American Galvanizers Association

Galvanize the Future Scholarship Essay Contest

Edgar K Schultz Memorial Fund

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Prompt: You are the chief engineer on a steel bridge project and you are confronted with the options to use paint, weathering steel or hot-dip galvanizing on the structure. The bridge has a design life of 60 years and is planned to be built in the Northeast where deicing salts, humid climate, and rainfall are prominent. Compare each method of corrosion protection to arrive at your decision on what you will specify as the most durable and cost effective solution. Provide supporting evidence for your recommendations.

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ABSTRACT

A preliminary feasibility study for Bridge No. 1, located in the Northeast United States, has been performed with respect to various corrosion protection methods. Bridge No. 1 can be expected to have exposure to atmospheric conditions including rainfall, a humid climate, and de-icing salts over the design lifespan of 60 years. Hot-dip galvanizing, paint, and weathering steel are compared, and recommendations for the most durable and cost effective corrosion protection method are provided herein.

BACKGROUND

The site conditions for Bridge No. 1 indicate the need for significant corrosion protection in order to withstand the atmospheric conditions presented. The variables of cost, durability, lifespan, ease of installation, maintenance, site applicability, sustainability, and aesthetics are taken into consideration. The supporting connection elements; including bolts, fasteners, welds, and cope cuts, should also be assessed for compatibility with each corrosion protection method. The superstructure and substructure design types should also be taken into consideration, which can commonly include integral, semi-integral or conventional bridges, which have different implications for corrosion based upon the location of bridge expansion joints, abutment types, and bearing locations. The superstructures are most commonly classified as steel trusses, straight beam and girders, curved beam and girders, or 3-span continuous cantilevered beams[6], which can indicate unique complications with drainage, runoff, and coating coverage. Each of these varying geometries have benefits and drawbacks for corrosion protection, which should be taken into consideration for the final design.

DESIGN CONSIDERATIONS

A. *Weathering Steel*

Weathering steel is a commonly used construction element, due to the low cost, wide availability, and relative ease of maintenance. The formation of a protective steel patina layer slows corrosion by impeding the passage of oxygen, moisture, and other corrosive elements. Weathering steel is also selected for it's natural and unique appearance. The connection elements should be coordinated with weathering steel, because expansion joints can cause additional exposure that would expedite the corrosion process. Welds, bolts, and bearing locations should be compatible so that bimetallic corrosion does not occur, and to maintain a uniform appearance. Cope cuts also pose a unique problem because the additional exposure often indicates that these areas should have a coat of paint applied to provide an additional level of protection. The atmospheric conditions can also have serious implications on how effectively this method protects the steel. Factors including marine environments, humid climates, the use of de-icing salts, and continuous exposure to wet or damp conditions will permeate the patina layer more rapidly and cause additional corrosion, resulting in a significant increase in maintenance and reduction of the useful lifetime. Additional measures must be taken for graffiti removal as well, if this is a concern at the project site. If graffiti cannot be removed with a gentle spray of scrub, more abrasive removal methods could result in the removal of the patina layer as well. This would require the development process to start over and result in an additional loss of section, which would also expedite the need for replacement and increase overall cost.

B. Paint

Paints come in a very wide array of compounds, and can provide varying levels of protection for steel. Paint is commonly used because the materials are widely available and the result often provides a superior aesthetic appeal on the finished product. The various paint types commonly used include coal tar epoxies, alkyds, zincs, epoxies, urethanes, and silicates; all of which are made up of varying pigments, binders, and solvents. Their corrosion protection can range from mild to extensive, based upon the coating system and thickness; the associated costs of this protection method can have a wide range as well[4]. Painting steel requires significant labor at several stages of construction, which increases the overall cost of this method. The steel must be prepared and coated initially, which often occurs in a shop prior to delivery onsite. This process can have associated time delays, based upon availability and notice; this can result in potential delays in construction. The steel may also require stripe painting over welds or other connections, which are often field applied. The maintenance of paint systems is the most extensive of the various corrosion protection methods, involving routine touch ups in the field as well as regular re-applications. This requires labor and is subject to accessibility issues after the structure is installed. The paint application process often releases volatile organic compounds into the atmosphere, which has both environmental and health and safety implications.

C. Hot-dip Galvanizing

Hot-dip galvanizing is a steel fabrication process that dips the metal into a molten zinc bath, which results in a chemical bond between the zinc and iron to form an alloy coating. This coating is a very effective corrosion protection method because the strong chemical bond on the outside of the steel that provides cathodic protection and yields both durability and a long lifespan. Several case studies performed by the American Galvanizers Association provide examples of the utility and effectivity of this corrosion protection method. The Dry Bridge Road Bridge has similar atmospheric conditions, located in New York with regular exposure to rain, snow, and exhaust from trains directly beneath the bridge. This bridge exhibits an expected timeframe of 90 years prior to the first maintenance of corrosion protection[2], which far exceeds the lifetime of Bridge No. 1. The Irondequoit Bay Bridge, located in New York and regularly subjected to extreme environmental conditions including marine exposure and de-icing salts provides additional insight. An inspection of the bridge concluded that the corrosion protection method has upheld with no need for maintenance and is expected to have a long lifetime[3], which would provide a case with similar conditions as Bridge No. 1. This protection method must be applied at a galvanizing manufacturing facility, which results in some time management issues or delays, as well as transport costs, depending on the location of the nearest facility. Hot-dip galvanizing also has a misconception toward the associated costs. If initial cost appears higher than alternative methods, the maintenance and lifetime of this option provide insight to its low overall estimated costs, as outlined in Table 1. The initial costs are often lower than anticipated by contractors and estimators though, because the other options have many additional associated costs that galvanizing eliminates. In addition to the quantitative benefit of using hot-dip galvanizing steel, there are several qualitative benefits that should be factored into the decision as well. This process been evaluated on a life cycle assessment analysis performed on the process in 2009, by the American Galvanizers Association. The results of this analysis show that this process is very sustainable because it positively benefits social, economic and environmental factors. The materials require approximately one third the total energy demand, have a high recyclable material factor rate, and can contribute to LEED qualification[1], which has rising prominence in the field of structural engineering.

COST COMPARISON

Table 1 compares various corrosion methods to hot-dip galvanizing, including their applicability to Bridge No. 1. The estimate is based upon anticipated parameters that were assumed for the preliminary assessment, and are subject to change when the final structural design is complete, which could alter these results.

Table 1: Cost Comparison of Corrosion Protection Methods[1]

Corrosion Protection Method	HDG Life Cycle Cost Savings*	Additional Considerations
Weathering Steel	(not available)	Low initial cost, comparable to bare structural steel, cost of maintenance highly variable – see design considerations for details
Paint, Epoxy	86%	Shop applied – consider strip paint and connection coverage efforts
Paint, Polyurethane	95%	Shop applied – consider strip paint and connection coverage efforts
Paint, Organic Zinc	91%	Shop applied – consider strip paint and connection coverage efforts
Duplex System Epoxy+HDG**	48%	**Compared to a paint system, not hot-dip galvanizing
*Cost estimate is based on an interest and inflation rate of 5% each, lifetime of 60 years, and 1000 SF of steel, surface preparation method SP-3, complex structure height <50' , with medium sized structural members in a heavy industrial atmospheric condition, used for preliminary comparison purposes only.		

The preliminary cost comparison of available corrosion protection methods for Bridge No. 1 indicate that hot-dip galvanizing is the most cost effective, both initially and in the overall lifespan of the bridge. These results factor in the amount of maintenance expected for each type of system, and therefore provide a more accurate assessment than the initial and upfront costs, which are often the only means used for comparison. A duplex system was compared to provide a design alternative for project planning purposes as well. This system had an average cost per square foot of $1.13, while hot –dip galvanizing was $0.19 for the parameters listed in Table 1. This price accounts for paint touch ups, regular maintenance, and full repainting of the duplex system. The paint in the duplex system could also be used as a superficial coating with no additional maintenance, which would reduce the cost of the duplex system significantly. This method would result in a synergistic blend of the protection methods, yielding 1.5-2.5 times that of galvanizing alone[5]. Aesthetics should have a more extensive consideration with this type of system. The color of the paint should match the hot-dip galvanizing beneath if the bridge is visible to the public, so that the eventual wearing of paint does not draw attention or public concern.

RECOMMENDATIONS

Weathering steel is very desirable in some applications, but due to the location and atmospheric conditions expected for Bridge No. 1, it is not considered the most durable method. Paint application is a very durable method of protection, but is the least cost effective method of the options considered, based upon the cost comparison outlined in Table 1. Hot-dip galvanizing has proven to be a very durable and cost effective corrosion protection method, and is therefore the preferred method of protection for Bridge No. 1. Additionally, a duplex system of paint and hot-dip galvanizing has displayed high durability and low cost, so the two should be compared after the final structural design is completed, in order to assess estimates of quantities accurately.

CONCLUSION

Various corrosion protection methods are considered favorable for differing site locations and structural applications. Bridge No. 1 has exposure to humidity, de-icing salts, rain, and moisture, which indicate that a more robust corrosion protection method should be implemented. After various design aspects and associated costs were considered, it is recommended that hot-dip galvanizing should be used in order to provide the most durable and cost effective protection for Bridge No. 1.

RESOURCES

CITED REFERENCES

1. American Galvanizers Association. *American Galvanizers Association*. American Galvanizers Association, 2015. Web. <http://www.galvanizeit.org>.

2. American Galvanizers Association. "Dry Bridge Road Bridge Case Study." *American Galvanizers Association Case Study.* (n.d.) *A Galvanized Steel Application Report*. Web.

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4. Appleman, B. R. "Painting of Highway Bridges and Structures." *SSPC Painting Manual - Good Painting Practices*. By R. R. Ramsey. Pittsburgh, PA: SSPC, 2002. 280-91. Print.

5. "Specifying Duplex Systems." *Construction Specifier*. N.p., n.d. Web. Mar. 2015. <http://www.constructionspecifier.com/specifying-duplex-systems-aesthetics-and-protection-with-hot-dip-galvanized-steel-and-coatings/>.

6. VTrans Structures Section. "VTrans Structures Design Manual." (n.d.): n. pag. 2010. Web. <http://vtransengineering.vermont.gov/sites/aot_program_development/files/documents/structures/Structures_Design_Manual.pdf>.

ADDITIONAL REFERENCES

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