Silicone Additives That Enhance Coating Durability in ETICS

Hatice Turgut, Kimy Yeung, Jean-Paul Lecomte, Jouko Vyoerykkae
Construction Chemicals, a Business Unit of The Dow Chemical Company
HTurgut@dow.com

Keywords: *ETICS, EIFS, coating, durability, silicone additives, dirt pick-up resistance (DPUR), color retention, water repellency, early rain resistance*
Discipline: *Building materials*

Introduction

ETICS (External Thermal Insulation Composite System), or the analogous EIFS (Exterior Insulation and Finish System), are multi-component exterior cladding systems used in residential and commercial buildings. The exterior system finish looks like stucco, but is in fact a non-cementitious render, typically based on an acrylic or styrene-acrylic binder. Figure 1 shows a cross section of an ETICS with descriptions for each section.

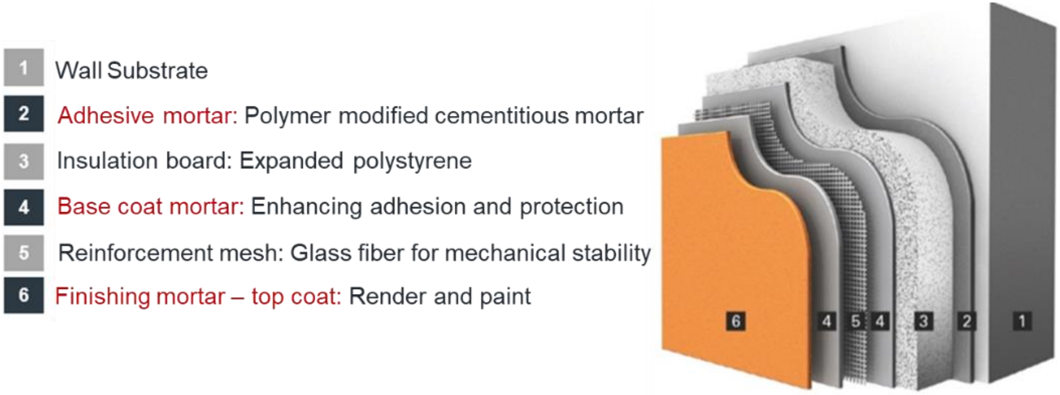


Figure 1. ETICS Components.

Since ETICS are used as exterior finishes, they are subject to weathering exposure year-round. As a result, their key critical-to-quality (CTQ) areas include durability, which encompasses color retention, dirt pick-up resistance (DPUR), UV-durability, water resistance, and aesthetics issues such as cracking. Silicone materials have been introduced into the current ETICS market to improve the water-vapor permeability of organic facades. However, the use of silicone co-binders has shown negative impact on color retention and DPUR. The color loss is in part due to photo-degradation of the organic components in the coating and partially due to poor binding efficiency.[1-3] Herein, this paper documents the work that Dow completed on the usage of different silicone additives (e.g., fluid, resin, emulsion types) in ETICS and EIFS formulations to study their effects on durability properties, such as color retention upon UV aging, water repellency, and DPUR. In addition, formulation variables were studied, including varying pigment volume concentration (PVC) and extenders, to understand their influence on color retention.

Experimental

Formulations: Dow has two starting point formulations, one that is primarily used in North America (noted as NA EIFS, 79 PVC) and one that is primarily used in Europe (noted as EU

ETICS, 82 PVC). Both formulations are shown in Table 1. Although the ingredient types are similar in both formulations, they are different based on binder, rheology modifier, coalescent, extenders, and PVC. For example, RHOPLEX™ EI-2000 Emulsion Polymer is an all-acrylic binder that is predominately used in North America while PRIMAL™ WDV-2001 ER Emulsion Polymer is an APEO-free version of RHOPLEX™ EI-2000 that is used in Europe. The authors choose to focus mostly on the ETICS finish to address the European audience.

NA EIFS (79 PVC)	% Weight	EU ETICS (82 PVC)	% Weight
RHOPLEX™ EI-2000	18.05%	PRIMAL™ WDV-2001 ER	15.79%
Ethylene Glycol	0.31%	HPMC	0.11%
Rozone 2000	0.13%	Rozone 2000	0.11%
Nopco NXZ	0.13%	Calgon N (10%)	1.07%
Attagel 50	0.63%	Nopco NXZ	0.11%
Ti-Pure R-746	4.07%	OROTAN™ 165A	0.20%
Unimin 50-30 sand	53.29%	Ti-Pure R-746	3.06%
Temisca #15 sand	8.92%	Unimin 50-30 sand	52.42%
Minex 4	8.59%	Temisca #15 sand	12.86%
UCAR Filmer IBT	0.25%	Omyacarb 40	5.36%
Ammonia (28%)	0.16%	Omyacarb 2	6.43%
ACRYSOL™ ASE-60	0.47%	DOWANOL™ DPnB	0.37%
Water	5.00%	NaOH (10%)	0.22%
		Water	1.89%
Total	100.0%	Total	100.0%

Table 1. Dow's starting point formulations for EIFS and ETICS.

Tint Retention (WOM/QUV): Both Xenon Arc Weather-OMeter (WOM) and QUV Accelerated Weathering Testers were used for the accelerated weather/color retention tests. The WOM is an Atlas Ci5000 model conforming to ASTM G-155b (WOM cycle: 102 minutes dry/18 minutes wet, 100% light, 0.35 W/m^2 irradiance). QUV tests conformed to ASTM G-154, with an 8-hour UV light (60 ˚C)/4-hour condensation (50 ˚C) cycle, using UVA-340 lamps. For accelerated weathering tests, an organic phthalo blue dye colorant (Colortrend 888-7214) was added at 2% by weight to the test formulations. Additives were added at the given percent based on total formulation.

Dirt Pickup Resistance (DPUR): DPUR tests were completed according to ASTM D3719. Test panels were prepared by troweling each test sample to a thickness of 1/16" on 4" x 12" aluminum Q-panels. The panels were then dried for two weeks in the CTR (22 ˚C/50% RH), followed by 24 hours of QUV 'A' (351 nm) exposure (100% light/50 ˚C – no condensation) prior to dirt pickup testing. Dirt pickup tests were carried out 16 hours after the panels were removed from the QUV by brush applying a brown iron oxide (Davis Colors Flagstone Brown 641) slurry (1/2 blend with water plus 0.03% OROTAN^{TM} 731A) to half the surface of the test panel (enough to cover the finish), drying the panels in the CTR for three hours, and then washing the samples under running water to remove the dry iron oxide slurry. To quantify dirt pickup performance, reflectance readings on a cleaned dirty section and an untested clean section were taken using a Gardner Colorgard II 45˚ Reflectometer. Three clean and three dirty readings were taken for each sample, with the average of the three readings used to calculate the % Y reflectance retained using the equation: $\%Y_{\text{Reflectance Retained}} = (Y_{\text{dirty}}/Y_{\text{clean}}) \times 100\%$

Early Rain/Washout Resistance: The early rain resistance test assesses the susceptibility of an applied EIFS/ETICS finish to washout failure resulting from water spray, simulating performance under conditions of wind driven rainfall. Using 1/16" foam tape as a guide, each test sample was troweled to a thickness of 1/16" on the same 6" x 8" EIFS basecoat section, which had been applied and cured on an EPS foam board test panel. The cementitious basecoat had been cured for at least 24 hours before test finish application. Separate panels were prepared for two different sets of drying conditions used in the evaluation. One is a standard room temperature dry schedule of 3 hours/22 ˚C/50% RH, which is conducted in a constant temperature/humidity room. A second low temperature/high humidity dry for 6.5 hours/10 ˚C/70% RH was also carried out using an adjustable temperature/humidity cabinet. After drying, the finishes were tested for early rain/washout resistance by placing the test panel in a vertical position, and subjecting it to a uniformly applied, 180 gallon per hour water spray across the panel surface using a traditional 1" x 4" garden hose nozzle. Panels were continually sprayed for up to two hours, with the time at which signs of failure (such as blistering, breakthrough, or erosion) start to appear being recorded.

Water Repellency: Some panels evaluated for tint retention with WOM exposure were also assessed for water repellency. This was evaluated by spraying the test panels with DI water using a squirt bottle. Contact angle (CA) is difficult to measure given the textured nature of the finish, so a subjective water repellency rating system was adopted: 'None' (CA < 10˚), 'Slight' (CA ~ 10˚ - 20˚), 'Good' (CA ~ 20˚ - 50˚), 'Very Good' (CA ~ 50˚ - 100˚), 'Excellent' (CA ~ 100˚ - 140˚), 'Excellent+' (CA ~> 140˚).

Results and Discussion

Color retention is one of the performance challenges when silicone-based products are used as cobinders. The initial focus was to define the degree of color loss in ETICS formulations containing silicone materials. Different types of silicone-based materials that are commercially available at Dow were studied in the formulations. Additionally, a mixture of a commercial UV absorber and a hinder amine light stabilizer (HALS) was evaluated as a benchmark to compare the additives' performances (Table 2).

Additive	Chemistry	Type	Active Solids
A	Silicone-based	Fluid	100%
B	Silicone-based	Resin	>96%
C	Silicone-based	Emulsion	60%
D	Silicone-based	Fluid	100%
E	Silicone-based	solution	40-45%
F	HALS and UV absorber	Fluid	100%

Table 2. Summary of additives evaluated in the EIFS and ETICS formulations. Additives A-E are commercial Dow products; additive F is a blended benchmarked additive.

Unless otherwise noted, additives were post-added to the formulations at the listed percentage relative to the total formulation. Figure 2 shows color retention results of ETICS formulations containing different additives which were exposed to 5000 hours under WOM conditions with 1% Colortrend Blue 888-7214 (organic blue dye). Historically, these formulations were exposed to 2000 hours; however, the formulations were exposed to 5000 hours to determine how the different finishes performed under extended exposure. Color readings were measured at about 1000-hour increments, and the results were reported as delta E (ΔE), which is a value that measures color change. As silicone-based materials differ in cost, the amount of additive varied between formulations to target a similar cost range between all finishes.

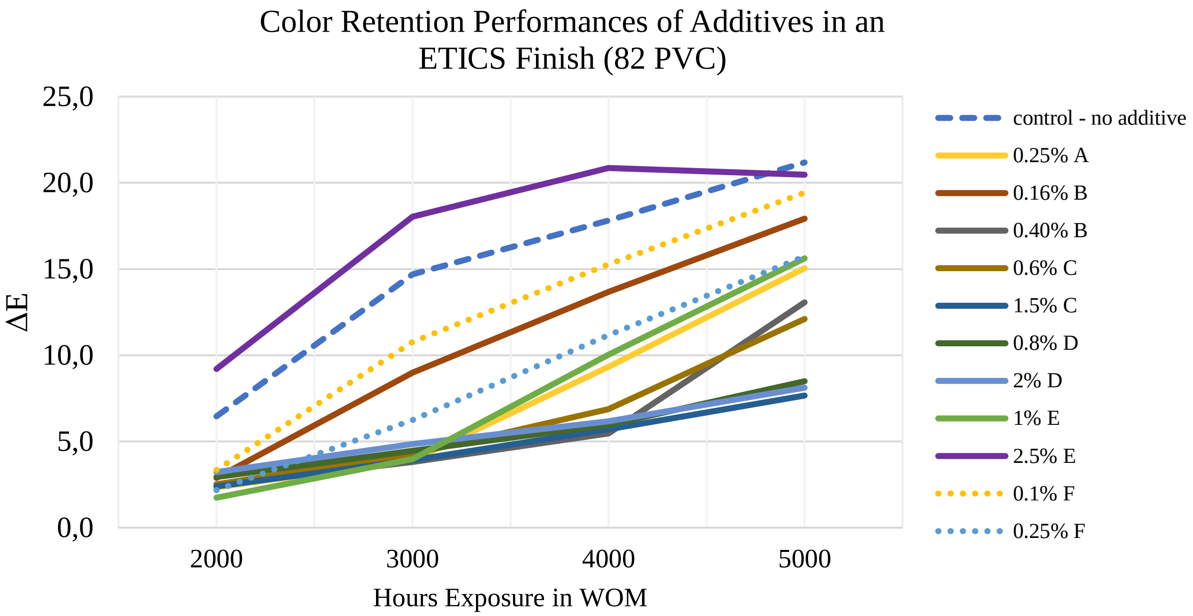


Figure 2. Color retention performances of benchmark additive and silicone additives in an ETICS formulation.

As Figure 2 shows, both additive D (at 0.8% and 2%) and additive C (1.5%) in the ETICS formulation outperformed all the additives in this series, showing lower ΔE values relative to the control, up to 3000 hours of exposure. The next best performing additive was additive B (at 0.4%), which had a similar color retention performance relative to additive C (at 0.6%). Additive E (1.0%) notably performed similarly to product A (at 0.25%). However, when its amount was increased to 2.5%, the finish had poorer color retention than the control. Overall, it is worth noting that after 3000 hours of exposure, most additives (ΔE ~5) offered some benefit relative to the control (ΔE ~15) and the benchmark additive F. While this difference diminished with longer exposure, the differences at this point were relevant as 3000 hours of WOM exposure is significant.

PVC Ladder Study: Varying PVC in EIFS and ETICS Formulations

In general, lower PVC finishes translate to higher binder content with less extenders. For the PVC ladder study, three PVC levels were explored: 79, 82, and 85 PVC. The formulations were adjusted by altering the binder level of the respective formulations to target the specific PVC. cPVC is defined as the point at which the binder level is minimally sufficient to coat the entire surface area of the pigment/filler/aggregate particles, as well as fill the gaps in between these particles, within a formulation. It is a key coating characteristic with most formulation properties showing abrupt changes in performance as PVC transitions across the cPVC boundary.

Firstly, the role of PVC on color retention performance with additive A in both the EIFS and ETICS formulations was investigated. Previous work that was completed at Dow indicated that increasing PVC results in color retention loss.[4] As expected, both control formulations (EIFS and ETICS) showed an increase in ΔE with increasing PVC (Figure 3). In the ETICS systems excluding additive A, a ΔE increase of about 5 units was observed with each 3% increase in PVC after 5000 hours WOM exposure. In comparison, an increase of about 5 units was observed in the EIFS systems from 79 to 82 PVC, with a slightly larger 11 unit increase from 82 to 85 PVC. Similar trends were observed with the additive A-modified finishes, albeit on a smaller scale, with lower ΔE values. Interestingly, when comparing the 82 PVC EIFS and ETICS finishes with 0.5% additive A to the 79 PVC finish control, the higher PVC finish with additive A performed better than the lower PVC finish. In contrast, the 85 PVC finish with the additive did not show a similar favorable comparison to the unmodified 82 PVC finish, which is likely due to the PVC being above cPVC. These results suggest that reducing the binder level by 16-17% by weight and replacing it with 0.5% additive A can produce finishes that have improved color retention without impacting the cost. In other words, an ETICS finish with a 3% increased PVC and a small percentage of additive A is similar in cost to a lower PVC ETICS finish even though the cost of additive A is seven times more expensive than the binder.

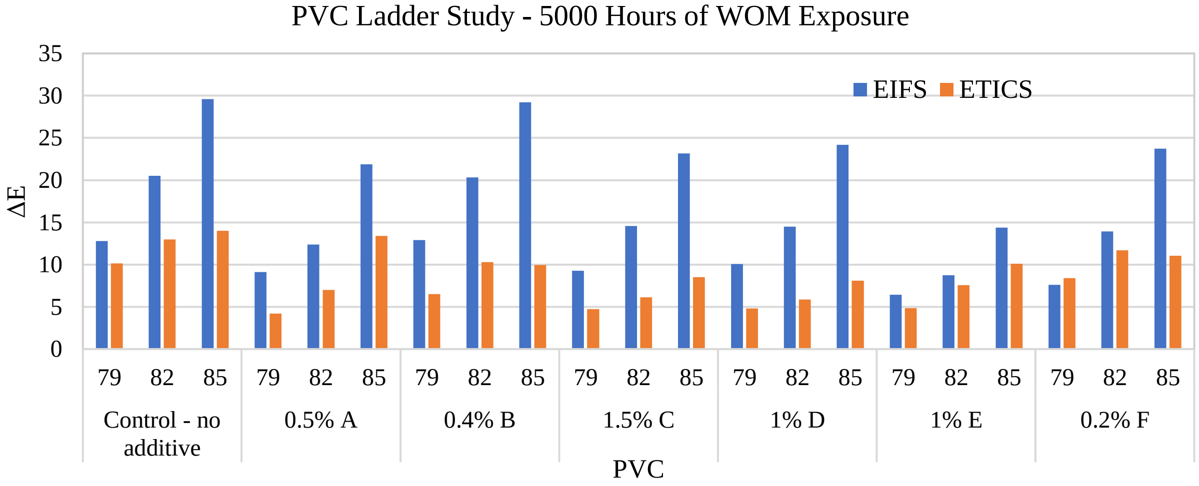


Figure 3. PVC ladder study that included EIFS and ETICS finishes with and without various silicone additives and the benchmark. Data was collected after 5000 h of WOM exposure.

Additional silicone additives were studied at varying PVC levels in the same formulations and benchmarked against additive F. Similar to the performance of additive A, increasing PVC resulted in an increase in ΔE for both EIFS and ETICS systems, where a smaller change in ΔE was observed in the ETICS systems (Figure 3). Additive A showed a similar performance as additive F in both ETICS and EIFS formulations. Additives C, D and E have synergistic effects with the formula while comparable results are observed with EIFS and additive F for this set. Furthermore, ETICS finishes with additives C, D, or E showed comparable color retention performances, but additive E in an EIFS finish had a lower ΔE when compared to EIFS finishes with additives C or D. Overall, additive E performed the best in this PVC ladder study, showing similar ΔE values at 79 and 82 PVC across two different formulations.

Mixed Extended System in an EIFS Finish

The NA EIFS formulation contains 8.6% Minex 4 which is made from nepheline syenite, an aluminosilicate material.[5,6] According to the manufacturer's website, Minex is "proven to offer superior color development, tint retention, and durability to a broad range of paints, coatings, adhesives, sealants, and inks." On the other hand, the EU ETICS formulation contains 11.8% $CaCO_3$. $CaCO_3$ is a cheaper extender when compared to Minex and is not known to offer durability benefits. To understand the influence of Minex in an EIFS formulation (79 PVC), select silicone additives were evaluated in a mixed extender system containing $CaCO_3$ and Minex in a 3:1 ratio. Additives C and D performed similar to the control, following the same trajectory from 1000 to 4000 h exposure (Figure 4). However, both additives showed higher ΔE (ca. +2 units) than the control at 5000 h. The benchmark additive performed the best after 5000 h of WOM exposure. Among the silicone additives, product E has the lowest ΔE, having a value of 8 which was 2 units higher than the benchmark additive.

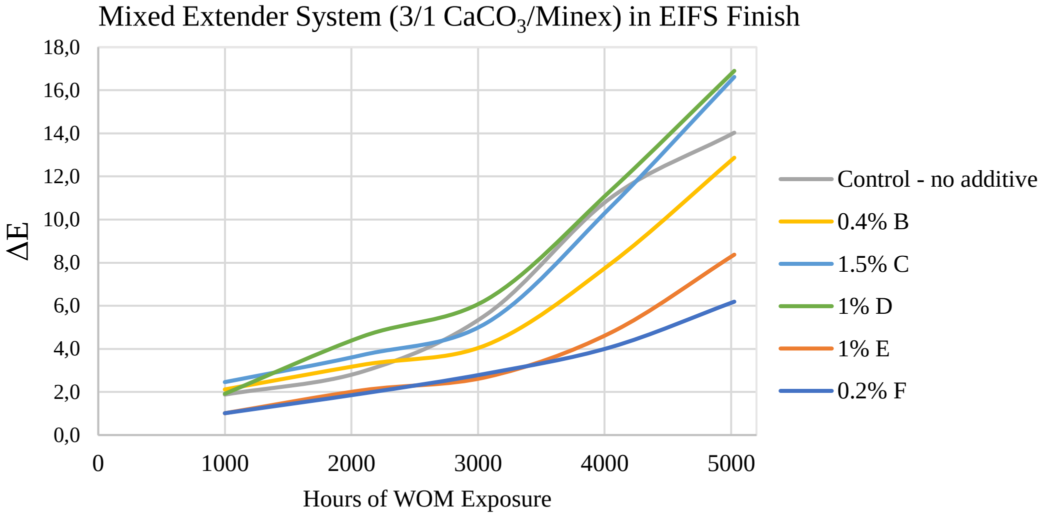


Figure 4. Color retention performances of EIFS finishes (79 PVC) prepared with mixed extenders.

When the mixed extender system was compared to the standard EIFS that contains 100% Minex, ΔE values after 5045 hours of WOM exposure were lower for the 100% Minex finishes, proving that the Minex improves the color retention performance (Table 3). Although the amount of additive F varied between the two systems (0.2% vs. 0.25%), this benchmark additive appeared robust as it showed the least minimal difference across the two different formulations. In comparison, out of all the silicone additives, additive E looked to be a robust silicone additive that demonstrated the lowest ΔE difference between the two formulations.

	3/1 $CaCO_3$/Minex after 5045 Hr	100% Minex after 5045 Hr	Difference
Control	14.0	9.9	4.1
0.4% additive B	12.9	9.0	3.9
1.5% additive C	16.6	7.2	9.4
1% additive D	16.9	9.1	7.8
1% additive E	8.4	6.7	1.7
Additive F	6.2	5.7	0.5

Table 3. ΔE values of different EIFS finishes after 5045 hours of WOM exposure.

Early Rain Resistance

Early rain resistance was evaluated for selected EIFS finishes. Results indicate that the addition of additives C, D, and E extended the time to failure by several minutes under these drying conditions (Table 4). For the RHOPLEX™ EI-2000 Emulsion Polymer finishes in this test, the addition of silicone additives afforded better resistance to early washout.

Additive	3h / 22 ˚C / 50% RH Dry	6.5h / 10 ˚C / 70% RH Dry
Control	Fail 5’	Fail 5’
1.5% C	Fail 15’	Fail 15’
2% D	Fail 10’	Fail 10’
1% E	Fail 20’	-

Table 4. Impact of silicone additives on early rain resistance in EIFS finishes.

Water Repellency

The main purpose of adding silicone additives in ETICS/EIFS systems is to provide water repellency. In the mixed extender finishes (3 parts $CaCO_3$ and 1 part Minex), all finishes initially showed good water repellency (Table 5). However, additives C and D showed a noticeably higher water repellency with longer WOM exposure time when compared to the unmodified control.

Additive	Initial	2000 Hrs	4000 Hrs	5000 Hrs
Control	Good	Slight	None	None
0.4% B	Good	Excellent	Very Good	Good
1.5% C	Good	Slight	Excellent	Very Good
1% D	Good	Very Good	Excellent	Very Good
1% E	Good	Good	Slight	None
0.2% F (benchmark)	Good	Slight	Slight	Slight

Table 5. Impact of silicone additives on water repellency in WOM-exposed EIFS finishes, containing 3 parts $CaCO_3$ and 1 part Minex.

Additive B showed the same trend, too. On the other hand, additive E had less impact on water repellency while the benchmarked additive had no impact. Overall, some length of WOM exposure is needed to enable a high level of water repellency, but at the expense of color change and chalking.

Dirt Pickup Resistance (DPUR)

The impact of various additives in EIFS finishes was also assessed for DPUR performance. Additives C, D, and E were selected for comparison against the benchmark. Both additives C and D had similar DPUR relative to the control and the benchmark (Figure 5). In contrast, additive E had superior DPUR, showing better Y reflectance than the unmodified control (47% vs. 28%).

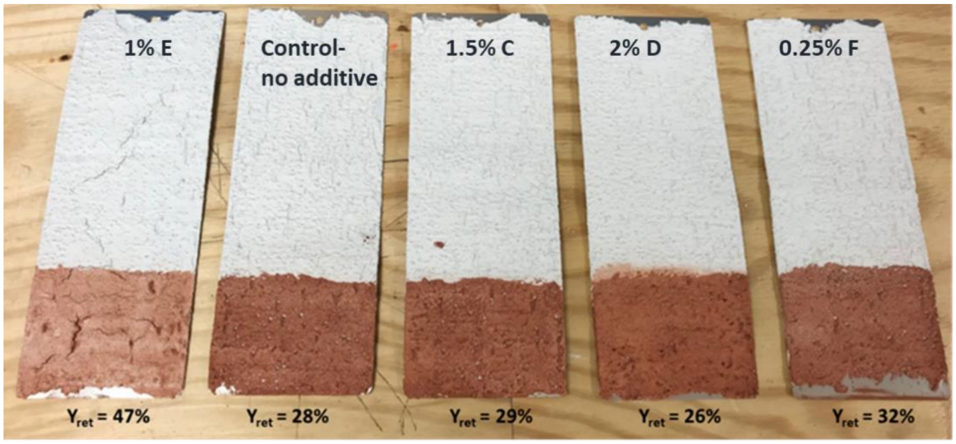


Figure 5. DPUR testing panels with additives C, D, E, and F post-added to EIFS finish (79 PVC).

A more extensive set of tests were carried out with additive E, but this time the additive was premixed with PRIMAL™ WDV-2001 ER Emulsion Polymer and then formulated into the ETICS finish formulation. Figure 6 shows the positive impact of additive E on the dirt pickup resistance. Increasing the additive level resulted in better dirt removal, with the 2% additive level showing a remarkable Y reflectance of 96%. Interestingly, the ETICS finish that contained 0.5% additive E (Figure 6) had similar DPUR performance to the EIFS finish that contained 1% additive E (Figure 5). These results suggest that a more pronounced DPUR effect was present in the ETICS finish, possibly attributable to the higher PVC.

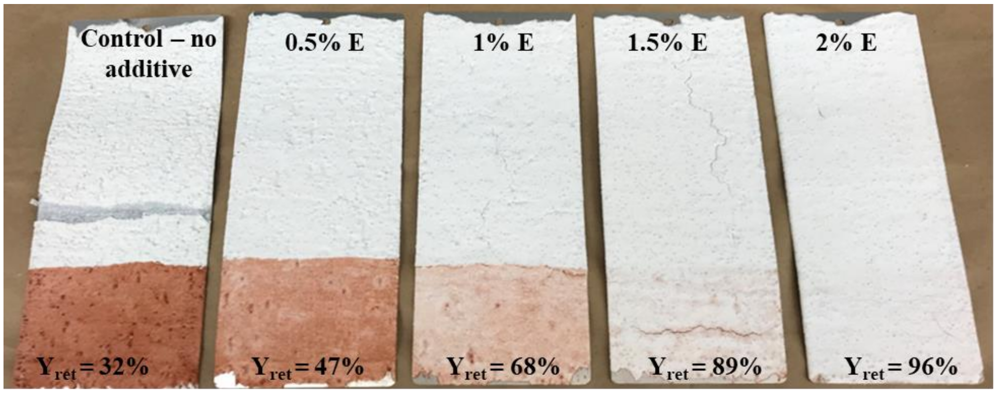
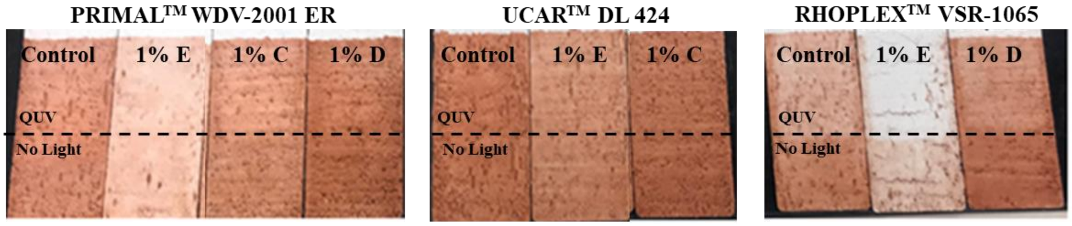


Figure 6. DPUR testing panels with additive E premixed in PRIMAL™ WDV-2001 ER in an ETICS finish (82 PVC).

Evaluating Additive E in Modified ETICS Formulations (82 PVC) Containing Different Latex Binders

Given the positive DPUR performance with Additive E in both EIFS and ETICS formulations, additional DPUR experiments were carried out to determine the versatility of this additive in conjunction with different acrylic latex compositions, including a styrene-acrylic latex (UCAR™ Latex DL 424 Emulsion Polymer) and an acrylic latex (RHOPLEX™ VSR-1065 Acrylic Emulsion) that contains an ambient crosslinking technology. For comparison, additives C and D were also evaluated at 1%. The test panels, shown in Figure 7, consisted of two sections: an exposed dirt test section with UV exposure on top and an exposed dirt test section blocked from UV exposure on the bottom.

From the DPUR experiments, additive E offered a clear boost to DPUR performance in each binder system (Figure 7). In contrast, the other silicone additives, C and D, had minimal impact on the DPUR. The RHOPLEX™ VSR-1065 Acrylic Emulsion finish containing 1% additive E showed the highest improvement, where the Y reflectance improved to 97% with UV exposure, compared to 59% for the unmodified control (Figure 7, right). Similarly, the PRIMAL™ WDV-2001 ER Emulsion Polymer finish containing additive E had about 20% Y reflectance improvement (66% vs. 47%) (Figure 7, left) while the UCAR™ Latex DL 424 Emulsion Polymer finish with the same additive had a smaller but noticeable improvement (48% vs. 36%) (Figure 7, middle). The UV-exposed sections showed improved DPUR performances over the unexposed sections, particularly for the all-acrylic binders, PRIMAL™ WDV-2001 ER and RHOPLEX™ VSR-1065. Overall, the DPUR results offer interesting perspectives on ETICS finish performance.



	Control	1% E	1% C	1% D	Control	1% E	1% C	Control	1% E	1% D
%Y_{ref} (UV Exposure on top)	47	66	44	36	36	48	35	59	97	46
%Y_{ref} (No UV Exposure on bottom)	36	55	33	26	33	45	32	41	70	34

Figure 7. ETICS panels that show the DPUR performance of finishes with different silicone additives and latex binders in a modified ETICS formulation containing 6% TiO_2.

Conclusion

In conclusion, this documentation reports the work that was completed to identify silicone additives that improve the durability properties in EIFS and ETICS after weathering exposure. Five silicone-based additives that are commercially available at Dow were tested against a commercially available benchmarked additive and evaluated for color retention, water repellency, early rain resistance, and dirt pickup resistance. Both additives A and E were identified as robust additives that can be used across different EIFS and ETICS model formulations to reduce color loss. Additive E also demonstrated an additional benefit of improving DPUR across an array of ETICS finishes with different latex binders. One particularly effective combination was the incorporation of 1% additive E with RHOPLEX™ VSR-1065 Acrylic Emulsion, which showed nearly complete resistance to dirt pickup under the standard UV exposure test protocol in an ETICS finish. In addition, studies on the role of PVC and extender selection on color retention were completed. Increasing the PVC in finishes resulted in color loss upon UV aging. However, the addition of selected silicone additives, like additive A, reduced the color loss at a higher PVC, which can help alleviate formulation cost. Lastly, replacing or adding Minex to a $CaCO_3$-rich finish also improved color retention though at a higher cost.

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