MEMO TO: D. V. Terrell
Director of Research

Last year when results of the state-wide acid water survey were reviewed from the standpoint of policies governing drainage pipe installations, the permanency of bituminous coatings on metal pipe was a point that remained undecided. No exception was taken to the conclusion that metal was adequately protected as long as the coating or pavement remained intact, but most of those attending the review meeting doubted whether the performance of coatings on a few pipe placed in the main highway system 25 or 30 years ago was representative of performance that could be expected from coatings on a variety of metal pipe placed since the beginning of the Rural Secondary program.

As a result of this concern, Mr. Bray requested that a fairly extensive survey of Rural Secondary projects be made to determine the conditions that existed. This was done by E. M. West during the past summer, and his findings are contained in the attached report. Almost 300 bituminous-coated culverts on 51 Rural Secondary roads were inspected. The roads were in 26 widely scattered counties, and the dates of installation ranged from 1949 to 1952 - about the extent to which a sampling of the R. S. program could be taken. All sizes of pipe and pipe arches were represented, and a few uncoated multiplate arches were included because of the convenience for inspection.

In essence the survey showed that on practically all pipe correctly installed the coatings and pavements were in excellent condition except at the ends, and at points where sustained wetting and drying has occurred. Invariably light - and particularly direct sunlight - has caused cracking of the bituminous material, so that only those pipes with ends shaded are free from severe cracking. This, of course, is mainly a result of exposure to ultra violet light, an influence to which unmodified asphalt cements have notoriously little resistance. Fortunately deterioration of this sort extends into the pipe only a short distance, and on the pipe inspected (maximum age about 6 years) there was no evidence of removal of the asphalt or deterioration in the metal, even though some of the cracks were deep enough to expose the metal. Conditions might have been different had any of the pipe been carrying acid water.
Scaling of the asphalt to slight depths was caused by frequent and sustained wetting and drying. This appeared most often along the elevation of low flow or the "trickle" line in culverts where flow is continuous but variations in the water level are very small except during periods of heavy runoff. Scaling in this manner extended throughout the length of the culvert. Normally the scales adhered and were not removed, particularly where flow was confined to the bituminous pavement. Wherever the culvert had been installed incorrectly and the pavement was not in the invert, scaling damage to the bituminous coating was always severe, provided the wetting and drying conditions prevailed.

Insofar as bituminous coatings and pavements are concerned, I doubt that there is a significant difference between those applied today and the ones applied by comparable manufacturers 25 or 30 years ago. Construction conditions which favored shading, heavy silting in most of the coated culverts that were found, and the installation of pipe in positions that did not permit continuous flow account for the absence of cracking and scaling in the structures which were studied in the acid water survey. All these locations were revisited this fall to correlate circumstances in the earlier and the recent studies.

The report contains some other observations about drainage structures that are worthwhile, and in addition it brings up to date our records of the test installation at Mortons Gap - which was started four years ago in conjunction with the acid water study. Progressive deterioration in some of the sections is evident, and another pipe has been removed since the last report was made. In brief the experiment continues to point up the often-told story about the cleaning power of acids in drainage systems, which closes with the admonition "..... don't use sulphuric acid - it eats hell out of the pipes."

Respectfully submitted,

L. E. Gregg
Assistant Director of Research

Copies to: Research Committee
Mack Galbreath (3)
Commonwealth of Kentucky
Department of Highways

AN INVESTIGATION OF BITUMINOUS COATINGS AND PAVEMENTS
ON CORRUGATED METAL CULVERTS
(Rural Secondary Projects 1949-1951)

by

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November, 1954
The object of this inspection was to determine the efficacy of bituminous coatings and paved inverts on corrugated metal pipe and culverts installed on Rural Secondary Projects during the past few years. The study originated after earlier investigations had led to recommendations concerning the resistance of various types of pipe and culvert materials in the presence of acid-bearing waters.*

One of the conclusions from the acid-water survey was that "bituminous-coated metal pipe is resistant to acid corrosion as long as the coating insulates the metal from contact with acids." The condition of bituminous-coated pipe located in the primary and secondary roads which were surveyed in 1952 conveyed the impression that these coatings could be relied upon to adhere well and protect the metal for periods upward from 15 years. This was based not only on the few (approximately 30) coated pipe in the roads surveyed that year, but also on information obtained from surveys in other states. The pipe represented in the 1952 survey ranged up to 30 years in age.

When recommendations contained in the report on the work were considered from the standpoint of policies that should be applied to cross drains and entrance pipes on various classes of roads, there was some doubt about the comparability of coatings placed on pipe more than 15 years ago and the coatings applied to pipe in recent years. This was based on occasional observations made by others on Rural Secondary Projects where the pipe had been installed since 1948. Numerous failures of coatings were reported.

Inasmuch as the acid-water surveys had not included any roads in the Rural Secondary class, there was no basis for direct comparison between the older and the more recent coatings. As a result, the Division of Research was asked to extend its observations of bituminous-coated pipe to include many of those installed since the beginning of the Rural Secondary program. This is the report of those observations, supplemented by data from the drainage test installation at Morton's Gap which was started in April 1951, and on which the last report was made in December 1952.
GENERAL CONSIDERATION

Selection of Culverts

Locations of coated and paved pipes were selected through a review of final estimates on Rural Secondary Projects dating from the beginning of the Rural Secondary program in 1948 to and including 1951. Only those roads for which the records indicated use of bituminous coated corrugated metal (BCCM) pipe were considered.

Inspections were made on the majority of these roads, the principal exceptions being cases where there were more than two or three such projects in a county, or where the projects were very close together. An attempt was made to spread the inspections in order to include reasonably representative samples from all the areas in which culverts of this type had been used. General locations of roads on which inspections were made are shown in Fig. 1.

Inspection Procedure

At the outset it was decided that an analysis of each structure by some physical test on the material or by some definite yardstick of performance would not be feasible. A reasonable alternative was to make a complete inspection of representative culverts on the roads chosen for study, and from that record as much field information as could be obtained through inspections of the inside coating and pavement in its entirety and the outside coating wherever possible. The evaluation included not only visual observations as such, but also a superficial test for adhesion by which attempts were made to peel the coating or pavement. In addition, resistance to penetration was roughly estimated by use of
Fig. 1 - Locations of Rural Secondary Roads on Which Inspections Were Made.
a knife blade - the result proving some measure of hardness or dryness of the coating material. Photographs showing the general conditions encountered, were taken at each location and kept as a visual record of the inspections.

Whenever the presence of acid water at a culvert site was definitely suspected, the pH was measured with methyl orange or methyl red, and the value recorded. Drops of methyl orange were placed in the water for the range of acidity of pH 3.1 to pH 4.4 and methyl red for the range of 4.4 to 6.0. Since the majority of streams associated with the culverts studied were dry at the time of inspection, the pH test had limited application. When possible, these tests were conducted in pools of water elsewhere in the stream, but always close to the culvert involved.

Note was made of any situation thought to have had some influence on the condition of the coating and pavement observed at the time of inspection. In addition, these data included information relating to suggested improvements as well as comments on errors in construction.

Records

Since there was no standard procedure for this type of field study, it was decided that performance of the culverts would be judged according to conditions set forth in an inspection form (See Fig. 2). The form was designed to include: (1) a full description of the structure, (2) the date of installation, (3) general classification of as much of the drainage area that it was feasible to observe in the field, and (4) apparent condition
<table>
<thead>
<tr>
<th>INSPECTION NO.</th>
<th>Bituminous Coated Coated &amp; Paved Paved Invert</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOCATION</td>
<td></td>
</tr>
<tr>
<td>Date Installed</td>
<td>Dia. Gage Pipe Arch No. Lgth.</td>
</tr>
<tr>
<td>Grade</td>
<td>Est. Cover (Skewed, Beveled, Headwall) Gen. Cond:</td>
</tr>
</tbody>
</table>

**FLOW:**
- Continuous
- Frequent
- Intermittent
- Filling
- Erosion:
  - Sand
  - Gravel
  - Boulders
  - Shale

**TYPE DRAINAGE:**
- Cult. Land
- Pasture
- Hilly Wooded
- Wooded Swamp
- Farmyard
- Sewage
- Mine Water
- pH Paper
- pH Meter
- Water Sample

**MAINTENANCE CONDITION:**
- Excellent
- Very Good
- Good
- Fair
- Poor
- Pvt. Alin.

**TYPE SOIL:**
- Black Loam
- Clay
- Shale
- Sandy

**ASPHALT:**
- Adhesion Excellent
- Adhesion Good
- Adhesion Fair
- Adhesion Poor
- Coating Checks
- Percent Missing
- Average Thickness
- Could be Stripped

**COATING CONDITION:**
- Adhesion Excellent
- Adhesion Good
- Adhesion Poor
- Longitudinal Cracks
- Circumferential Cracks
- Width of Cracks
- Depth of Cracks
- Percent Missing
- Ave. Thickness over Crests

**SPELTER:**
- Like New
- Pin Point Rust
- Tubercular Rust
- Spelter Gone
- Loose Scaly Rust
- Heavy Pitting
- Perforated

**INSPECTION DATE**

**INSPECTED BY**

**GENERAL COMMENTS:**

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Fig. 2 - Sample of Inspection Form used in recording data for the present study.
of the coating and pavement. Provision was made for some features that could influence the degree of performance as well as for symptoms of failure.

Even though the spelter coating of metal was not directly related to bituminous coatings, effort was made to note the condition of the spelter where metal had become exposed on BCCM pipe. Also, in a few instances where an uncoated pipe having the same service life was located close to a coated pipe, both were inspected for the purpose of comparison. Another type structure - the uncoated metal arch fabricated on the site - was encountered on several occasions and incidental observations were made at those locations because of its function and similarity to the structures in question.

Information from the inspection forms are summarized in Table 1 in the Appendix. Much of the original material has been abbreviated in the table, particularly in the column headed Remarks, the intent being to save space and eliminate comments in the field notes that had no particular bearing on coatings or pavements for corrugated metal pipe.
RESULTS OF FIELD OBSERVATIONS

After inspections had been completed on a few of the roads it was evident that certain features in the performance of the coatings and pavements were common to all the installations. Although deterioration is undoubtedly progressive, the tendency toward development of these features was independent of the age of the pipe, all of which were from 2 to 5 years old at the time. Also it was independent of location in the state, and with the exception of ponding it was independent of location with respect to various features of the stream.

The most significant influences were manner of placement of the culvert at the time of construction, shading or lack of shading at the inlet and outlet, slope of the pipe under some circumstances, and maintenance conditions. This, of course, did not apply to the uncoated structures which were included for reasons previously mentioned.

Condition of the Coating

In all but a few of the BCCM structures the overall condition of the coating ranged from good to excellent. There were a few cases where dripping had occurred (but never to any great extent), indicating that adhesion was reasonably good but temperature susceptibility of the bituminous material was too great. In some culverts there was evidence of slight checking of the coating in the end portion. However, in no instance did this action expose the metal. In many cases, scratching and scarring of the coating (caused by improper handling) was found.
The outside coating of structures of any age was usually cracked and flaking off, except when the exposed part of the pipe was located in a shaded area. Almost invariably the outside coating on that portion of pipe buried within the fill was rapidly deteriorating or completely removed. However, there were no locations where additional deterioration such as removal of the spelter and consequent rusting was noted.

There were two special cases of extreme deterioration in coatings, which were caused by service conditions for which the coatings were not intended. These are covered specifically later under headings dealing with improper placement and burning of drift.

**Condition of Pavement**

In approximately 90 percent of the locations the pavement was in an excellent state almost throughout the entire length of the culvert. At the extremities (for varying distances in from the inlet and outlet ends) cracking in the invert was prevalent. Sometimes the cracking pattern extended an appreciable distance back into the pipe—from a few inches in small structures to several feet in large arches.

Deterioration of this type was dependent upon exposure to light, and particularly to direct sunlight. Ends of pipe which were shaded, such as the one shown in Fig. 3, were generally free from cracks in the pavement. On the other hand, end openings that were fully exposed invariably showed pronounced cracking of the pavement. This was so whether the culvert consisted of a circular pipe (Fig. 4 and 5) or an arch (Fig. 6). The extent of cracking was influenced by both the size of opening and the thickness of pavement. As one would expect, cracks extended farther
Inlet of a 24-in. diameter coated and paved culvert completely shaded by overhanging rock. No scaling was evident, and only minor cracking had occurred for a distance of 3 to 5 in. These conditions were typical of all coated and paved pipe which were shaded and placed on sufficient slopes to prevent ponding of water at the inlet and outlet.

Fig. 3 - Inlet of a 24-in. diameter coated and paved culvert completely shaded by overhanging rock. No scaling was evident, and only minor cracking had occurred for a distance of 3 to 5 in. These conditions were typical of all coated and paved pipe which were shaded and placed on sufficient slopes to prevent ponding of water at the inlet and outlet.
Fig. 4 - Outlet ends of (a) 42-in. diameter pipe and (b) 58x36-in. pipe arch, both installed in 1949. Note the cracking patterns in the paved inverted.
Fig. 5 - Inlet (a) and outlet (b) ends of a 42-in. diameter coated and paved pipe placed in 1952. Cracking was pronounced, but deterioration had not progressed to the extent indicated for the pipe in Fig. 4 which had a greater period of exposure.
Fig. 6 - Views of a 34x59-in. coated and paved pipe arch showing (a) cracking of the pavement at the outlet, and (b) scaling of the outside coating at the same end of the arch. Date of installation - 1950.
toward the interior of the culvert as the size increased, and the widths of individual cracks were greater in the pavements having the greater thicknesses.

The direction of cracking was both longitudinal and circumferential, and usually occurred at each corrugation in the end portion that was exposed. At the extreme edge of a large, thickly paved culvert the cracks were as great as 3/8-in. wide, and in some cases deep enough to expose the spelter. This condition receded to the point where cracks became mere lines and disappeared farther back into the pipe. Usually adhesion remained good, even near the outer edge and seldom could these polygons of weathered asphalt be peeled off by hand.

A different type of deterioration, which obviously resulted from ponding of water at an end of the pipe is shown in Figs. 7, 8, and 9. Here scaling is associated with the cracking that occurred through exposure to light. The scaling condition existed invariably where ponding had occurred, and apparently it was dependent upon alternate wetting and drying at a relatively slow rate.

Generally scaling caused by ponded water was localized, since the possibilities for ponding are limited even in a culvert on 0 percent gradient. However, in a pipe having relatively low flow most of the time with slight fluctuations in the water surface, a favorable condition for wetting and drying exists throughout its entire length. Thus, scaling has occurred in several of the pipes at the general level of low flow or the so-called "trickle line". This is illustrated in Fig. 9.

Usually scaling action had progressed for only a slight distance into the bituminous pavement, and the scales were well attached to the
Fig. 7 - Combined scaling and cracking at the outlet of a 44x26-in. pipe arch installed in 1949. In some way this end of the structure had been bent upward providing for intermittent ponding to a slight depth, and consequent wetting and drying.
Fig. 8 - Scaling at both the inlet (a) and outlet (b) of a 65x40-in. pipe arch installed in 1949. Associated cracking was more extensive at the outlet than at the inlet, which is not subjected to direct sunlight.
Fig. 9 - Scaling along the edges of the low water level or "trickle line" in the paved invert of a 72x44-in. pipe arch installed in 1949. This condition extended throughout the entire length of the culvert.
underlying bituminous material. Still there were indications that the
deterioration might be appreciably progressive with time, and that
scaling does encourage failure of the underlying pavement. There were
some locations where the dry scales had hardened enough to become
brittle, and undoubtedly they could be broken off by the scouring action
of silt and debris.

At many locations where silting had occurred to appreciable depth
the usual symptoms of deterioration were not evident. Obviously the
accumulated material has insulated the pavement and prevented exposure
to both sunlight and wetting and drying.

Improper Placement of the Paved Invert

In about 30 percent of the culverts inspected, the paved section
had not been laid so that it formed the culvert invert. Instead, the
pavement was shifted to one side or the other, and sometimes even to
the top of the structure. Often this was the apparent cause of coating
failure, since there were no cases of failure in the coating when the
pavement had been properly placed in the invert.

Abuses of this nature led to peeling and scaling of the coating
with subsequent exposure of the spelter. As a rule, when the pavement
was positioned incorrectly and there was reasonably continuous low flow,
a portion of the bituminous coating was scaled and some of the coating
had been completely removed throughout the entire length of the culvert
at the trickle line. Damage to the coating was always confined to a
strip approximately 4 inches wide in small culverts and as much as one
foot wide in large sections. A typical example of misplaced pavement
is shown in Fig. 10.
Fig. 10 - Coated and paved pipe placed with the invert shifted almost 90 degrees to the left. The knife (see arrow) marks the lower edge of the pavement. Water has flowed on the coating since installation of the pipe in 1949, and considerable scaling has occurred in the trickle line.
Damage to Coating and Pavement Caused by Fire

Although damage to bituminous coatings and pavements caused by the burning of drift has no bearing on the ordinary performance of these materials, some aspects of this type damages are worth recording since two such incidents were encountered during the inspections. In at least one of the two locations there was evidence that the drift was burned by someone other than highway maintenance crews, indicating that probably the drift was blocking drainage to the extent of its becoming a nuisance.

Some of the effects of burning drift are illustrated by Fig. 11 and 12. The structures were installed in 1949, and about two years later the drift was burned. Both ends of the archs are now covered with rust, and much of the protective coating is gone even from the interior of the pipe adjacent to the one in which the burning occurred. Where rusting was severe, even the spelter was no longer available to provide protections.

Plain Multi-Plate Pipe Arches

Inasmuch as they were so easily accessible, a number of uncoated, multi-plate pipe arches were included in the inspection. The condition of the spelter on these structures of uncoated metal was of fundamental concern.

In the majority of cases there was evidence of rusting which generally covered the entire invert portion. As a rule, the rust pattern was a "pin point" type. Occasionally rusting had progressed to a point where scaling of the spelter had spread throughout the invert. Because of the obvious vulnerability of the metal to corrosion by acids whenever they may be present, water at each of the sites inspected was checked for acidity. There was no indication of acid at any of the locations.
Fig. 11 - Outlet end of 72x44-in. pipe arch in which drift has been burned. Although it is not evident in the photograph, the entire bituminous coating has been destroyed and only fragments of the pavement remain in the invert. Extensive rusting was present throughout the pipe at the elevation indicated by the pointer, and on the inside crown of the structure. Date of installation - 1949.
Fig. 12 - Outlet end of a companion 72x44-in. pipe arch placed alongside the arch shown in Fig. 11. The pavement was in good condition, but much of the coating on the left side had been removed by intense heat from fire in the adjacent structure.
Even without acid as a factor, the general condition of inverts in these somewhat major structures gave the impression that protective coatings at least similar to those placed on smaller culverts should be developed for the low-flow portions of multi-plate arches.

Miscellaneous Observations of Field Practice

An appreciable percentage of the culverts inspected had ends that were scarred, bent, partially collapsed, or completely broken off. Undoubtedly most of this type damage was caused by graders changing direction while pulling a nearby ditch, or in a few instances it could have been caused by mowing machines. The ends of some pipe are so obscured by their surroundings it is difficult to locate them, especially where there is dense plant growth. Under such circumstances the marking of culverts by posts, or the clearing of vegetation or debris would help avoid damage.

A number of locations illustrated the importance of care in bedding and backfilling at the time of construction. Occasionally large pipe arches were severely deformed and distorted in shape although there was no evidence of collapse. On the other hand, some pipe with insufficient cover were collapsed, and in a few cases the outlet was higher than the inlet indicating poor bedding conditions during construction.
TEST INSTALLATION AT MORTONS GAP

In the course of inspections on Rural Secondary Projects in the western part of the state, the drainage pipe test installation at Mortons Gap was observed and general performance conditions evaluated. This test installation, developed as a part of acid water investigations*, was well over four years old and pipe at that location were at about the median age of projects involved in the coating condition survey.

Because of the general differences in objectives of the studies, and the fact that acidity of water at the Mortons Gap site is almost always very high, no direct comparison between the two sets of conditions was intended. However, a progress report on results from Mortons Gap has not been made in written form within the past two years, and the opportunity thus afforded to combine material of similar nature is convenient.

The test installation originally consisted of 16 sections of 24-in. pipe. Two sections of each of the different types were installed in the following order, beginning at either end (See Fig. 13).

1. Reinforced concrete
2. Vitrified clay
3. Corrugated metal, asbestos bonded bituminous coated and paved
4. Corrugated metal, half-coated and paved
5. Corrugated metal, plain galvanized
6. Corrugated metal, full double coating without paving
7. Corrugated metal, full coated and paved according to Kentucky Special Specification No. 1-R
8. Corrugated metal, galvanized, asbestos bonded with bituminous seal coat

* See Report No. 2 on "A Survey of Acidity in Drainage Waters and the Condition of Highway Drainage Installations", issued by the Research Laboratory in December, 1952.
During the interim, as noted in the summaries of inspection that follow, some of the sections of pipe failed and were removed.

**Inspections Previously Reported**

Twelve inspections (or events), including the one at the time of the installation, have been reported previously. In essence the results were as follows:

1951 - April 25 - Date of installation. Specific resistance of water - 280 ohms.

May 22 - Date of first inspection. Specific resistance of water - 260 ohms. Spelter gone from plain galvanized metal pipe.

July 16 - Water tested 235 ohms. Invert eaten out of corrugated metal, plain galvanized sections. Concrete pipes showed slight etching.

August 20 - Water tested 240 ohms.

October 18 - Routine inspection; no significant changes.

1952 - March 9 - Water tested 300 ohms.

April 15 - Heavy rain dislodged several sections of pipe and deposited silt in the channel.

April 29 - Installation restored. Galvanized metal sections not replaced. Water tested 290 ohms.

June 18 - Routine inspection; no significant changes.

August 4 - Water tested 268 ohms.

August 28 - Routine inspection; no changes noted.

October 5 - Water tested 265 ohms. Concrete pipe beginning to show visible evidence of progressive corrosion. Aggregate exposed in the invert, but no appreciable reduction in thickness of material observed.
At the inspection on October 5, 1952, the vitrified clay sections and variously coated metal sections remained virtually unaffected, except at those points on metal pipe where the protective coatings had been scarred during placement. The half-coated galvanized metal sections showed some scarring where the uncoated portion was in contact with fill material. This was interpreted as a mild form of corrosion.

Inspections Not Previously Reported

In the period since 1952, inspections have been less frequent than they were prior to that time. This was partially because a basis for estimating the need for attention had been established, and partially because all the inspections were combined with other work by Research Laboratory personnel in the general vicinity of Mortons Gap. Four inspections were made, with the essence of results being as follows:

1953 - July 7 - Routine inspection; water tested 267 ohms. No changes noted.

September 7 - Full double coating gone in invert of one (upstream) section of pipe No. 6, metal corroding.

1954 - July 22 - Full double coated section (No. 6 from upstream end) removed with invert eaten out.

August 18 - Water tested 275 ohms. Pipe sections in the lower half of the installation were heavily silted. The pipe removed and reset. Downstream channel cleared to prevent silting if possible.

This being the latest inspection the following conditions observed in the upstream half of the installation are pertinent:
Fig. 13 - Test installation at Mortons Gap

Fig. 14 - Interior of reinforced concrete pipe. Exposure of coarse aggregate has resulted from corrosion and removal of mortar by acid water. Date-August, 1954 Age - 4-1/3 yr.
Fig. 15 - Vitrified clay pipe. Although staining and discoloration are evident at the edges of the flow line, structurally the pipe is in excellent condition. Date - August 1954; Age - 4-1/3 yr.
Fig. 16 - Corrugated metal, asbestos-bonded, bituminous coated and paved pipe. The flow line has been obscured by silt but the pavement in the invert has remained smooth and intact. There is no evidence of any deterioration. Date - August, 1954; Age 4-1/3 yr.
1. **Reinforced concrete** - In these two sections of pipe considerable corrosion has caused removal of mortar and exposure of the aggregate. (See Fig. 14) In this case, the aggregate used was Ohio River Gravel, and in view of other similar inspections, it is believed that corrosion would have progressed further had the coarse aggregate been limestone.

2. **Vitrified clay** - Both sections of pipe were in excellent condition with no visible deterioration (See Fig. 15).

3. **Corrugated metal, asbestos bonded, bituminous coated and paved** - Both sections were in excellent condition with no visible deterioration (See Fig. 16).

4. **Corrugated metal, half-coated and paved** - The pavement and coating in the remaining section was in excellent condition, and there was no evidence of corrosion in the upper portion or crown since that has not been exposed to the acid water flow (See Fig. 17). During periods of high flow the acidity is greatly reduced.

5. **Corrugated metal, plain galvanized** - Both sections removed and abandoned after two months of service.

6. **Corrugated metal, full double coating without paving** - Removed July 23, 1954, with invert eaten out (See Fig. 18).

7. **Corrugated metal, full coated and paved according to Kentucky Special Specification No. 1-R.** - As illustrated in Fig. 19, the coating was peeling at several points in this pipe, and there was evidence of serious rust at places where the coating was removed.
Fig. 17 - Corrugated metal, half-coated and paved pipe. Note that the pavement and coating are in excellent condition. Date - August, 1954; Age 4-1/3 yr.
Fig. 18 - Upstream section of corrugated metal pipe, full double coated without pavement. Note that part of the invert has been eaten away by corrosion (pipe is rotated 180 degrees). Date - August 1954. Date of removal - July 1954; Age at failure - 4-1/4 yr.
Fig. 19 - Corrugated metal pipe, full coated and paved according to Kentucky Special Specification No. 1-R. The coating has peeled at some points immediately above the pavement in the invert. Rusting has occurred to a minor extent in areas where the coating is missing. Date - August 1954; Age 4-1/3 yr.
8. Corrugated metal, galvanized, asbestos bonded with bituminous seal coat - Although there was no evidence of deterioration whatsoever on the inside of this section, the seal coat outside appeared very dry and tending to flake off or peel.
SUMMARY AND CONCLUSIONS

The performance of coatings on the inside of culvert pipe in the Rural Secondary System was good in every case where the culvert had been properly installed. Coating failures that were observed, resulted from one or more of the following: (1) abuse in handling and transportation, (2) improper positioning of the paved invert during installation, and (3) intentional burning of drift material within or adjacent to the pipe.

Apparently the fairly generalized peeling of coating material on the inside of one section of pipe No. 7 (corrugated metal full coated and paved according to Kentucky Special Specification No. 1-R) at the Mortons Gap installation has no connection with any of the influences mentioned above, and no direct cause is evident at this time. The exposed metal is far enough above low flow to avoid water of high acidity, but there is considerable rusting at places thus exposed.

Coatings on the outside of metal pipe lose adhesion, even when the pipe is covered by earth fill. Inasmuch as the coatings merely become loose but are not removed from pipe within the fill, no particular damage results at least within the period represented by the Rural Secondary projects inspected. Whenever a coated pipe projects beyond the earth fill, cracking, scaling, and removal of the bituminous material occurs within a relatively short period of time particularly if the pipe is exposed to direct sunlight. Even here the loss of protection has no inherently serious consequences, provided the spelter remains undamaged.
Pavements in metal pipe are giving dependable protection to the metal surface, except at the ends where exposure to light is rigorous and at points where ponding or low flow has developed frequent wetting and drying conditions. Cracking results from the exposure to light and scaling results from wetting and drying. Scaling has hardly impaired the protective ability of any of the pavements within the 2-to 6-year period of service, and because of the fact that the material scales to very slight depths, probably the time required to reform and remove several successive layers is great.

On the other hand, cracking starts at a very early age and some of the cracks carry through to the metal within a few years at the most, particularly where the pipe is exposed to direct sunlight. Even when cracks were pronounced there was no visible deterioration of metal beneath. That applies to situations where there was essentially no acidity in the water. Obviously in cases where there is appreciable acidity the chances for serious corrosion of metal at the base of the cracked pavement are great.

A full evaluation of protective coatings on metal drainage pipe would involve more than superficial observations such as those contained in this survey, and probably additional observations at many more culverts would merely confirm the results that have been obtained. The sample in this case is considered representative of the conditions that prevail.

Even though the service conditions are realistic, the lack of uniformity in installation, exposure, and probably manufacture, limit the possibility for estimating what can be expected from this type protective coating, and how it can be improved.
Inherently asphalts are vulnerable to deterioration under exposure to light, heat, and in some respects moisture. Unfortunately there is no reliable measure of the way or the extent to which deterioration occurs under a given set of circumstances. However, as demonstrated by the performance of asphalotic pavements for roads, by the performance of asphalotic coatings containing asbestos or rock wool fibers (and other features of fabrication), by pipe subjected to considerable depths of silting, or by mineralized asphalotic coatings in roofing materials, there are possibilities for creating favorable insulating conditions under which asphalotic coatings can perform to maximum advantage so far as weathering is concerned.

The extent to which basic concepts can be applied to coatings and pavements for metal pipe is, of course, within the province of manufacturers. Improved treatment for the ends of pipe seems especially needed, and no doubt that is a problem of which the industry is aware. From the standpoint of the Department, better service from drainage structures in the corrugated metal categories would be achieved if:

1. More care was used in positioning culverts with paved inverts at the time of construction;

2. Pipe were set slightly below grade so that a limited amount of silting (perhaps as much as 6 inches) would occur in the course of subsequent stream action;

3. The ends of culverts were plainly marked and guarded against damage from maintenance equipment and passing vehicles; and

4. Uncoated metal arches were given a protective coating - perhaps a pavement - in the invert at the time of installation.
It was noted during the inspections that corrosion in the inverts and at the base was extensive on most of the metal arches observed. In view of the size of arch culverts and the investment they represent, it appears inconsistent to be unduly concerned with coatings and pavements on several minor conduits when on the same road a single structure having no protection whatsoever is equal to all the minor conduits as a group. Probably the life of several arches now in service could be extended if their inverts were suitably paved and the lower portions of the sides suitably coated.
APPENDIX
# INDEX TO CULVERT LOCATIONS
(Accompanying Table 1)

<table>
<thead>
<tr>
<th>Inspection No.</th>
<th>County</th>
<th>Rural Secondary Project No.</th>
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<th>Inspections No.</th>
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<th>State (Abbrev.)</th>
<th>Total Cost</th>
<th>Flow Erosion</th>
<th>Type Drainage</th>
<th>Condition of Inlet &amp; Outlet</th>
<th>Remarks</th>
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<td>Concrete excellent condition.</td>
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**TABLE 1 - SUMMARY OF DATA FROM ALL INSPECTIONS**

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<th>Install Date</th>
<th>States</th>
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<th>Flow Erosion</th>
<th>Type Drainage</th>
<th>Condition of Inlet &amp; Outlet</th>
<th>Remarks</th>
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<td>MN</td>
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<td>0</td>
<td>0/0 0/0 0/0 Silted beyond inspection.</td>
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<td>0</td>
<td>0</td>
<td>Concrete polished in invert - erosion evidence on sill.</td>
</tr>
<tr>
<td>1949</td>
<td>TX</td>
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<tr>
<td>1949</td>
<td>OR</td>
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<td>Concrete excellent condition.</td>
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<tr>
<td>INSTALLATION</td>
<td>FLOW GROUN</td>
<td>TYPE DRAINAGE</td>
<td>MAINT. COATING</td>
<td>PAVEMENT</td>
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</tbody>
</table>

**Remarks**:
- Bull in invert, 8' point rust in invert at trickle line.
- Coating not exposed to sun.
- Coating in flow line. Wet and dry coating in pavement; dry and brittle.
- 1/38 erosion in trickle line.
- Excellent condition.
- Cracks have from em. High cut shaft correlates.
- Cracks have from em. High cut shaft correlates.
- Heat as radiating caused.
- Heat as radiating caused.
- Check out, exposed to air, and out.
- Cracking in invert, coating completely missing under well.
- Coating and pavement in poor condition.
- Coating is light. Outside coating off where exposed well.
- Peel reflects rotation. Breakdown in em.
- High above force. 80 pound rocks to culvert.
- Two trench lines of rock length plus.

**Cracks**:
- 1/32
- 1/8
- 1/6
- 1/32
- 1/32
- 1/6
- 1/6
- 1/32
- 1/6
- 1/6
- 1/6
- 1/6
- 1/6
- 1/6
- 1/6
- 1/6
- 1/6

**Remarks**:
- Pavement in invert, coating holding well.
- Poor alignment on invert.
- Coating in flow line 1/8" bare metal. Pavement 10" missing on the end 1/4". Outside coating cracked.
- Coating 1/8" deep through pipe. Coating disintegration at flow line.
- No drainage area, waste of material.
- Coating cracked 1/4" on ends. Outside coating covered by rocks.
- Rust and sheared good, west end radiation cracked.
- Sensors in flow line, radiation at flow line.
- Radiation under ground.
- Trickle flow under ground.
- Sensors at 990 o'clock at 3:00. Outside coating gone.
- Coating in flow line. Outside coating gone.
- Coating well.
- Excellent condition.
- Invert completely covered by Deposit. Several pipe areas in this area all washed. Possibly 5 years of life remaining.
- Typical weathering on inlet and outlet ends.
- Elbow sheared in: Coating missing at flow line, blistering. Pavement excellent under the end - like new.
- Typical condition, radiation weathering.

**Weathering**:
- Weathering first 1/8" from end.
- Weathering 1/8" from end. Trickle line erosion.
- Typical weathering and erosion at trickle line.
- Stalled full of sand.
- Invert advanced tabular crack 1/8" up on sides of each over entire area.
- Invert started in excellent condition.
- Outlet pavement typical cracks on end. Must have 100 head on end of culvert.
- Invert sheared in excessive and excellent condition.
- Outlet exposed typical weathering pattern.
- Coating good - pavement weathered light - 6" from end.

**Drainage**:
- 1/4" Metal
- 1/8" Metal
- 1/6" Metal
- 1/32" Metal

**Condition of Inlet & Outlet**
- Excellent
- Good
- Fair
- Poor
- Very Poor
<table>
<thead>
<tr>
<th>Inspection No.</th>
<th>Year Inspected</th>
<th>Flow Grown</th>
<th>Type Drainage</th>
<th>Maint. Cond.</th>
<th>Coating</th>
<th>Pavement</th>
<th>Remarks</th>
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<td>O</td>
<td>Width at Crack</td>
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<td>F</td>
<td>O</td>
<td>O</td>
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<tr>
<td>135</td>
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<td>O</td>
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**TABLE 1 - CONT'D.**

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<th>Maint. Cond.</th>
<th>Coating</th>
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<td>53 X</td>
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</table>

**INSTALLATION**

- High barrel flaking 2" deep. Lower barrel invert rusted - no acid by test.
- Some rust - partially protected by gravel bar in structure approximately 6" deep.
- Pavement badly checkered first 4" last 4", Typical weathering on outlet sealing etc. Molding and poor adhesion at outlet. Outside coating dry and ready.
- Excellent condition - Inlet and outlet protected by fill (fill and soil).
- 1/2" Full of all - no pavement inspection.
- Excellent condition - Inlet and outlet shaded. Excellent condition - Inlet and outlet shaded.
- No cracks - no peeling - excellent condition. Cost in shade. Some evidence of degradation in trickle line - no acid outside coating good.
- Excellent: In any way. At age dry installation, coated by green and soil.

**Type MAINT. TABLE**

- Water dripping first 4", last 4", Typical weathering at invert linings on ovals by radiation. Performed at 9:00.
- Both ends exposed - Typical weathering of pavement and sealing in first line. Cover transfilter.
- In excellent condition - likes covered both ends, shaded from weather and high enough to avoid water from standing in pipe. Coating sticking where pavement invert is not in bottom. Outlet coating at 9:00. Typical weathering at invert - excellent fill.

**Pavement**

- Typical flaking at outlet - Inlet good - shaded and vegetation.
- Typical flaking at outlet - Inlet good - shaded and vegetation. Typical flaking at outlet - Inlet good - shaded and vegetation. Typical flaking at outlet - Inlet good - shaded and vegetation.
- Typical weathering - both ends sealing crack filling and last 1". Typical flaking first and last three feet. Bag an average 72."
<table>
<thead>
<tr>
<th>Installation No.</th>
<th>Year Installed</th>
<th>Material of Inlet</th>
<th>Type of Inlet</th>
<th>Material of Outlet</th>
<th>Type of Outlet</th>
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**Remarks:**
- Last test of pavement having slight cracking. Inlet end in excellent condition.
- Typical cracking at outlet exposed 2%. Coating shows in trickle line.
- Outlet typical cracking. Inlet in excellent condition. Crossed joint in trickle line. Silted.
- Outlet typical cracking. Inlet in excellent condition. Crossed joint in trickle line. Silted.
- Typical weathing on paving, slight cracking, outsite coating cracked. Silted to exposed speckler. Rust no acid from test - abrasion possible. Rust in the invert.

**TABLE 1 (CONT'D.)**
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**Remarks**

- No cracks - ends fairly shadowed. Pavement slightly off center.
- Flushing good - shadowed by still and gravel. Full flow.
- Typical weathering at outlet - moderate.
- Grading through in very good shadowed condition - creates in pavement - outlet end and no chance of causing any damage to outlet end. inlet collapsed.
- Outside coating good.
- Good - no damage - shadowed - outside coating good.
- Cracking in pavement good - in excellent shape.
- Outside coating good. Typical weathering; expansive scaling and falling in trifle line. Extreme flaking in outlet. Coating perfect - all exposed - spotter good.
- Shielded - excellent condition both ends due to shade. Typical weathering; extreme flaking condition - no evidence of setting and drying. Small cracks in pavement material may be too dry; last 3' to 5'.
- Outlet end free and 3' of full. Some holes in base.
- Insert at 5 o'clock. Typical weathering on ends. Very little drainages on this road. Pavement at outlet at 5 o'clock. Typical weathering outlet and shadowed - in excellent shape.

- No cracks - ends fairly shadowed. Pavement slightly off center.
- No setting or drying. Typical weathering at outlet - moderate.
- Grading through in very good shadowed condition - creates in pavement - outlet end and no chance of causing any damage to outlet end. inlet collapsed.
- Outside coating good.
- Good - no damage - shadowed - outside coating good.
- No cracking at outlet. Protect and outlet and outlet - else good.
- Full flow - no pooling at outlet - outlet and outlet partially collapsed. Outlet pavement fails.

- No cracks - ends fairly shadowed. Pavement slightly off center.
- Grading through in very good shadowed condition - creates in pavement - outlet end and no chance of causing any damage to outlet end. inlet collapsed.
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- No cracks - ends fairly shadowed. Pavement slightly off center.
- No setting or drying. Typical weathering at outlet - moderate.
- Grading through in very good shadowed condition - creates in pavement - outlet end and no chance of causing any damage to outlet end. inlet collapsed.
- Outside coating good.
- Good - no damage - shadowed - outside coating good.
- Grading through in very good shadowed condition - creates in pavement - outlet end and no chance of causing any damage to outlet end. inlet collapsed.
- Outside coating good. Typical weathering; expansive scaling and falling in trifle line. Extreme flaking in outlet. Coating perfect - all exposed - spotter good.
- Shielded - excellent condition both ends due to shade. Typical weathering; extreme flaking condition - no evidence of setting and drying. Small cracks in pavement material may be too dry; last 3' to 5'.
- Outlet end free and 3' of full. Some holes in base.
- Insert at 5 o'clock. Typical weathering on ends. Very little drainages on this road. Pavement at outlet at 5 o'clock. Typical weathering outlet and shadowed - in excellent shape.
<table>
<thead>
<tr>
<th>INSTALLATION</th>
<th>FLOW DEPTH</th>
<th>TYPE</th>
<th>MAIN</th>
<th>COATING</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inspection No.</td>
<td>Year Installed</td>
<td>Size (inches)</td>
<td>Grade</td>
<td>Condition</td>
<td>Remarks</td>
</tr>
</tbody>
</table>

### Remarks

- **Type**: Drainage condition
- **Flow Depth**: Flow rate information
- **Main**: Main type of the drainage system
- **Coating**: Coating condition

#### Condition of Inlets & Outlets

<table>
<thead>
<tr>
<th>Inlet Location</th>
<th>Condition</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inlet A</td>
<td>Excellent</td>
<td>No cracks.</td>
</tr>
<tr>
<td>Inlet B</td>
<td>Good</td>
<td>Slight evidence of settling.</td>
</tr>
<tr>
<td>Inlet C</td>
<td>Fair</td>
<td>Cracks present in protruding outlet.</td>
</tr>
<tr>
<td>Inlet D</td>
<td>Poor</td>
<td>Outlet silted and high. Lost 6%.</td>
</tr>
</tbody>
</table>

#### Table 1 (Continued)

<table>
<thead>
<tr>
<th>Inlet Location</th>
<th>Condition</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inlet E</td>
<td>Poor</td>
<td>Outlet trickled line cracked to meets.</td>
</tr>
<tr>
<td>Inlet F</td>
<td>Fair</td>
<td>Silt in bottom seems to be protecting pavement.</td>
</tr>
<tr>
<td>Inlet G</td>
<td>Good</td>
<td>Slightly weathered.</td>
</tr>
<tr>
<td>Inlet H</td>
<td>Good</td>
<td>No cracks.</td>
</tr>
<tr>
<td>Inlet I</td>
<td>Excellent</td>
<td>No cracks.</td>
</tr>
</tbody>
</table>