WIN-DUCED MOTIONS OF “TREET” - A 14-STOREY TIMBER RESIDENTIAL BUILDING IN NORWAY

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ABSTRACT: This paper deals with the comfort properties in a planned 14-storey timber apartment building in Bergen, Norway. The building will be one of the tallest timber buildings in the world. The building consists of load-carrying glulam trusses with two intermediate strengthened levels. The truss carries prefabricated building modules. Herein, the evaluation with respect to dynamic behaviour of the building is described with emphasis on the horizontal acceleration due to wind forces.

KEYWORDS: Multi-storey buildings, comfort criteria, wind, vibration

1 INTRODUCTION

“Treet” is a 14-storey timber apartment building that is likely to be built in the Norwegian city of Bergen in 2014. At present it seems to become the tallest building in the world of its kind. It consists of a glulam timber frame with stacked prefabricated building modules. More on the design can be found in [5]. The building owner is BOB, Bergen og Omegn Boligbyggelag, a Norwegian housing association. The glulam will be delivered by Moelven Limtre AS and the modules by Kodumaja. The architect for the project is Artec. SWECO Norway is responsible for the technical design.

“Treet” is a relatively high building with low structural weight. Its natural frequencies lie in the domain where wind can cause annoying motions or nausea. The stiffness and mass properties for glulam and concrete are well known, but poorly described for complex, complete building modules. To get better knowledge of dynamic behaviour of the prefabricated building modules, testing was needed. Based on the structural design and the module testing a FEM analysis model was generated in order to calculate the building’s natural frequencies and modal mass. These parameters were used to determine the wind-induced accelerations of “Treet”.

2 DESIGN CRITERIA


3 MODULE TESTING

Due to the lack of information regarding the dynamic behaviour of building modules, Sweco contacted the Norwegian University of Science and Technology, NTNU, for non-destructive testing of modules delivered by Kodumaja. The tested modules were very similar to the modules that are planned to be used in “Treet”. Both single and stacked modules were tested. The test is described in the report [4]. Based on the test results a simplified FEM-model of a module was made. The module’s walls were represented by using vertical beam-elements with braces. For the module’s floor and ceiling we used shell-elements. The mass distribution of the module was added to the shell-elements, see Figure 1 for visualization.

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Figure 1: Simplified FEM-model of a building module
4 FEM-ANALYSIS

"Treet" consists of a vertical timber truss work that carries two intermediate platforms, denoted “power storey”. The "power storey" consists of a timber truss work carrying a concrete slab. The slab creates the foundation for 4 storeys of modules. One storey of residential modules is also placed inside the power storey. Four additional storeys are placed on the slab above the basement. The modules are only connected to load carrying structure at the concrete slabs. To analyze the dynamic behaviour of the building a FEM-model was made using Robot Structural Analysis Professional 2013. The global model is shown in Figure 2.

5 RESULTS

The module testing showed that the stack of four modules had much higher natural frequencies than the global response of the building. Therefore it was decided to avoid further connections than between the modules and the slab. A concrete slab was added to the top level of the building in order to interconnect the different truss-works, but also to add more weight to the structure. This gave the building higher modal masses and decreased the accelerations. Figure 3 shows the two first natural frequencies of the building.

The module test showed that stacked modules had a damping of approximately 3 %. The modules are so much stiffer than the whole building that their damping is of minor significance to the overall behaviour. A damping of 1.9 % was chosen based on [1].

The modal masses were found using the global FEM-model. The peak accelerations for mode 1 and 2 were calculated based on annex C in [1]. Figure 4 shows the calculated wind-induced peak acceleration at the top-floor for wind with one-year return period. The accelerations are plotted with red dots into Figure D.1 in [2].

6 CONCLUSION

The calculated maximum acceleration for "Treet" for mode 2 is slightly higher than the recommended values, but this is considered to be acceptable. In reference [3] the acceleration limit for nausea is given to be above 0.1 g. Based on this some of the residents in the top floors might in rare cases feel vibrations, but it is very unlikely that they will become uncomfortable. The chosen structural solution for "Treet" using glulam truss works and stacked prefabricated building modules gives a robust design and most probably insignificant effects from vibrations caused by wind exposure.

REFERENCES


Figure 2: Global FEM-model of "Treet"

Figure 3: Mode 1 East-West and mode 2 North-South

Figure 4: Peak accelerations