Review Article
Volume 11:1, 2021

Journal of Civil & Environmental Engineering

ISSN: 2165-784X

Open Access

A Review Paper on Durability Study on Steel Structure Joints against Corrosion by Using Natural Pigment

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Abstract

Since the 1970s, research projects and field studies have been conducted on different methods for protecting corrosion damage. The methods include alternative reinforcement and slab design, barrier methods, electrochemical methods, and corrosion inhibitors. Each method and its underlying principles are described, performance results of laboratory and/or field trials are reviewed, and systems are evaluated based on the results of the trials. Using performance results from the studies and costs obtained from transportation agencies, an economic analysis is used to estimate the cost of each system over a 75 year economic life using discount rates of 2%, 4%, and 6%. Epoxy-coated reinforcing steel is the most common corrosion protection method used in the United States today. Although controversial in many areas, epoxy-coated reinforcement has performed well in many states, including Kansas, since it was introduced in the early 1970s and is a low-cost backup to many other corrosion protection options. Research on stainless steel reinforcement indicates that it may remain free of corrosion in chloride contaminated for more than 75 years. At a low discount rate (2%), solid stainless steel reinforcement is a cost- effective option compared to other options, but at higher discount rates (4%+), the present value cost of a deck with solid stainless steel is significantly higher than that of an unprotected deck. Stainless steel clad reinforcement is much less expensive than solid stainless steel reinforcement. The performance of stainless steel-clad reinforcement will be similar to that of solid stainless steel bars if the stainless steel coating is continuous and if the black steel core, exposed at the bar ends, is protected so that it does not come into contact with pore solution. The present value of the cost of a bridge deck built with stainless steel-clad reinforcement is significantly lower than the present value for the cost of any other corrosion protection system. This method should be considered for experimental use.

Keywords: Corrosion inhibitors • Stainless steel reinforcement • Epoxy-coated • Chloride

Introduction

Corrosion is one of the major losses to industry area-costly billion per year in one state. The accepted concept of corrosion is that it is a result of an electrochemical reaction taking place on the surface of the metal where the metal is converted into metal oxides or other corrosion products. With some metals, they produce a tight skin on the metal surface, which hinders further corrosion, and if this surface layer is broken it is self-healing. These metals are said to be passivized and include lead, nickel, cadmium, chromium and aluminium. Zinc corrosion products form a fairly tight layer on zinc and further corrosion is slow. A tight layer of iron and chromium oxides forms on the surface of stainless steel and is the reason for the resistance of this metal. Iron and steel, however, form rust as a corrosion product, which is porous, is not firmly adherent and does not prevent continued corrosion.

There four basic methods for corrosion control and corrosion protection:

1. Material resistant
2. Protective coating
3. Cathodic protection
4. Corrosion Inhibitors

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Received 02 January, 2021; **Accepted** January 15, 2021; **Published** 22 January, 2021

In this study, there only 3 methods will be taken which are coating, cathodic protection and corrosion inhibitors. In this study also, there are specimens will be taken as default specimen which known as controlled specimen. This will become as a reference to the protected specimen. Millions of dollars are lost each year because of corrosion including cost of prevention, maintaining and loss. Much of this loss is due to the corrosion of iron and steel, although many other metals may corrode as well. The condition of the environment in the factory also main causes of corrosion happened where humidity, temperature, and PH of air become the major part. Many of factory owners didn't realize the disaster of corrosion and how to prevent it correctly causing many accident and bad quality result in product.

Project objective

- Study the corrosion behavior of steel structure
- Investigate the corrosion protection of steel structure for industrial application
- Study and analyze the corrosion protection and its effectiveness.
- To provide a better view on effect of corrosion to industry

Project scopes

- Sample preparation based on standard
- Exposures period
- The Effectiveness of the protection
- Corrosion analysis
- Surface observation
- Corrosion rate
- Composition analysis

Parameter of project

- Coating
- Inhibitors
- Cathodic protection
- Condition of environment in factory

Literature Review

The first line of defense against the corrosion of reinforcing steel is high quality. However, high quality can crack and, over time, chlorides can penetrate even the best low permeability [1]. Therefore, the final line of defense against corrosion in reinforced is the reinforcement itself. Conventional mild steel is not very resistant to corrosion, so to improve its performance in contaminated; it must either be coated with an effective and economical barrier, or replaced with a more corrosion-resistant material [1].

Barriers tend to be more economical than solid corrosion-resistant bars, and can be separated into two basic categories: organic and metallic. The most common coating for reinforcing steel in the United States is epoxy, which is organic. Epoxy coating isolates the steel from the chloride ions [1]. Metallic claddings for mild steel reinforcement include materials that can be either noble or sacrificial compared to the mild steel core. In bars with sacrificial coatings, the reinforcement will be protected at breaks in the coating; however, in bars with noble coatings, the integrity of the coating is important because the steel core will corrode at any breaks in the coating.

A good alternative reinforcement must be resistant to damage during shipping, storage at the construction site, installation, and placement. The reinforcement must also be able to maintain its structural function for the service life of the structure, even in severe service environments [1]. Finally, the alternative reinforcement must be economical when compared to conventional reinforcement.

Currently, the primary corrosion protection system for bridge decks in the United States is epoxy-coated reinforcing steel. Epoxy-coated reinforcing steel has been used in approximately 20,000 reinforced bridge decks since the early 1970s, and is estimated to have saved taxpayers billions of dollars in rehabilitation costs [1].

Epoxy-coated reinforcement was developed in the early 1970s, in response to the need for better corrosion protection on reinforced bridge decks. The method of coating reinforcing steel with epoxy was adapted from the method used by utility companies for coating pipes in the petroleum industry [2]. The bar is cleaned by blasting with grit to a near-white finish to remove mill scale, rust and contaminates. The bar is then heated to the temperature required for the application of the epoxy powder, typically 230°C, and passed through an electrostatic spray that applies charged, dry epoxy powder to the steel. The epoxy melts flows and cures on the bars, which then are quenched, usually with water spray bath [2].

Epoxy resins are thermosetting plastics that have good long-term durability in concrete and are resistant to solvents, chemicals and water [2]. Tests have shown that the diffusion rates of oxygen and chloride ions through a quality coating of adequate thickness (177 m, 7 mils) are extremely low, even in severe exposure conditions [2]. However, epoxy based coatings are not impermeable to water. Epoxy coatings function in two ways, first by acting as a barrier, keeping oxygen and chloride ions from reaching the surface of the steel, and second by increasing the electrical resistance between adjacent steel locations. Epoxy coatings reduce the magnitude of macro cell currents, which are responsible for extensive deterioration when they develop in bridge decks. Because the protective ability of epoxy coatings depends on their ability to act as both a physical and electrical barrier, effective quality control measures must be taken during coating of the bars and subsequent handling, shipping and storage of the bars [2]. ASTM A 775, A 934, and D 3963, and AASHTO M 284 provide guidelines to be followed during these processes.

The first use of epoxy-coated steel on a bridge deck was in 1973 on a bridge over the Schuylkill River near Philadelphia. By 1976, 19 states were participating in a national experimental program to evaluate epoxy-coated reinforcement. By 1977, 17 states had adopted epoxy-coated bars as standard and 9 more were using them on an experimental basis [2]. While there were 10 different types of prequalified coatings; the dominant coating, because of its relatively quick production capabilities and flexibility, was Scotchkote 213, which was manufactured by the 3M Company. As the use of epoxy-coated reinforcement increased, some problems were revealed, such as cracking of the coating during bending and damage to the coating during shipping and handling on the job site. New methods, such as bending the bars before coating, increasing the number of supports during shipping, padding the bundles, and using nylon slings for loading and unloading, were developed in an attempt to overcome these problems. Specifications also started to require plastic or epoxy-coated chairs and tie wires when they were in contact with the epoxy-coated reinforcement to minimize stray currents and to avoid the creation electrical couples within the structure [3,4]

Epoxy-coated steel, along with higher quality and deeper cover, has provided effective protection against corrosion distress in bridges in the Unites States and Canada for more than a decade. [3] In their opinion, reports of problems with epoxy-coated reinforcement are isolated, and each problem is caused by some shortcoming in the specific materials or construction in the particular structure However, recently, several investigators have been led to question the use of epoxy-coated reinforcement as a realistic strategy for preventing corrosion damage to structures These analysts believe that the failures of epoxy-coated steel in structures are indicative of generic shortcomings in the technology, and that additional problems will develop as structures continue to age.

In the 1970's, epoxy-coated bars were only used in the top mat of reinforcement in bridge decks. However, even at this time, it was known that macrocells could develop between the top and bottom layer of reinforcement. It was also understood that the rate of corrosion was controlled by the cathodic reaction. A large bottom mat acting cathodically could cause the development of highly anodic areas at defects in the coating on the top deck steel. A 1980 study by the Federal Highway Administration (FHWA) comparing test slabs with epoxy- coated reinforcement in the top mat only to slabs with epoxy-coated reinforcement in both slabs indicated that corrosion was reduced by 11.5 times with coated steel in the top mat only, and by 41 times when both mats of steel were coated [3]. In the 1980's, many states began using epoxy-coated reinforcement in both the top and bottom mats in bridge decks.

In 1974, a report was published by the FHWA entitled Nonmetallic Coatings for Concrete Reinforcing Bars (Clifton et al. 1974). The report covers immersion studies of epoxy-coated bars in water, saltwater, and other liquids, chloride permeability studies of epoxy films, and electrical resistance studies on coated bars and coated bars embedded in partially immersed in 3.5% sodium chloride solution. The tests showed that both powder and liquid epoxy coatings with a thickness of 25 to 100 m (1 to 4 mils) exhibited excessive holidays. The National Bureau of Standards performed two studies on coated bars in 3.5% sodium chloride solution. The results from the studies indicate that high resistance ratios correlated with good corrosion performance, since the resistance test served as a sensitive holiday detector [3].

Many of the epoxy films in the FHWA study appeared to be fairly impervious, even at a thickness of only 75 μm (3 mils). The three films tested that had a thickness between 178 and 254 μm (7 and 10 mils) had no measurable chloride ion permeability after 37 weeks in a permeability cell [5-10]. It is still believed that epoxies are relatively impermeable to chloride ions, but not water. The concept that the adhesion of epoxy-based coatings to steel is significantly reduced by exposure to water is not new, and was presented in the Handbook of Epoxy Resins, published in 1967. Results from a number of studies have supported this idea, indicating that the adhesion between the epoxy coating and the reinforcement is reduced as the moisture content in the increases [3]. Some studies have suggested that once the coating is allowed to dry, some of the original adhesion to the bar is salvaged. The adhesive strength necessary for epoxy-coatings to protect the underlying steel has never been established. Some studies have indicated that the mere loss of adhesion does not indicate that the coating is unable to protect the steel, but that in the presence of defects, performance is directly related to the adhesion of the coating (Adhesion 1995) [10]. Other studies have identified the loss of adhesion of the epoxy coating as an important failure mechanism for epoxy-coated reinforcing steel [3].

According to a study on adhesion loss conducted by the University of Western Ontario for the Ontario Ministry of Transportation in 1993, the loss of adhesion on epoxy-coated reinforcing steel does not change short-term performance in the absence of defects; but if defects are present, performance is directly related to the adhesion of the coating. The study also concluded that adhesion was decreased in the presence of contaminants, and improved by an increase in surface roughness, and that water penetrating the coating and displacing the epoxy from the steel surface seemed to be the main mechanism of adhesion loss [10].

The condition of epoxy-coated reinforcement taken in 1996 from 18 bridge decks, constructed between 1977 and 1995 in Virginia, was evaluated by Pyc et al. [10]. With the exception of too many holidays in bars from one deck, all of the Epoxy-coated reinforcement samples evaluated met the specifications for coating thickness and holidays that were in place at the time of construction. The adhesion of the epoxy-coatings was evaluated using MTO – Draft 93 10 27 "Hot Water Test for Epoxy-Coated Reinforcing Bars." In this test, an "x" cut is made in the epoxy coating between deformations, and an area of the bar is exposed by inserting the blade of a Xacto knife under the coating. The adhesion of the coating is given a value of 1 to 5. A newly coated bar would have an adhesion value of 1, meaning that the blade tip was unable to be inserted under the coating. If less than 2 mm^2 of steel is exposed, the adhesion rating is 2. Exposure of 2 to 4 mm^2 of steel gives an adhesion rating of 3. If more than 4 mm^2 of steel is exposed, the adhesion rating is 4 [10]. Finally, if the blade slides easily under the coating and levering action remove the entire section of coating, the adhesion rating of the coating is 5.

No reduction in adhesion was detected in bars from three decks, one built in 1983 and two built in 1995. The bars from the other decks exhibited a decrease in adhesion, with adhesion ratings ranging from 2 to 5. The study concluded that, although the reinforcement appeared to be in good shape, the loss of adhesion was a matter of concern for the long-term performance of epoxy-coated reinforcement in concrete. Ninety-four percent of the sample size showed evidence of adhesion reduction, including some complete coating disbondment. This coating disbondment was not caused by excessive coating damage or by the presence of chloride ions on the steel surface, but rather by water penetrating the coating.

According to the authors, these results indicate that epoxy coating will not maintain its bond to reinforcing steel in moist environments. If, when chloride ions arrive at the surface of the reinforcement, the coating has already disbonded, corrosion will take place under the coating. This corrosion will occur at a rate similar to that of a bare reinforcing bar in an acidic environment, which is faster than the corrosion of bare steel.

Other studies have found that reinforcement with high moisture contents generally suffers reduced adhesion of the coating [11-20].

Discussion and Conclusion

Many different methods have been used to help improve the durability of Steel structures. Some of these methods have performed better than others, but there is no one perfect method for every type of application. Based on the economic analysis performed in this study, the use of epoxy- coated reinforcement alone is more cost-effective than building a bridge with black steel reinforcement and no other corrosion protection method, but there are other methods that now appear to be more cost-effective than either of these options. The more cost-effective corrosion protection options include epoxy-coated reinforcement in combination with another system such as a membrane, overlay, or corrosion inhibitor. The increase in the cost of a new deck with epoxy-coated steel over black steel reinforcement is very small, so even if it is not expected to improve the service life of a structure, epoxy-coated steel is a low cost backup to other corrosion protection methods.

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How to cite this article: Manikandan, R. "A Review Paper on Durability Study on Steel Structure Joints against Corrosion by Using Natural Pigment." *Civil Environ Eng* 11 (2021): 373