Keeler St. Porous Pavement
Pre and Post Maintenance
Infiltration Test Results

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PAVE DRAIN®
STORMWATER'S ARCH ENEMY

ALL TESTING PERFORMED BY TETRA-TECH

TETRA TECH

MEMO

To:	Valerie Novaes, PE, DWSD
Cc:	James Rydquist and Dan Christian
From:	Tiffany T. Neubig
Date:	December 14, 2017
Subject:	Keeler St. and Artesian St. Porous Pavement Infiltration Testing

1.0 INTRODUCTION

On December 1, 2017, infiltration testing was performed at two separate locations on Keeler Street PaveDrain system and one location on the Artesian Street porous asphalt to determine how the two systems are operating without regular cleaning maintenance. On December 4, 2017, DWSD cleaned the area of PaveDrain and porous asphalt using the recommended PaveDrain attachment that is attached to a vacuum truck. On December 5, 2017, infiltration testing was performed at the same locations to determine the infiltration rate after cleaning. The results of the before and after testing of the infiltration of the pervious pavement is included in the attached memo.

2.0 TESTING LOCATIONS

Keeler Street contain PaveDrain system installed in the parking lanes along two city blocks between Outer Drive and Piedmont St. Infiltration testing was performed on each block on the south side of the road; Figure 1 shows the approximate testing locations.

Figure 1 Keeler Test Locations

Tetra Tech
65 Cadillac Square, Suite 3610, Detroit, MI 48226
Tel 313.964.0790 Fax 313.964.6957 tetratech.com

Artesian St. contains porous asphalt along two city blocks between Joy Road and Cathedral Street. Infiltration testing was performed on the east side of the road just south of Cathedral as shown in Figure 2.

Figure 2 Artesian Street Test Location

3.0 METHODOLOGY

Two infiltration testing methods were used to determine the infiltration rates. The first follows a standard ASTM test method, the second is a simple test method for porous pavements developed by North Carolina State University (NCSU).

3.1 ASTM

ASTM C1781 is a standard test method to measure the surface infiltration rate of a permeable unit pavement system. ASTM C1701 is an infiltration test for porous concrete. ASTM C1701 is also applied to asphalt pavements since no separate test method is available from ASTM for porous asphalt pavements. Test method C1781 and C1701 are functionally the same test method except that C1781 has provisions for positioning and securing the test ring to a discontinuous surface.

The basic test method is summarized as follows:

- Set 12” diameter ring on PaveDrain/ pavement in an area that shows a true representation of the pavers, joints and voids of the paving pattern.
- Mark location of test area
- Seal ring to the pavers/ pavement using putty not extending more than 0.5 inches from edge of ring to create a watertight seal.
- Remove any debris from the surface.
- Pour 1 gallon of water (8.0 +/- lbs.) on to PaveDrain surface while maintaining a constant head level between 0.4 and 0.6 inches and record how long it takes the water to drain.
    - If water drains in less than 30 seconds use 5 gallons (40 +/- lbs.) of water during official testing.
    - If water drains in 30 seconds are greater use 1 gallon (8.0 +/- lbs.) of water during official testing.
- Perform two tests to determine infiltration rate using the guidelines above.
- Calculate the Infiltration rate using the equation below.

Equation 1

$$I = (M/(D^2 * t) * K$$

I = Infiltration rate (in./hr.)

M = Mass of infiltrated water (lbs.)

D = Inside Diameter of infiltration ring (in.)

t = Time elapsed during test

*K = 126,870 (jn.^3*s/(lbs.*hr.))*

3.2 NCSU SIMPLE INFILTRATION TEST

The Simple Infiltration Test (SIT) developed at NCSU provides a rapid estimate of surface infiltration rate using easily-furnished materials and relatively small water volumes. Additionally the results are grouped into one of four categories based on the dewater time with recommended maintenance steps, refer to Table 1.

- Using a 2" x 4" board and assembled into a box with inside dimensions measuring 21" x 24".
- Set wooden box on pavers/ pavement in an area that shows a true representation of the pavers, joints and voids of the paving pattern.
- Mark location of test area
- Seal box to the pavers/ pavement using putty to create a watertight seal.
- Remove any debris from the surface.
- Pour 5 gallons of water on the surface to presoak the area.
- Pour 5 gallons of water (equivalent to the approximate 2.3 inch depth mark)
- Record the amount of time it takes the water to drain.
- Perform a minimum of two tests to determine the average infiltration rate using the guidelines above.
- Calculate the Infiltration rate using the Time elapsed in seconds, Drop in water level (inches) using equation 2.

Equation 2

$$I = \Delta H/T$$

ΔH *= Drop in Water Levels (in.)*

T = Time elapsed in Seconds

Table 1 Representative Dewatering Times for Simplified Infiltration Test

Description	Recommended Maintenance Step	Dewater Times
Newly Installed	Recently Maintained	< 30 seconds
Acceptable	Continue Preventative Maintenance	30 to 60 seconds
Partially Clogged	Restorative Maintenance Should be Scheduled	60 to 90 seconds
Clogged	Requires Restorative Maintenance Immediately	> 1.5 minutes

4.0 RESULTS

Infiltration rates increased substantially after cleaning of the pavement based on all test results. Table 2 provides a summary of each test at each site location. The infiltration testing prior to cleaning resulted in low infiltration rates. Upon visual inspection it was noted that Keeler St. had debris filled up to the top of the PaveDrain block and Artesian St. was visibly clogged on the surface.

Table 2 Test Results

Location	Method	Infiltration Before Cleaning (inch/hr.)	Infiltration After Cleaning (inch/hr.)	Observations
Keeler No. 1	ASTM	217	1,609	At the start of testing as water was poured on the PaveDrain, it was observed that water washed areas of the built up debris out of the voids between the blocks.
	NCSU SIT	59	753	
Keeler No. 2	ASTM	49	816	Prior to cleaning the testing area was filled with debris and leaves in the gutter line.
	NCSU SIT	32	233	
Artesian No. 1	ASTM	21	320	Prior to cleaning looked visibly dirty along the road
	NCSU SIT	24	154	

Table 3 shows the recorded drain times for the NSCU SIT method and matches the results up with the categories from Table 1.

Table 3 Dewater Time

Location	Method	Dewater Time Before Cleaning	Dewater Time After Cleaning
Keeler No. 1	NCSU SIT	2.2 min - Clogged	11 sec – Recently Maintained
Keeler No. 2	NCSU SIT	4.2 min - Clogged	34 sec – Acceptable
Artesian No. 1	NCSU SIT	5.7 min - Clogged	54 sec – Acceptable

Location 1 PaveDrain Prior to Cleaning

ASTM test ring on the PaveDrain

NCSU SIT Test Square

TETRA TECH

Date:	Site:	Job No.	Inspectors:	
12/1/2017	Keeler Street		T. Neubig / N. Trotter	
Location: No. 1 Between Outer Drive and Grandville St.		Rainfall from last rain event (in) 0		D = Test Ring inside Dia. (in) 12
Paving Units				
Type: PaveDrain blocks Pre-Cleaning		Thickness:		Age: 2 years

Set up
1. Set ring on pavers in an area that shows a true representation of the pavers, joints and voids of the paving pattern.
2. Mark location of test area
3. Seal ring to the pavers using putty not extending more than 0.5 inches from edge of ring to create a watertight seal.
4. Remove any debri on the surface

Pre - Wetting		
#	Time Elapsed (s)	Weight of Water (8.0 +/- lbs) (1 gallon)
1	21.41	8
2		

Test			
#	t = Time Elapsed (s)	M = Weight of Water (42.0 +/- lbs) (5	
1	171	42	
2	170	42	
Test 1:	I1 = (M/(D^2*t))*K =	216	in./hr
Test 2:	I2 = (M/(D^2*t))*K =	218	in./hr
	Average	217	in./hr

I = Infiltration rate (in./hr.)
M = Mass of infiltrated water (lbs.)
D = Inside Diameter of infiltration ring (in.)
t = Time elapsed during test
K = 126,870 (jn.^3*s/(lbs.*hr.))

TETRA TECH

Date: 12/1/2017	Site: Keeler St.	Job No.	Inspectors: T. Neubig / N. Trotter	
Location: No. 2 Between Grandville St. and Piedmont St.		Rainfall from last rain event (in) 0		D = Test Ring inside Dia. (in) 12
Paving Units				
Type: PaveDrain blocks Pre-Cleaning		Thickness:		Age: 2 years

Set up
1. Set ring on pavers in an area that shows a true representation of the pavers, joints and voids of the paving pattern.
2. Mark location of test area
3. Seal ring to the pavers using putty not extending more than 0.5 inches from edge of ring to create a watertight seal.
4. Remove any debri on the surface

Pre - Wetting		
#	Time Elapsed (s)	Weight of Water (8.0 +/- lbs) (1 gallon)
1	105	8
2		

* Since recorded time of pre-wetting was greater than 30 s, only 1 gallon of water was used in actual test.

Test			
#	t = Time Elapsed (s)	M = Weight of Water (8.0 +/- lbs) (5	
1	151	8	
2	139	8	
Test 1:	I1 = (M/(D^2*t))*K =	47	in./hr
Test 2:	I2 = (M/(D^2*t))*K =	51	in./hr
	Average	49	in./hr

I = Infiltration rate (in./hr.)
M = Mass of infiltrated water (lbs.)
D = Inside Diameter of infiltration ring (in.)
t = Time elapsed during test
K = 126,870 (jn.^3*s/(lbs.*hr.))

TETRA TECH

Date: 12/1/2017	Site: Artesian Street	Job No.	Inspectors: T. Neubig / N. Trotter	
Location: No. 1 Between Dover Ave. and Cathedral St.		Rainfall from last rain event (in) 0		D = Test Ring inside Dia. (in) 12
Paving Units				
Type: Porous HMA Pre-Cleaning		Thickness:		Age: 2 years

Set up

1. Set ring on pavers in an area that shows a true representation of the pavers, joints and voids of the paving pattern.
2. Mark location of test area
3. Seal ring to the pavers using putty not extending more than 0.5 inches from edge of ring to create a watertight seal.
4. Remove any debri on the surface

Pre - Wetting

#	Time Elapsed (s)	Weight of Water (8.0+/- lbs) (1 gallon)
1	182	8.0
2		

* Since recorded time of pre-wetting was greater than 30 s, only 1 gallon of water was used in actual test.

Test

#	t = Time Elapsed (s)	M = Weight of Water (8.0 +/- lbs) (5	
1	319	8.0	
2	365	8.0	
Test 1:	I1 = (M/(D^2*t))*K =	22	in./hr
Test 2:	I2 = (M/(D^2*t))*K =	19	in./hr
	Average	21	in./hr

I = Infiltration rate (in./hr.)
M = Mass of infiltrated water (lbs.)
D = Inside Diameter of infiltration ring (in.)
t = Time elapsed during test
K = 126,870 (jn.^3*s/(lbs.*hr.))

TETRA TECH

ALTERNATE TEST METHOD: 2' x 2' Wooden Box - NCSU SIT Pre-Cleaning

Date: 12/1/2017

Location: Keeler St.- Location No 1 Between Outer Drive and Grandville St.

Technician: Tiffany Neubig and Natalie Trotter

Method: 2' x 2' Wooden Box -21" x 24" inside dimensions

Test Pit #: No. 1 - PaveDrain

Liquid Used: Water **PH**

Depth of Water Table

Ground Temp at Depth ft

Infiltration Testing

Time: (T) (Minutes):	Min	Sec	Time Min + (Sec/60)	(T) Time Interval (Minutes):		Measurement, (inches):	(ΔH) Drop in water level, (inches):	I = (ΔH/(T/60)) Infiltration rate (inches per hour):	Remarks:
2:13	2	13	2.22	2.22	2.22	2.3	2.3	62	
2:20	2	20	2.33	2.33	4.55	2.3	2.3	59	
2:32	2	32	2.53	2.53	7.08	2.3	2.3	54	

Stabilized Infiltration Testing Rate (inches per hour): 59

TETRA TECH

ALTERNATE TEST METHOD: 2' x 2' Wooden Box - NCSU SIT Pre-Cleaning

Date: 12/1/2017

Location: Keeler - Location No. 2 Between Grandville St. and Piedmont St.

Technician: Tiffany Neubig and Natalie Trotter

Method: 2' x 2' Wooden Box -21" x 24" inside dimensions

Test Pit #: Location No. 2 - PaveDrain

Liquid Used: Water **PH**

Depth of Water Table

Ground Temp at Depth ft

Infiltration Testing

Time: (T) (Minutes):	Min	Sec	Time Min + (Sec/60)	(T) Time Interval (Minutes):		Measurement, (inches):	(ΔH) Drop in water level, (inches):	I = (ΔH/(T/60)) Infiltration rate (inches per hour):	Remarks:
4:06	4	06	4.10	4.10	4.10	2.3	2.3	34	
4:32	4	32	4.53	4.53	8.63	2.3	2.3	30	
4:01	4	01	4.02	4.02	12.65	2.3	2.3	34	

Stabilized Infiltration Testing Rate (inches per hour): 32

TETRA TECH

ALTERNATE TEST METHOD: 2' x 2' Wooden Box - NCSU SIT Pre-Cleaning

Date: 12/1/2017

Location: Artesian - Location no 1 Between Dover Ave. and Cathedral St.

Technician: Tiffany Neubig and Natalie Trotter

Method: 2' x 2' Wooden Box -21" x 24" inside dimensions

Test Pit #: Location No. 1 - Porous Asphalt

Liquid Used: Water **PH**

Depth of Water Table

Ground Temp at Depth ft

Infiltration Testing

Time: (T) (Minutes):	Min	Sec	Time Min + (Sec/60)	(T) Time Interval (Minutes):		Measurement, (inches):	(ΔH) Drop in water level, (inches):	I = (ΔH/(T/60)) Infiltration rate (inches per hour):	Remarks:
5:19	5	19	5.32	5.32	5.32	2.3	2.3	26	
6:05	6	05	6.08	6.08	11.40	2.3	2.3	23	

Stabilized Infiltration Testing Rate (inches per hour): 24

TETRA TECH

Date: 12/5/2017	Site: Keeler Street	Job No.	Inspectors: T. Neubig / N. Trotter	
Location: No. 1 Between Outer Drive and Grandville St.		Rainfall from last rain event (in) 0		Test Ring inside Dia. (in) 12
Paving Units				
Type: PaveDrain blocks Post-Cleaning		Thickness:		Age: 2 years
Set up				
1. Set ring on pavers in an area that shows a true representation of the pavers, joints and voids of the paving pattern.				
2. Mark location of test area				
3. Seal ring to the pavers using putty not extending more than 0.5 inches from edge of ring to create a watertight seal.				
4. Remove any debri on the surface				
Pre - Wetting				
#	Time Elapsed (s)	Weight of Water (8.0 +/- lbs) (1 gallon)		
1	15.35	8		
2				

Test			
#	t = Time Elapsed (s)	M = Weight of Water (42.0 +/- lbs) (5 gallon)	
1	23	42	
2	23	42	
Test 1:	I1 = (M/(D^2*t))*K =	1609	in./hr
Test 2:	I2 = (M/(D^2*t))*K =	1609	in./hr
	Average	1609	in./hr

I = Infiltration rate (in./hr.)
M = Mass of infiltrated water (lbs.)
D = Inside Diameter of infiltration ring (in.)
t = Time elapsed during test
K = 126,870 (jn.^3*s/(lbs.*hr.))

TETRA TECH

Date: 12/5/2017	Site: Keeler St.	Job No.	Inspectors: T. Neubig / N. Trotter	
Location: No. 2 Between Grandville St. and Piedmont St.		Rainfall from last rain event (in) 0		D = Test Ring inside Dia. (in) 12
Paving Units				
Type: PaveDrain blocks Post-Cleaning		Thickness:		Age: 2 years

Set up

1. Set ring on pavers in an area that shows a true representation of the pavers, joints and voids of the paving pattern.
2. Mark location of test area
3. Seal ring to the pavers using putty not extending more than 0.5 inches from edge of ring to create a watertight seal.
4. Remove any debri on the surface

Pre - Wetting

#	Time Elapsed (s)	Weight of Water (8.0 +/- lbs) (1 gallon)
1	18	8
2		

Test

#	t = Time Elapsed (s)	M = Weight of Water (42.0 +/- lbs) (5 gallon)	
1	46.86	42	
2	43.92	42	
Test 1:	I1 = (M/(D^2*t))*K =	790	in./hr
Test 2:	I2 = (M/(D^2*t))*K =	843	in./hr
	Average	816	in./hr

I = Infiltration rate (in./hr.)
M = Mass of infiltrated water (lbs.)
D = Inside Diameter of infiltration ring (in.)
t = Time elapsed during test
K = 126,870 (jn.^3*s/(lbs.*hr.))

TETRA TECH

Date:	Site:	Job No.	Inspectors:	
12/5/2017	Artesian Street		T. Neubig / N. Trotter	
Location: No. 1 Between Dover Ave. and Cathedral St.		Rainfall from last rain event (in) 0		D = Test Ring inside Dia. (in) 12
Paving Units				
Type: Porous HMA Post-Cleaning		Thickness:		Age: 2 years

Set up
1. Set ring on pavers in an area that shows a true representation of the pavers, joints and voids of the paving pattern.
2. Mark location of test area
3. Seal ring to the pavers using putty not extending more than 0.5 inches from edge of ring to create a watertight seal.
4. Remove any debri on the surface

Pre - Wetting		
#	Time Elapsed (s)	Weight of Water (8.0 +/- lbs) (1 gallon)
1	29	8
2		

Test			
#	t = Time Elapsed (s)	M = Weight of Water (42.0 +/- lbs) (5	
1	115.67	42	
2	115.3	42	
Test 1:	I1 = (M/(D^2*t))*K =	320	in./hr
Test 2:	I2 = (M/(D^2*t))*K =	321	in./hr
	Average	320	in./hr

I = Infiltration rate (in./hr.)
M = Mass of infiltrated water (lbs.)
D = Inside Diameter of infiltration ring (in.)
t = Time elapsed during test
K = 126,870 (jn.^3*s/(lbs.*hr.))

TETRA TECH

ALTERNATE TEST METHOD: 2' x 2' Wooden Box - NCSU SIT Post-Cleaning

Date: 12/5/2017

Location: Keeler St.- Location No 1 Between Outer Drive and Grandville St.

Technician: Tiffany Neubig and Natalie Trotter

Method: 2' x 2' Wooden Box -21" x 24" inside dimensions

Test Pit #: No. 1 - PaveDrain

Liquid Used: Water **PH**

Depth of Water Table

Ground Temp at Depth ft

Infiltration Testing

Time: (T) (Minutes):	Min	Sec	Time Min + (Sec/60)	(T) Time Interval (Minutes):		Measurement, (inches):	(ΔH)* Drop in water level, (inches):	I = (ΔH/(T/60)) Infiltration rate (inches per hour):	Remarks:
0:11	0	11	0.18	0.18	0.18	2.3	2.3	753	
0:11	0	11	0.18	0.18	0.37	2.3	2.3	753	

Stabilized Infiltration Testing Rate (inches per hour): 753

* Used 5 gallons of water - converted to cubic feet and divided by Area of box (21" x 24") to determine depth of water

TETRA TECH

ALTERNATE TEST METHOD: 2' x 2' Wooden Box - NCSU SIT Post-Cleaning

Date: 12/5/2017

Location: Keeler - Location No. 2 Between Grandville St. and Piedmont St.

Technician: Tiffany Neubig and Natalie Trotter

Method: 2' x 2' Wooden Box -21" x 24" inside dimensions

Test Pit #: Location No. 2 - PaveDrain

Liquid Used: Water **PH**

Depth of Water Table

Ground Temp at Depth ft

Infiltration Testing

Time: (T) (Minutes):	Min	Sec	Time Min + (Sec/60)	(T) Time Interval (Minutes):		Measurement, (inches):	(ΔH) Drop in water level, (inches):	I = (ΔH/(T/60)) Infiltration rate (inches per hour):	Remarks:
0:40	0	40	0.67	0.67	0.67	2.3	2.3	207	
0:32	0	32	0.53	0.53	1.20	2.3	2.3	259	
0:29	0	29	0.48	0.48	1.68	2.3	2.3	286	

Stabilized Infiltration Testing Rate (inches per hour): 233

* Used 5 gallons of water - converted to cubic feet and divided by Area of box (21" x 24") to determine depth of water

TETRA TECH

ALTERNATE TEST METHOD: 2' x 2' Wooden Box - NCSU SIT Post-Cleaning

Date: 12/5/2017

Location: Artesian - Location no 1 Between Dover Ave. and Cathedral St.

Technician: Tiffany Neubig and Natalie Trotter

Method: 2' x 2' Wooden Box -21" x 24" inside dimensions

Test Pit #: Location No. 1 - Porous Asphalt

Liquid Used: Water **PH**

Depth of Water Table

Ground Temp at Depth ft

Infiltration Testing

Time: (T) (Minutes):	Min	Sec	Time Min + (Sec/60)	(T) Time Interval (Minutes):		Measurement, (inches):	(ΔH) Drop in water level, (inches):	I = (ΔH/(T/60)) Infiltration rate (inches per hour):	Remarks:
0:50.02	0	50	0.83	0.83	0.83	2.3	2.3	166	
0:56.16	0	56	0.93	0.93	1.77	2.3	2.3	148	
0:56.17	0	56	0.93	0.93	2.70	2.3	2.3	148	

Stabilized Infiltration Testing Rate (inches per hour): 154

* Used 5 gallons of water - converted to cubic feet and divided by Area of box (21" x 24") to determine depth of water