INFLUENCE OF WATER-THERMAL CYCLIC TREATED ON THE ADHESION OF PROTECTIVE COATS, FORMED ON WOOD

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ABSTRACT

Wood outdoor exposed in normal atmospheric condition affect the colour and texture due to the impact of UV spectrum of light. Although UV rays penetrate into the wood to a depth of not more than 75–100 μm, they are main cause for initiation of weathering it, due to the conduct of complex and physical- chemical processes. As a result of the combined effects of climatic factors, significant structural changes occur in the surface layer (surface erosion). These changes are denoted by the term weathering. This is impact on the aesthetic appearance of the product and the quality of protective coatings. The water plays an important role for wood destruction. The weathering could be minimizing with surface treatment. These treatments can be performed both with soaking up funds forming protective and decorative coatings. The function of these coatings is to receive and minimize external impact and thus extended to life of articles, therefore increase their durability. It is perform an analysis of adhesion of protective and decorative coatings, formed on building wooden products, water-thermal cyclic treated. It is established that the adhesion decrease after water-thermal treating. It is establish that the water penetrates through to the coats distort its adhesion to wood surfaces. It is made recommendation about the conduct of appropriate activities for coating refresh.

Key words: wood elements, protective coats, building products; water-thermal treatment

INTRODUCTION

Outdoor exposed wood change color and texture in result of UV radiation. This rays penetrate in wood on deeep between 75–100 μm and proveke wood weathering in result of complex of phisical and chemical proceses. Finally it caused visible structure changes on surface layers (surface erosion) as the result of combined action of climate factors. These changes are deteminate as wood weahering. On figure 1 is showing a segment of spruce wood sample, which is exposed outdoor for five years. In consequence of these influence wood surface are picked. As results of hard pieces hits carried of surround air, it is removed and formed longitudinal hollow (on fiber direction).

Figure 1: Spruce wood sample 5 years outdoor exposed

It caused influence of aesthetical appearance of wood artilcles. The wood is turned grey and cracked. The water is responsible for cracking , with swelling in cells. The dissociation of this water provokes contraction. When this process became cycling, arise internal bending tension, which made cracking, at the first in the ends and after that on whole surface. The weathering is possible to be minimized with wood surface treatment. It can make by dipping in composition, which formed protective decorative coating. The function of these coatings is to minimize the external factors influence, in the result to increase wood articles life and their durability. These coatings are not eternal. They are growing old also by react of climate factors. (UV rays, water, low and high temperature, IR rays). On the figure 2 is shown a segment of entrance door, 4 years exploit in open terrace. It have good sight, that in the results of climate factors reaction, the coating begin to removed; on support laths is weathering and turned grey. In previous investigation is determinate, that it caused on arised surface tensions, which come of water and thermal influences [Panayotov :2003;2009;2012]. In the result of these influences probably decrease the coating adhesion to wood. In prooving this suggestion, experiments are made for determinating the adhesion of protective decorative coating, formed on samples of wood construction products, protected with polymer coating, exposed on watercycle treatment.

Figure 2: Vision of segment of entrance door, exploited on open terrace

MATERIALS AND EXPERIMENTAL METHODS

Samples with following sizes 50/50/20 mm (the last is on thickness of sample) were made for the experiment. The samples are made by solid wood (н) and three-layer glued wood (ч,с) of Scots pine (Б), larch (Л) and meranti (М) in two ways. The first way the metal stamps are glued on the marks, laying in the surface crossing the fibers direction (н, ч). The second way is heading of fibers direction, i.e. in the crossing section (с). Also, the samples are separate in two main groups: control group (2) and group of samples, exposed on cycling water treatment (3). There are made 16 tests for every set series. The applied index system of different sets is explained with following examples: Мс3- samples of three-layer glued lamella of meranti wood, designed for cycling water-treatment for determining the adhesion, using the metal stamp of heading section; Лс3-samples of three-layer glued lamella of larch wood, designed of cycling water-treatment for determinate the adhesion using a metal stamp glued on crossing section; Бс3-samples of three-layer glued lamella of Scots pine wood; designed for cycling water-treatment for determining the adhesion using a metal stamp, glued on the cross section. On the all sides of the samples are formed covered coatings with system, created by company Sikkens- Belgium, composed by preservative stain „Cetol WP 567 BPD" and topcoat „Cetol WF 950". Preservative stain „Cetol WP 567 BPD" is based on acrylate copolymer with beige-brown color (contains azure photo protective pigments). It is characterized with density 1,006 kg/l and viscosity 10,8 s, determinate by DIN 4. Top coating Cetol WF 950 is also water based acrylate copolymer. It is characterized with density 0,978 kg/l and viscosity 10,6 s, determinate by DIN 4. The coatings are made in laboratory conditions, using a brush. The sizes of samples are measured using a caliper-gauge with 0,05 mm accuracy. The samples are measured with electronic precision balance KERN EW with 0,001 mg accuracy in the beginning and in the end of process, which is made for determining the expenses and the containing of the liquid and dry coating. After the complete dry in room conditions, the samples are exposed of triple cycle water-treatment, which is consisted in contiguous soaking in water [72 h], freezing in refrigerator in minus 18 ^{o}C [7 d], UV irradiation [72 h], heating with IR heater [4 h], convective heating in drying kiln in 60 ^{o}C [4 h]. After 2 months conditioned in room conditions metal stamps are glued with cyanoacrylate glue Loctite, made by company Loctite Ireland Ltd.-Dublin in license of Henkel-Germany. After 3 full days conditioned in room conditions wresting strength is determinate on universal examined machine FU-1000 with aggregate, showed on figure 3. The adhesion is calculated on equation (1):

$$\sigma_a = 0{,}032.F, N/mm^2, \qquad \textbf{(1)}$$

Where F is draw power, wresting the metal stamp in kg. The measured results are standard deviation calculated using the method of the smallest squares. For proving the differences coefficient of Student – m_d is calculated with equation (2):

$$\mathrm{m_d} = \frac{\sigma_{a2} - \sigma_{a3}}{\sqrt{E_{r2}{}^2 + E_{r3}{}^2}} \leq 3 \qquad \textbf{(2)}$$

where: σ_{ai} is a medium arithmetical value of adhesion of following comparable series; E_{ri} is medium arithmetical mistake of adhesion in following comparable series.

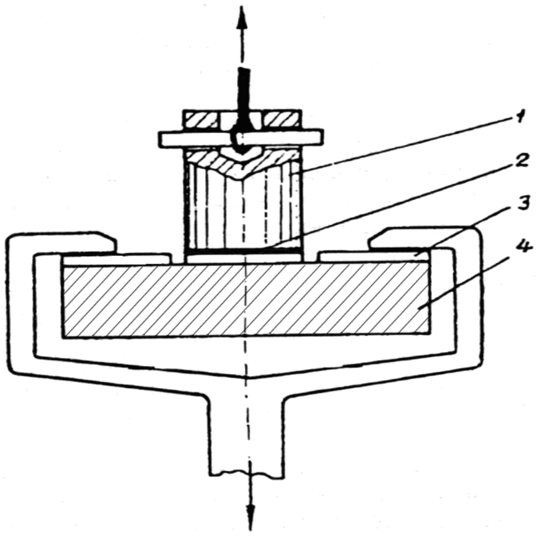

Figure 3: Aggregate for measurement of adhesion of the protective-decorate coating to the wood. 1-metal stamp; 2-glue film; 3-protective coating; 4-sample

RESULTS AND ANALIS

Medium values of the results are showed on table 1, 2; photos 4 and 5. In table 1 are showed medium arithmetical values of adhesion of not-treated and water-thermic treated protective coatings, formed on samples, made by natural solid and glued wood of larch, Scots pine and meranti. In the analyze of these results is proved that medium arithmetical values of the adhesion of not-treated coatings to the wood vary between 4,68 ± 0,18 to 14,24 ± 0,33 N/mm^2; on treated vary between 2,72 ± 0,18 to 5,76 ± 0,76. The differences in values of adhesion between two groups are authentic, becouse the coeficient of Studant has values, larger than 3 (vary between 4,63 to 38,09). The dry containing of coatings in both groups is the same. In not-treated coatings dry containing vary between 137 g/m^2 to 241 g/m^2; in treated coatings between 106 g/m^2 to 197 g/m^2. In analys of these values for different types of wood and the place of the metal stamp is determinated the highest values of adhesion are on not-treated coatings, created on cross section of the samples, i.e. heated of fibre direction. For example, samples made by glued wood of Larch adhesion cross to the fiber direction is 11,36 ± 0,21 *N/mm*^{2}, heated of fiber direction is 14,24 ± 0,33 *N/mm*^{2}. The difference of 2,88 N/mm^2 is authentic, becouse the coeficient of Studant has value of 6,40. In samples, made by glue wood of Scots pine, the adhesion crossing the fiber direction is 8,16 ± 0,31 *N/mm*^{2}, heated of fiber direction is 11,68 ± 0,31 *N/mm*^{2}. The difference of 3,52 N/mm^2 is authentic, becouse the coeficient of Studant has value of 8,03. In samples, made by glue wood of meranthi, the adhesion crossing the fiber direction is 4,68 ± 0,18 *N/mm*^{2}, heated of fiber direction is 11,36 ± 0,15 *N/mm*^{2}. The difference of 6,68 N/mm^2 is authentic, becouse the coeficient of Studant has value of 15,63. This can be explained with adhesion measurements in direction, crossing the fiber direction the destruction is prevalent cohesionally on the wood (summerwood vary between 55 % to 95 %). This fact shows that the cohesion (adhesion) of the coating has higher values in tense strength in wood in direction crossing the fiber direction. This occurrence is showing very good on picture, showed on figure 4.

Table 1:

Not-treated coatings				Treated coatings				m_d
Index	M_{cd} $[g/m^2]$	$\sigma_a \pm E_r$ $[N/mm^2]$	**R %**	**Index**	M_{cd} $[g/m^2]$	$\sigma_a \pm E_r$ $[N/mm^2]$	**R %**	
$Л_{н2}$	147	5,28 ± 0,32	90КД	$Л_{н3}$	136	3,52 ± 0,21	80КД	4,63
$Л_{ч2}$	139	11,36 ± 0,21	95КД	$Л_{ч3}$	106	2,72 ± 0,18	60КД	30,25
$Л_{с2}$	165	14,24 ± 0,33	95АГП	$Л_{с3}$	140	2,56 ± 0,21	100АГП	29,95
$Б_{н2}$	181	11,04 ± 0,67	55КД	$Б_{н3}$	146	5,76 ± 0,76	70КД	5,22
$Б_{ч2}$	241	8,16 ± 0,31	90КД	$Б_{ч3}$	113	3,48 ± 0,32	50КД	10,51
$Б_{с2}$	145	11,68 ± 0,31	80АГП	$Б_{с3}$	184	3,84 ± 0,32	100АГП	17,42
$М_{н2}$	168	5,64 ± 0,33	90КД	$М_{н3}$	146	3,04 ± 0,21	100АГП	6,67
$М_{ч2}$	137	4,68 ± 0,18	80КД	$М_{ч3}$	136	3,20 ± 017	100КД	5,92
$М_{с2}$	144	11,36 ± 0,15	85АГП	$М_{с3}$	197	3,36 ± 0,14	100АГП	38,09

Signature: M_{cd} - dry containing of the coating; σ_a -adhesion of coating to the wood; E_r - medium faux; R-prevalent destruction;КД-cohesional destruction on wood; АГП-adhesion destruction between the sealer and coating.

The prevalent destruction is in direction of the fiber direction (heated on fiber direction) is adhesionally in the board sealer-coating (ASC vary between from 80 % to 95 %).

Fifure 4: Vision of examinated samples of series 2-controls.

Figure 5: Vision of examinated samples if series 3-cycled treated

The differences in the adhesion of treated coatings in different types of wood are very small and unauthentic. In samples, made by glued wood of meranthi, the values of adhesion are as follow: 3,20 ± 017 *N/mm*^{2} in direction crossing of the fiber direction and 3,36 ± 0,14 *N/mm*^{2} in direction heated on fiber direction.. In samples, made by glued wood of Scots pine, the values of adhesion are as follow: 3,48 ± 0,32 *N/mm*^{2} in direction crossing of the fiber direction and 3,84 ± 0,32 *N/mm²* in direction heated on fiber direction. In samples, made by glued wood of Larch, the values of adhesion are as follow: 2,72 ± 0,18 *N/mm²* in direction crossing of the fiber direction and 2,56 ± 0,21 *N/mm²* in direction heated on fiber direction. These values are not too big and between the different wood species. They are also not authentic, because the coefficient of Student is also less than 3. Sensible decrease of adhesion of formed coatings after cycled water-thermic treatment is due to swallowing and evaporation of water by wood samples. The mass changes of examined samples are showed in table 2, 3 and 4.

Table 2: Mass changes in first cycle

Index	72 h – water treatment			7 d freezing conditioned		72 h UV irradiation		4h IR irradiation and 4 h drying kiln conditioned in 60 ^oC	
	Мн1 [g]	Мв1 [g]	ΔМв1 [g]	Мх1 [g]	ΔМх1 [g]	Muv1 [g]	ΔMuv1 [g]	Mir1 [g]	ΔMir1 [g]
Лн3	21,072	25,885	4,813	25,691	0,194	22,433	3,258	21,681	0,752
Лч3	28,198	31,259	3,061	31,185	0,074	29,179	2,006	29,116	0,063
Лс3	30,698	32,695	1,997	32,601	0,094	31,647	0,954	31,143	0,504
Бн3	25,434	30,654	5,220	30,536	0,118	28,683	1,853	26,027	2,656
Бч3	28,475	32,958	4,483	32,804	0,154	29,573	3,213	28,970	0,693
Бс3	29,038	32,101	3,036	32,024	0,077	30,278	1,746	29,964	0,314
Мн3	24,724	25,999	1,275	25,756	0,243	25,399	0,357	25,126	0,273
Мч3	20,077	23,248	3,171	23,141	0,107	20,982	2,159	20,518	0,464
Мс3	17,151	18,561	1,410	18,411	0,150	17,724	0687	17,289	0,435

Table 3: Mass changes in second cycle

Index	72 h – water treatment			7 d freezing conditioned		72 h UV irradiation		4h IR irradiation and 4 h drying kiln conditioned in 60 ^oC	
	Мн [g]	Мв2 [g]	ΔМв2 [g]	Мх2 [g]	ΔМх2 [g]	Muv2 [g]	ΔMuv2 [g]	Mir2 [g]	ΔMir 2 [g]
Лн3	21,681	29,287	7,606	29,122	0,165	22,272	6,850	21,072	1,200
Лч3	29,116	34,736	5,620	34,643	0,093	29,163	5,480	28,198	0,965
Лс3	31,143	35,301	4,158	35,028	0,273	31,778	3,250	30,698	1,080
Бн3	26,027	34,331	8,304	34,121	0,210	26,646	7,475	25,434	1,212
Бч3	28,970	36,696	7,726	36,614	0,082	29,520	7,094	28,475	1,045
Бс3	29,964	34,380	4,416	34,183	0,197	30,145	4,038	29,038	1,107
Мн3	25,126	27,090	1,964	27,010	0,080	25,305	1,702	24,724	0,581
Мч3	20,518	24,109	3,591	24,010	0,099	20,691	3,319	20,077	0,614
Мс3	17,289	19,741	2,461	19,721	0,020	17,624	2,097	17,151	0,473

Table 4: Mass changes in third cycle

Index	72 h – water treatment			7 d freezing conditioned		72 h UV irradiation		4h IR irradiation and 4 h drying kiln conditioned in 60 ^oC	
	Мн, [g]	Мв3 [g]	ΔМв3 [g]	Мх3 [g]	ΔМх3 [g]	Muv3 [g]	ΔMuv3 [g]	Mir3 [g]	ΔMir3 [g]
Лн3	21,072	24,800	3,728	24,780	0,020	21,926	2,854	21,616	0,310
Лч3	28,198	31,677	3,479	31,636	0,041	28,996	2,640	28,786	0,210
Лс3	30,698	33,243	2,545	33,230	0,013	31,382	1,848	31,037	0,345

Index	72 h – water treatment			7 d freezing conditioned		72 h UV irradiation		4h IR irradiation and 4 h drying kiln conditioned in 60 °C	
	Мн, [g]	Мв3 [g]	ΔМв3 [g]	Мх3 [g]	ΔМх3 [g]	Muv3 [g]	ΔMuv3 [g]	Mir3 [g]	ΔMir3 [g]
Бн3	25,434	32,398	6,964	32,393	0,005	26,773	5,620	25,872	0,901
Бч3	28,475	34,485	6,010	34,317	0,168	29,403	4,914	28,815	0,588
Бс3	29,038	32,408	3,370	32,343	0,065	29,792	2,551	29,333	0,459
Мн3	24,724	26,038	1,314	25,958	0,080	25,113	0,845	24,733	0,380
Мч3	20,077	22,807	2,730	22,623	0,184	20,641	1,982	20,226	0,415
Мс3	17,151	18,726	1,575	18,705	0,021	17,546	1,159	17,152	0,394

Description: Мн- mass at he beginning; Мв-mass after water treatment; Мх-mass after freezing treatment; Muv-mass after UV irradiation; Mir-mass after IR irradiation and drying kiln.

It is obviously the values of mass of the samples are higher after water treatment and the values are lower after next freezing, irradiation and heating, but before reaching the first stage. In these treatment, especially after heating are showing soft wrinkling in the forehead of the samples without other visional defects of the coatings.

CONCLUSION

Three-cycled water-heated treatment of protective-decorative coatings leads to obvious decrease of the cohesion (adhesion) to the wood substrate, but it is not enough for seriously damages. The values of adhesion are still enough, the inner pressure are still less for creating crackle of the wood and vision of slapping to the protective polymer film. The observed occurrences are showed formed coatings with system “Sikkens” are water penetrating (breathing), contained photo protectors are effective. The applied water-heated three-cycled treatment is not enough for imitating the real atmosphere influence (it is not included the factor of movement of mechanical parts in air surroundings).

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