CORROSION AND SERVICE LIFE OF CORRUGATED METAL PIPE IN KANSAS

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Nearly 2,000 corrugated metal pipes as old as 43 years were inspected in a research study in Kansas during a period of 6 years. Bituminous coatings applied to pipes seldom remained intact in exposed areas for more than 3 or 4 years; sometimes they were intact for only a few months. Consequently, they are not of sufficient value to justify their use in Kansas. Plain galvanized corrugated metal pipes without bituminous coatings have served well in Kansas for more than 40 years. A few pipes in localized strip pit coal mining areas have corroded excessively, but none has failed structurally. Aluminum pipes are in good condition but had been used in Kansas for only 7 years at the time of this study, and none was installed near coal mines.

•CORRUGATED metal pipes have been used successfully in Kansas for more than 40 years. Installations were made at farm and field entrances, for erosion control, and more recently on side roads and across the centerline of main highways. This report summarizes research studies of corrugated metal pipe recently conducted by the State Highway Commission of Kansas (1, 2, 3).

Figure 1 shows the 35 counties in which plain galvanized steel pipes were inspected in 1965, 1967, and 1968 to determine corrosion and service life. An investigation was conducted in 1969 to determine the effectiveness of bituminous coatings on corrugated metal pipes, both aluminum and galvanized steel. These locations included 53 counties that were well distributed throughout the state. Aluminum pipes have not been used long on the state highway system. They were used in 34 counties during the period from 1963 to 1966 (designated A, Fig. 1). Inspection of these was delayed until 1970 to provide more time for evaluation of performance.

PROCEDURE

Office records were searched to find the locations where corrugated metal pipes were used. The round pipes varied in diameter from 15 to 54 in.; 92 percent of them were 24 in. or less. The smaller pipes were usually 16 gauge, and the larger ones were either 14 or 12 gauge. The base metal was usually copper steel, galvanized on both sides by the hot-dip process with no less than 2 oz/ft^2 of double exposed surface. Pipes were inspected and certified at the time of construction but not verified during our investigation. From 2 to 6 pipes on each project were inspected in the field and rated according to the following system:

Condition	Rating
No corrosion, galvanizing intact	0
Superficial rust (edge and bolt heads), no pitting, weathered, zinc luster gone	1
Moderate rust, rust flakes tight, minor pitting	2
Fairly heavy rusting, rust flakes tight, moderate pitting, metal sound	3

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Condition	Rating
Heavy rusting, rust flakes easily removed, deep pitting into base metal	4
Heavy rust, deep pitting, perforated areas, unsound areas easily perforated with pick end of geologist hammer	5

The Hoffer test (4) was run on each soil sample obtained in 1967 to determine whether oxidizing or reducing conditions existed. Inasmuch as no significance was found, the test was not continued. The problem of abrasion was checked in the field, but only one pipe was found to be carrying much rock debris. That pipe was not abraded. A sample of soil from each steel pipe location was taken to the laboratory for determination of pH and soil resistivity. If water was standing in or flowing through a pipe, the water was sampled and taken to the laboratory for pH measurements. The water samples were always tested immediately after they were received in the laboratory in order to prevent possible changes in pH values resulting from biological growth or other changes that might occur in the water.

The percentage of aluminum pipes inspected was based on the number of pipes in each soil group. All of the pipe locations were numbered, and a table of random numbers was used to determine the 260 pipes to be inspected from the total of 921 that were installed from 1963 to 1966. Aluminum pipes are still permitted, but contractors have not elected to use them on the state highway system since that date. Aluminum pipes inspected were aluminum alloy conforming to AASHO Designation M 196.

Specifications called for the bituminous coatings to be at least 0.03 in. thick and to consist of asphalt cement 99.5 percent soluble in carbon bisulfide. Certification was required for stability, imperviousness, and resistance to impact and erosion.

Preliminary investigation of the bituminous-coated pipes revealed that bare galvanizing is usually exposed in fewer than 4 years after installation. Records were searched to find locations where bituminous-coated corrugated metal pipes were installed in 1965 and 1966. In addition, a few coated pipes were inspected that had been in place from 10 to 32 years to determine whether coating had any significant effect on the galvanizing or corrosion and whether perchance some of the older coatings may yet be good.

Inspections were made primarily of the inside of the pipes, where previous investigations in Kansas and elsewhere have shown that corrosion is most destructive. Graf, James, and Wendling (3) found in their study of pipe culvert corrosion that in almost all cases the invert of the pipe had the highest degree of corrosion. Studies in Kansas showed that abrasion was no problem and, therefore, would not cause invert deterioration. Haviland et al. (5) found that metal loss associated with corrosion originates on the culvert's interior surface and progresses toward the exterior surface. This was true for the inverts as well as for other portions of the pipe. Holt (6) and Malcom (7) state that strip corrosion, which can ultimately cause structural inadequacy, occurs from chemical corrosion on the interior of culverts from exposure to corrosive waters and not from galvanic spot corrosion on the exterior. Random perforations from localized spots were not found to connect to cause strip corrosion. In Nebraska, Bearg et al. (8) cut plug samples out of several pipes and found that in no case was there any pitting or measurable metal loss from the outside even though some of the culverts appeared to be deteriorated from the inside. Such research findings showing that most corrosion begins on the inside of the pipe indicated that there was no reason to remove the earth fill from the pipes to determine the condition of the bituminous coatings on the outside.

RESULTS ON BITUMINOUS-COATED PIPES

Table 1 gives a summary of results for pipes 3 and 4 years of age. The coatings were considered good only where no bare galvanizing was observed. This condition was found only on 12 percent of the pipes inspected. Most of the good coatings were found in storm sewer installations where the weather conditions are less severe. Even with these better conditions, bare galvanizing was usually exposed, leaving only 27 percent of the storm sewers with good coatings. When the storm sewer pipes are subtracted from the total number of pipes inspected, only 6 percent of the others have good coatings. Ten bituminous-coated aluminum pipes were inspected. The coatings on these pipes were in the same condition as that of the steel pipes.

The preceding discussion applies only to pipes 3 and 4 years old. Bare galvanizing was exposed at least near the outlet on all of the older pipes inspected, including storm sewers. Corrosion was not significantly different from that observed on uncoated steel pipes.

Figure 2 shows a pipe with strip bare in the invert. Figure 3 shows a pipe with about half of the coating gone. Sometimes the coatings were only cracked, and in a few cases they were entirely good.

Some bituminous coatings disappear during construction. Before grass is seeded and develops a sod cover, mud from bare back slopes, ditch slopes, and ditch bottoms is carried into newly installed pipes. Cohesive soil adheres to the bituminous coatings, and, when the soil dries and shrinks, it pulls the bituminous coating from the pipe. This has occurred without freezing and thawing, both in the field and in laboratory tests. Freezing and thawing has also removed bituminous coatings. Damage has occurred under both of these conditions at the end of the second cycle.

Some other states have indicated that bituminous coatings are helpful. Haviland et al. (5) reported that coated culverts included in a New York investigation had only 62 percent as much metal loss as uncoated culverts but that more than 40 years of service can be expected for most of their uncoated culverts. Beaton and Stratfull (9) in California reported that the actual added life varied from nearly 0 years in areas of continuous flow carrying heavy debris to more than 20 years in arid areas with infrequent runoff; an average of 6 years was added by bituminous coatings. In North Carolina, Welborn and Serafin (10) noted that the better condition of the asphalt coating on one section as compared with another seems to indicate that the coating's durability depends considerably on the type of asphalt used. The asphalt coating on the outside of the pipe usually exhibited a checked pattern of cracking and was found to have very little adhesion to the metal. Coated pipe that lost the coating early in service showed approximately the same amount of corrosion as uncoated pipe. In Kansas we have found that our bituminous coatings are of little benefit.

RESULTS ON ALUMINUM PIPES

The aluminum pipes were all good and had no pitting. Many of the pipes were clean, with no accumulation of soil. Soil samples were obtained from 23 of the 260 pipes inspected. The values of electrical resistivity and pH are given in Table 2. All pH values are in the range favorable to aluminum as well as to steel.

RESULTS ON STEEL PIPES

The number of steel pipes found with each rating is as follows:

Rating	Number	Rating	Number
0	11	3	176
1	455	4	55
2	213	5	19
		Total	929

Only a relatively few pipes had more than moderate rust with minor pitting. Table 3 gives the data collected in one county; there are 59 pages more of such tables.

A chart was developed in California (11) several years ago for estimating years to perforation based on pH and electrical resistivity of the surrounding soil. It was anticipated that the chart could be adjusted for conditions in Kansas. Our investigation of pipes from 7 to 43 years old revealed no correlation of pipe condition with pH and electrical resistivity. We had a relatively narrow range of values of pH, usually between 5.4 and 8.5, and little significance was attached to individual values for differences

Figure 1. Counties in Kansas where pipes were inspected.

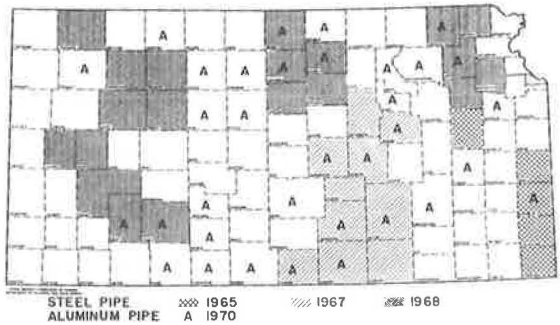

Table 1. Bituminous-coated pipes 3 and 4 years old.

	Total Pipes		Storm Sewer Pipes	
Division	Inspected	Coatings Good	Inspected	Coatings Good
1	133	9	42	8
2	57	4		
3	105	16	15	8
4	74	1	27	1
5	133	13	42	8
6	66	24	24	16
Total	568	67	150	41

Figure 2. Bituminous coating in 8-in. wide strip on 2-ft pipe gone in 3 years.

Figure 3. Bituminous coating on half of 2-ft pipe gone in 3 years.

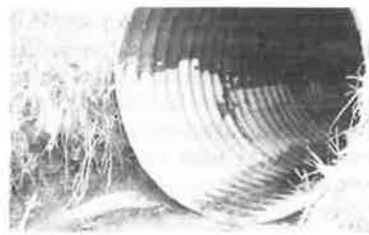

Table 2. Soil samples for aluminum pipes.

County	Station	Side	Use	Size (ft)	Resistivity	pH
Barber	62+30	Left	Entrance	2 by 24	4,315	8.3
Coffey	177+75	Right	Entrance	1.5 by 26	732	7.8
	153+93	Left	Entrance	1.5 by 26	1,050	7.9
	118+40	Right	Entrance	1.5 by 26	719	7.3
Commanche	291+80	Left	Entrance	7 by 40	1,145	8.3
Douglas	566+33	Left	Entrance	1.5 by 26	910	8.2
Edwards	7+00	Centerline	Crossroad	2 by 48	6,129	7.0
Geary	823+50	Right	Ramp	6 by 32	1,204	8.0
Gray	840+00	Centerline	Crossroad	6.8 by 40	1,976	8.1
	104+65	Right	Entrance	2 by 30	1,251	8.0
Greenwood	157+00	Right	Entrance	2.8 by 24	878	7.8
	95+51	Right	Entrance	1.5 by 24	876	7.8
Norton	42+35	Right	Entrance	2 by 36	1,301	8.6
Osborne	118+60	Right	Entrance	2 by 36	956	8.0
	156+80	Right	Entrance	2 by 40	813	8.0
Pottawatomie	202+10	Right	Entrance	2 by 20	1,247	8.0
	8+58	Left	Entrance	1.5 by 30	863	7.9
	572+95	Left	Entrance	2 by 24	976	8.5
Reno	1024+90	Right	Entrance	2 by 24	1,503	8.0
Riley	77+00	Left	Entrance	2 by 24	1,119	8.2
Russell	308+86	Left	Entrance	2 by 44	2,174	8.0
	226+92	Left	Entrance	2 by 32	1,008	Lost
	952+34	Right	Entrance	2 by 32	1,224	8.0

Table 3. Summary of pipe condition survey in Morris County.

									Predicted Life		
Station	Diameter (ft)	Sample	Soil From	Soil pH	Resistivity	Hoffer Color[a]	Water pH[b]	Age 1967	Actual Pipe	16-Gauge Pipe	Present Rating
51+00	4.5	101	Fill	7.4	1,865	Red		20	53	41	1
51+00[c]	4.5	102	Invert	7.7	1,215	Red		20	46	35	1
58+35	2.5	103	Fill	7.9	1,535	Red		20	49	38	2
58+35[c]	2.5	104	Invert	8.0	1,236	Red		20	47	36	2
61+70	2.5	105	Invert	7.8	1,055	Red		20	44	34	2
180+78	43.0	106	Fill	7.9	1,236	Red	7.8	20	83	36	1
408+50	1.5	107	Fill	7.7	1,008	Red		37	34	34	2
408+50[c]	1.5	108	Invert	7.5	1,055	Red		37	34	34	2
483+30	1.5	109	Invert	7.5	1,301	Red		37	36	36	3
483+30[c]	1.5	110	Fill	7.5	1,567	Red		37	38	38	3
501+37	1.5	111	Invert	7.5	1,724	Red		37	40	40	2

[a]Red indicates oxidizing conditions; blue indicates reducing conditions.
[b]Absence of values usually indicates intermittent flow and no water at the time of sampling.
[c]Same pipe as the one listed at this location in preceding line.

within this range. Neither was significance found for variation in resistivities that were generally between 700 and 2,300.

Evaluations were made for conditions that existed at the time of sampling. There is no doubt, for the older pipes at least, that environmental conditions have changed during the life of the pipes. For instance, the possible effect of chemical fertilizers and atmospheric and surface pollution of recent years probably is not much reflected in the present pipe life. It may be that galvanized pipe reaches a state of equilibrium with the soil and thereafter changes very slowly in the process of perforation. Hard water tends to produce a protective coating, and sometimes a pipe will have a buildup of iron rust from the soil and will not pit and perforate.

Several counties other than those shown in Figure 1 have had coal produced in them, and a study was made to ascertain the conditions in some of these areas. Usually the veins of coal are 14 in. or less in thickness and were mined from 40 to 60 years ago. No evidence was found that any of these old abandoned mine sources had affected pipes. However, another research study made near a current coal production site revealed that the entire invert of a normal galvanized steel test pipe was destroyed by corrosion in less than 1 year. The California chart also indicated a life of less than 5 years in this instance. In this same area, an entrance pipe had previously been replaced as a result of corrosion, the only case known in the entire state. Other pipes had been replaced for other reasons, and some of them have been slightly or severely corroded; but, as far as we know, no other pipe has been replaced on the state system of highways primarily because of corrosion. These studies show the importance of checking the geology reports and observing in the field the presence or absence of coal mines or coal seams. In case of doubt, especially if replacement would be expensive or difficult, perhaps metal pipes should not be used. Otherwise, long service life may be expected.

SUMMARY AND CONCLUSIONS

Variations of either pH or resistivity had little effect on corrugated metal pipe life in Kansas. All but 4 measured values of pH were between 5.4 and 8.5, and 90 percent of resistivities were between 700 and 2,300. Within these ranges, corrosion was not sufficient to determine a correlation such as that indicated by the California chart. In 3 surveys of galvanized steel pipes covering 43 years of service in 35 counties well distributed in the state, 929 pipes were inspected and only 19 perforated ones were found, most of which were in the vicinity of coal mines. All of them were serviceable. None had failed structurally.

This record of service indicates that corrugated metal pipes with normal galvanizing are satisfactory for most of Kansas except in the immediate vicinity of coal mines. No soil series was found that indicated that special pipes are needed. There are no entire counties or large areas of a county in Kansas where metal pipes need to be precluded. Additional attempts to designate critical areas are not practical. The presence or absence of coal mines in the vicinity of any project can be observed. A life of 40 to 50 years or more may be anticipated for normal galvanized steel pipe in Kansas at most locations other than near active coal mines.

Bituminous coatings on the inside of corrugated metal pipes in Kansas are usually cracked and partially lost in less than 3 years. In many cases the coatings are lost in only a few months. The condition of the bituminous coating on the buried portion of the outside of the pipe is not significant, because destructive strip corrosion originates on the interior surface and progresses toward the exterior surface. No noticeable corrosion was found on any of the aluminum pipes, all of which were 7 years or less in age.

IMPLEMENTATION OF RESULTS

The average annual expenditure for bituminous coating of metal culvert pipes in Kansas (computed as the additional cost for coated pipe over an equivalent amount of plain galvanized metal pipe and including costs for inspection of the coating) is approximately $25,000. This investment generally buys less than 3 years of coating life and probably no added pipe life. It is recommended that bituminous coatings be discontinued on metal pipes for highway construction in Kansas.

This investigation has shown that galvanized steel pipes may be used on any highways in Kansas and that no serious problems exist except as noted in connection with the mining of coal, which in Kansas is usually a strip pit operation. Otherwise galvanized steel pipes may be expected to last 40 to 50 years or longer. The geology report may be checked for the possibility of coal on or near a project. The presence of any detrimental coal mining waste or debris may be observed in the field during the design process, or it may be requested to be included in the geology or soils reports.

Inasmuch as the deleterious effluent from the coal mining areas contains sulfuric acid, we recommend that any pipe used in these areas where conditions are the worst be constructed of sulfate-resistant materials as recommended by Krizek et al. (12). Additional protection may be achieved by lining the ditch with broken limestone and using limestone screenings for backfill around the pipe (13, 14). The pollution abatement program of the state may eventually reduce or eliminate the sources of pollution from active coal mines (15).

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