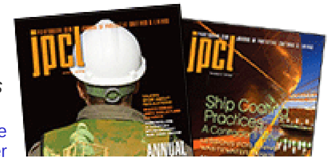


From poetry to painting

From *JPCL*, May 2012 | Free Product Information

Karen Kapsanis JPCL

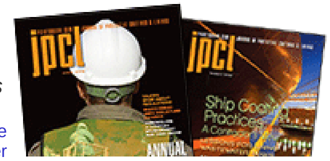
Like many editors, I majored in English and later taught it for a few years. Poetry courses were my favorites. When I was taking a class about teaching English, one phrase used frequently was 'building bridges' to help students connect with the literature. A common enough metaphor, 'building bridges' in the classroom wasn't hard to understand: teaching literature is a way of getting students from one place to another, from seeing a page of words to seeing beauty in the use of language.

Little did I suspect, back then, that I would find myself in a new career as editor of a journal about bridges, among other structures, and their maintenance. And little did I suspect that once I began to learn about bridge maintenance, I would not be able to cross a bridge or pass under one without wondering about its coating work, its condition, its structural integrity, its design, and its complexity. Most surprisingly, little did I suspect that I would find myself looking at a well-built, well-maintained bridge as a work of art.

We have articles this month about two bridges that are a testament to their function as well as to their aesthetic appeal: The Vincent Thomas Bridge in California and the Sydney Harbour Bridge in Australia. They, like all bridges, allow us to expand our boundaries to reach our jobs, our homes, our friends' homes, and many other destinations.

The Vincent Thomas and the Sydney Harbour Bridges are also among the many remarkable bridges of the world. Their maintenance and their preservation are critical not only to safe travel but also to their aesthetic appeal. And everything they provide-beauty as well as safe passage-can enrich our lives.

So, little did I suspect, when I moved from literature to the maintenance coating universe, that I would find safe passage to another kind of art.



The Buzz

From *JPCL*, May 2012 | Free Product Information

Anita Socci JPCL
What can be done to attract more young people to the coatings industry?

Pay better, promote more 40%

Subsidize training 18%

Make the industry more tech-savvy 16%

Recruit more aggressively 15%

Other 11%

Joseph Schinner: “Better pay would be nice and help once someone gets to ‘paint’; and many companies do subsidize their employees’ education. Chemists, Chem. Engineers, etc. don’t know about paint and corrosion control except incidentally, so more aggressive and creative recruiting would be more helpful to put paint on the map so some younger people could develop the ‘vision’ to get into paint at least somewhat like those who have the vision for law school, the medical field, acting, school teaching, etc. If you’re like me, you can’t even count each finger on your hands with names of schools with a paint-related program out of the thousands in the country.”

Michael Beitzel: “Coatings, corrosion control and other stuctural preservation techniques should be included as separate course material for Civil Engineering Students.”

It takes OSHA an average of about eight years to issue a rule, and some rules have taken more than 17 years. The General Accountability Office says this slow process leaves workers at risk. What do you think?

OSHA issues rules too slowly. 76%

OSHA’s pace of rule-making is about right. 21%

OSHA issues rules too quickly 3%

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Painters Spot Crack that Closes Bridge
Shoddy ‘Big Dig’ Paint to Cost $54M
Navy Trims Ship Painting Protocols
Navy Stealth Ship Sails into Oblivion
Body of MO Bridge Worker Recovered

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(As of May 11)

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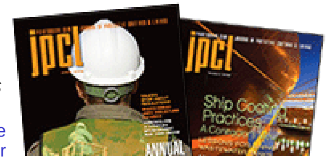


Top of the News

From *JPCL*, May 2012 | Free Product Information

The SSPC/*JPCL* Webinar Series, Education and Training in Protective Coatings, will include two one-hour sessions in the coming weeks on selecting abrasives and understanding the state of the technology of intumescent coatings.

SSPC is an accredited training provider for the Florida Board of Professional Engineers (FBPE). PEs in Florida can submit SSPC Webinar Exam CEUs. If interested in submitting webinar exam CEUs to the FBPE, you must download the FBPE CEU form and successfully pass the exam.

Participation in the webinars is free, but for those who wish to receive continuing education credits from SSPC, a test is available after each webinar for $25. You can register for the test through the SSPC Marketplace.

SSPC/JPCL Education Series Webinars provide continuing education for SSPC re-certifications as well as technology updates on important topics. Visit paintsquare.com/education for more information.

Intumescent Coatings

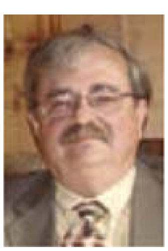
The webinar, "Intumescent Coatings: The State of the Technology," will be given on May 31, from 11:00 a.m. to noon, EST, by Sean Younger of Carboline Company.

This webinar is designed to give the attendee a greater understanding of how intumescent coatings work, types of intumescent coatings, intumescent application considerations, where to specify and use intumescent coatings, cost considerations, application highlights, and the overall benefits of fireproofing steel.

The Carboline Company is the sponsor of the webinar.

Selecting Abrasive

The webinar, "Selecting the Right Abrasive," will be given on June 13, from 11:00 a.m. to noon, EST, by Earl Bowry of Newport News Shipbuilding.



The wide variation in abrasive types, blasting processes, and operator proficiency result in huge fluctuations in the efficiency and cost of abrasive blasting operations. Therefore, significant cost reductions and productivity improvements are possible with proper selection and use of abrasives. This webinar will describe how to estimate abrasive productivity, consumption rates, and costs for specific blasting activities when specifying the type of abrasive to be used for surface preparation of a steel structure.

The webinar is sponsored by GMA Garnet.

Marco Buys BGRS

Marco has announced the acquisition of the assets of BGRS Inc.'s inventory of rental equipment.

The acquired assets include portable dust collectors, ranging from 2,500 to 45,000 CFM; portable vacuums; and blast grit recycler classifiers.

All equipment has been moved to Marco's Deer Park, TX, and Davenport, IA, locations.

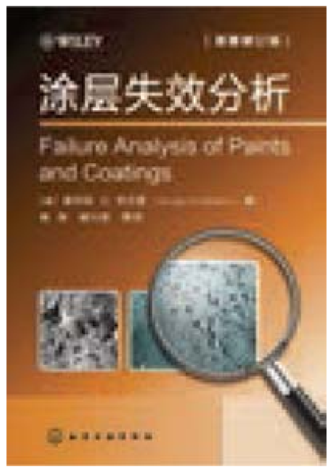
Marco provides blasting, painting, rental, and safety equipment; abrasives; engineered systems; and service and repair.

Deadline Approaching for SSPC 2013 Abstracts

The deadline to submit abstracts for SSPC 2013 featuring GreenCOAT is May 29, 2012. The conference and exhibition will be held in San Antonio, TX, on January 14–17, 2013.

Abstracts can be submitted to Christine Estvanik at estvanik@sspc.org.

Book on Failure Analysis Now in Chinese



The revised edition of "Failure Analysis of Paints and Coatings," by Dwight Weldon, has recently been translated into Chinese. The book, which has had sales in several countries, contains an introduction into paint chemistry, as well as extensive coverage of field and laboratory techniques for conducting failure analysis.

Weldon is the president of Weldon Laboratories, Inc. and has over 30 years of experience in the coatings industry. He is active in SSPC, ASTM, and the Pittsburgh Society for Coatings Technology. He is a certified SSPC Protective Coatings Specialist (PCS) and a contributing editor for *JPCL*.

The English version of the book is available through SSPC, as well as the publisher, John Wiley & Sons.

OSHA Issues Defective Respirator Alert

Federal safety officials have alerted employers and workers to a "critical defect" in a commercial respirator used in chemical and wastewater plants, tunneling, confined spaces, and other life-threatening applications.

Some of the CSE Corporation's SR-100 Self-Contained Self-Rescuers (SCSR) "have a critical defect that may cause the release of insufficient oxygen during start-up, a defect that could immediately result in a life-threatening situation for workers using the respirator," the Occupational Safety and Health Administration said in an alert issued on April 26, 2012.

Employers must remove the equipment from service no later than May 31, 2012, in accordance with the National Institute of Occupational Safety and Health (NIOSH) Respirator User Notice "Loss of StartUp Oxygen in CSE SR-100 Self-Contained Self-Rescuers."

The notice determined that the units had an unacceptable defect rate and no longer conformed to the minimum requirements for certification under 42 CFR Part 84. NIOSH stated that the agency had uncovered the defect during a routine inspection of the equipment as used in coal mines. Two units lacked sufficient startup oxygen; the manufacturer then discovered lack of start-up oxygen in one unit in production. NIOSH and the Mine Safety and Health Administration then conducted a test of 500 units, out of which five units were found to be defective, which is above the threshold set by the American Society for Quality.

More on this story can be found on *PaintSquare News*, at www.paintsquare.com.

Updates on ASTM Standards

ASTM International has issued a new copy of "D7091— Standard Practice for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to Ferrous Metals and Nonmagnetic, Nonconductive Coatings Applied to Non-Ferrous Metals."

The standard, developed by subcommittee D01.23, describes three operational steps necessary to ensure accurate coating thickness measurement calibration, verification, and adjustment of coating thickness measuring gages, as well as proper methods for obtaining coating thickness measurements on both ferrous and non-ferrous metal substrates.

ASTM has also updated the standard “D1212— Standard Test Methods for Measurement of Wet Film Thickness of Organic Coatings.” The standard covers two test methods used to determine the wet film thickness of organic coatings such as paint, varnish, and lacquer. To purchase and download the updated standard, visit www.paintsquare.com/standards.

ASTM has proposed a new standard that will detail a multilevel approach for performing above-and below-ground inspection of transmission poles and lattice towers in the field. ASTM WK35986, “Test Method for Field Inspection of Transmission Poles and Lattice Towers,” will be used by utilities to provide tools for maintenance departments that inspect and repair transmission structures.

The standard is being developed by subcommittee G01.10 on Corrosion in Soils, part of committee G01 on Corrosion of Metals. Representatives from utilities and utility contractors that are involved with transmission or distribution service life evaluation are welcome to join in the development of WK35986. The technical contact for the committee is Thomas J. Langill, American Galvanizers Association, tlangill@galvanizeit.org or 720-554-0900, ext. 14.

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The case of…October showers bring November rust spots

From *JPCL*, May 2012 | Free Product Information

More items for **Quality Control**

Jayson L. Helsel P.E.
Senior Coatings Consultant, KTA-Tator, Inc.
Jayson Helsel, P.E., a senior coatings consultant with KTA-Tator, Inc., manages failure investigations and coatings projects and is involved with coatings surveys and inspection of industrial structures.
He holds an MS in chemical engineering from the University of Michigan, is a registered professional engineer, and is a NACE-Certified Coatings Inspector. He has been published in the past in JPCL and in the Journal of Architectural Coatings, which featured his monthly column, "Getting It Right."

Richard Burgess
Series Editor, KTA-Tator, Inc.

In this month's *Cases from the F-Files*, rust spots became evident on the interior roof deck of a newly constructed, unoccupied warehouse. Were the rust spots a result of what was going on inside or outside of the warehouse?

Background of the Project

As a large warehouse building in the north-east U.S. that was being constructed for an automotive supplier was nearing completion, a problem was observed on the interior roof deck and the steel support structure for the roof deck. The roof structure was comprised of steel deck and associated steel joists supported by steel beams and columns. Various steel/iron piping was suspended from the roof. The large building was open from the floor to the roof except for a second-level mezzanine along one side of the building. The steel was specified to be shop-primed as follows:

- Roof deck: polyester primer, dry film thickness (DFT) of 0.20 to 0.30 mils
- Joists: alkyd dip primer, DFT of 0.8 to 1.2 mils
- Piping: no primer specified (reported to have a lacquer coating)

After erection, the roof structure was finish coated with a waterborne interior dry fall coating. Product information stated that the coating featured "good adhesion and resistance to flash rusting when applied to most types of interior ceilings and overhead surfaces in commercial and industrial buildings." The recommended DFT was 1.5 to 2 mils. Painting of the roof started at the south end of the building and progressed to the north.

Application of the coating to the roof structure began in late summer and continued into November. The polyester primer was shop-applied. In early November, following a reported period of heavy rain in late October, rust spots were observed on the roof deck (Fig. 1). The building had not been conditioned through at least October, and there was no control of conditions until the building's HVAC system was eventually in operation. The interior environment was reported to be humid following the wet period. An independent investigation into the cause of the rust spotting was requested.

Fig. 1: Typical corrosion/rusting along edge of corrugated roof deck. All figures are courtesy of KTA-Tator.

The Site Investigation

The roof deck structure was accessed in various locations throughout the facility. At each location, visual observations, adhesion evaluations, and coating thickness measurements were made. The finish coat applied to the roof deck and structure was white throughout the building.

Visual Examination

Although some rusting of the roof deck could be observed from the floor of the building, the extent of the problem was not obvious until the roof structure was examined from a close distance. Small rust spots were observed scattered over the roof deck in most locations. The rust spots typically had formed along the overlapping angled edges of adjacent deck pieces. When the finish coating was scraped from the deck at rust spots, little corrosion of the steel deck was found, but dark, black spots were evident, indicating the source of the corrosion (Fig. 2).

Rust spots were present on the roof deck to some degree in all locations examined, although the rusting was generally more prevalent toward the south end of the building. The white finish coat on the deck was typically glossy and uniform in coverage; however, some limited areas of incomplete coverage were found toward the north end of the roof. At these locations, gray deck primer could be seen beneath the white finish coat. Consistent with the north/south pattern described above, less rusting was present where the finish coat did not achieve complete coverage. Although painting the roof structure in the facility had been completed, the finish coat had not been applied on some locations along the west side because of limited access to these areas. The gray primer of the roof deck was examined in two such locations and appeared to be in relatively good condition. But when small darker spots were examined under magnification, it was obvious that some small rust spots were present in limited access areas where the finish coat had not been applied.

In addition to the north/south differences in the degree of rust spots observed on the roof deck, a lesser amount of rusting was observed on the mezzanine levels of the building along the eastern side. The lower roof deck, underneath the mezzanine deck, in particular, displayed less (but some) rust spots (Fig. 3). The main roof deck, or the upper level roof at the mezzanine, had some of the typical rust spot formation, but less overall than for the roof over the open portion of the building. Again, rust spots were most often present along the angled edges of overlapping deck pieces at the upper level of the mezzanine.

Fig. 2: Rusting on roof deck where coating was removed showing corrosion (black color) in the steel.

Fig. 3: Area of lesser corrosion on the roof deck.

Adhesion and Thickness

The adhesion of the finish coat, as assessed by the tape test method (ASTM D3359, Method A), was good (ratings of 4A or 5A) in all locations evaluated. The total thickness of the coating system was measured non-destructively using an electronic gage. The measurements were relatively consistent and showed a greater thickness on piping and roof structure components as compared to the roof deck. The total coating thickness for the roof deck ranged from 3 to 5 mils, with the thickness on the joist structure considerably higher at 5 to 15 mils (noting that the total thickness measurements included any existing primer layer on the component). The primer thickness of the roof deck was measured at 0.3 to 0.5 mils in the locations where the finish coat had not been applied. Representative samples were collected throughout the facility for laboratory analysis.

Laboratory Investigation

Laboratory analysis included visual and microscopic examination and infrared spectroscopic analysis of the roof deck primer. The results of the microscopy supported the field observations and described corrosion on the backside of coating samples removed from areas where rust spots were present on the roof deck and piping. The infrared spectroscopic analysis identified the roof deck primer as a polyester coating consistent with the product information for this primer. The finish coat thickness was in general accordance with the manufacturer's product recommendations and was typically greater than the recommended 2 mils. The primer thickness was thin but consistent with the specified range.

Pulling the Site and Laboratory Investigation Together

In reviewing all of the details related to work at the job site, the reported period of wet weather appeared to be a significant event. In fact, when records for a nearby weather station were reviewed, it was discovered that two significant rain events had occurred. The records showed a period of heavy rainfall (0.84 inches) in early October, including nearly a three-day period where the dew point temperature remained at or near the ambient air temperature (Fig. 4). Because the interior of the building was not conditioned, it was assumed that the interior temperatures were similar (or worse) than the exterior condition. A similar period of heavy rain also occurred in late October, with 0.75 inches of rain falling and another extended period where the dew point temperature remained very close to the ambient air temperature (Fig. 5). Rust spots on the roof structure were reported shortly after the late October wet period, but likely began to form after the earlier period of rainfall.

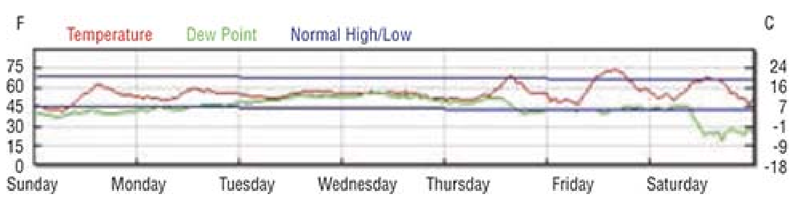

Fig. 4: Early October weather data

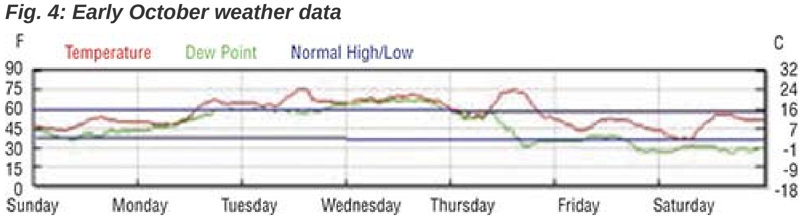

Fig. 5: Late October weather data

The investigation revealed that the formation of rust spots over the roof deck was caused by three factors:

- The use of a thin primer on the roof deck without substantial corrosion resistance properties
- The introduction of moisture inside the building from October rain events
- The use of a water-based acrylic finish coat in conjunction with the thin deck primer and moisture in the building

The polyester deck primer did not provide much corrosion resistance to the steel deck. The thin layer could not prevent corrosion of the steel deck after moisture was introduced in the building interior. Further, the use of the water-based acrylic finish coat could not prevent the formation of rust spots, given the thin roof deck primer and introduction of moisture in the building. Although the product information for the finish coat stated that the coating was resistant to flash rusting, water-based acrylic coatings generally do not provide optimal corrosion resistance. Lack of corrosion resistance allowed rust to come through the finish coat (Fig. 6). Significant moisture trapped in an interior environment can eventually permeate the coating to reach the steel substrate and initiate corrosion. Once this occurs, the coating film tends to hold the moisture, allowing corrosion to continue until corrosion and corrosion staining from the steel migrates through the coating, forming rust spots.

Fig. 6: Typical corrosion/rusting along edge of corrugated roof deck.

The degree of corrosion was not expected to worsen if the interior environment remained dry and environmentally controlled. The recommended coating repair was a new coat of the alkyd repair coating applied to the roof deck to sufficiently seal the surface and prevent any continued formation of rust spots. Since the building interior was conditioned at this point, extra control of the interior conditions was not specifically recommended.

Conclusion

The beginning of this article asked, “Were the rust spots a result of what was going on inside or outside of the warehouse?” The answer is both. Since the inside of the building was not conditioned, what happened outside—the significant rain and a dew point temperature that remained close to the ambient air temperature—affected the conditions inside, therefore causing a coating failure.

Tagged categories: **Coating failure**; **Roof coatings**; **Rust**; **Steel**

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Laboratory Investigations into the Edge Corrosion Protection Capacity of Organic Coatings

From *JPCL*, May 2012 | Free Product Information

More items for **Quality Control**

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Edge profiles in maritime steel constructions
From left: tank deck; offshore construction; cargo hold roof All photographs and drawings are courtesy of IFAM, Bremen; and Muehlhan AG, Hamburg.

The morphology and geometry of free edges on steel structures have a notable influence on the corrosion protection performance of coating systems. There is general agreement in the surface protection industry that a badly prepared edge, whether thermally or mechanically generated, will be a starting point for coating deterioration and subsequent steel corrosion.

There are three basic strategies available to improve the corrosion protection performance of organic coatings over edges: edge preparation, stripe coating, and edge retentive coatings.

The third approach is a material issue, while the other two are process issues. The second approach belongs to the painting process, whereas edge preparation is situated between primary and secondary surface preparation of the steel, and was the subject of a nationally funded, threeyear R&D project.

An initial report on the project on how edge geometry and coating type affect the corrosion protection performance of organic coatings on edges, with particular attention to ballast seawater tank applications, was presented at the PACE 10 Conference.[1] The report covered a discussion of the testing scenarios, an introduction to three assessment methods, and the initial results. The research program involved the use of different edge preparation tools and of different coating systems. The project focus, however, was on the use of thermal cutting tools, because these are an integral part of construction lines in modern shipbuilding yards. One aspect of the project was to investigate the applicability of these tools not only for cutting, but also for edge rounding.

Testing methods included the long-term testing of samples in a specially designed ballast tank coating test chamber (as per the IMO wave tank quoted in the PSPC), condensation chamber tests (ISO 6270-1), electric impedance spectroscopy (EIS), and dry film thickness (DFT) measurements on polished cross-sections of coated edges. The conclusions from this initial study were that edge preparation tool, edge geometry (radius), and paint system all had notable effects on the corrosion protection performance of the coating systems in condensation tests and the IMO test chamber. Also, the assessment methods used in the study allowed for a differentiation between the above-mentioned variables. Correlations between edge coverage and macro-geometry (edge radius) and the results obtained from corrosion protection tests (condensation and IMO testing, EIS) were observed.

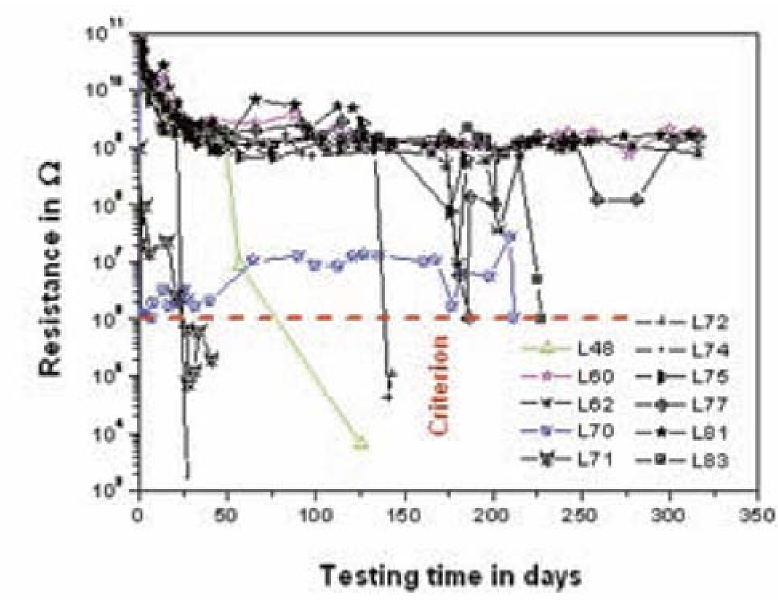

Fig. 1: Sudden drop in the resistance of edge coating systems during the EIS investigations (edge treatment method: solid-state laser)

The present article describes the results of the second part of this investigation project. The edge treatment methods/tools considered in this study included mechanical (milling, grinding) and thermal methods (laser, plasma) and are described in Reference 2.

Working Hypotheses

Based on the results of the initial systematic studies of effects on the edge protection performance of organic coatings and a statistical interpretation of the results, the following four hypotheses were postulated and investigated in a further series of tests.

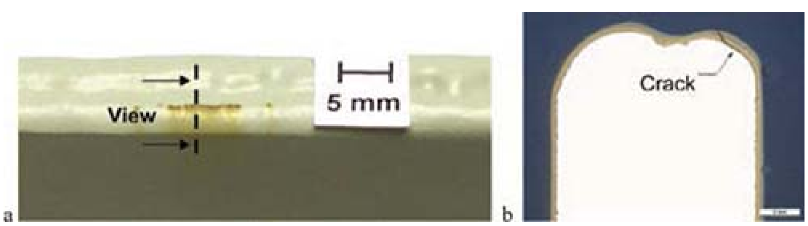

Fig. 2: Sample with cracked edge coating a - General view; b - Polished cross section

i. There is no definite, statistically proven effect of the edge radius on the DFT over edges.

ii. Edge preparation method/tool and coating system have definite effects on the DFT over edges.

iii. The effect of deviations due to coating application can be in the same order of magnitude as effects due to edge treatment and edge geometry.

iv. A ranking of the edge treatment methods depends on the state of tool development.

Results

Introduction of Deterioration of Edge Protection Coatings

The response of undamaged edge coating systems to early corrosive stress was simulated experimentally through electrochemical impedance spectroscopy (EIS). The experimental set-up is described in reference 1. The criterion for the assessment of the system performance was the time that went by until the electric resistance of a coating dropped to a value of $10^6\Omega$(considered poor performance). This procedure is illustrated in Fig. 1. It can be seen that the failure of the coating systems occurred rather suddenly and was not due to a gradual controlled decrease in the resistance.

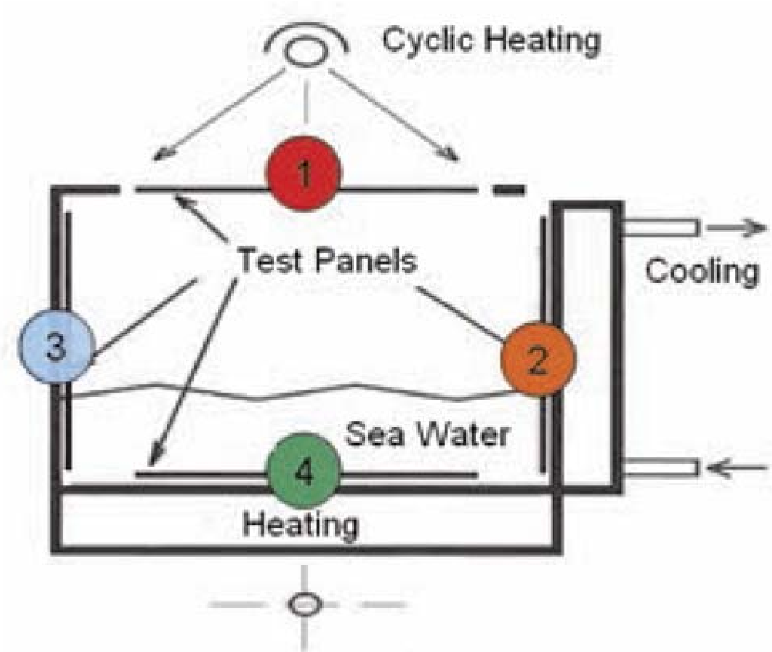

Fig. 3: Corrosive loading regimes (drawing modified from IMO, London). See Table 1 for detailed description

Closer examination of the failed samples indicated that the coatings cracked at particular edge locations. These locations were not identical to the locations with lowest DFT, as can be seen in Fig. 2. It is, from this point of view, questionable to define a particular DFT as a sole guarantee for a good edge protection performance of coating systems in water ballast tanks. It rather seems to be the response of coating systems to stresses generated due to thermal, physical, or aqueous stresses. This preliminary result would support the approach to develop reinforced organic coating systems for this application.[3,4]

Edge Protection Coating Deterioration—Local Corrosivity

As can be seen in Fig. 3, the corrosive stress on the samples in the IMO wave chamber will depend upon the exact location of the samples. Results of anti-corrosion effect (AE)-assessments (see reference 1 for how to assess AE) are given in Fig. 4.

The results are also summarized in Table 1 in terms of arithmetic mean and standard deviation of the anticorrosive effect numbers shown in Fig. 5 for the individual zones.

The average edge corrosion protection performance of the coatings was lowest in the cyclically immersed zone #4, followed by the thermally and cyclically loaded zones #1 and #2. The best performance was noted for the cyclically splashed zone #3. This zone also showed the least standard deviation among all four chamber locations. This result looks surprising because experience from offshore structures has shown that the corrosivity in terms of mass loss on steel due to corrosion is most severe in the splash zone of the structures.[5]

However, two notable differences should be considered. First, in the present study, coating deterioration—not steel corrosion—was evaluated. Second, the immersion was performed cyclically in the present study, and thermal effects were added in the other two zones. Worthy of note is the high standard deviation in the very corrosive zone #1. In this zone, performance was very sensitive to the effect of edge preparation and coating application, while changes in treatment and paint material were much less influential in zone #3. Regarding the treatment method, it can be shown that the effect on the coating performance also depended on the position in the test tank. The use of a plasma beam for generating a 1-mm edge, for example, led to very good corrosion protection performance of the "Edge" coating in zone #2, whereas the plasma-treated samples did not perform very well in zone #1.

The same finding can be applied to edge radius effects. The 1-mm edge, covered with a conventional water ballast tank coating, did not provide good corrosion protection in zone #4 but gave good results in zone #1, confirming that position in the test chamber, i.e., corrosivity of the environment, was the governing factor.

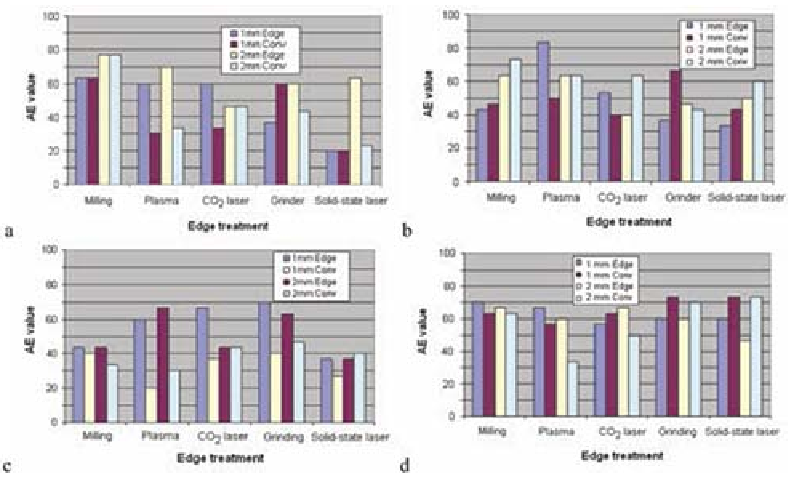

Fig. 4: Results of the AE assessment procedure (circled numbers correspond to Fig. 1).
a = ① ; b = ② ; c = ④ ; d = ③ ;
"Conv" = standard BWT coating system; "Edge" = edge retentive coating system

TABLE 1
Corrosive Loading Regimes

Situation / (zone 1)	Loading regime	Arithmetic mean AE	Standard deviation AE
①	Heated for 12 hrs to 50°C Cooled down for 12 hrs to 20°C Cyclically splashed	49	18
②	Temperature gradient of 20°C Splashed	52	13
③	Cyclically splashed	61	9
④	Cyclically immersed	45	14

Discussion

The specific hypotheses raised at the start of the project are discussed below in light of the testing carried out.

Hypothesis (i)

The effect of the different edge radii (1 mm, 2 mm), either on the DFT or on the parameter EC (edge coverage), was not statistically significant. A major reason was that the measurement of only one DFT value over the edge could not represent the entire edge geometry. Values for DFT varied notably in either direction of the edge. Examples are shown in Fig. 2, where DFT values over an edge length of 10 cm are presented. Edge radius may be considered a local geometry parameter, and it does not characterize the real situation at the edge. The definition of a global edge radius criterion cannot guarantee a definite DFT.

Cracks and coating failures do not necessarily originate at locations with low DFT. This is verified in Fig. 2. Cracks are a result of unfavorable internal stress conditions. Swelling due to water absorption may be one reason. If the crack, or the local failure, develops, the coating starts to deteriorate, and substrate corrosion is introduced.

Hypothesis (ii)

Edge preparation method and coating system both had statistically significant effects on the DFT over edges. Therefore, for a given coating system, DFT is more dependent on edge treatment method and not on edge radius. Edge radius effects were not relevant; the statistical significances were very weak. Further, for a given edge radius, the coating system would determine DFT. However, DFT is not the target parameter, but corrosion protection performance is the target parameter. A definite unique relationship between DFT and corrosion protection performance could not be established.

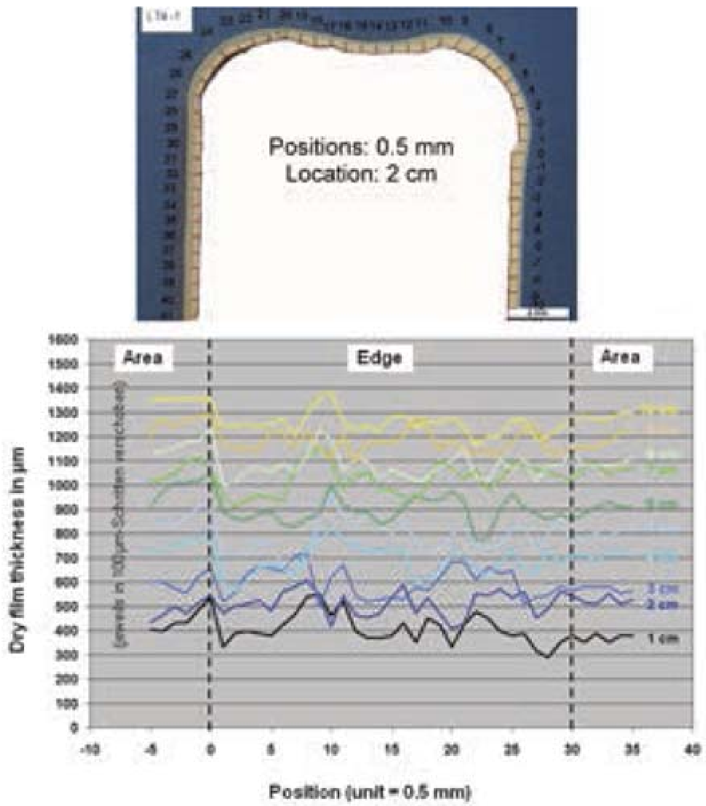

Fig. 5: Results of DFT measurements along edges (on polished cross sections) Upper image: cross section (2 cm) with measurement positions; lower graph: Results

Hypothesis (iii)

Numerous features of the coating application process, such as temperature, stripe coat application, brush condition, spraying process, and paint condition, affect the process and lead to variations. Surface preparation parameters, for example, cleanliness and local roughness, will also affect both DFT and corrosion protection performance of the coating systems. Because the statistical effects of the parameters varied in this study were not in general significant, it can be assumed that strong effects due to surface preparation and coating application parameters mask the influence of other effects. This particular statement, however, needs to be statistically verified.

Hypothesis (iv)

In terms of project time, three test cycles were carried out. The samples for the first test cycle were prepared with thermal tools that were not optimized for edge rounding processes. The samples for the third test cycle, however, were prepared with optimized thermal tools. The project partners responsible for the development improved the performance of these tools. Results of the corrosion protection performance tests, based on the IMO wave tank tests, are presented in Table 2. It can be seen that CO_2 laser profiling was among the worst performing methods for the first test cycle, but, after optimization, became the best performing edge treatment method for the last test cycle. These results clearly show that individual process parameters of the edge treatment methods have notable effects on the corrosion protection performance of organic coating systems applied to edges.

TABLE 2
Results of IMO Wave Tank Tests (Ranking Based on AE Assessment)

Cycle	First	Third
Ranking (Best to	1. Plasma Milling 2. Untreated	1. CO_2 laser 2. Plasma 3-pass grinding Milling

worst)	3. CO_2 laser Solid-state laser Grinding	Solid-state laser 3. Untreated

Summary

The prescription of a particular edge geometry parameter does not help to control the corrosion protection performance of organic coatings under simulated water ballast tank conditions. Other effects—edge treatment method/tool and coating application—are more important. It seems that DFT, or barrier resistance, is not a suitable parameter to control the deterioration of the coating systems, nor does it control their corrosion protection capability. More complex processes, such as combined mechanical, physical, and thermal loads, are responsible for the corrosion protection action of the systems.

Acknowledgements

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Editor's Note: This article, by Dr. Andreas Momber and his strong team of co-authors, is part of the series of Top Thinker articles appearing in *JPCL* throughout 2012. Dr. Momber is one of 24 recipients of *JPCL*'s 2012 Top Thinkers: The Clive Hare Honors, given for significant contributions to the protective coatings industry over the past decade. The award is named for Clive Hare, a 20-year contributor to *JPCL* who shared his encyclopedic knowledge of coatings in many forums. Professional profiles of all of the award winners, as well as an article by Clive Hare, will appear in a special 13th issue of *JPCL*, to be published in August 2012.

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Tagged categories: **Ballast tanks**; **Coating selection**; **Corrosion protection**; **Edge Preparation**; **Edge-retentive**; **Edge-retentive Primers**; **Organic Coatings**; **Steel**

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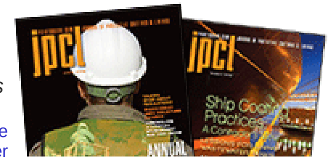

Relining Potable Water Tanks: Research and Field Work

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R. A. Francis Ph.D., Aurecon
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Melbourne Water supplies drinking water to the residents of Australia's second largest city through three retail water companies. The steel floor plates of a number of Melbourne Water's potable water tanks have suffered severe corrosion and perforation because of chloride salts in the limestone bedding material.[1] One method of remediation is to apply a reinforced organic lining to the steel base. Candidate lining and reinforcement types were investigated and are described in this article. A review of repair options concluded that installation of a reinforced epoxy lining, which provides mechanical strength in addition to corrosion protection, was the optimum solution. This article looks at the issues involved in selecting a lining that provides the required strength and flexibility as well as resistance to and compatibility with potable water, including a discussion of candidate glass reinforcement materials. Also described are practical issues involved in applying the lining in 2005 and the results of a recent inspection.

Photos courtesy of the authors

TANK FLOOR PLATES PROBLEMS AND SOLUTIONS

Tank Construction

Above ground storage tanks (ASTs) used for containing potable water are not very different from tanks for oil and petroleum products, petrochemicals, and chemicals. The design and construction of all types is much the same, although the petroleum industry may use more complicated designs, such as floating roofs and insulated tanks, which are not used in the water industry. The bottom of an AST consists of two separate areas. The central portion or bottom plate is essentially a membrane because it is supported by the foundation. The annular ring forms the perimeter of the tank bottom, supports the tank shell, and extends beyond the bottom-to-shell joint. Annular plates are thicker than bottom plates, often 13 mm (½ in.) or more, compared to a minimum of 6.5 mm (¼ in.) for the bottom plate. The shell/bottom plate juncture is commonly supported by a reinforced concrete ring wall. The tank bottom is often sloped to facilitate drainage. Support legs connected to the bottom of the tank support the roof. The tank bottom may be subject to corrosion from the soil side and from within the tank.

Corrosion of Tank Bottoms

Fresh water corrodes the internal steel base in the long term at a relatively low rate. Linings such as vinyl coatings, along with cathodic protection, have been applied to limit internal corrosion of the steel tank bottom and have been a cost-effective way of preventing leaks and extending the service life for many years. Unlike oil storage tanks, internal corrosion has generally not been a major problem in potable water ASTs.

In potable water tanks, however, soil-side corrosion of the tank bottom is a far more serious problem. Corrosive paddings, salt water, wooden surveyor pegs, stray current or other causes can result in external corrosion. On existing tanks, such soil-side corrosion cannot be mitigated by application of coatings or linings, and cathodic protection is usually required. However, this is rarely 100% effective over the entire area, and pitting corrosion from external causes often is a limiting factor in determining the life of tank bottoms with less corrosive products such as potable water.

Melbourne Water has traditionally mounted its above ground storage tanks on a crushed limestone base. Rapid and widespread corrosion of some tank bottoms has arisen with considerable metal loss because the limestone bed had been contaminated with chlorides. Despite the tanks' being well-drained, corrosion is attributed to large concentrations of highly hygroscopic calcium chloride contaminants, which are unevenly dispersed and vary greatly in concentration.[1]

LINING SELECTION

Selection of Tank Linings

Selection of linings for tank interiors requires consideration of a number of factors, although the following are most important for water tank linings.

- The lining must protect the steel base to prevent it from corroding.
- The lining must have additional properties, such as adhesion, similar thermal properties to the base, and resistance to cathodic dis-bonding.
- The lining must be applicable under the prevailing environmental conditions.
- The lining must be easy to repair.

In Australia, linings and any other materials that come into contact with drinking water must meet the requirements of AS 4020.[2] This standard, similar to NSF/ANSI Standard 61 used in the U.S., ensures that materials that come into contact with potable water meet requirements regarding odor, taste, appearance, ability to support the growth of aquatic micro-organisms, and the quantity of toxic metals and non-metallic substances that may be leached from the product. Linings or related components must be specified to meet such potability requirements.

Linings for tank bottoms generally cover the entire tank bottom and extend 300 to 500 mm (12 to 20 in.) up the shell of the tank. Linings should be applied in accordance with the manufacturer's recommendations for the number of coats, film thickness, recoat intervals, and curing conditions and times. Insufficient thickness will not provide adequate coverage and metal protection, while excessive thickness can lead to loss of adhesion and film integrity. Regardless of their thickness, linings cannot span existing perforations in the tank bottom. Minimum bottom thickness has to be restored in accordance with API 653[3], which requires that steel plates be welded over perforated regions. Further information on linings for tank bottoms is contained in API RP 652[4] and SSPC-PA 6/NACE No. 10.[5]

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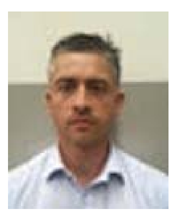

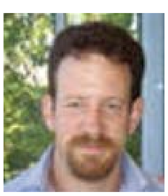

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For maximum durability of a lining, a clean, abrasive-blasted surface is required. A clean surface ensures maximum adhesion and avoids risk of osmotic blistering from soluble contamination. Because potable water tank floors have shown little if any water-side corrosion or blistering, problems with soluble salts are unlikely, and dry abrasive blasting to a class Sa 2½ (SSPC SP-10/NACE No. 2) will be adequate. A jagged profile of 50 to 100 microns (2 to 4 mils) should be specified to ensure good adhesion.

Resin Types

Reinforced polyester linings were among the first reinforced linings applied to petroleum industry tanks. Polyester resins have good resistance to acids and alkalis and dry heat, and are among the more economical resins. However, other properties such as shrinkage, alkali resistance, ease of application, etc., are poorer than alternatives, and they are rarely specified today. Reinforced vinyl ester linings have largely replaced polyester where chemical resistance is required. They have good chemical resistance and good adhesion, and they are resilient. However, as with polyester, they are difficult to apply and can shrink on curing. Baxter[6] claims that both vinyl ester and polyester pass the ASTM G8 cathodic dis-bonding test. However, the poorer adhesive strength and alkali susceptibility of some polyesters suggest that such products would be more vulnerable to cathodic protection than epoxies.

Epoxy resins have a range of chemical resistance properties. They have lower cure shrinkage than most other resins. They have better adhesion to both the substrate and any glass reinforcement and will usually produce a composite of superior strength. Other advantages include easier application, better recoatability, and lower odor, all of which result in better tolerance for application conditions. Cathodic disbondment resistance of epoxy resins is generally good.

Thick-film, spray-applied elastomeric polyurethanes and polyureas are relatively recent developments in linings that have been used for a range of environments and surfaces. They may be reinforced with an appropriate geotextile. Their elastomeric nature means that they can accommodate significant elongation, which is more important for cracking in concrete than for steel and they are mainly used for concrete. There are two main types:

- 100% solids polyurethane. Thin film, solvent-borne polyurethane coatings for decorative purposes have been widely used for many years, but for tank linings, solventless elastomeric formulations are used which have good adhesion and reasonable corrosion resistance, but limited UV resistance and are moisture sensitive during application. They have very good abrasion resistance but suffer from poor cathodic disbondment resistance.[7] Compared to epoxies, 100% solids polyurethanes are fast setting and can be quickly put into service. Against their advantages, they are more difficult to apply and repair than epoxies and require special plural component application equipment.[8]
- Polyurea is a relatively recent elastomeric technology similar to polyurethanes. Polyureas are very fast setting, within minutes, but without the moisture sensitivity of polyurethanes. They are elastic with very good abrasion resistance, are impermeable, and can produce a high film build. While the quick setting is desirable in many applications, it can make application difficult. Polyureas may not have the chemical and UV resistance of some other coatings, but this is not an issue with linings for water tanks.

Other linings, such as inorganic zinc, coal tar epoxy, or phenolic epoxy, are or have been used for specific chemicals but these are either no longer specified or not necessary for potable water applications.

Types of Tank Linings

Non-reinforced, thin-film linings (0.5 mm [20 mils] in thickness or less) are applied to new tanks or to tanks with minimal floor corrosion. They provide no protection against perforation from soil-side corrosion. Thin film linings when specified today for potable water tanks would most likely be based on epoxy resins. There are two types of non-reinforced epoxy linings—solvent-borne and solvent-free (also called solventless).

Solvent-borne epoxies have a good track record, with many years of successful experience. They are usually applied in multiple coats, which minimizes the risk of pinholes and other defects; are easy to mix and apply; and are more tolerant of a range of substrates, weather, and application problems. Problems with solvent-borne epoxies are that solvent retention can contaminate the water, the film can shrink during curing and solvent entrapment can lead to blistering. Solvent-containing coatings create volatile organic compounds (VOCs), which contribute to air pollution. The use of solvent-containing coatings is restricted in some parts of the world, and where allowed, the coatings should be specified only if they can be shown to be clearly superior to alternatives. Their principal advantages are low cost and ease of application.

Solventless epoxies are a more recent development in thin-film linings. Depending on their thickness, these may be applied over slightly pitted and other rough surfaces. Solvent-free epoxies avoid problems with solvents such as solvent retention, blistering, and pinholing, and they have environmental as well as health and safety advantages. Also, they can be applied in a single coat, reducing application costs, although the cost per liter may be higher. Against this, they are more difficult to mix and apply, and environmental conditions are more critical during curing compared to solvent-containing epoxies. Also, the chemical resistance of solventless coatings is not as good as their solvent-borne counterparts, although generally solventless epoxies will resist the less aggressive exposures such as potable water. Cathodic disbondment resistance of solvent-borne and solventless epoxies is similar, and should be acceptable with properly designed and maintained sacrificial or impressed current CP systems at ambient temperature.

Reinforced thick-film linings have DFTs usually greater than 1 mm (0.04 in.) in thickness, typically 2 to 6 mm (0.08 to ¼ in.). They are made from solventless resins (polyester, vinyl ester, or epoxy) reinforced with glass flakes, chopped glass fibers, glass mat, glass cloth or a similar material. Such systems are referred to as glass-reinforced plastic (GRP) or fiberglass-reinforced plastic (FRP) linings. Single laminate applications are most frequently used, although double laminates may be required for aggressive product-side and bottom-side corrosion. The laminates are less sensitive to pits and other surface irregularities because of their thickness and, more importantly, will provide mechanical strength and can bridge small perforations that may result from soil-side corrosion. According to API Standard 653[3], the minimum allowable remaining thickness of a steel tank bottom plate is 1.25 mm (0.05 in.) when lined with a reinforced lining, compared to a thickness of 2.5 mm (0.1 in.) if unlined or lined with a non-reinforced coating system. Reinforced linings are less susceptible to mechanical damage than thin-film linings. Reinforced thick-film linings require more time and effort to apply, and application is far more complex than for a non-reinforced lining. Protrusions such as seams and angles require puttying; edges must be feathered; layers of resin and glass must be carefully applied to prevent bubbles and provide a smooth surface; and a final gel coat must be applied to seal the surface. Also, non-destructive inspection of the steel bottom could be more difficult than through a thin-film lining.

Table 1 summarizes the properties of the main resin types discussed.

TABLE 1
Summary of Properties of Resin Types

Property	Polyester/Vinyl ester	Solvent-borne epoxy	Solventless epoxy	Elastomeric urethane/polyurea
Resistance to water	Good	Good	Good	Good
Adhesion	Moderate	Good	Good	Moderate
Abrasion resistance	Good	Good	Good	Very good
Resistance disbonding to cathodic	Poor to moderate	Moderate	Moderate	Poor
Flexibility	Low	Low	Low	Moderate-high
Cure shrinkage	High	Low	Low	Moderate
Ease of application	Moderate	Good	Moderate	Difficult
Curing	Moderate	Slow	Slow	Fast
Experience	Many years	Many years	Recent	Very recent

REINFORCEMENTS

Types of Reinforcements

Reinforcements are mainly included to increase the strength of the lining, but they have other effects such as reducing shrinkage during curing, reducing thermal expansion, and enabling high film thickness to be achieved, which lowers permeation. The reinforcement also ensures the lining has sufficient strength to meet the stresses from flexing and bending of the tank bottom, although this is not usually a problem. The resin, after mixing with the hardener, is used to saturate the glass fiber material, which forms a strong laminate of resin and glass when it has cured. The most common reinforcement is fiberglass, although other reinforcements may be used for specific chemical resistance. The following forms of fiberglass reinforcement can be used:

Glass flakes are small (up to about 3 mm [0.1 in.] in diameter) angular particles, typically 5 to 10 microns (0.2 to 0.4 mils) thick, which are applied with the resin and line up parallel to the surface after rolling, although small flakes may orient themselves without rolling. The flakes provide limited reinforcement and are usually added to enhance corrosion resistance and water vapor impermeability. Baxter[6] and Hearn[9] claim some tenfold improvement in water impermeability through the addition of glass flakes.

Chopped strand mat (CSM), non-woven glass mat or random fiber mat consists of glass fiber bundles, cut to 20 to 40 mm (0.8 to 1.6 in.) long, randomly formed into a mat, and held together with a binder that dissolves when the resin is applied. The resin is applied to the surface; then, the fiberglass mat is applied, with suitable overlap at all seams. The surface is rolled to remove air and thoroughly wet the fibers. Additional resin is applied to ensure the mat is fully saturated and no air remains. The mat comes in various thicknesses designated by grams per square meter or ounces per square foot. Such mats are pliable and readily worked into complex shapes and curves.

Chopped roving is reinforcement that has similar physical characteristics to chopped strand mat, except that the cutting and deposition are done as the resin is being applied. The feed material is a continuous length of glass roving, resembling a ball of string, consisting of hundreds of filaments of glass fiber wound together without twisting. This material is chopped into small lengths by a chopper gun, and sprayed with the resin onto the surface. The surface is then rolled to remove air and thoroughly wet the fibers. This process requires skilled and qualified applicators to ensure a proper application, and it is difficult to maintain a uniform thickness. However, a thick coating can be applied rapidly, and maintaining the correct glass to resin ratio is relatively easy. A problem with the random fiber processes is ensuring all the fibers are laying flat and fully encapsulated by the subsequent gel coat. The hand lay-up method produces a more uniform, consistent layer and requires less skill to apply than the chopped spray method.

Woven fabric is generally a box-weave fabric formed from either threads of glass (woven cloth) or from heavy roving (woven roving) and typically weighing around 200 grams or more per square meter (0.65 ounces per square foot). Woven roving has lower strength but is more economical than woven cloth and is easier to apply and wet out. Both types are applied with resin in a similar manner to the CSM. Both products provide greater strength and stiffness than the chopped strand mat, with the tighter the weave, the greater the strength. Woven fabric is more flexible and easier to saturate with resin than CSM, but is more expensive.

Properties of Reinforcements

The tensile strength and elastic modulus of a plastic material can be greatly increased by reinforcing fibers. Significant improvement in strength and stiffness requires fiber reinforcement. Figure 1 shows how stiffness and strength vary with volume fraction and arrangement of glass fibers.

The structural properties of the fiber-reinforced composite are determined by four factors.

- The relative properties of the matrix and the fibers. An epoxy resin matrix is slightly stronger than a polyester, although its modulus is about the same. Glass fiber is very strong and has greater stiffness than the resin, although significantly lower stiffness than steel and other metals. Stiffness is improved by increasing the thickness of the material, although when applied to steel as a lining, the substrate provides the bulk of the stiffness.
- The length of the individual fibers. Both stiffness and strength of CSM will generally increase with fiber length.
- The proportions of matrix and fibers. The ability to change the ratio of matrix to fibers enables changes in strength and stiffness to be achieved simply by varying their proportion, giving a range of moduli and strengths, from low for pure resin to high for pure glass. In practice, the need for workability during application imposes constraints on the permissible volume fraction.
- Geometrical arrangement of the fibers within the composite. In composites, the fibers can be arranged in one of three ways: randomly, woven (bidirectional), or unidirectional. Unidirectional reinforcement offers the greatest improvement in strength and stiffness, and allows the greatest volume fraction of fibers. However, the properties are achieved in only one direction (anisotropy of properties) and applications for unidirectional materials are limited to beams and items such as 'pultruded' ladders not relevant for tank linings. Woven reinforcement of continuous fibers permits a high volume fraction of fibers, with less anisotropy because properties are in the direction of the weave, usually at 90 degrees. Random orientation requires short fibers and has the lowest volume of fibers because they do not pack as well as woven. Improvement in properties is lowest for random orientation. In theory, it should result in isotropic properties, but in practice, flow during application results in some orientation of fibres. It is used for the cheapest jobs where high strength is not needed.

Environmental resistance of fiber-reinforced materials depends on the type of resin used, the proportion of resin to fiber, and the nearness of the fibers to the surface. Although the glass fibers are resistant to most environments (except high alkalinity), water can penetrate the lining by capillary action through fibers standing on the surface. This water weakens the resin/fiber bond. Moisture ingress is prevented by the use of gel coats on the surface. Thickness of the gel coat is important—too thick and it may craze, while a thin coat may not cover the fibers.

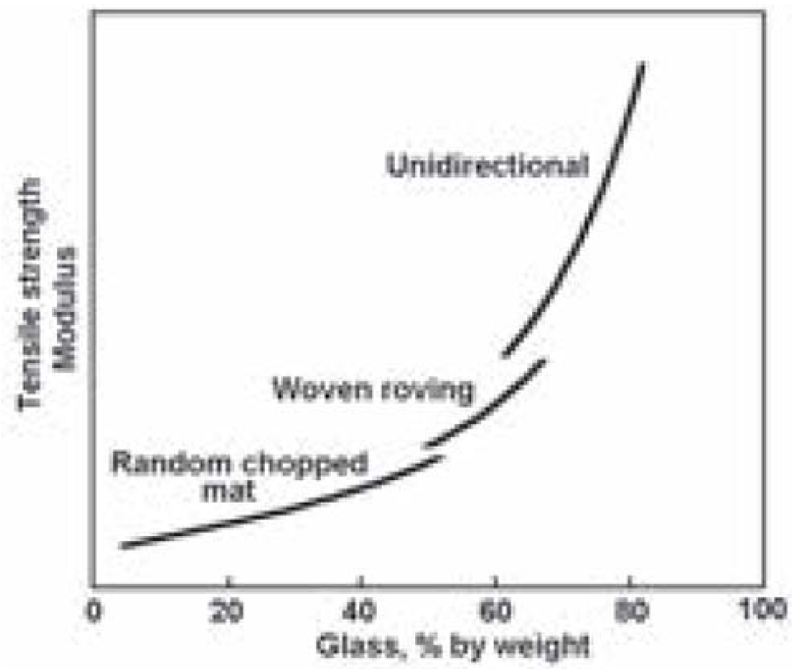

Fig. 1: Tensile strength/elastic modulus of glass fiber composites vs percentage weight of fibers

Hole Bridging Ability

Compared to non-reinforced linings, the main advantage of reinforced linings is their ability to bridge holes that may arise from soil-side corrosion. However, the size of a hole that can be bridged is not well documented. It depends on many factors including type and mechanical properties of the reinforcement (tensile strength, elastic modulus), coating thickness, and maximum load or pressure.

Lebleu[10] looked at structural properties of linings from both a theoretical and experimental viewpoint. In the first part of the work, he used stress and strain formulas to calculate the deflection and maximum loads on holes of four different sizes (13, 38, 100, and 200 mm or ½, 1½, 4, and 8 in.), using single-and double-laminate polyester systems. (The type of reinforcement is not specified, but appears to be woven fabric.) Of more practical interest were the results of a pressure test on laminates over various sized holes. Significant differences were found between calculated and actual deflections, and actual measurements were considered more valid. The experimental work was considered more severe than would occur in practice, because the drilled hole had a sharp edge that acted as a stress concentrator. However, based on the work, single laminate material can easily bridge a 100-mm (4-in.) diameter hole with a pressure of 350 kPa (50 psi), equivalent to a 35-meter (75-foot) head of water. A double laminate could bridge a 200 mm (8 in.) hole with the same pressure, although failure of the double laminate over this size hole occurred with a pressure of 450 kPa or a 45-meter head of water (65 psi or a 95-foot head).

Brown[11] also quoted hole-bridging capacities of some forms of reinforced materials in solvent-free epoxy (Fig. 2). Spray-applied chopped glass fiber can bridge a 188-mm (7½-in.) diameter hole in the floor of an 18-meter (38-foot) high tank, compared to 106-mm (4.2-in.) diameter hole for hand lay-up, non-woven glass mat, 41 mm (1.6 in.) for glass flake, and 11 mm (0.4 in.) for the unreinforced resin, all using the same solvent-free epoxy as resin. These figures were claimed to be obtained from both experimental sources and calculation. No figures were given for woven fabric, nor any explanation as to why there were significant differences between the spray-applied and hand lay-up non-woven products, even though they should have similar physical properties.

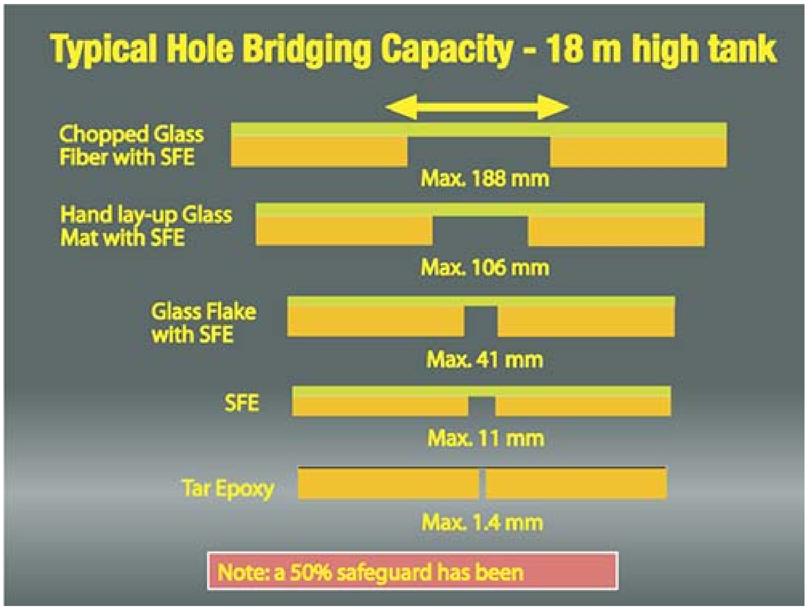

Fig. 2: Hole bridging capacity for different lining systems for an 18-meter (38-foot) high tank. (SFE: Solvent-free epoxy) [11]

SUMMARY OF SELECTION PROCESS

Although the chemical resistance of the different resin types varies, when properly applied, any of those discussed should provide good resistance to potable water. A life of 30 years or more should be achievable. Selection of the resin therefore depends on factors other than water resistance. Table 2 summarizes the important properties of candidate systems.

- The most experience in tanks linings is with polyester and vinyl ester, and experience shows they have generally performed well. They are also an economic choice. However, they are difficult to apply, have poorer adhesion, and have lower cathodic disbonding resistance.
- Unreinforced solvent-borne epoxy and solventless epoxy have many years of use and, when properly applied, have performed well. The solvent-borne product is perhaps the easiest to apply, and there is the least risk with application of this product. Solventless epoxy requires more care in application, but has safety and environmental advantages. However, neither of these provides sufficient mechanical strength if the bottom perforates.
- Thick-film polyurethanes and polyureas are a relatively recent lining and do not have the experience of the other products. Polyureas are very quick drying, making them difficult to apply. Because this property is not required, there seems little reason to consider the polyurea. The polyurethanes theoretically should provide good protection, although they are still fast curing and relatively difficult to apply compared to epoxies. Also, there is little experience with their use for steel tank floors, and no information was available regarding the hole-bridging capability when reinforced with geotextile.
- A reinforced epoxy system was considered to have the best combination of good chemical and physical properties, ease of application, and hole-bridging properties. Reinforcement with chopped fibers would probably be able to bridge small holes that may appear from soil-side corrosion; however, the double laminate provides even better hole bridging ability. Additional laminate may provide the best hole-bridging capacity, but would add excessively to application costs and would cause problems with non-destructive inspection of floor plates. As with any lining, reinforced epoxy systems require careful specification, skilled and trained applicators, and good quality assurance and inspection. Given proper and careful application, a reinforced epoxy lining should give 30 years or more life, and provide bridging capacity for typical perforations arising from soil-side corrosion.

In summary, a properly-applied double-laminate, woven fabric-reinforced epoxy system was considered to provide the best combination of application ease, durability, and hole bridging capacity.

TABLE 2

Properties of Candidate Coating Systems

Property	Reinforced polyester/vinyl	Polyurethane/polyurea	Non reinforced	Chopped strand	Woven fabric

	ester		epoxy	reinforced epoxy	reinforced epoxy
Water resistance	Good	Good	Good	Good	Good
Ease of application	Difficult	Difficult	Easy	Moderate	Moderate
Resistance to cathodic disbondment	Poor to moderate	Poor to moderate	Good	Good	Good
Hole bridging ability	Good/very good	Unknown	Limited	Good	Very good

RELINING OF ESSENDON TANKS

As a result of the above analysis, a specification for relining of two 62-meter (130-foot) diameter potable water tanks (Numbers 4 and 5) at Essendon in the northern suburbs of Melbourne was prepared. The work was awarded to Mattiolli Brothers of Notting Hill, Melbourne and carried out during 2005. The key features of the specification, materials used, and inspection requirements are given in Table 3.

TABLE 3

Main Requirements of Surface Preparation and Lining Application

Stage	Requirement
Environmental controls	Tanks to be dehumidified throughout project. Relative humidity, air and surface temperatures, dew point to be continuously monitored.
Surface preparation	Blast clean to AS 1627.4 Sa2½ with a profile of 50 to 100 microns.
Blast holding primer	Epoxy holding primer to 15 to 25 microns.
Fill edges and welds	Epoxy lining material plus filler as caulking material
Epoxy Lining	High-build solventless epoxy with two layers of reinforcement to a minimum thickness of 2.5 mm
Gel coat	Solventless epoxy to a minimum of 0.5 mm
Reinforcement	175 to 225 grams per square meter bi-directional woven roving fiberglass mat
Lining inspection	Visual for defects Dry film thickness to AS 3894.3 Holiday testing to AS 3894.1 (High voltage) Cure testing to AS 3894.4 Method D (Barcol)

Equipment Used

The main equipment used during surface preparation and lining application is listed in Table 4.

TABLE 4

Equipment Used for Surface Preperation and Lining Application

Surface Preparation	Lining Application
1000 cubic feet per minute compressors	Plural-component proportioner and airless spray guns
4 ton abrasive blast unit	Fiberglass application rollers
Air driers	Specially built woven roving application trolley
Abrasive recovery system	
20,000 cubic feet per minute dust collector	
30KVA generators, dehumidifiers, portable lighting, gas detection monitors, confined space PPE	

Lining Application

The application process of the laminate system involved two separate work crews working simultaneously, integrating coating and fiber-glass matting to produce initially a single laminate layer in accordance with the specification. This process was repeated to ultimately produce a double laminate system. Crew 1 managed coating application. Crew 2 managed hand laying of the fiberglass matting.

The coating was initially heated, the viscosity corrected, and the product spray-applied using a plural-component proportioning pump system. Crew 1 applied 500 microns (20 mils) directly to the primed surface and Crew 2 immediately hand laid woven roving fiberglass matting into the coating. The matting was wetted out using rib rollers before Crew 1 applied a further 1,000 microns (40 mils) over the wetted matting, completing the first laminate layer.

Other important aspects of the application included the following:

- maintaining correct overlap (100 mm [4 in.] overlap of direct mat to mat contact) of the fiberglass mat between each new work section, and
- ensuring the fiberglass mat was correctly "wetted out" and no air voids were visible, particularly at floor plate and patch plate intervals.

The management of the application was largely governed by the minimum and maximum recoat limits of the solventless epoxy coating. The floor area was strategically divided into work sections of appropriate sizes that not only manageable for the work crew, but also allowed for the application of the second laminate layer over sections that were hard enough to walk and fell within the maximum recoat limit. Figure 3 shows application of the lining and finished work.

Fig. 3: Lining application: (a) resin application, (b) rolling in fiberglass mat, (c) completed floor and (d) roof stands.

FIVE-YEAR INSPECTION

Visual inspection of the tanks after five years showed the liner to be largely in as-installed condition. There was one location where the liner had delaminated from the tank wall. The delaminated section was approximately 1,200 mm (4 ft) long and of indeterminate depth from the upper edge toward the floor. The delamination was believed to be caused by the presence of a level sensor cross-connection to an adjacent tank that had been inadvertently covered over during the application process. (The two tanks are normally operated as a pair with a common inlet and outlet pipe; however, this is not always the case. Operation of the tanks in non-paired mode resulted in a differential pressure across the liner, causing it to lift.) All other complex layup areas around the column grillages and scour sumps appeared to have good adhesion. Overall, the condition of the lining after five years was deemed to be highly satisfactory. Figure 4 shows floor and roof stand condition as observed during the inspection.

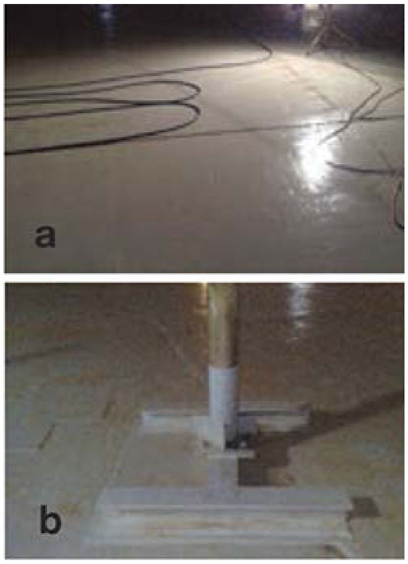

Fig. 4: Five-year inspection of (a) floor, (b) roof stands.

CONCLUSIONS

Relining of tank bases using fiberglass mat embedded in solventless epoxy was carried out on two of Melbourne Water's potable water tanks in 2005. Fibreglass mat was found to provide optimum strength for the corroded bases, and solventless epoxy resin good protection to the steel base along with ease of application. A five-year inspection showed that the lining system has performed very well.

Editor's Note: This article, by R. A. Francis and his strong team of co-authors, is part of the series of Top Thinker articles appearing in *JPCL* throughout 2012. Mr. Francis is one of 24 recipients of *JPCL*'s 2012 Top Thinkers: The Clive Hare Honors, given for significant contributions to the protective coatings industry over the past decade. The award is named for Clive Hare, a 20-year contributor to *JPCL* who shared his encyclopedic knowledge of coatings in many forums. Professional profiles of all of the award winners, as well as an article by Clive Hare, will appear in a special 13th issue of *JPCL*, to be published in August 2012.

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