NEWBuildS

Technical Note 3

July 2013

DIAPHRAGM STIFFNESS IN WOOD-FRAME CONSTRUCTION

KEYWORDS: Light wood frame floor; Diaphragm stiffness

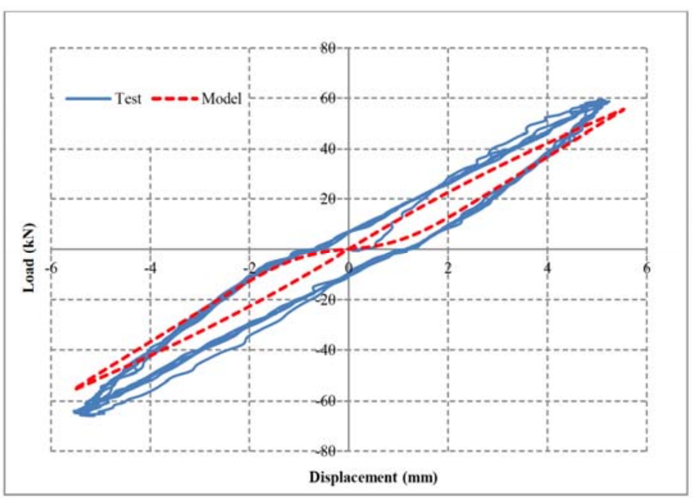
OVERVIEW OF PROJECT

The objective in this project was to study the in-plane stiffness of light wood-frame floors. The in-plane stiffness is an important factor in determining the distribution of forces onto shear walls for buildings subjected to lateral forces from wind or earthquakes. In engineering practice, wood-frame diaphragms are usually assumed to be flexible. This assumption greatly simplifies the calculation of forces, but its general validity has recently been drawn into question. Studying the actual flexibility of a wood-frame diaphragm is important because it can have a significant impact on the predicted force in each shear wall. If the force in a shear wall is underestimated, the wall may fail prematurely and cause unexpected structural damage and even loss of structural integrity.

The research approach adopted in this project involved the use of numerical models calibrated with test data. Detailed numerical models were built using a finite element program developed earlier at the University of British Columbia to study the in-plane behaviour of light wood-frame walls and floors. Existing full-scale diaphragm tests carried out at Virginia Tech were utilized to verify the models. The detailed numerical model simulates the nails that connect the plywood sheathing to the framing members. From a computational standpoint, this numerical model is prohibitively expensive for the analysis of an entire building. To solve this problem, i.e., to study the distribution of forces in an actual building, a simplified truss model was developed. The truss model simulates the floor diaphragm and the shear walls by means of braced truss panels. The axial stiffness of the diagonal truss members in each panel was calibrated against the above-mentioned detailed numerical model.

KEY RESULTS

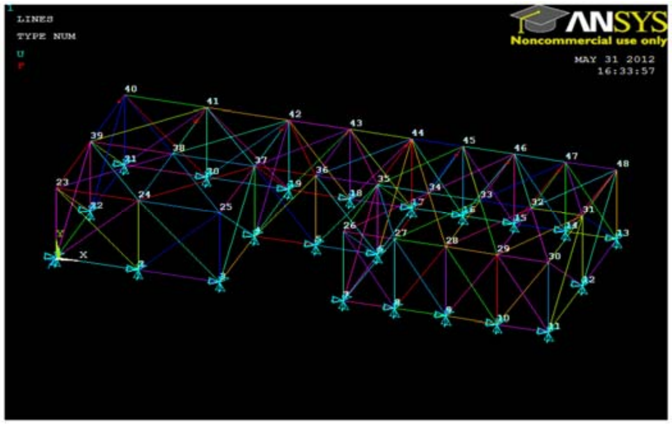
Selected results from this research project are presented below in the form of figures and associated comments.



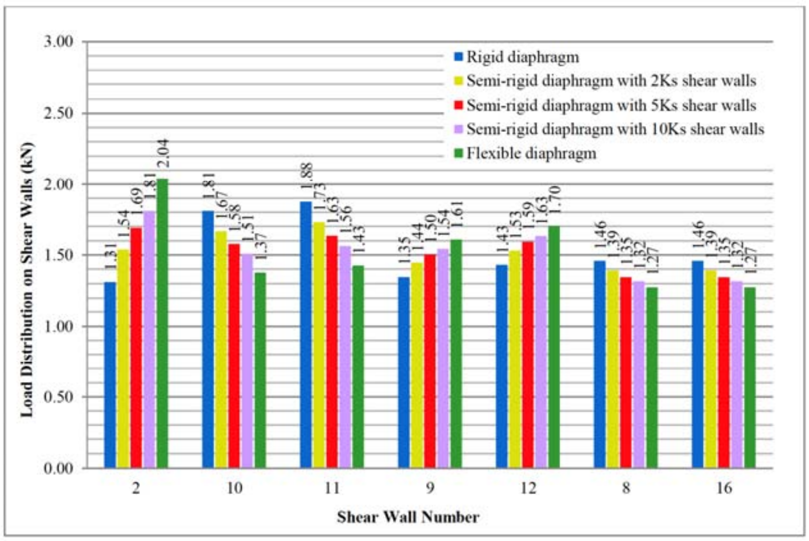
This figure shows test results (blue solid line) and calibrated results from the detailed numerical model (red dashed line) for one panel configuration. It is observed that the overall stiffness is quite similar in the model and the test specimen. The detailed numerical model contains finite elements for plywood and framing members, and parameters for the embedment properties of each nail that connects the plywood sheathing to the framing members. The embedment properties of each nail were calibrated with tests conducted in this project on small plywood specimens attached to small Douglas fir framing members.

Project code: T2-6-C3

Researchers: Xinlei Huang, Terie Haukaas and Frank Lam
Affliation: University of British Columbia
Contact email address: terje@civil.unb.ca



The results from the detailed numerical model were used to determine an average shear modulus value, *G*, which in turn was employed to calibrate the axial stiffness, *EA*, of the members of the simplified truss model shown in this figure. This facilitated the analysis of shear wall forces in a large building. A variety of diaphragm and shear wall stiffness values were explored to seek an understanding of the influence of in-plane stiffness on the shear-wall-force distribution.



This figure shows results from an analysis performed on a one-storey building using the truss model described above. Each set of columns in the figure represents the forces in one shear wall. In other words, the figure shows from left to right the forces in Shear Wall Number 2, 10, 11, 9, 12, 8 and 16. For each wall, the forces obtained from the truss model are compared with a completely rigid diaphragm (blue column) and completely flexible diaphragm (green column). The columns in between (yellow, red and purple) show shear wall forces for different values of the shear wall stiffness. Conversely, the floor diaphragm stiffness is calibrated against the previously described detailed numerical model. Interestingly, the results show a gradual transition from being close to the rigid diaphragm assumption to being close to the flexible diaphragm assumption. In other words, the stiffness of the shear walls is as important for the force distribution as the stiffness of the floor diaphragm. In contrast, the base-case result with default wall and diaphragm stiffness showed results that were quite close to the rigid diaphragm assumption. In short, it was found that that the distribution of lateral loads to the shear walls is strongly dependent on the *relative* stiffness of the diaphragm and the shear walls. As a result, the diaphragm flexibility classification results in this study agreed well with the International Building Code (IBC) rule, which characterizes the diaphragm as flexible if its displacement is more than twice that of the shear walls. It was also found that neither the rigid nor the flexible diaphragm assumption could assure conservative load demands for the design of shear walls. In general, an awareness of both extremes is necessary to ensure a conservative design.

THESIS

Huang, X. 2013. Diaphragm stiffness in wood frame construction. MASc thesis. University of British Columbia, Vancouver, BC.