DURABILITY OF TIMBER STRUCTURES IN DIFFERENT EXPLOATATION CONDITIONS

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UDK: 624.011.1.042/.044
DOI:10.14415/konferencijaGFS2017.007
Summary: *Timber as the material for structural building shows the good physical and mechanical characteristics. Thanks to that fact and the number of accompanying qualities of timber in its modern, technologically improved form, rational projecting of high range and various appliance constructions is a usual practice of building today. However, it must be said that besides good, timber as material, also has bad sides. That which is usually questioned is the durability of timber in different exploatation conditions, especially in the direct exposure to bad weather conditions, dynamic loads of high frequency or intensity, fire conditions… In this paper it has been given the review of modern methods and techniques with which, thanks to special technological treatments, carefully solved constructive details, timber structures significantly improve its resistance to different influences and loads and mechanical properties. Some of those methods have been used in practice by the author of this work himself.*

Keywords: *timber, chemistry, constructional details, technological treatment.*

1. INTRODUCTION

Timber structures and materials based on timber are very frequent in building design and construction. The main reasons for this are found in the fact that timber shows many positive characteristics such as the following:

- High mechanical properties at relatively low bulk density, e.g. in comparison to concrete,
- Low value of the coefficient of thermal conductivity(λ),
- High resistance to the frost,

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- Satisfactory resistance to the influence of certain chemical agents to which reinforced concrete and steel are unresisting,
- The ease of processing and more.

In Figure 1 is shown the example of the applicability of timber for building houses in conditions of very low temperatures.

Figure 1. Timber houses in cold mountain conditions

However, as other building materials, timber has a certain number of shortcomings which significantly impair its applicability in construction. Some of shortcomings are:

- Material heterogeneous and anisotropy,
- The presents of various defects in materials,
- Higroscopicity,
- Susceptibility of rotting, insects and microorganisms,
- Generally, permanence in different exploitation conditions.

Through preparing of timber, steps of processing and other technological steps, some of its negative characteristics can be fixed, or even eliminated. The knowledge of physical-mechanical, chemical, rheological and many other properties of timber is thus of great significance.

2. FACTORS THAT INFLUENCE THE DURABILITY OF TIMBER

On the basis of the quotes from bibliography and practical experience it can be concluded that there is a great number of facts which influence the durability of timber. Besides the environmental influence and the moisture of timber, these factors are: the influence of microorganism, fungi and insects, UV radiation, fire resistance, as well as many different mechanical damages and chemical substances.

2.1 Timber moisture

When the content of moisture in timber is taken into consideration it should be considered that it is the organic matter of natural origin. It is known that the lowest quantity of moisture timber contains in late autumn and during winter. That is why this period is the best for cutting of timber. However, no matter when timber is cut it still contains significantly high quantity of moisture which is divided in free and inherent. Free water is that water which flows through the fibers of wood pulp and it is presented as far as there are holes in wood pulp. Inherent water is divided into adhesion and constitutional water. Adhesion water is bounded by physical forces and fills the intercellular space in fibers. Constitutional water is in fact chemically bound water, so it is not found in liquid form, but is the constitutive element of cellulose which timber is made of.
When all free water vaporizes, there is only inherent water in timber. While continuing to dry, timber will start to lose adhesion water first. The lost of adhesion moisture always produces the shrinkage of timber because of compression of fibers. If drying in the phase when timber loses adhesion water is in non controlled conditions (natural drying) deformations and defects of timber accompanied by shrinkage of timber material will appear. The highest shrinkage is in tangential direction (et), less in radial (er), and the least in length (el), that is, in fiber. Because of the uneven drying there are warping, the appearance of cracks and other unwanted phenomena. In figure 2 on the left are tangential (t), radial (r) and length (l) directions in timber in relation to the direction of fiber spreading. In figure 5 on the right are shown deformations of shrinkage (and the opposite process of expansion) in stated directions depending on moisture. The values of shrinkage deformations are different for different types of timber, but mostly are in the following range: ε_l = 0,1–0,4%, ε_r = 2–5%, ε_t = 4–8%. When in drying timber loses all adhesion water its moisture, depending on the type of timber, is in the range between 6% and 12%. Such timber is considered to be dry timber and can be used in construction. In timber there is now only constitutional water and according to rules timber is not dried to the level when the lost of this water would start.

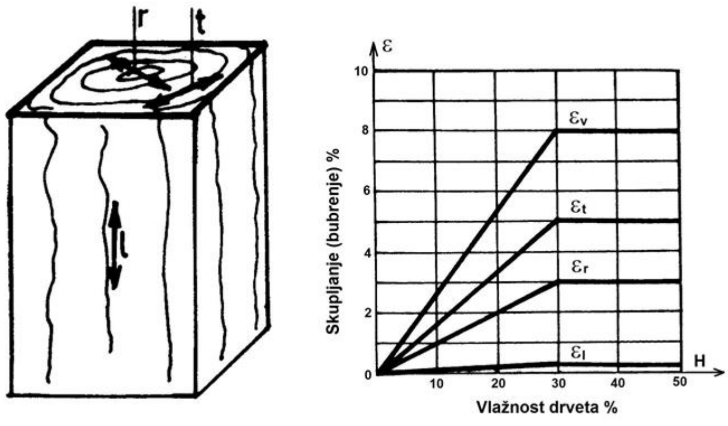

Figure 2. Directions in timber in relation to fiber directions (left) and shrinkage of timber in different directions in the function of timber moisture (right)

2.2 The influence of UV radiation

The resistance of different types of timber is noticeable during the exposure to the sun light (UV rays). As the first sign of the UV influence is the change of colour and erosion of timber surface – timber will become grey. The change of colour is rather intense in the first year of use, while other esthetic changes are negligible. The significant influence of erosion can be noticed only within more than ten years, at the depth of 6 to 8 millimeters. The penetration of UV rays is not deep, and the greatest influence is the decomposition of lignin. Since lignin has the role of binding matter, with its decomposition the consistency of timber tissue lowers, which can lead to the separation of the cellulose fibers from the surface. The exposure to varying weather conditions additionally speeds up deterioration. The cracks that have appeared additionally give way to microorganism, fungi and other vermin, which is another problem.

2.3 The influence of biotic factors

On the surface of timber there are often bacteria and fungi which can colour its surface so that at the beginning of their influence it represents the esthetic problem. Fungi go under the surface and secrete the enzymes that have the ability to decompose lignin and cellulose they feed with. If fungi decompose lignin the attacked part will colour in white and the fibers can easily detach in small bundles (white rot), figure 3. In brown or prismatic rot fungi attack cellulose, while lignin falls apart in the shape of prismatic parts. With both white and brown rot timber has already deteriorated so much that any protection does not have the influence. The influence of fungi significantly diminishes the solidity of timber, and if the constructions are considered, their loads can be annulled.
Fungi spread fastest along fibers, while in radial direction bring to deterioration of the member of timber cells. Fungi multiply best at the temperature of 22 to 27°C and at the timber moisture of 30 to 60%. The preserving of timber at low (under 5°C) or high (above 40°C) temperatures, as well as obtaining low (under 22%) timber moisture stands for the possible way of protecting timber, which is not easy to put in practice.
Besides microorganisms and fungi, timber is attacked by different insects which make channels in timber and damage it mechanically.

2.4 Fire resistance

Timber is inflammable material. It starts to burn at approximately 270 °C, where it changes anatomically and chemically completely. Fire resistance of each building material determines flammability and behavior of the construction built of that material under fire load (temperatures). The influence of extreme fire temperatures destroys all building materials. The difference is only in their behavior in that sense how long the structure can stay in accordance with its purpose.
Materials are divided according to behavior under influence of fire temperature. Thus, material can be flammable, can burn, and still resist far better to fire temperature than material which is inflammable and does not burn. The stated claims are based on

experimental research obtained in the last decade in the world. In figure 3 is shown the diagram of behavior of aluminum, steel and timber construction under fire influence. As the moment of structure fail is taken the load limit of 15% in relation to the load before fire.

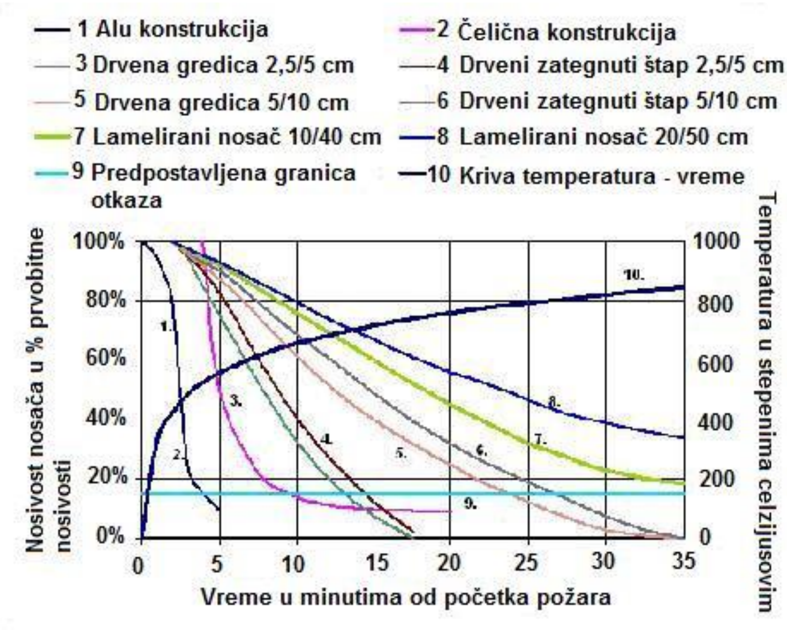

Figure 3. The behavior of aluminum, steel and timber construction under influence of fire

The timber tight bat of thickness of 5/10 cm endured in fire temperature for 26 minutes. Here it should be noticed that the behavior of aluminum and steel construction in fire is independent of the size of cross section, while in timber fire resistance increases immediately with the increase of dimensions of cross section. In table 1 are the results of testing timber and steel columns exposed to fire. The research was carried out in the Institute CSTB in Paris.

Table 1. Resistance to fire of timber and steel column

Type of protection	Resistance to fire	
	Timber column, 15/15 cm, height 230 cm	Steel column, profile HN-100, height 250 cm
Unprotected column	52 min	10 min
Gypsum protection of 1 cm	81 min	60 min
Gypsum protection of 2 cm	118 min	95 min

3. DURABILITY OF TIMBER IN DIFFERENT CONDITIONS

The most important factor of timber durability is the content of moisture in it. Timber in exploit is in hygroscopic balance with air that surrounds it. This balance is unstable, since it depends on the relative air humidity and temperature.
Alternating changes of hygroscopic balance significantly diminish timber durability. On the other hand, when timber is in dry spaces, of constant temperature and relative air humidity, timber has almost unlimited durability, while in moist spaces it has short durability. In other words, timber structures durability depends on the rehabilitation conditions and type of timber. Relative values of durability of common types of timber for our country are shown in table 2. As it can be seen from table 2, oak can be considered as the most permanent tree, while beech shows considerably lower durability.

Table 2. Relative and absolute durability of some types of tree

Type of tree	Relative durability		Absolute durability
	In the air	In fresh water	Unprotected in open/close space
Oak	1	1	120/800 years
Pine	0,4–0,85	0,8	85/1000 years
Fir	0,4–0,67	0,5	–
Beech	0,1–0,60	0,7	60/800 years

4. TIMBER PROTECTION

Considering all the above mentioned reasons we come to a conclusion that in the aim of providing longer timber permeability it is necessary to undergo certain measures of protection. Depending on what bad influence they have been taken, measures of protection are divided into:

- Leaching
- Protection against rot
- Protection against insects,
- Protection against firing and burning.

4.1 Leaching

Timber is ready for use when is dried to the level when it contains only constitutional moisture which in average is around 12%. However, before the process of drying is approached, it should do one other process which is called leaching.

Leaching is, in fact, the process of preparing timber for drying and it consists of soaking the timber and timber material in water or steam. Longer keeping of timber in water produces the dissolution of nutritive ingredients of timber (saps, resin) which in such a way leach out of timber, and water takes their place in timber capillaries. Later, it speeds up and eases the process of drying, and better conditions for applicability of timber protection means are created.
The duration of leaching depends on water temperature and thickness of timber and timber structure. In cold running water leaching takes a long time – one to six months, while in stagnant water that process can last even twice as longer. This process lasts for the shortest time in warm water (the temperature up to 70 °C) and is usually finished after ten days. The fastest way of leaching is steaming which lasts two to three days.
After leaching timber contains a high percentage of moisture and thus it should be dried. Drying is the best to do in dryers under controlled conditions. After finishing the process of drying timber is ready to use and for the applicability of suitable protection measures.

4.2 Protection against rot

Regarding that timber rot starts in moist environment under the influence of microorganisms and fungi, protection against rot consists of preventing the contact of dry timber with moisture and fungi.
The good enough way against rot is coating of the surface with different lacquers, enamels and colours. This is the most spread way of protection today. It is conducted manually or by mechanic coating of timber surface with waterproof and color proof materials. This way of protection will only be of use if timber is well prepared before to obtain good adhesion of the coating substance and timber surface. This protection as well is good against UV radiance. The disadvantage of this way of protection is in that it should be redone after certain time.
Protection against rot is carried out by the use of antiseptics. It is done by chemical products that are poisonous for fungi and microorganisms such as aqueous solutions: natrium fluoride (NaF), blue stone ($CuSO4\text{-}5H2O$), copper sulfate ($CuSO4$), zinc chloride ($ZnCl$) and other. For the same purpose, tar oils, tar from tree and coal, bitumen can be used. Antiseptics can be used in various ways: by coating the product on the surface, irrigation according to the process warm-cold, irrigation under pressure-impregnation, processing by antiseptic pastes.

4.3 Protection against insects

As the preventive means for protection against insects mostly are used the above mentioned antiseptics, provided that because of increased toxicity antiseptics usually are mixed with small quantities of certain substances (pentachlorophenol, phenol oxides and other). In the case that timber has already been attacked by insects different types of insecticides are used in different shapes: as suspensions, aerosols, and even in gas state.

4.4 Protections against firing and burning

For the protection against firing and burning two types of protection are in use in practice:

- Coating of different protective coats on the surface
- Irrigation of timber mass in proper chemical solutions (to the system warm-cols or under pressure-impregnation).

Materials that are used for protection against firing and burning are called antipirens. They are chemical compounds that are made on the base of: boric acid (H_3BO_3),, ammonium sulfate ($(NH_4)_2SO_4$),, ammonium phosphate ($(NH_4)_3PO_4$) and other compounds. The mechanism of timber protection of firing and burning is composed of that during fire there is the chemical dissolution of antipirens and creation of strong acids (sulfuric or phosphor). These acids have the quality of dehydrating of timber and of preventing the creation of easy inflammable high caloric gases. In that way at high temperatures timber does not burn but “smolders” and easily decomposes.
Some of antipirens melt at fire because of heating and form around timber the protective layer which protects the coming of oxide. Others release the uninflammable gases and in such a way prevent the timber and oxide contact. There are also antipirens that at fire temperatures expand (increase density) and create the protective layer around timber not allowing for a certain period for timber to warm to the point of burning.
In figure 9 on then left is shown the image of timber sample which has undergone the testing of the resistance to fire in the Institute IMS in Belgrade, while in the same figure on the right is the image of timber and steel post after fire.

Figure 4. Testing the fire resistance of timber (left), timber and steel column after fire (right)

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TRAJNOST DRVENIH KONSTRUKCIJA U RAZLIČITIM EKSPOLOATACIONIM USLOVIMA

Rezime*: Drvo kao materijal za izradu nosećih građevinskih konstrukcija odlikuje se dobrim fizičkim i mehaničkim karakteristikama. Zahvaljujući toj činjenici i nizu pratećih kvaliteta drveta u njegovoj savremenoj, tehnološki naprednoj formi, racionalno projektovanje konstrukcija velikih raspona i različitih namena uobičajena je praksa graditeljeske sadašnjosti. Ipak, mora se naglasiti da pored dobrih strana drvo kao materijal ima i loših. Ono što se najviše dovodi u pitanje jeste trajnost drveta u različitim eksploatacionim uslovima, posebno u uslovima direktne izloženosti nepovoljnim atmosferskim uticajima, dinamičkim opterećenjima visoke učestanosti ili intenziteta, požarnim uslovima... U ovom radu dat je pregled savremenih metoda i postupaka kojima se drvenim konstrukcijama, zahvaljujući posebnim tehnološkim tretmanima, posebno i pažljivo rešenim konstrukcijskim detaljima trajnost, otpornost na različite uticaje i opterećenja i mehanička svojstva, značajno poboljšavaju. Neki od tih postupaka, primenjeni su u projektantskoj praksi od strane autora ovog rada,*

Ključne reči*: drvo, trajnost, konstrukcijski detalji, tehnološki tretman.*