CONSTRUCTION-TECHNICAL SPECIFICS OF A PREFABRICATED WOOD CONSTRUCTION SYSTEM

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Abstract: Wood as a raw material and material in the construction of wooden buildings has an irreplaceable position in terms of the complex of mechanical, thermal-technical, aesthetic, utility, technological properties and the impact on the environment. In many countries of our region, it is a strategic, yet renewable raw material, which brings considerable profits to national economies, especially where it is comprehensively processed in products with high added value. Today's wood-based construction methods are very diverse and can be individually adapted and combined. Current wooden buildings intended for housing can in principle be divided according to the character and nature of vertical load-bearing structures into massive, skeletal and elementally constructed elements composed of individual elements. From the point of view of the efficiency of the construction process, an effective solution is especially construction systems that use elements of automation and prefabrication of structural elements of the construction site. The production process of prefabricated components is diverse depending on the specific manufacturer of the individual components. Pre-prepared structural elements and parts of structures more or less finalized are then transported to the construction site where they are assembled into the final form. In connection with prefabricated construction systems for the construction of wood-based structures, it is necessary to analyze their production process where it is possible to identify significant reserves and propose improvements to streamline the production process. From this point of view, in this paper we focused on the analysis of the production processes of a prefabricated wood-based construction system.

Keywords: construction, efficiency, sustainability, prefabrication, realisation, wood, wood buildings

1 Introduction

In the context of our region, wood is perceived as a historical building material. The traditional use of wood in Central Europe and Slovakia is due to historical development, as it is an available raw material and the construction of family houses made of wood has undergone an evolutionary development with many years of experience in addition to traditional carpentry craftsmanship. This is evidenced by the number of preserved historic buildings, as well as pioneering buildings in the 20th century. In many countries of our region, it is a strategic, yet renewable raw material, which brings considerable profits to national economies, especially where it is comprehensively processed in products with high added value [1,2]. There were positive responses from investors and architects, but also controversial views influenced by mostly surviving empirical knowledge from the era [3], when wooden buildings were perceived as temporary buildings with low demands on functional requirements. The fact remains that the current level of construction of wood, technology, design and material possibilities has moved wooden buildings to a completely different dimension and, on the contrary, as before, they are beginning to become the prerogative of a richer and more demanding clientele. The return to wooden architecture is not only an expression of the search for original values in today's volatile times [4-6]. Man, exposed to the onslaught of an over-technological civilization, is extremely sensitive to any contact with nature and natural material [7,8]. The comfort and atmosphere connected with nature are undoubtedly provided by wooden buildings [9].

Today's wood-based construction methods are very diverse and can be individually adapted and combined. Current wooden buildings intended for housing can in principle be divided according to the character and nature of vertical load-bearing structures into massive, skeletal and elementary structures composed of individual elements [10,11]. The individual groups differ considerably from each other by the construction method used, the appearance and the possibilities of production of their structural elements. The basis of massive buildings are log buildings realized to this day, but at present modern massive buildings have been added to them. Groups of skeletal and elementary structures have evolved from half-timbered structures and represent a structure of bar elements [12]. In addition to the classic wooden construction methods, the so-called hybrid methods developed in recent years that combine wood as a building material with other building materials [13-15].

2 Panel construction of wooden prefabricated building structures

At present, the panel building system for wood-based buildings is the most widespread. The basis of the panel construction is a wooden frame roughly clad with suitable large-area materials. The wooden frame of the panel is structurally adapted with respect to the function it performs - perimeter, partition, ceiling, roof, floor. The construction and dimensions of the frame are adapted to the different function. The space between the ribs is filled with heat-sound insulation. Particleboard, OSB board, gypsum fiber board, cement-bonded particle board and the like are used for the cladding. Assembly is quick and easy. The construction of a building from a panel system is relatively fast due to the fact that during the construction there is no wet process that would require a technological break [16,17].
The panels can be manufactured with many degrees of finishing, from thick frames clad on one side with large-area material to panels with built-in windows and doors and panels with finished interior and exterior finishing and with built-in wiring. The main advantage of the construction of the panel system is the possibility of maximum preparation of the construction in production and quick assembly and completion of the construction on the construction site. The panels can also be of various sizes - from panels measuring 1,200 × 2,600 mm with a weight of up to 80 kg, which do not require heavy mechanization, to full-wall panels up to 12 m long, which require heavy mechanization for transport and assembly [18] . During assembly, it is important to connect the panels correctly to each other, but also to anchor the panels to the foundation structure.

2.1 Technological analysis of prefabricated wooden buildings

The next chapter deals with the production of a panel wooden building, construction and energy design.

2.1.1 Phase of production of components of a panel wooden building

The key moment of this construction system is the elements of prefabrication in the production of individual components and structural parts of the building system. Prefabrication of wooden buildings is performed in several stages and in different systems [19]. These are either small modular panels of a wooden building not exceeding the weight of 80 kg, or classic wall panels, which are the most commonly used alternative. It is possible to create whole load-bearing and non-load-bearing walls, ceilings, floors and roofs from them [20]. The largest dimensions of the panels are optimized with regard to the method of transport and the construction site.

The production of prefabricated wooden building panels takes place on an assembly table. The completed panel is tilted to allow double-sided laying of construction boards and other materials used. A threshold is placed in the lower and upper part (in the lower part it is impregnated), between the thresholds there are vertical columns placed in a regular grid, which are anchored to the threshold by means of metal connecting corrugations or nails. The resulting wooden frame is covered with a construction board. Thanks to the choice of the right, the joints of the individual boards come out right in the middle of the vertical columns. The resulting solid wound of the wooden structure is flipped to the other side, the required layer of insulating material

is inserted between the individual columns. Then the selected material is folded again. The procedure is repeated. The distribution of engineering networks is also inserted into the prefabricated wooden building created in this way. The resulting product is placed vertically by installed construction carpentry products. In the case of the perimeter walls of a wooden building, the plaster is finally finished depending on the degree of finalization of individual components [21,22].

2.1.2 The phase of transport of components and the phase of implementation of a panel wooden building

Finished panels for prefabricated wooden buildings are shipped to the truck during shipment so that their arrangement corresponds to the subsequent procedure of building a wooden building. At the construction site, the panels are placed on a base plate using heavy machinery. The anchoring of the panels of the perimeter walls of prefabricated wooden buildings is first realized in the corners, in the places of their joints where the panels are pulled towards each other. We anchor most often with screws in predetermined places. Subsequently, the panel is fixed to the base plate with metal angles from the inside of the wall. The procedure with panels of internal partitions is similar [23]. Prefabricated ceilings are placed on such a complete block and fastened to the lower part of the building with screws. In the case of a multi-storey wooden building, a prefabricated staircase is inserted into the house and is also anchored to the walls and ceiling with metal connecting materials. The whole house is covered by a truss structure, which is also prefabricated. The prefabricated construction is completed by laying and anchoring the roof panels and the final laying of the roof covering [24-26]. Also, depending on the finalization stage of the individual panels, the finishing work on the construction site is carried out in direct proportion.

2.2 Production stages of preparation and prefabrication of wooden buildings

The different stages of production or prefabrication of wooden structures determine the extent to which the structural elements will be prepared in advance and in what condition they will leave the production plant for subsequent assembly on the construction site. Whereas in the past loose and unprocessed building elements were delivered to the construction site, today they are flat construction elements (elements). In these planar elements, the first stage of prefabrication of timber structures begins by comprising parts of the supporting structure and at least one layer of cladding. The wooden structure defined in this way is pre-assembled into a flat element, adjusted in height and width according to the required dimensions, including the preparation of openings for windows and doors. In the third stage, an insulating material is inserted between the structural elements and the elements are clad on both sides with OSB boards or gypsum fiber boards. The intermediate stage consists of the insertion of adapters for technical installations. The incorporation of windows and doors into flat elements is another stage of prefabrication. A high degree of prefabrication of wooden buildings can also be achieved if the façade is also installed in the production plant and, if necessary, the internal wall cladding is also installed [27,28]. Today's production is so far that they also carry out surface treatment in the plant. This is possible, but only under conditions of perfect protection of structural elements during transport, assembly, until the work is sold to the user. How far prefabrication is suitable in a plant depends on the specified construction system of the timber structure and the technology available in the design, manufacture, transport and assembly. It is also necessary to take into account the aspect of pollution or the risk of damage to the elements. Raw unmachined building elements are less vulnerable to climatic influences such as moisture, rain or UV radiation. In contrast, finished elements require better protection. Such complex elements are particularly susceptible to interventions by subsequent crafts. The number of elements between the design stages is innumerable and thus gives considerable potential for individual solutions [29]. The rationalization and industrialization of the construction industry encourages the development of work with larger building elements [30]. The main advantage is seen primarily in the relocation of the production process from the construction site to the production hall, independent of the weather conditions affecting the quality of the final work. Production in the workshop and factory brings additional benefits. It is possible to work better in a plant than on a construction site. Individual building elements, such as windows and doors, are directly built into larger or smaller large-area assemblies [31]. This ultimately leads to higher quality, provided the professional design and thoughtful course of construction, the resulting construction.

2.2.1 Areas of application of prefabrication of wooden buildings

Construction using panels with a load-bearing or non-load-bearing function is suitable for a myriad of construction tasks. Prefabricated components are used especially when fast implementation is required, due to the low weight of building components, low transport and assembly costs. Buildings can be designed and implemented as temporary or permanent. Demountable and relocatable space cells can be advantageously used for the construction of office buildings and the like [32,33]. In this case, in particular, an easy response to the time-limited scope of implementation is shown. At the beginning of their era, these applications were a temporary solution with a limited lifespan. Gradually, they evolved into this form. The industrial production of small or large elements, even whole spatial cells, is constantly being improved. The structural elements are transported to the construction site as a whole, including installations and often also with interior surface treatments.

2.3 Constructional design of a panel wooden building

In the subchapters I will deal specifically with the diffusely open structure and the diffusely closed structure, their basic properties and the differences between them.

2.3.1 Diffuse open construction

For the construction of wooden houses, which are formed by diffusely open structures, a functional physical quantity-diffusion is typical. It is a mechanism that is able to constantly transport molecules in different intensities through the wall in both directions. This process is often called the "ability of the wall to breathe." Diffusion alone does not bring anything new and beneficial. But by understanding its principles, returning to nature, it is possible to make the "diffusion" of a helper by the right choice and stamping of materials, which helps to ensure long life of buildings with above-standard wall parameters and healthy indoor home environment [34]. In order for this mechanism to bring advantages, it is absolutely necessary to ensure the exact arrangement of precisely defined materials into the wooden structure, otherwise diffusion methods rather problems and complications. Properly dimensioned element or construction system based on diffusely open construction for these reasons offers a safe composition of the wall verified by calculations, exact tests in laboratories, where the composition of individual layers was verified. The main principle of the wall is a vapor barrier layer, which is formed by quality OSB boards. Their joints must be glued and vapor-sealed with high-quality sealing material [35,36]. It is important to ensure that the vapor barrier layer is not damaged by installations in the house, therefore it uses installation walls for wooden buildings with a diffusely open construction. Another material is a special fine mineral insulation inserted between the wooden KVH profiles of the structure. The diffusion open system uses insulations without the chemical additives of formaldehyde or phenol. The last and thus the most important material in the composition is wood fiber insulation, which ensures the final transport of water molecules and evaporation to the exterior [10]. At the same time, the façade carrier is an excellent sound insulator and also an element slowing down the heat flow through the wall in the summer months.

Characteristic properties of diffusely open structures

This solution is a mechanism that transports moisture through the walls in different intensities in both directions. This is the so-called ability of the wall to breathe.

- vapor barriers or other foils are not used
- very effective in preventing heat leakage
- allows the passage of water vapor
- are impermeable to water as a liquid
- balance humidity in interiors
- provide good sound-insulating properties of buildings
- ensure very good fire resistance
- increase the air quality in the interior in a natural way
- they are fully organic
- constructions dry in the winter
- ability to regenerate in case of excessive wetting
- simple construction (fewer layers).

2.3.2 Diffusively closed construction

Diffusively closed construction of a wooden building is fully used for almost all construction systems of a wooden building, low-energy and passive wooden buildings. The principle of functionality of this closed composition depends on the materials used, especially on the selected vapor barrier, which should be suitably placed as close as possible to the interior. For wooden buildings on the principle of diffusion-closed construction, a vapor-tight foil is used, which has a very high diffusion resistance [37,38]. The correct functionality of the vapor barrier is ensured only if an impermeable house envelope is created without broken places, without joints and with sealing even the most complicated details. For these reasons, high-quality adhesive and sealing material is used for construction systems based on this principle, which ensures perfect properties throughout the life of the house. It is also important to mention the installation wall, which is used to guide all wiring (electrical installation, plumbing, heating, etc.). And which is a guarantee of the integrity of the vapor barrier, even after the installation of these wiring. Several principles must be observed when installing the vapor barrier: the vapor barrier film must be glued at the joints, it must not be broken anywhere and it must not be missing anywhere [39]. If the vapor barrier is of high quality and professionally made, the foil will not let water in any state and thus no moisture will penetrate into the structure. From the exterior, the wooden structure is covered with gypsum fiber boards and the cladding itself is solved with facade polystyrene. With its properties, it ensures that even if internal moisture penetrates into the composition of the wall, the structure will not get wet. All moisture is therefore retained in the living space of the interior and the construction of the wooden building is completely free of moisture. The amount of moisture in the interior must be removed from the building by means of ventilation, a fume hood or a fireplace. A suitable solution is to use controlled ventilation with recuperation or forced ventilation.

3 Conclusion

In accordance with the trend of streamlining processes in construction, the topic of this presented work deals with a prefabricated construction system which is popularly used in the implementation of modern wooden buildings. The introduction of the article specifies the basic context concerning a prefabricated construction system based on sandwich panels. In the following parts of the article, the technological, design but also production aspects of the analyzed design system are analyzed in more detail. As pointed out in this paper, a construction system based on prefabricated sandwich panels offers a number of advantages resulting in particular from the use of prefabrication elements and the pre-preparation of individual components and structural elements. The production process is basically dependent on the specific manufacturer and the technology used, but certain elements are common, as we stated in the analyzed parts of the article. The diversity of production processes raises a number of issues that can be explored and optimized the production process. For this reason, we intend to address this issue in the future and deepen our knowledge in this area of research.

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