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MOISTURE RETENTION PROPERTIES OF HIGH TEMPERATURE CURE ARP/MCU SALTSTONE GROUT

Kenneth Dixon

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Savannah River National Laboratory
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Prepared for the U.S. Department of Energy Under Contract Number DE-AC09-08SR22470

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ARP	Actinide Removal Process
BFS	Blast Furnace Slag
CSSX	Caustic side solvent extraction
FA	Fly Ash
K_r	Relative permeability
MCT	Mactec Engineering and Consulting, Inc.
MCU	Modular Caustic Side Solvent Extraction Unit
OPC	Ordinary Portland Cement
PA	Performance Assessment
RETC	RETention Curve
SPF	Saltstone Processing Facility
SRNL	Savannah River National Laboratory
SRNS	Savannah River Nuclear Solutions
SRS	Savannah River Site
USDA	United States Department of Agriculture
USDOE	United States Department of Energy
w/pm	water to premix ratio

1.0 EXECUTIVE SUMMARY

The primary focus of this task was to investigate the impact of high temperature curing on the moisture retention properties of ARP/MCU saltstone. To that end, eight mixes of ARP/MCU saltstone grout were prepared and cured at a temperature of 60°C for a 28 day period. Following this initial high temperature curing period, the samples were cured at room temperature for an additional 62 days for a total minimum curing period of 90 days. This curing profile was not intended to mimic the temperature profile of saltstone curing in a waste vault.

Samples from these mixes were tested for moisture retention characteristics using pressure extraction, measured vapor pressure (chilled mirror hygrometer), and controlled vapor pressure (vapor equilibrium). Additionally, the porosity and dry bulk density of each mix was measured and particle density was calculated from the measurements of dry bulk density.

Physical properties were measured by both SRNL and an offsite vendor (Mactec Engineering and Consulting, Inc. [MCT]). When these datasets were combined and averaged by batch, the dry bulk density of the high temperature cure saltstone was found to range from 0.886 to 0.993 g/cm^3. The porosity of the high temperature cure saltstone was found to range from 0.594 to 0.643 cm^3/cm^3.

Moisture retention properties of the high temperature cure saltstone grouts were measured by both MCT and SRNL. MCT measured the moisture retention properties over the wetter end of the drainage curve (0 to 15296 cm H_2O) and SRNL measured the moisture retention properties over the drier end of the drainage curve. The high temperature cure saltstone grouts drained considerably more than room temperature cured saltstone grout (Dixon et al., 2009) through 15 bar (15296 cm H_2O). The average mass of simulant expelled from the high temperature grouts through 15 bar was 5.42 g (about 6% of the total simulant volume) whereas the room temperature cure grout expelled an average of 0.6 g (less than 1 % of the simulant volume).

Characteristic curves for the high temperature cure grouts were compared to those based on room temperature cure saltstone grout. Although the characteristic curves for the high temperature cure grouts are similar in shape to those of room temperature cure grout, slight differences are noted at the wetter end of the retention curve. At 10,000 cm H_2O suction (approximately 95% saturation), the predicted relative hydraulic conductivity using the saltstone properties in the PA model would be about 5,000 times less than that predicted using the characteristic curves from either the high or room temperature cure saltstone.

2.0 INTRODUCTION

Several previous projects have undertaken the task of establishing the hydraulic and physical properties of saltstone grouts as related to various formulations, curing conditions, and measurement techniques. The more recent of these include Harbour et al. (2005), Harbour et al. (2007), Dixon and Phifer (2007), Dixon et al. (2008), Harbour and Williams (2008), Harbour et al. (2009) and Dixon et al. (2009). Results from these projects have provided insight into performance properties such as hydraulic conductivity, porosity, dry bulk density, and moisture retention characteristics.

Dixon et al. (2009) tested several different formulations of saltstone grout to address potential performance impacts due to variation in mix properties and curing temperature. The testing was based on a projected salt solution composition for the Actinide Removal Process/Modular Caustic Side Solvent Extraction Unit (ARP/MCU) stream that will be fed to the Saltstone Production Facility (SPF) over the next few years. A key finding from this study was that elevated curing temperature increased the hydraulic conductivity of the simulated saltstone grout. This is important because at field scale, the exothermic hydration reactions that occur during the curing process result in a temperature increase in the vaults that leads to an increased curing temperature for the grout. These findings provide the motivation for the current study which is aimed at determining the saltstone performance impacts associated with elevated curing temperature. Some of the performance properties measured for this study include saturated hydraulic conductivity, Young's Modulus, porosity, and dry bulk density. The results of these measurements are documented by Reigel and Edwards (2011).

The purpose of this report is to present the results of the moisture retention analysis of the high temperature cure saltstone grouts prepared by Reigel and Edwards (2011). These samples were a subset of samples that were part of a larger project to investigate operational and compositional factors that may affect saltstone performance properties. The study by Reigel and Edwards (2011) was not designed specifically to address the impacts of high temperature curing on saltstone moisture retention properties; however, samples from the project provide an opportunity to investigate potential impacts associated with elevated curing temperatures. The samples tested as part of this project were cured at 60^{o}C for a 28 day period. Following this initial high temperature curing period, the samples were cured at room temperature for an additional 62 days for a total minimum curing period of 90 days. This curing profile was not intended to mimic the temperature profile of saltstone curing in a waste vault.

A total of eight high temperature (60^{o}C) cure saltstone mixes were tested (Table 1) from samples that were part of the larger Reigel and Edwards (2011) project. Of the eight samples tested for this project, four were similar in composition to those tested by Dixon et al. (2009) and Table 2 provides a cross-reference of mix designs between the two projects.

3.0 METHODS

A total of eight high temperature (60^{o}C) cure saltstone mixes were tested (Table 1) from samples that were part of the larger project to investigate operational and compositional factors that may

affect saltstone performance properties (Reigel and Edwards, 2011). Details on sample preparation and curing are provided by Reigel and Edwards (2011). The high temperature cure samples were cured at 60°C for 28 days and subsequently cured for an additional 62 days at room temperature for a total minimum cure time of 90 days. This curing profile was not intended to be representative of the temperature profile of saltstone curing in a waste vault.

Samples were analyzed for moisture retention properties by Mactec Engineering and Consulting, Inc. using standard ASTM methods for pressure membrane extraction. SRNL also measured the moisture retention properties of the saltstone grouts using measured and controlled vapor equilibrium methods. These datasets were combined and characteristic curves were developed for the high temperature cure saltstone. The characteristic curves were compared to those created for room temperature cured saltstone based on data provided by Dixon et al. (2009). The following sections provide the methods used to conduct the tests.

3.1.1 Measurement of Moisture Retention Properties by Mactec

Mactec (MCT) measured the moisture retention properties of each batch of saltstone grout by pressure membrane extraction (ASTM D 6836 Method C or equivalent). This method provided the moisture retention properties of each grout sample to 15 bars (15296 cm H_2O). The laboratory tested wafers approximately 0.5 inches thick cut from the original mold samples of each saltstone grout. These samples were saturated in simulant prior to testing. For moisture retention analysis, the saturated samples were weighed to determine an initial weight. These samples were then subjected to increasing pressures in a pressure membrane extractor. Between each increase in pressure, the samples were weighed. Following the final pressure increase, the samples were weighed and then oven dried. The results from these measurements were subsequently adjusted for salt precipitation as described by Dixon et al. (2009). Porosity (initial moisture content) and dry bulk density were estimated for each water retention sample. These results were also adjusted for salt precipitation. Particle density for each sample was calculated based on dry bulk density and porosity [$\rho_s = \rho_b/(1-\eta)$].

3.1.2 Measurement of Moisture Retention Properties by SRNL

Mold samples from each batch of saltstone grout were also tested by SRNL for moisture retention properties, porosity, and dry bulk density. Particle density was inferred from the porosity and dry bulk density measurements [$\rho_s = \rho_b/(1-\eta)$]. Moisture retention properties for each batch listed in Table 1 were determined using a combination of methods including measured vapor pressure (chilled mirror hygrometer) and controlled vapor pressure (vapor equilibrium).

Thin wafers (approximately 0.5 inches thick) were cut from each saltstone core for measuring porosity and dry bulk density. The diameter and thickness of each sample were measured using a caliper. A minimum of three measurements of each dimension were made and the average was computed for use in subsequent calculations of porosity and dry bulk density. The samples were vacuum saturated in saltstone simulant prior to testing for physical properties. Periodic weight checks were used to determine when the samples were saturated.

To determine porosity and dry bulk density, the saturated wafers from each batch were oven dried at 105°C. The oven dried mass of each sample was corrected for salt precipitation (Dixon et al., 2009). The porosity and dry bulk density of each wafer was determined using the aforementioned physical measurements and the corrected dry mass.

In addition to the pressure extraction system, a measured vapor pressure method (chilled mirror hygrometer) was used to evaluate the moisture retention characteristics of the saltstone grouts. The chilled mirror hygrometer (Decagon Devices WP4-T) uses the chilled mirror dew point technique to measure the total moisture potential of porous materials (Nimmo and Winfield, 2002; Gee et al., 1992). Total moisture potential is the sum of osmotic and matric potential (neglecting hydrostatic pressure and gravitational effects). Generally, osmotic potential is negligible and the total potential is assumed to be equal to the matric potential. However, in the case of saltstone grout samples, there is a significant osmotic component due to the high salinity of the saltstone simulants used to batch the samples. Therefore, the total potential readings from the WP4-T include the osmotic potential due to the salt content of the simulant and the matric potential due to capillarity and adsorptive forces binding moisture to the saltstone particles. At the drier end of the moisture retention curve for saltstone, the osmotic potential is significantly greater than the matric potential which is the opposite of what is typically assumed for most materials.

Samples from each batch of saltstone grout were prepared for testing in the WP4-T by crushing the grout using a mortar and pestle. The crushed saltstone grout was then sieved to produce particles with a diameter of 1 mm or less. The bulk saltstone powder from each batch was stored in moisture tight containers until final preparation for testing in the WP4-T. No attempt was made to compact the saltstone powder to a specific bulk density prior to testing as it has been shown that moisture potential is virtually independent of bulk density for drier materials (potentials < -1020 cm H_2O). In dry materials, most large pores are drained and structure and porosity effects are minor compared to surface area effects such as adsorption (Gee et al., 1992).

Sub-samples of saltstone powder (2 g) from each batch were tested in the WP4-T for total moisture potential. These samples were initially tested at the "as-received" moisture content. After the initial moisture potential measurement, each sample was either air dried or oven dried to achieve a lower moisture potential (drier condition). Samples were sealed in plastic sample cups for a minimum of several hours to ensure equilibrium moisture conditions were achieved. Samples were sequentially dried and measurements of potential were made at each increment. When testing was complete, the samples were oven dried to determine the volumetric moisture content at each test increment.

A controlled vapor pressure method (vapor equilibrium) was used to provide a comparison to the measured vapor pressure method implemented with the WP4-T. For this method, a small amount of material is placed above a saturated salt solution inside a sealed container. The saturated salt solution produces a constant relative humidity in the headspace of the sealed container. Relative humidity is then related to total water potential by the following equation:

$$\ln\left(\frac{p}{p_o}\right) = 7.5\,x10^{-5}\left(h_m - h_o\right) \quad (1)$$

where: p/p_o = relative humidity
h_m = matric potential
h_o = osmotic potential

At equilibrium, the material is assumed to attain the same total potential (h_m-h_o) as the vapor in the headspace of the container (Nimmo and Winfield (2002). As with the measured vapor pressure method, this method is influenced by both osmotic and matric potential.

Several different saturated salt solutions were used to provide a range of moisture potentials for comparison to the measured vapor pressure method. The salt solutions used and their properties are provided in Table 3 (Lide, 2001).

For the controlled vapor pressure method, 1 g of saltstone powder (at the "as received" moisture content) was placed above the saturated salt solution. The samples were periodically weighed to determine when equilibrium was reached. The total potential of each sample was determined using Equation 1 and the relative humidity for each salt solution as provided in Table 3. The volumetric moisture content associated with the calculated potential was determined using the equilibrium weight of the sample and the dry bulk density of the saltstone material. The results from the controlled vapor pressure method were used to qualitatively confirm the results from the measured vapor pressure method (WP4-T).

3.2 DETERMINATION OF VAN GENUCHTEN TRANSPORT PARAMETERS

Direct measurement of the unsaturated hydraulic conductivity of large numbers of samples of cementitious materials is time consuming and cost prohibitive. An alternative to direct measurement is the use of theoretical methods to predict the unsaturated hydraulic conductivity based upon measured moisture retention data. These methods are generally based on pore-size distribution models, and have been shown to perform reasonably well for coarse textured soils and other porous media having relatively narrow pore-size distributions (USDA, 1998). Savage and Janssen (1997) compared measured drainage from concrete samples with predictive models produced from characteristic curves developed from van Genuchten curve fitting (i.e., RETC). They concluded that the van Genuchten method of predicting unsaturated hydraulic conductivity from moisture retention data was applicable to Portland cement concrete. This indicates that predictive models based on moisture retention data provide the most viable means of characterizing the hydraulic properties of large numbers of samples of cementitious materials. Therefore, this method was chosen to predict the unsaturated hydraulic conductivity of the saltstone grout samples based upon the measured moisture retention properties.

RETC (RETention Curve) (USDA, 1998), a U.S. Salinity Laboratory computer program designed for analyzing the hydraulic properties of unsaturated soils, was used to fit the measured moisture retention data for the saltstone grout samples. The program's curve fitting is based on van Genuchten's equation for soil moisture content as a function of pressure

$$\theta(h) = \theta_r + \frac{\theta_s - \theta_r}{\left[1 + (\alpha h)^n\right]^m} \qquad h \le 0 \tag{2}$$

$$\theta(h) = \theta_s \qquad h > 0 \tag{3}$$

where $\theta(h)$ is moisture content at the pressure head h, θ_r is residual moisture content, θ_s is the saturated moisture content, h is pressure head, α is a constant related to the inverse of the air-entry pressure, and n is a measure of the pore-size distribution. The constraint $m = 1 - 1/n$ was used as suggested by van Genuchten (van Genuchten, 1980; van Genuchten et al., 1991).

The generated moisture retention curves were based on moisture retention data only; no unsaturated hydraulic conductivity data were available for the samples. RETC's (USDA, 1998) van Genuchten $m = 1 - 1/n$ retention curve model was used to estimate curve fitting parameters ($\theta_r, \theta_s, \alpha, n$) for each sample.

The curve fitting parameters ($\theta_r, \theta_s, \alpha, n$) from RETC (USDA, 1998) were used to calculate the effective saturation (or reduced water content), S_e, at incremental pressure heads according to

$$S_e = \frac{S - S_r}{1 - S_r} = \frac{1}{\left[1 + (\alpha h)^n\right]^m} \tag{4}$$

where S_r denotes residual saturation. Using S_e, the relative hydraulic conductivity (K_r) was calculated at incremental pressure heads using the Mualem-van Genuchten type function

$$K_r = S_e^L \left[1 - \left(1 - S_e^{1/m}\right)^m\right]^2 \tag{5}$$

where L is an empirical pore-connectivity parameter and assumed to be 0.5.

Unsaturated hydraulic conductivity may be calculated according to

$$K_u = K_r K_s \tag{6}$$

Saturation (S) was calculated at various pressure heads according to

$$S = S_r + \left(\frac{1 - S_r}{\left[1 + (\alpha h)^n\right]^m}\right) \tag{7}$$

where residual saturation, S_r, is equal to θ_r / θ_s (the residual moisture content divided by the saturated moisture content).

4.0 RESULTS

The following sections present the results of the physical property testing and moisture retention analysis of eight high temperature cure (60°C) saltstone grouts (Table 1). Table 2 provides a cross reference to the room temperature cure batches tested by Dixon et al. (2009). This work was conducted in conjunction with a larger study to investigate the performance impacts of curing temperature on hydraulic properties such as saturated hydraulic conductivity. Those results are presented by Reigel and Edwards (2011).

4.1 PHYSICAL PROPERTIES OF HIGH TEMPERATURE CURE SALTSTONE

MCT measured the physical properties of each of the high temperature cure (60°C) saltstone grouts listed in Table 1. The results of these analyses are presented in Table 4 and the average of these properties is presented in Table 5. Dry bulk density was found to range from 0.869 to 0.990 g/cm^3 and porosity was found to range from 0.588 to 0.646 cm^3/cm^3. SRNL also measured the physical properties of each of the high temperature cure (60°C) saltstone grouts listed in Table 1. Properties measured included dry bulk density and porosity. The results of these measurements are presented in Table 6. Dry bulk density was found to range from 0.893 to 1.015 g/cm^3 and porosity was found to range from 0.582 to 0.644 cm^3/cm^3. These results are consistent with previous results presented by Dixon et al. (2009).

4.2 MOISTURE RETENTION RESULTS

Moisture retention properties of the high temperature cure formulations (60°C) were determined by both MCT and SRNL using a combination of methods. The results of these analyses are presented in Table 7 through Table 9 and in Figure 1 through Figure 11. The following sub-sections describe the results of the moisture retention testing and subsequent analysis.

4.2.1 Moisture Retention Properties as Determined by MCT

MCT used pressure membrane extraction to determine the moisture retention properties of the high temperature cure saltstone grouts for pressures ranging from 102 cm H_2O (0.1 bar) to approximately 15,296 cm H_2O (15 bar). Moisture retention curves for each batch as determined by MCT are presented in Figure 1 through Figure 8. For those batches where a room temperature cure moisture retention curve is available, that curve is presented for direct comparison (Dixon et al. 2009). Figure 9 presents a comparison of the moisture retention curves for each batch and Figure 10 shows the average moisture retention curve for all batches. The average MCT moisture retention curve was prepared by averaging the moisture retention data for each pressure increment across all batches of saltstone. Figure 10 also shows a comparison between the average MCT moisture retention curve for the high temperature saltstone grout to the average MCT moisture retention curve for room temperature cure (20°C) saltstone grout (Dixon et al., 2009). This figure clearly shows that the high temperature cure (60°C) grouts exhibited different drainage properties between 1 and 15 bar compared to the 20°C cure temperature grouts tested by Dixon et al. (2009).

Table 8 presents the mass of simulant expelled during the pressure extraction testing for each batch of high temperature cure saltstone. The average mass of simulant expelled over the

duration of the testing was 5.42 g. The average mass of simulant contained within a sample was 88.76 g. Thus, less than 6 percent of the total mass of simulant contained within a sample was released during the pressure extraction testing.

4.2.2 Moisture Retention Properties as Determined by SRNL

SRNL tested the moisture retention properties of the saltstone grouts using measured vapor pressure (chilled mirror hygrometer) and controlled vapor pressure (vapor equilibrium) methods. Sub-samples of each saltstone batch were tested for total moisture potential using the chilled mirror hygrometer (WP4-T). Samples were initially tested at the "as-received" moisture content. The average "as-received" saturation level of the high temperature cure saltstone samples was greater than 96 percent.

As previously discussed, the chilled mirror hygrometer measures total moisture potential. Total potential is the sum of the osmotic and matric potential where osmotic potential is due to dissolved salts in solution and matric potential is due to adhesive intermolecular forces between the solution and solid particles. Ordinarily, osmotic potential is negligible and the total potential reading is considered to be equal to the matric potential. In the case of saltstone grout, there is a significant osmotic component due to the high salinity of the salt solution used to batch the samples. Therefore, a cured sample of saltstone (which is essentially saturated) will have a significant osmotic potential when the matric potential is essentially zero. The osmotic and matric potential combine to produce negative (i.e. lower) water potentials relative to pure water. The combination of osmotic and matric potential will tend to keep saltstone grout at or near saturation for most field conditions. Water flow from the surrounding environment will be from areas of higher water potential to areas of lower water potential. As a result, field scale moisture flow could be from the surrounding vadose zone to the saltstone grout due to the large pressure gradient created by saltstone. In this case, the transport of ions from the saltstone matrix will be due to osmosis rather than advective transport via moisture movement.

Results from the measured vapor pressure method are presented in Table 9 and Figure 11. In some cases, multiple sub-samples of each grout were tested. As such, sample IDs were assigned a suffix (A, B, or C) for record keeping purposes. Total potential measurements for each sample are presented in Table 9 as well as calculated matric potential. Matric potential was calculated by subtracting the osmotic potential of low aluminate simulant (-24.6 MPa; Dixon et al., 2009) from the total potential measurements for each sample. This calculation is necessitated by the fact the governing equation for unsaturated moisture transport commonly implemented in most advective transport models is written in terms of matric potential.

Figure 11 compares the moisture retention curves derived from the measured and controlled vapor pressure methods. For the controlled vapor pressure method, each batch of high temperature cure saltstone was tested in sealed containers exposed to various saturated salt solutions. The results for each salt solution were averaged for presentation and are given in Table 10. Good agreement is noted between the measured and controlled vapor pressure datasets (Figure 11), which validates the measured vapor pressure results.

4.3 ANALYSIS OF MOISTURE RETENTION CHARACTERISTICS

The measured moisture retention data were analyzed to determine the van Genuchten curve fitting parameters and the relative hydraulic conductivity function. The moisture retention data were analyzed using the RETC model (USDA, 1998). The standard Mualem relationship between n and m (i.e., m = 1 – 1/n) was used. The SRNL and MCT moisture retention datasets were combined for the RETC analysis. None of the data were averaged for the analysis. All moisture retention values were given a weight of 1. Per ASTM D 6836, the chilled mirror hygrometer is best suited for matric potentials above 10000 cm H_2O (~10 bar). As such, data below this limit were excluded from this analysis.

RETC was allowed to optimize saturated moisture content (θ_s), residual moisture content (θ_r) and the curve fitting parameters α and n. RETC outputs α and n to five decimal places. The resulting characteristic curve for the high temperature cure saltstone grout is presented in Figure 12 and the curve fitting parameters are given in Table 11. Confidence limits (95%) for the van Genuchten parameters are provided in Table 12.

Figure 12 shows that the RETC fit to the moisture retention data is good (r^2=0.97) with the best accuracy noted for the measured vapor pressure dataset and the MCT data near saturation. In addition to the fit to the combined dataset, Figure 12 shows the RETC fit to just the MCT dataset. The characteristic curves obtained by using only the MCT data are considerably different than those obtained using the entire dataset and are not consistent with those typically associated with cementitious materials (Dixon et al., 2009). The relative permeability curve obtained using only the MCT data is particularly problematic in that a slight reduction in saturation (< 5%) produces more than 3 orders of magnitude reduction in relative permeability. This illustrates the importance of obtaining a more complete moisture retention dataset for defining the drainage properties of saltstone grouts.

Figure 13 shows a comparison of the characteristic curves based on the high temperature cure grouts to those based on room temperature cure saltstone from Dixon et al. (2009). Dixon et al. (2009) presented moisture retention properties and van Genuchten parameters in terms of total potential. To allow a direct comparison to the high temperature cure grout characteristic curves, matric potential was calculated from total potential as previously discussed and these data were reanalyzed using RETC. The curves for the high temperature cure grouts and the room temperature cure grouts (Dixon et al., 2009) are similar in shape. Differences noted are due to increased drainage observed at higher moisture contents for the high temperature cure grouts. Based on the limited dataset from this study, it appears that the impact of increased drainage observed at lower suctions for the high temperature grouts is minimal.

Figure 14 compares the high temperature and room temperature relative permeability curves to the relative permeability curve used in the most recent PA model. Although there appears to be minimal differences between the room temperature and high temperature cure relative permeability curves, a substantial difference is noted compared to the PA curve. At 10,000 cm H_2O suction (approximately 95% saturation), K_r = 0.31 and 0.61 for the high temperature and room temperature cure saltstone, respectively. However, for the same suction (10,000 cm H_2O), K_r = 0.0001 using the characteristic curve from the PA model. The predicted relative hydraulic conductivity using the saltstone properties in the PA model would be about 5,000 times less than

that predicted using the characteristic curves from either the high or room temperature cure saltstone.

5.0 SUMMARY

A total of 8 high temperature cure (60^oC) saltstone formulations were tested for physical and moisture retention properties. Physical properties measured included dry bulk density and porosity. Each of the 8 saltstone grouts were cured at 60^oC for 28 days and subsequently cured for an additional 62 days at room temperature for a total minimum cure time of 90 days. This curing profile was not intended to be representative of the temperature profile of saltstone curing in a waste vault.

The saltstone samples were submitted to Mactec Engineering and Consulting, Inc. (MCT) for physical property and moisture retention testing per ASTM standards. Results for dry bulk density and porosity are presented in Table 4 and average properties are presented in Table 5. The MCT moisture retention results are presented in Table 7. SRNL also measured the physical properties of the high temperature cure saltstone grouts and these results are presented in Table 6. SRNL moisture retention data are presented in Table 9 and Table 10.

The data for the high temperature cure saltstone were analyzed to determine the van Genuchten curve fitting parameters. These parameters are presented in Table 11 and confidence limits are provided in Table 12. Additionally, moisture retention data for room temperature cure (20^oC) saltstone from Dixon et al. (2009) was analyzed to determine the van Genuchten curve fitting parameters to provide a comparison to the high temperature cure results. The parameters for the room temperature cure saltstone are also presented in Table 11 with confidence limits provided in Table 12.

The high temperature cure saltstone grouts drained more than room temperature saltstone grout (Dixon et al., 2009) through 15296 cm H_2O (15 bar). The average mass of simulant expelled from the high temperature grouts through 15 bar was 5.42 g (about 6% of the total simulant volume) whereas the room temperature cure grout expelled an average of 0.6 g (less than 1% of the simulant volume). Although the characteristic curves for the high temperature cure grouts are similar in shape to those of room temperature cure grout, slight differences are noted at the wetter end of the retention curve. At 10,000 cm H_2O suction (approximately 95% saturation), the predicted relative hydraulic conductivity using the saltstone properties in the PA model would be about 5,000 times less than that predicted using the characteristic curves from either the high or room temperature cure saltstone.

6.0 REFERENCES

ASTM D 6836. Standard Test Methods for Determination of the Soil Water Characteristic Curve for Desorption Using a Hanging Column, Pressure Extractor, Chilled Mirror Hygrometer, and/or Centrifuge. ASTM International, West Conshohocken, PA.

Dixon, K. L. and M. A. Phifer. 2007. Hydraulic And Physical Properties Of MCU Saltstone. WSRC-STI-2007-00649. Washington Savannah River Company, Savannah River Site, Aiken SC.

Dixon, K. L., M. A. Phifer, and J. R. Harbour. 2008. FY09 PA/CA Maintenance Program: Additional Saltstone Property Testing. SRNL L3100-D1700-2009-00002, Rev. 0. Savannah River National Laboratory, Savannah River Nuclear Solutions, Aiken, SC.

Dixon, K. L., J. R. Harbour, and M. A. Phifer. 2008. Hydraulic and Physical Properties of Saltstone Grouts and Vault Concretes. SRNL-STI-2008-00421, Rev. 0. Savannah River National Laboratory, Savannah River Nuclear Solutions, Aiken, SC.

Dixon, K. L., J. R. Harbour, and M. A. Phifer. 2009. Hydraulic And Physical Properties Of ARP/MCU Saltstone Grout. SRNL-STI-2009-00419, Rev. 0. Savannah River National Laboratory, Savannah River Nuclear Solutions, Aiken, SC.

Gee, G. W., M. D. Campbell, G. S. Campbell, and J. H. Campbell. 1992. Rapid Measurement of Low Soil Water Potentials using a Water Activity Meter. Soil Science Society of America Journal, v56, 1068-1070.

Harbour, J. R., T. B. Edwards, E. K. Hansen, and V. J. Williams. 2005. Variability Study for Saltstone. WSRC-TR-2005-00447. Washington Savannah River Company, Savannah River Site, Aiken SC.

Harbour, J. R., T. B. Edwards, V. J. Williams, G. W. Scherer, and D. M. Feliciano. 2007. Permeability of Saltstone – Measurement by Beam Bending. WSRC-TR-2007-00437. Washington Savannah River Company, Savannah River Site, Aiken SC.

Harbour, J. R. and V. J. Williams. 2008. Saltstone Performance Indicator - Dynamic Young's Modulus. SRNL-STI-2008-00488, Rev. 0. Savannah River National Laboratory, Savannah River Nuclear Solutions, Aiken, SC.

Harbour, J. R., T. B. Edwards, and V. J. Williams. 2009. Impact of Time/Temperature Curing Conditions and Aluminate Concentration on Saltstone Properties. Savannah River National Laboratory, Savannah River Nuclear Solutions, Aiken, SC.

Lide, D. R. ed. 2001. CRC Handbook of Chemistry and Physics, 81st Edition, p 1525. CRC Press, New York, NY.

Nimmo, J. R. and K. A. Winfield. 2002. Water Retention and Storage: Miscellaneous Methods. p 710-711. In J. H. Dane and G. C. Topp (ed.), Methods of Soil Analysis, Part 4, Physical Methods, Soil Science Society of America.

Reigel, M. M. and T. B. Edwards. 2011. Operational and Compositional Factors that Affect the Performance Properties of ARP/MCU Saltstone Grout. SRNL-STI-2011-00665, Rev. 0. Savannah River National Laboratory, Savannah River Nuclear Solutions, Aiken, SC.

Savage, B. M. and D. J. Janssen. 1997. Soil Physics Principles Validated for Use in Predicting Unsaturated Moisture Movement in Portland Cement Concrete. ACI Materials Journal, Vol. 94, No. 1, January-February 1997, pp. 63-70.

USDA, 1998. RETC for Windows, 1998, Version 1.0.0.1, U.S. Salinity Laboratory, U.S. Department of Agriculture (USDA), www.ars.usda.gov/Services/docs.htm?docid=8952.

Van Genuchten, M. Th., 1980, A Closed-form Equation for Predicting the Hydraulic Conductivity of Unsaturated Soils, Soil Science Society of America Journal, v44, 892-898.

Van Genuchten, M. Th., F. J. Leij, and S. R. Yates, 1991, The RETC Code for Qualifying the Hydraulic Functions of Unsaturated Soils, Version 1.0, EPA Report 600/2-91/065, U.S. Salinity Laboratory, USDA, ARS, Riverside, California.

Table 1. High Temperature Cure (60°C) Saltstone Mixes that were Tested for Moisture Retention Properties.

Mix ID	Simulant Density (g/cm³)	Mass Salt 100 g grout	Water to Simulant	w/pm[1]	Aluminate Molarity	Premix BFS[2] (%)	Premix FA[3] (%)	Premix OPC[4] (%)
TR630, TR631	1.2527	14.27	0.703	0.65	0.28	45	45	10
TR632, TR633	1.2527	13.04	0.703	0.55	0.28	45	45	10
TR638, TR639	1.2374	12.07	0.721	0.55	0.05	45	45	10
TR641, TR642	1.2374	13.23	0.721	0.65	0.05	45	45	10
TR680, TR680	1.2374	12.07	0.721	0.55	0.05	40	50	10
TR696, TR697	1.2507	14.27	0.703	0.65	0.28	40	50	10
TR698, TR699	1.2507	13.04	0.703	0.55	0.28	40	50	10
TR700, TR701	1.2374	13.23	0.721	0.65	0.05	40	50	10

[1]Water to premix ratio
[2]BFS – Blast Furnace Slag
[3]FA – Carbon Burnout Fly Ash
[4]Ordinary Portland Cement (Type II)

Table 2. Cross Reference of 2011 and 2009 formulations.

FY2011 Mix ID (60°C Cure)	FY2009 Mix ID (20°C Cure)	w/pm	Aluminate Molarity	Premix BFS (%)	Premix FA (%)	Premix OPC (%)
TR630, TR631	TR588, TR589	0.65	0.280	45	45	10
TR632, TR633	TR582, TR583	0.55	0.280	45	45	10
TR638, TR639	TR575, TR576	0.55	0.05	45	45	10
TR641, TR642	TR577, TR578	0.65	0.05	45	45	10

Table 3. Salt Solutions used in Controlled Vapor Pressure Method.

Salt Solution	Relative Humidity (fraction)	(h_m-h_o)[1] (bar)	(h_m-h_o)[1] (cm)
Sodium Chloride (NaCl)	0.75	-372	-379837
Potassium Iodide (KI)	0.68	-496	-506179
Magnesium Nitrate Hexahydrate $Mg(NO_3)_2*6H_2O$	0.53	-840	-856253
Magnesium Chloride Hexahydrate $Mg(Cl)*6H_2O$	0.33	-1460	-1488474
Lithium Chloride (LiCl)	0.11	-2849	-2905106

[1]Total potential which is the sum of matric and osmotic potential.

Table 4. Physical Properties of High Temperature Cure (60^{o}C) Saltstone as Measured by MCT (90 day minimum curing period) from Moisture Retention Samples.

Batch ID	Lab	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density[1] (g/cm^3)
TR630-1	MCT	0.894	0.646	2.522
TR630-2	MCT	0.882	0.629	2.376
TR631-1	MCT	0.870	0.631	2.361
TR632-1	MCT	0.976	0.601	2.448
TR632-2	MCT	0.972	0.598	2.417
TR633-1	MCT	0.967	0.597	2.396
TR638-1	MCT	0.989	0.601	2.480
TR638-2	MCT	0.957	0.588	2.325
TR639-1	MCT	0.969	0.595	2.392
TR641-1	MCT	0.902	0.643	2.529
TR641-2	MCT	0.892	0.643	2.502
TR642-1	MCT	0.896	0.643	2.508
TR680-1	MCT	0.990	0.611	2.545
TR680-2	MCT	0.978	0.617	2.552
TR681-1	MCT	0.985	0.614	2.552
TR696-1	MCT	0.888	0.645	2.499
TR696-2	MCT	0.884	0.643	2.478
TR697-1	MCT	0.886	0.641	2.465
TR698-1	MCT	0.971	0.602	2.441
TR698-2	MCT	0.957	0.602	2.406
TR699-1	MCT	0.966	0.595	2.386
TR700-1	MCT	0.869	0.623	2.305
TR700-2	MCT	0.881	0.644	2.473
TR701-1	MCT	0.886	0.646	2.502

[1]Particle density calculated as $\rho_s = \rho_b/(1-\eta)$ where ρ_b is dry bulk density and η is porosity.

Table 5. Average Physical Properties of High Temperature Cure (60^{o}C) Saltstone as Measured by MCT (90 day minimum curing period) from Moisture Retention Samples.

Batch ID	Lab	Average Dry Bulk Density (g/cm^3)	Average Porosity (cm^3/cm^3)	Average Particle Density[1] (g/cm^3)
TR630, TR631	MCT	0.882	0.635	2.420
TR632, TR633	MCT	0.972	0.599	2.421
TR638, TR639	MCT	0.972	0.595	2.399
TR641, TR642	MCT	0.897	0.643	2.513
TR680, TR680	MCT	0.984	0.614	2.549
TR696, TR697	MCT	0.886	0.643	2.481
TR698, TR699	MCT	0.965	0.600	2.411
TR700, TR701	MCT	0.879	0.638	2.427

[1]Particle density calculated as $\rho_s = \rho_b/(1-\eta)$ where ρ_b is dry bulk density and η is porosity.

Table 6. Physical Properties of High Temperature Cure (60^{o}C) Saltstone as Measured by SRNL (90 day minimum curing period) for Each Formulation Tested.

Batch ID	Lab	Dry Bulk Density (g/cm^3)	Porosity (cm^3/cm^3)	Particle Density (g/cm^3)
TR630, TR631	SRNL	0.893	0.624	2.374
TR632, TR633	SRNL	0.990	0.598	2.464
TR638, TR639	SRNL	1.015	0.593	2.494
TR641, TR642	SRNL	0.914	0.628	2.455
TR680, TR680	SRNL	0.983	0.585	2.367
TR696, TR697	SRNL	0.929	0.644	2.609
TR698, TR699	SRNL	0.987	0.582	2.361
TR700, TR701	SRNL	0.992	0.626	2.655

[1]Particle density calculated as $\rho_s = \rho_b/(1-\eta)$ where ρ_b is dry bulk density and η is porosity.

Table 7. Moisture Retention Data for High Temperature Cure (60°C) Saltstone as measured by MCT (90 day minimum curing period).

Sample Id	Minimum Curing Period (days)	Bulk Density[a] (g/cm³)	Potential ($cm\ H_2O$)						
			0	-101.97	-509.87	-1,019.74	-5,098.72	-10,197.44	-15,296.16
			(0.00 bars)	(-0.10 bars)	(-0.50 bars)	(-1.0 bars)	(-5.0 bars)	(-10.0 bars)	(-15.0 bars)
			Volumetric Moisture Content[1] (cm^3/cm^3)						
TR630-1	90	0.894	0.646	0.643	0.642	0.641	0.627	0.623	0.622
TR630-2	90	0.882	0.629	0.625	0.625	0.625	0.615	0.611	0.610
TR631-1	90	0.870	0.631	0.628	0.627	0.626	0.606	0.598	0.597
TR632-1	90	0.976	0.601	0.599	0.599	0.597	0.592	0.584	0.576
TR632-2	90	0.972	0.598	0.595	0.594	0.592	0.588	0.585	0.576
TR633-1	90	0.967	0.597	0.596	0.595	0.594	0.593	0.589	0.578
TR638-1	90	0.989	0.601	0.598	0.594	0.589	0.581	0.577	0.575
TR638-2	90	0.957	0.588	0.584	0.581	0.578	0.569	0.564	0.561
TR639-1	90	0.969	0.595	0.591	0.587	0.586	0.579	0.573	0.570
TR641-1	90	0.902	0.643	0.640	0.639	0.638	0.629	0.616	0.608
TR641-2	90	0.892	0.643	0.639	0.639	0.637	0.628	0.621	0.617
TR642-1	90	0.896	0.643	0.640	0.638	0.636	0.628	0.623	0.616
TR680-1	90	0.990	0.611	0.609	0.608	0.606	0.561	0.554	0.552
TR680-2	90	0.978	0.617	0.611	0.609	0.608	0.602	0.596	0.592
TR681-1	90	0.985	0.614	0.608	0.608	0.605	0.580	0.577	0.575
TR696-1	90	0.888	0.645	0.641	0.638	0.634	0.589	0.586	0.583
TR696-2	90	0.884	0.643	0.639	0.638	0.634	0.611	0.604	0.600
TR697-1	90	0.886	0.641	0.637	0.636	0.634	0.580	0.575	0.574

Table 7. Continued.

Sample Id	Minimum Curing Period (days)	Bulk Density[a] (g/cm³)	Potential (cm)						
			0	-101.97	-509.87	-1,019.74	-5,098.72	-10,197.44	-15,296.16
			(0.00 bars)	(-0.10 bars)	(-0.50 bars)	(-1.0 bars)	(-5.0 bars)	(-10.0 bars)	(-15.0 bars)
			Volumetric Moisture Content[1] (cm³/cm³)						
TR698-1	90	0.971	0.602	0.601	0.600	0.598	0.583	0.581	0.578
TR698-2	90	0.957	0.602	0.599	0.597	0.594	0.571	0.567	0.562
TR699-1	90	0.966	0.595	0.591	0.589	0.586	0.562	0.558	0.555
TR700-1	90	0.869	0.623	0.617	0.614	0.613	0.565	0.559	0.551
TR700-2	90	0.881	0.644	0.633	0.631	0.630	0.580	0.575	0.561
TR701-1	90	0.886	0.646	0.640	0.638	0.636	0.600	0.594	0.587

Table 8. Mass of Simulant Released During Pressure Extraction Testing of High Temperature Cure Saltstone (60°C).

Sample ID	Mass of Simulant Released (g)	Total Mass of Simulant in Sample (g)	Percentage of Simulant Released	Sample ID	Mass of Simulant Released (g)	Total Mass of Simulant in Sample (g)	Percentage of Simulant Released
TR630-1	3.37	91.62	3.68	TR680-1	8.19	84.81	9.66
TR630-2	2.63	85.69	3.07	TR680-2	3.50	86.51	4.05
TR631-1	4.03	74.58	5.40	TR681-1	4.82	76.73	6.28
TR632-1	3.99	93.46	4.27	TR696-1	9.11	95.03	9.59
TR632-2	2.85	76.22	3.74	TR696-2	6.32	94.17	6.71
TR633-1	2.68	87.93	3.05	TR697-1	10.04	96.11	10.45
TR638-1	3.93	88.96	4.42	TR698-1	3.57	89.87	3.97
TR638-2	3.83	81.38	4.71	TR698-2	4.84	72.36	6.69
TR639-1	3.91	91.76	4.26	TR699-1	5.15	77.00	6.69
TR641-1	5.59	102.72	5.44	TR700-1	9.68	82.93	11.67
TR641-2	3.62	89.69	4.04	TR700-2	12.05	94.24	12.79
TR642-1	4.06	97.94	4.15	TR701-1	8.21	89.99	9.12

Table 9. Moisture Retention Data for High Temperature Cure (60^{o}C) Saltstone as Measured by SRNL using Chilled Mirror Humidity Sensor.

Sample ID	Volumetric Moisture Content (cm^3/cm^3)	Saturation (fraction)	Total Potential (bar)	Total Potential (cm H_2O)	Matric Potential (bar)	Matric Potential (cm H_2O)
TR630-C	0.466	0.747	255.0	260034.8	9.4	9585.6
TR630-C	0.439	0.703	298.1	303985.8	52.5	53536.6
TR630-C	0.384	0.616	354.7	361703.3	109.1	111254.1
TR630-C	0.339	0.543	435.3	443894.7	189.7	193445.5
TR630-C	0.293	0.470	509.0	519049.8	263.4	268600.6
TR630-B	0.203	0.326	757.9	772864.2	512.3	522415.0
TR630-C	0.202	0.324	709.6	723610.5	464.0	473161.4
TR630-C	0.166	0.266	948.3	967023.5	702.7	716574.3
TR630-B	0.149	0.239	1137.6	1160061.1	892.0	909611.9
TR630-C	0.093	0.149	1420.2	1448240.8	1174.6	1197791.6
TR630-B	0.068	0.109	2765.1	2819694.9	2519.5	2569245.7
TR630-C	0.066	0.106	2535.3	2585357.7	2289.7	2334908.5
TR632-C	0.445	0.744	290.4	296133.7	44.8	45684.5
TR632-C	0.378	0.633	376.0	383423.9	130.4	132974.7
TR632-C	0.312	0.521	500.5	510382.0	254.9	259932.8
TR632-C	0.255	0.425	592.0	603688.6	346.4	353239.4
TR632-B	0.171	0.287	757.9	772864.2	512.3	522415.0
TR632-C	0.159	0.266	955.6	974467.6	710.0	724018.4
TR632-B	0.115	0.193	1137.6	1160061.1	892.0	909611.9
TR632-C	0.112	0.186	1614.2	1646071.2	1368.6	1395622.0
TR632-C	0.073	0.123	2113.5	2155229.6	1867.9	1904780.4
TR632-B	0.059	0.099	2765.1	2819694.9	2519.5	2569245.7
TR632-C	0.054	0.091	3120.7	3182316.0	2875.1	2931866.8
TR638-C	0.423	0.713	285.0	290627.1	39.4	40177.9
TR638-C	0.358	0.603	367.2	374450.1	121.6	124000.9
TR638-C	0.321	0.541	441.4	450115.1	195.8	199665.9
TR638-C	0.265	0.447	542.1	552803.4	296.5	302354.2
TR638-C	0.163	0.275	816.8	832927.1	571.2	582477.9
TR638-B	0.161	0.271	732.5	746962.7	486.9	496513.5
TR638-C	0.117	0.197	1326.9	1353098.7	1081.3	1102649.5

Table 9. Continued.

TR638-B	0.114	0.192	1159.1	1181985.6	913.5	931536.4
TR638-C	0.071	0.119	1891.6	1928948.3	1646.0	1678499.1
TR638-B	0.057	0.096	3009.7	3069124.4	2764.1	2818675.2
TR638-C	0.052	0.088	3232.4	3296221.4	2986.8	3045772.2
TR641-C	0.452	0.721	274.7	280123.8	29.1	29674.6
TR641-C	0.399	0.635	329.5	336005.7	83.9	85556.5
TR641-C	0.354	0.564	409.3	417381.3	163.7	166932.1
TR641-C	0.309	0.493	484.9	494474.0	239.3	244024.8
TR641-B	0.228	0.363	658.7	671705.6	413.1	421256.4
TR681-B	0.328	0.561	313.4	319587.9	67.8	69138.7
TR681-B	0.249	0.425	436.4	445016.4	190.8	194567.2
TR681-A	0.197	0.338	798.7	814469.8	553.1	564020.6
TR681-A	0.113	0.193	1272.1	1297216.7	1026.5	1046767.5
TR681-B	0.090	0.154	974.2	993434.9	728.6	742985.7
TR681-B	0.081	0.138	1150.8	1173521.7	905.2	923072.5
TR681-A	0.065	0.112	1344.1	1370638.3	1098.5	1120189.1
TR681-A	0.037	0.064	2835.0	2890975.1	2589.4	2640525.9
TR681-B	0.037	0.063	2285.0	2330115.7	2039.4	2079666.5
TR696-A	0.369	0.574	374.4	381792.3	128.8	131343.1
TR696-A	0.178	0.276	722.6	736867.2	477.0	486418.0
TR696-A	0.123	0.191	1361.4	1388279.9	1115.8	1137830.7
TR696-A	0.059	0.091	2003.5	2043057.7	1757.9	1792608.5
TR696-A	0.031	0.049	2800.7	2855997.8	2555.1	2605548.6
TR698-A	0.375	0.598	255.8	260850.6	10.2	10401.4
TR698-A	0.321	0.511	424.5	432881.5	178.9	182432.3
TR698-A	0.158	0.252	767.0	782143.9	521.4	531694.7
TR698-A	0.122	0.194	1765.1	1799950.6	1519.5	1549501.4
TR698-A	0.077	0.122	2017.2	2057028.2	1771.6	1806579.0
TR698-A	0.041	0.065	2519.0	2568735.9	2273.4	2318286.7
TR700-A	0.398	0.636	267.7	272985.5	22.1	22536.3
TR700-A	0.335	0.534	419.5	427782.7	173.9	177333.5
TR700-A	0.162	0.259	809.8	825788.9	564.2	575339.7
TR700-A	0.117	0.186	1411.3	1439165.1	1165.7	1188715.9
TR700-A	0.053	0.085	2009.1	2048768.3	1763.5	1798319.1
TR700-A	0.008	0.012	2775.9	2830708.2	2530.3	2580259.0

Table 10. Average Moisture Retention Data for ARP/MCU Saltstone as Measured by SRNL using Vapor Equilibrium Method.

Salt Solution	Relative Humidity[1] (%)	Average Saturation (%)	Total Potential (bar)
Sodium chloride, NaCl	75	0.35	372.5
Potassium Iodide, KI	69	0.30	496.4
Magnesium Nitrate Hexahydrate, $Mg(NO_3)_2*6H_2O$	53	0.24	839.7
Magnesium Chloride Hexahydrate $Mg(Cl)*6H_2O$	33	0.18	1460.0
Lithium Chloride, LiCl	11	0.14	2848.9

Table 11. Van Genuchten Transport Parameters.

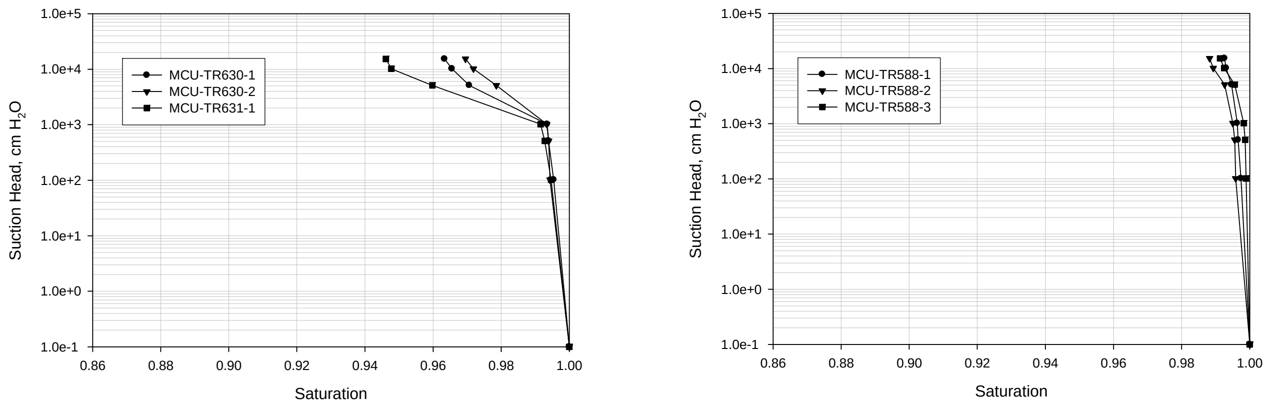
Material[1,2]	θ_s (cm^3/cm^{-3})	θ_r (cm^3/cm^3)	α (1/cm)	n	m	r^2
High Temperature Cure (60°C) Saltstone	0.60269	0.00000	0.00002	1.51007	0.33778	0.970
Room Temperature Cure (20°C) Saltstone[3]	0.60009	0.00492	0.00001	1.68609	0.4069	0.986

[1]Data analyzed using Mualem relationship between n and m where m = 1 – 1/n.
[2]Moisture retention data from SRNL and Mactec measurements were combined for this analysis.
[3]Moisture retention data for room temperature cure saltstone taken from Dixon et al. (2009) and reanalyzed in terms of matric potential.

Table 12. Confidence Limits (95%) for Van Genuchten Transport Parameters.

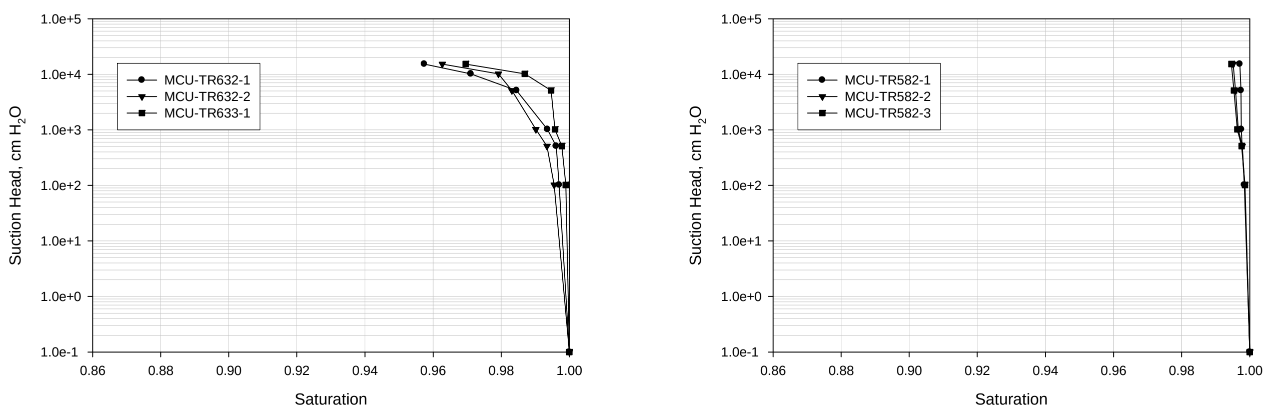
Material	θ_s (cm^3/cm^3)		θ_r (cm^3/cm^3)		α (1/cm)		n	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
High Temperature Cure (60°C) Saltstone	0.5912	0.6142	0.0000	0.0000	-[1]	-	1.4516	1.5685
Room Temperature Cure(20°C) Saltstone[2]	0.5938	0.6064	-0.0429	.0528	-	-	1.4587	1.9134

[1]RETC output precision for α insufficient to provide confidence limits.
[2]Moisture retention data for room temperature cure saltstone taken from Dixon et al. (2009) and reanalyzed in terms of matric potential.



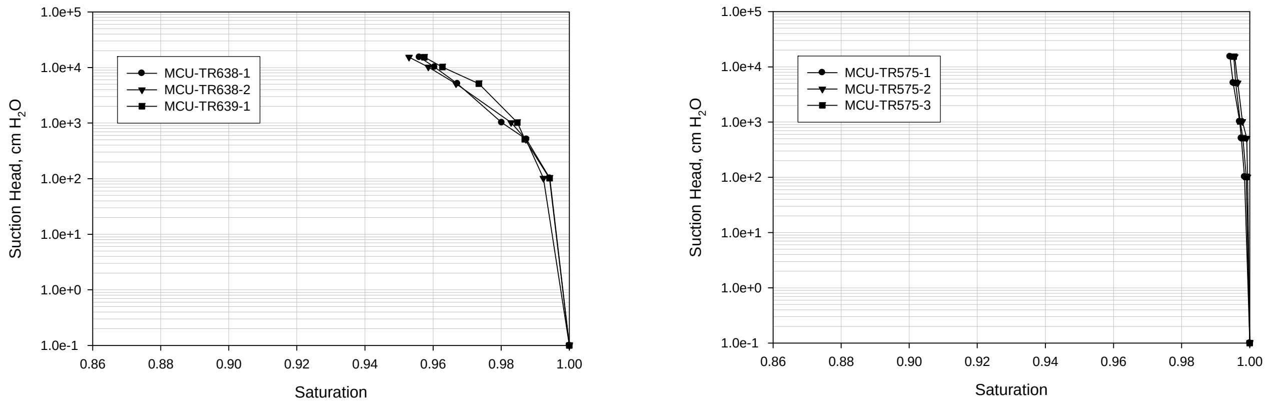
(a – 60°C) (b – 20°C)

Figure 1. Moisture retention curve for saltstone batch TR630, 631 (a) and TR588 (b, Dixon et al., 2009) as measured by Mactec.



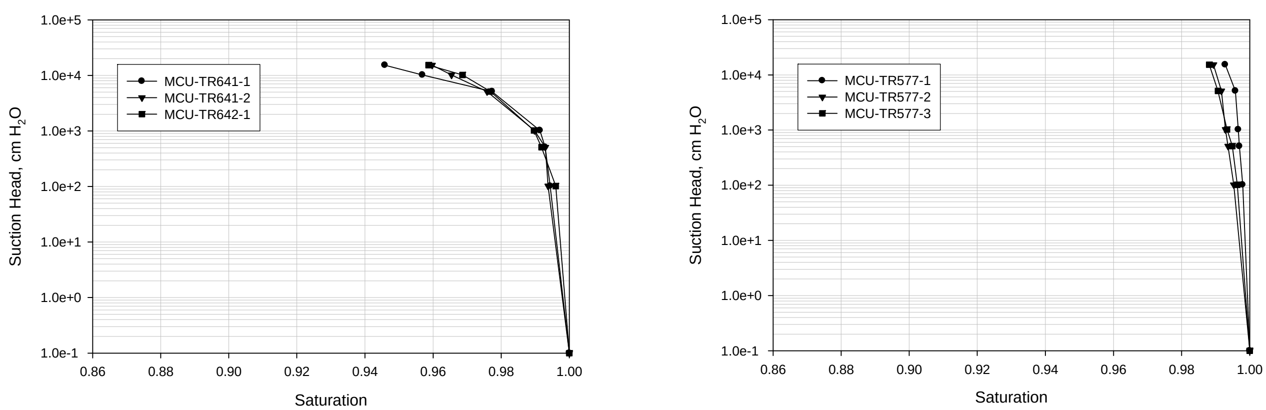
(a – 60°C) (b – 20°C)

Figure 2. Moisture retention curve for saltstone batch TR632, 633 (a) and TR582 (b, Dixon et al., 2009) as measured by Mactec.



(a – 60°C) (b – 20°C)

Figure 3. Moisture retention curve for saltstone batch TR638, 639 (a) and TR575 (b, Dixon et al., 2009) as measured by Mactec.



(a – 60°C) (b – 20°C)

Figure 4. Moisture retention curves for saltstone batch TR641, 642 (a) and TR577 (b, Dixon et al., 2009) as measured by Mactec.

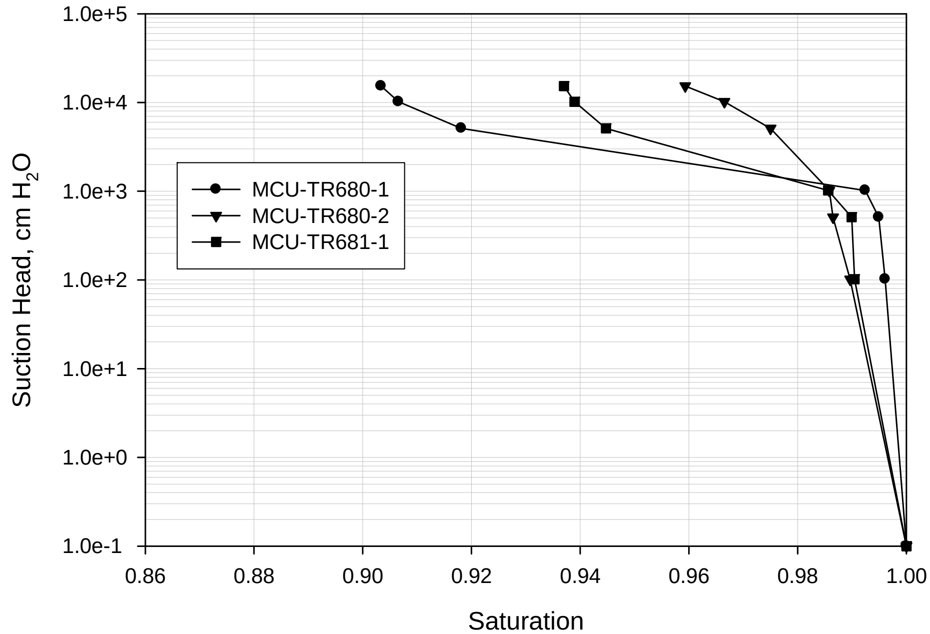


Figure 5. Moisture retention curve for saltstone batch TR680, 681 as measured by Mactec.

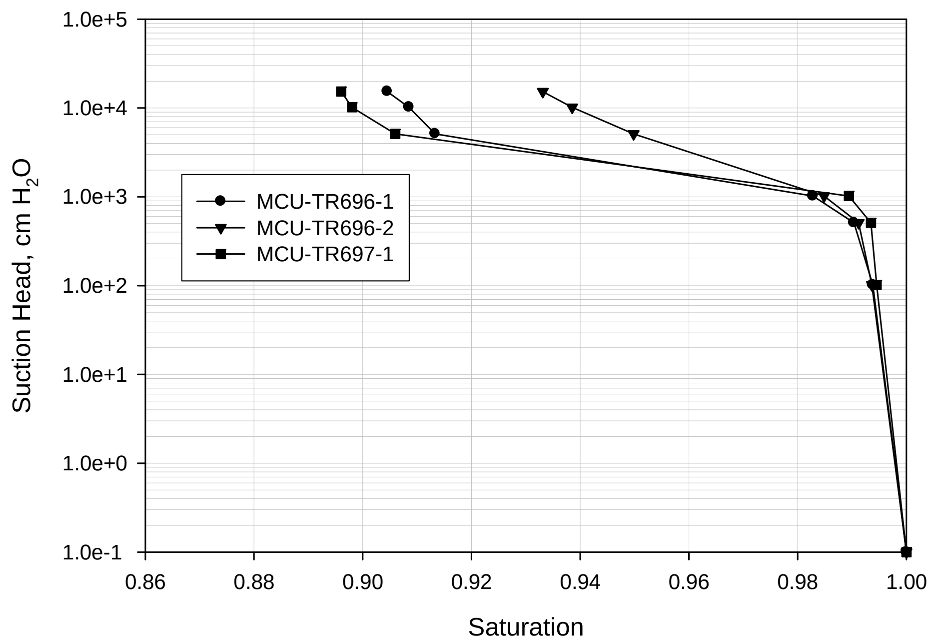


Figure 6. Moisture retention curve for saltstone batch TR696, 697 as measured by Mactec.

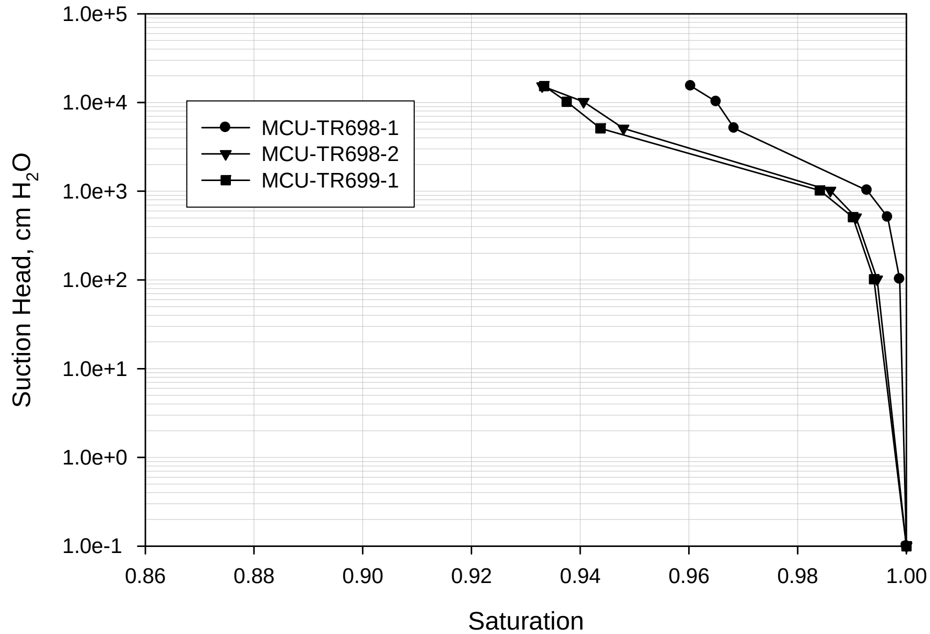


Figure 7. Moisture retention curve for saltstone batch TR698, 699 as measured by Mactec.

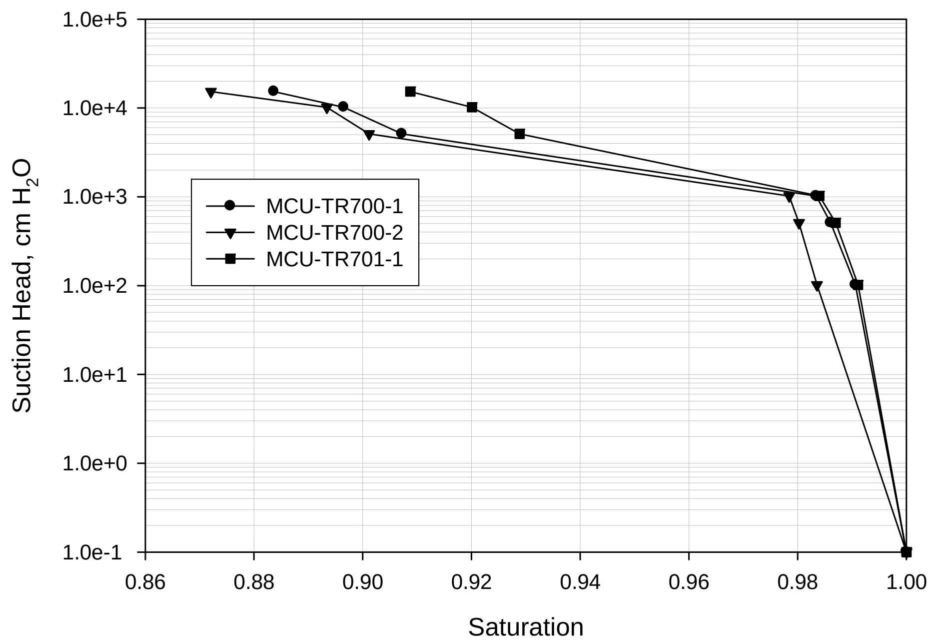


Figure 8. Moisture retention curve for saltstone batch TR700, 701 (b) as measured by Mactec.

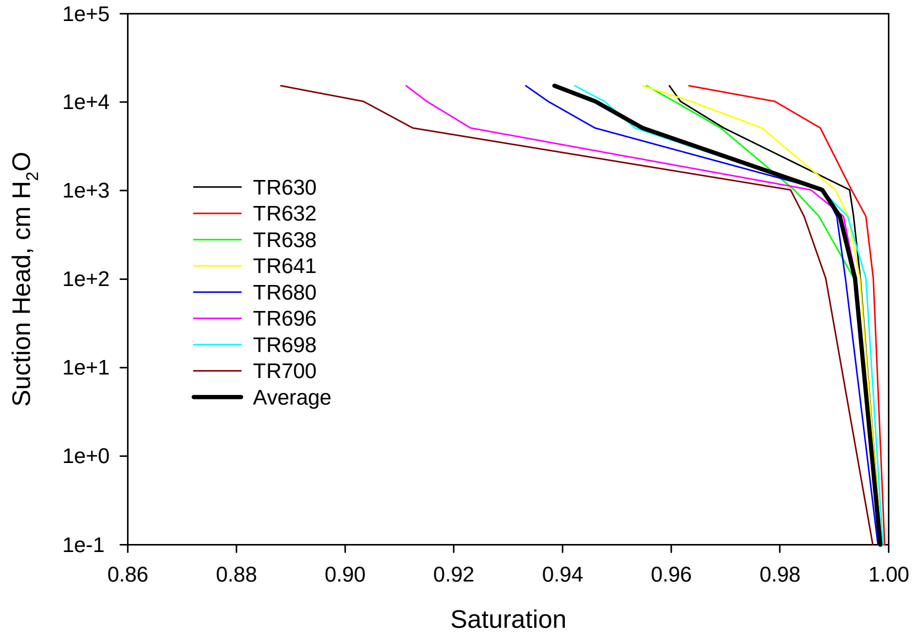


Figure 9. Combined moisture retention curves for the high temperature cure saltstone.

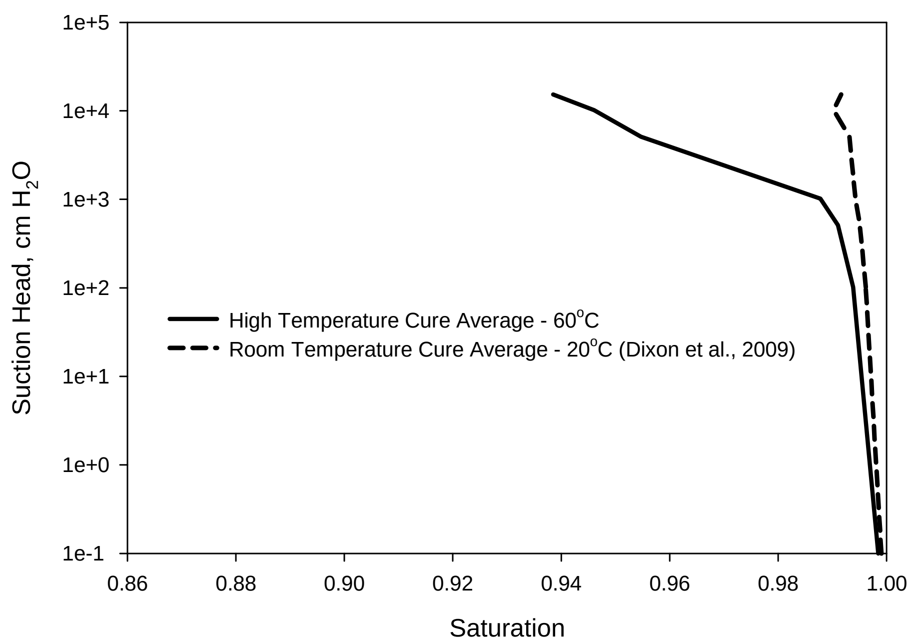


Figure 10. Comparison of the average moisture retention curve for the high temperature cure saltstone samples to the room temperature cure saltstone samples from Dixon et al. 2009.

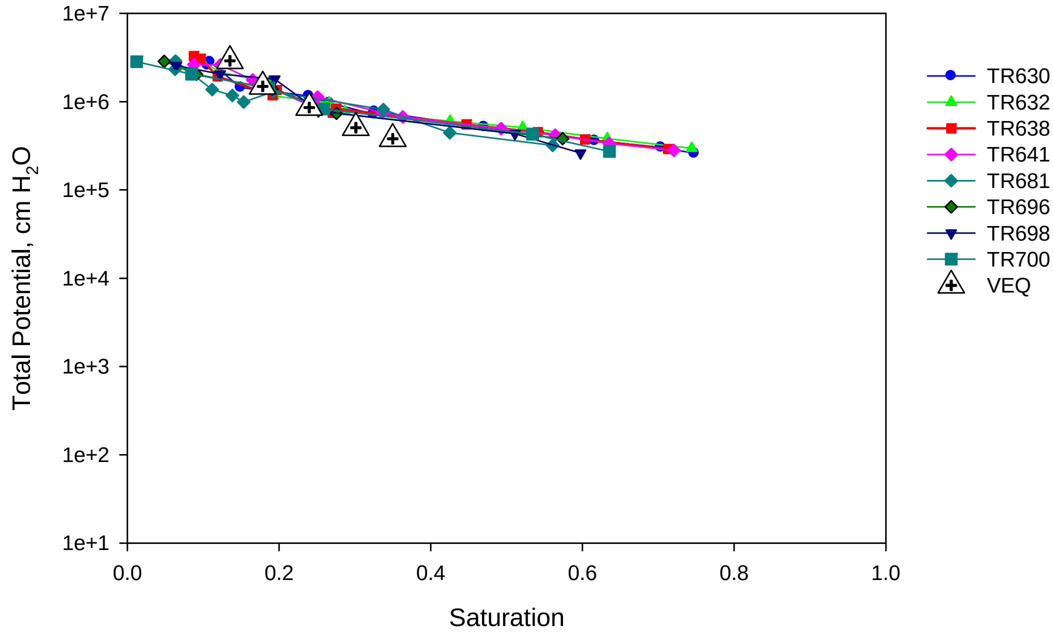


Figure 11. Comparison of moisture retention curves for the ARP/MCU saltstone samples as determined with a chilled mirror hygrometer to moisture retention data from vapor equilibrium (VEQ) method.

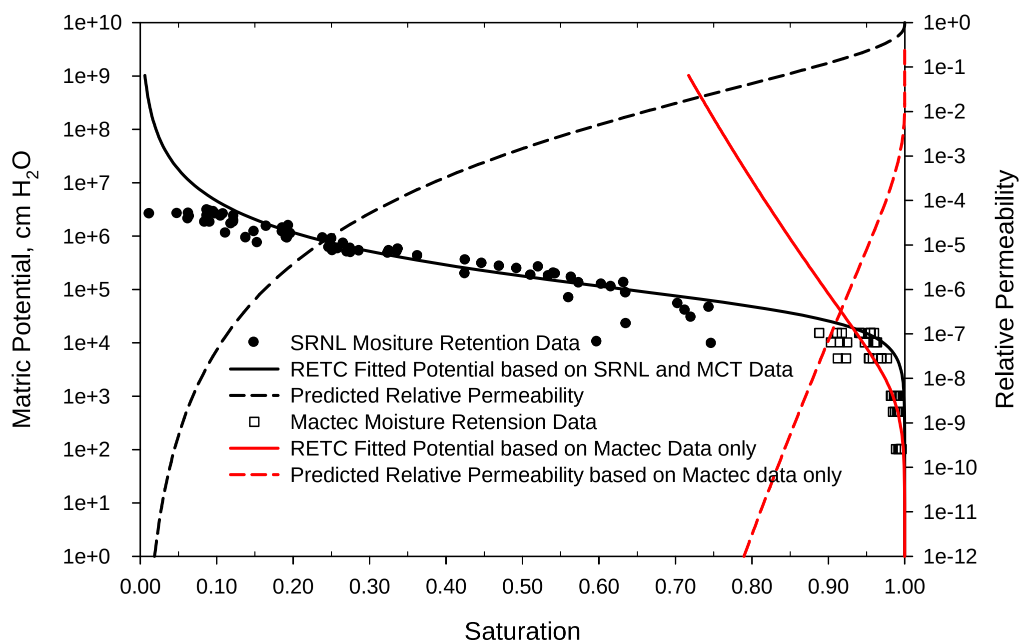


Figure 12. Characteristic curves for the ARP/MCU saltstone high temperature cure (60°C) samples.

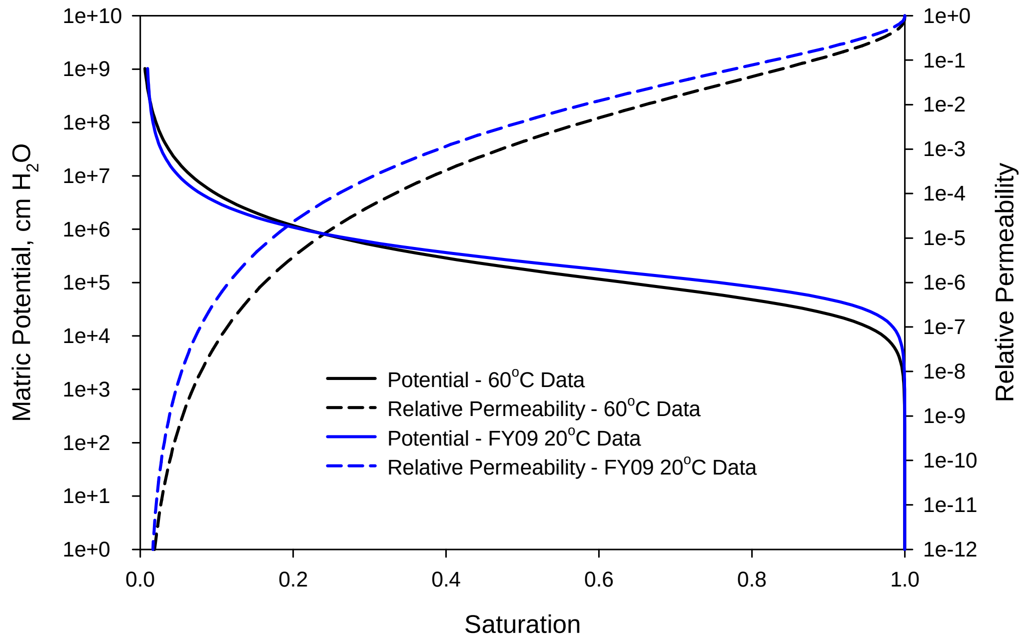


Figure 13. Comparison of characteristic curves for the high temperature cure (60°C) saltstone samples and the FY09 (20°C) saltstone samples from Dixon et al. (2009).

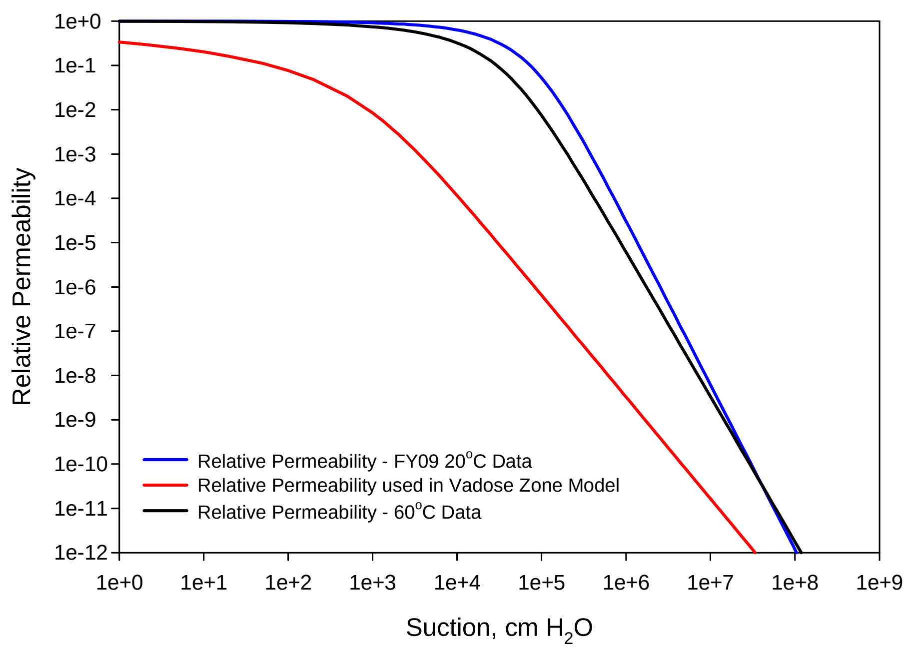


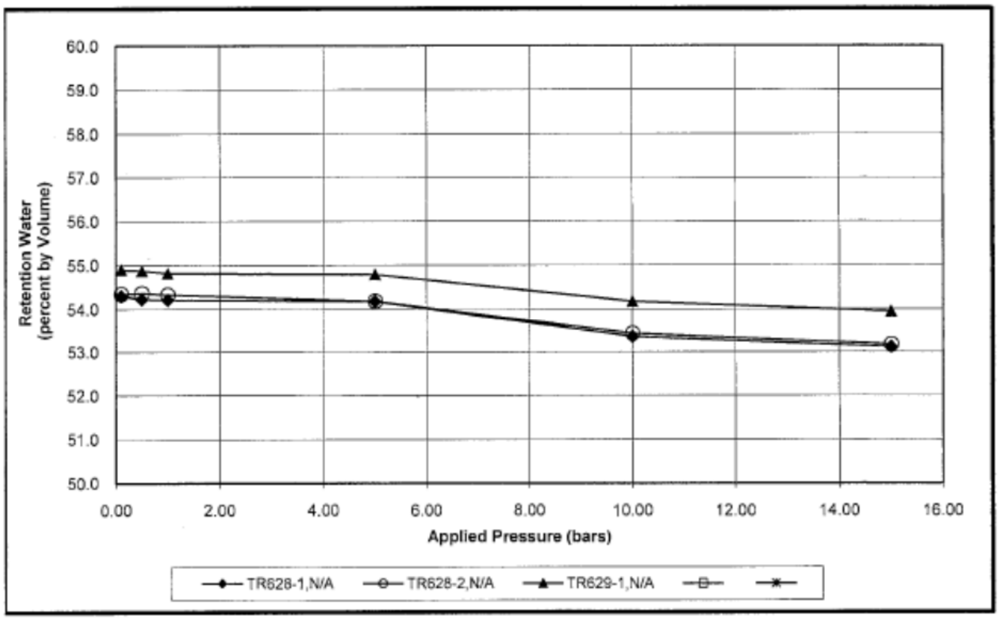
Figure 14. Comparison of relative permeability curves for the high temperature cure (60°C) saltstone samples and the FY09 (20°C, Dixon et al. [2009]) saltstone samples to the curve used in the PA vadose zone model.

APPENDIX A. MCT DATA SHEETS ON SALTSTONE

MACTEC

Water Retention Test
(ASTM D3152-72 (1994))

Project No	6155-08-0031.19	Project Name	PA SLA 21 Concrete Samples
Tested By	JW	Test Date	8/23/10
Reviewed By	JEJ	Review Date	10/6/11



Sample No. & Depth (ft)	Initial Moisture % by Vol.	Dry Unit Weight (pcf)	Applied Pressure (bars)									
			0.10	0.50	1.0	5.0	10.0	15.0				
			Retained Water (percent by volume)									
TR628-1,N/A	54.7	74.5	54.3	54.2	54.2	54.2	53.4	53.1				
TR628-2,N/A	54.8	73.9	54.3	54.4	54.3	54.2	53.4	53.2				
TR629-1,N/A	55.3	74.5	54.9	54.9	54.8	54.8	54.2	53.9				

Remarks: The effective porosity (effective drainage porosity as defined by ASTM D653, as a percent, is found for an applied pressure by subtracting the retained percent water (by volume) from the saturation percent water. When testing at pressures higher than one bar, ASTM D2325 using similar equipment designed for the required capacity.

MACTEC

Water Retention Test
(ASTM D3152-72 (1994))

Project No	6155-08-0031.19	Project Name	PA SLA 21 Concrete Samples
Tested By	JW	Test Date	8/23/2010
Reviewed By		Review Date	10/6/11

Boring No.	TR628-1	TR628-2	TR629-1		
Sample No.	TR628-1	TR628-2	TR629-1		
Depth (ft)	N/A	N/A	N/A		
Lab No.	10391	10392	10393		
Ring No.	N/A	N/A	N/A		
Container Weight. (g)	0.00	0.00	0.00		
Container Diameter (cm)	7.68	7.64	7.67		
Container Height, (cm)	2.62	2.49	2.70		
Container Volume (cm^3)	121.37	114.15	124.75		
Wt. of Wet Soil + Container (g)	211.27	197.78	217.93		
Wt. of Dry Soil + Container (g)	144.89	135.22	148.90		
Moisture Content (%)	45.8	46.3	46.4		
Dry Unit Weight (pcf)	74.49	73.92	74.48		
Initial Wt.Wet Soil + Container (g)	211.27	197.78	217.93		
Initial Wt. Container (g)	0.00	0.00	0.00		
Initial Moisture, % by Volume	54.7	54.8	55.3		

Remarks:

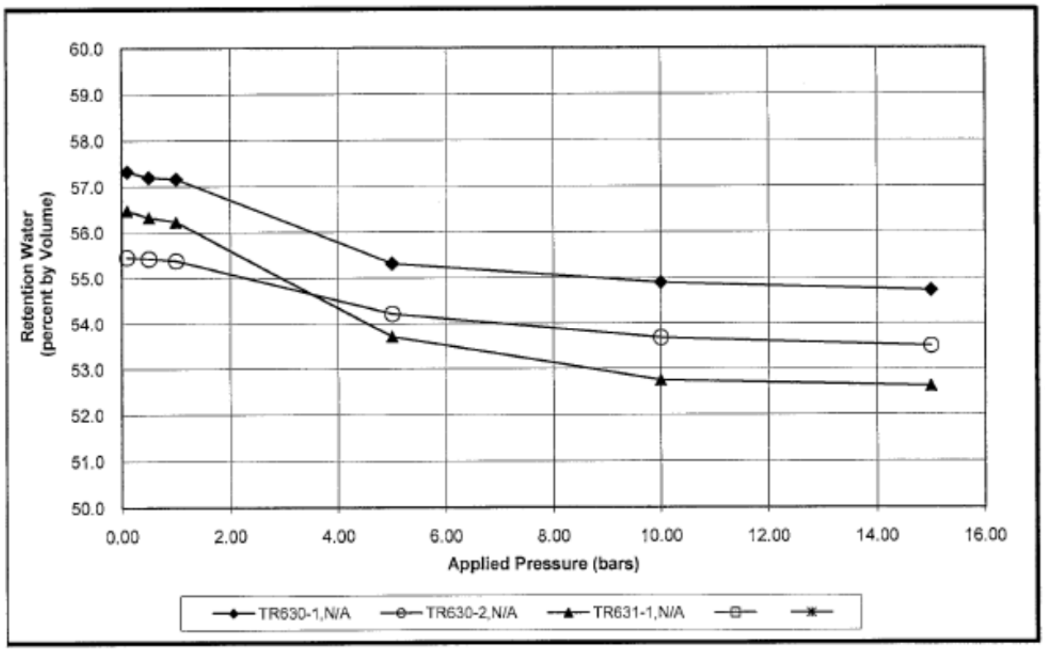
Lab No.	Pressure											
	psi	1.45	7.26	14.51	72.55	145.1	217.65				
	bars	0.1	0.50	1.0	5.0	10.0	15.0				
	Date / Read By	8/24/2010	8/26/2010	8/27/2010	8/30/2010	8/31/2010	9/1/2010				
10391	Weight of Soil + Ring	210.8	210.71	210.69	210.64	209.65	209.36				
TR628-1	Weight of Ring	0	0	0	0	0	0				
N/A	Retained Water (%)	54.3	54.2	54.2	54.2	53.4	53.1				
10392	Weight of Soil + Ring	197.26	197.28	197.24	197.07	196.21	195.92				
TR628-2	Weight of Ring	0	0	0	0	0	0				
N/A	Retained Water (%)	54.3	54.4	54.3	54.2	53.4	53.2				
10393	Weight of Soil + Ring	217.39	217.36	217.29	217.25	216.48	216.2				
TR629-1	Weight of Ring	0	0	0	0	0	0				
N/A	Retained Water (%)	54.9	54.9	54.8	54.8	54.2	53.9				

No. of Samples 3
No. of Tests per Sample 6

MACTEC

Water Retention Test
(ASTM D3152-72 (1994))

Project No	6155-08-0031.19	Project Name	PA SLA 21 Concrete Samples
Tested By	JW	Test Date	8/23/10
Reviewed By	[signature]	Review Date	10/6/11



Sample No. & Depth (ft)	Initial Moisture % by Vol.	Dry Unit Weight (pcf)	Applied Pressure (bars) 0.10	0.50	1.0	5.0	10.0	15.0			
			Retained Water (percent by volume)								
TR630-1,N/A	57.7	70.4	57.3	57.2	57.2	55.3	54.9	54.7			
TR630-2,N/A	55.9	69.5	55.5	55.4	55.4	54.2	53.7	53.5			
TR631-1,N/A	56.9	68.3	56.5	56.3	56.2	53.7	52.7	52.6			

Remarks: The effective porosity (effective drainage porosity as defined by ASTM D653, as a percent, is found for an applied pressure by subtracting the retained percent water (by volume) from the saturation percent water. When testing at pressures higher than one bar, ASTM D2325 using similar equipment designed for the required capacity.

MACTEC

Water Retention Test
(ASTM D3152-72 (1994))

Project No	6155-08-0031.19	Project Name	PA SLA 21 Concrete Samples
Tested By	JW	Test Date	8/23/2010
Reviewed By	[signature]	Review Date	10/6/11

Boring No.	TR630-1	TR630-2	TR631-1		
Sample No.	TR630-1	TR630-2	TR631-1		
Depth (ft)	N/A	N/A	N/A		
Lab No.	10394	10395	10396		
Ring No.	N/A	N/A	N/A		
Container Weight. (g)	0.00	0.00	0.00		
Container Diameter (cm)	7.66	7.69	7.67		
Container Height, (cm)	2.46	2.35	2.04		
Container Volume (cm^3)	113.37	109.15	94.26		
Wt. of Wet Soil + Container (g)	193.32	182.53	156.85		
Wt. of Dry Soil + Container (g)	127.91	121.51	103.22		
Moisture Content (%)	51.1	50.2	52.0		
Dry Unit Weight (pcf)	70.41	69.47	68.33		
Initial Wt.Wet Soil + Container (g)	193.32	182.53	156.85		
Initial Wt. Container (g)	0.00	0.00	0.00		
Initial Moisture, % by Volume	57.7	55.9	56.9		

Remarks:

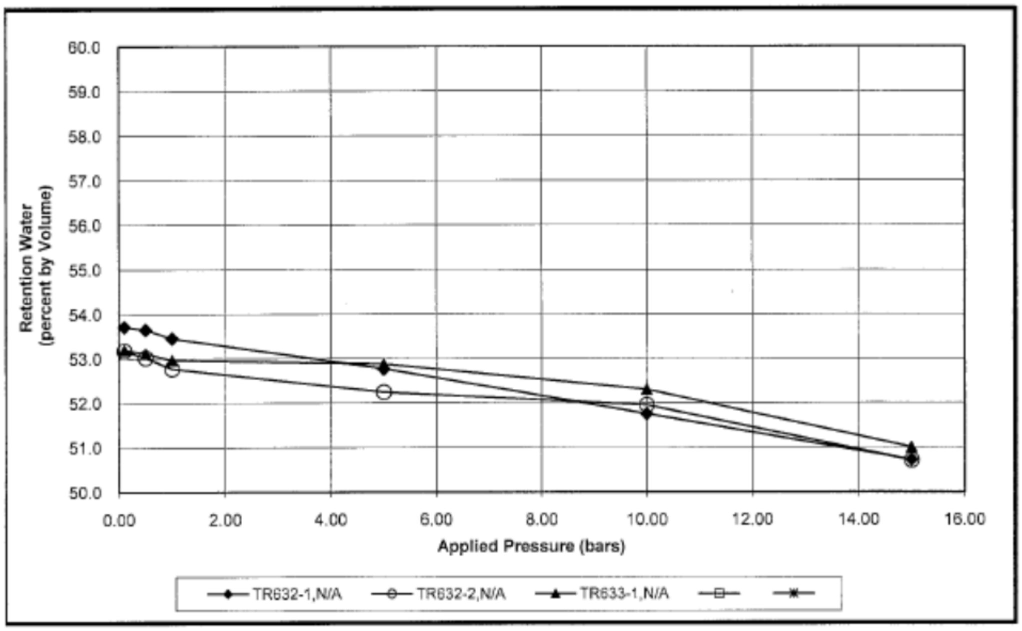
Lab No.												
	Pressure psi	1.45	7.26	14.51	72.55	145.1	217.65				
	bars	0.1	0.50	1.0	5.0	10.0	15.0				
	Date / Read By	8/24/2010	8/26/2010	8/27/2010	8/30/2010	8/31/2010	9/1/2010				
10394	Weight of Soil + Ring	192.9	192.76	192.72	190.62	190.15	189.95				
TR630-1	Weight of Ring	0	0	0	0	0	0				
N/A	Retained Water (%)	57.3	57.2	57.2	55.3	54.9	54.7				
10395	Weight of Soil + Ring	182.04	182.01	181.96	180.68	180.1	179.9				
TR630-2	Weight of Ring	0	0	0	0	0	0				
N/A	Retained Water (%)	55.5	55.4	55.4	54.2	53.7	53.5				
10396	Weight of Soil + Ring	156.45	156.31	156.22	153.84	152.94	152.82				
TR631-1	Weight of Ring	0	0	0	0	0	0				
N/A	Retained Water (%)	56.5	56.3	56.2	53.7	52.7	52.6				

No. of Samples 3
No. of Tests per Sample 6

MACTEC

Water Retention Test
(ASTM D3152-72 (1994))

Project No	6155-08-0031.19	Project Name	PA SLA 21 Concrete Samples
Tested By	JW	Test Date	8/31/10
Reviewed By	JEF	Review Date	10/6/11



Sample No. & Depth (ft)	Initial Moisture % by Vol.	Dry Unit Weight (pcf)	Applied Pressure (bars) 0.10	0.50	1.0	5.0	10.0	15.0
			Retained Water (percent by volume)					
TR632-1,N/A	53.9	74.4	53.7	53.6	53.5	52.8	51.8	50.7
TR632-2,N/A	53.5	74.2	53.2	53.0	52.8	52.2	51.9	50.7
TR633-1,N/A	53.3	73.9	53.2	53.1	53.0	52.9	52.3	51.0

Remarks: The effective porosity (effective drainage porosity as defined by ASTM D653, as a percent, is found for an applied pressure by subtracting the retained percent water (by volume) from the saturation percent water. When testing at pressures higher than one bar, ASTM D2325 using similar equipment designed for the required capacity.

MACTEC

Water Retention Test
(ASTM D3152-72 (1994))

Project No 6155-08-0031.19
Tested By JW
Reviewed By JEJ

Project Name PA SLA 21 Concrete Samples
Test Date 8/31/2010
Review Date 10/6/11

Boring No.	TR632-1	TR632-2	TR633-1		
Sample No.	TR632-1	TR632-2	TR633-1		
Depth (ft)	N/A	N/A	N/A		
Lab No.	10397	10398	10399		
Ring No.	N/A	N/A	N/A		
Container Weight. (g)	0.00	0.00	0.00		
Container Diameter (cm)	7.69	7.69	7.69		
Container Height, (cm)	2.67	2.19	2.53		
Container Volume (cm^3)	124.01	101.72	117.51		
Wt. of Wet Soil + Container (g)	214.8	175.33	201.71		
Wt. of Dry Soil + Container (g)	147.91	120.90	139.10		
Moisture Content (%)	45.2	45.0	45.0		
Dry Unit Weight (pcf)	74.43	74.17	73.87		
Initial Wt.Wet Soil + Container (g)	214.80	175.33	201.71		
Initial Wt. Container (g)	0.00	0.00	0.00		
Initial Moisture, % by Volume	53.9	53.5	53.3		

Remarks:

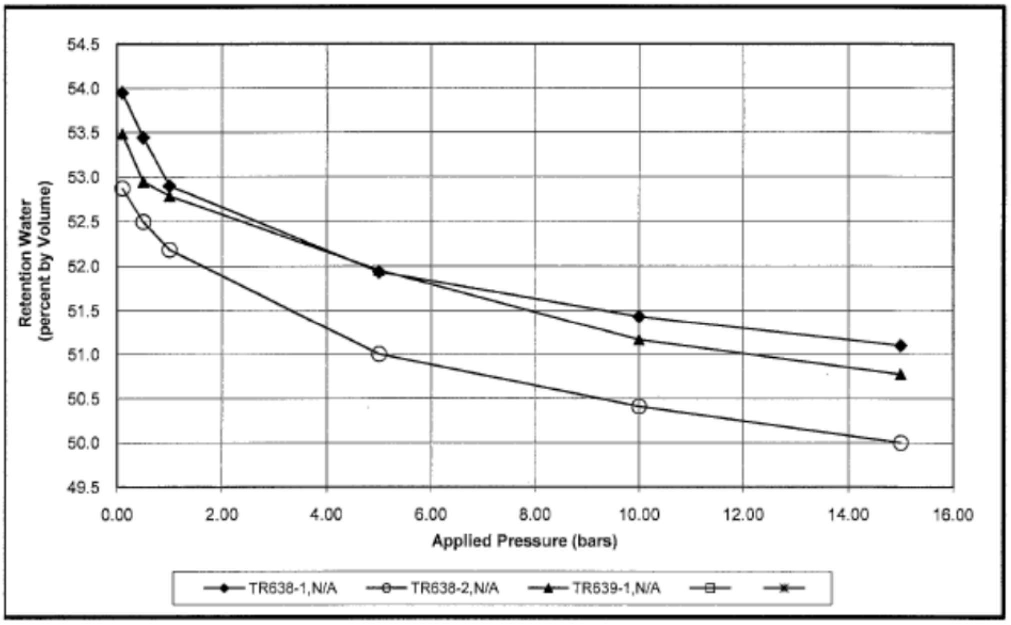
Lab No.	Pressure											
	psi	1.45	7.26	14.51	72.55	145.1	217.65					
	bars	0.1	0.50	1.0	5.0	10.0	15.0					
	Date / Read By	9/3/2010	9/7/2010	9/8/2010	9/9/2010	9/10/2010	9/13/2010					
10397	Weight of Soil + Ring	214.52	214.44	214.2	213.35	212.09	210.81					
TR632-1	Weight of Ring	0	0	0	0	0	0					
N/A	Retained Water (%)	53.7	53.6	53.5	52.8	51.8	50.7					
10398	Weight of Soil + Ring	174.99	174.83	174.58	174.04	173.74	172.48					
TR632-2	Weight of Ring	0	0	0	0	0	0					
N/A	Retained Water (%)	53.2	53.0	52.8	52.2	51.9	50.7					
10399	Weight of Soil + Ring	201.62	201.52	201.34	201.24	200.56	199.03					
TR633-1	Weight of Ring	0	0	0	0	0	0					
N/A	Retained Water (%)	53.2	53.1	53.0	52.9	52.3	51.0					

No. of Samples 3
No. of Tests per Sample 6

MACTEC

Water Retention Test
(ASTM D3152-72 (1994))

Project No	6155-08-0031.19	Project Name	PA SLA 21 Concrete Samples
Tested By	JW	Test Date	8/31/10
Reviewed By	JEF	Review Date	10/6/11



Sample No. & Depth (ft)	Initial Moisture % by Vol.	Dry Unit Weight (pcf)	Applied Pressure (bars) 0.10	0.50	1.0	5.0	10.0	15.0				
			Retained Water (percent by volume)									
TR638-1,N/A	54.4	74.2	54.0	53.4	52.9	51.9	51.4	51.1				
TR638-2,N/A	53.4	71.8	52.9	52.5	52.2	51.0	50.4	50.0				
TR639-1,N/A	57.9	72.8	53.5	52.9	52.8	52.0	51.2	50.8				

Remarks: The effective porosity (effective drainage porosity as defined by ASTM D653, as a percent, is found for an applied pressure by subtracting the retained percent water (by volume) from the saturation percent water. When testing at pressures higher than one bar, ASTM D2325 using similar equipment designed for the required capacity.

MACTEC

Water Retention Test
(ASTM D3152-72 (1994))

Project No 6155-08-0031.19
Tested By JW
Reviewed By JEZ

Project Name PA SLA 21 Concrete Samples
Test Date 8/31/2010
Review Date 10/6/11

Boring No.	TR638-1	TR638-2	TR639-1		
Sample No.	TR638-1	TR638-2	TR639-1		
Depth (ft)	N/A	N/A	N/A		
Lab No.	10400	10401	10402		
Ring No.	N/A	N/A	N/A		
Container Weight. (g)	0.00	0.00	0.00		
Container Diameter (cm)	7.68	7.67	7.67		
Container Height, (cm)	2.59	2.42	2.70		
Container Volume (cm^3)	119.98	111.81	124.75		
Wt. of Wet Soil + Container (g)	207.94	188.39	212.72		
Wt. of Dry Soil + Container (g)	142.70	128.65	145.47		
Moisture Content (%)	45.7	46.4	46.2		
Dry Unit Weight (pcf)	74.22	71.80	72.76		
Initial Wt.Wet Soil + Container (g)	207.94	188.39	217.72		
Initial Wt. Container (g)	0.00	0.00	0.00		
Initial Moisture, % by Volume	54.4	53.4	57.9		

Remarks:

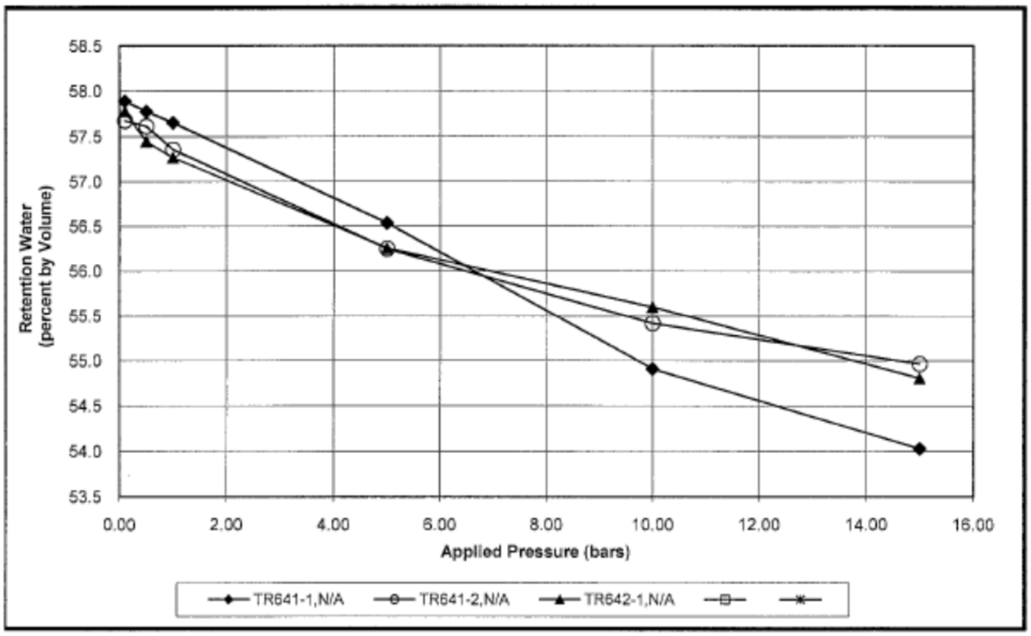
Lab No.	Pressure psi	1.45	7.26	14.51	72.55	145.1	217.65				
	bars	0.1	0.50	1.0	5.0	10.0	15.0				
	Date / Read By	9/17/2010	9/20/2010	9/21/2010	9/23/2010	9/24/2010	9/28/2010				
10400	Weight of Soil + Ring	207.43	206.82	206.17	205.01	204.41	204.01				
TR638-1	Weight of Ring	0	0	0	0	0	0				
N/A	Retained Water (%)	54.0	53.4	52.9	51.9	51.4	51.1				
10401	Weight of Soil + Ring	187.77	187.35	187	185.68	185.02	184.56				
TR638-2	Weight of Ring	0	0	0	0	0	0				
N/A	Retained Water (%)	52.9	52.5	52.2	51.0	50.4	50.0				
10402	Weight of Soil + Ring	212.19	211.52	211.32	210.28	209.3	208.81				
TR639-1	Weight of Ring	0	0	0	0	0	0				
N/A	Retained Water (%)	53.5	52.9	52.8	52.0	51.2	50.8				

No. of Samples 3
No. of Tests per Sample 6

MACTEC

Water Retention Test
(ASTM D3152-72 (1994))

Project No	6155-08-0031.19	Project Name	PA SLA 21 Concrete Samples
Tested By	JW	Test Date	9/27/10
Reviewed By	Jef	Review Date	10/6/11



Sample No. & Depth (ft)	Initial Moisture % by Vol.	Dry Unit Weight (pcf)	Applied Pressure (bars)									
			0.10	0.50	1.0	5.0	10.0	15.0				
			Retained Water (percent by volume)									
TR641-1,N/A	58.3	69.6	57.9	57.8	57.7	56.5	54.9	54.0				
TR641-2,N/A	58.2	69.1	57.7	57.6	57.4	56.3	55.4	55.0				
TR642-1,N/A	58.1	69.3	57.8	57.4	57.3	56.3	55.6	54.8				

Remarks: The effective porosity (effective drainage porosity as defined by ASTM D653, as a percent, is found for an applied pressure by subtracting the retained percent water (by volume) from the saturation percent water. When testing at pressures higher than one bar, ASTM D2325 using similar equipment designed for the required capacity.

MACTEC

Water Retention Test
(ASTM D3152-72 (1994))

Project No 6155-08-0031.19
Tested By JW
Reviewed By

Project Name PA SLA 21 Concrete Samples
Test Date 9/27/2010
Review Date 10/6/11

Boring No.	TR641-1	TR641-2	TR642-1
Sample No.	TR641-1	TR641-2	TR642-1
Depth (ft)	N/A	N/A	N/A
Lab No.	10403	10404	10405
Ring No.	N/A	N/A	N/A
Container Weight. (g)	0.00	0.00	0.00
Container Diameter (cm)	7.65	7.66	7.66
Container Height, (cm)	2.82	2.45	2.68
Container Volume (cm^3)	129.62	112.91	123.50
Wt. of Wet Soil + Container (g)	220.1	190.63	208.87
Wt. of Dry Soil + Container (g)	144.48	124.95	137.12
Moisture Content (%)	52.3	52.6	52.3
Dry Unit Weight (pcf)	69.56	69.06	69.28
Initial Wt.Wet Soil + Container (g)	220.10	190.63	208.87
Initial Wt. Container (g)	0.00	0.00	0.00
Initial Moisture, % by Volume	58.3	58.2	58.1

Remarks:

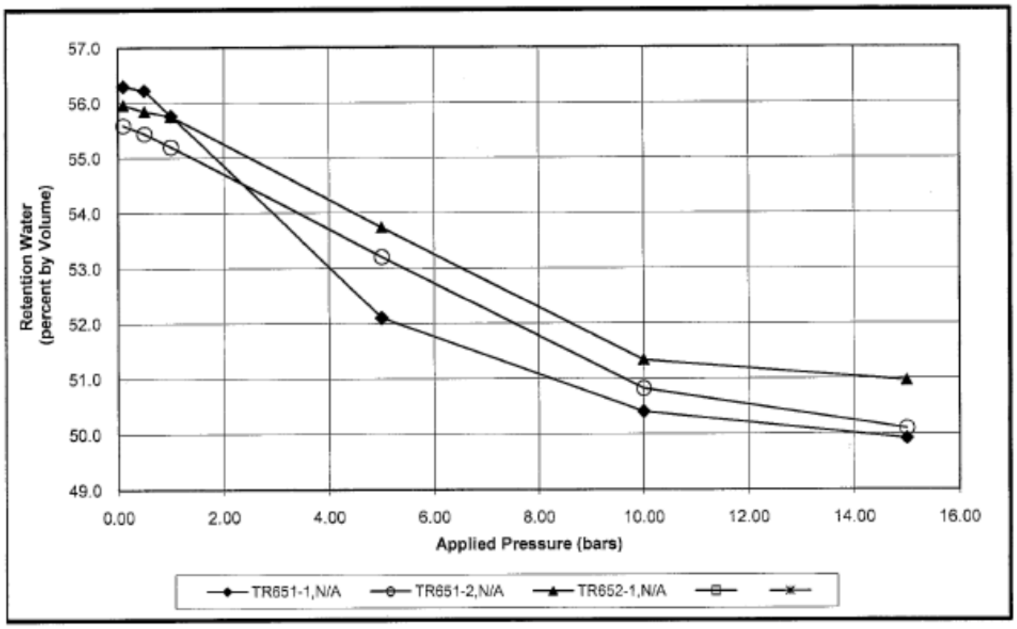
Lab No.	Pressure psi	1.45	7.26	14.51	72.55	145.1	217.65
	bars	0.1	0.50	1.0	5.0	10.0	15.0
	Date / Read By	9/30/2010	10/4/2010	10/5/2010	10/6/2010	10/7/2010	10/8/2010
10403	Weight of Soil + Ring	219.52	219.37	219.21	217.76	215.65	214.51
TR641-1	Weight of Ring	0	0	0	0	0	0
N/A	Retained Water (%)	57.9	57.8	57.7	56.5	54.9	54.0
10404	Weight of Soil + Ring	190.07	190	189.71	188.46	187.52	187.01
TR641-2	Weight of Ring	0	0	0	0	0	0
N/A	Retained Water (%)	57.7	57.6	57.4	56.3	55.4	55.0
10405	Weight of Soil + Ring	208.48	208.07	207.85	206.6	205.79	204.81
TR642-1	Weight of Ring	0	0	0	0	0	0
N/A	Retained Water (%)	57.8	57.4	57.3	56.3	55.6	54.8

No. of Samples 3
No. of Tests per Sample 6

MACTEC

Water Retention Test
(ASTM D3152-72 (1994))

Project No	6155-08-0031.19	Project Name	PA SLA 21 Concrete Samples
Tested By	JW	Test Date	11/8/10
Reviewed By	JEF	Review Date	10/6/11



Sample No. & Depth (ft)	Initial Moisture % by Vol.	Dry Unit Weight (pcf)	Applied Pressure (bars) 0.10	0.50	1.0	5.0	10.0	15.0				
			Retained Water (percent by volume)									
TR651-1,N/A	57.0	74.6	56.3	56.2	55.8	52.1	50.4	49.9				
TR651-2,N/A	56.2	74.3	55.6	55.4	55.2	53.2	50.8	50.1				
TR652-1,N/A	56.5	73.7	56.0	55.9	55.8	53.7	51.3	51.0				

Remarks: The effective porosity (effective drainage porosity as defined by ASTM D653, as a percent, is found for an applied pressure by subtracting the retained percent water (by volume) from the saturation percent water. When testing at pressures higher than one bar, ASTM D2325 using similar equipment designed for the required capacity.

MACTEC

Water Retention Test
(ASTM D3152-72 (1994))

Project No 6155-08-0031.19
Tested By JW
Reviewed By

Project Name PA SLA 21 Concrete Samples
Test Date 11/8/2010
Review Date 10/6/11

Remarks:

Boring No.	TR651-1	TR651-2	TR652-1
Sample No.	TR651-1	TR651-2	TR652-1
Depth (ft)	N/A	N/A	N/A
Lab No.	10489	10490	10491
Ring No.	N/A	N/A	N/A
Container Weight. (g)	0.00	0.00	0.00
Container Diameter (cm)	7.64	7.67	7.67
Container Height, (cm)	2.23	2.33	2.74
Container Volume (cm^3)	102.23	107.66	126.60
Wt. of Wet Soil + Container (g)	180.48	188.8	221.16
Wt. of Dry Soil + Container (g)	122.22	128.27	149.57
Moisture Content (%)	47.7	47.2	47.9
Dry Unit Weight (pcf)	74.60	74.35	73.72
Initial Wt Wet Soil + Container (g)	180.48	188.80	221.16
Initial Wt. Container (g)	0.00	0.00	0.00
Initial Moisture, % by Volume	57.0	56.2	56.5

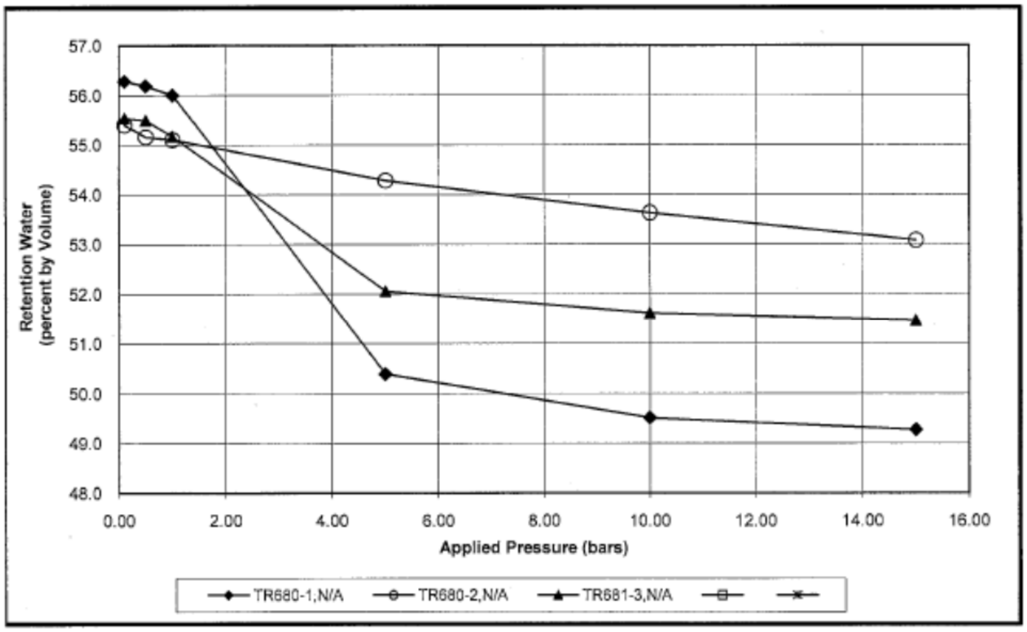
Lab No.	Pressure						
	psi	1.45	7.26	14.51	72.55	145.1	217.65
	bars	0.1	0.50	1.0	5.0	10.0	15.0
	Date / Read By	11/15/2010	11/17/2010	11/19/2010	11/29/2010	11/30/2010	12/1/2010
10489	Weight of Soil + Ring	179.78	179.7	179.23	175.48	173.75	173.25
TR651-1	Weight of Ring	0	0	0	0	0	0
N/A	Retained Water (%)	56.3	56.2	55.8	52.1	50.4	49.9
10490	Weight of Soil + Ring	188.12	187.96	187.7	185.55	182.98	182.2
TR651-2	Weight of Ring	0	0	0	0	0	0
N/A	Retained Water (%)	55.6	55.4	55.2	53.2	50.8	50.1
10491	Weight of Soil + Ring	220.42	220.28	220.16	217.6	214.56	214.09
TR652-1	Weight of Ring	0	0	0	0	0	0
N/A	Retained Water (%)	56.0	55.9	55.8	53.7	51.3	51.0

No. of Samples 3
No. of Tests per Sample 6

MACTEC

Water Retention Test
(ASTM D3152-72 (1994))

Project No	6155-08-0031.19	Project Name	PA SLA 21 Concrete Samples
Tested By	JW	Test Date	2/2/11
Reviewed By	JEF	Review Date	10/6/11



Sample No. & Depth (ft)	Initial Moisture % by Vol.	Dry Unit Weight (pcf)	Applied Pressure (bars) 0.10	0.50	1.0	5.0	10.0	15.0				
			Retained Water (percent by volume)									
TR680-1,N/A	56.6	73.6	56.3	56.2	56.0	50.4	49.5	49.3				
TR680-2,N/A	56.2	73.6	55.4	55.2	55.1	54.3	53.6	53.1				
TR681-3,N/A	56.3	73.7	55.5	55.5	55.2	52.1	51.6	51.5				

Remarks: The effective porosity (effective drainage porosity as defined by ASTM D653, as a percent, is found for an applied pressure by subtracting the retained percent water (by volume) from the saturation percent water.
When testing at pressures higher than one bar, ASTM D2325 using similar equipment designed for the required capacity.

MACTEC

Water Retention Test
(ASTM D3152-72 (1994))

Project No	6155-08-0031.19	Project Name	PA SLA 21 Concrete Samples
Tested By	JW	Test Date	2/2/2011
Reviewed By	JEJ	Review Date	10/6/11

Boring No.	TR680-1	TR680-2	TR681-3		
Sample No.	TR680-1	TR680-2	TR681-3		
Depth (ft)	N/A	N/A	N/A		
Lab No.	10579	10580	10581		
Ring No.	N/A	N/A	N/A		
Container Weight. (g)	0.00	0.00	0.00		
Container Diameter (cm)	7.68	7.67	7.67		
Container Height, (cm)	2.42	2.44	2.18		
Container Volume (cm^3)	112.11	112.74	100.72		
Wt. of Wet Soil + Container (g)	195.73	196.28	175.71		
Wt. of Dry Soil + Container (g)	132.30	132.93	119.04		
Moisture Content (%)	47.9	47.7	47.6		
Dry Unit Weight (pcf)	73.64	73.58	73.75		
Initial Wt.Wet Soil + Container (g)	195.73	196.28	175.71		
Initial Wt. Container (g)	0.00	0.00	0.00		
Initial Moisture, % by Volume	56.6	56.2	56.3		

Remarks:

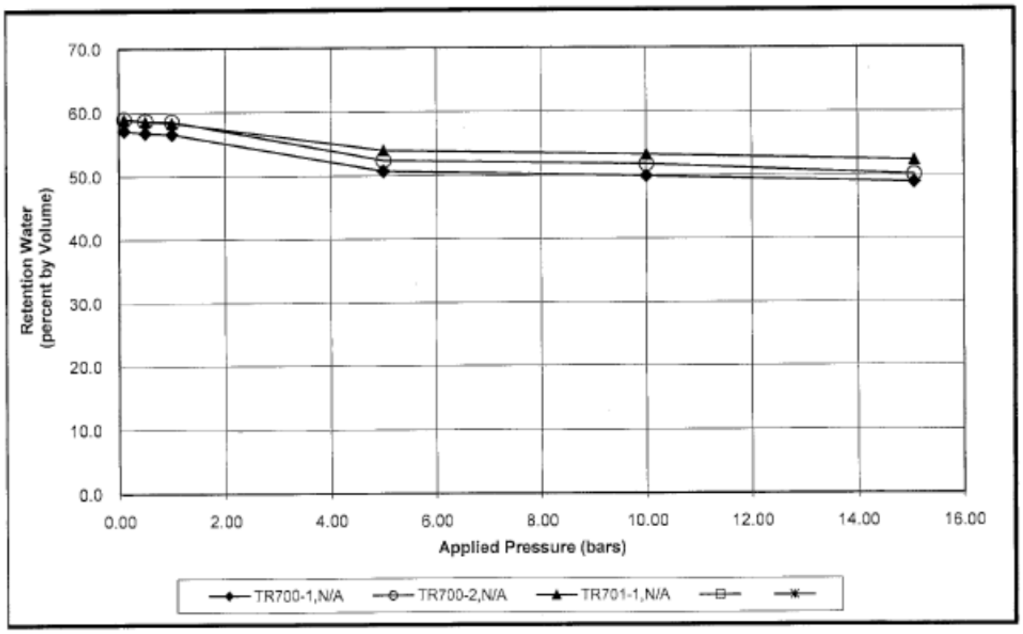
Lab No.	Pressure psi	1.45	7.26	14.51	72.55	145.1	217.65
	bars	0.1	0.50	1.0	5.0	10.0	15.0
	Date / Read By	2/16/2011	2/18/2011	2/21/2011	2/24/2011	2/25/2011	2/28/2011
10579	Weight of Soil + Ring	195.4	195.3	195.09	188.79	187.81	187.54
TR680-1	Weight of Ring	0	0	0	0	0	0
N/A	Retained Water (%)	56.3	56.2	56.0	50.4	49.5	49.3
10580	Weight of Soil + Ring	195.39	195.12	195.06	194.13	193.4	192.78
TR680-2	Weight of Ring	0	0	0	0	0	0
N/A	Retained Water (%)	55.4	55.2	55.1	54.3	53.6	53.1
10581	Weight of Soil + Ring	174.98	174.94	174.61	171.48	171.04	170.89
TR681-3	Weight of Ring	0	0	0	0	0	0
N/A	Retained Water (%)	55.5	55.5	55.2	52.1	51.6	51.5

No. of Samples 3
No. of Tests per Sample 6

MACTEC

Water Retention Test
(ASTM D3152-72 (1994))

Project No	6155-08-0031.19	Project Name	PA SLA 21 Concrete Samples
Tested By	JW	Test Date	7/5/11
Reviewed By	JEJ	Review Date	10/6/11



Sample No. & Depth (ft)	Initial Moisture % by Vol.	Dry Unit Weight (pcf)	Applied Pressure (bars) 0.10	0.50	1.0	5.0	10.0	15.1				
			Retained Water (percent by volume)									
TR700-1,N/A	57.9	66.2	57.2	56.8	56.6	50.7	49.9	48.9				
TR700-2,N/A	60.3	67.1	59.0	58.7	58.6	52.4	51.8	50.1				
TR701-1,N/A	49.0	67.9	59.0	58.6	58.4	54.0	53.3	52.4				

Remarks: The effective porosity (effective drainage porosity as defined by ASTM D653, as a percent, is found for an applied pressure by subtracting the retained percent water (by volume) from the saturation percent water.
When testing at pressures higher than one bar, ASTM D2325 using similar equipment designed for the required capacity.

MACTEC

Water Retention Test
(ASTM D3152-72 (1994))

Project No	6155-08-0031.19	Project Name	PA SLA 21 Concrete Samples
Tested By	JW	Test Date	7/5/2011
Reviewed By	JET	Review Date	10/6/11

Boring No.	TR700-1	TR700-2	TR701-1		
Sample No.	TR700-1	TR700-2	TR701-1		
Depth (ft)	N/A	N/A	N/A		
Lab No.	10965	10966	10967		
Ring No.	N/A	N/A	N/A		
Container Weight. (g)	0.00	0.00	0.00		
Container Diameter (cm)	7.68	7.67	7.68		
Container Height, (cm)	2.33	2.56	2.43		
Container Volume (cm^3)	107.94	118.28	112.57		
Wt. of Wet Soil + Container (g)	177.01	198.44	189.69		
Wt. of Dry Soil + Container (g)	114.52	127.13	122.52		
Moisture Content (%)	54.6	56.1	54.8		
Dry Unit Weight (pcf)	66.21	67.07	67.92		
Initial Wt.Wet Soil + Container (g)	177.01	198.44	177.63		
Initial Wt. Container (g)	0.00	0.00	0.00		
Initial Moisture, % by Volume	57.9	60.3	49.0		

Remarks:

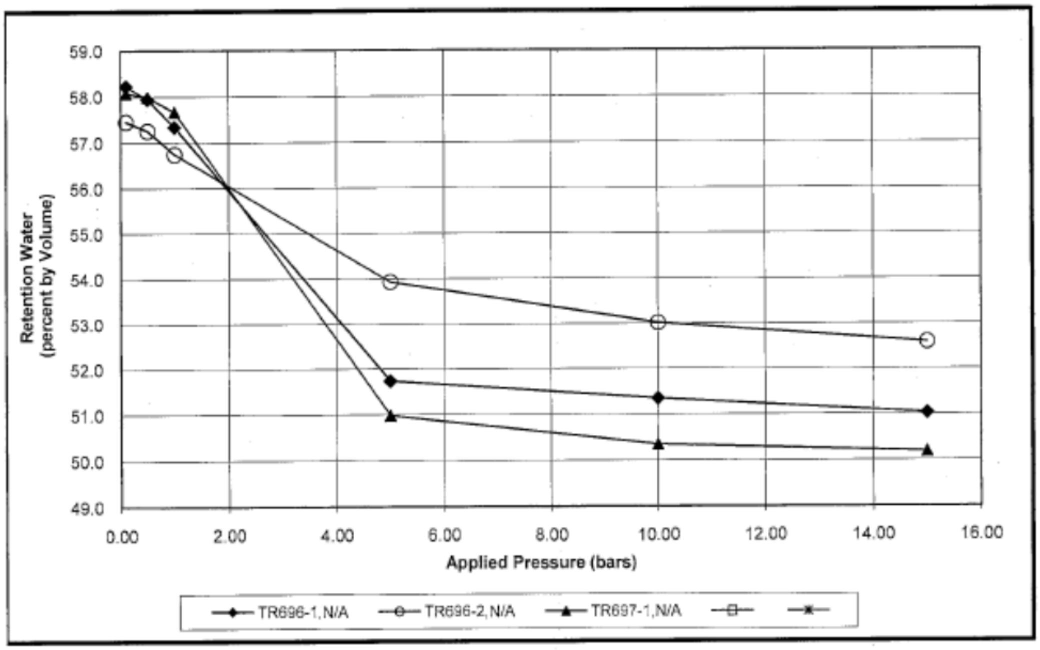
Lab No.												
	Pressure psi	1.45	7.26	14.51	72.55	145.1	218.65				
	bars	0.1	0.50	1.0	5.0	10.0	15.1				
	Date / Read By	7/15/2011	7/18/2011	7/21/2011	7/26/2011	7/27/2011	7/28/2011				
10965	Weight of Soil + Ring	176.23	175.85	175.63	169.29	168.4	167.33				
TR700-1	Weight of Ring	0	0	0	0	0	0				
N/A	Retained Water (%)	57.2	56.8	56.6	50.7	49.9	48.9				
10966	Weight of Soil + Ring	196.89	196.58	196.41	189.13	188.4	186.39				
TR700-2	Weight of Ring	0	0	0	0	0	0				
N/A	Retained Water (%)	59.0	58.7	58.6	52.4	51.8	50.1				
10967	Weight of Soil + Ring	188.89	188.52	188.25	183.29	182.5	181.48				
TR701-1	Weight of Ring	0	0	0	0	0	0				
N/A	Retained Water (%)	59.0	58.6	58.4	54.0	53.3	52.4				

No. of Samples 3
No. of Tests per Sample 6

MACTEC

Water Retention Test
(ASTM D3152-72 (1994))

Project No	6155-08-0031.19	Project Name	PA SLA 21 Concrete Samples
Tested By	JW	Test Date	6/23/11
Reviewed By	JEJ	Review Date	10/6/11



Sample No. & Depth (ft)	Initial Moisture % by Vol.	Dry Unit Weight (pcf)	Applied Pressure (bars) 0.10	0.50	1.0	5.0	10.0	15.0				
			Retained Water (percent by volume)									
TR696-1,N/A	58.7	69.1	58.2	58.0	57.3	51.7	51.4	51.0				
TR696-2,N/A	58.0	69.2	57.5	57.3	56.7	53.9	53.0	52.6				
TR697-1,N/A	58.5	68.8	58.1	58.0	57.7	51.0	50.3	50.2				

Remarks: The effective porosity (effective drainage porosity as defined by ASTM D653, as a percent, is found for an applied pressure by subtracting the retained percent water (by volume) from the saturation percent water. When testing at pressures higher than one bar, ASTM D2325 using similar equipment designed for the required capacity.

MACTEC

Water Retention Test
(ASTM D3152-72 (1994))

Project No	6155-08-0031.19	Project Name	PA SLA 21 Concrete Samples
Tested By	JW	Test Date	6/23/2011
Reviewed By	JEJ	Review Date	10/6/11

Boring No.	TR696-1	TR696-2	TR697-1		
Sample No.	TR696-1	TR696-2	TR697-1		
Depth (ft)	N/A	N/A	N/A		
Lab No.	10900	10901	10902		
Ring No.	N/A	N/A	N/A		
Container Weight. (g)	0.00	0.00	0.00		
Container Diameter (cm)	7.67	7.68	7.66		
Container Height, (cm)	2.56	2.54	2.62		
Container Volume (cm^3)	118.36	117.45	120.57		
Wt. of Wet Soil + Container (g)	200.56	198.3	203.42		
Wt. of Dry Soil + Container (g)	131.05	130.22	132.87		
Moisture Content (%)	53.0	52.3	53.1		
Dry Unit Weight (pcf)	69.09	69.18	68.77		
Initial Wt.Wet Soil + Container (g)	200.56	198.30	203.42		
Initial Wt. Container (g)	0.00	0.00	0.00		
Initial Moisture, % by Volume	58.7	58.0	58.5		

Remarks:

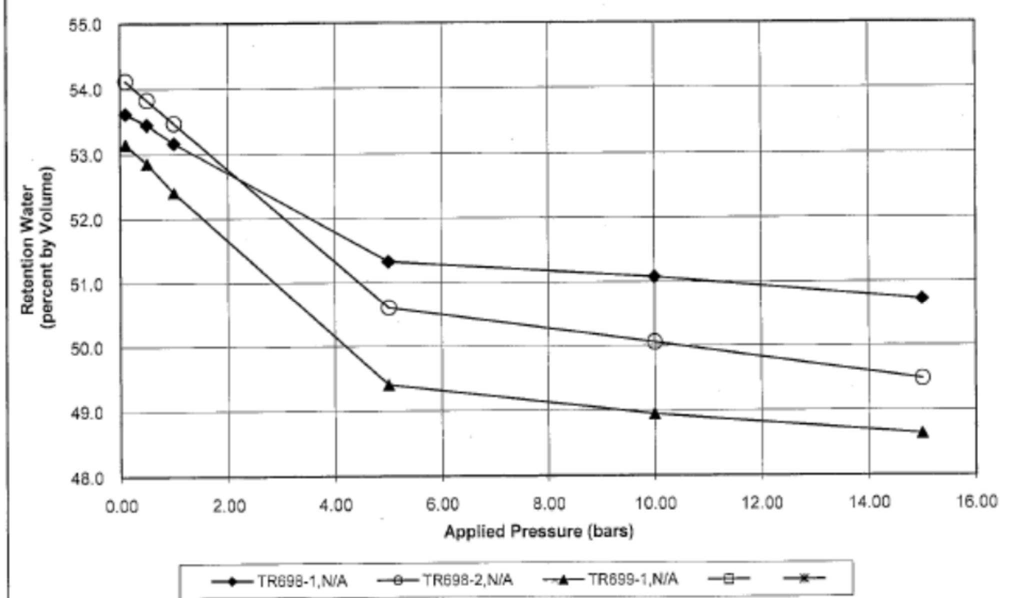
Lab No.											
	Pressure psi	1.45	7.26	14.51	72.55	145.1	217.65				
	bars	0.1	0.50	1.0	5.0	10.0	15.0				
	Date / Read By	6/27/2011	6/28/2011	6/30/2011	7/5/2011	7/6/2001	7/8/2011				
10900	Weight of Soil + Ring	199.97	199.64	198.92	192.29	191.83	191.45				
TR696-1	Weight of Ring	0	0	0	0	0	0				
N/A	Retained Water (%)	58.2	58.0	57.3	51.7	51.4	51.0				
10901	Weight of Soil + Ring	197.7	197.47	196.87	193.56	192.49	191.98				
TR696-2	Weight of Ring	0	0	0	0	0	0				
N/A	Retained Water (%)	57.5	57.3	56.7	53.9	53.0	52.6				
10902	Weight of Soil + Ring	202.89	202.79	202.4	194.34	193.57	193.38				
TR697-1	Weight of Ring	0	0	0	0	0	0				
N/A	Retained Water (%)	58.1	58.0	57.7	51.0	50.3	50.2				

No. of Samples 3
No. of Tests per Sample 6

MACTEC

Water Retention Test
(ASTM D3152-72 (1994))

Project No	6155-08-0031.19	Project Name	PA SLA 21 Concrete Samples
Tested By	JW	Test Date	6/23/11
Reviewed By	JEJ	Review Date	10/6/11



Sample No. & Depth (ft)	Initial Moisture % by Vol.	Dry Unit Weight (pcf)	Applied Pressure (bars) / Retained Water (percent by volume) 0.10	0.50	1.0	5.0	10.0	15.0				
TR698-1,N/A	53.7	74.1	53.6	53.5	53.2	51.3	51.1	50.7				
TR698-2,N/A	54.5	72.7	54.1	53.8	53.5	50.6	50.1	49.5				
TR699-1,N/A	53.6	73.3	53.2	52.9	52.4	49.4	48.9	48.6				

Remarks: The effective porosity (effective drainage porosity as defined by ASTM D653, as a percent, is found for an applied pressure by subtracting the retained percent water (by volume) from the saturation percent water. When testing at pressures higher than one bar, ASTM D2325 using similar equipment designed for the required capacity.

MACTEC

Water Retention Test
(ASTM D3152-72 (1994))

Project No	6155-08-0031.19	Project Name	PA SLA 21 Concrete Samples
Tested By	JW	Test Date	6/23/2011
Reviewed By	JEJ	Review Date	10/6/11

Boring No.	TR698-1	TR698-2	TR699-1		
Sample No.	TR698-1	TR698-2	TR699-1		
Depth (ft)	N/A	N/A	N/A		
Lab No.	10903	10904	10905		
Ring No.	N/A	N/A	N/A		
Container Weight. (g)	0.00	0.00	0.00		
Container Diameter (cm)	7.66	7.68	7.66		
Container Height, (cm)	2.60	2.07	2.26		
Container Volume (cm^3)	119.60	95.93	103.86		
Wt. of Wet Soil + Container (g)	206.24	164.04	177.63		
Wt. of Dry Soil + Container (g)	142.00	111.73	121.97		
Moisture Content (%)	45.2	46.8	45.6		
Dry Unit Weight (pcf)	74.09	72.68	73.28		
Initial Wt.Wet Soil + Container (g)	206.24	164.04	177.63		
Initial Wt. Container (g)	0.00	0.00	0.00		
Initial Moisture, % by Volume	53.7	54.5	53.6		

Remarks:

Lab No.	Pressure psi	1.45	7.26	14.51	72.55	145.1	217.65				
	bars	0.1	0.50	1.0	5.0	10.0	15.0				
	Date / Read By	6/27/2011	6/28/2011	6/30/2011	7/5/2011	7/6/2001	7/8/2011				
10903	Weight of Soil + Ring	206.13	205.93	205.59	203.39	203.09	202.67				
TR698-1	Weight of Ring	0	0	0	0	0	0				
N/A	Retained Water (%)	53.6	53.5	53.2	51.3	51.1	50.7				
10904	Weight of Soil + Ring	163.65	163.37	163.03	160.28	159.75	159.2				
TR698-2	Weight of Ring	0	0	0	0	0	0				
N/A	Retained Water (%)	54.1	53.8	53.5	50.6	50.1	49.5				
10905	Weight of Soil + Ring	177.17	176.87	176.4	173.28	172.8	172.48				
TR699-1	Weight of Ring	0	0	0	0	0	0				
N/A	Retained Water (%)	53.2	52.9	52.4	49.4	48.9	48.6				

No. of Samples 3
No. of Tests per Sample 6

APPENDIX B. RECOMMENDED CHARACTERISTIC CURVE DATA FOR HIGH TEMPERATURE AND ROOM TEMPERATURE CURE SALTSTONE

Table B.1. Recommended Characteristic Curves for High Temperature Cure (60°C) ARP/MCU Saltstone.

Saturation	Suction Head (cm)	Saturation	Relative Permeability kr
1.0000000000000E+00	0.00E+00	1.0000000000000E+00	1.000000E+00
9.9999999970609E-01	5.00E-02	9.9999999970609E-01	9.982605E-01
9.9999999916288E-01	1.00E-01	9.9999999916288E-01	9.975232E-01
9.9999999761568E-01	2.00E-01	9.9999999761568E-01	9.964737E-01
9.9999999048776E-01	5.00E-01	9.9999999048776E-01	9.943757E-01
9.9999997290688E-01	1.00E+00	9.9999997290688E-01	9.919951E-01
9.9999992283233E-01	2.00E+00	9.9999992283233E-01	9.886098E-01
9.9999969214059E-01	5.00E+00	9.9999969214059E-01	9.818545E-01
9.9999912314393E-01	1.00E+01	9.9999912314393E-01	9.742086E-01
9.9999750251272E-01	2.00E+01	9.9999750251272E-01	9.633711E-01
9.9999003644936E-01	5.00E+01	9.9999003644936E-01	9.418703E-01
9.9997162246543E-01	1.00E+02	9.9997162246543E-01	9.177371E-01
9.9991918240463E-01	2.00E+02	9.9991918240463E-01	8.839024E-01
9.9967773325848E-01	5.00E+02	9.9967773325848E-01	8.181011E-01
9.9908318836675E-01	1.00E+03	9.9908318836675E-01	7.464407E-01
9.9886824350425E-01	1.15E+03	9.9886824350425E-01	7.291774E-01
9.9860304464927E-01	1.32E+03	9.9860304464927E-01	7.108704E-01
9.9827591531661E-01	1.52E+03	9.9827591531661E-01	6.914803E-01
9.9787250399484E-01	1.75E+03	9.9787250399484E-01	6.709711E-01
9.9737519108427E-01	2.01E+03	9.9737519108427E-01	6.493118E-01
9.9676237464420E-01	2.31E+03	9.9676237464420E-01	6.264783E-01
9.9600761559618E-01	2.66E+03	9.9600761559618E-01	6.024548E-01
9.9507862291924E-01	3.06E+03	9.9507862291924E-01	5.772369E-01
9.9393606126740E-01	3.52E+03	9.9393606126740E-01	5.508345E-01
9.9253216863302E-01	4.05E+03	9.9253216863302E-01	5.232746E-01
9.9080918200968E-01	4.65E+03	9.9080918200968E-01	4.946060E-01
9.8869758697078E-01	5.35E+03	9.8869758697078E-01	4.649031E-01
9.8611423587023E-01	6.15E+03	9.8611423587023E-01	4.342705E-01
9.8296042274776E-01	7.08E+03	9.8296042274776E-01	4.028482E-01
9.7912006479853E-01	8.14E+03	9.7912006479853E-01	3.708157E-01
9.7445822316698E-01	9.36E+03	9.7445822316698E-01	3.383958E-01
9.6882029934665E-01	1.08E+04	9.6882029934665E-01	3.058567E-01
9.6203236046845E-01	1.24E+04	9.6203236046845E-01	2.735117E-01
9.5390315883141E-01	1.42E+04	9.5390315883141E-01	2.417148E-01
9.4422848359897E-01	1.64E+04	9.4422848359897E-01	2.108519E-01
9.3279846233275E-01	1.88E+04	9.3279846233275E-01	1.813262E-01
9.1940824935134E-01	2.16E+04	9.1940824935134E-01	1.535373E-01
9.0387213242639E-01	2.49E+04	9.0387213242639E-01	1.278555E-01
8.8604043259332E-01	2.86E+04	8.8604043259332E-01	1.045937E-01
8.6581772205483E-01	3.29E+04	8.6581772205483E-01	8.397982E-02
8.4318002296358E-01	3.79E+04	8.4318002296358E-01	6.613533E-02
8.1818807087945E-01	4.35E+04	8.1818807087945E-01	5.106409E-02
7.9099375588059E-01	5.01E+04	7.9099375588059E-01	3.865474E-02

Table B.1. Recommended Characteristic Curves for High Temperature Cure (60°C) ARP/MCU Saltstone.

Saturation	Suction Head (cm)	Saturation	Relative Permeability kr
7.6183768959846E-01	5.76E+04	7.6183768959846E-01	2.869673E-02
7.3103740371824E-01	6.62E+04	7.3103740371824E-01	2.090712E-02
6.9896755680777E-01	7.61E+04	6.9896755680777E-01	1.496284E-02
6.6603511931580E-01	8.76E+04	6.6603511931580E-01	1.053244E-02
6.3265331096661E-01	1.01E+05	6.3265331096661E-01	7.302224E-03
5.9921788779939E-01	1.16E+05	5.9921788779939E-01	4.994055E-03
5.6608840144332E-01	1.33E+05	5.6608840144332E-01	3.374409E-03
5.3357570534139E-01	1.53E+05	5.3357570534139E-01	2.256049E-03
5.0193570560991E-01	1.76E+05	5.0193570560991E-01	1.494619E-03
4.7136844157184E-01	2.03E+05	4.7136844157184E-01	9.824698E-04
4.4202112370153E-01	2.33E+05	4.4202112370153E-01	6.415537E-04
4.1399368963677E-01	2.68E+05	4.1399368963677E-01	4.166101E-04
3.8734562491098E-01	3.08E+05	3.8734562491098E-01	2.692822E-04
3.6210309589350E-01	3.54E+05	3.6210309589350E-01	1.733837E-04
3.3826575621941E-01	4.07E+05	3.3826575621941E-01	1.112813E-04
3.1581285716616E-01	4.68E+05	3.1581285716616E-01	7.123500E-05
2.9470849519681E-01	5.39E+05	2.9470849519681E-01	4.550160E-05
2.7490596686576E-01	6.20E+05	2.7490596686576E-01	2.901293E-05
2.5635128386436E-01	7.13E+05	2.5635128386436E-01	1.847261E-05
2.3898594356037E-01	8.19E+05	2.3898594356037E-01	1.174770E-05
2.2274906619318E-01	9.42E+05	2.2274906619318E-01	7.463794E-06
2.0757900937955E-01	1.08E+06	2.0757900937955E-01	4.738346E-06
1.9341456122572E-01	1.25E+06	1.9341456122572E-01	3.006199E-06
1.8019580004928E-01	1.43E+06	1.8019580004928E-01	1.906269E-06
1.6786469448141E-01	1.65E+06	1.6786469448141E-01	1.208282E-06
1.5636550421005E-01	1.90E+06	1.5636550421005E-01	7.656053E-07
1.4564502963659E-01	2.18E+06	1.4564502963659E-01	4.849773E-07
1.3565274852881E-01	2.51E+06	1.3565274852881E-01	3.071430E-07
1.2634086934495E-01	2.88E+06	1.2634086934495E-01	1.944827E-07
1.1766432411266E-01	3.31E+06	1.1766432411266E-01	1.231282E-07
1.0958071834966E-01	3.81E+06	1.0958071834966E-01	7.794393E-08
1.0205025127641E-01	4.38E+06	1.0205025127641E-01	4.933613E-08
9.5035616278486E-02	5.04E+06	9.5035616278486E-02	3.122582E-08
8.8501889038067E-02	5.80E+06	8.8501889038067E-02	1.976219E-08
8.2416408809696E-02	6.67E+06	8.2416408809696E-02	1.250645E-08
7.6748656836192E-02	7.67E+06	7.6748656836192E-02	7.914343E-09
7.1470134780207E-02	8.82E+06	7.1470134780207E-02	5.008194E-09
6.6554245203445E-02	1.01E+07	6.6554245203445E-02	3.169097E-09
6.1976175493760E-02	1.17E+07	6.1976175493760E-02	2.005304E-09
5.7712786169869E-02	1.34E+07	5.7712786169869E-02	1.268871E-09
5.3742504145441E-02	1.54E+07	5.3742504145441E-02	8.028753E-10
5.0045221278943E-02	1.77E+07	5.0045221278943E-02	5.080117E-10
4.6602198350106E-02	2.04E+07	4.6602198350106E-02	3.214365E-10

Table B.1. Recommended Characteristic Curves for High Temperature Cure (60°C) ARP/MCU Saltstone.

Saturation	Suction Head (cm)	Saturation	Relative Permeability kr
4.3395974470716E-02	2.35E+07	4.3395974470716E-02	2.033824E-10
4.0410281843657E-02	2.70E+07	4.0410281843657E-02	1.286853E-10
3.7629965719431E-02	3.10E+07	3.7629965719431E-02	8.142207E-11
3.5040909356554E-02	3.57E+07	3.5040909356554E-02	5.151737E-11
3.2629963765239E-02	4.10E+07	3.2629963765239E-02	3.259596E-11
3.0384881998626E-02	4.72E+07	3.0384881998626E-02	2.062399E-11
2.8294257749081E-02	5.43E+07	2.8294257749081E-02	1.304910E-11
2.6347468006477E-02	6.24E+07	2.6347468006477E-02	8.256344E-12
2.4534619539043E-02	7.18E+07	2.4534619539043E-02	5.223894E-12
2.2846498963988E-02	8.25E+07	2.2846498963988E-02	3.305220E-12
2.1274526183685E-02	9.49E+07	2.1274526183685E-02	2.091251E-12
1.9810710973048E-02	1.09E+08	1.9810710973048E-02	1.323157E-12
1.8447612514233E-02	1.25E+08	1.8447612514233E-02	8.371756E-13
1.7178301685648E-02	1.44E+08	1.7178301685648E-02	5.296895E-13
1.5996325923122E-02	1.66E+08	1.5996325923122E-02	3.351399E-13
1.4895676481827E-02	1.91E+08	1.4895676481827E-02	2.120463E-13
1.3870757937936E-02	2.19E+08	1.3870757937936E-02	1.341637E-13
1.2916359779085E-02	2.52E+08	1.2916359779085E-02	8.488666E-14
1.2027629942297E-02	2.90E+08	1.2027629942297E-02	5.370858E-14
1.1200050167156E-02	3.34E+08	1.1200050167156E-02	3.398192E-14
1.0429413040700E-02	3.84E+08	1.0429413040700E-02	2.150067E-14
9.7118006186404E-03	4.41E+08	9.7118006186404E-03	1.360367E-14
9.0435645152277E-03	5.08E+08	9.0435645152277E-03	8.607168E-15
8.4213073612809E-03	5.84E+08	8.4213073612809E-03	5.445833E-15
7.8418655366890E-03	6.71E+08	7.8418655366890E-03	3.445628E-15
7.3022930900175E-03	7.72E+08	7.3022930900175E-03	2.180080E-15
6.7998467637910E-03	8.88E+08	6.7998467637910E-03	1.379356E-15
6.3319720495591E-03	1.02E+09	6.3319720495591E-03	8.727310E-16

Table B.2. Recommended Characteristic Curves for Room Temperature Cure (20^{o}C) ARP/MCU Saltstone.

Saturation	Suction Head (cm)	Saturation	Relative Permeability kr
1.0000000000000E+00	0.00E+00	1.0000000000000E+00	1.000000E+00
9.9999999999041E-01	5.00E-02	9.9999999999041E-01	9.999050E-01
9.9999999996914E-01	1.00E-01	9.9999999996914E-01	9.998471E-01
9.9999999990070E-01	2.00E-01	9.9999999990070E-01	9.997540E-01
9.9999999953451E-01	5.00E-01	9.9999999953451E-01	9.995387E-01
9.9999999850213E-01	1.00E+00	9.9999999850213E-01	9.992578E-01
9.9999999518009E-01	2.00E+00	9.9999999518009E-01	9.988061E-01
9.9999997740558E-01	5.00E+00	9.9999997740558E-01	9.977618E-01
9.9999992729489E-01	1.00E+01	9.9999992729489E-01	9.964002E-01
9.9999976604708E-01	2.00E+01	9.9999976604708E-01	9.942113E-01
9.9999890329333E-01	5.00E+01	9.9999890329333E-01	9.891591E-01
9.9999647099472E-01	1.00E+02	9.9999647099472E-01	9.825860E-01
9.9998864440099E-01	2.00E+02	9.9998864440099E-01	9.720547E-01
9.9994677189330E-01	5.00E+02	9.9994677189330E-01	9.479119E-01
9.9982875601193E-01	1.00E+03	9.9982875601193E-01	9.168477E-01
9.9978326806304E-01	1.15E+03	9.9978326806304E-01	9.086708E-01
9.9972570281941E-01	1.32E+03	9.9972570281941E-01	8.997119E-01
9.9965285717000E-01	1.52E+03	9.9965285717000E-01	8.899009E-01
9.9956068057235E-01	1.75E+03	9.9956068057235E-01	8.791628E-01
9.9944405210799E-01	2.01E+03	9.9944405210799E-01	8.674176E-01
9.9929649964005E-01	2.31E+03	9.9929649964005E-01	8.545801E-01
9.9910984649165E-01	2.66E+03	9.9910984649165E-01	8.405602E-01
9.9887376766624E-01	3.06E+03	9.9887376766624E-01	8.252632E-01
9.9857523361187E-01	3.52E+03	9.9857523361187E-01	8.085907E-01
9.9819781488737E-01	4.05E+03	9.9819781488737E-01	7.904415E-01
9.9772081590610E-01	4.65E+03	9.9772081590610E-01	7.707126E-01
9.9711820046276E-01	5.35E+03	9.9711820046276E-01	7.493020E-01
9.9635726651473E-01	6.15E+03	9.9635726651473E-01	7.261107E-01
9.9539702366433E-01	7.08E+03	9.9539702366433E-01	7.010468E-01
9.9418622564935E-01	8.14E+03	9.9418622564935E-01	6.740301E-01
9.9266101463003E-01	9.36E+03	9.9266101463003E-01	6.449983E-01
9.9074214842155E-01	1.08E+04	9.9074214842155E-01	6.139146E-01
9.8833181238990E-01	1.24E+04	9.8833181238990E-01	5.807774E-01
9.8531007339372E-01	1.42E+04	9.8531007339372E-01	5.456316E-01
9.8153112550323E-01	1.64E+04	9.8153112550323E-01	5.085819E-01
9.7681961969234E-01	1.88E+04	9.7681961969234E-01	4.698068E-01
9.7096757462091E-01	2.16E+04	9.7096757462091E-01	4.295737E-01
9.6373263758244E-01	2.49E+04	9.6373263758244E-01	3.882516E-01
9.5483878828223E-01	2.86E+04	9.5483878828223E-01	3.463202E-01
9.4398089936517E-01	3.29E+04	9.4398089936517E-01	3.043702E-01
9.3083477223160E-01	3.79E+04	9.3083477223160E-01	2.630921E-01
9.1507416673746E-01	4.35E+04	9.1507416673746E-01	2.232476E-01
8.9639569660056E-01	5.01E+04	8.9639569660056E-01	1.856232E-01

Table B.2. Recommended Characteristic Curves for Room Temperature Cure (20^{o}C) ARP/MCU Saltstone.

Saturation	Suction Head (cm)	Saturation	Relative Permeability kr
8.7455105653629E-01	5.76E+04	8.7455105653629E-01	1.509659E-01
8.4938386748816E-01	6.62E+04	8.4938386748816E-01	1.199093E-01
8.2086586192487E-01	7.61E+04	8.2086586192487E-01	9.290220E-02
7.8912507609489E-01	8.76E+04	7.8912507609489E-01	7.015625E-02
7.5445835938401E-01	1.01E+05	7.5445835938401E-01	5.162728E-02
7.1732273275451E-01	1.16E+05	7.1732273275451E-01	3.703627E-02
6.7830476715969E-01	1.33E+05	6.7830476715969E-01	2.592542E-02
6.3807272544965E-01	1.53E+05	6.3807272544965E-01	1.773433E-02
5.9732051514668E-01	1.76E+05	5.9732051514668E-01	1.187703E-02
5.5671383343385E-01	2.03E+05	5.5671383343385E-01	7.804285E-03
5.1684700571332E-01	2.33E+05	5.1684700571332E-01	5.042795E-03
4.7821512018513E-01	2.68E+05	4.7821512018513E-01	3.211440E-03
4.4120190820797E-01	3.08E+05	4.4120190820797E-01	2.019992E-03
4.0608077486918E-01	3.54E+05	4.0608077486918E-01	1.257407E-03
3.7302494720972E-01	4.07E+05	3.7302494720972E-01	7.759635E-04
3.4212265059817E-01	4.68E+05	3.4212265059817E-01	4.754554E-04
3.1339398958950E-01	5.39E+05	3.1339398958950E-01	2.896333E-04
2.8680725967414E-01	6.20E+05	2.8680725967414E-01	1.756038E-04
2.6229339519352E-01	7.13E+05	2.6229339519352E-01	1.060625E-04
2.3975800559185E-01	8.19E+05	2.3975800559185E-01	6.386424E-05
2.1909094159924E-01	9.42E+05	2.1909094159924E-01	3.836070E-05
2.0017360736552E-01	1.08E+06	2.0017360736552E-01	2.299657E-05
1.8288435655886E-01	1.25E+06	1.8288435655886E-01	1.376450E-05
1.6710233747365E-01	1.43E+06	1.6710233747365E-01	8.228439E-06
1.5271012753001E-01	1.65E+06	1.5271012753001E-01	4.914115E-06
1.3959544983793E-01	1.90E+06	1.3959544983793E-01	2.932463E-06
1.2765221075512E-01	2.18E+06	1.2765221075512E-01	1.748839E-06
1.1678104655626E-01	2.51E+06	1.1678104655626E-01	1.042445E-06
1.0688952339217E-01	2.88E+06	1.0688952339217E-01	6.211367E-07
9.7892098729729E-02	3.31E+06	9.7892098729729E-02	3.699876E-07
8.9709924040461E-02	3.81E+06	8.9709924040461E-02	2.203338E-07
8.2270546632789E-02	4.38E+06	8.2270546632789E-02	1.311872E-07
7.5507552016045E-02	5.04E+06	7.5507552016045E-02	7.809714E-08
6.9360175914839E-02	5.80E+06	6.9360175914839E-02	4.648647E-08
6.3772906047415E-02	6.67E+06	6.3772906047415E-02	2.766792E-08
5.8695087244465E-02	7.67E+06	5.8695087244465E-02	1.646621E-08
5.4080538787739E-02	8.82E+06	5.4080538787739E-02	9.799075E-09
4.9887189507601E-02	1.01E+07	4.9887189507601E-02	5.831173E-09
4.6076733830000E-02	1.17E+07	4.6076733830000E-02	3.469850E-09
4.2614310333690E-02	1.34E+07	4.2614310333690E-02	2.064679E-09
3.9468203266570E-02	1.54E+07	3.9468203266570E-02	1.228526E-09
3.6609566728133E-02	1.77E+07	3.6609566728133E-02	7.309848E-10
3.4012170745938E-02	2.04E+07	3.4012170745938E-02	4.349366E-10

Table B.2. Recommended Characteristic Curves for Room Temperature Cure (20°C) ARP/MCU Saltstone.

Saturation	Suction Head (cm)	Saturation	Relative Permeability kr
3.1652168179765E-02	2.35E+07	3.1652168179765E-02	2.587847E-10
2.9507881221864E-02	2.70E+07	2.9507881221864E-02	1.539739E-10
2.7559606185157E-02	3.10E+07	2.7559606185157E-02	9.161208E-11
2.5789435254776E-02	3.57E+07	2.5789435254776E-02	5.450745E-11
2.4181093901592E-02	4.10E+07	2.4181093901592E-02	3.243075E-11
2.2719792705032E-02	4.72E+07	2.2719792705032E-02	1.929553E-11
2.1392092396507E-02	5.43E+07	2.1392092396507E-02	1.148035E-11
2.0185781007118E-02	6.24E+07	2.0185781007118E-02	6.830501E-12
1.9089762079314E-02	7.18E+07	1.9089762079314E-02	4.063958E-12
1.8093952978568E-02	8.25E+07	1.8093952978568E-02	2.417939E-12
1.7189192415814E-02	9.49E+07	1.7189192415814E-02	1.438603E-12
1.6367156363043E-02	1.09E+08	1.6367156363043E-02	8.559261E-13
1.5620281612275E-02	1.25E+08	1.5620281612275E-02	5.092503E-13
1.4941696291710E-02	1.44E+08	1.4941696291710E-02	3.029884E-13
1.4325156712013E-02	1.66E+08	1.4325156712013E-02	1.802688E-13
1.3764989970475E-02	1.91E+08	1.3764989970475E-02	1.072544E-13
1.3256041791253E-02	2.19E+08	1.3256041791253E-02	6.381301E-14
1.2793629126303E-02	2.52E+08	1.2793629126303E-02	3.796675E-14
1.2373497084115E-02	2.90E+08	1.2373497084115E-02	2.258903E-14
1.1991779792279E-02	3.34E+08	1.1991779792279E-02	1.343977E-14
1.1644964835426E-02	3.84E+08	1.1644964835426E-02	7.996238E-15
1.1329860942531E-02	4.41E+08	1.1329860942531E-02	4.757510E-15
1.1043568627108E-02	5.08E+08	1.1043568627108E-02	2.830569E-15
1.0783453510752E-02	5.84E+08	1.0783453510752E-02	1.684099E-15
1.0547122085026E-02	6.71E+08	1.0547122085026E-02	1.001986E-15
1.0332399688951E-02	7.72E+08	1.0332399688951E-02	5.961499E-16
1.0137310499710E-02	8.88E+08	1.0137310499710E-02	3.546904E-16
9.9600593525948E-03	1.02E+09	9.9600593525948E-03	2.110296E-16

APPENDIX C. DESIGN CHECK DOCUMENTATION

Re: Design Check of SRNL-STI-2011-00661
Ralph Nichols to: Kenneth Dixon 12/16/2011 01:42 PM

I have completed a design check of SRNL-STI-2011-006611 Rev.0. The design check consisted of the following:

1) Spot checking lab notebook entries, spreadsheets, off-site lab data sheets, and computer software input and output files for internal consistency. This included computer files titled: salt_remove_60_r1_matric.ret, saltstone_data_FY11_r0.xslx, vanGenuchhten_recommended_r0.xls, moisture_salt_entry_fy11_r1. Lab notebook SRNL-NB-2009-00037 and Mactec data sheets in the appendix of the report under review.

Based on these spot checks and a review of SRNL-STI-2011-006661, Rev. 0 I find the report to be technically accurate and the conclusions to be reasonable.

Ralph L. Nichols
Fellow Engineer
Environmental Management Directorate
Savannah River National Laboratory
Bldg. 773-42A
Aiken, SC 29808

email: ralph.nichols@srnl.doe.gov
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Kenneth Dixon Ralph, Please conduct a design check of SRNL-... 12/07/2011 05:50:34 PM

From: Kenneth Dixon/SRNL/Srs
To: Ralph Nichols/SRNL/Srs@Srs
Date: 12/07/2011 05:50 PM
Subject: Design Check of SRNL-STI-2011-00661

Ralph,

Please conduct a design check of SRNL-STI-2011-00661. The spreadsheets and word document are located at the following path on winsan1:

\\L0400\L0420\kld\Salt_FY11_Design_Check

This design check may include but is not limited to:
1)Spot check data entry from the Mactec lab sheets into the appropriate spreadsheets.
2)Spot check data entry from the laboratory notebook (SRNL-2009-NB-00037) into the appropriate spreadsheet.
3)Check the logic of the spreadsheets.
4)Review the report for technical accuracy and check that the conclusions are reasonable.

Please charge your time to 02PSL4W402.

Thanks,
Ken
5-5205

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