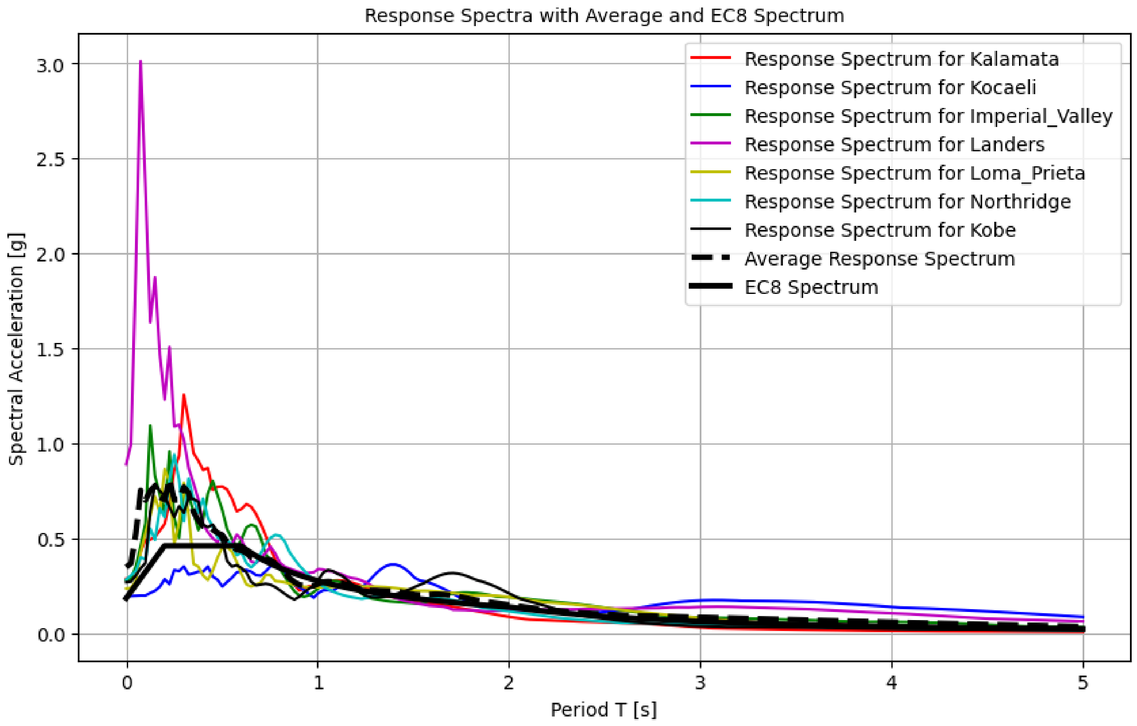
Earthquakes are catastrophic events that have caused in Europe over 200 000 deaths and 250 billion Euros in damages, in the 20th century alone. The inherent unpredictability, in terms of occurrence intervals, intensity and direction, of seismic events complicates the design for seismic-resilient structures.
Timber, with its low carbon footprint and excellent performance under ground motion, is a promising construction material; however, limited experimental data on timber structures under seismic loads highlights the need for advanced modeling and testing methods, particularly pertaining to engineered wood products such as CLT (cross-laminated timber).
The scope of this thesis is the optimal seismic design of one of these shear wall of a prototype tall structural timber building.

Methodologies

For the evaluation of seismic performance, 3 types of analyses were conducted:

- Modal analysis, to obtain the first fundamental period of the structure
- Lateral force method (EC8): an equivalent static method that utilizes the first period of the structure to estimate the ground acceleration it undergoes, from which base, storey shear forces and overturning moments around the base are derived
- Non-linear dynamic time-history analysis: results from the solution of the system equations after applying an seismic record accelerogram at its base

For this analysis, seven seismic records were selected to match the elastic response spectrum of the EC8 [1], whose response spectra are shown in figure 1.



Expected behaviour

The literature attests for the desirable performance of timber and engineered wood products under seismic loading. Timber has a high strength-to-stiffness ratio and is lightweight, which allows it to withstand significant ground motions without sustaining permanent deformations and remaining elastic, as demonstrated by full-scale tests on shake-tables. [3]
Seismic energy dissipation achieved via plastic deformations is concentrated in the steel connections, both timber-to-timber [2] and ground-to-timber (hold-downs, angle-brackets) [4].

Footnotes

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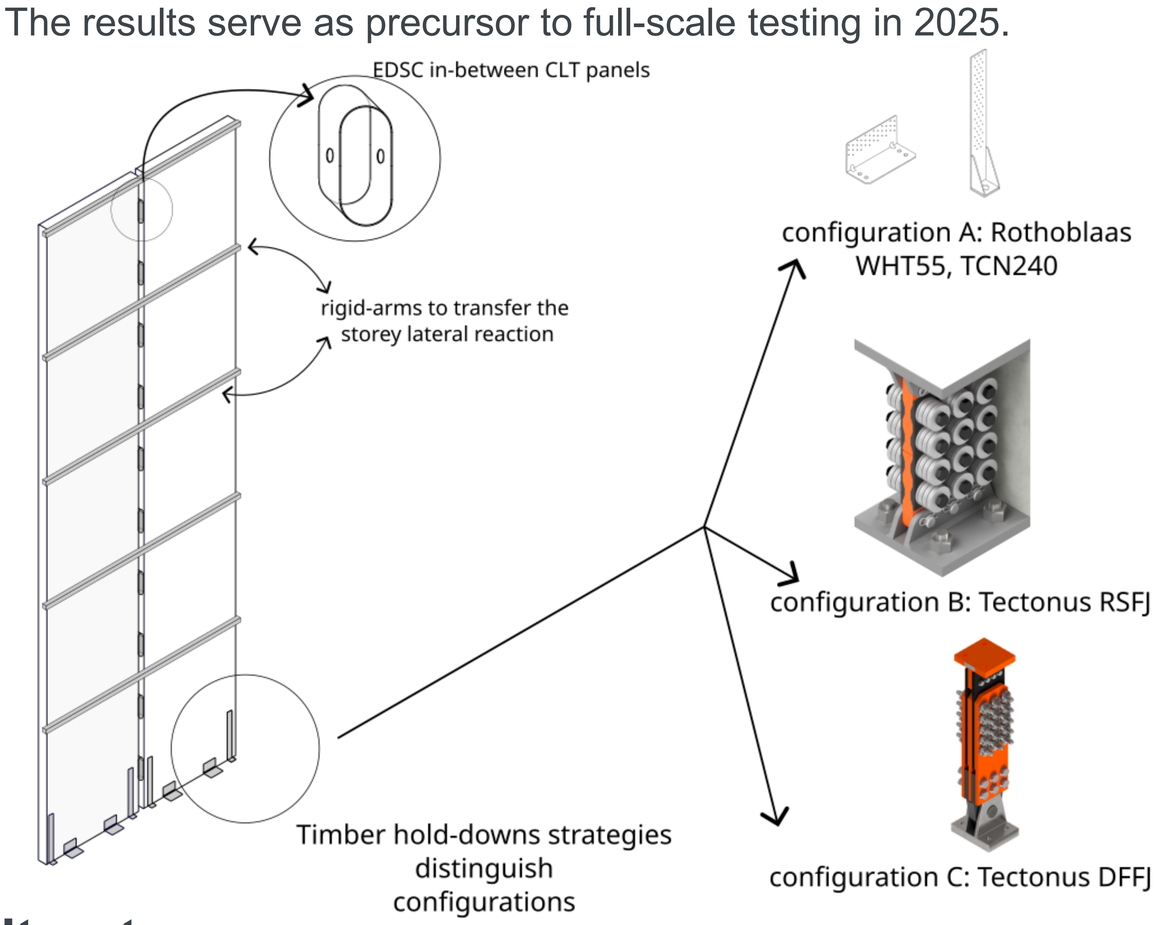
Analyses Performed

A shear wall was modelled in SeismoStruct, consisting of two CLT-panels connected by seismic dissipators denoted as EDSC from [2]. Three configurations were distinguished by the timber-to-ground connectors: one utilized non-seismic-designed standard connectors, two utilized instead connectors for seismic design, respectively self-centering and friction hold-downs, as fig. 2.
Preliminary analyses were conducted in OpenseesPy to obtain the design shear forces and moments of the CLT-wall, which was subjected to dynamic-time history analyses. Different subconfigurations were tested for different degrees of coupling in the seismic dissipators.

Results

The overall performance reflected the literature findings. The CLT panels remained elastic whereas the seismic dissipation was concentrated in seismic connectors. Only configuration with standard hold-downs failed, but is believed it can lead to success in further studies as in [4].
The results serve as precursor to full-scale testing in 2025.



Literatur

[1] European Commission for Standardization 2004, *Eurocode 8: Seismic Design of Structures*. European Commission for Standardization, 2004

[2] Güllü, A., Smyrou, E., Khajehdehi, A., Ozkaynak, H.: *Numerical Modelling of Energy Dissipative Steel Cushions*. (2019)

[3] Ceccotti, A., Sandhaas, C., Okabe, M., Yasumura, M., Minowa, C., Kawai, N.,: *SOFIE project- 3D shaking table test on a seven-storey full-scale cross laminated timber building*. (2013)

[4] Hashemi, A., Loo, W.Y., Masoudnia, R., Zarnani, P., Quenneville, P.: *Ductile CLT platform structures with passive damping* In: Proceedings of the World Conference on Timber Engineering (WTCE2016), 2016

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