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DYNAMIC PROPERTIES OF TALL MASS TIMBER BUILDINGS UNDER WIND-INDUCED VIBRATION

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Due to the lightweight nature of wood construction, wind-excitation induces vibration with larger amplitude when compared to buildings built with heavier materials such as steel and concrete [1]. Excessive vibration of buildings can cause occupants discomfort as well as damage to finish materials, services and equipment in the building. These kinds of vibrations are not safety-related issues but may affect market acceptance of mid- to high-rise wood buildings. The design method provided in the National Building Code of Canada (NBC) requires the natural frequencies and damping ratios as input parameters. However, there are little data available for mid- to high-rise wood buildings.

Therefore, FPInnovations launched a multi-year research project to measure mid- to high-rise wood buildings' natural frequencies and damping ratios to expand the database and validate or adapt the existing equations to estimate the natural frequencies. Two high-rise wood buildings equipped with an anemometer and accelerometers are also being constantly monitored to study how the wind excites the building.

Objective

In an attempt to improve the understanding of tall mass timber buildings, the natural frequencies and the damping ratios of some mid- to high-rise mass timber buildings will be measured. The measured natural frequencies will be compared with the simple equation given in Subsection 4.1.8 of the NBC for predicting the fundamental lateral period of vibration for shear walls and other structures. Short- and long-term monitoring measurements will be performed to monitor how tall timber buildings behave under wind load.

What Is the Damping Ratio?

The damping ratio, ζ, is a critical variable that an engineer needs to know when designing a structure for dynamic loads (e.g. earthquake and wind loads). A greater damping ratio results in lower building movement and thus reduces the risk of perceptible movement from the occupants. Figure 1 shows graphically how a free oscillation decays as a function of the damping ratio.

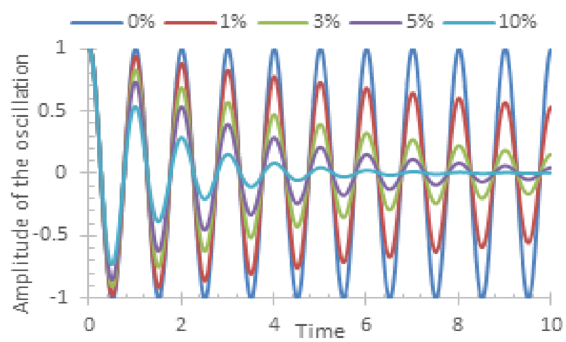

Figure 1. Decay of a free oscillation for different damping ratios

Methods

The natural frequencies of building and the damping ratio are measured from ambient vibration test (AVT) methods that are performed in a single day of measurement. This allows to measure several buildings. The AVT method uses the ambient load, as the heavy traffic and the wind as the excitation of the building. Consequently, no special device is needed to create artificial load. Figure 2 shows an AVT measurement on the Origine building being performed.

In an attempt to better understand how tall timber buildings behave under wind load, two buildings are constantly monitored: Arbora in Montreal and Origine in Quebec City. There are accelerometers and anemometers located at the top of the buildings and accelerometers located at their ground level.

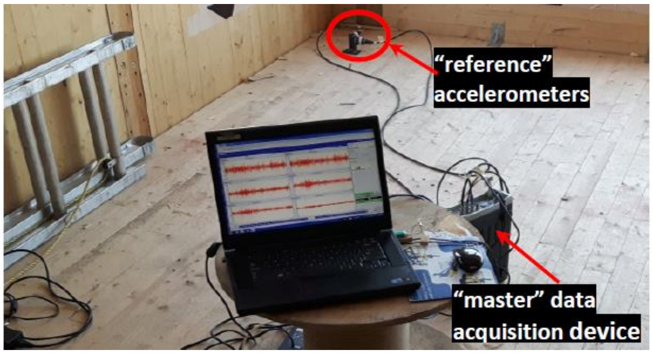

Figure 2. AVT measurement being performed at the Origine building in Quebec City

Results of AVT

A strong correlation can be observed between the simple equation of the NBCC to predict the fundamental natural frequency and the measured natural frequency, except for the CSN building (Figure 3). The CSN building was however the first contemporary tall mass timber building built in Canada. Conservative hypotheses were therefore employed which can explain this difference.

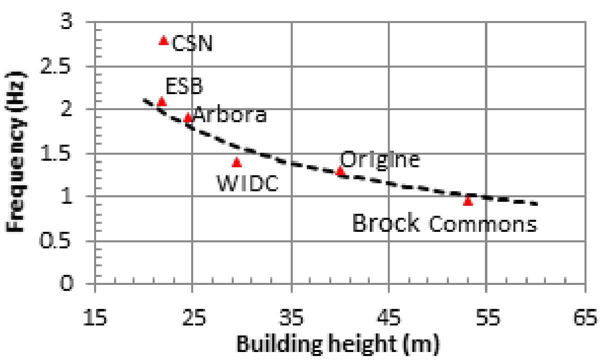

Figure 3. Results of AVT in comparison of the NBCC equation

Preliminary Results of Monitoring

A tendency between the measured peak acceleration and the wind velocity can also be observed (Figure 4). Moreover, the peak acceleration never exceeded the maximum peak acceleration stated in the NBCC. A preliminary damping ratio of 2.5% has been extracted with a time-varying filter empirical mode decomposition (TVF-EMD) algorithm (Figure 5) which is in the expected range for this type of tall timber buildings.

Next Steps

Computational fluid dynamic and wind-tunnel testing will be performed on the monitored buildings. The damping ratio will be extracted for different wind velocity to propose a damping ratio for future tall mass timber buildings to be build. Some design principles for when wind-tunnel testing is necessary for tall mass timber buildings will also be defined.

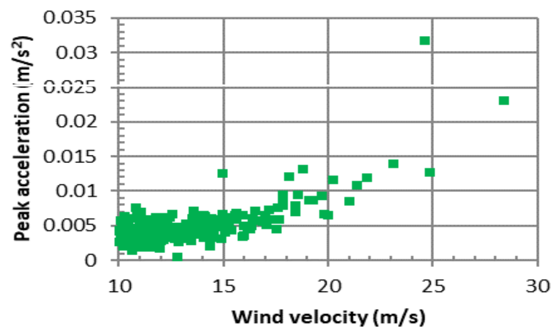

Figure 4. Peak acceleration response measured for different wind velocity for the Arbora building in Montreal

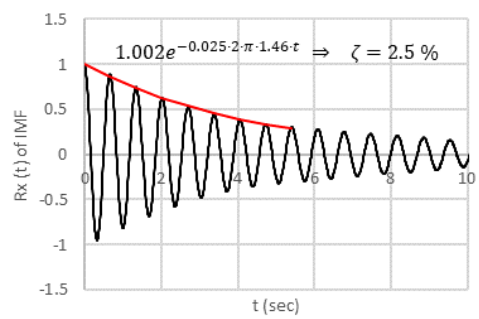

Figure 5. Extraction of the damping ratio with autocorrelation function from the TVF-EMD algorithm

References

[1] M. Johansson, A. Linderholt, Å. Bolmsvik, K. Jarnerö, J. Olsson and T. Reynolds, *Building higher with light-weight timber structures – the effect of wind induced vibration*, in Inter.noise, San Francisco, California, 2015

[2] Cuerrier Auclair, S., 2020. *Expanding wood use towards 2025:Assessment and monitoring of high-rise timber building vibration*. FPInnovations preliminary report, Natural Resources Canada. Quebec, Quebec

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