Use of Prefabrication in Staircase Solutions in Multi-storey Apartment Blocks Based on Wooden Structures

IOP Conf. Series: Materials Science and Engineering **603** (2019) 022015 doi:10.1088/1757-899X/603/2/022015

Use of Prefabrication in Staircase Solutions in Multi-storey Apartment Blocks Based on Wooden Structures

Barbora Kovarova [1]

[1] Brno University of Technology, Institute of Technology, Mechanization and Construction Management, Veveří 95, 602 00 Brno, Czech Republic

kovarova.b@fce.vutbr.cz

Abstract. Structural design of the staircase is a separate issue in the design and realization of residential buildings. The design needs to be addressed in terms of static, fire safety, layout requirements and in the case of wood-based apartment buildings, also in terms of acoustics. The paper deals with the design of the staircase in terms of all the above mentioned factors. In addressing this issue, emphasis is placed not only on the design of the staircase, but also on the construction itself. The author of the solution focused precisely on the area of the prefabrication in the construction solution. The staircase is designed as a separate space cell, which is produced as part of the pre-production preparation of the building, and is then installed as a finished product. This issue is addressed within the MPO TRIO FV10075 "New technology multi-storey energy efficient buildings made of glued sandwich panels with the possibility of foundation based ground screws using the technology of prefabricated housing units" project and the staircase solution is an integral part of this project.

1. Introduction

Recently timber construction is becoming increasingly important in the construction market. Wooden constructions are constructions, whose horizontal as well as vertical support structures are elements on material-based wood. Wood is a renewable material with the best ecological balance, has excellent thermal insulation properties, creates a pleasant environment and it works well on human psyche. However, wooden buildings are not new; the biggest development was already recorded in the 14th century. Gradually, the wood was replaced by other materials, especially for construction effort and, at that time, little developed technology and machinery for manufactory. Due to increasing demands for speed and accuracy of construction, the timber is once again the leading building material. The construction of the wooden building is very fast and can be built during the whole year. During the construction of the wooden building, only a few construction waste is produced, which has to be landfilled. Due to low weight wooden elements can be used prefabrication to move part of the construction from construction site to precision manufacturing plants. [1] With timber structures, prefabrication can take the form of planar prefabrication, spatial prefabrication, or a combination of the two.

Planar prefabricated sections are delivered to the construction site in the form of variously completed panels. These are used as vertical and horizontal supporting structures, as well as inclined supporting structures (sloping roofs). There are panels with a wooden frame, structural insulated panels (SIPs) and layered all-wood panels.

In comparison with planar prefabrication, spatial prefabrication represents a higher level of sophistication. Spatial prefabricated units mainly consist of panel elements that are connected to form completed functional units. The creation of the resultant rooms as 3D units (3D prefabricated sections) in a factory allows them to be delivered to the construction site in as complete a state as possible, meaning that surface finishes and fixtures are already in place. However, prefabrication also has its disadvantages. Increased prefabricated unit dimensions translate into a rapid decrease in the simplicity of transport and handling at the production plant as well as transport both to and at the place of final assembly. The dimensions of spatial prefabricated units need to be kept at a level which does not necessitate their categorization as oversize loads for transportation purposes with regard to both their size and weight, i.e. the equipment required to handle such units at the construction site must be considered. The limits mentioned above were optimized for the production of SIPs. [2]

2. Wooden constructions in the construction of houses and apartment buildings

Wooden buildings are currently more widespread in the market of family houses. Development of wooden buildings on the market of apartment buildings is slower. This is mainly due to different - increased requirements for construction of apartment buildings compared to family houses. While the static requirement - mechanical resistance and stability - is for both types of buildings the same, the differences are in particular requirements for fire resistance and in acoustic requirements.

While by family house it is about one fire section, situation by apartment building is more complex. Apartment building based on wooden construction is in terms of Czech project standards limited by fire height 9 m, because it is flammable structural system. [3] Residential building is according to ČSN 73 0802 non-production object, further it must meet the requirements of the ČSN 73 0833 Building Fire Safety - Housing Buildings and accommodation (it is building of group OB2). In individual flats it is necessary to consider computational fire load p_v = 40 or 45 kgm^{-2}, which is the highest value in object used only for purposes of living. Other areas report the same fire risk (cellars) or lower (corridors, prams). For this highest risk, the characteristics of the fire compartments are determined - the degree of fire safety, and it is SP IV or SP V. The fire resistance of the carriers is required for these fire safety levels - fire separating structures 60 minutes in ordinary floor and 30 minutes in last floor at SP IV, respectively 90 minutes in ordinary floor and 45 minutes in last floor at SP V.

Same as it is in case of fire resistance requirements it is in acoustics requirements for residential houses comparing to family houses. As well as for walls separating two separate units (flats) are more stringent requirements for ceiling and staircase construction. Just for buildings based on laminated panels is very difficult to find a structure of construction meeting the requirements of the Czech standard ČSN 73 0532 Acoustics - Noise Protection in buildings and assessment of acoustic properties of construction products - Requirements. [4]

Table 1. Requirements for sound insulation between rooms in buildings (ČSN 73 0532)

Protected Area (Sound Reception Room)					
Line	**Noisy Space** (Sound Source Room)	**Sound insulation requirements**			
		Ceilings		**Walls**	**Doors**
		$\mathbf{R'_w}$, $\mathbf{D_{nT,w}}$ [dB]	$\mathbf{L'_{n,w}}$, $\mathbf{L'_{nT,w}}$ [dB]	$\mathbf{R'_w}$, $\mathbf{D_{nT,w}}$ [dB]	$\mathbf{R_w}$ [dB]
B. Apartment buildings - living rooms of apartments					
2	All rooms of second apartments, including accessories	**53**	**55**	53	-

3. Staircase in wooden buildings of apartment buildings

Based on of the above-mentioned limits of residential buildings, the following requirements can be defined for staircases as an integral and very important part of a residential building:

- Self-supporting,
- separated from surrounding structures with regard to acoustic bridges,
- possibility of placement inside disposition as well as outside the facility ,
- possibility of using the structure for the elevator shaft (especially in the future after removal of the object's height restriction),
- possibility of prefabrication (flat or spatial),
- variability of solution,
- fire resistance,
- easy adaptation to changing dimensions.

The supporting structure of the staircase, to meet the above requirements, is designed for wooden elements as a staircase based on wooden staircase and riser. Mezzanine level is designed as wooden, from structural pint of view, it is analogy to the ceiling structure – the beam ceiling. The staircase must meet requirements mentioned above. Therefore it is not dealt separately. A solution to such staircase is shown in figure 1.

The above described staircase solution for a residential building can be prepared as a prefabricated structure. It could be prefabricated elements, as above, in the form of walls with prepared staircases, as well as prefabricated 3D elements over half a floor. [5]

Based on the above assumptions and boundary requirements there was prepared the staircase for the experimental object. This was done for testing purposes, especially acoustic properties. The building was implemented in research project of the Ministry of Industry and Trade FV10075 "New multi-storey energy-efficient building technology from glued sandwich panels with the ability to be grounded on earth crusts with using the technology of prefabricated sanitary units." The building is made as a two-storey building, grounded on earth crusts. The vertical supporting structures are made of SIPs panels, horizontal structures were alternatively (for measurement purposes) made on the basis of wooden beam ceiling with different pieces. The trial - experimental object was created especially for to test laboratory measurements on a real object, especially in relation to acoustic requirements. The solution of the experimental object is in figure 2.

Measurement results in the experimental object was taken as a starting point for subsequent work on "Stair cell." Based on these results, the combination of a planar and spatial prefabrication looks as the best solution. The spatial prefabrication will cover the staircase over half the structural height of the floor as one prefabricated element, followed by the solution of the related construction.

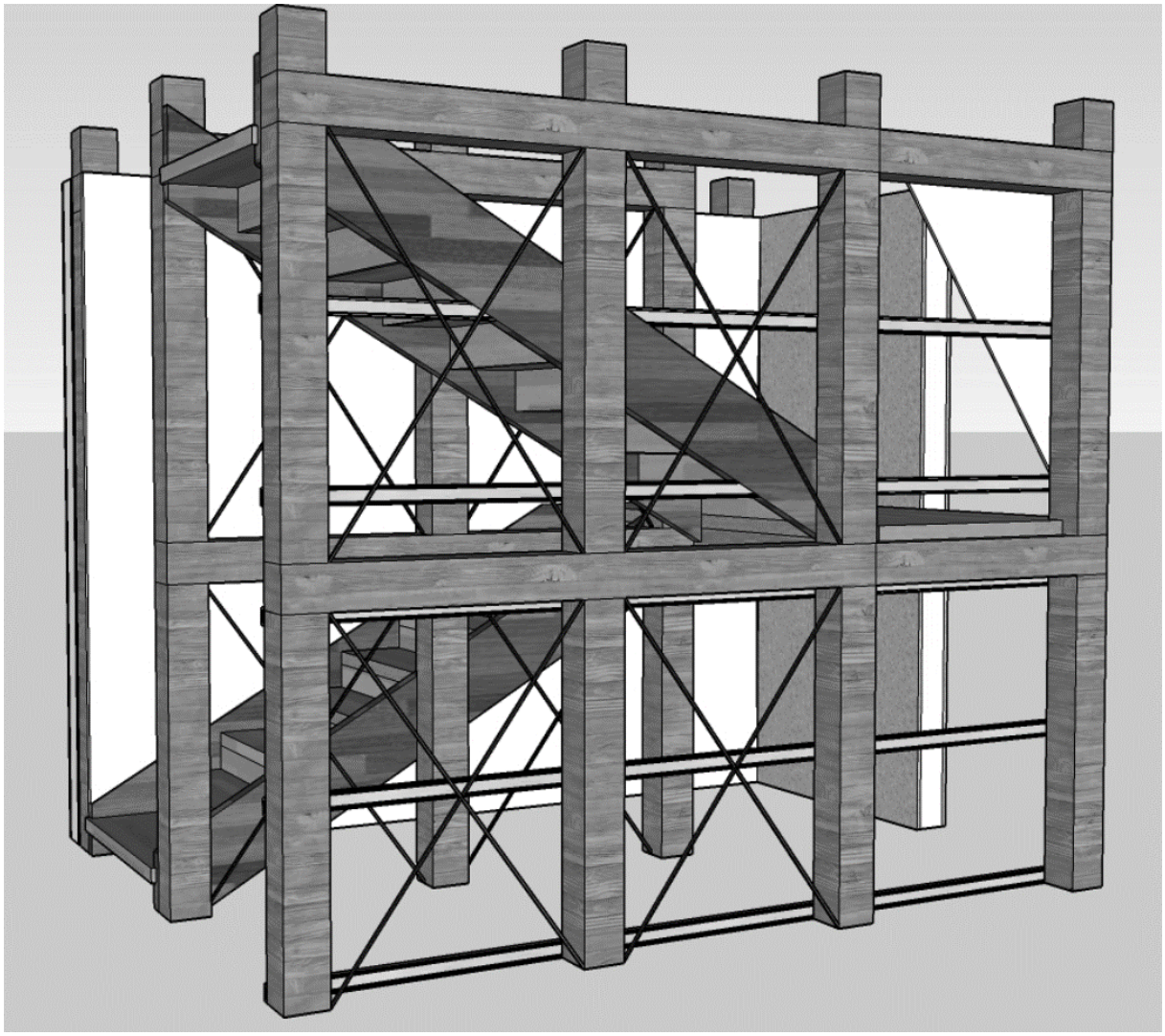

Figure 1. Visualization of staircase

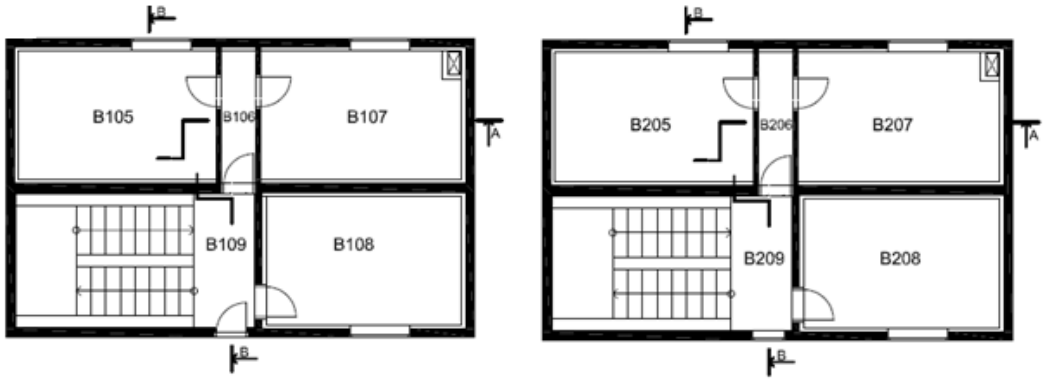

Figure 2. Ground plan of the experimental object

4. Conclusion

The proposed solution meets the initial conditions according to the currently valid legislation, but it is prepared to be responded to its possible changes, in particular the change in the height limitation of the building (see above "possibility of use for the elevator shaft").

Detailed solution of the spatial stair cell is the part of the research project of MPO FV10075, see above, and therefore, the individual dimensions of the stair elements, respectively the entire spatial cell may be published after finishing the project and his final scientific defence.

References

[1] B. Kovářová, "Spatial Prefabrication in Timber Structures," In *3rd World Multidisciplinary Civil Engineering, Architecture, Urban Planning Symposium (WMCAUS 2018). IOP Conference Series: Materials Science and Engineering.* 1. Bristol BS1 6HG United Kingdom: IOP Publishing, 2019. pp. 1-5. ISSN: 1757-8981.

[2] B. Kovářová, "Construction philosophy "Light building"," In *Advances and Trends in Engineering Sciences and Technologies.* Leidem, Netherlands: CRC Press Balkema, 2015. pp. 293-298. ISBN: 978-1-315-64464-6.

[3] V. Motyčka, M. Rusinová, J. Šlanhof, "Stanovení požární odolnosti vybraných skladeb s využitím konstrukčních prvků Europanel®," *Výzkumná zpráva č. 5/2018 v rámci řešení projektu MPO FV10075 "Nová technologie vícepodlažních energeticky úsporných budov z lepených sendvičových panelů s možností zakládání na zemních vrutech s využitím technologie prefabrikovaných bytových jader,"* Brno, 2018

[4] V. Motyčka, Z. Fišarová, L. Kalousek, P. Liška, J. Šlanhof, "Výsledky měření zvukoizolačních vlastností staveb z lepených sendvičových panelů," *Výzkumná zpráva č. 3/2018 v rámci řešení projektu MPO FV10075 "Nová technologie vícepodlažních energeticky úsporných budov z lepených sendvičových panelů s možností zakládání na zemních vrutech s využitím technologie prefabrikovaných bytových jader,"* Brno, 2018

[5] V. Motyčka, B. Kovářová, J. Patloka, "Konstrukční řešení schodiště," *Výzkumná zpráva č. 10/2017 v rámci řešení projektu MPO FV10075 "Nová technologie vícepodlažních energeticky úsporných budov z lepených sendvičových panelů s možností zakládání na zemních vrutech s využitím technologie prefabrikovaných bytových jader,"* Brno, 2017