

## **Durability of water-soluble coatings on wood, weathered in natural conditions**

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**Abstract:** *Durability of water-soluble coatings on wood, weathered in natural conditions.*

The appearance and durability of coatings on wood joinery is important for economic and aesthetic reasons. This paper discusses the results of observations carried out after 36 months of exposure in natural conditions according to the requirements of PN-EN 927-3. The degree of changes of paint coatings applied to samples of wood – pine and larch, was evaluated.

*Keywords:* exterior wood joinery, paint coatings on wood, natural weathering of paint coatings, color change, appearance change, adhesion.

### INTRODUCTION

The user of any product (including construction products) is interested most in its suitability, functionality and reliability. For wood joinery, the functionality and reliability of its operation is greatly affected by the type and quality of paint coating. Paint coating – provided it retains its continuity – ensures reduction of adverse phenomena accompanying the changes of linear dimensions of respective joinery elements, thus protecting the wood against deformations and the joinery structure against mechanical damage. In turn, maintaining continuity of the coating as well as uniformity of color and gloss ensures acceptable degree of aesthetics. These properties jointly comprise the criteria for economic evaluation of the applied solution.

Joinery, especially the exterior joinery (external windows and doors) made of wood requires surface finish to eliminate or at least mitigate the impact of variable thermal and hygrographic conditions on its structure and, additionally, to ensure acceptable degree of aesthetics. Finishing with water-soluble coatings has been, in the recent years, the main surface finish method. Wood coatings of various types, including water-soluble coatings, were the subject of interest of many papers [Paprzycki, Proszyk, Krystofik, Lis, Nożewnik-Mateńko, Kędzierski, Policińska-Serwa, Sudoł et al.] and still the available knowledge is insufficient, particularly that related to the possibility of estimating durability of coatings in years, evaluation of changes in their physical appearance and appearance during use, relationship between changes in physical properties with changes in appearance as well as quick methods for estimation the expected optimum lifetime. Systematic observation of coating behavior over time, together with a possibility to analyze the changes and their rate is necessary for obtaining knowledge being of particular interest when launching new products on the market and when a need arises for preparation of expert opinions on this subject.

This paper presents the results of studies evaluating the changes in properties of water-soluble coatings applied to pine and larch wood surfaces which occurred as a result of action of natural factors present in the urban environment of Warsaw. The scope of this study includes the evaluation of appearance and properties of coating before weathering and after natural weathering in multi-year cycles, together with comparison of observation results of the same coatings but weathered artificially by UVTest device according to the method described in standard No. PN-EN 927-6.

### EXPERIMENTS

The program of tests has been prepared in accordance with recommendations of applicable standards and own procedures. The samples for natural weathering tests were prepared according to the recommendations of standard No PN-EN 927-3:2008, whereas the samples for weathering tests in

artificial conditions were carried out according to recommendations of standard No PN-EN 927-6. The samples have been made of the following wood: larch and pine, without included sapwood and with growth ring orientation between 5% and 45%.

Paint coatings have been applied in industrial conditions, by method recommended by the coating system manufacturer. Prior to coating application, the wood has been conditioned to achieve humidity recommended by the coating system manufacturer. The same water-soluble coating system has been applied on both wood species.

The coating system include:

- wood preservation, by immersion method;
- priming coating, by immersion method;
- intermediate coating, spray application (180-200µm wet film thickness);
- protection of frontal cross-sections;
- top coating, spray application (150-175µm wet film thickness);

After curing of the coatings, the first round of laboratory tests, also known as opening tests, were conducted. Parameters which are the most important for window users were evaluated and include both the evaluation of surface appearance and mechanical properties. The criteria for evaluation of sample surface appearance were the properties characterizing the degree of bubbling, scaling, cracking, color, gloss, adhesion to substrate, furthermore the checks included hardness and abrasion resistance of coatings, chalking, stickiness, resistance to scratching; besides, each sample was weighed before exposure.

The impact of natural environment on the behavior of coatings was assessed systematically, i.e. quarterly in the first year and twice a year in subsequent years.

The impact of artificial weathering was evaluated after 12-week action, as per PN-EN 927-6.

The tests of hardened coatings were carried out according to generally adopted testing methods set out in PN-EN ISO standards. On the surface of samples – after multi-year exposure, dried dust, sand particles and sporadically rainwater marks were present. The sample surfaces after weathering exposure in natural conditions were carefully rinsed with water and dried mechanically. No chemicals agents were used for cleaning of the samples. No biological corrosion signs were found on the surface of samples.

## RESULTS

This paper presents the results of selected tests of paint coatings applied on pine and larch wood substrate. These tests have been found to most accurately represent the degree and rate of changes observed during natural action of atmospheric factors during exposure. Tables 1 and 2 present test results after exposure to natural weathering carried out in Warsaw in annual intervals. Tables 3 present results after exposure to artificial ageing 12 weeks in UVTest, accordance EN 927-6.

The impact of artificial environment was evaluated after 12 weathering cycles that took a total of 12 weeks. Each cycle included:

24 hours of condensation, T45+30C;

168 h of intermittent actions:

2.5 h illumination by UVA -340 lamp, radiation intensity of 0.89 W/m<sup>2</sup> (wavelength 340 nm),

T60+30 C;

0.5 h spraying with demineralized water without UV action, spraying intensity of 6-7 l/min.

**Table 1**

List of test results of coatings before and after natural weathering on pine wood

Test name	Test results, exposure time – months, average values												Test standard
	0	12	$\Delta_{12-0}$	24	$\Delta_{24-12}$	36	$\Delta_{36-24}$	48	$\Delta_{48-36}$	60	$\Delta_{60-48}$	$\Delta_{60-0}$	
<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>	<i>8</i>	<i>9</i>	<i>10</i>	<i>11</i>	<i>12</i>	<i>13</i>	<i>14</i>
Gloss <sup>1)</sup>	46.1	45.4	0.7	44.8	0.6	43.7	1.1	36.1	7.6	29.9	6.2	16.2	PN-EN

Test name	Test results, exposure time – <i>months</i> , average values												Test standard
	0	12	$\Delta_{12-0}$	24	$\Delta_{24-12}$	36	$\Delta_{36-24}$	48	$\Delta_{48-36}$	60	$\Delta_{60-48}$	$\Delta_{60-0}$	
<i>I</i>	2	3	4	5	6	7	8	9	10	11	12	13	14
													ISO 2813
Adhesion <sup>2)</sup>	0	0	0	0	0	1	1	1	0	1	0	1	PN-EN ISO 2409:
<b>Colour<sup>3)</sup></b>													PN ISO 7724 -1; PN ISO 7724 -2; PN ISO 7724 -3
L	37.52	36.51	1.01	35.62	0.89	34.92	0.70	30.20	4.72	29.14	1.90	9.22	
a	14.15	13.35	0.8	11.74	1.61	10.10	1.64	8.10	2.00	7.97	1.95	8.00	
b	15.69	13.28	2.41	11.90	1.38	10.60	1.30	10.10	0.50	9.99	1.08	6.67	
<b>Initial appearance</b>													PN-ISO 4628-1; PN-ISO 4628-2; PN-ISO 4628-4; PN-ISO 4628-5
- blistering	(S0)0	(S0)0	0	(S0)0	0	(S2)1	(2)1	(S2)1	0	(S2)1	0	0	
- flaking	(S0)0	(S0)0	0	(S0)0	0	(S0)0	0	(S1)1	0	(S1)1	0	0	
- cracking	(S0)0	(S0)0	0	(S0)0	0	(S0)0	0	(S0)1	0	(S0)2	(0)1	0	
<sup>1)</sup> measurements with a spectrophotometer, in the following measurement conditions: lighting d/8, observer 10°, normal illuminator D65, without gloss trap, 10 measurements for each sample <sup>2)</sup> measurement with a multi-blade device with blade distance of 3 mm, 3 measurements for each sample <sup>3)</sup> measurements with a glossmeter, measurement angle of 60°, light beam directed in parallel to fibres, 5 measurements for each sample													

**Table 2**

List of test results of coatings before and after natural weathering on larch wood

Test name	Test results, exposure time – <i>months</i> , average values												Test standard
	0	12	$\Delta_{12-0}$	24	$\Delta_{24-12}$	36	$\Delta_{36-24}$	48	$\Delta_{48-36}$	60	$\Delta_{60-48}$	$\Delta_{60-0}$	
<i>I</i>	2	3	4	5	6	7	8	9	10	11	12	13	14
Gloss <sup>1)</sup>	40.1	39.0	1.1	37.9	1.1	36.0	1.9	24.0	12.0	23.3	0.7	16.8	PN-EN ISO 2813
Adhesion <sup>2)</sup>	0	0	0	0/1	1	1/2	1	1/2	0	1/2	0	1/2	PN-EN ISO 2409:
<b>Colour<sup>3)</sup></b>													PN ISO 7724 -1; PN ISO 7724 -2; PN ISO 7724 -3
L	36.43	36.12	0.31	35.69	0.43	35.12	0.57	29.07	6.05	28.07	1.00	8.36	
a	13.58	13.48	0.10	11.33	2.15	10.89	0.44	10.08	0.81	10.00	0.08	3.58	
b	15.37	14.25	1.12	11.75	2.50	11.11	0.64	8.50	2.61	7.30	1.20	8.07	
<b>Initial appearance</b>													PN-ISO 4628-1; PN-ISO 4628-2; PN-ISO 4628-4; PN-ISO 4628-5
- blistering	(S0)0	(S0)0	0	(S0)0	0	(S2)4	(2)1	(S2)4	0	(S2)4	0	(2)4	
- flaking	(S0)0	(S0)0	0	(S0)0	0	(S1)1	0	(S1)1	0	(S1)1	0	(1)1	
- cracking	(S0)0	(S0)0	0	(S0)3	(0)3	(S0)3	0	(S1)4	(0)1	(S1)4	0	(1)4	
<sup>1)</sup> measurements with a spectrophotometer, in the following measurement conditions: lighting d/8, observer 10°, normal illuminator D65, without gloss trap, 10 measurements for each sample <sup>2)</sup> measurement with a multi-blade device with blade distance of 3 mm, 3 measurements for each sample <sup>3)</sup> measurements with a glossmeter, measurement angle of 60°, light beam directed in parallel to fibres, 5 measurements for each sample													

**Table 3**

List of test results of coatings before and after artificial weathering on pine and larch wood

Test name	Test results, exposure time – <i>weeks</i> , average values						Test standard
	<i>pine</i>			<i>larch</i>			
	0	12	$\Delta_{12-0}$	0	12	$\Delta_{12-0}$	
<i>I</i>	2	3	4	5	6	7	8
Gloss <sup>1)</sup>	43.9	29.9	14.0	39.1	30.4	8.7	PN-EN ISO 2813
Adhesion <sup>2)</sup>	0	0	0	0	0	0/1	PN-EN ISO 2409:
<b>Colour<sup>3)</sup></b>							PN ISO 7724 -1; PN ISO 7724 -2; PN ISO 7724 -3
L	37.02	33.68	3.34	36.52	33.79	2.72	
a	13.75	10.15	3.6	13.44	9.67	3.77	
b	15.46	10.10	5.36	15.42	10.10	5.32	
<b>Initial appearance</b>							PN-ISO

Test name	Test results, exposure time – <i>weeks</i> , average values						Test standard
	<i>pine</i>			<i>larch</i>			
	0	12	$\Delta_{12-0}$	0	12	$\Delta_{12-0}$	
1	2	3	4	5	6	7	8
- blistering	(S0)0	(S0)0	0	(S0)0	(S0)0	0	4628-1; PN-ISO
- flaking	(S0)0	(S0)0	0	(S0)0	(S0)0	0	4628-2; PN-ISO
- cracking	(S0)0	(S0)0	0	(S0)0	(S0)1	(0)1	4628-4; PN-ISO 4628-5
<sup>1)</sup> measurements with a spectrophotometer, in the following measurement conditions: lighting d/8, observer 10°, normal illuminator D65, without gloss trap, 10 measurements for each sample <sup>2)</sup> measurement with a multi-blade device with blade distance of 3 mm, 3 measurements for each sample <sup>3)</sup> measurements with a glossmeter, measurement angle of 60°, light beam directed in parallel to fibres, 5 measurements for each sample							

Analyzing the results given in the table above, it may be concluded that

- The change in gloss of the coating applied on the wood was evaluated in accordance with standard No PN-EN 927-1:2000.

The initial gloss characterized by reflection rate, on the pine and larch wood of the following values: 46.1 and 40.1 grades may be classified as semi-gloss.

The gloss value obtained after 12, 24, 36 and 48 months of natural weathering on pine wood characterized by values ranging between: 45.4, 44.8, 43.7 36.1 and, on larch wood, after 12, 24 and 36 months – characterized by values: 39, 37.9 and 36 may be classified as semi-gloss while after 60 months, on pine wood, of 29.9 on – on larch wood, after 48 and 60 months – characterized by values of 24 and 23.3 grades may be classified as semi-matte. Final gloss obtained after 12 weeks of artificial weathering, characterized by values ranging from: 29.9- (pine) to: 30.4 (larch) grades, may be classified as semi-matte.

- The change of color expressed as  $\Delta E^*ab$ . was determined in accordance with PN ISO 7724-3:2003.

The calculated value of color change after weathering in natural conditions after 12, 24, 36, 48 and 60 months was: 2.73, 4.88, 7.01, 11.02 and 13.91 units respectively for pine wood and 1.17, 4.33, 5.21, 10.7 and 12.2 respectively for larch wood.

The measured color change of difference exceeding 5 units is clearly visible with naked eye

The calculated value of color change after weathering in artificial conditions after 12 weeks was 11.0 units for pine wood and 10.2 for larch wood.

The measured color change is clearly visible with naked eye

- The evaluation of coating appearance was carried out according to PN-EN ISO 4268-1:2005, -2; -4; -5.

The changes in appearance of coatings after natural at least 24 month weathering are non-observable, in subsequent months the changes on both species are basically comparable, although on the larch wood they appear earlier and are a bit more intense. This refers mainly to blistering and cracking.

Artificial weathering observed after 12 weeks caused a minor change in appearance of coatings as compared to initial status. The observations showed that the appearance of coatings on both wood species is comparable, no changes were observed in terms of blistering, cracking or scaling.

- The adhesion evaluation was carried out according to PN-EN 2409:2008

The adhesion of coatings on pine wood after 12 to 24 months and after 12 months on larch wood was unchanged with regard to the initial measurement and reaches the highest value of 0, whereas after 36, 48 and 60 months on pine wood and after 24 months on larch wood it decreases to 1; on larch wood after further months it still retains the value between 1, but there are cases in which value of as low as 2 are observed.

Adhesion of coatings after artificial weathering – both on pine and larch wood – remains at value of 0.

The measured adhesion on pine wood is satisfactory (boundary value of 1), on larch tree starting from month 36, single samples with too low adhesion value of 2 were observed. For samples for which the measured adhesion after 36 months in use was close to level above 1, rapid deterioration in adhesion was observed in subsequent months.

## CONCLUSION

- The conducted works confirmed visual degradation of coatings over time as a result of action of external factors such as atmospheric precipitation, temperature or UV radiation emitted by sun and pollution from air.
- The tested samples were not subjected to any chemical agents which means that the observed changes on the surface of samples resulted solely from the above described impacts and potential dimension changes of samples that resulted from hygroscopic properties of wood and natural tendency to equilibrium.
- At the same time, it was found that the condition of coatings on samples after natural weathering deteriorates systematically, whereby it was almost unnoticeable for more than 36 months and the tested parameters were satisfactory. After passage of further 12-month test periods, the color, gloss and adhesion (for larch wood) of coats changed gradually significantly.
- The biggest changes were observed between month 36 and month 48.
- The color and gloss changes obtained in artificial weathering are comparable to natural weathering in the period between month 48 and month 60.
- Natural weathering of tested coatings results in loss of color, gloss and adhesion irrespective of the type of wood on which the coating was applied.
- The changes in coating appearance on pine and larch wood after 60 months are comparable, whereby for natural weathering they reach higher values than for artificial weathering as per PN-EN 927-6.
- The adhesion of coatings to substrate after 48 months was in both cases satisfactory, although for boundary values for larch, significant appearance changes occurred (particularly in the scope of coating blistering).
- The observed impact of an approximately 60 month natural weathering cycle on decorative and qualitative aspects of coatings, in which time also the deterioration of technical and visual parameters of coatings may occur, may be a premise to plan, in such a cycle, careful observation of technical condition of coatings on wood joinery and potential maintenance activities.
- The observations of the condition of water-soluble coatings after natural weathering cycles indicate that the quality of coating may be satisfactory for at least 60 months (5 years), whereby the first changes in appearance may occur earlier, hence regular observation of coating appearance, particularly for earlier location and removal of coating discontinuities such as cracking or flaking, is recommended.
- Due to progressing deterioration of aesthetic value of water-soluble coatings, it is not possible to avoid regular observation and maintenance of coated surfaces.
- The simultaneous tests of the behavior of coatings after natural and artificial weathering suggest that the changes in color and gloss obtained in artificial weathering are comparable to changes after ca. 48 months, while the changes in adhesion and appearance after artificial

weathering are far less pronounced than the changes from natural weathering and may be compared to changes after not more than 24 months.

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**Streszczenie:** Trwałość powłok wodorozcieńczalnych na drewnie starzonych w warunkach naturalnych. Opracowano wyniki cyklicznych obserwacji powłok wodorozcieńczalnych naniesionych na drewno sosny i modrzewia, starzonych w warunkach naturalnych na ekspozycji zewnętrznej (Warszawa). Kontrole prowadzono począwszy od stanu wyjściowego (0), co 12 miesięcy przez 5 lat. Ponadto w celu porównania tempa starzenia w warunkach naturalnych – długotrwałego, przywołano wyniki badań starzenia sztucznego – krótkotrwałego, próbek bliźniaczych, przedstawione w [5]. Celem prowadzenia badań obiema metodami starzenia, było sprawdzenie, w jakim tempie i jakiego rodzaju zmian należy spodziewać się podczas eksploatacji, porównanie wyników z obu metod, oraz próba szacowania tempa naturalnego zużycia powłok tj. trwałości powłoki i tempa zachodzących zmian podczas wieloletniej eksploatacji na podstawie wyników badań przeprowadzonych po starzeniu wyłącznie sztucznym - krótkotrwałym. W badaniach nie stwierdzono pełnej korelacji pomiędzy wynikami uzyskanymi wg obu metod starzenia, jednakże w przybliżeniu poszczególne wyniki uzyskane po upływie, co najmniej 36, 48 lub nawet 60 miesięcy są porównywalne z efektami starzenia 12 tygodniowego. Po starzeniu naturalnym nie stwierdzono dużych rozbieżności pomiędzy zmianami połysku i barwy, natomiast zanotowano większe tempo zmian w zakresie spęcherzenia, złuszczenia i spękania oraz przyczepności do podłoża, próbek z drewna modrzewia. Podobną analogię stwierdzono po starzeniu sztucznym. Kryteriami oceny były: wygląd powłok (stopień spęcherzenia, złuszczenia, spękania), połysk, barwa, przyczepność do podłoża. Zasady przygotowania próbek, wykonywania ekspozycji oraz metody są zgodne z PN-EN lub PN-EN ISO.

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