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Effect of sodium chloride and silicon dioxide aqueous impregnation on the selected properties of plywood

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Abstract: *Effect of sodium chloride and silicon dioxide aqueous impregnation on the selected properties of plywood.* Beech veneers were impregnated with aqueous solutions of NaCl and SiO_2 hydrosol. Resultant retentions ranged from 0.44% to 5.2% for 0.1% SiO_2 and 30% NaCl, respectively. It was found that impregnation improved veneer wetting, while shear strengths remained intact. No fire-protection effect was observed.

Keywords: sodium chloride, silicon dioxide, plywood, fire retardant

INTRODUCTION

Production of plywood derived boards makes a significant branch of woodworking industry. The boards are made for building purposes and used for furniture production mainly. The boards used as interior decorations, insulation, construction and lining elements must comply not only with high strength but with high fire resistance requirements also. Today, buildings and building materials must comply with high fire safety requirements. The new buildings and the existing ones must comply with the conditions as provided by fire protection regulations. As far as fire safety is concerned, the materials used for building industry should be characterized by low combustion heat, low smoking intensity in fire conditions and toxicity of combustion products should be leas possible. Producers of wood derived building elements do their utmost to ensure full safety by realization of the goals as mentioned above (Jaskółowski and Borysiuk, 2010)

The fire safety in buildings is regulated in building codes regarding two main areas, the reaction to fire and the resistance to fire. In Poland, the basic requirements for construction materials are enclosed in the Regulation of the Minister of Infrastructure dated 12 April 2002. on the technical conditions to be met by buildings and their location.. Classification and criteria for materials enclosed in the standard PN EN 13501: 2010. The reaction to fire concerns with surface lining materials. The reaction to fire is also called the early fire behaviour taking in account what is happening in the initial stage of fire development (before flashover). The initial stage of fire include parameters like ignition, heat release, fire spread and growth and smoke production. In the initial or pre-flashover fire, the building content is of major importance, however this is in most cases not regulated mainly because contents are not considered as an integral part of a building. The resistance to fire concerns with structural elements and what is happening with the elements under fully developed fire conditions. The resistance to fire deals with the load bearing capacity, integrity and insulation properties. This is important in order to limit the fire to the room of origin. To achieve the goal, which is more than often it is necessary to fire treated wooden materials.

Lowering wood flammability is based on three main methods: (1) impregnation of wood with fire retardant, (2) admixture of a flame retardant with the binder or (3) material

surface treatment by flame retarding agent (Grexa et al. 1999). Most of inorganic fire retardans used for wood protection are based on compounds of phosphorus, chlorine, bromine, boron and nitrogen (Liodakis et al. 2006). It is agreed that ammonium phosphate provides high efficiency, however it is accompanied by high cost (Pyne et al. 1996). However, it must be underlined that impregnation with fire retardant results in reduced flammability of a material. Not does it turn into inflammable one (Wilczkowski 2000, Fojutowski and Grabowski 2000). Fire retardants currently used not only for its advantages, which also have some disadvantages that limit their use. Therefore, always looking for a new fire retardants, which are more effective. Some hopes are associated with nanotechnology, which also is used in the field to reduce the flammability of materials (Mahltig et al. 2008)

In this work two low-cost inorganic compounds – sodium chloride (NaCl) and nano silicon dioxide (SiO_2) were used for veneer impregnation and the effect of the treatment on veneer water wetting, plywood flammability and bondline shear strength were described.

EXPERIMENTAL

Beech (*Fagus syilvatica*) veneers of dimensions 250 × 250 × 1.6 mm^3 were subjected to impregnation (100 mbar, 35 min, 23°C) in aqueous solutions as follows: 15% NaCl, 30% NaCl and 0.1% nano-SiO_2 Then veneers were dried at 103°C to constant weight. Fire retardant retention was calculated from the relation (1):

$$ret = (m_2 - m_1) / m_1 * 100\% \quad (1)$$

ret – retention [%], m_2 – weight of a dry specimen after impregnation [g], m_1 – weight of a dry specimen before impregnation [g].

Veneer water wetting was measured on a Phoenix 300 (SEO, Korea) contact angle analyzer for deionized water. Contact angle (θ) was recorded 60 s after droplet deposition. Presented θ values are means of 15 measurements.

Shear strength tests were made on a universal testing machine (tensile speed 30 mm/min) and calculated from the relation (2):

$$f_v = \frac{F}{S} \quad (2)$$

where:

f_v – tensile shear strength [N/mm^2], F – force at failure [N], S – lap area [mm^2].

Plywood flammability tests were performed according PN-EN 11925:2-2010 standard. X-ray density profiling of the plywood was made on a Da-X (GreCon) instrument at scanning speed 0.05 mm/s.

Three-ply plywood bonding parameters were as follows: platen temperature 120°C, unit pressure 1.0 N/mm^2, time 5 min. Adhesive unit formulation: 20.0 g MUF, 4.0 g wheat flour, 2.0 g hardener H-42. Glue load 120 g/m^2, gel time 60 s at 100°C.

RESULTS AND DISCUSSION

The obtained retention values were as shown in Table 1. It is apparent that the concentration of the impregnating solution is crucial for the amount of fire retardant absorbed by a veneer. The amount of inorganic compound retented in the veneer must be accompanied by its deposition onto veneer surface. Subsequently, its wetting must be affected, too. Since the adhesives used in plywood manufacturing are mostly aqueous solutions of the resins, water contact angle (θ) is the measure of ease of surface wetting by the adhesive. Our results

showed that impregnations with NaCl and SiO_2 significantly improved veneer wetting. The respective data is shown in Table 1.

Tab. 1 Retention (*ret*) of NaCl and SiO_2 and water contact angle (θ)

impregnating agent	***ret* [%]**	**θ [°]**
15% NaCl	3.9	29 ± 4
30% NaCl	5.2	20 ± 6
0.1% SiO_2	0.44	0
non-impregnated reference	–	49 ± 6

Contact angle values demonstrate that hydrophilic compound deposited on the veneer surface improves wetting. However, the strongest effect was observed for silicon dioxide which at concentration as low as 0.1% provided perfect wetting (θ = 0°), while highly concentrated NaCl solutions reduced θ to 30–20° only. The observations allow concluding that that type of impregnation provides satisfactory veneer wetting by aqueous solutions of adhesives, so that tensile shear strengths are to be retained.

The results of shear strength tests were presented in Table 2. The data confirm the above assumption on retaining bondline performance regardless of the impregnation. The difference in shear strength of the SiO_2 series come from the properties of the material rather than from the SiO_2 effect, since wood failure in that series reached 100%.

Tab. 2 Dry tensile shear strength of the plywood

series	**f_v [N/mm^2]**	**sd [N/mm^2]**	**wood failure [%]**
non-impregnated reference	2.1	0.4	100
15% NaCl	2.2	0.4	100
30% NaCl	2.5	0.6	100
0.1% SiO_2	1.1	0.1	100

Interestingly, density profiles revealed increased in density of superficial layers of the veneers impregnated in 30% NaCl solution (Fig. 1). Moreover, for that series – unlike for any other – increased thickness of the bondline is observed. The phenomenon, probably comes from the deposits of the salt in the face layers as well as might possibly ease penetration of the adhesive into the veneer, due to the enhanced wetting.

Plywood flammability tests were performed in two modes: (1) edge exposure and (2) surface exposure. It was shown that smoldering paths observed for the impregnated plywood were not significantly shorter than that for the reference (Table 3). Exception for the series

impregnated in 30% NaCl. It is clear that the treatments with both NaCl and SiO_2 are effective only in the case of short exposure to single flame.

Tab. 3 Smouldering path and flame sustaining ability for the tested plywoods after 15 and 30 s

	Smouldering path [mm]		**Flame sustaining**	
	15 s	**30 s**	**15 s**	**30 s**
non-impregnated reference	40	60	YES	YES
15% NaCl	35	60	NO	YES
30% NaCl	32	47	NO	YES
0.1% SiO_2	40	55	NO	YES

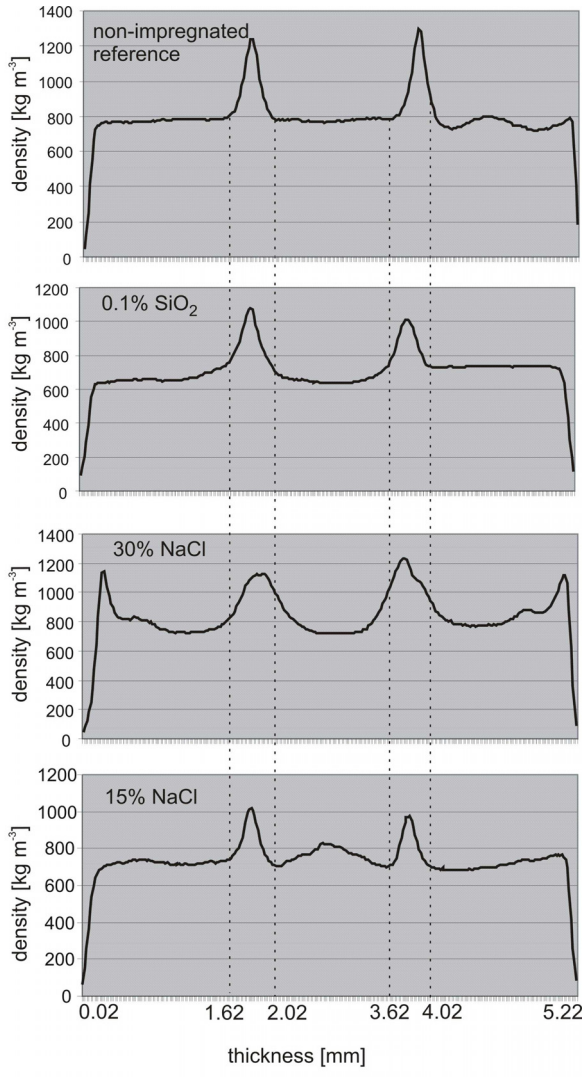

Fig. 1 Plywood density profiles

CONCLUSIONS

It was shown impregnation of veneers in concentrated aqueous solutions of NaCl or diluted SiO_2 did not affect their applicability in plywood manufacturing. Additionally,

absorbed inorganic compound made surface wetting with aqueous solution easier. Tensile shear strengths were not affected. As far as fire retarding activity of sodium chloride and silicon dioxide are concerned, no significant effect was found. However, it seems that using nano-SiO_2 solutions of higher concentration might occur effective in fire protection.

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Streszczenie: *Wpływ impregnacji wodnymi roztworami chlorku sodu i zawiesiną dwutlenku krzemu na wybrane właściwości sklejki.* Przeprowadzono impregnację fornirów bukowych roztworem NaCl i hydrozolem SiO_2. Uzyskano retencje od 0.44% do 5.2%, odpowiednio, dla 0.1% roztworu SiO_2 i 30% NaCl. Wyniki wskazują, że impregnacja powoduje poprawę zwilżalności fornirów, a wytrzymałości na ścinanie pozostają nie zmienione. Nie uzyskano oczekiwanej poprawy odporności na ogień.

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