TESTING AND EVALUATION OF CORRUGATED POLYETHYLENE PLASTIC DRAINAGE TUBING

J. D. Culp

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E. V. Erickson, Chairman;
Charles H. Hewitt, Claude J. Tobin, Peter B. Fletcher
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Corrugated polyethylene plastic drainage tubing has gained popular usage in the agricultural field for draining subsurface water from soil. Unperforated tubing is used to transport ground water and perforated tubing is used to collect and transport ground water. This report evaluates the perforated plastic tubing for use in highway edge drains and bank drains. Obvious advantages of polyethylene plastic tubing are its permanent immunity to corrosion and decay and the labor savings involved in its placement. Samples submitted for testing and evaluation were 6-in. diameter corrugated polyethylene tubing from Interlock Plastics, Inc., Flint, Michigan and Advanced Drainage Systems, Inc., Columbus, Ohio.

Load Bearing Requirements

A flexible pipe such as that being considered has relatively little inherent strength and thus depends on the development of the passive pressure of the surrounding soil to produce the compressive ring stresses necessary to support the vertical loads applied to it. With a properly compacted backfill these light weight flexible pipes can support loads equivalent to those supported by rigid pipes (e.g. concrete pipe, clay tile, bituminized fiber pipe) with a much greater factor of safety against failure and blockage of the drain line. Even when crushed, the tube does not fracture, and therefore maintains some flow capacity. By utilizing the surrounding soil in this manner the flexible pipe becomes a much more efficient load bearing structure as compared to rigid pipe.

The loads applied to underdrain pipe consist of the dead load of the soil above the pipe and the live loads applied on the soil surface. The live loads are applied by earth moving equipment during the construction phase and later from direct traffic loading. It is apparent that the loading applied to the underdrain pipe during the construction of a given section of highway produces the most severe loading condition and hence the strength requirements should be based on this. Since underdrain pipe may be placed above the frost line it must also be immune to freeze fracture or embrittlement at subfreezing temperatures.

Pertinent Specifications

The only specification on corrugated polyethylene drainage tubing currently in use is the U. S. Department of Agriculture (USDA) Engineering Standard No. 606. This specification calls for a "sandbox test" procedure to test for the required strength. This test somewhat simulates the actual loading condition of the pipe by placing the test section in dry sand and applying the crushing load to a bearing plate resting on the sand 9-in. above the top of the pipe.

The American Society for Testing and Materials (ASTM) has drafted a proposed standard specification for polyethylene tubing. This specification calls for the testing of pipe stiffness as described in ASTM D 2412, "External Loading Properties of Plastic Pipe by Parallel-Plate Loading." This type of strength test is much easier to perform and is reliable in checking for minimum strength as long as the required pipe stiffness has been shown to be indicative of a pipe section which provides the required crushing strength in the sandbox test.

The "Standard Specifications for Highway Materials" of the American Association of State Highway Officials (AASHO) does not include polyethylene pipe for use in underdrains. However, a task force has been established by the Subcommittee on Materials to study the product. The Michigan Standard Specifications for Highway Construction currently does not include corrugated polyethylene pipe for use in underdrains (section 6.02).

Testing Procedure

A "sandbox test" was set up according to the specifications in the USDA Engineering Standard No. 606 (Fig. 1). Plexiglass ends on the box permit observation of the pipe during loading. The hydraulic ram applies the load to a 12 by 12-in. steel bearing plate which distributes the load to the sand. The pipe test sections were 6 in. in diameter and 18 in. in length. They were bedded in loose dry Ottawa sand with a 3-in. underlayer and 9 in. of cover over the top of the test section. The test pipes are loaded to failure which is taken to be the maximum load value reached before a steady decline in load occurs. The crushing strength of the tubing in lb/sq in. is tabulated as the pounds of force applied at failure divided by the area of the loading plate.

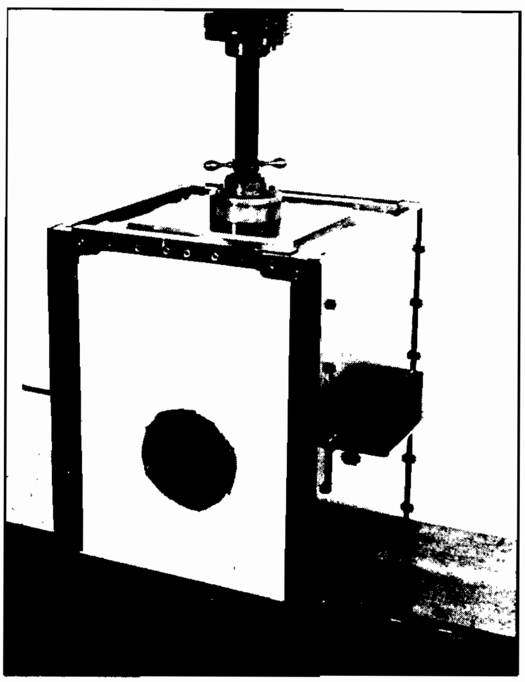

Figure 1. Test set up for the USDA sandbox test.

From the polyethylene pipe samples provided by Interlock Plastic and Advanced Drainage Systems, three specimens were tested from each as specified in the USDA Engineering Standard No. 606. The average crushing strength of the three samples is shown in Table 1. Also listed in Table 1 is the minimum crushing strength required according to the USDA specification. An additional test was run on a section of each tubing type after bringing the temperature of the sand and pipe down to 0 F. The resulting crushing strength was 75 psi for both specimens and no embrittlement of the plastic due to the subfreezing temperature was observed.

TABLE 1
SANDBOX TEST AND PARALLEL PLATE TEST
RESULTS AND RECOMMENDED MINIMUM VALUES

	USDA Sandbox Test (Strength in psi)	ASTM Parallel Plate Test (Stiffness in psi)			
		Corrugator Seam Vertical		Corrugator Seam Horizontal	
		5% defl.	10% defl.	5% defl.	10% defl.
Interlock Plastics, Inc.	65	32	25	38	29
Advanced Drainage Systems, Inc.	67	47	36	45	35
Minimum Required per Specification	23.5 (USDA)	30 (ASTM)	25	30	25
Recommended Minimum for Highway Underdrain	50	40	30	40	30

Several additional sandbox tests were performed on samples of the pipe with the test sections bedded in Granular Material Class I at its optimum moisture content and compacted to 95 percent of its maximum unit weight rather than the loose sand specified in the above standard test. This bedding procedure is representative of the backfilling procedure specified in the Controlled Density Method, 2.08.08a of the Michigan Standard Specifications for Highway Construction for the placement of underdrain pipe. Upon loading, the test specimens were subjected to a crushing stress of over 150 psi with no visible deformation or failure. This is over twice the strength developed by the tubing in loose sand where complete collapse occurred at the maximum load and illustrates the important effect that the soil compaction (density) has on the bearing strength of a flexible type conduit.

Next a series of parallel plate tests was performed on the tubing samples in conformance to the procedure specified in ASTM D 2412 with the following exceptions (Fig. 2). The test specimens were 12 in. long, a wooden plate was used for the upper loading plate and the outside diameter change was determined during loading by measuring the travel of the lower cross-head. In the parallel plate test the minimum required pipe strength is specified as the pipe stiffness in lb/sq in. at a change in diameter of 5 percent and 10 percent of the initial pipe diameter. The pipe stiffness is defined as the load per in. applied to the pipe divided by the vertical change in the diameter. Since there is no confining soil pressure around the pipe section in this test the load required to deform the specimen is small and not related to the bearing capacity of the pipe when confined in soil. However, this test will indicate the comparative strengths of several different pipe samples and is much easier to perform for a quality control test.

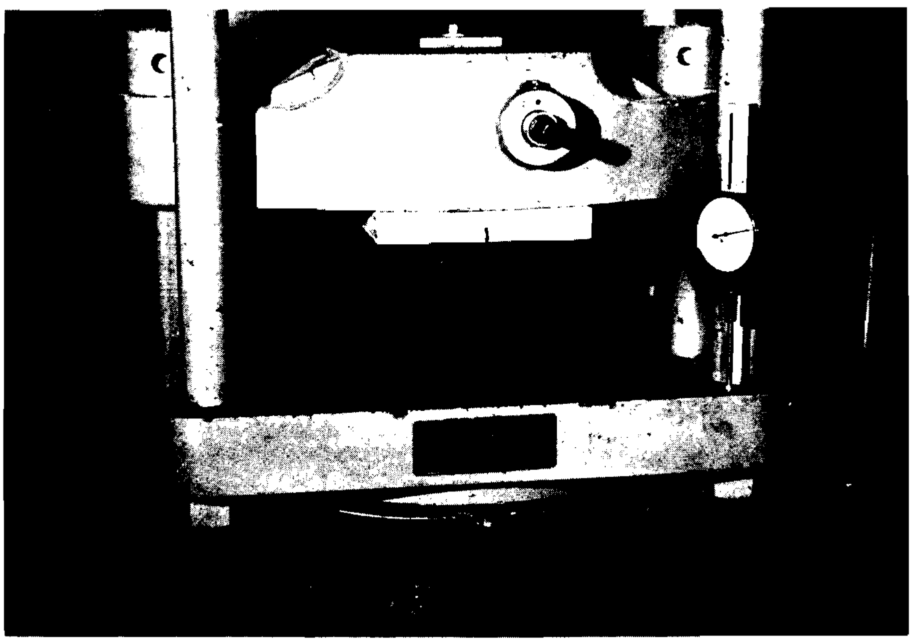

Figure 2. Test set up for the ASTM parallel plate test.

In testing corrugated polyethylene tubing of this type in a parallel plate test the orientation of the two corrugator seams present from the manufacturing process can effect the results. The strength of a test specimen can vary by rotating it in the test fixture and thus the minimum strength must be determined. In testing the pipe samples from the two producers, three specimens were tested from each with the corrugator seams in a horizontal plane and three specimens each with seams in a vertical plane. The results of these tests are shown in Table 1 as the average pipe stiffness of each three specimens.

Physical Characteristics and Requirements

For the pipe samples submitted, the exterior corrugations were 1/2 in. deep by 3/8 in. wide and the inside corrugations were 1/2 in. deep by 5/16 in. wide. The pipe wall thickness varied from 0.035 in. for the outside corrugation to 0.080 in. for the inside corrugation. Such wall thickness variations are acceptable as long as the pipe section can meet the specified strength requirements. However, in no case should the wall thickness be accepted at less than 0.030 in. or localized wall buckling may occur upon load application.

The compounds used in the manufacture of corrugated polyethylene drainage tubing should conform with the requirements of Type III, Class C, Category 3, Grade P33 polyethylene, as specified in ASTM D 1248.

The water inlet perforations in the samples submitted were 0.075 in. by 1.5 in. saw cut slits on every other inside corrugation. These slits are placed in three longitudinal rows, evenly spaced around the circumference of the pipe. It is standard practice in highway applications of underdrain tubing to place all perforations on the lower half of the circumference, thus preventing gravity assisted infiltration of fine materials from occurring at the top of the pipe. Elimination of the top row of slits in the pipe samples submitted would conform to this practice and still provide adequate water inlet area of 1.80 sq in./ft. As an alternate, the water inlet perforations could be formed during the pipe extrusion process as four rows of holes formed on the inside corrugations, simular to those in corrugated galvanized steel culvert pipe as specified in M 36 - 18.1.5 of the AASHO Highway Materials Specification, Part I. The size of such holes should not exceed 3/16 in. in a direction longitudinal to the pipe and 5/16 in. in the circumferential direction. They should be spaced along the rows to provide a water inlet area between 1.00 and 1.80 sq in./ft of pipe. Should this hole configuration be used the pipe section needs to be carefully tested in the "sandbox test" to insure that it still provides the required bearing strength.

Evaluation and Recommendations

The 6-in. diameter corrugated polyethylene tubing is recommended for use in highway edgedrains and bank drains. The tubing can be obtained in rolls of up to 300 ft in length and a significant savings can be realized in the labor involved in placing the underdrain system. Once the tubing is properly placed and backfilled it is immune to corrosion and decay and is virtually indestructable when subjected to normally encountered highway loadings. Thus the underdrain system should never suffer a failure and should require no maintenance.

The recommended minimum strength requirements for the corrugated polyethylene tubing are as shown in Table 1. Based on the testing done in this investigation it is concluded that any tubing section that can sustain a crushing stress of 50 psi in the standard USDA sandbox test will be adequate for highway use if the pipe is properly bedded and backfilled. This stress requirement is equivalent to the most severe loading condition that the pipe could be subjected to during the construction of a section of highway, i.e., the heaviest wheel load on the subgrade with a minimum of 12 in. of cover over the drainage tubing. A Euclid TS - 24 scraper, fully loaded, develops a wheel load of 50 kips distributed over an area of approximately 25 by 32 in. This is the loading used for establishing the strength requirements of the tubing.

A pipe section that has a sandbox crushing strength of 50 psi should provide a minimum pipe stiffness of 40 psi at a 5 percent change in diameter and 30 psi at a 10 percent change in diameter as measured by the ASTM parallel plate test. These strength requirements are well within the manufacturing capabilities of the various suppliers of polyethylene tubing. The parallel plate test is much easier to perform and is recommended for use in acceptance testing.

In acceptance testing of corrugated polyethylene tubing a stretch resistance test should also be conducted. A minimum of three test specimens, 5 ft in length, should be tested. Subject each test specimen to a stretching (longitudinal) force of magnitude 5D lb, where D is the nominal inside diameter in inches. The specimens are hung in a vertical manner with the test force applied as a dead weight to the bottom end of the tube. The gage-length for determining the percent stretch is the middle 3 ft portion of the specimen. A small tare weight (less than D lb) may be applied initially before marking the 3 ft gage length; this tare weight will help to hold slightly curved specimens more vertical. The test weight is applied gently, and allowed to remain for three minutes; the gage length is then remeasured to the nearest 0.125 in. to determine stretch. Elongation (E) shall be calculated as the percent of stretch over the initial 3 ft gage length. The maximum elongation that should be accepted is 5 percent.

In placing polyethylene tubing the soil compaction technique determines how strong the buried pipe will be. Backfilling for drains within the roadbed must be as specified in the Michigan Department of State Highways Standard Specifications under Controlled Density Method, 2.08.08a using only Granular Material Class I or Aggregate 22A as specified in 6.02.05. Since the bearing capacity of a flexible walled pipe depends on the development of the passive pressure of the surrounding soil, the backfill must be compacted to 95 percent of the maximum unit weight as specified in the Controlled Density Method to provide this lateral pressure. A flexible tubing incorrectly backfilled will have little bearing strength and can be easily crushed. In no instance should heavy construction equipment be allowed to drive over the buried pipe unless the backfill has been properly compacted to a depth of at least 12 in. above the top of the pipe.

Since the product is flexible, thin-walled and made of polyethylene some precautions must be taken during installation. The pipe will temporarily weaken when heated. Caution should be used to avoid crushing or stretching on hot days with bright sunlight. The tubing is purchased in coiled form and it becomes increasingly difficult to lay level and straight as it becomes colder. Extra care must be used in cold weather installations. Since the density of the polyethylene is less than water, a tendency of the pipe to float may complicate the placement of a drainage system where the ground water table is high.

If chemicals of a questionable nature will be present in the proximity of the tubing, their effect on polyethylene should be carefully evaluated. Polyethylene is flammable and should not be installed where exposed to any fire hazard. Also polyethylene deteriorates (becomes brittle) under ultra violet attack and therefore should not be used or stored where exposed to direct sunlight for a period exceeding 12 months.

Sections of the tubing are easily jointed in straight joints, in elbows or in tees by molded couplings provided by the manufacturer (Fig. 3). Once properly secured these couplings provide a very good joint and chances of misalignment should be relatively small as compared to other types of drainage pipe.

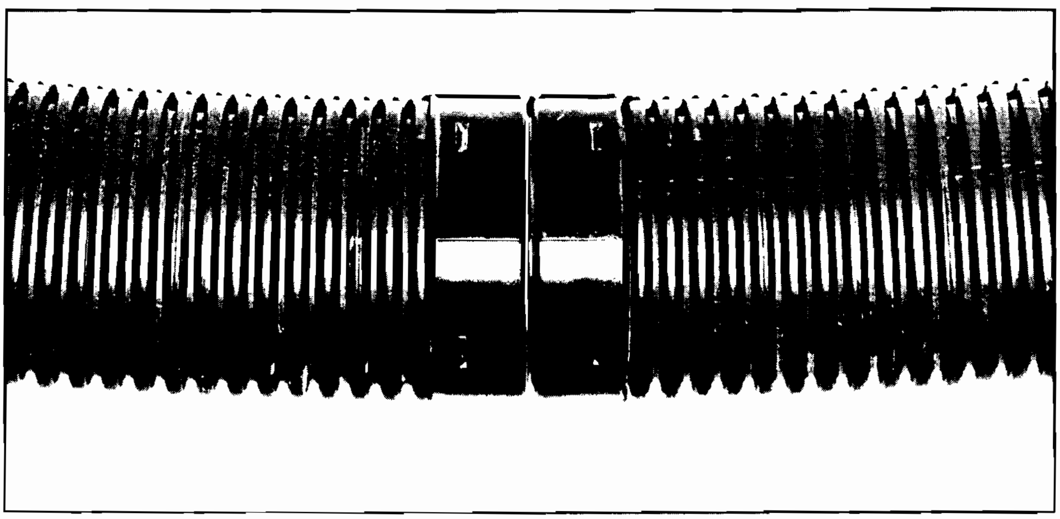

Figure 3. Straight joint coupling for circular corrugated polyethylene tubing.