SRR Savannah River Remediation
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INTEROFFICE MEMORANDUM

SRR-CWDA-2015-00160

Revision 0

January 4, 2016

TO: G. C. Arthur, 241-284H

FROM: M. H. Layton, 705-1C MHL

REVIEWED BY: Kent H. Rosenberger 1/4/2016

K. H. Rosenberger, 705-1C

EVALUATION OF THE PERFORMANCE ASSESSMENT IMPACT OF USING AN ALTERNATIVE FILL GROUT IN THE H-AREA TANK FARM

Purpose

The purpose of this memo is to evaluate the proposed activity of using an alternative fill grout meeting the requirements of Specification C-SPP-Z-00012 while completing tank closure operations in the H-Area Tank Farm (HTF). Use of an alternative grout formula with an increased flowability is desired in order to minimize the potential for voids during the final grout pours. This memo is not intended to address all of the operational aspects related to use of an alternative fill grout. The scope of this memo is limited to the impact that changing grout properties would have on the HTF Performance Objectives detailed within the HTF Performance Assessment (PA) [SRR-CWDA-2010-00128].

Background

Bulk Fill Grout Discussion

Filling a cleaned tank with grout prevents possible future subsidence of the closed facility. The grout fill also helps to reduce water movement to the residual contaminants. Reducing the amount of water retards the migration of residual contaminants from the tank to the environment. Testing has demonstrated the chemical and physical characteristics of the grout formula used at SRS. HTF tank closure activities typically use reducing grout, with low reduction potential (Eh), thus minimizing the mobility of certain radionuclides after closure. All grout formulas are alkaline because grout is a cement-based material that naturally has a high pH which is compatible with the carbon steel waste tank liner. The tank fill grout characteristically has high compressive strength and low permeability, enhancing its ability to limit the migration of infiltrating water, and thus contaminants after closure.

The nominal waste tank grout fill formulation specification (C-SPP-F-00055 Rev 4) was created to ensure the cured grout meets the HTF PA assumptions. The HTF PA contains assumptions regarding both mechanical and chemical properties of the tank fill grout. These assumptions pertain to the grout's performance with respect to 1) grout chemical properties, 2) waste tank stability, 3) inadvertent intruder prevention, and 4) tank flow modeling.

The alternative fill grout (meeting the requirements of Specification C-SPP-Z-00012) that is proposed to be used may not meet all of the nominal mechanical and chemical properties assumed for grout material as specified in the HTF Tank Farm PA, but will still perform satisfactorily so that tank closure performance objectives are met. It should be noted that non-reducing grout (Controlled Low Strength Material (CLSM)) was used for bulk fill previously on Tanks 17 and 20 (PIT-MISC-0004), and the alternative grout formula proposed (Specification C-SPP-Z-00012, Rev. 1) was used as a clean cap grout in the Saltstone Disposal Facility (SDF) and for the last few feet in Tank 16.

Performance Assessment Grout Assumptions

Residual contaminants will be stabilized by filling the waste tanks with grout after the removal of waste. Grout is commonly used to solidify and stabilize radioactive wastes and the technology is at a mature stage of development. Stabilization with grout maintains the tank structure and minimizes water infiltration over an extended period of time, thereby impeding the release of stabilized contaminants into the environment. [DOE/SRS-WD-2014-001]

Grout will be used to fill the entire volume of the Type I, II, III/IIIA and IV tanks. Operational closure activities will be carried out using reducing grout to minimize the mobility of certain redox sensitive contaminants after closure (e.g., Tc-99). The grout formula is alkaline because grout is a cement-based material that naturally has a high pH, which is compatible with the carbon steel tank liner. The tank fill grout typically has a high compressive strength and low permeability, enhancing its ability to limit the migration of contaminants after operational closure. [SRR-CWDA-2010-00128]

The grout attributes important to tank operational closure are:

- Low hydraulic conductivity
- High pH
- Low E_h
- High degradation resistance
- High flowablity
- Self-leveling
- Low bleed water
- High compressive strength

Grout requirements consist of both mechanical and chemical properties. The mechanical requirements of the grout are adequate compressive strength to withstand the overburden load and provision of a physical barrier to discourage intruders. The chemical requirements of grout include high pH and a low E_h. Table 1 outlines some of the key properties captured in the HTF PA.

Table 1: Mechanical and Chemical Properties for Grout

Properties	Attribute
Rheology	ASTM D 6103 - 04
Set Time	< 24 hours
Compressive Strength (nominal)	2,000 psi
Leveling Quality	Self
Segregation	Minimal
Heat of Hydration	Low Heat Mass Pour
Initial E_h	< 0 mV
Initial pH	> 12.5

[Table 3.2-9, SRR-CWDA-2010-00128]

Grout is composed primarily of cement, sand, water, fly ash, slag, silica fume, viscosity modifier and high range water reducer. The grout mix must be flowable, pumpable and self-leveling. Previous grout studies evaluated the chemical and mechanical properties of grout for tank closure. [SRNL-STI-2011-00551, WSRC-STI-2007-00369]

Grout Chemical Properties

The HTF PA assumes that the chemical properties (e.g., reducing capacity) of the fill grout changes as a function of pore volume flushing [SRNL-STI-2012-00404]. Once enough water flows through the pore volumes of the grouted waste tank, these models assume that the fill grout chemical properties transition from reducing to oxidizing conditions. Because the timing of these transitions is determined based on grout formulation, the grout components (e.g., slag quantity) were developed with specific chemistry impacts (e.g., extended reducing capacity) in mind. It should also be noted that while the PA waste release analyses assumed a nominal slag composition [Table 2, SRNL-STI-2012-00404] for modeling purposes, the modeling recognized that "small deviations from these nominal values on rates of grout degradation would be small relative to the effects of other uncertainties". [SRNL-STI-2012-00404]

Assumed Grout Properties in the HTF PA and Impact of Using Alternative Grout

The HTF closure documents contain assumptions regarding both mechanical and chemical properties of the tank fill grout. These assumptions pertain to the grout's performance with respect to 1) grout chemical properties, 2) waste tank stability, 3) inadvertent intruder prevention, and 4) tank flow modeling. These grout performance areas and their implications with respect to assumed performance are addressed in additional detail below.

Grout Chemical Properties

Using an alternative grout formula as fill grout while completing the grout lifts would not impact the tank grout's overall effective reducing capacity, since the alternative grout has a greater weight percent slag than the nominal tank grout (45 wt% slag per C-SPP-Z-00012, Rev. 1) versus 210 pounds slag per cubic yard grout (approximately 6 wt% slag per C-SPP-F-00055, Rev. 4). The alternative grout formula exceeds the slag content recommended by SRNL (at least 210 lbs of slag per cubic yard of reducing grout) to ensure that the tank grout will provide high reducing capacity over the long term. [SRNL-STI-2011-00551]

Waste Tank Stability

In the HTF PA, it is assumed that the waste tank is filled with grout and therefore structural failure (i.e., collapse) is not considered. Per Section 3.2.3 of the HTF PA, fill grout must have an adequate compressive strength to withstand the overburden load on the tank at closure, but that compressive strength was not a functional requirement. Compressive strength testing was performed on Z-Area Vault 4 clean cap cylinders created using essentially the same grout formula, with the only difference being clean cap material used Grade 100 slag while the alternative fill grout will use Grade 120 Slag. The compressive strength testing showed the cylinders cured to a compressive strength over 5000 psi (average compressive strength for four test results 6202 psi), as documented in the attached URS test reports 2014-07V1JE4002-0002 and 2014-07V1JE4002-0003. Since the change in Slag Grade is expected to either improve or have no impact on the compressive strength, there are no compressive strength concerns associated with a change in grout formula.

The long-term structural behavior/integrity of a grout filled waste tank was evaluated previously through calculation [T-CLC-F-00421]. This calculation stated that because the grout-filled tanks are essentially monoliths of grout in the ground, structural collapse cannot occur. With regard to stability and tank collapse prevention, the calculation assumed that tank was filled with grout to prevent large void formation. The alternative grout will limit void formation and therefore does not impact the fill grout material's overall functionality with regards to tank stability.

Waste Tank as Inadvertent Intruder Barrier

Multiple elements of waste tank design serve as an inadvertent intruder barrier. The HTF closure cap, waste tank concrete roof (for all but Type IV Tanks), and waste tank grout fill are considered sufficient to prevent drilling into the waste form given well drilling practices in the region and the presence of nearby land without underground concrete obstructions. The presence of the earthen cover and the intruder barrier will prevent the worker from coming in contact with the waste form during construction of a basement for a residence as an inadvertent intruder. The fact that an alternative grout formula will be used as fill grout will not impact the ability of the waste tank design elements to serve as inadvertent intruder barriers. Since the previously discussed compressive strength testing indicated that the alternative fill grout will have a cured compressive strength greater than or equal to 2000 psi, the alternative fill grout can also serve as an intruder barrier in a Type IV Tank.

Tank Flow Modeling

The tank grout minimizes the flow of water from the tank top to the contamination zone at the bottom of the tank. The HTF PA describes the assumed grout material properties in PA Section 4.2.2.2.4. The properties assumed in the modeling were selected from the testing described in WSRC-STI-2007-00369 and SRNL-STI-2011-00551, and are shown in PA Table 4.2-28 and PA Figure 4.2-30. The grout formula was developed to meet the assumed material properties (SRNL-STI-2011-00551), with conformance to the grout formulation validated through adherence to the grout specification requirements.

Saturated hydraulic conductivity testing was performed on Z-Area Vault 4 clean cap cylinders created using essentially the same grout formula, with the only difference being clean cap material used Grade 100 slag while the alternative fill grout will use Grade 120 Slag. The three hydraulic conductivity tests performed showed the cylinders had an average saturated hydraulic conductivity (average over the three tests) comparable to what was assumed for HTF grout (2.2E-09 cm/s for the cylinders vs. 2.1E-09 cm/s assumed in the HTF PA), as documented in the attached permeability test reports. Since the change in Slag Grade is expected to either improve or have no impact on the hydraulic conductivity, there are no HTF PA tank flow modeling concerns associated with a change in grout formula.

Conclusion

Use of an alternative fill grout meeting the requirements of Specification C-SPP-Z-00012 for HTF tank grouting can be carried out in compliance with the HTF Performance Objectives detailed within the PA.

References

1. C-SPP-F-00055, Rev. 4, *Furnishing and Delivery of Tank Closure Grout Procedure Specification*, Savannah River Site, Aiken, SC, December 2012.
2. C-SPP-Z-00012, Rev. 1, *Vault 4 Clean Cap Grout*, Procurement Specification, Savannah River Site, Aiken, SC, March 2014.
3. DOE/SRS-WD-2014-001, Rev.0, *Basis for Section 3116 Determination for Closure of H-Tank Farm at the Savannah River Site,* Savannah River Site, Aiken, SC, December 2014.
4. PIT-MISC-0004, Rev. 2, *Industrial Wastewater Closure Module for the High Level Waste Tank 17 System*, Savannah River Site, Aiken, SC, August 1997.
5. SRR-CWDA-2010-00128, Rev. 1, *Performance Assessment for the H-Tank Farm at the Savannah River Site,* Savannah River Site, Aiken, SC, November 2012.

6. SRNL-STI-2011-00551, Rev. 1, Langton, C. A., and Stefanko. D. B., *Tanks 18 and 19-F Structural Flowable Grout Fill Material Evaluation and Recommendations*, Savannah River Site, Aiken, SC, April 2013.
7. SRR-CWDA-2014-00011, Rev. 0, *Evaluation of Vendor Supplied Clean Cap Material for Saltstone Disposal Units*, Savannah River Site, Aiken, SC, March 2014.
8. SRR-CWDA-2015-00073, Rev. 0, *Tank 12 Special Analysis for the Performance Assessment for the H-Tank Farm at the Savannah River Site*, Savannah River Site, Aiken, SC, August 2015.
9. SRNL-STI-2012-00404, Rev. 0, Denham, M., and Millings, M. R., *Evolution of Chemical Conditions and Estimated Solubility Controls on Radionuclides in the Residual Waste Layer During Post-Closure Aging of High-Level Waste Tanks,* Savannah River Site, Aiken, SC, August 2012.
10. WSRC-STI-2007-00369, Rev. 0, Dixon, K., and Phifer, M., *Hydraulic and Physical Properties of Tank Grouts and Base Mat Surrogate Concrete for FTF Closure*, Savannah River Site, Aiken, SC, October 2007.
11. T-CLC-F-00421, Rev. 0, Carey, S.A., *Structural Assessment of F-Area Tank Farm After Final Closure*, Savannah River Site, Aiken SC, December 18, 2007.

cc:		
	J. E. Occhipinti, 704-56H	S. P. Simner, 705-1C
	G. R. Davis, 241-156H	B. A. Martin, 705-1C
	R. O. Voegtlen, 241-162H	L. B. Romanowski, 705-1C
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	S. A. Thomas, 705-1C	L. K. Pressley, 705-1C

Attachment 1 - Z-Area Vault 4 Clean Cap Cylinder Compressive Strength Testing

ASR 18-335 (04/13)

ASTM C 39-(04a) ASTM C 31-(03a) ASTM C 143-(05)
ASTM C 94-(04a) ASTM C 138 -(01a) ASTM C 172-(04)
ASTM D 4832-(02) ASTM C 1611-(N/A)

URS
Savannah River Site
Concrete/CLSM Test Report

ASTM C 192-(N/A) ASTM C 617-(12)
ASTM C 231-(04) ASTM C 1064-(12)
ASTM D 6103-(N/A) Page of

Report No.: 2014-07V1JE4002-0002 Work Package No.: 1333140-01 Date Molded: 6-16-2014 Contractor: SRR
Project No.: N/A QCIR No.: N/A Time Molded: 1150 Supplier: Argos
Report Date: 6-16-2014 Design Category: PS Design Strength: N/A psi @ N/A days Weather: Clear &Hot
Placement Location: Z-AREA Vault 4 Cell J 1st Lift Placement Method: Pump
Mix Design: 006NV208 Type Admixture(s) : N/A

Ambient Temp. (°F) : 88

Test Performed:	Acceptance Range	Test Results
Slump (in.)	N/A	N/A
Air Content (%)	N/A	N/A
CLSM Flow (in.)	26 - 38	*31 / 34
Conc./CLSM Temp. (°F)	N/A	79

Batch Ticket Number	Truck I.D.	Time of Mixing	Batch Size, yds.	Time Start/Stop Discharge	Water Allowed / Water Added, gals.
038767	7120	1051	7	1125 / 1210	6.8 / 4

Cementitious Materials, lbs.	Aggregates, lbs.	Plant Water, gals.	Field Water, gals.	WRA, oz.	AEA, oz.	HWRA, oz.	Measure & Concrete, lbs.	Measure, lbs.	Calibration Factor	Unit Weight, lbs./cu.ft.	Total Weight of Materials Batched	Yield, cu.ft.	Yield, cu.yd.
13160	N/A	759	4	N/A	N/A	N/A	35.90	8.55	4.00	109.4	19516	25.5	0.9

INFORMATION ONLY

Initial Curing: Conforming MMT-103 / 9-12-14 Technician (Print/Sign): C. E. Santo / Level
Pick-up Date: 6-17-2014 HI/LO Temp. °F : 79-62 Time: 1015 Initials: Technician (Print/Sign): L. D. Briggman / Level II
Laboratory Curing: N/A N/A / N/A Cast in Lab.: Yes ☐ No ☐

Lab. Number	Days Aged	Date Tested	Capped Height, Inches	Diameter, Inches	Area, Square Inches	Total Load, lbs.	Unit Load, psi	1	2	3	4	5	6	Technicians Initials/ Level
140081	534	12/2/2015	6.23	3.02	7.16	41517	5800		X					GS III
	534	12/2/2015	6.27	3.00	7.06	39260	5560		X					GS III
	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

M& TE /Cal.: SC- 03 10-23-14 TG- 420 7-7-14 AM- 131 8-29-14 UWB- 131 8-29-14 S- 103 10-22-14 TM- 5 1-12-16

Remarks: tWO* Tests taken for Information Only
Two cylinder sent to AMEC for Hydraulic Conductivity
Two Hold Cylinders
N/A
N/A

Procedure No.: C-QCP-002 Rev.: 0 PCN(s): N/A
Specification No.: C-SPP-Z-00012 Rev.: 1
DCF(s): N/A
Drawing No(s).: N/A Rev.: N/A
DCF(s): N/A

Technician (Print/Sign): Glenn C Spencer / Level III Date: 12-2-15
Reviewer (Print/Sign): Johnathan Seigler / Level II Date: 12-10-15
NCR No.: N/A
Test Results: Info Only

THIS REPORT SHALL NOT BE REPRODUCED, EXCEPT IN FULL, WITHOUT THE WRITTEN APPROVAL OF THE LABORATORY.

ASR 18-335 (04/13)

ASTM C 39-(04a) ASTM C 31-(03a) ASTM C 143-(05)
ASTM C 94-(04a) ASTM C 138 -(01a) ASTM C 172-(04)
ASTM D 4832-(02) ASTM C 1611-(N/A)

URS
Savannah River Site
Concrete/CLSM Test Report

ASTM C 192-(N/A) ASTM C 617-(12)
ASTM C 231-(04) ASTM C 1064-(12)
ASTM D 6103-(N/A) Page of

Report No.: 2014-07V1JE4002-0003 Work Package No.: 1333140-01 Date Molded: 6-19-2014 Contractor: SRR
Project No.: N/A QCIR No.: N/A Time Molded: 0815 Supplier: Argos
Report Date: 6-19-2014 Design Category: PS Design Strength: N/A psi @ N/A days Weather: Clear & Mild
Placement Location: Z-AREA Vault 4 Cell J Second Lift Placement Method: Pump
Mix Design: 006NV208 Type Admixture(s) : N/A

Ambient Temp. (°F) : 77

Test Performed:	Acceptance Range	Test Results
Slump (in.)	N/A	N/A
Air Content (%)	N/A	N/A
CLSM Flow (in.)	26 - 38	35
Conc./CLSM Temp. (°F)	N/A	70

Batch Ticket Number	Truck I.D.	Time of Mixing	Batch Size, yds.	Time Start/Stop Discharge	Water Allowed / Water Added, gals.
038782	0717	0725	7	0820 / 0841	8.8 / 8.8

Cementitious Materials, lbs.	Aggregates, lbs.	Plant Water, gals.	Field Water, gals.	WRA, oz.	AEA, oz.	HWRA, oz.	Measure & Concrete, lbs.	Measure, lbs.	Calibration Factor	Unit Weight, lbs./cu.ft.	Total Weight of Materials Batched	Yield, cu.ft.	Yield, cu.yd.
14902	N/A	757	8.8	N/A	N/A	N/A	35.85	8.6	4.00	109	21281	27.9	1.0

INFORMATION ONLY

INFORMATION ONLY

Initial Curing: Conforming MMT-103 / 9-12-14 Technician (Print/Sign): C. E. Santo / Level
Pick-up Date: 6-20-2014 HI/LO Temp. °F : 83-62 Time: 0615 Initials: Technician (Print/Sign): L. D. Briggman / Level II
Laboratory Curing: N/A N/A / N/A Cast in Lab.: Yes ☐ No ☐

Lab. Number	Days Aged	Date Tested	Capped Height, Inches	Diameter, Inches	Area, Square Inches	Total Load, lbs.	Unit Load, psi	1	2	3	4	5	6	Technicians Initials/ Level
140083	531	12/2/2015	6.21	3.02	7.16	47015	6570			X				GS III
	531	12/2/2015	6.24	3.02	7.16	49285	6880			X				GS III
	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

M& TE /Cal.: SC- 03 10-23-14 TG- 420 7-7-14 AM- 131 8-29-14 UWB- 131 8-29-14 S- 103 10-22-14 TM- 5 1-12-16

Remarks: * Tests taken for Information Only
One cylinder sent to AMEC for Hydraulic Conductivity
Three Hold Cylinders

Procedure No.: C-QCP-002 Rev.: 0 PCN(s): N/A
Specification No.: C-SPS-G-00085 Rev.: 1
DCF(s): N/A
Drawing No(s).: N/A Rev.: N/A
DCF(s): N/A

Technician (Print/Sign): Glenn C Spencer / Level III Date: 12-2-15
Reviewer (Print/Sign): Johnathan Seigler / Level II Date: 12-10-15
NCR No.: N/A
Test Results: Info Only

THIS REPORT SHALL NOT BE REPRODUCED, EXCEPT IN FULL, WITHOUT THE WRITTEN APPROVAL OF THE LABORATORY.

Attachment 2- Z-Area Vault 4 Clean Cap Cylinder Hydraulic Conductivity Testing

amec foster wheeler Nuclear Quality Assurance Program	Records Transmittal Form	Page 1 of 1

Record Transmittal Form

TO	Bill Joyce, STR SRNS Building 730-2B Room 2158 Aiken, SC 29808	Transmittal No.: SRNS14-006 (optional)	
FROM	Name Jianren Wang	Date 9/30/15	Page 1 of 1
	Department/Company Amec Foster Wheeler	Extension/Phone Number 404-817-0255	Bin No./Address **N/A**

The records listed on this form are: ☒ QA ☐ Non-QA

The records listed on this form pertain to: ☒SRNS

Individual preparing this Record Transmittal shall complete the columns below.						Completed by Doc. Mgmt.	
Item No.	Record Number, Version Number, and Record Title	Record Date	Number of Pages	R-type	Sub-Type	Rcvd.	On Hold
1	Test Report – Vault #4 Clean Cap Cylinders, Subcontract No. 0000138886, DO. 7	12/22/2015	10	N/A	N/A		
2							
3							
4							
5							
6							
7							
8							
9							
10							

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Comments

Transmittal Received By:	Date:	Documents Verified By:	Date:	Completed in Documentum By:	Date:

If a copy of this Record Transmittal form is desired after the record storage process has been completed by Document Management, please enter your name:

amec foster wheeler

December 21, 2015

Savannah River Nuclear Solutions
Bldg. 730-2B Room 2158
Aiken, SC 29808

Attention: Mr. Bill Joyce, STR

Subject: **Test Report – Vault #4 Clean Cap Cylinders**
Subcontract No. 0000138886, Delivery Order No. 7 Rev.1
Specification K-SPC-G-00013, Rev. 14
Amec Foster Wheeler Project No. 6163-14-0088.07

Dear Mr. Joyce:

Amec Foster Wheeler Environment & Infrastructure has completed the assigned testing services for Delivery Order No. 7, Rev. 1 Subcontract No. 0000138886. The test results are included in Attachment 1. An equipment list used in this Delivery Order is included in Attachment 2. The tests performed in this Delivery Order are listed below along with applicable ASTM or other procedures:

Hydraulic Conductivity	Modified ASTM D5084-10 Method F

These tests were performed in accordance with the above referenced contract order and Amec Foster Wheeler QAPD Revision 1 for Subcontract No. 0000138886.

We appreciate the opportunity of serving your geotechnical laboratory testing needs. If you have questions, please contact us.

Sincerely,

Amec Foster Wheeler

John E Lynch

Jianren Wang
Technical Lead

John Lynch
Consultant

Cc: SRNS
Vendor Documents
Building 704-IN/Room 137
Aiken, SC 29808
(VendorDocuments@srs.gov)

SRNS
Procurement Administrator
Building 730-4B/Room 2161
Aiken, SC 29808

ATTACHMENT 1

amec foster wheeler

HYDRAULIC CONDUCTIVITY

Project No.	*6163-14-0088.07*	Tested By	*JW*
Project Name	*Vault 4 Clean Cap Cylinders*	Test Date	*12/9/2015*
Boring No.	*140081-A*	Reviewed By	JEJ
Sample No.	*140081-A*	Review Date	12/21/15
Sample Depth	*N/A*	Lab No.	*14385*
Sample Description	***Grout***		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*33.4*
Wet Unit Weight, pcf:	*111.0*
Dry Unit Weight, pcf:	*83.2*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***2.7E-09***

Remarks:

PERMEABILITY TEST
(ASTM D5084 - 10) (Method F, Constant Volume Falling Head)

amec foster wheeler

Project Number	6163-14-0088.07	Tested By	JW
Project Name	Vault 4 Clean Cap Cylinders	Test Date	12/09/15
Boring No.	140081-A	Reviewed By	gct
Sample No.	140081-A	Review Date	12/21/15
Sample Depth	N/A	Lab No.	14385
Sample Description	Grout		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	SS-10
Location 1	4.090	Location 1	3.031	Wet Soil+Pan, grams	948.76
Location 2	4.090	Location 2	3.026	Dry Soil + Pan, grams	733.83
Location3	4.088	Location 3	3.029	Pan Weight, grams	90.37
Average	4.089	Average	3.029	Moisture Content, %	33.4
Volume, in^3	29.46	Wet Soil + Tare, grams	858.32	Dry Unit Weight, pcf	83.2
SG Assumed	2.45	Tare Weight, grams	0.00	Saturation, %	97.7
Soil Sample Wt., g	858.32	Dry Soil +Tare, grams	643.46	Diameter, in.	N/A
Dry UW, pcf	83.2	Moisture Content, %	33.4	Length, in.	N/A
Saturation, %	97.7			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
3750	2.30	29.10	28.30	0.80	20.2	32.4	31.4	4.52E-09	4.50E-09
7380	2.30	29.10	27.80	1.30	20.2	32.4	30.8	3.77E-09	3.75E-09
11340	2.30	29.10	27.40	1.70	20.3	32.4	30.3	3.23E-09	3.21E-09
15060	2.30	29.10	27.10	2.00	20.3	32.4	29.9	2.88E-09	2.86E-09
18240	2.30	29.10	26.90	2.20	20.3	32.4	29.7	2.63E-09	2.61E-09
77460	2.30	29.10	25.00	4.10	20.1	32.4	27.3	1.20E-09	1.20E-09
88920	2.30	29.10	24.80	4.30	20.2	32.4	27.0	1.10E-09	1.10E-09

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

Avg. k at 20 °C 2.7E-09 cm/sec

a_s = 0.76712 cm^2
A = 46.48 cm^2
L = 10.39 cm
S=L/A= 0.22347 1/cm

a_p= 0.031416 cm^2
M_1= 0.03018
M_2= 1.04095
$C = M_1S/(G_{Hg}-1)$= 0.0005366 for 15° to 25°

Remarks:

amec foster wheeler

HYDRAULIC CONDUCTIVITY

Project No.	*6163-14-0088.07*	Tested By	*JW*
Project Name	*Vault 4 Clean Cap Cylinders*	Test Date	*12/9/2015*
Boring No.	*140081-B*	Reviewed By	JGB
Sample No.	*140081-B*	Review Date	12/21/15
Sample Depth	*N/A*	Lab No.	*14386*
Sample Description	*Grout*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*32.1*
Wet Unit Weight, pcf:	*111.0*
Dry Unit Weight, pcf:	*84.1*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***2.4E-09***

Remarks:

PERMEABILITY TEST
(ASTM D5084 - 10) (Method F, Constant Volume Falling Head)

amec foster wheeler

Project Number	6163-14-0088.07	Tested By	JW
Project Name	Vault 4 Clean Cap Cylinders	Test Date	12/09/15
Boring No.	140081-B	Reviewed By	JEJ
Sample No.	140081-B	Review Date	12/21/15
Sample Depth	N/A	Lab No.	14386
Sample Description	Grout		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	SS-47
Location 1	3.936	Location 1	3.032	Wet Soil+Pan, grams	973.46
Location 2	3.948	Location 2	3.033	Dry Soil + Pan, grams	772.28
Location3	3.938	Location 3	3.028	Pan Weight, grams	144.78
Average	3.941	Average	3.031	Moisture Content, %	32.1
Volume, in^3	28.43	Wet Soil + Tare, grams	828.64	Dry Unit Weight, pcf	84.1
SG Assumed	2.45	Tare Weight, grams	0.00	Saturation, %	96.0
Soil Sample Wt., g	828.64	Dry Soil +Tare, grams	627.50	Diameter, in.	N/A
Dry UW, pcf	84.1	Moisture Content, %	32.1	Length, in.	N/A
Saturation, %	96.0			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
2460	2.30	29.30	28.90	0.40	20.2	33.9	33.4	3.26E-09	3.25E-09
4500	2.30	29.30	28.60	0.70	20.2	33.9	33.0	3.14E-09	3.12E-09
10920	2.30	29.30	28.10	1.20	20.2	33.9	32.3	2.24E-09	2.23E-09
14880	2.30	29.30	27.70	1.60	20.2	33.9	31.8	2.21E-09	2.20E-09
20340	2.30	29.30	27.30	2.00	20.2	33.9	31.3	2.04E-09	2.03E-09
25020	2.30	29.30	26.90	2.40	20.3	33.9	30.8	2.00E-09	1.99E-09
83400	2.30	29.30	23.20	6.10	20.1	33.9	25.9	1.66E-09	1.66E-09

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

Avg. k at 20 °C 2.4E-09 cm/sec

a_a = 0.76712 cm^2
A = 46.55 cm^2
L = 10.01 cm
S=L/A= 0.21502 1/cm

a_p= 0.031416 cm^2
M_1= 0.03018
M_2= 1.04095
$C = M_1S/(G_{Hg}-1)$= 0.0005162 for 15° to 25°

Remarks:

amec
foster
wheeler

HYDRAULIC CONDUCTIVITY

Project No.	*6163-14-0088.07*	Tested By	*JW*
Project Name	*Vault 4 Clean Cap Cylinders*	Test Date	*12/9/2015*
Boring No.	*140083*	Reviewed By	JEA
Sample No.	*140083*	Review Date	12/21/15
Sample Depth	*N/A*	Lab No.	*14387*
Sample Description	*Grout*		

ASTM D5084 - Method F (CVFH)

Sample Type:	*Core*
Sample Orientation:	*Vertical*
Initial Water Content, %:	*30.0*
Wet Unit Weight, pcf:	*110.9*
Dry Unit Weight, pcf:	*85.4*
Compaction, %:	*N/A*
Hydraulic Conductivity, cm/sec. @20 °C	***1.5E-09***

Remarks:

PERMEABILITY TEST
(ASTM D5084 - 10) (Method F, Constant Volume Falling Head)

amec foster wheeler

Project Number	6163-14-0088.07	Tested By	JW
Project Name	Vault 4 Clean Cap Cylinders	Test Date	12/09/15
Boring No.	140083	Reviewed By	JEJ
Sample No.	140083	Review Date	12/21/15
Sample Depth	N/A	Lab No.	14387
Sample Description	Grout		

Initial Sample Data				Final Sample Data	
Length, in		Diameter, in		Pan No.	SS-51
Location 1	4.101	Location 1	3.028	Wet Soil+Pan, grams	1005.93
Location 2	4.111	Location 2	3.026	Dry Soil + Pan, grams	806.92
Location3	4.104	Location 3	3.026	Pan Weight, grams	144.68
Average	4.105	Average	3.027	Moisture Content, %	30.1
Volume, in^3	29.54	Wet Soil + Tare, grams	860.84	Dry Unit Weight, pcf	85.4
SG Assumed	2.40	Tare Weight, grams	0.00	Saturation, %	95.6
Soil Sample Wt., g	860.24	Dry Soil +Tare, grams	662.24	Diameter, in.	N/A
Dry UW, pcf	85.4	Moisture Content, %	30.0	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_e (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
1800	1.80	28.60	28.30	0.30	20.2	32.3	31.9	3.51E-09	3.50E-09
4380	1.80	28.60	28.20	0.40	20.2	32.3	31.8	1.93E-09	1.92E-09
10800	1.80	28.60	28.00	0.60	20.2	32.3	31.6	1.18E-09	1.17E-09
14760	1.80	28.60	27.80	0.80	20.2	32.3	31.3	1.15E-09	1.15E-09
20280	1.80	28.60	27.70	0.90	20.2	32.3	31.2	9.46E-10	9.42E-10
24960	1.80	28.60	27.50	1.10	20.2	32.3	30.9	9.44E-10	9.39E-10
83340	1.80	28.60	25.50	3.10	20.1	32.3	28.4	8.30E-10	8.28E-10

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

Avg. k at 20 °C 1.5E-09 cm/sec

a_a = 0.76712 cm^2
A = 46.42 cm^2
L = 10.43 cm
S=L/A= 0.22464 1/cm

a_p= 0.031416 cm^2
M_1= 0.03018
M_2= 1.04095
$C = M_1 S/(G_{Hg}-1)$= 0.0005394 for 15° to 25°

Remarks:

ATTACHMENT 2

Equipment List
SRNS Delivery Order No. 7
Subcontract No. 0000138886
AMECFW Project No.: 6163-14-0088.07

Equipment Name	Laboratory ID
Oven	109
Balance	416
Caliper	4217
Pressure Transducer	3638
Timer	2608