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CHANGES IN EIGENFREQUENCIES OF CLT ELEMENTS DUE TO A VARIATION OF AMBIENT CONDITIONS

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ABSTRACT

Wood is widely used in the construction sector and gaining increased market share. It is interacting with the surrounding so that its mechanical and geometrical properties (stiffness, strength, swelling, density, …) change with temperature and humidity levels. In a full-scale building, the eigenfrequencies are hence also varying with the climate. In the current paper, results from a preliminary experimental study are presented. A beam made from cross-laminated timber was hanging freely supported inside a climate chamber. Enforced vibrations from a controlled shaker were taken to obtain the eigenfrequencies. With decreasing moisture content, the first and third eigenfrequencies were increasing (bending modes) while the second eigenfrequency was decreasing (torsional mode). A finite element study allowed for checking which parameters is influencing to which degree so that individual changes can be combined.

Keywords: wood, CLT, forced excitations, eigenmodes, controlled climate, stiffness, density.

INTRODUCTION

Timber has been used as a construction material for a very long time. In the last couple of years, its market share is quickly increasing, partly since it is considered a more sustainable alternative to steel and concrete. A booster was the introduction of cross laminated timber (CLT) whereby large elements are produced with a high degree of accuracy prefabrication. CLT is uses for wall and slab elements in apartment buildings and offices but also for, e.g., schools.

With the use of CLT and other engineered wood products (such as glulam or laminated veneer lumber), some of the drawbacks of sawn timber in the construction sector have overcome, far larger dimensions are possible, a high predictability of the material quality is possible as well as an increased form stability is achieved. Still, being a material sourced from nature and with its highly structured internal structure, wood is strongly interacting with the surroundings more than other building materials. Particularly moisture content is influencing basically all mechanical parameters, such as stiffness and strength but also density. Additionally, swelling occurs with increased moisture content.

INFLUENCE OF MOISTURE ON DYNAMIC PROPERTIES

In a recent study [1], a 4-story office building was analysed with respect to the dynamic properties throughout the first four years after construction. A monitoring system was included so that the changes in eigenmodes and -frequencies could be correlated to the moisture content (MC) in the CLT slabs. It was found that the frequencies were lower when the CLT was driest (during winter) and were higher when the CLT became moister (during summer).

The equation for calculation of the natural frequency for a single degree of freedom (SDOF) system is given in Equation 1, with the stiffness k and the mass m:

$$f_n = \frac{1}{\pi}\sqrt{\frac{k}{m}} \tag{1}$$

In a simplified evaluation, a higher moisture content in the structure means higher mass, and hence a lowered frequency. Additionally, a higher MC goes long with a decrease in stiffness of wood – which should also lead to a reduced frequency. In the analysis of the mentioned building, though, both phenomena are not found. Nevertheless, also other factors can be thought of which depend on moisture content and have an influence on the overall structural performance of a structure, e.g., connections, internal cracks, or swelling, see also [2].

To study some of the phenomena on a much smaller case, a CLT plate (with three layers of 40 mm each) of dimensions 4.0 m x 0.50 m x 0.12 m was put into a climate chamber. The free-hanging plate was excited by a shaker under controlled conditions four times a day during summer 2022. At the same time, relative humidity in the climate chamber was lowered to around 30 %RH at a constant temperature of 20 °C. Figure 1 shows three weeks of dry-out and the humidity reading of sensors in the CLT plate at different positions and depths. During the same time, the first three eigenfrequencies were also determined, see Figure 2 for the variation.

Fig. 1 – Changes of humidity in the different positions in the CLT at three different depths.

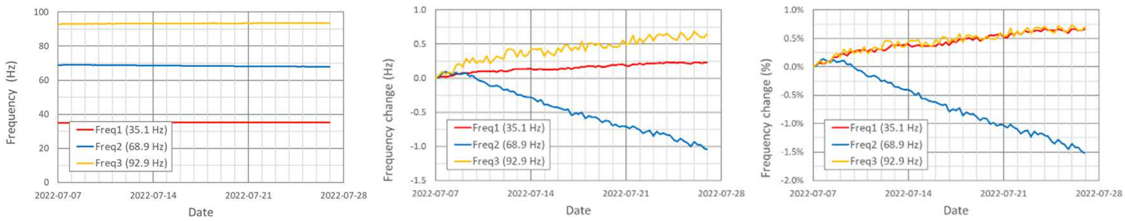

Fig. 2 – Changes of the first three eigenfrequencies; numbers in brackets are the frequencies at the start of the dry-out period.

RESULTS AND CONCLUSIONS

The study showed that changes in moisture influence the eigenfrequencies, depending on the mode differently though: eigenmode 1 and 3 were identified as bending modes with increasing frequency during dry-out; for eigenmode 2, though, a torsional mode, frequency decreased during the same time – a negative correlation. The experiments will continue in combination with a FEM analysis so that some parameters and correlations/causations will be identified in more detail.

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