Spatial Prefabrication in Timber Structures

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Abstract. The term “timber structures” is considered to mean buildings whose horizontal and vertical structures are fabricated from wood-based elements. With timber structures, prefabrication can take the form of planar prefabrication, spatial prefabrication, or a combination of the two. 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. Spatial prefabrication means a significant increase in effectiveness through the use of building units that are assembled at a manufacturing plant before being transported to the building site and added to the structure under construction. These 3D sections have usually already been provided with their final surface finish and fittings at the factory, so all that is required at the construction site is for such units to be incorporated into the rest of the building. The amount of onsite finishing work is eliminated to a maximum degree and transferred to the production plant, where it must be carried out using certified materials and procedures while respecting the requirements of SIP (structural insulated panel) technology. It is undeniable that timber structures are used for a large proportion of constructed low-energy and passive houses. For this reason, efforts should be also made to maximise the use of these types of timber structures in combination with the highest possible degree of prefabrication in the construction of apartment buildings. Such use brings considerable savings as regards the life cycle of buildings and the lowering of ecological load during the production of building materials as well as the construction process itself.

1. Introduction

Wood is a renewable material which offers the best ecological balance, has excellent thermal insulation properties, creates a pleasant environment and has a beneficial influence on the human psyche. The term “timber structures” is considered to mean buildings whose horizontal and vertical structures are fabricated from wood-based elements [1]. Moreover, timber structures can be built very quickly and throughout the whole year, with only a small amount of construction waste being produced during the building process. Due to the low weight of timber elements, prefabrication can be used, meaning that some construction activities can be moved from the building site to precision manufacturing plants. With timber structures, prefabrication can take the form of planar prefabrication, spatial prefabrication, or a combination of the two.
2. Type of prefabrication

2.1. Planar prefabrication

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). Today, timber structures built from prefabricated panels have the greatest share in the European timber structure market. Hundreds of companies produce panels in a hugely varied range of sizes, material compositions and levels of completion. However, when examining such products in greater detail, one discovers that the prefabricated timber panels available on the market are based on three fundamental panel construction principles. There are panels with a wooden frame, structural insulated panels (SIPs) (see figure 1) [2] and layered all-wood panels [3]. The three types of construction principle are listed according to their date of appearance, the oldest being the panel with a wooden frame, which was patented as far back as in 1880. In this article we will examine only SIPs.

![Figure 1. Typical SIP panel](image)

2.2. Spatial prefabrication

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 [4].

However, prefabrication also has its disadvantages. The variability of built structures decreases with the degree of prefabrication employed, and prefabricated sections also suffer limits on their versatility. When spatial prefabricated units are used, the buildings that contain them have to be designed “around” them, greatly limiting variability in terms of building layout. If one considers that today the application of spatial prefabrication is mainly limited to sanitary units with a direct link to the kitchen area, its usefulness is thus very limited. Clearly, it allows designers very few options for creating the layout of buildings as a whole.

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.

3. SIP-based timber structures

The basis of SIP technology is a panel produced by the gluing of large-format structural facings onto a core made from a thermal insulator. It is necessary to use a core with sufficient strength as the panel does not contain any reinforcing elements. SIPs are thus sometimes described as layered insulated panels without reinforcing ribs. Building envelopes can be constructed from boards based on ferrous and non-ferrous metals, chipboards and fibreboards, as well as cement-bonded particleboards and fibre cement boards. Expanded or extruded polystyrene is most frequently used as a thermal insulator. Hereinafter the article will only investigate panels with OSBs (oriented strand boards) on the outer surfaces and a filling of thermal insulation material based on either expanded polystyrene (EPS), extruded polystyrene (XPS) or polyurethane foam. Special adhesives are used to connect the layered structure to form a solid whole which excels in the precision of its dimensions and the ease by which it can be processed further.

The result of the optimization of planar prefabrication is, as was mentioned before, a basic panel with a width of 1200-1500 mm. The thickness of the panel is derived from the required thermal resistance of the structure. The means by which panels are connected to one another differ depending on the manufacturer. One most frequently encounters a combination of special adhesive and stapled buckles, or a combination of special adhesive with self-tapping screws [5].

As far as dimensions are concerned, panels can be obtained in the correct format directly from the manufacturer according to the installation documentation or, depending on the complexity of the task required, modifications can be made directly at the construction site. However, onsite modifications extend the period of construction as installation cannot take place continuously with regard to the distribution of the workforce. Auxiliary workers will be needed to modify the SIPs, i.e. to alter the dimensions of the surface panels and adapt them for inclusion in the building (connectors).

Currently, this system is most widely used for the construction of single-family homes. This is due to the construction system itself as well as the valid legislation that governs its use. Not only does the legislation place limitations on the use of timber structures in terms of the total permissible height of such buildings, but it also imposes limiting factors on the implementation of SIPs and spatial prefabrication with regard to fire safety and the acoustic requirements of buildings containing prefabricated elements [6]. One needs to be aware that the supporting system itself is wood-based and therefore additional fire safety measures need to be taken as on its own the system does not fulfil the legal fire resistance requirements for structures.

4. Spatial prefabrication using SIPs

As previously mentioned, one aspect of the classification of prefabrication is the degree to which it is employed.

Planar prefabrication using SIPs enables the production of large-format panels with prepared openings for windows and doors. The advantage of the system is that buildings can be assembled quickly at the construction site. However, one downside is the system’s “sensitivity” to deviations in dimensions and the quality of execution of the foundation. The use of the panel formats stated above, i.e. with a width of up to 1250 mm, eliminates this problem to a great degree, though this comes at the cost of a lengthened construction process and an increased workload at the building site. Generally, planar fabrication based on SIPs means an increase in the effectiveness of building production compared with standard building materials. On the other hand, it must be said that the scope of auxiliary finishing work during building production remains practically unchanged compared with standard construction methods.

In contrast, spatial prefabrication means a significant increase in effectiveness through the use of building units that are assembled at a manufacturing plant before being transported to the building site.
and added to the structure under construction. These 3D sections have usually already been provided with their final surface finish and fittings at the factory, so all that is required at the construction site is for such units to be incorporated into the rest of the building. The amount of onsite finishing work is eliminated to a maximum degree and transferred to the production plant, where it must be carried out using certified materials and procedures while respecting the requirements of SIP technology. On the one hand, spatial prefabrication speeds up the assembly process at the construction site but on the other, it places greater requirements on the accuracy of foundation structures and the precision with which the building’s utility lines are placed.

Currently, the most widely used example of spatial prefabrication employed with timber structures made from panels is the prefabricated sanitary unit (see figure 2), which is provided with all fittings necessary for connection to the water distribution system, sewage system and electrical grid. Such units feature a high level of completion, with the walls and the inner ceiling already provided with their final surface finish [7, 8].

As with every new building technology, the spatial prefabrication of timber structures or their parts offers many advantages in terms of the construction process. Some of the most important are the acceleration of the process and an increase in its quality by moving part of it away from building sites to central manufacturing plants with repeatable high precision production capabilities and an output of spatial prefabricated sections that feature a maximum level of completion. This advantage is particularly relevant with regard to the low basic weight of the materials used, i.e. the size of a prefabricated part of a structure is now limited in terms of the available transportation options by its dimensions rather than by the total weight of the section, as was once the case.
5. Conclusions

It is undeniable that timber structures are used for a large proportion of constructed low-energy and passive houses. For this reason, efforts should be also be made to maximise the use of these types of timber structures in combination with the highest possible degree of prefabrication in the construction of apartment buildings. Such use brings considerable savings as regards the life cycle of buildings and the lowering of ecological load during the production of building materials as well as the construction process itself.

References

[1] http://www.timberframedesign.net; access: 05/2018.
[2] ANSI/APA PRS-610.1, “Standard for Performance-Rated Structural Insulated Panels in Wall Applications,” 12/2009.
[3] http://sipbuilding.wordpress.com; access: 05/2018.
[4] http://www.vareamodul.cz; access: 05/2018.
[5] Liška, L. 2009, “Univerzálny stavebný systém pre drevostavby – technológia SIPS, Universal Building System for Wooden Buildings - SIPs Technology” Stavebné materiály, vol. 11/2009, pp. 28-31 (in Czech).
[6] Liška, L. 2011, “SIPs technologie konstrukčních izolovaných panelů, SIPs technology of insulated panels“ Realizace staveb, vol. 5/2011, pp. 14-17 (in Czech).
[7] http://www.europanel.cz; access: 05/2018.
[8] http://www.dimensioncanada.ca; access: 05/2018.