Log cottage – a case study

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Abstract. Wood is considered to be one of the oldest building materials, alongside stone. Although wood is characterized by a lower durability, due to multiple factors, we can say that it has many uses, especially in rural areas, in the proximity of woods. An important reason for using wood as a building material was its lower processing cost. However, we cannot omit the fact that, in today's Romania, due to changes in the forestry legislation, a "wood crises" has been generated, which led to higher costs in purchasing, processing and transport. Over time, wood has proved its qualities as an excellent building material, due to its physical and mechanical properties. It is a good thermic and phonic isolator, it is light and resistant, especially if it has been treated against fire, woodworms and fungi. This paper presents generalities regarding wood as a building material, updated and specific data about a log cottage, highlighting its advantages and disadvantages, its building and production costs. The case study could represent a small guidance for investors, giving, at the same time, an overview of the current availability of the total volume of wood in Romania.

1. Introduction

The world wood plan and superior wood products have exceeded the period of their use as roof and auxiliary structures, being increasingly present in the construction of important buildings, such as the ones with large openings (e.g. sports halls, warehouses and industrial halls), and not only. Building holiday cottages in secluded or hard-to-reach areas in Romania has led many investors, architects and builders to prefer wood as the main building material, both for economic and aesthetic reasons. The beauty of the seemingly wooden construction elements, the architectural and structural success, the safety in operation and, last but not least, the low price have attracted positive reviews from many users.

Having multiple qualities, wood is a living material, with cosy, pleasant, physical and mechanical properties. Wooden constructions have proved good behaviour and safety over time, especially if the wood is properly treated against biological agents (insects, fungi) and fire [1].

2. The present situation of the volume of wood in Romania

In Romania, there is the question of the real existence of the quantity of wood that is harvested for production. The National Forestry Institute (NFI) statistical data show that less than half of the growth of forests of the national forest fund is harvested.

According to the definitions that are used in our country, the forest vegetation consists of the national forest fund and the forest vegetation outside the national forest fund (two categories).

Romania has a total forest area of 7.046 million hectares, out of which the land actually covered with trees is 6.9 million hectares. The largest forest area is found in Transylvania, where 37% of the total

land area is covered by forest vegetation, according to data from the first cycle of the National Forestry Inventory (NFI) [2].

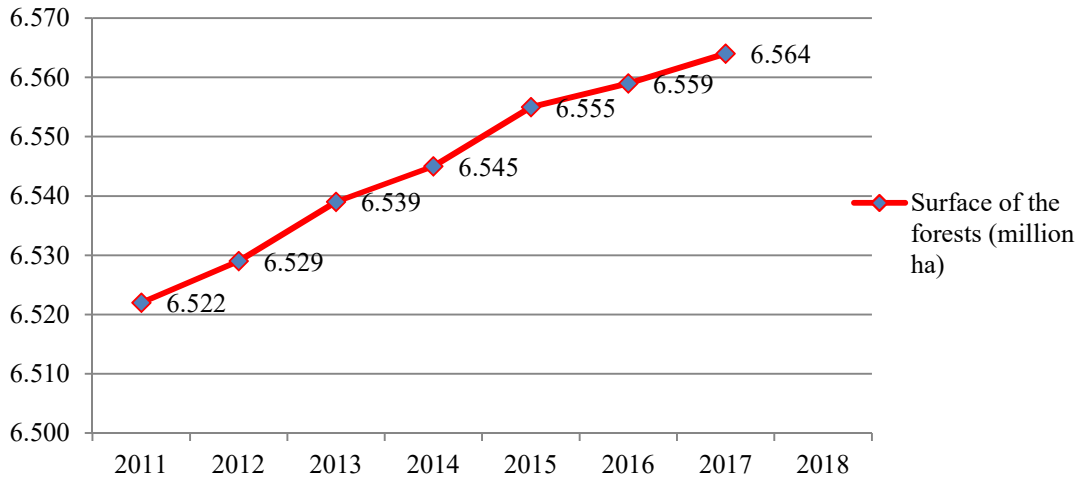

Figure 1. Evolution of the forest fund between 2011 and 2018.

Beech is the main forest species in our country. It occupies 31% of the area covered by the forest. It is followed by softwood species (spruce, fir, pine etc.) with a share of 26%, various hardwood species (hornbeam, acacia, ash, maple etc.) with 20% share and cvercinee or oak species (pedunculate oak etc.) with a share of 16% in the forest area. On the last place there is the group of various softwood species (linden, poplar, willow etc.) which occupies 7% of the forest area [1].

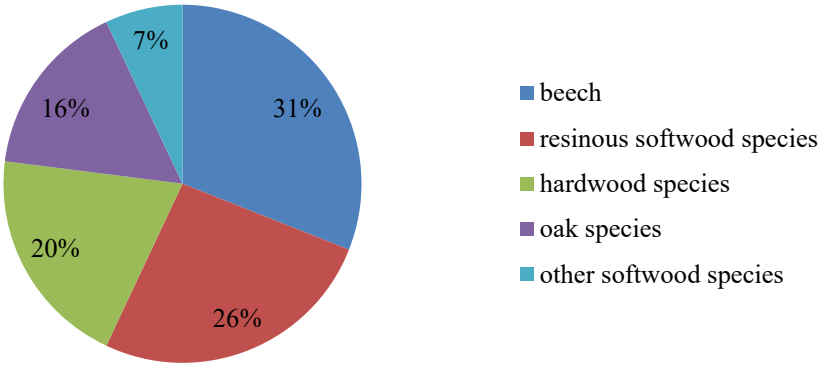

Figure 2. Tree species that can be found in Romanian forests.

Depending on the topography, 65% of the total mountainous region in Romania is covered with forest. For the hill region, the forests represent 27 % of the area and, for the plain region, forests occupy 5% of the area.

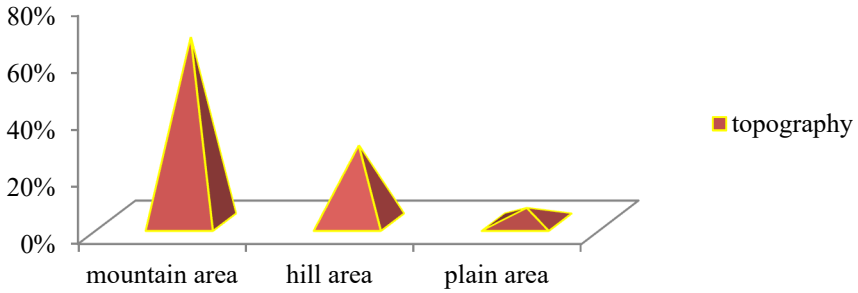

Figure 3. Forest area depending on the topography.

NFI data also reveal that, according to the age class distribution, the largest area of the forest (21%) is in the IInd age class (21- 40 years old), followed by the IVth age class (61-80 years old) and the IIIrd one (41-60 years old) with 19% and 18% of the forest area. Summing up, the forest area of the three age classes represents over 58% of the total forest area.

Nearby age categories are known as age classes. Depending on the source of the trees and the treatments applied, the arboreta can be grouped into 5, 10 or 20 years old. The age classes are expressed in hectares, their summation representing the actual wooded area of the forest in question. However, this area does not always correspond to the total area under regeneration: the difference is non-regenerated land or land affected by the forest administration.

Figure 4. Age classes of arboreta [3].

Out of the total state forests, 60% are in the Ist functional group (having special protection features) and 40% are in the Ind functional group (having both protection and production features).

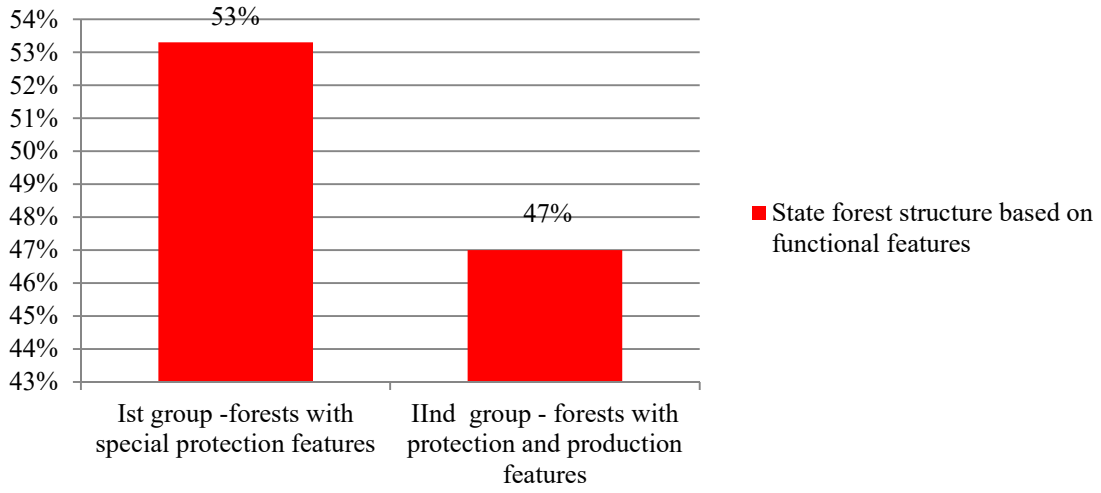

Figure 5. State forest structure based on functional features.

At present, Romania harvests around 18 million m^3 of wood material annually. Considering the annual wood exploitation rhythm, we can say that it is influenced by natural calamities, which temporarily affect certain areas, as well as the periods of restriction provided by the legal regulations. As a result, the most important volumes of wood are exploited within March and April, as well as between September and November.

Considering the wood harvesting species, the largest exploitation is of beech species (33%) and, close to it, the resinous species (31%), as presented in figure 6 [4].

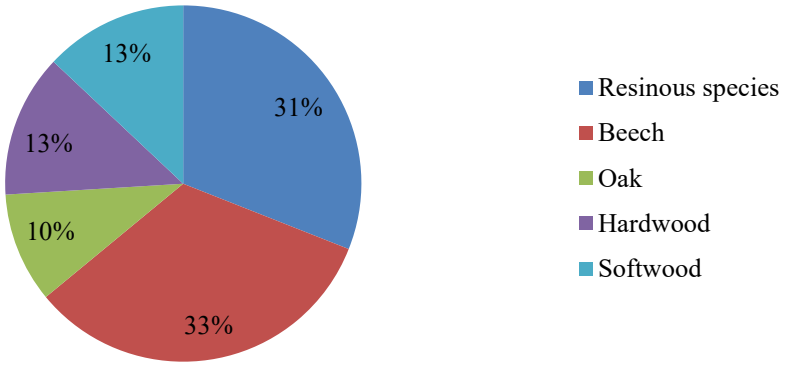

Figure 6. Situation of the wood species exploited per year.

As a result of the legal measures taken in 2015 in order to reduce illegal deforestation and illegal tree harvesting, it can be said that, at the moment, we have enough wood to support the development of sustainable wooden constructions. Probably the most important measure taken was the foundation of the Forest Guards, institution with legal personality established under the Emergency Ordinance no. 32/2015, subordinated to the Ministry of the Environment, Waters and Forests. The Forest Guards provide forestry and hunting inspections and controls of the central public authority responsible for forestry, regardless the form of ownership, of the national forest fund and the forest vegetation outside it. Also, the Forest Radar was a sustainable measure that lead to a significant reduction of illegal

harvesting, due to the easy process of checking the legal status of a tree transport and reporting it to the responsible authorities in case of illegal proof.

Concerns about the regeneration of arboreta on forest funds from which wood has been harvested as a result of the application of main product cuttings, for the afforestation of land without forest vegetation, which have not had other uses attributed to forestry, as well as for the ecological reconstruction of the lands affected by different forms of degradation, have also constituted priority objectives in the last years. The harvesting of forests based on the age cycle classes insures a sustainable and, at the same time, healthy exploitation of wood.

3. Building a wooden cottage

3.1. The Advantages and Disadvantages of Wooden Buildings

This chapter intends to emphasize the main advantages and disadvantages of wood as construction material. As any construction material, it has positive and negative aspects that one must take into consideration before deciding if it is the suitable material for a future house or cottage.

3.1.1. The Advantages of Wooden Buildings. One of the main advantages of wood as constrution material would be its apparently low density compared to relatively high resistance. Compared to the density of the other main building materials (masonry, reinforced concrete, steel etc.), it can be seen that wood is lighter and the ratio between strength and density has the value comparable with the one of steel, both in compression and stretching.

Another advantage is due to the low weight of wood that makes all constructions made of this material exhibit favorable behavior in seismic action, or be placed more easily on difficult foundation terrains. It also requires less consumption of materials in foundation structures. There is a well-known seismic experiment based on wood constructions on the famous pagoda style in Japan, which have been proved to resist to an earthquake of more than 9.0 magnitude.

Also, the easy machining and shaping of wood, both in the plant and on the site, with the possibility of building wood construction in any season without requiring special measures is another important advantage. The execution speed is high, by eliminating wet works specific to reinforced concrete or masonry. The commissioning of timber constructions is possible immediately after the finishing works. The easy shaping also leads to the possibility of making special shapes and gauges that are difficult or even impossible to achieve with other building materials. There are wooden constructions in the form of arches or domes with openings reaching 100 m.

Regarding the thermal properties, we can say that wood is a favorable construction material. Compared to steel, concrete and even brick, the wood has a much lower coefficient of thermal conductivity, which justifies its use as a proper insulation material with good efficiency. Wood provides thermal resistance when passing a heat flow through it, 300-400 times larger than steel and 7-10 times larger than concrete. The linear thermal expansion coefficient along the reduced fiber makes it unnecessary to have thermal expansion joints in wooden constructions and to exhibit a good fire resistance behavior. For resinous wood, for example, the coefficient is 2-3 times lower than the coefficient of thermal expansion of steel and of reinforced concrete [5].

If we take into consideration the economical aspect while building a house or a cottage, the high durability of wooden constructions, which are in an optimum operating system, in terms of environmental conditions could be a plus in choosing wood as construction material. The maintenance costs are normal, except for the exterior polish that requires periodic maintenance (laquer at 7, 8 years). Interventions on wood elements, for consolidation or restoration, are easily made on the spot.

Although it may seem unbelievable at a first glance, wood also has a relatively good behavior in terms of fire resistance. It is a fuel material, but it behaves well in terms of structural resistance to fire since the massive elements are consumed relatively slowly at a rate of 0.5 - 0.7 mm/minute, which implies a decrease in the transversal section of 1 cm on each face, within a quarter of an hour. In the

meantime, the fire temperature can reach 700-800^{o} C. On the other hand, the strength and stiffness of wood inside the charred section remain practically unchanged [5].

The possibility of re-using wood in making other building elements or using it for energy production triggers reduced waste. Also, the outstanding architectural features and cosiness of wood make it be used not only as a structural material, but also as a finishing or apparent material, with special aesthetic effects. There is the possibility to associate wood with steel or concrete, conducive to the formation of efficient mixed structures.

3.1.2. The Disadvantages of Wooden Buildings. Of course that, as any other construction material, wood has its negative parts too, mostly due to the fact that it is a natural product of organic origin, having a non-homogeneous and anisotropic structure. An important disadvantage is the very high variability of characteristics between various species and within the same species, due to very diverse variables. There is also a high variation of mechanical and physical characteristics in different directions than the fiber's direction. Due to the non-homogeneity of the wood structure, the resistance is different along the trunk of the wood and on the cross-section, its variation being between 10 and 40% [5].

Another disadvantage is the high influence of humidity on the physical-mechanical characteristics, on the dimensions and the durability of the wood. For example, moisture variation from 5 to 15% leads to some wood species dropping compression strength by almost 2 times. Increasing humidity also favours the biological degradation of wood, in particular due to the action of fungi, and creates health problems for the people living in the building [5].

The limited range of wood material, both in terms of cross-sectional dimensions and lengths is also a disadvantage. The use of elements in the form of beams or pillars, with large cross-sections (usually over 20 cm) or great lenght (over 5-6 m) often leads to high prices. This disadvantage can be eliminated by using composite elements or elements made of glued battens.

Natural defects in wood (defects in shape and structure, cracks etc.), defects caused by fungi, insects or chemicals, as well as the effects of decontraction and swelling phenomena are important drawbacks in choosing wood as construction material. It is vital to apply a proper treatament against natural attacks on wood when deciding to use it as construction material for a house or a cottage.

3.2. Description of the construction

3.2.1. Functional description. The aim of this paper is to present a case-study on how to make a wooden holiday cottage. At a volumetric level, the concept consists of using the land surface as efficiently as possible. From a functional point of view, the ground floor is the "living space" where the dining room, the kitchen and two service bathrooms are located, and, in the attic, there is the "sleeping space", where there are bedrooms with bathrooms. Having in mind that the cottage could serve as a guest house, the intention was to provide a high level of comfort, so every bedroom has its own bathroom, various in size.

The designed construction has ground floor and attic, with a built area of: Ba = 89.44 m^2 and a usable area of: Ua = 159.1 m^2, of which the ground floor has 66.17 m^2, the attic, designed as first floor, has 69.0 m^2, the terrace has 7.0 m^2, and the balcony has 6.93 m^2. The wood cottage is built of calibrated roundwood with a diameter of 20 cm, and for the construction 75.0 m^3 of finished product are necessary - calibrated wood, equivalent of 94.0 m^3 of raw product - raw wood.

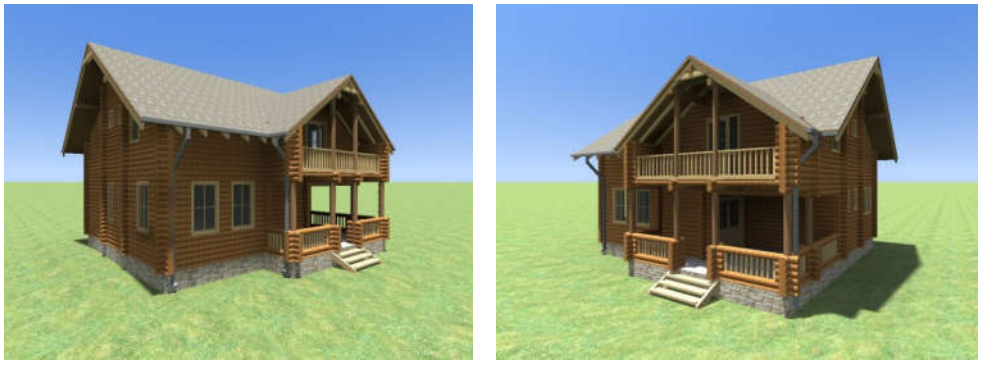

Figure 7. Calibrated log (roundwood) cottage.

The ground floor consists of a living room, a kitchen, two service bathrooms, a lobby, a pantry, the staircase and a covered terrace, as shown below.

Figure 8. Ground floor of the wooden cottage.

Figure 9. Attic of the wooden cottage.

The access in the building is made through the terrace, entering the living room. The first floor, designed as a completely used attic, has four bedrooms, each having a small bathroom, a lobby and the staircase and a covered balcony, as shown in figure 9.

3.2.2. Description of the construction solution. The foundation solution designed for this log cottage consists of rigid continuous foundations with plain concrete soles, class C8/10, with monolithic reinforced concrete elevations and C16/20 reinforced concrete soles and polypropylene fibers. For a better behavior over time, especially in the outdoor terrace area and patio access steps, the concrete slab was additionally reinforced with polypropylene fibers dispersed throughout the whole volume of concrete [6 - 8].

The resistence structure is made up of calibrated roundwood walls, with a diameter of 20 cm. The floor plan over the ground floor is made of square wooden beams that discharge onto the resistence walls. The roof is designed to have a wooden structure with metallic tile cover. The wood used to make the structure of the roof is fir of C24m class and the tiles have been chosen to have a proper colour to fit the natural environment.

The inner compartments are made of calibrated roundwood walls, having a diameter of 20 cm and 10x10 cm trimmed wood. For the bathrooms, specific waterproofing is planned to be used, then ceramic tiles will be attached on the walls and floors. The exterior walls will be treated with special solutions, so as to avoid insects and fungi attacks. On the ground floor, the ceiling will be left in apparent solution. In the attic, there will be a false ceiling made of larch wainscoting. Due to the natural aspect that is intented to be kept in the building and on the outside area surrounding the cottage, natural material and colours were planned to be used, so as to give a pleasant and comfortable view, a cosy atmosphere and a good rapport between price and quality.

The inner and outer carpentry will be made of solid wood, dark brown colour, for a perfect integration with the roundwooded walls. For the external finishes, socket and exterior walls, good quality treatament solutions and a natural laquer will be used to keep the natural color of the roundwood walls. The roof will also be in the same color with the carpentry, a dark brown colour that will give elegance to the entire building but, at the same time, it will make it fit perfectly in the natural environment. Due to the fact that the attic will be fully used for sleeping spaces, the roof system will ensure a good insulation, both against cold and humidity. It will consist of metallic tiles cover, slats, waterproof foil, rafters of 10x15cm, between which fireproof mineral wool of 15 cm width is placed. On the roof, the chimney will also be colorly integrated in the whole assembly of the building.

Concerning the outdoor landscaping, walkways were designed around the cottage, made of prefabricated slabs, which will be placed on a sand bed with 5% slopes. A covered terrace having the floor made of natural stone and green spaces that will be a pleasant scenery for the viewer are also intended to be part of the entire ensemble of the cottage.

4. Conclusions

The estimated average price of such a log cottage in Romania, including the foundation as described above and finishings, could be about 560 Euro/m^2, considering local building and human resources. If we take into account a neccessity of 54.0 m^3 of concrete for the foundation, at the price of 100 euros/m^3, plus 90.0 m^2 of calibrated spruce roundwood, for which the price varies between 40 and 130 euros/m^3, depending on the age class and quality, the tiles and insulation for the roof surface and the interior and exterior facilities, the price will be more than 50,000 euros. It it important to know that the prices mentioned above are the final prices, for the finite materials, including harvesting, calibration, transport, and any other additional costs that may be involved between the harvesting place and the location of the construction. The same is valid for the concrete price, which includes all the costs of production and transport to the final location, and, also, for all the materials used during the building process of the roundwood cottage.

As a conclusion, if one asks whether wood can be considered a sustainable construction material, the answer is certainly YES! According to IFN data, the volume of wood material harvested annually in

Romania is slightly increasing, the measures to keep the balance between the age classes of the harvesting forests is very properly guarded by the responsibles of the forest administrations. More and more people choose wood for their cottages and even for their houses, both as raw material or prefabricated components. In the near future the green buildings and the eco buildings could be considered to have a strong wood basis, hoping to reach energetical independence too, through their facilities [9]. So, wood is a sustainable building material and there is no danger of loosing our forests if we use it.

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