THE UNIVERSITY OF KANSAS
School of Engineering

Civil, Environmental & Architectural Engineering

Kien Nguyen, M.Sc., EIT
PhD Student
2150 Learned Hall, 1530 West 15th St, Lawrence, KS 66045
Email: qkien@ku.edu

AGA Scholarship Committee
The American Galvanizers Association's (AGA) *Galvanize the Future: An Edgar K Schutz Memorial Scholarship*
6881 South Holly Circle, Suite 108
Centennial, Colorado 80112

Dear AGA Scholarship Committee,

My name is Kien Nguyen; currently I am a Ph.D. student in Structural Engineering at the University of Kansas. I am working on the research project NCHRP 10-94 "Mitigation of Weldment Cracking of Highway Steel Structures due to the Galvanizing Process". I am proud to get involved in this project, which will help designers, galvanizers, and fabricators to make reliable, sustainable, and durable galvanized steel structures.

Through the process of writing this essay, I have had the opportunity to learn more about hot-dip galvanizing and have become more and more interested in it.

Thank you very much for considering me for the Edgar K. Schutz Memorial Scholarship.

Sincerely,

Kien Nguyen

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THE APPLICATION OF HOT-DIP GALVANIZING IN BRIDGES AND HIGHWAY STRUCTURES

1. Introduction

In the United States, galvanized steel structures and components are used widely in many parts of the economy, such as building construction, transportation, agriculture, manufacturing, energy supply, mining, and offshore production. It is easy to find galvanized steel wherever you look: nuts and bolts in garages, irrigation systems on farms, wheels at amusement parks, light poles on streets, and cranes on shipyards. Those structures are generally galvanized to combat steel corrosion in the harsh environments.

Figure 1. Typical galvanized bridge and highway structures (*www.galvanizeit.org*).

The application of hot-dip galvanizing in bridges and highway structures are hugely important (Figure 1). There are more than 200,000 steel bridges across the United States (Koch et al. 2002), and the number of highway structures (e.g., sign, luminaire, and traffic signal structures) are multiple times. A large portion of those steel bridges and highway structures are exposed to aggressive environment conditions, such as rivers and coastal areas, which likely introduce corrosion on the steel components. Therefore, it is critical to coat the steel for corrosion protection, and the use of hot-dip galvanizing has been proved to be an effective way. It is hard to imagine of those structures without the galvanizing protection.

2. How does hot-dip galvanizing improve our lives?

2.1 Hot-dip galvanizing provides safety for people using bridges and highway structures

During the galvanizing process, zinc combines with iron to form a protective layer on the surface of the steel. The galvanizing coating gives two basic corrosion protection mechanisms: (1) it serves as a barrier to block the environment from changing the steel properties, and (2) it provides a catholic protection, since zinc is more active than steel in the galvanic series, as shown in Figure 2. The hot-dip galvanized coating protects steel from corrosion, and it can help maintain the

structural integrity and protect steel structures from failure. Therefore, it provides safety to the public who use those types of steel structures.

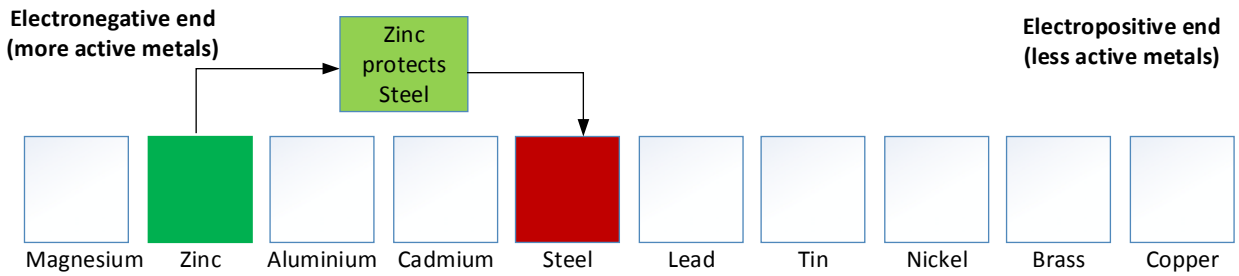

Figure 2. Zinc's position in the galvanic series (*www.egga.com*).

Galvanizing coating helps protect steel structures for a long life service compared to conventional protective coatings. The "Time to First Maintenance" chart in Figure 3, which was the result of real world data collection, can provide estimation of galvanizing longevity in various environment conditions. For example, according to ASTM A123, a steel of 1/4 inch thick must have a minimum of 3.9 mils of zinc (ASTM 2013). Assume the steel is placed at the industrial (gray) environment, the galvanizing coating provides approximately 72 years until first maintenance. Practically, this approximated number of year covers the design-service-life of most of bridges and highway structures, which is around 50 years or more.

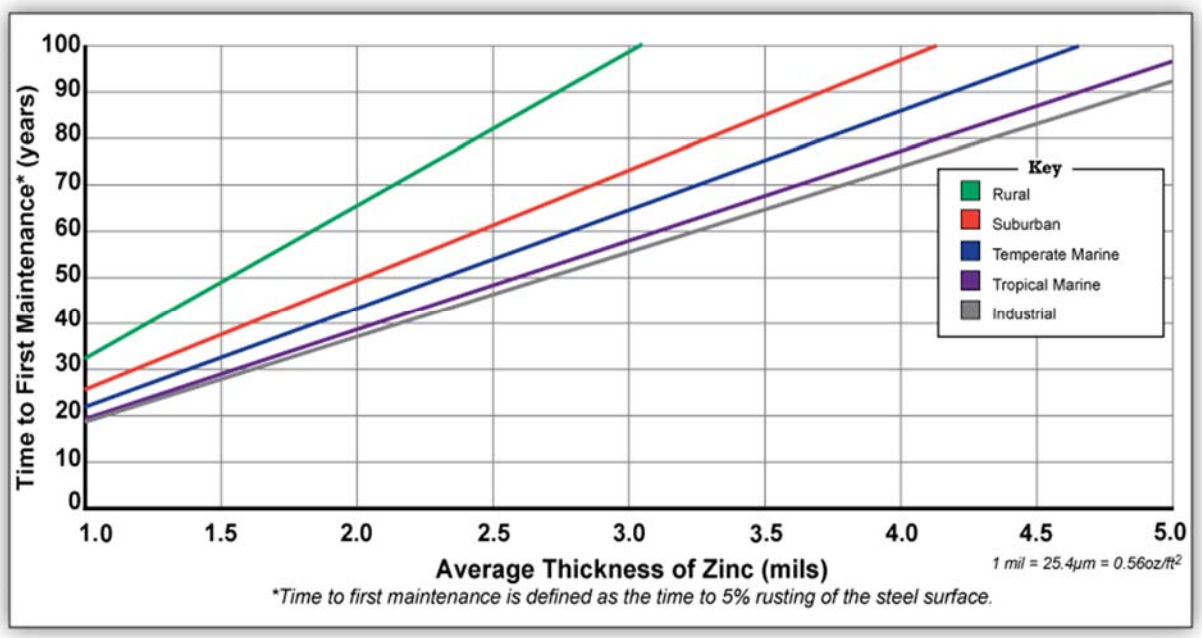

Figure 3. The Time to First Maintenance chart (*www.galvanizeit.org*).

2.2 Hot-dip galvanizing helps protect our environment

Hot-dip galvanizing helps minimize environmental impacts, as it has some key environmental advantages. Firstly, zinc and iron, two chemicals forming hot-dip galvanized steel, are natural

materials. Iron ore and zinc are the 4th and 27th most abundant elements in the Earth's crust, respectively. Notably, zinc is a critical element in human health, which is naturally cycled through the environment by plant and animal life. Secondly, zinc and steel are infinitely recyclable without the loss of any physical or chemical properties. In other words, they can be used again and again, without compromising their integrity. Steel is the leading material for recycling (100%) in the world, while that rate for zinc is also very high (80%), according to Steel Recycling Institute (2009) and International Zinc Association (2004). Therefore, the use of hot-dip galvanizing is safe to the eco-system, and minimizes factors that harm our environment.

Figure 4. Zinc is a natural material (*www.zinc.org*).

The use of hot-dip galvanizing in bridges and highway structures helps avoid waste from corrosion, which is a big concern. It helps reduce the number of activities that are bad to the environment. For example, in order to have a new bridge to replace a corroded one, a lot of energy consumption during manufacture, transportation, and construction is required. Because of a large number of steel bridges and highway structures around the country, choosing the right corrosion protector for those types of structures is playing a vital role in the environmental impact.

2.3 Hot-dip galvanizing reduces costs that we need to spend on transportation systems

Corrosion is a huge problem in every country in the world. It costs Japan 3.5% of its GDP to rust maintenance, 3.5 % in the U.K., and 3.0 % in Germany (Chen and Hsu 2014). In the U.S., according to the results from Koch et al. (2002), a joint effort among the National Association of Corrosion Engineers (NACE), CC Technologies, and the Federal Highway Administration (FHWA), the direct cost of metallic corrosion to the U.S. economy was 3% of the GDP, or approximately $400 billion per year. However, the cost can be up to 10 times greater if other indirect costs are to be considered, such as losses to businesses, detours, and so on. Apparently, it is necessary to protect our infrastructures, especially bridges and highway structures, from corrosion.

It has been proved that hot-dip galvanizing is more economic than other corrosion protection methods. The research by Chen and Hsu (2014) showed that the use of hot-dip galvanizing saved about 3.5 % of the total cost of a bridge project, in a comparison to paint systems. Many specifiers

have a long-held-misconception that initial cost of hot-dip galvanizing is too expensive, and ignore the life-cycle costs. However, the cost of many corrosion protection systems has increased in recent years. Now, hot-dip galvanizing often costs less than many high-performance paint systems in both initial and life-cycles costs. Therefore, use of hot-dip galvanizing helps reduce costs that we need to spend on transportation systems.

3. What if hot-dip galvanizing steel were not used in bridges and highway structures?

3.1 We would not be safe when using bridges and highway structures

Corrosion affects the integrity of steel structures. Thus, corroded bridges and highway structures may not be safe for people using them, especially when the structures are placed in high-density traffic areas. If a structure has some corrosion issue during its service life, it will be more susceptible to failure under the impact of natural hazards, such as tornados, severe windstorms, and earthquakes. The failure of those structures can result in severe injuries or even loss of lives.

Figure 5. Silver Bridge before and after collapse (*www.transportation.wv.gov*).

One of the tragedies related to corrosion was the collapse of Silver Bridge connecting West Virginia to Ohio on December 15, 1967 (Figure 5). The collapse caused the deaths of 46 people, and many others were seriously injured. In addition, a major transportation route connecting West Virginia and Ohio was destroyed, disrupting the lives of many and striking fear across the nation. It was found that stress corrosion cracking was the major contributor to the fracture of the eye-bar, a critical element in the bridge. Stress corrosion cracking is the development of brittle cracks in a corrosive environment. Note that at the time of construction of the bridge, stress corrosion cracking was not known to occur in the bridge material used under the conditions of rural areas.

Another accident was the breakdown of Lowe's Motor Speedway Bridge on May 20, 2000 in Concord, North Carolina (Figure 6). The accident injured more than 100 people. Corrosion was identified as the main cause of the failure.

3.2 Our environmental would be worse

As mentioned earlier, hot-dip galvanizing is an environment friendly corrosion protection method. If it was not used in the market of bridges and highway structures, our environment would be affected by corrosion and the use of other corrosion protection methods. Many of our bridges and highway structures would be aging faster. Then we would need to replace a large number of them because of their shortened service life. Manufacturing of new bridges and highway structures requires the consumption of a lot of energy input, and creates a lot of emissions to the atmosphere. If other corrosion protection systems (e.g., painting) are used, many harmful chemicals will be discharged to our environment, such as lead and volatile organic compounds (VOC).

Figure 6. The collapse of Lowe's Motor Speedway Bridge (*www.nace.org*).

3.3 We would have to pay more tax for the rising costs related to corrosion

The use of hot-dip galvanizing for bridges and highway structures saves a lot of money associated with repeated maintenance activities for steel structures. If it was not used, maintenance costs would be a burden for our national budget, resulting in more tax from each citizen. In addition, it would cost more to local businesses, when they would need to move their businesses to different locations because of construction and maintenance activities. Transportation and other activities would need to be adjusted to facilitate maintenance activities. The situation would irritate everyone, result in wear and tear on automobiles, increase gasoline use, delay in product transport, and cause missed appointments.

3.4 Bridges and highway structures would be unattractive

If hot-dip galvanizing steel were not used, we would see many corroded structures, such as those shown in Figure 7. The image of corroded steel is definitely unpleasant, and it degrades the quality of our lives. Alternative corrosion protection methods can be used, but they are not as good as hot-dip galvanizing. Thus, corrosion could not been avoided. The image of corrosion would invade our society, as we could see it wherever we look.

Figure 7. Example of bridge and highway structures getting corrosion (*www.galvanizeit.org*).

4. Conclusion

Hot-dip galvanizing has been used for bridges and highway steel structures based on its advantages to make reliable, durable, and sustainable galvanized steel structures with economic cost. Without the use of hot-dip galvanizing in this sector, bridges and highway structures would easily get corroded. Their appearance would not be good, and would be unattractive to people. Safety concerns would hang on our mind whenever we used or got close to those structures. The environmental impacts would be hard to correct. Finally, each citizen would need to pay more tax for the consequences.

Currently the U.S. is sustaining the burden of aging transportation systems with many bridges and highway structures being corroded. One of the reasons is the use of improper protective coatings in the past. Therefore, to avoid such a burden for our future generations, proper corrosion protection system should be used, and hot-dip galvanizing is the right one.

5. References

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