SSPC

PERFORMANCE OF ALTERNATE COATINGS IN THE ENVIRONMENT (PACE)

Volume II: Five-Year Field and Bridge Data Of Improved Formulations

Prepared for:

U.S. Federal Highway Administration
400 Seventh Street, SW
Washington, DC 20590

Prepared by:

Dr. Bernard R Appleman, Executive Director
Dr. Simon K. Boocock, Director of Research
Steel Structures Painting Council
4400 Fifth Avenue
Pittsburgh, PA 15213

December, 1989

SSPC 89-11

RECOMMENDATIONS

1. Recommendations on Coatings

The following types of alternative coatings are considered suitable for the indicated conditions:

- Marine environment, hand cleaned steel: petroleum wax coatings, lead-free oil-alkyds (slightly reduced performance expected).
- Marine environment, blast cleaned steel: water-borne inorganic zinc, acrylic latex, lead-free oil alkyd (long-term performance [8+ years] of latter, three systems requires further corroboration).
- Industrial environment, hand-tool cleaned: wax coatings, lead-free oil-alkyd, selected other coatings.
- Industrial environment, blast cleaned steel: acrylic latex, lead-free oil-alkyd, styrene acrylic latex, selected water-borne epoxies, water-borne inorganic zinc primer with suitable topcoat.

Other coatings that have shown outstanding performance but may not meet the requirements for VOC compliance include certain inorganic and organic zinc-rich coatings. Conventional solvent-borne epoxies, chlorinated rubber coatings and moisture-cured urethane primer systems. Highway agencies are encouraged to undertake field service evaluations of the new coatings identified in this study.

Long-term performance. The chlorinated rubbers were not included in PAGE 1. Further discussion will be given subsequently.

The next level of group performance included styrene acrylic latex, oil-alkyd (lead-containing), the petroleum wax coatings; these all exhibited approximately 2/3 survival after 52 months.

The oil-alkyd lead- and chromate-free were significantly poorer in performance than those previously mentioned, showing 20 percent failure after only 29 months and 50 percent survival after 52 months.

The poorest performing groups were the urethanes, vinyl, and epoxy systems. These results are attributable primarily to poor scribe undercutting resistance.

Hand tool cleaned Substrates

Table 20 ranks the generic groups on their performance over hand tool cleaned steel using failure criterion R7 S8. The petroleum wax coatings were by far the best group over hand tool cleaned steel. This phenomenon is discussed in subsequent paragraphs.

The second tier included oil-alkyd lead-free and oil-alkyd lead- and chromate- containing coatings. For these coatings 20 percent failure occurred after about 20 months, with the oil-alkyd lead-free giving a longer time to reach 50 percent failure.

The next level is the acrylic and styrene acrylic latexes. Both of these showed 20 percent failure in about a year and 50 percent failure in about 2 years.

One performance level lower were the chlorinated rubber and epoxy. The chlorinated rubbers, although performing best over blast cleaning, are not normally recommended for hand tool cleaned steel. The vinyl and urethane coatings also exhibited very early failure over hand tool cleaned steel. Discussion of each of these groups is given below.

D. ANALYSIS OF PERFORMANCE WITHIN COATING GROUPS

Tables 21 through 26 summarize the performance of coatings by groups for both hand tool cleaned and blast cleaned steel. The main parameter analyzed is the time for 1/3 of the panels to fail by R7 S8 criterion for hand tool cleaned and R8 S4 criterion for blast cleaned panels.

1. Oil-Alkyd, Lead- and Chromate-Containing

Table 21 shows the rather large variation in performance among the oil-alkyd lead and chromate systems. For hand tool cleaned steel, most of the coatings show 33 percent failure at about 2 years (21 to 29 months), but two of the coatings failed in about a year. Over blast cleaned steel, all but two of them lasted more than 4 years. In this group there is good correlation between the performance over hand and blast cleaned steel substrates. The rapid failure of coatings F-1 and F-4 is attributed to very early scribe undercutting, particularly at the marine location. The relationship between performance and dry film thickness will be discussed in a later section.

2. Oil-Alkyd, Lead- and chromate-Free

For hand tool cleaned steel, most of the coatings showed 1/3 failure occurring between 21 and 29 months; two of the systems (TT-P-641 and system with proprietary pigment #4) gave excellent performance and two systems (F-20 and F-24) gave inferior performance (table 22). The early failures are again attributed to scribe undercutting at the marine site.

For the blast cleaned steel, four of the systems lasted 52 or more months, four about 42 months, five at about 28 months, and one failed at 5 months.

Three proprietary pigments were evaluated in this study. Pigment #4 showed the best overall performance for hand tool cleaned steel, with pigments #1 and #3 about equal for this substrate. Pigment #4 compares favorably with red lead and basic lead silico-chromate, which were contained in TT-P-86, Type II, and TT-P-615, which were the best in the group of lead-and chromate-containing oil and alkyds (Group 1).

Over blast cleaned steel, the three pigments gave more comparable performance, with #1 overall slightly superior to the other two. Pigment #1 was approximately equivalent to zinc chromate, but not as good as basic lead silico chromate (TT-P-615) or red lead (TT-P-86), the top formulations in this group. Overall, the best paint in this group is F-35.

3. Acrylic Latex

As a group, the acrylic latex systems did not perform well over hand tool cleaned steel (table 23). The only notable exception was paint F-33, which achieved 42 months life; two others lased as long as 2 years, with almost half failing after 14 months.

The acrylic latex did extremely well over blast cleaned steel. About half of the 15 panels lasted 52 months or more. Additional details are shown in table 17; 5 acrylic latexes were among the coatings with zero failures after 77 months at the Kure Beach and Neville Island exposures.

This finding indicates that acrylic latexes are suitable for marine as well as industrial environments. Previous data had suggested that the system is less effective at marine exposures. Current results indicate that at least through 77 months the system is performing extremely well.

The majority of the paints in this group were formulated with proprietary pigment #4, which showed consistently good performance over blast cleaned steel. Pigments #3 and #10, though tested to a much lesser degree, also gave outstanding performance over blast cleaned steel.

Table 25. Variations among coatings in other generic groups (continued).

	Description of Primer	Hand Tool Clean Times for 3 of 9 Failures (Mos.)	Blast Clean Times for 2 of 6 Failures (Mos.)	Average DFT(Mils)
Styrene acrylic latex coatings				
F-29	1% strontium chromate pigment	20	42	5.9
F-30	red iron oxide pigment	21	>52	7.5
F-32	zinc phosphate-zinc chromate primer pigment, acrylic latex-aluminum topcoat	9	>52	11.8
Wax coatings				
F-31	Petroleum wax	52	52	9.6
F-39	Calcium sulfonate wax—aluminum	>52	>52	9.4
F-40	Calcium sulfonate wax	>52	>52	N/A

Chlorinated Rubber

The primers for most of the chlorinated rubber systems are variations of SSPC-Paint 17, which is part of a chlorinated rubber painting system developed in the early 1980s. The specification includes a chlorinated rubber formulation with requirements for the type and amount of chlorinated rubber resin and for an inhibitive pigment. The pigment is not specifically identified, which allows formulators some latitude in selecting one. The specification also includes a control paint formulation, which incorporates basic lead silico chromate (BLSC) as the inhibitive pigment. The specification includes the following performance requirements as well:

- 500 hours of salt fog.
- 60 days of exterior exposure of painted channels.
- 500 hours of fresh water immersion.

The candidate formulations (with alternate inhibitive pigments) must meet or exceed the performance of the basic lead silico chromate control.

In this group, coating F-52 is the BLSC control, and F-13, F-53, F-17 and F-55 the candidate coatings. The results clearly indicate that each of these has exceeded the performance of the BLSC control (table 24). Three of these coatings are listed among the top performers in table 17, along with F-36 and F-56, which are proprietary formulations containing pigment #4. Other pigments which have excellent performance are red iron oxide and zinc phosphate.

The chlorinated rubber systems are not intended for hand tool cleaned surfaces, and the results show overall poor performance for this substrate. One system, F-36, was rated in the third best group in table 18.

Epoxy Coatings

The epoxy coatings as a group did quite poorly over both hand tool cleaned and blast cleaned steel as shown in table 25. The best system was F-9, a military specification paint (MIL-P-52192). This paint gave essentially perfect performance in rust rating for both hand and blast cleaned substrates, but it showed high susceptibility to scribe undercutting and consequently was not rated among the top systems. The other coatings in this group also failed predominantly by scribe undercutting, as shown in supplementary table F-X8, only one epoxy panel out of 30 failed over blast cleaned surfaces by rusting.

SSPC-Paint 22 is structured similarly to Paint 17, with a control formulation based on basic lead silico chromate as the inhibitive pigment. In this instance the lead-free coating (F-16) performed significantly poorer than the control (F-28).

The coatings in this group should not be considered representative of epoxies in general, as these were experimental systems with only one a standard reference coating.

Urethane Coatings

In this group, a series of systems with moisture-curing urethane primers was evaluated. Four of the five contained aluminum pigmentation. These systems exhibited very early scribe undercutting failure, which accounted for the low ratings on both hand tool cleaned and blast cleaned substrates. As with the epoxies, the rust ratings were 10's for 4 or more years for almost all of the panels in this group. In many cases, however, beyond that period, rust ratings could not be taken because of the extensive amount of failure from the undercutting.

Vinyl Red Lead

The vinyl red leads were included as standard reference control paints. Similar to the epoxy and urethane systems, these failed early due to poor scribe undercutting resistance. This was similar to the results obtained in branch D of PACE 1. It was shown that vinyl give good performance in rust ratings, but is extremely susceptible to scribe undercutting.

Styrene Acrylic Latex

The coatings in this group performed extremely well over blast cleaned steel, but poorly over hand tool cleaned steel. Two of these coatings, including the Caltrans specification system (F-32) were among the top-ranked coatings in table 17. Only one of these coatings, however, F-30, was lead and chromate-free.

These data corroborate the data from PACE 1 study regarding the performance over blast cleaned steel. Systems F-29 and F-30 showed zero failures by rusting over hand tool cleaned steel, but incurred substantial undercutting within 2 years.

Wax Coatings

The wax coatings were by far the best coatings over hand tool cleaned steel. Two systems showed zero failure for the duration of the exposures in all three environments. Both of these were based on calcium sulfonate. These systems also performed very well over blast cleaned steel. System F-39 did not show any failures using the more stringent failure criterion for blast cleaned steel (R8 S4).

Systems F-40 did not dry sufficiently to allow measurement of dry film thickness.

Miscellaneous Coatings

These are shown in table 26. the inorganic and organic zinc-rich coatings both gave good performance over blast cleaned steel as expected. The inorganic zinc was in the second group rather than the first group in table 17 because of some early scribe undercutting in one of the panels.

Not expected was the good performance of these systems over hand tool cleaned steel. The ability of the zinc primers to resist scribe undercutting (a major cause of failure in other systems) was a contributing factor.

Please find enclosed the original copies of test results from PowerTech Labs in Surrey B.C. The results are for tests run for Alberta Transportation and Utilities (Exhibit A) and a second report (Exhibit B) which was funded by the international Calcium Sulfonate Alkyd Manufacturers Association. The first set of results marked (Exhibit A) shows the results of the first round of testing begun in the fall of 1993 and completed in the spring of 1994. There were 17 coating systems submitted for testing in the first round. There results are broken down into four test categories.

Durability Test# 1 Aged alkyd was over coated and then put into a KTA Tator Envirotest cabinet according to ASTM Standard Practice Draft #1 dated 4/10/92.

Chamber conditions were:

Temperature: 60 degrees C (140 F)
Salt Concentration: 4% by weight
Cycling: 420 degree rotation every two hours
Lamps: UVB

Durability Test# 2 Aged Alkyd panels were put into a cabinet to test Water Resistance according to ASTM 2247-87 exposure to 100% relative humidity at 38 degree C + -1 degree C.

Durability Test# 3 & 4 are the same as Tests# 1 & 2 except the coating systems were applied to bare steel prepared to a SSPC-SP6 commercial blast standard.

The results from exhibits 1 & 2 for Calcium Sulfonate Alkyd (CSA) coatings are summarized in Table 1. We have also included results from two, 3 coat zinc, epoxy, moisture cured urethane coating systems as a comparison.

Looking at the results you will notice that in Test# 1 the CSA performed better at 5 mils DFT then both the Moisture Cured Urethane systems and the CSA at 10 mils DFT. These two coating systems tied for first place in the first round of testing. The 5 mil DFT film of CSA went 320 hours longer then the two first place coatings from the first round of testing. The thin film CSA also performed better in test# 2&4. In test# 3 the CSA's performed at 5 mils DFT was 2218 hours. This was ½ the 4445 hours performed at 10 mils DFT. This data shows a linear relationship between DFT and performance of CSA. For example if we expect 30 + years performance at 10 mils DFT we could anticipate 15 years performance at 5 mils DFT in the field.

The data from the second test at 5 mils DFT (CSA) confirmed our own test results that when we overcoat at a thinner DFT we get quicker moisture transmition from the existing coating's surface thru the top coat to the atmosphere. It is this reason that allowed the 5 mil DFT film to perform better in all tests except test# 3 then the 10 mil DFT film in the PowerTech test. The failure mode for the coating was blister size. The 10 mil DFT film would not transmit the moisture as quick thus the blisters grew larger then the size allowed by the testing protocol. As mentioned the CSA at 10 mils DFT still tied for first as a overcoat and won over blasted steel by a large margin in the envirotest. As a side bar when the panels coated with 10 mils corrosion was found when destructive testing was done on areas were there was blistering.

The main reason Alberta Transportation and Utilities chose the Envirotest cabinet was the 3 immersion cycles coupled with the bake cycle at 140 degrees F and the UVB Lamps duplicate the circumstances which cause severe coating failure on their structures. This failure mode is called Poltius rusting. This phenomena occurs on structural plates and flanges were sand, salt, and dirt collect. This mixture cakes up in these areas and usually never dries creating a situation of almost continuous immersion and accelerated coating failure. The envirotest in a good indicator as to how a coating will perform in the field under these circumstances.

I would suggest calling John Inch at PowerTech Labs (1-604-590-7451) and ask him to send you a complete copy of the report # 4757-44. For additional information call Alberta Transportation & Utilities, Paul carter materials research specialist who headed up the team who developed the testing program and the computerized coating selection program which utilizes the PowerTech test results. The report has all the testing methods laid out in detail.

I hope this explanation gives you some more insight into and helps further your understanding of Calcium Sulfonate Alkyd (CSA) coatings. If you have any questions please call me.

TABLE 1

POWERTECH TEST RESULT SUMMARY

PRODUCT DESCRIPTION	AGED ALKYD		BLASTED STEEL	
	TEST# 1	TEST# 2	TEST# 3	TEST# 4
CALCIUM SULFONATE 5 MIL DFT	1200 hrs	168 hrs	4445 hrs	192 hrs
CALCIUM SULFONATE 5 MIL DFT	1520 hrs	240 hrs	2218 hrs	1080 hrs
NOTE: As an overcoat CSA is specified at 5-6 mils DFT over tightly adhering coating systems				
As a comparison here are the results of two systems from round 1 of the PowerTech test				
Wasser 2 coat (MCU) 8 mil DFT	1200 hrs	288 hrs	N/A	N/A
Wasser 3 coat (MCU) 12 mil DFT	N/A	N/A	1968 hrs	1056 hrs
Xymax 2 coat (MCU) 6 mil DFT	1000 hrs	288 hrs	N/A	N/A
Xymax 3 coat (MCU) 9 mil DFT	N/A	N/A	1968 hrs	1056 hrs