University Transportation Research Center - Region 2

Final Report

Long-term Infiltration Capacity of Different Types of Permeable Pavements

Performing Organization: Manhattan College

August 2017

Sponsor:
University Transportation Research Center - Region 2

University Transportation Research Center - Region 2

The Region 2 University Transportation Research Center (UTRC) is one of ten original University Transportation Centers established in 1987 by the U.S. Congress. These Centers were established with the recognition that transportation plays a key role in the nation's economy and the quality of life of its citizens. University faculty members provide a critical link in resolving our national and regional transportation problems while training the professionals who address our transportation systems and their customers on a daily basis.

The UTRC was established in order to support research, education and the transfer of technology in the field of transportation. The theme of the Center is "Planning and Managing Regional Transportation Systems in a Changing World." Presently, under the direction of Dr. Camille Kamga, the UTRC represents USDOT Region II, including New York, New Jersey, Puerto Rico and the U.S. Virgin Islands. Functioning as a consortium of twelve major Universities throughout the region, UTRC is located at the CUNY Institute for Transportation Systems at The City College of New York, the lead institution of the consortium. The Center, through its consortium, an Agency-Industry Council and its Director and Staff, supports research, education, and technology transfer under its theme. UTRC’s three main goals are:

Research

The research program objectives are (1) to develop a theme based transportation research program that is responsive to the needs of regional transportation organizations and stakeholders, and (2) to conduct that program in cooperation with the partners. The program includes both studies that are identified with research partners of projects targeted to the theme, and targeted, short-term projects. The program develops competitive proposals, which are evaluated to insure the mostresponsive UTRC team conducts the work. The research program is responsive to the UTRC theme: “Planning and Managing Regional Transportation Systems in a Changing World.” The complex transportation system of transit and infrastructure, and the rapidly changing environment impacts the nation’s largest city and metropolitan area. The New York/New Jersey Metropolitan has over 19 million people, 600,000 businesses and 9 million workers. The Region’s intermodal and multimodal systems must serve all customers and stakeholders within the region and globally.Under the current grant, the new research projects and the ongoing research projects concentrate the program efforts on the categories of Transportation Systems Performance and Information Infrastructure to provide needed services to the New Jersey Department of Transportation, New York City Department of Transportation, New York Metropolitan Transportation Council , New York State Department of Transportation, and the New York State Energy and Research Development Authorityand others, all while enhancing the center’s theme.

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16. Abstract

Permeable pavements such as porous asphalt, pervious concrete and permeable interlocking concrete pavers are relatively novel alternatives to conventional pavement that allow rain and snowmelt to infiltrate, thereby reducing runoff, flooding and nonpoint source pollution. A barrier to wider adoption of these runoff-reducing alternative pavements is uncertainty over their long-term performance. Infiltration capacity (IC) can decrease over time if pores in permeable pavement become clogged with particles. Indeed, several studies have found rapid reduction in infiltration from clogging [2-4], but other studied sites have maintained high IC for multiple years [2, 5-8]. The purpose of this project was to measure IC on three different types of permeable pavement: porous asphalt (PA), pervious concrete (PC) and permeable interlocking concrete pavers (PICP). Combined with previous results [1], the results from this project provide further understanding of how IC changes over time in different types of permeable pavements.

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Long-term infiltration capacity of different types of permeable pavements

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Introduction

Permeable pavements such as porous asphalt, pervious concrete and permeable interlocking concrete pavers are relatively novel alternatives to conventional pavement that allow rain and snowmelt to infiltrate, thereby reducing runoff, flooding and nonpoint source pollution. A barrier to wider adoption of these runoff-reducing alternative pavements is uncertainty over their long-term performance. Infiltration capacity (IC) can decrease over time if pores in permeable pavement become clogged with particles. Indeed, several studies have found rapid reduction in infiltration from clogging [2-4], but other studied sites have maintained high IC for multiple years [2, 5-8]. The purpose of this project was to measure IC on three different types of permeable pavement: porous asphalt (PA), pervious concrete (PC) and permeable interlocking concrete pavers (PICP). Combined with previous results [1], the results from this project provide further understanding of how IC changes over time in different types of permeable pavements.

Site Description

The project was conducted on a 0.4-ha parking lot at the United States Environmental Protection Agency (USEPA) Edison Environmental Center (EEC) in Edison, NJ. The parking lot was constructed in 2009 for the purpose of assessing the performance of different types of permeable pavements. As seen in Figure 1, the lot was surfaced with three different types of permeable pavements: permeable interlocking concrete pavers (PICP), pervious concrete (PC and PC-N), and porous asphalt (PA). The construction and characteristics of the parking lot are described in detail by Borst et al. [9] and Brown and Borst [1]. In the parking lot, each double-parking row (PICP, PC, and PA) measures 494 m^2 while the northernmost single parking row (PC-N) measures 247 m^2 [1]. The driving lanes between the parking rows are surfaced with conventional hot-mix asphalt. Runoff flows in a north to south due to the 1.6% slope in that direction. As a result, there is an expectation that the northern edge of the permeable pavement rows will experience more and quicker clogging than the middle or southern edge.

IC in the parking lot was measured from 2009 to 2012, with the results published by Brown and Borst in 2014 [1]. In their paper, Brown and Borst indicated maintenance to remove accumulated solids had not been performed, no slope along the east-west direction, and more runoff delivered to the westernmost parking spaces as indicated in Figure 1. Toward the end of the present study in May 2016, the PC, which was degrading over time, was replaced by a currently available PICP product (referred to as PICP_NEW in this report). The space between the interlocking concrete pavers was reduced compared to the existing old PICP (no-longer commercially available) to comply with the Americans with Disability Act.

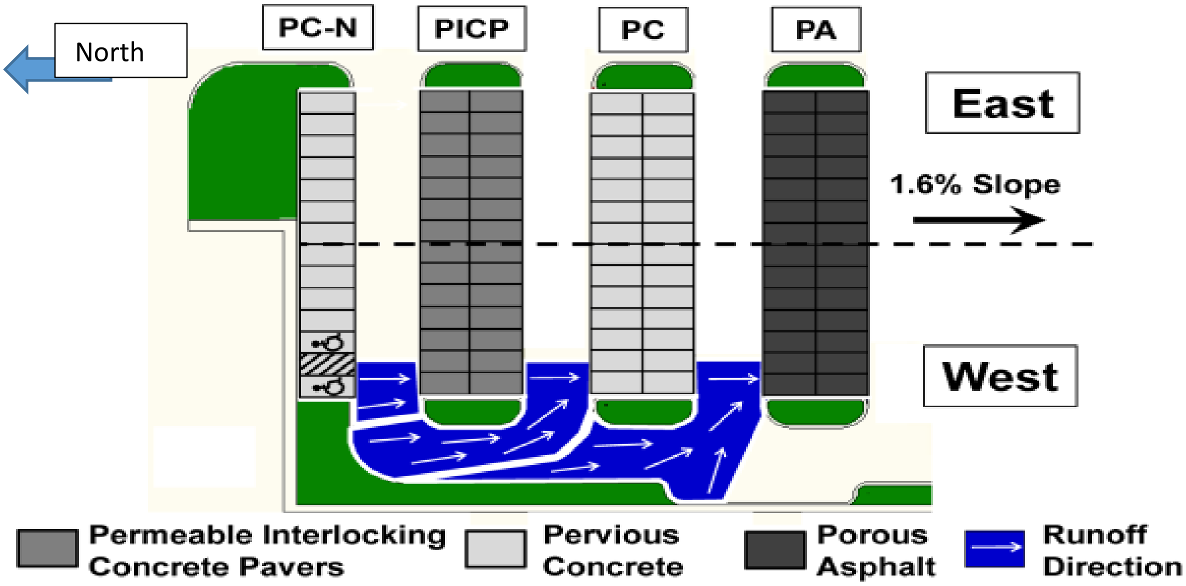

Figure 1: Parking lot's plan view depicting permeable pavement types: the north pervious concrete (PC-N), permeable interlocking concrete pavers (PICP), pervious concrete (PC) and porous asphalt (PA). New PICP (PICP_NEW) replaced the PC and PC-N in 2016. Adapted from Brown and Borst [2014].

Materials and Methods

Regular measurements of IC were restarted in late October 2014 after a two-year gap with the goal of testing all locations in each pavement type (see Figure 3) and continued through August 2016. The present study followed Brown and Borst's methods for monitoring IC in these pavements: a modified version of ASTM C1701 [10], which applies to measurement of IC of pervious concrete, for all three types of pavements. Briefly, the apparatus used was a 0.15 m (6 in) long section of 0.302 m (11.875 in) diameter PVC hollow cylinder (Figure 2), which was placed on the pavement. This cylinder was placed on a 12.7 mm (0.5-in) thick ring of Neoprene to form a seal with the pavement. To minimize leakage, the PVC pipe was pressed tightly against the pavement by applying weight at the corners of a wooden panel fitted with two fastening belts running over the top of the PVC cylinder. Additional strips of Neoprene were placed in the gap between individual pavers under the PVC cylinder when testing the PICP pavement.

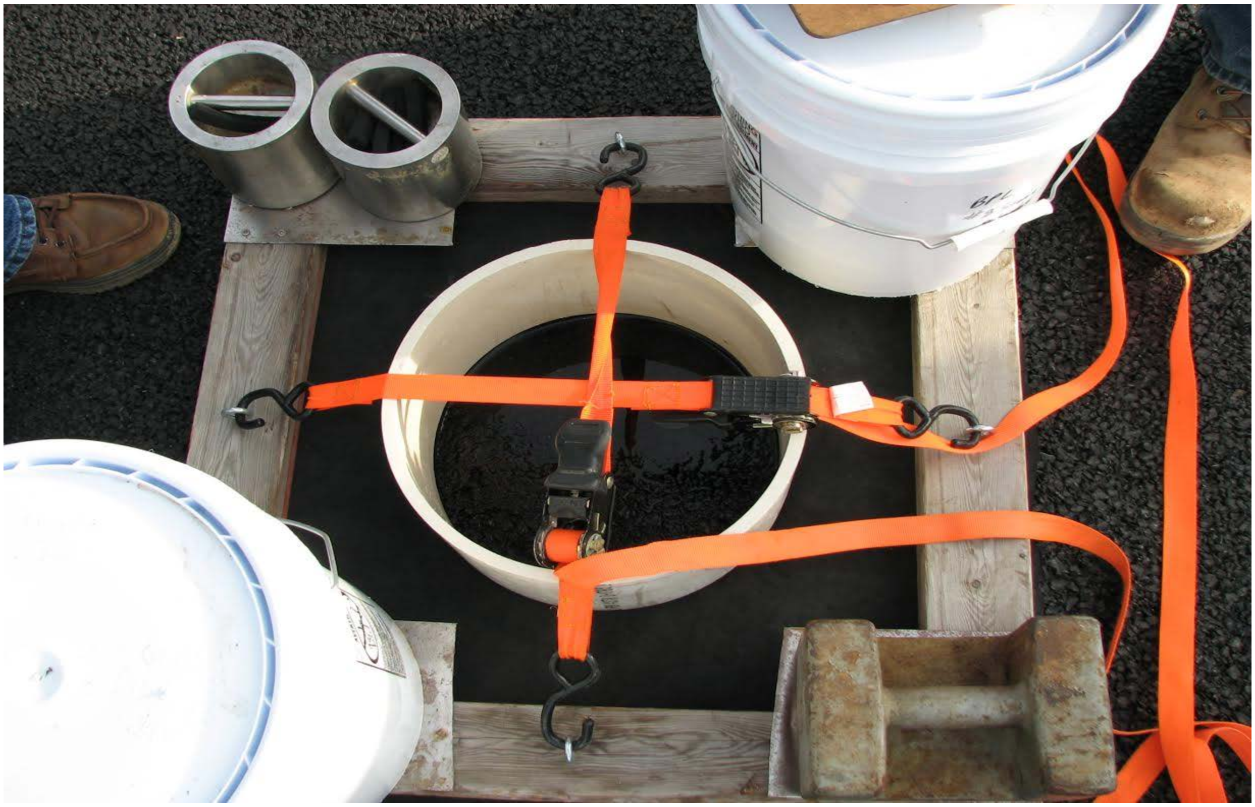

Figure 2: Study apparatus showing the PVC pipe and Neoprene compressed with applied weights to minimize leakage. Photo provided by Thomas O'Connor of USEPA.

After positioning the PVC cylinder at a test spot for infiltration rate measurement, a pre-wet test was first performed. A bucket was filled with 3.6 kg of water. Water was poured from the bucket into the cylinder, maintaining the water level between 10.0 and 15.0 mm (0.4 and 0.6 in) above the pavement surface, over a maximum pre-wet test time of 30 minutes. If the entire 3.6 kg of water (equivalent to 50 mm or 2 in. depth) was applied, the time from when the water first impacted the permeable pavement surface to when water was no longer visible on the surface was measured with a stopwatch and recorded as the "pre-wet time". If the test lasted the entire 30 minutes without infiltrating the entire 3.6 kg (which infrequently), the mass of water that infiltrated during the 30 minutes was computed by subtracting the mass of water remaining in the cylinder and in the bucket from 3.6 kg.

If the pre-wet time was less than 30 minutes, IC was measured in a separate test, following the same procedure as the pre-wet test, except when the measured pre-wet time was less than 30 seconds, in which case 18.0 kg of water (equivalent to 250 mm or 10 in.) was used to conduct the infiltration measurement instead of 3.6 kg.

Carboys with 18.0 ± 0.05 and 3.6 ± 0.05 kg of water were prepared in the EEC laboratory. Infiltration measurements were performed within 2 minutes of the pre-wet measurement. No testing was to be conducted within 24 h after measurable (0.1 mm) rainfall.

Testing spots were chosen based mostly on accessibility on the day of monitoring since the site is an active parking; access was not controlled and some spaces were occupied by cars. This fact made it impossible to adopt Brown and Borst's method for selecting monitoring locations, which consisted of a random selection of three test locations on the eastern and western half of each pavement to be tested monthly and a selection of fixed sites to be tested quarterly. For this study, test locations were set along transects from the driving lanes towards the parking stalls to provide a gradient in distance from the source of runoff and clogging materials. Test locations along a transect were separated by at least 1 m (39 in) to avoid interference among the locations. Each pavement type was tested at 21 or more locations. In most cases, there were at least two parking spaces between adjacent transects to minimize the effect of water interference.

Figure 3 shows the test locations along with the number of tests at each location. Most locations were only tested once. As such, it was not possible to assess trends at individual locations. Figure 3 also shows the number of infiltration rate tests performed on each pavement type. These ranged from 21 for PA to 39 for PICP. The figure does not include tests on the PICP_NEW that replaced the PC in 2016; 25 measurements were taken on the PICP_NEW.

In addition, the testing spots were divided into edge locations and interior locations (triangles and circles on Figure 3, respectively) to assess whether spots on the edge had lower infiltration capacities presumably from clogging. The edge spots are the nearest to the driving lane on the north side of each pavement type while all remaining spots are considered interior testing locations.

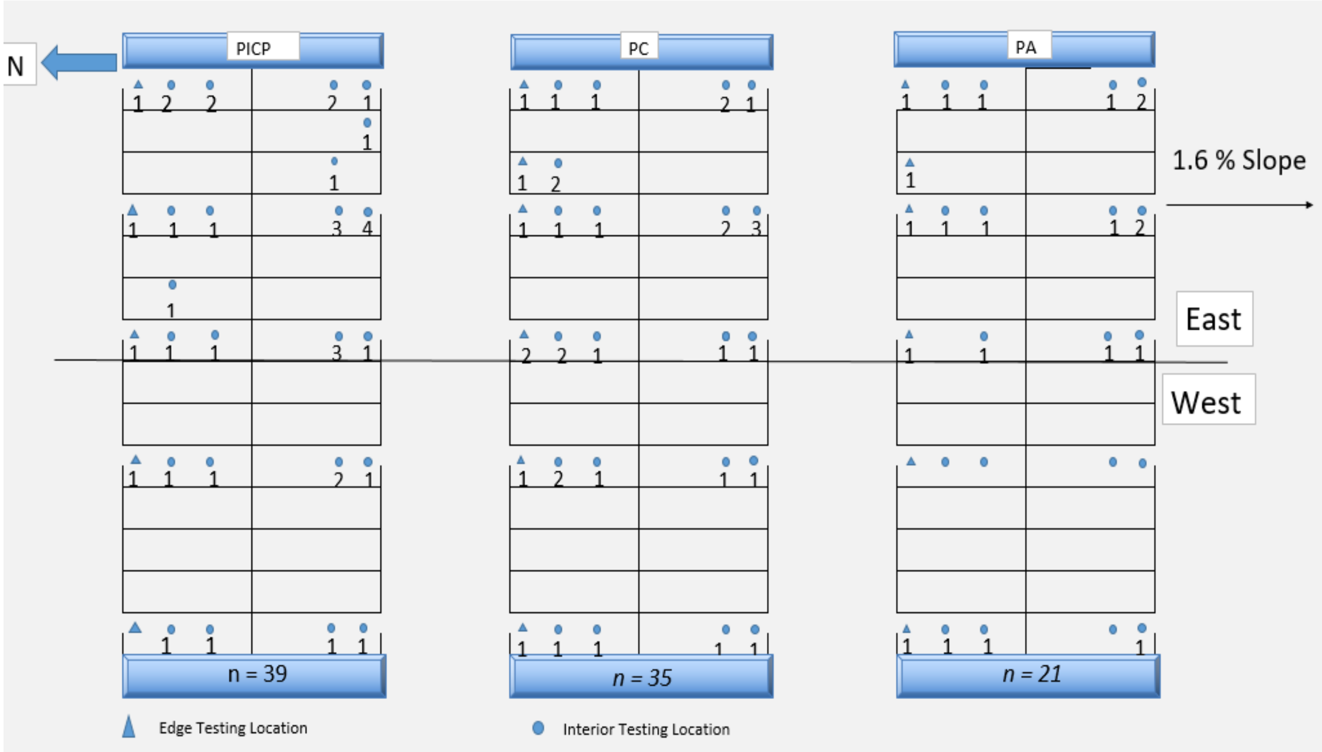

Figure 3: Testing locations with number of infiltration rate tests performed and the total number performed (n) for PICP (n=39), PC (n=35), and PA (n=21). For PICP_NEW (not shown), n = 25.

The infiltration rate (depth of water infiltration per unit time) was calculated using ASTM standard test method for infiltration rate as:

$$I\,(\frac{mm}{h}) = \frac{M}{\rho * t * 0.25\,\pi D^2}\frac{kg}{(kg/m^3)\cdot s\cdot m^2} * 3600\,\frac{s}{h} * 10^9\ \frac{mm^3}{m^3} = 4.586 * 10^9(\frac{M}{t * D^2}) \qquad [10]$$

Where:

I = infiltration rate (mm/h)
M = mass of water (kg) infiltrated
ρ = density of water (taken as 1000 kg/m^3 since its variation with temperature is less than 0.05% from 0 to 30 ^{0}C)
D = inside diameter of the PVC cylinder (mm)
t = measured drain time (s).

The infiltration **capacity** is the maximum rate at which water can infiltrate through a surface, unlimited by the supply of water. Since the surface remained ponded during the tests, the IC is equal to the measured infiltration rate.

Statistical Methods

During a period of almost two years, 129 infiltration tests were conducted: 36 PC, 39 PICP, 25 PICP_New and 29 PA. Seven PA data points were rejected because of excessive leakage due to faulty equipment preparation. One PA data point and one PC data point were discarded as outliers because their reported pre-wet times were much less than the pre-wet times of other tests for the corresponding pavement type, suggesting leakage. Consequently, 120 data points (35 PC, 21 PA, 39 PICP and 25 PICP_NEW) were used in the statistical analysis.

Three separate hypotheses were tested on the infiltration capacity results:

1. Average infiltration capacities varied by pavement type.
2. Average infiltration capacities for the edge testing locations were less than the average of the interior testing locations.
3. Average infiltration capacity of each pavement type decreased with time.

The second and third hypothesis were not tested on the new PICP since it was installed in 2016; there was only one round of infiltration testing done on it.

The hypothesis were tested using statistical tests implemented by an add-in to Excel 2016 named *Real Statistics Using Excel* (real-statistics.com) with the standard significance level (α) of 0.05.

The standard and pre-wet infiltration rate data sets were first tested for normality using the Shapiro-Wilk Test. For the standard tests, PC's data ($p = 0.089$) did fit a normal distribution while the infiltration data for PA ($p = 4.2E\text{-}06$), PICP ($p = 0.0005$) and PICP_NEW ($p = 0.0005$) were not normally distributed. For the pre-wet test data, PCIP ($p = 0.0004$), and PC ($p = 0.0045$) were not normally distributed while PA ($p = 0.0548$) and PICP_NEW ($p = 0.486$) were normally distributed. Since some data sets were not normally distributed, the non-parametric Kruskal–Wallis (KW) test was used to determine if a "statistically significant" difference (α=0.05) exists between the infiltration capacities of the different pavement types, or between the edge and interior location infiltration capacities. The same statistical test was used when comparing pre-wet and standard infiltration capacities. In addition, as the sample sizes (number of infiltration tests in each pavement type) were unequal, post hoc comparison by pairs of pavement type was conducted using Dunn's Test. A linear regression analysis was performed between time (expressed as number of months since installation of the pavement) and measured IC for each pavement type. A slope for each regression line was determined to provide the rate of change, if any, in IC in cm/hr per month. To evaluate how closely pre-wet and standard infiltration capacities agreed with each other, Spearman rank correlation test was conducted and p-values reported.

Results and Discussion

The result for all infiltration tests are presented in the appendix.

Hypothesis #1: IC by pavement type

The KW test resulted in $p = 4.8E\text{-}12$ indicating that there was a "statistically significant" difference among the mean infiltration capacities of the different pavement types as shown in Table 1. By rank, PC > PICP_NEW > PICP > PA. PA's mean IC was much less than the other pavements. All of the mean ICs are very high relative to the reference threshold for high-IC soils of 0.8 cm/hr (i. e., sandy soils; termed Hydrologic Soil Group A) [13].

Table 1 shows the results from the post hoc analysis using Dunn's test to determine which pairs of pavements showed statistically significant differences (*d-stat > d-crit=2.64*) in the mean IC. PA's mean IC was statistically different from all others. PC's mean IC was statistically different from PICP's but not from PICIP_NEW's mean IC. Although PICP_NEW's mean IC was much greater than PICP's (1,043 vs 649 cm/h), the difference was NOT statistically significant (*d-stat = 2.1*).

Table 1: Mean infiltration capacity for each pavement type, sorted by rank, and pairwise differences in means. Bolded values indicate significant difference (α = 0.05) between pairs based on Dunn's test (d-stat > d-crit=2.64).

Pavement Type	Mean infiltration capacity with 95% confidence interval, cm/h	Number of tests		Pavement Type (Mean Infiltration Capacity)		
			PC	PICP_NEW	PICP	PA
			Difference in mean, (cm/h)			
PC	1,568 ± 385	35	---	+525	**+918**	**+1547**
PICP_NEW	1,043 ± 241	25	-525	---	+396	**+1022**
PICP	649 ± 206	39	**-918**	-396	---	**+628**
PA	21 ± 8	21	**-1547**	**-1022**	**-628**	---

Hypothesis #2: IC of edge testing locations vs interior testing locations

The edge and interior data were analyzed, also with the with non-parametric Kruskal-Wallis test, to determine if there was a statistical difference in mean IC within each pavement type.

There was a significant difference between the interior and edge locations for all three pavement types, with mean IC of the edge locations reduced dramatically by 38% to 86%.

A reduction was expected because edge locations are more susceptible to clogging because they are closer to the source of clogging materials, i.e. the driving lane. The reduction in IC was less dramatic for PA (38%) than for PC (82%) and PICP (86%). This might be because the smooth surface of PA allows runoff (and the load of solids it carries) to travel faster and therefore further into the interior, causing clogging to occur in the interior, whereas clogging is concentrated along the edge in the rougher PC and PCIP.

Table 2: Comparison of mean IC of edge and interior locations for different pavement types, with significance of differences tested by the Kruskal-Wallis test

	Interior		Edge				
Pavement Type	Mean Infiltration Capacity (cm/h)	Number of samples	Mean Infiltration Capacity (cm/h)	Number of samples	Reduction (cm/h)	Percent Reduction	p-value
PC	1823	29	333	6	1489	82%	0.001
PA	16	16	10	5	6	38%	0.046
PICP	730	34	100	5	630	86%	0.0004

Hypothesis #3: IC decline over time

Because there were relatively few edge locations (Table 2) and there was a significant difference between mean IC of edge and interior locations, the analysis of time variance in IC was applied to interior locations only. A linear regression was performed between months since the beginning of monitoring and the mean monthly IC for each of the three pavement types in consideration, as shown in Figures 5-7 with the results summarized in Table 3.

All three pavement types showed a declining trend in IC with time, but the correlation was weak in all cases, with all p-value ≥ 0.15 and all R^2 values ≤ 0.36. Furthermore, none of the pavement types showed consistently decreasing trends, with both increases and decreases occurring from monitoring event to the next.

The slope of the regression line (measured in cm/hr/month) was lowest (by nearly 100x) for PA. This can be partially explained by the fact that the observed IC is much less for PA, so it will naturally change by less. PICP showed the sharpest decline (slope of -54 cm/hr/month), with the regression line headed toward an IC of 0 at ~25 months (Fig. 6), but with a low R^2 value, the regression line is not a reliable predictor.

Table 3: Summary of linear regressions between mean IC for interior locations vs. month, for all pavement types

Pavement Type	Number of tests	Slope, cm/hr/month	R^2	p-value
PC	29	-44.	0.28	0.28
PA	16	-0.2	0.05	0.68
PICP	34	-54.	0.36	0.15

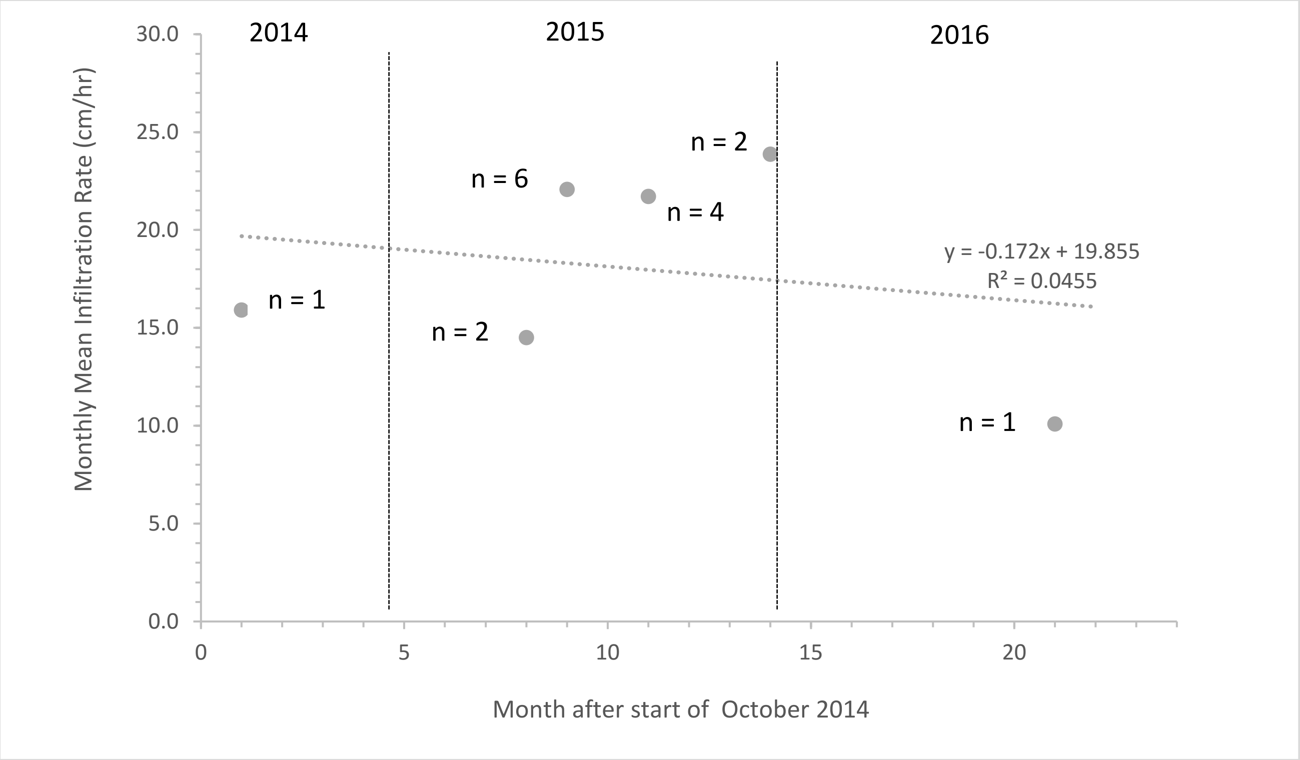

Figure 4: Linear regression of mean monthly infiltration capacity for PA on the interior testing locations with the number of monthly samples (n)

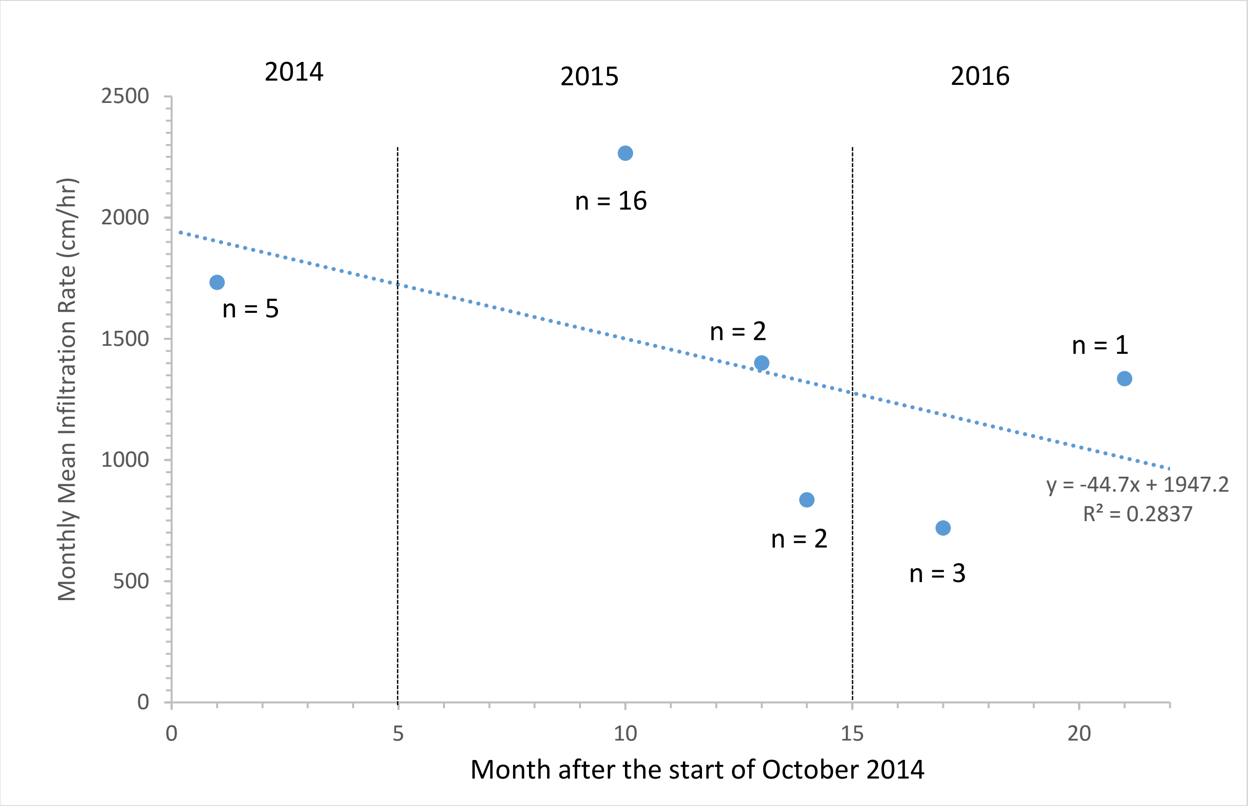

Figure 5: Linear regression of mean monthly infiltration capacity for PC on the interior testing locations with number of monthly samples (n)

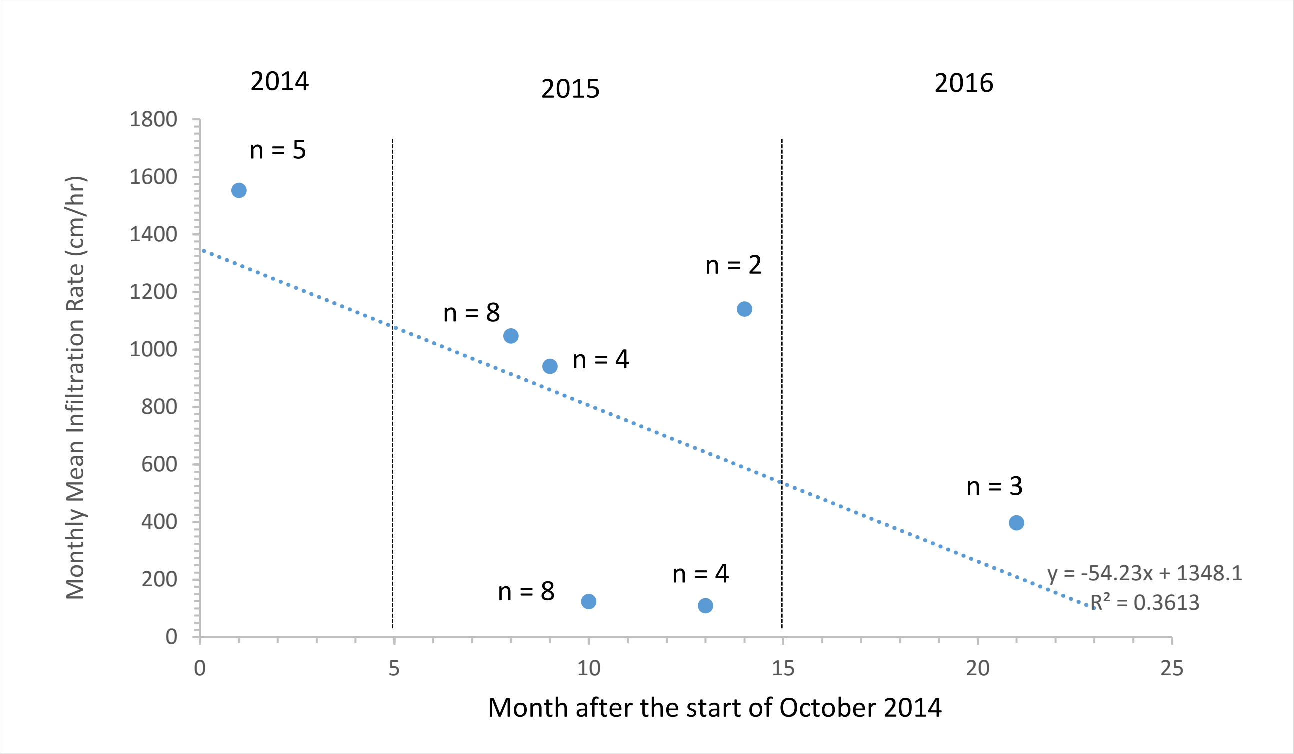

Figure 6: Linear regression of mean monthly infiltration capacity for PICP on the interior testing locations with number of monthly samples (n)

To further assess how IC declined over time, results from the current study were compared with those from Brown and Borst's study in Table 4. IC declined markedly (>67%) for all three pavement types. PA declined the most percentage-wise (86%), which is contrary to what was found during the current study, in which the linear regression for PA predicted only a slight decline (Fig. 4) . The rank order remained the same: PC > PICP > PA.

Table 4: Mean infiltration capacities with 95% confidence interval by pavement type comparing Brown and Borst study (2009-2012) and the present study (2014-2016)

Pavement Type	2009-2012 Mean Infiltration Capacity (cm/h)	2014-2016 Mean Infiltration Capacity (cm/h)	Reduction in Infiltration Capacity (cm/h)	% Reduction In Infiltration Capacity
PC	4,799 ± 250 (n=162)	1,568 ± 385 (n=35)	3,231	67 %
PICP	2,074 ± 90 (n=162)	649 ± 206 (n=39)	1,425	69 %
PA	145 ± 28 (n=162)	21 ± 8 (n=21)	124	86 %

Conclusion

Seven years after initial testing, mean IC remain very high for PC and PICP (>1000 cm/h). Mean IC was much less for PA (21 cm/h) but still much greater than the soil type with highest IC. IC has declined significantly over this time, likely due to clogging. This explanation is supported by the fact that IC of interior locations was much greater (≥68%) than that of edge locations, which are more susceptible to clogging. Linear regression was not a reliable predictor of the rate of decline in IC. PA, in addition to having lowest IC, had the largest percentage decline in IC (86% comparing 2009-2012 to 2014-2016), suggesting it is more vulnerable to clogging from solids in run-off.

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Appendix

I. Infiltration rate calculation

The infiltration rate was calculated using:

$$I = 4.586 * 10^6 \frac{M}{t * D^2} \left(\frac{cm}{hr}\right) \qquad [10]$$

1. For pre-wet infiltration rate, M is 3.6 kg and t is the pre-wet time (second)
2. For standard infiltration rate:
- M is 18.0 kg if pre-wet time is less than 30 seconds
- M is 3.6 kg if pre-wet time is more than 30 seconds
- t is standard time
3. D = 11.875 in = 30.16 cm

Notes:

- underlined values represent edge testing locations
- Strikethrough values are the rejected values due reported excess leakage or outliers
- The parking spot for each is presented in the next appendix (Testing locations)

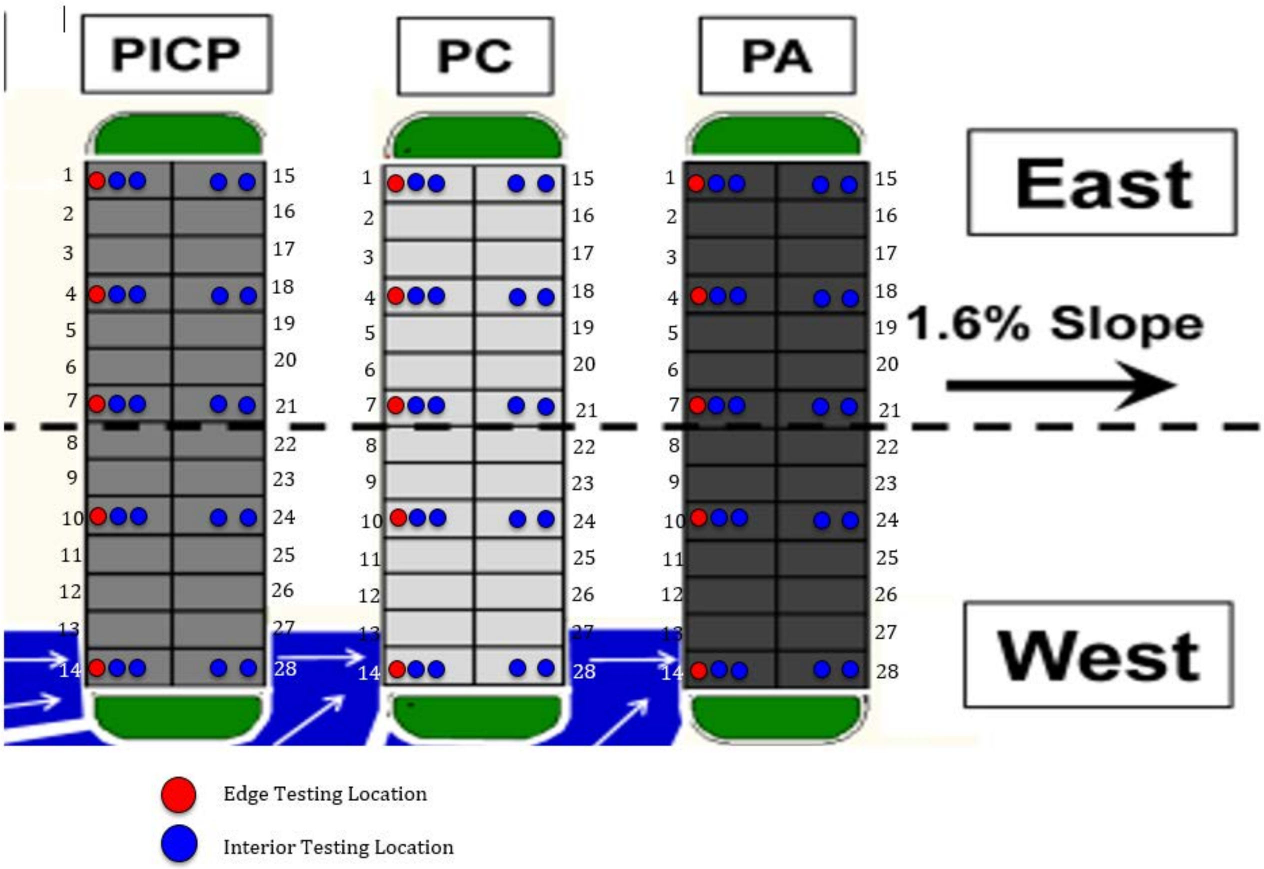
Date	Pavement type	Parking spot #	Pre -wet time (s)	Pre-wet infiltration rate (cm/hr)	Standard time (s)	Standard infiltration rate cm/hr
10/29/2014	PICP	2	10.29	1764.48	46.44	1954.22
10/29/2014	PICP	16	10.57	1717.74	56.50	1606.27
10/29/2014	PICP	17	11.5	1578.83	53.54	1695.07
10/29/2014	PICP	4	10.19	1781.80	42.30	2145.49
10/29/2014	PICP	6	31.84	570.24	41.00	442.84
10/29/2014	PICP	13	261.04	69.55	50.00	363.13
10/29/2014	PC	10	7.26	2500.90	42.51	2134.89
10/29/2014	PC	3	184.97	98.16	960.00	18.91
10/29/2014	PC	3	6.55	2771.99	28.33	3203.46
10/29/2014	PC	3	6.27	2895.78	34.71	2614.64
10/29/2014	PC	2	30.66	592.19	125.01	145.24
10/29/2014	PC	7	34.65	524.00	166.05	109.34
10/29/2014	PC	7	20.03	906.47	151.58	598.72
10/29/2014	PA	3	1401.44	12.96	1800.00	10.09
10/29/2014	PA	3	209.44	86.69	1142.06	15.90
5/26/2015	PICP	15	14.2	1278.63	78.32	1158.76
5/26/2015	PICP	15	29.07	624.58	108.74	834.60
5/26/2015	PICP	15	13.65	1330.15	76.08	1192.88
5/26/2015	PICP	15	11.53	1574.72	62.30	1456.73
5/26/2015	PICP	2	29.96	606.03	112.72	805.13
5/26/2015	PICP	2	15.23	1192.16	76.42	1187.57
5/26/2015	PICP	2	30.21	601.01	101.02	179.73
5/26/2015	PICP	2	10.23	1774.83	57.89	1567.70
5/26/2015	PA	15	124.32	146.05	960.00	18.91
5/26/2015	PA	2	126.74	143.26	1800.00	10.09

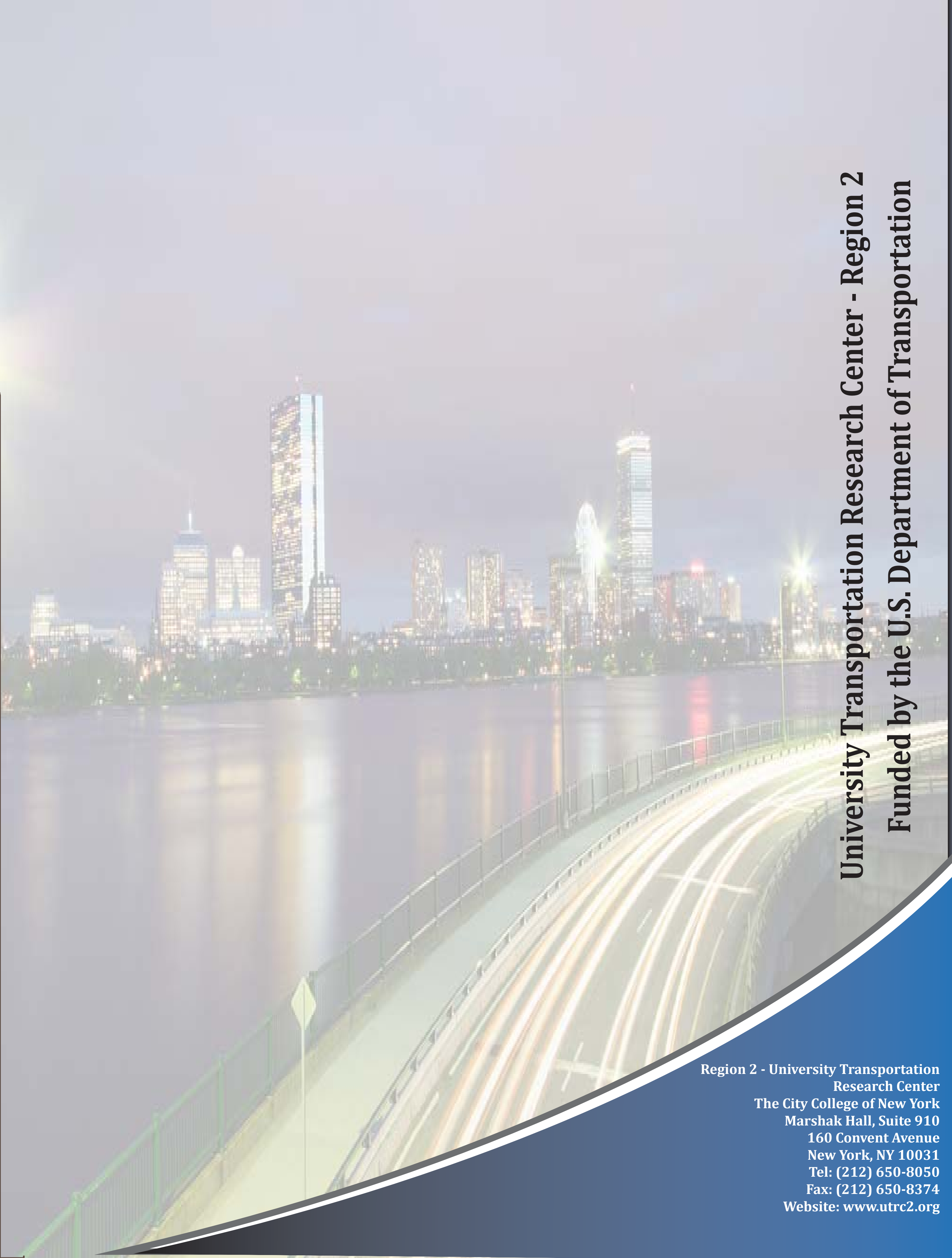
Date	Pavement type	Parking spot #	Pre -wet time (s)	Pre-wet infiltration rate (cm/hr)	Standard time (s)	Standard infiltration rate cm/hr
6/25/2015	PICP	7	46.9	387.13	893.00	20.33
6/25/2015	PICP	7	21	864.60	144.00	630.24
6/25/2015	PICP	7	10	1815.65	63.00	1440.54
6/25/2015	PICP	4	39	465.55	822.00	22.09
6/25/2015	PICP	4	17.69	1026.37	115.00	789.17
6/25/2015	PICP	4	14	1296.90	100.00	907.54
6/25/2015	PA	4	306	59.34	1800.00	10.09
6/25/2015	PA	4	131	138.60	960.00	18.91
6/25/2015	PA	4	202	89.88	960.00	18.91
6/25/2015	PA	18	100	181.57	820.00	22.14
6/25/2015	PA	18	85	213.61	914.00	19.86
~~6/25/2015~~	~~PA~~	~~21~~	~~24~~	~~756.52~~	~~201.00~~	~~451.51~~
6/25/2015	PA	21	58	313.04	555.00	32.71
6/25/2015	PA	7	86	211.12	917.00	19.80
7/24/2015	PICP	24	87	208.70	101.00	179.77
7/24/2015	PICP	24	103	176.28	110.00	165.06
7/24/2015	PICP	10	57	318.54	51.60	351.87
7/24/2015	PICP	10	88	206.32	867.00	20.94
7/24/2015	PICP	10	236	76.93	2732.00	6.65
7/24/2015	PICP	28	147	123.51	336.00	54.04
7/24/2015	PICP	28	75	242.09	91.00	199.52
7/24/2015	PICP	14	232	78.26	936.00	19.40
7/24/2015	PICP	14	364	49.88	2700.00	6.72
7/31/2015	PC	1	32	567.39	249.00	72.92
7/31/2015	PC	1	10	1815.65	46.00	1972.92
7/31/2015	PC	1	9	2017.39	44.00	2062.59
7/31/2015	PC	15	5	3631.31	30.00	3025.14
7/31/2015	PC	15	5	3631.31	28.00	3241.22
7/31/2015	PC	18	5	3631.31	23.00	3945.83
7/31/2015	PC	18	7	2593.79	38.00	2388.27
7/31/2015	PC	4	7	2593.79	38.00	2388.27
7/31/2015	PC	4	5	3631.31	28.00	3241.22
7/31/2015	PC	4	50	363.13	290.00	62.61
~~7/31/2015~~	~~PC~~	~~7~~	~~60~~	~~302.61~~	~~1360.00~~	~~13.35~~
7/31/2015	PC	7	15	1210.44	92.00	986.46
7/31/2015	PC	7	13	1396.66	82.00	1106.76
7/31/2015	PC	21	8	2269.57	48.00	1890.71
7/31/2015	PC	21	12	1513.04	59.00	1538.21
7/31/2015	PC	24	5	3631.31	33.00	2750.12
7/31/2015	PC	24	6	3026.09	39.00	2327.03
7/31/2015	PC	10	11	1650.59	61.00	1487.77
7/31/2015	PC	10	11	1650.59	48.00	1890.71
7/31/2015	PC	10	18	1008.70	100.00	907.54

Date	Pavement type	Parking spot #	Pre -wet time (s)	Pre-wet infiltration rate (cm/hr)	Standard time (s)	Standard infiltration rate cm/hr
8/21/2015	PA	14	1800	10.09	1800.00	10.09
8/21/2015	PA	14	1658	10.95	1800.00	10.09
8/21/2015	PA	14	1965	9.24	1800.00	10.09
8/21/2015	PA	15	66	275.10	383.00	47.41
8/21/2015	PA	15	121	150.05	943.00	19.25
10/20/2015	PICP	21	51	356.01	90.00	201.74
10/20/2015	PICP	21	53	342.58	109.00	166.57
10/20/2015	PICP	1	82	221.42	374.00	48.55
10/20/2015	PICP	1	409	44.39	785.00	23.13
10/20/2015	PICP	1	354	51.29	1800.00	10.09
10/20/2015	PC	28	62	292.85	140.00	129.69
10/20/2015	PC	28	17	1068.03	34.00	2669.24
11/10/2015	PICP	18	14.6	1243.60	69.00	1315.28
11/10/2015	PICP	18	16	1134.78	94.00	965.47
11/10/2015	PC	14	19.4	935.90	62.00	1463.78
11/10/2015	PC	14	29	626.09	439.00	206.73
11/10/2015	PC	14	20.9	868.73	114.00	796.09
11/10/2015	PA	1	114	159.27	663.00	27.39
11/10/2015	PA	1	187	97.09	892.00	20.35
~~2/24/2016~~	~~PA~~	~~1~~	~~41~~	~~442.84~~	~~92.00~~	~~197.35~~
~~2/24/2016~~	~~PA~~	~~1~~	~~35~~	~~518.76~~	~~127.00~~	~~142.96~~
~~2/24/2016~~	~~PA~~	~~1~~	~~37~~	~~490.72~~	~~254.00~~	~~71.48~~
2/24/2016	PC	15	23	789.41	87.00	1043.15
2/24/2016	PC	15	52	349.16	68.00	267.01
2/24/2016	PC	1	27	672.46	107.00	848.17
6/9/2016	PA	1	850	21.36	2149.00	8.45
6/9/2016	PICP	15	97	187.18	108.00	168.12
6/9/2016	PICP	18	44.67	406.46	48.20	376.69
6/9/2016	PICP	21	31	585.69	28.00	648.45
6/9/2016	PC	24	19	955.61	68.00	1334.62
6/9/2016	PA	28	1800	10.09	1800.00	10.09
8/8/2016	PICP - New	28	41.68	435.62	34.19	531.05
8/8/2016	PICP - New	28	31.43	577.68	63.40	286.38
8/8/2016	PICP - New	14	41.4	438.56	36.90	492.05
8/8/2016	PICP - New	14	36.99	490.85	39.14	463.89
8/8/2016	PICP - New	14	37.67	481.99	34.48	526.58
8/8/2016	PICP - New	10	30.98	586.07	28.42	638.86

Date	Pavement type	Parking spot #	Pre -wet time (s)	Pre-wet infiltration rate (cm/hr)	Standard time (s)	Standard infiltration rate cm/hr
8/8/2016	PICP - New	10	30.42	596.86	28.92	627.82
8/8/2016	PICP - New	10	32.5	558.66	36.97	491.12
~~8/8/2016~~	~~PA~~	~~24~~	~~150~~	~~121.04~~	~~152.00~~	~~119.45~~
~~8/8/2016~~	~~PA~~	~~24~~	~~50~~	~~363.13~~	~~60.08~~	~~302.21~~
~~8/8/2016~~	~~PA~~	~~21~~	~~66~~	~~275.10~~	~~116.20~~	~~156.25~~
~~8/8/2016~~	~~PA~~	~~21~~	~~45~~	~~403.48~~	~~53.40~~	~~340.01~~
8/8/2016	PA	7	915	19.84	1200.00	15.13
8/24/2016	PICP - New	1	24.6	738.07	53.30	1702.70
8/24/2016	PICP - New	1	38.3	474.06	32.00	567.39
8/24/2016	PICP - New	1	34.3	529.35	26.50	685.15
8/24/2016	PICP - New	15	30.5	595.30	27.90	650.77
8/24/2016	PICP - New	15	30.6	593.35	29.70	611.33
8/24/2016	PICP - New	18	28.3	641.57	51.50	1762.22
8/24/2016	PICP - New	18	35.1	517.28	31.50	576.40
8/24/2016	PICP - New	4	32.5	558.66	29.80	609.28
8/24/2016	PICP - New	4	27.5	660.24	61.20	1482.91
8/24/2016	PICP - New	4	27.4	662.65	72.10	1258.73
8/24/2016	PICP - New	7	25.6	709.24	50.90	1782.99
8/24/2016	PICP - New	7	28.6	634.84	63.20	1435.98
8/24/2016	PICP - New	7	25.6	709.24	46.30	1960.13
8/24/2016	PICP - New	21	23.9	759.69	51.30	1769.09
8/24/2016	PICP - New	21	23.3	779.25	48.10	1886.78
8/24/2016	PICP - New	24	22.7	799.85	57.90	1567.43
8/24/2016	PICP - New	24	19.4	935.90	53.40	1699.52

II. Testing Locations





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