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Savannah River Site

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List of Abbreviations

CUA	The Catholic University of America
ES	Energy*Solutions*
HLW	High Level Waste
LLW	Low Level Waste
SOW	Statement of Work
SRS	Savannah River Site
SRR	Savannah River Remediation, LLC
VSL	Vitreous State Laboratory at The Catholic University of America

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1. INTRODUCTION

1.1. Background

At the Savannah River Site (SRS), 36 million gallons of liquid radioactive waste, currently contained within underground carbon-steel waste tanks, is to be disposed of through separation into high-level waste (HLW) and low-level waste (LLW) components, which are immobilized by vitrification and grouting, respectively. Once the tanks are emptied to the maximum extent practical, the tanks are filled with a specialized grout which functions to:

- Physically stabilize the facility by filling the empty volume in the tank,
- Provide a barrier for inadvertent intrusion into the tank,
- Reduce contaminant mobility by limiting the hydraulic conductivity of the closed tank and reducing the contact between the residual waste and infiltrating water, and
- Provide an alkaline, chemically reducing environment in the closed tank to control speciation and solubility of selected radionuclides.

The cooling coils within the tank are flushed to remove the cooling fluid and the flush water is collected for final treatment and disposal. A tremie (a long flexible pipe/hose) is then inserted into the tank (through one of the tank risers) to guide the placement of the tank closure grout and limit the free fall of the grout to five feet or less. When the grout level reaches the tremie, the tremie is dropped into the tank and a new tremie is then positioned approximately five feet above the grout. This process is repeated until the tank is filled with grout. Savannah River Remediation (SRR) would like to simplify the above operations by implementing the following changes:

- Allowing the tank closure grout to be poured into standing water in the waste tank which originates from flushing of the tank cooling coils (as opposed to collection and removal of the flush water), and
- Allowing the tank closure grout to free-fall (up to 42 feet) from the roof of a waste tank as opposed to placement using a tremie located approximately five feet above the placement surface.

To support these operational changes, SRR requested Energy*Solutions* (ES) and its long term partner, the Vitreous State Laboratory (VSL) at The Catholic University of America (CUA), to perform large scale tests at the ES Barnwell facility (located in South Carolina) to determine if the operational changes will negatively impact the long-term performance of the tank closure grout. The details of the testing are described in a test plan [1] that was developed to address the testing objectives outlined in the SRR Statement of Work (SOW) G-SOW-H-00174, Revision 0 [2]. This final report provides a description of the work performed and analytical results of cured grout samples that were analyzed by the VSL.

1.2. Objectives

The objective of this work was to characterize the physical properties of cured grout which has been dropped into a containment area under a variety of scenarios. Specifically, the testing was designed to:

- Determine the compressive strength and hydraulic conductivity of 28-day cured grout samples which have been dropped from a height of 42 feet using a tremie located 5 feet above the containment surface which contains no water (Test 1).
- Determine the compressive strength and hydraulic conductivity of 28-day cured grout samples which have been dropped from a height of 42 feet using a tremie located 5 feet above the containment surface which contains 4 inches of water[1] (Test 2).
- Determine the compressive strength and hydraulic conductivity of 28-day cured grout samples which have been dropped from a height of 42 feet without a tremie onto the containment surface which contains no water (Test 3).
- Determine the compressive strength and hydraulic conductivity of 28-day cured grout samples which have been dropped from a height of 42 feet without a tremie onto the containment surface which contains 4 inches of water (Test 4). Note: this scenario was not performed.
- Determine the segregation effects of the grout samples from the scenarios above using optical microscopy.
- Record (still and video) the grout impact with the containment surface and subsequent spreading of the grout to the containment extremities, including any evidence of segregation effects.

2. TEST DESCRIPTION

2.1. Test Matrix

The effects of the operational changes being considered by SRR are not known and need to be tested. To determine the impact of the operational changes, four large scale tests utilizing approximately 8 cubic yards of grout per test, were performed and are listed below.

[1] The standing water depth is based on the cooling coil volume (>5000 gallons) being completely emptied into the tank and conservatively assumes a n on-level surface inside the tank with mounds such that the water could collect in areas up to a depth of 4 inches.

- Test 1 - Dropping tank closure grout at the center point of a 20 foot diameter circular containment area from a height of 42 feet through a tremie positioned 5 feet above an unyielding surface.
- Test 2 - Dropping tank closure grout at the center point of a 20 foot diameter circular containment area filled to a 4-inch depth with standing water from a height of 42 feet through a tremie positioned 5 feet above an unyielding surface.
- Test 3A/3B - Dropping tank closure grout at the center point of a 20 foot diameter circular containment area from a height of 42 feet without a tremie onto an unyielding surface. It should be noted that this scenario was repeated as Test 3B due to failure of the containment area during the first attempt (designated Test 3A). Since only four containment areas were available for testing, the 42 foot drop test without a tremie into four inches of standing water (Test 4) was not performed.

Table 1 provides a matrix of the testing parameters.

Table 1 – Test Matrix

Test #	Grout Drop Height, feet	Tremie used?	Height Tremie above Surface	Water Depth, inches
1	42	Yes	5 feet	0
2	42	Yes	5 feet	4
3A	42	No	-	0
3B	42	No	-	0

Grout drop test without a tremie into water (Test 4) was not performed.

2.2. Test Setup

The large scale testing was performed at the ES Barnwell Facility located in Barnwell, South Carolina. Four circular containment areas were prepared by placing an 8 foot x 10 foot steel plate (1” thick) on the ground which represented the unyielding surface of the tank bottom. A layer of sand was placed around the steel plates to form a level base so that a 20 foot diameter above ground pool (Intex 20’ x 52” Ultra Frame Pool Set) could be erected on top of the steel plate. Once the pool was erected, a 7’ x 7’ x 14.5 mil pond liner was taped to the floor of the pool to provide additional protection to the pool liner. The above ground pools were selected for their ease of assembly, to ensure that the grout could be easily contained, and to ensure that the grout and/or water did not soak into the ground. Figure 1 – Figure 4 show the preparation and setup of the containment areas.

Figure 1 – Impact plates for containment areas

Figure 2 – Buildup of sand around impact plates

Figure 3 – Containment structures erected over impact plates

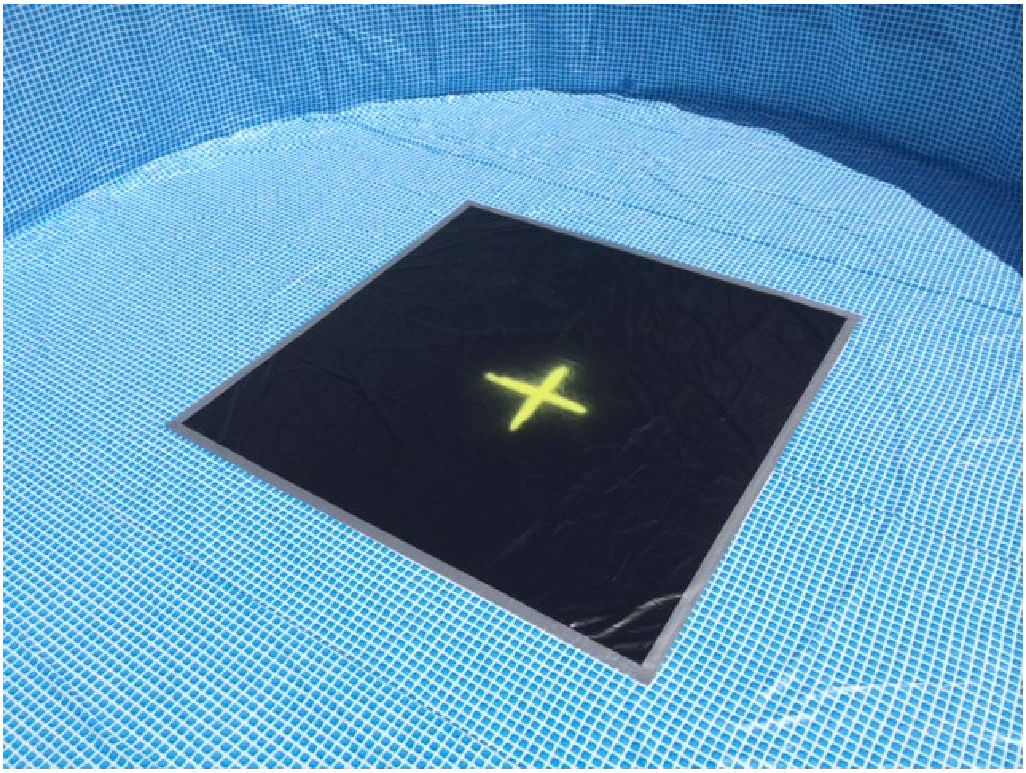


Figure 4 – Pond liner attached to floor of containment structures

For each test scenario, the SRR supplied grout was transferred to a boom pumper truck that was able to drop the grout from the desired test height over the center of the containment area. Although the pumper truck (shown in Figure 5) could easily achieve the desired pumping rate of 70 to 74 cubic yards per hour (1.17 to 1.23 cubic yards per minute), the speed control for the pump was very coarse and did not have a specific setting for pumping rate. As a result, the time to pump down the hopper (which had a volume of approximately 1 cubic yard) was determined and adjustments were made to the pump speed control in an attempt to achieve the desired rate. A tremie was attached to the boom pumper truck as required by the test matrix. The free-end of the tremie was located 5 feet above the center of the containment area. When no tremie was utilized, a plumb bob was attached to the pumper truck outlet (located 42 feet over the test area) to ensure that it was located above the center of the containment area. For Test 2, four inches of water was added to the containment area prior to the grout transfer.

Figure 5 – Boom pumper truck with tremie attached

2.3. Test Materials

Tank Closure Grout – For each test, SRR supplied approximately 8 cubic yards of tank closure grout in a cement mixer truck. The grout (LP#8-16) was prepared in accordance with the SRR specification for furnishing and delivering tank closure grout [3]. All tank closure grout provided by SRR was also prepared in accordance with ASTM C94. For this work, SRR was responsible for verifying the correct grout composition had been delivered as well as ensuring that the time to placement did not exceed 90 minutes. Prior to placing the grout, ES performed slump flow tests to verify proper grout properties.

Tremie – A tremie was used for Tests 1 and 2. The tremie was 5 inch diameter Oroflex-20 which is equivalent to that used in the tank grouting by SRR. Two 37 foot sections were procured for this testing (one for each test). One end of the tremie had an appropriate connector to interface with the outlet of the pumper truck. A new tremie was utilized for each test. A cut sheet of the Oroflex-20 is shown in Figure 6.

OROFLEX 20

OROFLEX

APLICATIONS

- Air compressors for road and construction work
- Compressors for drilling machinery
- Pumping of high performance liquids
- Applications requiring very high resistance to abrasion

CHARACTERISTICS

Colour: Yellow.

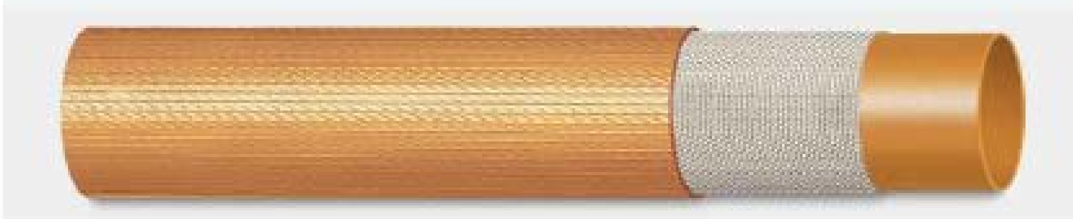
Composition: Synthetic rubber and Polyester-Polyamide textile.

Surface: Fine ribbed, highly resistant to abrasion.

Service Temperature: >From -20 °C to + 80 °C

Standard Length: 60 m (up to 200 m to order).

WATER SERVICE PRES. = 5/3 AIR SERVICE PRES.



Code	Nominal diameter		Wall thickness	Weight/ metre	AIR Service/Bursting Pressure	Traction limit for no tearing	Curvature radius
	mm.	Inches	mm.	gr.	bar	Kg	mts
01200	19	3/4	2,5	180	20 / 160	300	0,250
-	19	3/4	3,5	230	20 / 160	300	0,250
01201	27	1	3,5	235	20 / 100	750	0,250
-	27	1	4	275	20 / 100	750	0,250
01203	38	1 1/2	3,5	440	15 / 75	1.200	0,650
01204	46	1 3/4	3,5	520	15 / 75	1.400	0,750
01205	62	2	3,5	650	10 / 50	1.500	1,200
*01208	66	2 1/2	4	750	10 / 50	2.050	1,250
01206	76	3	4	950	10 / 50	2.600	1,300
01207	102	4	4	1.275	10 / 50	3.780	1,700
*01208	127	5	4	1.800	10 / 50	5.980	1,970
*01209	152	6	4	2.100	10 / 50	7.280	1,970
*01210	204	8	4,5	2.550	10 / 50	9.320	2,250

Figure 6 – Cut sheet for the Oroflex-20 Tremie

3. SAMPLE COLLECTION AND ANALYSIS

3.1. Sample Locations

Samples from each test were collected for compressive strength measurement, saturated hydraulic conductivity measurement, and optical microscopy. A total of six samples for each analysis were collected with 3 of the samples being analyzed and 3 samples held in archive. Samples were collected at 1 foot, 5 feet, and 9 feet from the center of the test area to assess any effects on the grout properties as a function of distance from the drop impact point. Figure 7 shows the location of the samples collected for each test. For Test 1, SRR requested that an additional three samples for hydraulic conductivity and compressive strength be taken for analysis. These samples were located adjacent to the other samples collected at 1 foot, 5 feet, and 9 feet from the center of the test area.

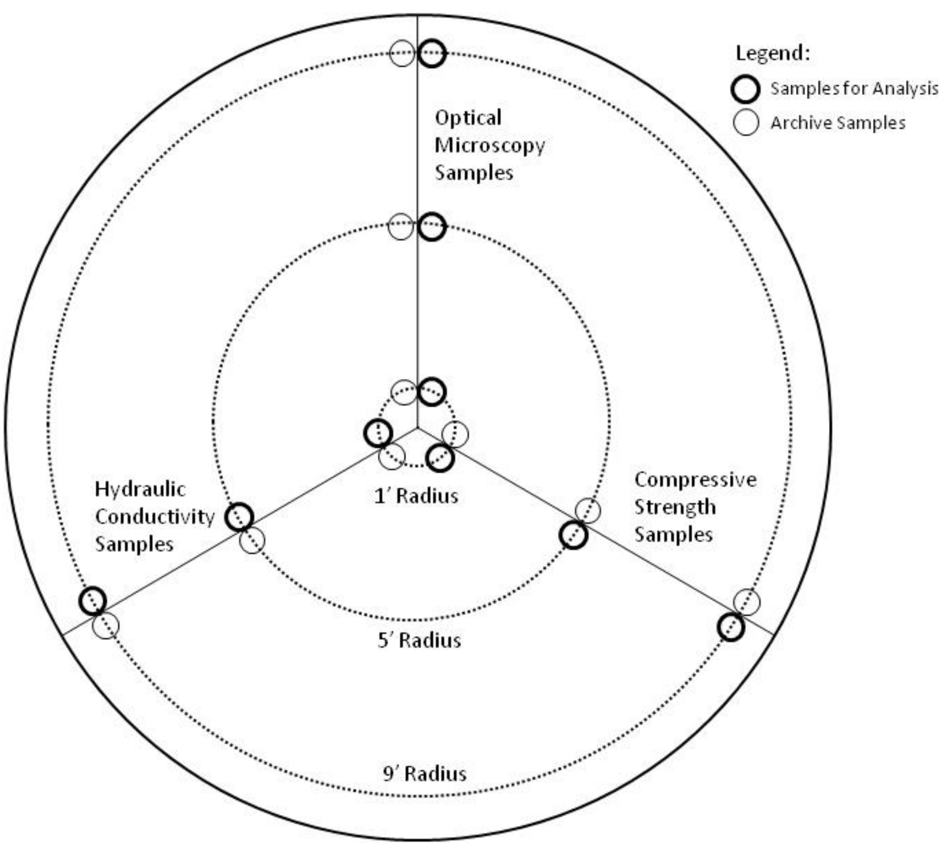


Figure 7 – Sample collection location within the 20 foot diameter test area

3.2. Sampling Equipment

Grout sampling assemblies were placed in the grout after placement to collect samples for analysis. These sampling assemblies consisted of a 3” schedule 40 PVC pipe (approximately 20 inches long) that was pushed into the grout until it hit the containment floor. A 4” schedule 40 PVC pipe (approximately 16 inches long) was then placed over the 3” pipe to isolate the 3” pipe from the surrounding grout. This pipe in pipe method was used to prevent the inner pipe from sticking to the surrounding grout allowing easier removal of the sample. Figure 8 is a section view showing the sampling assembly. Unfortunately, this collection method did not work as planned since the inner pipe could not be removed after the grout had cured, and core drilling was used instead to collect the samples. See Section 4.2 for more information.

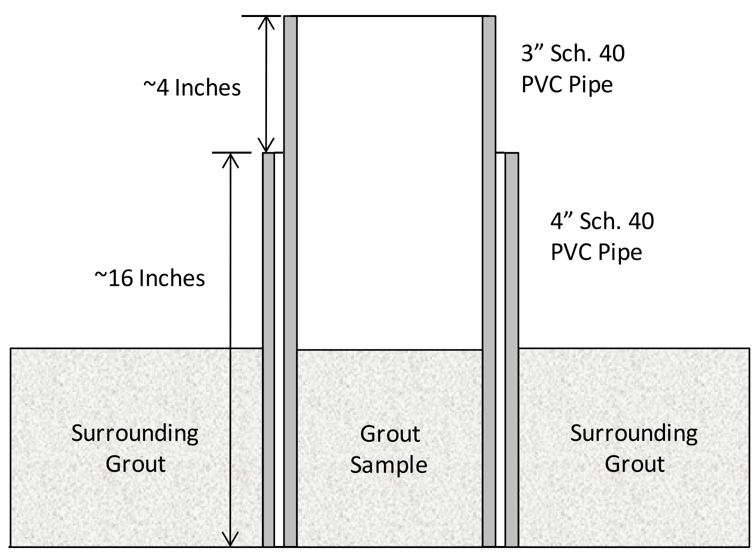


Figure 8 – Section view of the pipe-in-pipe sampling assembly

3.3. Sample Characterization

Prior to performing each test pour, the SRR-supplied tank closure grout was evaluated for slump flow. Cured tank closure grout samples were evaluated by the VSL for compressive strength, saturated hydraulic conductivity, and segregation effects using optical microscopy.

Slump Flow Determination - The slump flow of the tank closure grout was determined per ASTM C1611 to ensure it was within the 26 – 30 inch grout specification [3]. Samples collected from the cement mixer truck were poured into the slump cone mold that was positioned on a smooth, non-absorbent, flat surface with a minimum width of at least 36 inches. The mold was then removed by raising

it vertically, allowing the grout to spread. After spreading ceased, two diameters of the grout were measured in approximately orthogonal directions, and slump flow was the average of the two diameters.

Compressive Strength Determination – For each test, a minimum of three samples were evaluated for compressive strength. Compressive strength, or the capacity of a material to withstand an axial force, was measured by applying a compressive axial load to the sample at a rate that was within a prescribed range until failure occurred. The compressive strength of the sample was then calculated by dividing the maximum load attained during the test by the cross-sectional area of the specimen in accordance with ASTM C39 / C39M. The grout specification requires that the compressive strength be greater than 2000 psi after curing for 28 days [3].

Saturated Hydraulic Conductivity Determination – Hydraulic conductivity provides a measure of the ease with which a fluid can move through a porous material and depends on the density and viscosity of the permeating fluid. It is measured using a permeameter in accordance with ASTM D5084-10. For the tank closure grout samples, the permeating fluid was deionized water. Hydraulic conductivity measurements were performed by a qualified laboratory (AMEC) and required the use of 2.75 inch diameter by 3 inch thick samples cut from the interior of the cylindrical samples. All hydraulic conductivity samples were obtained from the center of the cured grout sample.

Optical Microscopy/Digital Analysis – The three samples reserved for optical microscopy for each test were sawed into halves through the long axis of the cylinder to expose the cross sections of the internal texture. The cross sections of the samples were then photographed using a digital camera. The picture files were then imported and various image filter steps were taken to attempt to capture the area coverage of the aggregate. First, the images were sliced into 200-pixel width vertical strips offset from the previous strip by 100 pixels. This was an attempt to isolate large-scale color deviations from one side of the cut to the other. A median filter was initially used on these strips to identify pixels that were far from the median value since aggregates could be lighter or darker than the median pixel values. An adaptive binarization was used to identify regions of likely aggregate. To clean up the boundaries of the aggregates, geodesic closing filters and a low-pass filter were used. Finally, an erosion and dilation step was taken to further clean the boundaries. The area coverage fraction of the aggregate was calculated as the number of pixels in the aggregate zone divided by the total number of pixels.

Unfortunately, because of the wide variation of the colors and tones in the images, some artifacts in the image analysis process were still evident. These were regions where the matrix had passed through the filter due to coloring or shading, but were clearly not aggregates. Further work could possibly remove these artifacts, although finding a filter that would allow for all possible color variations and specific shading situations would have diminishing returns. Higher contrast images, through dyes, for example, would make the filtering and image analysis more accurate.

4. TESTING RESULTS

4.1. Tank Closure Grout Pouring

As discussed above, four tank closure grout pouring tests were performed. This section discusses the observations and data collected during the placement of the grout. Table 2 (located at the end of this section) provides a summary of grout pouring parameters collected during the testing.

Test 1 – Grout Placement with Tremie and No Water

The first test performed was the baseline test which utilized a tremie with its outlet 5 feet above the center of the test area. Once the SRR provided grout arrived at the Barnwell complex on June 24, 2014, the slump flow was determined (see results in the next section) and found to be acceptable. At this point, the grout was placed utilizing the pumper truck. The pumping rate was estimated to be 1.52 cubic yards per minute which was above the target rate of 1.17 to 1.23 cubic yards per minute. This rate assumes that 7 cubic yards of grout was placed during the test and that 1 cubic yard of grout was lost in the pump truck lines and from slump tests. The placement time was estimated to be 4.6 minutes from video footage of the pour. The total time from initial batching to placement of the grout was 87 minutes. See Table 2 for a summary of the pouring data.

During the placement, the grout flowed fairly evenly to the edge of the containment area with some splashing of the grout reaching the containment walls. There was no indication that the grout segregated during placement. Grout depth measurements were performed after the grout placement was completed. The grout depth at the center was approximately 11.5 inches deep and between 5 and 6 inches deep around the perimeter of the containment structure (10 feet from the center). Figure 9 shows the grout flowing to the edge of the containment structure and Figure 10 shows the containment area once all of the grout was placed.

Figure 9 - Grout flowing to containment walls during Test 1

Figure 10 - Grout condition at end of Test 1

Approximately one hour after the placement of the grout, the sampling assemblies were inserted into the grout. Due to the excessive ambient temperature at the time of the test (90 - 95°F), the operations personnel had difficulty inserting the assemblies as the grout had begun to set. Although the sampling assemblies were successfully installed, installation of the assemblies for future tests were performed immediately after the grout placement was completed.

Test 2 – Grout Placement with Tremie and 4" of Water

Test 2 was performed several hours after the completion of Test 1. The containment area was filled with 4 inches of water[2]. Measurements of the depth of water at the edges of containment area (at 90 degree intervals) were 4", 4", 4.5", and 6" indicating that the containment area was not completely level. After the slump flow was determined (see results in the next section) and found to be acceptable, the grout was placed utilizing the pumper truck. The pumping rate was estimated to be 0.80 cubic yards per minute which was below the target rate of 1.17 to 1.23 cubic yards per minute. As with Test 1, the volume of grout placed was assumed to be 7 cubic yards. The placement time was estimated to be 8.75 minutes from video footage of the pour. The total time from initial batching to placement of the grout was 80 minutes. See Table 2 for a summary of the pouring data.

During the initial placement, it appeared that there was segregation of the grout with the aggregate settling to the bottom and the finer material quickly mixing with the water and floating to the edges of the pool. This segregation was confirmed during installation of the sampling assemblies when the placement was completed. The assemblies near the center were more difficult to push through the grout due to the aggregate and much easier near the walls of the containment structure. Figure 11 shows the containment structure at the start of the test with the finer grout material floating away from the center during the pour. Figure 12 shows the grout at the completion of the test. Grout depth measurements showed that the grout depth at the center was approximately 13 inches (11.5 inches of grout and 1.5 inches of water). Grout depth around the perimeter of the containment was between 10 - 12 inches (approximately 3 – 5 inches of grout and 5.5 – 8 inches of water).

At the end of the day, the containment structures for Tests 1 and 2 were covered with a heavy mil plastic tarp to minimize moisture loss and to protect the test area against the environment. The grout was then allowed to cure for approximately three weeks before samples were collected and sent out for analysis.

[2] The standing water depth is based on the cooling coil volume (>5000 gallons) being completely emptied into the tank and conservatively assumes a n on-level surface inside the tank with mounds such that the water could collect in areas up to a depth of 4 inches.

Figure 11 - Start of grout pouring for Test 2 showing finer material floating in the water

Figure 12 - Grout condition at end of Test 2

Test 3A – Grout Placement without a Tremie and No Water

Test 3A was performed on June 25, 2014 and did not utilize a tremie to place the grout. Instead, the pumper truck boom was raised to 42 feet above the center of the containment area. After the slump flow was determined and found to be acceptable, the grout was placed utilizing the pumper truck. The pumping rate was estimated to be 0.88 cubic yards per minute which was below the target rate of 1.17 to 1.23 cubic yards per minute. The volume of grout placed was assumed to be 7 cubic yards. The placement time was estimated to be 8 minutes. The total time from initial batching to placement of the grout was 67 minutes. Table 2 provides a summary of the pouring data.

During placement, the grout remained in a tight stream as it left the pumper truck nozzle. However, as it dropped closer to the containment area, the stream began to segregate into small clumps of grout as shown in Figure 13. These smaller clumps of grout then impacted the containment area resulting in violent splashing and splattering of the grout out to the containment walls. Although there was a heavy buildup of grout on the containment walls, it did not appear that there was any segregation of the grout when the placement was completed. The surface of the grout placement appeared relatively smooth.

After the placement was completed, an inspection of the outer edge of the containment found wet sand and grout, indicating a possible breach of the liner. Further indication of a liner breach was found during the installation of the sampling assemblies. Although some of the assemblies could be fully inserted into the grout, several assemblies could only be inserted a few inches into the grout as shown in Figure 14. Further investigation found that the liner was very close to the surface of the grout in some locations. Measurement of the grout depth showed that the center was approximately 10.5 inches. Depth measurements around the perimeter of the containment were 4, 5.25, 8, and 2.25 inches depth at 90 degree intervals. Therefore, it was deduced that the grout had eroded through the heavy mil pond liner and pool liner at the center of the containment area which allowed grout to flow underneath the liner. Given this result, a decision was made by ES and SRR personnel to stop testing for the day and implement a solution to ensure that the liner was sufficiently protected for the final test.

Figure 13 - Photo of grout falling from 42 feet in Test 3A

Figure 14 - Sampling assemblies inserted into the grout for Test 3A. Note the varying depths of the assemblies into the grout caused by the failure of the containment liner.

Test 3B – Grout Placement without a Tremie and No Water

For the final test, an additional 1” thick steel plate was placed on top of the containment liner to prevent its erosion due to the falling grout. A picture of the containment area prior to the start of the test is shown in Figure 15. ES and SRR personnel also decided that the grout placement without a tremie and no water would be repeated instead of performing the test with four inches of water given the significant segregation of the grout observed in Test 2. Test 3B was performed on June 26, 2014 and was started after the slump flow was determined. The pumping rate was estimated to be 1.27 cubic yards per minute which was slightly above the target rate of 1.17 to 1.23 cubic yards per minute. The volume of grout placed was assumed to be 7 cubic yards and the placement time was estimated to be 5.5 minutes from video footage of the pour. The total time from initial batching to placement of the grout was 90 minutes. See Table 2 for a summary of the pouring data.

As with Test 3A, the grout remained in a tight stream as it left the pumper truck nozzle, but dispersed into small clumps of grouts as it fell through the air. The grout heavily splattered the containment wall immediately after impacting the steel plate. Figure 16 shows the grout impacting the steel plate at the start of the test. Once the grout was deep enough in the center to absorb the impact of the falling grout, the splattering and splashing was significantly reduced. The grout continued to flow to the containment walls in a similar manner as Test 1. Figure 17 shows the condition of the grout after final placement. There was no visual indication of grout segregation throughout the entire test. Measurement of the grout thickness after the placement was completed indicated that the center was approximately 9.5 inches above the liner (measurement includes the steel plate height of 1 inch). Grout depth

around the perimeter of the containment ranged between 4.5 and 7 inches. After the sampling assemblies were inserted, the containment area was covered to prevent moisture loss. The grout was then allowed to cure for approximately 3 weeks.

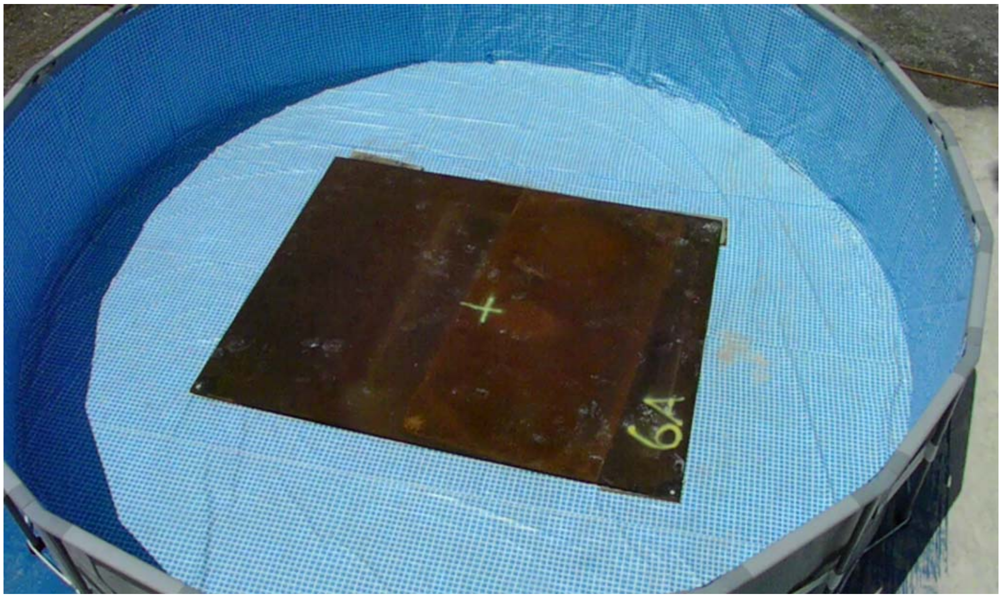


Figure 15 - Photo of the containment area for Test 3B showing the steel plate used to protect the liner

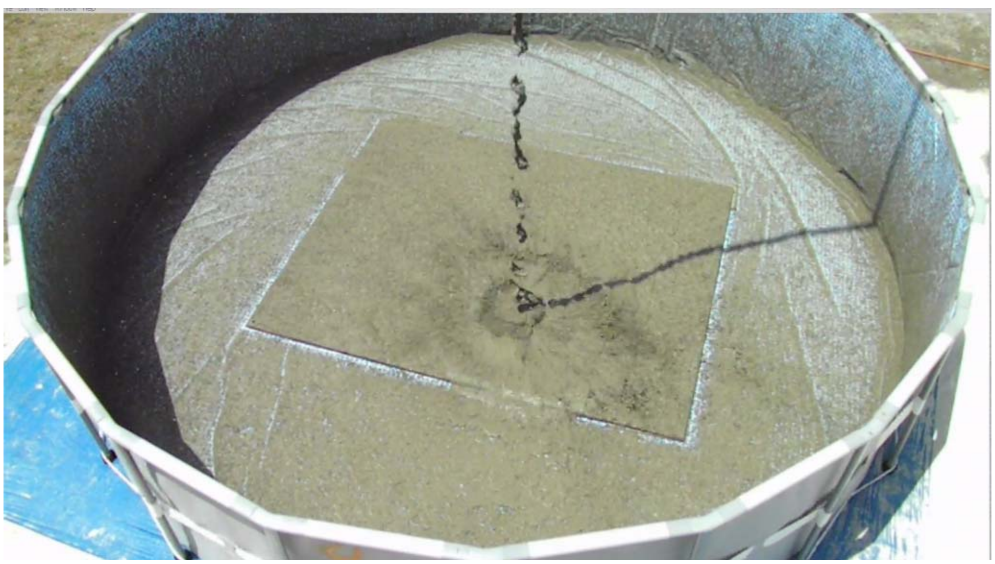


Figure 16 - Photo of the grout impacting the steel plate at the start of Test 3B

Figure 17 - Condition of the grout immediately after placement of the grout in Test 3B

Table 2 - Summary of Grout Pouring Data

Test #	Date Test Performed	Grout Pump Rate, yd^3/min*	Time to Placement, min	Total Cement Mixer Revolutions
1	6/24/14	1.52	87	270
2	6/24/14	0.80	80	161
3A	6/25/14	0.88	67	127
3B	6/26/14	1.27	90	192

* Pump rate assumes that 7 yd^3 of grout was placed within the containment area. Total grout pump time was determined from video footage

4.2. Sample Collection

After the grout had cured for approximately 21 days in the containment areas, attempts were made to remove the inner 3” pipe (which contained the sample) while the 4” outer pipe remained in the cured grout. Every effort was made to remove the samples, but the cured grout firmly adhered to the PVC preventing its removal. There was no shrinkage of the grout away from the outer tube as shown in Figure 18. This problem was anticipated and mitigating controls were discussed (such as form release agents), but none were implemented due to the inability to identify a lubricant or form release agent that could be proven to not contaminate the samples and potentially interfere with the analyses.

Figure 18 – Cured grout around sampling assemblies. Note that there was no shrinkage of the grout away from the PVC pipe.

Samples from the containment areas were collected using a 3” core drilling machine. Figure 19 shows the core drilling during the collection of samples for Test 2.

Figure 19 - Core drilling of the cured grout to collect samples

Once the samples were removed, they were marked to indicate which surface was the top surface. Each sample was then given a unique identification number for traceability and tracking purposes. The samples were wrapped with a damp cloth, sealed in a plastic bag to prevent moisture loss, and shipped to the VSL for analysis. Additional samples for hydraulic conductivity and compressive strength were collected for Test 1 on September 4, 2014. These samples were packaged in a similar manner as the other samples and shipped to the VSL for analysis.

Figure 20 – Figure 22 show the location of the samples as well as the sample numbers for each test. Table 3 – Table 5 provide information on the samples that were collected for each test and the analysis performed on each sample. It should be noted that many of the archive samples originally collected for Test 1 and 3B were used for additional analysis subsequently requested by SRR. For Test 3B, additional samples were collected for SRR use and were not delivered to the VSL for analysis. These samples are identified with an 'X' in Figure 22. Due to the failed liner on Test 3A, samples were not collected for analysis.

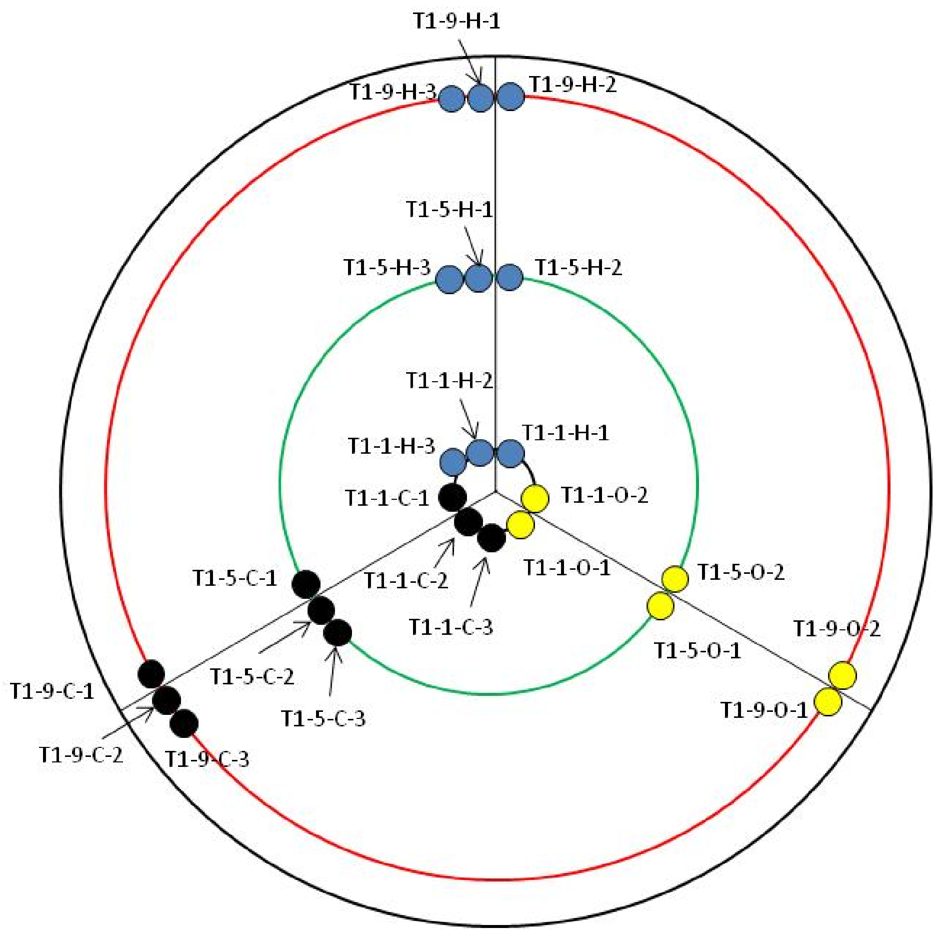


Figure 20 - Test 1 sample location and sample numbers (North is up)

Table 3 - Test 1 Sample Collection Summary - Samples Collected on July 15, 2014

Sample Number	Sample Location From Center, ft	Required Analysis
T1-1-C-1	1	Compressive Strength, 28 days
T1-1-C-2	1	Compressive Strength, 56 days*
T1-1-C-3**	1	Compressive Strength, 90 days*
T1-1-H-1	1	Hydraulic Conductivity, ~7 weeks
T1-1-H-2	1	Hydraulic Conductivity, 90 days*
T1-1-H-3**	1	Hydraulic Conductivity, 90 days*
T1-1-O-1	1	Optical Microscopy
T1-1-O-2	1	Compressive Strength, 90 days*
T1-5-C-1	5	Compressive Strength, 28 days
T1-5-C-2	5	Compressive Strength, 56 days*
T1-5-C-3**	5	Compressive Strength, 90 days*
T1-5-H-1	5	Hydraulic Conductivity, ~ 7 weeks
T1-5-H-2	5	Hydraulic Conductivity, 90 days*
T1-5-H-3**	5	Hydraulic Conductivity, 90 days*
T1-5-O-1	5	Optical Microscopy
T1-5-O-2	5	Compressive Strength, 90 days*
T1-9-C-1	9	Compressive Strength, 28 days
T1-9-C-2	9	Compressive Strength, 56 days*
T1-9-C-3**	9	Compressive Strength, 90 days*
T1-9-H-1	9	Hydraulic Conductivity, ~7 weeks
T1-9-H-2	9	Hydraulic Conductivity, 90 days*
T1-9-H-3**	9	Hydraulic Conductivity, 90 days*
T1-9-O-1	9	Optical Microscopy
T1-9-O-2	9	Compressive Strength, 90 days*

* Additional analysis requested by SRR. Analysis not required per the test plan.
** Samples collected on September 4, 2014.

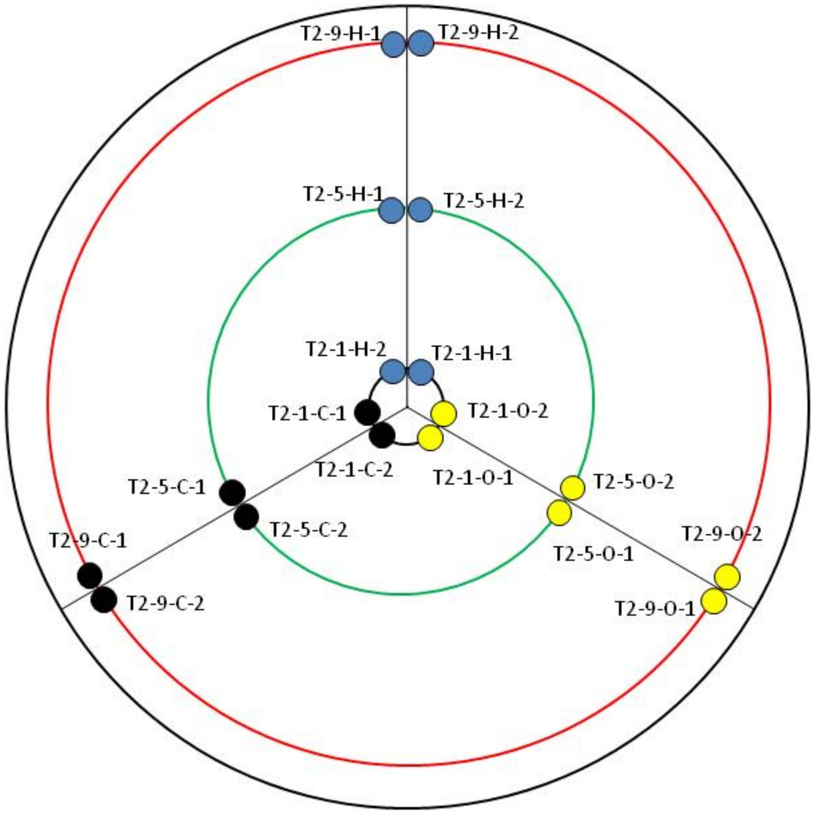


Figure 21 - Test 2 sample location and sample numbers (North is up)

Table 4 - Test 2 Sample Collection Summary - Samples Collected on July 15, 2014

Sample Number	Sample Location From Center, ft	Required Analysis
T2-1-C-1	1	Compressive Strength, 28 days
T2-1-C-2	1	Compressive Strength (Archive)
T2-1-H-1	1	Hydraulic Conductivity, ~ 7 weeks
T2-1-H-2	1	Hydraulic Conductivity (Archive)
T2-1-O-1	1	Optical Microscopy
T2-1-O-2	1	Optical Microscopy (Archive)
T2-5-C-1	5	Compressive Strength, 28 days
T2-5-C-2	5	Compressive Strength (Archive)
T2-5-H-1	5	Hydraulic Conductivity, ~ 7 weeks
T2-5-H-2	5	Hydraulic Conductivity (Archive)
T2-5-O-1	5	Optical Microscopy
T2-5-O-2	5	Optical Microscopy (Archive)
T2-9-C-1	9	Compressive Strength, 28 days
T2-9-C-2	9	Compressive Strength (Archive)
T2-9-H-1	9	Hydraulic Conductivity, ~ 7 weeks
T2-9-H-2	9	Hydraulic Conductivity (Archive)
T2-9-O-1	9	Optical Microscopy
T2-9-O-2	9	Optical Microscopy (Archive)

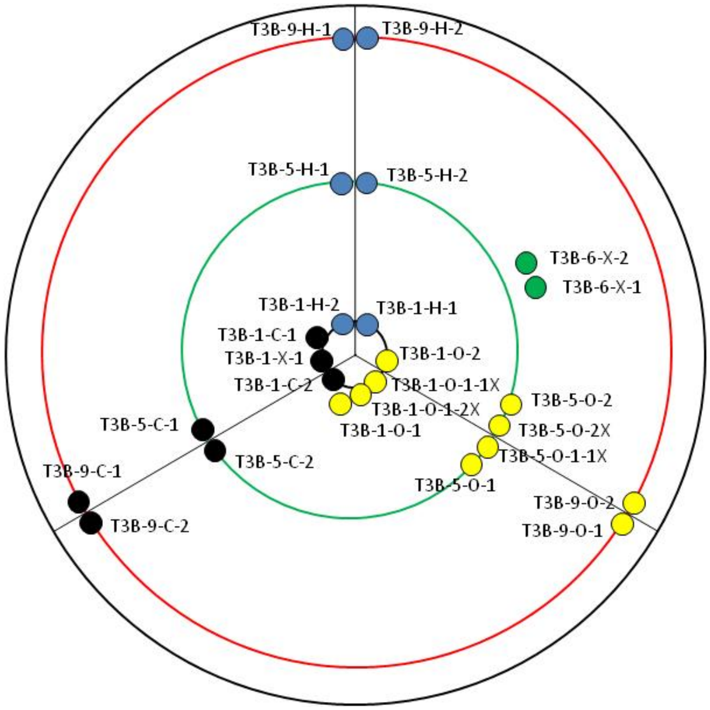


Figure 22 - Test 3B sample location and sample numbers (North is up). Note – Sample numbers containing an 'X' were samples collected for SRR use.

Table 5 - Test 3B Sample Collection Summary - Samples Collected on July 17, 2014

Sample Number	Sample Location From Center, ft	Required Analysis
T3B-1-C-1	1	Compressive Strength, 28 days
T3B-1-C-2	1	Compressive Strength, 113 days*
T3B-1-H-1	1	Hydraulic Conductivity, ~ 7 weeks
T3B-1-H-2	1	Hydraulic Conductivity, ~18 weeks*
T3B-1-O-1	1	Optical Microscopy
T3B-1-O-2	1	Optical Microscopy (Archive)
T3B-5-C-1	5	Compressive Strength, 28 days
T3B-5-C-2	5	Compressive Strength, 113 days*
T3B-5-H-1	5	Hydraulic Conductivity, ~ 7 weeks
T3B-5-H-2	5	Hydraulic Conductivity, ~18 weeks*
T3B-5-O-1	5	Optical Microscopy
T3B-5-O-2	5	Optical Microscopy (Archive)
T3B-9-C-1	9	Hydraulic Conductivity, ~18 weeks *
T3B-9-C-2	9	Compressive Strength, 28 days
T3B-9-H-1	9	Hydraulic Conductivity, ~ 7 weeks
T3B-9-H-2	9	Compressive Strength, 113 days*
T3B-9-O-1	9	Optical Microscopy
T3B-9-O-2	9	Optical Microscopy (Archive)

Note: SRR samples (denoted with an 'X' in Figure 22) are not included in this table.
* Additional analysis requested by SRR. Analysis not required per the test plan.

4.3. Sample Analysis

This section discusses the analysis performed on the grout and cured samples. Prior to analyzing the cured samples at the VSL, the as-received samples from Barnwell were visually inspected. Particular attention was paid to the direction of the top surface of each cylindrical sample.

Slump Flow Measurements

Prior to the start of each test, the slump flow of the grout from the cement truck mixer was determined in accordance with ASTM C1611. Figure 23 shows the slump measurement being performed for one of the tests. The slump flow measurements for each test are provided in Table 6. All measurements were within the 26 – 30 inch slump as required in the grout specification [3].

Figure 23 - Slump flow measurement being performed by ES personnel

Table 6 - Slump Flow Measurements

Test #	Date Performed	Slump Flow, inches
1	6/24/14	28
2	6/24/14	27.5
3A	6/25/14	27
3B	6/26/14	26.5

Compressive Strength Measurements

For each test, three samples were measured for compressive strength after curing for 28 days. For Test 1, additional samples were measured for compressive strength after curing for 56 and 90 days (Table 3). Compressive strength was measured by applying a compressive axial load to the sample at a rate that was within a prescribed range until failure occurred. The compressive strength of the sample was then calculated by dividing the maximum load attained during the test by the cross-sectional area of the specimen in accordance with ASTM C39/C39M.

The drilled samples had a diameter of approximately 2.75" and a range of 5" to 11" in length depending on the sample locations. Usually the samples at 1 ft from the impact center were the longest, e.g., 9" to 11", and those at 9 ft were the shortest, e.g., 5.5" to 6". The cylindrical samples were sawed to ensure that the ratio of length to diameter fell between 1.8 and 2.2 as required by ASTM C39/C39M. Before sawing, the top surface of a cylindrical sample was verified and the lower portion of the cylinder was removed. The upper portion of the cylindrical sample was used for compressive strength measurement. A thin layer of the top surface was removed if it was uneven. The diameter and length of an individual cylindrical sample were measured using a calibrated caliper and the cross-sectional area was calculated.

Results for compressive strength are shown in Table 7. The compressive strength for all the samples measured ranged from 939 to 2761 psi after curing for 28 days. In general, for each test, compressive strength decreased with increasing distance from the impact center, particularly for Tests 1 and 2 where a tremie was used. Taking Test 1 as an example, the 28 day compressive strength was determined to be 2761 psi for the sample drilled at 1 ft from the impact center. The sample near the impact center had a higher 28-day compressive strength than the SRNL laboratory-prepared sample LP#8-16 [4] with the same mix composition (Table 7). The compressive strength decreased to 1755 psi for the sample at 5 ft and further decreased to 1533 psi for the sample drilled at 9 ft from the impact center. Decreasing compressive strength with increasing distance from the impact center was much more evident for Test 2 where both tremie and 4" of standing water were used. The compressive strength was 2462 psi at 1 ft from the impact center, and the value decreased to 1320 psi at 5 ft and 939 psi at 9 ft. In contrast, the decrease in compressive strength with

increasing distance from the impact center was less evident in Test 3B where no tremie and no water were used. The observations are summarized in Figure 24. At fixed locations, Test 3B had the highest compressive strength, Test 2 had the lowest compressive strength and Test 1 had intermediate compressive strength. Test 3B, where no tremie and no water were used, showed the least variation with distance while Test 2, where both tremie and 4” water were used, showed the greatest variation.

It is likely that the 4” of standing water present in Test 2 was forced to mix with the fresh grout during the grout drop causing the water to cement ratio to increase locally, particularly toward the edge. The higher water to cement ratio would reduce the viscosity making segregation of coarse aggregates more likely; this would explain the lower compressive strength values observed in samples T2-5-C-1 and T2-9-C-1. Observations on coarse aggregate segregation are presented later in this report.

Additional grout samples from Test 1 were measured for compressive strength after curing for 56 and 90 days. The compressive strength increased with increasing curing time from 28 days to 90 days for the samples drilled at all the locations (Table 7). However, the rate of compressive strength increase between 28 days and 56 days was larger than that between 56 days and 90 days, indicating that compressive strength after curing for 56 days was approaching its limiting value. The results are presented in Figure 25 and Figure 26. Figure 25 presents the compressive strength data obtained for the samples sent to VSL in the middle of July 2014 and stored at VSL until the measurement was performed. Sample T1-5-O-2 (90 days) had an unexpectedly low compressive strength which may be ascribed to a premature failure since a small piece of grout on the top edge was chipped off when it was crushed. In Figure 26, the 90 day data for the samples drilled in July 2014 (with IDs ending with O-2) were replaced with the values for the samples drilled in early September 2014 (with IDs ending with H-3); the 90-day compressive strength was above 2000 psi for the grout samples drilled at all locations. Two sets of Test 1 grout samples cured for 90 days, drilled in July 2014 and drilled in early September 2014, did not show significant differences in measured compressive strength.

Archive samples from Test 3B were measured for compressive strength after curing for 113 days. As with the Test 1 samples, the compressive strength increased over the 28 day compressive strength samples drilled at all of the locations. The compressive strength results are shown in Table 7 and presented in Figure 27. All of the samples were stored at the VSL in a moist environment until the measurements were made.

Table 7 - Compressive Strength of Drilled Grout Samples Cured for 28, 56, 90, and 113 Days

Test#	Drop conditions	Sample ID	Curing Times	Compressive Strength (psi)
1	Tremie, no water	T1-1-C-1	28 days	2761
		T1-5-C-1	28 days	1755
		T1-9-C-1	28 days	1533
		T1-1-C-2	56 days	2991
		T1-5-C-2	56 days	2104
		T1-9-C-2	56 days	1926
		T1-1-O-2	90 days	3088
		T1-5-O-2	90 days	1878*
		T1-9-O-2	90 days	2029
		T1-1-C-3**	90 days	2869
		T1-5-C-3**	90 days	2267
		T1-9-C-3**	90 days	2120
2	Tremie, 4" water	T2-1-C-1	28 days	2462
		T2-5-C-1	28 days	1320
		T2-9-C-1	28 days	939
3B	No tremie, no water	T3B-1-C-1	28 days	2566
		T3B-5-C-1	28 days	2112
		T3B-9-C-2	28 days	2281
		T3B-1-C-2	113 days	3611
		T3B-5-C-2	113 days	2681
		T3B-9-H-2	113 days	2865
Laboratory Sample***		LP#8-16	28 days	2680

* The unexpectedly low compressive strength may be ascribed to a premature failure due to a small piece on the top edge that was chipped off during crushing.
** Sample cured in grout test monolith. Samples were drilled and collected on September 4, 2014.
*** Stefanko and Langton [4].

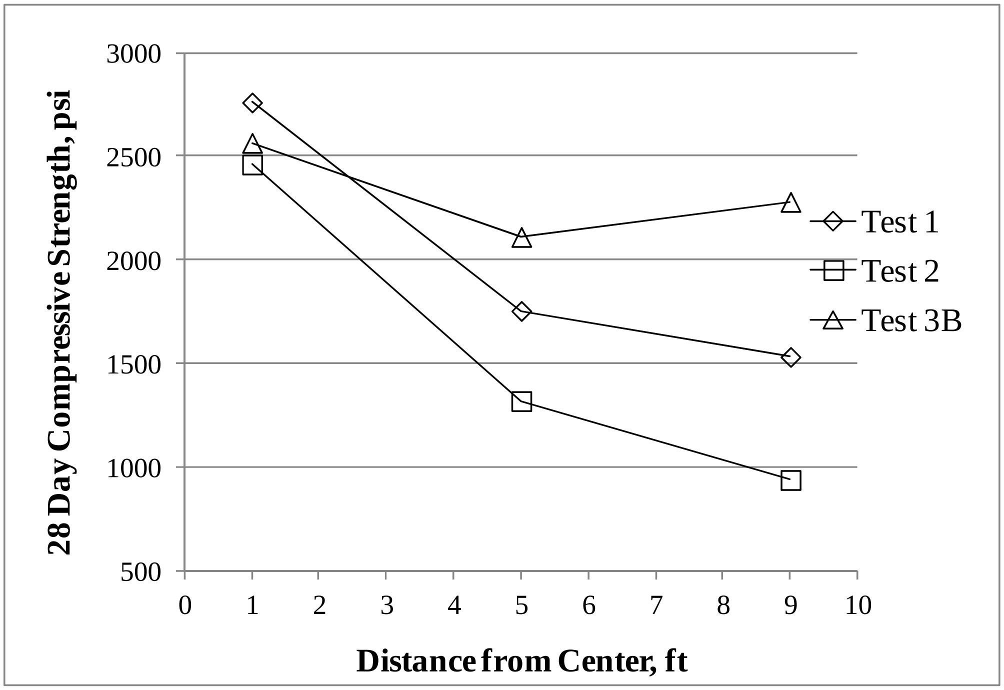


Figure 24 – 28-day compressive strength as a function of distance from impact center (radius)

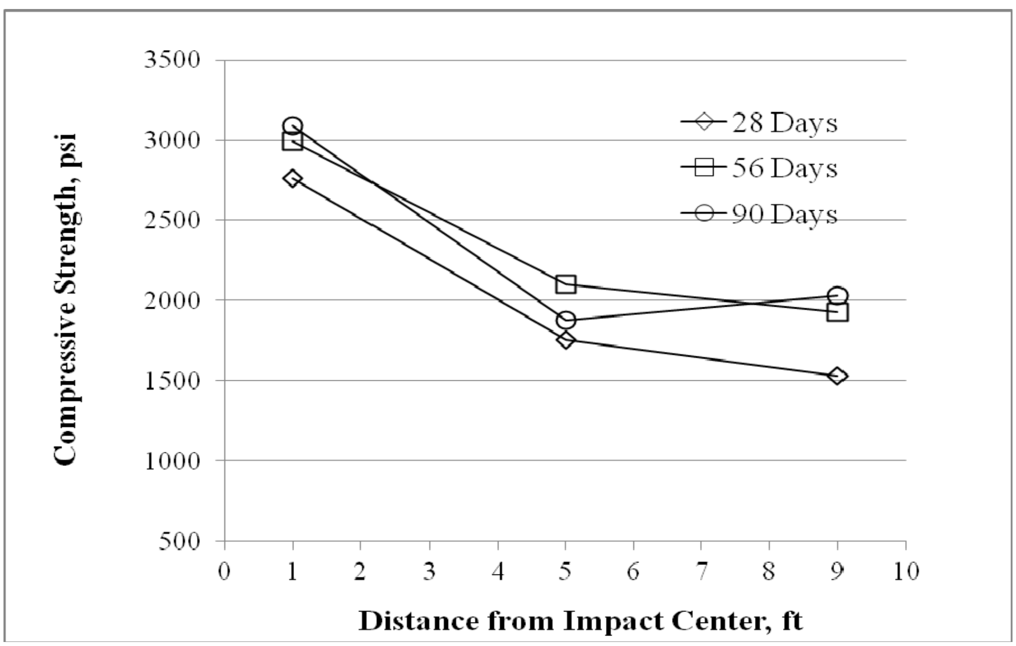


Figure 25 - Test 1 compressive strength as functions of curing time and distance from impact center. All samples were sent to the VSL in July 2014 and were stored at VSL in a moist environment until they were measured for compressive strength.

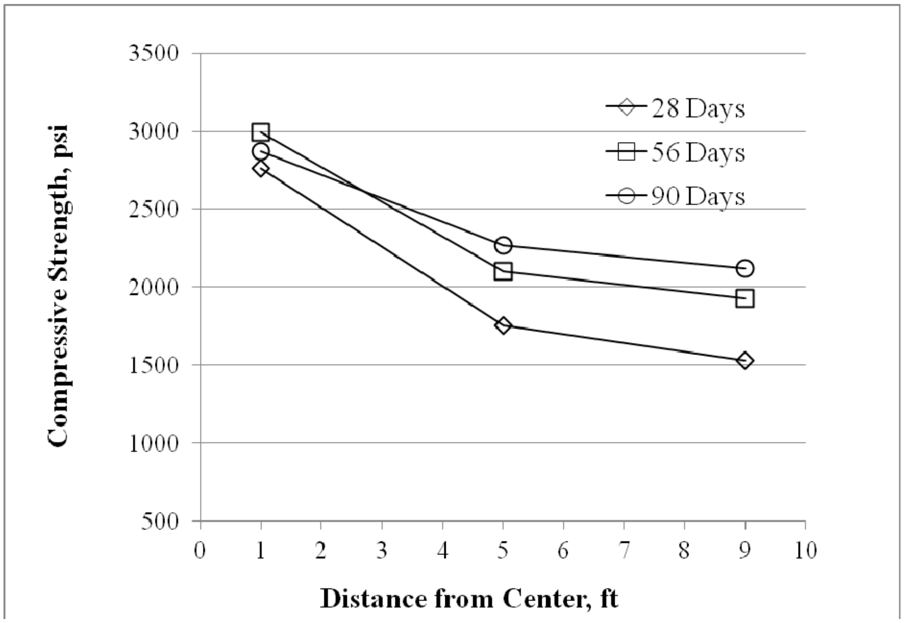


Figure 26 - Test 1 compressive strength as functions of time and distance from impact center. The samples for 28 and 56 days were sent to the VSL in July 2014 and were stored at VSL in a moist environment until they were measured for compressive strength. The samples for 90 days were drilled and sent to VSL in early September 2014 and measured shortly thereafter.

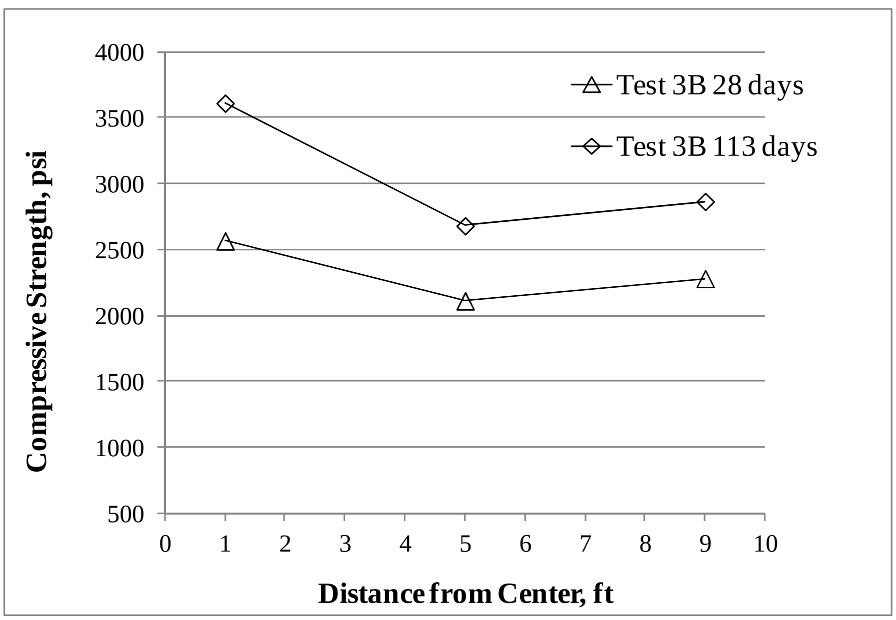


Figure 27 - Test 3B compressive strength as a function of curing time and distance from impact center. All samples were sent to the VSL in July 2014 and were stored at VSL in a moist environment until they were measured for compressive strength.

Saturated Hydraulic Conductivity Measurements

AMEC started the hydraulic conductivity procedure (ASTM D5084-10) on 8/13/14, at which time the samples had been cured for approximately 7 weeks. Hydraulic conductivity data associated with the samples for each test are shown in Figure 28. The data are also listed in Table 8. The hydraulic conductivity values ranged from $9.5x10^{-7}$ to $4.5x10^{-9}$ cm/s for all the samples tested. For each test, hydraulic conductivity increased with increasing distance from the impact center, as seen in Figure 28. Taking Test 1 as an example, the hydraulic conductivity was $3.8x10^{-8}$ cm/s at 1 ft from the impact center, increased to $1.70x10^{-7}$ cm/s at 5 ft, and further increased to $4.6x10^{-7}$ cm/s at 9 ft. For Test 3B, the hydraulic conductivity was $5.7x10^{-8}$ cm/s at 1 ft, increased to $2.9x10^{-7}$ cm/s at 5 ft, and further increased to $9.5x10^{-7}$ cm/s at 9 ft.

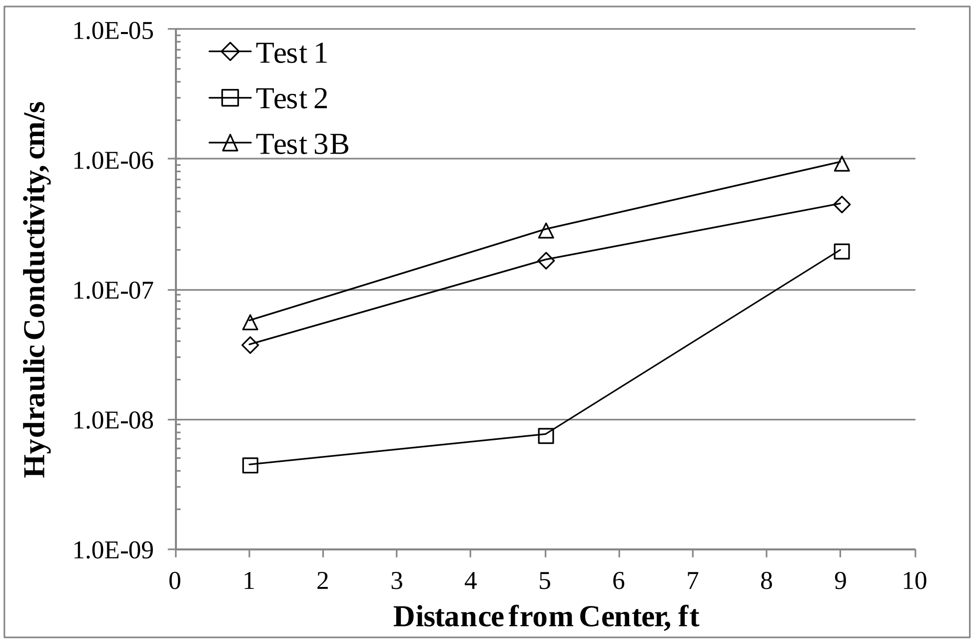


Figure 28 – Saturated hydraulic conductivity for samples cured for 7 weeks as a function of distance from the impact center

Table 8 - Saturated Hydraulic Conductivity of Grout Samples Cured for About 7 Weeks

Test #	Drop Conditions	Sample ID	Sample Location (Radius, ft)	Hydraulic Conductivity, cm/s
1	Tremie, no water	T1-1-H-1	1	$3.80x10^{-8}$
		T1-5-H-1	5	$1.70x10^{-7}$
		T1-9-H-1	9	$4.60x10^{-7}$
2	Tremie, 4" water	T2-1-H-1	1	$4.50x10^{-9}$
		T2-5-H-1	5	$7.60x10^{-9}$
		T2-9-H-1	9	$2.00x10^{-7}$
3B	No tremie, no water	T3B-1-H-1	1	$5.70x10^{-8}$
		T3B-5-H-1	5	$2.90x10^{-7}$
		T3B-9-H-1	9	$9.50x10^{-7}$

For the samples collected at all locations, Test 3B (no tremie and no water) had the highest hydraulic conductivity values, Test 2 (with tremie and 4" water) had the lowest values, and Test 1 (with tremie and no water) had intermediate values. The difference in hydraulic conductivity among the three tests increased with increasing distances from the impact center. Based on the data, the impact of the grout drop on hydraulic conductivity was more evident when no tremie was used.

The impact of the grout drop on compressive strength was most evident in Test 2 (tremie and 4" water), presumably due to the additional water. In contrast, the effect on hydraulic conductivity was most evident in Test 3B (no tremie and no water). Figure 29 shows the relationship between compressive strength and hydraulic conductivity of grout samples in the three tests. The general trend is decreasing hydraulic conductivity with increasing compressive strength.

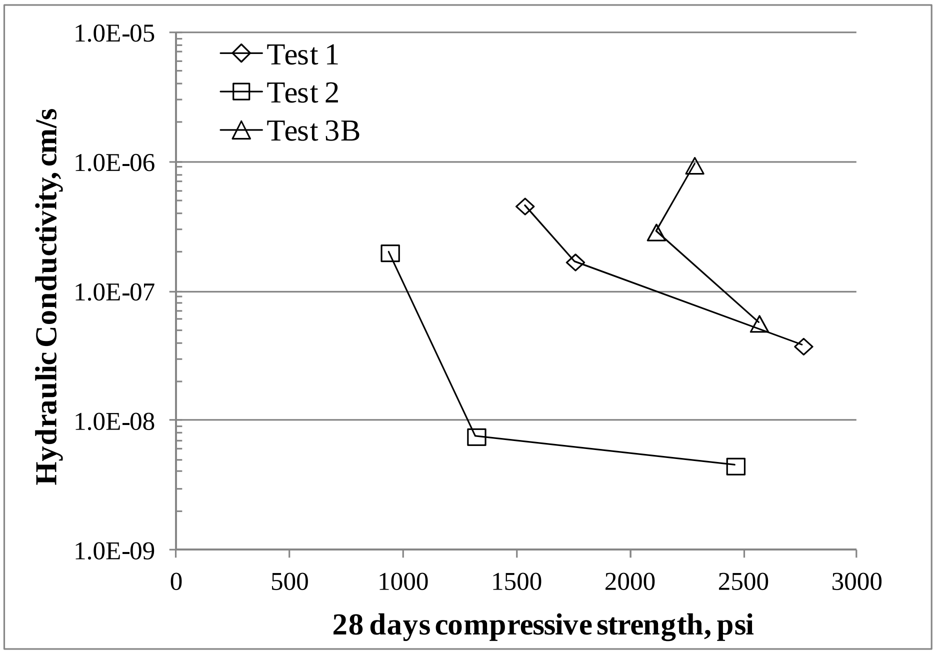


Figure 29 - Relationship between saturated hydraulic conductivity (7 week) and 28-day compressive strength

Six additional samples from Test 1 were subjected to the ASTM D5084-10 procedure for hydraulic conductivity after curing for 90 days. The results for hydraulic conductivity are presented in Table 9 – Additional Test 1 Data on Saturated Hydraulic Conductivity of Grout Samplesand Figure 30 with 7 week data included for comparison. The three samples with IDs ending with H-3 were core drilled on September 4, 2014 from the concrete monolith poured on June 22, 2014 and are identified as “90 days newly drilled” in Figure 30. The three samples with IDs ending with H-2 were drilled in July 2014 and stored at VSL in a 100% RH environment and are identified as “90 days aged” in Figure 30.

Table 9 – Additional Test 1 Data on Saturated Hydraulic Conductivity of Grout Samples

Sample ID	Sample Location (Radius, ft)	Curing Time	Hydraulic Conductivity, cm/s
T1-1-H-1	1	~7 weeks	$3.80x10^{-8}$
T1-5-H-1	5	~7 weeks	$1.70x10^{-7}$
T1-9-H-1	9	~7 weeks	$4.60x10^{-7}$
T1-1-H-2	1	90 days	$4.00x10^{-9}$
T1-5-H-2	5	90 days	$4.50x10^{-9}$
T1-9-H-2	9	90 days	$2.00x10^{-9}$
T1-1-H-3	1	90 days	$4.10x10^{-9}$
T1-5-H-3	5	90 days	$8.50x10^{-7}$
T1-9-H-3	9	90 days	$8.90x10^{-7}$
LP#8-16*	Laboratory Sample	70 days	$2.10x10^{-9}$

*Laboratory sample with the same grout mix composition (Stefanko and Langton [4]).

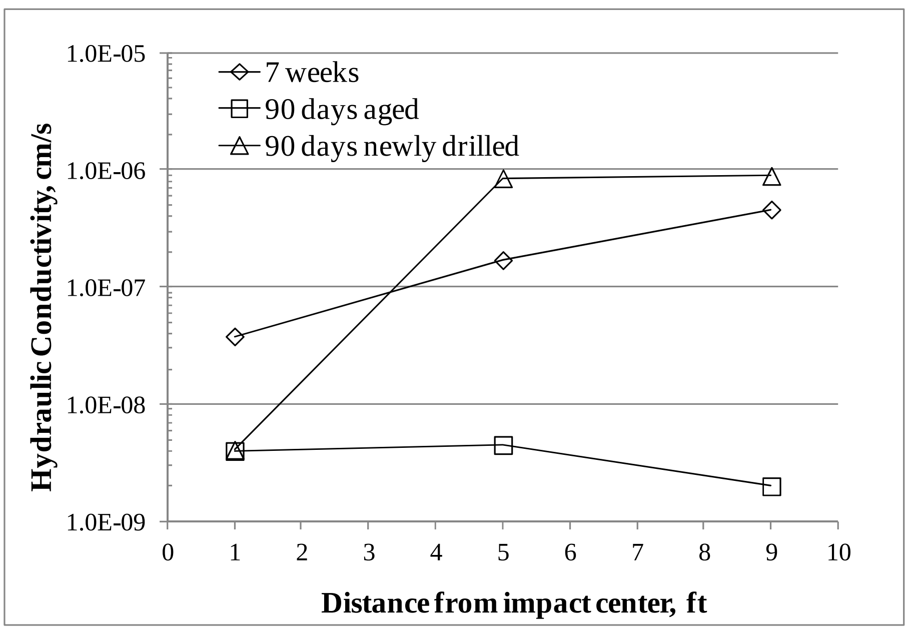


Figure 30 - Saturated hydraulic conductivity as a function of distance from the impact point for Test 1. The “90 days aged” samples were sent to VSL in the middle of July 2014 and stored in a moist environment until testing. The “90 days newly drilled” samples were drilled and sent to VSL in early September 2014 and measured shortly thereafter.

As a general trend, the 90-day hydraulic conductivity increased with increasing the distance from the impact center, which was consistent with the 7 week results. All the samples drilled in July 2014 (identified as 90 days aged in Figure 30) had saturated hydraulic conductivity values on the order of 10^{-9} cm/s at all sampling locations, very close to the value for the laboratory prepared sample (LP#8-16; [4]) with the same mix composition (Table 9). The newly drilled samples (identified as 90 days newly drilled in Figure 30) showed rather different behavior. Two of the three grout samples, T1-5-H-3 and T1-9-H-3 gave very high hydraulic conductivity values, on the order of 10^{-7} cm/s. The 90-day hydraulic conductivity values were even higher than those for the samples cured for only 7 weeks (Table 9). Two grout samples, T1-1-H-2 and T1-1-H-3, with different curing histories, gave hydraulic conductivity values on the order of 10^{-9} cm/s, close to the value for the laboratory sample (Table 9), suggesting that the effect of the grout drop is least near the impact center.

To verify the unexpectedly high hydraulic conductivity values for the two newly drilled samples at the 5 and 9 ft locations, (T1-5-H-3 and T1-9-H-3), AMEC tested the effect of confining pressure on the hydraulic conductivity of the samples. The test was intended to investigate the possibility of a leak along the cylindrical wall due to uneven wall surfaces caused by wobbling during drilling. The test results showed comparable hydraulic conductivity values at confining pressures of 10 psi and 15 psi. In addition, AMEC repeated hydraulic conductivity testing on the two samples on October 2, 2014. The results showed only a slight reduction in hydraulic conductivity. Thus, the newly drilled samples T1-5-H-3 and T1-9-H-3 do appear to have higher hydraulic conductivity values.

It is suggested that the combined effects of the grout drop and microstructural damage produced by drilling could be the underlying cause for the unexpectedly high hydraulic conductivity. The lower compressive strengths observed for the samples from the 5 ft and 9 ft locations as compared to those from the 1 ft location may have caused the microstructural damage produced by drilling to be greater for the 5-ft and 9-ft samples, leading to the higher observed values of hydraulic conductivity for those samples. Additionally, continued curing of grout samples under the moist storage conditions after drilling may result in some degree of self-healing of micro-cracks. This may be the case for the samples drilled in July 2014 and continually cured for an additional 2 months after drilling (90 days aged in Figure 30). During the additional time of curing under the 100% RH environment, $Ca(OH)_2$ would be released during continued hydration of Portland cement and soluble silicate would be released by continued hydration of blast furnace slag and fly ash. Soluble silicate transported along micro-cracks can then react with hydrated lime to precipitate calcium silicate hydrate (CSH). The precipitated CSH can tend to fill and sealed the micro-cracks. Self-healing of micro-cracks would be favored only when sufficient moisture was present in the grout. In contrast, the samples with IDs ending with H-3 were submitted for hydraulic conductivity testing immediately after drilling. It is likely, therefore, that there was not enough time for self-healing of the damage caused during drilling, leading to a higher hydraulic conductivity.

Self healing is a well-known phenomenon in Portland cement based concrete [5, 6]. For a newer concrete, further hydration of unreacted Portland cement particles provides the source of soluble silicate for formation of CSH that may precipitate in the microcracks. For aged concretes, carbonation of $Ca(OH)_2$ and precipitation of calcium carbonate in microcracks can be the dominant mechanism. Certain pozzolans such as blast furnace slag and/or Class F fly ash can be added to the concrete mix to promote self-healing [7]. The pozzolans hydrate slowly and provide soluble silicate for formation of CSH during the service time of concrete (Portland cement will complete hydration in a few years). In the present case, self-healing of micro-cracks could be stimulated by further hydration or alkali activation of blast furnace slag and fly ash under conditions in which free water is present during curing.

Archive samples from Test 3B that were stored at the VSL under a 100% RH environment had hydraulic conductivity measurements performed after 18 weeks of curing and the results of the measurements are shown in Table 10. As with the Test 1 samples, hydraulic conductivity values were significantly lower than the Test 3B samples that were analyzed after approximately 7 weeks of curing. The results further corroborate the self-healing of the grout samples over time and that the initial unexpectedly large hydraulic conductivity results of the samples cured for 7 weeks was likely the result of damage caused by the drilling of the samples. Figure 31 shows a comparison of the Test 3B samples cured for 7 and 18 weeks.

Table 10 - Additional Test 3B Data on Saturated Hydraulic Conductivity of Grout Samples

Sample ID	Sample Location (Radius, ft)	Curing Time	Hydraulic Conductivity, cm/s
T3B-1-H-1	1	~7 weeks	$5.70x10^{-8}$
T3B-5-H-1	5	~7 weeks	$2.90x10^{-7}$
T3B-9-H-1	9	~7 weeks	$9.50x10^{-7}$
T3B-1-H-2	1	~18 weeks	$6.50x10^{-9}$
T3B-5-H-2	5	~18 weeks	$5.40x10^{-9}$
T3B-9-C-1	9	~18 weeks	$3.60x10^{-9}$
LP#8-16*	Laboratory Sample	70 days	$2.10x10^{-9}$

*Laboratory sample with the same grout mix composition (Stefanko and Langton [4]).

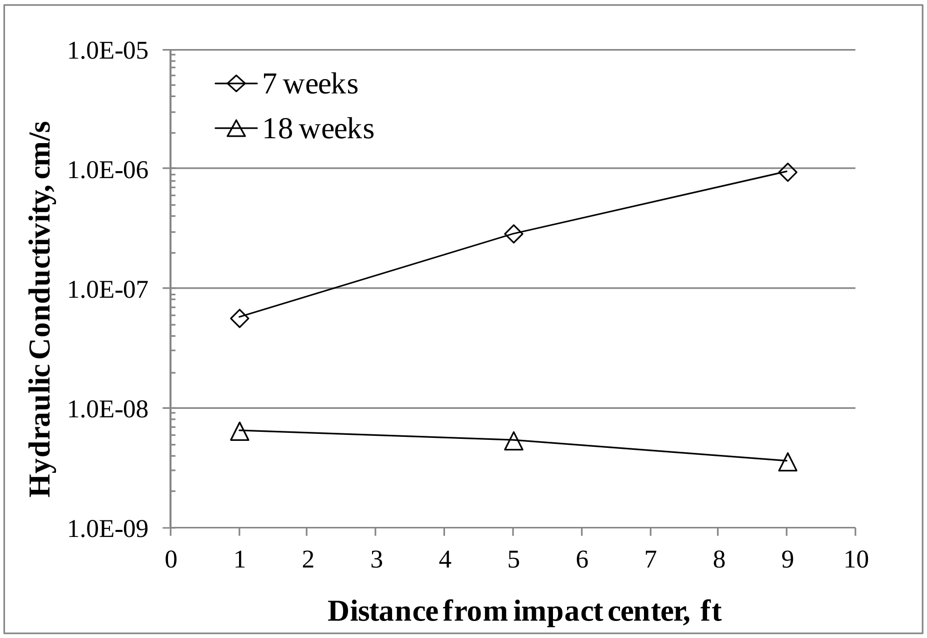


Figure 31 – Saturated hydraulic conductivity as a function of distance from the impact point for Test 3B samples. All samples were sent to VSL in the middle of July 2014 and stored in a moist environment until testing.

Optical Microscopy/Digital Analysis

Figure 32 – Figure 34 show photographs of the cylindrical samples for image analysis before being sawed into halves. The core samples from Test 1 show relatively uniform distribution of aggregate within the sample, although there appears to be a slight decrease in aggregate at the top of T1-9-O-1 (sample collected at the 9 foot radius position). Test 2 samples show clear segregation of the samples as the distance increase from the center of the containment area. Lack of aggregate in the top of samples T2-5-O-1 (5 foot radius sample) and T2-9-O-1 (9 foot radius sample) is consistent with the visual observations seen during the test. The fine material within the grout immediately mixed with the water and floated out towards the containment area walls. After the pour was completed, the fine material then settled on top of the grout resulting in the upper portion of the samples containing no aggregate. Samples from Test 3B are similar to Test 1 and show a uniform distribution of aggregate within all of the samples.

Figure 32 - Core Samples from Test 1 (1 foot radius sample at left and 9 foot radius sample on right)

Figure 33 - Core samples from Test 2 (1 foot radius sample at left and 9 foot radius samples on right)

Figure 34 - Core samples from Test 3B (1 foot radius sample at left and 9 foot radius sample on right)

Figure 35 - Figure 37 show optical images of cross sections where coarse aggregates were fully exposed and plots of the volumetric fractions of coarse aggregates (vertical axis) determined by image analysis as a function of distance from the top surface of the grout sample (horizontal axis). The cross sections of each sample have been rotated 90 degrees in the figures so that the top of the sample is on the left of the figure. Variations in volumetric fraction of coarse aggregates are indicative of the extent of aggregate segregation. Among all nine samples studied, two samples in Test 2, T2-5-O-1 and T2-9-O-1, showed significant segregation of coarse aggregates (see Table 11). Both samples were associated with the test where a tremie and 4” of standing water were used. The material within about 6 cm of the top surface of sample T2-9-O-1 was essentially free of coarse aggregates (Figure 36). Note that a small hump in the plotted aggregate fraction in the segregation zone was caused by artifacts in the image analysis, which is easily identified in the image (Figure 36). In the same test, there was little aggregate segregation present near the impact center. Little to no segregation of coarse aggregates was observed in the samples from Tests 1 and 3 (Figure 35 and Figure 37).

Table 11 - Information on Segregation of Coarse Aggregates in Grout Samples

Test	Drop Conditions	Sample ID	Segregation?
1	Tremie, no water	T1-1-O-1	Not evident
		T1-5-O-1	Not evident
		T1-9-O-1	Slight
2	Tremie, 4” water	T2-1-O-1	Not evident
		T2-5-O-1	Evident
		T2-9-O-1	Evident
3B	No tremie, no water	T3B-1-O-1	Not evident
		T3B-5-O-1	Not evident
		T3B-9-O-1	Not evident

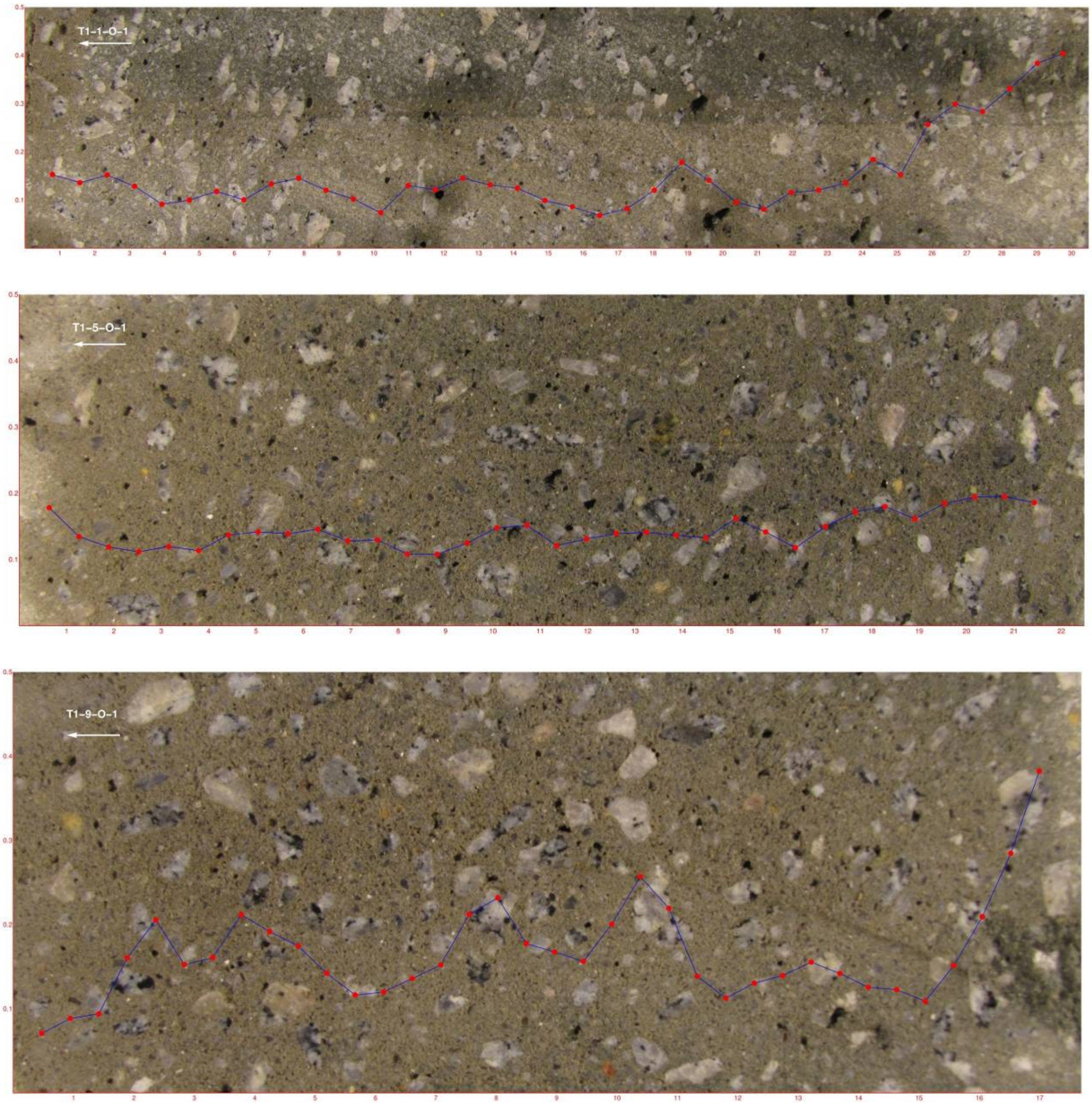


Figure 35 - Optical images of grout cross sections and spatial distribution of aggregate for Test 1. Top of sample is oriented to the left. Vertical axis is fraction of aggregate and horizontal axis is distance from top of sample in cm.

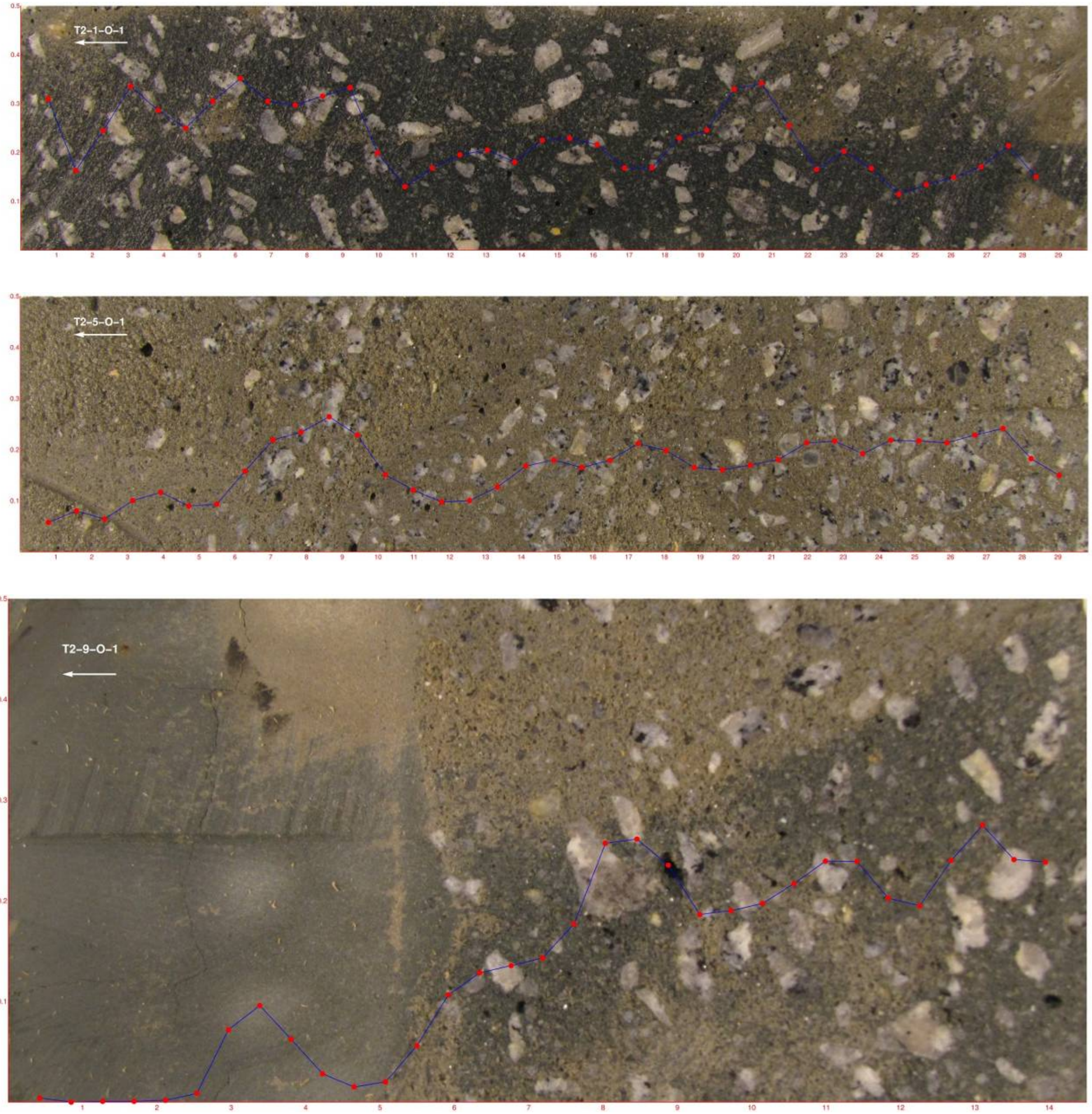


Figure 36 - Optical images of grout cross sections and spatial distribution of aggregate for Test 2. Top of sample is oriented to the left. Vertical axis is fraction of aggregate and horizontal axis is distance from top of sample in cm.

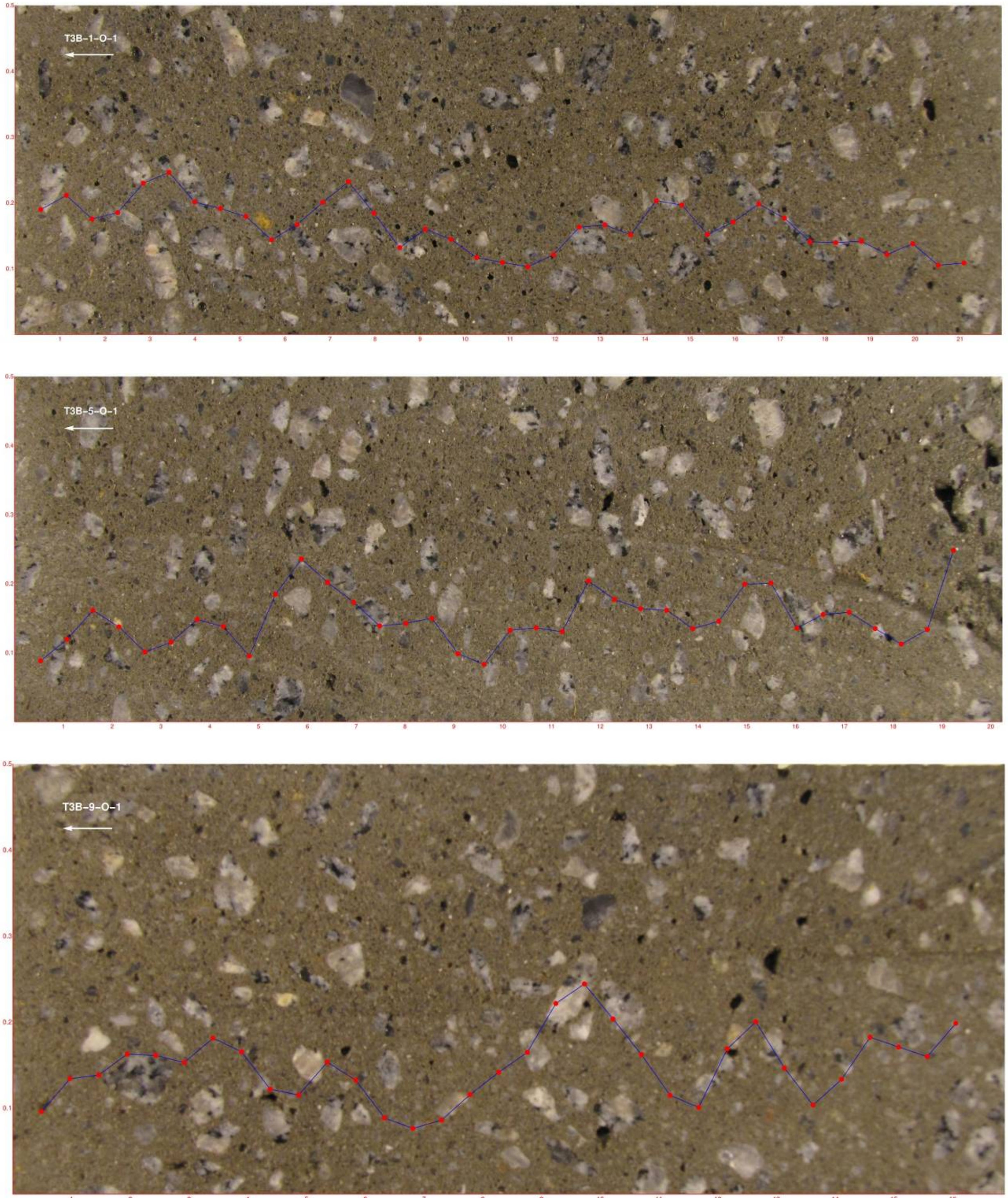


Figure 37 - Optical images of grout cross sections and spatial distribution of aggregate for Test 3B. Top of sample is oriented to the left. Vertical axis is fraction of aggregate and horizontal axis is distance from top of sample in cm.

5. CONCLUSIONS

Four large scale tank closure grout drop tests were performed in the ES Barnwell Facility in South Carolina to assess potential operational changes being considered by SRR. Tests 1 and 2 dropped tank closure grout from a height of 42 feet into a containment area utilizing a tremie positioned five feet above the impact point which contained no water and four inches of water, respectively. Tests 3A and 3B dropped SRR-provided tank closure grout from 42 feet into a containment area without a tremie and no water present. Dropping grout 42 feet without a tremie into four inches of water was not performed.

All tests were completed using the SRR-provided tank closure grout which was prepared in accordance with ASTM C94. Slump flow measurements for each test were within the 26 – 30 inch slump as required in the grout specification [3]. There were no visible signs of aggregate segregation during the placement of the tank closure grout during Tests 1, 3A, and 3B. However, during placement of the grout for Test 2, there was segregation of the grout with the aggregate settling to the bottom and the fines quickly mixing with the water and floating to the edges of the containment area.

Grout samples from three tests (Tests 1, 2, and 3B) were subjected to compressive strength measurements, saturated hydraulic conductivity testing and optical microscopy/imaging analysis for aggregate segregation. Effects of the impact of the grout drop were evident on compressive strength and hydraulic conductivity of cured grouts, primarily towards the edge of the pour. The major observations are given as follows:

- 28-day compressive strength decreased with increasing distance from the impact center. The effect of the grout drop was greater toward the edge of the pour.

- For Tests 1 and 3B, compressive strength increased with increasing curing time, as shown in Figure 25 and Figure 26. The grout samples at all locations had compressive strengths over 2000 psi after curing for at least 90 days.

- Grout drop conditions affected the compressive strength of the grout samples. The 28-day compressive strength was lowest for the samples from Test 2 where a tremie and 4” of standing water were used. Mixing of water into the grout was likely the main reason for lower compressive strength. Compressive strength was highest for samples from Test 3B where no tremie or water was used. Intermediate compressive strength values were found for samples from Test 1.

- Saturated hydraulic conductivity for the samples cured for 7 weeks increased with increasing distance from the impact center for each of the three tests. Grout drop conditions affected the hydraulic conductivity of the grout samples. The hydraulic conductivity was lowest for samples from Test 2 where a tremie and 4” standing water were used. The hydraulic conductivity was highest for samples from Test

3B where no tremie or water was used, and was intermediate for the samples from Test 1.

- The 90-day cured samples from Test 1 drilled from the grout monolith in early September, 2014 at 5 and 9 ft from the impact center showed significantly higher hydraulic conductivity, on the order of 10^{-7} cm/s, even after curing in the testing field for approximately 90 days. In comparison, the 90-day grout samples from the same test cured in a moist environment in the laboratory for 2 months after drilling had a low hydraulic conductivity, on the order of 10^{-9} cm/s, that was close to that observed for the laboratory sample, LP#8-16 cured for 70 days, reported by SRNL [1]. It is suggested that this behavior is due to damaged caused by drilling that self-heals during subsequent moist curing in the laboratory.

- Test 3B samples that were cured for 18 weeks and stored under a 100% RH environment had hydraulic conductivity measurements that were significantly lower than the Test 3B samples that were analyzed after 7 weeks of curing. The results further corroborate the self-healing of the grout samples over time and that the initial unexpectedly large hydraulic conductivity results of the samples cured for 7 weeks was likely the result of damage caused by the drilling of the samples.

- Optical microscopy/image analysis suggested that most of the samples showed little segregation of coarse aggregates with the exception of two samples farthest from the center in Test 2, which included 4” of standing water.

Based on the data collected, pouring tank closure grout into a tank without a tremie would not impact the properties of the cured grout. Both compressive strength and saturated hydraulic conductivity would be within the grout specification and segregation of the grout is not likely to occur. However, pouring grout into a conservatively estimated four inches of standing water is not recommended as significant segregation occurs and the grout will likely not meet the grout specification requirements for compressive strength. Additional testing would be needed to determine the grout performance at shallower water depths.

6. QUALITY ASSURANCE

ES performed this work under the SRR-approved Quality Assurance Program Plan [8]. This work was performed in accordance with the applicable requirements as outlined in the SRR SOW. In addition, these requirements were passed down to the VSL. Testing at the VSL was performed according to the existing quality assurance programs that are in place at the VSL which is compliant with applicable criteria of 10 CFR 830.120; Office of Civilian Waste Management DOE/RW-0333P, Quality Assurance Requirements and Description (QARD) Revision 20; the American Society of Mechanical Engineers (ASME) NQA-1, 2000; and DOE Order 414.1 C, Quality Assurance. For this scope of work, the requirements of DOE/RW-0333P were not applicable.

7. REFERENCES

[1] "Savannah River Remediation Tank Closure Grout Assessment Test Plan," G. Diener, PL-5539-EG-0009, Rev 0, Energy*Solutions*, Columbia, MD, June 17, 2014.

[2] "General Technical and Quality Requirements for EnergySolutions/Vitreous State Laboratory for Tank Closure Grout Assessment," Statement of Work, G-SOW-H-00174, Rev. 0, Savannah River Remediation, LLC, Aiken, SC, May 8, 2013.

[3] "Furnishing and Delivery of Tank Closure Grout," Procurement Specification, C-SPP-F-00055, Rev. 4, Savannah River Remediation, LLC, Aiken, SC, December 20, 2012.

[4] "Tanks 18 and 19-F Structural Flowable Grout Fill Material Evaluation and Recommendations," D. B. Stefanko and C. A. Langton, SRNL-STI-2011-00551 Revision 0, Savannah River National Laboratory and Savannah River Nuclear Solutions, LLC, Aiken, SC 29808, 2011.

[5] "A Review: Self-Healing in Cementitious Materials and Engineered Cementitious Composite as a Self-Healing Material," M. Wu, B. Johannesson and M. Geiker, Construction and Building Materials, 28 (2012) 571- 583.

[6] "Self-Healing in Cementitious Materials – A Review," K. Van Tittelboom and N. De Beli, Materials 6 (2013) 2182 - 2217.

[7] "Effect of Blast Furnace Slag on Self-Healing of Microcracks in Cementitious Materials," H. Huang, G. Ye and D. Damidot, Cement and Concrete Research, 60 (2014) 68 - 82.

[8] "Engineering and Technology Savannah River Remediation LLC Quality Assurance Project Plan for the Liquid Waste Operations Project," ET-SRR LWO-QAPP, Rev. 3, Energy*Solutions*, June 5, 2010.

8. ATTACHMENT – SATURATED HYDRAULIC CONDUCTIVITY DATA SHEETS

amec

December 2, 2014

The Catholic University of America
Vitreous State Laboratory
Cardinal Station
Hannan Hall #32
Washington D.C. 20064

Attention: Mr. Weiliang Gong

Subject:: **Report of Laboratory Hydraulic Conductivity Tests/Certificate of Conformance**
VSL Req# 38917/CUA PO0000082081, 8/7/2014
AMEC Project Name: CUA Grout Sample Testing
AMEC Project Number: 6163-13-0012

Dear Mr. Gong:

AMEC Environment & Infrastructure, Inc. (AMEC) has completed the second group of 18 hydraulic conductivity tests for the above referenced project. The test results are included in Attachment 1. An equipment list used in testing is included in Attachment 2. The equipment was calibrated in accordance with the applicable requirements of AMEC's Nuclear Quality Assurance Program and was NIST traceable. The tests performed are listed below along with applicable procedure:

Hydraulic Conductivity	Modified ASTM D5084-10

We hereby certify that the services supplied under this VSL Req# 38917/CUA PO0000082081 were performed in accordance with the applicable requirements of AMEC's Nuclear Quality Assurance Program and the requirements of the subject Contract VSL Req# 378917/CUA PO0000082081.

Please contact us if you have any questions.

AMEC Environment & Infrastructure, Inc.

Technical Lead — [signature] Jianren Wang — Date: 12/2/14

Chief Technical Lead — [signature] Paul Brafford — Date: 12/02/14

Quality Assurance Representative — JDM Digitally signed by John D Martin 2014.12.02 14:15:07 -05'00' — John D. Martin — Date:

Attachment 1

HYDRAULIC CONDUCTIVITY

Project No.	*6063-13-0012*	Tested By	*JW*
Project Name	*CUA Grout Sample Testing*	Test Date	*8/13/2014*
Boring No.	*T1-1-H-1*	Reviewed By	JEJ
Sample No.	*T1-1-H-1*	Review Date	9/12/14
Sample Depth	*N/A*	Lab No.	*12920*
Sample Description	*Concrete Core*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*11.9*
Wet Unit Weight, pcf:	*134.6*
Dry Unit Weight, pcf:	*120.3*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***3.8E-08***

Remarks: ______________________

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

amec

Project Number	6063-13-0012	Tested By	JW
Project Name	CUA Grout Sample Testing	Test Date	08/13/14
Boring No.	T1-1-H-1	Reviewed By	JGF
Sample No.	T1-1-H-1	Review Date	9/12/14
Sample Depth	N/A	Lab No.	12920
Sample Description	Concrete Core		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	V-81
Location 1	2.952	Location 1	2.732	Wet Soil+Pan, grams	634.31
Location 2	2.961	Location 2	2.733	Dry Soil + Pan, grams	567.39
Location3	3.008	Location 3	2.731	Pan Weight, grams	16.78
Average	2.974	Average	2.732	Moisture Content, %	12.2
Volume, in^3	17.43	Wet Soil + Tare, grams	616.00	Dry Unit Weight, pcf	120.3
SG Assumed	2.50	Tare Weight, grams	0.00	Saturation, %	102.5
Soil Sample Wt., g	616.00	Dry Soil +Tare, grams	550.61	Diameter, in.	N/A
Dry UW, pcf	120.3	Moisture Content, %	11.9	Length, in.	N/A
Saturation, %	100.2			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	70
Back Pressure, psi	60
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used water

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
1120	2.10	21.30	19.40	1.90	20.7	32.0	28.7	4.65E-08	4.58E-08
2880	2.10	21.30	17.10	4.20	21.3	32.0	24.7	4.30E-08	4.17E-08
990	2.10	22.20	20.70	1.50	21.4	33.5	30.9	3.92E-08	3.79E-08
2970	2.10	22.20	18.40	3.80	21.5	33.5	26.9	3.54E-08	3.41E-08
4980	2.10	22.20	16.00	6.20	21.5	33.5	22.7	3.73E-08	3.60E-08
1200	2.10	22.00	20.30	1.70	21.5	33.1	30.2	3.72E-08	3.59E-08
4500	2.10	22.00	16.60	5.40	21.5	33.1	23.8	3.54E-08	3.41E-08

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
7	Core	N/A	N/A	Vertical

Avg. k at 20 °C 3.8E-08 cm/sec

a_a = 0.76712 cm²

A = 37.82 cm²

L = 7.55 cm

S=L/A= 0.19971 1/cm

a_p= 0.031416 cm²

M_1= 0.03018

M_2= 1.04095

$C = M_1S/(G_{Hg}-1)$= 0.0004795 for 15° to 25°

Remarks:

HYDRAULIC CONDUCTIVITY

Project No.	*6163-13-0012*	Tested By	*JW*
Project Name	*CUA Grout Sample Testing*	Test Date	*8/13/2014*
Boring No.	*T1-5-H-1*	Reviewed By	JEA
Sample No.	*T1-5-H-1*	Review Date	9/12/14
Sample Depth	*N/A*	Lab No.	*12921*
Sample Description	*Concrete Core*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*11.9*
Wet Unit Weight, pcf:	*132.5*
Dry Unit Weight, pcf:	*118.4*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***1.7E-07***

Remarks:

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

amec

Project Number	6163-13-0012	Tested By	JW
Project Name	CUA Grout Sample Testing	Test Date	08/13/14
Boring No.	T1-5-H-1	Reviewed By	JEJ
Sample No.	T1-5-H-1	Review Date	9/12/14
Sample Depth	N/A	Lab No.	12921
Sample Description	Concrete Core		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	V-75
Location 1	3.218	Location 1	2.735	Wet Soil+Pan, grams	680.92
Location 2	3.243	Location 2	2.735	Dry Soil + Pan, grams	603.49
Location3	3.192	Location 3	2.732	Pan Weight, grams	16.18
Average	3.218	Average	2.734	Moisture Content, %	13.2
Volume, in^3	18.89	Wet Soil + Tare, grams	656.96	Dry Unit Weight, pcf	118.4
SG Assumed	2.50	Tare Weight, grams	0.00	Saturation, %	103.9
Soil Sample Wt., g	656.96	Dry Soil +Tare, grams	587.31	Diameter, in.	N/A
Dry UW, pcf	118.4	Moisture Content, %	11.9	Length, in.	N/A
Saturation, %	93.5			Volume, in^3	N/A

Consolidation	
Chamber Pressure, psi	70
Back Pressure, psi	60
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used water

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
370	2.10	21.00	18.30	2.70	20.7	29.1	24.7	2.25E-07	2.22E-07
480	2.10	21.00	17.90	3.10	20.7	29.1	24.1	2.02E-07	1.99E-07
720	2.10	21.00	16.80	4.20	20.7	29.1	22.3	1.89E-07	1.86E-07
180	2.10	20.30	19.30	1.00	20.7	28.0	26.4	1.70E-07	1.67E-07
390	2.10	20.30	18.30	2.00	20.7	28.0	24.8	1.61E-07	1.59E-07
540	2.10	20.30	17.80	2.50	20.7	28.0	24.0	1.48E-07	1.46E-07
900	2.10	20.30	16.30	4.00	20.7	28.0	21.6	1.50E-07	1.47E-07

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
7	Core	N/A	N/A	Vertical

Avg. k at 20 °C 1.7E-07 cm/sec

a_a = 0.76712 cm²

A = 37.88 cm²

L = 8.17 cm

S=L/A= 0.21578 1/cm

a_p= 0.031416 cm²

M_1= 0.03018

M_2= 1.04095

$C = M_1S/(G_{Hg}-1)$= 0.0005181 for 15° to 25°

Remarks:

HYDRAULIC CONDUCTIVITY

Project No.	*6163-13-0012*	Tested By	*JW*
Project Name	*CUA Grout Sample Testing*	Test Date	*8/13/2014*
Boring No.	*T1-9-H-1*	Reviewed By	JEJ
Sample No.	*T1-9-H-1*	Review Date	9/12/14
Sample Depth	*N/A*	Lab No.	*12922*
Sample Description	*Concrete Core*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*12.4*
Wet Unit Weight, pcf:	*131.6*
Dry Unit Weight, pcf:	*117.1*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***4.6E-07***

Remarks: ______________________

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

amec

Project Number	6163-13-0012	Tested By	JW
Project Name	CUA Grout Sample Testing	Test Date	08/13/14
Boring No.	T1-9-H-1	Reviewed By	OEJ
Sample No.	T1-9-H-1	Review Date	9/12/14
Sample Depth	N/A	Lab No.	12922
Sample Description	Concrete Core		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	R-5
Location 1	3.193	Location 1	2.733	Wet Soil+Pan, grams	670.96
Location 2	3.181	Location 2	2.735	Dry Soil + Pan, grams	591.58
Location3	3.183	Location 3	2.736	Pan Weight, grams	16.66
Average	3.186	Average	2.735	Moisture Content, %	13.8
Volume, in^3	18.71	Wet Soil + Tare, grams	646.14	Dry Unit Weight, pcf	117.1
SG Assumed	2.50	Tare Weight, grams	0.00	Saturation, %	103.7
Soil Sample Wt., g	646.14	Dry Soil +Tare, grams	574.92	Diameter, in.	N/A
Dry UW, pcf	117.1	Moisture Content, %	12.4	Length, in.	N/A
Saturation, %	93.1			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	70
Back Pressure, psi	60
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used water

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
60	2.10	18.00	17.20	0.80	21.6	24.7	23.4	4.60E-07	4.42E-07
120	2.10	18.00	16.40	1.60	21.6	24.7	22.1	4.73E-07	4.55E-07
180	2.10	18.00	15.60	2.40	21.6	24.7	20.8	4.87E-07	4.69E-07
240	2.10	18.00	14.90	3.10	21.6	24.7	19.7	4.85E-07	4.66E-07
360	2.10	18.00	13.70	4.30	21.6	24.7	17.7	4.71E-07	4.53E-07
60	2.10	19.00	18.10	0.90	21.6	26.3	24.8	4.87E-07	4.69E-07
120	2.10	19.00	17.30	1.70	21.6	26.3	23.5	4.73E-07	4.55E-07

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
7	Core	N/A	N/A	Vertical

Avg. k at 20 °C 4.6E-07 cm/sec

a_a = 0.76712 cm²

A = 37.89 cm²

L = 8.09 cm

S=L/A= 0.21353 1/cm

a_p= 0.031416 cm²

M_1= 0.03018

M_2= 1.04095

$C = M_1S/(G_{Hg}-1)$= 0.0005127 for 15° to 25°

Remarks:

HYDRAULIC CONDUCTIVITY

Project No.	*6163-13-0012*	Tested By	*JW*
Project Name	*CUA Grout Sample Testing*	Test Date	*8/13/2014*
Boring No.	*T2-1-H-1*	Reviewed By	JEJ
Sample No.	*T2-1-H-1*	Review Date	9/12/14
Sample Depth	*N/A*	Lab No.	*12923*
Sample Description	*Concrete Core*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*12.3*
Wet Unit Weight, pcf:	*134.7*
Dry Unit Weight, pcf:	*120.0*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***4.5E-09***

Remarks: ____________________

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

amec

Project Number	6163-13-0012	Tested By	JW
Project Name	CUA Grout Sample Testing	Test Date	08/13/14
Boring No.	T2-1-H-1	Reviewed By	JEJ
Sample No.	T2-1-H-1	Review Date	9/12/14
Sample Depth	N/A	Lab No.	12923
Sample Description	Concrete Core		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	R-29
Location 1	3.255	Location 1	2.739	Wet Soil+Pan, grams	690.29
Location 2	3.223	Location 2	2.736	Dry Soil + Pan, grams	616.20
Location3	3.226	Location 3	2.738	Pan Weight, grams	16.5
Average	3.235	Average	2.738	Moisture Content, %	12.4
Volume, in^3	19.04	Wet Soil + Tare, grams	673.49	Dry Unit Weight, pcf	120.0
SG Assumed	2.50	Tare Weight, grams	0.00	Saturation, %	102.9
Soil Sample Wt., g	673.49	Dry Soil +Tare, grams	599.70	Diameter, in.	N/A
Dry UW, pcf	120.0	Moisture Content, %	12.3	Length, in.	N/A
Saturation, %	102.5			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	70
Back Pressure, psi	60
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used water

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
3600	2.00	27.30	26.30	1.00	21.6	38.7	37.1	6.06E-09	5.83E-09
5400	2.00	27.30	26.00	1.30	21.6	38.7	36.6	5.29E-09	5.09E-09
8850	2.00	27.30	25.40	1.90	20.7	38.7	35.7	4.78E-09	4.70E-09
12420	2.00	27.30	25.00	2.30	21.3	38.7	35.0	4.16E-09	4.03E-09
15480	2.00	27.30	24.50	2.80	21.5	38.7	34.2	4.11E-09	3.96E-09
18660	2.00	27.30	24.00	3.30	21.6	38.7	33.5	4.06E-09	3.91E-09
22740	2.00	27.30	23.40	3.90	21.7	38.7	32.5	4.00E-09	3.84E-09

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
7	Core	N/A	N/A	Vertical

Avg. k at 20 °C 4.5E-09 cm/sec

$a_a =$ 0.76712 cm²

A = 37.98 cm²

L = 8.22 cm

S=L/A= 0.21634 1/cm

$a_p =$ 0.031416 cm²

$M_1 =$ 0.03018

$M_2 =$ 1.04095

$C = M_1 S/(G_{Hg}-1) =$ 0.0005194 for 15° to 25°

Remarks:

amec

HYDRAULIC CONDUCTIVITY

Project No.	*6163-13-0012*	Tested By	*JW*
Project Name	*CUA Grout Sample Testing*	Test Date	*8/13/2014*
Boring No.	*T2-5-H-1*	Reviewed By	JGJ
Sample No.	*T2-5-H-1*	Review Date	9/12/14
Sample Depth	*N/A*	Lab No.	*12924*
Sample Description	*Concrete Core*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*12.1*
Wet Unit Weight, pcf:	*134.6*
Dry Unit Weight, pcf:	*120.0*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***7.6E-09***

Remarks:

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

amec

Project Number	6163-13-0012	Tested By	JW
Project Name	CUA Grout Sample Testing	Test Date	08/13/14
Boring No.	T2-5-H-1	Reviewed By	JEF
Sample No.	T2-5-H-1	Review Date	9/12/14
Sample Depth	N/A	Lab No.	12924
Sample Description	Concrete Core		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	V-32
Location 1	3.218	Location 1	2.740	Wet Soil+Pan, grams	674.00
Location 2	3.135	Location 2	2.738	Dry Soil + Pan, grams	601.89
Location3	3.132	Location 3	2.738	Pan Weight, grams	15.06
Average	3.162	Average	2.739	Moisture Content, %	12.3
Volume, in^3	18.62	Wet Soil + Tare, grams	657.95	Dry Unit Weight, pcf	120.0
SG Assumed	2.50	Tare Weight, grams	0.00	Saturation, %	102.5
Soil Sample Wt., g	657.95	Dry Soil +Tare, grams	586.83	Diameter, in.	N/A
Dry UW, pcf	120.0	Moisture Content, %	12.1	Length, in.	N/A
Saturation, %	101.1			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	70
Back Pressure, psi	60
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used water

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
4620	2.00	26.90	25.00	1.90	21.2	39.0	35.9	9.09E-09	8.83E-09
7680	2.00	26.90	24.30	2.60	21.3	39.0	34.7	7.60E-09	7.37E-09
10590	2.00	26.90	23.50	3.40	21.4	39.0	33.4	7.34E-09	7.10E-09
13500	2.00	26.90	22.40	4.50	21.5	39.0	31.6	7.83E-09	7.56E-09
17640	2.00	26.90	21.30	5.60	21.6	39.0	29.9	7.67E-09	7.38E-09
21180	2.00	26.90	20.30	6.60	21.6	39.0	28.2	7.73E-09	7.44E-09
23640	2.00	26.90	19.70	7.20	21.6	39.0	27.2	7.69E-09	7.40E-09

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
7	Core	N/A	N/A	Vertical

Avg. k at 20 °C 7.6E-09 cm/sec

a_a = 0.76712 cm²
A = 38.00 cm²
L = 8.03 cm
S=L/A= 0.21131 1/cm

a_p= 0.031416 cm²
M_1= 0.03018
M_2= 1.04095
$C = M_1S/(G_{Hg}-1)$= 0.0005073 for 15° to 25°

Remarks:

HYDRAULIC CONDUCTIVITY

Project No.	*6163-13-0012*	Tested By	*JW*
Project Name	*CUA Grout Sample Testing*	Test Date	*8/13/2014*
Boring No.	*T2-9-H-1*	Reviewed By	JEJ
Sample No.	*T2-9-H-1*	Review Date	9/12/14
Sample Depth	*N/A*	Lab No.	*12925*
Sample Description	*Concrete Core*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*14.4*
Wet Unit Weight, pcf:	*131.9*
Dry Unit Weight, pcf:	*115.3*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***2.0E-07***

Remarks:

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

Project Number	6163-13-0012	Tested By	JW
Project Name	CUA Grout Sample Testing	Test Date	08/13/14
Boring No.	T2-9-H-1	Reviewed By	JEF
Sample No.	T2-9-H-1	Review Date	9/12/14
Sample Depth	N/A	Lab No.	12925
Sample Description	Concrete Core		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	R-19
Location 1	3.247	Location 1	2.736	Wet Soil+Pan, grams	675.18
Location 2	3.227	Location 2	2.736	Dry Soil + Pan, grams	591.66
Location3	3.225	Location 3	2.733	Pan Weight, grams	16.62
Average	3.233	Average	2.735	Moisture Content, %	14.5
Volume, in^3	18.99	Wet Soil + Tare, grams	657.60	Dry Unit Weight, pcf	115.3
SG Assumed	2.50	Tare Weight, grams	0.00	Saturation, %	103.0
Soil Sample Wt., g	657.60	Dry Soil +Tare, grams	575.04	Diameter, in.	N/A
Dry UW, pcf	115.3	Moisture Content, %	14.4	Length, in.	N/A
Saturation, %	101.8			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	70
Back Pressure, psi	60
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used water

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
390	2.00	23.00	20.10	2.90	21.0	32.1	27.5	2.07E-07	2.02E-07
690	2.00	23.00	18.30	4.70	21.0	32.1	24.7	2.00E-07	1.95E-07
345	2.00	19.30	17.40	1.90	21.0	26.5	23.5	1.83E-07	1.79E-07
660	2.00	19.30	16.00	3.30	21.1	26.5	21.2	1.74E-07	1.70E-07
660	2.00	18.00	14.30	3.70	21.2	24.5	18.6	2.17E-07	2.11E-07
345	2.00	19.50	17.10	2.40	21.2	26.8	23.0	2.32E-07	2.26E-07
420	2.00	18.00	15.70	2.30	21.2	24.5	20.8	2.01E-07	1.95E-07

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
7	Core	N/A	N/A	Vertical

Avg. k at 20 °C 2.0E-07 cm/sec

$a_a =$ 0.76712 cm²

A = 37.90 cm²

L = 8.21 cm

S=L/A= 0.21665 1/cm

$a_p =$ 0.031416 cm²

$M_1 =$ 0.03018

$M_2 =$ 1.04095

$C = M_1 S/(G_{Hg}-1) =$ 0.0005202 for 15° to 25°

Remarks:

HYDRAULIC CONDUCTIVITY

Project No.	*6163-13-0012*	Tested By	*JW*
Project Name	*CUA Grout Sample Testing*	Test Date	*8/13/2014*
Boring No.	*T3B-1-H-1*	Reviewed By	JEA
Sample No.	*T3B-1-H-1*	Review Date	11/12/14
Sample Depth	*N/A*	Lab No.	*12926*
Sample Description	*Concrete Core*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*11.9*
Wet Unit Weight, pcf:	*133.1*
Dry Unit Weight, pcf:	*119.0*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***5.7E-08***

Remarks: ______________________________

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

amec

Project Number	6163-13-0012	Tested By	JW
Project Name	CUA Grout Sample Testing	Test Date	08/13/14
Boring No.	T3B-1-H-1	Reviewed By	JEF
Sample No.	T3B-1-H-1	Review Date	11/12/14
Sample Depth	N/A	Lab No.	12926
Sample Description	Concrete Core		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	R-18
Location 1	3.047	Location 1	2.723	Wet Soil+Pan, grams	644.53
Location 2	3.050	Location 2	2.737	Dry Soil + Pan, grams	574.59
Location3	3.059	Location 3	2.733	Pan Weight, grams	16.32
Average	3.052	Average	2.731	Moisture Content, %	12.5
Volume, in^3	17.88	Wet Soil + Tare, grams	624.72	Dry Unit Weight, pcf	119.0
SG Assumed	2.50	Tare Weight, grams	0.00	Saturation, %	100.6
Soil Sample Wt., g	624.72	Dry Soil +Tare, grams	558.27	Diameter, in.	N/A
Dry UW, pcf	119.0	Moisture Content, %	11.9	Length, in.	N/A
Saturation, %	95.6			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	70
Back Pressure, psi	60
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used water

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
690	2.10	21.70	20.00	1.70	21.5	31.8	28.9	6.75E-08	6.52E-08
1350	2.10	21.70	18.80	2.90	21.5	31.8	26.9	6.10E-08	5.89E-08
1980	2.10	21.70	17.50	4.20	21.5	31.8	24.7	6.28E-08	6.06E-08
600	2.10	19.50	18.40	1.10	21.5	28.2	26.4	5.59E-08	5.39E-08
1050	2.10	19.50	17.50	2.00	21.5	28.2	24.8	5.98E-08	5.77E-08
1800	2.10	19.50	16.40	3.10	21.5	28.2	23.0	5.61E-08	5.41E-08
2640	2.10	19.50	15.30	4.20	21.5	28.2	21.1	5.40E-08	5.21E-08

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
7	Core	N/A	N/A	Vertical

Avg. k at 20 °C 5.7E-08 cm/sec

$a_a =$ 0.76712 cm²

A = 37.79 cm²

L = 7.75 cm

S=L/A= 0.20512 1/cm

$a_p =$ 0.031416 cm²

$M_1 =$ 0.03018

$M_2 =$ 1.04095

$C = M_1 S/(G_{Hg}-1) =$ 0.0004925 for 15° to 25°

Remarks:

HYDRAULIC CONDUCTIVITY

Project No.	*6163-13-0012*	Tested By	*JW*
Project Name	*CUA Grout Sample Testing*	Test Date	*8/13/2014*
Boring No.	*T3B-5-H-1*	Reviewed By	JEA
Sample No.	*T3B-5-H-1*	Review Date	11/12/14
Sample Depth	*N/A*	Lab No.	*12927*
Sample Description	*Concrete Core*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*11.6*
Wet Unit Weight, pcf:	*133.8*
Dry Unit Weight, pcf:	*119.9*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***2.9E-07***

Remarks:

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

amec

Project Number	6163-13-0012	Tested By	JW
Project Name	CUA Grout Sample Testing	Test Date	08/13/14
Boring No.	T3B-5-H-1	Reviewed By	[signature]
Sample No.	T3B-5-H-1	Review Date	11/12/14
Sample Depth	N/A	Lab No.	12927
Sample Description	Concrete Core		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	R-25
Location 1	3.145	Location 1	2.735	Wet Soil+Pan, grams	668.18
Location 2	3.127	Location 2	2.734	Dry Soil + Pan, grams	597.15
Location3	3.149	Location 3	2.735	Pan Weight, grams	16.63
Average	3.140	Average	2.735	Moisture Content, %	12.2
Volume, in^3	18.44	Wet Soil + Tare, grams	647.68	Dry Unit Weight, pcf	119.9
SG Assumed	2.50	Tare Weight, grams	0.00	Saturation, %	101.6
Soil Sample Wt., g	647.68	Dry Soil +Tare, grams	580.52	Diameter, in.	N/A
Dry UW, pcf	119.9	Moisture Content, %	11.6	Length, in.	N/A
Saturation, %	96.1			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	70
Back Pressure, psi	60
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used water

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
840	2.00	19.20	12.20	7.00	21.3	27.1	15.6	3.32E-07	3.21E-07
300	2.00	15.30	13.00	2.30	21.3	21.0	17.2	3.34E-07	3.24E-07
600	2.00	15.30	11.30	4.00	21.3	21.0	14.4	3.16E-07	3.07E-07
270	2.00	15.40	13.50	1.90	21.3	21.1	18.0	2.99E-07	2.90E-07
480	2.00	15.40	12.10	3.30	21.3	21.1	15.7	3.12E-07	3.02E-07
180	2.00	14.40	13.30	1.10	21.3	19.5	17.7	2.72E-07	2.64E-07
300	2.00	14.40	12.70	1.70	21.3	19.5	16.8	2.59E-07	2.51E-07

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
7	Core	N/A	N/A	Vertical

Avg. k at 20 °C 2.9E-07 cm/sec

a_a = 0.76712 cm²

A = 37.89 cm²

L = 7.98 cm

S=L/A= 0.21050 1/cm

a_p= 0.031416 cm²

M_1= 0.03018

M_2= 1.04095

$C = M_1S/(G_{Hg}-1)$= 0.0005054 for 15° to 25°

Remarks:

amec

HYDRAULIC CONDUCTIVITY

Project No.	*6163-13-0012*	Tested By	*JW*
Project Name	*CUA Grout Sample Testing*	Test Date	*8/13/2014*
Boring No.	*T3B-9-H-1*	Reviewed By	JEJ
Sample No.	*T3B-9-H-1*	Review Date	11/12/14
Sample Depth	*N/A*	Lab No.	*12928*
Sample Description	*Concrete Core*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*11.7*
Wet Unit Weight, pcf:	*133.4*
Dry Unit Weight, pcf:	*119.5*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***9.5E-07***

Remarks:

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

amec

Project Number	6163-13-0012	Tested By	JW
Project Name	CUA Grout Sample Testing	Test Date	08/13/14
Boring No.	T3B-9-H-1	Reviewed By	JEJ
Sample No.	T3B-9-H-1	Review Date	11/12/14
Sample Depth	N/A	Lab No.	12928
Sample Description	Concrete Core		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	V-25
Location 1	3.110	Location 1	2.732	Wet Soil+Pan, grams	659.25
Location 2	3.110	Location 2	2.734	Dry Soil + Pan, grams	586.92
Location3	3.098	Location 3	2.739	Pan Weight, grams	14.47
Average	3.106	Average	2.735	Moisture Content, %	12.6
Volume, in^3	18.25	Wet Soil + Tare, grams	639.16	Dry Unit Weight, pcf	119.5
SG Assumed	2.50	Tare Weight, grams	0.00	Saturation, %	103.5
Soil Sample Wt., g	639.16	Dry Soil +Tare, grams	572.45	Diameter, in.	N/A
Dry UW, pcf	119.5	Moisture Content, %	11.7	Length, in.	N/A
Saturation, %	95.4			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	70
Back Pressure, psi	60
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used water

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
30	2.00	20.00	19.00	1.00	21.3	28.7	27.0	9.92E-07	9.62E-07
60	2.00	20.00	18.00	2.00	21.3	28.7	25.4	1.02E-06	9.92E-07
94	2.00	20.00	17.00	3.00	21.3	28.7	23.7	1.01E-06	9.82E-07
125	2.00	20.00	16.00	4.00	21.3	28.7	22.0	1.05E-06	1.02E-06
29	2.00	20.00	19.00	1.00	21.3	28.7	27.0	1.03E-06	9.95E-07
32	2.00	20.00	19.00	1.00	21.3	28.7	27.0	9.30E-07	9.02E-07
54	2.00	20.00	18.50	1.50	21.3	28.7	26.2	8.40E-07	8.14E-07

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
7	Core	N/A	N/A	Vertical

Avg. k at 20 °C 9.5E-07 cm/sec

a_a = 0.76712 cm²
A = 37.90 cm²
L = 7.89 cm
S=L/A= 0.20814 1/cm

a_p= 0.031416 cm²
M_1= 0.03018
M_2= 1.04095
$C = M_1 S/(G_{Hg}-1)$= 0.0004997 for 15° to 25°

Remarks:

HYDRAULIC CONDUCTIVITY

Project No.	*6163-13-0012*	Tested By	*JW*
Project Name	*CUA Grout Sample Testing*	Test Date	*9/22/2014*
Boring No.	*T1-1-H-2*	Reviewed By	JEF
Sample No.	*T1-1-H-2*	Review Date	11/12/14
Sample Depth	*N/A*	Lab No.	*13000*
Sample Description	*Concrete Core*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*12.8*
Wet Unit Weight, pcf:	*134.0*
Dry Unit Weight, pcf:	*118.9*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***4.0E-09***

Remarks:

PERMEABILITY TEST

(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

amec

Project Number 6163-13-0012
Project Name CUA Grout Sample Testing
Boring No. T1-1-H-2
Sample No. T1-1-H-2
Sample Depth N/A
Sample Description Concrete Core

Tested By JW
Test Date 09/22/14
Reviewed By JGA
Review Date 11/12/14
Lab No. 13000

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	R-38
Location 1	3.131	Location 1	2.729	Wet Soil+Pan, grams	666.98
Location 2	3.170	Location 2	2.728	Dry Soil + Pan, grams	592.83
Location3	3.174	Location 3	2.731	Pan Weight, grams	16.24
Average	3.158	Average	2.729	Moisture Content, %	12.9
Volume, in^3	18.48	Wet Soil + Tare, grams	650.18	Dry Unit Weight, pcf	118.9
SG Assumed	2.50	Tare Weight, grams	0.00	Saturation, %	102.9
Soil Sample Wt., g	650.18	Dry Soil +Tare, grams	576.59	Diameter, in.	N/A
Dry UW, pcf	118.9	Moisture Content, %	12.8	Length, in.	N/A
Saturation, %	102.2			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	75
Back Pressure, psi	60
Confining Pressure, psi	15
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used water

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
9660	2.00	23.40	21.70	1.70	21.5	33.5	30.8	4.56E-09	4.40E-09
15540	2.00	23.40	21.00	2.40	21.6	33.5	29.6	4.08E-09	3.92E-09
18780	2.00	23.40	20.60	2.80	21.7	33.5	29.0	3.98E-09	3.82E-09
21720	2.00	23.40	20.20	3.20	21.7	33.5	28.3	3.97E-09	3.82E-09
23940	2.00	23.40	20.00	3.40	21.7	33.5	28.0	3.85E-09	3.70E-09
2550	2.00	25.00	24.50	0.50	21.5	36.0	35.2	4.58E-09	4.42E-09
6060	2.00	25.00	24.00	1.00	21.5	36.0	34.4	3.90E-09	3.76E-09

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
7	Core	N/A	N/A	Vertical

Avg. k at 20 °C 4.0E-09 cm/sec

$a_a =$ 0.76712 cm²
A = 37.75 cm²
L = 8.02 cm
S=L/A= 0.21253 1/cm

$a_p =$ 0.031416 cm²
$M_1 =$ 0.03018
$M_2 =$ 1.04095
$C = M_1 S/(G_{Hg}-1) =$ 0.0005103 for 15° to 25°

Remarks:

amec

HYDRAULIC CONDUCTIVITY

Project No.	*6163-13-0012*	Tested By	*JW*
Project Name	*CUA Grout Sample Testing*	Test Date	*9/22/2014*
Boring No.	*T1-5-H-2*	Reviewed By	JEA
Sample No.	*T1-5-H-2*	Review Date	11/12/14
Sample Depth	*N/A*	Lab No.	*13001*
Sample Description	*Concrete Core*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*12.4*
Wet Unit Weight, pcf:	*131.8*
Dry Unit Weight, pcf:	*117.2*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***4.5E-09***

Remarks:

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

amec

Project Number	6163-13-0012	Tested By	JW
Project Name	CUA Grout Sample Testing	Test Date	09/22/14
Boring No.	T1-5-H-2	Reviewed By	JEJ
Sample No.	T1-5-H-2	Review Date	11/12/14
Sample Depth	N/A	Lab No.	13001
Sample Description	Concrete Core		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	V-16
Location 1	3.132	Location 1	2.732	Wet Soil+Pan, grams	650.48
Location 2	3.111	Location 2	2.726	Dry Soil + Pan, grams	577.87
Location3	3.117	Location 3	2.736	Pan Weight, grams	15.4
Average	3.120	Average	2.731	Moisture Content, %	12.9
Volume, in^3	18.28	Wet Soil + Tare, grams	632.37	Dry Unit Weight, pcf	117.2
SG Assumed	2.50	Tare Weight, grams	0.00	Saturation, %	97.5
Soil Sample Wt., g	632.37	Dry Soil +Tare, grams	562.47	Diameter, in.	N/A
Dry UW, pcf	117.2	Moisture Content, %	12.4	Length, in.	N/A
Saturation, %	93.9			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	75
Back Pressure, psi	60
Confining Pressure, psi	15
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used water

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
5760	2.10	24.80	22.80	2.00	21.5	36.0	32.7	8.41E-09	8.11E-09
10620	2.10	24.80	22.30	2.50	21.6	36.0	31.9	5.77E-09	5.55E-09
15300	2.10	24.80	21.80	3.00	21.7	36.0	31.1	4.87E-09	4.67E-09
21840	2.10	24.80	21.10	3.70	21.7	36.0	29.9	4.29E-09	4.11E-09
24900	2.10	24.80	20.80	4.00	21.7	36.0	29.4	4.10E-09	3.93E-09
5580	2.10	23.00	22.30	0.70	21.5	33.2	32.0	3.20E-09	3.09E-09
12960	2.10	23.00	21.80	1.20	21.7	33.2	31.2	2.39E-09	2.30E-09

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
7	Core	N/A	N/A	Vertical

Avg. k at 20 °C 4.5E-09 cm/sec

a_a = 0.76712 cm²

A = 37.80 cm²

L = 7.92 cm

S=L/A= 0.20964 1/cm

a_p= 0.031416 cm²

M_1= 0.03018

M_2= 1.04095

$C = M_1S/(G_{Hg}-1)$= 0.0005033 for 15° to 25°

Remarks:

HYDRAULIC CONDUCTIVITY

Project No.	*6163-13-0012*	Tested By	*JW*
Project Name	*CUA Grout Sample Testing*	Test Date	*9/22/2014*
Boring No.	*T1-9-H-2*	Reviewed By	JEJ
Sample No.	*T1-9-H-2*	Review Date	11/12/14
Sample Depth	*N/A*	Lab No.	*13002*
Sample Description	*Concrete Core*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*12.8*
Wet Unit Weight, pcf:	*132.1*
Dry Unit Weight, pcf:	*117.1*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***2.0E-09***

Remarks:

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

Project Number	6163-13-0012	Tested By	JW
Project Name	CUA Grout Sample Testing	Test Date	09/22/14
Boring No.	T1-9-H-2	Reviewed By	JEJ
Sample No.	T1-9-H-2	Review Date	11/12/14
Sample Depth	N/A	Lab No.	13002
Sample Description	Concrete Core		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	R-11
Location 1	3.226	Location 1	2.731	Wet Soil+Pan, grams	671.15
Location 2	3.200	Location 2	2.734	Dry Soil + Pan, grams	596.03
Location3	3.209	Location 3	2.736	Pan Weight, grams	16.51
Average	3.212	Average	2.734	Moisture Content, %	13.0
Volume, in^3	18.85	Wet Soil + Tare, grams	653.66	Dry Unit Weight, pcf	117.1
SG Assumed	2.50	Tare Weight, grams	0.00	Saturation, %	97.6
Soil Sample Wt., g	653.66	Dry Soil +Tare, grams	579.52	Diameter, in.	N/A
Dry UW, pcf	117.1	Moisture Content, %	12.8	Length, in.	N/A
Saturation, %	96.3			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	75
Back Pressure, psi	60
Confining Pressure, psi	15
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used water

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
3720	2.00	23.90	23.30	0.60	21.7	33.7	32.8	4.02E-09	3.86E-09
6780	2.00	23.90	23.00	0.90	21.7	33.7	32.3	3.34E-09	3.20E-09
65700	2.00	23.90	20.00	3.90	21.5	33.7	27.5	1.61E-09	1.56E-09
5460	2.00	25.70	25.30	0.40	21.5	36.5	35.9	1.68E-09	1.62E-09
12840	2.00	25.70	25.00	0.70	21.6	36.5	35.4	1.26E-09	1.21E-09
19200	2.00	25.70	24.70	1.00	21.7	36.5	34.9	1.21E-09	1.16E-09
25380	2.00	25.70	24.30	1.40	21.8	36.5	34.3	1.29E-09	1.24E-09

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
7	Core	N/A	N/A	Vertical

Avg. k at 20 °C 2.0E-09 cm/sec

a_a = 0.76712 cm²
A = 37.87 cm²
L = 8.16 cm
S=L/A= 0.21543 1/cm

a_p= 0.031416 cm²
M_1= 0.03018
M_2= 1.04095
$C = M_1S/(G_{Hg}-1)$= 0.0005172 for 15° to 25°

Remarks:

HYDRAULIC CONDUCTIVITY

Project No.	*6163-13-0012*	Tested By	*JW*
Project Name	*CUA Grout Sample Testing*	Test Date	*9/22/2014*
Boring No.	*T1-1-H-3*	Reviewed By	gez
Sample No.	*T1-1-H-3*	Review Date	11/12/14
Sample Depth	*N/A*	Lab No.	*13003*
Sample Description	*Concrete Core*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*11.7*
Wet Unit Weight, pcf:	*135.0*
Dry Unit Weight, pcf:	*120.9*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***4.1E-09***

Remarks:

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

amec

Project Number	6163-13-0012	Tested By	JW
Project Name	CUA Grout Sample Testing	Test Date	09/22/14
Boring No.	T1-1-H-3	Reviewed By	JGF
Sample No.	T1-1-H-3	Review Date	11/12/14
Sample Depth	N/A	Lab No.	13003
Sample Description	Concrete Core		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	R-19
Location 1	3.231	Location 1	2.733	Wet Soil+Pan, grams	690.25
Location 2	3.238	Location 2	2.730	Dry Soil + Pan, grams	618.77
Location3	3.240	Location 3	2.732	Pan Weight, grams	16.6
Average	3.236	Average	2.732	Moisture Content, %	11.9
Volume, in^3	18.97	Wet Soil + Tare, grams	672.33	Dry Unit Weight, pcf	120.9
SG Assumed	2.50	Tare Weight, grams	0.00	Saturation, %	102.4
Soil Sample Wt., g	672.33	Dry Soil +Tare, grams	602.17	Diameter, in.	N/A
Dry UW, pcf	120.9	Moisture Content, %	11.7	Length, in.	N/A
Saturation, %	100.5			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	75
Back Pressure, psi	60
Confining Pressure, psi	15
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used water

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
2430	2.10	23.00	22.50	0.50	21.4	32.0	31.2	5.42E-09	5.24E-09
5310	2.10	23.00	22.00	1.00	21.5	32.0	30.4	5.02E-09	4.84E-09
12240	2.10	23.00	21.00	2.00	21.6	32.0	28.8	4.47E-09	4.31E-09
18150	2.10	23.00	20.50	2.50	21.7	32.0	28.0	3.82E-09	3.67E-09
21360	2.10	23.00	20.00	3.00	21.7	32.0	27.2	3.95E-09	3.80E-09
24300	2.10	23.00	19.80	3.20	21.7	32.0	26.9	3.73E-09	3.58E-09
26520	2.10	23.00	19.60	3.40	21.8	32.0	26.5	3.65E-09	3.50E-09

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
7	Core	N/A	N/A	Vertical

Avg. k at 20 °C 4.1E-09 cm/sec

a_a = 0.76712 cm²
A = 37.81 cm²
L = 8.22 cm
S=L/A= 0.21741 1/cm

a_p= 0.031416 cm²
M_1= 0.03018
M_2= 1.04095
$C = M_1S/(G_{Hg}-1)$= 0.0005220 for 15° to 25°

Remarks:

HYDRAULIC CONDUCTIVITY

Project No.	*6163-13-0012*	Tested By	*JW*
Project Name	*CUA Grout Sample Testing*	Test Date	*9/22/2014*
Boring No.	*T1-5-H-3*	Reviewed By	JEJ
Sample No.	*T1-5-H-3*	Review Date	11/12/14
Sample Depth	*N/A*	Lab No.	*13004*
Sample Description	*Concrete Core*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*12.4*
Wet Unit Weight, pcf:	*132.2*
Dry Unit Weight, pcf:	*117.6*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***8.5E-07***

Remarks:

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

amec

Project Number	6163-13-0012	Tested By	JW
Project Name	CUA Grout Sample Testing	Test Date	09/22/14
Boring No.	T1-5-H-3	Reviewed By	JEJ
Sample No.	T1-5-H-3	Review Date	11/12/14
Sample Depth	N/A	Lab No.	13004
Sample Description	Concrete Core		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	R-18
Location 1	3.097	Location 1	2.734	Wet Soil+Pan, grams	650.96
Location 2	3.094	Location 2	2.732	Dry Soil + Pan, grams	577.86
Location3	3.101	Location 3	2.737	Pan Weight, grams	16.5
Average	3.097	Average	2.734	Moisture Content, %	13.0
Volume, in^3	18.19	Wet Soil + Tare, grams	631.14	Dry Unit Weight, pcf	117.6
SG Assumed	2.50	Tare Weight, grams	0.00	Saturation, %	99.6
Soil Sample Wt., g	631.14	Dry Soil +Tare, grams	561.36	Diameter, in.	N/A
Dry UW, pcf	117.6	Moisture Content, %	12.4	Length, in.	N/A
Saturation, %	95.1			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	75
Back Pressure, psi	60
Confining Pressure, psi	15
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used water

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
90	2.00	13.00	11.40	1.60	21.4	17.6	14.9	9.10E-07	8.80E-07
180	2.00	13.00	10.30	2.70	21.4	17.6	13.1	8.17E-07	7.90E-07
90	2.00	12.40	10.90	1.50	21.4	16.6	14.1	9.01E-07	8.71E-07
180	2.00	12.40	9.70	2.70	21.4	16.6	12.1	8.73E-07	8.44E-07
270	2.00	12.40	8.70	3.70	21.4	16.6	10.5	8.54E-07	8.26E-07
180	2.00	12.20	9.50	2.70	21.4	16.3	11.8	8.93E-07	8.63E-07
270	2.00	12.20	8.40	3.80	21.4	16.3	10.0	9.06E-07	8.76E-07

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
7	Core	N/A	N/A	Vertical

Avg. k at 20 °C 8.5E-07 cm/sec

a_a = 0.76712 cm^2

A = 37.88 cm^2

L = 7.87 cm

S=L/A= 0.20766 1/cm

a_p= 0.031416 cm^2

M_1= 0.03018

M_2= 1.04095

$C = M_1S/(G_{Hg}-1)$= 0.0004986 for 15° to 25°

Remarks:

HYDRAULIC CONDUCTIVITY

Project No.	*6163-13-0012*	Tested By	*JW*
Project Name	*CUA Grout Sample Testing*	Test Date	*9/22/2014*
Boring No.	*T1-9-H-3*	Reviewed By	JCF
Sample No.	*T1-9-H-3*	Review Date	11/24/14
Sample Depth	*N/A*	Lab No.	*13005*
Sample Description	*Concrete Core*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*14.4*
Wet Unit Weight, pcf:	*132.2*
Dry Unit Weight, pcf:	*115.6*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***8.9E-07***

Remarks: ______________________________

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

Project Number	6163-13-0012	Tested By	JW
Project Name	CUA Grout Sample Testing	Test Date	09/22/14
Boring No.	T1-9-H-3	Reviewed By	JES
Sample No.	T1-9-H-3	Review Date	11/24/14
Sample Depth	N/A	Lab No.	13005
Sample Description	Concrete Core		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	
Location 1	3.169	Location 1	2.729	Wet Soil+Pan, grams	
Location 2	3.153	Location 2	2.729	Dry Soil + Pan, grams	
Location3	3.153	Location 3	2.726	Pan Weight, grams	
Average	3.158	Average	2.728	Moisture Content, %	#DIV/0!
Volume, in^3	18.46	Wet Soil + Tare, grams	640.51	Dry Unit Weight, pcf	115.6
SG Assumed	2.50	Tare Weight, grams	0.00	Saturation, %	#DIV/0!
Soil Sample Wt., g	640.51	Dry Soil +Tare, grams	560.00	Diameter, in.	N/A
Dry UW, pcf	115.6	Moisture Content, %	14.4	Length, in.	N/A
Saturation, %	102.7			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	70
Back Pressure, psi	60
Confining Pressure, psi	10
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used water

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
60	2.00	14.00	12.80	1.20	21.6	18.8	16.8	9.36E-07	9.01E-07
120	2.00	14.00	11.70	2.30	21.6	18.8	15.1	9.47E-07	9.12E-07
180	2.00	14.00	10.80	3.20	21.6	18.8	13.6	9.23E-07	8.88E-07
60	2.00	11.00	10.10	0.90	21.6	14.1	12.6	9.36E-07	9.01E-07
120	2.00	11.00	9.30	1.70	21.6	14.1	11.3	9.32E-07	8.97E-07
60	2.00	12.00	11.00	1.00	21.7	15.7	14.0	9.36E-07	8.98E-07
120	2.00	12.00	10.20	1.80	21.7	15.7	12.7	8.83E-07	8.48E-07

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
7	Core	N/A	N/A	Vertical

Avg. k at 20 °C 8.9E-07 cm/sec

$a_a =$ 0.76712 cm²

A = 37.71 cm²

L = 8.02 cm

S=L/A= 0.21274 1/cm

$a_p =$ 0.031416 cm²

$M_1 =$ 0.03018

$M_2 =$ 1.04095

$C = M_1 S/(G_{Hg}-1) =$ 0.0005108 for 15° to 25°

Remarks:

HYDRAULIC CONDUCTIVITY

Project No.	*6163-13-0012*	Tested By	*JW*
Project Name	*CUA Grout Sample Testing*	Test Date	*10/14/2014*
Boring No.	*T3B-1-H-2*	Reviewed By	JEF
Sample No.	*T3B-1-H-2*	Review Date	11/12/14
Sample Depth	*N/A*	Lab No.	*13052*
Sample Description	*Concrete Core*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*12.2*
Wet Unit Weight, pcf:	*133.4*
Dry Unit Weight, pcf:	*118.8*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***6.5E-09***

Remarks:

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

amec

Project Number	6163-13-0012	Tested By	JW
Project Name	CUA Grout Sample Testing	Test Date	10/14/14
Boring No.	T3B-1-H-2	Reviewed By	JEJ
Sample No.	T3B-1-H-2	Review Date	11/12/14
Sample Depth	N/A	Lab No.	13052
Sample Description	Concrete Core		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	V-13
Location 1	3.019	Location 1	2.705	Wet Soil+Pan, grams	625.91
Location 2	3.024	Location 2	2.695	Dry Soil + Pan, grams	555.93
Location3	3.034	Location 3	2.701	Pan Weight, grams	15.45
Average	3.026	Average	2.700	Moisture Content, %	12.9
Volume, in^3	17.33	Wet Soil + Tare, grams	606.63	Dry Unit Weight, pcf	118.8
SG Assumed	2.50	Tare Weight, grams	0.00	Saturation, %	103.5
Soil Sample Wt., g	606.63	Dry Soil +Tare, grams	540.48	Diameter, in.	N/A
Dry UW, pcf	118.8	Moisture Content, %	12.2	Length, in.	N/A
Saturation, %	97.8			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	80
Back Pressure, psi	60
Confining Pressure, psi	20
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used water

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
6780	2.00	25.80	23.50	2.30	21.3	38.9	35.0	7.81E-09	7.57E-09
9960	2.00	25.80	22.70	3.10	21.4	38.9	33.6	7.31E-09	7.06E-09
14640	2.00	25.80	21.60	4.20	21.5	38.9	31.8	6.92E-09	6.68E-09
16980	2.00	25.80	21.10	4.70	21.6	38.9	30.9	6.77E-09	6.51E-09
20040	2.00	25.80	20.70	5.10	21.6	38.9	30.2	6.29E-09	6.05E-09
22860	2.00	25.80	20.00	5.80	21.6	38.9	29.1	6.39E-09	6.15E-09
2680	2.00	25.80	25.10	0.70	21.6	38.9	37.7	5.79E-09	5.58E-09

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
7	Core	N/A	N/A	Vertical

Avg. k at 20 °C 6.5E-09 cm/sec

a_a = 0.76712 cm²

A = 36.95 cm²

L = 7.69 cm

S=L/A= 0.20800 1/cm

a_p= 0.031416 cm²

M_1= 0.03018

M_2= 1.04095

$C = M_1 S/(G_{Hg}-1)$= 0.0004994 for 15° to 25°

Remarks:

amec

HYDRAULIC CONDUCTIVITY

Project No.	*6163-13-0012*	Tested By	*JW*
Project Name	*CUA Grout Sample Testing*	Test Date	*10/14/2014*
Boring No.	*T3B-5-H-2*	Reviewed By	JEA
Sample No.	*T3B-5-H-2*	Review Date	11/12/14
Sample Depth	*N/A*	Lab No.	*13053*
Sample Description	*Concrete Core*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*12.1*
Wet Unit Weight, pcf:	*131.9*
Dry Unit Weight, pcf:	*117.6*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***5.4E-09***

Remarks: ______________________

PERMEABILITY TEST
(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

amec

Project Number	6163-13-0012	Tested By	JW
Project Name	CUA Grout Sample Testing	Test Date	10/14/14
Boring No.	T3B-5-H-2	Reviewed By	JEJ
Sample No.	T3B-5-H-2	Review Date	11/12/14
Sample Depth	N/A	Lab No.	13053
Sample Description	Concrete Core		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	C-37
Location 1	3.111	Location 1	2.730	Wet Soil+Pan, grams	646.77
Location 2	3.101	Location 2	2.722	Dry Soil + Pan, grams	574.93
Location3	3.124	Location 3	2.713	Pan Weight, grams	16.02
Average	3.112	Average	2.722	Moisture Content, %	12.9
Volume, in^3	18.11	Wet Soil + Tare, grams	626.75	Dry Unit Weight, pcf	117.6
SG Assumed	2.50	Tare Weight, grams	0.00	Saturation, %	98.4
Soil Sample Wt., g	626.75	Dry Soil +Tare, grams	558.91	Diameter, in.	N/A
Dry UW, pcf	117.6	Moisture Content, %	12.1	Length, in.	N/A
Saturation, %	92.9			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	80
Back Pressure, psi	60
Confining Pressure, psi	20
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used water

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
6660	2.10	26.30	24.20	2.10	21.3	38.5	35.0	7.19E-09	6.97E-09
9840	2.10	26.30	23.50	2.80	21.4	38.5	33.8	6.59E-09	6.38E-09
14520	2.10	26.30	22.80	3.50	21.5	38.5	32.7	5.68E-09	5.48E-09
16860	2.10	26.30	22.50	3.80	21.6	38.5	32.2	5.35E-09	5.15E-09
19980	2.10	26.30	22.20	4.10	21.6	38.5	31.7	4.91E-09	4.73E-09
22740	2.10	26.30	21.70	4.60	21.6	38.5	30.9	4.90E-09	4.72E-09
25680	2.10	26.30	21.30	5.00	21.6	38.5	30.2	4.77E-09	4.59E-09

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
7	Core	N/A	N/A	Vertical

Avg. k at 20 °C 5.4E-09 cm/sec

a_a = 0.76712 cm²
A = 37.53 cm²
L = 7.90 cm
S=L/A= 0.21059 1/cm

a_p= 0.031416 cm²
M_1= 0.03018
M_2= 1.04095
$C = M_1 S/(G_{Hg}-1)$= 0.0005056 for 15° to 25°

Remarks:

amec

HYDRAULIC CONDUCTIVITY

Project No.	*6163-13-0012*	Tested By	*JW*
Project Name	*CUA Grout Sample Testing*	Test Date	*10/14/2014*
Boring No.	*T3B-9-C-1*	Reviewed By	JEJ
Sample No.	*T3B-9-C-1*	Review Date	11/12/14
Sample Depth	*N/A*	Lab No.	*13054*
Sample Description	*Concrete Core*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*12.0*
Wet Unit Weight, pcf:	*132.3*
Dry Unit Weight, pcf:	*118.1*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***3.6E-09***

Remarks:

PERMEABILITY TEST

(ASTM D5084 - 03) (Method F, Constant Volume Falling Head)

amec

Project Number	6163-13-0012	Tested By	JW
Project Name	CUA Grout Sample Testing	Test Date	10/14/14
Boring No.	T3B-9-C-1	Reviewed By	JCJ
Sample No.	T3B-9-C-1	Review Date	11/12/14
Sample Depth	N/A	Lab No.	13054
Sample Description	Concrete Core		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	V-19
Location 1	3.040	Location 1	2.736	Wet Soil+Pan, grams	637.16
Location 2	3.041	Location 2	2.730	Dry Soil + Pan, grams	568.41
Location3	3.052	Location 3	2.730	Pan Weight, grams	15.15
Average	3.044	Average	2.732	Moisture Content, %	12.4
Volume, in^3	17.85	Wet Soil + Tare, grams	619.69	Dry Unit Weight, pcf	118.1
SG Assumed	2.50	Tare Weight, grams	0.00	Saturation, %	96.8
Soil Sample Wt., g	619.69	Dry Soil +Tare, grams	553.26	Diameter, in.	N/A
Dry UW, pcf	118.1	Moisture Content, %	12.0	Length, in.	N/A
Saturation, %	93.5			Volume, in^3	N/A

Consolidation

Chamber Pressure, psi	80
Back Pressure, psi	60
Confining Pressure, psi	20
Initial Burett Reading	0
Final Burett Reading	0
Volume Change, cc	0

Permeant used water

Elapsed Time (sec)	z_o (cm)	za (cm)	zb (cm)	Δz_p (cm)	Temp (°C)	Intial Hydraulic Gradient	Final Hydraulic Gradient	k cm/sec	k cm/sec at 20 °C
1950	2.10	26.80	26.00	0.80	21.3	40.2	38.8	8.63E-09	8.37E-09
6360	2.10	26.80	25.60	1.20	21.4	40.2	38.1	4.01E-09	3.87E-09
11460	2.10	26.80	25.10	1.70	21.5	40.2	37.3	3.18E-09	3.07E-09
15300	2.10	26.80	24.80	2.00	21.5	40.2	36.8	2.83E-09	2.73E-09
19140	2.10	26.80	24.60	2.20	21.6	40.2	36.4	2.50E-09	2.40E-09
24900	2.10	26.80	24.30	2.50	21.6	40.2	35.9	2.19E-09	2.11E-09
4740	2.10	25.80	25.20	0.60	21.3	38.5	37.5	2.77E-09	2.68E-09

No. of Trials	Sample Type	Max. Density (pcf)	Compaction %	Sample Orientation
7	Core	N/A	N/A	Vertical

Avg. k at 20 °C 3.6E-09 cm/sec

a_a = 0.76712 cm²

A = 37.82 cm²

L = 7.73 cm

S=L/A= 0.20446 1/cm

a_p= 0.031416 cm²

M_1= 0.03018

M_2= 1.04095

$C = M_1S/(G_{Hg}-1)$= 0.0004909 for 15° to 25°

Remarks:

Attachment 2

Equipment List

VSL Req#38917/CUA PO0000082081
AMEC Project Name: CUA Grout Sample Testing
AMEC Project No.: 6163-13-0012

Equipment Name	Laboratory ID	Calibration Due Date
Oven	109	11/28/2014
Balance	416	4/16/2015
Thermometer	2866	8/11/2015
Caliper	2376	1/31/2015
Pressure Transducer	3638	6/3/15
Timer	2607	12/13/2014
Timer	2608	12/13/2014