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# ACETYLATED WOOD IN CONSTRUCTIONS

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***Abstract:*** *The durability and resistance of wood and wood products to fungi, insects and moisture, can be increased and obtained by using the appropriate protective agents and various processing techniques. One of the procedures for improving the durability of wood is the acetylation of wood, a chemical modification process, with liquid acetic anhydride which changes the physical, mechanical and aesthetic properties. Because small hydroxyl groups are substituted with larger acetyl groups, the ability of wood to absorb water is significantly reduced and the wood becomes considerably more stable and very durable. This paper presents characteristics, advantages and application area of acetylated wood in constructions.*

***Key words:*** *acetylated wood, properties, advantages, application.*

## 1. Introduction

Wood is one of the oldest building materials. For many years it was the main material for construction because it was possible to use it for creation of simple buildings with very few tools or even without it. Wood is a rewarding material primarily because it can be used multiple times, and demolition of structures made of wood is reduced to their disassembly. Its characteristics allow a high degree of prefabrication, quick installation in the field and immediate habitability. Wood is a renewable, environmentally friendly material because it binds carbon dioxide.

In recent decades, the wood is increasingly used in construction of modern architectural buildings thanks to the development of methods for improving physical and mechanical properties and durability of wood. Properties of wood, such as dimensional stability, water absorption, resistance to biodegradation and mechanical properties can be improved with thermal and chemical processes. Thermal modification involves exposing wood to high temperatures while chemical treatment of wood represents its modification with different chemicals. For decades, various chemicals were applied, such as oil, petroleum products and variety of inorganic chemicals. Out of all methods for chemical modification of wood acetylation is most commonly researched [1].

Due to improved properties, wood remains competitive material in construction industry, especially for various applications in open space: from doors and windows to open porches and bridges.

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## 2. Characteristics of Acetylated Wood

The chemical modification of wood treated with liquid acetic anhydride was discovered in the beginning of 20th century. However, the high costs of the treatment at that time prevented wider use of acetylated wood. Nowadays commercial acetylation is performed mainly in Europe and in North America.

The main task of acetylation is to improve the dimensional stability of wood and its resistance to biodegradation. The wood is impregnated with liquid acetic anhydride in the reactor, heated to 120 ° C and for specific time kept at that temperature, Fig. 1.

Fig. 1. *The chamber for chemical modification of wood*

During that time, the hydroxyl groups of the cell wall polymers (cellulose, polyose and lignin) replace the acetyl groups. During acetylation, acetic acid is formed as a by-product which can be converted into acetic anhydride and be used again, Fig. 2. Acetyl group covalent bond are resistant to hydrolytic degradation and wood absorbs less water and has lower equilibrium moisture content.

Acetylation in laboratory conditions is relatively easy process because samples are small. In commercial applications the dimensions of samples and the type of used wood have an important role. There are certain types of wood that are difficult to impregnate, such as spruce which is not suitable for acetylation if it has large dimensions [2].

Larsson et al. [3-5] have shown that acetylation increases the amount of acetyl groups in wood by about 20%, while in the untreated wood it is 1-2%. Diffusion of new acetyl groups into wood causes cellulose change [6], which, in combination with reduced binding of water molecules, results in increased dimensional stability. Due to acetylation, the equilibrium moisture content of wood becomes very low and wood will stay very dry. If acetylated up to 20% weight percent gain (WPG), the wood moisture content will never exceed 10%. Furthermore it takes acetylated wood a considerable longer time to reach this equilibrium compared to the untreated wood.

Acetylation successfully prevents

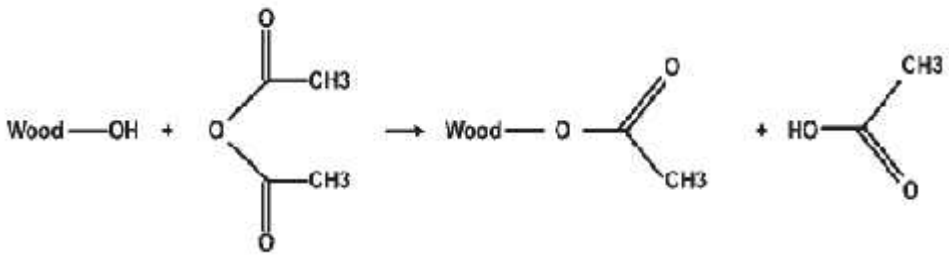


Fig. 2. *The reaction of wood with acetic anhydride [2]*

degradation of wood by white rot and brown rot fungi such as the dry rot fungus and the cellar fungus. It is important to emphasize that the improvement of these characteristics is achieved without negative effects on the mechanical characteristics of wood.

Mechanical properties of wood are influenced in various ways by acetylation. Research by Dreher [7] showed that the compression strength increased by 6-36% and hardness increased by 22-31%. Bending strength and E-modulus in bending were not influenced, while shear strength was slightly reduced [8-12]. Hillis [13] found that bending strength and hardness of Scots pine increased by 15-20%, which still was the case after a long term exposure to high relative humidity. This is opposite to untreated pine which had its mechanical properties decreased when exposed to high relative humidity [14].

After acetylation, swelling and shrinkage of wood can be reduced by up to 80%. Since the shrinkage and swelling are small, paint on acetylated wood will stay good for a very long time and will not demand extensive maintenance. The acetylation has made the wood dimensionally stable and, as a result, stresses were low on the paint film, which, consequently, will stay intact for longer time. This has been shown both in accelerated and outdoor weathering tests [14].

Although the acetylation of wood does not significantly change its natural color at first, the acetylated wood eventually turns gray, which is consistent with the fact that acetylation has stabilized the cellulose but less lignin.

If wood is acetylated well enough it will have durability comparable to first class durability, it does not rot at all in ground contact regions for more than 25 years.

## 3. Acetylated Wood in Constructions

Chemical modification of wood with liquid acetic anhydride results in material with reduced hygroscopicity, increased dimensional stability and natural durability.

Acetylated wood is primarily used in the flooring industry for making high-quality parquet. Due to its high dimensional stability it is suitable for making large format flooring. It can be installed in areas with high humidity, such as saunas, bathrooms or indoor pools. In addition to flooring, acetylated wood is suitable for outdoor use as a floor covering for patios, porches, gardens, around the pools but also for bridges, docks and piers, Fig. 3. It can also be used for making cladding.

Fig. 3. *Floor covering made of acetylated wood*

Acetylated wood is increasingly used for making windows and front doors because it has lower thermal conductivity than that of untreated wood and has ensured stability of the cross-section, Fig. 4. The surface can be treated with transparent and non-transparent coatings where the period between the necessity for renewal of the coating is extended when compared to

untreated wood. Acetylated wood is more stable due to greater resistance to cracking when exposed to outdoor conditions.

Fig. 4. *Front doors and windows made of acetylated wood*

Acetylated woods resistance to water and its improved mechanical characteristics in comparison to the untreated wood, primarily hardness and bending strength, enable new possibilities of its application in the construction industry. For example, making the banks of the canals, railway sleepers, poles for electrical lines or street lighting.

Taking into account the increased durability, resistance to fungi, insects and moisture, acetylated wood is an ideal material for making major structural elements of residential buildings, commercial and sports facilities, bridges.

Moses invisible bridge in the Netherlands, for example, is a work of the Dutch-Belgian architectural studio RO & AD Architecten. The authors of the bridge were inspired by the biblical image of Moses crossing the Red Sea. The bridge was built in Halsteren, in the municipality of Bergen op Zoom in the Dutch area of West Brabant. The river is split in two parts; a bridge passes through the water, not over it, Fig. 5. It creates the illusion that people crossing the bridge go through the river. The bridge is invisible from a distance because the water line reaches all the way to the upper edge of the bridge parapet. It was built from acetylated wood in two months. Life expectancy of this bridge is estimated at 50 years.

Another known acetylated wood construction is the bridge in Sneek in the Netherlands, Fig. 6. Bridge capacity is 60 tons. The bridge is 20 m high and the main carrier beams are made of acetylated glued laminated timber beams that span 35 m,

Fig. 5. *Moses invisible bridge in the Netherlands*

Fig. 6. *Sneek Bridge in the Netherlands*

with dimensions of 1080 by 1400 mm. Approximately 1200 m3 of acetylated wood was used for the construction of the bridge. Wooden beams were designed and custom-tailored in a production plant, transported to the construction site for the finishing of the assembly and erection of the structure on previously completed concrete base. Designed life expectancy of this structure is 80 years.

Acetylated wood is a suitable material for the production of tables, chairs, spaces for children to play and as a wood in the landscape architecture, Fig. 7.

Fig. 7. *Acetylated wood in architectural constructions*

In these applications, the beauty, the strength and the durability of acetylated wood in all weather conditions become prominent.

It can be used as raw material for wood products made from reconstructed wood in order to increase the dimensional stability and mechanical properties. It is a material that will not bend and shrink and at the same is non-toxic and safe for humans and animals. All of these characteristics are kept even when the acetylated wood is in contact with salt water.

## 4. Conclusions

Acetylated wood is a material that has already been present in the European market for many years. Growing consumption and ever wider application points to a series of positive characteristics. First class durability of wood is achieved by acetylation, wood life is increased, span and dimensional stability are attained, while absorption is reduced. Use of acetylated wood in construction helps restoring forest resources because it extends the durability of used wood. The process of acetylation is non-toxic because nothing is added except the substances that already exist in the wood naturally, making it environmentally friendly.

**References**


1. Richter, K.: Neue Materialen und Beschichtungen für den Oberflächenschutz. In: Schweizer Holzbau 7 (2005), p. 12-17.
2. Homan, W.J., Jorissen, A.J.M.*: Wood modification developments*. In: HERON 49 (2004) No. 4, p. 361-386.
3. Larsson, P., Simonson, R., et al.: *Acetylation of solid wood using microwave heating. Part 1*. In: Holz als Roh-und Werkstoff 57 (1999), p. 259-263.
4. Larsson, P., Simonson, R: *Acetylation of solid wood using microwave heating. Part 2*. In: Holz als Roh-und Werkstoff 57 (1999), p. 383-389.
5. Larsson, P., Simonson, R., et al.: *Resistence of acetylated wood to biological degradation*. In: Holz als Roh-und Werkstoff 58 (2000), p. 331-337.
6. Evans, P.D., Wallis, A.F.A., et al.: *Weathering of chemically modified wood surfaces. Natural weathering of Scots pine acetylated to different weight gains.* In: Wood Sci Tech. 34 (2000), p. 151-165.
7. Dreher, W.A., Goldstein, I.S., et al.: *Mechanical properties of acetylated wood.* In: Forest Products Journal 14 No. 2 (1964), p. 66-68.
8. Akitsu, H., Norimoto, M., et al.: *Effect of humidity on vibrational properties of chemically modified wood.* Wood and Fiber Science 25 No. 3 (1993), p. 250-260.
9. Goldstein, I.S., Jeroski, E.B., et al.: *Acetylation of wood in lumber thickness*. In: Forest Products Journal 11 No. 8 (1961), p. 363-370.
10. Larsson, P. and Tillman, A.M.: *Acetylation of lignocellulosic materials.* The International Research Group on Wood Preservation. Document no. IRG/WP/3516 (1989).
11. Milita, H.: *Die Verbesserung des Schwind- und Quellverhaltens und der Dauerhaftigkeit von Holz mittels Behandlung mit unkatalysiertem Essigsäureanhydrid*. In: Holz als Roh- und Werkstoff 49 (1991), p. 147-152.
12. Rowell, R.M. and Keany, F.M.: *Fiberboards made from acetylated Bagasse fiber*. In: Wood and Fiber Science 23 No. 1 (1991), p. 15-22.
13. Hillis, W.E: *High temperature and chemical effects on wood stability*. In: Wood Sci. Technol. 18 (1984), p. 281-293.
14. Homan W, Tjeerdsma B, et al.: *Structural and other properties of modified wood*. Congress WCTE (2000), Whistler, Canada, pp 3.5.1-1–3.5.1.-8