Resin technology

Waterborne masonry coatings give lower environmental impact

Advanced technologies also give higher performance

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Pure acrylic waterborne technology improves the exterior durability of coatings applied on various substrates. Furthermore, the use of pigment encapsulation technology (PET) in masonry paints gives good adhesion to mineral substrates. Replacing part of the TiO_2 and binder with an opaque polymer (OP) also brings improvements and PET and OP when used together also show benefits.

Although solventborne coatings represent a large part of the exterior coatings market, their waterborne counterparts have seen significant growth over the last 15 years. This is due to the demands of environmental legislation and a continuous improvement in performance. Waterborne masonry paints in particular have seen a lot of developments aimed at improving their overall durability over several types of substrates. The main requirement, besides aesthetics, is to protect the substrate in order to increase its life. To protect the substrate, a coating film must adhere well, keep its integrity and be resistant to liquid water penetration, but nevertheless allow water vapour to exit if needed. The resistance to dirt pick up, changes in colour or gloss, to algae and mildew growth needs also to be satisfied to maintain the initial aesthetics of the coating.

The binder provides many important attributes to a coating. Substrate preparation and the quality of the application are very important for the final durability of the exterior coating. This article concentrates on the formulation and more specifically on the binder choice and the optimized use of OP for superior substrate protection and aesthetic longevity.

Pure acrylic technology

Exposure under real-life conditions has shown that pure acrylic waterborne paints have better durability than other waterborne or solvent borne technologies [1]. Styrene-acrylic binders chalk more than pure acrylic ones as they are more sensitive to UV light. Binders containing vinyl acetate are also less durable due to their inherent water sensitivity. Ethylene vinyl acetate polymers are probably the most water sensitive binders and therefore are usually only used for interior coatings.

The performance and appearance of pigmented waterborne coatings greatly depend on the degree to which the pigments and extenders are dispersed throughout the dried film [2]. The ideal state of dispersion is usually when all particles are reduced to and remain as non-flocculated primary particles. Polymer particles, pigments and fillers which are not optimally dispersed can hinder the provision by the coating of an adequate barrier to electrolytes to provide, water, gases, etc., good mechanical properties and optical properties. Recently acrylic latices have been designed that give an optimal binding with mineral particles such as pigments or extenders in a paint or particles coming from the mineral substrate. This results in optimal film integrity and better adherence and thus a longer exterior durability.

When pigments such as titanium dioxide are well-dispersed, properties such as hiding, film gloss, colour and the effectiveness of the coating as a barrier are maximized. One way to achieve an optimized pigment and extender distribution is to encapsulate the mineral particles with the organic binder by effectively increasing the interaction between them and latex particles. During the drying process and film formation, this can prevent titanium dioxide and extender particles from agglomerating.

A new approach is to use a new latex particle which can bind to mineral surfaces and thus give more uniform particle distribution. Significant improvements occur in wet abrasion, stain-blocking and stain resistance, metal adhesion, corrosion resistance, film gloss and efflorescence resistance [3]. The micrographs shown in [3] indicate that a bond exists between the organic binder particles and mineral particles (titanium dioxide in this case) in a latex containing this pigment encapsulating technology. This gives a tighter dry film with superior hiding, film resistance and enhanced colour due to better pigment spacing.

Pigment encapsulation

Styrene acrylic binders are widely used in masonry coatings in Europe despite their chemistry being more prone to chalking. The exterior durability of a typical masonry paint based on a styrene acrylic binder (total PVC 54%) compared to the same formulation based on a pure acrylic PET binder, but at PVC of 58%, shows that the superior binding capacity of the PET binder allows a reduction in its content while maintaining properties such as wet scrub resistance.

Two coats of both paints were applied by roller on a fibre-cement panel the top third of which had been sealed with a clear acrylic under coat. The panel was exposed South Vertical in a site, located in the Southern French Alps, which has annually about 200 days of sunlight, with a daily temperature change from -8℃/-10℃ to 18℃/20℃ in winter and 8℃/10℃ to 35℃/40℃ in summer and an average annual rain fall of 900 mm. Coatings submitted to these climatic conditions age faster than in most other Western European locations.

After an exposure of almost two years (*Figure 1*), the styrene acrylic based paint (paint # 8) showed efflorescence (whitish crystal deposits on the un-sealed bottom part and even slightly on the sealed upper part) whereas the PET based paint (paint #9) showed none. After 23 months, the styrene acrylic based paint had chalked over the whole surface (significant colour fading). Both white paints were still very clean after almost two years exposure.

The L, a, b values of the aluminium panels coated with paints #8 and #9 were regularly measured. *Figure 1* shows that the styrene acrylic based paint exhibited whitening or colour faded more than the PET based paint. Since this cannot be due to efflorescence (not a cementitious substrate), it is explained by chalking, i.e. some loss of film integrity letting some mineral particles (TiO_2 and extenders) leave and create a “haze” on the blue surface. This confirms the observation made on the fibre-cement panel.

In another series, a masonry paint was formulated based on a styrene acrylic binder (Tg~14℃) at a total PVC of 49%. Two variants with same hiding were prepared with a pure acrylic PET binder (Tg approx. 6℃) at about 54% PVC. Here again the superior pigment-dispersion yield of the PET binder made the lowering of the TiO_2 level possible and also enabled a reduction of the binder level due to the better binding power without compromising the film resistance. The two variants differed slightly in terms of TiO_2 reduction (17% or 20% less by weight versus initial paint) and rebalance of the functional extenders

As before, two coats of each of the three paints were applied in white or blue on fibre-cement panels and aluminium panels. The exposure data show that, after 23 months in the Southern Alps, the higher PVC PET-based paints gave better performance. *Figure 2* shows the delta L measured on the blue paints applied on aluminium panels. Negative delta L values indicate a whitening of the paint due to chalking.

Organic opacifiers

Hollow sphere pigments, or opaque polymers (OP), have now become accepted worldwide as standard ingredients in decorative paints. In the wet paint, the void of the hollow sphere is filled with water that is replaced with air upon drying of the film. Because of the difference in refractive index between the OP shell (n~1.6) and that of the air (n=1), light is scattered and opacity is increased. The introduction of OP helps also improving the scattering efficiency of the titanium dioxide by optimizing the spacing between the TiO_2 particles.

Since TiO_2 is a major contributor to formulation cost, the main reason for using OP has been economic considerations and thus the performance benefits have been under estimated. The smooth, non-porous surface of the OP beads results in a lower binder demand in comparison to traditional pigments or extenders. Therefore in reality, the value of critical PVC is increased, i.e. more binder is available to ensure good film cohesion at higher PVC. Additionally, replacing mineral particles with smooth organic beads leads to a film surface less prone to dirt pick up and mildew growth. Paints reformulated with OP to match the hiding and gloss of the original ones give a slightly higher total PVC (3 to 5 units higher).This leads to a harder, smoother and brighter surface, since part of the TiO_2 and of some extenders is replaced with the spherical organic beads of lower binder demand.

Numerous OP exposure studies have been carried out over the last 25 years under various climatic conditions and environments. Most studies have shown the benefit of using OP to improve dirt pick-up resistance (DPUR) and colour retention. The inherent advantage of OP on DPUR was shown by replacing almost the whole amount of calcium carbonate with OP as shown in the *Table 1*. The TiO_2 PVC (17%) and the total PVC (55%) were kept constant. This does not correspond to a typical reformulation for a hiding match and cost savings; however, the objective was to replace 30% PVC of $CaCO_3$ with 30% PVC of OP and compare the film cleanliness after a period of exposure.

Figure 3 shows the delta L values of the paints, with OP (#4) or without (#5), exposed in the Southern Alps. It clearly shows the positive influence of OP on dirt pick up resistance. After 12 months exposure, the delta L value for the paint containing OP is higher than for the reference sample without OP. It became lower after 29 months. This is because the L values were measured after 12 month exposure and just after rain fall containing sand. Both paints were very dirty, but the sand and dirt were removed by later rain falls. The film with OP was cleaned better, probably due to the presence of the smoother organic beads which reduced the dirt adhesion to the film. This has been observed in other exposure tests.

Better colour retention

In the exposure tests, the white panels allowed dirt pick up to be assessed and the blue panels colour retention and efflorescence or chalking. The paints were applied on aluminium panels to judge the film behaviour on an inert substrate. The panel orientation was chosen depending on what was to be observed: north-vertical orientation to accelerate algae and mildew growth, south-vertical for dirt pick up resistance (usually on white paints) and south 45° gives us accelerated data on gloss and colour retention.

The following series compared the exterior durability of pure acrylic paints formulated without or with two levels of OP. The total PVC was increased from 55% to 61% according to the respective amount of OP used. This changed the fraction of theoretical critical PVC from 0.85 to 0.96. The white paints were also coloured blue using an organic phthalo blue pigment. L, a, b values of the white and coloured paints applied on inert aluminium panels exposed south vertical in the Southern Alps were measured over time.

Figure 4 shows that the delta L of the three white paints evolves in a similar fashion over the 18 months exposure time (a difference of 0.5 units is invisible to the eye). Thus the dirt pick up of the three paints is similar. Therefore, the use of OP enables the PVC of a paint to be increased to just below CPVC without reducing its dirt pick up resistance.

The evolution of the L, a, and b of the blue paints was also observed and *Figure 5* shows the delta L values with time. Since these paints, based on the same pure acrylic binder (no chalking), were applied on an inert substrate (no efflorescence), and since they had similar dirt pick up (similar delta E for the white paints), the comparison of their delta L represents the respective film colour change. The higher the delta L, the greater the darkening.

As paint containing an OP ages, some of the voids in the paint film vanish. The actual number of voids lost is relatively small; thus has no impact on paint's hiding ability. The loss diminishes the paint's ability to scatter and reflect light, leaving the paint slightly darker. This occurs only in tinted paints; white paints do not change. Negative delta L indicates colour fading. The graph above confirms clearly that the higher the OP level, the higher the colour darkening which in reality means that the paint colour will not fade as early; thus the aesthetics of the coating is prolonged.

As previously mentioned when a paint is reformulated with an OP, part of the pigment and extender content is removed and the film surface is smoother. The higher the level of OP in the paint, the more OP particles there are on the surface.

More hydrophobic organic particles on the coating surface gives less observed dirt collection. Paints of total PVC 35% or 37% with respectively 0% or 15% PVC OP have been exposed for three years in the Southern Alps. A photograph of the test panel was analyzed with image-processing software using a L value threshold to show the darker spots on the coating surface. These black dots are colonies of a fungi identified as *aspergilus niger*. Their presence on the coating without OP was because the surface was rougher and more prone to dirt collection and therefore fungal growth. A similar observation was made on paints with and without OP applied on stucco. In this case, the black spots on the paint without OP were also *aspergilus niger*.

PET and OP

The development of the PET allows stronger adhesion to substrates such as fibre cement. Water borne acrylic binders based on this technology are recommended for such exterior coatings. An optimal level of OP in the formulation of exterior paints also brings clear durability benefits. Therefore, the combination of a PET binder with OP replacing part of the TiO_2 and extenders will improve the durability of an exterior coating applied on mineral substrate. Several tests have proved that this optimal combination gives improved efflorescence resistance and superior tint retention.

In particular, a series was prepared to verify whether the introduction of OP in a PET paint gave the same improvement in tint retention as with conventional acrylic binder. A PET based paint was reformulated with OP to give the same hiding. This resulted in an increase of total PVC from 61% to 65% corresponding to respective fractions of calculated critical PVC of 0.91 and 0.98. The blue paints were applied on aluminium panels, exposed South 45° and their L, a, b values measured over time. Here again, as can be seen in *Figure 6*, the delta L are higher with the paint containing OP, indicating a darkening effect. After 16 months exposure south 45°, the paint without OP shows some colour fading (negative delta L). Therefore, the use of OP allows formulation at a higher PVC, gives cost savings and provides an exterior coating that will last longer before colour starts to fade.

Results at a glance

- Waterborne pure acrylic technology improves exterior durability of coatings on various substrates.
- Pigment encapsulation technology (PET) gives masonry paints strong adhesion to mineral substrates and therefore an improved efflorescence resistance.
- Replacing part of the TiO_2 and binder with an opaque polymer allows an improvement in dirt pick up resistance and the tint retention of the coating while reducing its cost.
- The superior binding capacity of the PET polymer and its ability to disperse pigment efficiently permits the reduction of binder and pigment content in the paint whilst maintaining or improving the film properties.
- The optimal combination of a PET acrylic binder with an opaque polymer gives the formulator the best cost performance balance as well as a good positioning in terms of environmental impact since the total amount of binder and TiO_2 will be reduced.

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References

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[2] Larson G., Procopio L.and Rosano W., 2001 Proceedings of the International Waterborne, High Solids and Powder Coatings Symposium.
[3] Rosano W., Bleuzen M., Garzon A., Gebhard M., Larson G. and Procopio L., "Improved Performance of Waterborne Coatings through Polymer-Pigment Composite Particle Formation," Proc. of the 28th FATIPEC Congress, 2006.

Figure 1: Delta L = f(t) after 16 months exposure onto aluminum panels, South 45°, Southern Alps, blue systems based on PET binder

Figure 2: L =f(t) measured onto aluminum panels exposed South 45°, Southern Alps, blue tinted systems

Figure 3: Delta L =f(t) measured onto fibercement panels exposed South vertical, Southern Alps, blue tinted systems

Figure 4: Delta L=f(t) after 19months exposure onto aluminum panels,South vertical, Southern Alps, white systems based on Pure Acrylic binder

Figure 5: Delta L=f(t) after 19months exposure onto aluminum panels,South vertical, Southern Alps, blue systems based on Pure Acrylic binder

Figure 6: Delta L = f(t) after 16 months exposure onto aluminum panels, South 45°, Southern Alps, blue systems based on PET binder

Table 1: Formulations used to test effect of OP on dirt-pick-up resistance

	Paint #4	Paint #5
	Same pure acrylic binder used	
Total PVC, %	55	55
Titanium dioxide PVC, %	17	17
OP PVC, %	30	0
Calcium carbonate PVC, %	8	38