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EFFECT OF NON-STRUCTURAL COMPONENTS ON THE NATURAL PERIOD OF WOOD LIGHT-FRAME BUILDINGS

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ABSTRACT: This research deals with field testing of wood-framed and hybrid building structures with a view to establish a database of their essential dynamic characteristics, such as natural frequencies, mode shapes and structural damping. The main goal of this study is to investigate, through testing and modelling, the applicability of the simplified seismic demand calculation procedures of the National Building Code of Canada (NBCC) to wood frame structures, and suggest improvements where applicable. The research methodology initially involved a series of ambient vibration tests (AVT) conducted on wood-based buildings located in several regions of Canada. Modal properties were then extracted from the AVT records using frequency domain decomposition techniques, with the intent to improve the NBCC period formula for wood shear wall buildings. This paper presents ambient vibration field testing of a four-storey wood-framed building located in Ottawa, Canada.

KEYWORDS: Mid-rise wood buildings, Ambient vibration, Natural period, Lateral Stiffness

1 INTRODUCTION

Light frame wood buildings represent a typical construction type in North America for low-rise residential and commercial occupancies. The main types of structural components of wood-based buildings that resist lateral loads are horizontal diaphragms, vertical shear walls and roof (horizontal or inclined).

The maximum structural response values of velocity, displacement, and acceleration resulting from earthquake motion can be determined from earthquake response spectra using the fundamental natural frequency and damping ratio as input values. Therefore, it is critical that the natural period of a building be estimated with reasonable accuracy, so that realistic values of base shear exerted on the building be used in design.

This paper discusses a case study of a four-storey residential condominium building where the fundamental frequencies, mode shapes and damping ratios were investigated.

2 FUNDAMENTAL PERIOD (T_a)

The National Building Code of Canada (NBCC) provides an empirical expression for computing the fundamental sway period of wood shear walls in seismic design using ESFP:

$$T_a = 0.05 * h_n^{3/4} \tag{1}$$

where h_n is the building height in m above the base. It is seen that this expression is entirely reliant on the building height and therefore does not account for parameters such as structural lateral stiffness and mass of structural and non-structural components, which in reality are the factors that determine the fundamental period of a building structure. This empirical formula is based on data from several measured buildings (mostly concrete) in California, subjected to ground motion during seismic events such as the San Fernando and Northridge earthquakes. The general accuracy of this formula is questionable considering that it has not been calibrated to wood-framed buildings. Since more and taller (mid-rise) wood-based and hybrid buildings are being constructed in Canada, there is a need to investigate the Code formula and the engineering seismic design.

3 FEATURES OF TEST STRUCTURE

The selected test structure is located in downtown Ottawa

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(Canada) with the building front facing an arterial road. Wind and noise from surroundings (mostly traffic) induce micro tremors in the building, which can be recorded by AVT instruments deployed on building floors/roof. The structure is resting on a concrete foundation having an irregular shape with plan symmetry along y-axis (see Figure 1). The building has a footprint of 65.5 m X 33 m and total height of 12.7 m above ground level. Clear floor height is 2.77 m throughout. The wall system is made of Spruce-Pine-Fir (SPF) #1 grade. Most of the shear walls are oriented in the transverse short direction (y-axis) making the structure stiffer along this direction. Four shear walls are oriented diagonally that would also participate in the first mode response (see Figure 1).

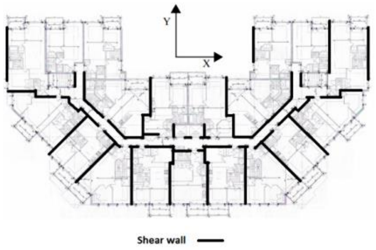

Figure 1: *Distribution of shear walls*

4 BUILDING STIFFNESS

The strength and stiffness of the structure are mainly dependent on the characteristics of the structural components and their connections, such as shear walls nail-slip characteristics between the sheathing panels and framing elements, anchorage deformation, bending deformation of the studs and in-plane deformation of the sheathing panels. The stiffening effect of the "non-structural" components is significantly higher in light frame wood structures than in structures made of other materials such as masonry, concrete, and steel due to the relative low weight and stiffness of the wood shear walls compared to that of non-structural finish materials.

5 EXTRACTION OF MODAL PROPERTIES

The dynamic properties of the structure are extracted from the recorded signals using Enhanced Frequency Domain Decomposition (EFDD) [1]. The records measured at different sensor locations are analysed together to estimate the natural frequencies through the decomposition of spectral density matrices into singular values function lines (see Figure 2), which are similar to typical frequency spectra. The EFDD technique is an improvement of FDD where, a single degree of freedom (SDOF) bell shape function is created and modal parameters are estimated using a range of frequencies in the neighbourhood of the picked point (SDOF spectral bell). The frequency range of the analysis was limited to the seismic response range of interest (0-20Hz) to reduce the noise effect and to accelerate data processing. By picking the highest and closely-spaced peaks of EFDD functions, the natural frequencies and corresponding mode shapes of the tested buildings were obtained. The set of mode shapes and frequencies most representative of the seismic response of the structure were then chosen.

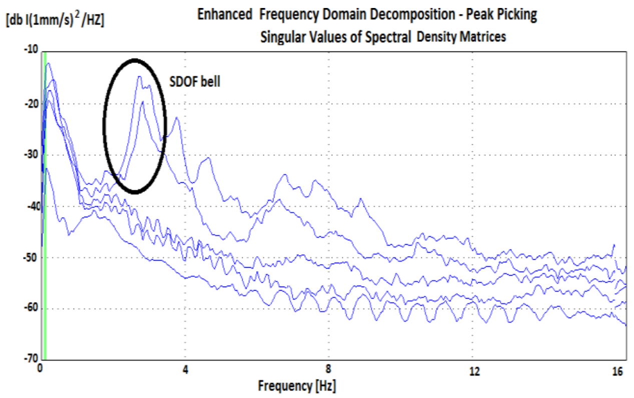

Figure 2: *SDOF Bell in EFDD - Peak Picking*

6 RESULTS AND CONCLUSIONS

Table 1 shows the fundamental sway mode frequencies and damping ratios obtained in ambient condition for the test structure in the longitudinal (x-axis) and transverse (y-axis) directions. It can be seen that the frequencies in Phase 2 (complete building) are significantly higher in both directions than those obtained in Phase 1, indicating that the non-structural components have a significant effect in stiffening the structure.

Table 1: *Frequency estimation by EFDD*

Construction Stage	Frequency (Hz)		Damping Ratio (%)	
	X-axis	Y-axis	X-axis	Y-axis
Phase 1	2.7	2.9	2.2	4.6
Phase 2	4.3	4.0	3.7	3.1

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