OFFICE MEMORANDUM

MICHIGAN
STATE HIGHWAY DEPARTMENT
JOHN C. MACKIE, COMMISSIONER

September 4, 1963

To: W. W. McLaughlin
Testing and Research Engineer

From: E. A. Finney

Subject: Rusting of Cadmium-Plated Bolt Assemblies on Bridge Railings. Research Project R-63 G-130. Research Report No. R-433.

A memorandum from N. C. Jones to W. W. McLaughlin, dated May 29, 1963, forwarded to the Research Laboratory Division for action, inquired about rusting of cadmium-plated anchor bolts, nuts, and washers on three Southfield Expressway bridges. Advice was requested as to whether the use of cadmium-plating should be eliminated in favor of galvanized bolts, or heavier cadmium plating should be specified to secure better corrosion resistance.

Investigation of this problem was conducted in two phases: a literature review and a field inspection. In addition to cadmium plating and galvanizing, the possibilities of using aluminized and/or aluminum fasteners were considered. The following summary is reported by Paul G. Gray.

Literature Review

Review of the literature began with examination of appropriate chapters in a major text, Burns and Bradley's Protective Coatings for Metals (1). This led to study of a report of tests conducted jointly by the International Nickel Co. and the Bell Telephone Laboratories (2), using different thicknesses of cadmium and zinc coatings in different types of environments. These tests showed that for the same coating thickness, zinc was relatively superior to cadmium in most industrial areas, while in severe marine environments the cadmium was better by a substantial margin.

ASTM Standard A 153 for zinc coatings on hardware is applicable to the type of fasteners used in anchoring bridge railings, and calls for a minimum coating thickness

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1. Burns, R. M., and Bradley, W. W. "Protective Coatings for Metals." New York: Reinhold Publishing Corp. (2nd Edition, 1955). ACS Monograph Series No. 129.

2. Sample, C. H., Mendizza, A., and Teel, R. B. "A Comparison of the Corrosion Behavior and Protective Value of Electrodeposited Zinc and Cadmium Coatings on Steel." ASTM Special Technical Publication No. 197 (1957), pp. 49-65.

of approximately 1.7 mils. ASTM Standard A 165 for electrodeposited coatings of cadmium on steel specified a thickness of 0.5 mils for type NS cadmium. However, these standards recognize that circumstances may exist where heavier cadmium coatings are required.

In connection with possible use of aluminum fasteners, an Alcoa Research Laboratories report (3) indicates that aluminum alloys exhibit good resistance to alkaline building products provided that certain protective measures are taken. An Alcoa pamphlet on aluminum highway railings (4) gives typical specifications including those for aluminum fasteners.

Use of aluminum coating (hot dip) on steel fasteners and hardware was also considered. A Bethlehem Steel Co. publication (5) reports tests of zinc versus hot-dip aluminum coatings, which showed a marked superiority for the hot-dipped aluminum process.

Field Inspection

The first bridge inspected was B02 of 82192D, carrying M 39 (Southfield Expressway) over the Rouge River. Railings here had been exposed 8 months (since November 1962). There was practically no rust on the anchor bolts, nuts, and washers, although one slightly rusted washer was noted. However, all nuts were rusted on the bolts holding together the aluminum pipe railing sections (Fig. 1); bolts for these splices were not rusted.

The next bridge inspected was B01 of 82192A, carrying M 39 over Ecorse St. in Allen Park. Records indicated that the railing fasteners here also had been in place about 8 months. There was no rust on the washers or threads, and the railings here had not required splicing. Nuts on the anchor bolts on the west railing (southbound bridge) were all rusted, as were about half those on the east railing (northbound bridge), and all those on the northbound service road railing. One nut was rusted on the west railing of the southbound service road, and two on the east railing.

S21 of 82022 at the M 39 interchange with I 94 exhibited the most severe rusting encountered. In 13 months since railing erection, all washers and nuts had rusted, in most cases over the whole surface (Fig. 2). Some threads also were rusted.

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3. Walton, C. J., McGeary, F. L., and Englehart, E. T. "The Compatibility of Aluminum with Alkaline Building Products." Alcoa Research Laboratories (1957).

4. "Alcoa Aluminum Highway Railings for Bridges and Roadways." Alcoa (1957).

5. "Why Bethalume Coatings Keep Fasteners on the Job." Bethlehem Steel Co. (undated).

These three Southfield bridges were in the same general area and environment, which did not appear to contain any unusual corrosive gases such as those containing surfur. Railing drawings specified ASTM A 165 type NS cadmium coating, which is 0.5 mils in thickness. The electroplater said that this had been the thickness applied, although there is no indication that this was checked during construction.

In addition, two pedestrian bridges over the Edsel Ford Expressway in Harper Woods, constructed in 1959, were also inspected, located at Woodland Drive (B3 of 82510) and Woodmont Ave. (B5 of 82510). Nearly all nuts and washers had varying degrees of rust (Figs. 3 and 4), although railings were rust-free.

Finally, an experimental installation of four aluminized (hot dip) anchor bolts on Bridge B2 of 23-6-4 (Willow Hwy. Overpass over I 96) were resurveyed. Fasteners here had been exposed approximately 28 months. The four aluminum coated fasteners showed no appreciable rust, but the remaining fasteners on the bridge, which were confirmed to be cadmium-plated by means of chemical tests, had severely rusted washers.

Conclusions and Recommendations

From the field observations it is apparent that cadmium-plated coatings on fasteners as furnished for Departmental construction have a shorter protective life than galvanized coatings, in the type of environment encountered in most Michigan urban areas. The poor performance of cadmium coatings may result from inadequate thickness, but determination and control of such coatings is particularly difficult to obtain on fasteners. Galvanized coatings for fasteners, while having a longer life than cadmium coatings, appear to rust after a few years of exposure. From the limited field survey and on the basis of a limited experimental installation, it appears that the hot-dipped aluminized coating may out-perform both galvanized and cadmium-plated coatings. On the basis of the study, it is recommended that:

1. Aluminum fasteners be specified for connection of aluminum tube railings, and for post-to-rail connections on aluminum rail assemblies.

2. Hot-dip galvanized coatings rather than cadmium coatings be specified for anchor bolts, and for other fastenings for steel railing assemblies.

3. Controlled experimental field tests be expanded to include additional bridges besides the Willow Hwy. overpass previously mentioned, for comparative performance evaluation of hot-dip aluminum versus galvanized coatings on

anchor bolts and other fastenings on bridge rail assemblies. Aluminum alloy bolts should also be included in the evaluation, for possible use on parapet-type aluminum railings. Detailed recommendations concerning bolting alloys and protection of aluminum bolts during concreting operations will be made for any such trial installation.

OFFICE OF TESTING AND RESEARCH

E. A. Finney, Director
Research Laboratory Division

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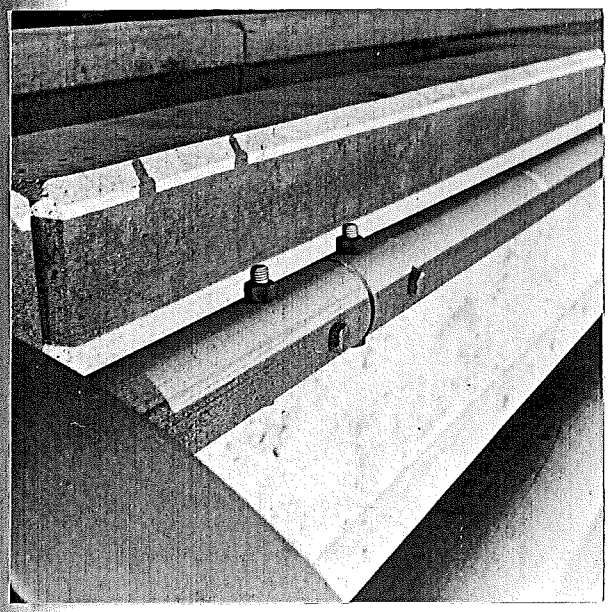

Figure 1. Rusting of cadmium-plated nuts on Bridge B02 of 82192.

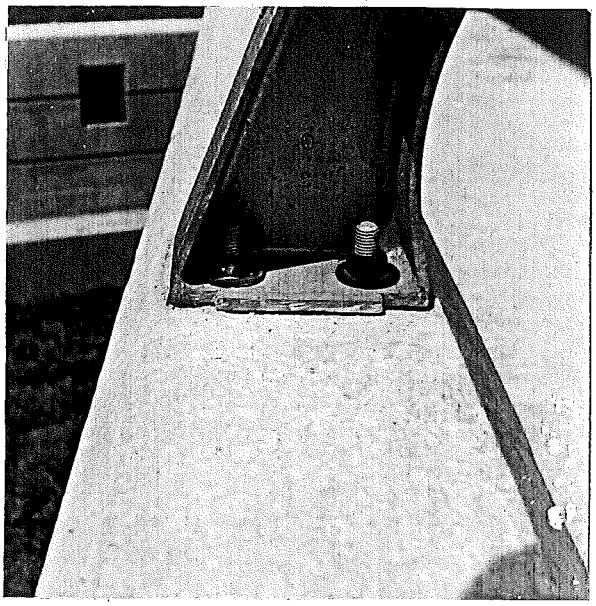

Figure 2. Rusting of cadmium-plated nuts and washers on Bridge S21 of 82022.

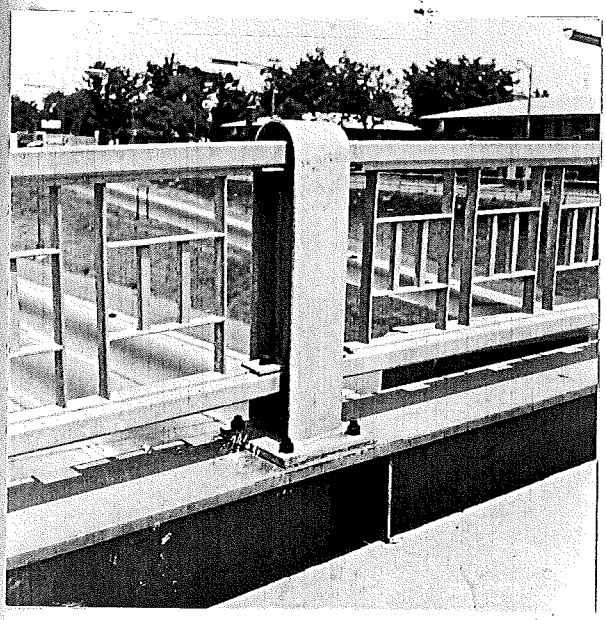

Figure 3. Rusting of galvanized fasteners on galvanized rail of Pedestrian Bridge B5 of 82-5-10.

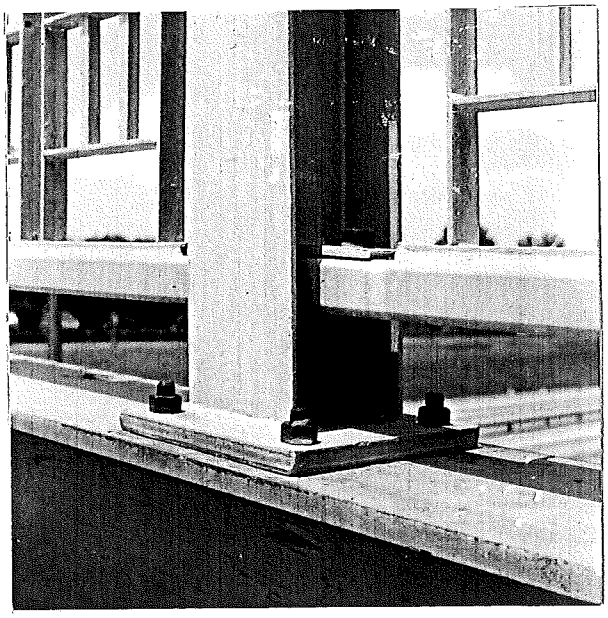

Figure 4. Detailed view of rusting shown in Figure 3.