CUSTOMIZED SOLUTIONS FOR BRIDGE COATING/CORROSION PROJECTS - LESSONS LEARNED

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ABSTRACT

The service life of coating system is affected by different bridge site conditions such as humidity, temperature, presence of salt (Chloride, Sulphates, and Nitrates), exposure to ultraviolet radiation; rock chips and direct salt spray. Many state agencies across US face the challenge in achieving the long service life from the bridge coatings system. This publication will demonstrate the lessons learned over time in designing the coating/corrosion protection system to increase the performance and minimize the future long term maintenance cost. Customized solutions were developed based on the bridge type, specific site conditions, environment, and maintenance needs to significantly increase the service life of the coatings system while saving millions of dollars.

1. BEST PRACTICES

Several measures from the design phase to construction phase can be taken to improve the performance of the coating/corrosion system. Developing a site-specific Technical Special Provision (TSP) to address the unique aspects of the project and to supplement the Standard Specification helps develop the customized solution to increase the service life of the paint system. Sometimes the field condition drastically changes from the time it was designed to actual construction (for example excessive rain, flooding, environmental constraints etc.). All the constraints and the basis of design should be well documented during the design phase and should be revisited during the construction phase to ensure the proposed design is the optimum solution for current field condition.

2. DESIGN PHASE

For new structures, thorough study and research of the geographical area, along with the history of painting/coating and condition of the existing structure within the close proximity is required to get to the bottom of the existing problems. Seek the input from the operating and maintaining entity for their observation during regular field inspection as well as the challenges they have faced over the years in a particular region. For existing structures, develop a comprehensive checklist of the field observations and address individual problems by providing a customized solution to overcome the local problem which will be compatible with the overall painting/coating solution. For instance, the presence of mill scale under the existing paint indicates a potential need for additional surface preparation, if mill scale is observed; specify abrasive blasting in the design. Thoroughly inspect coating type, thickness, and adhesion to estimate the efforts for removing the existing paint system as well as to gauge the rate of applying paint. Attention should be given to the localized rust and presence of mill scale on the surface of the steel as they promote premature coating failure and will require extra effort to ensure the proper degree of surface preparation as well as the proper coating thickness is achieved in these areas.
3. CONSTRUCTION PHASE

Start the construction phase with a pre-paint/pre-metalizing conference with the contractor as well as the Client/Owners and Inspectors. Establish required submittals, minimum information to be included in each submittal and format for approval. Evaluate the contractor’s resources, capabilities, and work experience. Clearly communicate your expectations and the area of the problems which will require special care and attention. For new construction, it is extremely important for the contractor to identify and prepare all surfaces that will become inaccessible after erection or installation, while they are accessible. Revisit the criteria when coating/metalizing will not be allowed. For instance perform surface preparation work when the air temperature, wind speed in the immediate coating area, relative humidity, temperature of the steel surface, and the maximum time period between each operation is within the range specified in the project documents. These site specific parameters could very well be stricter than the manufacturer’s specifications/recommendations. Establish the inspection control points during the conference such as; after cleaning, completion of surface preparation, paint coating, metalizing, and seal coat applications. Identify areas of active corrosion prior to the start of work, for instance around splice plates, power tool and/or hand tool cleaning should be expected to remove all loose corrosion from the areas.

4. CUSTOMIZED SOLUTIONS

Each painting/coating site is unique and possesses its own challenges. Thorough research/study and understanding of the uniqueness of the site is necessary to develop a customized solution to increase the service life of the painting/coating system. Presence of oil, grease, dirt, dust, soluble salts, corrosion, rusting, peeling coating, caulking, weld spatter, and/or mill scale has a direct impact on the selection of method and material including selection of appropriate surface preparation. For instance, bridge cable system abrasive blasting with polyurethane foam blast media tends to leave fragments between the strands. Therefore, more suitable material such as fine coal slag abrasive may be proposed at low air pressure. When excessive moisture is present, consider two coats of an elastomeric acrylic primer and one coat of waterborne acrylic finish paint to achieve durability.

The bridges near the boat ramps in the non-snow states should be designed as the bridges in the snow states. When the boat users leave boat ramps after the boating activity, they typically drain the salt water on the roadway. This salt water often drains on the bridge deck located within the close proximity of the boat ramps exposing the deck as well as beams to salt water runoff.

If the three coat system is utilized with a prime coat of organic zinc rich epoxy as the initial corrosion protector, assisted by epoxy intermediate and polyurethane finish (see Figure 1), consideration should be given to integration of penetrating sealers and caulking to minimize corrosion issues for splice plates and other bolted or riveted connections.

Figure 1- Three Coat System Illustration
4.1 Surface Preparation

This is one of the most crucial steps in order to make your painting project successful. It is extremely important to pressure wash the surface utilizing injected liquid soluble salt remover to remove any loose corrosion, and/or pack rust, and flush out chlorides from these areas of voids where moisture has penetrated and accumulated into the active corrosion cell prior to surface preparation. Improper surface preparation is one of the most common reasons for paint failures. For example, steel box girder should have two separate procedures for flat and non-flat surface preparation.

Insufficient coverage of the blasted substrate (due to poor workmanship and aggressive blasting to achieve production) causes peaks and valleys, and the peaks sticks through the top coating and causes the paint to fail. For abrasive blasting, the specification tolerance is from 1mil to 3mil. Recycled steel abrasive, a very aggressive coarse material, is often used to increase production and could very well result in 6mil roughness. The specs tolerance for the zinc primer is 3mil to 5mil. Even if the high side value of 5mil is used to overcome the aggressive blasting, the peaks will still stick out of the paint by 1mil and will not visible to the naked eye. Thus, very aggressive use of coarse blasting material such as recycled steel abrasive may lead to premature paint failures.

In situation where the power tool cleaning does not provide enough surface profile (less than 1mil), prime coat may not develop bond with the steel and often results in paint failure.

Pressure washing is typically proposed after surface preparation for the bridges located on the intra-coastal waterway. Due to the high moisture content in the air, the surface could be exposed to salt in the time period between drying and the first coat. To avoid this, we recommend minimizing exposure of surface as much as possible during the entire paint operation.

4.2 Primary Coat

The performance of organic zinc-rich primers over well prepared surfaces is good due to galvanic protection of the zinc coating system (acting as a sacrificial anode when in direct contact with ferrous metal substrates). Organic zinc offers one of the best choices for field primer application in the industry today. It also becomes a barrier coat once fully cured, thus making it more difficult for the electrolyte to reach the substrate.

4.3 Intermediate Coat

Multiple coat systems offer additional edge protection with the application of separate products, each serving a designed purpose in making up the total coating system. In addition, these systems should be specified with a brush-applied stripe coat (at a minimum) of the primer and epoxy mid-coat. Aliphatic acrylic polyurethane offers a favorable aesthetic appearance of the finished product, combined with high solids, thin film build, high gloss finishes, and exceptional weathering performance characteristics.

4.4 Finish Coat

Finish coating provides the color and gloss required for the completed coating system. A finish coat is typically comprised of a single pigmented coating or a pigmented coating with a clear coat. The clear coat contains a dissipating colorant. The dissipating colorant should be visible for a minimum of 12 hours after application and should completely dissipate within 96 hours after application (FDOT Standard Specs).

4.5 Customized Solution from Structural Engineering Perspective

4.5.1 Comparing Contract Plans with the Latest Available Technology

It takes months, sometime years, for any project to go from design phase to construction phase. During this time new technology, material, equipment, and design may be available that produces more cost effective, durable and safe solutions. Many state agencies have a Value Engineering Cost Proposal (VECP) or Cost Savings Initiative (CSI) program in place to make changes to the original design. The approach towards these programs should be such that the proposed solution should result in greater quality, more; durability and should minimize the cost associated with future long term operations and maintenance.
4.5.2 Bridge Span Lengths Study

One common item to look for during VECP/CSI is bridge span lengths and the superstructure type. Prior to 2010, most bridges in Florida with span lengths greater than 170ft were designed with a steel superstructure option or post tensioning system. However, when these bridges came to construction phase, prestressed (non-post tension) concrete superstructure option was available to span lengths up to 210ft. Hence, many contractors took the route of VECP or CSI to utilize prestressed concrete (non-post tension) superstructure option in lieu of steel. Thorough research, study, and analysis are required to ensure all aspects are covered including the shipping routes, shipping vehicle, handling, and erection of these girders. It may require taking a closer look at the turning radius of the shipping vehicle as that may result in the temporary widening of certain intersections to overcome the limitations on the turning radius of the shipping vehicle.

4.5.3 Bridge Design Options

Typically, for high-aesthetics-level curved bridges with larger spans, either steel box girder or posttensioned segmental box girders are used. However, now with new technology, the Curved Precast Spliced U-Girder option is available for larger spans (275ft+). This box beam can be considered at locations where steel box girder is less desirable and segmental construction is not feasible.

Bridge geometry should be carefully designed for proper deck drainage. Additionally, if the overpass bridge is considerably wide and has abutment with continuous wall will cause the tunnelling effect. The tunnelling effect is also very common in the depressed roadways. In tunneling effect, the salt water from the roadway underneath splashes on the bottom flange of the beams and accelerate the corrosion as each vehicle pass by underneath the bridge. The rate of corrosion due to tunneling effect is directly proportional to amount of truck traffic, speed limit, amount of de-icing chemicals/salt on the roadway, and the runoff spread. To avoid or minimize this condition, consider two separate bridges with gap in between in lieu of one larger width bridge, reduce the speed limit in the grade separation portion of the roadway below, and reduce the amount of surface water runoff spread by properly grading the roadway below and by keeping the drainage inlet unclogged.

4.6 Customized Solution on the Projects

4.6.1 SR 292 Gulf Beach Highway Bridge over the Intracoastal Waterway, Escambia County, Florida Department of Transportation, District 3, FL

The steel spans on the SR 292 Gulf Beach Highway Bridge over the Intracoastal Waterway have been repainted at frequent intervals since the bridge opened in 1974. The cross frame and bottom lateral bracing bolted connections were deteriorated to an advanced state. A customized and practical design was developed to extend the life expectancy of the new paint system on this bridge by proposing a 4 coat system (4th coat being the application of the ultraviolet (UV) light resisting colorless clear coat on the outside face of exterior girders only) and by disassembling the bolted cross frame and removing unnecessary bottom lateral bracing members. This allowed more thorough blast cleaning and surface preparation, as well as provided an opportunity to replace damaged or deformed bracing members.

4.6.2 Painting of Bridge No. 930061 (SR A1A over Boynton Inlet), Palm Beach County, Florida, Florida Department of Transportation District 4.

Florida Department of Transportation, District 4 has administered this painting/coating project for the first time with the Design Build delivery method. This bridge is located over coastal-salt water in a corrosive (extremely aggressive) environment and tested positive for cadmium, chromium, lead, and zinc. Additionally, the presence of sea-grasses, mangroves, manatees, sea turtles and small tooth sawfish within the vicinity of the project adds to the complexity by making it environmentally sensitive. A value added specification requirement was adopted to obtain a seven year warranty. The design build team studied the project and determined that it would be more cost effective to replace all the hardware (nuts and bolts) with new ones, than to galvanize each one of them. Florida Department of Transportation is inspecting this bridge every year and sending the results of the inspection to the design build team to keep them abreast of the condition of the coating each year. This annual inspection reports will allow contractor to take the corrective actions/preventative measures, if any in the early stages of deterioration when it is less expensive as compared to taking actions at the end of the warranty period.
The Authority removed the deteriorated concrete, prepared the surface, patched, and painted the beam ends to slow down the rate of corrosion. However, simple patching and spot painting the beam ends resulted in premature failure of coatings and continued corrosion of strands within prestressed beams. There was concern that repeating the same repair method will not only fail prematurely but will also allow the strands to continue to corrode leading to replacement of the deck and the prestressed beams.

After inspecting the beams, several sacrificial corrosion mitigation systems were considered (i.e. activated zinc tubular anodes, thermally sprayed zinc anode, discrete zinc anodes in concrete patches, and thermally sprayed Aluminum-Zinc-Indium). After evaluating the merits and demerits of these anodes, thermally sprayed Aluminum-Zinc-Indium anode was selected for beam ends since it did not require anything than simple patching and the application of anode coating on concrete surface. Plans and technical special provisions were developed for thermally sprayed Aluminum-Zinc-Indium anode (galvanic corrosion protection) to detail materials, installation, testing, and monitoring to ensure that the beam ends are protected. The bond of the coating and its effectiveness was also tested to fully protect the strands at beam ends.

5. WEATHERING STEEL WITH AND WITHOUT COATINGS

The weathering steel is an alloy of two percent or less of various combinations of copper, phosphorous, chromium silicone, and/or nickel. This property of weathering steel reduces corrosion by formulating tight adherent protective oxide coating (Patina) about the same thickness as a heavy coat of paint on the surface that seals against further corrosion. Weathering steel is not able to form a quality patina at locations with heavy rainfall, fog, and high humidity. Coastal area bridges with high alkaline air moisture stay wet for majority of time; this will reduce performance of weathering steel.

When specifying weathering steel, the design details should include the insulation of welded flange drip bars in areas of low stress and a reduction in the number of deck drains (scuppers) to increase flow and minimize drain blockage. Additionally, when weathering steel is specified in the snow states, consider specifying the maintenance painting (zone painting) at bridge begin/end and at each joint location for a distance of approximately 10ft to 15ft, to minimize the corrosion due to leaking of de-icing chemicals/salts from the faulty joints.

The process for painting weathering steel is the same as painting traditional steel, except the rust from the weathering steel should be thoroughly removed by hand/power tools prior to pressure washing with chloride-reducing cleaner (additives) injected into the water stream. Abrasive blast cleaning operations must first be completed on failing weathering steel portion of the beams.

6. METALIZING

Metalizing is a thermal spray application of metallic coating. Metalizing is getting popular in the non-snow states as an alternative to increase the service life of bridge superstructures. Additionally, compatible primer, metalizing material, and the seal coat results in better service life. Prior to beginning the metalizing process, the surface needs to be abrasive blast-cleaned with appropriate blast material type, (such as steel grit and aluminium oxide) and size to create the sharp angular surface profile and ridges (not round surface profile). After metallizing, seal with an air-cured sealer all accessible areas including fasteners except splice plates. Extreme caution is required while computing the quantities for metalizing to avoid overruns of the quantities. (FDOT 675)

7. CONCRETE STRUCTURE

Deterioration of beam ends is a common problem in prestressed concrete beams (see Figure 2). If left unaddressed, it can lead to expensive repairs or even replacement. Replacement requires that the deck be replaced as well.
One solution is to consider joint less bridge with integral abutments. However, it has limitations in span length. If corrosion is already occurring, it is important to quantify corrosion and the length of beam affected by corrosion. This will allow one to understand what type of corrosion mitigation is suitable to address on-going corrosion of strands. One solution is to use thermally sprayed Aluminum-Zinc-Indium on beam ends to reduce corrosion of strands and preserve the superstructure (see Figures 3).

Most coatings fail prematurely due to improper surface preparation and application of coating. If the thickness of metallizing is less than what was specified, the life of the corrosion protection may be too short. If the thickness is significantly more than what was specified, the coating may debond and prematurely fail. With proper oversight, many metallizing projects have been completed successfully extending the life of prestressed beams.
It is necessary to include a provision in technical special provision where contractor is required to demonstrate means and methods to achieve the desired results. The agency should retain a testing agency (independent of the contractor) to document surface preparation, the coating installation procedure, thickness of the coating, and its bond strength (see Figure 4). The thickness and bond strength must be measured at random locations so that a true measure is obtained. The project specification can be enforced knowing that the contractor has already demonstrated his ability to perform the work and achieve the project goals at the start of the project. In case of metallizing, it is important to have trained CEI personnel on site to ensure that the project specification is followed throughout the project.

Figure 4. Measuring Thickness and Bond Strength of Metallizing

The agency should also consider retaining a cathodic protection specialist (certified by National Association of Corrosion Engineers (NACE) International) to measure the level of corrosion protection achieved by metallizing. This requires specific tests to measure the protection current flow and equivalent protection levels achieved (see Figure 5).

When prestressed concrete superstructure is proposed in extremely corrosive environment, consider designing your prestressed beams for zero tension. The zero tension condition will help minimize cracks due to superimposed loads and will help avoid moisture from getting into the beams. To provide additional protection against corrosion, increase durability and reduce the future long term maintenance associated with superstructure and substructure, specify calcium nitrate in all concrete superstructure as well as substructure in extremely corrosive environment. Calcium nitrite reacts with the reinforcing steel while the unhardened concrete is being placed. This chemical reaction forms a protective oxide film around the reinforcing bar which helps to prevent chloride attack on the reinforcing bars.

Alternately, consider proposing cast in place (CIP) superstructure in lieu of either prestressed or posttensioned superstructure for low level bridges over water in extremely corrosive environment where minimum vertical clearance is less than 12 feet. If a strand in the prestressed or posttensioned beam in superstructure is corroded will result in the significant loss of strength with great reduction in structures capacity and may require replacement lot sooner before its service life. However, if a rebar in a CIP superstructure is corroded will not significantly impact the
structure strength and capacity. Additionally, increasing the minimum vertical clearance over 12ft will avoid any splashing of salt water on the superstructure and protect it from corrosion as most common recreational marine traffic (Jet Ski etc.) has tail water less than 12 feet.

Figure 5. Corrosion Protection Test Station and Testing in Progress

8. BRIDGES IN SNOW AND NON-SNOW STATES

Bridge decks in the snow areas are often sprayed with the salt to avoid ice formation. This salt has the adverse effect on the bridge deck as well as the superstructure. This salt mixes with the water and typically diffuses into deck as well as leaks from the bridge joints and splashes onto beam ends. This causes the beam ends to corrode at faster rate. This condition requires a thorough study of the corrosion rate at beam ends. With this corrosion rate data, corrosion mitigation must be designed to reduce or stop corrosion of strands at beam ends. This will minimize construction cost now as well as in the future as the beams ends will have the more or less same service life as the middle portion.

Another option to protect the beam ends is to enclose the beam ends in concrete and protecting the strands by installing activated tubular anodes within the concrete enclosure. This may be the appropriate monitor the corrosion by installing anodes as well as periodic visual inspections. Additionally, due to the extreme temperatures (fatigue), exposure to salt (corrosion), and icy conditions, the bridge joints tend to have less than expected service life. Hence, these joints should be replaced prior to coating/painting any bridges.

Snow states bridges located in the coastal area will require a completely different design. Each site requires a detailed study of bridge characteristics, geometry, minimum vertical clearance, deck drainage, superelevation, and direction of wind to develop a customized solution. For instance, the exterior girder on the south side of bridges on the east-west roadway will see more corrosion if the direction of wind is predominantly from south to north. This will require a different design for the exterior girder on the south such that the coating life of this girder is similar to other girders.

Current practice is to minimize the salt exposure by regularly pressure washing the bridge. With all the site constraints, bridge washing from underneath can be challenging. Additionally, the pressure washing will most likely not clean the pits and will continue to corrode the beams underneath the prime coat; hence power tools should be used for surface preparation at the location where pits are formed.

Even though bridges in non-snow states have more uniform corrosion, the individual bridges still require a customized solution. Depending upon the wind direction, the exterior girder designs may differ. Depending upon the location of the bridge intra-coastal, inland or near boat ramps will have different designs. Corrosion rates at each location should be carefully studied and taken into consideration while developing the customized solution.
9. EFFECT OF WIND DIRECTION ON CORROSION

Wind direction plays an important role for in-land bridges located in the east coastal states with extremely aggressive environmental condition. For instance, the bridges spanning from south to north with a general wind direction from west to east, the west exterior girder will have more exposure to the alkaline moisture as compared to the east exterior girder. Hence, west exterior girder will have greater corrosion rate as compared to the east exterior girder.

It is customary to design one coating system uniformly to a bridge. However, in this instance if one coating system is designed for west exterior girder, applying this coating to all other girders may not be cost effective. Customized approach to this condition includes careful study of the corrosion rates of the west exterior and other girders followed by comparing the two corrosion rates. The west exterior girder coating should be custom designed to match the service life of all other girders.

10. CORROSION FROM FOWL

Corrosion due to bird droppings has been a major issue in steel plate as well as box girder bridges. Birds normally get in the steel boxes if the access opening is not properly secured. The bottom plate of the steel plate girder is affected due to the bird droppings as well. The bird droppings contain compounds of ammonia which reacts with the moisture to form acid. Properly securing the access openings of the steel box girders and regularly washing the bottom flange of the steel plate girders help prevent the corrosion caused by the bird droppings. Additionally, ecofriendly bird deterrent systems can be installed on the bridges to deter the birds away from the bridges.

11. APPROACH TO PROCUREMENT FOR COATINGS PROJECT

It is extremely important to understand the effect of the procurement process on your painting/coating project. Typically the project can be let with three different types of procurement process, Traditional Design-Bid-Build; Low Bid Design-Build; and Design-Build. Bridge project should be carefully studied and appropriate procurement process should be selected. With this approach the resources will be efficiently utilized and can drastically increase the service life of the painting/coating system. Benefits of each of these three procurement type is explained below:

11.1 Design-Bid-Build

This method of procurement is traditional and very popular among many agencies for the coatings and paintings project. With this method, the project can be constructed in accordance with basic standard specifications/technical special provisions and the plans. This method of procurement should be used for simpler, smaller size, and relatively straightforward projects with minimal constraints.

11.2 Low Bid Design-Build

The low bid design build method of procurement allows owners and maintaining agencies to customize the design and construction criteria and also request several value added features including greater warranty period. Some agencies have modified the low bid design build procurement to include the Alternative Technical Concept (ATC) to bring the innovations/cost savings ideas on the project. An innovative aspect typically does not include revisions to specifications, standards or established policies. Innovation is normally limited to Design-Build Firm’s means and methods, and approach to Project. The ATC process allows innovation, flexibility, time and cost savings on the design and construction of Design-Build Projects while providing the best value for the public. These ATCs are typically presented to the clients via ATC discussion/meetings by Design-Build Firm to describe proposed changes to current design and/or construction criteria. The alternative technical concept should provide an approach that is equal to or better than what is required by the client/owner. This method of procurement should be used for customized designs and construction on midsize relatively complex projects. This is one step selection process where design-build team is selected based on the bid and the compliance with the criteria established by client/owner and typically no compensation is involved from client/owner to prepare the project approach and bid.
11.3 Design-Build

In the design build project the technical proposal is graded based on the criteria established in the Request of Technical Proposal (RFP) and method of procurement allows owners and maintaining agencies to customize the design and construction criteria and also request several value added features including greater warranty period. This method also allows for the innovation/cost savings ideas via ATC. This method of procurement should be used for customized designs and construction on large size as well as most complex projects. The selection of a design-build team is done in two steps, first shortlist (based on qualifications) and then selection (based on project understanding and approach). The shortlisted unsuccessful design-build team typically receive compensation from client/owner to cover the portion of the cost incurred by the design-build team to prepare the technical approach and the bid.

12. CONCLUSION

Maintaining agencies are extremely frustrated by not getting a durable product after spending millions of dollars due to failure of bridge coating/corrosion protection system prior to the end of its service life. Several factors mentioned above in design, inspection, construction, and maintenance can increase the service life of bridge structures and avoid the expensive bridge repair/replacement. Proper incentive for the contractor, more research from the industry, and a checklist approach developed based on the lessons learned should be taken to increase the service life of the coating/corrosion system.

We recommend that Construction Inspection team be identified and selected ahead of bidding and owner/maintaining agency should arrange a place and equipment (bucket truck etc…) to thoroughly inspect the bridge prior to receiving the bids on the project. We also recommend CEI team include a National Association of Corrosion Engineers’ (NACE) Certified Corrosion or Cathodic Protection Specialist (CPS) to perform all testing related to metallizing or coatings.

Best Practices should be developed for design, construction, inspection, and maintenance unique to each bridge type, location as well as work type. Proper training should be developed and provided to designers, contractors, and inspectors based on the best practices, checklists, and lessons learned which will also allow them to move forward in the direction of taking customized approach.

13. REFERENCE

Florida Department of Transportation – Standard Specifications (FDOT SPEC) 2014.

Florida Department of Transportation – Topic No.: 675-000-000 Materials Manual Steel and Miscellaneous Metal Products (FDOT 675) 2014

Florida Department of Transportation – District 4 Design Build Painting of Bridge No. 930061 (SR A1A over Boynton Inlet), Palm Beach County, Florida Project (FDOT D4) 2009