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Seismic response of tall timber buildings

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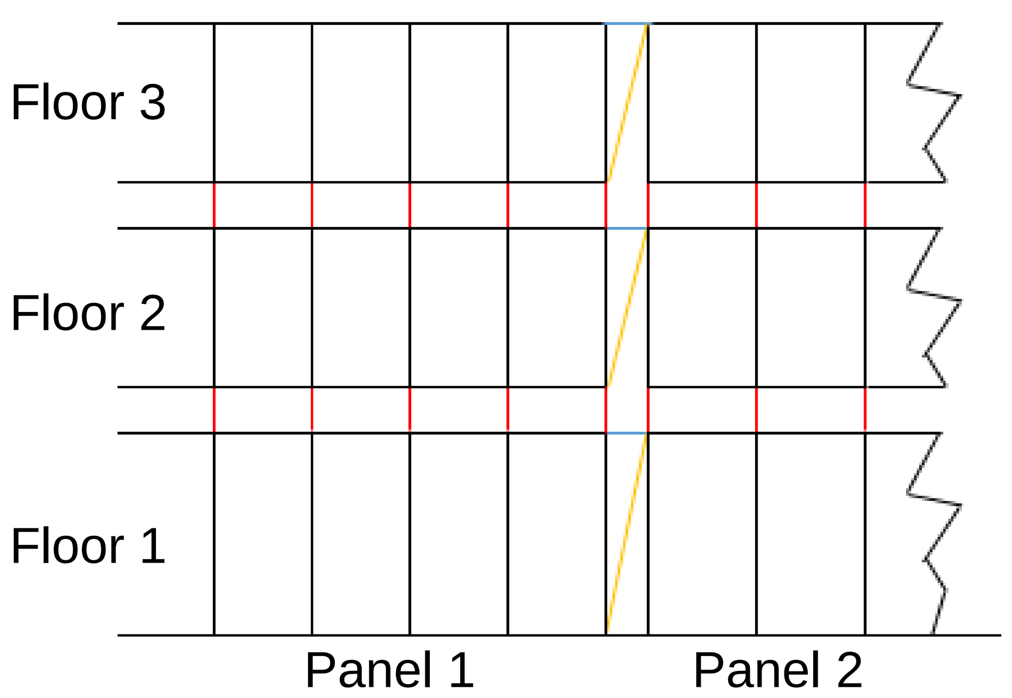
Introduction

Cross-Laminated Timber (CLT) as a timber material but has similar action capacity to a reinforced concrete slab. The CLT provides relatively high strength and stiffness properties, giving itself a chance to be used as a construction material. This study explores employed Advanced Finite Element models to examine the nonlinear behavior of CLT walls subjected to a series of static and dynamic lateral loads.

Methods

A 7-storey CLT building is created in the OPENSEES software, to estimate the nonlinear behaviour when subjected to a series of seismic loads. The connectors in CLT buildings play a significant role to resist the lateral force during earthquakes. Therefore it is important to mark the connectors clearly in the model. Then, monitoring and analysing the responses of the structure during the different earthquakes.

Connection details of the model



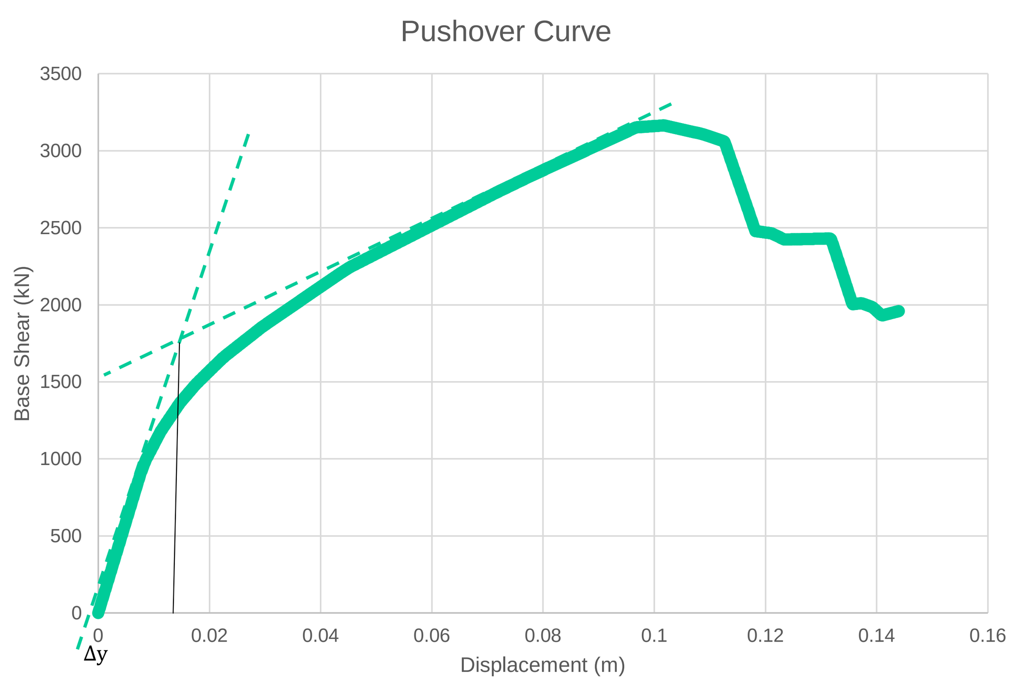
The figure shows how the floors and panels are connected in the model. The gaps between panels and floors are all $1 \times 10^{-5}\ m$.

Red line – Uniaxial Hysteretic Material acts as the connectors between floors

Blue line – Rigid Material with high Young's modulus connects panels to ensure the same displacement of panels.

Yellow line – Uniaxial Hysteretic Material acts as the connectors between panels.

Static, non-linear Analysis



Pushover is used to determine the response of a structure under permanent vertical forces and general increasing horizontal forces. From the curve:

Δy is the limited point, at point before Δy, the timber wall undergo a elastic performance; when the point exceed Δy, the structure becomes plastic until the largest point is reached. After the peak point, the structure will fail. From the diagram, $\Delta y = 0.015\, m$ and the Base shear is around $1800\ kN$.

Dynamic, non-linear Analysis

Figure 1

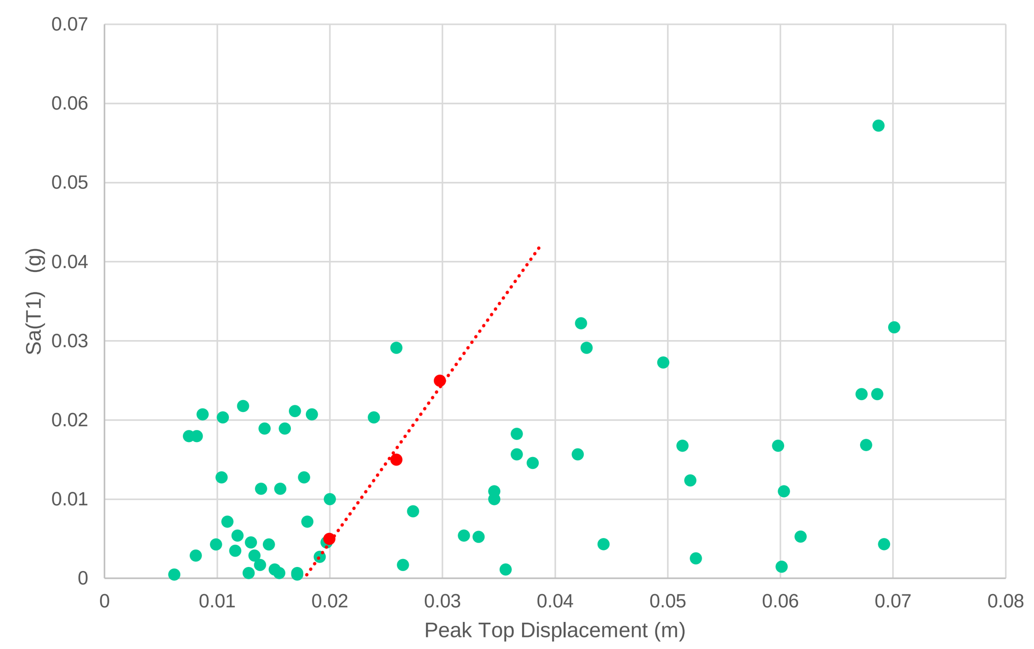


Figure 1 is the relationship between Spectral Acceleration (SA) and the Peak Top Displacement of the structure. Each green point represent one earthquake, red dots is the mean value of the logarithmic number of the displacement in every intervals, here the intervals are 0.01 at y-axis.

From this figure, the SA is proportional to the mean value of the logarithmic value.

Figure 2

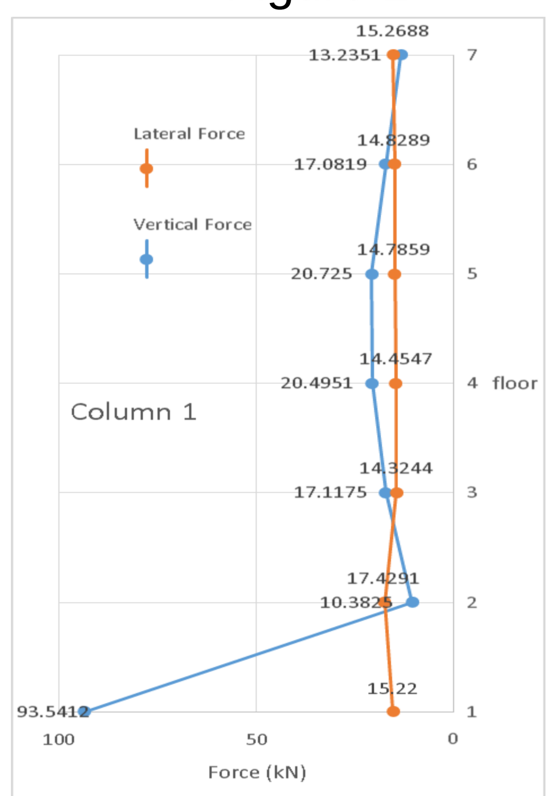


Table 1

Column 2	
Vertical Force	Lateral Force
392.796	706.672
234.892	1272.218
199.258	1329.156
185.964	1208.574
179.5576	951.796
166.2024	639.62
117.2096	275.226

Figure 2 indicates the load distribution on the column subjected the earthquakes. The lateral forces distribute equally for all the floors, the same happens to the vertical forces at top six floors. However, the vertical force at first floor is very large.

Table 1 shows the inter-panel forces during the same earthquake as that in Figure 1. The vertical force decreases from the bottom to the top and the maximum lateral force acts at third floor.

Conclusion

- The Spectral Acceleration has a linear relationship with logarithmic mean of top displacement as well as maximum drift between storeys. Therefore, the range of top displacement and drift can be estimated for a specific earthquake.
- During the earthquake, the main forces are carried by the connections between panels, therefore, very stiff connectors should be used here; while the forces on the nodes are relative small except the vertical force at first floor.

Acknowledgement

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Reference

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