Binders for Exterior Coatings Exhibiting Low Soiling Tendency

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Summary: Elastomeric coatings protect building facades and flat roofs from moisture and weather exposure. As a drawback, these coatings are prone to dirt-pickup due to the low glass transition temperature of the used polymeric binders. Strategies to overcome this enhanced soiling tendency are discussed, and the results of laboratory and outdoor soiling tests are compared. A novel method for the assessment of wet soiling tendency is presented.

Introduction

Elastomeric (wall) coatings are capable of bridging fissures in substrates up to about 2 mm width without necessity of prior treatment of the cracks with sealers. They are expected to withstand the dimensional changes caused by extension and contraction of the substrates. Furthermore, elastic coatings provide reasonable protection e.g. for flat roof constructions against water infiltration. The good protection can also be ascribed to the fact that by application of elastomeric coatings, further opening of the existing cavities by freezing water during the winter is avoided.

They should also impart protection against CO_2-passage through the applied film and against environmentally adverse influences. At the same time the coating should permit the ′breathing′ of the building: The potential of water vapour to pass the coating barrier must be given, otherwise moisture accumulating in the building might give rise to the growth of fungi.

Besides these technical requirements for elastomeric coatings, there exist also aesthetical ones, which have to be fulfilled in order to meet market′s expectations: The coatings

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should not exhibit yellowing or other unwanted colour changes. Chalking and soiling should not occur either, since all these factors bring about substantial changes of the initial optical aspect of the paint film.

One potential drawback of these coatings is their inherent tendency for dirt-pickup due to the low glass transition temperature of the polymeric binders used. To provide the desired low-temperature elasticity needed for efficient gap bridging, the T_g of binders used for elastomeric coatings is usually in the range between –10 and –40°C.

Unlike conventional facade paints exhibiting higher glass transition temperature of the polymeric binder, elastomeric coatings contain polymers being always in a fluid-like state in the temperature range encountered in a temperate climatic zone (-10 to +35°C).

At the usual pigment volume concentrations of elastomeric paints, the soft continuous matrix of the binder shows poor resistance to indentation of e.g. dirt and dust particles.

To overcome this disadvantage, different concepts have been used to develop a technical solution to the problem.

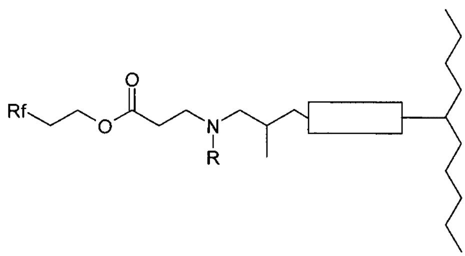
Inter alia, polymer emulsions with high fluorine content have been studied.[1] Although these polymers impart hydrophobic and oleophobic properties to the coated surface, cost considerations exclude the general use of binders with high fluorine content in elastomeric coatings.

Also, silicones are widely used as anti-soiling agents. However, doubts about their effectiveness have been reported recently, since these additives did not prevent the surface deposition of dust particles in (styrene) acrylic-based facade coatings.[2] In this case, the soiling tendency may be ascribed to the hydrophobic coating surface, attracting the lipophilic fraction of the dust.

Another concept used to impart dirt repellence to elastomeric coatings is based on the observation, that soiling can be inhibited by superficial crosslinking reactions of the binder, triggered for example by UV-irradiation. Such a surface reticulation has successfully been accomplished by the use of photoinitiators like benzophenone. [3]

Further approaches to reduce soiling include microstructuring of surfaces[4], application of nanoparticle top-layers on coatings or thin films of hydrophobic silanes. Finally, the use of low molecular weight amphiphilic substances like perfluoroalkane carboxylic acid salts which migrate to the coating surface has been proposed for soiling reduction of coatings.[5]

Here we report on the soiling tendency of especially modified binders for elastomeric wall coatings (EWCs). The modified binders contain moieties of the type shown schematically in structure **I**[6]. Furthermore, an own newly developed system for laboratory wet soiling of samples will be described.



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This method was established in our laboratory with the intention to better mimic the dirt-deposition processes occurring in outdoor weathering under changing humidity conditions, where continuous adsorption/desorption of particles from coating surfaces takes place. We believe that laboratory dry soiling tests are no suitable probe for the determination of soiling tendency, since the crucial role of the water in the soiling process is ignored: Water can transport dirt in form of aqueous dirt suspensions into film cavities, but also wash off dirt particles adhering to the surface. To mimic these transport mechanisms, we continuously pumped an aqueous dirt suspension over the test panel surfaces and evaluated the soiling after defined cycles.

Experimental

Paint manufacture:

Different pure acrylic (PA) and one styrene acrylic (SA) binders (see table 1) have been used to produce elastomeric wall coatings with pigment volume concentration 42%. Mill base has been prepared using a dissolver. The ready mill base was allowed to equilibrate for 24 h prior to addition of binder and final adjustment of paints (see table 2).

Dry soiling:

For dry soiling studies, coatings were directly applied to glass plates with a doctor blade (200 µm wet film thickness) and allowed to dry for 24 h at 23°C, 50% relative air humidity. Determination of the brightness L^* of the CIELAB system was accomplished with an Erichsen colorimeter model Nr. 526, using a white standard with $L^* = 94{,}33$. Then a mixture of 99.5% fly ash and 0.5% soot was applied to the substrates with a brush, and surplus particles were brushed off. The measurement of L^* was then repeated with the soiled substrates, and the difference to the initial L^*-value is named ΔL^*-value in this work. Soiling reduction in % is defined by the quotient of ΔL^*-values obtained for the coating containing the modified (ΔL^*mod) and the unmodified (ΔL^*) binder:

$$\% \text{ Soiling reduction} = [1-(\Delta L^*\text{mod}/\Delta L^*)] \times 100 \quad (1)$$

Table 1. Tested aqueous polymer emulsions

Sample Nr.	Emulsion	Glass transition temperature [°C]	Solids content [%]
1	PA 1	-30	approx. 60
2	PA 2	-30	approx. 60
3	PA 3	-30	approx. 60
4	PA 4	-35	approx. 60
5	SA 1	-30	approx. 60
6	PA 1 mod 1	-30	approx. 60
7	PA 1 mod 2	-30	approx. 60
8	PA 1 mod 3 (comparison)	-30	approx. 60

Table 2. Preparation of EWC-coatings (PVC 42%)

	Component	Weight-parts	Comment
	Mill base:		
1	Water	100	Add components 2 – 6
2	Calgon N (10% aqu. solution)	5	in component 1 and mix
3	Coatex P 90	1,4	under stirring.
4	Foammaster 111 FA	2	Then shear the mixture for 15 min at 5000 rpm
5	Kronos L 2310	80	using a dissolver.
6	Durcal 2	380	Allow the mill base to equilibrate for 24 h.
7	Emulsion (s.c. about 60%)	382,3	Add components 7 and 8 at 500 rpm and stir for 5 min.
8	Ammonia (20% aqueous solution)	1	
	Final adjustment:		
9	Mergal K9	2	Add comp. 9 – 14 under stirring
10	Butyl diglycol	2	
11	Propylene glycol	10	
12	White spirit 17/18	5	
13	Coatex BR 100	7,5	dissolved in
14	water	22,5	
			Allow paint to equilibrate for at least 24 h.

Wet soiling:

Sample preparation was the same as for dry soiling, but as substrates Eterplan fibre cement panels (300 x 150 x 4 mm) have been used. Wet film thickness was 300 µm. Dried samples were fixed with the coated side up on a support, and the test panels formed an angle of 60° with the horizontal. Then a coating surface was continuously rinsed with a standardized aqueous dirt suspension by means of a peristaltic pump (500 ml/min) for 30 minutes per cycle. Dirt suspension dripping from the samples was collected in a petri dish equipped with a magnetic stirrer bar to keep dirt particles in suspension. After each 30 minutes-cycle, the panels were allowed to dry for 24h at 23°C/50% rel. air humidity. L^* and ΔL^* were determined after each cycle. Freshly prepared dirt suspension was used for each cycle. The dirt suspension was prepared as follows:

17g gas soot FW 200, 70g Japanese standard dust nr. 8 and 13g special pitch nr. 5 (Worlee) were weighed out in a 1000 ml powder bottle and 400 cm^3 glass pearls were added. The mixture was homogenized for 24 h on a 'Rollenbock'. Then the glass pearls were removed by sieving. The resulting powder was further homogenized in a mortar. 1g of the resulting material, 1g of butyl glycol, and 998 g of water were mixed using a magnetic stirrer. The suspension was continuously stirred with a magnetic stirrer bar to avoid settling.

Outdoor exposure:

Eterplan panels were treated with a water-based primer and afterwards dried for 24 h. Then, twice about 400 g/m^2 (wet mass) paint was applied by brush. The first coating was allowed to dry 24 h prior to applying the next layer.

Sample panels were placed in a southward direction 45° inclined to the horizontal.

Initial brightness L^* of the panels was determined, then L^* was measured after 3 months.

Results and Discussion

Dry soiling:

The terms 'PA' for pure acrylics and 'SA' for styrene acrylics have been used in this work to name the tested emulsions.

As can be seen from table 3b, dry soiling tendency of acrylic polymer PA1 can be reduced by the polymer modification. However, the effect was rather moderate. As a comparative system the emulsion PA 1 was also modified by simple addition of a commercially available fluorinated additive (giving PA1 mod 3). In this case, however, the used additive had no functional group for reaction with the polymer backbone. Dry soiling was not reduced at all by addition of the fluorinated additive in this test. It has to be marked here that soiling tests reveal only qualitative tendencies and give no quantitative results.

Table 3a. Dry soiling results of EWCs containing emulsions PA 1 – SA 1, fly ash/soot mixture

Sample Nr.	Emulsion	ΔL^*
1	PA 1	32.3
2	PA 2	30.7
3	PA 3	30.7
4	PA 4	27.7
5	SA 1	25.1

Table 3b. Reduction of dry soiling by polymer modification, fly ash/soot mixture

Sample Nr.	Emulsion	Soiling reduction [%]
6	PA 1 mod 1	4.3
7	PA 1 mod 2	11
8	PA 1 mod 3 (comparison)	0

Wet soiling:

In contrast to the rather moderate dirt-repellent effect in dry soiling, a markedly reduced soiling of the corresponding paint films is observed when emulsions modified with the Clariant-technology are examined in the wet-soiling test. Soiling reductions between 30 and 50% have been observed (see PA 1 mod 1 and mod 2 in table 4b). The same trends as in dry soiling experiments are observed, but with much more pronounced differentiation. The coatings produced with unmodified binders do not exhibit the same ranking in soiling resistance as in the dry dirt-pickup test, emulsion SA 1 which has the lowest dry dirt-pickup, shows by far the highest wet soiling.

Table 4a. Wet soiling results of EWCs containing emulsions PA 1 – SA 1, 5 cycles

Sample Nr.	Emulsion	ΔL^*
1	PA 1	3.6
2	PA 2	3.1
3	PA 3	2.5
4	PA 4	2.6
5	SA 1	4.2

Table 4b. Reduction of wet soiling by polymer modification, 5 cycles

Sample Nr.	Emulsion	Soiling reduction [%]
6	PA 1 mod 1	47.2
7	PA 1 mod 2	32
8	PA 1 mod 3 (comparison)	5

Outdoor exposure:

In order to get quick results from the outdoor soiling tests, the test panels have been placed in the area of Mexico City, being faced with high dust immission. The TSP (total suspended particulate, corresponding to the dust fraction in air with particle sizes range from 0.1 to 100 µm) in Mexico City is roughly six times higher than the TSP values observed in the United States (about 300 µg/m³ mean value for Mexico City[7] compared to about 50 µg/m³ for US cities with 120 µg/m³ maximal immission concentration tolerated by the WHO).

As a result of the high concentration of suspended particulates in the air, soiling proceeds much faster than in cities with lower TSP: A parallel outdoor exposure soiling test in an industrial area of Frankfurt am Main, Germany, gave only about half as high reduction of L^* at equal exposure times and comparable test panel preparation. However, the general trends of dirt-pickup extent observed in outdoor soiling studies accomplished in Mexico and Frankfurt are comparable.

In the same way, Wagner reported on the high soiling tendency of facade coatings exposed to the atmosphere of Jakarta, Indonesia. After two months of outdoor weathering at 45° inclination against the horizontal, an optical differentiation of the test panels was not really possible any longer.[2]

Measurement of L^* after 3 months outdoor exposure in the area of Mexico City showed clearly that suitable binder modification can reduce the dirt deposition (table 5a,b). As in the case of the wet soiling 'quick test' using an aqueous dirt suspension, outdoor weathering results suggest that modifications mod 1 and mod 2 of PA 1 are effective in terms of soiling prevention. They show a much better soiling resistance compared to the non-modified binder, which exhibit already reasonable dirt-repellence.

The styrene acrylic emulsion SA 1 and the unmodified pure acrylic emulsion PA 1 exhibit the highest dirt-pickup, whereas the pure acrylic binder PA 2 resists dust adsorption and indentation most.

Table 5a. Soiling after 3 months outdoor exposure in Mexico City

Sample Nr.	Emulsion	ΔL^*
1	PA 1	9.3
2	PA 2	6.3
3	PA 3	7.8
4	PA 4	8.2
5	SA 1	8.5

Table 5b. Soiling reduction by polymer modification, 3 months outdoor exposure in Mexico City

Sample Nr.	Emulsion	Soiling reduction [%]
6	PA 1 mod 1	43
7	PA 1 mod 2	13
8	PA 1 mod 3 (comparison)	2.2

Conclusion

The data show that the correlation between laboratory quick soiling tests and outdoor exposure is not reliable enough. However, the laboratory wet soiling test is a useful method to quickly determine the main trends in soiling behaviour. After such preliminary screening, the outdoor weathering of the selected samples is essential to get reliable results.

Exposure of test panels to areas with high TSP-concentrations in the air gives a differentiated picture of coatings′ soiling resistance after few months.

The obtained results show that with the emulsions modified according to the Clariant-technology, binders are available which lead to elastomeric wall coatings with markedly enhanced soiling resistance.

References

[1] K. Nishiwaki, M. Katou, *Colloids and Surfaces* **1999**, *153*, 317.
[2] O. Wagner, *Farbe & Lack* **2001**, *107*, 105.
[3] US 3,320,198, T. B. Hill, D. Hill to E.I. du Pont de Nemours and Company, 1967.
[4] K. Tsujii, T. Yamamoto, T. Onda, S. Shibuichi, *Angew. Chem.* **1997**, *109,* 1042.
[5] US 4,208,496, R. A. Bergfeld, S. P. Patel, L. M. Schlickenrieder to N L Industries, 1980.
[6] Patent application 2001DE507, Clariant.
[7] Data from UNEP, United Nations Development Programme.