How to Control Dirt Pick-Up of Exterior Coatings

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Summary : The composition of dirt and the tendency of coatings to pick up dirt are determined largely by the location. The factors affecting the tendency of coatings to pick up dirt are varied and complex. That is why the problem of dirt pick-up on exterior coatings can only be resolved satisfactorily by optimisation of the paint formulation as a whole (PVC, type of formulation, surface texture) and of all the raw materials (binders, pigments, fillers, additives).

Introduction

Exterior coatings are used to protect building materials from the weather and to give buildings a decorative finish and aesthetic appearance. That is why the contamination of newly coated exterior walls with dirt, which sometimes appears very quickly, is viewed as unsatisfactory by the end-users and requires improvements. To achieve these, however, we need to know more about the causes of this contamination and the composition of the dirt.

Types of dirt on buildings

Our own recent studies show that it is mainly deposits of soot, dust and inorganic crystallites on the surface of a coating which are responsible for the dirty or grey appearance of weathered coatings.

In studies with scanning electron microscopy (SEM) and atomic force microscopy (AFM) it was possible to detect both coarse dust particles (with a diameter of approx. 10 to > 50 μm) and also, for the first time, ultra-fine dust particles (with a diameter < 100 nm, see Figure 1) on weathered surfaces of exterior coatings.

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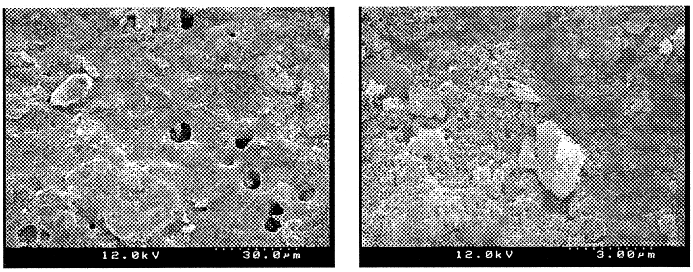

Figure 1a. SEM images of a very dirty exterior coating (PVC = 42 %)

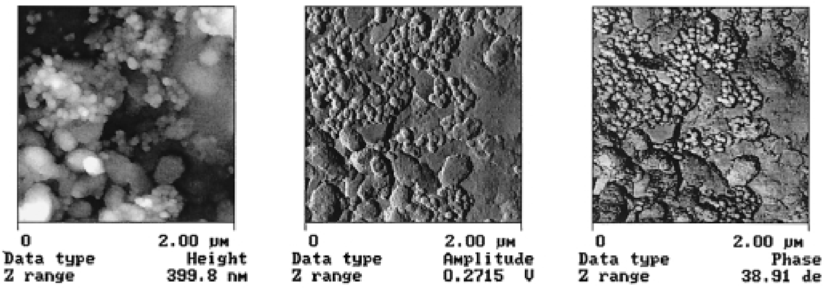

Figure 1b. AFM images (topography and phase contrast with finely dispersed (< 100 nm) deposits on a weathered exterior coating (PVC = 42 %)

At the same time, with regard to calcitic formulations, serious microscopic changes in the coating surface were observed – in the worst case after only one year of outdoor exposure (45°, south) – without any visible sign of chalking. Sometimes micropores and holes appear in the coating and particles of dirt can then become embedded in them (see Figure 2).

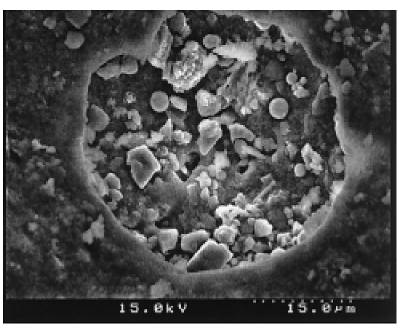

Figure 2. Particles of dirt embedded in holes; exterior paint PVC = 42 % after 1 year of outdoor weathering (45° south, Limburgerhof)

In addition, coatings can be affected by micro-organisms (algae, fungi, lichen and mosses) after prolonged weathering (starting after just one year, more evident after about 2 years of weathering at 45° south) and especially on the weather side of buildings. This can be kept under control within certain limits by using film preservatives, usually combined products consisting of algicides and fungicides (see Figure 3).

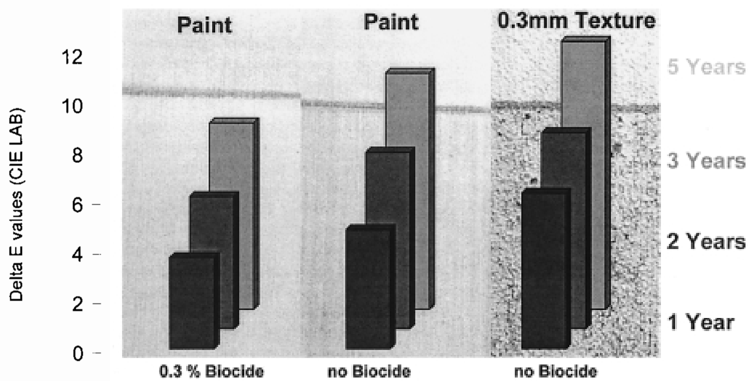

Figure 3. Results of outdoor weathering on paints and 0,3mm textured coatings with and without added biocide[1]

Plant growth tends to increase as the PVC increases and occurs on a larger scale with paints with a PVC exceeding the CPVC.

Overall, paints based on hydrophobic acrylate-styrene emulsions show a less marked tendency to plant growth than the more hydrophilic pure acrylate systems.

This is confirmed in Figure 4 by exterior paints modified with silicone resin. Owing to the styrene, which is a considerably more hydrophobic monomer, the acrylate-styrene emulsion absorbs less water than the pure acrylate and this can be seen in the differences in behaviour with regard to the swelling and shrinking of the coating film. As a result, the tendency to plant growth is reduced significantly.

After 5 years of subjection to outdoor weathering, however, it was impossible to detect any reduction in dirt as a result of the addition of the silicone resin emulsion, irrespective of the binder used.

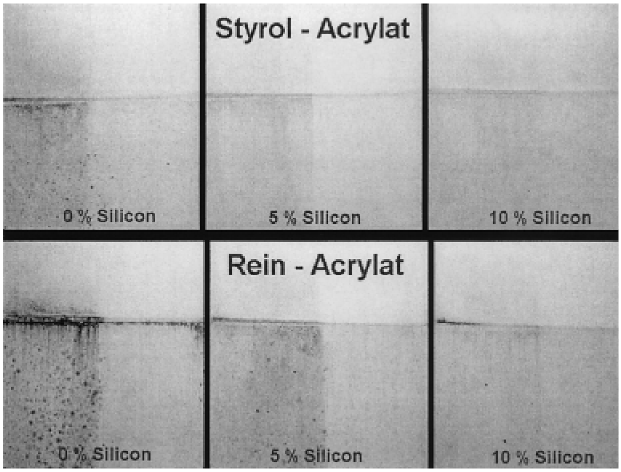

Figure 4. Effect of the binder and addition of silicone resin on plant growth in exterior paints after 5 years of outdoor weathering (45°, south, Limburgerhof)[1]. Left: dirty condition. Right: after washing.

The locational factor

The composition of the dirt depends very much on the location, as shown by studies by Nakaya[2] in Japan and confirmed by our own studies. In this connection, the proportion of carbon and the ratio of lipophilic dirt to hydrophilic dirt vary. In conurbations, organic dirt with a high proportion of carbon (e.g. diesel soot) predominates owing to the large amount of traffic and the many firing plants, whilst in rural areas there is mainly mineral, inorganic or biogenic material (parts of plants, pollen, spores etc.) and not much elementary carbon. Generally, however, significant amounts of inorganic particles containing Si, Fe, Al, K or Mg are always detectable on the surface of dirty exterior coatings, regardless of the location.

Nowadays, there is a very large amount of knowledge available in the literature regarding the sources, composition and particle size distribution of fine dusts in the environment[3].

Anthropogenic sources, such as road traffic, construction work and industrial activity, and combustion processes are responsible primarily for finely dispersed suspended particles (typically < 2.5 µm particle diameter, with some amounts down to particle diameters of less than 50 nm).

Natural processes, like the formation of marine aerosols, the swirling up of mineral dust or biological material by the wind (mainly with a particle diameter of 2.5 - 10 µm) and the formation of secondary aerosols from gaseous atmospheric pollutants (e.g. ammonium sulphate or ammonium nitrate) are other sources of fine dusts.

A study from Switzerland[4] shows that about one third of the suspended particulate comes from incomplete combustion processes (of which 50 % are soot particles), one third consists of secondary aerosols and the final third is made up of mineral particles from wind erosion, construction work, wearing away of roads etc..

Dust particles are generally spread around by air movement and rainwater or, in the case of the finest particles, by Brownian movement and thus come into contact with exterior coatings. And so the amount of suspended dust in the air at the weathering location has a determining effect on the dirtiness of the coating. That is why coatings in conurbations which have a high concentration of suspended dust become dirty much more quickly than in a rural environment with a lower overall dust concentration.

For an international comparison one has to turn to the so-called TSP values. TSP (Total Suspended Particulate) concentrations are the pollution figures for suspended dust in μg/m^3 and, by definition, comprise particles from 0.1 to 100μm (see Figure 5).

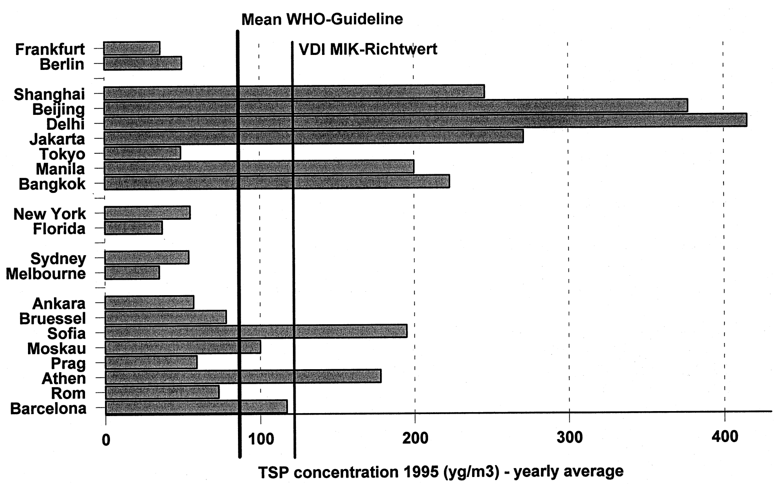

Figure 5. TSP concentrations (annual average) of various towns in 1995[1]

There are severe problems with dirt and atmospheric pollution in the developing and semi-developed countries of Asia, with figures of 200 μg/m^3 and higher, and South America (e.g. Mexico City with 410 μg/m^3). In industrial cities in China, such as Lanzhou (Gansu Province), TSP concentrations of 500 μg/m^3 and higher were measured, statistically, every second week in the first half of 2000. Cities like Peking also have ten times more SO_2 pollution in the atmosphere than, for example, Frankfurt. These differences make it clear that (formulation and weathering) results obtained in one region cannot necessarily be applied to other regions of the world.

Factors affecting the tendency to attract dirt

One problem with regard to the study of the factors affecting the dirtying of exterior coatings is the fact that, to date, no reliable laboratory dirt tests are available[1,5] and even outdoor weathering studies related to a particular site and kind of exposure (angle of inclination: 45°, 60° or 90°; and direction: south, north, west) provide conflicting results.

Based on many years of practical experience, it is nonetheless possible to make the following statements concerning the determining factors:

Apart from the polarity, resultant wettability, and swellability of the coating surface due to rain water, there are other factors, such as the thermoplasticity, surface tack, porosity and surface texture (roughness) of the coating, which have a crucial impact on its tendency to attract dirt.

Effect of the constituents of a formulation

The factors affecting the tendency of a paint formulation to pick up dirt are shown, together with an indication of their impact, in Table 1 and will be discussed below with reference to examples.

Table 1. Influencing factors on dirt pick-up of architectural coatings

Influencing factor	**Impact**
PVC	Strong
Type of formulation (emulsion, silicate or silicone paint)	weak – strong (to be explained in more detail below)
Binder	Strong
Solvent/plasticiser	Weak
Titanium dioxide	moderate – strong
Thickening agent	Moderate
Filler	Weak

The effect of the binder on the tendency of water-based coatings to pick up dirt is determined primarily by its polarity, glass transition temperature, morphology, cross-link density and thermoplasticity (see Figure 6, 7, 8) [1,6-10].

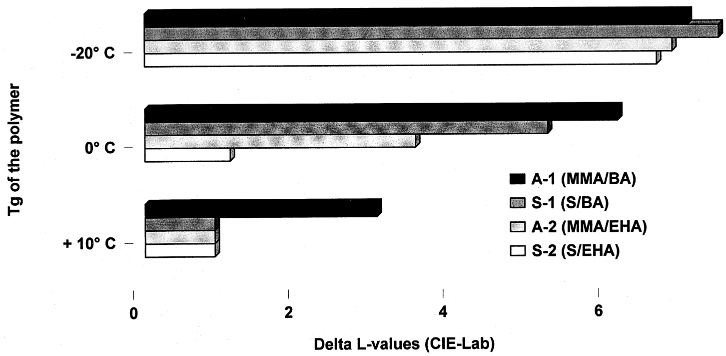

Figure 6. Effect of the glass transition temperature (Tg) and the monomers of the binders on the greying ΔL of exterior paints after 3 years of outdoor weathering (45°, south) in Limburgerhof[1]

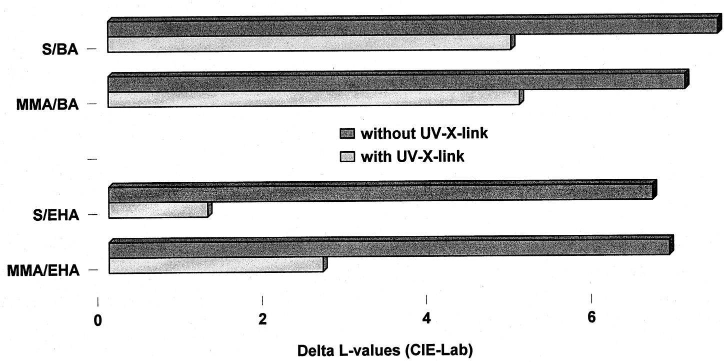

Figure 7. Effect of UV curing of the binders on the greying ΔL of pure acrylate and SA exterior paints after 3 years of outdoor weathering (45°, south) in Limburgerhof[1]

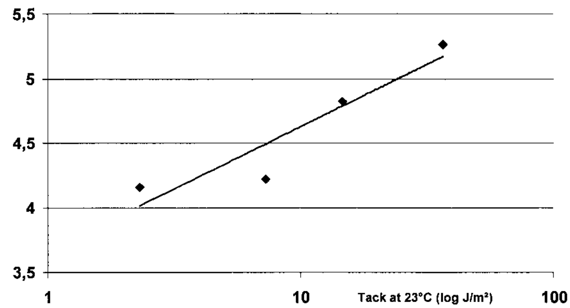

Figure 8. Correlation between the dirt pick-up ΔL of pure acrylate exterior paints (PVC=42%) and the tack of the emulsion film.

The film-forming aids and plasticisers (Figure 9) as well as the thickening agents (Figure 10), fillers and grades of titanium dioxide chosen (Figure 11)[7] are also formulation parameters which have an effect on the tendency of aqueous dispersion-based coatings to pick up dirt.

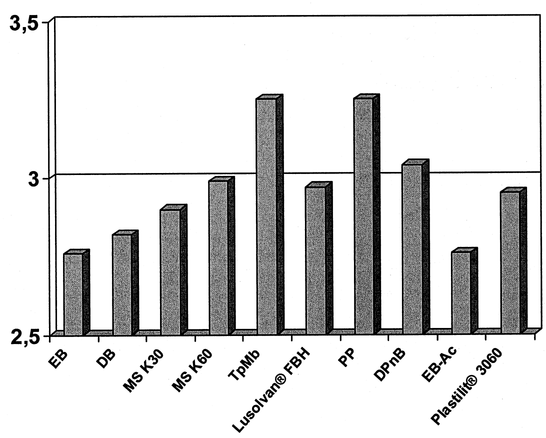

Figure 9. Effect of 2% of different film-forming aids and plasticisers on the dirt pick-up ΔL of exterior paints (PVC = 50%) after 1 year of outdoor weathering (Limburgerhof, 45°, south)

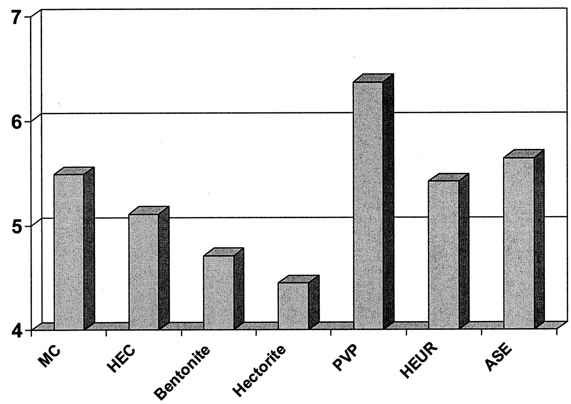

Figure 10. Effect of different thickening agents on the dirt pick-up ΔL of exterior paints (PVC = 42%) after 1 year of outdoor weathering (Limburgerhof, 45°, south)

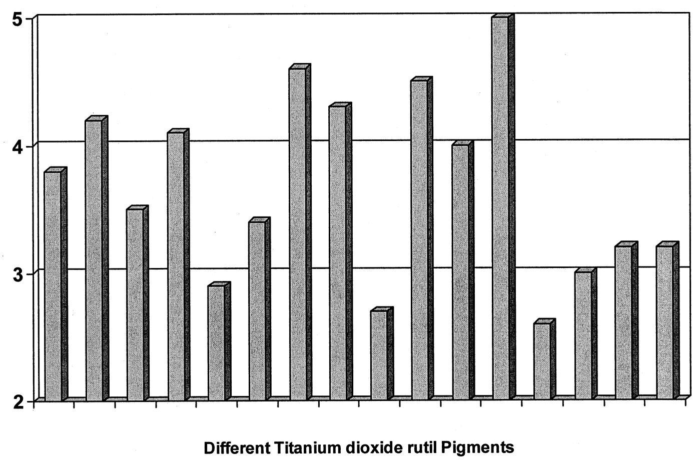

Figure 11. Effect of different grades of titanium dioxide on the greying ΔL of exterior paints (PVC = 45 %) after 2 years of outdoor weathering (45°, south, Limburgerhof)

In addition, the pigment volume concentration[1,10] plays a crucial role via the quantity of binder used (see Figure 12, 13), and the type of formulation chosen (emulsion paint, silicate paint, silicone resin paint – Figure 13) also has a determining effect.

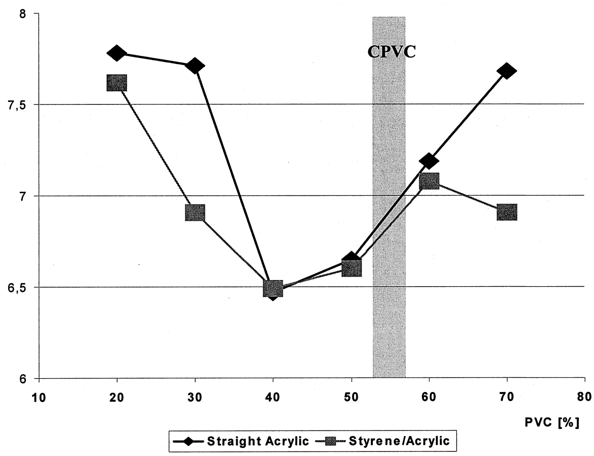

Figure 12. Effect of the PVC and the binder on the dirt pick-up ΔL of solvent-free and biocide-free exterior paints after 1 year of outdoor weathering (Limburgerhof, 45°, south)

It can be seen clearly from Figure 12 that dirt pick-up which is dependent on the PVC can be broken up into two areas with different causes. Below the CPVC the surface tack determines the amount of dirt pick-up, whereas above the CPVC the porosity encourages the depositing of biogenic material.

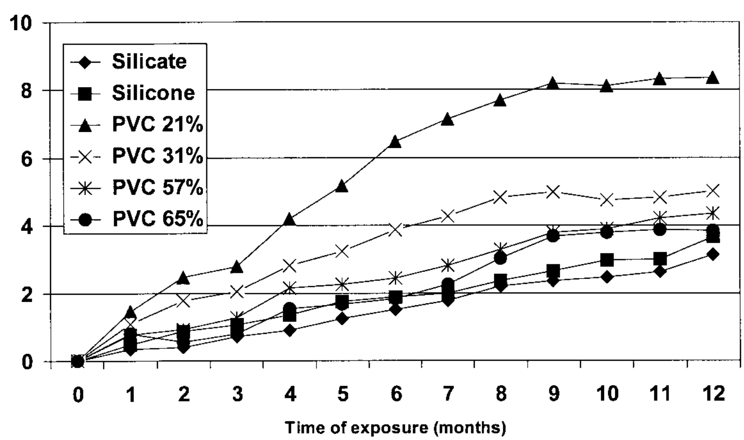

Figure 13. Effect of the PVC and the type of formulation on the dirt pick-up Δ L of exterior paints subjected to outdoor weathering, Indonesia Vertical

When the amount of dispersion in the various types of formulation (silicate, silicone and emulsion paint with PVC = 65%) is more or less the same, the tendency to pick up dirt is also approximately the same. Presumably, this is due primarily to the coating having similar surface tack values and porosity levels.

Conclusion

It has been shown, that as far as the binder is concerned, a high Tg, distinct underlying hydrophobic properties (styrene/acrylates are better than comparable pure acrylates) and curing (e.g. UV crosslinking) help to ensure that the coating formulations have a low tendency to pick up dirt. In addition, the grade of titanium dioxide chosen (manufacturing process and surface treatment) has a strong effect on the amount of dirt picked up by the coatings after weathering.

In general, as the PVC rises, up to the critical PVC (CPVC), the tendency to pick up dirt decreases and the differences between binders level off noticeably. Beyond the CPVC, however, the increasing susceptibility to contamination by micro-organisms has an increasingly detrimental effect on the aesthetic appearance of the coatings. The latter is due to the increasing porosity and reduced water resistance of the coatings as the PVC increases. High-boiling film-forming aids or even long-lasting plasticisers reduce the resistance to dirt pick-up, since they remain in the coating permanently and lower the glass transition temperature of the binder appreciably. The effect which the thickening system chosen to provide the rheological properties has on the tendency of the coating to pick up dirt is surprisingly strong.

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