WCTE 2014 Quebec City Canada August 10-14
World Conference on Timber Engineering

SEISMIC PERFORMANCE OF MID-RISE LIGHT WOOD FRAME BUILDING CONNECTED TO A STIFF CORE

Lina Zhou[1], Ying-Hei Chui[2], Chun Ni[3]

ABSTRACT: The storey limit of residential light wood frame buildings in Canada was raised from 4 to 6 in the Province of British Columbia in 2009. Increase in height leads to a more flexible building system, necessitating the need to rely on the stiffer elevator shaft and stairwell core to reduce building deflection under lateral loads. In this paper, a two-dimensional numerical model was used to simulate the seismic performance of a hybrid building consisting of a light wood frame structure and reinforced masonry core. The model was developed using commercial software ABAQUS V6-10 together with a user-defined subroutine that incorporates the Bouc-Wen-Barber-Wen (BWBN) model that describes the hysteresis behaviour of various building components. The results provide a preliminary indication of the interaction between wood frame and stiff core and may eventually lead to design guidelines that can be adopted by design professionals to effectively deal with the design of mid-rise hybrid wood frame buildings.

KEYWORDS: Hybrid wood-masonry building, Mid-rise wood building, Seismic performance, Numerical modelling

1 INTRODUCTION

In North America, light wood frame buildings have traditionally been restricted to 4-storey in building codes. In design practice, the elevator shaft and stairwell core made of reinforced concrete or masonry are usually treated separately from the wood frame structure. To achieve this, a physical gap, as much as one inch (25.4 mm), is often left between the wood frame and stiff core to ensure no structural interaction under lateral loads. As the storey limit of residential building has been increased from 4 to 6 (mid-rise), there is a potential need to rely on the stiffer core, which is often present as elevator shaft and stairwell, to provide additional resistance to reduce building deflection under lateral loads. Physically attaching the wood frame to the stiff core causes uncertainty of the structural performance of hybrid building system under environmental loads as these two materials have vastly different physical and mechanical properties. From a structural perspective, there is currently a lack of design guidelines for the design of such hybrid building under lateral load, especially under seismic actions. Two key uncertainties arise. The first factor is related to the determination of seismic force modification factor. The seismic force modification factor for shear wall system made of wood is 5.1 while for moderate ductile reinforced masonry system is 3. According to the National Building Code of Canada (NBCC) [1], if two systems are rigidly connected, the lower value of the force modification factor, R_dR_o (R_d: ductility-related force modification factor; R_o: over-strength related force modification factor) of the two systems shall be used for the hybrid building system which is likely to be conservative. However, no design information is provided in the code if the two systems are connected with ductile connections. Another uncertainty comes from the estimation of fundamental natural period of hybrid building system. In the equation suggested by Clause 4.1.8.11.3) c) of NBCC, the fundamental natural period of a shear wall building is only related to its height irrespective of structural material, while light wood frame building systems usually have longer natural period than masonry with the same building height. A modified equation depending on the material stiffness and resistance ratio of sub-systems in a hybrid building is needed to accurately calculate the fundamental period of hybrid buildings.

In this paper, a two-dimensional (2-d) model built with ABAQUS V6-10 together with a user-defined subroutine

[1] Lina Zhou, University of New Brunswick, 28 Dineen Drive, Fredericton, NB, Canada. Email: lina.zhou@unb.ca
[2] Ying-Hei Chui, University of New Brunswick, Canada
[3] Chun Ni, FPInnovations, Canada

that incorporates the Bouc-Wen-Barber-Wen (BWBN) hysteresis model was used to simulate the seismic performance of hybrid buildings with different stiffness and ductility properties of sub-systems and connections under a series of earthquake ground motions. The purpose of these analyses was to get a better understanding of the interaction between wood frame and stiff core and how the performance is influenced by the characteristics of sub-systems and connections.

2 DESIGN OF HYBRID BUILDING SYSTEM

The six-storey building was assumed to be located at Vancouver (City Hall), Canada with site class of D (stiff soil). The total building height of the structure was 16.8m above ground level with 2.8m for each storey. The floor area was about 696 m^2. Dead load of 0.7kPa, 1.3kPa and 0.5kPa were assigned respectively to roof, floor and partition walls of this building. The self-weight of reinforced masonry wall is ignored here as the value is relatively small compared to the weight of wood building. The fundamental period and seismic force modification factor of the hybrid building system were estimated by a proposed approach that is based on the original values of the two sub-systems and their resistance ratio.

3 TWO-DIMENSTIONAL 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. Figure 1 shows the schematic of the 2-d modeling approach.

This 2-d model was implemented using the commercial software ABAQUS V6.10 together with a user developed subroutine developed by Xu and Dolan [2] that incorporates the Bouc-Wen-Barber-Wen (BWBN) model to describe the hysteretic elements of the building. 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].

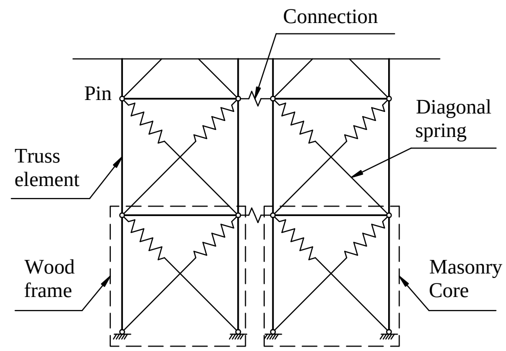

Figure 1: *Schematic of 2-d modelling approach*

4 TIME HISTORY ANALYSIS

Ten earthquake ground motions were obtained from PEER Ground Motion Database [4] with specified magnitude range of 6.5 - 7.6 and the average shear wave velocity within top 30 m of V_{s30}=180 – 360 m/s which meets the site class D assumption. Each of the ground motions was normalized with its peak ground velocity and then scaled to a specific level on which the average response acceleration of the 10 ground motions equal to the design value of the target response spectrum at the fundamental period of the interested building system.

5 CONCLUSIONS

The proposed approches can potentially be used to estimate system seismic force modification factor and fundamental period of the hybrid building for design purposes. Attaching the wood frame structrue to a stiff core can significiently reduce the building defletion under lateral loads.

ACKNOWLEDGEMENT

Funding of this project is provided by NSERC Strategic Research Network on Innovative Wood Products and Building Systems (NEWBuildS).

REFERENCES

[1] NRC: National Building Code of Canada 2010. National Research Council (NRC), Ottawa, Canada, 2010.
[2] J. Xu and J. D. Dolan: Development of a wood-frame shear wall model in ABAQUS. J. Struct. Eng., 135(8): 977-984, 2009.
[3] J. Xu: Development of a general dynamic hysteretic light-frame structure model and study on the torsional behavior of open-front light-frame structures. PhD dissertation, Washington State Univ., Pullman, WA, 2006.
[4] PEERC: PEER Ground Motion Database. Pacific Earthquake Engineering Research Center, <http://peer.berkeley.edu/peer_ground_motion_database> (Apr. 30, 2013).