OFFICE MEMORANDUM

MICHIGAN
DEPARTMENT OF STATE HIGHWAYS

July 14, 1972

To: L. T. Oehler
Engineer of Research

From: J. T. Ellis

Subject: Corrugated Metal Pipe Culvert Disintegration, I 75, Mackinac County
Research Project 72 TI-106, Research Report No. R-824.

In accordance with P. J. Marek's request of June 7, 1972 to investigate the corrugated metal pipe (CMP) culvert disintegration on I 75 in Mackinac County the following items have been accomplished.

1) On June 13, 1972, along with C. V. Iansiti of this Laboratory, I met with Mr. Sweeney of the St. Ignace Maintenance Garage to see the removed section of the badly corroded CMP culvert from Sta. 616+75. As noted in O. F. Eichen's letter of June 6, 1972 to P. J. Marek, several square feet from the bottom of one end and from the top of the opposite end of the culvert were disintegrated (Fig. 1). The remainder of the culvert section was very rusty and quite thin in spots. Mr. Sweeney showed us the site (Sta. 616+75) where the culvert section had been removed and replaced with a section of 15-in. diameter CMP culvert. During the balance of June 13 and on the morning of June 14, we inspected the remaining culvert sections at Sta. 616+75 and all other culverts in the immediate vicinity starting with the culvert at Sta. 603 and continuing north to Sta. 775. Also, several other culverts as far north as Sta. 898 about four miles south of M 28, were inspected. In addition to the CMP culverts, several concrete culverts immediately south of the damaged culvert area were inspected. The inspection consisted of crawling into the culverts as far as possible, probing the bottom with a sharp geologist hammer, observing the visible area with a strong flashlight, photographing damaged areas, and performing on-site pH measurements of the water traversing many of the culverts.

2) Samples of water and soil were returned to the Laboratory for more complete chemical analysis.

3) Several people outside the Department were contacted for information and recommendations.

The findings of the inspection, results of field and laboratory analysis of the water and soil samples and information obtained from those outside the Department are as follows:

Visual Inspection

Three culverts at Stations 603+00, 616+75, and 626+00 were found to be perforated (i.e., the pipe eaten through by corrosion). The following summarizes the condition of these pipes.

Sta. 603+00 - The east end of the culvert under the northbound I 75 lanes had one large hole approximately 12 by 6 in. and several smaller holes up to about 1 in. in diameter (Fig. 2). The remainder was quite rusty with much of the galvanizing removed. The culvert under the southbound lanes appeared to be solid, without serious attack, but much of the bottom was obscured under about 12 in. of muck and water.

Sta. 616+75 - The east end section under the northbound lanes had been replaced with a 15-in. diameter CMP. The west end section under the northbound lanes (Fig. 3) and the east end section under the southbound lanes had several holes ranging up to about 5 in. in diameter. The remaining sections under both the northbound and southbound lanes were quite rusty with much of the galvanizing removed.

Sta. 626+00 - The east end section under the northbound lanes had two holes about 6 by 3 in. in the bottom and lower side. The east end under the southbound lanes had one 3-in. diameter hole in the side. At the west end of the culvert under the southbound lanes, backfill soil had settled several feet forcing the culvert down about 3 in. below the headwall, causing partial collapse of the culvert so that about 2/3 of the original opening remains (Fig. 4).

Other culverts, as far north as Sta. 889+30 (about four miles south of M 28), showed various degrees of corrosion attack. Some culverts were quite rusty with large areas of galvanizing removed while others were in good condition with only slight rusting at plate joints and on rivet heads. Several culverts contained considerable amounts of stones and gravel and showed signs of abrasion as indicated by worn or removed galvanizing on the upstream side of the corrugations. The abrasion probably occurred during periods of high water when the current flow was swift.

Several concrete culverts in the area immediately south of the perforated CMP culvert area showed no significant sign of deterioration and are performing satisfactorily.

Chemical Analysis

The pH of the water and soil samples were measured immediately upon returning to the Laboratory. The water samples and water soluble extracts of the soils were further analyzed for chlorides, copper, iron, sulfate, and calcium (Table 1). All pH values were found to be in the near neutral range

TABLE 1
CHEMICAL DATA

Station No.	Soil					Water				
	pH	Chloride ppm	Sulfate ppm	Calcium ppm	Iron ppm	pH	Chloride ppm	Sulfate ppm	Calcium ppm	Iron ppm
603+00*	7.9	56	752	317	<1	7.7	4	1,070	260	<1
616+75*	7.1	68	5,433	1,770	<1	7.5	46	922	256	<1
626+00*	7.4	50	1,452	798	<1	7.5	20	679	270	<1
[illegible]	6.1	65	1,942	566	<1	---	--	----	---	--
700+00	6.6	128	2,573	580	3	6.5	40	-0-	156	<1
772+00	6.7	447	7,607	5,806	<1	---	--	----	---	--
865+50	7.6	57	2,691	267	<1	7.8	18	8	150	<1
1080+00	8.1	18	56	240	<1	7.8	107	21	172	<1

* Perforated culverts.

of 6 to 8, indicating that neither the soils nor the water samples were significantly acidic or alkaline. No copper or significant amount of iron was found in any of the soil or water samples. One soil sample (Sta. 772+00) had a moderate amount of chloride. Relatively large amounts of calcium and sulfate were found in both the soil and water samples at several culvert sites. It is not suprising that calcium and sulfate are present in the clay type soil of the area since clays often contain gypsum, a naturally occurring form of calcium sulfate. Sulfate solutions are known to be very corrosive to zinc. It has been reported that the corrosion rate of zinc is 22.2 mil/year in a 1 percent quiet unagitated sulfate solution.[1] Galvanized CMP has a zinc coating thickness of about 1.7 mil/side. One of the water extracts of the soils yielded a 0.8 percent sulfate solution and several others yield 0.2 to 0.5 percent sulfate solutions. Three of the water samples, from Sta. 603+00, 616+75, and 626+00 (the perforated culverts) were equivalent to sulfate solutions ranging from 0.07 to 0.11 percent. While most of the sulfate values found in the soils and waters are somewhat less than the highly corrosive 1 percent sulfate solution reported above, the sulfate containing soils are often in direct contact with culverts, and the waters are not unagitated but highly aerated, rapid flowing, and abrasive. This combination of direct contact between culverts and sulfate bearing soil, and flowing-aerated sulfate-containing water would likely be a very corrosive environment to CMP.

[1] Corrosion Resistance of Metals, ACS Monograph No. 158, p 235.

Comments of Outside Contacts

Mr. George Stemac, Northern Michigan Pipeline Co., confirmed earlier information that his company was having a similar corrosion problem with their gas pipe in this area. Mr. Stemac offered the following additional comments. a) The corrosion problem is most critical in the area from M 123 north to the Pine River. b) A similar problem exists near Escanaba. c) The corrosion is caused by acid soils and waters. d) The Cathodic Protection Service in Houston, Texas has performed a complete chemical survey of the soil in the area and he has a copy of their report in his Escanaba office and will send it to F. LaTocha, Utility Engineer at Newberry, as soon as he returns to Escanaba (this report was never received). e) Magnesium anodes attached to the pipe at the rate of four per mile has solved their problem and he is convinced they would stop the corrosion of our culverts. f) He thought one anode on each end of the culverts would be sufficient and he would be willing to install a few for us for testing.

Mr. Ronald Hall, an engineer with the Cathodic Protection Service Co. in Houston, Texas supplied the following information via telephone. a) His company does not conduct pH or chemical measurements on soil. They do perform soil resistivity measurements, but to his knowledge they have never performed any such measurements in Michigan. However, he said it was possible that their Denver, Colorado branch could have worked in the Michigan area. b) He recommends using bituminous coated pipe with magnesium anodes attached, in highly corrosive areas. c) He thought that one anode on each end of the culvert would stop corrosion if the culvert was bituminous coated but, if not coated, additional anodes might be required.

Mr. John Daesen of the Galvanizing Institute in Park Ridge, Illinois offered the following comments. a) The corrosion problem could be due to a poorer quality of galvanizing which was prevalent several years ago during the period when the I 75 CMP pipes were manufactured. At that time producers of galvanizing did not use aluminum in their galvanizing baths, causing thick zinc-iron alloy layers and zinc chloride flux inclusions. Such flux inclusions are focal points for corrosion to start. b) He has no knowledge of magnesium anodes being used to protect CMP and is not sure how they would perform, particularly on culverts where the galvanizing has been partially removed. c) The State of New York uses bituminous coated CMP culverts in corrosive areas and he also recommends their use.

Mr. John Knittle, Engineer in Charge of Cathodic Protection Division, Harco Corporation of Cleveland, Ohio, offered the following comments. a) All major pipeline companies in northern Michigan, and Michigan Bell, use cathodic protection on their pipelines in the form of anodes or applied current. b) He thought magnesium anodes would solve our corrosion problem but recommended a soil resistivity survey to determine the number of anodes needed for each culvert.

Conclusions'

1) Soil and water conditions which are seriously corrosive to CMP may exist along I 75 between St. Ignace and Sault Ste. Marie. At least three CMP culverts have failed and require immediate replacement or repair. The relatively high concentration of sulfate found at several culvert sites is the probable cause of rapid corrosion of the culvert pipe. Abrasion has removed galvanizing from the bottom of some culverts and this has contributed to their corrosion.

2) The consensus is that magnesium anodes would stop corrosion of CMP.

3) Visual inspection indicated that concrete culverts in an environment similar to that of the corroded CMP culverts are not deteriorating.

Recommendations

1) Have Maintenance personnel inspect all CMP culverts on I 75 between St. Ignace and Sault Ste. Marie, and along other highways where similar soil and water conditions may exist. This may require damming the culvert entrance and cleaning the invert.

2) Conduct soil resistivity measurements at CMP culvert sites to determine the severity of corrosion conditions. The Geophysical Unit of the Testing Laboratory may be equipped to do this.

3) Replace or repair perforated culverts.

Consider:

(a) Inserting a bituminous coated CMP or a reinforced, sulfate-resistant concrete pipe inside the damaged culvert and grouting the space between the old and new pipes.

(b) Installing a new culvert using reinforced, sulfate-resistant concrete pipe.

4) Install magnesium anodes on CMP culverts where the need is indicated by the soil resistivity measurements.

TESTING AND RESEARCH DIVISION

J. T. Ellis - Chemist
Spectroscopy and Photometry Unit

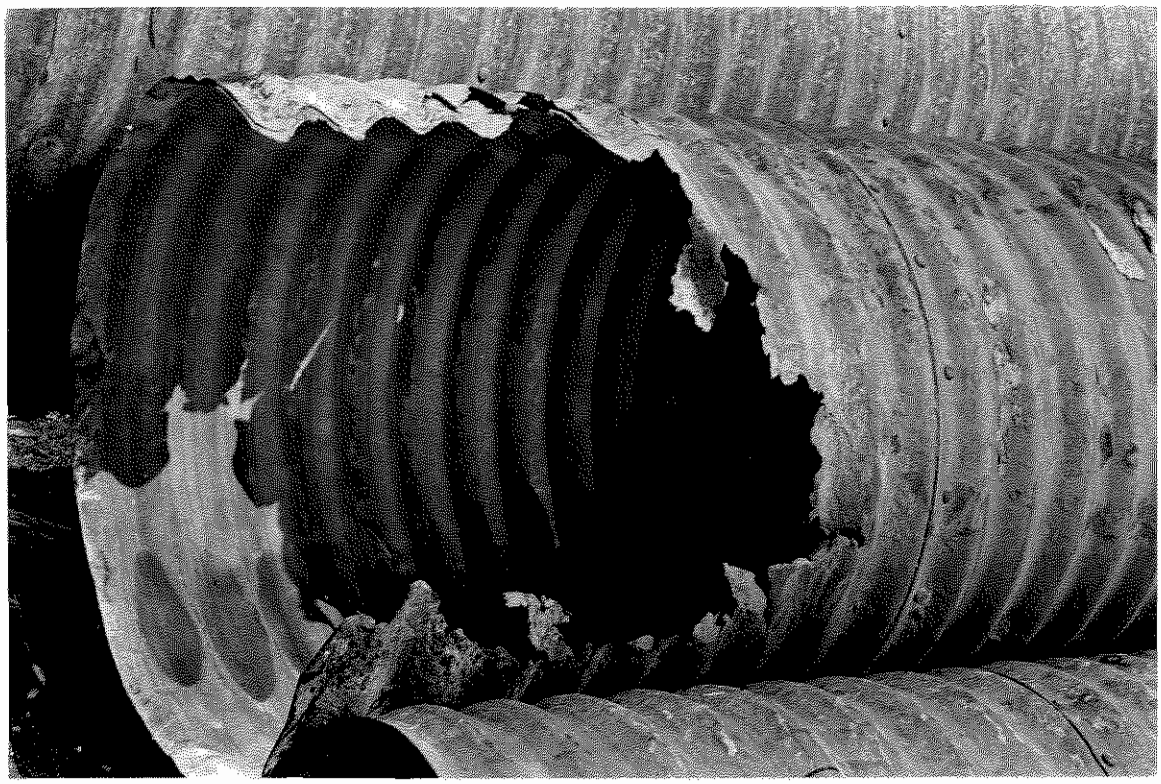

Figure 1. Section of culvert removed at Sta. 616+75.

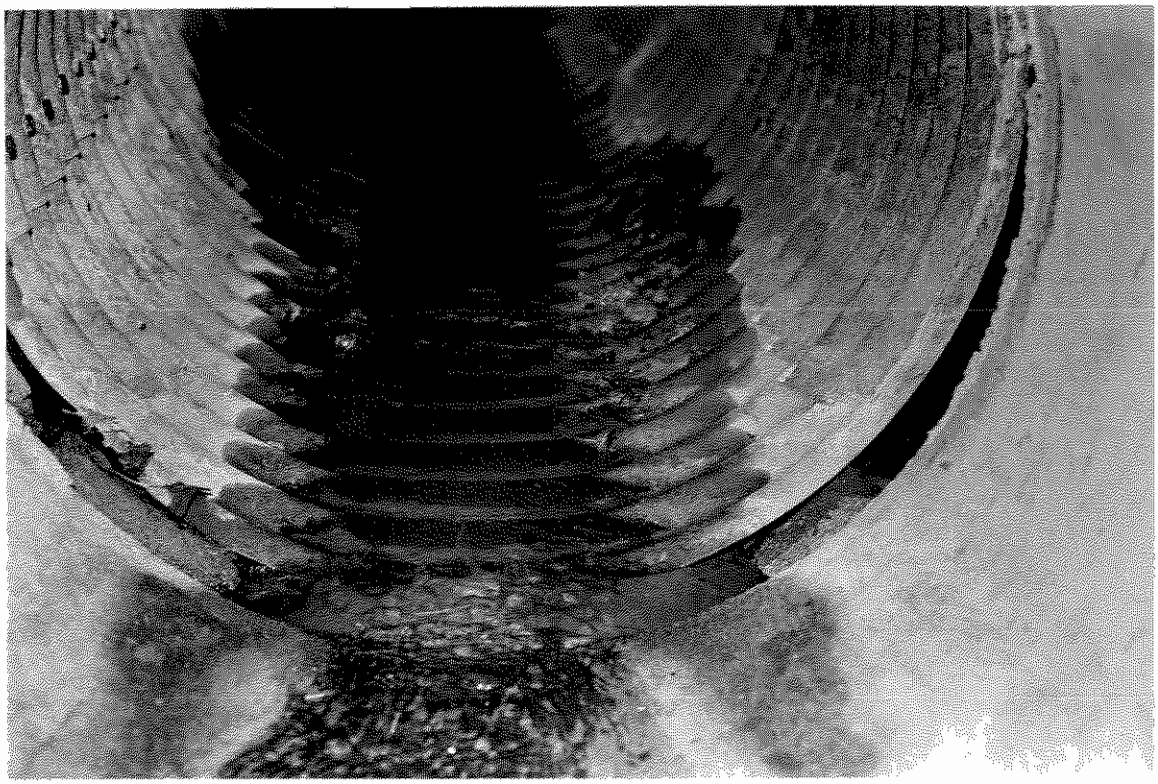

Figure 2. Perforated culvert still in-place at Sta. 603+00.

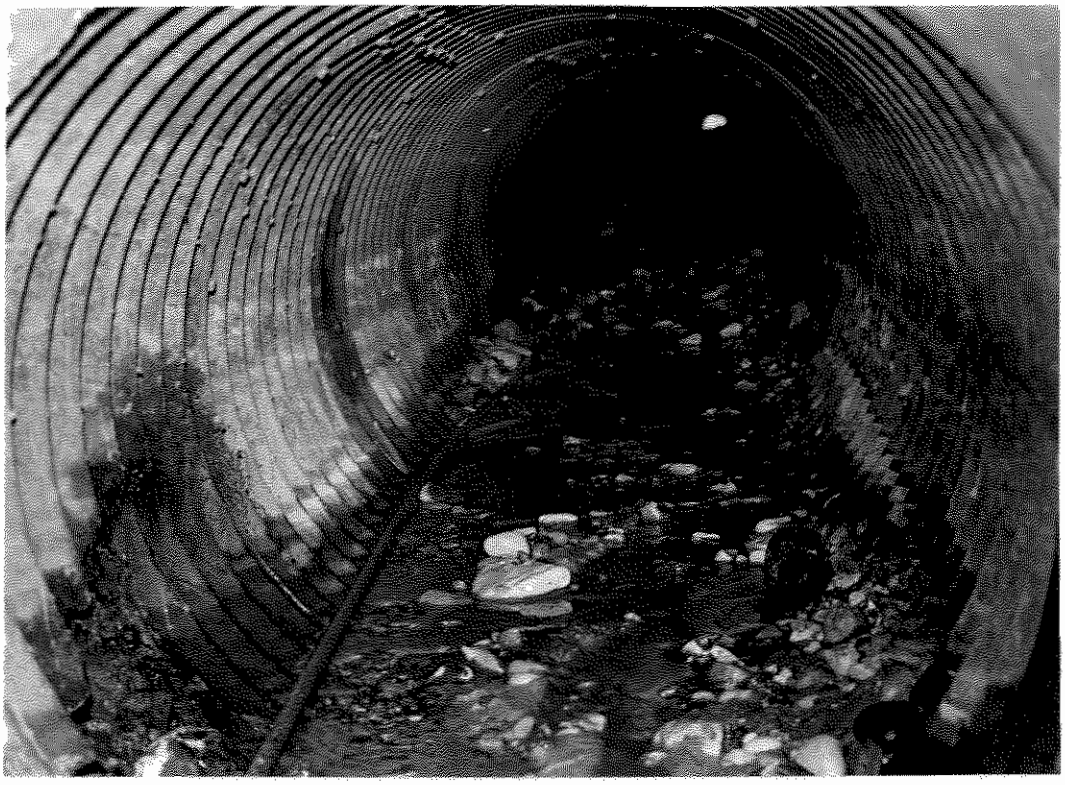

Figure 3. Perforated culvert section still in-place at Sta. 616+75.

Figure 4. Settled embankment over culvert at Sta. 626+00.