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The treehouses

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Abstract. The goal of this research is to evaluate and find new solution in the area of wooden constructions placed in the treetops, which are interesting mainly due to their independence and amazing view among the treetops, and enable the utilization of the land below the treehouse itself. Treehouses can be constructed as a detached object without having to interfere with the trunk, or anchored into the trunk using special anchoring elements, where compact root system of surrounding trees is essential for healthy grow of the tree. Wood is also a specific natural material, which offers a possibility to create architecturally interesting and modern construction. This article is focused on evaluation of anchoring suitability of these constructions in treetops, evaluation of using these houses for recreational purposes as well as permanent living, effect of climate conditions on suitably chosen wood type and construction of these objects.

1. Introduction

Modern wooden constructions use wood as a specific material, from which highly functional and architecturally interesting buildings can be created. Such buildings use industrially manufactured building system, where primary load-bearing structure consists of glued, composite or stacked blocks. Those components are used for vertical, horizontal and roof constructions. Such flat structural systems are set with insulation on the exterior side. With this type of buildings, we can achieve huge effective load transfer and high dimensional stability, while preserving interesting visual properties of wood. Besides large solid constructional components, we can see also small format structural members can be used to assemble a flat construction at building site.

Besides using timber when handling the load-bearing structure, we can see it in other architectonically-constructional elements as a part of structural composition, interior or exterior. Wood as a quality material has many ways of usage when designing wooden constructions and it is desirable that the carpentry is articulated. When designing wooden constructions like treehouses, the tree trunk is mostly used as structural member into which the load-bearing structure is anchored. The significant element of the whole construction is then ladder, staircase or ramp, which becomes main and the most important part of the construction.

During residential building planning it is customary to supply the carpentry with wooden façade. Less common is to supply this construction with more solid wood elements, either in the interior or exterior. Nevertheless, wood is very variable structural material with great potential for use. It is also possible to suitably complement such building with metal structures, while considering convenience of the solution as well as climate conditions where the building is placed.

The treehouses are the embodiment of freedom and pleasantly comfortable safety. Their independence is captivating and brings a stunning view among the treetops. One of the original purposes of a treehouse, to protect us from predators, is now rare and its function is fulfilled only in areas with wildlife, which is dangerous to humans. Each house has its own structure and a ladder as a way into the house itself, which can be pulled up any time, enabling us to disappear among the treetops and hide from the chaotic world on the ground.



The interior of such houses creates individual distinctive and spiritual space, which depicts mainly our inner path. With such space we can experiment boldly by letting this mysterious area to ascend to the surface. It is not entirely necessary to own a tree for building a “treehouse” –freestanding slab construction, which doesn’t interfere its structure into the tree itself (or surrounding trees), can perfectly assimilate its qualities. A treehouse does not have to be available only for individuals with the luxury of owning a robust and structurally binding tree. Urban treehouse has as much authenticity as the one spread in the treetop with trunk carrying its weight. Every modern building which draws inspiration from treehouses, but without founding and anchoring into the tree itself, deserves our attention as well. In many ways structural engineering has offered satisfying environmental answers that respect the tree itself.

2. Characteristics of the wooden construction

Solid-wood buildings and architectonically-constructional elements of solid wood are entirely specific in their characteristics. Therefore, it is necessary to know physical and mechanical properties of wood and regularities of building physics precisely, as well as to keep basic principles of designing using wood. Considering these properties and principles helps to reduce negative effects and material degradation, while achieving desired outcomes and utilizing natural properties and benefits of solid wood adequately. Buildings with wood in their structure are very specific from the building physics perspective; therefore we needed to take their special characteristics into consideration during the designing process, whether it is for carpentry, space frame or skeletal structure. Based on characteristics of wood, such as moisture regain, change in dimensions and susceptibility to damage by various factors, it is necessary to design both construction and all wooden elements based on structural principles which can help to increase lifetime of a wooden product. Wood as a natural material has special characteristics also from environmental point of view. Besides all that, its usage in structure and interior positively influences microclimate of the building and living comfort.

For using wood in building industry its life span is crucial. Many factors affect deterioration of wood and its life span. These can be influenced to a large extent, resulting in prolonging the longevity of wooden elements to its maximum.

3. Specifics for designing wooden structures

Since wood is a natural material, which significantly reacts to a direct contact with water and its presence in the air, weather conditions and other factors, it is necessary to follow certain principles when designing wooden buildings or architectonically-constructional elements to achieve as high durability and resistance as possible. Wood as a biological material is naturally inhomogeneous on all levels from submicroscopic to macroscopic one. Moreover, other factors influence the characteristics of wood during its growth. Various kinds of wood differ in resistance against degradation factors; therefore, the initial phase of the design consists in choosing the suitable material based on the purpose and surroundings in which the building will be constructed. European wood species with high durability include larch, oak, ash, pine or elm [4].

Of course, natural durability of wood can be improved with impregnation or other artificial proofing. Nevertheless, constructional protection of wood is still primarily preferred as it eliminates exposure of wood to degradation effects [2].

Indeed, we choose timber without defects. The most serious degradation factors are dry rot and insects that significantly lower strength of the wood. Their occurrence requires temperature around 20°C, increased relative atmospheric humidity and moisture content in the wood above 20% [1].

For all this it is crucial to prevent the wood from being exposed to water already during storage and mounting. Wooden elements should be stored directly at construction site for a minimum period of time. Also, during mounting wooden elements and buildings should be sufficiently protected when weather conditions are bad. With finished building, the most dangerous is warm and humid environment, where moisture easily penetrates into the wood and cumulates there. It is similarly dangerous if walls are not vapour permeable. Especially during winter period, when air pressure on the inside of the building is higher than outside, it is crucial that diffusion resistance towards outer wall layers is decreasing and structure contains vented air layer for vapour outtake. With diffusion-closed outer wall structures, we

use vapour control layers placed as close to the interior as possible, to minimize vapour penetration into the structure. Condensed water drainage needs to be placed in the structure wherever we assume higher occurrence of vapour condensation. Wood should be incorporated into the structure with dampness corresponding approximately with the future operational dampness. This is usually around 8% in the interior [1]. This should prevent both formation of dry-out cracks, which could enable insects or fungus to contaminate the wood, and bulking in case of overdrying. It is also essential to prevent carpentry or wooden elements to come in contact with ground dampness, splashing rainwater or snow. That is why wooden buildings and all exterior elements are set to be 300 to 400 mm above surrounding ground [3].

Due to its flammability we need to keep certain fire safety precautions when planning to use wood at certain situations. Wooden elements should be sized based on safety factor, which is secured by smaller wood surface in proportion to its volume (therefore also higher fire resistance), and finished with smooth surface or inflammable top. Of course, wooden construction has to consider fire risk, comply with applicable legislation and should be equipped with fire safety precautions [1].

4. Lifespan and wear of wooden structure

When designing modern wooden structures timber is used as a specific material to create architecturally interesting and highly functional buildings. This material is very shapeable and has a great potential use in construction and architecture. In wooden structures it's standard to supply load-bearing structure with wooden enclosing shell [4].

All structures wear out physically and morally. Physical wear-out indicates useful value decline owing to defect rise. This wear-out can be influenced by structure protection and taking care of it. Moral wear-out rises owing to development and increasing demands on the construction. Wear-out value is connected with lifespan of structure, which includes physical, moral and economic life. Moral life is connected especially with aesthetics and requirements for construction and elements. Economic life is based on economy review from point of view of comparing running cost, abatement and maintenance cost to structure usability. Length of these lifespans differ and is also different for individual structural parts. Parts with longer physical life are load-bearing, beam or roof structure. On the other hand, floor, roofing or enclosing shell can be among the elements with shorter life. Nevertheless, all of these always depend on particular conditions, placing of the elements and their execution and on level of protection and maintenance. Among most common factors negatively influencing life span of wooden structure are insufficiencies and mistakes in design, its execution or mounting or during usage [1], [2].

When designing structures and buildings it is important to choose suitable type of wood for the enclosing shell so that it would perfectly resist weather conditions in which the building is placed and sub-sequentially to choose suitable surfacing. From the architectural point of view it's preferable to focus on lightfastness and color changes of wooden element so that it would comply with architectural brief. So when designing enclosing shell from particular type of wood we have to consider color change in advance, or assume such changes and choose the pattern according to expected color changes. Wood surfacing significantly influences lifespan and lightfastness of the wooden element.

Significant way to apply solid wood on the exterior of modern wood construction is wooden façade. Such façade solution consists of exfiltrated load-bearing grid, which is covered with layer of solid wood elements. These elements can be planed planks, unplanned boards or split shingles. For correct functionality and achieving maximum lifespan of wooden façade it is necessary to keep the same principles of structural protection as with external elements. Façade should be protected by the roof overlapping against direct sunlight and rainwater as much as possible. Individual elements of joinery facing have to be protected against withholding water in joints and its capillary action in them. Details design therefore has to enable draining of water; weatherboarding boards have to overlap one another in direction of rainfall. For fluent drainage the façade should be offset to the face of substructure at least 30 mm and should have water nib milled [3].

Besides all this, air flow around wooden elements should be ensured via keeping sufficient spacing between them, so that they can dry fast and completely. Development in area of wooden facades focuses mainly on prolonging their lifespan and on reducing and simplifying the care of it. The question being discussed is, if treated or untreated wood should be used. Some types of surfacing and impregnation have negative effects on ecological aspect of the material. Additionally, surfacing needs to be repeated

regularly. Untreated façades naturally degrade by sunlight and greys unevenly due to the sunshine. More significant greying happens on surfaces more exposed to the sunlight, that is, on southern side of the façade and on sunspaces. Color changes do not influence durability or quality of the wood.

Untreated wooden façades are commonly used in Austria, as opposed to Scandinavian countries. The reason for this can be the fact that in Central Europe quality and resistive larch wood is accessible, whereas in Scandinavia façades are constructed of spruce or fir wood.

Suitable, but very costly alternative to larch could be oak wood. To execute wooden façade we can use thermowood as well. Wooden façade can be either vertical or horizontal. The most common type of wooden elements on façade in our country is planed plank. Somewhat more durable version would be unplanned board, which is used mainly in northern Europe. Probably the longest lifespan has split-shingle façade, where splitting does not intact wood fibers [5].

5. Modern constructions

Modern wood constructions are based on principles of using wood as a specific building material, which can be used to create architecturally interesting and highly functional buildings. Aesthetical legacy of traditional wood constructions prevails in modern wood constructions in the form of visually admitted wood. Modern wood constructions use prefabricated building system, where the load-bearing structure is made up of flat solid blocks formed by gluing, lamination or folding. These flat components can be used in horizontal, vertical or roof structure. This is a flat-acting load-bearing structure with insulation on the exterior side, where at least half of the load-bearing layer is made of solid wood. With this type of constructions, it is possible to achieve very efficient transmission of large loads and to reach high stability of dimension while keeping interesting visual characteristics of the solid wood. Besides using large-size solid-wood structural components we can use small-size load-bearing elements, which are assembled into flat construction at the construction site [6].

6. Possibilities of treehouses and their types

We can divide treehouses based on composition type of the perimeter structure – per thermal insulation thickness used in such composition and way of use of these engineering structures. Such structures are specific in particular by their load-bearing structure, which lifts the whole structure and has to be adjusted to designed composition of the perimeter structure.

First type is recreational housing – in Czech Republic we can see such houses in Lelekovice near Brno – which serves mainly for amusement purposes during summer months. In our country such small house is the most common and its structural composition brings to mind classic summer houses. Conception of perimeter structure is simple and do not apply load to load-bearing structure or trunk, which the structure is anchored to. Interior of such housing is equipped and furnished simply and functionally, and its internal space does not even enable more complicated internal layout. No utility networks are installed in such buildings.

The other type is housing for yearlong occupancy with more complicated conception of perimeter structure. These houses require more stable and stronger main load-bearing structure or anchoring into the trunk. Such engineering structures are not very common in Czech Republic and can be found more often abroad where climate is more favorable and temperature swings are smaller. Interior of such building is more articulated and more complex than in the first type, also internal layout more resembles common family house and installation of utility networks is customary there.

7. Anchoring elements of treehouses

Based on the load-bearing structure, treehouses can be divided into two categories. Either freestanding treehouses, which interfere with the treetops and do not need or require anchoring of the load-bearing structure into the trunk; or houses, which require anchoring into the trunk of the tree (or trees), or to be hung on ropes with trees serving only as anchoring element, trunk is not mechanically disrupted and tree is not damaged. With every such type of construction stress and loading of trees need to be evaluated [7].

Treehouses are interesting architectural works; however, it is important to evaluate if intervention in the trunk is inevitable and consider possible impacts on lifespan of such tree. It is not only about the

mechanical intervention – that is anchoring with bolts directly into the trunk, but also any suspension of load-bearing structure on trees. It is also necessary to review the quality of the root system and generally it is a fact, that the more trees are surrounding the damaged tree, the longer its lifespan. Therefore, it is inappropriate to choose solitary trees (or tree) with sparse root system for such types of constructions.



Figure 1. Mechanical anchoring to the tree.

8. Composition of enclosing shells – treehouses

Coefficient of thermal transmittance and thermal resistance (basically it is so-called inverse value of U) are basic quantities characterizing thermal insulating properties of any building structure. When choosing particular house, or better said, particular building system, we need to observe the composition of the enclosing shell, its thermal insulating properties and its ability of heat accumulation. Materials used for thermal insulation have more or less the same thermal conductivity, which defines how well (or poorly) the insulant conducts the heat. Heat capacity, on the other hand, is very different – it influences thermal inertia and so-called phase shift.

When the house is designed correctly, we can use solar gain to compensate heat loss and to support improvement of energy balance of the building and to lower heating expenses. To prevent overheating, windows need to be equipped with shading for the summer. Windows with efficient thermal insulation are becoming a necessity instead of needless comfort.

Wood is an organic matter and as such it has to breathe. Therefore, edge venting and venting of roof cladding is essential part of wood construction. Those are done as diffusely-open, so that natural convection of air outtakes all the dampness from the structure and secure its dry state. For outer walls this issue is solved by exfiltrated façade systems.

From the point of thermo-insulation properties, it is important to mention, that suitable composition of structure should be chosen based on the building type and its usage. For recreational housing simple composition would be sufficient, eventually with higher standard it is possible to choose a composition with thicker thermal insulation layer. In case of building for year-round housing we need to deal with coefficient of thermal transmittance for enclosing shell and suggest suitable composition to comply with ČSN (Czech Technical Standards).

9. Conclusion

The purpose of the research is to find and evaluate new solution in the area of treehouses that are interesting mainly due to their independence and amazing view among treetops, and which enable us to utilize the land below the house itself. Treehouses can be constructed as freestanding object without necessity to interfere with the tree trunk or anchoring it there using special anchoring elements, where surrounding roots system is crucial for healthy growth of the tree. Wood is a specific natural material and offers possibilities to create architecturally interesting modern structures. This work focuses on evaluating suitable anchoring elements for these structures among treetops, also usability of these objects for recreational activities and permanent housing, and last but not least, evaluating the effects of climate conditions on suitably chosen type of wood and on the structure of these buildings.

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