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SIMULATION OF THE LATERAL DRIFT OF MULTI-STOREY LIGHT WOOD FRAME BUILDINGS BASED ON A MODIFIED MACRO-ELEMENT MODEL

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ABSTRACT: Deflection calculation of shear wall in multi-storey wood buildings is one of the barriers for design of mid-rise buildings. In this paper, the deflection of mid-rise light wood frame buildings (LWFBs) is investigated by numerical simulation method. The deformation mechanism of the shear wall under lateral load was analysed, and based on this, a modified macro-element model that can predict the lateral and corresponding vertical deformation of shear wall was proposed. Through the finite element analysis of multi-storey LWFBs, the feasibility of using the macro-element model of shear wall to develop the FEM for multi-storey LWFBs will be assessed; the effect of the rotation of the shear wall on the upper-storey shear wall will also be determined; and the APEGBC procedure for estimating the lateral drift of mid-rise LWFBs will be evaluated.

KEYWORDS: Multi-storey structures, Lateral drift, Seismic response, Macro-element model, Finite element method.

1 INTRODUCTION

Timber is one of the most common and oldest structural materials. It was used to build tall structures centuries ago in Asia and Europe, such as Yingxian Wood Pagoda which was built in 1056 AD and is currently the highest standing wood pagoda in the world with nine storeys and a total height of 67.31 m. During the 20th century, however, timber has been used mostly in low-rise (four storeys or lower) residential buildings in Canada. Nowadays, increased emphasis on sustainable building designs and the emergence of new generation of engineered wood products and systems have led to renewed interest in using wood products beyond the current low-rise residential market. Coincide with a renewed interest in timber was the need to improve the wood structural design code and to remove barriers for use of timber in mid-rise construction.

Deflection calculations of wood shear wall in multi-storey wood buildings is one of the challenges for design of mid-rise buildings. The Canadian wood design standard, CSA O86 [1], introduced a calculation procedure for predicting the deflection of light wood shear walls. This calculation procedure however is only applicable to a single-storey shear wall. Based on the one-storey shear wall formula given in CSA O86, an analytical approach that takes into account the cumulative rational effect has been proposed in APEGBC [2] guidelines for predicting the lateral deflection of 6-storey light wood frame buildings (LWFBs). While this provides an interim solution, there is a need to confirm that the procedure is able to reasonably predict the deformation level of the buildings. The main objective of this paper is to investigate the deflection of mid-rise LWFBs by numerical simulation method.

2 DEFORMATION MECHANISM OF WOOD SHEAR WALLS

Under lateral load, shear walls behave in the same way as a deep cantilevered I-beam, where the sheathing acts as a web resisting the shear forces, while the chord members carry the axial forces that resist the applied bending moment [3]. Construction details such nailing schedule and hold-down connections affect the shear wall resistance. Therefore, the deflection equation consists of four components contributing to the shear wall deflection (Δ): deflection due to shear wall bending (Δ_b), sheathing shear (Δ_v), fastener slip (Δ_n), and anchorage deformation (Δ_s). In addition, rotations of shear wall are induced by the bending and anchorage deformation. Since the rotation has little effect on the lateral drift of low-rise LWFBs, it is

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usually ignored. However, in mid-rise LWFBs the influence of rotation on the cumulative lateral drift may be significant.

3 A MODIFIED MACRO-ELEMENT MODEL

So far, most of the existing models can only predict the lateral deformation of shear walls without rotation. In this study, a modified macro-element model that accounts for both the lateral deformation, Δ, and the rotation, θ, of shear wall was developed, as shown in Figure 1. The complete model is composed of three boundary framing members, one diagonal modified Bouc-Wen-Barber-Noori (BWBN) hysteretic spring, K_{SW}, and two vertical foundation springs, K_{BU}.

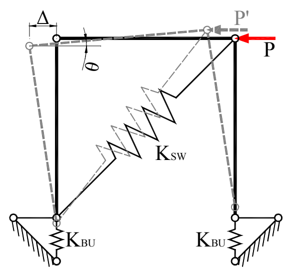

Figure 1: *A modified macro-element model for wood shear wall*

The modified BWBN hysteretic spring, which resists the lateral load and induces the corresponding lateral deformation of shear wall, was build as a UEL subroutine in ABAQUS/Standard [4]. The rotation induced by bending and anchorage deformation of the shear wall and the compression of top and bottom plates was simulated using a foundation spring that deforms vertically under the overturning induced by the lateral load, *P*.

4 LATERAL DRIFT OF MULTI-STOREY LWFBs UNDER EARTHQUAKES

To evaluate the proposed macro-element mode of shear wall and validate the APEGBC procedure for estimating the lateral drift of multi-storey LWFBs and investigate the effect of rotation of shear wall on the upper-storey shear walls, 4- and 6-storey buildings were designed to the NBCC [5] structural requirements applicable to Vancouver with stiff soil condition (Site Class D). Accordingly, three-dimensional finite element models were developed using the modified macro-element model to represent the shear wall and the CONNECTOR technique for the foundation spring (Figure 2) in the finite element software, ABAQUS [4].

The natural periods and seismic response of the multi-storey building models will be investigated by conducting frequency and non-linear time history analysis. The feasibility of using the macro-element model of shear wall to develop the FEM for multi-storey LWFBs will be assessed; the effect of the rotation of the shear wall on the upper-storey shear walls will be determined; and the APEGBC procedure for estimating the lateral drift of mid-rise LWFBs will be evaluated. Since the analysis is underway, results will be presented in the full length paper later.

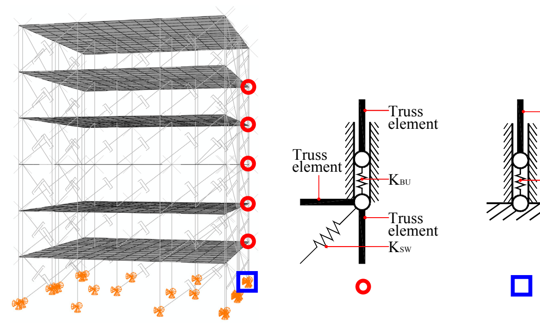

Figure 2: *FE model of 6-storey LWFB with Connector Technique for the Foundation Springs*

5 CONCLUSIONS

A modified macro-element model that estimates the lateral and corresponding vertical deformation of shear wall was developed in accordance with the deformation mechanism of the shear wall under lateral load. The influence of the rotation of the shear wall on the lateral drift of the mid-rise LWFBs will be investigated by conducting numerical simulation.

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