Influence of Different Kinds of Paints on Self-Cleaning Process of the Facade Coating

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Abstract. This work summarizes assessing the durability results of facade coatings in the area of their resistance of the self–cleaning effect. To characterize this feature three different types of samples were chosen: silicone paint, photocatalysis effect paint and lotus flower effect paint. Test samples were exposed on natural conditions and artificial weathering process in laboratory at the same time. After this research, durability effect of self–cleaning properties and stain resistance by established criteria were obtained. LM and SEM micrographs, contact angle and profilometry were used widely to measure this factor. In conclusion, all of tested facade coatings based on silicon exhibit the highest effect of self-cleaning.

1. Introduction

In today's behavior of buildings and their elements due to the impact [1-10], they are subject to only a part of a larger whole. Connected with the requirements of sustainable development [11], including environmental protection, mainly air [12,13], care for natural sources of energy [14] and aggregates [15,16], as well as the necessity of joining the environment in terms of architecture. Facade materials play very important role in the protection of building structures against harmful external agents. They are exposed to external influences f.e.: UV radiation, water (rain, snow, water vapour contained in the atmosphere), microorganisms or atmospheric pollution (dust, gases and aerosols) [17-21]. Depending on the region of the country, these aggressive factors may very intensity of precipitation, occurrence of temperatures or constituents of air pollution. In addition, they should meet the aesthetic requirements.

The article deals with façade coatings made of paints. Facade coatings exhibit impact on durability of facade and determine the final aesthetic effect. These coatings are widely used on concrete surfaces, ceramic brick and sand-limestone, cement-limestone plaster silicate and organic plaster [21-23].

Depending on the types of surface and desire effect, facade paints were based on different chemical composition e.g. vinyl, acrylic, silicate, acrylic-silicate and calcareous.

Resistance to the above-mentioned factors determine the durability of the paint and their properties. The most important features for consumer are protection and decorative factors by applying on the building desire colour form or restore/improve the original surface of old buildings. Criteria for
choosing the types of facade paint are different and depends on coated surface, geographic localization and architecture character of the building [23-25].

The aim of this study was investigation of the self-cleaning effect in artificial weathering for three different kinds of facade paints. Research has been undertaken, due to the appearance on the buildings market, growing number of paints and coatings with declared of self-cleaning effect and pollution resistance.

2. Materials and methodology
Tests covered three kinds of paints with declared of self-cleaning effect:
• silicone paint, resistant to moisture, pollution and water-repellent,
• paint with self-cleaning effect of photocatalysis,
• paint with lotus-flower effect.

Due to minimalize the variable parameters of experiment all samples were exposed to weathering processes in artificial and natural conditions. References samples were prepared and stored in laboratory in condition of 21±2°C and 50±5% of humidity without UV radiation access.

The samples for natural weathering process were mounted on stand rack at angle of with a 45 degrees with the exposure surface facing the equator. The orientation of samples – noon. The test stand was prepared according with Polish-European Standard PN-EN 2810:2005 [26]. Samples arrangement was eliminated possibility of dripping water from one sample to another. The tests were taken 27 months.

The samples for artificial weathering process are performed using specialist equipment which contained UV-lamp, heating and water spraying systems. Test was done in the following cycles (single cycle involved 4h of UV radiation and 4h of water condensation):
• 50 – duration time was 200 h of UV radiation and 200 h of water condensation,
• 200 – duration time was 800 h of UV radiation and 800 h of water condensation,
• 400 – duration time was 1600 h of UV radiation and 1600 h of water condensation.

All types of paints were applied by brush according to the recommendations of Polish European Standards. Surfaces after aging processes characterized by contact angle measurements, SEM and grey scale observations, spectrocolorimetry and profilometry. The tests were carried out according to PN-EN 2810:2005.

3. Results and discussions
Figures 1÷3 shows SEM images of tested samples before and after aging process. All reference samples of silicone paint (fig. 1a,d) exhibit smooth, homogenous, fine-grained, free of cracks microstructures. Additionally, few large pores and linear texture associated with direct of coat application were observed. High magnification (fig. 1d) revealed fine product of hydration and pieces of non-hydrolysed binders or fillers. In contrast with references samples, fine-grained with single cracks, large pores and pronounced linear texture associated with direct of coat application were characterized after aging processes (fig. 1b,c,e,f).

Reference state of second kind of façade paints (fig. 2a,d) shows smooth, uniform, free of cracks microstructure. High magnifications (fig. 2d) identified small agglomerates of hydration products. After aging processes (fig. 2b,c) state granular, smooth with single cracks and bulges microstructure were observed. Also high magnifications (fig. 2e,f) exhibit small agglomerates of hydration products.

Images of two stages for reference (fig. 3a) and after aging processes (fig. 3b,c) exhibits heterogeneous, smooth microstructures without cracks and relatively small porosity. At high
magnifications particles of hydration products were observed, respectively fig. 3d, e and f. However on surface of samples after aging processes (fig. 3e, f) small scratches were identified.

Figure 1. Microstructure of tested samples: a, d) reference silicon samples; b, e) silicon samples after natural conditions; c, f) silicon sample after artificial conditions

Figure 2. Microstructure of tested samples: a, d) reference photocatalysis sample; b, e) photocatalysis sample after natural conditions; c, f) photocatalysis sample after artificial conditions
Figure 3. Microstructure of tested samples: a,d) lotus flower effect sample; b,e) lotus flower effect sample after natural conditions; c,f) lotus flower effect sample after artificial conditions.

Representative macro images of samples for grey scale and spectrophotometry are shown in Figure 4, which include: reference sample (a), silicon (b), photocatalysis effect (c), lotus flower effect (d).

Figure 4. Samples for grey and spectrophotometry test: a) reference, b) silicon, c) photocatalysis effect, d) lotus flower effect.

Test results are shown in Table 1. A slightly different results for all samples in grey scale measurements were obtained. It should be noted that for samples conditioned in natural larger changes were observed in compared with samples conditioned in laboratory. The impact of pollution factors presented in natural conditions samples caused more vulnerable surface for fly ash adhesion. In the laboratory that phenomenon was not identified. A significant change of colour was observed for photocatalysis effect paint. Whereas a slightly change of colour were characterized for silicon and lotus flower effect paints.
Table 1. Colour change results for natural and artificial weathering samples – grey scale

| Type of coat          | Natural condition (4 months) | Natural condition (15 months) | Artificial weathering (1000h UVA) | Artificial weathering (1600h UVA) |
|-----------------------|-----------------------------|-------------------------------|-----------------------------------|-----------------------------------|
| Silicon               | 4 (4/5)                     | 4 (4/5)                       | 5                                 | 5                                 |
| Lotus flower effect   | 4 (4/5)                     | 4 (4/5)                       | 5                                 | 5                                 |
| Photocatalysis effect | 4 (3/4)                     | 4 (3/4)                       | 5                                 | 4/5                               |

Colour change diagrams are presented in Figure 5. All reference samples exhibit following values: $L=95.98$, $a=-0.51$, $b=3.09$. Due to this results, samples exhibit more significant changes in this process, than in grey scale method. Artificial weathering process had significantly impact to each parameters, caused increasing trend, except coordinate $b^*$. This value was reduced. For all researched natural conditioned paints colour was changed towards respectively, to darker, red and yellow shades. Whereas for artificial weathering paints coordinate $L^*$ towards to darker shades, coordinate $a^*$ towards to green shades and coordinate $b^*$ towards to blue shades. Samples after natural condition process reveal $\Delta E > 5$, changes were observed by unaided eye, but for artificial weathering samples only for lotus flower effect paint the same effect was noted. Silicon and photocatalysis effect samples exhibit $\Delta E<5$. Changes can be observed only by using microscopy methods.

![Graphs](image_url)

**Figure 5.** Colour change results coordinate a) $L^*$, b) $a^*$, c) $b^*$, d) $\Delta E$

Representative contact angle results of tested samples are shown in Table 2÷4. Compared with references samples, all tested paint exhibit increase trend of contact angle measurements. Only for silicone paint decreasing effect was observed after exposure in natural condition (12 and 27 month) and artificial weathering after 1600 h. A slightly changes od contact angle were observed during this test. The reason of this phenomena was large surface roughness of tested samples. The maximum values were noted for lotus flower effect paint above 150 degree.
As the wetting increases, contact angle decreases for all kinds of paints both for reference samples and for samples under various aging conditions. It was observed that for silicone samples of silicone paint the contact angle decreases in proportion to the aging time. Inverse relationship, namely the angle slightly increases in proportion to the aging time occurs for samples of paint with self-cleaning effect of photocatalysis.
The profilometry analysis of investigated samples are shown in Figure 6. The obtained results are comparable. Studies of surface roughness showed a slight difference between samples in different aging conditions. The most impact variable is texture surface $R_a$ which is the results of the application method. For silicon and photocatalysis effect paint values are close and for lotus flower effect paint practically double. After aging process values approach, each other and the difference between them is a maximum of about 3 for natural conditions and 2 for artificial weathering.

The texture surface of samples increases in the results of the aging process. Only for lotus flower effect paint decreasing trend was observed in both kinds of aging (from 16.46 µm to 11.13 µm in natural aging process and to 11.79 µm in artificial aging process). The largest increase was noted for photocatalysis effect paint between natural aging and artificial aging process from 8.08 µm to 9.93 µm (1.85 µm). For silicon paint increase was equal 1.16 µm and for lotus flower effect paint – only 0.66 µm.

4. Conclusions

The method of measuring the changes of colour using a spectrophotometer allows to seen the more differences related to researched paints. However, these results corresponded with results obtained by visual inspection and confirmed occurrence of self-cleaning effect.

The increasing trend of contact angle also confirmed self-cleaning effect of investigated paints. High hydrophobicity of the coating did not affect to the degree of contamination. Coatings with high hydrophobicity and large contact angle did not achieved better results than for paint with relatively lower contact angle (silicone paint with the lowest contact angle exhibited the largest self – cleaning effect).

It has been shown that self – cleaning effect is comparable for all tested paints. After 27 months of exposure, sample reveal the largest change of colour on a grey scale. Samples are devoid of efflorescence, biological corrosion, peeling, loosening and cracks. Scanning Electron Microscope (SEM) results shows no significant changes of tested samples surface in all stages. Surface roughness measurements obtained a slight difference between samples depends on coatings application method.

Based on the literature observation, it has been concluded that the self-cleaning effect is related with hydrophobic effect and it is an effective method for facade surface cleaning.

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