R-569

CORROSION PERFORMANCE OF ALUMINUM CULVERTS
First Progress Report

J. T. Ellis
J. E. Simonsen

Research Laboratory Division
Office of Testing and Research
Research Project 60 NM-26
Research Report No. R-569

State of Michigan
Department of State Highways
Lansing, March 1966

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Synopsis

State and county installations of corrugated aluminum pipe culvert are being observed in comparison with galvanized steel pipe culverts to establish data on relative corrosivity and service life. Initial laboratory tests of local soil and water are reported, as well as early developments in culvert performance. Future performance observations are outlined.

In the late summer of 1965, the Michigan Department of State Highways completed an 8.4-mile portion of relocated US 2 in Gogebic County. Although this project (F 27023B, C3) was only a small part of the total roadway mileage completed in 1965, it was unique in being the first state project containing corrugated aluminum pipe culverts. This type of culvert is relatively new, compared to galvanized steel or concrete culverts, and field installations in other states are under observation by both manufacturers and users to obtain data for use in establishing the service life of aluminum culverts. The US 2 installation and county road installations in Gogebic and Ontonagon Counties were inspected by T. A. Lowe of the Kaiser Aluminum Co. in July 1965. A copy of his inspection report was transmitted to W. W. McLaughlin with a letter dated August 30, 1965 from M. J. Bohrer, Regional Engineer, Kaiser Aluminum Co. Before receiving the Lowe report, Mr. McLaughlin had requested that the Research Laboratory conduct a performance evaluation of the Department's aluminum culvert installation.

There is much difference of opinion in the literature as to all of the possible causes of underground corrosion,[1] but it is generally believed that the corrosivity of soil to metals is related to the resistivity and pH of the soil, and to the uniformity of the soil mass contacting the metal. The resistivity of the soil is a measure of its ability to be electrically conductive and is influenced by the amount and kind of chemicals present, the moisture content, and the temperature. The pH is a measure of the hydrogen ion concentration and indicates the degree of acidity or alkalinity of the soil. The uniformity of the soil mass refers to how uniformly the backfill soil is compacted after installation of the culvert. Since there

1. Lowe, T. A. and Koepf, A. H. Corrosion Performance of Aluminum Culvert. Highway Research Record No. 56, 1964.

is no way to determine the uniformity of the backfill soil, it appears that the two main factors to be considered in evaluating the corrosion performance of a metal culvert are the soil resistivity and pH of its environment.

The evaluation program prepared by the Research Laboratory consists of two phases:

1. An inspection to select culvert samples, obtain general information on site conditions, and examine the selected culverts for corrosion attack.

2. Periodic examinations of corrosion progress, until sufficient data have been collected to warrant conclusions on the corrosivity of metal culverts, and an attempt to determine causative factors by performing soil resistivity tests and chemical analyses of soil and water samples.

The field survey was performed October 25-29, 1965. Laboratory work on the field data has been completed, and the results of both are reported here. A brief discussion of Phase 2 has been prepared and is included later in this report.

Location and Description

The Department's aluminum culvert installation is located on relocated US 2 from Gogebic Station to a point approximately 6 miles east, and contains a total of 27 aluminum culverts. Of these, six were selected as samples to be examined. To obtain information on the corrosion performance of aluminum culverts installed in various environments, four culverts of this material located on county roads were also included in the inspection--one in the vicinity of Bessemer in Gogebic County, and three in Ontonagon County near Bruce Crossing, Ewen, and Wood Spur.

For the purpose of comparing the corrosion resistance of aluminum culverts to that of galvanized steel culverts, four of the latter type were selected for inspection. Three of these were installed on Construction Project F 27023D, C4, which was also completed in 1965 and is adjacent to the aluminum project. The fourth galvanized steel culvert was located near the point of beginning of Project F 27023B, C3 at Gogebic Station. Because the county road aluminum culverts were replacements for failed culverts (with the exception of the one at Bessemer which was placed parallel to two existing 30-in. concrete culverts to minimize flood conditions in the spring), there was no newly installed galvanized steel culvert in the immediate area from which to select samples for comparison evaluation.

The aluminum culverts were fabricated from Alclad 3004-H34 sheets. The galvanized steel culverts are the standard types used by the Department. The US 2 culverts are embedded in a layer of porous material with each end protected by a precast concrete end section, except in one case in which a standard headwall was used. The county culverts are placed on the natural soil. The backfill at the Bessemer location consists of iron ore waste material, at Bruce Crossing and Ewen a sandy-gravelly material was used as backfill, and the Wood Spur culvert was backfilled with the natural soil. At all four locations, the culverts extend through the backfill slopes without the protection of headwalls or precast concrete end sections.

Field Inspection

The location, properties, and environmental site conditions of each culvert selected for examination are summarized in Table 1. The natural soil in the area where the US 2 projects are located consists mostly of the Adolph, Skanee, and Wakefield series, with peat and muck areas occurring at frequent intervals throughout the projects. The area generally exhibits poor drainage conditions and at the time of inspection ponded water was noted in many of the culverts. The drainage pattern at the county locations was much better, because the area's natural slope provided a sufficient gradient to prevent water from ponding in the culverts. Figure 1 illustrates drainage conditions at three culvert locations.

At each culvert, samples of the natural soil and backfill material, and the water, were taken for determination of pH values in the laboratory. The analysis showed the natural soils to be slightly acidic with the exception of Sta. 96+00 where it was slightly basic. The backfill at nine locations was in the basic range of the pH scale and at four locations in the acid range. The water was found to be acidic at six culverts and alkaline at eight.

Examination for corrosion attack of the culvert surfaces consisted of visual observations. On the soil-side surface, approximately 2 sq ft was exposed for examination at one end of the culvert by excavating through the backfill. Inspection of the water-side surface was limited to the surface above the existing water level. Because of the presence of water, only the two arched county culverts could be entered and examined on the inside for their entire length. At the other locations only the immediate end areas were checked. The presence of sand and silt in the inverts indicates that stream velocities of sufficient speed to carry this material into the culverts had occurred prior to the inspection. Again, because

TABLE 1

CULVERT PROPERTIES AND ENVIRONMENTAL SITE CONDITIONS

Project	Corrugated Pipe Type	Location	Dimensions			Embedment Depth, ft	Years of Exposure	Natural Soil Series	pH Values			Stream Characteristics		
			Length, ft	Diam, in.	Gage				Original Soil	Back-Fill	Water	Depth, in.	High-Water line, in.	Abrasiveness
F27023D, C4	Steel	Sta. 643+00	140	24	14	14.3	0.9	Adolph	5.2	7.1	5.4	3	Not Visible	Stagnant; small amount of silt in invert.
F27023D, C4	Steel	Sta. 549+50	140	24	14	12.5	0.9	Adolph	5.4	5.8	6.2	4	9	Slowly flowing; 3-in. layer of sand and silt in invert.
F27023D, C4	Steel	Sta. 622+00	104	24	16	6.5	0.9	Adolph	5.1	6.6	5.6	2	11	Slowly flowing; small amount of silt in invert.
F27023B, C3	Steel	Sta. 96+00	88	36	14	5.3	0.3	Peat	7.2	8.4	8.0	16	26	Stagnant; 8-in. layer of sand and silt in invert.
F27023B, C3	Aluminum	Sta. 114+50 Rt.	56	18	16	5.0	0.3	Skanee	5.9	8.5	6.7	1	6	Slowly flowing; 1/2-in. layer of sand and silt in invert.
F27023B, C3	Aluminum	Sta. 121+75	72	24	14	5.7	1.5	Adolph	6.8	- -	6.3	2	8	Stagnant; 1/2-in layer of sand and silt in invert.
F27023B, C3	Aluminum	Sta. 181+10	116	36	8	10.8	1.8	Peat	6.2	8.1	8.2	6	8	Slowly flowing; 1-in. layer of sand and silt in invert.
F27023B, C3	Aluminum	Sta. 330+00	80	24	14	6.2	1.3	Peat	4.9	7.6	7.6	6	11	Stagnant; 3-in. layer of sand and silt in invert.
F27023B, C3	Aluminum	Sta. 420+35	120	30	14	9.0	1.2	Peat	5.1	8.5	7.0	15	21	Stagnant; 7-in. layer of sand and silt in invert.
F27023B, C3	Aluminum	Sta. 458+50	100	36	8	16.0	1.7	Skanee	6.2	8.2	6.2	4	16	Stagnant; 3-in. layer of sand and silt in invert.
COUNTY	Aluminum	Bessemer	44	30	14	4.0	2.0	Adolph	6.0	6.9	7.4	3	Not Visible	Flowing at about 2.5 ft/sec; invert fairly clean.
COUNTY	Aluminum	Bruce Crossing	36	84* 60	8	4.0	2.0	Roselawn	4.7	8.2	7.0	5	Not Visible	Slowly flowing; 3-in. layer of sand and silt in invert; large boulders toward inlet end.
COUNTY	Aluminum	Ewen	41	84* 60	8	4.0	1.2	Ontonagon	6.5	8.0	7.4	2	Not Visible	Slowly flowing; invert fairly clean.
COUNTY	Aluminum	Wood Spur	36	24	14	2.5	2.0	Ontonagon	6.4	6.7	8.0	0 to 12	Not Visible	Stagnant; invert fairly clean.

* Arched Culverts

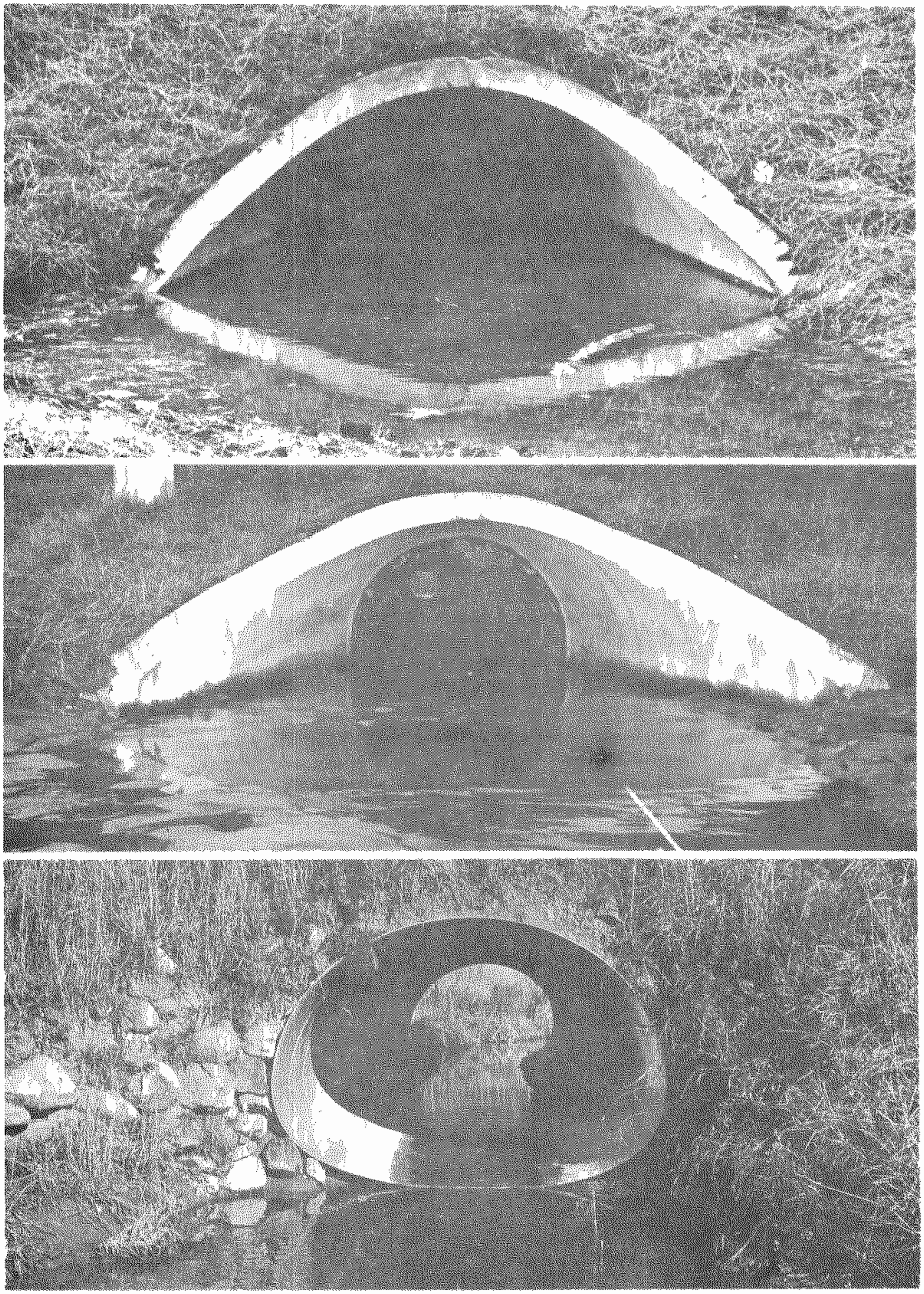


Figure 1. Drainage conditions for a US2 galvanized steel culvert (top: Sta. 96+00), a US2 aluminum culvert (center: Sta. 181+10), and the Ewen aluminum culvert (bottom).

of the presence of water, it was not possible to determine if this earlier abrasiveness of the streams had caused any detrimental effect on the invert culvert surface. Corrosion conditions are shown in Figures 2 through 5, and corrosion of each culvert is described in the following notes.

Condition of Galvanized Steel Culverts

Sta. 96+00. The soil-side surface at the culvert's north end was examined and found to be in excellent condition. No evidence of corrosion was noted on the water-side surface at the north end, but at the south end a line of white corrosion had formed about 1 in. above present water level. This corrosion had not seriously impaired the galvanizing.

Sta. 549+50. The north end of the culvert was inspected. The soil-side surface was in excellent condition. Several spots of white rust, up to 1/2-in. diam, were noted on the fifth, sixth, seventh, and eighth corrugations from the culvert end on the water-side surface. No serious attack on the galvanizing had occurred.

Sta. 622+00. The exposed soil-side surface at the north culvert end showed no corrosion. Examination of the water-side surface at the north end revealed several small spots up to about 1/16-in. diam of white rust on the first three corrugations from the culvert end. The water-side surface at the south end was in good condition.

Sta. 643+00. Small, dark-stained spots were noted on soil-side surface at the north end but the galvanizing was not impaired. The water-side surface of both ends showed white rust spots from 1/8- to 1/4-in. diam. Several rivet heads were covered with red rust.

Condition of Aluminum Culverts

Sta. 114+50 Rt. The examined soil-side surface at the west end showed many white blotches. Several white spots up to 1/8-in. diam were noted on the water-side surface at the high waterline mark at the west end. Dark brown stains were also present just below this line. The cladding did not appear to be affected. At the east end the water-side surface was in good condition.

Sta. 121+75. At this location the soil-side surface was not inspected, because of deep embedment at both culvert ends. Both the north and south ends of the water-side surface were in good condition, except for several small spots of white stain along the high waterline mark at the south end.

Figure 2. Lines of "white rust" spots along riveted joint in a US 2 galvanized steel culvert (north end, Sta. 549+50).

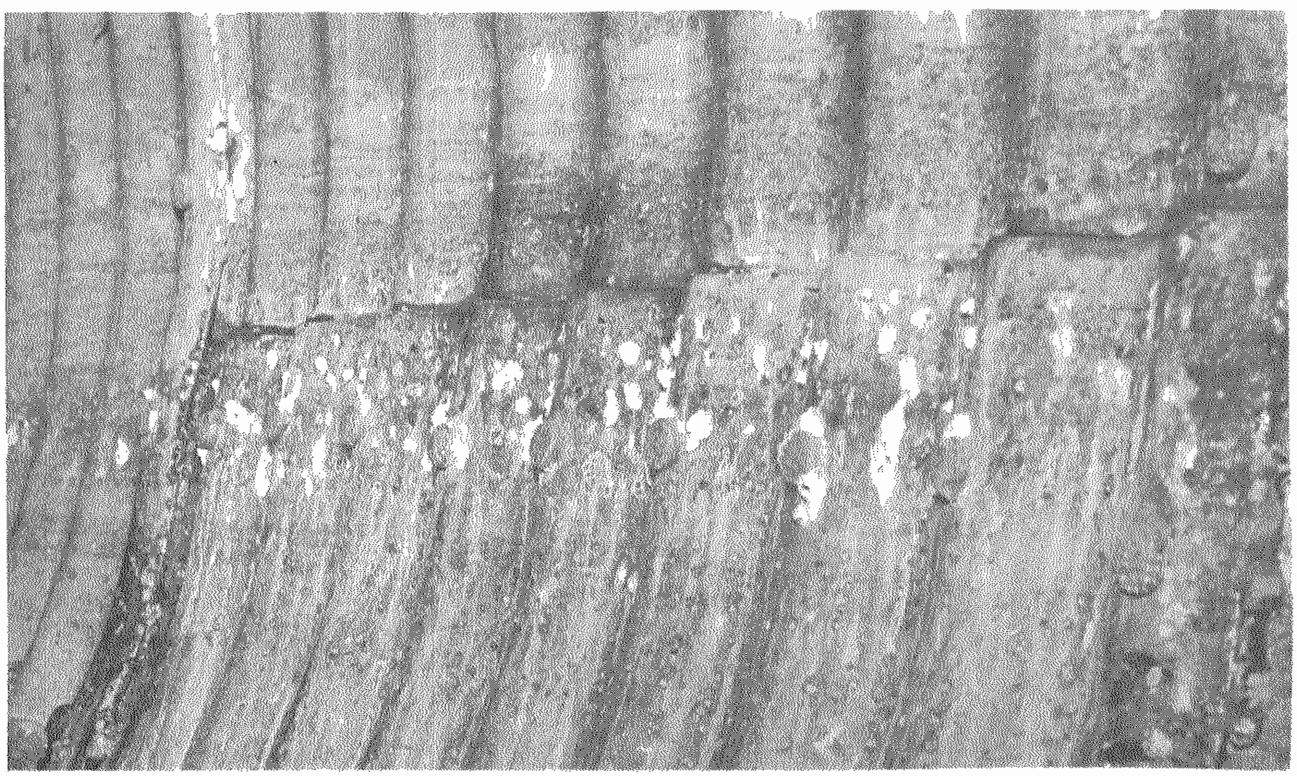
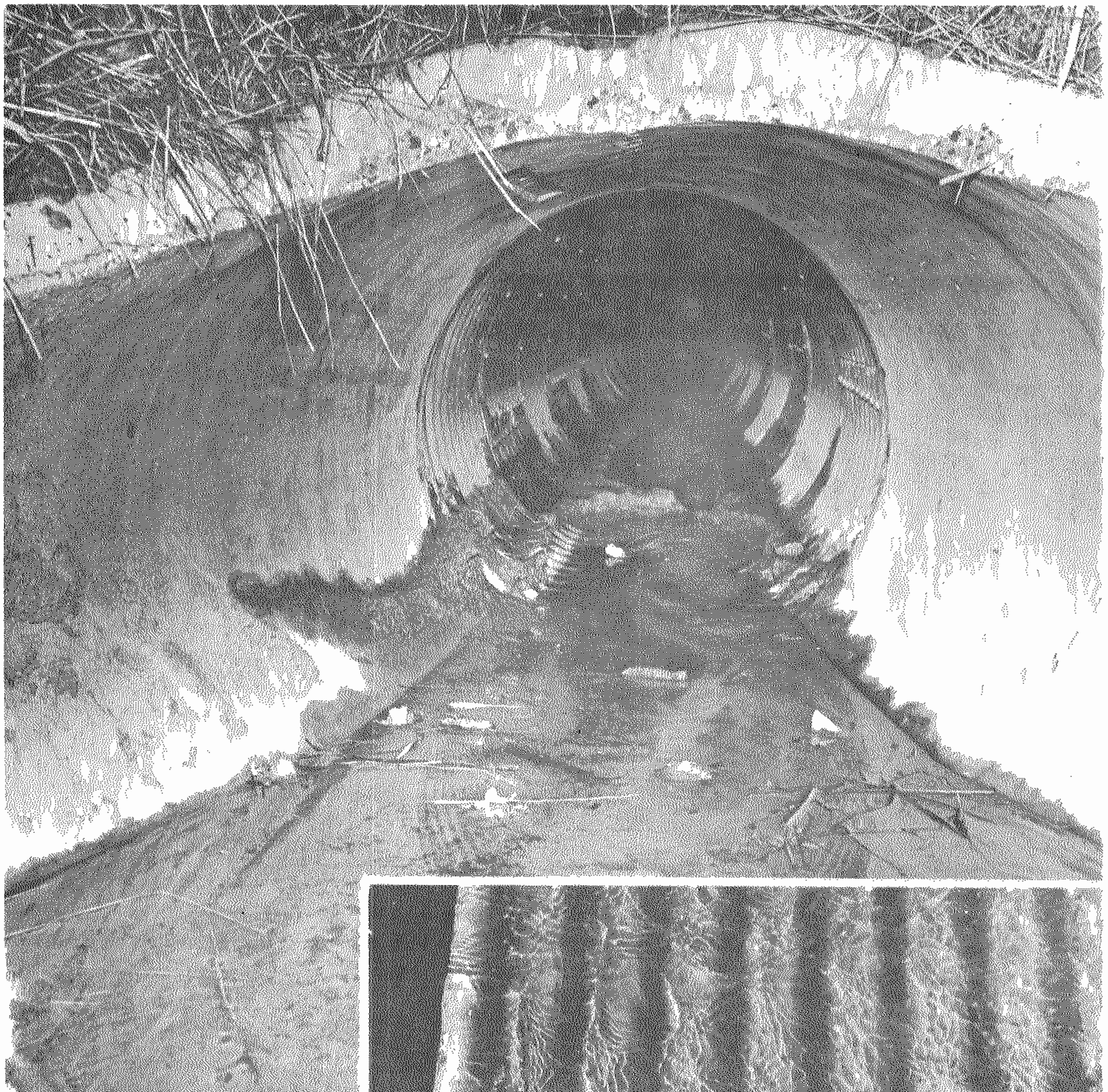


Figure 3. White spots along a former air-water interface in a US 2 aluminum culvert (north end, Sta. 121+75).



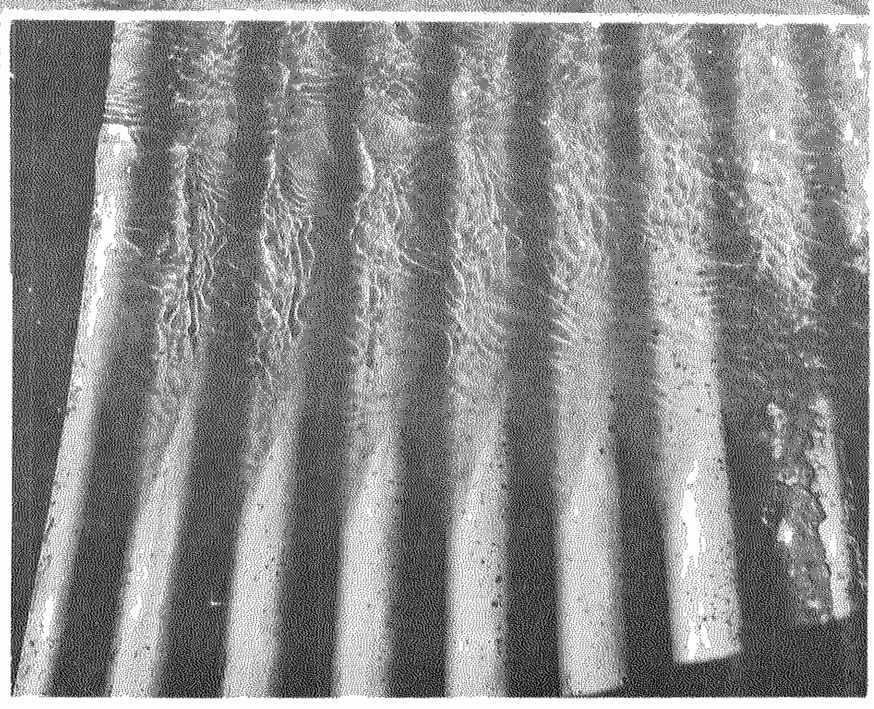


Figure 4 (above). Brown stains below some riveted joints in a US 2 aluminum culvert (south end, Sta. 121-75).

Figure 5 (right). Small dark spots indicate penetration of cladding on the Ewen aluminum culvert.

Sta. 181+10. The first six corrugations of the soil-side surface from the south culvert end were examined. On the exposed surface four small areas were noted that appeared to be imperfections in the cladding. At the north end the water-side surface was in good condition. At the south end a faint line of white stain was visible for about 3 ft along the high waterline mark. Dark brown stains were found along and below the horizontal rivet joint in some of the culvert sections.

Sta. 330+00. Several small areas of surface discoloration were noted on the exposed soil-side surface at the north culvert end. White spots ranging from 1/8- to 1/4-in. diam were found at both culvert ends at the waterline mark. Neither surface was corroded.

Sta. 420+35. The soil-side surface at the north end was in good condition. The water-side surface at this end exhibited brown stains between the present water surface and the high waterline mark. At the south end a line of small white spots was visible at the former water-air interface about 16 in. above the bottom of the culvert invert.

Sta. 458+50. Corrosion attack of the soil-side surface was noted on the exposed surface at the north end. This attack was confined to the cladding and consisted mostly of minute pits. The second, third, and fourth corrugations in a 12-in. length had 16, 15, and 12 pits, respectively. Numerous white spots along the high waterline mark were visible on the water-side surface at the north end. At most of these spots the cladding exhibited minute pitting, and in some cases it appeared the cladding had been removed. The largest area in this condition was 1/4-in. diam, with most in the 1/16- to 1/8-in. range. The south end was not examined as closely, but corrosion conditions appeared much less severe at that location. It was learned from construction personnel that this culvert was half-filled with standing water for a long period because of drainage problems at the outlet end. Thus, the air-water interface line remained at constant level for an abnormal length of time, which could possibly account for the noted corrosion attack on the cladding. The drainage condition was improved recently by excavating an outlet ditch toward the west.

Bessemer. Approximately 3 ft of the culvert extends beyond the backfill slope at each end. These exposed surfaces were covered with many white blotches or stains, which appeared to be etched or at the point of incipient corrosion. Random pits up to about 1/8-in. diam were noted on the exposed surface, as well as on a small portion of the surface from which the backfill was removed. The entire water-side surface above present water level was covered with small white spots. Reddish-brown stains were noticeable at and below a former air-water interface.

Bruce Crossing. Inspection of the uncovered soil-side surface end revealed several white blotches and three minutely pitted areas in the cladding, each area being about 1/8-in. diam. The entire water-side surface above present water level was covered with small white spots. There was no apparent evidence of corrosive attack on the cladding.

Ewen. The soil-side surface was not examined because of almost vertical backfill slopes. On the water-side surface, the portion above the present water level showed only a few minor, randomly located white spots. Below the water surface the invert was quite severely pitted. At the outlet end of the culvert, 6 to 8 pits per sq in. were common, with a few pits up to 1/4-in. diam. The pitting became progressively less severe toward the inlet end. Most pits had penetrated the cladding. No significant difference was noted in corrosion attack on the upstream and downstream faces of the corrugations.

Wood Spur. The first seven corrugations of the soil-side were examined at the south end of the culvert. The cladding was damaged by pitting in randomly located areas. The largest area was about 1/2-sq in. At the south end, water standing in the corrugations was cleaned out and the invert surface inspected below this level. Several areas of white blotches and 18 small pits up to 1/4-in. diam were found in the first six corrugations. No corrosion attack was visible above the standing water. The north end was not inspected because of 12-in. water depth.

Summary

The inspection revealed no serious corrosion on either type of culvert. Corrosion of galvanized steel culverts was limited to small spots or lines of white corrosion, generally located at or near former water-air interfaces. At none of the inspected culverts had the galvanizing been penetrated. Of the aluminum culverts, the one at Sta. 458+50 on the US 2 project and the Ewen culvert exhibited the most severe corrosion attack. At both locations the cladding appeared to have been penetrated. At the remaining aluminum culvert locations, only white or brown surface stains were noted, with minute pitting noticeable in some of the white-stained areas.

Future Evaluation

Because of the complexity of corrosion reactions and the difficulty in predicting corrosion rates, a rigid inspection schedule can not be made at this time. However, based on the present condition of the culverts, the next field inspection has been tentatively planned for the summer of 1967. The results of that inspection will be used as a guide to determine if more frequent inspections will be required.

At the next inspection, as in the case of the first, surface corrosion will be observed visually and the depth as well as the size of the area attacked will be estimated. If in the future it should be necessary to obtain more accurate information on these properties, an attempt will be made to cut samples from the attacked areas for laboratory analysis of both soil- and water-side surfaces.

A new group of soil and water samples will be taken and subjected to chemical analysis to determine if chemical substances are present that are known to influence the corrosion of the two types of culvert material.

Based on the corrosion condition of the culverts at the next inspection, certain culvert locations will be selected for soil resistivity tests. Tentatively, the soil resistivity will be obtained at 2.5-, 5.0-, and 10-ft depths, and also in the backfill where the culvert is embedded. Possible variation in resistivity values due to moisture content and temperature will be checked by performing tests in the summer, fall, and spring of each year in which inspection is performed.

Progress reports on corrosion performance of aluminum culverts and on laboratory analyses designed to determine factors causing corrosion will be issued after each field inspection.