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This report was prepared for: Douglass Moody
Tradewinds International

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Wednesday, February 12, 2014

To: Douglass Moody, Tradewinds International

Re: Hydraulic Conductivity Testing

This document represents a full report of the data, applicable procedures, analysis and interpretation for this project.

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Report completed on: 02/12/2014

Samples: Four concrete cores, coated by the client

CPG sample #	Date received	Client sample description
12166-1	12/11/2013	S-1, KS- KrystalSeal (penetrating epoxy sealer)
12166-2	12/11/2013	S-2, EK/P EpoxiKote Patch (highly chemical-resistant epoxy coating)
12166-3	12/11/2013	S-3, TWI-500 S/L (self-leveling expansion joint compound)
12166-4	12/11/2013	S-4, TK-100 (impact-resistant epoxy coating)

1 Summary....2
2 Samples....2
3 Experimental....2
4 Results....3
5 Equipment, materials and notes....7

1 Summary

Tradewinds International (Tradewinds) requested assistance in testing the hydraulic conductivity of its concrete sealing coatings after application to concrete. Tradewinds is interested in meeting or surpassing 40 CFR 264.573 which specifies a hydraulic conductivity of less than or equal to 1×10^{-9} m/s. Cambridge Polymer Group outsourced this testing and analyzed the results, finding that all four coating samples provided by Tradewinds surpassed this criterion by approximately 2 orders of magnitude.

2 Samples

4 uncoated cores of high-strength concrete (rated between 4,000 and 5,000 psi) were prepared at the outsourcing lab and sent to Tradewinds for coating. The cores were approximately 3" in diameter and 3" in length. Tradewinds applied coatings to each core per their standard procedure and the cores were returned for testing to determine the hydraulic conductivity of the coated core. The coatings and sample numbers are given in Table 1.

Table 1: Sample Numbers and Descriptions.

CPG Sample #	Client Sample Description
12166-1	S-1, KS KrystalSeal (penetrating epoxy sealer)
12166-2	S-2, EK/P EpoxiKote Patch (highly chemical-resistant epoxy coating)
12166-3	S-3, TWI-500 S/L (self-leveling expansion joint compound)
12166-4	S-4, TK-100 (impact-resistant epoxy coating)

3 Experimental

Hydraulic conductivity testing was conducted at an outsourced lab per ASTM D5084: Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter, using Method C: Falling Head, Rising Tail. In this method, a flexible head permeameter is applied to a water-saturated core of the material of interest, and the changing applied head and tailwater elevation are recorded at specific intervals. This method is appropriate for specimens that have a hydraulic conductivity of less than 1 x 10^{-6} m/s.

4 Results

The hydraulic conductivity results are summarized in Table 2. ASTM D5084 calls for the tests to be terminated once the hydraulic conductivity reaches a "steady" value (defined as four consecutive measurements within 25% of the mean of those measurements) and once the ratio of outflow to inflow is between 0.75 and 1.25. During the testing of these samples, the outflow was so low that, based on past experience with testing similar samples, the tests were terminated early. The additional time that it would have taken to reach the termination criteria for these tests, given the extremely low hydraulic conductivity values, was not practical.

Table 2: Average hydraulic conductivity at 20 °C.

Sample	Hydraulic conductivity [m/s]
12166-1	7.13E-12
12166-2	7.98E-12
12166-3	1.10E-11
12166-4	6.50E-12

The full data sets are provided in Table 3 – Table 9 and also shown in Figure 1. Incremental hydraulic conductivity, *k*, is calculated using the following equation:

$$k = \frac{a_{in} \times a_{out} \times L}{(a_{in} + a_{out}) \times A \times \Delta t} \ln\left(\frac{\Delta h_1}{\Delta h_2}\right)$$

Where a_{in} is the cross-sectional area of the inflow tube, a_{out} is the cross-sectional area of the outflow tube, L is the specimen length, A is the cross-sectional area of the specimen, Δt is the time between measurements 1 and 2, and h_1 and h_2 are the head loss at times 1 and 2, respectively.

Table 3: Test specimen data.

Sample	Specific gravity	Initial mass [g]	Initial diameter [in]	Initial length [in]	Initial volume [cm^3]	Final mass [g]	Final diameter [in]	Final length [in]	Final volume [cm^3]	Saturation [%]
12166-1	2.7	691.61	3.012	2.950	344.49	691.61	3.014	2.962	346.42	97
12166-2	2.7	656.44	3.011	2.975	347.14	656.44	3.021	2.976	349.68	96
12166-3	2.7	660.39	3.010	2.941	343.02	660.39	3.018	2.950	345.78	98
12166-4	2.7	661.46	3.016	2.981	348.99	661.46	3.017	2.997	351.02	97

Table 4: Test boundary conditions.

Sample	Permeant liquid	Average back pressure [psi]	Effective consolidation pressure [psi]	Area of headwater tube [cm^2]	Area of tailwater tube [cm^2]	Length during permeation [cm]	Area during permeation [cm^2]
12166-1	deaired tap water	68.75	6.25	0.879	0.876	7.52	46.04
12166-2	deaired tap water	68.75	6.25	0.897	0.899	7.56	46.25
12166-3	deaired tap water	68.75	6.25	0.859	0.855	7.49	46.14
12166-4	deaired tap water	68.75	6.25	0.898	0.899	7.61	46.11

Table 5: Permeation data for Sample 12166-1.

Date	Time	Temperature [°C]	Total head [cm]	Total inflow [cm^3]	Total outflow [cm^3]	Incremental conductivity at 20 °C [m/s]
1/16/2014	8:30	19.5	197.2	0.0	0.0	n/a
1/16/2014	12:55	20.0	193.2	3.7	-0.2	9.2E-10
1/16/2014	18:30	19.5	189.6	7.1	-0.4	6.9E-10
1/17/2014	7:00	18.0	185.2	11.2	-0.6	4.0E-10
1/17/2014	18:00	20.0	183.2	13.0	-0.7	1.9E-10
1/18/2014	12:20	19.0	182.1	14.1	-0.8	6.9E-11
1/19/2014	12:45	18.5	181.4	14.8	-0.9	3.2E-11
1/20/2014	7:35	17.0	181.0	15.2	-0.9	2.5E-11
1/21/2014	7:25	17.0	180.8	15.5	-1.1	8.4E-12
1/22/2014	7:15	19.4	180.7	15.7	-1.2	5.3E-12
1/23/2014	7:15	19.8	180.5	15.9	-1.2	1.1E-11
1/24/2014	7:15	19.8	180.3	16.1	-1.2	1.1E-11
1/25/2014	12:55	19.0	180.0	16.5	-1.4	8.6E-12
1/26/2014	9:45	17.5	179.9	16.6	-1.4	6.4E-12
1/27/2014	9:00	19.0	179.6	16.9	-1.4	1.4E-11
1/28/2014	8:25	19.8	179.5	17.0	-1.4	5.4E-12
1/29/2014	8:00	20.0	179.5	17.0	-1.4	2.7E-12

Table 6: Permeation data for Sample 12166-2.

Date	Time	Temperature [°C]	Total head [cm]	Total inflow [cm^3]	Total outflow [cm^3]	Incremental conductivity at 20 °C [m/s]
1/16/2014	8:30	19.5	200.5	0.0	0.0	n/a
1/16/2014	12:55	20.0	200.0	0.4	0.0	1.80E-10
1/16/2014	18:30	19.5	199.7	0.7	0.0	6.10E-11
1/17/2014	7:00	18.0	199.1	1.3	-0.1	4.80E-11
1/17/2014	18:00	20.0	198.9	1.5	-0.1	2.10E-11
1/18/2014	12:20	19.0	198.4	2.0	-0.1	3.20E-11
1/19/2014	12:45	18.5	197.8	2.6	-0.2	2.40E-11
1/20/2014	7:35	17.0	197.5	2.9	-0.2	1.60E-11
1/21/2014	7:25	17.0	197.2	3.1	-0.2	1.30E-11
1/22/2014	7:15	19.4	197.0	3.3	-0.2	9.80E-12
1/23/2014	7:15	19.8	196.7	3.6	-0.2	1.20E-11
1/24/2014	7:15	19.8	196.6	3.7	-0.2	7.20E-12
1/25/2014	12:55	19.0	196.2	4.2	-0.4	1.20E-11

Date	Time	Temperature [°C]	Total head [cm]	Total inflow [cm^3]	Total outflow [cm^3]	Incremental conductivity at 20 °C [m/s]
1/26/2014	9:45	17.5	196.0	4.4	-0.4	1.20E-11
1/27/2014	9:00	19.0	195.7	4.7	-0.4	1.50E-11
1/28/2014	8:25	19.8	195.7	4.7	-0.4	0.00E+00
1/29/2014	8:00	20.0	196.6	4.8	-0.4	4.90E-12

Table 7: Permeation data for Sample 12166-3.

Date	Time	Temperature [°C]	Total head [cm]	Total inflow [cm^3]	Total outflow [cm^3]	Incremental conductivity at 20 °C [m/s]
1/15/2014	10:50	20.4	199.0	0.0	0.0	n/a
1/15/2014	19:20	20.5	198.4	0.4	0.1	6.6E-11
1/16/2014	6:45	18.0	197.7	1.0	0.1	6.3E-11
1/16/2014	18:30	19.5	197.5	1.2	0.1	2.0E-11
1/17/2014	7:00	18.0	196.9	1.7	0.1	4.8E-11
1/17/2014	18:00	20.0	196.8	1.8	0.1	1.0E-11
1/18/2014	12:20	19.0	196.2	2.3	0.1	3.2E-11
1/19/2014	12:45	18.5	195.6	2.8	0.1	2.4E-11
1/20/2014	7:35	17.0	195.3	3.1	0.1	2.0E-11
1/21/2014	7:20	17.0	194.8	3.5	0.1	2.1E-11
1/21/2014	16:00	18.3	194.7	3.6	0.1	1.4E-11
1/22/2014	7:15	19.4	194.7	3.6	0.1	0.0E+00
1/23/2014	7:15	19.8	194.3	4.0	0.1	1.7E-11
1/24/2014	7:15	19.8	193.9	4.3	0.1	1.7E-11
1/25/2014	12:55	19.0	193.3	4.8	0.1	2.0E-11
1/26/2014	9:45	17.5	193.1	5.0	0.1	1.2E-11
1/27/2014	9:00	19.0	192.8	5.2	0.1	1.0E-11
1/28/2014	8:25	19.8	192.6	5.4	0.1	1.0E-11
1/29/2014	8:00	20.0	192.3	5.7	0.1	1.2E-11

Table 8: Permeation data for Sample 12166-4.

Date	Time	Temperature [°C]	Total head [cm]	Total inflow [cm^3]	Total outflow [cm^3]	Incremental conductivity at 20 °C [m/s]
1/16/2014	8:30	19.5	196.9	0.0	0.0	n/a
1/16/2014	18:30	19.5	196.6	0.3	0.0	3.5E-11
1/17/2014	7:00	18.0	196.1	0.8	0.0	4.9E-11

Date	Time	Temperature [°C]	Total head [cm]	Total inflow [cm^3]	Total outflow [cm^3]	Incremental conductivity at 20 °C [m/s]
1/17/2014	18:00	20.0	195.9	0.9	0.0	1.1E-11
1/18/2014	12:20	19.0	195.5	1.3	0.0	2.6E-11
1/19/2014	12:45	18.5	195.1	1.7	0.0	2.0E-11
1/20/2014	7:35	17.0	194.7	2.0	0.0	2.0E-11
1/21/2014	7:25	17.0	194.3	2.3	0.1	2.1E-11
1/22/2014	7:15	19.4	194.2	2.4	0.1	5.0E-12
1/23/2014	7:15	19.8	194.0	2.6	0.1	9.8E-12
1/24/2014	7:15	19.8	193.6	2.9	0.1	1.5E-11
1/25/2014	12:55	19.0	193.0	3.5	0.1	2.4E-11
1/26/2014	9:45	17.5	192.8	3.6	0.1	6.0E-12
1/27/2014	9:00	19.0	192.6	3.8	0.1	1.0E-11
1/28/2014	8:25	19.8	192.6	3.8	0.1	0.0E+00
1/29/2014	8:00	20.0	192.4	4.0	0.1	1.0E-11

Table 9: Initial hydraulic gradients, defined as the initial head loss across the sample (in m water) divided by the sample length.

Sample	Initial Hydraulic Gradient
12166-1	23.36
12166-2	23.25
12166-3	23.45
12166-4	23.09

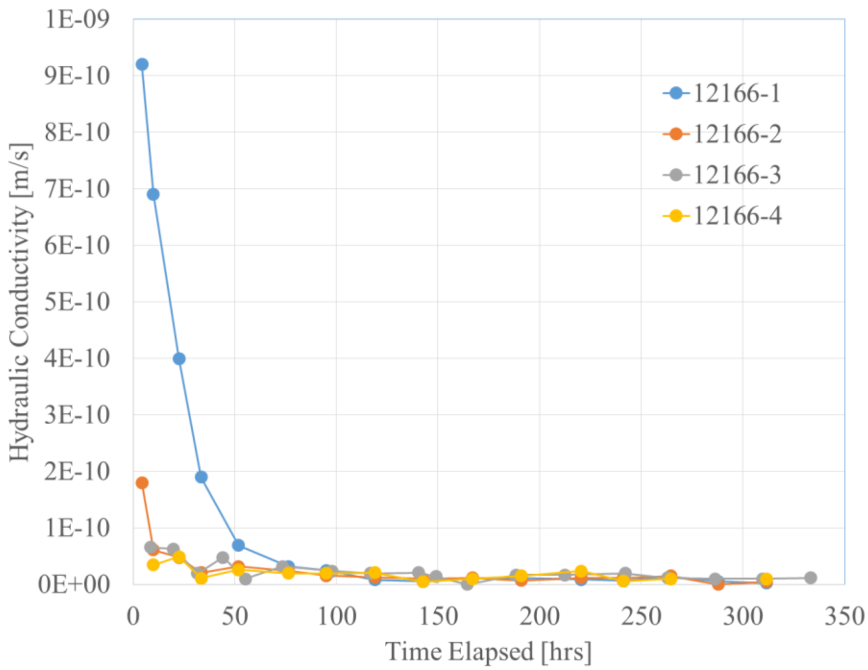

Figure 1: Evolution of hydraulic conductivity over time during testing.

5 *Equipment, materials and notes*

Listed below are notes that may impact the data presented here.

Protocols used

Protocol/Standard	Revision Date or number
ASTM D5084-10	2010

Protocol Deviations

Impacted Standard	Impacted section #	Deviation
ASTM D5084	1.3.2	Larger samples were used (3” diameter as opposed to 1” diameter).
ASTM D5084	9.5.5	Tests were terminated before outflow/inflow ratio criterion were met, based on previous testing experience.