PERFORMANCE OF PROTECTIVE COATINGS ON STRUCTURAL PLATE PIPE AND PIPE ARCHES

by

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(The opinions, findings, and conclusions expressed in this report are those of the author and not necessarily those of the sponsoring agencies.)

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SUMMARY

The performance of bituminous coatings on structural plate pipe and pipe arches was evaluated in a limited field study supplemented by a survey of information from other agencies. Of the two available application techniques, immersion of individual plate elements in hot asphalt and spraying of a cold asphalt mastic on completed pipe sections, it appears that the latter provides a more adherent and more consistently satisfactory coating.

It is recommended that the use of asphalt mastic sprayed on the assembled structures be specified, whenever possible, in preference to coating by hot immersion. The application of asphalt mastic to large sections of pipe assembled at the plant and shipped to the construction site should be explored. Elimination of the coating requirement is not recommended at this time, but it is suggested that data on the real cost of the coatings be collected by the operating divisions and that the progress of broader studies of the performance of coatings proposed or under way in other agencies be followed.

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INTRODUCTION

The Virginia Department of Highways and Transportation requires that corrugated steel pipe and structural plate drainage structures installed under interstate and high class primary highways be protected by a bituminous coating. In accordance with common practice, the Virginia specifications allow the use of either of two coating techniques: immersion of pipes or structural plate elements in hot asphalt, or spraying of a cold asphalt mastic on assembled large-diameter pipes or arches.(1)

Reports from the field have indicated that shortly after construction of the pipes, the protective coatings were stripped from the interior surfaces, particularly in those instances where the bituminous material had been applied by immersion. In considering the elimination of the immersion coating technique from the specifications, the Drainage Committee of the Department of Highways and Transportation requested the assistance of the Research Council in investigating the failure of the coatings. At a meeting between the committee and research personnel, it was agreed that an assessment of the problem would be made through field inspections of representative structures and contacts with other agencies.

This report presents the findings of the Council's limited study. It is believed that the field survey, coupled with information from the Department's districts, has revealed the extent of the problem in Virginia. Much of the relevant information from elsewhere was unpublished. The results indicate that the sprayed-on material provides a more adherent and more consistently satisfactory protective coating. The ultimate question of the cost-effectiveness of both types of bituminous coatings could not be answered.

COATING TECHNIQUES

As mentioned earlier, there are two commonly used methods for applying a bituminous coating to structural plate pipe and arches: immersing the plate elements or spraying completed pipe sections. Polymeric coatings applied to the rolled stock are available, but to date only in gage thicknesses suitable for smaller pipes.

In the immersion process, plate segments are dipped in a vat of hot (400° + 5° F) asphalt. The specification for the asphalt (AASHTO M190) is very general in nature, while the Virginia requirements govern the temperature of the asphalt and the preheating of the pipe. The general nature of the material specification and varying degrees of compliance with the specific temperature requirements may have resulted in a considerable variation in the bond of the coating that was observed in the field.

A significant, and apparently unavoidable, problem associated with the immersion process is the flow of the asphalt toward the downward edge of the plate. As may be seen in Figure 1, the coating at the downward edge is thicker than elsewhere on the plate, a condition that was seen during field inspections to have produced difficulties in aligning the plates and developing the proper torque in the bolts.

The asphalt mastic, composed of oxidized petroleum asphalts with long fiber asbestos and finely divided mineral fillers, is a different material from the pure asphalt used in the immersion process. While the mastic is available in consistencies for spraying, brushing or trowelling, it has usually been sprayed on assembled structures at the site. Field inspections disclosed that the material was tough and tightly adhered to the pipe surface; and because the structure had been assembled prior to application, the joining of the plates presented no problems.

An alternative to spraying the pipe at the site is routinely used by a fabricator in Bristol. There the pipes are assembled in lengths of 35 to 40 feet, which are suitable for shipment by tractor-trailer, and coated at the plant as shown in Figures 2 and 3. A typical joint which was tight and well coated is shown in Figure 4. The completed pipe could be shipped to the construction project and lifted into place with a minimum of on-site time and labor, and the least possible adverse effect on the environment.

Prior to the initiation of the present research study, the Drainage Committee contacted the Mid-Atlantic Corrugated Steel Pipe Association to obtain the industry's viewpoint. The producers favor retention of the current specification, which allows both coating techniques, without modification. They believe that the maximum flexibility in specifications will lead to the least cost, but it is noted that the methods could be combined or that field coating alone could be specified on individual projects.

FIELD SURVEY

General

All eight construction districts were contacted to ascertain their experience with structural plate pipe and arches. It appears that the problem is of most concern in the southwest portion of the state—the Bristol and Salem Districts. Field inspections were made at three locations in the Bristol District,

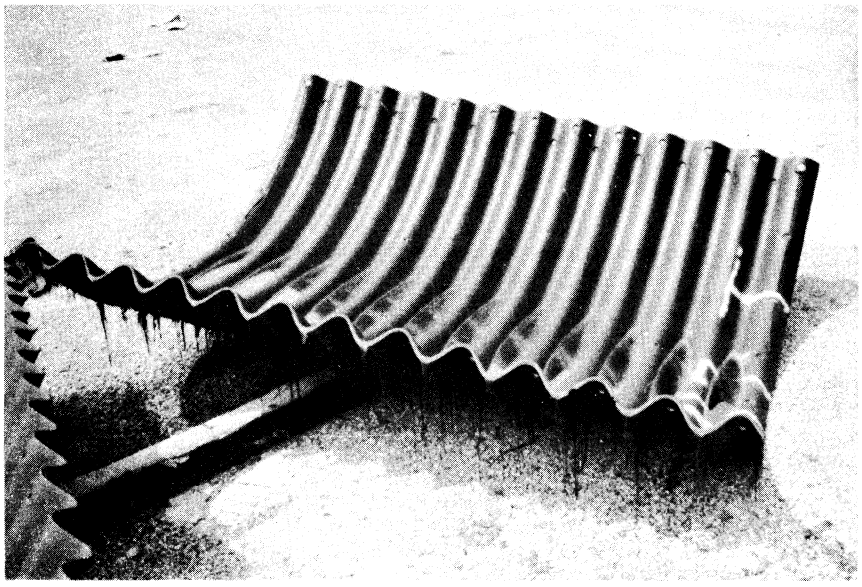

Figure 1. Asphalt coated structural plates. Heavy coating at edge of plate on right was due to flow during application.

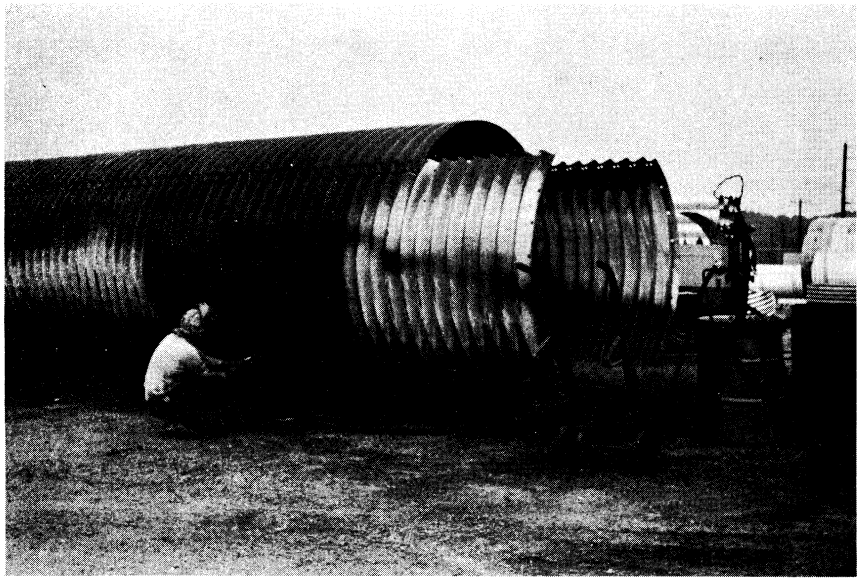

Figure 2. Application of asphalt mastic to structural plate pipe assembled at fabricator's plant.

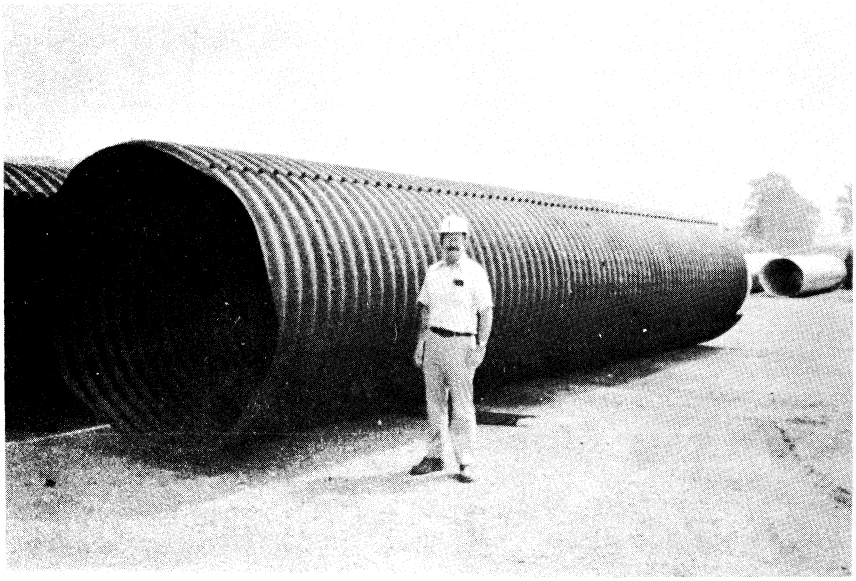

Figure 3. Structural plate pipe assembled and coated at plant in lengths suitable for trucking to site.

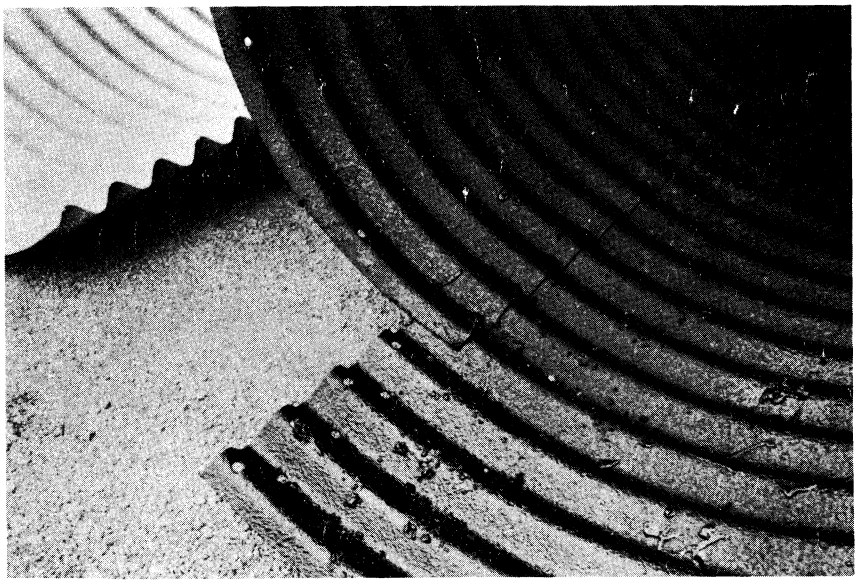

Figure 4. Joint in pipe coated with sprayed asphalt mastic.

one in the Salem District, and six in the Suffolk District. These numbers represented a good percentage of the limited number of sites in the Bristol and Suffolk Districts, and it is believed that the ten installations provided a valid assessment of the problem.

The findings at each site will be described and then the general results will be discussed in a later section of the report.

Bristol District

1. Route 460, West of Richlands
   Coating Type: Asphalt mastic, sprayed at site.
   Service Exposure: 8 years

As was found to be typical of sprayed mastic applications, this coating was thinner than those deposited by immersion. The coating has been removed to the depth of the waterline. Fairly heavy rusting is evident in the invert, which remains sound, and the rusting ceases at a height of 6 to 8 inches above the invert, as indicated in Figure 5. Above the waterline, the coating remains intact and tightly bonded to the steel.

2. Route I-77, off Route 21, North of Bland
   Coating Type: Asphalt, applied by immersion, on-site assembly.
   Service Exposure: 3 years

The structural plate elements used in this pipe were first coated at an out-of-state plant and assembled at the site. Problems with peeling were encountered during construction, with the result that most of the surface below the spring line was patched in the field and about 1,200 feet of the invert was paved with concrete at that time. Approximately 200-300 feet near one end of the pipe is made up of plate sections that were recoated at the fabricator's Bristol plant under inspection by Department personnel. The coating in this portion of the pipe is more tightly adherent than elsewhere, possibly because great care was taken to allow the steel plates to reach the temperature of the asphalt. However, in spite of its improved adhesion, the coating has been removed from the invert by the flow.

The original coating of asphalt applied out-of-state could be easily peeled from the metal surface, as in Figure 6, once a cut was initiated. There was no foreign matter apparent at the interface of the asphalt and the pipe, but all of the coating seemed loosely bonded.

A more serious problem arose due to the varying thickness of the dipped coating. Excess asphalt had been extruded from many of the joints, but several were open more than half an inch. As shown in Figure 7, there was intrusion of soil into the culvert at several points, and water was flowing in an opening in one of the joints. Difficulties in aligning the plate sections caused the omission of several bolts over the length of the culvert. It was also impossible, in some of the bolts, to develop the torque required by the AASHTO Specifications.[2]

Figure 5. Culvert on Route 460. Close view of typical area where protective coating has been lost.

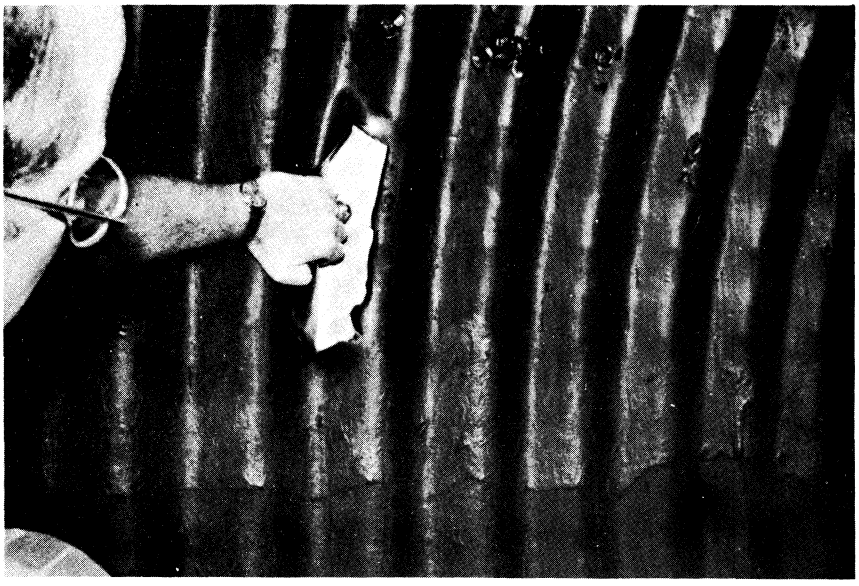

Figure 6. Peeling of asphalt coating from pipe surface.

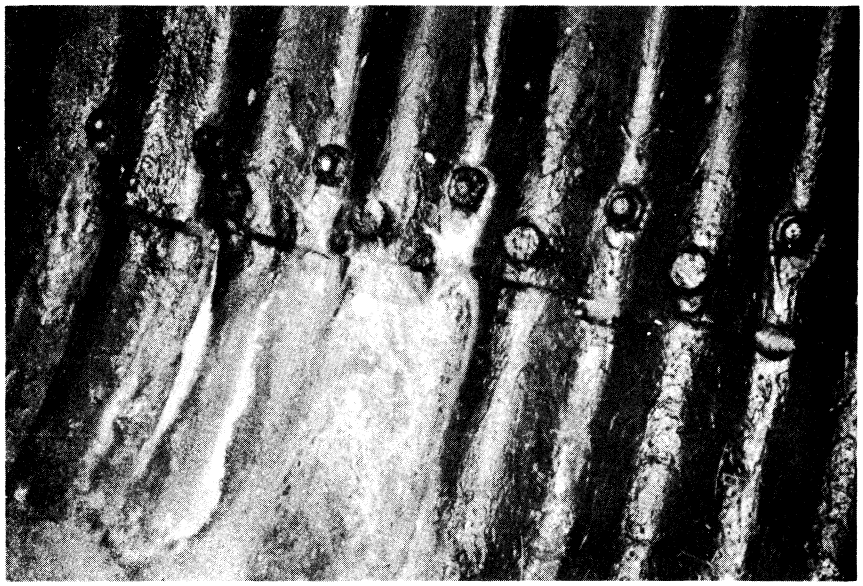

Figure 7. Intrusion of soil through partially open joint between plates coated with asphalt before assembly.

3. Rte I-77 near New River Crossing and Austinville, Wythe County
   Coating Type: Asphalt, applied by immersion, partial plant assemblies joined at site.
   Service Exposure: 1 year

The coating for this installation was applied by immersion at the fabricator's Bristol facility. The pipe was then assembled in lengths of 35 to 40 feet and trucked to the site.

As noted at the previous site, the coating applied in Bristol was superior to that applied out-of-state, although the procedures were supposedly alike. Adhesion to the pipe seemed good, and the coating was intact except at one end where flow had removed it from the invert.

Salem District

1. Rte I-77 at interchange with Rte 775, Carroll County
   Coating Type: Asphalt, applied by immersion, on-site assembly
   Service Exposure: 2 years

The asphalt coating on this pipe lacks adhesion, as do others applied out-of-state.

The material has been removed from the invert, as shown in Figure 8, and the remaining material can be peeled off easily. There is some staining, but little or no rusting of the bare metal.

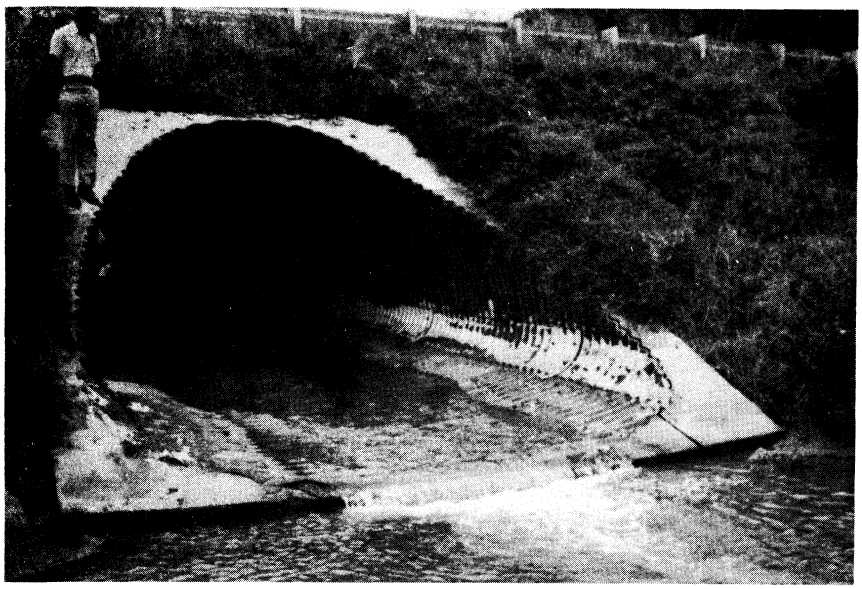

Figure 8. Loss of asphalt coating, Route I-77, Carroll County.

Suffolk District

1. Rte 642 (Wilroy Road) over Magnolia Creek, city of Suffolk
   Coating Type: Asphalt mastic, sprayed at site.
   Service Exposure: 4 years

While these two large plate arch structures are nearly submerged, the visible coating appears to be tightly bonded and in good condition. There is no sign of loss of coating with the exception of several very small, insignificant spots on the exposed top surface at the ends of the pipe.

2. Rte 642 (Wilroy Road) over Brewers Creek, city of Suffolk
   Coating Type: Asphalt mastic, sprayed at site.
   Service Exposure: 4 years

The visible coating on this partially submerged triple line of large structural plate arches is tightly bonded with no evidence of loss. While the lower portion of the pipe cannot be inspected, it appears unlikely that the coating would be subject to impact under high velocity flow at this location, Figure 9.

3. Rte 645 over Speights Run (City Reservoir), city of Suffolk
   Coating Type: Asphalt, applied by immersion, on-site assembly.
   Service Exposure: 20 years

As shown in Figure 10, the bituminous coating has been almost completely lost from this large diameter pipe which has rusted severely. Bituminous material remaining in the joints of this culvert, the oldest installation

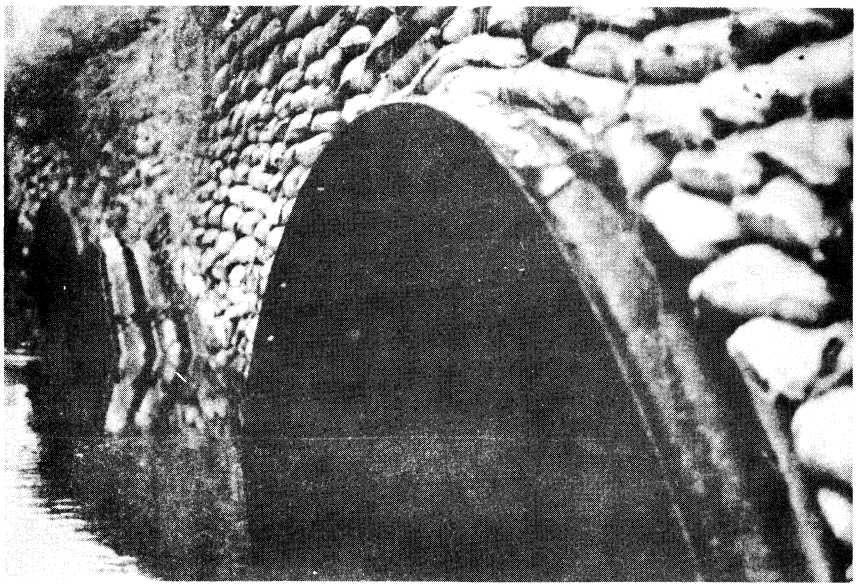

Figure 9. Pipe arches, Route 642 over Brewers Creek, city of Suffolk.

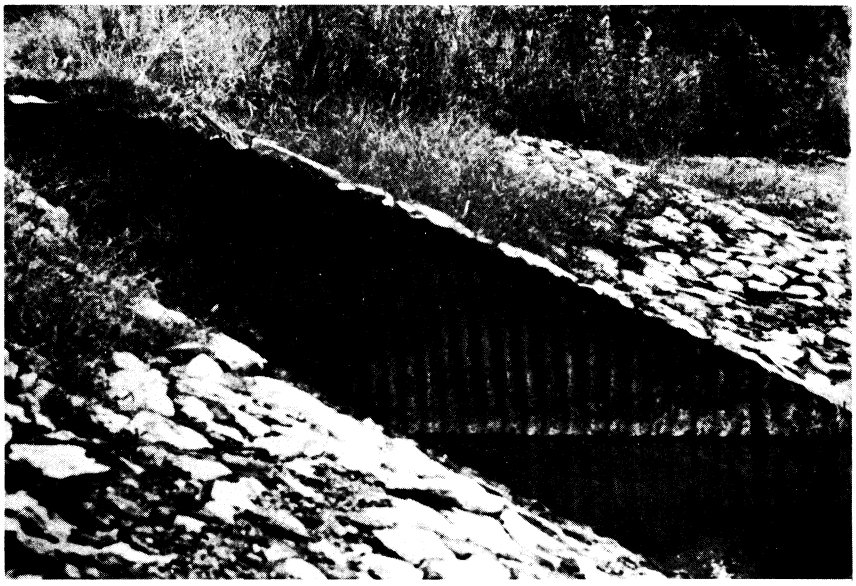

Figure 10. Structural plate pipe, Route 645 over Speights Run, city of Suffolk. Entire pipe has rusted.

inspected, indicates that the plates were coated by immersion. The water level was low at the time of inspection due to severe drought conditions, and it is likely that the flow is placid but much deeper.

4. Rte 688 over Kilby Creek, city of Suffolk
   Coating Type: Asphalt mastic, sprayed at site.
   Service Exposure: 4 years

This triple line of plate arch pipe is filled to a depth of approximately 2 feet with soil. The asphalt mastic coating is tightly bonded and intact with no sign of loss of coating. While the coating is relatively thin, as is typical of sprayed applications, it appears most serviceable.

5. Rte 636 near Windsor, Isle of Wight County
   Coating Type: Asphalt, applied by immersion, on-site assembly.
   Service Exposure: 7 years

The adhesion of the asphalt coating on this double line of plate arch pipe, while less than that of an asphalt mastic, was superior to the adhesion of similar coatings in the Bristol District. It was, however, still possible to peel the coating from the pipe surface. The invert of one of the pipes was paved with concrete and that of the other was heavily silted. No loss of the coating was apparent elsewhere on the pipes.

6. Rte 629 over Corrowaugh Swamp, Isle of Wight County
   Coating Type: Asphalt, applied by immersion, after assembly.
   Service Exposure: 1 year

These relatively small (71 inch x 47 inch) arch pipes were assembled and then coated. No loss of coating was observed at the time of inspection about 17 months after installation, and the adhesion of the asphalt appears to be good, as it was on several regular culverts described under item 7 below.

7. Rte 58, city of Suffolk—several pipe culverts of varying diameters
   Coating Type: Asphalt applied by immersion of fabricated pipe.
   Service Exposure: 5 years

Several corrugated steel culverts serving as side drains on Route 58, while not composed of structural plate, were inspected to determine the condition of their asphalt coatings. In every case the coatings were found to be tightly adherent. They were better bonded than similar coatings on structural plate elements in the Bristol District or elsewhere in the Suffolk District.

SURVEY OF OTHER AGENCIES

Other organizations and agencies were contacted in an effort to obtain a wider perspective on the state of the art of coatings for pipes. There is much recent work, some of it in early stages, but unfortunately some of the findings are as yet unpublished or were intended only for internal distribution. The information in this section is, therefore, based on personal contacts as well as those formal reports that could be gathered. All of the information refers to coatings in general rather than the coating of plate structures.

Assessments of the increase in service life afforded by bituminous coatings vary between agencies, as the effectiveness of the coatings depends greatly on the protection afforded by site conditions. According to the American Iron and Steel Institute's Handbook of Steel Drainage and Highway Construction Products[3], which quotes research performed in New York and California, coatings add 6 to 10 years to the life of the interior of a pipe under nonabrasive flow conditions and 25 years to the exterior. Utah, in fitting service life data to soil resistivity, soluble salts and pH values, concluded that the coatings added about 16 years to the lifespan of pipes.[4] Corrosion of the exterior surface under exposure to the alkaline soils of Utah was found to be the critical factor.

Distress of bituminous coatings on culverts is not a new problem, nor has it been solved. The problem as noted in culverts on the Blue Ridge Parkway was discussed in a 1946 issue of Public Roads[5], and the findings were similar to those from a later study conducted by the author.[6] Both studies found deterioration, cracking, and loss of the coating, all generally concentrated at the ends of the culverts.

A synthesis of highway practice on the "Durability of Drainage Pipe" (Topic 20-5-09) has been prepared in draft form as part of the National Cooperative Highway Research Program by the Transportation Research Board staff. Regretably, the publication of the document is being delayed by the difficulty in resolving questions raised by reviewers, but Thomas L. Copas of the TRB indicated that a number of agencies are questioning the effectiveness of bituminous coatings. One such agency is the Tennessee Department of Transportation, which recently stopped the use of coatings on the basis of a survey of culverts reported internally by J. B. Wylie, materials engineer. His conclusion was that, except in areas where pH is a problem, the coatings were not cost-effective. The coatings were found to be cracked and torn, with large pieces removed by the flow. Tennessee experimented with the temperature requirements for immersion coatings without attaining appreciable improvement in the end product.

A 1970 Kansas study also favored the elimination of protective coatings.[7] Inspections of more than 500 bituminous coated culverts disclosed that the coatings were in good condition on the interior surfaces of only 12 percent of the pipes that were 3 and 4 years old and none of the older pipes. It was concluded that the contribution of the coating on the exterior surface was not significant, because destructive corrosion proceeded from the interior outward. Considering an estimated cost for bituminous coatings, including the cost of inspection, of $25,000 annually, it was recommended that bituminous coatings be discontinued.

A separate study of 810 bare steel pipes ranging in age from 7 to 43 years old concluded that most of the serious corrosion in Kansas occurs in coal strip-mining areas.[8] The pH and electrical resistivity of the water and soil were found to be the main factors influencing corrosion. The generally non-aggressive conditions reported would seem to support the elimination of bituminous coatings.

A study by the Louisiana Department of Transportation and Development of pipes at 10 field installations, all with 2 years of field exposure, found that the asphalt coatings were generally cracking, with some disbonding, on the

interior and exterior surfaces.[9] It was also concluded that the electrical resistivity of the effluent was the primary factor controlling the corrosion of the culverts.

A study performed by the Oregon Division of the FHWA, while concentrating on asbestos bonded coatings, reported on 6 bituminous coated pipes.[10] Two of these, aged 5 and 13 years, were considered to be in "good" condition, although there was some distress of the coating; the remaining 4, after 22 years of service, were rated "poor". A study of uncoated culverts by the Oregon Department of Transportation allowed their use in environments having pH values between 4.5 and 10 and resistivity values above 1,500 ohm-cm.[11] However, the use of uncoated galvanized steel culverts was not recommended in areas west of the Cascade Mountain range in the coastal region under any conditions.

An extensive study of pipe coatings is planned for contract by the FHWA in the near future. It is proposed that the study, which will involve several states, will consider factors beyond those of soil resistivity and pH which have been the preeminent parameters in past work.

In summary, there has been dissatisfaction with the durability of bituminous coatings and some states have discontinued their use. These decisions have been based on the conclusion that the coatings are not cost-effective, not that protection is not needed. Bare galvanized steel drainage structures can be used only under certain conditions, and information on the pH and resistivity of both water and soil at the site would be required. It is possible that some of the later studies will provide better information on warrants for coatings and, possibly, better coating systems will be found.

DISCUSSION

Coating Specifications

Virginia's specification for the coating of structural plate pipes and arches appears to follow the practices of other agencies. Problems with the asphalt coatings applied by immersion appear to be concentrated in the southwestern portion of the state, which area is apparently served by a single fabricator. Factors affecting the performance of the coatings could include the compounding of the asphalt or variations in the temperature requirements. The AASHTO materials specification for the asphalt, M190, is broad, but it is likely that the temperature requirements, which specify the time of immersion in the hot asphalt, are more critical. It was found that a better asphalt coating was provided when the application was done at Bristol, under the attention of the district materials engineer, rather than at an out-of-state plant. Virginia's specification is probably acceptable, but difficult to enforce at remote locations.

Field Survey

The survey of structural plate pipes and arches in the Bristol and Suffolk Districts indicated that, while coating performance is not considered a problem throughout the state, a more durable coating is provided by the asphalt

mastic sprayed on the assembled pipe. It is difficult to scrape the mastic from the surface of the metal, while the asphalt coating can often be peeled from the metal once an initial cut is made.

A more serious problem in the case of the asphalt coating may be the difficulties in assembling the precoated plates and obtaining the required torque on the bolts due to the presence of a heavy coating caused by flow of the asphalt during dipping. This may be an unavoidable problem with serious ramifications. Joining of the plates is, of course, not a problem when the structure is coated after erection.

Environmental concerns reflected in the current stringent erosion control standards could, at times, mandate the use of precoated plates. However, it would appear that the assembling and subsequent coating of the structure at plant and the shipment of large sections to the site would minimize the time that an excavated section need be uncovered and, thus, the chances of damage to the environment. This procedure is used by at least one fabricating plant.

Regardless of the application technique, the survey indicated that bituminous coatings provide long-term protection to the exterior surface of the structure. While the coating appears to be performing well at locations such as the Route 642 sites in Suffolk, the added protection at sites carrying intermittently heavy, high velocity flow in more mountainous areas might often be even less than the 6 years projected by the AISI handbook.[3] It is possible, however, that more serious corrosive conditions can exist at the soil-pipe interface.

Elimination of Coating Requirement

It is likely that Virginia's coating requirement for corrugated steel pipe is conservative, and there are problems with the performance of the coatings here and elsewhere. For these reasons, it is reasonable to question the need for bituminous coatings. Unfortunately there appears to be little available data on cost of coatings and pipe durability to aid in this decision, and the gathering of needed information involves a level of effort beyond that envisioned for the present study. Factors such as the real cost of the coatings and the service life experience with coated and bare steel culverts in various soil and effluent conditions should be considered. While culvert studies at the Council have indicated a generally mild environment across the state, very aggressively corrosive sites do exist. Continuance of the current general policy of requiring protective coatings, therefore, seems advisable.

RECOMMENDATIONS

The following recommendations are based on the limited study made by the author and the information available from other agencies.

1. The Virginia Department of Highways and Transportation should continue its general policy requiring a protective coating on structural plate pipe and arches at specified locations.

2. Asphalt mastic, applied to plate structures after assembly, should be specified in preference to asphalt applied by immersion of individual plates, unless construction or environmental considerations rule otherwise, as the mastic generally provides a more serviceable coating.

3. The application of the asphalt mastic at the plant to large sections of assembled pipe, which are subsequently shipped to the construction site, should be fully explored, as the practice appears to minimize field operations and environmental damage.

4. The policy regarding the use of a coating or the type to be specified should be reviewed in light of future research results, and the Department should cooperate in any broad studies such as that proposed by the FHWA.

5. A procedure for defining the real cost of bituminous protective coatings of both types should be developed within the operating divisions, as this information would be a prime factor in determining the warrants for the coatings. Because of the work under way elsewhere, further formal research by the Research Council would not appear to be a high priority need at this time.

ACKNOWLEDGMENTS

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Much of the information on the activities of other agencies was provided by Dr. Bernard Appleman, Physical Chemist in the Materials Division of the FHWA's Fairbanks Highway Research Station. The assistance of T. L. Copas of the Transportation Research Board and J. B. Wylie of the Tennessee Department of Transportation was also most helpful.

The great assistance provided during the field survey by J. W. French, Materials Technician, Virginia Highway and Transportation Research Council, is also greatly appreciated.

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