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HYBRID WOOD-MASONRY WALL TEST AND VERIFICATION OF TWO-DIMENSIONAL MODELLING APPROACH

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ABSTRACT: Elevator shaft and stairwell core in multi-storey light wood frame buildings are usually constructed with non-combustible materials like reinforced concrete or masonry. As the storey limit of light wood frame building has been increased from 4 to 6 in the Province of British Columbia, it is beneficial to take advantage of the stiffer core to reduce building deflection under lateral loads. In this paper, two-storey hybrid wood-masonry wall systems bolted at the floor level were tested under reversed cyclic loads to simulate the performance of hybrid building systems under seismic load. The test results were used as verification data for a two-dimensional (2-d) model which would be used to predict the seismic performance of hybrid buildings under a series of earthquake ground motions. The test results show that the connection system is the weak part of the hybrid system if load was transferred from wood frame to masonry core. And the 2-d model could predict the performance of hybrid building accurately if reliable input properties of system elements are provided.

KEYWORDS: Hybrid wall system, Wood-masonry connection, Reversed cyclic load, Numerical modelling

1 INTRODUCTION

Elevator shaft and stairwell core in multi-storey light wood frame buildings are usually constructed with non-combustible materials like reinforced concrete or masonry, making the construction a multi-material hybrid building system [1]. Although in design practice for low-rise light wood frame building up to 4-storey, the reinforced concrete or masonry core is designed separately from wood frame, the increase of storey limit from 4 to 6 may necessitate the need to rely on the stiffer core to reduce building deflection under lateral loads. Structurally attaching wood frame to stiff core leads to uncertainty of the seismic response of hybrid building systems as these two principal materials have vastly different physical and mechanical properties. In this paper two-storey wood-masonry hybrid wall systems bolted at the floor level were tested under reversed cyclic load as well as one-storey wood shear wall, one-storey reinforced masonry wall and wood-masonry connections to simulate the seismic performance of hybrid building system and its related components. The purpose of these tests was to get a general understanding on how lateral loads are transferred between wood wall and masonry wall through the connection system. The results of the wall tests were used to verify a two-dimensional (2-d) numerical modelling approach which would be used to predict the seismic performance of multi-storey light wood frame building connected with a reinforced masonry core.

2 EXPERIMETAL PROGRAM

In total there were 4 walls being tested in this program including a one-storey wood shear wall, a one-storey reinforced masonry shear wall and 2 two-storey hybrid wood-masonry wall specimens with load applied at the second storey of wood wall and masonry wall respectively. The wood-masonry connection systems were recommended by a design engineer and a total of 3 replicates were tested for each type.

2.1 MATERIALS AND DESIGN CONFIGURATIONS

The fully grouted reinforced masonry wall was constructed with 20 cm hollow concrete block joined with Type S mortar. No. 10 rebar was located horizontally at every 600 mm. 16 mm (5/8 in.) threaded rod was used as vertical reinforcement.

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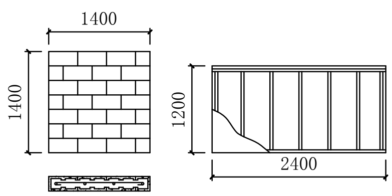
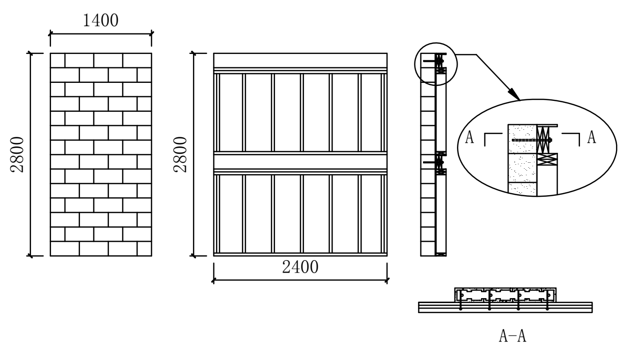
The wood shear wall was constructed with 2 × 4 spruce-pine-fir (SPF) No.2 grade and better dimension lumber, and sheathed with 12.5 mm OSB on one side. The lumber-to-lumber nails were 83 mm (3.25 in.) in length. The lumber-to-sheathing nails were 57 mm (2.25 in.) in length. Sheathing nail spacing was 100 mm at edges and 300 mm in the middle. In two-storey wood shear walls, the floor headings were constructed with double 2 × 8 dimension lumber. The floor was connected to the 1^{st} storey wall with toe nails and 2^{nd} storey wall with two rows of 83 mm (3.25 in.) nails. To ensure efficient shear transfer mechanism, 20 mm bolts were put through the floor and adjacent walls vertically at every 400 mm.

The masonry wall and wood wall were connected with grade 8 bolts at the floor level. Figure 1 shows the configuration details of the one-storey single walls and two-storey hybrid walls.



(a) One-storey masonry wall (b) One-storey wood wall



(c) Two-storey hybrid wall

Figure 1: *Wall configurations*

3 VERIFICATION OF 2-D NUMERICAL MODEL

3.1 DISCRIPTION OF NUMERICAL MODEL

A 2-d numerical model was used to analyze the seismic performance of hybrid buildings under a series of earthquake ground motions. In the 2-d model, all wood shear walls in a storey were grouped into one super element. Likewise, the reinforced masonry walls were represented by another super element. The super element contains three rigid truss elements and two diagonal springs simulating the lateral hysteretic performance of the walls. The two super elements were connected by a pair of hysteretic springs that represent the bolted connections.

This 2-d model was implemented using the commercial software ABAQUS V6.10 together with a user-defined subroutine developed by Xu and Dolan [2] that incorporates the Bouc-Wen-Barber-Wen (BWBN) hysteresis model. The BWBN model contains 13 parameters to describe the hysteresis performance of the wall elements and connections. Detailed explanation of the significance of each parameter and equations controlling the hysteresis loops can be found in reference [3].

3.2 VERIFICATION

The 2-d model of the two-storey hybrid wood-masonry wall system was built with ABAQUS and applied a reversed cyclic load at the second storey of wood wall or masonry wall respectively. The properties of walls and wood-masonry connection elements came from the test data in this project. The hysteresis loops and energy dissipating capacity of numerical hybrid wall systems were compared with that of the test data to prove the accuracy of the modeling method.

4 CONCLUSIONS

The wood shear wall, reinforced masonry shear wall and connection systems all exhibited highly nonlinear, inelastic, strength/stiffness degradation and history dependent phenomenon under reversed cyclic load. When the load was applied at the top storey of wood wall, the connection failed first while when the load was applied at the top storey of masonry wall, masonry wall failed first. The 2-d numerical model could predict the performance of hybrid building accurately if reliable input properties of system elements are given.

ACKNOWLEDGEMENT

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