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The Society for Protective Coatings

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FEATURES

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NO MAGIC NUMBER: COATING CONCRETE AFTER 28 DAYS

By R.A. Nixon, Corrosion Probe, Inc.

Historically, the coatings industry has specified 28 days of cure time for concrete before coatings are applied. This 28-day curing period was designated to address two key concerns: cement paste shrinkage continuing after coating application resulting in the formation of cracks and excess moisture unnecessary for cement hydration escaping from the substrate and causing problems at the coating/concrete interface. The author examines this "magic" number and presents real-world cases.

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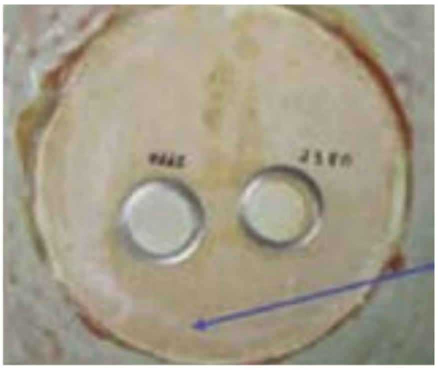
CERAMIC EPOXY COATINGS IN IMMERSION

By Ben Rowland, Induron Protective Coatings, Inc.

The term "ceramic epoxy coatings" refers to an epoxy binder with ceramic media used as a pigment/filler. This article explores ceramic epoxy coatings for use in water storage, wastewater and pipeline applications and examines properties and characteristics that differ from traditional epoxies used in these environments.



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THE EFFECT OF CAUSTIC SODA SOLUTIONS ON FUSION-BONDED EPOXY COATINGS AT HIGH TEMPERATURES

By Hassan Al-Sagour and Mana Al-Mansour, Saudi Aramco

In the article, "Qualification Tests for High-Temperature FBE Coatings" in the July 2018 issue of *JPCL*, the results of qualification testing of high-temperature fusion-bonded epoxy (FBE) coatings were reported by the authors. Three candidate products were immersed at a high temperature and all showed satisfactory performance in distilled water, synthetic sea water and a 5-percent NaCl solution. Most products, however, experienced severe discoloration when immersed in a 5-percent NaOH (caustic soda) solution. In this article, the authors describe further testing conducted on one of the candidate products to determine the significance of this discoloration.

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Major Highway Bridge Collapses in Italy; Experts Knew of Corrosion on Cables

Dozens have been reported dead and more injured after the collapse of a 200-meter (656-foot) section of the prestressed concrete Morandi Bridge in Genoa, Italy, on Aug. 14.

Authorities currently suspect that structural weakness caused the collapse, though witnesses also noted severe weather at the time of the incident. Traffic was also likely heavier than normal due to Ferragosto, a major Italian holiday. During the incident, vehicles fell onto rail tracks, buildings and a river running underneath.

Eyewitness Pietro M. all'Asa said that, just after 11:30 a.m. local time, lightning struck the bridge. Another unnamed witness said that they heard "an incredible roar," thinking that it was just thunder nearby. Traffic was disrupted, and the "city was paralyzed." A heavy thunderstorm was reported at the time of the incident, with recorded 35-mile-per-hour winds, and a gulf now divides two sections of the bridge.

Authorities say that it's unlikely anyone was under the bridge at the time of the incident. Roughly 30 cars and several heavy-duty trucks were on the section of span that failed. According to estimates, there could be as many as 35 dead as a result of the collapse.

The cable-stayed concrete bridge, known as the Polcevera Viaduct and completed in 1968, was designed by Italian civil engineer Riccardo Morandi. According to website Retrofutur, the bridge is characterized, as are other Morandi structures, by thin prestressed concrete girders and relatively few stays.

At the time of the incident, authorities thought a structural weakness was responsible for the collapse. More than a week after the collapse of the bridge, new reports indicated that experts found corrosion on the cables of the bridge months prior to the disaster. In February, experts reported that the damage to the bridge had weakened the structure by 20 percent. There seemed to be no significant safety adjustments, however, as none of the entities involved, including the ministry or the highway company, ordered traffic limitations.

Morandi himself reportedly warned several decades ago that the bridge would need constant maintenance to remove the rust, as both sea air and pollution, especially from a nearby steel plant, were contributing to corrosion.

In 2012, the leader of Genoa's business federation noted that the bridge could collapse within 10 years. In 2011, a report from Autostrade per l'Italia, the operator of the A10 highway that ran over the bridge, warned of intense decay.

In the days after the collapse, the Italian government has proclaimed that there will be a nationwide safety assessment of its infrastructure, which may be mired due to the lack of a central authority overseeing quality control. Authorities report that there may be other issues with the country's infrastructure, but there is no way to determine the extent due to having such little information. What remains unclear is whether or not the Morandi Bridge collapse is indicative of a countrywide infrastructure crisis.

The integrity of the remaining structure is still a concern, as creaking along the east end was heard after the collapse. According to fire services, the sound was not caused by the wind. In response, several hundred people have been evacuated from residences around the base of the bridge.

California Anti-Offshore Drilling Bills Pass Committee

Two bills under consideration by the California state legislature are intended to stop oil and gas drilling off the state's coast before it begins, in a rebuke of the federal government's efforts to expand offshore production throughout the country.

Senate Bill 834 and Assembly Bill 1775, both introduced early this year and amended in the spring, have passed the respective chambers' appropriations committees and were ordered to a third reading in each body. In the California legislature, a third reading leads to a roll-call vote; if passed by both chambers the bills would then be resolved and could be approved to send to Gov. Jerry Brown for his signature.

The legislation would prevent the State Land Commission or local trustees from authorizing new oil-and-gas-related construction "upon tidelands and submerged lands within state waters associated with Outer Continental Shelf leases issued after January 1, 2018."

The bill would essentially quash any plans for drilling in federal waters off the state's coast by preventing the construction of new pipelines and related infrastructure in state waters, a necessity for transporting oil or gas from federal waters to land efficiently as the state controls everything within three nautical miles of the coast.


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At least 18 California coastal cities and nine coastal counties have local laws that ban the construction of pipelines, onshore oil terminals and other oil equipment without a public vote.

In February, the State Land Commission announced it would block new pipelines off the state's coast in an effort to prevent new development in federal waters. That action could easily be reversed by a new administration, however, while a law like the one being considered by the legislature would make the ban more permanent.

New drilling in state waters has been banned since 1994 after a moratorium that began in 1969 after the Santa Barbara oil spill, the third-largest oil spill in U.S. history. Drilling in federal waters off of California was subject to a moratorium from 1984 through 2008, and since the moratorium was removed, no new leases have been sold. A handful of drilling operations continue to function off the coast of southern California, grandfathered in prior to the ban.

Earlier this year, though, Secretary of the Interior Ryan Zinke proposed a new offshore lease plan that would reopen much of the federal water off the Pacific coast, including California, to new oil and gas exploration.

OSHA Issues Silica Rule Guidance

The Occupational Safety and Health Administration announced on Aug. 22 that new frequently asked questions and training videos on the use of respirable crystalline silica in construction were recently published to the agency's website.

OSHA, working in collaboration with industry and labor organizations, created the FAQs to provide employers and workers with guidance on the standard's requirements.

Six new training videos have also been uploaded to the website, instructing users on how to control exposure to silica dust when working in construction, or using construction equipment. Topics covered include handheld power saws, jackhammers, drills and grinders.

Other resources recently published include a customizable slide presentation for training workers and a five-minute video on protecting employees from silica dust.

In January, OSHA released more than a dozen fact sheets that cover more specific topics such as handling dust controls for crushing machines, dowel drilling rigs and drivable saws. The fact sheets also include information on heavy equipment used during demolition; heavy equipment used for grading and excavating; small and large drivable drilling machines; rig-mounted core saws; vehicle-mounted drilling rigs and walk-behind milling machines and floor grinders.

Correction

Graco Inc. was inadvertently excluded from the SSPC Organizational Members list as a Patron Member (*JPCL*, August 2018). We apologize for the error.

PAINTSQUARE COMMENTS

In Response to, "Coatings Luminary Clive Hare Dies at Age 76" (*PaintSquare News*, July 19)

Photo courtesy of Robert Hare.

The protective coatings community offered condolences and fond memories of industry stalwart and thought leader Clive Hare, who passed away July 14.

Robert Audlee:
"Clive was the chemist for our company ... His intelligence and wit will be missed. The term is thrown around quite a bit these days, but Clive was a true genius. The Nicola Tesla of coatings, if you will. Clive was able to explain processes on the back of an envelope that only in the last few years have we been able to confirm with SEM, laser scintillometry and other newfangled techniques. We were very fortunate and grateful to have benefitted from his guidance and expertise."

Ken Tator:
"I knew Clive Hare quite well. He was friendly, uniquely knowledgeable, and his books and publications have been, and still are, a tremendous technical resource in the paint and coatings industry. I sincerely regret his passing and the loss to our industry of his wisdom and knowledge. My sympathies to his family and industry co-workers."

Robert Hare:
"Thank you to [my father's] industry friends and colleagues who took time out to share a piece of his legacy here and elsewhere. I was blessed to work for him for a very short time while I was in college. While my future path was not in the coatings industry, I did learn my passion for photography from my father. More importantly, I learned how to dedicate myself to a trade and to work with humility and a willingness to share my craft with those willing to learn. It has been a great privilege to hear from so many that knew and worked with my father over the years. However, it was the honor of my life to call this great man my father. Everything I am I owe to him, my mother and the love and dedication they showed to myself and siblings as parents. Love you, Dad."

In Response to, "WI Firm Cited in Fatal Blast Shop Incident"

(*PaintSquare News*, Aug. 17)

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Worker safety and proper use of the deadman switch when abrasive blasting was the topic of conversation after a Wisconsin-based construction equipment manufacturing firm was cited and fined by OSHA in the wake of a fatal work accident last year.

Franjo Tomljenovic:
"[W]orking with an electric or pneumatic 'deadman' switch allows blasters to stop blasting immediately, when and if they need to do so. This improves worker safety and reduces the amount of abrasive material waste. Give your frontline blasters the control they need without sacrificing productivity."

E. Thomas:
"Make sure the switch is not taped on ... defeats the purpose of the safety switch."

Daniel Stahl:
"I recently heard a story of a blaster climbing a ladder while holding a blast hose [on which] somebody else had taped the deadman [switch]

down. The hose flipped up and blasted out a large chunk of flesh from his armpit. Luckily, he survived."

Wan Mohamad Nor Wan Abdul Rahman: "We are too complacent about safety at sites. When an accident occur[s], then the blame game starts. Prevention is better than curing."

Problem Solving Forum

paintsquare.com/psf

Which DFT statistics should be recorded in a daily inspection report, and why are they relevant to a good coating QC record?

Ryder Ruschke, Niles Industrial Coatings: "Depending on the project, a good rule of thumb would be to follow SSPC-PA 2. Unfortunately, this isn't a one-size-fits-all, and each job specification should be written specifically for that job as the needs of a tank lining are different for field welds/touch-up. I think the most important readings are the ones that are considered out-of-spec, and what was done to correct the deficient areas. After this, you would want to show your average, range and the standard deviation to determine how consistent the mil thickness was. It is relevant to a good coatings QC record if there is an issue with the coating system or a failure in the future. It protects the coating contractor from potential rework or, even worse, litigation."

■ ■ ■

Jeff Kim, The Sherwin-Williams Company: "It's important to measure and record the DFT readings of any primers or intermediate coats applied the previous day or days, before applying another coat. Because these previously applied coats were likely not dry enough to measure DFT the day they were applied, it's imperative that any non-compliance is identified and dealt with before 'burying' the problem."

COATINGS CONVERSATION

PAINT POLL

paintqsuare.com/poll

Officials from chemical company Arkema were recently indicted over explosions that occurred at a Texas plant during Hurricane Harvey last year. Should the company face charges over an incident brought on by such extreme conditions?

No. The area got nearly 50 inches of rain in a matter of a few days; it's impossible to safeguard against conditions so out of the ordinary. 68%

Yes. The company should have had more safeguards in place to prevent such extreme damage from a single mode of failure (flooding). 26%

Other. 6%

Steve Brunner:

"This should be a case-by-case evaluation. I understand Arkema had a plan in place but failed to cover a 100-to-500-year flood. Maps for a 100-to-500-year flood are outdated and in need of revision. As far as the incident is concerned, it appears to have been handled properly for the given conditions. So, in this case there should be no indictment."

Michael Halliwell:

"I have to agree, Steve. I don't know of any jurisdictions using a 1-to-500-year design for flooding and if the 1-to-100-year map changed after construction, there will be limits to how much additional Arkema could do. Still, Arkema will need to prove that they did everything reasonably foreseeable on this one as part of a due diligence defense. The 50 inches of water in just a few days is extraordinary and I don't know of many homes or businesses that have contingencies for such an extreme event."

Norman Fisher:

"I agree with both Mr. Brunner and Mr. Halliwell. If [Arkema] followed existing regulations, had a reasonable plan in place and followed that plan to the best of their ability given the circumstances, then no, nobody should be indicted."

PAINTSQUARE NEWS TOP 10

paintsquare.com/news, Aug. 6 – Sept. 2

1. Major Highway Bridge Collapses in Italy
2. NTSB: Serious Cracking Before FIU Collapse
3. Contractor Admits Guilt in Metro Concrete Fraud
4. Report: Experts Knew of Corrosion on Morandi Cables
5. Judge Dismisses Sherwin-Williams Site Cleanup Suit
6. WI Firm Cited in Fatal Blast Shop Incident
7. Judge, NTSB Squabble Over FIU Collapse Records
8. $814M Bridge Build Planned for Tampa
9. Self-Installing Turbine Erected Off Spanish Coast
10. New Steel to Double Pipeline Service Life

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Does Temperature Have an Effect on Coating Thickness Readings?

BY DAVID J. BARNES, ELCOMETER LTD.

A simple search of the internet will tell you that the speed of sound in a material changes with temperature. Concern has therefore been expressed that temperature may have a noticeable effect on the speed of sound when taking coating thickness measurements with an ultrasonic gauge.

The method of measuring the coating thickness using ultrasonics is defined in ASTM D6132-13 as follows.

Instruments complying with this test method measure thickness by emitting an ultrasonic pulse into the coating that is reflected back from the substrate to the probe. The travel time is converted into a thickness reading. The instrument's probe must be placed directly on the coating surface to take a reading.

After verifying accuracy on a known coated part of the object or material of the same kind, the instrument probe is coupled with the coated specimen, after proper cure and conditioning according to the coating manufacturer's instructions.

It should be recognized that the accuracy of the measurements can be influenced when:

The coated object to be measured is not planar with respect to the transducer face at the point of measurement,

Coating density is not uniform, and

The substrate peak-to-valley surface profile of the coated specimen exceeds the coating thickness.

While the theory of ultrasonic measurement can be a daunting proposition to some users, gauges produced today are essentially "point-and-shoot" devices — the user simply reads the thickness, in digits off of the gauge screen; there is no opportunity for confusion or for different operators to read the numbers differently. However, the onus is on the operator to verify that the gauge is reading correctly, and if temperature might affect this, the operator needs to take note and adjust accordingly.

This article looks at the effect of temperature on the speed of sound in coating materials and the subsequent effect on coating thickness readings.

METHODOLOGY

A series of tests were carried out using an epoxy resin coating. Six samples were prepared by applying the coating onto a steel plate using a casting knife film applicator, each at a different known thickness ranging from 168-to-680 µm. The plate and coating samples were heated (or cooled) to nominal temperatures and a digital dew meter was used to confirm surface temperature. Sample thicknesses were measured using two ultrasonic coating thickness gauges, Gauge A and Gauge B. A standard digital dry film thickness (DFT) gauge was also used as a control method to verify results.

At each selected measurement temperature, Gauge A was calibrated on the thinnest sample (the 168 µm sample) using the one-point method recommended via the manufacturer's instructions. In the field of ultrasonic

Tables 1 and 2: Sample Thickness Readings with Gauge A Calibrated at Each Test Temperature.

Nominal Sample Thickness (µm)	TS (C)	Speed of Sound (m/s)	Calibrated Gauge A Reading (µm)	Variance (%) Nominal vs. Gauge A	Digital DFT Gauge Reading (µm)	Gauge B Reading (µm)	Variance (%) Nominal vs. Gauge B
168	9.8	2263	170	1.19	167	133	20.83
168	21.4	2061	170	1.19	168	167	0.6
168	30.7	1921	168	0	169	160	4.76
168	44.3	1673	168	0	169	166	1.19
235	10.5	2263	235	0	234	190	19.15
235	21.4	2061	209	11.06	233	226	3.83
235	30.9	1921	238	1.28	234	210	10.64
235	43.1	1673	230	2.13	233	229	2.55
304	10.7	2263	309	1.64	303	225	25.99
304	21.3	2061	296	2.63	301	309	1.64
304	31.4	1921	300	1.32	304	265	12.83
304	43.2	1673	292	3.94	302	320	5.26
600	11.2	2263	568	5.33	600	485	19.17
600	21.3	2061	537	10.5	598	623	3.83
600	31.2	1921	562	6.33	598	482	36.17
600	38	1820	601	0.17	602	560	6.67
620	10.5	2263	626	0.97	621	600	3.23
620	21.4	2061	596	3.87	618	660	6.45
620	29.8	1921	591	4.68	623	540	12.9
620	37.4	1820	653	5.32	619	682	10
680	10.4	2263	692	1.76	677	617	9.26
680	21.4	2061	670	1.47	679	703	3.38
680	30.2	1921	675	0.74	681	570	16.18
680	38.1	1820	707	3.97	680	763	12.21

Nominal Sample Thickness (µm)	TS (C)	Speed of Sound (m/s)	Calibrated Gauge A Reading (µm)	Variance (%) Nominal vs. Gauge A	Digital DFT Gauge Reading (µm)	Gauge B Reading (µm)	Variance (%) Nominal vs. Gauge B
168	9.8	2263	170	1.19	167	133	20.83
235	10.5	2263	235	0	234	190	19.15
304	10.7	2263	309	1.64	303	225	25.99
600	11.2	2263	568	5.33	600	485	19.17
620	10.5	2263	626	0.97	621	600	3.23
680	10.4	2263	692	1.76	677	617	9.26
168	21.4	2061	170	1.19	168	167	0.6
235	21.4	2061	209	11.06	233	226	3.83
304	21.3	2061	296	2.63	301	309	1.64
600	21.3	2061	537	10.5	598	623	3.83
620	21.4	2061	596	3.87	618	660	6.45
680	21.4	2061	670	1.47	679	703	3.38
168	30.7	1921	168	0	169	160	4.76
235	30.9	1921	238	1.28	234	210	10.64
304	31.4	1921	300	1.32	304	265	12.83
600	31.2	1921	562	6.33	598	482	36.17
620	29.8	1921	591	4.68	623	540	12.9
680	30.2	1921	675	0.74	681	570	16.18
168	44.3	1673	168	0	169	166	1.19
235	43.1	1673	230	2.13	233	229	2.55
304	43.2	1673	292	3.94	302	320	5.26
600	38	1820	601	0.17	602	560	6.67
620	37.4	1820	653	5.32	619	682	10
680	38.1	1820	707	3.97	680	763	12.21

thickness measurement, the use of a known thickness calibration is generally accepted as providing the most accurate calibration and hence, the most accurate measurement.

The samples were initially cooled to a temperature of approximately 10 C. The plate was then allowed to warm up to room temperature and the calibration and measurements were repeated. Subsequently, the plate was heated to approximately 30 C, and then 40 C; Gauge A was calibrated and readings were taken at each temperature. The calibration reading was taken from the middle of each sample, where the thickness of the sample was known. After the one-point calibration was completed, the speed of sound was read in m/s from the screen on Gauge A.

Measurements taken using Gauge B, also calibrated based on its manufacturer's instructions, and the digital coating thickness gauge were also taken to compare with the measurements from Gauge A.

RESULTS

Table 1 shows the results for the six epoxy samples from Gauge A, Gauge B and the digital DFT gauge, at approximately 10 C, 30 C, 40 C and at room temperature. The difference between the nominal value of the sample and the readings from Gauge A are also included. As the temperature during the nominal 40 C tests varied by approximately 5 C, it was decided to re-calibrate the gauges for the "lower" temperature.

Table 2 shows the same results as Table I, but the results are now sorted by temperature. The first group are all the thickness samples at a nominal 10 C, the second group at a nominal 20 C, and so on.

Table 3 (p. 16) shows the results for the six epoxy samples measured using Gauge A, at approximately 10 C, 30 C, 40 C and at room temperature. The difference between the nominal values of the samples and the readings from Gauge A is also included as is the variance between the nominal and the digital coating thickness gauge reading. In this case, Gauge A was only calibrated once at room

Table 3: Samples Measured at Each Nominal Test Temperature with Gauge A Calibrated at Room Temperature

Nominal Sample Thickness (µm)	TS (°C)	Gauge A Reading (µm)	Variance (%) Nominal vs. Gauge A	Digital DFT Gauge Reading (µm)	Variance (%) Nominal vs. Digital DFT Gauge
168	9.8	163	2.98	167	0.60
168	21.1	168	0.00	168	0.00
168	29.5	175	4.16	169	0.60
168	38.6	199	18.4	169	0.60
235	10.5	233	0.85	234	0.43
235	21.1	238	1.28	233	0.85
235	29.5	231	1.70	234	0.43
235	38.3	241	2.55	233	0.85
304	10.7	308	1.32	303	0.32
304	21.1	307	0.99	301	0.99
304	29.4	306	0.66	304	0.00
304	38.2	319	4.93	302	0.66
600	11.2	556	7.33	600	0.00
600	21.1	589	1.83	598	0.33
600	30	593	1.17	598	0.33
600	37.7	597	0.50	602	0.33
620	10.5	602	2.90	621	0.16
620	21.1	618	0.32	618	0.32
620	30.2	625	0.81	623	0.44
620	37.9	621	0.16	619	0.16
680	10.4	661	2.79	677	0.44
680	21.1	678	0.29	679	0.15
680	29.9	684	0.59	681	0.15
680	38.6	697	2.50	680	0.00

temperature giving a speed of sound of 2,047 m/s.

When Gauge A was calibrated at different temperatures, there was a measurable change in the speed of sound, indicating that temperature does indeed have an effect. However, when the gauge was correctly calibrated at the same temperature as the measurement was to be taken, the gauge was generally shown to be within the stated accuracy. Experimental error was expected due to thermal expansion of the coating, but this was shown not to be the case by checking the thickness measurement using a digital coating thickness gauge.

The ability to maintain the samples at the test temperature is a source of error in these tests, but the general trend shows that the thicker the coating, the greater the potential variance. This would be expected, as the greater the thickness, the greater potential for expansion or contraction due to temperature and hence, the greater change in speed of sound. There will, however, be an experimental error in the recorded temperature as the samples will cool (or heat up depending on target temperature) during the thickness measurement process.

Overall, regardless of whether Gauge A was calibrated at the specific temperature or not, Gauge A consistently provided more accurate results than Gauge B.

CONCLUSION

In conclusion, it is clear that the speed of sound in an epoxy coating is affected by temperature significantly — enough that the thickness measurements made by an ultrasonic gauge of that coating will also be affected. This error can be overcome if the gauge is able to be calibrated on a known thickness of coating at the same temperature at which the thickness measurements are to be taken.

There are typically three different options provided for calibrating ultrasonic gauges: known thickness (measured mechanically); material selection (a list of known velocity values for specific materials); and velocity input (speed of sound data determined independently).

The known thickness method, used for Gauge A, uses a metal mold into which a sample of the coating to be applied is poured. Once the coating has cured, a non-destructive digital or mechanical coating thickness gauge can be used to measure the thickness of the sample reliably. This value can then be used to adjust the ultrasonic gauge, allowing it to calculate the speed of sound in the coating. In this way, the gauge will be calibrated at a known thickness for the material to be tested.

The benefit of using a digital dry film thickness (DFT) gauge in this calibration process is that the verification of the DFT gauge can be done using certified, measured foils (shims). Certified foils provide traceability to national standards for the verification of the DFT gauge across its range of operation and therefore the traceability is extended to the calibration of the ultrasonic coatings-on-concrete thickness gauge. Traceability is important in the calibration, adjustment and verification of a gauge, instilling confidence in the user and enabling him or her to report findings to the client with increased certainty and credibility. This is of particular importance if an audit of the inspection and test process is to be undertaken. Some gauges contain a pre-loaded list of probable materials for coatings. It should be noted that published data for materials and the velocity of sound can be misleading as specific formulations of generic materials can significantly change the speed of sound in the material under test.

As speed of sound in the coating is affected by a change in temperature, this one-size-fits-all method of calibration should be used with caution, and definitely not at any temperature other than room temperature. The user can also simply input the speed of sound in the coating if it is known. Again, this should be done with caution, especially if the temperature at which this speed applies is not known

ABOUT THE AUTHOR

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Photos courtesy of Sherwin-William Protective and Marine Coatings.

Extending Fish Hold Tank Maintenance Intervals on the *F/V Cornelia Marie*

BY RAY MEADOR, SHERWIN-WILLIAMS PROTECTIVE & MARINE COATINGS

In the commercial fishing industry, as with any other industry in which corrosion can affect the bottom line, it's not just time that's money; it's also cleanliness. And when a vessel shows up at a processing plant with fish hold tanks containing rusty water or floating paint chips, the processor may refuse the contaminated load, causing the owner to lose out on an entire haul.

"If we don't have good fish holds, we don't have a way to keep our product in good condition," said Casey McManus, Captain of the famed *F/V Cornelia Marie* from the Discovery Channel's documentary-style TV show *Deadliest Catch*. "And if we can't keep the product in good condition, there's no reason to go out and get it."

Proactively addressing fish hold maintenance can be tough for vessel owners, as the thin-film polyamide epoxy coatings traditionally used to coat fish holds need to cure for about a week before returning the tanks to service. That's a lot of downtime to plan for in dry-dock when other areas of the vessel are likely prioritized for coatings maintenance. Making matters worse, the polyamide epoxy coatings typically last only about five years, forcing vessel owners to keep up with short maintenance intervals.

McManus prefers to take his risks crabbing in the unforgiving Bering Sea – not at a seafood processing facility where a contaminated load of king crab could mean a loss of more than $560,000 per fish hold at dock prices. To protect over $3 million of potential catch, he recently restored the *Cornelia Marie*'s six fish holds.

In doing so, he also made a strategic specification change based on the recommendation from a global coating manufacturer's technical representative to switch from a traditional polyamide epoxy coating to a more durable ultra-high-solids epoxy amine coating that

Figs. 1 and 2: The *Cornelia Marie*'s six fish holds showed visible signs of corrosion.

could deliver a longer service life and triple the expected fish hold maintenance interval to about 15 years.

"The beauty in the fish hold coating application was in prepping the tanks efficiently, coating them within a couple of days, and returning them to service 24 hours later, knowing that we may not have to redo them for another 15 years," said McManus.

FISH HOLD RESTORATION

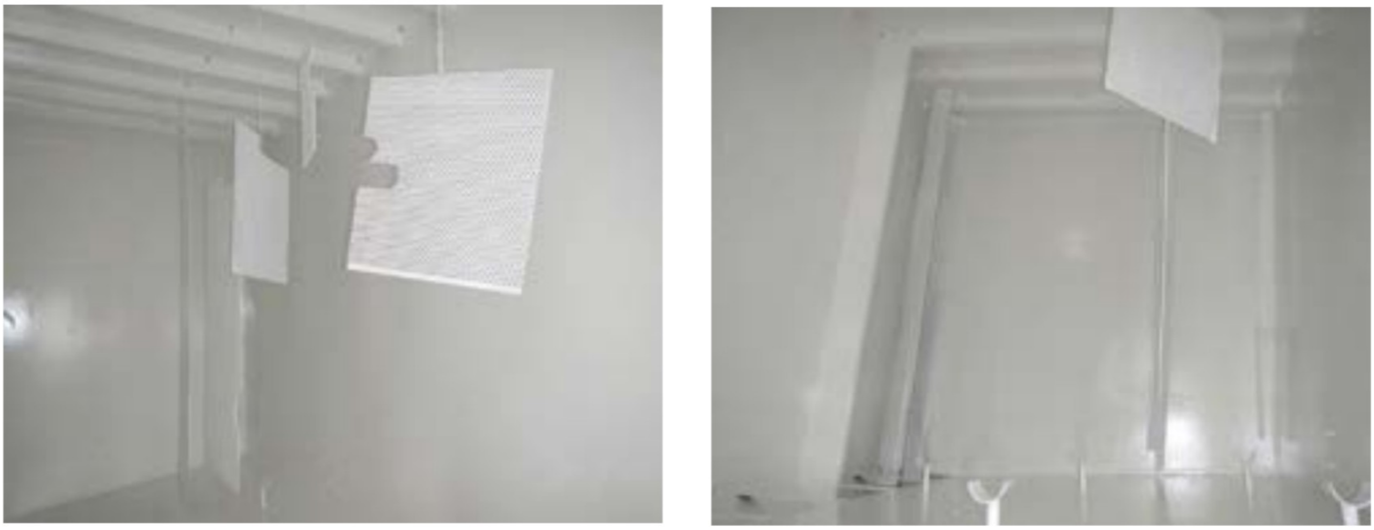
Vessel owners take a potentially costly risk when they postpone fish hold maintenance. Similar to the ballast tanks, cargo holds and other components on large marine structures, the protective coatings inside of the *Cornelia Marie*'s fish hold tanks are subject to immersion in saltwater, temperature swings and bumps and scrapes from operating equipment and marine life captured at sea. In this challenging environment, coatings may crack and peel, allowing corrosion to proliferate and potentially contaminate a vessel's catch.

Following about 10 years of service with no overhaul and minimal coating touchups, the *Cornelia Marie*'s fish holds were run down, showing visible signs of corrosion and flaking paint – the very issues that could spell disaster for a day's catch. To restore the vessel's six fish holds, which have a total volume of over 15,000 cubic feet, McManus' crew drydocked the vessel at a Seattle-area shipyard in April of 2017.

Fig. 3: Abrasive blast-cleaning the fish holds to an SSPC SP-10 standard removed all coatings and contaminants from the steel substrates.

At the shipyard, a crew from a U.S.-based industrial and marine surface preparation and painting contractor first set up containment systems and then removed salt contamination before abrasive blast-cleaning the fish holds to prepare the steel substrate for coating. Contractors prepared the surfaces to the SSPC SP-10/NACE No. 2, "Near-White Blast Cleaning" standard, being sure to remove all rust, debris and mill scale and producing a 3- to 4-mil surface profile.

Next, the contractor crew sprayed the 100-percent-solids, plural-component epoxy amine coating, directly to the metal substrate at 20-to-30 mils dry film thickness (DFT) in a single application. The edge-retentive properties of the coating provided a high build on the numerous sharp edges and corners in the fish holds to enable a longer service life. In addition, the product's flexibility helped to accommodate temperature swings inside the fish holds,



Figs. 4 and 5: An epoxy coating was applied at a 20-to-30-mils DFT over all the fish hold surfaces, including sharp edges, corners and grates.

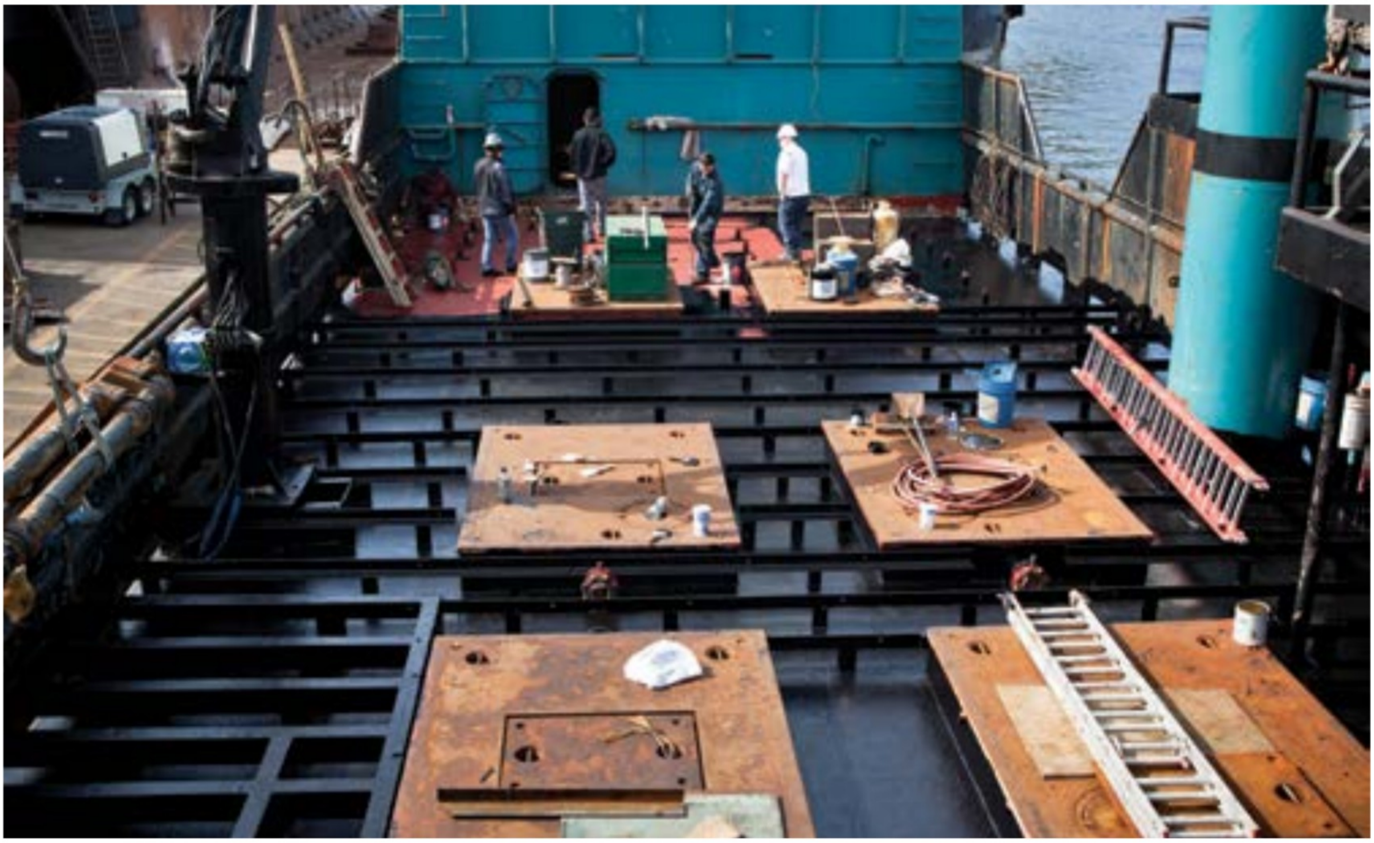


Fig. 6: The *Cornelia Marie* crew applied three coats of epoxy to the vessel's main deck by brush and roller.

which range from about 27 F to 68 F.

The restoration project took about two weeks, with the majority of time spent on equipment staging and surface preparation. The painting contractor completed the coating application over two days for all six fish holds, and McManus was able to return the tanks to service one day after the epoxy application was complete. This was a significantly faster return to service than the typical seven-day waiting period for the solvents in polyamide epoxy coatings to cure prior to service.

"Fish holds are often the last area to get addressed at the shipyard, which means you may have to wait another week to get back out on the water making money," said McManus, noting that the fast curing of the coating and return to service "can basically give us an extra six days at sea."

Following a year and three months of service, the epoxy coating application has held up exceptionally well. The *Cornelia Marie*'s fish holds show minimal to no wear, despite housing thousands of pounds of seafood and enduring the rigors of offloading catches. The durable cured epoxy amine coating has withstood scrapes from sharp crab shells, hard impacts from brailers used to

Fig. 7: Work on the underwater hull and freeboard of the *Cornelia Marie* involved taking the surfaces down to an existing tight antifouling coat, priming exposed bare steel, edge feathering above the waterline and spray-applying primer, an antifouling epoxy and an acrylic polyurethane gloss coating.

offload crabs and violent knocks from nozzles and hoses used to offload salmon.

"The challenging fish hold environment is really putting the product to the test," said McManus. "After nearly 300 offloads, none of the coatings have fractured."

With 20-to-30 mils protecting the steel substrate below, McManus expects to realize about 15 years from the application before requiring significant maintenance. Should impact damage occur in the meantime, the vessel's crew can touch up those areas using cartridge tubes, helping the *Cornelia Marie* stay in service longer with fewer delays for coating maintenance.

HULL, FREEBOARD AND SUPERSTRUCTURE RECONDITIONING

While the newly restored fish holds represent the latest major coatings restoration performed on the *Cornelia Marie*, the owners had restored the underwater hull, freeboard and areas of the superstructure two years prior.

For the hull restoration, the vessel drydocked at a shipyard in Kodiak, Alaska, where *Cornelia Marie* crew members cleaned the underwater hull, first removing algae growth and slime using a light pressure wash and then finishing with ultra-high-pressure waterjetting at 38,000 psi to take the hull down to the existing tight antifouling coat.

Next, the crew completed surface preparation on the hull, removing loose debris with hand and power tools before securing approval from on-site QA/QC personnel. The crew then prepared the vessel for spray-application of an antifouling coating, setting up a containment system and masking freeboard areas to protect lettering and other design elements.

Finally, applicators from an Alaska-based painting contractor primed any bare steel using an aluminum and micaceous iron oxide- (MiO) filled urethane coating and then spray-applied a tie coat of a modified epoxy phenalkamine primer to the hull. The contractor followed with a single 10-to-12-mil wet film thickness (WFT) coat of an antifouling polyamide epoxy within hours to avoid delamination. As the final step, the contractor applied a high-solids polyurethane gloss topcoat at 3-to-5 mils WFT in the distinctive *Cornelia Marie* teal color.

A few months later, the *Cornelia Marie* docked in Seattle to receive new engines and updates to its living areas. At the same time, the vessel's crew

Fig. 8: The fully-restored *Cornelia Marie* features its distinctive teal color.

recoated the main deck, lower house and engine room, applying three coats of the phenalkamine epoxy by brush and roller at 5-to-7 mils DFT per coat on the main deck. For the engine room, a crew from the shipyard spray-applied a coat of epoxy at 5-to-7 mils DFT, followed by a polyurethane topcoat at 3-to-5 mils DFT.

CONCLUSION

Between the previous restoration work and the new fish hold application, coatings are now protecting the *Cornelia Marie* from its haul to its hull. The applications will help keep corrosion at bay and extend maintenance intervals so that the vessel can stay in the water as long as possible between drydocks and maximize its earning potential.

ABOUT THE AUTHOR

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Photo courtesy of the author.

NO MAGIC NUMBER:

COATING CONCRETE AFTER 28 DAYS

R. A. NIXON, CORROSION PROBE, INC.

Historically, the coating industry has prescribed 28 days of cure time for concrete before coating application. The 28-day threshold was based on conventionally specified strength gain values such as a minimum of 5,000 psi compressive strength at 28 days. The logic behind the adoption of the 28-day rule was twofold.

Firstly, the majority of minimum specified strength gain is empirically reached within the first 28 days. Therefore, if the compressive strength has mostly been achieved, then most of the tensile stress that forms cracks will have developed. This assumes that most of the shrinkage of the cement paste has largely occurred but ignores the all-important water-to-cementitious-materials ratio and the paste-to-aggregate ratio. These are the major contributors to shrinkage along with temperature and timing of excess moisture loss from the concrete. Coincidently, these factors are both inextricably tied to the water content in the mix design, which leads us to point number two.

Typically, it is believed that all of the excess water not necessary for cement hydration has left the concrete after 28 days. Therefore, the detrimental effects from the exit of moisture from the concrete on coating cure or coating adhesion have been eliminated. This assumes that excess moisture leaving the concrete after 28 days will not inhibit a coating's curing mechanisms. This also ignores the material principles at work in cement hydration.

The problem with the magic 28-day number is that there is just as much empirical evidence that 28 days isn't necessary, as there is for its requirement or a longer cure time prior to coating.

This article will discuss the many factors affecting the timing for concrete shrinkage (and related cracking) as well as the rate of loss of excess moisture — factors that are not reliant on 28 days of concrete cure time. In addition, case histories will be presented evidencing successful coating application on concrete well before 28 days of cure time versus coating problems experienced well beyond 28 days of concrete cure.

Further, we will examine mix design and material-related parameters that should be followed when schedule needs for coating concrete prior to 28 days of cure are essential.

THE BASICS

When we break down the 28-day issue into dissectible parts, we realize that we have two keynote concerns. First, there are considerations about cement paste shrinkage continuing after coating application, resulting in the formation of cracks in the concrete which propagate through the coating film.

Secondly, we don't want excess moisture unnecessary for cement hydration to come out of the substrate and cause havoc at the coating/concrete interface. This process can result in early-stage cure problems for certain coating chemistries. It can also cause the formation of blisters in the coating over time (liquid-filled or dry) and inhibit good coating adhesion. This is associated with detrimental effects on coating cure, high excess moisture content in the concrete and the prevention of adequate wetting properties of the coating.

DRYING SHRINKAGE AND EXCESS WATER IN CONCRETE SUBSTRATES

Drying shrinkage in concrete is what causes cracks to occur over time. If surface cracks form while the concrete remains plastic (wet) due to rapid moisture loss at the upper surface, this plastic shrinkage cracking can be repaired prior to coating application. This cracking will be evident in the first several hours after concrete placement. Drying shrinkage happens as the volume change in the cement paste (the combination of the cement and water) occurs naturally. All cement paste shrinks as it loses the excess water it doesn't need. The volume change due to drying shrinkage alone would not cause cracking if there were no restraint to the shrinkage, but there always is. This is caused by subgrade drag in the case of slabs-on-grade or by the presence of reinforcing steel and thickness changes in concrete, among other factors. The combination of drying shrinkage and restraint develops tensile stresses within the concrete. When these stresses exceed the tensile strength of the concrete itself, which is inherently low, cracking generally occurs.

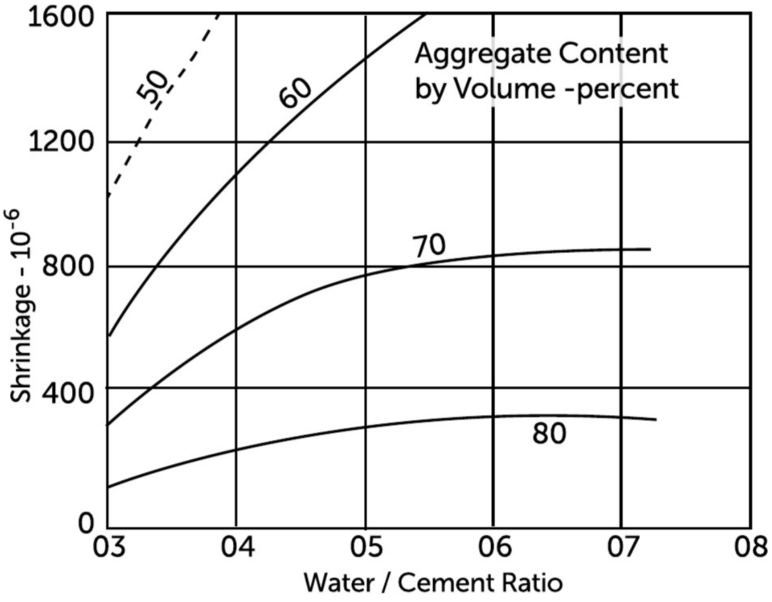


Fig. 1: Concrete shrinkage increases with the water-to-cement for a given aggregate content. Figure courtesy of ACI 224R.

The drying shrinkage that causes these stresses to develop occurs in the hardened cement paste. This can happen after much of the concrete's strength gain has developed. Aggregate reduces the unit volume of the cement paste and provides internal restraint that greatly reduces the magnitude of these volume changes. This internal restraint to shrinkage within the concrete paste and aggregate matrix prevents shrinkage cracking in contrast to external sources of restraint to shrinkage. The major factors which control drying shrinkage and excess water escape follow.

Relative humidity and drying time control the amount and rate of shrinkage. Research has shown that 80-to-85-percent relative humidity (RH) for the ambient air is good for low shrinkage rates, whereas 100 percent RH can actually promote paste swelling. Drying and ultimate shrinkage is quite slow because the loss of excess or free water (not needed for cement hydration) is diffusion-controlled. So, we don't want the air to be too hot or too dry. More humid and cooler conditions minimize drying shrinkage[1].

Relative humidity also affects the rate at which free water diffuses out of concrete. The rate of drying is influenced by the amount of free water and the distance through which this water must migrate to the external surface where it can evaporate. Here at the outer surface, the rate of drying is largely controlled by the RH of the air. Residual Portland cement paste in concrete has the propensity to maintain an internal RH of about 78-to-80 percent. Below that RH, cement hydration ceases to occur. Above that RH range, the uncombined or free water wants to leave the concrete and come to equilibrium

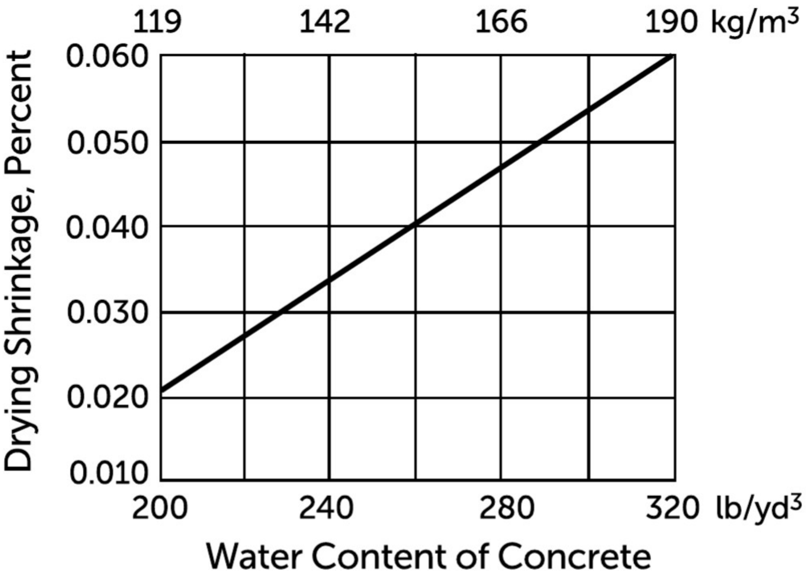


Fig. 2: This graph shows the typical effect of water content on drying shrinkage. Figure courtesy of ACI 224R.

with the ambient air RH. So, if the ambient RH is high, the drying time is extended. If the ambient RH is low, the drying time is faster[2].

The quantity and type of aggregate have substantive effects on drying shrinkage. This is because the more aggregate, the less paste there is, and therefore, the less volume change will be possible. The type of aggregate is more about its absorption properties than anything else. Aggregates with low absorption capacity are best because these materials do not add more excess water to the mix design that will then come out over time. This is often a problem with lightweight aggregate in concrete that has greater absorption capacities. Lightweight aggregates in concrete also contribute to longer drying times which can be detrimental to good coating adhesion.

Aggregates provide an elastic restraint to the effects of paste shrinkage, which prevents shrinkage from causing stress development, which then leads to cracking[3].

In addition to the quantity and type of aggregate used, size matters. The largest possible size of coarse aggregate that can be used without causing detriment to workability and good consolidation is always desirable.

The larger the aggregate, the less surface area must be coated by the cement paste. If the aggregate is too small, more surface area requires more paste. This means more drying shrinkage and the propensity for more cracking. This point leads this discussion to the importance of paste content in the concrete.

Cement paste volume relative to aggregate volume or paste-to-aggregate ratio is of critical importance to the degree of drying shrinkage, and therefore, to the extent of cracking that occurs. More water and more cement are needed to achieve a certain slump with respect to the size of the aggregate used.

The water-to-cement ratio is also of major import to the degree of drying shrinkage that occurs. Only about .19 to .20 lbs. of water are needed to hydrate one pound of Type I Portland Cement of normal grind size. However, approximately twice that amount of water has been shown to be necessary to wet-out all the cement particles and achieve a high-hydration-conversion percentage[4]. So, we need about .38 to .40 lbs. of water to one pound of cement for hydration in modern construction practices. All of the water in the water-to-cement ratio beyond that .38-to-.40 limit contributes to more and higher rates of drying shrinkage in the concrete. Also, this excess water for hydration greatly adds to the degree of porosity in the hydrated cement paste. One can conclude that both drying shrinkage and the tendency for concrete to crack are greatly reduced when a lower water content is used in the concrete mix. And the more excess water initially present in the mix, the longer it takes that water to come out of the concrete or be tied up in longer-term hydration reactions. In addition, the lower the volume of paste in the mix, even at the same water-to-cement ratio, the less drying shrinkage occurs. Therefore, at lower paste volume, the tendency for cracking is further reduced significantly and less free water is present to diffuse out of the concrete.

Water-to-cement ratio and aggregate content are therefore pivotal to the extent of shrinkage that occurs in concrete. Figure 1 (p. 25) demonstrates that concrete shrinkage

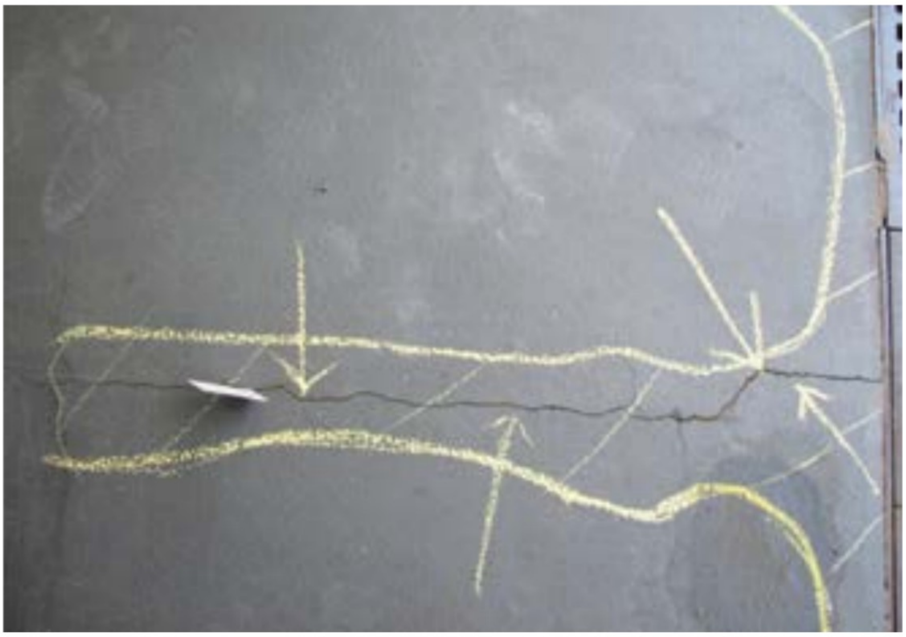


Fig. 3: Reflective cracking which appeared approximately one month after a floor coating system was installed in a pharmaceutical plant. Photo courtesy of the author.

Fig. 4: No reflective cracking and no moisture-related problems have been observed since this floor coating was installed in a building at a wastewater treatment plant after two years in service. Photo courtesy of the author.

increases with the water-to-cement ratio for a given aggregate content. It also illustrates that this effect is more pronounced with lower aggregate content.

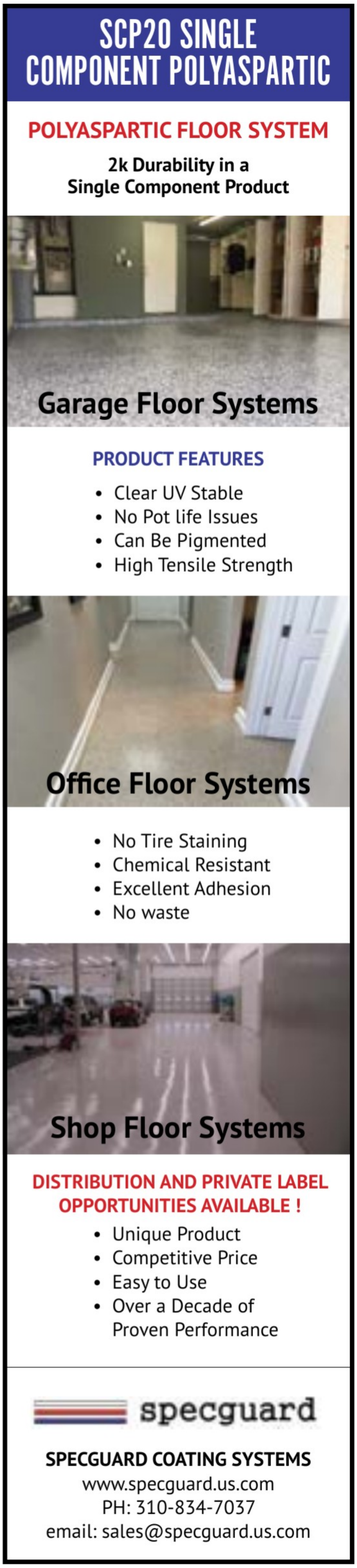
Based on proportioning calculations as outlined in American Concrete Institute's ACI 211.1, "Standard Practice for Selecting Proportions for Normal, Heavyweight and Mass Concrete," for normal-weight concrete (150 lbs./ft.^{3}) for the cement paste volume relative to the aggregate volume, the experience of this author has shown that paste-to-aggregate ratios of 0.33 or lower have produced the lowest degree of drying-shrinkage-related cracking in concrete.

Concrete member or element size also influences the extent and rate of drying shrinkage in concrete cement paste. The size and shape of the member affects the ratio of surface area to core area in the member. A higher ratio of exposed surface area relative to concrete member thickness tends to result in higher surface-drying rates. For a given concrete-mix design, the observed shrinkage at a given time decreases with an increase in size of the specimens. This is related to the surface and interior concrete conditions. Concrete shrinks due to the formation of strain. Shrinkage strain is greatest at the surface where the moisture content is lowest and decreases where the moisture content is highest. Consequently, the tensile stresses that cause cracking to develop at or near the exposed surfaces cause compressive stresses to develop at or near the core of the concrete member.

The size of the member also has a significant influence on concrete drying time (loss of free water). This free water is present both as liquid water and as water vapor in the air held within the concrete's porosity. The thicker the member, the longer the diffusion of this excess water will require to reach the outer concrete surface.

Another factor that affects the extent of concrete cement-paste shrinkage is non-uniform moisture loss which is directly associated with the effect of curing practices and methods on drying shrinkage.

Concrete can be wet-cured with constant water contact or seal-cured with curing agents or sealers. The duration of wet-curing or moist-curing does not have significant effects on the ultimate drying shrinkage of the hardened cement paste[5]. The California Department of Transportation did work in 1963 that showed that mostly the same extent of shrinkage occurred in concrete that was moist cured for 7, 14 or 28 days. And long-term moist-curing has been shown not to reduce concrete's tendency to crack due to drying shrinkage. Other research has indicated that



sealed-curing is better than wet-curing in reducing drying shrinkage. The exception to this is in very low water-to-cement ratio concrete in which hydration is slowed down with sealed curing because no additional water is available for hydration[6]. Wet-curing has, however, been shown empirically to reduce surface region cracking under hot and low-RH conditions in the first few days of hydration.

Other curing conditions clearly do affect drying shrinkage including exposure to wind and direct sunlight. These are conditions that accelerate concrete drying yet increase the likelihood of shrinkage-related cracking.

The effect of admixtures on the magnitude and rate of shrinkage of cement paste is unclear according to ACI 224 except where water reducers help to lower the effective water-to-cement ratios for workability[2].

One other factor that can affect drying shrinkage is the internal temperature of the concrete materials. Obviously, higher temperatures prior to mixing and release of heat of hydration can drive drying rates and associated shrinkage to be greater.

If we summarize what we know about drying shrinkage and the loss of excess moisture, one can surmise the following.

1. If the water-to-cement ratio can be kept at approximately 0.40 or lower, there is very little excess water present to come out of the concrete and detrimentally affect coating cure at the concrete surface. This does not eliminate the need to conduct testing for the presence of excess moisture. ASTM D4263, “Standard Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method” is recommended as a minimum. This disregards high moisture-vapor transmission problems due to the presence of wet soil conditions under a slab. In addition, this low water-to-cement ratio results in substantially less drying shrinkage in the cement paste.
2. If the cement paste-to-aggregate ratio in a concrete mix is approximately .33 on a volumetric basis (or conversely, if there is about three times more aggregate than paste), then there is substantially less drying shrinkage in the concrete which means a much lower tendency for crack development.
3. Intuitively, these facts about low water-to-cement and paste-to-aggregate ratios also tell us that the lower the cement content, the lower the water demand in the concrete. This is germane to modern-day construction because engineers frequently specify high cement contents to produce higher early strength gain. This means high compressive strengths are achieved earlier, forms can be removed more quickly, and other construction trades can begin working sooner as the building comes together. However, this practice often causes more problems than it solves in this author’s experience because higher

Fig. 5: Blisters formed in the coating on concrete walls in a wastewater treatment plant only two months after installation. Photo courtesy of the author.

cement contents give higher earlier strength gains, but the time required for drying shrinkage and excess moisture loss to occur are extended. The irony here is that front-end schedule gains are lost on the back end because coating problems are encountered if the coating work is implemented too soon. In short, specifying lower strength gains in the first 28 days will likely help the overall construction schedule if coating the concrete is important. This does not account for the structural need for higher strength concrete at 5,000 psi plus. But in many cases, 5,000 psi compressive strengths are specified when 3,000 psi in 28 days will more than satisfy the strength and loading requirements. Specifying lower strengths for concrete that are adequate for structural purposes is worthy of consideration to keep water demand down in the mix design.

Cement content and water demand in the concrete can reduce the problems with our reliance on the 28-day concrete-cure rule. Figure 2 (p. 26) shows the typical effect of water content on drying shrinkage.

4. Assuming the concrete's water-to-cement and aggregate-to-paste ratios can be optimized as described herein, the use of curing agents or sealers appears to provide a better curing method than long-term wet-curing. However, if ambient conditions include very low RH and elevated temperatures, moist- or wet-curing for the first few days (three-to-five) followed by sealed curing is prudent.

REAL-WORLD EXPERIENCE

Case History No. 1

An elevated concrete floor slab was placed and finished in a pharmaceutical manufacturing plant in June 2010. The concrete was sealer-cured for approximately 74 days prior to being shotblasted and coated with a trowel-applied epoxy floor-coating system. Approximately a month after the floor coating system was installed, reflective cracking appeared at several locations on this level of the facility (Fig. 3, p. 26).

The floor coating was well-adhered to the concrete and cured properly. The reflective cracking mirrored substrate cracking that was not visible prior to the floor coating installation.

Forensic examination of the concrete revealed the following.

- Petrographic examination estimated the original water-to-cement ratio to be very

high — in the 0.55-to-0.60 range.

- In addition, the maximum coarse aggregate size used in this 8-inch-thick slab was ¾-inch stone. The cement paste-to-aggregate ratio was approximately .41 volumetrically per cubic yard.
- The specified compressive strength was 4,000 psi in the first 28 days.

The strength gain specified was achieved, but the high cement content drove the mix design to have a high water demand. The relatively small coarse aggregate size meant the paste content required to coat all the aggregate surface area had to be high as well. The end result was longer-term, higher drying shrinkage after 74-plus days that caused late-stage cracking of the concrete to reflect through the epoxy floor coating.

Case History No. 2

In 2012, a concrete floor slab on grade was placed as part of an addition to a building in a wastewater treatment plant. The slab was 6-inches thick nominally. The new slab was specified to be 5,000 psi concrete in the first 28 days. It was placed in October in a controlled-environment building. It had an initial water-to-cement ratio of 0.38 and was admixed with a super plasticizer for workability. The maximum coarse aggregate size was 1-½ inches and the cement paste-to-aggregate ratio was 0.33. The slab was placed over a moisture-vapor retarder with a sand base over that plastic sheet. The slab was coated with a double-broadcast, epoxy floor coating, 20 days following concrete placement. The fast-track needs for the operations of the plant for the project drove this rapid turnaround schedule. The concrete was seal-cured with an acrylic curing agent after moist-curing for the first three days.

No reflective cracking or moisture-related problems have been observed since this work was completed. Figure 4 (p. 27) shows the finished floor coating work after two years in service.

Case History No. 3

A wastewater treatment plant tank was constructed in 2005. The walls were lined with a 120-mil-thick epoxy coating that was spray-applied with plural-component equipment. A filler surfacer mortar was used to fill all bugholes first. The concrete walls of the tank were a minimum of 12-inches thick. The exterior of the tank walls was waterproofed where below grade. The concrete was placed and had cured for over 90 days before the coating was applied. The concrete was dry abrasive blast-cleaned and a minimum CSP-4 profile was specified.

Within two months after the coating had been applied, blisters of various sizes began to appear in the coating film. The blisters were filled with liquid that was found to be primarily water. The coating had cured properly, but the tank had been heated and ventilated during the coating work.

Forensic examination of the cores taken from the concrete revealed the concrete's water-to-cement ratio had been very high — in the 0.55 to 0.60 range. The maximum coarse aggregate size had been 1-½ inches which was reasonable for the spacing between reinforcing steel bars and formwork. The cement paste-to-aggregate ratio was found to be close to .35 which was also considered to be acceptable. The high water content for the 5,000 psi concrete mix design left too much excess or free water in the concrete that needed to come out over time. In addition, the adhesion of the coating at the non-blistered areas was quite varied. The concrete surface profile specified had not been achieved uniformly which explained the variation in large- and small-sized blister formation (Fig. 5, p. 29).

CONCLUSIONS

Based on the technical literature review and associated real-world experience discussed herein, the following conclusions can be drawn.

1. The 28-day-cure-time rule of thumb for coating concrete has no scientific or engineering basis. Simply because the majority of compressive strength gain is achieved within 28 days, there is no sound correlation with regard

to when it is appropriate to coat concrete.

2. The factors that influence concrete drying shrinkage that cause concrete to crack are material-property related and not only time specific.
3. The factors that influence the movement of excess or free water out of concrete (not necessary for hydration) are mainly material-property and environmentally driven rather than specifically time influenced.
4. The water-to-cement (or cementitious materials) ratio, the cement paste-to-aggregate ratio in the concrete and the environmental conditions under which the concrete is cured are the major metrics that should be controlled, measured and monitored. These factors are the most important influences in determining whether or not excess moisture or concrete shrinkage will be problematic to coating concrete at a given point in time.
5. More work is required to better understand these contributing influences and how to better determine when and when not to coat concrete after initial placement.

ABOUT THE AUTHOR

Randy Nixon is president and founder of Corrosion Probe, Inc., which has been in business for over 34 years, specializing in corrosion and materials engineering, consulting, testing and inspection services. Nixon has more than 39 years of experience and has published over 65 technical papers and articles through SSPC, NACE, WEF, AWWA and TAPPI. He is widely recognized in the water/wastewater industry for his expertise and extensive experience in piping corrosion, concrete degradation evaluation, protective coatings and linings, and overall materials performance. Nixon is also president and owner of CTL, which provides corrosion and materials testing services.

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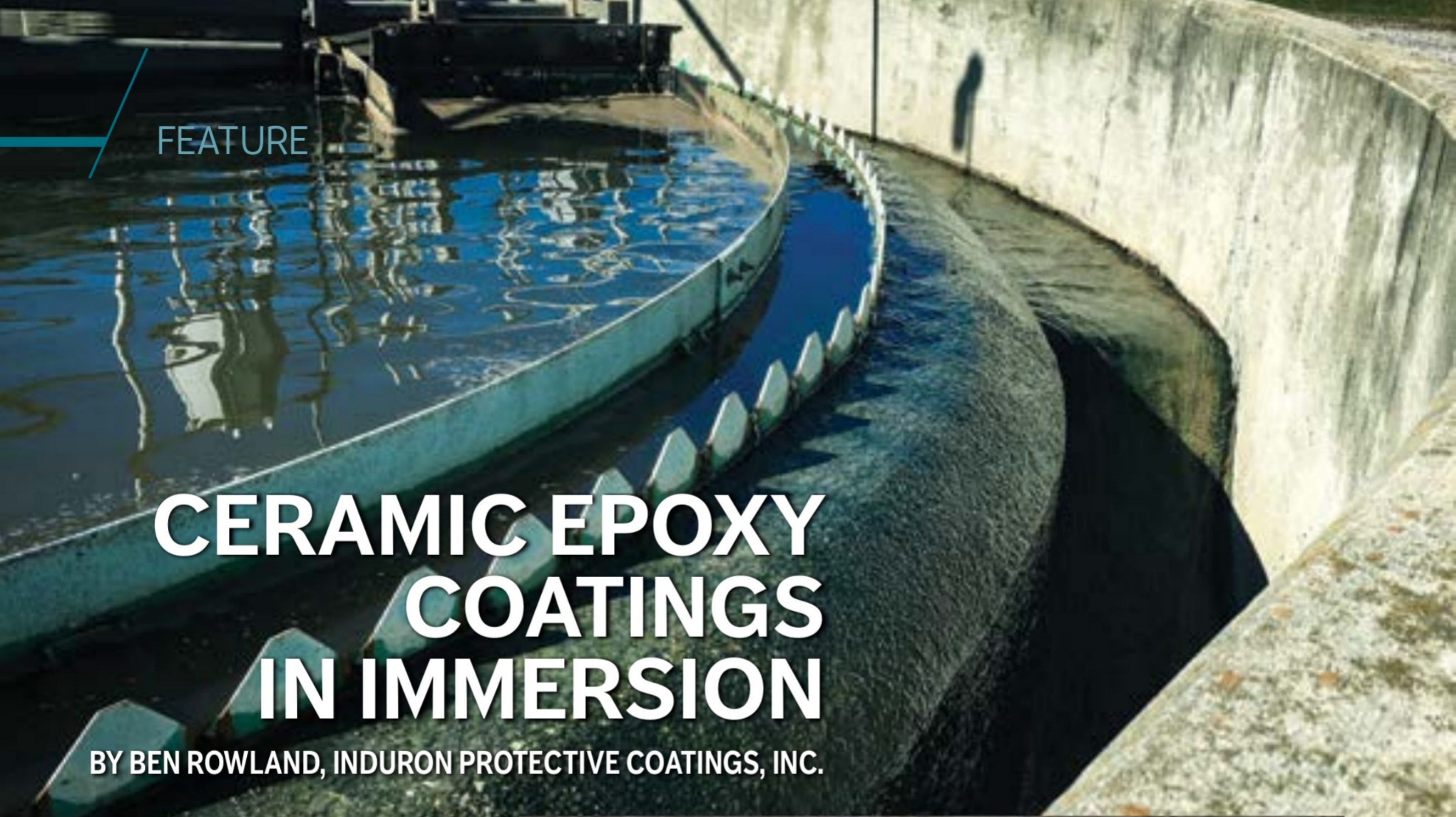
4. "ACI 224r Control of Cracking in Concrete," page 15, paragraph 3.4.5.
5. Ibid.
6. "ACI 224r Control of Cracking in Concrete," page 13, paragraph 3.4.6. ***JPCL***



CERAMIC EPOXY COATINGS IN IMMERSION

BY BEN ROWLAND, INDURON PROTECTIVE COATINGS, INC.

Fig. 1: Application of ceramic epoxy coating. Photos courtesy of Induron Protective Coatings.

Due to previous success in the ductile iron domestic sewer wastewater pipe market, ceramic epoxy coatings are increasingly being specified for nearly every substrate used in immersion service in both the water and wastewater industries. Some unique characteristics set these epoxy coatings apart from their traditional counterparts. For instance, ceramic epoxy systems provide high-film builds, eliminate undercutting, minimize permeability and provide superior edge retention, allowing these qualities to be achieved with familiar application methods that resemble more traditional means.

WHAT IS A CERAMIC EPOXY COATING?

In its most basic definition, when we say ceramic epoxy coatings we are referring to an epoxy binder with ceramic media used as a pigment/filler.

CERAMIC EPOXIES VERSUS TRADITIONAL EPOXIES

Ceramic epoxy coatings contain many of the same characteristics as conventional epoxy systems, particularly with regard to application (Fig. 1). Most ceramic epoxy coatings can be applied with conventional equipment but some, such as 100-percent-solids ceramic epoxy systems, can require heated, plural-component spray rigs. Ceramic epoxies can also be applied in excess of 50.0 dry mils using traditional epoxy-resin packages. Unlike faster-cure, high-film-build products, such as instant-set polyurethanes and polyureas, ceramic epoxy coatings wet out the substrate like traditional epoxy systems. From an application perspective, they are more forgiving and more recognizable to the people that apply traditional coating systems to all varieties of water and wastewater applications. They also remain flexible, even with rigid, high-build films.

HIGH-FILM BUILD

The addition of ceramic media allows for higher-film builds — more so than traditional epoxy coatings — without adding significant weight on the film that may cause curtaining or runs when applied to vertical surfaces. These higher-film builds offer notably better edge protection to irregular, angular edges than do low-film-build epoxy coatings. Edges are often the areas where corrosion first appears due to the shrinking away of the paint film near edges. In the past and even to this day, traditional coating systems in immersion are specified and applied in two-to-three coats that would yield a system thickness of approximately 12.0-to-15.0 dry mils. Being able to apply upwards of 50.0 dry mils in one-to-two coats, adequate film thickness can be effectively maintained on these irregular edges to protect the substrate.

PERMEABILITY

Permeability, or rather the lack thereof, is one of the primary attributes of ceramic epoxy in immersion applications. The ceramic media helps to form a film that creates a highly circuitous route for anything attempting to migrate through the film to the substrate. It was tested as per ASTM D1653, “Standard Test Methods for Water Vapor Transmission of Organic Coating Films” and measured below 1 metric perm confirming its vapor barrier capability. The circuitous route is achieved by using ceramic media utilizing particle sizes varying by three orders of magnitude. Many traditional epoxy films may have fillers such as calcium carbonates that may differ in size by two orders of magnitude. This results in a substantial impact on the film’s density.

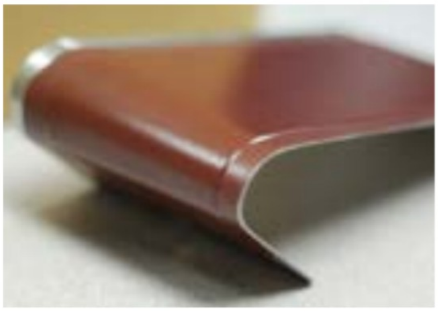


Fig. 2: A mandrel bend test was conducted as per ASTM D522, “Standard Test Methods for Mandrel Bend Test of Attached Organic Coatings” to determine the ceramic epoxy coating’s elongation or flexibility.

Fig. 3: A 1.5-million-gallon ground water storage tank in Alabama lined with ceramic epoxy.

This ceramic pigment works much in the same way as epoxy and micaceous iron oxide (MiO) coatings but differs in the following respects. It’s lighter, which allows for better high-build spray qualities, especially on vertical surfaces. Its spherical shape provides intimate contact between the binder and pigment, as opposed to other jagged-shaped pigments which result in micro voids between the binder and the pigment.

Ceramic epoxies are applied using conventional spray methods, requiring no extensive set-up as with FBE coatings. With the exception of pipe, most of these coatings are being applied on-site, in the field to protect vast square footages, which is not feasible for FBE. Ceramic epoxies also have good resistance to microbial growth. The ceramic media itself is inert, creating a film that is slightly alkaline in nature. This results in systems that naturally resist the growth of biofilm and other microbial materials.

ADHESION VERSUS COHESION

When compared to traditional epoxies, ceramic epoxies have an inverted relationship with respect to adhesive versus cohesive strength. While most epoxy coatings have higher cohesive strength (sticking together within the film) than they do adhesive strength (sticking to the substrate), ceramic epoxies have a higher adhesive strength than cohesive strength. This characteristic is important because higher adhesive strength (as opposed to higher cohesive strength)

Fig. 4: Ductile iron pipe lined with ceramic epoxy.

affords ceramic epoxies a superior ability to resist undercutting. When the film is inevitably compromised — whether one year from the application or 20 years later — it will maintain a stronger bond to the substrate than to itself. When the corrosion can no longer undercut the coating to the substrate, it remains in a passive state enabling the coating to continue to protect the substrate. Pull-off tests typically result in an adhesive glue failure, but when the film is broken, it is always cohesive, leaving a film of ceramic epoxy protecting the substrate.

FLEXIBILITY

A mandrel bend test was conducted as per ASTM D522, "Standard Test Methods for Mandrel Bend Test of Attached Organic Coatings" to determine the coating's elongation or flexibility (Fig. 2, p. 33). The word "ceramic" might often have the connotation of a material or object that is rigid or even brittle. With respect to an industrial coating making use of a ceramic pigment package, the author found this coating to have essentially the same flexibility as other comparable coatings formulated with the same resins without ceramic, even at higher-film builds.

SUMMARY

Having been used on over 50-million linear feet of ductile iron wastewater pipe and in potable water storage tanks for almost four decades, ceramic pigments in coatings have provided superior corrosion protection for substrates in immersion in water and wastewater applications (Figs. 3, p. 33 and 4).

Conventional immersion coating systems offer a wide variety of features that are beneficial in preventing corrosion in immersion applications, but few offer as many features as do ceramic epoxy coating systems. The fact that ceramic epoxies are less expensive than traditional products coupled with their ability to achieve required minimum DFTs with less coats makes them cost effective, as well.

ABOUT THE AUTHOR

Ben Rowland joined Induron Protective Coatings in 2006 and has served the company in various capacities, including 10 years as a representative assessing, specifying and inspecting industrial coating projects with a concentration in water infrastructure. He is currently the company's technical service director. During his time in the industrial coatings industry, Rowland has attained several designations including NACE Coating Inspector-Level III, SSPC Protective Coatings Specialist and SSPC Concrete Coatings Inspector. ***JPCL***

The Effect of Caustic Soda Solutions on Fusion-Bonded Epoxy Coatings at High Temperatures

BY HASSAN AL-SAGOUR AND MANA AL-MANSOUR, SAUDI ARAMCO

In the article, "Qualification Tests for High-Temperature FBE Coatings" in the July 2018 issue of *JPCL*, the results of qualification testing of high-temperature fusion-bonded epoxy (FBE) coatings were reported by the authors. This testing involved immersion in different solutions at a high temperature to examine the chemical resistance of various FBE coatings. Three candidate products were immersed at a high temperature and all showed satisfactory performance in distilled water, synthetic sea water and a 5-percent NaCl solution. Most products, however, experienced severe discoloration when immersed in a 5-percent NaOH (caustic soda) solution.

In this article the authors describe further testing conducted on one of the candidate products to determine the significance of this discoloration. While it is common in the coating industry to consider discoloration a failure, discoloration has sometimes been claimed a result of the reaction between coloring pigments and test solutions indicating no impact on a coating's properties. Hence, this work has been carried out to more closely examine the source of color change and address the changes in coating properties in more detail.

THE BACKGROUND

In the previous test, FBE coated panels were subjected to immersion in a 5-percent NaOH solution for 30 days, at 140 C. An attached cell was used in this method and a condensation system was utilized to maintain the solution's temperature at 85-to-95 C. Before immersion, measurements were taken for initial thickness, adhesion and electrochemical impedance spectroscopy (EIS) readings. Then, the immersed panels were tested for the same properties after immersion. Comparison between these properties before and after immersion in such conditions is shown in Table 1.

In Table 1, all tested samples showed a color change and the coating's thickness increased significantly in all samples. Adhesion dropped drastically, but although the coating maintained fairly high barrier properties, its impedance reading had dropped slightly.

Four months after the coated samples were removed from the NaOH solution, the three samples had dried and were put aside for further examination. All three samples had a salt-like deposit on their surfaces, but it was unclear what exact color was underneath this layer.

The scope of this current testing is to further analyze the effect of this

Table 1: DFT, Adhesion and EIS Before and After Immersion in NaOH Solution.

Coating Samples		Visual	DFT (mils)	Adhesion (psi)	EIS (ohm-cm²)
Sample 1	Before	-	18 – 22	3,445	1.00×10^{11}
	After	Color Change	33 - 37	1,077 – C*	1.49×10^{10}
Sample 2	Before	-	20 – 24	3,445	
	After	Color Change	39 – 48	2,380 – C*	N/A
Sample 3	Before	-	20 – 24	3,445	
	After	Color Change	31 - 39	1,256 – C*	N/A

C* = Cohesive Failure

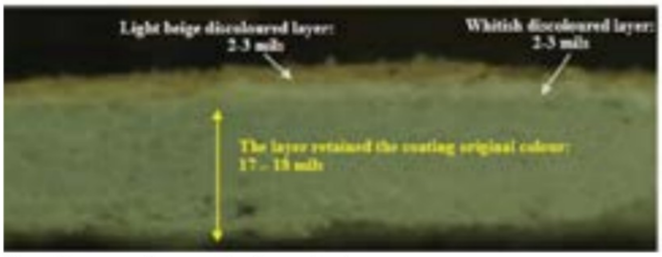


Fig. 1: Cross-section examination at 80-times magnification. Figures courtesy of the authors.

Fig. 2: Color, DFT and adhesion on Sample 1.

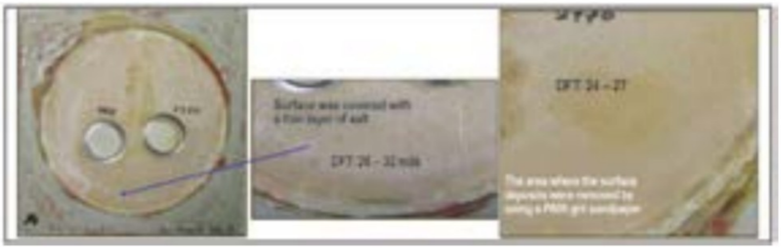


Fig. 3: Color, DFT and adhesion on Sample 2.

Fig. 4: Color, DFT and adhesion on Sample 2.

discoloration. Using force, a sample chip was removed by cutting into the entire thickness of one coated panel to reach the substrate. The sample was used for cross-section examination at 80-times magnification. The test methods used to examine the discolored layers of the coating included the following.

- Microscopic examination.
- Dry film thickness (DFT) measurements.
- Pull-off adhesion.
- EIS.
- X-ray diffraction analysis (XRD).
- Energy dispersive X-ray spectroscopy (EDX).
- Differential scanning calorimetry (DSC).
- Attenuated total reflectance, Fourier transform infrared spectroscopy (ATR-FTIR).

MICROSCOPIC EXAMINATION

The cross-section microscopic examination revealed three colors: a light beige deposit, a white top color and the original color underneath (Fig. 1). In this representative sample chip, the thickness of the layers was estimated as follows.

- Light beige deposit (2-to-3 mils).
- Top whitish color (2-to-3 mils).
- Bottom original color (17-to-18 mils).

DRY-FILM THICKNESS

Prior to immersion in NaOH, the samples measured in the range of 19-to-24 mils. Immediately after immersion, the DFT of the three samples ranged between 31-to-48 mils. Four months later, DFT measurements on the same three samples ranged from 26-to-32 mils. In general, after all of the samples had dried out and the deposit layer was removed with sandpaper, they all indicated a thickness of 7-to-8 mils higher than the control samples before immersion. The sample chip was further refined with 60-grit sandpaper and the remaining DFT measured in the range of 21-to-24 mils.

Table 2: Composition of the Top Layer.

No.	Name	Compound Formula	Percentage (%)
1	Gobbinsite	$Na_4Ca(Si_{10}Al_6)O_{32}\cdot 12H_2O$	58.4
2	Sodium Aluminum Silicate Hydrate	$Na_{3.6}Al_{3.6}Si_{12.4}O_{32}\cdot 14H_2O$	14.3
3	Barite	$BaSO_4$	10.0
4	Rutile	TiO_2	8.7
5	Quartz	SiO_2	4.8
6	Halite	NaCl	2.9
7	Cuprite	CuO_2	0.9
			Total 100

Table 3: Composition of the Intermediate Layer.

No.	Name	Compound Formula	Percentage (%)
1	Rutile	TiO_2	38.6
2	Barite	$BaSO_4$	31.2
3	Gobbinsite	$Na_4Ca(Si_{10}Al_6)O_{32}\cdot 12H_2O$	13.2
4	Witherite	$BaCO_3$	9.1
5	Sodium Aluminum Silicate Hydrate	$Na_{3.6}Al_{3.6}Si_{12.4}O_{32}\cdot 14H_2O$	5.3
6	Cuprite	CuO_2	2.6
			Total 100

The increase in thickness or swelling was a clear sign that the electrolyte managed to seep into the coating layers. This led the authors to initially assume that the coating had lost its adhesion and barrier properties.

PULL-OFF ADHESION

Adhesion prior to immersion measured as high as 3,445 psi. Post-immersion, adhesion of the top layer was reduced to 1,077-to-1,256 psi. The remaining non-discolored layers displayed high pull-off adhesion values (Figs. 2 through 4, p. 37).

Losing adhesion on only the top portion of the coating and retaining it underneath suggests that the electrolyte did not penetrate all the way through the thickness of the coating. Had it done so, adhesion would have dropped drastically, even in the bottom layers.

ELECTROCHEMICAL IMPEDANCE SPECTROSCOPY

Impedance post-immersion dropped by only one order of impedance (the Log-Z value dropped from 11 to 10). Despite the slight drop in impedance, this reading indicated that the coating still maintained a very strong barrier behavior, counter to the initial assumption of the authors.

To this point, all of the findings suggested that, to some degree, the coating allowed the NaOH solution to seep in, which impacted color, adhesion and thickness at least at the top layer. Therefore, additional testing was conducted to either confirm or challenge this hypothesis.

X-RAY DIFFRACTION

Long after immersion, XRD was used to identify any crystalline material that may have existed on the top layer of the sample. The test was conducted on two powder samples, one from the light beige deposit layer and another from the top whitish layer, which were extracted via grit paper. The powder samples were mounted on a glass

Table 4: Elemental Composition Comparison (EDX vs. XRD).

	H	C	O	Na	Al	Si	S	Cl	K	Ca	Ti	Fe	Cu	Ba
EDX	-	36.67	39.80	6.57	0.92	2.37	1.06	0.03	0.12	0.10	4.96	0.07	0.58	6.76
XRD	0.36	0.55	36.67	1.27	2.04	4.27	4.29	-	-	0.41	23.13	-	2.31	24.69

slide and scanned, and the diffractions were analyzed by comparison with standard patterns. The relative proportions of different phases in multi-phase specimens were estimated by comparing peak intensities attributed to the identified phases.

As shown in Table 2, the sample collected from the deposit layer indicated that it was mainly composed of crystalline compounds of sodium salts: hydrated sodium calcium aluminum silicate (gobbinsite [$Na_4Ca(Si_{10}Al_6)O_{32}\cdot 12H_2O$]) and hydrated sodium aluminum silicate (sodium aluminum silicate hydrate [$Na_{3.6}Al_{3.6}Si_{12.4}O_{32}\cdot 14H_2O$]), together with a moderate amount of barium sulphate scale (barite [$BaSO_4$]), titanium oxide (rutile [TiO_2]) and silicates (quartz [SiO_2]).

The composition of the sample collected from the top layer indicated that it was composed of both crystalline compounds and non-crystalline materials. The results showed that the crystalline components of the sample were predominantly fillers. Like the top layer sample, the deposit light-beige layer consisted of titanium oxide (rutile [TiO_2]), barium sulphate scale (barite [$BaSO_4$]) and sodium salt: hydrated sodium calcium aluminum silicate (gobbinsite [$Na_4Ca(Si_{10}Al_6)O_{32}\cdot 12H_2O$]), together with a moderate amount of barium carbonate (witherite [$BaCO_3$]) and hydrated sodium aluminum silicate (sodium aluminum silicate hydrate [$Na_{3.6}Al_{3.6}Si_{12.4}O_{32}\cdot 14H_2O$]) (Table 3).

Examining the XRD analysis results of both samples, it was clear that the crystalline compounds were very similar in both the deposit light-beige layer and the top whitish layer. This finding led the authors to believe that the deposit layer was merely an inorganic material on the coating surface or a filler material that leached out from the top discolored layer.

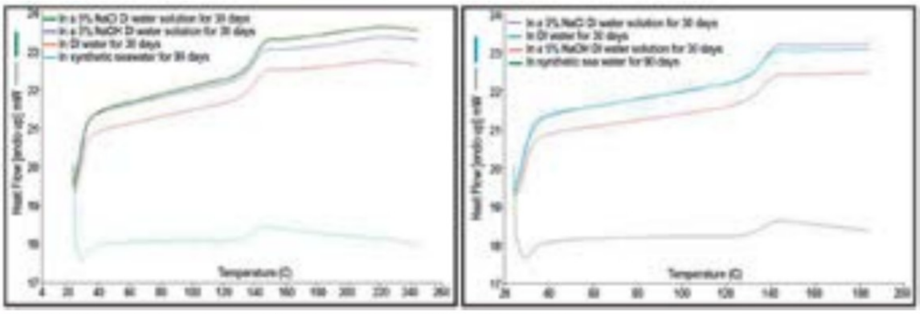


Fig. 5: DSC scans from panels after immersion in different solutions.

Table 5: DSC Scan of the Same Coating in Different Solutions.

Sample No.	2	4	5	6
Test Medium	5% NaOH	Distilled Water	Synthetic Sea Water	5% NaCl
Tg$_3$ (C)	141.4	140.0	140.1	141.4
Tg$_4$ (C)	136.4	136.0	137.1	137.4

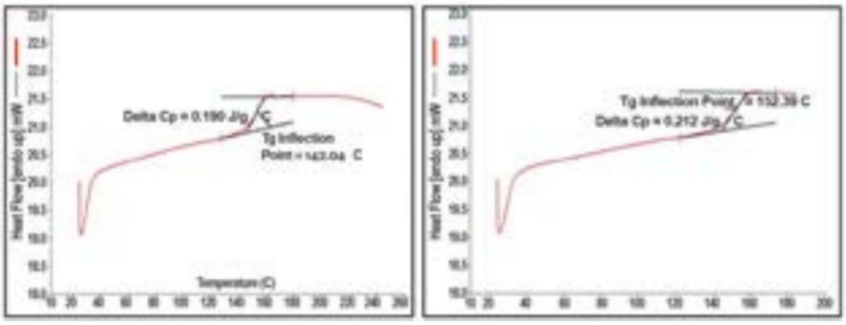


Fig. 6: DSC scan of the coating after dry heat.

ENERGY DISPERSIVE X-RAY SPECTROSCOPY

To analyze the surface of the FBE coating, the authors used the energy dispersive X-ray spectroscopy technique, which was mainly to provide an accurate elemental analysis by characterizing the chemical elements of the coating sample. Unlike XRD, EDX is expected to produce more information on the composition of the coating. Here, EDX was used to analyze a sample only from the top discolored portion containing the light-beige layer over the whitish layer.

The values of the elemental composition calculated from the XRD graph shows a direct comparison in composition between EDX and XRD (Table 4, p. 39).

As shown in this table, the most dominant elements from the EDX analysis were carbon (C) (composing 36.7 percent of the sample) and oxygen (O) which composed 39.8 percent. The next moderately abundant elements were barium (Ba), sodium (Na), titanium (Ti) and silicon (Si), together forming 20.8 percent of the sample with minor traces of sulfur (S), aluminum (Al), copper (Cu), potassium (K), calcium (Ca), iron (Fe) and chlorine (Cl).

XRD analysis suggested that this layer contained both organic and inorganic material. EDX analysis confirmed this as well, by showing higher values in content of carbon, barium and titanium. This layer contained both crystalline and non-crystalline compounds.

DIFFERENTIAL SCANNING CALORIMETRY

To determine the thermal properties of the three layers of the coating, DSC was conducted on samples from each layer and no glass transition temperature (Tg) was detected in the light-beige layer. This indicated that the main components of the deposit layer had a low molecular mass. Combining the findings of XRD, EDX and DSC, the authors deduced that this material with low molecular mass was composed of fillers leaching from the coating.

The Tg of the sample from the top whitish layer was 129 C. This Tg is much lower than the coating's original Tg of 157 C which indicated a significant degradation of the coating's properties at this layer.

Tg$_3$ and Tg$_4$ were found to be 141 C and 136 C, respectively. A ΔTg of 5 C was considered a bit high, so prior to reaching a conclusion, the DSC scan was repeated at different end temperatures, namely: 190 C, 200 C and 220 C. When the end temperature was set to 190 C, both Tg$_3$ and Tg$_4$ measured 141 C (given the standard deviation). This finding indicated that the initial difference between Tg$_3$ and Tg$_4$ was due to the change in test setup and not to thermal degradation. Still, this temperature of 141 C was lower than the original Tg of 157 C by almost 17 degrees. At this point, it is not conclusive whether or not this drop in Tg was caused by thermal degradation.

To further clarify whether or not this drop in Tg was caused by water absorption (wet Tg) or by degradation (hydrolysis), DSC was also conducted on samples from other panels that had been submersed in different solutions, namely distilled water, synthetic sea water and 5-percent NaCl solutions for the same 30-day period and conditions (140 C panel, 95 C solution). As shown in Figure 5 and Table 5, Tg was 141 C regardless of the type of solution. This finding led the authors to believe that the drop in Tg was due to water absorption and not hydrolysis.

To examine this finding even further, a panel of the same coating was subjected to dry heat of 140 C in an oven for 30 days. A small coating sample was then removed from the panel after it reached room temperature and a DSC analysis was carried out. As expected, the dry Tg_3 and Tg_4 were approximately 152 C and 153 C (Fig. 6). These values are slightly lower than 157 C, the original Tg of the control sample. Because the thermal degradation is negligible at 140 C (dry), it should be safe to conclude that the temperature of the testing solution (95 C) should be less aggressive. That is, the drop in Tg values was reasonable at approximately 11 C. This drop was not a sign of thermal degradation, but rather due to immersion.

ATTENUATED TOTAL REFLECTANCE FOURIER TRANSFORM INFRARED SPECTROSCOPY

This test was selected for quantitative analysis. To analyze the microstructure of samples from different layers, the test identifies the functional groups by their characteristic absorption bands and the content is determined by band intensity. The ATR-FTIR analysis was conducted on four samples, as follows.

- A sample from the deposit layer.
- A sample from the top discolored layer.
- A sample from the bottom non-discolored layer.
- A sample from an untested panel for comparison.

DISCUSSION

This experiment was designed to investigate the cause of discoloration that occurred on a fusion-bonded-epoxy coating after immersion for 30 days in a caustic 5-percent NaOH soda solution at a temperature of 140 C.

A sample taken from an affected tested panel was examined at a microscopic level to define the extent of discoloration across the dry-film thickness of the coating. There was a deposit material of a light-beige color on the surface, a discolored top layer of about 3 mils and then the bottom layer of about 18 mils retained its original color.

XRD revealed that the deposit layer was composed of a crystalline, inorganic material. The top discolored layer was found to be a combination of crystalline material and organic material.

EDX was carried out only on the top discolored layer, which further confirmed that this layer contained both organic and inorganic content, especially after the elemental analysis comparison with XRD-interpreted values.

DSC was also conducted on the three layers. The deposit had no Tg, indicating low molecular values of crystalline elements. The top discolored layer was found to be thermally degraded. The bottom layer did not thermally degrade. The drop in Tg that was experienced was due to being wet and not to thermal degradation or hydrolysis.

ATR-FTIR graphs were consistent with all of the findings from XRD, EDX and DSC.

CONCLUSION

When testing FBE coatings in a caustic soda solution for 30 days at a temperature of 140 C, some products showed discoloration. To evaluate whether this discoloration was a sign of failure, further testing revealed that the top few mils of the coating's thickness had been degraded, however, the thicker bottom layer of the coating retained its full properties including its original color.

Whether this coating should be qualified depends on how representative this accelerated test is of actual conditions and for how many years. If other coatings can withstand these testing environments, this discoloration should be considered a failure. If no coating could pass these conditions, this coating may retain its properties for an unknown number of years until the electrolyte fully penetrates the entire thickness.

FUTURE WORK

To further confirm the findings of this experiment, various coatings from various manufacturers should be subjected to the same testing program before reaching a final conclusion.

Also, more research is needed to define how many years of natural exposure these accelerated 30-day tests correlate to. A confirmed and direct relationship between the number of test days and years they represent will allow a qualification decision of a discolored FBE coating to be made.

ABOUT THE AUTHORS

Hassan Al-Sagour is a coating engineer at Saudi Aramco. He has a Bachelor's degree in mechanical engineering from California State University, Long Beach (2004) and a Master's degree in polymers, colorants and fine chemicals from the University of Leeds (2017). Al-Sagour started his career as a maintenance engineer in refineries and gas

plants. He later became a projects/maintenance lead engineer and a shutdown director. Currently, Al-Sagour works in the Consulting Services Department where he is responsible for developing engineering standards, qualifying products and providing technical support to operation and project teams. He is a certified SSPC Protective Coatings Specialist (PCS).

Mana Al-Mansour is an engineering consultant at Saudi Aramco and the chairman of the protective coating standards committee. He joined Saudi Aramco in 1997 and has been working exclusively in the field of protective coatings including standards development, providing technical support to capital programs and operations, introducing new technologies and mentoring new engineers. Al-Mansour is a member of the SSPC Board of Governors. In addition, he is an SSPC-certified Protective Coatings Specialist and the chairman of the SSPC Saudi Chapter.

ACKNOWLEDGMENT

The authors would like to thank Amal Al-Borno, Xianyi Chen and Sherry Rao of Charters Coatings Laboratories for their help in designing the scope of this test and conducting it, based on our requirements.

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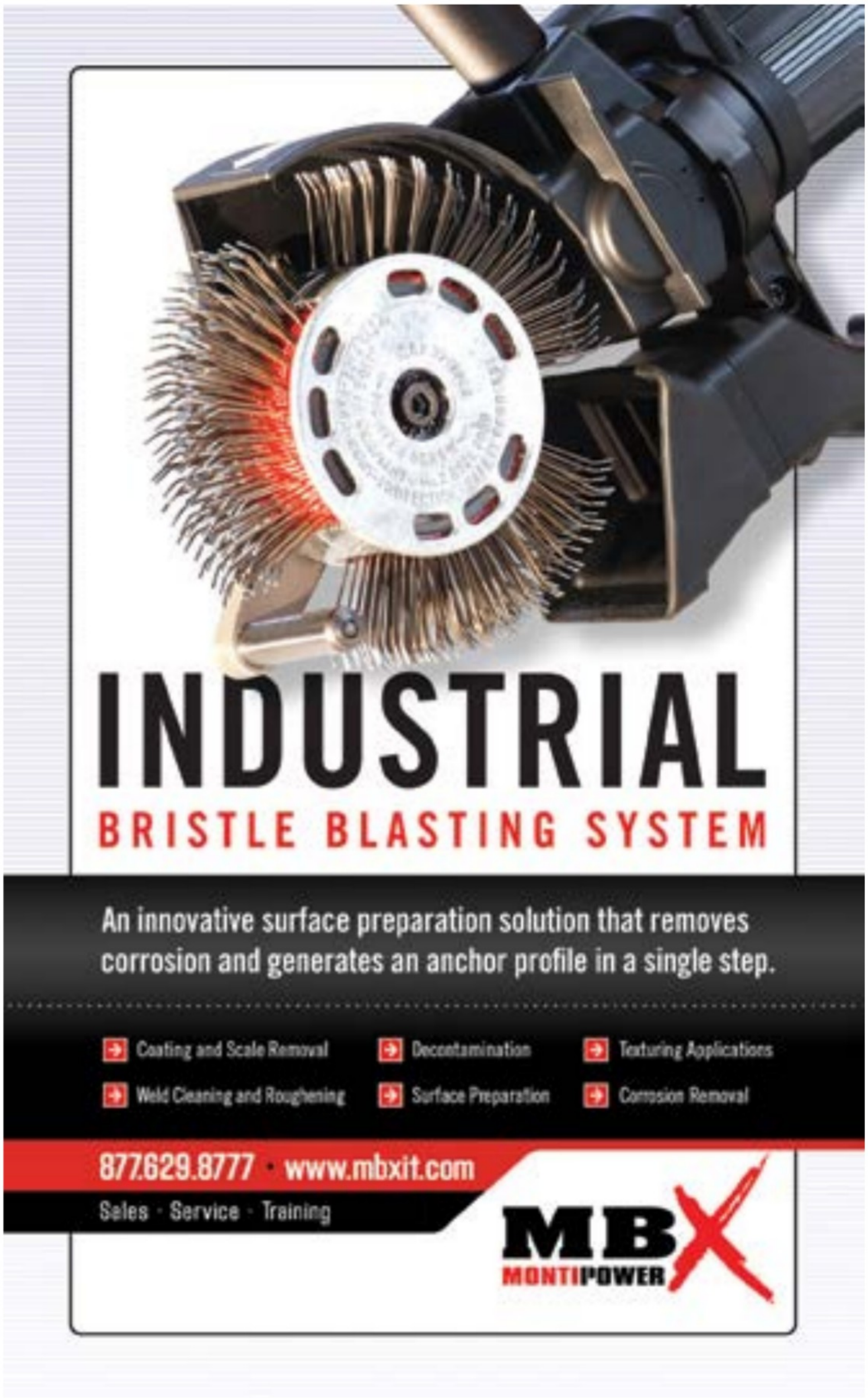

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SSPC COATINGS+2019

Technical Program

Coatings+ 2019, SSPC's rebranded annual conference and exhibition dedicated to protective coatings, will take place Feb. 11 to 14, 2019, at Disney's Coronado Springs Resort in Orlando, Fla.

The Coatings+ 2019 technical program will feature presentations from a variety of speakers representing different industry sectors. The following is a list of scheduled presentations, current as of press time.

The official Coatings+ website, www.sspc2019.com, contains complete information on the conference, including the SSPC training course schedule, special events and awards, an exhibitors list and more. Additional sections of the Coatings+ conference and exhibition will also be previewed in upcoming issues of *JPCL*.

MONDAY, FEB. 11

MORNING 8:30 TO 11:00 A.M.

Session 1: ABCs of QP

- "Benefits of QP: Union and Non-Union," by Henry Arato, Brent Miller and Joe Berish, SSPC; Cory Allen, Vulcan Painters; and Contractors TBD.

Session 2: Quality in a Developing Workforce

- "Assuring Quality with Certified Coating Contractors, Applicators, and Inspectors," by Troy Fraebel and Alison Kaelin, ABKaelin, LLC.
- "Discover SSPC's Trainthepainter Program," by Jennifer Buzzatto, SSPC.
- "Bringing Coatings to Our Youth," by Dontrae Walls, Newport News Shipbuilding.

Session 3: Case Studies

- "Accelerating Construction in Sewer Collection: Madison CMIC Pump Station #1: A Case Study," by Eric Zimmerman, The Sherwin-Williams Company.
- "The Importance of Routine/Timely Maintenance of Water Storage Tanks," by Gregory "Chip" Stein, Tank Industry Consultants.
- "Enhanced Corrosion Protection and Increased Service Life of Powder Coated Parts on Sea Vessels," by Chris Lucy, Chemquest.
- "Corrosion Under Insulation Management," by David A. Hunter, Pond & Company.

Session 4: Environmental, Health & Safety

- "Regulatory Update: New and Revised Regulations and Actions Affecting the Coatings Industry," by Alison Kaelin, ABKaelin, LLC.
- "Warning! Technical Challenges of Compliance with the New CA Proposition 65 Regulations," by Kim Reynolds Reid, Gradient.

- "The Rebranding of a Safety Culture," by Christopher Peightal, KTA-Tator, Inc.
- "The Threat of Silica and the Solution," by Mark Stewart, ARS Recycling Systems.
- "Corrosion Protection & Safety Assurance — Understanding Hazardous Location Conduit Systems for Safety & Performance," by Stephanie Ellis and Steve Voelzke, Robroy Industries.

AFTERNOON 1:30 TO 4:30 P.M.

Session 1: Workshop

- "Basic Coatings Inspection Instrument Use," by Bill Corbett, KTA-Tator, Inc.

Session 2: Workshop

- "Coatings 101," by Charles Brown, GPI.

COATINGS+ 2019 EXHIBITORS

This list of companies planning to exhibit at Coatings+ 2019 is current as of press time. For information on exhibiting, contact Nicole Lourette, SSPC event/exhibit specialist, at lourette@sspc.org or 412-288-6023.

Abrasives Inc.
Air Systems International
Airtech
APE Companies
Arid-Dry
ARS Recycling Systems, LLC
Atlantic Design Inc.
Axxiom Mfg./ Schmidt Engineered Abrasive Systems
Barton International
Bellemare Abrasives & Minerals
BlastOne International
BrandSafway
Bullard
Carboline Company
CESCO
Chemours
Chlor*Rid International, Inc. (Borchers)
Church & Dwight / ARMEX
Clemco Industries Corp.
CoatingsPro Magazine
Cortec Corporation
CSI Services
Dampney
DeFelsko Corporation
Dehumidification Technologies, LP
DESCO Manufacturing Inc.
Detroit Tarpaulin, Inc.
D.H. Charles Engineering, Inc.
DocoPro Ltd.
Doosan Portable Power
Dupont Protection Solutions
Dustnet by EMI
Eagle Industries
Easy Kleen Pressure Systems Ltd.
Elcometer
EnTech Industries
Ervin Industries
Fischer Technology, Inc.
Forensic Analystical Consulting Services (FACS)
GMA Garnet USA
Graco Inc.
Green Diamond Performance Materials
Greener Blast
Greenman-Pedersen Inc. (GPI)
Harsco Minerals
Hempel
Herc Rentals
Hippwrap Containment
HoldTight Solutions, Inc.
HRV Confirmance Verification Associates Inc.
Indian Valley Industries
InduMar
Induron Protective Coatings
Industrial Vaccuum Equipment Corp.
International Paint
IUPAT/ Finishing Trades Institute
Kennametal
KTA-Tator, Inc.
Marco
MES – Rentals & Supplies
Minerals Research, Inc.
MONTI Tools
Montipower
NACE Institute
NACE International
National Equipment Corp. (NECO)
NCERCAMP @ The University of Akron
Nextec, Inc / PreTox
Novatek Corporation
Nu Way Industrial Waste Mgmt., LLC
Olimag Sand
P & L Metalcrafts
Paul N. Gardner Co. Inc.
Pinnacle Central Co. Inc.
Polygon
Polyset
PPG Protective & Marine Coatings
Rapid Prep
Raven Lining Systems
RBW Enterprises, Inc.
Ring Power
SAFE Systems, Inc.
San-Blast-Ture
Sand Express
SciTeex Sp. z.o.o. / Mettalisation
Shanghai Xiang Rong Industrial Equipment Co. Ltd.
The Sherwin-Williams Company
Somay Q Technologies (CBC America)
Sponge-Jet
Sulzer Mixpac USA
Surface Prep Supply
Tank Industry Consultants
Tarps Manufacturing
Technofink, LLC
Technology Publishing Co.
Tinker & Rasor
Titan Tool
Tnemec
TruAbrasives by Strategic Materials
TruQC
Ultimate Linings
U.S. Minerals
Valentus Specialty Chemicals
Van Air Systems
Vector Technologies Ltd
W Abrasives
The Warehouse Rental & Supply
Western Technology
WIWA
ZIBO TAA Metal Technology Co, Ltd.

Session 3: Workshop

- "SSPC Instructor Workshop," by Anne McHenry and Jennifer Buzzatto, SSPC.

Session 4: Concrete

- "The Effects of Salt and How to Remove Salt from Concrete," by Frank Yantek, Wicktek, Inc.
- "Texture Standards for Concrete Coatings," by Tom Murphy, VP Marketing.
- "Bring on the Heat: A Novel Technique to Assess Thick-Film Thermoset Plural Component Coating Application," by Dudley Primeaux II, Primeaux Associates, LLC.
- "'Clearing the Hurdles' – A Look at the South Valley Sewer District, Jordan Basin Water Reclamation Facility Membrane Basins Rehabilitation Project," by Greg Hansen, The Sherwin-Williams Company.
- "Don't Forget the Details When Preparing and Coating Concrete," by John Sierzega, The Sherwin-Williams Company.
- "Measuring Vertical Concrete Surface pH for High-Performance Protective Linings: Test Method for Severe Service Exposures," by Vaughn O'Dea, Tnemec Company, Inc.

TUESDAY, FEB. 12

MORNING 10:30 TO 12:30 P.M.

Session 1: Failure Panel

- "Exploring Differing Views on Causes of Coating Failures," moderated by Dudley Primeaux, Primeaux Associates LLC; with panelists Charles Harvilicz, Newport News Shipbuilding; Chris Farschon, GPI; and Gunnar Ackx, Scicon Worldwide.

Session 2: Coating Application

- "Dry Film Thickness: Is More Coating Always Better?" by Robert Francis, R A Francis Consulting Services.
- "Forced Cure of Applied Linings," by Shawn Evans, The Sherwin-Williams Company.
- "The Advantages of 100% Solids Polyurethane vs. 100% Solids Epoxy in Steel Potable Water Storage Tanks," by Murray Heywood, The Sherwin-Williams Company.
- "Effect of Feathering on Coating Performance," by Patrick Cassidy, Elzly Technology Corporation.

Session 3: Coating Types, Part 1

- "Mechanical Performance of Nano-Particles Enriched Zinc Rich Coatings," by Saiada Fuadi Fancy, Florida International University.
- "Novel Isocyanate-Free Resins for 1k and 2k Protective Coatings,"

by Denis Heymans, Hexion Research Belgium SA.
- "Trials and Tribulations Involved with Finding the Optimal Lining Material," by Stephanie Prochaska, U.S. Bureau of Reclamation.
- "The Benefits and Use of Fluoropolymer Coatings," by Eric Brandhorst, The Sherwin-Williams Company.

AFTERNOON, 1:30 TO 4:30 P.M.

Session 1: Workshop
- "ESCAPE ROOM: Interactive Coating Failure Investigation," by Valerie Sherbondy and Rick Huntley, KTA-Tator, Inc.

Session 2: Surface Preparation of Steel
- "On the Effect of Abrasive Blast Media on Corrosion of Steel," by Carl Reed, GPI.
- "Introducing Peak Count Density Variable to the Surface Preparation of Galvanized Steel," by Yanick Croteau, The Sherwin-Williams Company.
- "Effects of Additional Waterjet Cleaning on the Surface Cleanliness and Coating Performance," by HeeBaek Lee, Hyundai Heavy Industries.
- "Pipeline Internal Surface Preparation and Quality Control Testing," by Kristopher Kemper, Aegion.
- "Abrasive Selection Economics — Cost or Price?" by Brad Gooden, BlastOne International.
- "Navigating New Classifications for Wet Abrasive Equipment," by Wade Hannon, Graco, Inc.

Session 3: Navy/Marine
- "Coating Performance Over Localized/Partially Abrasive Blasted Surfaces," by Patrick Cassidy, Elzly Technology Corporation.
- "The Development of Water-Based Peelable Paint for Reduction of Repair Coating Process," by SeungGon Choo, Hyundai Heavy Industries.
- "Partnering with the US Navy: A Guide to Effective, Long-Term Water Storage Tank Maintenance on a Global Scale," by Gregory "Chip" Stein, Tank Industry Consultants.

Session 4: Inspection
- "Performance of Autonomous Aerial Robotics for Dry Film Thickness Measurement," by Jamie Branch, Apellix, Working Drones, Inc.
- "How Have the Latest Instrument Developments Changed the Way We Measure Profile?" by David Barnes, Elcometer Limited.
- "Calibration, Verification, and Adjustment: Ensuring Accurate Inspection Measurement," by David Beamish, DeFelsko Corp.
- "Building Success Through In-field Reporting," by Justin Rigby, DocoPro.
- "Considering Overcoating? Details to

Examine," by William Seavy, The Sherwin-Williams Company.

WEDNESDAY, FEB. 13

MORNING 8:30 TO 9:30 A.M.

Session 1: Mini Session

- "Maintenance Prioritization of Aging NASA Wind Tunnels," by Robert Ernsting, Jacobs Engineering.

Session 2: Owner Considerations Mini Session

- "Is Your Specification Style Costing Your Customers Money? Providing Better Value Through Changing One Factor in Your Specification," by John Hilton, The Sherwin Williams Company.
- "That Sounds Great, But How Long Will It Last?" by Chuck Fite, The Sherwin-Williams Company.

Session 3: Mini Session

- "Does PA 2 Go Far Enough in Outlining DFT Measurement and Assisting the User to Carry Out the Most Efficient Inspection?" by David Barnes, Elcometer Limited.

Session 4: Mini Session

- "Writing an Effective Scope of Work is Just Smart Business," by Russell Brown, Polygon Group.

MID-MORNING 10:00 A.M. TO 12:00 P.M.

Session 1: Bridge

- "Integrating Steel Repairs on Bridge Painting Projects," by Kevin Keith, LiRo Group.
- "Remediation of Soluble Salts from Steel Bridges During Repainting," by Pete Ault and Nick Fabritiis, Elzly Technology Corporation.

Session 2: Fireproofing

- "Selecting the Right Primers on Galvanized Surfaces Protected by IFRM," by Ernst Toussaint, Hilti North America.

Session 3: Coating Types, Part 2

- "Penny Wise or Pound Foolish? Holding Primers for Solvent Free Tank Linings," by Mike O'Donoghue, Ph.D., and Vijay Datta, MS, International Paint, LLC; and Margaret Pardy, Mag Consulting, Inc.
- "Fast-Cure Without Compromise: Enhanced Productivity through Fast-Cure High Performance Coatings," by Mary Roley, Carboline Company.
- "Myth Busters: Superhydrophobic Additives for Coatings," by Allen Skaja, U.S. Bureau of Reclamation.
- "The Use of VCI Inhibitors in Conjunction with or Replacement of Traditional Corrosion Inhibitors," by Markus Bieber, Cortec Corporation.

- "Corrosion Protection Systems Based on Lamellar Zinc Pigments," by Guy Decelles, ECKART Suisse SA.

Session 4: Coating Failures

- "Mitigation of MIC of Steel in Marine Fouling Environments with Coatings," by Samanbar Permeh, Florida International University.
- "Investigation of Transport and Installation Damages to Coatings of Offshore Structures," by Tom Marquardt, Muehlhan AG.
- "Elastomeric Coating: A Failure Analysis Using Heat and Water Submersion," by Nizar Alrafie, GHD, Inc.
- "A Breakdown of the System," by Terry L. Gabbert, USAF Corrosion Prevention and Control Office.

AFTERNOON 3:00 TO 5:00 P.M.

Session 1: Workshop

- "Leadership Session," sponsored by the SSPC Women in Coatings.

Session 2: Shipyard Ventilation

- "Lessons Learned from Dehumidification Specifications, Good and Bad," by Don Schnell, Polygon Group.
- "Choosing the Right Technology to Control Climates in Drydockings: Some Trials and Some Errors," by Nick Kline, Polygon Group.
- "Dust Collection and Ventilation," by Mark LaPlant, Entech Industries.
- "Containments and Climate Control for Non-Skid Deck Coatings," by Scott Eisel, International Flooring & Protective Coatings, Inc.
- "Measuring and Monitoring," by Kevin Phillips, Huntington Ingalls Industries - Newport News Shipbuilding.

Session 3: Workshop

- "Coating Inspection Forum," by Peter Ault, Elzly Technology Corp.; and Chris Farschon, GPI.

Session 4: Corrosion

- "Corrosive Soils and Risk Management," by Paul Trautmann, The Sherwin-Williams Company.
- "Quantification of Rustback and Flash Rust of Prepared Steel," by Anthony Monda, Elzly Technology Corporation.
- "'The Weakest Link' — Crevice Corrosion of Critical Assets," by Rick Noles, Watson Coatings, Inc.
- "Understanding the Environments," by Terry L. Gabbert, USAF Corrosion Prevention and Control Office.

THURSDAY, FEB. 14

MORNING 8:30 TO 10:30 A.M.

Session I: Latin American Session, Part I

- "Gestión de la Corrosión con Recubrimientos en Proyecto de Integridad," by Abel De La Cruz, Inforcorrosion.
- "Corrosión del Concreto," by Guillermo Loayza, Productos Setmix.

Session 2: Galvanizing Mini Session

- "Inspection and Touch Up & Repair of Hot Dip Galvanizing," by Amanda Swanberg, Valmont Coatings.
- "Successful Detailing for Hot-Dip Galvanizing and Duplex," by Kevin Irving, AZZ Metal Coatings.

Session 3: Mini Session

- "Superhydrophobic Versus Freezing Point Depression — Exploring Different Chemistry and Test Methodology of Ice Adhesion to Coatings," by Andrew Recker, BASF.

Session 4: Mini Session

- "Aluminum Corrosion & Corrosion Prevention in a Seacoast Atmospheric Environment," by Kenneth Tator, KTA-Tator, Inc.

MID-MORNING 10:00 A.M. TO 12:00 P.M

Session 1: Latin American Session, Part 2

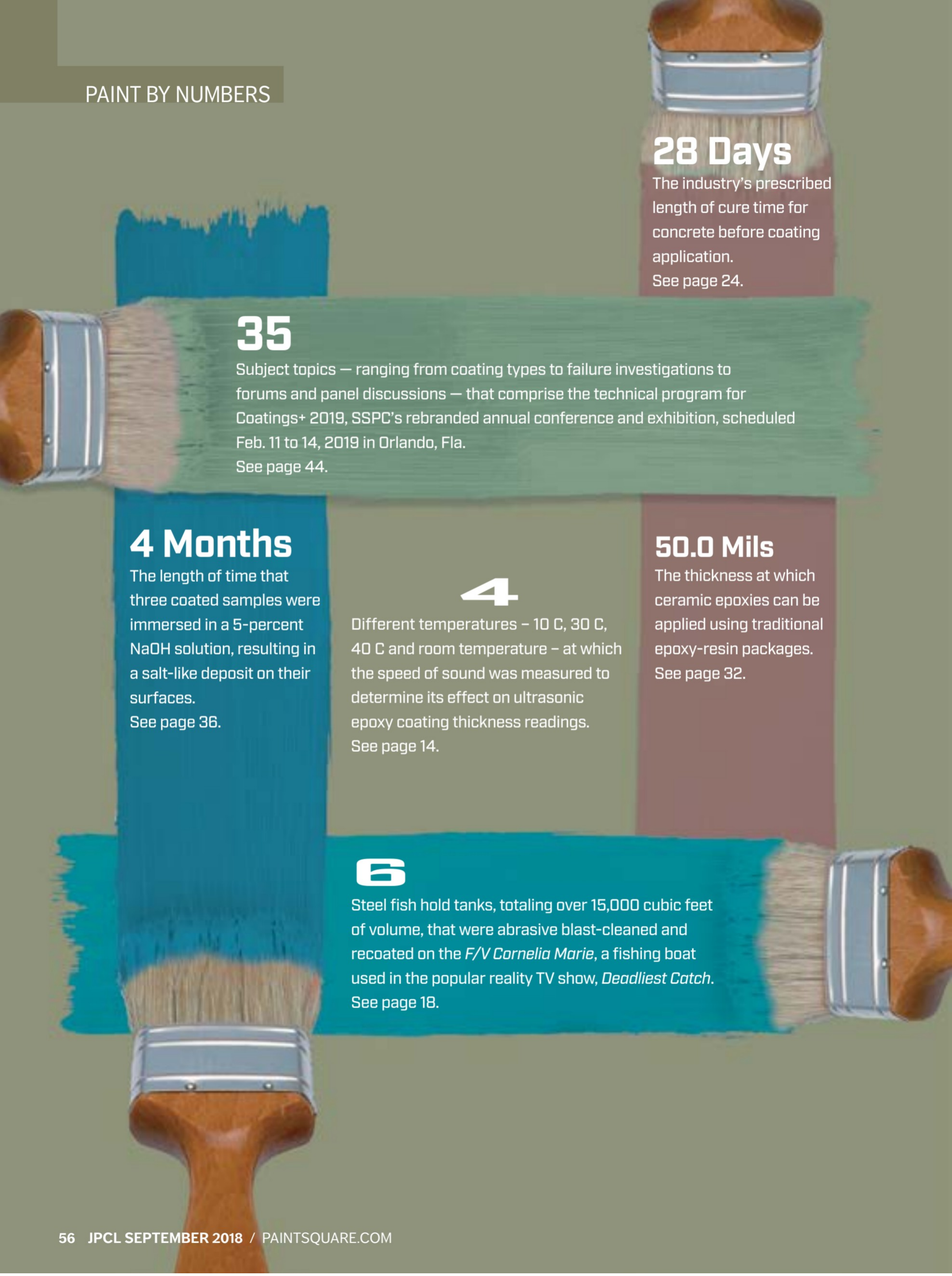
- "Waterjetting: Fundamentals and the Benefits of Environmentally Friendly Surface Preparation," by Juan Caballero, NIS SA, Panama.
- "Certified Contractors for Mexico's New Airport: A Step Change Technology Approach," by Jose Valdes, Altamira & CIA S.C., Mexico.

Session 2: Asia Pacific Session

- "The Mill Certificate for Polymeric Paints," by Melissa Chin Han Chan, Institute of Materials, Malaysia.

Session 3: EIS

- "Comparison of Field Impedance Measurements to Laboratory Data," by Bobbi Jo Merten, U.S. Bureau of Reclamation.
- "Identifying the Performance of Epoxy Mastic Coating with Non-Ideal Surface Preparation by EIS," by Md Ahsan Sabbir, Florida International University.
- "EIS Study on the Behavior of High Performance Topcoats over Metal Substrates," by Donald Lawson III, AGC Chemical Americas, Inc.



28 Days

The industry's prescribed length of cure time for concrete before coating application.
See page 24.

35

Subject topics — ranging from coating types to failure investigations to forums and panel discussions — that comprise the technical program for Coatings+ 2019, SSPC's rebranded annual conference and exhibition, scheduled Feb. 11 to 14, 2019 in Orlando, Fla.
See page 44.

4 Months

The length of time that three coated samples were immersed in a 5-percent NaOH solution, resulting in a salt-like deposit on their surfaces.
See page 36.

4

Different temperatures – 10 C, 30 C, 40 C and room temperature – at which the speed of sound was measured to determine its effect on ultrasonic epoxy coating thickness readings.
See page 14.

50.0 Mils

The thickness at which ceramic epoxies can be applied using traditional epoxy-resin packages.
See page 32.

6

Steel fish hold tanks, totaling over 15,000 cubic feet of volume, that were abrasive blast-cleaned and recoated on the *F/V Cornelia Marie*, a fishing boat used in the popular reality TV show, *Deadliest Catch*.
See page 18.