CULVERT PERFORMANCE

AT

TEST SITES IN COLORADO

AUGUST 1968

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Prepared By

STATE DEPARTMENT OF HIGHWAYS
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In Cooperation With

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FEDERAL HIGHWAY ADMINISTRATION
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S U M M A R Y

In the six years that this culvert study has been conducted, it has been observed that most types of materials for culverts have an equally adequate service life in a majority of locations in Colorado. Although a six year period is not a very long interval in the life of most highway materials and structures, several conclusions may be presented regarding the performance of the culverts to date.

CONCLUSIONS

1. Asbestos-bonded, asphalt-dipped, corrugated-steel culverts and reinforced, concrete culverts are particularly durable for use in roadway construction. Both types are especially effective for use in water that is highly alkaline or acidic or in areas where extensive corrosion of standard corrugated-steel culverts has been experienced.

2. Except where alkalinity is unusually high, corrugated steel and aluminum perform well and both are acceptable culvert materials. Aluminum culverts are installed with greater ease because they weigh less; generally, only manual labor is required to handle sections of short length and small diameter. Since aluminum does not have the resiliency of steel, additional care in backfilling around aluminum culverts is necessary and a minimum of two feet of cover is recommended to prevent damage from heavy equipment.

3. The stainless steel culverts observed at test sites in Colorado since 1965 have shown considerable corrosion when placed in an alkaline environment. Considering cost and performance to date, there is <u>no reason</u> to recommend the use of stainless steel culverts at this time.

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INTRODUCTION

Metal culverts have been used successfully in Colorado since 1907. Installation of culverts in the Colorado Highway System today is at the rate of approximately 100,000 linear feet per year, and an almost equal amount of footage is placed on the County Road System.

With different types of culverts being used to supply this annual demand, there is some question as to which types are best suited for use throughout the State of Colorado.

This research program is primarily concerned with the comparative performance of different types of culverts placed at 6 different locations in Colorado since 1962.

LOCATION OF TEST SITES

Figure 1 shows the general location of the six test sites. The type of culvert and date of installation at each site are as follows:

Site 1 - 13 miles south of Punkin Center on State Highway 71 - summer of 1962. Two 36" diameter aluminum culvert installations in the vicinity of several corrugated metal culverts for comparison of performance in Pierre Shale having the following typical chemical analysis:

soil - (backfill material for the aluminum culverts)

Loss on ignition	4.76%
Insoluble residue	87.22%
Iron and Aluminum Oxides	5.40%

Calcium Oxide	1.61%
Magnesium Oxide	0.79%
Sulfates as SO_4	3.5%
Alkali as SO_4 (water soluble)	0.8%
pH	8.1

Water - No samples taken-only intermittent flow in the stream S 0023(10)

Site 2 - On S. H. #96, 6.85 miles west of the junction of Highway 165 west of Wetmore. Placed spring of 1962. A 36" diameter aluminum culvert placed 6 feet from a standard corrugated galvanized steel culvert for comparison of performance in disintegrated Pikes Peak granite type of backfill. Stream flow is intermittent. S 0016(23)

Site 3 - Along U. S. Highway #6, at the east edge of Fruita near Grand Junction. Aluminum, stainless steel and standard corrugated galvanized steel culverts have been placed between the roadway and the north right-of-way fence in a very alkaline area. Approximately one third of the time, the culverts are under water. Culverts were placed in 1964.

Site 4 - Between U. S. #50 and the east right-of-way fence approximately 1 mile north of Whitewater. A single 18" aluminum culvert placed in a very damp alkaline soil in 1962.

Site 5 - At Fossil Creek between the roadway and the west right-of-way fence on Interstate 25 approximately 0.75 mile north of the Windsor Interchange (Highway #392). Placed in running water at this site in 1964 was an asbestos-bonded asphalt-dipped corrugated steel culvert. In 1966, reinforced concrete culverts made of Type II and Type V cement, an aluminum culvert, a stainless steel culvert and a standard zinc galvanized steel culvert were placed in the stream for performance tests. The water has a pH of 7.4, a sulfate content of 1160 ppm and a bicarbonate alkalinity of 533 ppm. The soil has a pH of 9.2 and has a high calcium carbonate and magnesium sulphate content.

I 25-3(35)

Site 6 - On State Highway #56 east of Berthoud and approximately 0.7 mile west of I 25 is a 36" aluminum culvert. Approximately 0.6 mile west of this culvert is a 42" aluminum culvert. Both culverts were placed in 1962 with an A-6(7) type soil for backfill. S 0074(1)

PERFORMANCE OF REINFORCED CONCRETE CULVERTS

Reinforced concrete has been used as a material for culverts since 1911 in Colorado.[1] The record for concrete culverts is one of good performance throughout the years as they are especially resistant to corrosion promoted by chemicals present in soils and water found in Colorado. There have probably been very few culvert failures due to the deterioration of the concrete itself. Failures are more likely attributed to seepage at joints, or loss of sections due to erosion at outlets, or to some other mechanical process.

[1]See Reference (1) in Bibliography

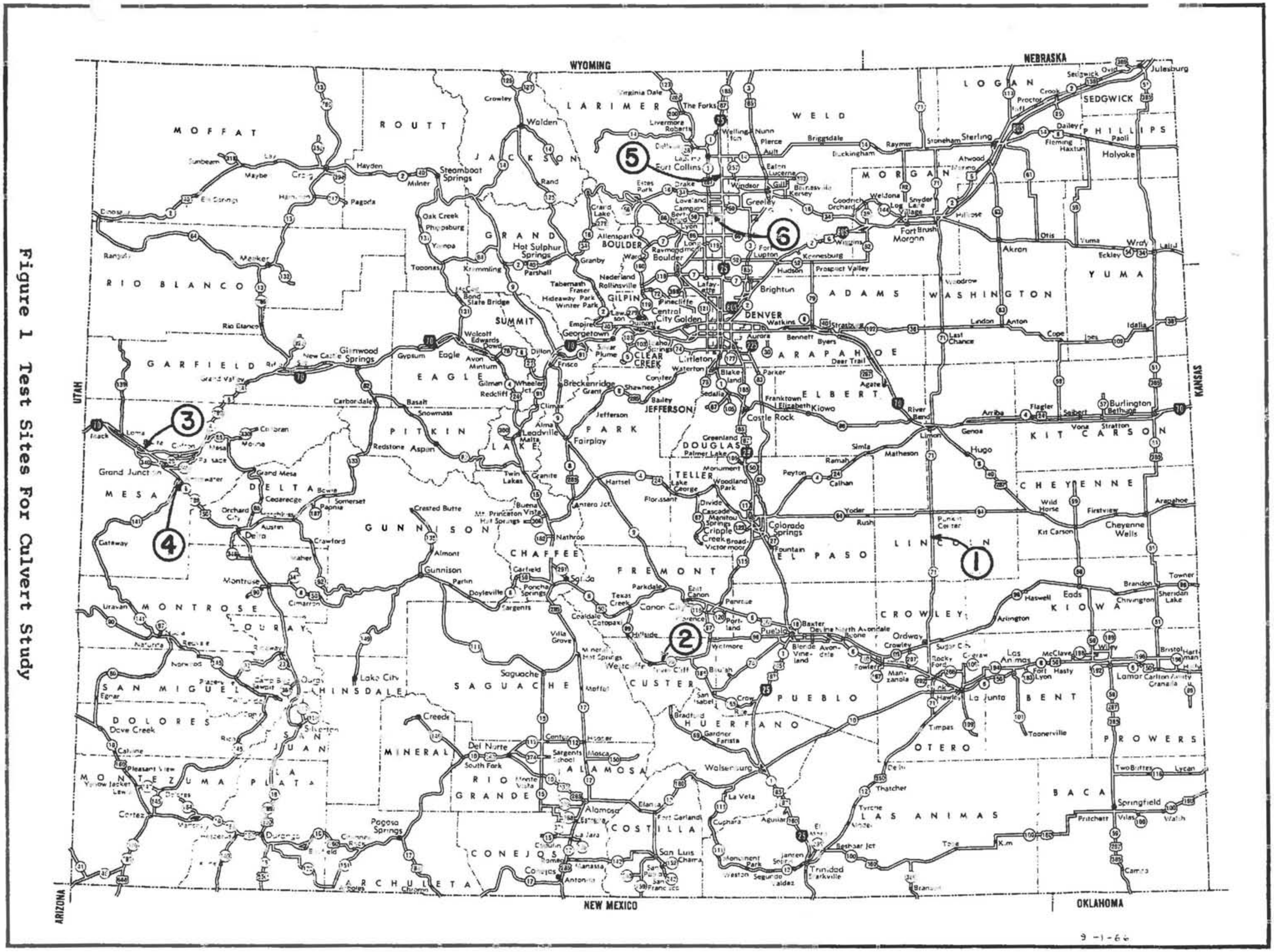


Figure 1 Test Sites For Culvert Study

In 1964, two six-foot sections of concrete pipe 18 inches in diameter and made of Class II and Class V cement respectively were placed at the Fossil Creek site just north of the Windsor interchange on Interstate 25. The soil and water at this location have been detrimental to steel and aluminum, but corrosion was non-existent on the concrete pipe as of June 1968.

In May 1958, a test section of 36 inch No-joint concrete pipe, 600 feet long, was installed beneath the Valley Highway just south of Alameda Avenue, in Denver. During an inspection in October 1959, a hairline crack extending virtually the entire length of the installation was discovered along the top inside of the pipe. It has never widened or shown any tendency to offset. It was the consensus of opinion that it was a shrinkage crack and had formed shortly after construction. As of June 1966 the crack was still minute and showed no signs of spalling or moisture seepage. The entire pipe was in very good condition and performing satisfactorily. No corrosion or other deterioration had been observed by midyear 1966.

PERFORMANCE OF CORRUGATED ALUMINUM CULVERTS

Sections of aluminum culverts are located at all six test sites described at the beginning of this report. At three of these sites (south of Punkin Center, west of Wetmore and east of Berthoud) the pipes were installed during roadway construction. At the other sites (Fruita, Fossil Creek and Whitewater) representative samples of aluminum culverts have been placed next to existing highways in soils and water known to have a deteriorative effect on standard corrugated steel. The former locations provided an opportunity to evaluate the installation of aluminum culverts while all sites will provide answers as to how well aluminum will withstand deterioration caused by various chemicals and chemical processes.

An important advantage of aluminum culvert installation is the light weight of the metal as compared to any other culvert material. Normally only manual labor without the aid of special equipment is required in handling standard sections of the pipe. Resident engineers on all three construction projects pointed out, however, that a certain amount of special care must be exercised when placing aluminum culverts since it is less resilient and more easily dented than steel. It was noted by one engineer that a particular pipe "deflected under load impact from contractors equipment or heavy trucks and failed to recover from this deflection . . . . . . resulting dents had to be jacked out of the top third of the pipe."[2] Deformations were noted in pipes on the other projects also, presumably resulting from the same cause. To guard against damage of this nature, the consensus of opinion among resident engineers was that a minimum of two feet of cover be required over aluminum culverts. Pipes at these three locations have performed satisfactorily to date with no further deformation from any source. None of the pipes show any sign of corrosion.

The soils at three locations of aluminum pipe (Fossil Creek, Fruita and Whitewater) have a history of severe corrosion of galvanized steel pipe. A piece of 16 gage aluminum culvert sheet 3 inches by 15 inches was placed at Fossil Creek in July 1966. Only slight corrosion of the metal has been detected since then, with small pits no larger than 1/16 inch in diameter. The 18 inch culvert near Whitewater rests in damp and highly alkaline soil, but is very seldom covered with water. It was placed in 1962 and since then has developed only slight corrosion. Due to the alkali in the area, a white

[2]See Reference (2) in Bibliography

encrustation forms on the pipe, but when the surface is wiped clean, it is intact and in good condition.

The site near Fruita is similar to the one near Whitewater, but the pipes are underwater more often and are nearly buried in the heavily alkaline soil. However, the aluminum pipe, placed in 1964, is in good condition at this time. In 1966, the rivets were found to be slightly corroded but not in serious condition; the corrosion has not progressed since that time.

One of the two aluminum pipes east of Berthoud is in a damp area and at times has been half full of mud but has never shown signs of corrosion. The soil in the area is not considered to be extremely detrimental to metals, however. Both culverts near Berthoud are in excellent condition.

Two aluminum culverts were installed as part of a construction project south of Punkin Center in 1962. Pierre shale is the predominant soil in the area and is not particularly detrimental to standard corrugated steel culverts. Since the annual rainfall in the area is low, the culverts very seldom carry a large amount of runoff.

Analyses of soil samples obtained at the sites did not indicate the presence of materials commonly associated with corrosion of aluminum. In August 1965 a representative of a well-known metals company employed polarization techniques to determine the corrosion rate of one of the aluminum culverts. The in situ polarization curve on the culvert indicated a corrosion current of 20 milliamps which according to the metals expert "...is negligible when considering a total pipe area of approximately 680 square feet."

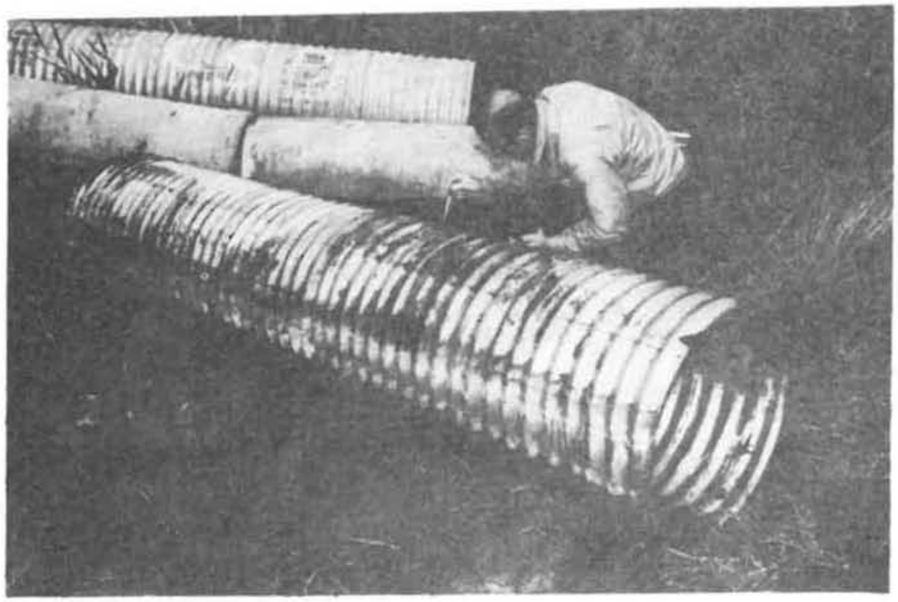
In September 1965, the backfill material was removed from around one culvert and when viewed from the top, some damage from construction equipment was evident. Subsequent inspections have confirmed that mowing machines and motor graders have caused more damage to the ends of the aluminum culverts than to corrugated steel pipes; however, no corrosion has been detected.

The aluminum culvert west of Wetmore is also in excellent condition. The material surrounding the pipe is composed of disintegrated Pikes Peak granite and is not expected to have any adverse effects on the metal. Extreme care was used during the installation of this pipe and as a result, only very minor denting occurred.

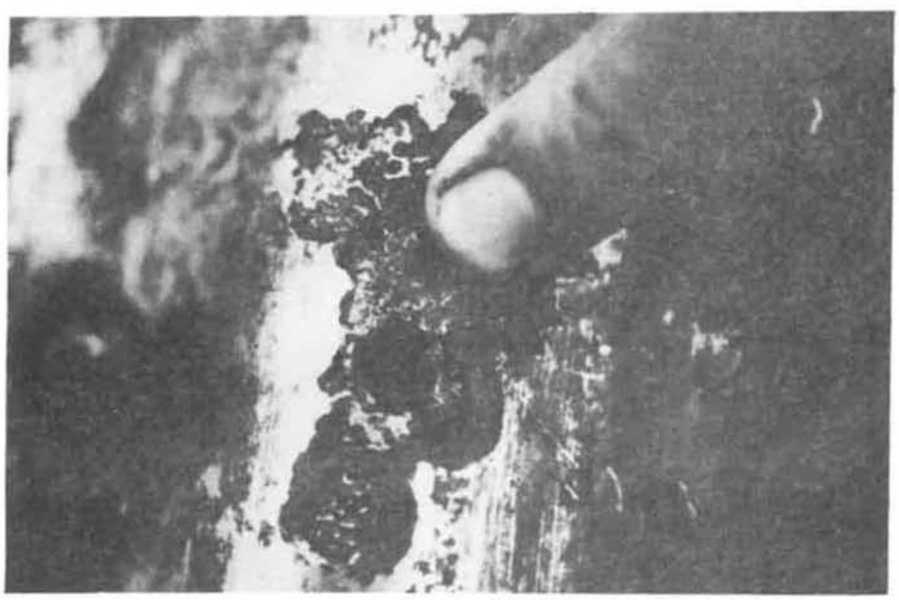
PERFORMANCE OF STAINLESS STEEL CULVERTS

Two sections of stainless steel pipe, furnished by a steel company, were placed near Fruita and at Fossil Creek in July 1966. These samples have undergone extensive inspections and analyses in the past two years.

In April 1967, a routine inspection of the pipe at Fossil Creek revealed several ¼ inch to 2 inch diameter areas of corrosion on the bottom of the pipe. Some of these spots were corroded completely through with the resulting holes measuring up to 1/16 inch in diameter. The bottom of the pipe was completely covered with a very plastic black mud. At other places on the pipe, exposed only to water, a yellow stain had formed, which when removed exposed pits approximately 1/32 inch in diameter and depth, but no severe corrosion as had been detected on the bottom of the pipe. (See Figure 2.) Between April 1967 and August 1968, three of the holes mentioned above enlarged to ¼" diameter, but no new areas of corrosion were formed. Since the corrosion is confined to small distinct areas on the culvert, and the remainder of the surface is in good condition, there is a feeling among



Fossil Creek. The yellow stain on the stainless steel pipe in the foreground is said to indicate the presence of iron chloride - a factor in the corrosion of stainless steel. Note the concrete and steel pipes in the background and the asbestos bonded pipe in the upper right corner.



Fossil Creek. This picture shows the typical corrosion and perforation of the stainless steel pipe.

Figure 2

the inspectors that the metal comprising these stainless steel culverts is not completely homogeneous. For some reason, certain areas of the culvert appear to be more susceptible to corrosion than other areas. At any rate, the corrosion has been observed to take place in a very blotchy manner.

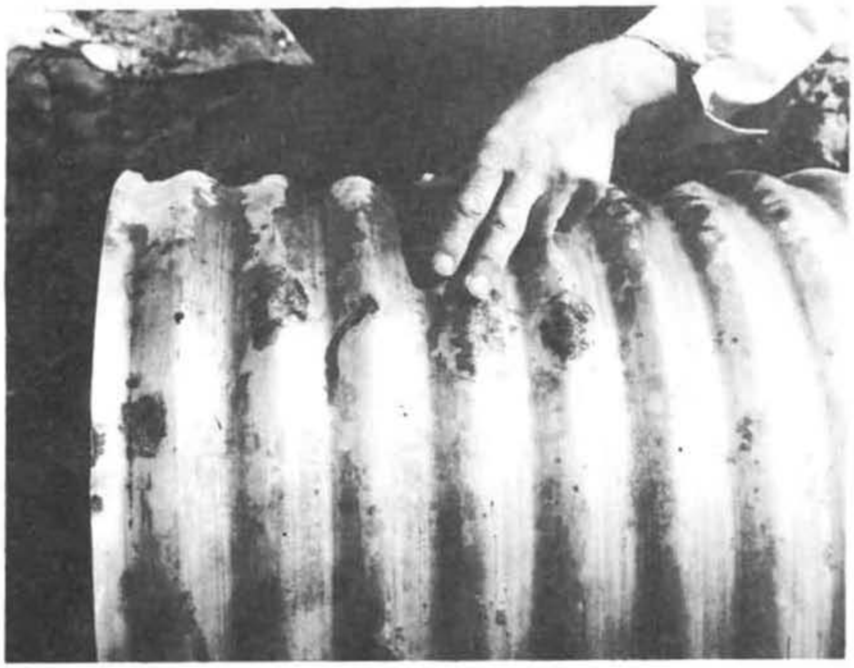
The pipe at Fruita is in about the same condition as the one at Fossil Creek except that no holes have been detected. The yellow stain exists on the pipe at Fruita also with the same small pits underneath. (See Figure 3) A representative of a steel firm visited both test sites in June 1968 and offered the following explanation for the yellow stains and serious corrosion:

> "Chlorides, which exist as salts in the soil, will form iron chlorides (the yellow stain indicates the formation of these chlorides) and will then convert under acidic conditions to hydrochloric acid. (The water at both locations is mildly acidic.) This acid breaks down the passivity to corrosion that stainless steel possesses. A lack of oxygen as might exist under a layer of mud in a swampy condition prevents this passivity from reforming and corrosion of the stainless steel follows."

PERFORMANCE OF ZINC COATED CORRUGATED STEEL CULVERTS

The history of galvanized steel culverts in Colorado has generally been a record of good performance. Only in the areas around Delta and Montrose, Colorado, where there exists extremely high concentrations of alkali, has this type of culvert shown a limited life.

When the type of material for culvert pipe is not specified in a construction contract in Colorado, corrugated steel is selected by the low bidder in more than 90% of the contracts. (An excellent treatise on corrosion is included in a report published by the State of New York Department of Transportation entitled "Durability of Corrugated Metal Culverts.")



Fruita. Corrosion on the stainless steel pipe which was uncovered for evaluation. Note the alkali on the ground surface in the upper left corner.

Figure 3

In recent years, some corrugated steel pipe fabricators have converted from riveted to spirally welded joints. This new type of steel pipe possesses the strength of the riveted ones but is much more difficult to band together in a strong watertight connection. Actually, a completely satisfactory band is still unavailable in Colorado.

Standard corrugated steel culverts are located at all test sites except near Whitewater and east of Berthoud. (Although standard culverts are probably in place near the Berthoud and Whitewater sites, none have been singled out for periodic inspection and comparison of performance to other pipes at these sites.)

A standard galvanized culvert was installed immediately adjacent to the aluminum culvert west of Wetmore. This arrangement provides an excellent opportunity for a comparison of the two materials in the future. But, to date both pipes are in excellent condition and since soil and weather conditions are not severe in the area, their performance will probably be satisfactory for years to come.

The standard pipes at Fruita and Fossil Creek are in the same corrosive surroundings mentioned earlier in the performance of other culvert types. The bottom of the standard pipe at Fossil Creek has never been covered with as much mud as the stainless steel culvert at the same location. In April 1967, however, the galvanizing in the submerged area of the pipe showed the grain pattern more clearly than the portion above water. This indicates that the galvanizing was being attacked. However, nowhere had the galvanizing been eaten through and no rust spots had developed. By June 1968 the condition of the culvert had not appreciably worsened.

The deterioration of the standard pipe at Fruita appears to be more pronounced. In June 1968, one end of the culvert was uncovered revealing that the galvanizing had been heavily attacked. Most of the zinc had been converted to a white powder. There were areas on the outside of the pipe where the galvanizing was completely gone resulting in severe rusting and pitting of the exposed base metal. It should be noted, however, that the pipe is almost completely covered with a highly alkaline soil and is underwater approximately one-third of the time.

Reports from other states have indicated that asbestos lengthens the life of steel culverts and has been recommended for use in water that is extremely alkaline or acidic or where records show a high rate of corrosion to steel culverts.[3,4] The 84-inch, asbestos-bonded, asphalt-dipped, corrugated-steel pipe at Fossil Creek extends beneath a frontage road and the mainline of Interstate Highway 25. It was installed in February 1964 and is in excellent condition at this time.

COMPARATIVE COSTS

Since corrugated aluminum pipes were specified in two construction contracts in 1962, that year is used to compare costs of different types of culverts. The average cost to the state for each linear foot of 36 inch diameter pipe was:

Corrugated steel	$ 10.38
Reinforced concrete	12.19
Corrugated aluminum	13.60
Asbestos bonded CSP	14.03

The stainless steel pipe was fabricated in Denver for experimental purposes and no cost estimate could be obtained. It would be more costly than standard corrugated steel pipe.

[3]See Reference (3) in Bibliography

[4]See Reference (4) in Bibliography

CONCLUSIONS

The performance of culverts has been observed in Colorado since May 1962. Although a six year period is not a very long interval in the life of most highway materials and structures several conclusions may be presented regarding the performance of the culverts to date.

1. Asbestos-bonded, asphalt-dipped, corrugated-steel culverts and reinforced, concrete culverts are particularly durable for use in roadway construction. Both types are especially effective for use in water that is highly alkaline or acidic or in areas where extensive corrosion of standard corrugated-steel culverts has been experienced.
2. Except where alkalinity is unusually high, corrugated steel and aluminum perform well and both are acceptable culvert materials. Aluminum culverts are installed with greater ease because they weigh less; generally, only manual labor is required to handle sections of short length and small diameter. Since aluminum does not have the resiliency of steel, additional care in backfilling around aluminum culverts is necessary and a minimum of two feet of cover is recommended to prevent damage from heavy equipment.
3. The stainless steel culverts observed at test sites in Colorado since 1965 have shown considerable corrosion when placed in an alkaline environment. Considering cost and performance to date, there is <u>no reason</u> to recommend the use of stainless steel culverts at this time.

BIBLIOGRAPHY

(1) Bulletin No. 1 1910 State Highway Commission, State of Colorado.

(2) "Report on Experimental Project Aluminum Culverts" March 1965 Department of Highways, State of Colorado.

(3) "Durability of Corrugated Metal Culverts" November 1967 State of New York Department of Transportation.

(4) "Culvert Performance Evaluation" April 1965 Washington State Highway Commission, Department of Highways.