Hot-Dip Galvanizing

# COSTS LESS, LASTS LONGER

Information and Case Studies Examining the Cost-Effective Nature of Hot-Dip Galvanizing

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# INTRODUCTION

Sustainable development is increasingly important to specifiers and the general public throughout the construction industry. Sustainable development is the social, economic, and environmental commitment to growth and development that meet the needs of the present without compromising the ability of future generations to meet their own needs. Often lost in the emphasis on sustainability is the economic factor. To achieve true sustainability, environmentally friendly structures must also be economically responsible for future generations to thrive.

As social pressure continues to drive the sustainability movement, specifiers are becoming more invested and analytical in the evaluation of materials utilized in their projects. Sustainability centers on thinking about the future; thus, the short-sightedness of only considering initial cost should be augmented with the long-term life-cycle cost analysis. Evaluating the cost of a project throughout its life ensures more economic stability for future generations.

# MATERIAL SELECTION

Steel, a readily available, efficient building material, has been used in construction since the Industrial Revolution. Cost effective, aesthetically pleasing, sustainable, and strong – if steel has one weakness, it is the fact it corrodes when exposed to the atmosphere. To combat corrosion and improve steel's longevity, specifiers can select from a variety of corrosion protection systems.

Each corrosion protection system has a unique set of characteristics including: method of application; adhesion to the base metal; corner, edge, thread protection; coating hardness, density, thickness; and others. All of these characteristics affect the corrosion resistance of the protection system and its applicability in various environments. When a corrosion protection system is used in an unsuitable environment, longevity is compromised, leading to increased maintenance costs as well as unnecessary consumption of natural resources.

# COATING SYSTEMS

Therefore, when specifiers are selecting materials for a given project, it is paramount to consider more than just the initial cost of protection system. Taking into account the overall service life, expected time to first maintenance, and corresponding economics related to the initial and continued upkeep provides a more accurate prediction of the project's impact on future generations.

Two common steel corrosion protection systems are hot-dip galvanizing and paint. In addition to hot-dip galvanizing and the numerous combinations and formulations of paint, steel may also be protected by metallized coatings, duplex coatings (combination of paint or powder coating and hot-dip galvanizing), and other corrosion inhibiting systems such as stainless and weathering steel. However, more often than not, hot-dip galvanizing is compared to paint systems. Many specifers have the misconception hot-dip galvanizing is more expensive than paint on an initial basis. In fact, hot-dip galvanized steel is often more economical both initially and over the life-cycle of a project – making it a sustainable choice for today and tomorrow.

Paint coatings are readily understood; however, not all specifiers realize some of the inherent characteristics with a brush or spray-on coating such as: the difficulty applying a consistent coating thickness, particularly on corners and edges, as well as the strict application limits for climate and humidity for the best adhesion results. Also, there are a number of different paint systems available, including one, two, and three coat systems, all of which have differing and specific requirements and performance.

Hot-dip galvanized steel is created by immersing fabricated steel into a bath of molten zinc. While in the bath, the iron in the steel reacts with the zinc to form the galvanized coating. The coating grows perpendicular to every surface – meaning corners and edges, as well as interior surfaces, have the same coating thickness as flat areas. Furthermore, the coating is metallurgically bonded to the steel at 3,600 psi (25 MPa), providing great abrasion resistance.

A duplex system utilizes a combination of hot-dip galvanizing and either paint or powder coating. The two coatings work in synergy to provide long lasting corrosion protection. Duplex systems are often specified for aesthetic reasons, but using the dual coating also has a synergistic effect – extending the time between maintenance cycles 1.5 to 2 times the length of paint alone on bare steel. The extended maintenance cycles leads to economic savings during the life-cycle.

Metallizing is a spray-applied zinc coating which can be applied in the shop or field. It is commonly used on parts too large for hot-dip galvanizing when a zinc coating is desired. It has a higher bond strength than paint coatings, but also is susceptible to thinner coatings on coatings and edges. Metallizing also requires more specialized equipment and operators than paint coatings.

*"Paint coatings are readily understood; however, not all specifiers realize some of the inherent characteristics with a brush or spray on coating."*

# COST ANALYSIS

When analyzing coating systems, one of the most important factors is cost. As has been highlighted, it is important to consider both initial and life-cycle costs of a project. In addition to direct initial and maintenance costs, one must consider indirect costs – site accessibility, loss of productivity during maintenance, commuter delay, etc. – incurred when a coating system needs repair. Estimates show indirect costs are typically 5-11 times the total direct maintenance cost.

Precisely predicting the timing and cost of future maintenance is difficult, but utilizing empirical data and common accounting calculations to estimate the value of money over time provide specifers with reasonable estimates. ASTM A1068 *Standard Practice for Life-Cycle Cost Analysis of Corrosion Protection Systems on Iron and Steel Products* gives specifers an evaluation equation to compare total cost of steel corrosion protection systems.

To facilitate life-cycle cost analyses, the American Galvanizers Association (AGA) took the accepted calculation in ASTM A1068 and developed an automated, online calculator at lccc.galvanizeit.org. The Life-Cycle Cost Calculator (LCCC) uses data from a KTA Tator, Inc. survey of paint manufacturers, as reported in NACE Paper No C2014-4088 *Expected Service Life and Cost Considerations for Maintenance and New Construction Protective Coating Work* (2014) and a nationwide survey of AGA members.

The LCCC takes user input selections to calculate the initial and life-cycle cost of hot-dip galvanizing or a duplex system compared to 30+ other coating systems including metallizing.

# INITIAL COST

Initial cost is often a primary determinant for the selection of a corrosion protection system. However, initial cost does not reflect the true cost of a corrosion protection system over its life. Simply selecting a low cost option may be a gross disservice to future generations who will pay to maintain the system.

Many specifiers believe hot-dip galvanizing is more expensive than paint initially. However, over the last 5-10 years, paint costs have increased dramatically while hot-dip galvanizing prices have remained relatively stable. This has led to hot-dip galvanizing being more economical in initial cost than most high performance, industrial paint systems.

*Table 1* displays hot-dip galvanizing's initial cost compared to other typical paint systems and coatings.

*Table 1: Initial Cost*

| Coating System | Initial Cost | |
|---|---|---|
| | $/ft$^2$ | Total |
| Hot-Dip Galvanizing | $1.76 | $88,000 |
| Epoxy/Epoxy | $2.61 | $130,600 |
| Epoxy/Polyurethane | $2.82 | $141,200 |
| IOZ/Epoxy | $2.85 | $142,700 |
| IOZ/Epoxy/Polyurethane | $4.17 | $208,800 |
| Galvanizing/Epoxy/Polyurethane (Duplex) | $5.22 | $260,750 |
| Zinc Metallizing/Sealer | $8.13 | $406,450 |

Notes: 75 Year Project Life • C3: Medium corrosion environment • Typical mix of sizes and shapes (250ft$^2$/ton • 50,000 ft$^2$ project/40 tons • 3% Inflation, 2% Interest

# CALUMET INDUSTRIAL FACILITY

## CASE STUDY

In 1995, the City of Chicago was in the process of constructing a solid-waste recycling facility comprised of four buildings. Originally the project was specified to use a three-coat epoxy paint system. However, because of the fast-track schedule and the design engineer's familiarity with the benefits of hot-dip galvanizing, the contractor offered a substantial rebate to the city if the specification was changed to hot-dip galvanizing.

One of the primary reasons for changing the specification to hot-dip galvanizing for this project was the quick turnaround. However, what the City of Chicago soon realized was using hot-dip galvanizing not only saved them time (money) during construction, but would also save the tax payers money throughout the life of the project.

Using the original specifications from the Calumet Industrial Waste Facility, a life-cycle cost analysis using 2014 data was run in the life-cycle cost calculator at **lccc.galvanizeit.org** .

**Original Specifications:**
- 7,400,000 lbs. (3,356,854 kg) of structural steel
- 470,000 ft$^2$ (43,664 mi$^2$) of building
- Three-coat epoxy paint (changed to hot-dip galvanizing)

| Coating System | Initial Cost | | Life-Cycle Cost | |
|---|---|---|---|---|
| | $/ft$^2$ | Total | $/ft$^2$ | Total |
| Hot-Dip Galvanizing | $1.76 | $1,628,000 | $1.76 | $1,628,000 |
| Painting Operation | $3.18 | $2,941,500 | $14.95 | $8,103,000 |
| Reduced Cost by 79% | | | | |

Ultimately, the hot-dip galvanized facility was delivered on schedule and for less money than a painted facility would have been. The engineers and contractors readily admitted the project simply could not have been built on schedule and within budget if hot-dip galvanizing had not been specified. For the City of Chicago, the decision will continue to pay dividends, as galvanizing simply costs less and lasts longer.

When calculating a system's initial cost, there are a number of items to take into consideration. First and foremost one must account for the material (epoxy, alkyd, acrylic, metallizing, etc.) as well the number of coats. Additionally, it is important to consider the cleaning method (SP-6, SP-10), whether the coats will be applied in the shop or the field (corresponding labor), the structural member type, and the size of the job. Let's look at each of these in more detail.

## Material

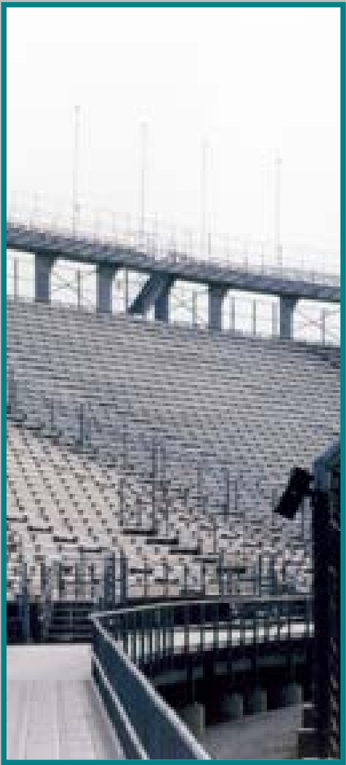
There are many different paint systems (acrylic, epoxy, polyurethane, zinc-rich) and each requires its own unique labor, application parameters (humidity, temperature), and number of coats. Because of the vast options, the initial cost of each paint system varies and must be accounted for in the KTA Tator, Inc. data. Hot-dip galvanizing is comprised of at least 98% pure zinc and is applied in the same method by all galvanizers, simplifying the material selection.

# CASE STUDY

## INDIANAPOLIS MOTOR SPEEDWAY

When the Indianapolis Motor Speedway was originally constructed, all of the steel (grandstands, debris fence, handrail, light poles, etc.) were painted. Over time, this decision led to the speedway hiring a full-time crew to continually repaint areas section by section to keep corrosion at bay. The time and cost of the perpetual painting was overwhelming; so finally, in 1991, IMS decided to test hot-dip galvanized steel by incorporating it into the new construction on Turn 3.

A thousand tons of steel bleachers were galvanized during the 1991 renovation, and the success of the coating led IMS to set a goal to replace one section of bleachers each year between scheduled events until the entire structure was protected by hot-dip galvanizing. In 2009, nearly 20 years after the original galvanizing was installed, an inspection of the steel in Turn 3 was conducted to test the zinc coating thickness. Even after being subjected to years of constant foot traffic, debris, and constant exposure to Indiana's weather, the hot-dip galvanized coating was thick enough to meet the minimum coating specification.

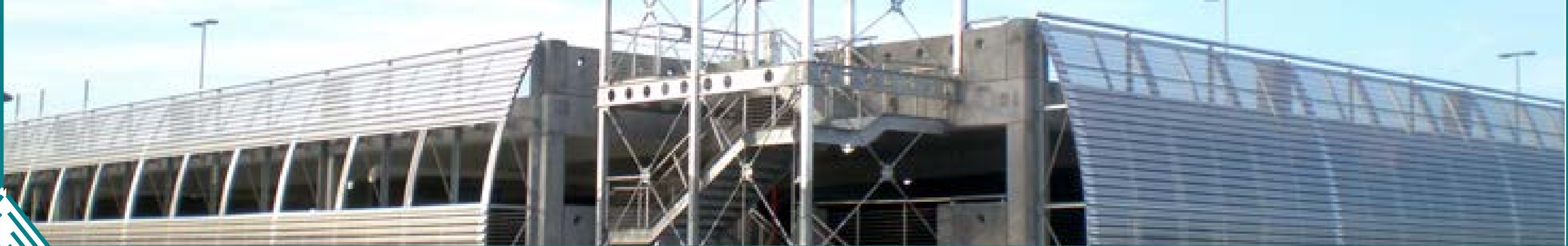


**Original Specifications:**

- 1000 tons of steel (mix of elements/sizes)
- High-performance paint system (unknown, comparison uses common system)

| Coating System | Initial Cost | | Life-Cycle Cost | |
|---|---|---|---|---|
| | $/ft² | Total | $/ft² | Total |
| Hot-Dip Galvanizing | $1.76 | $440,000 | $1.76 | $440,000 |
| Painting Operation | $3.76 | $940,500 | $9.74 | $2,435,000 |
| Reduced Cost by 81% | | | | |

The Indianapolis Motor Speedway made the smart decision to stop throwing good money after bad, and made the investment in converting their steel to hot-dip galvanizing. The decision has paid off by eliminating maintenance costs and the need for the full-time crew responsible for the upkeep of the steel. Indianapolis Motor Speedway can now use the money previously spent on maintenance for other renovations and improvements to the facility. Once again, this example shows hot-dip galvanizing is a sustainable choice – it costs less and lasts longer.



## Surface Preparation

Similar to material selection, there are a number of cleaning method/grades available for the various paint systems. Paint and powder coating surface preparation can be blast or hand power, conventional or automated, using expendable or recyclable abrasives. Each surface preparation method requires different amounts of labor, equipment and material; therefore, this variable is important for the initial cost calculation of a painted system.

The surface preparation required for hot-dip galvanizing is inclusive in the process. The steel is batch immersed in a series of three cleaning baths: degreasing, pickling (mild acid), and flux solutions. The cost for cleaning is contained in the material cost for hot-dip galvanizing.

## Location of Application

Hot-dip galvanizing is always applied in a factory-controlled environment, therefore it is independent of weather and can be done 24/7/365 if necessary. Paint and powder coatings may be applied in the shop or in the field, or a combination of both; however, they are always dependent on temperature and humidity conditions. Field application, whether the initial topcoat or maintenance repainting, costs significantly more than a coat applied in the shop.

## Structural Member Type

Small structural steel members and complex fabricated assemblies are handled and coated efficiently in the hot-dip galvanizing process. As the size of the steel members increase in terms of weight per lineal foot, immersion time in the zinc bath increases, which leads to a higher cost per square foot.

Conversely, painting/powder coating small structural members or complex fabricated assemblies is more expensive than simple, more massive structural sections. The size and shape of the steel pieces not only affects the initial cost, but the life-cycle costs as well. More complex and/or difficult to access structures cost more to maintain, increasing the life-cycle cost.

# LIFE-CYCLE COST

Although the initial cost of a corrosion protection system cannot be discounted, the life-cycle cost should be a key determining factor in the selection process because to achieve true sustainability, structures must be economically responsible for future generations. Life-cycle cost is the analysis of the true cost of a coating system throughout its entire service life – taking into consideration initial cost, maintenance costs, and the value of money over time (inflation and interest).

As *Table 2* shows, when life-cycle costs are considered, hot-dip galvanizing is the most economical system for corrosion protection. Also of note, often the least expensive systems initially are the most expensive in life-cycle cost, because they require more maintenance; whereas the duplex system, which was one of the most expensive initially (*Table 1*, page 5), is the second most economical due to the extended maintenance cycle afforded to the paint coating.

*Table 2: Life-Cycle Cost*

| Coating System | Life-Cycle Cost | | |
|---|---|---|---|
| | $/ft$^2$ | Total | AEAC $/ft$^2$ |
| Hot-Dip Galvanizing | $4.17 | $208,500 | $0.11 |
| Galvanizing/Epoxy/Polyurethane (Duplex) | $22.45 | $1,122,500 | $0.58 |
| IOZ/Epoxy | $35.91 | $1,795,500 | $0.93 |
| IOZ/Epoxy/Polyurethane | $38.26 | $1,913,000 | $0.99 |
| Epoxy/Epoxy | $38.31 | $1,915,500 | $0.99 |
| Epoxy/Polyurethane Epoxy/Epoxy | $51.90 | $2,595,000 | $1.34 |
| Zinc Metallizing/Sealer | $60.99 | $3,049,500 | $1.58 |

Notes: 75 Year Project Life • C3: Medium corrosion environment • Typical mix of sizes and shapes (250ft$^2$/ton • 50,000 ft$^2$ project/40 tons • 3% Inflation, 2% Interest

When evaluating life-cycle cost, there are a few additional factors to consider. First, the environment in which the structure will be located will have a significant impact on the maintenance costs. Second, the value of money over time must be evaluated, as a dollar today will not be worth the same in the future. The calculations for the time-value of money are complex and cumbersome; however, the calculations are automated in the online LCCC at **lccc.galvanizeit.org**. Let's look at each of these life-cycle variables in more detail.

## Environment

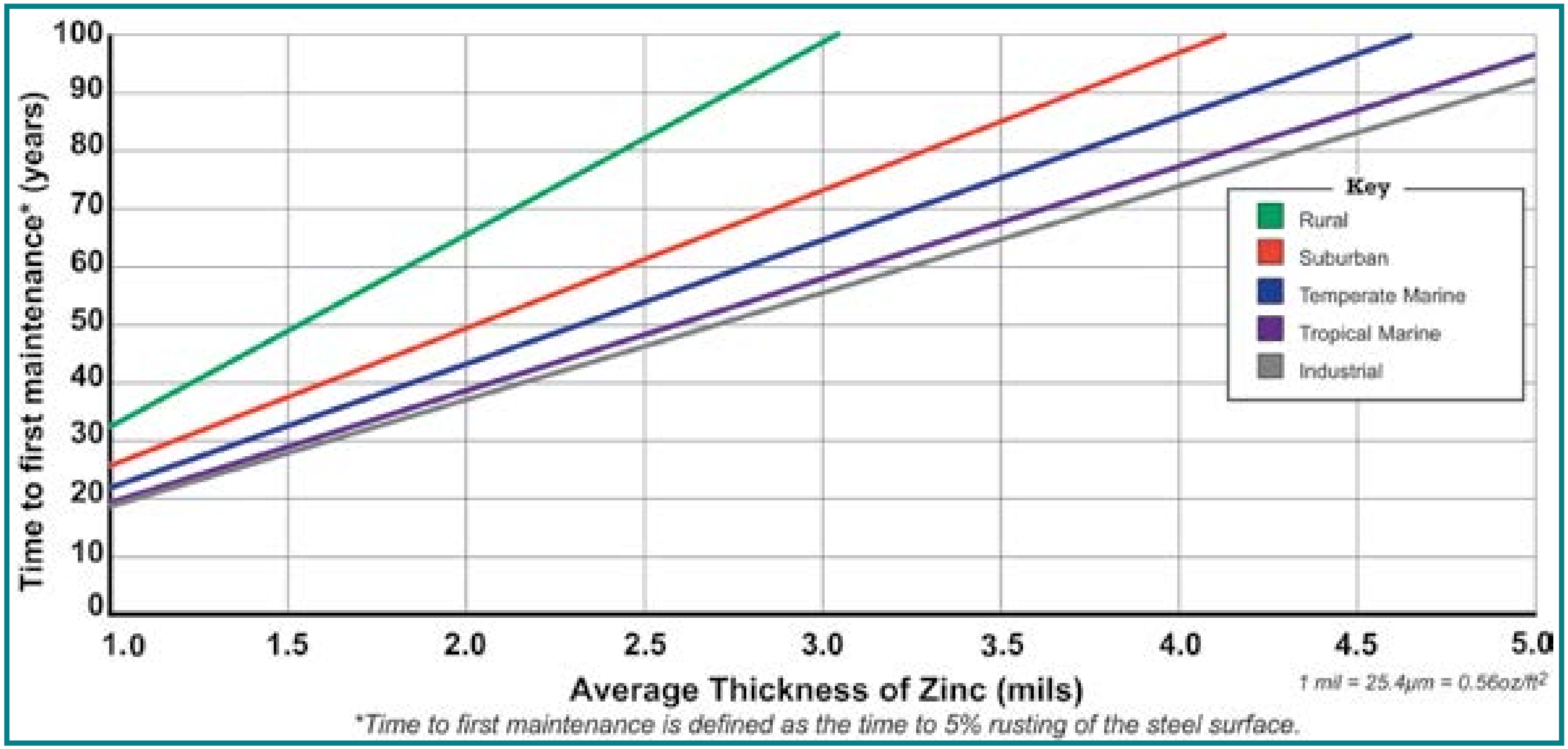
When evaluating steel corrosion protection systems, understanding the severity of the service environment is very important. The maintenance schedules for corrosion protection systems are dictated by the environment where the project is located. Each corrosion protection system, whether paint or hot-dip galvanizing will have an estimated time to first maintenance based on the corrosion rate in the given environment *(Figure 1)*.

The International Standards Organization (ISO) has identified four atmospheric environments with distinct corrosion rates:

ISO Atmospheric Environments:

- C5-I: Very High, Industry - Industrial areas with high humidity and aggressive atmospheres
- C5-M: Very High, Marine - Coastal and offshore areas with high salinity
- C3: Medium - Urban and industrial atmospheres, moderate sulfur dioxide pollution; coastal areas with low salinity
- C2: Low - Atmospheres with low levels of pollution, most rural areas

*Figure 1: Time to First Maintenance*




The environmental factor is an important variable in the life-cycle cost calculation because the different coating systems corrode at different rates in each of these conditions. The corrosion kinetics involved with hot-dip galvanized steel are quite different than the corrosion of painted or powder coated steel.

Each paint manufacturer provides a practical time to first maintenance for the specific coatings in the NACE paper. Similarly, the hot-dip galvanizing industry, using real world data from around the globe, has estimated the time to first maintenance of galvanized steel in five environments *(Figure 1, page 8).*

## Value of Money Over Time

When evaluating life-cycle cost, one of the key factors is the change of the value of money over a period of time. The value of money fluctuates due to interest and inflation rates; thus, it is necessary to evaluate the impact both have over the life of an investment (project).

Money saved on the initial cost of a corrosion protection system could be invested and earn interest over the life of the project. However, selecting the lower cost corrosion protection system may lead to more substantial investment in the future to maintain the project. Maintaining the structure in the future is likely to cost more than it would today, because of inflation.

# CENTER FOR GREAT APES

CASE STUDY

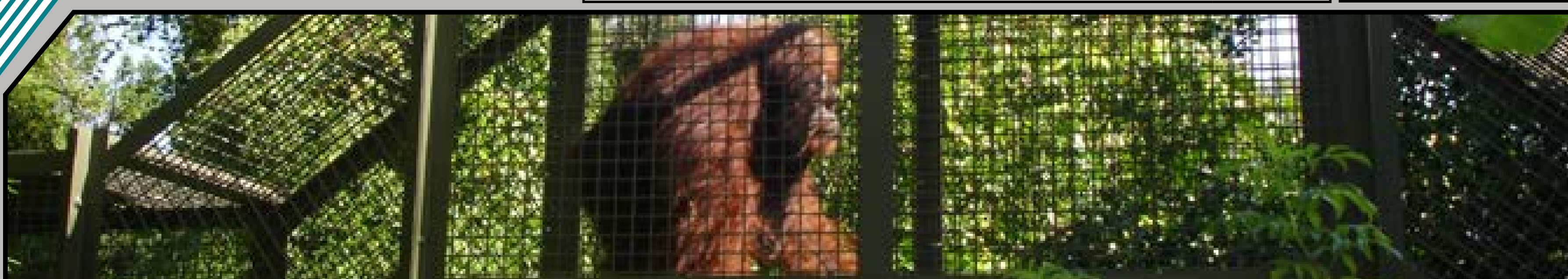
With a winding maze of chutes and walkways woven throughout the treetops, the Center for Great Apes is a charitable organization that provides sanctuary for more than 40 chimpanzees and orangutans that have retired from the entertainment industry, completed research, or were formerly kept as pets. Patti Ragan had the vision and desire to develop the sanctuary as close to natural as possible for the great apes who cannot be returned to the wild. Part of the desire to keep the enclosure as natural as possible included painting the structure to match the surroundings. However, Ragan also had to consider the humid, coastal Florida weather as well as the strength and life expectancy of the animals. The durability of hot-dip galvanized steel seemed to be a match for the safety of the animals, but a painted system could more easily blend in with the natural environment. Ragan decided to consider a duplex system of galvanizing and paint in comparison to paint alone.

When all of the factors were considered, and looking at the cost savings over the life of the structure, Ragan decided to specify a duplex system. The decreased maintenance requirement throughout the structure's life not only saves money, but saves time and causes less disruption to the animals. The upfront cost of paying for both systems will easily balance out over the life of the Center, which is important as Ragan noted, "It feels good to know these structures will be here providing sanctuary to these apes long after I am gone."

**Original Specifications:**

- 10,000 tons of steel (mix of products)
- Two-coat paint system (changed to galvanizing)

| Coating System | Initial Cost | | Life-Cycle Cost | |
|---|---|---|---|---|
| | $/ft² | Total | $/ft² | Total |
| Duplex (Hot-Dip Galvanizing + Expoxy/Polyurethane) | $5.47 | $27,350 | $14.63 | $73,150 |
| IOZ/Epoxy/ Polyurethane | $4.44 | $22,210 | $30.45 | $152,200 |
| Reduced Cost by 51% | | | | |



# CASE STUDY

## CARIBBEAN POWER PLANT

Located in Puerto Rico's corrosion-conducive environment, just 500 yards from the Caribbean's salt water, this power plant was initially specified to be painted with a two-coat system. The final fabrication and painting schedule was undetermined, because of concerns with weather variables and a debate about whether to apply the top coat in the shop or the field.

After diligent efforts by the galvanizer, fabricator, and design team, the owner reconsidered his paint specification and opted to hot-dip galvanize the steel. The steel items were a mix of heavy, medium, and light structural steel, and the project would utilize roll-on/roll-off trucking and shipping by barge. Because of the climate and delivery method, hot-dip galvanized steel had logistical advantages over the painted steel as well. The table below shows a life-cycle cost analysis (2014 data) using the specifications from the Caribbean Power Plant to give an idea of the cost savings the owner used to make his decision.

**Original Specifications:**

- 10,000 tons of steel (mix of products)
- Two-coat paint system (changed to galvanizing)

| Coating System | Initial Cost | | Life-Cycle Cost | |
|---|---|---|---|---|
| | $/ft² | Total | $/ft² | Total |
| Hot-Dip Galvanizing | $2.20 | $4,400,000 | $2.20 | $4,400,000 |
| Painting Operation | $2.23 | $4,466,000 | $7.32 | $14,640,000 |
| Reduced Cost by 69% | | | | |

The result of the owner's decision to switch to galvanizing was a win/win both economically and in scheduling fabrication and erection. The durability of hot-dip galvanized steel during shipment and erection was key to ensuring the structure's success throughout its lifetime. In the end, the owner, fabricator, and design firm all agreed the decision to galvanize the power plant's steel was the best way to deliver an operational plant on schedule and within budget. Furthermore, the owner is convinced the minimal maintenance hot-dip galvanized steel will require over the life will help limit shutdowns, and provide additional profits for generations to come.

There is a standard formula to account for these financial factors (interest/inflation), shown here:

$$NPV=NFV/(1+r)^n \text{ where } NFV=\text{current cost } (1+i)^n$$

Where: NPV = net present value NFV = net future value
r = interest rate
n = lifetime of the project
i = inflation rate

In addition to total life-cycle cost, some specifiers prefer to look at the average annual equivalent cost (AEAC), which converts the entire stream of present and future costs to a present worth (i.e. takes NPV and distributes that sum in equal amounts over the structure's life). The formula for AEAC is as follows:

$$AEAC=NPV\ [r(1+r)^n/(1+r)^{n-1}]$$

When evaluating life-cycle cost, hot-dip galvanizing has a distinct advantage because of its maintenance-free longevity. In fact, with hot-dip galvanizing, often the initial cost is the final cost. Painted steel often requires several maintenance cycles (touchup, maintenance, and full repaint) throughout a structure's life, which increases the overall cost.

Duplex systems, which utilize hot-dip galvanized steel top-coated with paint or powder, require maintenance to keep the top coat (paint/powder) intact, but the maintenance cycle is extended 1.5 to 2 times what it would be on bare steel.

## SUMMARY

Sustainable development is here to stay, and the specifiers of today shoulder the responsibility of ensuring what is built today benefits rather than burdens future generations. Many specifiers have long held the misconception hot-dip galvanizing is too expensive on an initial cost basis, and neglected to evaluate life-cycle costs. The focus on sustainability, both environmental and economic, has led to more specifiers considering the long-term consequences of their decisions.

As the costs of many corrosion protection systems has risen in the last decade, hot-dip galvanizing costs have remained relatively stable. Now, hot-dip galvanizing is often less expensive than high-performance paint systems in both initial and life-cycle costs. Do not fall victim to shortsighted decisions, but rather make the logical, sustainable choice to hot-dip galvanize for the future.

American Galvanizers Association

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