THE EFFECT OF TREATMENT WITH NaCl SOLUTIONS ON COMPRESSION STRENGTH OF SOME CONIFEROUS WOODS

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Abstract

Among properties which characterize the application of wood in buildings is its compression strength parallel to the grain. In the framework of improvement of this mechanical property, a comparison study, based on the method cause – consequence, was carried out to evaluate the influence of treatment with different concentration of sodium chloride (NaCl) solutions of silver fir (*Abies alba* Mill.) and pine (*Pinus nigra* Arn.) wood, which are the most wood species used for load bearing structures. There were tested 120 samples for each species. The samples were prepared from static bending samples, tested before. These last ones were sawn from kiln dried boards produced from fir and pine logs, originated from central Albania. 90 samples from each species belonged to wood treated for 72 hours in NaCl solutions, respectively 30 in 10% concentrations, 30 in 20% and the last batch in 30% concentration. After weight percent gain was calculated, the treated and non treated samples were dried and conditioned and then tested by means of mechanical testing machine applying the method specified to the norm ISO 3787. The weight percent gain of treated fir in solution of 10% concentration resulted 6.09%, of 20% resulted 4.33% and of 30% respectively 5.39%. Compression strength of non treated fir resulted 37 N/mm^2, while for treated wood in 10%, 20% and 30% NaCl solutions resulted respectively 2.14%, 5.35% and 6.71% higher. Regarding pine wood, the weight percent gain resulted 9.32% for 10% concentration, 3.15% for 20% and 4.02% for 30% concentration. Compression strength of non treated pine resulted 41 N/mm^2, while for treated wood in 10%, 20% and 30% NaCl concentrations resulted respectively 2.73%, 3.34% and 5.22% higher than non treated wood. It seems that treatment of coniferous woods in NaCl solutions affects positively their mechanical properties, opening so positive perspective for structural applications. It presents a simple, low cost and ecological method.

Keywords: wood, compression strength, NaCl solutions.

Introduction

Wood is one of the most important raw materials for construction and for many other uses. It can be found in diverse species which are different in density, colour and durability, mechanical, chemical and technological properties. It is renewable and part of cyclic ecosystem transformations. Its versatile utilization is based on availability as well as on easy processing with low energy requirement.

In an effort to improve its performance, wood has been modified and treated in many different ways. Some of the treatments that have been studied are still in the experimental stage, but many others have been applied. Successful procedures or near the success that can be used to improve wood performance, have been listed dozens of years ago. There are known four main categories of wood modifications, chemical, thermal, surface and impregnation modifications. Unfortunately, most of techniques can not improve all the properties of wood. Some properties become short of after treatment.

One of chemical treatment, formaldehydesation, has been recognized for a long time. It is known as a method with high anti-shrinkage efficiency and gives a small increase in weight of the timber. The process consists in heating the timber in the presence of formaldehyde vapors and a catalyst (mineral acid). By the other side, formaldehydesation is related with negative effects, such as significant reduction of friction and tensile strength (Stamm, 1960).

Another well known chemical treatment, acetylating, has been industrially applied since 1961 in boards used in buildings (Rowell, 1985). According to results regarding to pine wood, is noted that acetyl treatment increases more than 55% the dimensional stability of wood but reduces about 50% its tensile modulus (Ramsden *et al*., 1997). It is found that Anti Shrinkage Efficiency (ASE) of acetyl treated pine, spruce, birch and beech arrive from 45 to 50%, and the modules of elasticity (MOE) and rupture (MOR) are reduced about 15% (Epmeier, 2003). Other studies show that Brinell hardness of acetylated pine is increased up to 20%, but Janka hardness is not significantly affected (Larsson & Simonson, 1994; Papadopoulos & Tountziarakis, 2010). This treatment improves wood's resistance against biodegradation and color changes but reduces some of wood's technological properties (ability of gluing) (Nasheri *et al*., 2005; Papadopoulos *et al*., 2010; Mohebby & Militz, 2010; Ajdinaj *et al*., 2010).

The chemical treatment of wood with polymeric agents intends to fill the timber with substances that do not dissolve in water. The products show significant improvements in dimensional stability, but after a certain time some mechanical properties will be reduce (Stamm, 1960).

Thermal treatment of wood is by far the most advanced commercially in comparison with all various wood modification processes that have been studied. During this process wood is heated under controlled conditions, increasing its dimensional stability (Keith & Chang, 1978). There is always a reduction in mechanical properties, especially of tensile and shear strength in radial and tangential directions, up to 40% (Th.A.Finnish, 2003). Static bending strength is reduced significantly, but there is no a significant effect on the modulus of elasticity (Mitchell, 1988; Bekhta & Niemz, 2003).

Surface modification of wood is used to improve the ultraviolet stability of wood, to change the surface energy of wood (to reduce wetting by water and/or improve compatibility with coatings), as well as to improve bonding between wood surfaces (Hansmann *et al*., 2004; Hill *et al*., 2001; Kiguchi & Yamamoto 1991, 1992).

Almost all modifications and treatments are expensive and present human health and environmental issues. Wood treatment has to represent a process that improves wood properties, but in the same time the material produced, at the end of its life cycle must not present environmental issues greater than those associated with the disposal of untreated wood.

There has been considerable commercial interest shown in wood modification over the past decade, with products based upon thermal modification and furfurylation now being actively marketed. Also, acetylation and impregnation modification are just commercialized.

Although wood treatment has been the subject of many studies for many years, there are many other methods which must be taken into consideration with regard to improvement of wood performance during its application.

Actually, silver fir (*Abies alba* Mill.) and pine (*Pinus nigra* Arn.) wood are the most common coniferous species in Europe and Albania. They are the most wood species used for load bearing structure as well. Among properties which characterize their application in buildings is their compression strength parallel to the grain. In the framework of improvement of this mechanical property, as well as to find more economical and more environmental methods for wood treatment, a study was performed to assess the effect of treatment in different concentrations of

sodium chloride (NaCl) solutions of silver fir and pine wood. The study was focused on maximum crushing strength (MCS) during compression process parallel to the grain.

Materials and method

The study was based on comparative experimental investigation, cause-consequence (Creswell, 2003). The method consisted to quantity evaluation of a specific phenomenon caused by a provocative factor and after that, the evaluation of the same phenomenon in the situation of the factor's absence. In our case, the phenomenon was the crushing strength of two wood species, silver fir and pine woods, and the provocative factor was the treatment in solutions of sodium chloride of the samples.

The test samples were prepared from static bending samples, tested before. These last ones were selected from pieces of kiln dried boards without deformations or structure defects, which could influence on mechanical strength. The boards were sawn from silver fir and pine logs, respectively from areas of Librazhdi and Mirdita regions, located in central and north of Albania.

There were produced 120 samples for measuring the strength in compression parallel to the grain, with dimensions 20×20×50 mm for each species, according to the standard ISO 3787 (ISO3787, 1975). 90 samples from each species were treated for 72 hours in NaCl solutions, respectively 30 in 10% concentrations, 30 in 20% and the last batch in 30% concentration.

To calculate the Weight Percent Gain (WPG), silver fir and pine blocks from the same wood material, with dimensions 20×20×50 mm were immersed, too. Before immersion, blocks were oven dried in temperature 103ºC ± 1ºC, until they reached equilibrium state, corresponding to 0% moisture content and were weighed. The same procedure was repeated after 3 days and the WPG was calculated.

The compression samples were conditioned to reach equilibrium moisture content around to 12% and were tested by means of mechanical testing machine (Controlab, FRANCE) in the Faculty of Forestry Sciences of Tirana. Crushing strength of NaCl solutions treated and non treated samples were calculated in N/mm^2, according to standards ISO 3787 as follows:

$$MOR = \frac{P_{\max}}{bh}$$

where P_{max} was the crushing load in newtons (N), b and h were respectively two edges of the test piece in (mm).

During testing, the density of wood species was measured according to the standard ISO 3131, (ISO3131, 1975).

Results

Mean value of the density of untreated silver fir and pine wood used in our study resulted respectively 0.42 g/cm^3 and 0.57 g/cm^3, with a standard deviation respectively 0.052 and 0.057.

Mean values of weight percent gain (WPG) and bending strength (MOR), together with respective standard deviations, measured in static bending tests are shown in Tables 1 and 2.

The compression strength parallel to the grain of non treated fir resulted 37 N/mm^2, while for treated wood in 10%, 20% and 30% NaCl solutions respectively 2.14%, 5.35% and 6.71% higher. With regard to pine wood, the compression strength of non treated pine resulted 41 N/mm^2, while for treated pine in 10%, 20% and 30% NaCl concentrations resulted respectively 2.73%, 3.34% and 5.22% higher than non treated wood. On the first sight crushing values of untreated woods appeared to be at the same level referring to data reported by literature (Kollmann & Côté, 1968). From examination of results can be noted that crushing strength was

little influenced by the treatment with NaCl, especially for pine wood. This, because of pine presented considerable resin content.

Table 1. Results of weight gain (WPG) and crushing strength of silver fir

Samples	Weight gain [%]	Stand. Dev.	MOR [N/mm^2]	Stand. Dev.
Untreated	0	-	36.93	6.32
10% NaCl concentration	6.09	0.48	37.68	6.66
20% NaCl concentration	4.33	0.26	38.92	5.82
30% NaCl concentration	5.39	0.43	39.41	6.07

Table 2. Results of weight gain (WPG) and crushing strength of pine

Samples	Weight gain [%]	Stand. Dev.	MOR [N/mm^2]	Stand. Dev.
Untreated	0	-	40.87	7.55
10% NaCl concentration	9.32	0.58	42.00	7.73
20% NaCl concentration	3.15	0.24	42.24	6.72
30% NaCl concentration	4.02	0.29	43.01	7.63

With regard to increment of silver fir density, which resulted 4.33 % after treatment in solution of 20% NaCl concentration, the increment of crushing strength with 5.35% appeared to be a pin pointing correlation. Anyway, such increment of density was a negative factor with regard to applications of silver fir wood in constructions. For all samples of fir wood, it was noted a negative correlation between increment of weight percent gain and increment of crushing strength.

With regard to pine wood, for the mid weight percent gain 4.02%, the increment of crushing strength got the highest value, almost 5.22%. As fir, for all samples of pine wood, it was noted a negative correlation between weight percent gain and crushing strength.

It seems that NaCl solutions with concentration 20% give the better results comparing to other concentrations, for both species. During analyses was noted that the salt was located to peripheral substrates of samples. The method applied did not make possible the control of the quantity of NaCl penetrated in the wood. To avoid these issues, the hot NaCl solutions treatment must to be set up. This way can provide dissolution and uniform localization of the salt in all sample's volume, as well as a control on the wood density increment. Even the time of treatment will be reduced considerably.

Conclusions

There has been a significant increase in the use of materials obtained from non-renewable sources as substitutes for timber in some markets. These significant changes in the timber sector have resulted in a significant increase in interest in wood modification as a mean of improving the properties of the material. The modification of wood needs to be compatible with the increasing demands at the environmental level, the social role of forests and woods' and the technical characteristics needed to create certain materials.

In the framework of improvement of mechanical properties, as well as to find more economical and more environmental methods for wood treatment, a study was carried out to evaluate the

influence of treatment with different concentration NaCl solutions on compression strength parallel to the grain of silver fir (*Abies alba* Mill.) and pine (*Pinus nigra* Arn.) wood. The study was based on mechanical tests performed according to norms ISO 3787.

Based on research results obtained during this comparison study we can say that NaCl treatment of silver fir and pine wood presents a better performance in comparison to untreated wood with regard to mechanical features in compression. The immersion of samples in 10%, 20% and 30% NaCl solution concentrations for a period of 72 hours, increases with 2.14%, 5.35% and 6.71% the crushing strength of silver fir and with 2.73%, 3.34% and 5.22% the bending strength of pine wood, while the weight percent gain is respectively 6.09%, 4.33% and 5.39% for silver fir and 9.32%, 3.15% and 4.02% for pine wood. Anyway, up to now, there is no result about effects of NaCl treatment on other physical and mechanical properties of wood. Other methods of NaCl treatment have to be studied to conceive a possible application in the future in industrial scale.

Although the use of timber in some markets has decreased, the consumption of timber overall continues to rise. Projections have been made until the middle of the 21st century that in most cases show a rise in demand for timber and an increase in production (Brooks *et al*., 1996). There is, however, concern that the supply of timber for industrial purposes may not be able to match demand. This requires the urgent development of new technologies to ensure the more efficient use of the resource by, for example, extending the life of timber-based products. In this framework, NaCl wood treatment appears as an ecological method which is not studied profoundly yet. It presents a simple and low-cost wood modification which must be further developed with the aim to clarify shortcomings related to wood application and its performance in buildings.

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