

Bridge Coating Technology Team

A primary goal of the Bridge Coatings Technology Team is the analysis, demonstration, and, where appropriate, implementation of new, cost effective and durable coatings technology. FHWA-sponsored research studies had identified metallizing as a promising technology for steel bridge corrosion protection (see tech note). However, the cost and details of the process remained as barriers to use by highway agencies. To analyze and demonstrate the potential for this technology, Illinois Department of Transportation conducted a pilot application on a replacement steel project. The FHWA Bridge Coatings Technology Team monitored and reported on the specifics of this project...

METALLIZING: THE ILLINOIS EXPERIENCE

Introduction

The construction of the Interstate highway system from the late 1950's through the 1970's created a large number of steel structures which are now reaching an age where significant maintenance or rehabilitation is required. The deteriorating condition of these bridges coupled with increasing costs for coatings work have created problems for bridge owners in determining which maintenance painting strategies are the most cost-effective. Maintenance painting is not the only major concern for bridge owners, but coating systems for new structural steel remain a high priority as the need for long term performance becomes more pronounced.

Various types of coatings have been tried on many structures, all with different degrees of success. As regulations governing the protection of the environment and workers continue to tighten, bridge owners are forced to look at new and better methods to protect and maintain their bridge inventories. Longer lasting coatings are continuing to be developed for both new steel structures and for those undergoing maintenance painting. Owners are beginning to look at coatings other than the common paint systems that have been used in the past. Galvanizing and metallizing are two options that owners have for protective coatings. However, the use of these materials has been limited due to relatively high initial costs. Bridge management concepts indicate that first costs cannot be the sole factor in selecting maintenance and coating strategies. Life cycle cost analyses are necessary in order to optimize the expenditure of funds. As a result of life cycle cost analyses, one of the coating options that is beginning to be selected more frequently throughout the country is the process of metallizing.

Metallizing is a term used to describe thermal sprayed metal coatings. For corrosion control coatings on steel structures, metallizing refers to the thermal spraying of zinc or aluminum alloys as a coating directly onto steel surfaces. The coatings are created by using a heat source (either flame or electric-arc) to melt the metal which is supplied as a wire or in powder form. An airstream sprays the molten metal onto the steel surface in a thin film. Once the metal strikes the steel it resolidifies to become a solid coating. Metallized coatings provide corrosion protection to steel by sacrificial and barrier protection. The coating itself provides a barrier between the environment and the steel surface, especially when applied in combination with conventional sealers as topcoats. Due to the electrochemical reaction between steel and zinc or aluminum in an aqueous and salt-contaminated environment, these coatings tend to "sacrifice" themselves to protect the steel at the site of any damage or holidays in the coating. This sacrificial protection is similar to the protection provided by zinc-rich primers or galvanizing.

Metallizing has been reported to be highly effective in numerous research projects and in observation of historical applications, providing greater and much longer time for protection against rust than paint systems. Many reports have proclaimed that a metallized structure will last 25 to 40 years with no need for maintenance touch-up. By contrast, standard paint systems have been reported to last only as little as 6 to 12 years with some optimistic estimates of up to 30 years using certain "high tech" paint systems. As with most anything, a much greater life expectancy and higher effectiveness also brings a higher initial cost. But as mentioned previously, life cycle cost analyses

may show that metallizing provides a lower long term cost.

A project recently completed by the Illinois Department of Transportation (IDOT) incorporated metallizing technology as an experimental feature. For this project, the structural steel was metallized in the shop then transported and erected in the field. There have been several bridge rehabilitation projects around the country which have had metallizing done in the field on existing steel, but only a few have been completely metallized in the shop. The production rates, cost concerns, logistics, handling and construction issues were looked at for this study in order to assist in determining the feasibility of and issues involved in using metallizing in shop applications.

Project Information

Metallizing was specified on the westbound I-80 bridge over US 30 in New Lenox, Illinois, which is approximately 15 miles southwest of the City of Chicago. The work on this bridge consisted of complete superstructure replacement and widening and was a part of a much larger 7.7 mile Interstate reconstruction project. The structure consists of nine spans and has a total length of 617 feet. Six of the nine spans consisted of seven lines of beams and the remaining three spans had eight lines. The beams were all curved I-beams with a depth of 33 inches. This project was let in November, 1996, started on March 17, 1997, and was reopened to traffic October 20, 1997.

The eastbound section of the same Interstate was reconstructed in 1996. That project included superstructure replacement on the eastbound bridge of the set of dual structures and had almost identical work done on it with the exception of the protective coating system. The eastbound structure was painted with an inorganic zinc coating in the shop and field coated with an epoxy intermediate and polyurethane top coat system. This system was specified to allow for a long term study of the two side-by-side bridges comparing the performance of a metallized bridge with the bridge painted with a "cadillac" paint system.

The total cost of the Interstate reconstruction project was \$18.8 million dollars. The bridge portion of the contract was approximately 13% of the entire contract. The prime contractor for the westbound reconstruction was Ganna Construction with the bridge subcontractor being Dunnet Bay. The fabricator who supplied the structural steel was Industrial Steel Construction (ISC) located in Gary, Indiana, approximately 33 miles from the project site. United States Corrosion Engineers, Inc. (USCE) conducted the metallizing operation at the fabrication plant.

Metallizing Cost

Under normal IDOT bidding procedures, a contract is developed which includes a pay item, "Furnish and Erect Structural Steel". This is generally a lump sum bid item and includes the cost of fabrication, erection as well as shop and field painting. However, in an attempt to identify the cost of metallizing alone, the contract for this project was written with a separate pay item for metallizing. This item was also required to be bid as a lump sum. An additional pay item, *Furnish and Erect Structural Steel* was then also included to pay for the cost of fabrication and erection. Three contractors bid on this project. The results of the bidding for the metallizing and furnishing and erecting of structural steel is shown in the following table.

Contractor	Metallizing	F&E Structural Steel	Total Cost
Low Bidder	\$505,000	\$650,000	\$1,115,000
2nd Low Bidder	\$200,000	\$968,200	\$1,168,200
3rd Low Bidder	\$410,000	\$827,134	\$1,237,134

As can be seen from this table, the bid for the metallizing itself varied significantly with each contractor. However, the contractors that bid low on the metallizing seemed to correspondingly raise their bids for furnishing and erecting structural steel. Therefore, it is prudent to add the metallizing and the furnish and erect bid items and compare the totals. As can be seen from the table, all three contractors were very close in their final bids. With this available data, it is difficult to get a good handle on the true costs of metallizing and additional investigative work is necessary to determine actual contractor costs.

Items that were specified to be metallized include the following:

- 74 stringers (W33X)
- 265 diaphragms (W12X and W16X)
- 360 splice/fill plates
- 332 base plates, fill plates, side restrainers

The estimated surface area of all members to be metallized was 55,000 square feet. Using the prime contractor's bid price of \$505,00, the unit cost of metallizing on this project was **\$9.18 per square foot**.

One of the problems with multiple tiers of contracting (i.e. prime contractor, bridge subcontractor, steel fabricator, and metallizer) is that each level of contractor tends to escalate price quotes to cover costs of overhead and to make some profits. As an example, on this project, the metallizer submitted a bid to the fabricator which computed to be \$4.76 per square foot. The fabricator increased this unit cost to \$5.60 per square foot for his extra cost incurred in surface preparation and additional handling. We were unable to determine how much the bridge subcontractor increased this bid item, but the final bid price by the prime contractor was almost double the metallizer's quote. Looking at the metallizer's bid price, it seems that metallizing can be cost competitive with conventional paint systems.

To further compare metallizing versus painting, the steel fabricator indicated that they would typically quote about \$2.55 per square foot for a similar bridge with three shop coats of a standard paint system. Comparing this to the fabricator's quote for metallizing (\$5.60 per square foot), it is obvious that painting is much more economical from a first cost analysis. The disparity becomes much more pronounced when comparing the prime contractor's bid price for metallizing to a typical shop painting application (\$9.18/square foot vs \$2.55/square foot).

Project Specifications:

Project specifications required that all metallizing be performed in the fabrication shop. Field touch-up work would be done as necessary after erection. All surfaces of the structural members were to be metallized except for the areas on the top flange of the I-beams where the shear studs would later be placed. No sealing of the metallized surface was specified with the exception of the outside of the fascia girders which were to receive an intermediate epoxy coat and a top coat of polyurethane, primarily for aesthetic purposes.

The surface of the steel was specified to be cleaned in accordance with the requirements of Steel Structures Painting Council (SSPC) Surface Preparation Specifications SP1 for Solvent Cleaning and SP10 for Near White Blast Cleaning. A blast profile of 50 to 100 microns (2 to 4 mil) was specified. The specifications required an angular surface profile which excluded steel shot as an acceptable final blasting media.

The metallized coating thickness was required to be 200-250 microns (8-10 mils). Each spray operator was required to be qualified according to ANSI/AWS C2.18-93. The coating was dictated to be applied in at least two passes at right angles to each other with the gun 125-230 mm (5-9 in) from the surface to ensure the metal was still plastic when it impacted the surface.

The wire used for metallizing was specified to be zinc or 85%/15% zinc/aluminum per ASTM B-833, Standard Specification for Zinc Wire for Thermal Spraying (Metallizing). The metallizing material was to satisfy the requirements for Class B or better slip coefficient and creep resistance per Appendix A of the "Specification for Structural Joints Using ASTM A325 or A490 Bolts" by the Research Council on Structural Connections. The test results for the slip coefficient were required to be provided by the contractor prior to the start of work.

A test plate was required for each batch or lot of wire supplied. This test plate was required to be approximately 300 mm x 300 mm (12 inch x 12 inch). Two locations on each beam were also required to be tested for adhesion by using a cut test. This involved cutting through the coating with a knife or chisel and determining if the metallizing or any part of it could be lifted from the base

metal 6 mm (1/4 inch) or more ahead of the cutting blade.

The specifications also required that the contractor develop a quality control program to ensure that the work accomplished complies with the specifications. The quality control program was to consist of:

1. Qualified personnel to manage the program and conduct quality control tests.
2. Proper quality measuring instruments.
3. Quality Control Plan.
4. Condition and quality recording procedures.

The entire metallizing specification is provided as Attachment A to this report.

Production Set-Up:

The metallizing contractor negotiated with the steel fabrication plant to have an entire building dedicated to his operation. The building was previously not being used by the fabricator except for some occasional painting work and storage. The agreement was for the fabricator to shot blast the steel (Wheelabrator) for initial cleaning in one building, then to move the pieces into the building used for the metallizing. That building contained a staging area, an enclosed blasting booth and another area for the metallizing operation. An overhead crane was available to handle the steel. Completed beams were stored both indoors and outdoors.

Production included moving the pre-blasted steel from the staging area into the blasting booth. The metallizing contractor then used his personnel to reblast the steel using recyclable ferrous oxide (grit). The material was #30 grade (medium) and could be recycled from 3 to 5 times. A 2-4 mil angular profile was easily obtained using this material.

From the blasting booth, the steel was moved to the metallizing area where ultimately three Thermion Bridgemaster units were used to apply the coating. After appropriate quality control checks, the steel was placed in both indoor and outdoor storage areas until delivery to the project site was necessary.

Production Rates:

The main concern that many people have with metallizing is high initial costs. These high costs have been substantially attributed to historically slow production rates. However, recent advances in equipment and technology have significantly increased production. On this project, USCE used arc spray equipment to apply 85%/15% zinc/aluminum wire. The selected wire had a 3/16 inch diameter. Traditionally, metallizers have used wire of only 1/8 inch diameter. This increased diameter allows for a much greater deposition rate provided that the power source amperage and other factors are properly set.

Another effort to increase production rates on this project was the use of production packs versus traditional spools of wire. Production packs are 500 pound packs of wire whereas the spools contain only 50 pounds of wire. Three metallizing units were used on this project and each was simultaneously fed by two production packs. The two production packs on the metallizing equipment can last up to 10 hours without the need for shut-down to change spools. Other systems require equipment shut-down once per hour or so to change spools resulting in significant inefficiencies. The manufacturer of the metallizing equipment developed a special feeder system which would allow continuous feeding of the larger wire from the coiled production packs.

Equipment set-up for the metallizing operation began on April 2, 1997. Start-up and testing began on April 9, 1997. Full production with two metallizing units began the week of April 14, 1997 and full production with three units began during the week of April 23, 1997. The operation was substantially complete by May 30, 1997. The metallizing equipment had time recorders installed so that production rates could be easily tracked. Although the entire project lasted approximately 8 weeks, the recording devices indicated actual working time on the machines was 2.56 weeks per unit (using a 40 hour work week). Using 55,000 square feet as the estimated surface area to be metallized, the total average production rate on this project was calculated to be **179 square feet**

per hour per unit.

Production Problems:

As with many projects with new techniques or equipment, this project did not proceed without its share of problems. One of the initial problems was the selection of appropriate power sources. The contractor experienced a great deal of difficulty early in the project with inadequate power sources causing an unacceptable coating. On one particular day, the contractor had to shut down production up to 25 times due to various problems. After some trial and error, the contractor managed to find a proper power source which allowed for more efficient metal deposition and increased quality.

An additional problem on this project was delays induced through handling of the steel members. Communication problems between the metallizing contractor and the fabricator caused significant delays in the handling of steel. USCE expected that the fabricator would handle all the steel in a timely and coordinated manner so that the actual metallizing would not have to be significantly interrupted. However, as the project went on, confusion existed as to who was supposed to handle the steel from delivery through the blasting booth, to the metallizing area and to final storage. Often times, the metallizing contractor had to pull his men off of the metallizing operation to handle and move steel members. It was estimated by USCE that 50% of production time was lost due to handling problems.

A third problem that was not as significant was the fairly large quantity of overspray on this project. It was estimated that approximately 30% of the zinc/aluminum material was lost due to overspray. Much of the overspray material was collected off of the floor and equipment and sent to a recycler. The problem with the overspray is when the applicator metallizes the top half of the beams, some of the overspray material settles on the bottom flange. Then, when the applicator returns to the bottom flange to apply additional material, the overspray material can interfere with the proper adherence of the additional coating. Care is therefore necessary to complete the metallizing of the bottom surfaces prior to metallizing the top half of the beams. An alternate to this would be to ensure that the beams are kept clean by compressed air or other means. An additional problem with the overspray is some of the health concerns associated with inhaling zinc/aluminum particles. Although the vast majority of the oversprayed material settles to the ground immediately, there is still a problem with the smaller particles being constantly suspended in the air. The applicators and inspectors must deal with this problem day after day and continual exposure can put workers at risk if precautionary measures are not taken.

Quality Control Personnel and Testing:

As required, USCE provided a QC manager responsible for testing and inspection during the entire metallizing process. A comprehensive quality control manual was submitted which was approved by IDOT. The QC program included a procedure for **daily** testing of the equipment and the applicators by requiring blast cleaning and coating of qualifying coupons. The coupons were evaluated for proper mil thickness and then bent 180 degrees around a 0.50 inch mandrel in a hydraulic bending test machine. The bend test passed if there was no cracking or only minor cracking visually observed on the bend-radius. The bend test failed if the coating cracked and could be "picked off" with a knife blade.

Quality control sheets were completed for the various structural members. Each stringer had an individual QC sheet completed (74 sheets total). Each row of diaphragms had a QC sheet (41 sheets total). Splice plates required 7 QC sheets and miscellaneous pieces required another 3 sheets. The QC sheets included equipment usage, anchor profile readings, coating thickness readings, results of adhesion tests and other general data. A quick review of the quality control data sheets showed that all specifications were satisfied and the coating thickness of 8 to 10 mils was obtained.

The Illinois Department of Transportation also had an inspector on site who was responsible for quality assurance testing. This inspector reviewed and signed off on the quality control reports and also performed some additional independent testing.

Field Handling and Erection:

Since the steel was metallized in the shop and transported and erected in the field, the main concern which this project presented which has not been explored in other studies was whether the handling of the steel would damage the metallized surface. After metallizing, many of the beams were stored outside on timber blocks. After erection, the locations of these blocks were evident from the marks left on the bottom of the flange. However, these areas were not found to have the metallized surface gouged or peeled off in any way. It simply created a nonaesthetic marking which could have been prevented by using padded blocks.

The beams were transported to the job site and unloaded using a typical metal lifting claw. This claw was also used in picking the beams up during erection. Upon inspection of five or six beams, it was found that only one had a small (1-2 square inches) area on the edge of the top flange where the metallized coating was damaged due to the metal claw grabbing the beam. Numerous sets of diaphragms were observed to be moved using a choke chord and none of these displayed a damaged coating, only a surface which was slightly abraded.

The specifications did not dictate the use of special pads or precautions in the handling and erection of structural steel. Ironworkers at the site expressed concern that requiring padding or other protective measures may cause problems with the ability to hold the beams properly. Ironworkers were generally in favor of the rougher surface which afforded higher friction than painted surfaces.

The surfaces of the beams appeared mottled after a relatively short time outside due to spray patterns and nonuniform oxidation. It appeared very difficult to produce a surface uniform in appearance. However, the exterior surfaces of the fascia beams were painted so this did not greatly affect the overall aesthetics of the bridge. If aesthetics is a major concern, it is recommended that a seal coat be considered for all surfaces.

Since the area of the top flange where the shear studs were to be placed was not metallized, this surface oxidized quickly. Rust stains were observed to be transferred to the metallized surfaces from water transport and from normal operations of the ironworkers. Occasionally, this rust staining made it difficult to tell if the metallized coating had a deficiency in it. Usually, upon further inspection of an area of rust, it was discovered to be oxidized matter transferred from the shear stud area.

Parallel bridge observations:

As mentioned previously, a primary reason that this location was selected for Illinois' first metallizing project was that a parallel bridge was built the year before that would provide an excellent comparison between two protective coating systems. IDOT developed an experimental work plan for this project which will compare performance of the dual bridges over a period of at least 5 years.

Recent field reviews showed that the eastbound structure with the inorganic zinc/epoxy/polyurethane system was performing very well. The only problems that were noted were at a few elastomeric bearings where the paint was damaged due to normal expansion/contraction of the structure.

It is too early to make a good comparison of performance between the two structures, but we were able to determine some cost comparison between the two systems. Because the eastbound (painted) structure was bid using IDOT's standard practice, the cost for painting was incorporated into the bid item, "Furnish and Erect Structural Steel." Direct painting costs, therefore, could not be readily determined. The westbound (metallized) structure was bid using a separate bid item for metallizing so reasonable cost data could be obtained.

Another problem with the cost comparison was that the amount of surface area of steel to be coated was not exactly the same for both structures. Because the eastbound structure had some additional width due to an exit ramp, additional lines of beams were necessary. The basic configuration of the two structures were very similar (same beam sizes, diaphragms, etc.); however, the weight of the structural steel for the eastbound structure was estimated to be 980,300 pounds

while the weight for the westbound structure was 874,950 pounds.

In order to derive a reasonable cost comparison, it was necessary to compute the cost per pound for furnishing and erecting structural steel including the protective coating. Using this method, the cost comparison is as follows:

Furnish and Erect Structural Steel (including protective coating)

Eastbound Bridge (Painted):	\$0.97 per pound
Westbound Bridge (Metallized):	\$1.32 per pound

On a per pound basis, it appears that the metallizing costs approximately 36% more than the painting (prime coat - shop, intermediate and top coats - field). It is important to note that economies of scale may play a part in this unit cost. That is, since the eastbound structure had more steel (12% more), the contractor may have been able to provide a lower bid for furnishing and erecting structural steel. It is also important to note that these bridges had different contractors and different contractors tend to weight their bids for various items depending on their circumstances. Therefore, true costs may not necessarily have been reflected in the bids for these items.

Conclusions

Illinois' first metallizing project was considered to be successful. Although there were some production problems, the new equipment that was used showed that metallizing can be done much faster than in the past. The quality of work seemed to be very good. There is some problem with a non-uniform surface appearance, but all specifications were proven to be satisfied and good performance is expected. Sealing of only the outside of the fascia girders helped to solve the possible aesthetics problem since the public will only see the fascias.

This project showed that the cost of metallizing is still too high to compete with traditional paint systems if first cost analysis is used. The bid price of \$9.18 per square foot versus \$2.00-\$2.50 per square foot for painting tends to lean owners away from the metallizing option. However, if life cycle costing is used as recommended through bridge management concepts, metallizing can be proven to be advantageous. The estimated service life of 25-40 years without the need for touch-up can certainly compete with painting systems provided life cycle costs are considered.

Illinois' experimental project comparing the parallel structures will help assess the field performance of metallizing versus painting in a true side-by-side comparison. It may be many years before a judgement can be made on the ultimate performance of these materials, but in the mean time, it was shown that metallizing can be performed very successfully in the shop with good production speeds and can compete with traditional paint systems in certain applications. Owners need to consider this technology as an effective strategy for maintaining their bridge inventories.