Galvanizing Reduces Bridge Rail and Guardrail Maintenance in Michigan

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• THE MICHIGAN State Highway Department operates and maintains a trunkline system of some 9,200 centerline miles. The roads vary from 2-lane 20-ft widths to 4, 6 and 8 lanes in certain urban areas of heavy traffic concentration. Two thousand miles of this system, 50 percent completed, is in freeways consisting of Interstate and arterial highways. Most of the freeway mileage is in the form of limited-access highways, which consist of two widely divided, 24- or 36-ft paved strips, each carrying one-way traffic only.

At present this system includes about 2,500 bridges (3,000 when current construction is completed in a few years), all of which conform to the standards of the American Association of State Highway Officials. According to Michigan classification, a "bridge" starts at a 20-ft span.

BRIDGE RAILINGS

The bridge railings, like the bridges, vary widely in concept, structure, and basic construction materials. Stone, precast concrete, ornamental ironwork in numerous configurations, and aluminum, are serving as the protective bridge railings. Most iron bridge railing has in the past been specified as black steel which, having the necessary inherent factors of strength and impact resistance, has served well. Approximately 53 miles of railing of this type are currently being utilized.

Protection of this bridge railing from weather corrosion has involved substantial maintenance. Speaking generally, the steel railings called for repainting every three years. They were not necessarily painted every three years, but this was the cycle which experience indicated as most desirable.

Sandblast cleaning was impractical, considering the openwork design of the railings. Therefore, the steel was cleaned with power-operated and hand brushes and scrapers. Spot priming, and even complete repriming with a top quality red lead primer, was followed by a surface coat of aluminum paint.

Prior to World War II the total cost for repainting these railings was about $1 per linear foot. After the war, as wages and material costs rose sharply, maintenance costs for bridge rail repainting began to run as high as $3 and $4 per foot. One pilot job of railing painting performed in October 1962, primarily for reporting in this paper, and typical in respect to condition of protective coating, cost $4.45 per linear foot. Some 80 percent of the total cost, of course, was in the cleaning and preparation of the surface before painting. For 50 miles (264,000 ft) of steel bridge rail at $4.00 per foot, $1,056,000 would be needed every three years (or $352,000 a year) for painting bridge rail.

In 1956 one section of bridge rail was cleaned and hot-dip galvanized to study its corrosion endurance as compared to that of painting. After two years of exposure no deterioration was visible, although paint of similar age would have begun to show considerable signs of failure. Accordingly, the rails of the entire bridge were galvanized. A steel fabricator, under contract, removed the railings, trucked them to a hot-dip galvanizer where they were cleaned and galvanized to a 5-mil or 3-oz specification, returned them to the bridge, and reinstalled them. The contractor also erected temporary pipe rails as a safety precaution while the permanent railings were being galvanized.

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The cost ($8.50 per foot) was not economical, but analysis of the operation showed many steps which could be taken to lower the costs approximately one-half, as discussed later.

This bridge was inspected periodically during three years to provide performance data (actually 6 years of exposure in the case of the single section of railing that had been galvanized in 1956). Observations throughout this period, when paint would have failed, gave convincing evidence that galvanizing offered excellent service life. No surface deterioration was observed during this period. Consequently, in 1961 galvanization of bridge railings was adopted as a basic maintenance program throughout the State.

Current costs come to $2.25 a foot for the stripping and galvanizing with approximately $3.00 a foot to be added for the operations of removal, trucking, return, and re-erection. Regular highway department crews and trucks are used for this work. The temporary safety railings erected during the work consist of old cable guardrail supporting snow fencing. The work is done largely in the colder months of the year when structure maintenance is at a minimum and personnel are most readily available. Safety was naturally a principal consideration during the period when temporary railings are in place, but experience indicates that the incidence of bridge impacts by cars is actually lower in winter months than in summer. Apparently, greater driver care and attention is enough to offset the often more dangerous driving conditions.

Alternatives to provide satisfactory protective coatings have been tested. One bridge was metallized with aluminum; but the cost was high, minute rust pock marks developed at an early date, and some peeling of the coating is taking place. Epoxy resin paints were also tested, but spot failures began to appear after only one winter's exposure.

GUARDRAIL

A change in organizational structure of the Michigan State Highway Department brought bridge maintenance and highway maintenance together in one organization in 1959, at which time the analysis applied to protecting bridge rail from corrosion was extended to include highway guardrail. The department used black steel plate guardrail approximately two years before changing to galvanized beam. In these two years 25 miles of guardrail were constructed. Of this length, approximately 75 percent has been recoated with hot-dip galvanizing. Currently all new guardrail is of steel, hot-dip galvanized before fabrication.

Originally, maintenance of guardrail consisted of cleaning with hand tools such as wire brushes and scrapers. This was followed by one coat of good red lead primer and a top coat of white paint. Repainting of guardrail was required on a shorter cycle than that required for bridge rail. Owing to the concentrated exposures to salt in snow and slush and to the physical impact of snow removal equipment, normally guardrails needed repainting every one to two years.

The cost of painting guardrail was most recently $0.40 a foot. The cost of galvanizing is about $0.30 a foot, with the cost of removing, trucking and replacing adding another $0.20 a foot. In at least one district, galvanized guardrail is installed on a rotating basis to replace the guardrail being removed for galvanizing, thereby avoiding double handling and the need for temporary protection.

CONCLUSIONS

As a result of experience to date, the Michigan State Highway Department now purchases no steel bridge rail for maintenance purposes or highway guardrail which is not hot-dip galvanized. The latest design of bridge railing uses a one-tube galvanized steel rail over a 22-in. parapet wall, making an overall railing height of 36 in. Inspections of galvanized guardrail over a 4-year period have shown no surface deterioration, as compared to the 1- to 2-year life expectancy of paint systems. In the future, it is planned to protect all highway guardrail and bridge rail by regalvanizing when it becomes necessary. The anticipated service life is not known precisely, but 8 to 10 years is expected for highway guardrail and 12 to 15 years for bridge rail. Perhaps galvanizing may have a part in other areas of the department's operation. For example, a highway bridge in which a 34-ft span is protected by hot-dip galvanizing is currently under exposure test. If exposure results warrant, it is hoped to adopt this form of protection for large structural bridge members.

Another area of promise for large structural steel beams may lie in the field of metallizing with zinc.

Rising prices have brought painting and hot-dip galvanizing to roughly comparable cost ranges for initial application. Because the service life expectancy of galvanizing is in the nature of four or five times that of paints, there is little question as to the desirability and the substantial savings to be expected from the decision to drop painting in favor of galvanizing in the maintenance program.

Discussion

JOHN R. DAESEN, Director, The Galvanizing Institute, Park Ridge, Ill. —Highway engineers will find Mr. Cardone's report of the satisfactory and economical use of hot-dip galvanizing for protection of steel bridge rail and guardrail of value. This discussion is meant to provide additional information regarding the life expectancy of the coating and the most feasible and economical methods of maintenance.

The life will depend largely, but not entirely, on the weight of coating. Most of the bridge rail and guardrail hot-dip galvanized after fabrication is specified to carry a minimum average coating of 2 oz per square foot of surface (equivalent to 3.4 mils thickness) in accordance with ASTM Specification A-123. With such a coating in a moderately industrial atmosphere a life of at least 20 years may be expected before the first appearance of rust of the base, rather than the 8- to 15-year life mentioned by the author. Complete failure of the coating might be expected no sooner than about twice the time to first rust. This presumes no conditions of continuous immersion in water.

It is noted that Mr. Cardone's department specifies guardrail of steel hot-dip galvanized before fabrication. Aside from differences in chemical composition and structure of this type of coating, as contrasted with the galvanized after type of coating on which the Michigan Highway Department experienced such fine results, the galvanized before fabrication material is often furnished to meet ASTM Specification A-93 with a much lighter weight of coating. The highest weight class of A-93, 2.75 oz (pot yield) per square foot of sheet, not surface, has a minimum weight, determined by averaging two sides of a 5.06-sq in. test sample, that is only 1 oz per square foot of surface, or one-half that of the weight required under ASTM Specification A-123.

Assuming that this heaviest class of coating under A-93 is used, the life to be expected from this galvanized before fabrication material is one-half that of the galvanized after fabrication, meeting ASTM Specification A-123. As Mr. Cardone's figures are in line for cost of guardrail galvanized after fabrication, highway officials will find it profitable to examine this difference closely.

The weight difference is not the only important difference, however. Some recently produced 0.109-in. (12-gage) steel guardrail, galvanized before fabrication and exposed only a few months, although still exhibiting the spangles and lustre, have many fine pits in the surface. The source of this unsoundness of surface is found to be oxide inclusions in the coating, originating from the use of a higher amount of aluminum (0.05 percent or more) in the galvanizing bath than is used or permitted in ASTM Specification A-123.

The structure of the coating on ¼-in. steel galvanized after fabrication discloses that the zinc-iron alloy layers that bond the outer zinc layer to the steel base are very prominent in the galvanized after coating, but are greatly reduced, and in some areas almost entirely lacking, in the galvanized before product. This is the principal difference in the structures of the two products.

The practical elimination of the intermediate alloy layer promotes ductility to permit severe forming, such as bending or seaming, and most of the thin gage strip galvanized in continuous coils is made using an increased amount of aluminum to practically inhibit formation of the alloy layer. Such ductility is not needed, of course, in guardrail, where material with substantial alloy layers with a coating 3.4 mils thick has completely adequate ductility to permit moderate bends or straightening out after distortion by impact.

The alloy layers of galvanized after fabrication coatings tend to maintain uniformity of thickness of coating, because their growth by diffusion in the bath is regular and controlled by time and temperature of immersion in the galvanizing kettle. The bulk of the coating on the material galvanized before fabrication, which contains enough aluminum to greatly restrict formation of the alloy layer, is controlled largely by drainage of molten zinc from the work. It is for this reason that coatings containing enough aluminum to greatly restrict alloy formation (0.05 to 0.15 percent) are seldom produced with weights of coating in excess of 1 oz per square foot of surface.

The coating on 0.036-in. (20-in. gage) steel sheets galvanized by the older process, in which aluminum in the molten bath was kept at a value of 0.01 percent or less, is broken up by more massive inclusions, in this case of flux, resulting from entrapment of the molten flux particles on the sheet. At the high speed of travel of these sheets through the galvanizing bath, there was much less time for this material to wash off, as compared with the longer time of immersion in the hot-dip galvanizing of structurals, or guardrail or bridge rail galvanized after fabrication. The fact that many of these flux inclusions open up to the surface of the sheet explains why these sheets were darkly stained although never exposed out-of-doors.

The thin discontinous alloy layer on the 0.109-in. gage guardrail, compared with that of the 0.036-in. and ¼-in. gage material, indicates an aluminum content of about 0.05 percent in the galvanized before fabrication guardrail, a value which neither completely inhibits the formation of alloy nor allows it to grow at the normal rate. The rapid destruction of the flux, with attendant problems of oxide inclusions, is the reason why aluminum contents of this magnitude are prohibited in ASTM Specification A-123 (aluminum 0.01 percent maximum).

These defects have their effect in reducing the life of the coating and causing unattractive darkening of the surface. The photomicrographic evidence is shown, not to prove relative quality, since good and less desirable structures may be found in all manufactured materials, but to explain differences that occur on test and in use that otherwise might be erroneously charged to mere spread of values, inevitable in production operations. It will be seen that such structural differences are related to differences in manufacturing practices used in producing the two types of materials.

Although Mr. Cardone indicates that the Michigan Highway Department anticipates regalvanizing the bridge and guardrail when necessary, it will probably be found, that after the coating has gradually weathered away so that the corrosion product turns tan or brown, indicating that the zinc-iron alloy layers are gradually dissolving, it will be in order to paint the rail.

The objection to high cost of painting will not apply here, because there will have been no pitting of the steel and preparation will consist only of hand brushing instead of expensive sand blasting. A treatment by phosphate coating or a coat of wash primer is required before applying the paint unless the paint is a zinc-dust paint, a cement-base paint, or the new calcium-ortho-plumbate type.

Such pretreatment is even more necessary when galvanized structures are painted (for reasons of visibility or appearance) when they are first installed. The adherence of paint coats is affected by differences in the type of galvanizing (low or high aluminum content) and the type of steel base. White specks of zinc oxide are sometimes formed with the gray basic zinc carbonate in normal weathering of zinc or sound galvanizing. Failure of the paint coat to adhere can often be laid to improper selection or application of preparatory treatment, as the metal base remains normal.

The roughness of galvanized coatings is sometimes the result of differences in the steel base, although rough galvanizing can occur on any base improperly handled. Pits due to rough galvanizing may "fester," lifting the paint coating and causing failure. Dark staining on the weathered galvanized surface shows the effect of these pits.

Paint producers have given increased attention to providing for differences in the type of galvanized coatings. They can provide foolproof systems for use on coatings of any type of manufacture, but the type of galvanizing must be considered and the coating must be sound.