Research Report
KTC-93-27

FIELD PERFORMANCE REPORT ON CORRUGATED POLYETHYLENE PIPE ON KY 17 KENTON COUNTY

by

L. John Fleckenstein
Engineering Geologist

and

David L. Allen
Chief Research Engineer

Kentucky Transportation Center
College of Engineering
University of Kentucky
Lexington, Kentucky

in cooperation with
Transportation Cabinet
Commonwealth of Kentucky

and

Federal Highway Administration
U.S. Department of Transportation

October 1993

Technical Report Documentation Page

1. Report No. KTC-93-27	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle FIELD PERFORMANCE REPORT ON CORRUGATED POLYETHYLENE PIPE ON KY 17, KENTON COUNTY		5. Report Date October 1993
		6. Performing Organization Code
7. Author(s) L. J. Fleckenstein and David L. Allen		8. Performing Organization Report No.6 KTC-93-27
9. Performing Organization Name and Address Kentucky Transportation Center, College of Engineering, University of Kentucky, Lexington, KY 40506-0043		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. Federal Aid Research Task 43
		13. Type of Report and Period Covered Final
12. Sponsoring Agency Name and Address Kentucky Transportation Cabinet, State Office Building, Frankfort, KY 40622		14. Sponsoring Agency Code

15. Supplementary Notes

Publication of this report was sponsored by the Kentucky Transportation Cabinet in cooperation with the U.S. Department of Transportation, Federal Highway Administration

16. Abstract

This report documents the installation and performance of corrugated smooth lined polyethylene pipe installed during construction of KY 17 in Kenton County. The majority of the pipe installed was N-12 pipe manufactured by Advanced Drainage Systems, Inc., and is designated as ADS N-12. ADS N-12 is a corrugated high-density polyethylene (HDPE) pipe. The pipe has a corrugated exterior for increased strength and a smooth interior to provide maximum flow capacity.

Sags in grade, misalignment, poor coupling, and vertical deformation were observed during visual inspections and do not appear to be a material related problem but are largely due to poor construction techniques.

The pipes appear to be functioning satisfactorily even with sagging, misalignments, and vertical deformation. Pipes that have vertical deformation over 10 percent should be monitored for any additional movement.

This report makes recommendation on the usage of polyethylene pipe in Kentucky.

17. Key Words Backfill, Compaction, Deflection, Polyethylene	18. Distribution Statement Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	8	

Form DOT 1700.7 (8-72) Reproduction of completed page authorized

EXECUTIVE SUMMARY

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INTRODUCTION

The Kentucky Transportation Center was requested by the Kentucky Transportation Cabinet to monitor the field performance of corrugated, smooth-lined polyethylene pipe on KY 17 in Kenton County (Project NO. SSP-059-0017-018-021-068C). The initial research was scheduled to evaluate Project No. SSP-059-7965-0270; however, because of construction delays the KY 17 project was evaluated.

Corrugated, smooth-lined polyethylene pipe has been used in Kentucky on an experimental basis since 1987. Most of the pipe that has been installed was manufactured by Advanced Drainage Systems, Incorporated, and is designated as ADS N-12.

The field performance of the pipe was visually monitored during construction and after placement. The conclusions and recommendations included in this report are based largely on those observations.

BACKGROUND

The current AASHTO design methodology for conduit considers the composite performance of the structure and the soil in which it is to be buried. The structural behavior of the composite system is generally referred to as soil-structure interaction. The structures are classified as either flexible or rigid and the soils are classified as either compressible or incompressible. The conduit ring and the surrounding soil envelope play a vital role in the structural design and performance of the culvert. Design considerations include strength properties of the conduit material and soil parameters of the foundation, bedding, side fill, and embankment materials. The adequacy of any soil-structure system may be nullified by poor installation practices such as improper bedding, inadequate compaction of the side fill and embankment, non uniformity of the foundation, as well as other factors.

Permissible fill-height tables, based upon the AASHTO Design Guidelines, have been developed. Designs are based upon material parameters designated by AASHTO materials specifications for the various types of conduit and current bedding details included in the Kentucky Department of Highways' Standard Specifications for Road and Bridge Construction and Standard Drawings. Current bedding details were developed during the late 1950's with nominal modifications throughout the years. It should be noted that structural performances of conduits which have been installed in strict conformance with existing guidelines have been excellent.

The majority of structural distresses which have been observed throughout the years, for the most part, have been traced to poor installation practices. Distresses have been observed in rigid and flexible conduit. Thorough investigations of those distresses nearly always revealed nonconformance to installation guidelines. Conduit which meet AASHTO materials requirements and which are installed in strict conformance with current bedding details may realistically be expected to provide many years of service.

The American Society for Testing and Materials (ASTM) has a standard practice for installation of thermoplastic pipe (ASTM D 2321). One of the most important portions of that standard practice is the description of the recommended backfill materials for thermoplastic pipe. In that document, Class IVB soils (fine-grained soils with high plasticity) and Class V soils (organic soils) are not recommended as backfill materials. Class III soils (coarse-grained soils with fines present) and Class IVA soils (fine-grained soils with low plasticity) are recommended with severe restrictions. Soil Classes IA, IB, and II are generally recommended for backfill, assuming migration of fines into the backfill is not a problem. Sharff and Chambers (1), in their commentary on this ASTM standard, emphasize the "soil-structure" interaction problem and the need for long-term support for the pipe. In addition, they state that "Class I materials, which include all manufactured aggregates such as crushed stone, will generally provide maximum stability and pipe support for a minimum amount of installation effort." They state further that "Classes II through V, which include all naturally occurring soils from coarse-grained gravel and sands to fine-grained silts, clays, and organics, generally require increasing installation effort with decreased reliability of performance."

The American Association of State Highway and Transportation Officials (AASHTO) has published recommended design procedures for soil-thermoplastic interaction systems (Section 18) in their Standard Specifications for Highway Bridges (2). This design standard indicates the performance of flexible culvert pipe is dependent on soil-structure interaction and soil stiffness. AASHTO also recommends side fill soils that classify as A-1, A-2, or A-3 soils according to the AASHTO soil classification system. These soils are generally regarded as granular soils (Section 18.1.6.1).

FIELD OBSERVATIONS

During 1991 and 1992, approximately 4,244 feet of N-12 pipe were installed on KY 17. Approximately 1,304 feet were used as entrance pipe and 2,940 feet were used as storm drains (Table 1). As indicated by the resident engineer, the majority of the storm drains were backfilled with sand. Entrance pipes were backfilled with existing trench material and/or sand.

On June 14 and 16, 1993, a final pipe inspection was performed. Final inspection information is contained in Table 2. Information obtained during that inspection indicated 27 percent of the entrances or storm drains inspected had deflected over five percent, and nine percent had deflected over 10 percent. The inspection also indicated that 15 percent of the entrance pipes had a maximum vertical deflection that was greater than 5 percent. Approximately 50 percent of the storm drains (includes outlet pipe, drop box inlets, and grated drop inlets) had a maximum vertical deflection greater than 5 percent.

Vertical and horizontal offsets were also observed in approximately 30 percent of the drains. Sags within the grade of the drains were also observed in 30 percent of the drains.

Figures 1 and 2 show the drop grate and storm drian, respectively, at approximate Milepost 19.36 through 19.41 (northbound) where 10 percent vertical deflection was recorded. Figure 3 shows the vertical offset that was observed under a driveway entrance at Milepost 19.432.

Measured horizontal deflection at this location was 1.4 percent.

A significant number of the pipes that had high vertical deflections were located in a 24-inch storm drain and 24-inch storm drain outlet both located on the north end of the project. These pipes were also installed during early stages of the construction.

These drains were inspected shortly after installation in the fall of 1991. Approximately 12.5 percent deflection was noted in a 24-inch outfall storm drain pipe which discharges into a large concrete box culvert on the north end of the project. The pipe is approximately 110 feet long. The pipe shape had become elliptical (Figure 4). Approximately 80 percent of the drain appears to be elliptical in shape. The wall of the pipes had buckled in several areas.

In 1991, significant changes in grade (sags) were observed in two, 24-inch storm drains. The storm drains are approximately 150 feet and 180 feet in length. There was no noticeable vertical or horizontal deflection at the time of the inspection. Sagging was apparent in several areas, 0.5-inch to 1.5-inch vertical offsets at several joints were observed.

These drains were inspected again on July 16, 1993 during the final inspection. Three deflection measurements were taken in both storm drains. The 180-foot storm drain had deflected vertically approximately 3.5 percent, 5.2 percent, and 8.5 percent. Larger deflections were measured in the 150-foot storm drain. The drain had deflected vertically approximately 11.2 percent, 7.7 percent, and 14.6 percent. The majority of the 150-foot storm drain was deflected.

Although the deflections on several of the 24-inch drains are greater than 10 percent, it appears they are functioning properly. It appears the backfill around the 24-inch outlet pipes was not uniform on both sides causing the pipe to become egg-shaped. it further appears the backfill around the 24-inch storm drains may not have been properly densified since there was little noticeable pipe deflection immediately after installation but considerable deflections were observed during the final inspection. It appears that the drains probably deflected from a lack of compaction on the side walls and haunches. The pipe deflected vertically and horizontally which forced additional compaction of the backfill at the springline.

DISCUSSION AND ANALYSIS

Backfill

As stated earlier, the importance of the interaction between the flexible pipe and the soil backfill cannot be overstressed. To keep the pipe in ring compression, it is critical to provide high shear resistance at the springline of the pipe. This implies that a material having a large angle of internal friction would provide the best side support for the pipe. Granular natural soils and manufactured aggregates are the most appropriate materials to provide and maintain high side resistance (4).

General Construction Considerations

Because of the large number of dips in grade and vertical offsets at the joint it is apparent that additional pipe bedding may be required to sufficiently stabilize the trench bottom. Sags and vertical displacement at the joints have only been noticed on three polyethylene pipe installations in this region of the state.

Because polyethylene pipe is lightweight, the pipe has a tendency to rise or drift during backfilling. To eliminate this, the contractors should bed each side equally to approximately 1/2 to 3/4 of the pipe height before compacting.

It should be emphasized that because of the flexibility of the pipe more care should be exercised in the installation process. Installation specifications should be followed carefully. The contractor should pay particular attention to bedding and backfilling operations.

CONCLUSIONS

Sags in grade, misalignment, poor coupling, and vertical deformation do not appear to be a material related problem but are largely due to poor construction techniques.

The pipes appear to be functioning satisfactory even with sagging, misalignments, and vertical deformation. Pipes that have vertical deformation over 10 percent should be monitored for any additional movement.

RECOMMENDATIONS

It is recommended that polyethylene pipe used under the following limitations:

1. All polyethylene pipe should be installed according to Kentucky Standard Drawing No. RDI-20-04, with the addition of granular backfill. Granular backfill should be used to a minimum height of one foot above the crown of the pipe.

2. An ASTM Class I or Class II type backfill should be used for polyethylene pipe.

3. Entrance pipe should have a minimum of one foot of cover.

4. More aggressive inspection of all pipe installations should be implemented.

5. Continued long-term inspections of selected installations using various materials are suggested.

REFERENCES

1. Sharff, P. A. and Chambers, P. E., "The New ASTM Standard for Installation of Plastic Sewer Pipe," Public Works Magazine, November 1991, pp. 52-57, 82.

2. American Association of State Highway and Transportation Officials (AASHTO), Section 18, "Soil-Thermoplastic Pipe Interaction Systems," pp. 233-238.

3. Subcommittee on New Highway Materials, (AASHTO-AGC-ARTBA), Task Force 22, Development of Cross-Reference for Materials Specification for Waterways, Airports, Railroads, Transit and Highways, "Report on Drainage Pipe," September 1988.

4. Fleckenstein, L. J. and Allen, D. L. , "Field Performance Report on Corrugated Polyethylene Pipe", Kentucky Transportation Center, Report No. KTC-91-17, November 1991

TABLE 1. QUANTITY OF POLYETHYLENE PIPE INSTALLED ON KY 17

Polyethylene Pipe Installed on KY 17, Kenton County			
Entrance Pipe		Culvert Pipe	
Size (inches)	Quantity (feet)	Size (inches)	Quantity (feet)
15	444	12	69
18	190.5	15	341.5
24	252	18	1768
30	418	24	761.8
Total	1,304.5		2,940.3
Total Feet Installed = 4,244.8			

TABLE 2. KY 17, FINAL PIPE INSPECTION

MILEPOST (DIRECTION)	DATE INSPECTED	STORM DRAIN	CROSS DRAIN	ENTRANCE PIPE	DIAMETER (inches)	VERTICAL DEFLECTION (%)	HORIZONTAL DEFLECTION (%)	SAGGING	JOINT OFFSET (feet)	OVERALL PIPE CONDITION
19.112 NB	7-14-93			X	15					Good
19.362-19.412 NB	7-14-93	X			18	10.4	8.8	Occasional	0.5	Moderate-Good
19.432 NB	7-14-93			X	18	0.33	1.4	Occasional	1.25	Moderate-Good
19.462 NB	7-14-93			X	18	5.2	5.8		0.81	Moderate-Good
20.012 NB	7-14-93	X			18	approx. 5.0-8.0				Moderate-Good (short section of pipe deflected near junction box)
20.052 NB	7-14-93	X			18				slight	Good
20.112 NB	7-14-93	X			18	slight			slight	Good
20.112 NB	7-14-93		X		18	5.2	2.3	Occasional	slight	Moderate-Good
20.162 NB	7-14-93	X			18				slight	Good
20.187 NB	7-16-93	X			18			Occasional		Good
20.197 NB	7-16-93	X			18					Good
20.212 NB	7-16-93	X			18					Good
20.262 NB	7-16-93	X			18					Good
20.262 NB	7-16-93		X		18					Good
20.302 NB	7-16-93	X			24	3.5, 5.2, 8.5	4.4, 3.0, 6.8		1.0	Moderate, Pipe was bent to meet box
20.302 NB	7-16-93		X		24					Good
20.312 NB	7-16-93	X			24	11.2, 7.7, 14.6	7.7, 9.9, 10.7	Occasional		Poor-Moderate
20.312 NB	7-16-93			X	18					Good
20.382 NB	7-16-93	X (Outlet Pipe)			24	14.58, 10.28 (45 degree angle)				Poor-Moderate, Pipe is elliptical, nonuniform compaction on sides.
20.362 SB	7-16-93	X (storm grate inlet)			18	3.8, 9.0	4.0, 7.7			Moderate, Deflection occurring in storm grate inlet.
20.362 SB	7-16-93		X		18	Approx. 5.0		Occasional		Moderate, Pipe shape is irregular side to side
20.312 SB	7-16-93	X (storm grate)			12			Occasional		Good
20.312 SB	7-16-93		X		18					Good, some sediment in invert
21.302 SB	7-16-93	X			18					Good
20.197 SB	7-16-93	X (storm grate inlet)			18			Occasional		Good
19.812 SB	7-16-93			X	15					Good
19.762 SB	7-16-93			X	24					Good
19.562 SB	7-18-93			X	24					Good
19.432 SB	7-16-93			X	30	0.83	3.0	Occasional	slight	Good
19.412 SB	7-16-93			X	30	0.83	2.4		2.5 (1st joint)	Moderate-Good
19.162 SB	7-16-93			X	24	5.2	4.47	Occasional		Moderate-Good
19.112 SB	7-16-93			X	24	7.0	6.3		slight	Moderate-Good
19.012 SB	7-16-93			X	15					Good
18.912 SB	7-16-93			X	15					Good
18.862 SB	7-16-93			X	15					Good

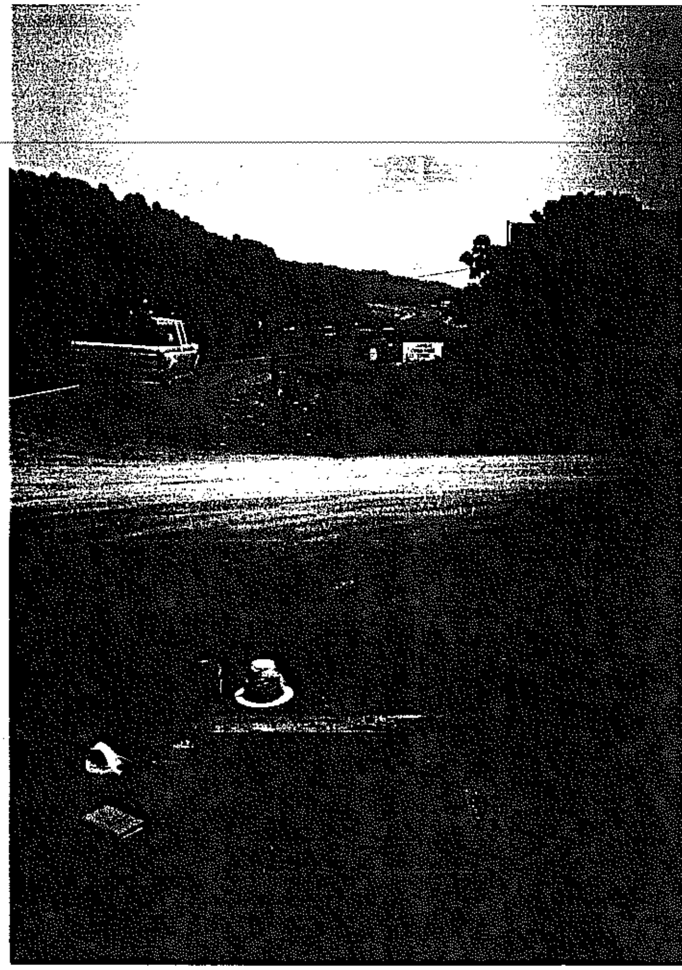

Figure 1. Drop Grate Storm Drain (18-Inch) on KY 17.
(See Figure 2 for View Inside Drain)

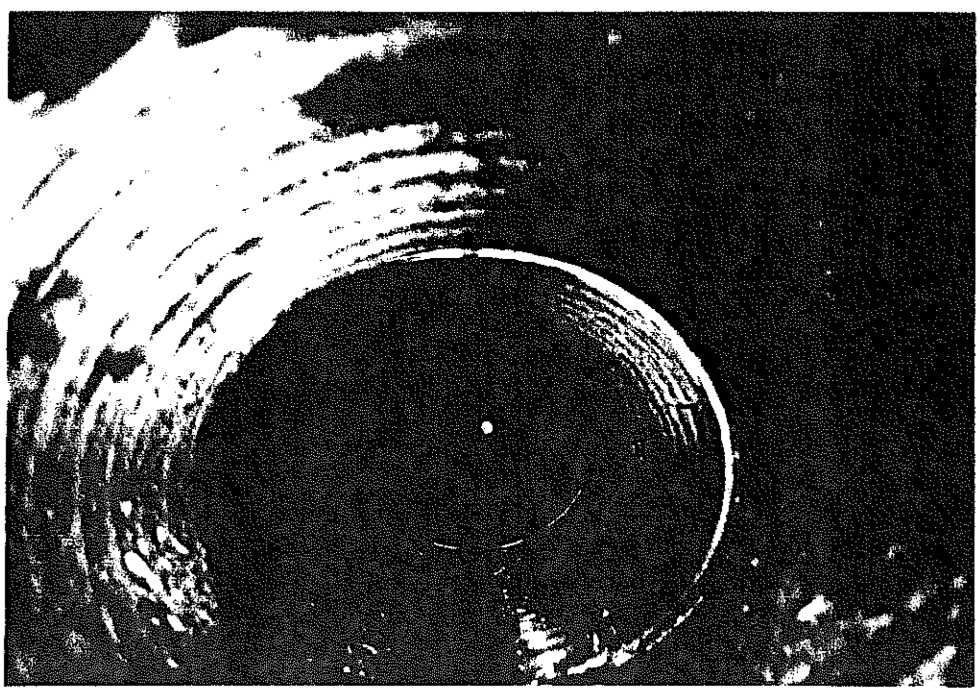

Figure 2. View of 18-Inch Pipe Deflected Vertically 10 Percent.

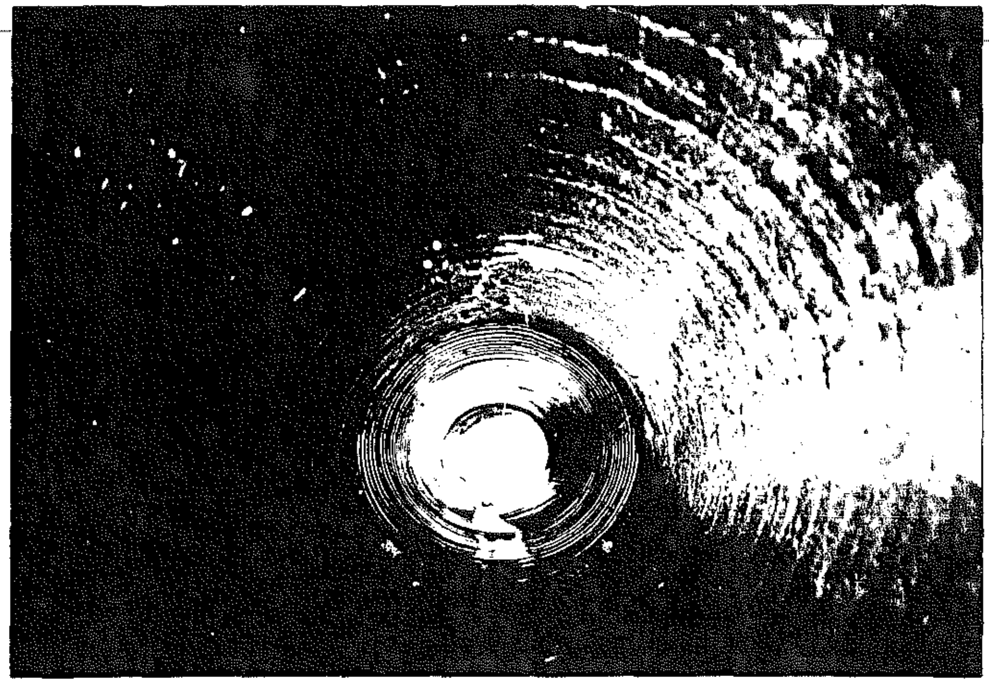

Figure 3. Entrance Pipe with 1.25 Inches of Vertical Offset at Joint.

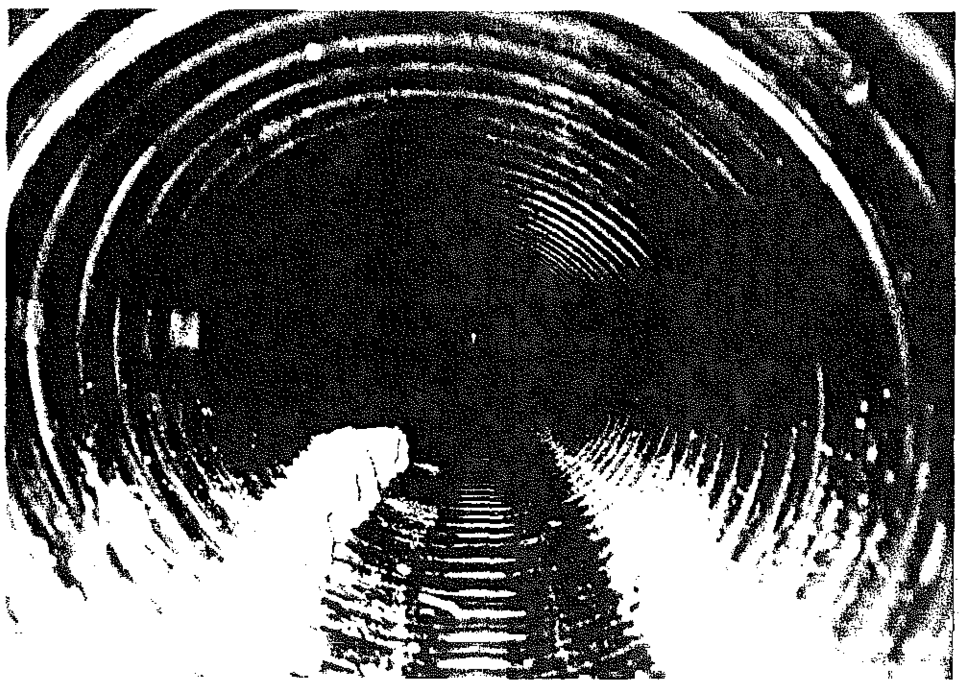

Figure 4. Elliptical 24-Inch Outlet Pipe, Deflected 14.5 Percent.