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The impact of wood staining with specific synthetic dyes on pine wood gluability

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Abstract: *The Impact of Wood Staining with Specific Synthetic Dyes on Pine Wood Gluability*. For the purpose of the paper tests were carried out to determine the shear strength of polyvinyl acetate and polyurethane adhesive-bonded joints in pine wood stained with varied kinds of synthetic dyes used to colour wood or impregnates designed to protect wood. The shear strength of adhesive-bonded joints in stained wood was compared against that in natural wood. The tests were performed in dry and wet conditions.

Key words: wood bonding, wood staining, bonded construction wood,

INTRODUCTION

The recent years have seen remarkable developments in the production of lumber construction elements.

This has been possible due to the introduction of state-of-the-art technologies of processing wood designed for construction. Among other things, the use of weather-proof adhesives, methods of bonding selected lumber and weather-proof impregnates ensure a higher durability of elements, thus alleviating the need to carry out maintenance and apply corrosion protection while they are in use. State-of-the-art technologies of bonded constructions make these elements more durable compared to solid wood and provide more flexibility when it comes to the shaping of these constructions, with transport possibilities being the only limitation.

Impregnation protects wood from the destructive influence of biotic and abiotic factors, whereas its additional staining influences its aesthetics and finish. The quality and aesthetics of finish is greatly enhanced by synthetic dyes being added to impregnates.

MATERIAL AND EXPERIMENT METHOD

The aim of the paper was to determine the impact that staining pine elements bonded with the single element polyurethane adhesive Kestopur 1010 and the single element polyvinyl acetate Kestokol D 400 has on the durability of adhesive-bonded joints. The following dyes used in stains and impregnates were applied: an acid dye – metanil yellow extra 100% (Acid Yellow 36), a base dye – malachite green (Basic Green 4) and a hellion dye – Hellion Red 8B 125% (Direct Red 81). Acid dyes are mainly sodium salts or calcium salts of nitroso, azo, nitro and other dyes. They contain the characteristic groups —$S0_3H$, —COOH and —OH and dissolve in water well, creating small particles in the solution. Base dyes are ammonium, sulphonium or oxonium salts of hydrochrolic, oxalic and sulphuric acids and contain the characteristic amid groups. Base dyes dissolve easily in water and ethanol, creating small particles in the solution. Hellion dyes are a group of direct ones (these are mainly azo dyes with the characteristic group —N=N—), have a higher light resistance and

are primarily used for dying cellulose fibres (wool, viscose, flax, hemps, etc.) and polyamide fibres. Due to longitudinal joints occurring more often than cross joints and shear stress being of predominant importance, a test method of determining the shear strength of adhesive-bonded joints in wood was selected. Their strength was determined following the PN-EN 302-1:2006 standard: "Adhesives for load-bearing timber structures – Test methods – Part 1: Determination of bond strength in longitudinal tensile shear strength". The shear strength was determined for single lap joints samples with adhesive-bonded joints created between two rectangular bonded wooden elements which were subjected to longitudinal tensile stress. The samples were subjected to the stress after they had been soaked for 24 hours and until they were destroyed. Before the samples were bonded, the surfaces of the wood were stained twice by means of a cotton pad and then left in laboratory conditions for their moisture to level off and for the excess of water from the dye to evaporate. The moisture content of the wood to be bonded with the polyvinyl acetate adhesive amounted to 8%, whereas it stood at 15% for the wood bonded with the polyurethane adhesive because it was cured in the presence of moisture. The bonding parameters for the polyvinyl acetate adhesive were as follows: application – 160 $g \cdot m^{-2}$, open time – 5 minutes, press time – 25 minutes at 20^{o}C, press pressure – 0.5 $N \cdot mm^{-2}$. The polyurethane adhesive, in turn, had the following bonding parameters: application – 220 $g \cdot m^{-2}$, open time – 5 minutes, press time – 35 minutes at 20^{o}C, press pressure – 0.7 $N \cdot mm^{-2}$. Natural samples were bonded in the same conditions for the sake of comparison. Before the samples were cut out, the bonded material was conditioned in laboratory conditions for three weeks. For each version of wood being bonded and stained 40 samples were destroyed.

RESULTS

The results of the determination of the shear strength of adhesive-bonded joints for dry conditions are shown in Table 1, whereas Table 2 presents the results for wet conditions.

Tab. 1. The longitudinal tensile shear strength of polyvinyl acetate adhesive and polyurethane adhesive bonds in natural pine wood and wood stained with synthetic dyes in dry conditions.

Dye	**Average shear strength of adhesive-bonded joints in dry conditions**					
	Type of adhesive-bonded joints					
	Polyvinyl acetate			**Polyurethane**		
	R [N·mm^{-2}]	**σ [N·mm^{-2}]**	**v [%]**	**R [N·mm^{-2}]**	**σ [N·mm^{-2}]**	**v [%]**
Metanil yellow	9.1	2.2	26	10.4	2.2	28
Malachite green	8.6	1.7	20	8.9	1.6	14
Hellion red	10.0	1.8	18	10.9	2.0	17
Natural wood	8.5	1.7	16	9.3	1.5	15

Tab. 1. The longitudinal tensile shear strength of polyvinyl acetate adhesive and polyurethane adhesive bonds in natural pine wood and wood stained with synthetic dyes in dry conditions after it was soaked (24 hours).

Dye	Average shear strength of adhesive-bonded joints in wet conditions					
	Type of adhesive-bonded joints					
	Polyvinyl acetate			Polyurethane		
	R [N·mm^{-2}]	σ [N·mm^{-2}]	v [%]	R [N·mm^{-2}]	σ [N·mm^{-2}]	v [%]
Metanil yellow	8.5	0.9	15	9.7	0.8	16
Malachite green	7.9	0.8	13	8.0	0.8	12
Hellion red	9.9	0.6	10	10.6	0.8	13
Natural wood	8.1	0.7	10	8.8	0.3	5

The shear strength of the polyvinyl acetate adhesive-bonded joints in dry conditions in the pine wood stained with two kinds of dyes, i.e. acid and hellion ones, was higher than the strength of the polyvinyl acetate adhesive-bonded joints in natural wood. To be more specific, it was higher by about 7% for the wood stained with metanil yellow, and by about 18% for the hellion dye. The strength of adhesive-bonded joints in the natural and stained wood was similar for the one stained with a base dye – malachite green. Similarly, the shear strength of polyurethane adhesive-bonded joints in dry conditions was higher for the wood stained with acid and hellion dye than the one in the natural wood. The shear strength of the polyurethane adhesive-bonded joints created in the wood dyed with metanil yellow was about 12% higher than the shear strength of polyurethane adhesive-bonded joints in the natural pine wood. The shear strength of the polyurethane adhesive-bonded joints created in the wood dyed with hellion red was about 17% higher. The respective rises may have been caused by the fact that pine wood surface was homogenised as a result of the application of a uniform layer of the dye.

The samples were put in water at the temperature of 20^{o}C for 24 hours, which caused the strength of the adhesive-bonded joints to decrease compared to their strength in dry conditions in all versions of bonding; however, in the case of polyvinyl acetate and polyurethane adhesive-bonded joints in the wood stained with hellion red the fall was at the verge of statistical significance. After being soaked in water, polyvinyl acetate and polyurethane adhesive-bonded joints in the natural pine wood showed a decline of their strength by about 5% against the strengths of the joints tested in dry conditions. After being soaked in water the polyvinyl acetate adhesive-bonded joints showed the following falls in their strengths compared to dry joints: about 7% for samples being stained with metanil yellow and about 8% for samples being stained with malachite green. In the case of the polyurethane adhesive-bonded joints the falls in the strengths were as follows: about 7% for samples being stained with matanil yellow and about 11% for those stained with malachite green. When one compares the strength of adhesive-bonded joints after they were soaked in water as for the strength of adhesive-bonded joints in natural wood, it is possible to ascertain that the treatment merely caused a significant fall in the strength of the polyurethane adhesive-bonded joints in the wood stained with malachite green (about 10%). In the case of the other bonding options the shear strength of the joints in the stained wood was equal to or higher than the shear strength of the joints in the natural wood.

SUMMARY

The figures obtained in the tests and supported by statistical calculations enable presenting the following conclusions:

1. The shear strength of polyvinyl acetate and polyurethane adhesive-bonded joints in pine wood tested in dry conditions and stained with three kinds of synthetic dyes, i.e. acid, base and hellion ones compared to the strength of the adhesive-bonded joints in the natural wood increases in varied degrees depending on the type of dye used.
2. The increase in the strength of adhesive-bonded joints in stained wood may have been caused by the surfaces of bonded wood having been homogenised.
3. A 24-hour-long soaking of the samples in water at 20^{o}C causes a slight fall in the shear strength of adhesive-bonded joints both in the stained and natural wood.

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Streszczenie: *Wpływ barwienia drewna wybranymi barwnikami syntetycznymi na sklejalność drewna sosnowego*. W ramach pracy wykonano oznaczenia wytrzymałości spoin klejowych na ścinanie z klejów polioctanowinylowych i poliuretanowych w drewnie sosnowym wybarwionym różnymi rodzajami barwników syntetycznych używanych do barwienia drewna lub impregnatów przeznaczonych do ochrony drewna. Oznaczenia wytrzymałości spoin w drewnie wybarwionym porównywano z wytrzymałością spoin klejowych w drewnie naturalnym. Badania przeprowadzano na sucho i po moczeniu w wodzie.

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