

Modular element system in high-rise wooden buildings: challenges, advantages and perspective

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1. Modular construction from the Baltic perspective

Modular building elements produced off-site by using an industrialized process and controlled environmental conditions ensure precision, reduction of waste, high quality and shorter construction time. Modular construction allows the buildings to be re-used rather than demolished. Modular construction way could be used in especially re-enforced modular shelters, which meet challenges of global climate changes, affordable housing solutions or LEGO-like housing and/or high-tech based modular office-buildings which international corporations like Google are looking for [1-7]. However, a background for any breakthrough is created by massive production of modules for multi-story apartments.

History of the modular construction in Baltic states started as kind of relocation of workplaces from the booming Scandinavian construction industry to economically more efficient region. However, you can recognize that there is another trend where innovative characteristic of the modular construction comes to the first place.

In Lithuania, Latvia and Estonia, it is possible to find a bunch of factories producing various, mainly timber-frame, modules for up to 5 floors high apartment houses with full inside finishing and engineering devices. Number of modules they are producing differs from 5.000 to 75.000 m² of living area yearly.

Timber design LT works with the biggest of these factories across the Baltic States. It is now calculated more than 120.000 m² of total area reference projects of multi-story apartment houses in Scandinavia completed by Timber design LT.

Accumulated experience in timber-frame modular construction empowered us to work with engineered wood based structures, firstly, CLT (cross laminated timber). CLT is used for various side structures of timber-frame modular buildings like balconies, galleries, lifts and staircase shafts. Growing confidence in the market towards modular construction is also raising demand on modular structures suitable for higher than 5 floors buildings. From the structural perspective, CLT is one of the best solutions. However, extensive usage of wood challenges to find out the most efficient method to optimize the structure. Thus, this leads us to semi-modular solutions, where beside main structure of CLT based modules, some prefab wall elements are used to optimize the usage of these materials and logistical solutions.

Let us examine this approach in more detail on the base of MOXY hotels. Vastint Hospitality with Marriott International new MOXY hotel brand now is implementing a program to build 50 MOXY hotels based on semi-modular structure of CLT across the Europe in 5 years. Working on some of these projects we could analyse in more detail the solutions which are applied here.

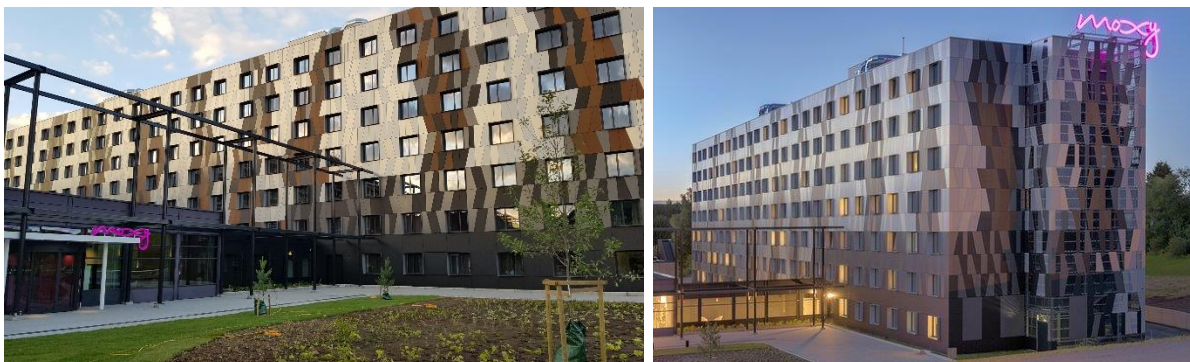


Figure 1: Hotel MOXY Oslo X, 2017

2. Modular elements system

The modular hotel concept was developed by Vastint Hospitality. For engineering solutions Wood Beton S.p.A, Italy was engaged.

The building is formed of many standardized volumetric and planar CLT elements. The main elements are prefabricated, box-like modules, prefabricated panels, and prefabricated slabs. Each module comprises a bathroom and a service area. The modules are aligned horizontally and vertically to extend the multi-resident building. There are two general panels, the first of them form inner wall and second one form outer wall. The slabs are to form floors and rooms of box-like, panel-built rooms. The length of slab equals half of the length of a module. The building method is performed by extending the module arrays in different directions at the same time while the panels and slabs are connected to the modules as they are connected to the arrays [8]. The general structural spatial scheme and possible floor layouts are shown in Figure 2.

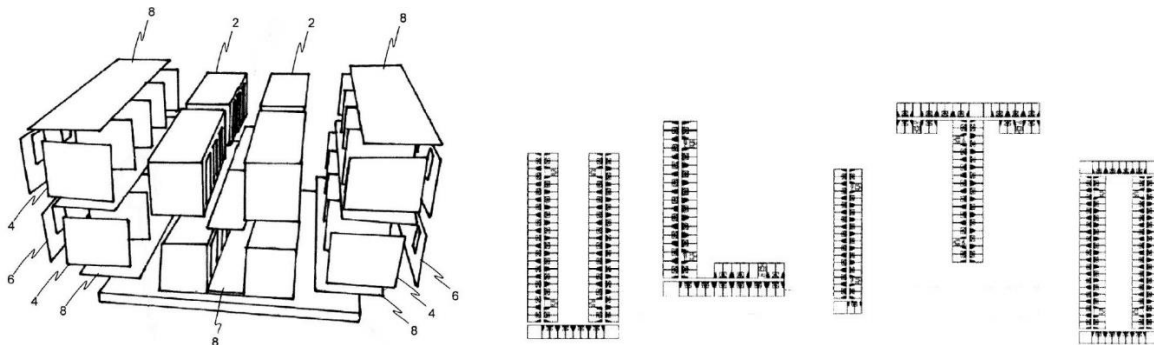


Figure 2: Hotel MOXY principal structural scheme (left) and possible floor layouts (right) [5]. 2) module (webox); 4) and 6) façade panel; 8) slab panel (room and corridor)

The external dimensions of the modules and panels have to fit to the standard size of trucks in order transportation and distribution be optimized to keep the cost low. According the primary concept, the maximum number of floors is 6.

In 2015, Timber design LT took part in structural design of Hotel Moxy X Oslo (Fig. 1) as a subcontractor for design works of the wooden part of the building.

3. Structural design

Despite the concept developed for all Europe, a building each time has to be adjusted to the local circumstances and standards; this means that the statics of the building should be performed each time in accordance with country's national standards. The same was done for Moxy X Oslo. Even more, while the concept covered only 6 floor high modular building, more efforts were required for the structure which was 7 floors high (Fig. 3).

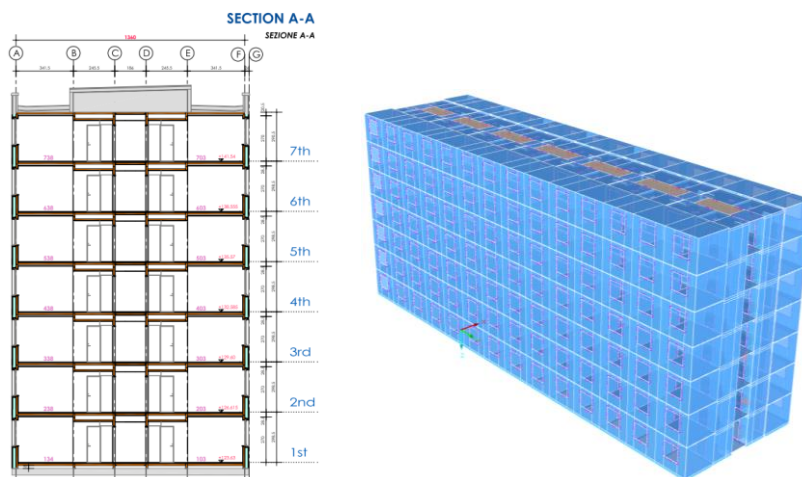


Figure 3: Hotel MOXY Oslo X: principal section (left) and FE model (right)

3.1. Challenges, advantages and perspective

Design of modular wooden buildings is always time consuming and knowledge requiring procedure. While there is no unified or standardised design procedure, the structural engineer must always be confident in his own experience and in the assumptions made by him or her. While the cross-laminated timber itself is quite a new building material, the volumetric modules of CLT are more recent way of construction. All this together creates an issue for the engineer.

During the design procedure, following tasks were solved: distribution of vertical and horizontal forces within a structure, in normal and accidental design situations of fire and earthquake respectively, distribution of loads onto foundation and to the adjacent concrete structure, implementation of finite element method into design, box-like effect of the modules on the global stiffness and distribution of internal forces, local and global stability of the elements and the building itself. The performed numeric and analytic analysis showed that the system where load-bearing CLT elements are 9 and 10 cm thick only can be used for 7 floors tall building. The CLT itself can take even more loads from extra storeys but the connections to foundation and connections between the CLT elements have to be observed.

This structural system could be used for similar types of buildings like student apartments, hospital or other condominiums.

4. References

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