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## Durability of Paint and Varnish Coatings Depending on the Quality of their Appearance

To cite this article: Valentina Loganina 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **471** 022044

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# Durability of Paint and Varnish Coatings Depending on the Quality of their Appearance

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**Abstract.** The aim of the work is to study the regularities of the influence of the quality of the appearance of coatings on their durability during the operation. Object of research - paint and varnish coatings of building products and construction. Information on the effect on the longevity of coatings of the quality of their appearance is given. It is shown, that coatings with a high roughness index are characterized by low durability during exploitation. Are revealed the influence of the rheological properties of the paint, the porosity of the substrate on the surface roughness of the coatings. Determined, that regardless of the type of paint composition, the strength and relative deformations are reduced, the plastic deformation is increased and the elastic deformation are reduced with increasing roughness of surfaces. A mathematical model is obtained of the dependence of the tensile strength on the roughness of the surface of the films. It is established, that during the moistening of the coatings in the first stage (up to 30 days), the roughness of the surface is reduced, i.e., the surface micro relief is levelled due to the plasticizing effect of moisture (swelling of the coatings). In the future, due to the destructive effect of moisture, the surface roughness increases, caused by the appearance of micro cracks, rashes, and bubbles. It is established, that in the process of cyclic freezing-thawing the cracks appear locally and are formed near defects on the surface of the coating. The researches allow to develop recommendations for increasing the resistance of coatings and to select the optimum rheological properties of paints depending on the porosity of the substrate.

## 1. Introduction

Building and conservation the working condition of buildings and structures require a large number of paint and varnish compositions. Increasing competition in the market of finishing materials, increasing demands of consumers require from manufacturers to obtain high-quality painted surfaces. However, the practice of finishing works shows, that often the quality of the finish is bad. It leads to premature unscheduled repairs and additional costs [1]. In accordance with the statistical theory of the strength of solids, the probability of destruction of coatings is determined by the presence and concentration of defects, including on the surface of the coatings. Consequently, the quality of the appearance of coatings determines their stress state and resistance in the process of exploitation [2,3,4]. In [5] were established regularities of the formation of the quality of the appearance of coatings on a metallic substrate from the rheological properties of the paint, paint's ability to flow on surface of substrate. It is noted in [6], that the destruction of coatings on a metal substrate begins around different defects. Coatings on a porous cement substrate have their own peculiarities [7]. The porous structure of the cement substrate effects on the formation of the quality of the appearance of the coatings. They are characterized by a lower quality of appearance. This, of course, has an effect on the resistance of coatings during operation. Meanwhile, an analysis of scientific and technical literature shows, that the durability of coatings on a cement substrate has not been studied sufficiently



## 2. Materials and methods of research

In the study used the following paint: alkyd enamel PF-115 grade, oil paint brands MA-15, polystyrene paint brands PS-160, acrylate paint Universal.

The surface quality of the paintwork was evaluated a roughness, which is determined by profilograph TR- 100.

Assessment deformation of coating was carried out with the help of a tensile machine IR 5057-50 with the samples after 28 days of curing. The method is based on the sample stretching until it ruptures (deformation speed of 1mm/min). The 1x1x5 cm samples were fixed in the clips of the tensile machine so, that their longitudinal axis was in the direction of stretching, and the force was applied equally all over the sample section. The tests were carried out at the temperature of 20° C and relative air humidity of 60%. The ultimate tensile strength estimation was carried out for four samples [8,9]. The ultimate tensile strength  $R_{kog}$  for each sample was calculated by formula:

$$R_{kog} = \frac{F_{Pi}}{S_{Oi}} \quad (1)$$

, where  $F_{Pi}$  - the stretching loading at the time of a rupture, N;

$S_{Oi}$ - the initial cross-sectional area of a sample, mm<sup>2</sup>.

The modulus of elasticity was calculated according to the chart "tension-deformation".

The modulus of elasticity for each sample ( $E_{upr}$ ) in MPa was calculated by formula:

$$E_{upr} = \frac{R'_{kogi}}{\varepsilon'_i} \cdot 100 \quad (2)$$

where  $R'_{kogi}$  – the ultimate tensile strength at the time of the tangent separation from the chart "tension-deformation", MPa;

$\varepsilon'_i$  – relative lengthening at the time of rupture, %.

## 3. Results of researches

The presence of defects on the surface of the coatings will undoubtedly affect the physico-mechanical properties of paint coatings. It is revealed, that coatings have the elastoplastic character of the destruction (Tables 1, 2).

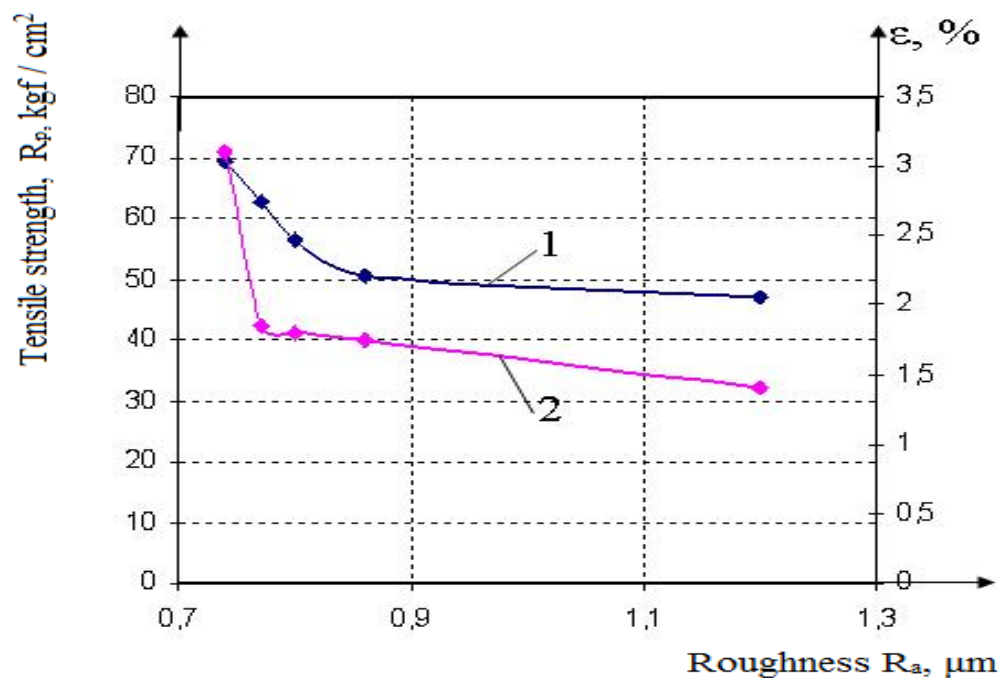
**Table 1.** Deformations of films based on polystyrene paint PS-160 depending on surface roughness

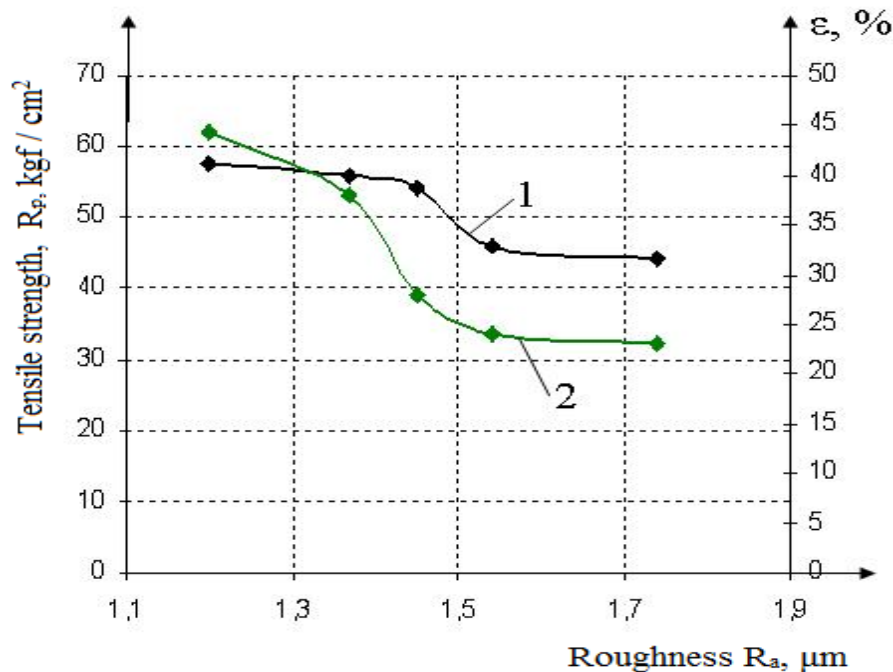
Coating surface roughness, Ra, μm	Strength at Stretching, $R_P$ kgf / cm <sup>2</sup>	Relative deformation $\varepsilon_{rel}$ %	Elastic deformation $\varepsilon_{el}$ %	Plastic deformation $\varepsilon_{pl}$ %	Share of Elastic component Deformation $\varepsilon'_{el}$	Share of plastic component Deformation $\varepsilon'_{pl}$
0.74	69.4	3.1	2.9	0.2	0.935	0.065
0.77	62.8	1.86	1.63	0.23	0.876	0.124
0.8	56.5	1.8	1.5	0.3	0.833	0.167
0.86	50.5	1.75	1.44	0.31	0.82	0.18
1.2	47.2	1.4	1.1	0.3	0.7857	0.2143

**Table 2.** Deformations of films based on paint PF-115 depending on surface roughness

Coating surface roughness, $R_a$ , $\mu\text{m}$	Strength at Stretching, $R_p$ , $\text{kgf/cm}^2$	Relative deformation $\varepsilon_{rel}$ , %	Elastic deformation $\varepsilon_{el}$ , %	Plastic deformation $\varepsilon_{pl}$ , %	Share of elastic component Deformation $\varepsilon'_{el}$	Share of plastic component Deformation $\varepsilon'_{pl}$
1.2	57.7	44.3	21.3	23	0.481	0.519
1.37	56.1	38	13.9	24.1	0.367	0.633
1.45	54.3	28	9	19	0.321	0.679
1.54	45.9	24	7	17	0.292	0.708
1.74	44.1	23	6.44	16.56	0.281	0.719

Regardless of the type of paint, the strength and relative deformations are reduced, the plastic deformation is increased and the elastic deformations are reduced with increasing roughness of surface (Fig. 1, 2). Thus, when the surface of coatings roughness based on paint PS-160 is  $R_a = 0.74 \mu\text{m}$ , the tensile strength  $R_p$  is  $69.4 \text{ kgf/cm}^2$ , the relative strain  $\varepsilon_{rel} = 3.1\%$ , and with a roughness  $R_a = 0.86 \mu\text{m}$  -  $R_p = 50.5 \text{ kgf/cm}^2$  and  $1.75\%$  respectively. At a roughness of the film based on the paint PF-115  $R_a = 0.74 \mu\text{m}$ , the tensile strength  $R_p$  is  $57.7 \text{ kgf/cm}^2$ , the relative strain  $\varepsilon_{rel} = 44.3\%$ , at a roughness  $R_a = 1.74 \mu\text{m}$  -  $R_p = 44.1 \text{ kgf/cm}^2$  and  $23\%$  respectively.

**Figure 1.** Dependence of the tensile strength (1) and the relative elongation (2) on the roughness of the film surface on the basis of paint PS-160



**Figure 2.** Dependence of the tensile strength (1) and the relative elongation (2) on the roughness of the film surface on the basis of paint PF-115

The dependence of the tensile strength on the roughness of the surface of the films can be approximated by an expression of the form:

$$R_p = a \cdot e^{b \cdot R_a} \quad (3)$$

where:

$R_a$  - is the surface roughness,  $\mu\text{m}$ ;

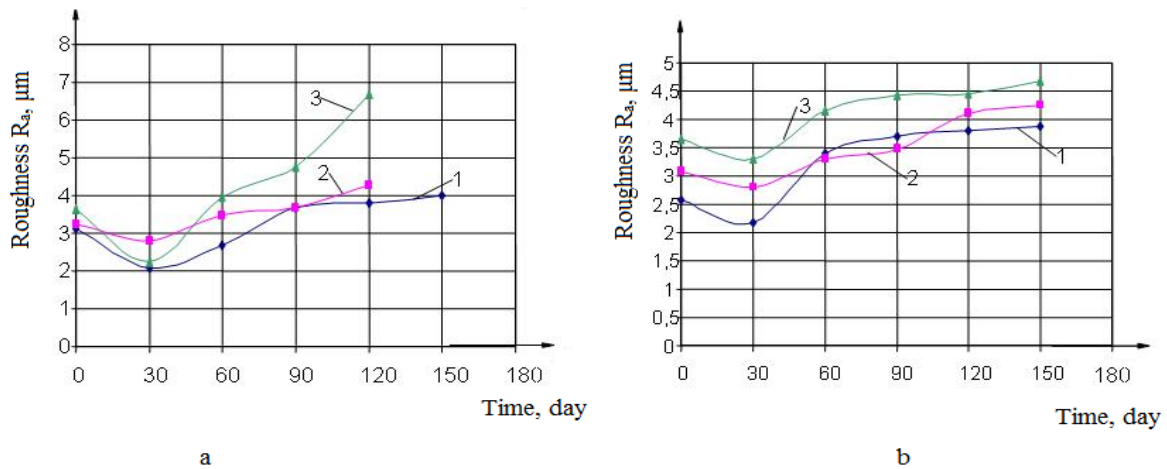
$b$  - is a coefficient that takes into account the degree of reduction in strength from roughness,  $\mu\text{m}^{-1}$ ;

$A$  - coefficient, characterizes the value of tensile strength, at  $R_a = 0$  (ideal model).

The quality of the coatings is determined by the rheological properties of the paint, the porosity of the substrate. The presence of inclusions, shagreen, streaks, waviness on the surface of coatings determines their stress state and endurance during operation. In Fig. 3-4 shows the results of measuring the surface roughness of coatings during the moistening process. It is established, that irrespective from the rheological properties of the paints and the porosity of the substrates during the moistening of the coatings in the first stage (up to 30 days), the roughness of the surface is reduced, ie, the surface micro relief is levelled due to the plasticizing effect of moisture (swelling of the coatings). In the future, due to the destructive effect of moisture, the surface roughness increases, caused by the appearance of micro cracks, rashes, and bubbles.

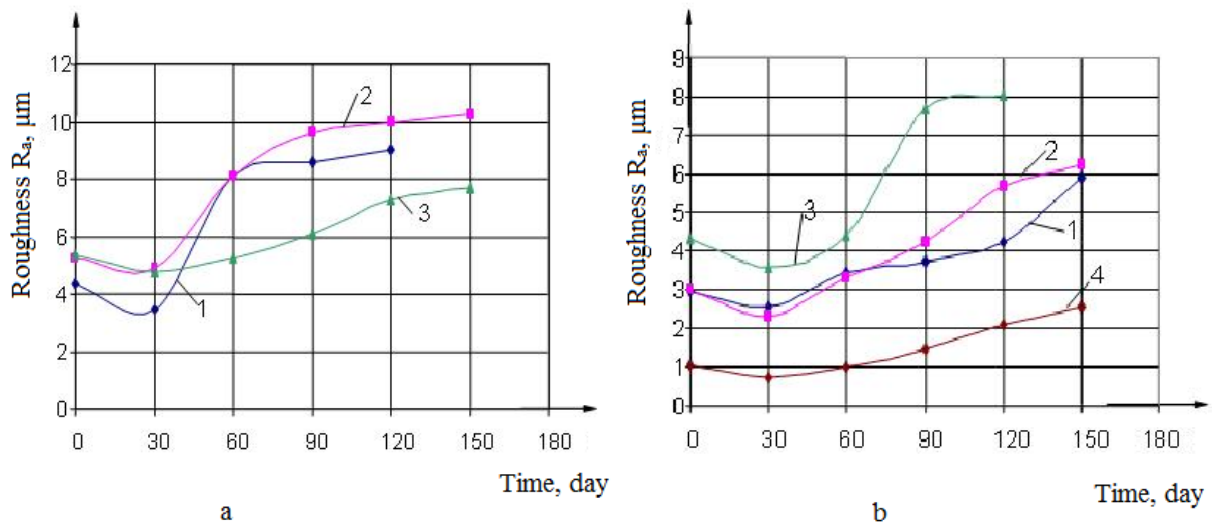
A more stressed state of the coating in places of greater roughness contribute to destroy the coating in these places during operation. It is established, that in the process of cyclic freezing-thawing the cracks appear locally and are formed near defects on the surface of the coating. In particular, on a coatings based on paint MA-15 with a roughness  $R_a = 0.23 \mu\text{m}$  appeared racks after 5 freeze-thaw cycles, and on a coating with a roughness  $R_a = 0.14 \mu\text{m}$  - after 15 cycles tests.

Similar regularities are also characteristic for other coatings. The obtained data correlate well with other indices of the protective and decorative properties of the coating (colour change, gloss variation, chalking, mud retention, bronzing).



**Figure 3.** Change of the roughness of coatings in the process of moistening:

- a.** based on paint PF-115 (a method of applying- brush, porosity 24%): 1 – viscosity is  $0.001 \cdot 10^3 \text{ Pa}\cdot\text{s}$ ; 2 - viscosity is  $0.00065 \cdot 10^3 \text{ Pa}\cdot\text{s}$ ; 3- viscosity is  $0.00026 \cdot 10^3 \text{ Pa}\cdot\text{s}$ .
- b.** based on dispersion paint (a method of applying- brush, on the surface of the putty): 1 – viscosity is  $0.0347 \cdot 10^3 \text{ Pa}\cdot\text{s}$ ; 2 - viscosity is  $0.02317 \cdot 10^3 \text{ Pa}\cdot\text{s}$ ; 3- viscosity is  $0.013 \cdot 10^3 \text{ Pa}\cdot\text{s}$ .



**Figure 4.** Change of the roughness of coatings in the process of moistening:

- a)** - based on paint MA-15 (airless method, porosity 24%): 1-viscosity is  $\eta_1 = 0.0026 \cdot 10^3 \text{ Pa}\cdot\text{s}$ ;  
2 - viscosity is  $\eta_2 = 0.0020 \cdot 10^3 \text{ Pa}\cdot\text{s}$ ; 3 - viscosity is  $\eta_3 = 0.0014 \cdot 10^3 \text{ Pa}\cdot\text{s}$
- b)** - based on paint PF-115 (method pouring): 1 – viscosity is  $0.001 \cdot 10^3 \text{ Pa}\cdot\text{s}$ , porosity 24%;  
2 - viscosity is  $0.001 \cdot 10^3 \text{ Pa}\cdot\text{s}$ , porosity 28%; 3 - viscosity is  $0.001 \cdot 10^3 \text{ Pa}\cdot\text{s}$ , porosity 32%;  
4 - viscosity is  $0.001 \cdot 10^3 \text{ Pa}\cdot\text{s}$ , on the surface of the putty.

#### 4. Conclusions

The elastoplastic character of the destruction for the coatings studied are revealed. The models of the strength of coatings depending on the roughness of surface are given. It is established, that irrespective

of the rheological properties of paint and the porosity of the substrates during the moistening of the coatings in the first stage the roughness of the surface is reduced, the surface micro relief is leveled due to the plasticizing effect of moisture (swelling of the coatings). In the future, due to the destructive effect of moisture, the surface roughness increases. A more stressed state of the coating in places of greater roughness contribute to destroy the coating in these places during exploitation. It is established, that in the process of cyclic freezing-thawing the cracks appear locally and are formed near defects on the surface of the coating.

The obtained data correlate well with other indices of the protective and decorative properties of the coating (colour change, gloss variation, chalking, mud retention, bronzing).

The researches allow to develop recommendations for increasing the resistance of coatings and to select the optimum rheological properties of paints depending on the porosity of the substrate

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