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NUMERICAL SIMULATION FOR THE SEISMIC BEHAVIOUR OF MID-RISE CLT SHEAR WALLS WITH COUPLING BEAMS

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ABSTRACT: In this paper, an innovative type of mid-rise Cross Laminated Timber shear walls with coupling beams was designed. The 5-layer CLT panels were continuous along the height. Hold-downs and angle brackets were installed at the bottom of the panels. Coupling beams with energy dissipation devices were used to decrease the deformation and internal forces of the walls, providing adequate stiffness and strength. A numerical model was developed in OpenSees for a six storey prototype to investigate its seismic behaviour with different configurations. Strength degradation, stiffness degradation, and pinching effect were considered in the connection models. The structural performance was evaluated through a series of static and transient analyses. The simulation results indicated adequate lateral resistance and deformation capacity of this structural type. This study will lead to more application of large size CLT panels in multi-storey CLT buildings as lateral resistant systems.

KEYWORDS: Cross Laminated Timber, Mid-rise, Shear wall, Coupling beam, OpenSees

1 INTRODUCTION

Cross Laminated Timber (CLT) is an innovative wooden product. It is fabricated by bonding timber boards together with structural adhesives to produce a solid timber panel with each layer oriented crosswise to the next. A number of experimental studies on CLT panels has been conducted in Europe and Canada [1-3]. Based on experimental work, numerical modelling of CLT panels was performed to predict the structural behaviour [4-6]. These studies indicated that, (1) CLT panels are relatively stiff, (2) the ductility and energy dissipation of the structures comes from the connections between wall panels, and between panels and base, dominated by rocking and slip mechanisms, and (3) connection details and panel sizes have significant effect on the lateral resistant performance of CLT panels.

Coupling beams are commonly used components in reinforced concrete shear wall structures. Being utilized in CLT structure systems, the details between beams and walls significantly influence the structural performance of the buildings. Improper design of coupling beams may fail to meet the lateral strength and stiffness requirements of the CLT shear walls. However, this has seldom been studied.

In this paper, a numerical study of a six storey CLT shear walls with coupling beams was carried out to evaluate the seismic behaviour of such structural type in OpenSees [7]. Design of connections were calibrated to match expected structural performance. The periods and modes, global responses and local responses of the structure were discussed through a series of static and dynamic analyses. Optimal design for such structure type was selected though target performance evaluation. Design recommendations were given based on the analytical results.

2 DESIGN AND SIMULATION

2.1 PROTOTYPE

The prototype of cross laminated timber shear walls with coupling beams has six storeys with the elevation shown in Figure 1. The walls and coupling beams were made of 175 mm thick 5-layer CLT panels. The walls were continuous in the long direction prefabricated in the factory. The panels were connected to the base with hold-downs on the sides and angle bracket in the centre (Figure 2). Coupling beams were adopted to connect the two walls with steel plates. The steel plates with dowels will transfer lateral forces. The low yielding dampers in the centre of the coupling beams will undergo shear deformation during the earthquake to dissipate energy (Figure 3).

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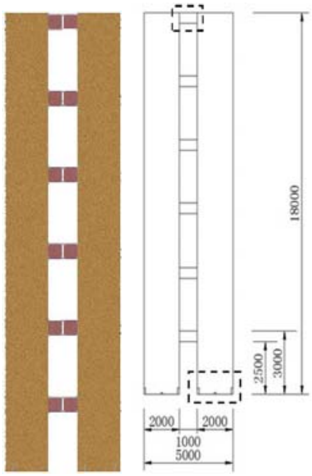

Figure 1: *Elevation of the shear wall with coupling beams*

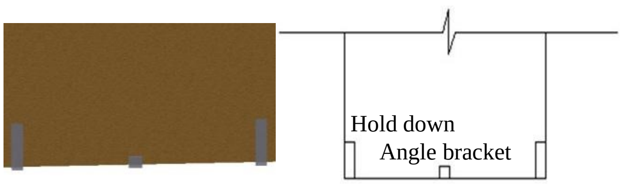

Figure 2: *Configurations of hold downs and angle brackets*

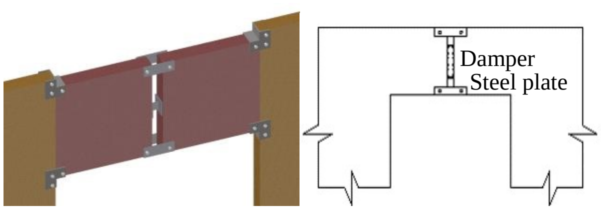

Figure 3: *Configurations of dampers*

2.2 NUMERICAL SIMULATION

2.2.1 Connection model

In OpenSees, CLT panels were modelled with *quad* element. Hold downs and angle brackets were modelled by *ZeroLength* element with *Piching4* material. This material considers the strength degradation, stiffness degradation, and the pinching effect of the connections. Opensees provided an elastic *No-tension* material which could be applied to the additional *ZeroLength* elements to model the high compression stiffness at the base. The dampers were modelled by *TwoNodeLink* element with *Steel01* material in the vertical direction, and rigid in the horizontal direction. The models were calibrated based on existing experimental data [5, 8].

2.2.2 Numerical analyses

Push over analyses were firstly conducted for seven configurations of connectors to find an optimal design. The calibrated design was then subjected to a set of time history analyses of ten ground motions at three hazard levels. The results were discussed to evaluate the structural performance of the shear walls and connections.

3 CONCLUSIONS

Innovative mid-rise CLT shear walls with coupling beams were designed in this study. Numerical modelling, structural analysis and performance evaluation of the proposed structural type with different configurations were conducted. The results implied that, the shear resistance is controlled by the angle brackets, while the deformation capacity is controlled by the hold downs and coupling beam connections. The relatively high shear and uplift demand for mid-rise CLT shear walls is significant in configuration design. The research will be conducive to study the seismic performance of CLT structures and develop the application of CLT in midrise constructions.

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