Improving the Performance of Exterior Emulsion Paint by the Variation of the Chemical Nature of Polymer Latex

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This paper presents a study that underlines the importance of the choice of polymer dispersions in the composition of an exterior emulsion paint in order to improve its quality with respect to the action of external factors. All these properties which facilitate the application and increase the durability are due to the homogeneous distribution of inorganic particles in an organic binder. In order to emphasize this influence, various types of polymer latexes were used: a dispersion of an acrylic copolymer and methacrylic ester, but also combinations thereof with a potassium silicate solution, with silicone latex, with a colloidal suspension containing an alkyd resin with 70% solids dissolved in White Spirit, by comparison with a dispersion of nano silica particles in an organic polymer. All these types of paints which were obtained were analyzed by measuring their hardness, contact angle, elasticity, dirt pickup and chalking resistance, color retention during accelerated (artificial) aging, water vapor diffusion and water permeability, thus proving the existence and efficiency of the inorganic particles of the paint composition.

Keywords: acrylic dispersion, silicone paints, -acrylic-silicon, solvent based alkyd resins, accelerated aging resistance

During the last years, water based acrylic and modified acrylic coatings used for exterior paint jobs have become the basic finishing products in the varnish and paint industry, exceeding solvent based alkyd products from the point of view of their use. This higher consumption is due to a series of benefits they bring along: higher opacity (coverage power) and whiteness index, permeability to water vapors [1-6], reduced drying time, increased durability in time and low content of volatile organic compounds. Exterior water-based coatings contain polymers or acrylic and/or methacrylic copolymers, acrylic coatings being distinguished by the excellent resistance of their color to UV light [7]. For exterior coatings “soft” pure acrylic resins with a glass transition temperature Tg = 0-10^0 C are preferred to the “hard” ones with Tg = 0-24^0 C, which can not penetrate fine cracks.

There are several chemical components which can provide protection against the external factors for the exterior coat of paint, but resins are the most important ones in terms of both their chemical composition and used quantity. The quality and quantity of these resins can be noticed in the properties of exterior paints, such as: scratching resistance, mold and bacteria resistance, durability of the applied paint film [8-9].

In this study an acrylic polymer copolymerized with methacrylic esters has been analyzed, used for exterior coatings having no repair role but a protection and decoration role only. In order to demonstrate the improved protection of the exterior paint we tried a series of variants of combination between the polymer and inorganic composites. From these combinations other types of dispersions resulted in the end - organic-inorganic composites hybrids: silicates, silicones, synergetic blend of acrylic dispersion with solvent-based alkyd resin. These were compared with a dispersion of nano silica particles in an organic polymer , which is the basic ingredient of glass and quartz.. The combination between the elastic organic material and the hard mineral -inorganic hybrid composite ensures a high performance finished product. Organic-inorganic hybrid composites combine the flexibility of an organic component with the hardness of an inorganic component. Organic-inorganic composite materials have been analyzed in a variety of applications including medicine, electronics, cosmetics, adhesives, surface coatings [10-12] and separation membranes [13-15].

Silicone emulsion paints combine the properties necessary for a mineral coating with those of an organic coating. As a result, they are superior to both mineral and polymer-bound coatings [16-18]. Coating systems based on silicone resins are suitable for almost every kind of sublayer. The amount of silicone in the resin is between 5 and 30% w/w. If the amount is over 10% they are usually called silicone paints. Silicone resins are high-molecular weight three-dimensional compounds with reticulate silica/oxygen links similar to those of quartz. Silicone paints are intended for exterior use due to their quality [19].

There are various methods to obtain silica/organic nano composites, but in order to achieve the desired performance by adding nano-particles, the targeted organic polymer must display specific tendencies of interaction with inorganic particles. The organic polymer matrix encapsulated with silica particles must also be prepared by means of a phase-inversion emulsification. Atom transfer radical polymerization (ATRP) has been used to obtain a polymer coated with inorganic silica particles [20].

Experimental part

Materials and devices

Polymer latexes are basic components of some exterior paints which were varied to demonstrate the importance of their choice in order to obtain guaranteed performance for the exterior paints. These polymer latexes, hereinafter referred to as polymers, resins or emulsions, were chosen based on their performances in this field, being already traded on the market, synthesized and used to obtain exterior emulsion paints.

The uncombined polymer latexes characteristics are presented in table 1 and the characteristics of polymeric latexes to be combined are presented in table 2.

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Table 1
CHARACTERISTICS OF UNCOMBINED POLYMERIC LATEXES

No.	Type of emulsion	Copolymer emulsion based on acrylic and methacrylic esters			Nano dispersion of silica in an organic polymer		
	Sample designation - abbreviation	Sample 1 – M 1			Sample 2 – M 2		
1	PROPERTY	VALUE	UNIT	METHOD	VALUE	UNIT	METHOD
2	Solids Content	60	%	DIN 53 189 / ISO 1625	35	%	DIN 53 189 / ISO 1625
3	pH Value	8.5		DIN 53 785 / ISO 1148	9		DIN 53 785 / ISO 1148
4	Viscosity, Brookfield-viscometer RVT; spindle no. 3; 20 min-1	2500	mPas	ISO 2555; 23 °C	75	mPas	ISO 2555; 23 °C
5	Mean Particle Size	0.2 - 0.4	µm	Interior regulation	0.05 - 0.1	µm	Interior regulation
6	Glass Transition Temperature, TgDSC, heating rate 10 K/min	12	°C	DIN 53765		°C	DIN 53765
7	Minimum film forming temperature (MFFT)	5	°C	DIN 53 787 / ISO 2115	<1	°C	DIN 53 787 / ISO 2115
8	Density	1.03	g/cm³	ISO 8962	1.11	g/cm³	ISO 8962
9	Organic ingredients				60	%	Interior regulation

Table 2
CHARACTERISTICS OF POLYMERIC LATEXES WHICH WILL BE COMBINED WITH SAMPLE 1

No.	Type of emulsion	Solution of potassium silicate			Emulsion of a silicone resin			Colloidal suspension		
	Sample designation - abbreviation	Sample 3 – M 3			Sample 4 – M 4			Sample 5 – M 5		
1	PROPERTY	VALUE	UNIT	METHOD	VALUE	UNIT	METHOD	VALUE	UNIT	METHOD
2	Solids Content	45	%	DIN 53 189 / ISO 1625		%	DIN 53 189 / ISO 1625	13.86	%	DIN 53 189 / ISO 1625
3	pH Value	6		DIN 53 785 / ISO 1148	5		DIN 53 785 / ISO 1148	6		DIN 53 785 / ISO 1148
4	Viscosity, Brookfield-viscometer RVT; spindle no. 3; 20 min-1	300	mPas	ISO 2555; 23 °C	1000	mPas	ISO 2555; 23 °C	600	mPas	ISO 2555; 23 °C
5	Minimum film forming temperature (MFFT)	8	°C	DIN 53 787 / ISO 2115						
6	Glass Transition Temperature, Tg DSC, heating rate 10 K/min	9	°C	DIN 53765						
7	Density	1.25	g/cm³	ISO 8962	1.04	g/cm³	ISO 8962	0.95	g/cm³	ISO 8962
8	Organic ingredients	1.4	%	Interior regulation (IR)	50	%	intern	7	%	Interior regulation (IR)

Main equipment

To obtain the proposed types of paints according to the laboratory scale a dispersing instrument – Dispermat was used.

In order to test the obtained types of exterior water based paints the following instruments were used: a spectrophotometer to characterize the three important characteristics of the dry paint film: opacity, whiteness and yellowness indexes, dE value for colors, namely the difference of color against an initial standard, an automatic applicator, black-white glossy cards, Brookfield, Cone and Platan and Stormer viscometers, a metallic pycnometer, a drying chamber heated at 105^0 C, an electronic pH meter, a thermometer, glass pieces, wet scrub instrument, a Persoz Pendulum Hardness Tester, Xenon Arc Lamps and Dynamic Moisture Permeation Cells.

Procedure

The proposed variants are obtained in the laboratory disperser - Dispermat, using a minimum quantity of 5 kg for each variant, maintaining the same weighing errors (the same electronic scale), the same batches of raw materials, the same technology and the same order of introduction of the raw materials, the same homogenization time, all performed by the same operator.

The technological process is as follows: half of the quantity of water and half of the quantity of defoamer are mixed together at an average speed of 400-500 rpm for 5 min, then the cellulose thickener is added, at the same speed, and the mix is allowed to thicken for 15 – 20 min, then the other ingredients are added one by one: the neutralizing agent, the biocide, the surfactant, the dispersants and wetting agents, the fillers (white pigment and extenders) at high speed of 1000-1200 rpm, then some more water is added, if the paste is too thick, and the mix is blended for 1-2 h in order to obtain an appropriate fineness (less than 50 µm) which is measured with a Fineness of Grind Gage. A thin layer of the product can then be applied on a glass plate in order to see the degree of dispersion. If the paste is fine enough the rotation speed shall be reduced to 300-400 rpm and the solvents, the glycols, the rest of defoamer and the resin shall be added mixing for another 5 min to obtain a complete homogenization. Then the paint is adjusted from a rheologic point of view by adding HASE and / or HEUR rheology modifier/s, dissolved in a minimum quantity of water in order to avoid the formation of agglomerations and the mix is allowed to rest for 20 min to finalize the thickening and stabilization processes.

The parameters studied in this paper and the used analysis methods are presented in table 3.

Table 3
ANALYSIS METHODS

Parameters	Details about the test method
Fineness of Grind	ASTM D 1210, a higher number indicates a greater fineness of the particles
STORMER Viscosity	ASTM D 562, a higher number indicates a higher viscosity of the paint in the container
BROOKFIELD Viscosity	ASTM D 1131, a higher number indicates a higher viscosity of the paint in the container
ICI Viscosity	ASTM D 4287, a higher viscosity (at 12000 s-1) indicates a higher load of the brush, and the forming of a better film
Water resistance test	ISO 11998, a greater loss of the dry film thickness upon washing at the same number of cycles, indicates a weaker resistance to water
Hardness by measuring the damping time with an oscillating pendulum	ASTM D 4366, & DIN EN ISO 1522, a higher number indicates a higher hardness of the paint film .
Artificial (accelerated) aging	ASTM G 154
Permeability to moisture	ASTM F2298 - 03(2009)e1, a lower value indicates a higher resistance of the paint film to moisture , a better "breathing" of the paint
Permeability to water	ASTM E2396 – 05, a higher value indicates a higher resistance of the paint film to the penetration of water
Elongation at break	SR 8994-10, a higher value indicates a higher elasticity
Contact angle measurement	ASTM D 7334-08, a lower value of the contact angle indicates a better absorption of the water drop on the system surface
Contrast ratio, whiteness and yellowness indexes, dE for shades	E275-8 - a higher opacity, a higher whiteness index and a low yellowness index are the ideal values for a white paint film, while for a colored paint a dE as closer to zero as possible indicates a color accepted against a standard

The variants obtained in this study are presented in table 4.

Table 4
VARIANTS OF EXTERIOR WATER BASED PAINTS

Ingredients / Steps	Composition % Variant 1 – P1	Composition % Variant 2 – P2	Composition % Variant 3 – P3	Composition % Variant 4 – P4	Composition % Variant 5 – P5	Chemical composition
1. Pigment grind						
Solvent	27.6	27.02	28.45	25.26	22.6	Water
Thickener (HEC)	0.55	0	0	0	0,5	Hydroxyethyl cellulose
Thickener and stabilizer	0	0	0,5	0	0	Polysaccharides
Thickener (MHEC)	0	0,13	0	0,6	0	Methylhydroxyethyl cellulose
Dispersing agent	1	1	0	0	0,8	Nonionic wetting agent
Dispersant and plasticizer	0	0	0,3	0	0	Aqueous anionic solution of the phosphonic acid salt
Dispersant	0	0	0	0,4	0	Polycarboxylic acid
Low VOC stabilizer for the potassium silicate resin	0	0	0,2	0	0	Hydrophilic aqueous solution
Biocide	0.25	0,3	0	1.2	0,25	Alkoxylated alkylammonium compound
Defoamer	0.5	0.3	0.3	0.3	0.4	Emulsions of paraffin based on mineral oils and hydrophobic components
Anti-frost agent	0.45	0	0	0	0.5	Contains silicone
Neutralizing agent	0.2	0.2	0	0,1	0,2	Aminomethyl propanol
Surfactant	0.25	0,25	0,25	0,25	0,25	Quaternary ammonium salt
White pigment	10	10	10	10	10	Titanium dioxide
Talc	2	2	0	0	2	Talc
Filler	40	40	40	40	40	Natural calcium carbonate
2. Letdown						
Latex 1	15	0	5	5	5	Sample: M 1
Latex 2	0	15	15	15	15	Samples: M2, M3, M4, M5
Water repellent	0	0	0	1	0.4	Polysiloxane modified with silicone resin
Coalescent agent	0,2	2	0	1	0,2	. 2-methyl propionic acid monoester with 2,2,4-trimethyl-1,3-pentandiol
Rheology modifiers (HASE, HEUR)	2	1,6	0	0	2	Hydrophobically modified acrylic and/or polyurethane agents

Table 5
CHARACTERISTICS OF THE PREPARED PAINT VARIANTS

Characteristic	Values / Variants				
	P 1	P 2	P 3	P 4	P 5
pH	9.65	9.7	9.87	9.27	9.1
Density, g/cm3	1.4595	1.4787	1.4522	1.4566	1.4582
Brookfield Viscosity, cP	11520	10300	13258	10783	9870
Stormer Viscosity, KU	129.1	105.6	115	110	108
ICI Viscosity, P	1.08	1.48	0.8	1.2	0.95
Solids Content, %	62.14	62.13	61.2	58.11	62.8
VOC, g/l	21	10	24	20	40
Opacity, %	99.68	99.43	99.37	99.33	99.17
Whiteness Index	91.55	91.38	91.43	91.5	91.4
Yellowness Index	0.24	0.15	0.33	0.3	1.04
Wet scrub resistance, after 30 days	20100	38400	22600	33200	24050

P 1 = acrylic paint, contains Sample 1;
P 2 = nano paint, contains Sample 2;
P 3 = silicate paint, contains a mix of Sample 1 and Sample 3;
P 4 = silicone paint, contains a mix of Sample 1 and Sample 4;
P 5 = colloidal paint, contains a mix of Sample 1 and Sample 5;

We make the assumption that all five recipes have almost identical values for the: PVC, VOCs, density (when wet), total solid mass and solid volume. The raw materials chosen for this study are available on the market.

Latex 1 = *dispersion of the acrylic copolymer and of the methacrylic ester – Sample M1;*

Latex 2 = dispersion of nano silica particles in an organic polymer – Sample M2; potassium silicate solution – Sample M3; silicone latex – Sample M4; colloidal suspension containing an alkyd resin with 70% solids dissolved in White Spirit – Sample M5;

Five different exterior paint recipes were prepared in order to assess the resin influence on the quality of the paint, as determined by measured values.

The obtained variants were stored in the same conditions of temperature and humidity in the laboratory (20 ± 3^0 C, 50%) and were analyzed in terms of their characteristics after 24 h as of preparation. The analysis of the characteristics was performed by the same operator by complying with the same working conditions to eliminate as many errors as possible.

Results and discussions

The physico-chemical characteristics of the five variants P1-P5 of liquid paint obtained in the laboratory are presented in table 5.

All five recipes were adjusted with thickeners and rheology modifiers to obtain approximately the same physico-chemical characteristics in order not to place any variant at a disadvantage.

In table 5 we notice that variant P5 which contains a colloidal suspension of an alkyd resin in an organic solvent, presents the highest VOC value (the maximum allowed by the law is 30 g/L). This is due to the alkyd resin, which is also responsible for the high yellowness index of the product 1.04 determined by the color of the resin . On the other hand, this resin has a high scrub wash resistance, value measured by the obtained washing cycles.

Pendulum hardness

The pendulum hardness is a good parameter in order to evaluate the resistance of a covering. The higher the pendulum hardness the harder the surface and consequently the deterioration of the surface of the film is less likely. The pendulum hardness of the five different paint variants was measured for the films applied on glass [120 μm wet] after allowing them to dry at room temperature for 24 h (fig. 1).

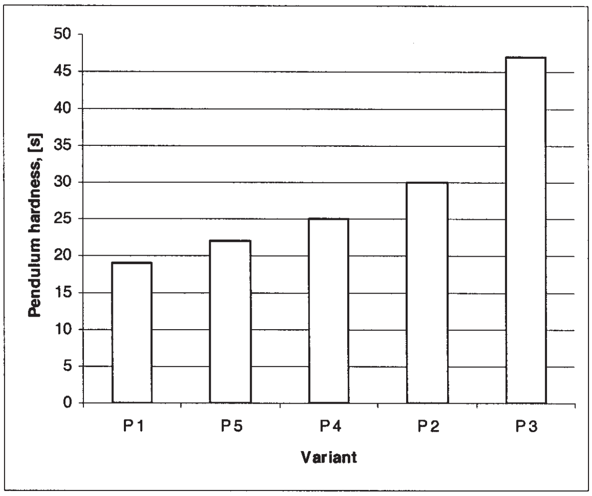

Fig. 1. Pendulum hardness [s] of paint films

Figure 1 shows that the inorganic silicate paint, P3, presents the highest film hardness. This indicates a very rigid surface with low tackiness. On the other hand, such a silicate paint is no longer flexible, corresponding to a pendulum hardness of 47 s /23 °C, it is very brittle , having an elongation at break < 3 % at room temperature. This means that a silicate paint with an organic fraction smaller than 6 % is subjected to cracking and therefore allows the penetration of water into the brickwork, if its adhesion to the mineral sublayer is not good enough.

The silicone resin paint, P4, is much less flexible (with a elongation at break of < 3% / 23°C, similar to that of silicate paint, P3) but has a surface hardness similar to that of acrylic paint P1. Therefore the combination between a low elasticity and a low surface hardness , typical to silicone resin paints is rather a disadvantage. However only overcritical formulations enable silicone paints to achieve an excellent water vapor permeability.

By comparison with silicate paint P3, the emulsion of nano silica and organic polymer P2 has a high surface hardness, the reason for that being the presence of silica particles on the paint surface. As these are purely inorganic, they contribute to the increase of the hardness up to 30 s pendulum hardness. Nevertheless, as a unique feature of the nano emulsion paints, their films are still flexible, having an elongation at break of approx. 20 % at 23 °C, being the second highest after acrylic paint. The origin of such flexibility is the organic matrix of the nano emulsion paint, in contrast to the purely inorganic network of a silicate paint. In conclusion, nano paint P2 is the best option even

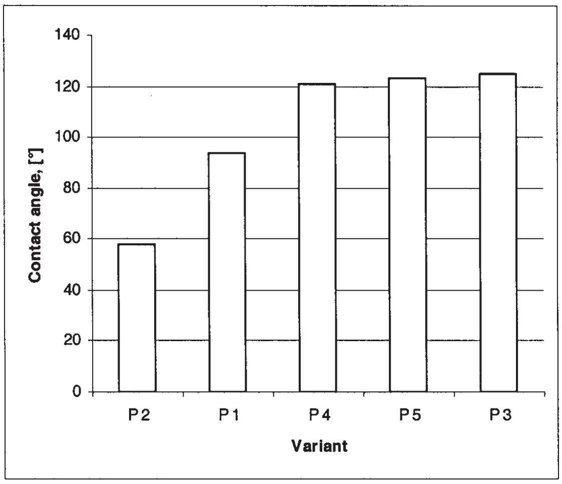

Fig. 2. Contact angle [°] of a water droplet on a barely dried paint film

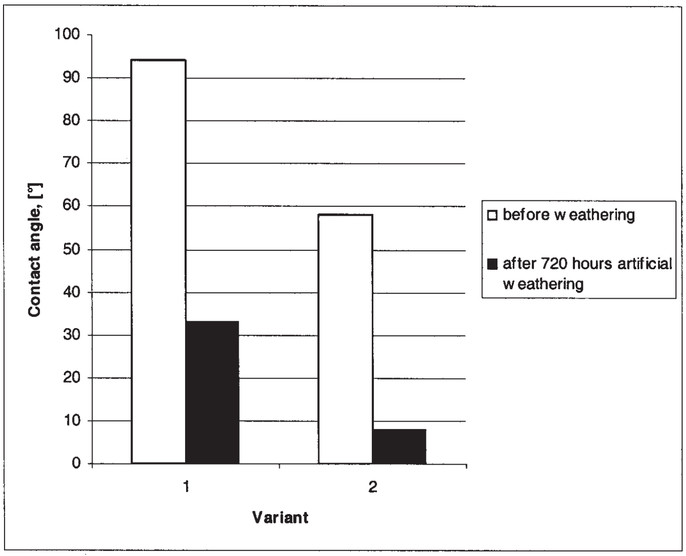

Fig. 3. Contact angle [^{0}] of an acrylic dispersion paint – P1 and a nano dispersion paint – P2 before and after 720 h of artificial weathering

if silicate paint P3 has a higher hardness value , but a combination between this value and an appropriate break elongation give a better solution as a whole.

Contact angle

Another important feature of exterior paints is shown in figure 2. Here the contact angle [°] was determined by spreading of a water droplet on a barely dried painted surface.

By comparing the contact angles of the water droplet on the analyzed paint systems, it is obvious that the emulsion of nano paint (silica particles in an organic polymer) P2 has , by far, the smallest contact angle. This indicates the higher hydrophilic character of such nano paint in comparison with all the other studied systems. Therefore, only the nano paint with a very low contact angle provides a weak interaction with any other type of hydrophobic dirt, which is a clear advantage with respect to the outdoor exposure. The silica particles located on the film surface determine the low contact angle due to their strong hydrophilic character. As the silica creates a network which cannot be penetrated throughout the whole film, this effect is continuously rebuilt even if the film is damaged.

The evolution of the contact angle after the ageing of the paint (fig. 3) is very important in practice. After 720 h of artificial (accelerated) ageing we obtain data not only about the initial interaction with the dirt source, but also a clue about the behaviour during the surface degradation.

In figure 3 contact angles of an acrylic dispersion-P1 and a nano dispersion paint-P2 are compared. As seen before, the nano based paint has a smaller contact angle than the acrylic paint (58° compared to 94°). After 720 hours of artificial weathering (Xenon-Test) the contact angles were calculated again. It was noticed that due to their hydrophilic character, the contact angles of both paints dropped. However, the nano based paint presented a contact angle, which was very difficult to measure , as the water droplet was completely spread and absorbed by the paint surface. In conclusion, nano paint P2 had smaller values of the contact angle both before and after the 720 h of artificial weathering, which means that this paint will not interact with a hydrophobic group, such as a dirt pick-up, upon its outdoor exposure.

Dirt pick-up resistance (dE) and chalking

One of the most important properties of facade coatings is the performance upon outdoor exposure. A low dirt pick-up character, expressed by low dE values, together with marginal chalking tendency are highly desirable. Apart from polarity, wettability and resistance of the coating during rain, there are other factors such as thermoplasiticity, surface tack and porosity which have a crucial impact upon these studies.

After 720 h of artificial weathering, the surface of the paint film changed significantly. Since the polymer was deteriorated by the UV irradiation, particles of filling particles and pigment traveled towards the surface. This effect can be explained by the increase of the hydrophilic character, and can also be explained as a chalking phenomenon, which occurs when the pigments and fillers are no longer embedded in full in the polymer matrix.

Table 6 shows the results after 720 h of artificial weathering, results presented as opacity, whiteness and yellowness indexes for all five studied paints.

After 720 h of artificial weathering all studied paint films became yellowish, giving the impression of a better opacity, but the whiteness indexes are lower and the yellowness indexes are higher. The wet paint film thickness was of 150 µm. Figure 4 shows the results of the lab tests with carbon black powder .

Nano paint P2 displays a high dirt pick-up resistance on all the lab tests, compared to silicone paint P4, which although has a higher pendulum hardness and a lower surface tack, in combination with a lower contact angle it gives a higher dirt pick-up character. These conclusions result from the dE values (2 compared to 3.2) read with the help of the spectrophotometer.

Table 6
VARIATION OF OPACITY, WHITENESS AND YELLOWNESS INDEXES AFTER 720 HOURS OF ARTIFICIAL WEATHERING FOR THE STUDIED PAINTS

Parameters	Values / Variants				
	P 1	P 2	P 3	P 4	P 5
Opacity, %	99.7	99.65	99.46	99.62	99.33
Whiteness Index	89.33	89.67	89.47	89.5	88.78
Yellowness Index	0.9	0.73	1.15	0.98	2.75

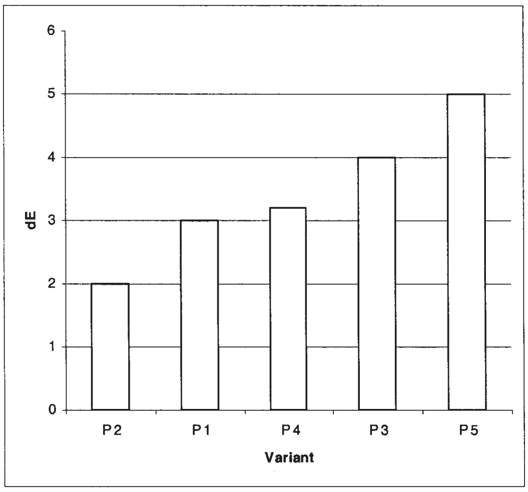

Fig. 4. Dirt pick-up resistance (dE) after 720 h of artificial weathering and lab test with carbon black powder

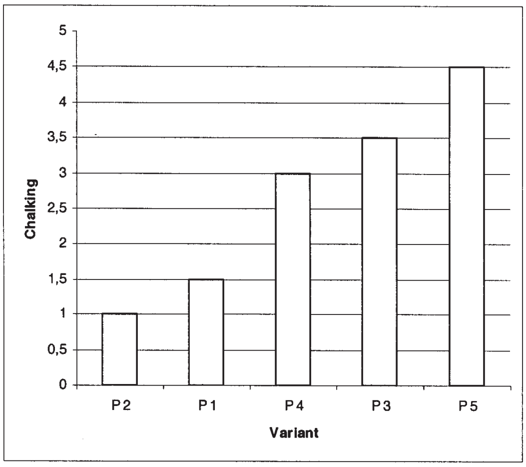

Fig. 5. Chalking resistance after 720 h of artificial weathering

Figure 5 shows the results of the chalking of the five types of paint after 720 h of artificial weathering (0 = excellent, 5 = worst).

Nano paint P2 displays a lower chalking value during all the lab tests. No severe chalking is also observed with the acrylic based paint P1 either, leading to the conclusion, that dirt pick-up resistance derives mostly from the surface “hardness” of the paint combined with it hydrophilicity.

In the case of silicone resin paint P4, the hydrophobic groups are responsible for the low dirt pick-up resistance. In addition it has a low surface hardness, which leads to adherence of dirt on the tacky surface.

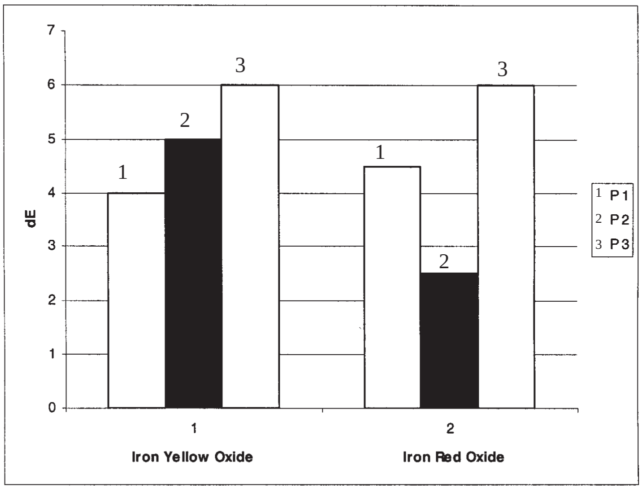

Fig. 6. dE values for acrylic-P1, nano-P2 and silicate-P3 paints tinted with various inorganic pigments (Iron Yellow Oxide and Iron Red Oxide) after 1440 hours artificial weathering with the Xenon-Test

Color retention after weathering

Another important property of a facade paint is color retention even after weathering. Inorganic pigments are used for tinting for these tests due to their higher resistance to UV light than organic pigments. The dE values after 1440 h of artificial ageing with a Xenon-Test of all the five studied paint systems, tinted with inorganic pigments, are displayed in figure 6.

The silicate paints P3 showed a typically poor color retention , reflected by the chalking and washing out of the surface; however the behavior of acrylic paint P1 is comparable to that of nano paint P2.

Table 7 presents the results of the artificial weathering after 1440 h expressed by opacity, whiteness and yellowness indexes for all five studied white paints.

After 1440 h of artificial weathering, all white studied paint films became yellowish, thus providing a slightly higher opacity. But the whiteness indexes decreased while the yellowness indexes increased. The thickness of the wet film of paint was of 150 μm. The only paint that did not show a significant increase of the yellowness index was nano paint emulsion P2, which showed a very good resistance to yellowing upon exposure to air.

Water Vapor diffusion and Water Permeability

Table 8 presents the results for acrylic paint P1 after the water vapor diffusion and water permeability (for 24 h) in comparison with nano paint P2. The higher water permeability of the nano emulsion is desirable.

Table 7

VARIATION OF OPACITY, WHITENESS AND YELLOWNESS INDEXES AFTER 1440 h OF ARTIFICIAL WEATHERING FOR THE STUDIED PAINTS

Parameters	Values / Variants				
	P 1	P 2	P 3	P 4	P 5
Opacity, %	99.80	99.7	99.50	99.81	99.45
Whiteness Index	89.00	89.01	89.11	89.15	88.25
Yellowness Index	1.17	0.86	1.26	1.22	4.15

Table 8

WATER INFLUENCE UPON THE TWO TYPES OF STUDIED EMULSIONS

Emulsion type	Water Vapor Diffusion, Sd (m)	Water Permeability, 24 h, (Kg/[m.sup.2] [h.sub.0.5])
P 1- acrylic paint emulsion	0.91	0.03
P 2- nano paint emulsion	0.07	0.18

Conclusions

This paper emphasis the advantages of combining inorganic and organic components in order to finally obtain better properties than those of the standard organic (acrylic) dispersions or those of mineral inorganic ones taken separately. Nano paints with both inorganic and organic components have properties such as a high surface hardness due to the inorganic components and the appropriate elasticity due to the organic components. This is the basis for an optimal combination of low dirt pickup and high durability due to crack-resistance.

The nano paints displayed excellent resistance to dirt pick-up, and a cleaner appearance. These functional and aesthetic properties when combined with a high water vapor permeability clearly show that organic-inorganic hybrid systems (the nano paint emulsion described in this article) represent an excellent binder choice obtaining high performance exterior coatings.

Abbreviations

HEC = average molecular weight hydroxyethyl cellulose, with a viscosity range of 1100-1500 cP, sol 1%, Brookfield viscosity;
HMHEC = hydrophobically modified hydroxyethyl cellulose, with a viscosity range of 1300-1800 cP, sol 1%, Brookfield viscosity;
HASE = hydrophobically modified alkali-soluble emulsions;
HEUR = hydrophobically modified ethoxylated urethane emulsions;
PVC = pigment volume concentration;
NVW = non-volatile weight;
NVV = non-volatile volume,
VOC = volatile organic content

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