CULVERT STUDIES

An Evaluation of Bituminized Fiber Pipe Culverts

by
Wallace T. McKeel, Jr.
Highway Research Engineer

Virginia Highway Research Council
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SUMMARY AND RECOMMENDATIONS

This report describes the results to date in a limited study, including laboratory tests and field evaluations, of the suitability of bituminized fiber pipe for use as highway culverts.

Crushing strength data obtained from three-edge bearing tests indicate that bituminized fiber culverts, as currently produced, are not as strong as, and should not be considered an alternate to, plain concrete pipe. A need exists for a strength specification for bituminized fiber pipe in practical culvert diameters.

Bituminized fiber pipe offers relative ease of handling and installation in comparison to concrete and steel culverts of equivalent diameter, but the observance of proper installation practices is apparently critical. The field test installations have served adequately under moderate loading conditions for periods as long as seven years, including five years' exposure to highly acidic runoff. Assuming the use of proper installation techniques, it appears that bituminized fiber pipe might be suitable for use in many locations having non-abrasive flow conditions on low traffic volume, rural secondary routes.

Accordingly, it is recommended that bituminized fiber pipe culverts be considered for judicious use in the secondary road system, particularly in cases where acidic runoff is encountered. Such action will increase the experience of the Department of Highways with bituminized fiber culverts and allow the state to avail itself of any advantages the product may offer.

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INTRODUCTION

Bituminized fiber pipe is composed of several layers of fibrous material bonded together and pressure impregnated with pitch. The pipe is currently available in diameters as large as 48 inches with a maximum wall thickness of 3/4 inch. Pipes of 4 inch diameter and larger can be produced in lengths of 20 feet. The manufacturer claims the pipe material to be resistant to damage from repeated freezing and thawing and from exposure to pH values from 1.5 to 11.5.(1) Bituminized fiber perforated pipe has been used in highway underdrains for several years, and half and third circular sections have been used to pave slope drains.

In 1963, the Virginia Highway Research Council initiated a limited study of the suitability of bituminized fiber pipe for use as culverts.(2) The purpose of this report is to relate the results of the study to date and to present an initial recommendation on the use of bituminized fiber culverts.

SCOPE OF THE VIRGINIA INVESTIGATION

The investigation of bituminized fiber pipe culverts conducted by the Virginia Highway Research Council has been quite limited in nature. The project has included three-edge bearing tests of 12 and 24 inch lengths of 10, 12, 15 and 18 inch diameter pipes; and evaluations of three test installations, one each of 15, 18 and 30 inch diameter pipe. The field tests included the gathering of information on installation techniques and periodic visual inspections of the three pipes, each of which was located on a low traffic volume, rural secondary road.

RESULTS

Three-Edge Bearing Tests

The three-edge bearing tests were performed at the outset of the project in March 1963, by Thomas H. Forrer, then a highway research engineer at the Council. One test was performed for each length of each diameter in accordance with ASTM Designation D 1862-61T, "Tentative Specifications for Laminated Wall Bituminized Fiber Drain and Sewer Pipe."

Forrer's results, summarized in Table I, indicated considerable variation in crushing strengths for the individual specimens tested. It was also noted that the pipe was quite brittle and failed suddenly when the crushing strength was reached.

For comparative purposes the average crushing strengths obtained in the Council tests are presented in Table II along with strength data from the pipe manufacturer and the current Virginia Department of Highways requirements for plain concrete pipe.[3,4] The limited data suggest that bituminized fiber pipe of the larger diameters tested, 15 and 18 inches, does not meet the requirements for plain concrete pipe. The available ASTM and AASHO specifications for bituminized fiber pipe do not contain crushing strength requirements for diameters greater than 8 inches.[5,6]

Because of the relatively low crushing strengths obtained in the laboratory tests compared to the requirements for plain concrete pipe and the high variability of certain of the test results, Forrer warned that a rather large margin of safety would be required in specifying minimum cover for bituminized fiber pipe.

Field Installations

Albemarle County

In April 1963, two culverts, one of 15 inch diameter and one of 18 inch diameter, were installed to carry light, intermittent runoff under Route 731 in Albemarle County. Although the installation of these pipes was not observed by Council personnel, notes on the procedure were obtained from the job superintendent approximately one month afterward.

The superintendent estimated that installation of the pipes, which were easily handled and joined, was completed in only one-fourth

TABLE I

RESULTS OF THREE-EDGE BEARING TESTS

Diameter (in.)	Nominal Wall Thickness (in.)	Speciman Length (in.)	Crushing Strength (lb./ft.)	Average Crushing Strength (lb./ft.)
10	1/2	12	1850	1656
10	1/2	24	1463	
12	9/16	12	1695	2214
12	9/16	24	2733	
15	9/16	12	1500	1509
15	9/16	24	1518	
18	3/4	12	2030	2142
18	3/4	24	2255	

TABLE II

COMPARISON OF CRUSHING STRENGTHS (lb./ft.)

Diameter	VHRC Tests*	Manufacturer's Tests**	Plain Concret Pipe***
10"	1656	2000	----
12"	2214	1800	1800
15"	1509	1800	2125
18"	2142	1900	2400

*From Table I above.

**Reported in 1965 Brochure, SONOCO Products, Co., Hartsville, S.C.

***Requirements, Va. Dept. Highways Road and Bridge Specifications Sec. 240.02(a), 1966.

the time required to install a concrete pipe of similar size. Fill heights were 3¼ feet over the 18 inch culvert and 2 feet over the 15 inch culvert; 7 inches of crushed stone base was later added at both locations. Both culverts were backfilled with local material in a powdery dry condition, and it is doubtful that any degree of compaction was obtained.

The lack of proper compaction of the backfill was evidenced by the fact that, although the pipes were laid straight on a 5.3 percent grade, both were noticeably out of alignment horizontally and vertically at the time of the first inspection in May 1963. Subsequent inspections have disclosed a flattening of the pipes at the midpoints, the condition, first reported in 1966, being quite pronounced in the case of the 15 inch pipe. The pavement over the 15 inch pipe has been patched twice since installation of the culvert, apparently as a result of subsidence of the poorly compacted backfill material. The small pipe diameters preclude any measurement to determine the rate of flattening, but some concern over the long term structural adequacy of the bituminized fiber material has been expressed.(7)

Photographs taken during the initial inspection showed separation of the fiber layers at the outfall end of the 18 inch pipe, which was possibly damaged during shipping or installation. Subsequent inspections have disclosed no appreciable increase in the delamination which, at present, does not extend into the loaded area of the pipe, and, accordingly, the distress is not considered to be serious.

Finally, it should be noted that all inspections have shown the bituminized fiber pipes to be providing adequate service, despite the flattening and minor distress discussed previously.

Wise County

A 30 inch diameter bituminized fiber culvert was installed at the intersection of Routes 680 and 691 in Wise County in May 1963. The water at this site is contaminated with mine wastes, and a pH as low as 3.2 has been recorded on several occasions. The fiber culvert and a concrete culvert were placed side by side at the ends of aluminum and bituminous coated steel culverts already being tested at the site. Some difficulty was experienced in joining the two sections of fiber pipe, but otherwise installation was much faster than that of the adjacent concrete culvert.

Local backfill material was placed and hand tamped in layers approximately 6 inches thick to a height somewhat above the spring line of the culverts. The remainder of the backfill, to a height 3 to 4 feet above the tops os the pipes, was placed rapidly by a front-end loader and compacted by running the loader across the fill after some hand tamping.

The pipe wall at one end of the culvert was damaged during shipping, causing separation of the fiber layers. Subsequent inspections have shown a slight spreading of the delamination around the rim of the pipe, possibly because of deterioration of the bituminous mastic under exposure to sunlight. Similar deterioration of the exposed bituminous material at the ends of coated steel pipes has

been noted.[8] Exposure to freezing and thawing has not appreciably accelerated the delamination, which presently extends a maximum distance of only 1½ inches into the pipe. As in the case of the 18 inch pipe in Albemarle County, the delamination is not considered a serious defect.

No flattening or other distortion of the culvert has been noted in any inspection. The bituminous coating on the surface of the pipe has been removed from the invert, possibly through abrasion, but the underlying impregnated fiber material appears sound. The overall condition of the culvert is entirely satisfactory at this time.

It is important to note that the bituminized fiber pipe has withstood 5 years of exposure to acidic runoff having a pH as low as 3.2 with no apparent distress. The invert of an aluminum culvert placed earlier at the site was severely pitted within one year and had been completely removed in 2 years. A coated galvanized steel culvert installed in 1961 is severely corroded wherever the bituminous coating has been removed or lost, but the pipe is generally providing good service. While the concrete pipe installed simultaneously with the fiber pipe is also rendering good service at this time, acid attack on the invert has exposed the aggregate and caused spalling of the rim at the outfall end.

DISCUSSION

The results of the three-edge bearing tests conducted at the Council indicate that bituminized fiber pipe should not be accepted as an alternate to plain concrete pipe. However, the field tests demonstrate that under moderate loading conditions bituminized fiber culverts can provide upwards of seven years' service. At this time, it is impossible to estimate the ultimate service life of the product.

The settlement out of alignment and flattening of the Albemarle County pipes are probably not a fair test of the structural adequacy of bituminized fiber pipe since they result from failure to obtain proper compaction of the backfill, which the manufacturer states is a requirement for proper service. While the question of the long-term structural adquacy of the 15 inch culvert in Albermarle County remains unanswered, the Wise County installation, also installed by state forces, shows no signs of structural distress. It is obvious that the manufacturer's recommendations that the backfill be properly compacted, the bed be free of sharp protrusions, and the minimum cover be at least 12 inches and preferably 15 to 18 inches must be followed to ensure proper performance. The maximum fill height allowable in bituminized fiber culvert installations cannot be accurately determined at this time since it depends on the strength of the pipe, but the data from the three-edge bearing tests indicate that fill heights should be less than the 15 feet allowed for plain concrete pipe.

The field tests also indicate that the exposed ends of bituminized fiber pipe are quite susceptible to damage during shipment and installation due to the brittle nature of the impregnated fiber material. It is likewise possible that the ends of the pipe may be damaged during maintenance operations such as mowing after installation, but in any event the results of the damage noted in the field tests have not been serious. All possible care should be used by personnel handling the pipes to avoid damage to the ends, and the pipes should be inspected upon receipt from the shipper to detect any distress.

The most important finding of this investigation is the fact that the bituminized fiber test culverts have served satisfactorily in the field for periods of five and seven years. It is particularly significant that exposure to highly acidic runoff has not adversely affected the fiber culvert in Wise County while the concrete culvert at the site is showing distress. Bituminized fiber pipe would be cheaper and easier to install than the coated galvanized steel pipe which has shown the best performance to date in the acid conditions. Another alternative under investigation at the site is stainless steel culvert which, at best, is vastly more expensive than the fiber pipe.

It is unlikely that the results of this study should be extrapolated far beyond the test conditions, that is, suitability for low traffic volume, rural secondary routes. The crushing strength

data indicate that currently produced bituminized fiber pipe is not an alternate to concrete pipe and the question of the long-term structural adequacy raised by the performance of the Albemarle County culverts is as yet unanswered. This limited study provides no indication of the suitability of fiber pipe under severely abrasive conditions, and care should be exercised in specifying the pipe at sites at which either large or small grained aggregate particles are carried at high velocity. Such questions can only be answered by further experience with the product. It does appear that, used judiciously, bituminized fiber pipe may be both suitable and relatively economical for use as culverts in many locations in the state, particularly at those sites where acidic runoff limits the service life of other materials.

There are no ASTM or AASHO specifications that govern the strength of bituminized fiber pipe in practical culvert sizes, and the determination of a suitable specification was beyond the scope of this investigation. The problem will require further study, possibly with the cooperation of the manufacturer.

CONCLUSIONS

1. Crushing strength data obtained from three-edge bearing tests indicate that bituminized fiber culverts, as currently produced, are not as strong as, and should not be considered an alternate to, plain concrete pipe. A need exists for a strength specification for bituminized fiber pipe in practical culvert diameters.

2. Bituminized fiber pipe offers relative ease of handling and installation in comparison to concrete and steel culverts of equivalent diameter. Due care must be exercised, however, to avoid damaging the brittle impregnated fiber material during handling.
3. While the ends of bituminized fiber pipes are susceptible to damage, the effect of delamination of the rims, as occurred in this study, was not serious, and exposure of the damaged pipe to freeze-thaw cycles in the field has not significantly increased the distress.
4. The resistance of bituminized fiber pipe to the effects of highly acidic runoff (pH 3.2) has been excellent.
5. Observance of proper techniques in the installation of bituminized fiber pipe is apparently critical. There must be no sharp protrusions in the bedding adjacent to the pipe, backfill material must be properly compacted, and minimum cover over the pipe must be at least 12 inches and preferably 15 or 18 inches. The maximum fill height should be less than the 15 feet allowed for plain concrete pipe.
6. The field test installations have served adequately under moderate loading conditions for periods as long as seven years, in spite of poor backfill compaction at the Albemarle County sites. Assuming the use of proper installation techniques, it appears that bituminized fiber pipe might be suitable for use in many locations having non-abrasive flow conditions on low traffic volume, rural secondary routes.

RECOMMENDATION

In accordance with the findings to date in the field study of bituminized fiber pipe culverts it is recommended that such culverts be considered for judicious use in the secondary road system, particularly in cases where acidic runoff is encountered. Such action will increase the experience of the Department of Highways with bituminized fiber culverts and allow the state to avail itself of any advantages the product may offer. It is acknowledged that use of bituminized fiber pipe would depend on the development of a suitable strength specification for pipes of diameters larger than 8 inches.

REFERENCES

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