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THE IMPACT OF CLIMATE PARAMETERS ON THE SURFACE OF BUILDINGS' WALLS

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The durability of surface layers of enclosures (outside walls of buildings) is highly influenced by stresses occurring in the plane of contact between finishing materials and that of the enclosure. Damage to external walls depends on a high moisture content, which in turn depends on high water absorption during driving rains. One example of such damage is damage due to direct water penetration in homogeneous walls. The other negative effects of a high moisture content are impaired heat insulation and accelerated degradation. This article investigates the external layer of walls and the durability of different paints. In case of bi-laminar system "paint film - the wall being painted" two opposite processes take place: the water flow rate from the outside towards the wall, and the water vapor flow rate of the wall to the outside. The optimum selection of paint is necessary. An investigation of the durability of wall surface paints in a climatic chamber is instructive only after intermediate investigations and measurements of the substrates' physical and mechanical properties that aid in predetermining durability. The influence of moisture deformations upon degradation of coatings depends on the porosity of surface materials being coated, and on the origin and macrostructure of the coating.

Keywords: Painted render, Water sorption, Water vapor permeability, Water vapor resistance factor, Moisture state.

1 INTRODUCTION

Façade paints decorate building exteriors and protect against deteriorating atmospheric effects. In the literature, much information is given on paint and coatings, including the physical and chemical nature of paints, structure formation, and the results of investigations of physical and mechanical values (Lentinen 1996; Freitas *et al.* 1996; Carmeliet and Roels 2001). However, data after complex investigations of the surfaces already coated are insufficient.

Durability of the paints applied to external surfaces of walls has been investigated by evaluation of a number of complex effects withstood in a climatic chamber simulating outside climate variations (Miniotaite 1998, 2001). The following factors of climate effects were evaluated: temperature; frequency and amplitudes of temperature variation; wind velocity; the amount of mineral admixtures containing precipitation falling on the walls; ultraviolet radiation dose; the number of thaws; and the influence of construction factors increasing or decreasing the energy of the above effects. Deterioration degree of the paints was evaluated by examining the physical-mechanical essence of adhesion and by determining paint-substrate adhesion.

Stage-by-stage methodics were prepared to analyze insufficiently investigated physical and mechanical values, then aggregate-complex investigation methods were developed (Miniotaite 2001, 2006). Functional links between the physical and mechanical values of the paint and the walls painted sought to substantially amend the data on water vapor permeability of the formed two-layer surface, and the data on the water sorption coefficient. Detailed investigations of a) deformations due to moisture, b) the processes of opposite-direction sorption-desorption, and c) "rain permeability"—i.e., water vapor leakage from the walls—enabled to us compile the database necessary for further investigation and practical application.

The influence of counteraction of water penetrating the paint surface and of escaping water vapor based upon durability of the paint was evaluated, and subsequent durability tests were carried out in a climatic chamber. Adequate results of finishing-layer durability can be obtained only after the classification of the paints according to their nature and substrates—based upon their microstructure (Miniotaite 2001, 2006).

Below is summary of the durability data on various finishing layers applied to different substrates, together with acceptable values of their physical parameters based on paint origins. This investigation of paint durability and adhesion helped determine the nature of paint destruction, and decide which of the paints required an increase in fastness and which ones were in adhesion with the substrate (wall).

2 INVESTIGATION OF PAINT DURABILITY

Some data on the physical and mechanical properties of finishing materials predetermine the durability of such materials (Miniotaite 2001, 2006). These data are often insufficient and fragmentary. To properly investigate paint durability, it is necessary to compose a methodical chain, with stage-by-stage and chamber-type consecutive investigations. These were the methods we designed:

(1) improvement of sorption investigation methods and research;

(2) development of moisture deformation investigation methods and research;

(3) investigation of contrary processes of vapor permeability and surface-water sorption;

(4) analytical evaluation of adhesion as an indicator for determining durability;

(5) investigation of durability in a climatic chamber under complex effects and according to a fixed program.

It was found that the specific physical and mechanical properties of individual paints might change when applied to different paint/substrate combinations. Comparative results of durability were obtained by classifying coatings into three groups by their composition: 1) silicates, 2) polyacrylate (also silicone solutions in organic solvents, or silicone dispersions), and 3) aqueous polymeric dispersions.

In the case of a bi-laminar system "paint film - wall painted", we encountered water (i.e., rain) flowing from the outside towards the wall, and water vapor migrating from the wall to the outside. The optimum selection of paint is necessary. Water vapor may accumulate in the wall when precluded from escaping through a very dense (vaportight) film, which might in turn cause blisters, or result in delamination of the whole film or at least some sections.

Given the many different surfaces to be coated, several hundred combinations of coating and substrate are possible. In this study, cement plaster and lime-cement plaster were the substrates chosen for investigation. The lime-cement plaster and cement plaster were coated using 17 paints of different origin. Analyses of compositions of the paints indicate that vapor permeability depends on the paint used, the polarity of film-makers, and the bonding agents used.

The water vapor permeability coefficient was determined in a 23^{o}C environment according to requirements of the EN ISO 12572 (2001). Measurements were performed using 3 plaster specimens of 100 mm diameter and 25 mm thickness uncoated, and 3 specimens with surfaces painted with each of the 17 coatings in the study. The painted specimens were fixed on a cup, paint facing down (cup method). Water-vapor resistance Z_p, [m^2·h·Pa/mg] was in reverse proportion to vapor permeability δ_p, [mg/(m·h·Pa)].

The specimens used for determining vapor permeability were also used for determining the surface water sorption coefficient by DIN 52 617 (1987). The specimens oriented with the paint facing downward were soaked in a water bath maintained at 20^{o}C. The water sorption coefficient w, [kg/(m^2·h$^{0.5}$)] was calculated.

After the vapor permeability coefficient and surface water sorption were determined, a new stage of methodical investigation in a climate chamber took place, where the value of resistance to complex effects was detected in the modeled cycles (Miniotaite 2006). The necessary data on vapor permeability (vapor resistance) of the materials, the surface layer formed by such materials, “rain-penetration” (i.e., surface water absorption and water sorption coefficient), and coating adhesion were determined in parallel with durability investigations, carried out in a climatic chamber divided into two sections by masonry partition. The climatic equipment was installed on one side of the partition, while the other held equipment for maintaining indoor air conditions.

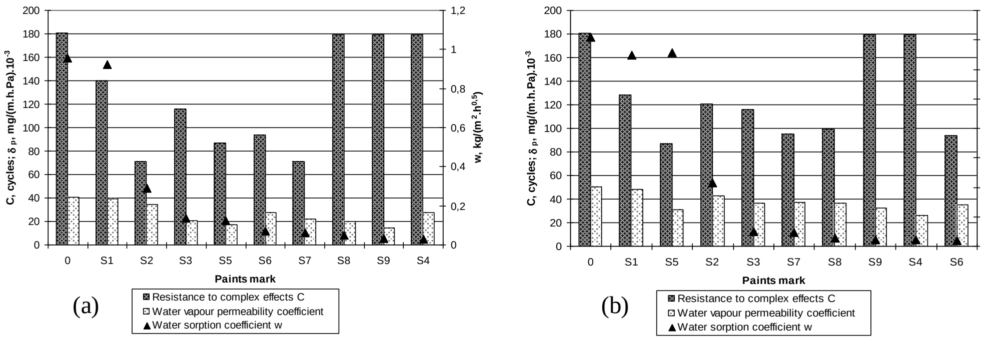
The basic conditions and means used for climatic tests were as follows:

- In the warm section of the chamber, room temperature was automatically maintained at θ_i = 18^{o}C ± 2^{o}C and RH ϕ = 50%-70%;
- An automatic climatic regime was maintained in the cold section of the chamber;
- The room temperature over 15 hours was lowered to θ_e = -15^{o}C ± 5^{o}C;
- The temperature of a protective finished layer of the wall θ_{se} = 15^{o}C-20^{o}C during reheating over 8 hours; a UV light lamp was used during the last hour of heating; irradiation intensity was at 600 W/m^2.

In the cold section of the chamber, water-spray equipment was installed. During a one hour water-spray operation, the finish of the wall was covered by a uniform water film (with a spray intensity = 1 L/m^2 min, temperature θ = 7^{o}C-12^{o}C, and water pressure = 0.15 MPa); air circulation at the velocity of v = 2-4 m/s was maintained by a ventilating device installed in the cold section of the chamber.

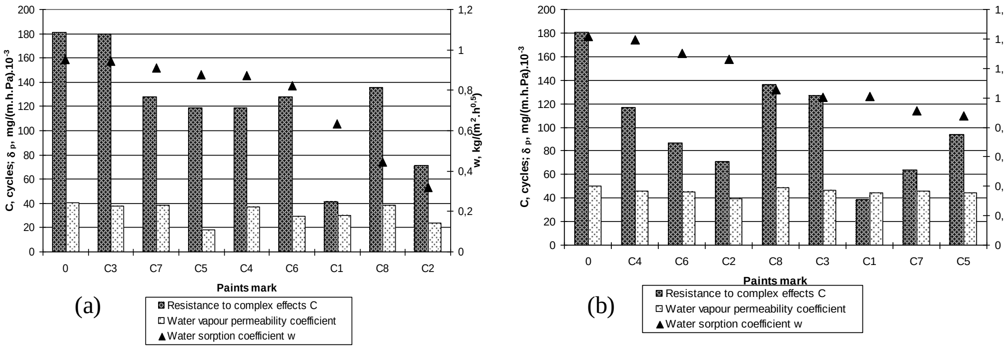
3 RESULTS

The physical properties (i.e., vapor resistance and water sorption coefficient) of the surface layer (0.025 m) of the cement plaster and lime-cement plaster coated with silicate paint, polyacrylate paint, and silicone-solution paint, are compared in Figures 1 and 2:



(a) (b)

Figure 1. The comparison of physical values of cement plaster (a), lime cement plaster (b) and durability of paints made out of polyacrylates and silicone solutions in organic solvents or silicone dispersions. Notes: paints marked 0 = non-painted plaster.



(a) (b)

Figure 2. The comparison of physical values of cement plaster (a), lime cement plaster (b) and durability of silicate paints. Notes: paints marked 0 = non-painted plaster.

As anticipated, the theoretical characterization of the paints (high vapor resistance—high rain penetration, i.e., "bad") can be insufficient to evaluate a paint's durability. Therefore, during the investigations, changes in the surface layer, resulting in decreases in adhesion between the paint and plaster, were fixed. After the results of the exposures in the climate chamber were analyzed, the reliability of the theoretical statement was verified. The value of vapor resistance due to complex effects created by application of the coating on the plasters was compared with the resistance of non-painted plasters surface for the selected cycles.

The results indicated that the paints of identical vapor resistance could be compared even though the nature of the deterioration and aging, as well as the protective significance of such paints for the painted surface, were different. The mechanism of such differences is explained taking into account the complex effects of the moisture-caused deformations of the substrate, and the physical and mechanical values of the paints. The durability of the paints (considering two basic physical properties) is described in Figures 1 and 2 above.

3.1 Paints Based of Polyacrylate, Silicone Solution in Organic Solvents, or Silicone Solution

Hardened films of polyacrylates or silicones constitute uniformity of the paints. They have no emulsifiers. Adhesion of paint-substrate is ensured by intermolecular interaction between the bonding agents of paint and substrate. Because of the organic polymers of silicons are highly resistant, their films are stronger, more elastic, and more resistant to temperature.

In respect to plaster, the paints concentrate on the scale of low and average water sorption moisture. The macrostructure of the surface is uniform, not textured. The durability of the paints containing pigment of the above groups is extremely sensitive to vapor resistance. With increase of $Z_p > 0.94$ $m^2 \cdot h \cdot Pa/mg$, the negative influence of vapor resistance grows fast (Figure 1).

The appearance of blebs indicate reduced adhesion. The nature of destruction is close to lamination: occurrence of tiny blebs—their merging and bursting; lamination or "scale" type cracking of a paint contributed to the phenomenon.

Chemically-unstable paints are spotty. In some cases, the spots are already observed after 100-110 testing cycles. Appearance of spots preceding the mechanical disintegration of paints is not analyzed in this paper, even though the spots decrease the paints' aesthetic appreciation. Aesthetic degradation is also typical of some compositions with acceptable mechanical durability.

3.2 Paints Formed of Silicates

As can be seen in Figure 2, the negative influence of water sorption and the positive influence of vapor permeability upon silicate-paint durability prevail. This influence is especially distinct for paint durability (see Figure 2, C8). The water sorption coefficient distinctly decreased and vapor permeability distinctly increased. A high water sorption coefficient [$w = 0.94$ $kg/(m^2 \cdot h^{0.5})$ and $w = 1.22$ $kg/(m^2 \cdot h^{0.5})$] has negative effects on nondurable paints (e.g., Figure 2, C1 and C2).

Parameters of surface water sorption and vapor resistance have approximately identical influence upon paint durability. Vapor resistance should be $Z_p \leq 0.7$ $m^2 \cdot h \cdot Pa/mg$ and water sorption coefficient—$w < 0.85$ $kg/(m^2 \cdot h^{0.5})$. Reducing the water sorption coefficient to $w = 0.5$ $kg/(m^2 \cdot h^{0.5})$ and the vapor resistance to $Z_p = 0.5$ $m^2 \cdot h \cdot Pa/mg$ might increase durability 15%-20%.

The durability of properly hardened paints should be attributed to the category of acceptable durability (C = 115–140 cycles). 150 accelerated cycles in the climatic chamber correspond to 12 years at an average natural aging. The resistance of the non-painted lime-cement plaster surface was found to be about 180 cycles.

By analyzing the results of grouped paints, it was found that peculiar nature of vapor permeability and water sorption was typical of each group. The distribution of the paint destruction is different. The nature of paint destruction depends on the moisture-caused deformation of the substrate on the different level.

4 CONCLUSIONS

The method used for investigation of paint durability can be employed both for the determination of the physical aging of the paint coating and for the estimation of its aesthetic degradation. The nature and signs of deterioration and aging of paints develop in a different way.

Silicate paints' resistance to climate effects is more dependent on surface water absorption, and less dependent upon vapor permeability. Water absorption of non-durable paints is high; vapor resistance has no significant influence. Surface water absorption of usable paints decreases faster than vapor permeability.

Resistance of paints made out of polyacrylates, and silicone solutions in organic solvents, or silicone dispersions to climate effects, depends on the investigations. There were no lamination and no cracks in the case of nonpigment silicone paints. Hydrophobic properties of such paints decrease with time.

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