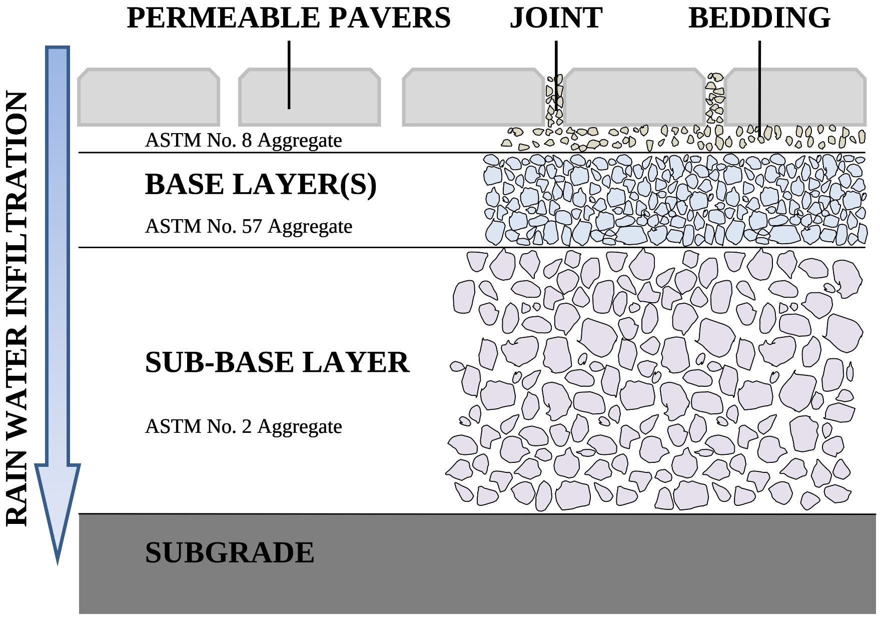
Permeability Testing
Interlocking Concrete Block Pavement



For
Barkman Concrete Ltd.
152 Brandt Street
Steinbach, Manitoba R0A 2A0

By

APPLIED RESEARCH ASSOCIATES, INC.

UNIVERSITY OF MANITOBA

5401 Eglinton Avenue West, Suite 105
Toronto, Ontario M9C 5K6
Tel: (416) 621-9555   Facsimile: (416) 621-4917
Web: www.ara.com\transportation

Table of Contents

BACKGROUND

Barkman Concrete Ltd. (Barkman) retained Applied Research Associates, Inc. (ARA) to develop a testing protocol and complete permeability testing for a new Barkman permeable paver product. As Barkman has a manufacturing facility in the Winnipeg, Manitoba area, ARA teamed with the Pavement Research Group at the University of Manitoba to complete the laboratory testing locally. This report documents the construction, testing procedure and results of the permeability testing conducted in April 2009.

PERMEABILITY TEST PROTOCOL

The purpose of the laboratory testing was to determine the permeability of a typical interlocking concrete block pavement structure under a constant head of water. Permeability testing was carried out on a full-scale permeable pavement structure that consisted of interlocking concrete blocks placed over 50 mm of ASTM No. 8 bedding chips, Armtec 200 non-woven geotextile, 100 mm of ASTM No. 57 base and 300 mm of ASTM No. 2 subbase. The joints between the pavement blocks were filled with the ASTM No. 8 bedding chips. The paving stones were set in a herringbone pattern.

After completing initial testing, additional testing was performed after contaminating the joint sand with a fine ‘dust’ material to simulate possible long-term ‘clogging’ of the joints.

TEST PROTOCOL

The permeability testing was carried out in accordance with ASTM D2434-68 (2006), Standard Test Method for Permeability of Granular Soils (Constant Head), with modifications to accommodate testing a full-scale structure of interlocking concrete block pavement. The modifications included a larger sample size and cross section of the permeameter, revising the process of saturating the base material and the application of a constant water head. To determine permeability of the base and subbase materials, additional manometers were used at the bottom of the base and the bottom of the bedding chip layer in order to better determine the permeability of individual layers.

TEST SETUP CONSTRUCTION AND MATERIALS

Figure 1 shows the permeameter that was designed and constructed by the Pavement Research Group at the University of Manitoba. The dimensions of the permeameter are 850 mm by 850 mm (width to length) by 750 mm (depth) and it consisted of the following:

1. Elevated floor of the test setup (Figure 2) to support the pavement structure equipped with four (50 mm diameter) outlet drains.
2. The screen (Figure 3) was used on top of the elevated floor and designed to support and retain the granular materials while passing infiltrated water through the

permeameter. The screen was constructed of a perforated plywood sheet grooved two directions with holes drilled at the intersecting points of the grooves.

3. Plywood sidewalls with the joints between sidewalls and between sidewalls and the base of the permeameter sealed with silicone and tested for water leakage;
4. A 550 litre capacity water tank. It was found that using the tank for charging the system reduced the intake of air and to prevent temperature fluctuations during the test. The tank was placed at an elevated platform to supply the water without the need for a pump;
5. Inlet (Figure 4), including a fabric screen to slow and remove air from the water and prevent scouring of the joint material;
6. Overflow outlet (Figure 5), with an adjustable gate to control the water level in the permeameter to ensure a constant head over the pavement structure;
7. Two drain valves (Figure 6), connected to the drain outlets at the bottom of the permeameter. The drain values were used to ensure saturation of the pavement structure and to discharge water during the test;
8. A scaled container to measure the discharging water over a specific period of time; and
9. Manometers to monitor the water head at bottom of the pavement structure, at bottom of the base and at the bottom of the bedding chip layer.

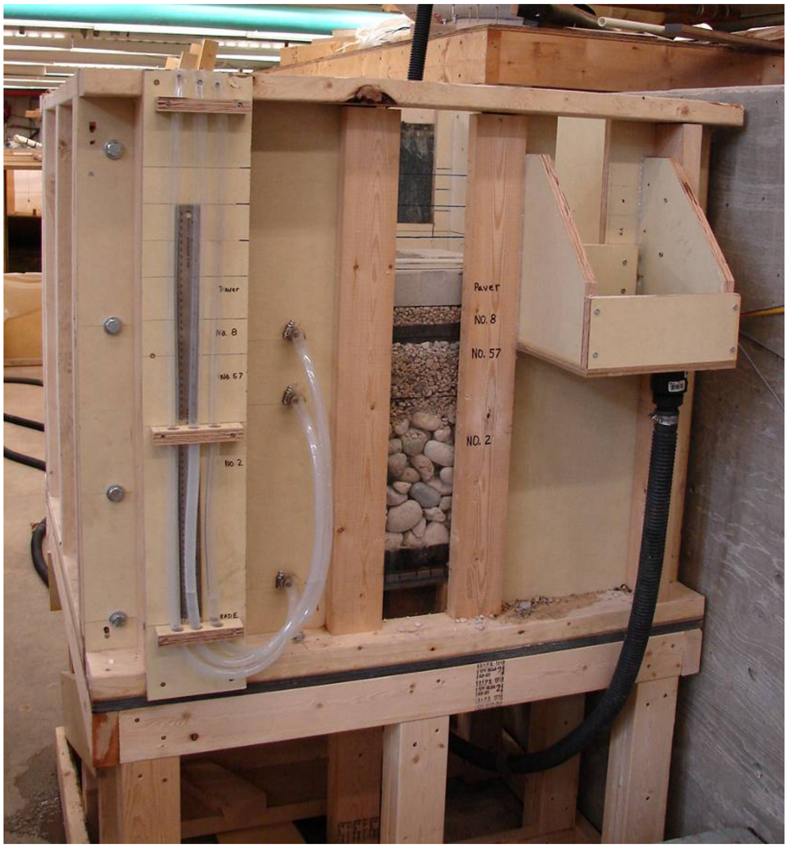


Figure 1. Permeameter setup

Figure 2. Elevated floor of the setup

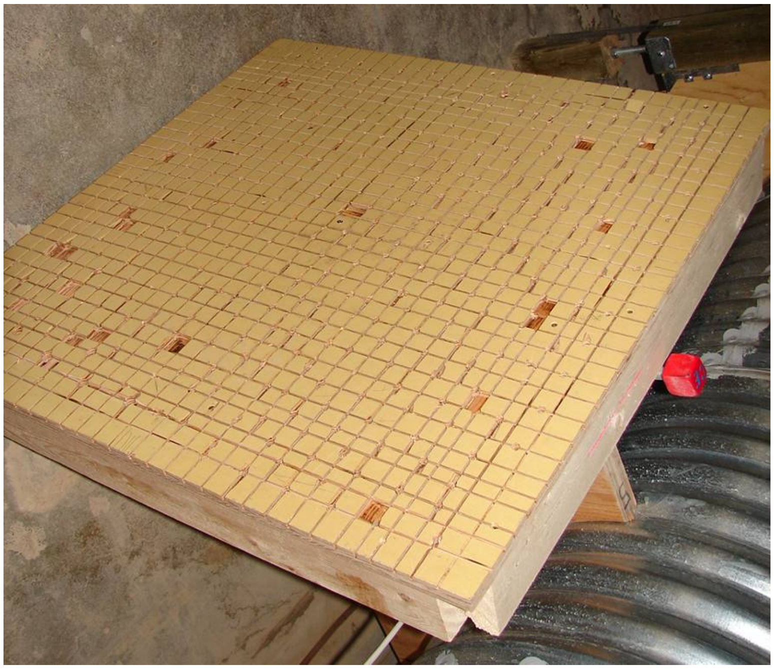


Figure 3. Plywood screen

Figure 4. Water inlet

Figure 5. Overflow to ensure constant head of water

Figure 6. Drain valves

The pavement structure was constructed inside the permeameter as follows:

1. Armtec 200 non-woven geotextile fabric was placed on the plywood screen;
2. A 300 mm layer of granular subbase conforming to the gradation requirements of ASTM No. 2 was compacted in two layers;
3. A 100 mm layer of granular base conforming to the gradation requirements of ASTM No. 57 was placed and compacted in one layer;
4. Armtec 200 geotextile fabric was placed on top of the base;
5. A 50 mm layer of bedding chips conforming to the gradation requirements of ASTM No. 8 were placed, leveled with a straight edge and compacted;
6. Paving stones were placed in a herringbone pattern, as shown in Figure 7; and
7. The paving stone joints were filled with joint material (bedding chips), as shown in Figure 8.

Given the small area of the pavement, all of the granular materials were compacted manually using a tamping tool. The ASTM gradation specifications for the granular materials are given in Table 1.

SATURATING THE PAVEMENT STRUCTURE

The pavement structure was saturated from the bottom up, through the drain valves, to aid in the release of air bubbles from the system prior to testing (Figure 9). Water from the tank was supplied slowly from the outlet at the bottom of the permeameter to minimize disturbances to the structure. Saturation was complete when the water reached the overflow outlet and the drain valves were then closed. The entire system was then checked for leaks before the testing proceeded.

Table 1. Gradation specifications for subbase, base and bedding chips

Sieve size		Amount finer than each laboratory sieve, Mass percent		
(mm)	(in)	Subbase material (ASTM No. 2)	Base material (ASTM No. 57)	Bedding chips (ASTM No. 8)
75	3	100	---	---
63	2.5	90 to 100	---	---
50	2	35 to 70	---	---
37.5	1.5	0 to 15	100	---
25	1	---	95 to 100	---
19	0.75	0 to 5	---	---
12.5	0.5	---	25 to 60	100
9.5	0.375	---	---	85 to 100
4.75	No. 4	---	0 to 10	10 to 30
2.36	No. 8	---	0 to 5	0 to 10
1.18	No. 16	---	---	0 to 5

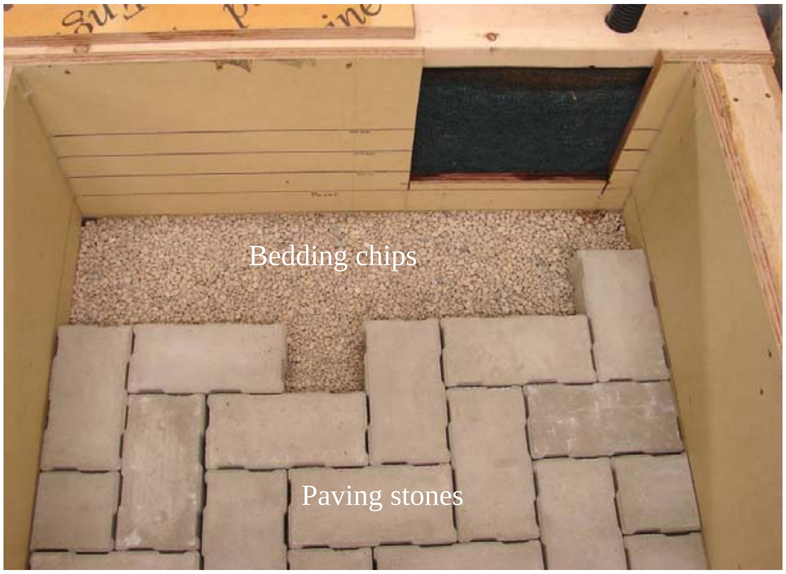


Figure 7. Herringbone paving block pattern

Figure 8: Applying joint material

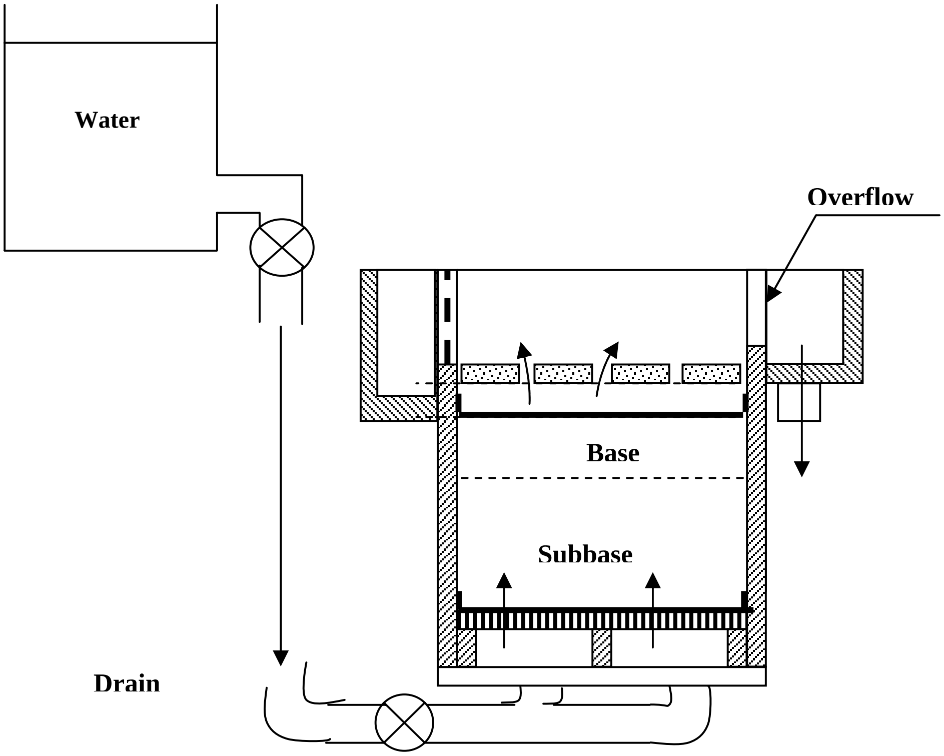


Figure 9. Initial saturation of the pavement structure

TEST PROCEDURE

Two series of duplicate tests were completed for each test setup. The first series of two tests was completed using the as-built pavement structure in the permeameter as described above. For the second test series, fine dust material (passing 850 µm (No. 20) sieve size) was swept into the joints to simulate “contamination” of the joints after a number of years in service. Figure 10 shows the setup and measurement locations. The tests were carried immediately after saturating the pavement structure as follows:

1. The inlet valve was opened and when the water level reached the level of the overflow gate, all the manometer readings were recorded at height position zero (H0). The drain valves were then closed;
2. The outlet valve was slowly opened;
3. The water levels at each measuring location were monitored;
4. Measurements did not commence until the levels in the manometers were stable;
5. The quantity of water (Q) that was collected during time (t) and the manometer readings were recorded (H1, H2 and H3); and
6. The process was repeated after contaminating the joints with dust (Figure 11).

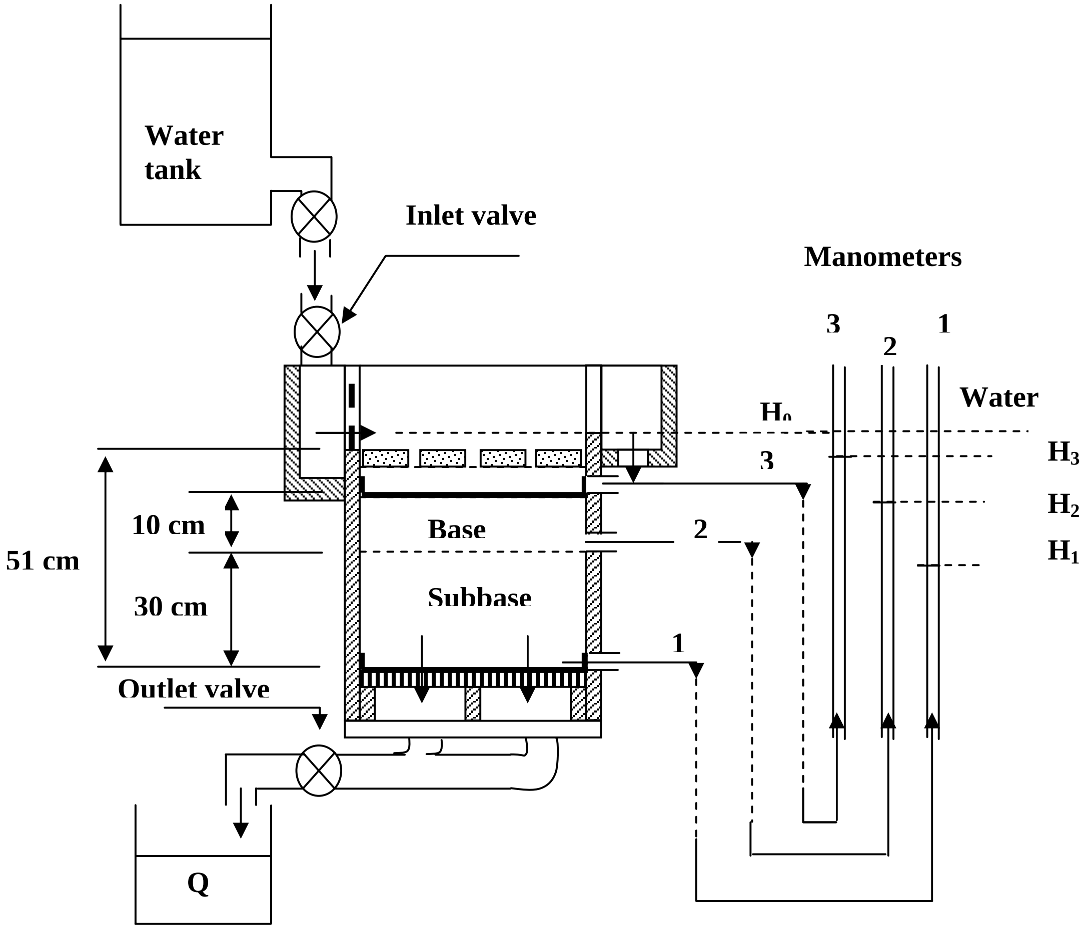


Figure 10. Permeability test measurements

a) Brushing out top 4 to 6 mm of joint sand

b) Placing fine material (passing 850 µm (No. 20) sieve size)

c) Adding water to soak fine material into the joints

Figure 11. Process of contaminating the joint sand

PERMEABILITY TEST MEASUREMENTS AND RESULTS

The coefficient of permeability, k, for each layer was calculated as follows:

$$k=\frac{QL}{Ath}$$

where:

Q = water discharge (cm^3),
L = depth of the pavement structure (51 cm), thickness of subbase (30 cm) and thickness of base (10 cm),
A = cross-section area of the structure (cm^2),
t = total time of discharge, and
h = difference in water head monitored by the manometers; the pavement structure = H_0 –H_1, base = H_3 –H_2, and subbase = H_2 –H_1

The test measurements and results are listed in Table 2 to 4.

Table 2. Results of permeability testing for the entire pavement structure

Test No.	**Manometers**		**Head, h (cm)**	**Q (cm^3)**	**t (s)**	**Q/At**	**h/L**	**Temp (^{o}C)**	**k (cm/s)**
	H_0	**H_1**							
Prior to contaminating the joint sand									
1	54.7	37	17.7	250,000	167	0.207	0.347	20.1	0.597
2	55.3	38.3	17	250,000	170	0.204	0.333	22	0.611
								Average	**0.604**
After contaminating the joint sand									
1	54.7	18.5	36.2	250,000	228	0.152	0.710	22	0.214
2	54.7	16.7	38	200,000	225	0.123	0.745	21	0.165
								Average	**0.190**

Table 3. Measurements and results of permeability testing for the base

Test No.	**Manometers**		**Head, h (cm)**	**Q (cm^3)**	**t (s)**	**Q/At**	**h/L**	**Temp (^{o}C)**	**k (cm/s)**
	H_3	**H_2**							
Prior to contaminating the joint sand									
1	41.9	37.3	4.6	250,000	167	0.2072	0.460	20.1	0.45
2	43.6	38.3	5.3	250,000	170	0.204	0.530	22	0.38
								Average	**0.43**
After contaminating the joint sand									
1	21.4	18.6	2.8	250,000	228	0.152	0.280	22	0.54
2	23.8	16.9	6.9	200,000	225	0.123	0.690	21	0.18
								Average	**0.36**

Table 4. Measurements and results of permeability testing for the subbase

Test No.	Manometers		Head, h, (cm)	Q (cm^3)	t (s)	Q/At	h/L	Temp (°C)	k (cm/s)
	H_2	H_1							
Prior to contaminating the joint sand									
1	37.3	37	0.4	250,000	167	0.207	0.01	20.1	20.70
2	38.3	37.5	0.8	250,000	170	0.204	0.027	22	7.63*
								Average	**20.70**
After contaminating the joint sand									
1	18.6	18.4	0.2	250,000	228	0.152	0.0067	22	22.77
2	16.9	16.7	0.2	200,000	225	0.123	0.0067	21	18.45
								Average	**20.76**

* Not used in the average calculation. This value is considered out of expected range.

SUMMARY

Laboratory testing was completed to determine the permeability of an interlocking concrete pavement consisting of 300 mm of ASTM No. 2 subbase, 100 mm of ASTM No. 57 base, 50 mm of ASTM No. 8 bedding chips surfaced with permeable paving stones placed in a herringbone pattern. Two series of duplicate tests were completed. Tests were completed before and after contaminating the joint material with fine dust to simulate possible long-term clogging of the permeable pavement.

The overall pavement structure had an average permeability coefficient (k) of 0.604 cm/s (855 in/hr) immediately after construction. These values are typical of other testing completed for permeable interlocking concrete pavements. The permeability of the base (0.43 cm/s) and subbase (20.70 cm/s) are also typical of permeability values measured for ASTM No 2 and 57 gradations.

The joint material was then “contaminated” to simulate the possible long-term clogging of the joints. The permeability of the pavement structure after “contamination” was measured to be 0.190 cm/s (270 in/hr) representing a reduction in permeability of about 70 percent. The reduction in permeability is due to the clogging of the joints between the pavers. The permeability of the base and subbase were not significantly affected.

While the reduction in permeability of the overall pavement structure may seem significant, it should be recognized that for a 100 year storm event in Minneapolis about 0.0045 cm/s (6.2 in/hr) of rain would be expected. In Winnipeg, a 100 year storm would expect to have a 0.0031 cm/s (4.2 in/hr) rainfall. These major storm events have substantially lower rainfall intensity than even the ‘clogged’ joint pavements.

In conclusion, the results of the laboratory testing of the Barkman permeable pavers with a typical permeable base/subbase structure has more than sufficient permeability to accommodate the infiltration of surface water from even the most severe local storms.