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Final Report

On

Evaluation of Capiphon Drain Belt

To

Evan Rothblatt, EIT

Program Manager for Engineering

American Association of State Highway and Transportation Officials
AASHTO
The Voice of Transportation

By

Mario Paredes
TRI/Environmental
Senior Research Engineer
Pipe Testing Division

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Introduction

TRI/Environmental was commissioned by the AASHTO APEL program to test a new product submitted for use by state Department of Transportation’s (DOTs) in the United States. The purpose of the project was to characterize basic properties of a water extracting mat used in soils. The name of the product is Capiphon Drain Belt, produced by Capiphon USA.

APEL provided TRI with a specific list of properties of interest identified by its members. The list was divided into two sections characterizing the product properties as manufactured and the basic material properties of the polymer used to fabricate the product. The list of tests for the product included: thickness: width: hardness: impact resistance: tensile properties: brittleness: cellular plastic compressive properties: and water permeability in 3 different conditions. The basic material properties of interest are impact resistance, brittleness, and tensile properties. The test methods and the results obtained are described in each respective section below. Pictures are included, where available, for reference.

Samples

The properties of the product, Capiphon, as well as material properties tested on compression molded plaques are presented below. Plaque thicknesses were fabricated as required by the each specific test method. A roll of Capiphon was received at the TRI lab in Austin, Texas on February 14, 2018.

Specimen Preparation

Specimens were obtained from either the material as manufactured or die cut from a plaque as required by the corresponding test methods.

Figure 1

TEST PROCEDURES AND RESULTS

Thickness and Width

The thickness and width of the product were determined in accordance with *ASTM D 5199 Standard Test Method for Measuring the Nominal Thickness of Geosynthetics.* This method was adopted due to the flexible nature of the product that makes it hard to make measurements accurately if the measuring load causes specimen deformation. The test method defines procedures for the determination of linear dimensions of Geosynthetic materials. The thickness and width were determined using calipers.

Table 1

Width (ASTM D 5199)											TEST RESULTS
Test Replicate Number	1	2	3	4	5	6	7	8	9	10	Mean
Width (inches)	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	**7.9**

Table 2

Thickness (ASTM D 5199)											TEST RESULTS
Test Replicate Number	1	2	3	4	5	6	7	8	9	10	Mean
Width (mils)	75.2	77.1	75.9	79.2	83.4	77.0	75.8	76.9	78.0	77.1	**77.6**

Durometer Hardness

The hardness of the product was determined in accordance with ASTM D2240, *Test Method for Rubber Property—Durometer Hardness*. This test method permits hardness measurements based on initial indentation caused by a specific indenter. Indenter Type A was used which has a 0.1 mm radius tip and a 2.5 mm length. A manual (hand held) digital durometer was used to take 5 measurements in different locations of the specimen.

The results were as follows:

Table 3

DUROMETER HARDNESS						TEST RESULTS
Test Replicate Number	1	2	3	4	5	Mean
Hardness	94	94	95	96	97	**95**

IZOD Impact Strength

The IZOD impact strength of the material was determined in accordance with ASTM D 256, *Determining the IZOD Pendulum Impact Resistance of Plastics,* on specimens cut from a plaque. Testing was performed using a Dynisco Basic Pendulum Impact Tester with a hammer capable of delivering 8 ft-lbf of energy. Specimens for the material were die cut using a 0.5” wide die from a 0.100" thick plaque made for this test, and conditioned at laboratory testing environment for a minimum of thirty minutes prior to testing.

Figure 2a shows the specimen in the grip system used to secure when struck by the hammer. Figure 2b shows the whole apparatus illustrating how the hammer strikes the specimen during test.

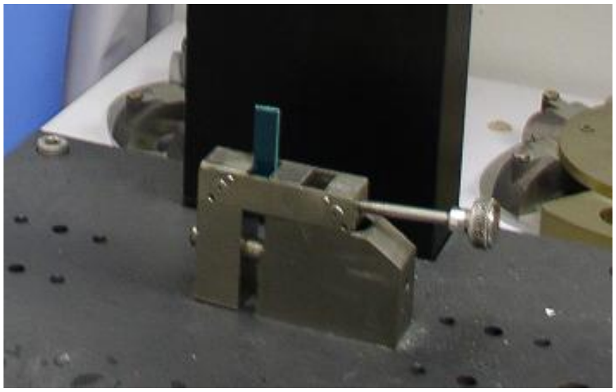

Figure 2a

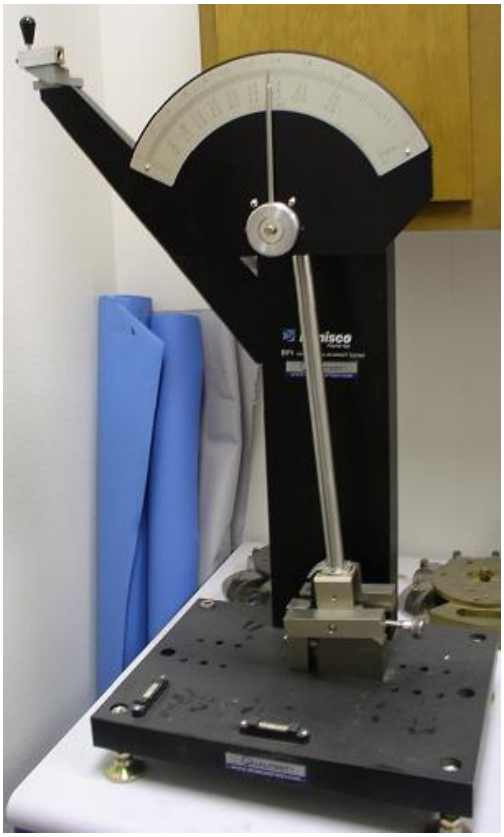

Figure 2b

The results are presented in the following table.

Table 4

MATERIAL TEST RESULTS (ASTM D256)						
Test Replicate Number	1	2	3	4	5	Mean
Impact Strength (ft-lbs/in^2)	39.13	47.20	48.83	52.73	42.58	46.09
Failure Code	NB	NB	NB	NB	NB	NB

(NB – No Break)

The specimen had an incomplete break that extended less than 90% of the distance between the vertex of the notch and the opposite side leading to the failure code "NB" as defined by the method.

An attempt was made to make IZOD specimens from the product however, the specimens were not able to support themselves due to the extremely thin back layer (0.0015" thickness) supporting the capillary. In addition, the specimens could not be put in the small vice that serves as specimen holder as the specimen folds under the load applied to firmly hold the specimen during the impact test. Thus, no product IZOD impact strength was obtained.

Tensile Properties

The tensile properties of the material, as well as the product, were determined in accordance with ASTM D 638, *Test Method for Tensile Properties of Plastics.* Testing was performed using an Instron 5565 tension testing machine equipped with Merlin "smart" data acquisition system and scored grip faces for specimen clamping. Die cut specimens were conditioned in the laboratory testing environment for a minimum of thirty minutes prior to testing. The strain was then measured, using an extensometer connected at the end of the gauge area, on the product as manufactured and on plaques fabricated in the lab. The results are presented in the following table.

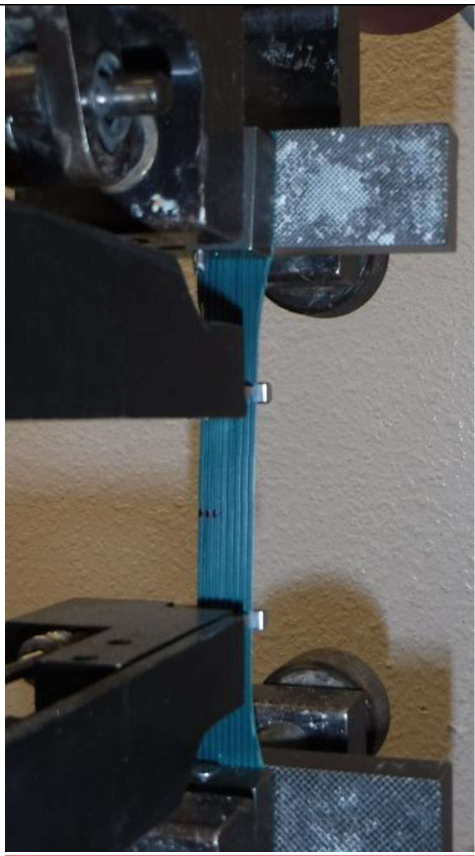

Figure 3a Product Specimen

Figure 3b Plaque Specimen

The material and product did not display a clear yield point as shown in the following figure so no yield properties are reported.

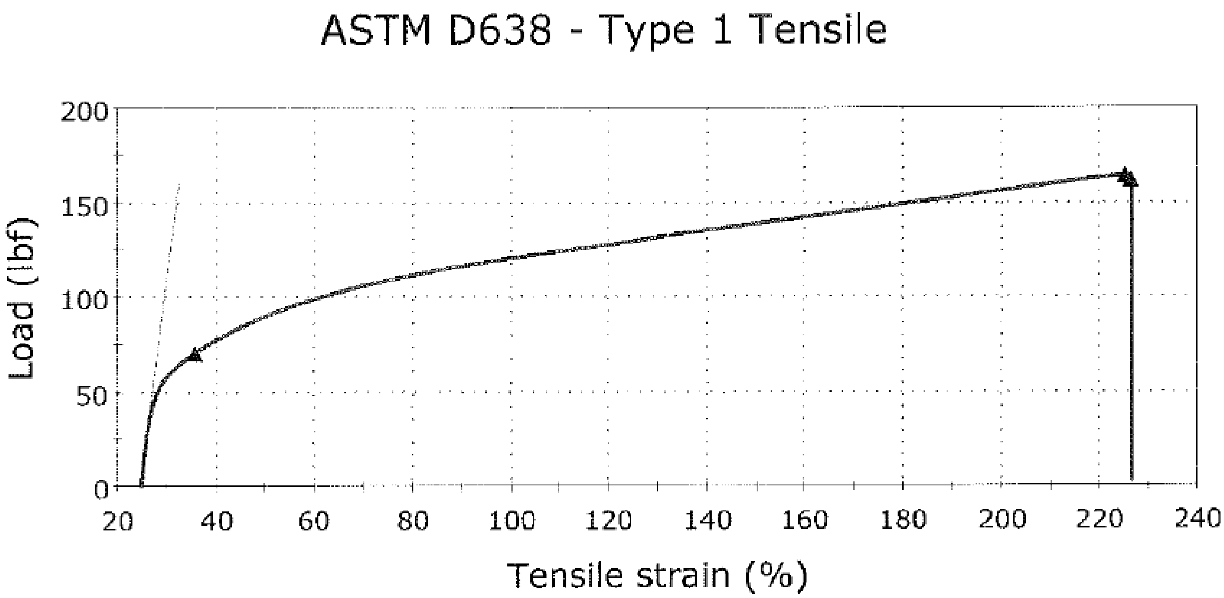

Figure 4 Load vs. Strain Data Curve

Table 5

PRODUCT TENSILE PROPERTIES (ASTM D 638)						TEST RESULTS
Test Replicate Number	1	2	3	4	5	Mean
Tensile Break Load (lbs)	67	71	71	67	70	**69.2**
Tensile Break Strength (psi) Assuming 0.5" x 0.0776" cross-section	1,727	1,830	1,830	1,727	1,804	**1,783.6**
Tensile Break Strain (%)	122	139	144	105	141	**130.2**
Young's Modulus (psi)	59,958	50,377	47,694	47,604	44,074	**36,550**

The tensile breaking strength, calculated above, has a significant amount of uncertainty due to the inability to measure the cross-section of each specimen. Caution should be used when applying this number. The breaking load is recommended for comparison purposes.

Table 6

MATERIAL TENSILE PROPERTIES (ASTM D 638)						TEST RESULTS
Test Replicate Number	1	2	3	4	5	Mean
Tensile Break Load (lbs)	162.03	173.64	148.7	167.43	172.36	**164.83**
Tensile Break Strength (psi)	3,018	3,121	2,726	3,124	3,219	**3,042**
Tensile Break Strain (%)	226.1	203.0	164.7	235.4	214.8	**208.8**
Young's Modulus (psi)	38,781	38,556	35,136	34,252	36,026	**36,550**

The specimens lacked a definitive yield point however, it is estimated that had one presented itself it would have been 1500 to 1800 psi.

Compressive Properties

The Compressive properties of the product were determined in accordance with ASTM D 1621, *Test Method for Compressive Properties of Rigid Cellular Plastics.* Testing was performed using an Instron 5565 Compression/tension testing machine equipped with Merlin "smart" data acquisition system and steel plates to sandwich the specimen pieces. Strain was measured using an extensometer connected at the end of the gauge area. Specimens were conditioned in the laboratory testing environment for a minimum of thirty minutes prior to testing. The test was carried out on the product as manufactured rather than plaques. The specimens were die cut to produce a block specimen with a cross-section of 2" in test area and 1" thick. The individual pieces are not thick enough to produce a block, multiple pieces are required. In addition, the surface texture of the material doesn't permit contact end to end of the same material without deleterious effects being generated; multiple pieces of the material were sandwiched between metal plates to produce a sample. The following figure shows the specimen.

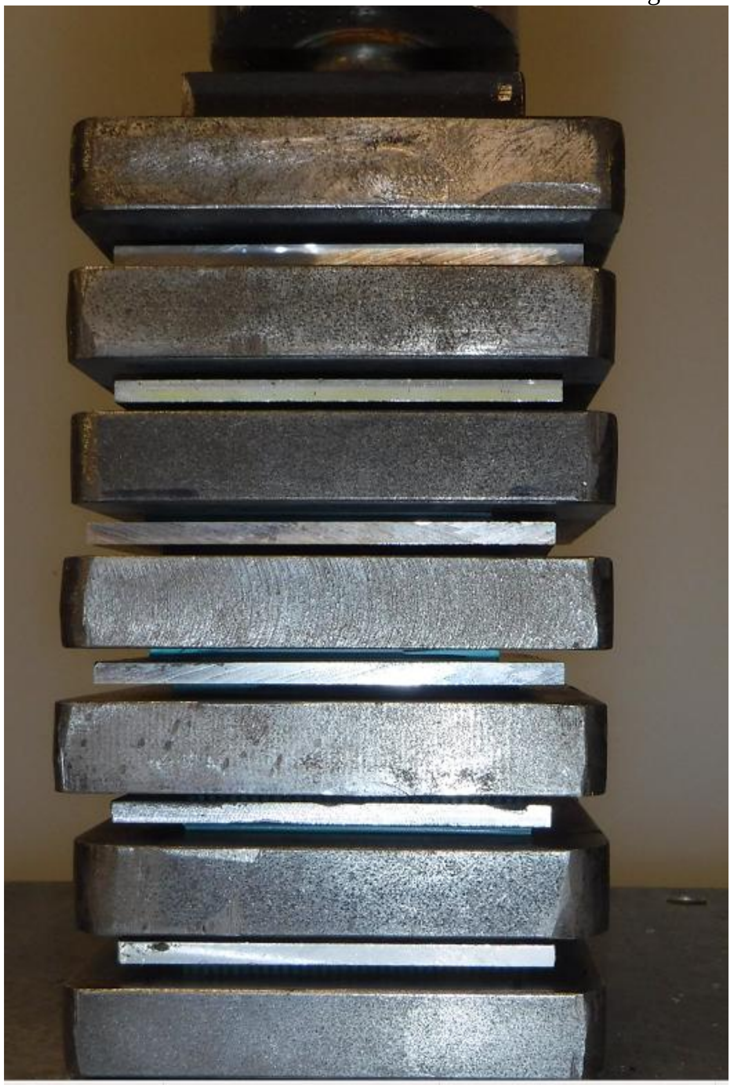

Figure 5 Compression Test Specimen

Twelve pieces of Capiphon were placed in between the steel plates, to create a good representation of product when exposed to compressive loads. The results are presented in the following table.

Table 7

PRODUCT COMPRESSIVE PROPERTIES (ASTM D 1621)						TEST RESULTS
Test Replicate Number	1	2	3	4	5	Mean
Compressive Yield Strength (psi)	754.1	742.3	814.3	873.1	824.5	**801.7**
Compressive Yield Strength (%)	7.15	7.20	7.60	7.07	6.70	**7.07**

Brittleness Temperature

The temperature at which both the material and the product become brittle was identified in accordance with ASTM D 746, *Test Method for Brittleness Temperature of Plastics and Elastomers by Impact*. The test was performed on both the product as manufactured and plaques produced according to the specifications set forth in the method. The test consists of holding small pieces of the polymer in a cantilever position in a cold environment created by liquid methanol and dry ice. Dry ice is added to the methanol until it reaches the desired temperature for the test. Once the specimens reach the test temperature, an air driven striking edge delivers a hit with a speed of 2000 mm/s to each of 10 separate specimens of the sample. The temperature, at which 50% of the specimens break during the test, is defined as the brittleness temperature. One must keep in mind that just like other temperatures defining polymer behavior, the brittleness temperature is more a range than a single temperature. Brittleness is reported as a single value however, as with most temperatures defining polymer behavior, it is actually a range that the reported values fall within.

The following figures show the test setup during cooling as well as right after the last specimen is stricken by the hammer. The hammer is release by hydraulic action to provide repeatable blows.

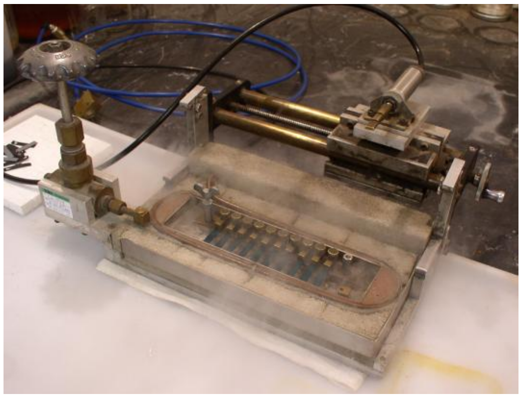

Figure 6

Figure 6

The following table shows the results obtained for both the product as well as the sample made from a plaque.

Table 8

Product Brittleness (ASTM D 746) At -29°C										
Test Replicate Number	1	2	3	4	5	6	7	8	9	10
Pass/Fail	P	P	P	P	P	F	F	F	F	F

Table 9

Material Brittleness (ASTM D 746) At -29°C										
Test Replicate Number	1	2	3	4	5	6	7	8	9	10
Pass/Fail	P	P	P	P	P	P	P	P	P	P

Hydraulic Transmissivity

The in-plane hydraulic transmissivity of the product was determined in accordance with ASTM D4716, *Test Method for Determining the In-Plane Flow rate per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using Constant Head*. This test method is used to measure the flow rate per unit width within the manufactured plane while subjecting the product to various compressive strengths under a constant head. This allows measurements to be taken of the water flow rate when the product is compressed by a load during the application of a constant water gradient between the inflow and outflow. This is an adaptation to this product as the test method is intended for Geosynthetics. The following figure illustrates the test setup. The method places the product between two plates and 2 tanks and the capillaries within Capiphon connect the two tanks. A load is then applied to Capiphon through the top plate restricting the water to flow between tanks through the Capiphon only.

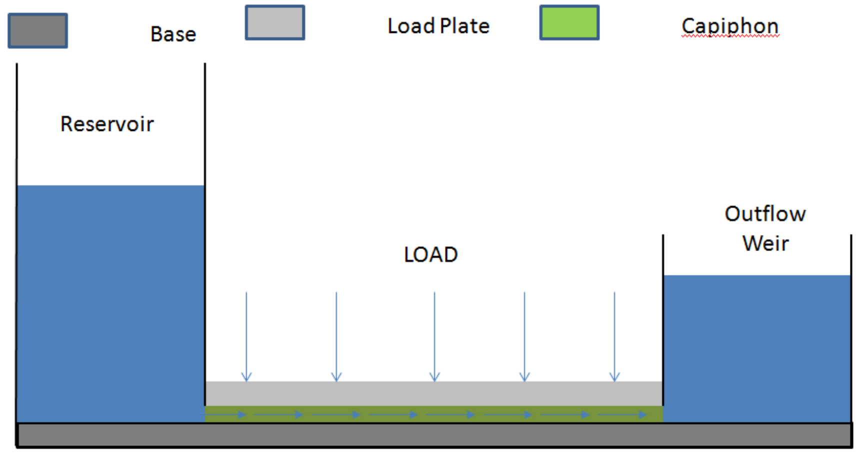

Figure 7

Each result below represents the average of six readings (two specimens with three readings each).

Table 10

TRANSMISSIVITY			
Load (psi)	**Hydraulic Gradient**	**Flow Rate** (GPM/ft width)	**Transmissivity** (m^2/s)
10	0.25	0.32	2.63E-04
10	0.5	0.60	2.50E-04
10	1	1.13	2.34E-04
25	0.25	0.31	2.56E-04
25	0.5	0.59	2.42E-04
25	1	1.10	2.29E-04

The flow rate is proportional to hydraulic gradient indicating the added stress does not significantly change the transmissivity of the material as shown above

Flow in Crimped Condition

The water flow of Capiphon in a simulated crimped condition was evaluated using ASTM D6918, *Testing of Vertical Strips Drains in the Crimped Condition.* This test method is an adaptation of a test used for vertical drains to evaluate Capiphon's ability for water flow when conditions occur that may restrict the flow of water through its capillary. The test is carried out with a given set of conditions as defined by the water height differences (head) between the in and out water reservoirs. The test consists of placing Capiphon in line to provide water flow between the two reservoirs. A water flow restriction is introduced by application of air pressure on the material simulating consolidation of soil. The test is performed twice, once with a straight piece of Capiphon and once with a 90° bent/crimped (crimped) piece of the product. The following figure from the test method illustrates the test.

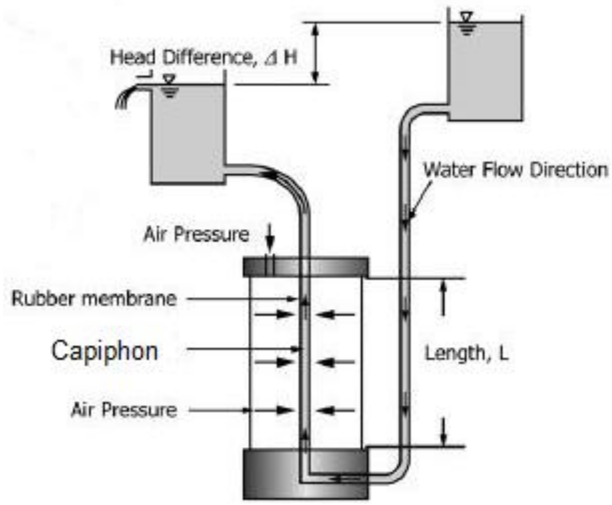

Figure 8 Crimped Test

It should be noted that the 90° bend/crimp is not there while testing the straight specimen. The tests are carried out in triplicate for each set of conditions and the same piece of material. Each result below represents the average of 3 readings. The results obtained were as follows:

Table 11

TRANSMISSIVITY			
Pressure (psi)	Hydraulic Gradient	Crimp Condition	Discharge Capacity (m^3/s)
10	1	Straight	3.41E-05
25	1	Straight	1.58E-05
10	1	Crimped	5.17E-06
25	1	Crimped	4.83E-06

The test results indicate that, while increasing the confining pressure does reduce the discharge capacity by more than half, the introduction of the crimp reduces this by 1 order of magnitude. Taking this into consideration, it is recommended that a bend/crimp in the product should be avoided. The angle at which this becomes a significant issue requires further evaluation. It is hypothesized that this may not be an issue at angles below 45.

Permeability/Permittivity/Conductivity

To evaluate the improved water permeability provided by Capiphon in a low saturated porous soil, the hydraulic conductivity of Capiphon was measured by adapting *ASTM D5084 Standard Test method for Measurement of Hydraulic Conductivity of Saturated Porous Material Using a Flexible Wall Permeameter*.

The hydraulic conductivity of a remolded specimen of soil was evaluated with and without the presence of a Capiphon drain using a flexible wall hydraulic conductivity cell / permeameter complying with ASTM D5084 requirements.

Sandy clay was selected for testing. The sample was remolded into a suitable test specimen and placed into the flexible wall hydraulic conductivity device. It was then consolidated under an effective stress of 15 psi and brought to a point at which the B-value was equal to or greater than 0.95 (evaluated in accordance with ASTM D5084). The sample was then permeated and a hydraulic conductivity of 3.8E-9 ft/s was measured.

Following permeation of the sandy clay, the test device was then de-pressurized and the test specimen was removed. The specimen was halved down its longitudinal axis and a rectangular insert of Capiphon was added and placed back into the test apparatus. It was consolidated and permeated as previously described and the hydraulic conductivity was, once again, measured. The soil-drain system was measured as 2.6E-7 ft/s under an effective stress of 15 psi which resulted in a 68-fold increase in the system hydraulic conductivity. The specimen was removed from the testing apparatus for visual inspection and found to readily separate around both sides of the drain with no evidence of intrusion into the drain system by the soil.

Mario Paredes, PE
Senior Research Engineer