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Revised Rapid Soils Analysis Kit (RSAK) – Wet Methodology

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Abstract

ERDC research on crater formation from detonation of improvised explosive devices identified the significance of soil type on crater shape and size. Military Explosive Ordnance Disposal (EOD) teams required an expedient means of classifying soil from small field samples, according to the Unified Soil Classification System, to help identify characteristics of buried explosives. The existing Rapid Soils Analysis Kit (RSAK), developed at ERDC, was modified to shrink its cube volume, improve its accuracy, and adapt it to the EOD mission. As such the RSAK was changed from a dry, pulverization-based (D-RSAK) system to a wet, wash-based (W-RSAK) system similar to that used in a commercial laboratory to improve accuracy of determining fines content. Modifications were focused on increasing speed and accuracy from the original D-RSAK. This report presents comparisons of classification results on 14 different soil types by both the traditional laboratory, dry-based and wet-based systems to demonstrate the strengths and weaknesses of the new W-RSAK procedure. The kit in its current configuration with the wet process was demonstrated to significantly improve classification estimations. Revised software to process the data obtained from the W-RSAK equipment was developed using Matlab and Android platforms to enable deployment on multiple software platforms.

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Preface

This study was conducted for the National Ground Intelligence Center (NGIC) Combat Incidence Analysis Division (CIAD) under Project 354894 CALDERA. The technical monitor was Dr. John Q. Ehrgott Jr.

The principal investigator for this study was completed by the Airfields and Pavements Branch (GMA) of the Engineering Systems and Materials Division (GM), U.S. Army Engineer Research and Development Center, Geotechnical and Structures Laboratory (ERDC-GSL). Other personnel who assisted in this research effort were Mr. David R. Daily, Information Technology Laboratory (CEERD-ITL) and Mr. Naveen Ganesh, Coastal and Hydraulics Laboratory (CEERD-CHL). Laboratory testing was conducted by the Concrete and Materials Branch (GMC) by Mr. Charles E. Carter, Mr. Larry D. Dunbar and Ms. Alfreda S. Thomas. At the time of publication, Dr. Timothy W. Rushing was Chief, GMA; Mr. Chris Moore was Chief, GMC; Dr. Gordon W. McMahon was Chief, GM; Mr. Charles W. Ertle was Acting Deputy Director, ERDC-GSL; and Mr. Bartley P. Durst was Director.

COL Bryan S. Green was the Commander of ERDC. Dr. David W. Pittman was Director.

Unit Conversion Factors

Multiply	By	To Obtain
cubic yards	0.7645549	cubic meters
feet	0.3048	meters
inches	0.0254	meters
pounds (force)	4.448222	newtons
pounds (force) per foot	14.59390	newtons per meter
pounds (force) per square foot	47.88026	pascals
pounds (force) per square inch	6.894757	kilopascals
pounds (mass) per cubic foot	16.01846	kilograms per cubic meter
square feet	0.09290304	square meters
tons (force)	8,896.443	newtons

1 Introduction

1.1 Background

The CALDERA program (Ehrgott et al. 2016) is focused on developing tools to enable the soldier to estimate the size and depth of a buried improvised explosive device (IED) based on factors such as soil type, soil density, soil moisture, and dimensional characteristics of the crater left behind from an explosion. This research effort is a key component in the crater forensic capabilities necessary for the success of the CALDERA program at ERDC to better identify the soil conditions as part of the analysis procedure. Companion research efforts ongoing within CALDERA address the integration of field data collection with predictive models to estimate the charge size and depth of burial.

Previous to this research effort, it was understood that the volume of air voids played a role in the ultimate air-blast effect of a buried explosive on an object (Ehrgott 2011). The research focused primarily on coarse-grained sand or gravel material that has a uniform response to blast effects in both the laboratory and numerically. The size and shape of the post-blast crater was not considered, since the ultimate goal was identifying blast effects on neighboring objects. However, most soils are not uniform sand or gravel, and experimentation has shown that similar air void contents between soil types result in markedly different crater shapes. The CALDERA program sought to identify soil factors that contribute to the change in crater dimension; soil classification, density and moisture content were pinpointed as essential parameters. To enable military Explosive Ordinance Disposal (EOD) personnel to obtain this information during forensic analysis, a rapid yet durable capability for obtaining these parameters was required. This report discusses the solutions provided to meet this demand.

1.2 Objectives

The objective of this study was to modify the current Rapid Soils Analysis Kit (D-RSAK) developed by ERDC (Berney and Wahl 2008), to shrink its cube volume, improve its accuracy and adapt it to the nature of the EOD mission. As such the D-RSAK was adapted from a dry, pulverization-based soil processing system to a wet, wash-based soil processing system (W-RSAK) similar to that used in a commercial laboratory to improve

accuracy of determining fines content. Sieve capacity was expanded; heating was converted from microwave to hot plate. These changes and manual sieving all allowed reduction in size while increasing speed and accuracy from the D-RSAK. A comparison was then made between the original dry-based D-RSAK and the new wet-based W-RSAK to show improvements in time and accuracy. Further, a comparison was made between this new technology and the existing Army soils kit to show extension of this system to a broader engineering audience.

1.3 Scope

In order to make an accurate post-blast prediction of the effective net explosive weight, the analyst must have some idea of the soil type and the in-place soil conditions. This research project was designed to provide soldiers who have minimal to no experience in soil analysis simple, repeatable tools that will enable them to determine the soil classification, density, and moisture state of the ground at the site of an existing crater location. As a more accurate approach to obtaining field classification than the textural-based expedient soil classification process developed early in the CALDERA program (Ehrgott et al. 2016) (Appendix A), this research details the deliberate procedure modifying the existing D-RSAK, an expedient technology developed for contingency construction (Berney and Wahl 2008) to obtain a near-ASTM standard accurate soil classification, moisture content, and an estimate of field density in less than 60 min.

2 Current State of Expedient Soil Classification

2.1 Typical geotechnical testing

The ability to determine an accurate engineering soil classification without the need for time-consuming laboratory testing is critical to enabling real-time site analysis for crater forensics. Currently, when a soil sample is obtained from a field setting, the engineering classification can be obtained via a visual classification (ASTM D2488) or TM 3-34.43 (Dept. of the Army, 2015). This procedure provides a rough estimate of the ASTM soil engineering classification (ASTM D2487) and an estimate of the plasticity of the soil by identifying it as either silt or clay at a high or low plasticity. However, several of the aforementioned field techniques require an experienced user to obtain repeatable results given the large number (20) of engineering classifications possible. As well, the field tests for plasticity typically involve wetting and later drying of the soil to determine the strength of dried silt/clay. This is not feasible in the short timeframe (5 min to 1 hr) demanded of the CALDERA program (Ehrgott et al. 2016). Nor does the field visual classification provide any estimate of field moisture or density.

For obtaining density and moisture content there are a number of manual, electronic, and nuclear methodologies to accomplish this task (Berney et al. 2013, 2016). Notably are the sand cone test for density, the nuclear densometer for density and moisture (Troxler, 2007), and a host of electronic devices that can measure density and moisture. Determining density in this way requires an expensive and bulky piece of test equipment that must be carried into the battlespace. For nuclear methods, additional radiation protection must be provided for the user and team. Electronic means require calibration of the soil prior to obtaining a valid reading using a secondary technique, making application of this technology moot. For moisture content, a number of means can be employed in the field and are discussed in Berney et al. 2011. For a microwave and electric burner, power must be supplied to dry the soil, but the technique can be accomplished in a few minutes. A gas burner can also provide an expedient drying technique given ready access to fuel.

2.2 Army test set, soil

The military state of the practice for assessing soil classification and engineering properties in the field is performed using the Army test set, soil (LIN V99259), whose components are detailed in Appendix D, and those specifically related to the capabilities of the RSAK shown in Figure 1 and Figure 2 courtesy of the Fort Leonard Wood training facility.

Figure 1. Standard Army soils field kit (drying oven not shown).



Figure 2. Army soils kit drying oven in comparison to RSAK drying apparatus.



Figure 5. Dynatest gravel roads test kit.



Cornell University (Irwin 2011) developed a simplified procedure for assessing the gradation of road materials using a wash technique, portions of which were incorporated into the new W-RSAK system. They suggest determining a rough gradation of road aggregate by obtaining a large field sample size (20 kg), hand-separating particles greater than 1-in. in diameter, and obtaining their weight. The next step is drying and weighing the minus 1-in. particle diameter sample before washing over a #200 sieve. As an alternative, they suggest washing the soil in a bucket and decanting the material that has not settled after 15-20 sec, repeating for approximately 10 wash cycles (Figure 6). Then dry and reweigh the washed sample and screen over the #10 sieve (or 1/8" hardware cloth). This provides an assessment of coarse gravel (plus #10 fraction), sand (#10-#200 fraction), and fines (washed material). The bucket and decanting procedure is the key piece adopted from this procedure that enables the W-RSAK system to operate as it does.

Figure 6. Wash and decanting process for removing fines (minus #200 sieve) material using the Cornell quick wash procedure.



3 Methodology of New RSAK

3.1 Overview

EOD personnel have minimal time at the incident site so the CALDERA expedient technique is typically employed at the blast location (Windham 2015). A summary of the classification system and a new modification made for the case of obtaining USCS classification is given in Appendix A. In instances when a severe event occurs and a more detailed soil assessment is required, a deliberate soil classification technique may be employed.

3.2 Equipment

The RSAK kit was selected as an ideal candidate to provide a rapid means of obtaining a deliberate soil assessment in theater. In its original JRAC configuration, the D-RSAK equipment set was considered too large for EOD personnel, making it impractical for deployment during a post-blast site reconnaissance (Figure 7). Therefore, for the CALDERA program, the RSAK was modified from its original configuration and process in order to reduce the amount of equipment required and increase the accuracy of the measurements with the resulting equipment list shown in Figure 8 and Table 1.

Figure 7. Dry-based Rapid Soils Analysis Kit (D-RSAK) as packaged for the JRAC program.



Figure 8. Wet-based Rapid Soils Analysis Kit as developed for the CALDERA program.



Table 1. Parts list for the wet-based Rapid Soils Analysis Kit.

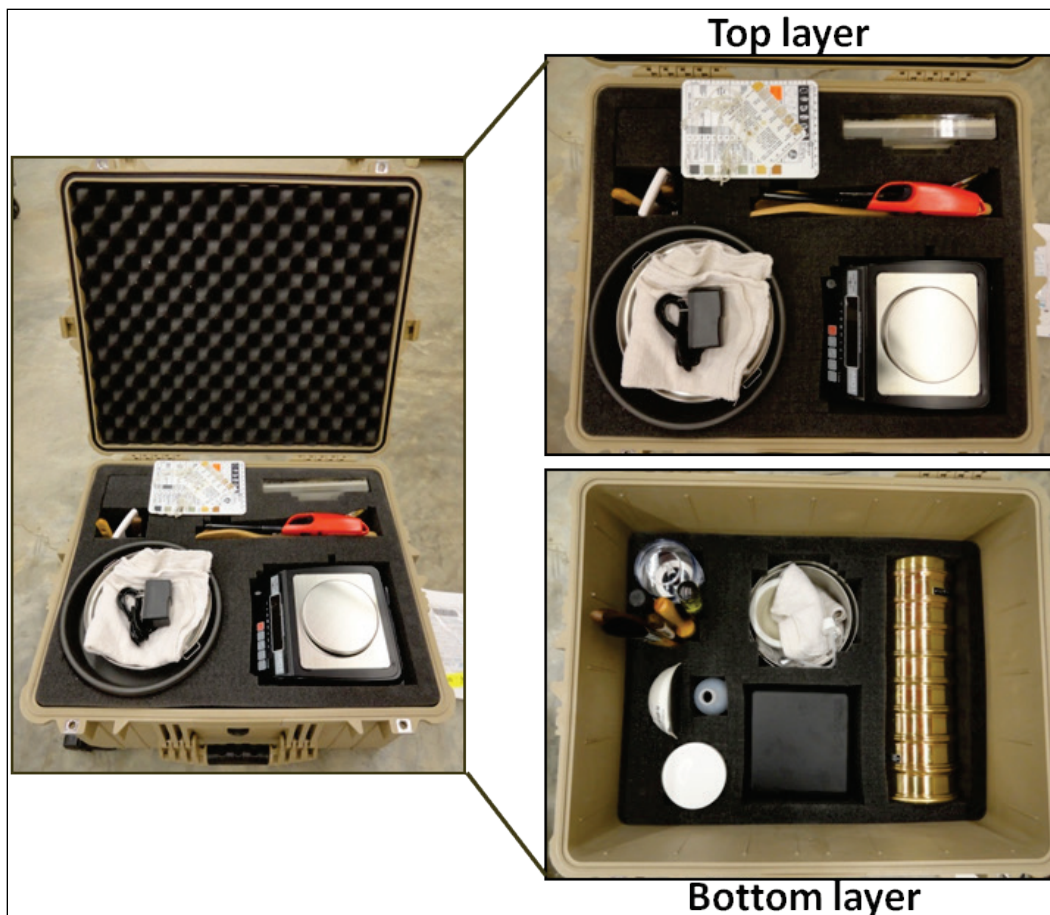
Plastic Limit Roller with paper	1	Multi fuel stove	1
Porcelain Bowls	1	Alpine Cookset	1
Long spoon	1	Plastic funnel	1
Rubber pestle	1	Electric Burner	1
Long spatula	1	2000-gram scale	1
Short spatula	1	Geotechnical Gauge	1
Sample Cups	2	Sand Gauge	1
Sample Pans	2	Small pack of towels	1
Water Bottle (Squeeze)	1	1/2" Scraper	1
Sieve Brush - Fine	1	15amp 50' extension cord	1
Sieve Brush - Coarse	1	Timer	1
Wire Sieve Brush	1	Sharpie Pens	2
Set of 5 inch diameter brass sieves in 1", 1/2", #10, #20, #40, #100, #200	1	Stirring spoons	2
Sampling trowel	1	Coffee Grinder	1
Plastic Bowl	1	1620 Pelican Case	1
		1560 Pelican Case	1

The new version of the RSAK developed for the CALDERA program (W-RSAK) eliminates the original dry-based analysis in favor of a water-based analysis. The water-based approach is analogous to the ASTM wash sieve technique (ASTM C117 2004). This approach simplified the soil preparation from the earlier D-RSAK version and provided a more accurate determination of the fines content of the soil. By washing the fines out of the soil the sieving process also became easier as only coarse-grained material remained. A summary of the key hardware changes in development of the W-RSAK kit is shown in Table 2. Employing the wash technique allowed the use of larger sample sizes and removal of bulkier components of D-RSAK, namely the 1/2-in. diameter splitter and the sieve shaker. Using an electric hotplate or multi-fuel stove eliminated the need for a bulky microwave, and the stove allowed for a non-electric-based drying approach for environments when no AC power was accessible. Removal of the microwave also increased the range of soils that could be dried as very gravelly soils can lead to exploding particles and metallic minerals can cause arcing. Each of these would result in damage to the sample and failure of the moisture measurement test. The overall cube volume of the kit was reduced by a factor of 3 or greater, from two large 1660 Pelican cases (11.32 cu ft) to a single 1620 pelican case (2.56 cu ft) and a 1560 case (1.55 cu ft) for the hot plate if necessary, as shown in Figure 9. Weight wise, this reduced the kit from two 75-lb packages to a single 48-lb package (not including water). The low logistic requirement and high data quality of the W-RSAK were key parameters to its acceptance in CALDERA.

Table 2. Modifications made from the original dry-based RSAK to the wet-based RSAK.

Original Dry RSAK	New Wet RSAK
Microwave oven drying	Replaced with electric hot plate and/or gas burner (gas burner requires no power source)
Porcelain bowls	No longer necessary without microwave. Replaced with plastic and aluminum bowls
Crush and pulverize dried field sample for sieving.	Wash dried field sample to remove fines prior to sieving coarse fraction.
3-inch diameter sieves	Replaced with 5-inch diameter sieves
Sample splitter to reduce sample size for 3-inch diameter sieves	No longer necessary as the entire sample can be run through 5-inch diameter sieves
Sieve Shaker	Replaced by manual sieving of 5-inch sieve stack. Without fines, sieve process required less intensity.
500-gram scale	2000-gram scale for heavier sample/sieve weighing
Software in .NET environment	Software in Matlab executable and Android App

Figure 9. Wet-based RSAK (W-RSAK) packaged in a single 1620 Pelican Case.



3.3 Procedure

Figure 10 introduces the basic steps in conducting a RSAK experiment both from the wet and dry approach. Figure 11 illustrates the procedural steps required in conducting the wet RSAK procedure. These steps are outlined in the ERDC Post-Blast Crater Collection and Analysis Guide (Windham 2015) used for training EOD personnel.

In the RSAK, a relatively small 200-500 g sample is obtained from a field specimen. The sample is dried to obtain the initial moisture content. Drying consists of cooking and weighing the soil on a burner or hot plate repeatedly, until a mass change of less than 1% occurs, indicating that constant moisture content has been achieved. Once dried, the fines are washed from the soil by stirring the dried sample in a small aluminum pan filled with water. After setting for 30 sec, the water is decanted off along with the fines in the soil. The washing procedure is repeated six or more times (ten times was suggested by Irwin 2011), until the water becomes

much less cloudy and a majority of the fines have been removed. Then the sample is dried on the hot plate/burner and passed through the sieve stack to achieve a coarse grain size distribution. Sieving occurs by the user shaking a sieve stack for approximately 2 min. Smaller size fractions may need to be pulverized using the accompanying coffee grinder or mortar and pestle to reduce hard bound clay masses that pose as small sand grains into a powder form and then reinserted into the sieve stack to pass the #200 sieve. The mass of dry soil lost through washing is appended to the coarse grain size sieve information to provide a complete grain size distribution including the fines content.

To determine the Atterberg limits, a portion of the remaining original sample is dried until only a 2% mass differential occurs to reduce error in determining the plastic limit due to over drying certain soil types. Then the soil is ground, passed through the #40 sieve, and rewetted until threads can be rolled based on the principles of the plastic limit test (ASTM D4318 2010). The threads are then dried similarly to the original sample and the moisture content of the threads recorded as the plastic limit. A textural evaluation of the #40 fraction during workup of the threads to identify primarily silty or clayey material is noted and entered into the software. This dictates which regression curve approximates the liquid limit based on the plastic limit measured to finalize the USCS classification. Determination of the fine-grained soil texture can be accomplished by techniques detailed in Windham 2015 and the Dept. of the Army TM 3.34-43.

Figure 10. Procedural differences between wet and dry RSAK methods.

<u>WET mode steps</u>	<u>DRY mode steps</u>
1. Collect a 200 to 500-gram field soil sample	1. Collect a 200 to 500-gram field soil sample
2. Dry the field sample with a burner	2. Dry the field sample with a burner
3. Wash fine soil (silt/clay) from dried sample using water in repeated cycles	3. Separate out coarse and fine soil from the dried sample
4. Re-dry the washed soil	4. Pulverize fine soil to remove clumps
5. Sieve the dried soil through the brass sieves	5. Sieve the dried soil through the brass sieves
6. Prepare a 20-40 gram sample of dried field sample passing the #40 sieve	6. Collect all soil passing the #40 sieve
7. Perform the plastic limit test	7. Perform the plastic limit test
8. Determine the soil texture	8. Determine the soil texture
9. Soil classification is returned	9. Soil classification is returned

Figure 11. Illustration of procedural steps in conducting a wet RSAK experiment.

1. Collect field sample



Pour fuel into stove



Ignite burner



2. Dry field sample



3. Wash fines – add water



Stirring sample for 20 sec.



Pour off fines after 30 sec



Repeat rinsing until
water begins to clear



4. Redry washed sample



5. Sieve coarse sample



Illustration of soil on sieve



Weigh each sieve full



6. Prepare soil for
plastic limit test



7. Perform plastic limit



Example of proper thread



8. Establish soil texture



In the D-RSAK, after drying, the initial sample had to be processed to release fines from coarse aggregate as well as grinding of material down to its smallest native particle size. This was a long task, often longer than the wash technique, and yielded much fewer fines. Handling of the soil, lack of proper fine removal from aggregates, and improper grinding techniques often led to loss of fines and/or creation of improper grain sizes in friable soils that collapsed during the grinding process. The wash technique removes much of this burden on the user, only requiring judgment as to when to stop the decanting process. Any remaining fines in the original sample that have not been decanted can then easily be ground when dried and captured in the sieve stack.

3.4 Software

The software for the W-RSAK was rewritten from the D-RSAK version to account for the changes in procedure found in the wet-based approach. The base algorithms for determining the moisture-density curves and CBR curves remained unchanged. Further, the software was implemented in a variety of methodologies to accommodate various IT scenarios. The original software was developed in a DotNet environment, which proved to be troublesome with ever-changing operating systems. The W-RSAK software was written in OpenGL to enable use on Android devices such as portable phones or tablets. It was also rewritten as a MatLab executable, so that it could be run on any PC or device that had a MatLab compiler installed on it. The MatLab version also ties in with the overarching CALDERA software requested by EOD and CALDERA Android applications. Figure 17 through Figure 17 illustrate the software operation of the MatLab executable for the steps outlined in Figure 11.

Once the user has completed entering the data into the software, an analysis window is displayed in either the Matlab or Android software. This window enables the user to display the grain size distribution (Figure 18) (ASTM D422 2007), select a moisture density curve at standard or modified proctor energy (Figure 19) (ASTM D698 2010), and display the California Bearing Ratio (CBR) (ASTM D1883 2016) value of a compacted soil in standard or modified energy in either soaked or unsoaked conditions (Figure 20). The grain size curve is the key element employed by the EOD teams. The construction guidance is of more value to engineering and field design. The algorithms used to calculate the construction curves are provided in Berney and Wahl (2008).

Figure 12. Introductory screen to begin RSAK data input in Matlab executable.

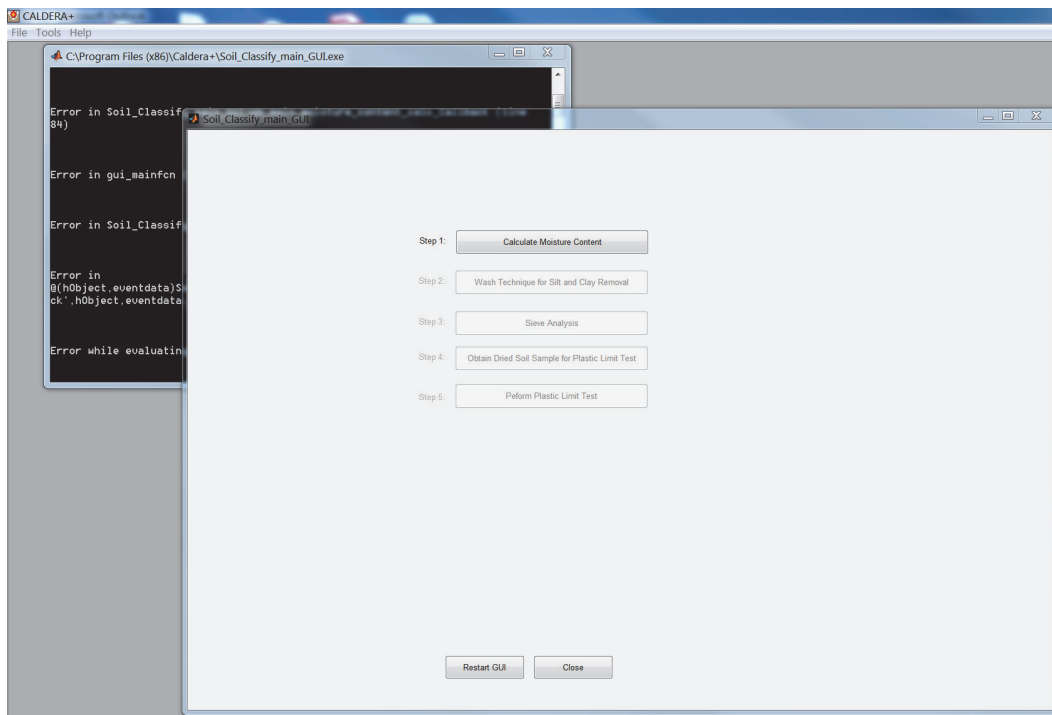


Figure 13. Determination of initial moisture content of soil.

Determine the Moist Content of Field Sample

Weight the Pot Empty: 206.16 g

Place about 200-400 grams of moist soil in pan.

Weight the Pot with Moist Soil: 462.98 g

Place pan and soil on open flame burner and stir for one minute.

Reweight the Pot with Dry Soil: 461.5 g

Continue drying soil in 1 minute increments until the program stops asking for weight.

Continue Drying Process

Moisture Content of the Original Sample: 1.6 %

Close

Pot + Dried Soil Weight (g) 461.5 g

Percent Change (%) 0.97344

Figure 14. Drying of washed soil to prepare for sieve analysis.

Wash Technique to Remove Silt and Clay From Soil Sample

Weight the Pot Empty: g

Pour the dry soil sample from the pan into the bowl and rinse

Weight the Pot with Wet Soil: g

Place pot and soil on open flame burner and stir for one minute

Reweight the pot with dry soil: g

Continue drying soil in 1 minute increments until the program stops asking for weight.

Remove the hot soil pot from the burner and let it cool

Pot + Dried Soil Weight (g) Percent Change (%)

434.01 g

430	1.6545
425	1.826
420	1.826
419	0.3652

Figure 15. Input of sieve weights empty and after soil has been introduced.

Weigh the Sieves

	Empty	Full	
1" Sieve	533.08	533.08	g
1/2" Sieve	515.92	515.92	g
#4 Sieve	502.99	504.37	g
#10 Sieve	479.12	481.08	g
#20 Sieve	432.76	441.13	g
#40 Sieve	411.1	440.6	g
#100 Sieve	375.85	416.56	g
#200 Sieve	390.81	458.67	g
Pan	303.14	310.21	g

Instructions

Pour the dried soil sample into the sieve stack being careful to brush all soil from the pan

Shake the sieve stack side to side vigorously for approximately 2 minutes

Weigh the sieves full and discard soil when completed

Figure 16. Determination of plastic limit by weighting rolled threads.

Perform moisture content calculation to compute Plastic Limit

Weight the Pot Empty: g

Place the moist threads into the pan

Weight the Pot with Moist Soil: g

Place pot and soil on open flame burner and stir for one minute

Reweight the Pot with Dry Soil: g

Continue drying soil in 1 minute increments until the program stops asking for weight.

Plastic Limit of the Soil: %

Pot + Dried Soil Weight (g) Percent Change (%)

110 g 1.6887

109.8 0.83333

109.7

Figure 17. Final input screen in RSAK to determine texture and output final USCS classification and index properties.

Step 6: Textural Determination of the Fine Material

If the Soil is Silty enter the number 1.
If the Soil is Clay enter the number 2.
If you don't know enter the number 3.

Texture:

Results

USCS Soil Classification:

Moisture Content: %

Plasticity Index: %

Liquid Limit: %

Plastic Limit: %

Figure 18. Data analysis window demonstrating grains size distribution curve.

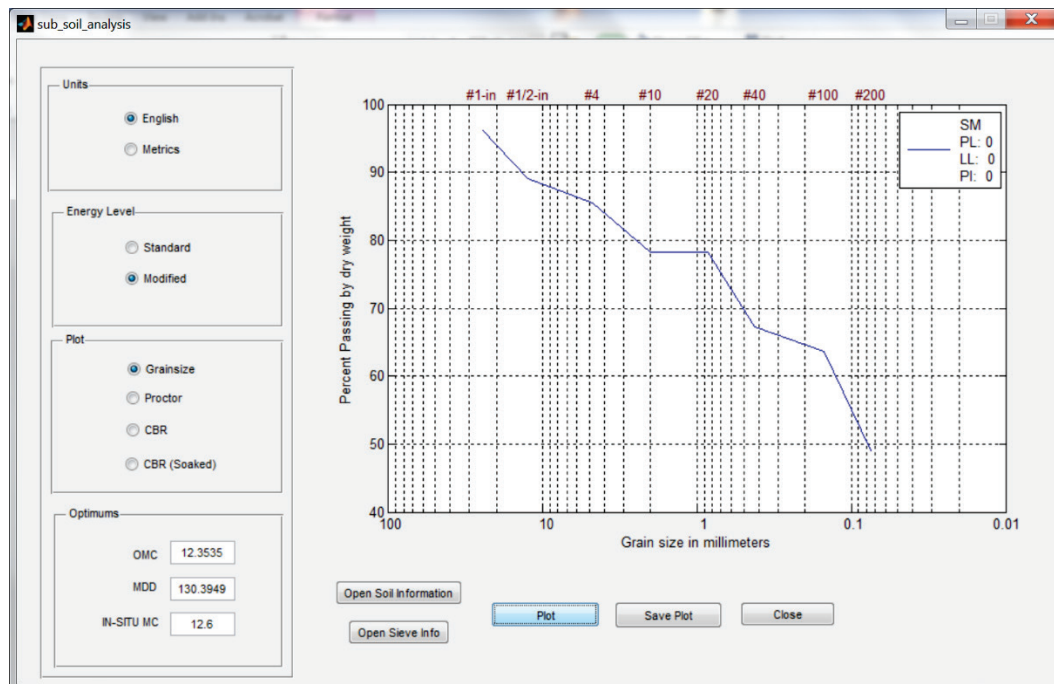


Figure 19. Data analysis window displaying modified proctor density curve.

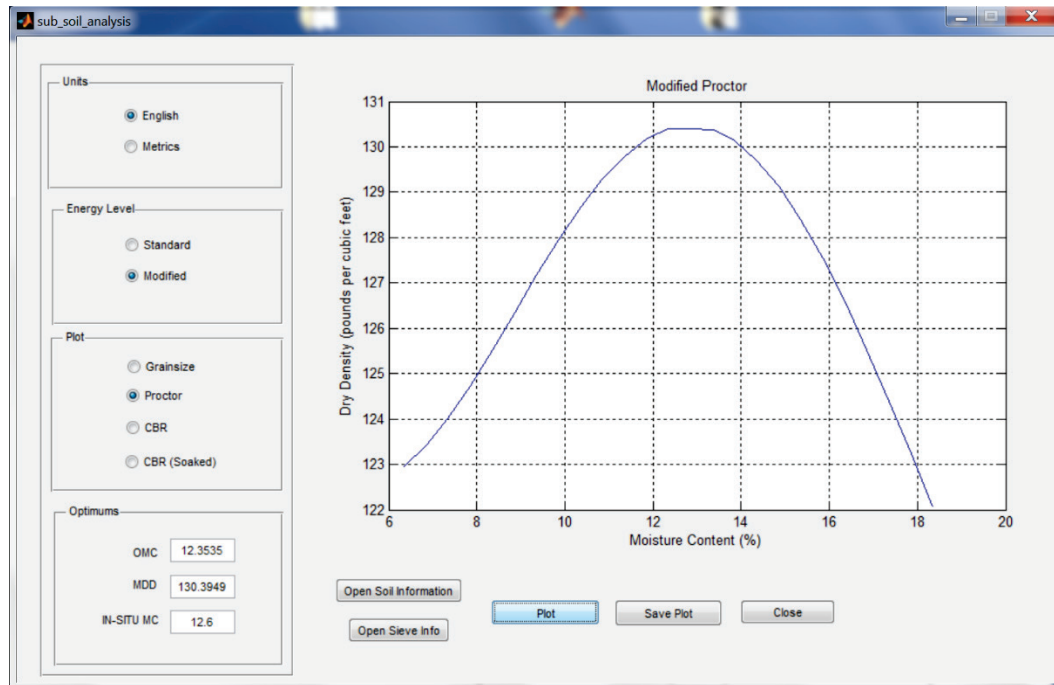
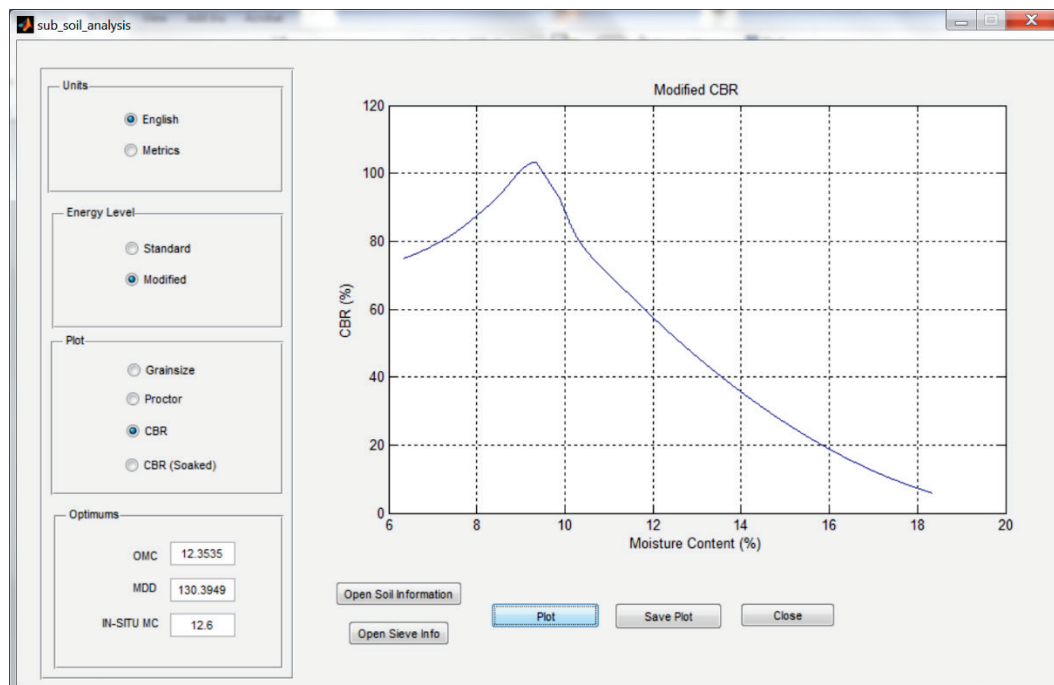


Figure 20. Data analysis window displaying modified proctor CBR curve.



4 Experimentation

4.1 Soils tested

To determine the accuracy of the W-RSAK versus the D-RSAK technique, a series of 14 soils ranging from coarse grained to fine grained were selected (Table 3). Most of the soils tested had significant fine-grained material, as these soils represented the greatest limitation between past performances of the D-RSAK technique to the ASTM procedure. Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) were determined from the standard proctor compaction effort (ASTM D698 2012).

Table 3. Summary of soil properties tested.

Soil ID	Description	Atterberg Limits			Grain size (percent by weight)			MDD (pcf)	OMC (%)	G _s
		LL	PL	PI	Fines	Sand	Gravel			
CL-1	Sandy Clay (CL)	27	13	14	56.9	42.1	1	119.5	12.0	2.67
CL-2	Sandy Clay (CL)	39	11	28	64.1	34.0	1.9	115.5	14.2	2.72
SC-1	Clayey Sand (SC)	31	12	19	40.0	55.0	5	122.3	10.9	2.71
CH-2	Clay with sand (CH)	56	23	33	82.0	17.6	0.4	92.3	25.9	2.76
SC-2	Clayey Sand (SC)	25	14	11	32.1	66.0	1.9	122.8	11.3	2.69
CH-3	Sandy Clay (CH)	36	14	22	64.9	32.4	2.7	108.9	14.8	2.71
CL-3	Sandy Clay (CL)	21	13	8	55.4	40.5	3.8	126.6	9.4	2.70
CH-ERDC	Clay (CH)	73	24	49	95.1	4.9	0	85.7	24.6	2.76
MH	Silt (MH)	109	72	37	97.5	2.5	0	55.7	62.0	2.58
ML	Silt (ML)	No Plasticity			87.8	11	1.2	109.5	15.8	2.75
SP	Sand (SP)	No Plasticity			3.1	92	4.9	109.7	1.9	2.67
SM	Sandy Silt (ML)	No Plasticity			50.3	47	2.7	121.8	10.0	2.71
SP-SC	Sand with Clay and Gravel (SP-SC)	23	13	10	8.0	50.7	41.3	128.8	8.0	2.68
Lime	Gravel (GP-GM)	15	12	3	6	41	53	136.3	6.8	2.68

4.2 Experimental procedure

For each soil type, nine soil samples were obtained for W-RSAK, D-RSAK, and ASTM-based testing according to the tests outlined in Table 4. Three replicate sieve analyses were performed on each platform to provide a robust data set for statistical evaluation. Atterberg limits conducted by the ERDC Materials Test Center are considered the reference standard for the expedient lab plastic limit tests conducted in the RSAK instances.

Therefore, only six replicate plastic limit tests were conducted -- three each for the Dry and Wet procedures.

Table 4. Standard laboratory tests conducted for soil classification.

Test Description	Standard Method	Properties Measured
Particle Size Analysis (USCS Classification)	ASTM C 136	• % Passing 1", ½", #4, #10, #20, #40, #100 and #200 sieves
Standard Proctor Compaction Effort	ASTM D 698	• Maximum Dry Density (MDD) • Optimum Moisture Content (OMC)
Atterberg Limits	ASTM D 4318	• Plastic Limit (PL) • Liquid Limit (LL) • Plasticity Index (PI)
USCS Soils Classification	ASTM D 2487	• Engineering classification

Testing of all the samples was carried out by a single technician who had limited experience conducting these types of soil tests, representing an inexperienced field soldier with basic training in the RSAK technique. With repetition, the technician became more comfortable and efficient with the test procedure, but data were evaluated during testing by the engineer to ensure no bias was obtained due to initial versus final testing.

The ASTM procedure included obtaining three representative samples of each soil (Figure 21) using an appropriate size fraction based on maximum particle size, which typically was much larger than the 500-g or less sample used for each RSAK test sample (Figure 21), then washing the soils in a deep #200 sieve under constant water pressure and oven drying specimens (ASTM D2216 2010) to obtain moisture contents and prepare soil for sieving (Figure 23 and Figure 24). Sieving was conducted using 8-in.-diameter sieves and a mechanical shaker. These procedures were in contrast to the RSAK procedures, which used 500-g or less sample sizes, drying conducted with a burner, washing in a pan and/or pulverizing, and all sieving conducted with 5-in.-diameter sieves that are manually shaken on a tabletop or by hand. A summary of sieve data collected from the three methodologies is presented in Appendix C, Table 9.

Figure 21. Three replicates of limestone soil ready for washing for ASTM grain size determination.



Figure 22. Clay gravel dried and after washing over #200 sieve (note large ASTM sample size used versus a typical 500-g RSAK sample).



Figure 23. Washing fines in deep #200 sieve for ASTM procedure.



Figure 24. Oven drying limestone soil samples in large oven for at least 16 hr.



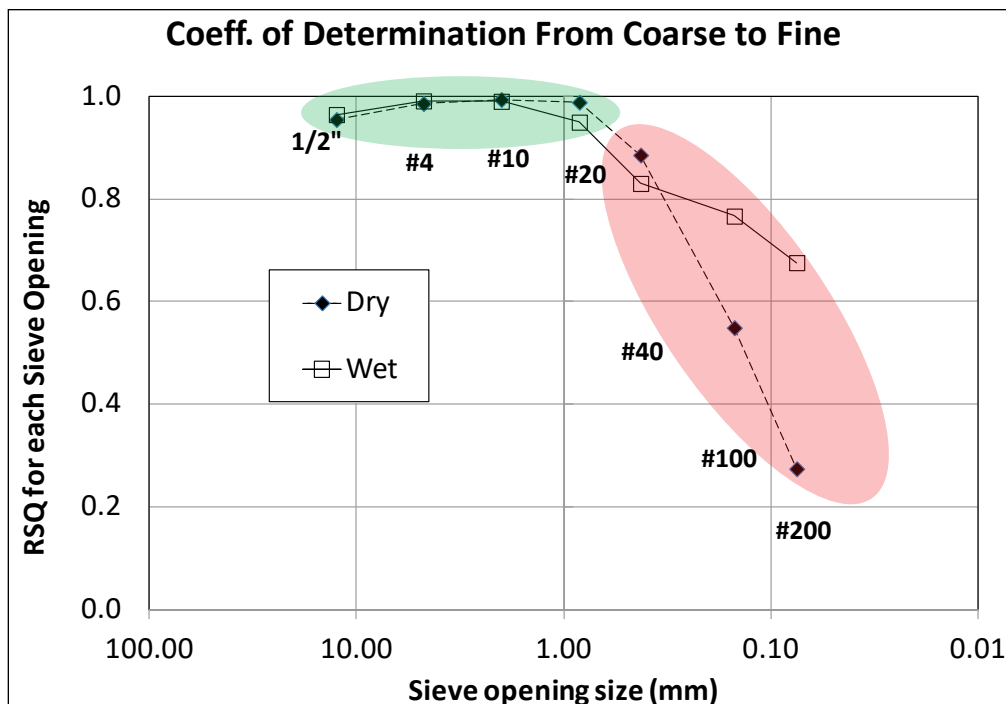
Adherence to ASTM procedures ensured that the best possible conditions were provided to obtain the gradation and classification; however, this study still exhibited differences in relation to the formal laboratory gradations shown in Appendix A. This might be explained due to sampling error or operator differential between technicians. Nonetheless, this demonstrates that even with careful soil preparation, sampling error can lead to gradation differences that can alter the eventual classification.

5 Data Analysis

5.1 Particle size distribution

In determining the suitability of each technique to achieve the closest estimate of the ASTM grain size distribution and soil classification, the coefficient of determination, R^2 (RSQ), was obtained for each sieve size across all 14 soils tested for both the dry- and wet-based procedures. Figure 25 illustrates that for sieves ranging from the #40 and coarser (>0.42 mm), the RSQ values are similar and high for each approach. This suggests that coarse soils sieve equally well using a variety of techniques. However, as soil size decreases below the 0.42-mm threshold, there is a greater reduction in RSQ for the dry method than the wet, indicating increasing error compared to the ASTM method as summarized in Appendix C. The data suggest that the wet procedure produces a far better approximation of percent passing the smaller sieves than does the dry procedure and is able to be achieved in a much more reproducible fashion. This is primarily due to the inability to remove fine material stuck to larger, coarser aggregate and an inability to completely pulverize tightly bound clay material, which therefore behaves as fine sand.

Figure 25. Average Coefficient of Determination between ASTM and RSAK sieve methodologies by sieve opening size for all soils tested.



5.2 Atterberg limits

The plastic limit was determined by rewetting a portion of dried soil and rolling threads using the plastic limit roller. Table 5 shows the comparison between the laboratory Atterberg limits and the RSAK determination for the soils that exhibited plasticity. In the laboratory approach, plastic limit and liquid limit are determined independently. In the RSAK only the plastic limit is determined independently, and the liquid limit is predicted based on correlations dependent on the silt or clay textural classification. Since there is no difference in soil preparation between the dry and wet RSAK procedures, the average of all six independent plastic limit tests are presented in Table 5. Table 6 shows the accuracy of the RSAK approach when comparing either all six tests as independent data points to the laboratory values (Total) or the average of the six tests (Average) to the laboratory values. There is some variation between the two RSAK methods, but the variation is not a function of procedure, rather operator variability at time of testing. An RSQ of 94% for both the plastic limit and prediction of the liquid limit produced an 83% correlation to the plasticity index, which is the principal value for identifying soil classification. This suggests the RSAK approach is a good estimator of Atterberg limits when time constraints prevent use of the liquid limit.

Table 5. Atterberg limit comparison between laboratory and RSAK methods.

Soil Type	Laboratory			RSAK		
	LL	PL	PI	LL	PL	PI
CL-1	27	13	14	24	13	12
CL-2	39	11	28	29	15	14
SC-1	31	12	19	27	14	13
CH-2	56	23	33	59	26	33
SC-2	25	14	11	26	14	13
CH-3	36	14	22	31	16	15
CL-3	21	13	8	25	13	12
CH-ERDC	73	24	49	79	32	46

Table 6. RSQ summary from Atterberg limit comparison.

RSQ for Atterberg Limits					
	Wet-RSAK		Dry-RSAK		All Data
	Total	Average	Total	Average	Average
Plastic Limit	0.874	0.900	0.888	0.939	0.935
Liquid Limit	0.861	0.886	0.940	0.958	0.935
Plasticity Index	0.759	0.781	0.832	0.852	0.826

5.3 Compaction indices

Once the particle size distribution and Atterberg limit information is obtained from the field sample, the RSAK software estimates the optimum moisture content (OMC), the maximum dry density (MDD), and the associated moisture-density curves for that soil type at standard and modified proctor energy. In this experiment, the standard proctor energy compaction test (ASTM D698) was the basis for comparison between the RSAK output and the laboratory values shown in Table 7.

Table 7. Comparison of optimum moisture content and maximum dry density between laboratory and RSAK methods.

Soil Type	Maximum Dry Density					Optimum Moisture Content			
	Laboratory	Predicted				Laboratory	Predicted		
		ASTM	Wet	Dry			ASTM	Wet	Dry
Sand	109.2	116.4	116.3	116.8		9.8	10.8	10.7	10.4
SM	121.8	124.4	123.1	120.3		10	12.9	12.8	10.7
SP-SC	128.8	126.4	125.8	128.8		8	8.6	8.7	7.5
Lime	135.9	136.1	136.3	136.6		5.2	5.3	6.8	5.1
SC-1	122.3	120.8	123.2	119.0		10.9	11.1	10.0	11.6
SC-2	122.8	118.5	118.8	116.5		11.3	11.7	11.5	12.3
CH (ERDC)	85.7	94.0	98.4	95.7		24.6	24.3	22.3	23.0
CH-2	92.3	101.2	102.1	100.2		25.9	20.7	20.0	20.6
CH-3	108.9	116.3	115.6	113.8		14.8	13.3	13.3	13.9
ML	109.5	124.7	121.1	116.8		15.8	17.0	15.5	13.7
CL-1	119.5	119.4	116.9	117.4		12	11.5	11.8	12.0
CL-2	115.5	117.3	116.9	115.8		14.2	12.7	12.9	13.0
CL-3	126.6	122.3	120.4	120.3		9.4	10.2	10.7	10.7
Correlation		0.85	0.87	0.89			0.92	0.94	0.95

Using the regression analysis developed to predict MDD and OMC according to the guidance given in Berney and Wahl (2008), the appropriate sieve information from the ASTM, Dry RSAK method, and Wet RSAK method were input. The predicted MDD and OMC were calculated and compared to the laboratory results obtained from the standard proctor moisture-density curve. A coefficient of determination was calculated based on the 14 soil samples tested to compare the ability of the software and the influence that each sieve approach has on the overall prediction. It was found that little variation existed between approaches with RSQ values of the MDD varying between 85% and 89% and 92% to 95% for OMC. It is not obvious why the Dry-RSAK method exhibited the highest values and the ASTM the lowest, but for the particular soils tested, the error in transfer of particle gradations to a coarser mix influenced the calculation positively. It is not expected that this would be the case in all instances of the calculations and for all soils. Both the wet and dry RSAK

approaches yielded almost identical RSQ, suggesting that the regression technique is applicable as an expedient estimate of the true moisture-density curves.

5.4 USCS classification

While the Dry-RSAK method appears to show a slight advantage when determining OMC and MDD, a major consideration is its inability to properly obtain the soil classification from the grain size distribution. In Table 8, a comparison of the USCS classifications obtained from the laboratory the ASTM wash method and Wet and Dry RSAK methods shows that as the percentage of captured fines diminishes, the classification can change radically. For almost all soils tested with the D-RSAK, the classification falls between SP and SM, with only two of the clay samples having enough fines (5% to 12%) captured to reach the SP-SC category. The W-RSAK performed much better, providing a clay classification for almost all soils with a laboratory clay classification. However, this technique was still unable to capture enough fines to reach a full CH and CL classification in most instances (>50% fines). The primary reason for the discrepancy is that the initial drying of the soil sample hardens small clay fractions into coarse granules that are difficult to disburse. The D-RSAK relies strictly on grinding and soils that are attached to truly coarse-grained materials cannot be ground away. The wash technique improves on this considerably by softening the hard granules, allowing them to be washed away; yet the heaviest clays still do not soften enough to disburse the clods. The ASTM and laboratory methods used water pressure and physical movement of the soil to wash the fines away; this led to a far better estimate of fines content, but is a technique that is often not available in the field. Subsequent investigations have shown that secondary grinding of the smaller sieved particles in the W-RSAK method can recover many of the granulated fines and provide a much better fines estimate than only washing can provide.

Table 8. Comparison between USCS soil classifications between Laboratory, ASTM, and RSAK methods.

Soil Type	Classification			
	Laboratory	Predicted		
		ASTM	Wet	Dry
Sand	SP	SW-SM	SW	SW
SM	ML	ML	SM	SM
SP-SC	SP-SC	SP-SC	SC	SP
Lime	GP-GM	SP-SM	SP-SM	SP
SC-1	SC	SC	SC	SP
SC-2	SC	SC	SC	SP
CH (ERDC)	CH	CH	SC	SP
CH-2	CH	CH	SC	SP
CH-3	CH	CL	SC	SP
ML	ML	ML	ML	SM
CL-1	CL	SC	SC	SP-SC
CL-2	CL	CL	CL	SP
CL-3	CL	CL	SC	SP-SC

The importance of obtaining the correct USCS classification with the RSAK software is that a proper shape and expanse of the compaction curve is dependent on this input variable. Even if the OMC and MDD are appropriately determined, if the wrong curve shape is chosen, then the user runs the risk of incorrectly estimating an appropriate moisture and compaction range to guide the construction process. This consideration demonstrates the primary limitation of the dry-RSAK method when dealing with cohesive soil types. For non-cohesive or low plasticity soils, the methodology works well but breaks down when dealing with medium plasticity soils.

6 Conclusions and Recommendations

6.1 Conclusions

The wet-based RSAK was developed to provide a systematic means to furnish accurate grain size information and an ASTM-based USCS classification. Based off of the original ERDC designed RSAK using a drying and pulverizing methodology to reduce a field sample to a grain size fraction suitable for sieving, the wet-based RSAK uses a wash technique to eliminate fines and provide a better estimate of the fine-grained fraction of soil samples. Based off of series grain size experiments conducted on 14 soils of varying USCS classifications, the W-RSAK improved upon the dry RSAK's ability to capture fines content and was able to correctly identify the fines classification and overall classification of the soil far better than the dry RSAK. All of this was accomplished using a set of field equipment less than half the cube volume of the prior RSAK method and a stove-powered drying technique that enables the wet-RSAK to be completely self-contained in the field. An optional hot-plate drying technique can be employed with moisture content results equal to that of the traditional oven-dried technique.

6.2 Recommendations

For measurement of expeditionary soils, the use of the CALDERA expedient soil test and the wet-RSAK technology provides a thorough examination of the soil. With a few hours of training, soldiers can be prepared to provide soil classifications and engineering assessments of local materials in a matter of minutes. The data obtained from these tests provide insight to the analyst on soil properties and behavior useful in both forensic and construction analysis.

6.3 Areas for future study

In looking at the successes and limitations of the RSAK, several areas are available to improve both accuracy and deployment capabilities. The following outline the primary areas of concern for future research.

6.3.1 Expedient liquid limit test

Past research has been unable to identify a liquid limit test that can be performed in a compressed time frame on in-situ soil material. Any future

research that can overcome this obstacle will provide a great benefit to the accuracy of the RSAK as error collected during prediction of the liquid limit carries through to errors in classification, in OMC and MDD prediction and strength prediction. Further, the liquid limit prediction requires the user to be familiar with the soil's texture, which may not be a simple task for a user who has had little contact with soil. This has been an enduring problem with the RSAK and one that is sorely needed to provide a complete suite of tests that adequately approximate ASTM methodologies and no longer necessitating familiarity with soil texture prior to use.

6.3.2 Reduction in kit volume

Due to the expeditionary nature of the RSAK, any reduction in cube volume is a desirable outcome of future research. As mobile military units are forced to carry greater amounts of equipment, making systems smaller and lighter enables adoption and deployment of new equipment to be more feasible. Custom-made sieves, a smaller heating device, smaller balance, and customized packaging all can make the system lighter and more portable. When every military service is presented the RSAK, the first question asked is always, "Can it be made smaller?" The W-RSAK is the answer to NGIC for the CALDERA program and an even smaller kit is on request by Air Force Special Operations Command.

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Appendix A: Expanded Expedient Soil Classification

The expedient soil classification system developed for the CALDERA program is a simplified method to distill the USCS system into a set of three basic categories each with two variants: Coarse = Gravel or Sand, Intermediate = Intermediate Gravel or Intermediate Sand, and Fine = Silt or Clay (Figure 26) (Ehrgott et al. 2016). This basic visual and textural classification system modeled after the Army Materials Testing Manual (TM 3.34-3, 2015) enables a rapid means to assign a soil classification that can characterize soil behavior during IED blast conditions. To make this procedure compatible with a USCS classification, a simple dissection of the grain size can lead the user to subdivide each of the general colored categories in Figure 26 into either a poorly or well-graded coarse soil (RED); a mixture with silt or clay (BLUE); or a high or low plasticity clay (GREEN). Figure 27 and Figure 28 illustrate this process using a color reference back to the original 6-soil classification at the conclusion of flowchart path. This provides 12 base USCS classifications including GW, GP, GM, GC, SW, SP, SC, SM, ML, MH, CL, and CH.

Figure 26. Simplified soil classification chart for CALDERA.

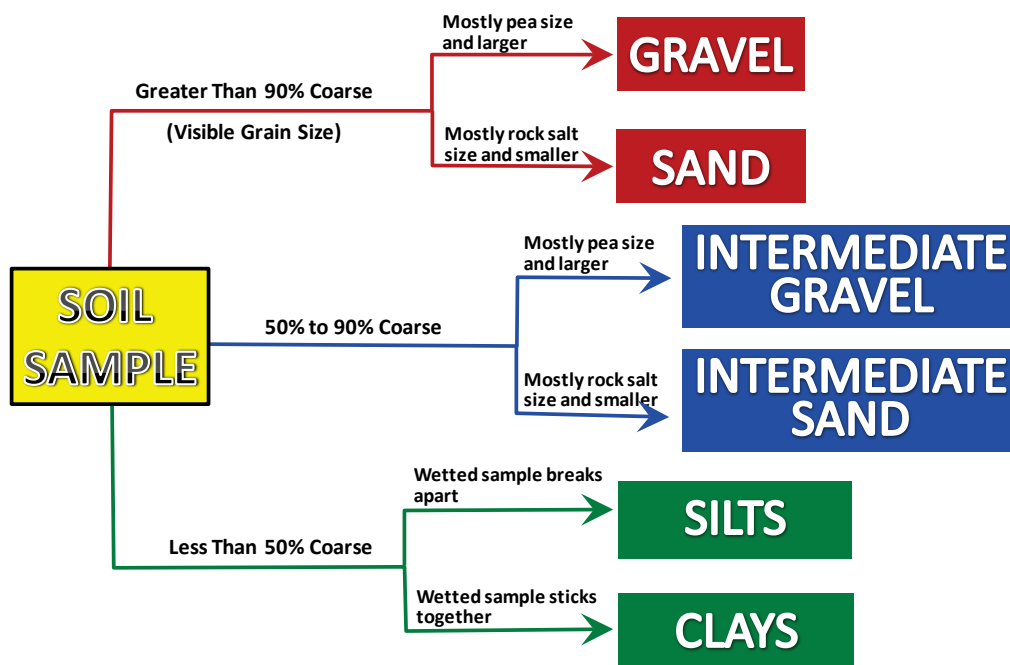


Figure 27. USCS classification breakdown for coarse-grained soils.

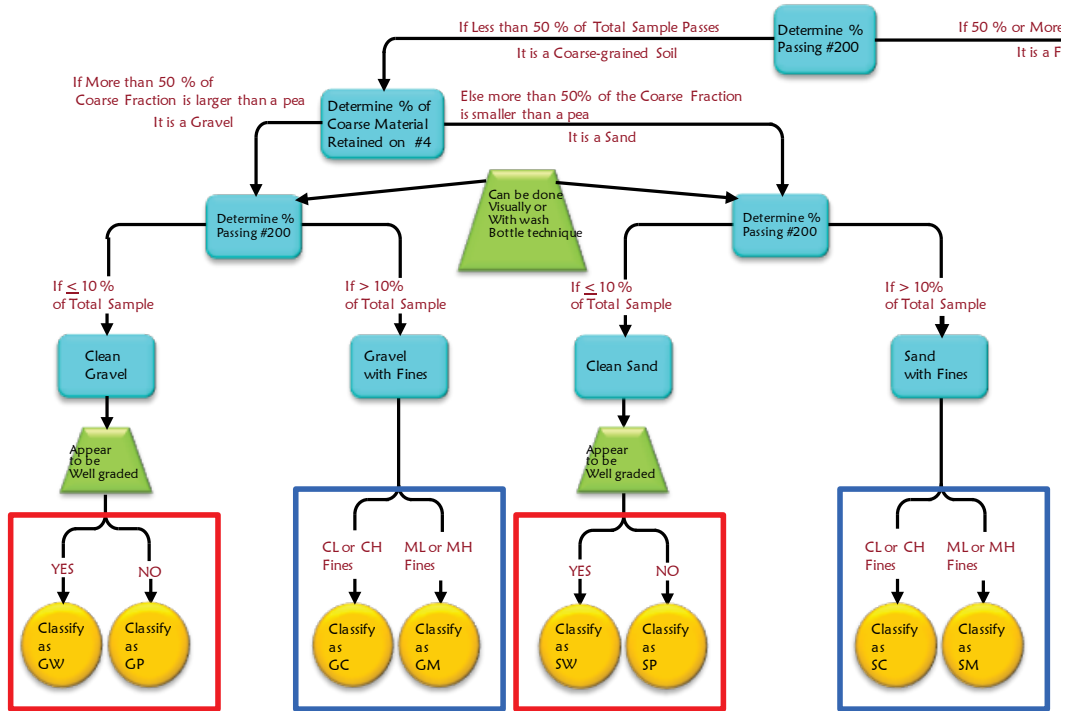
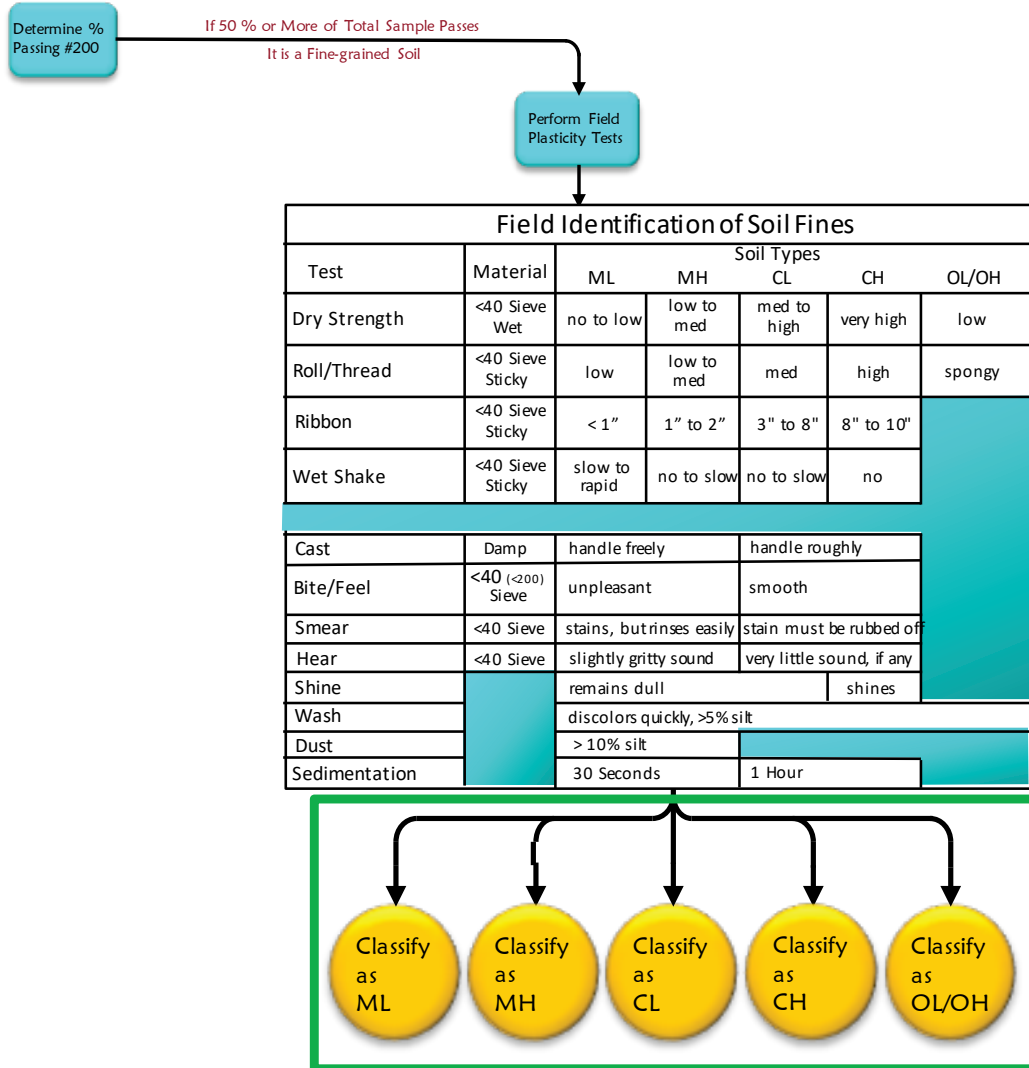
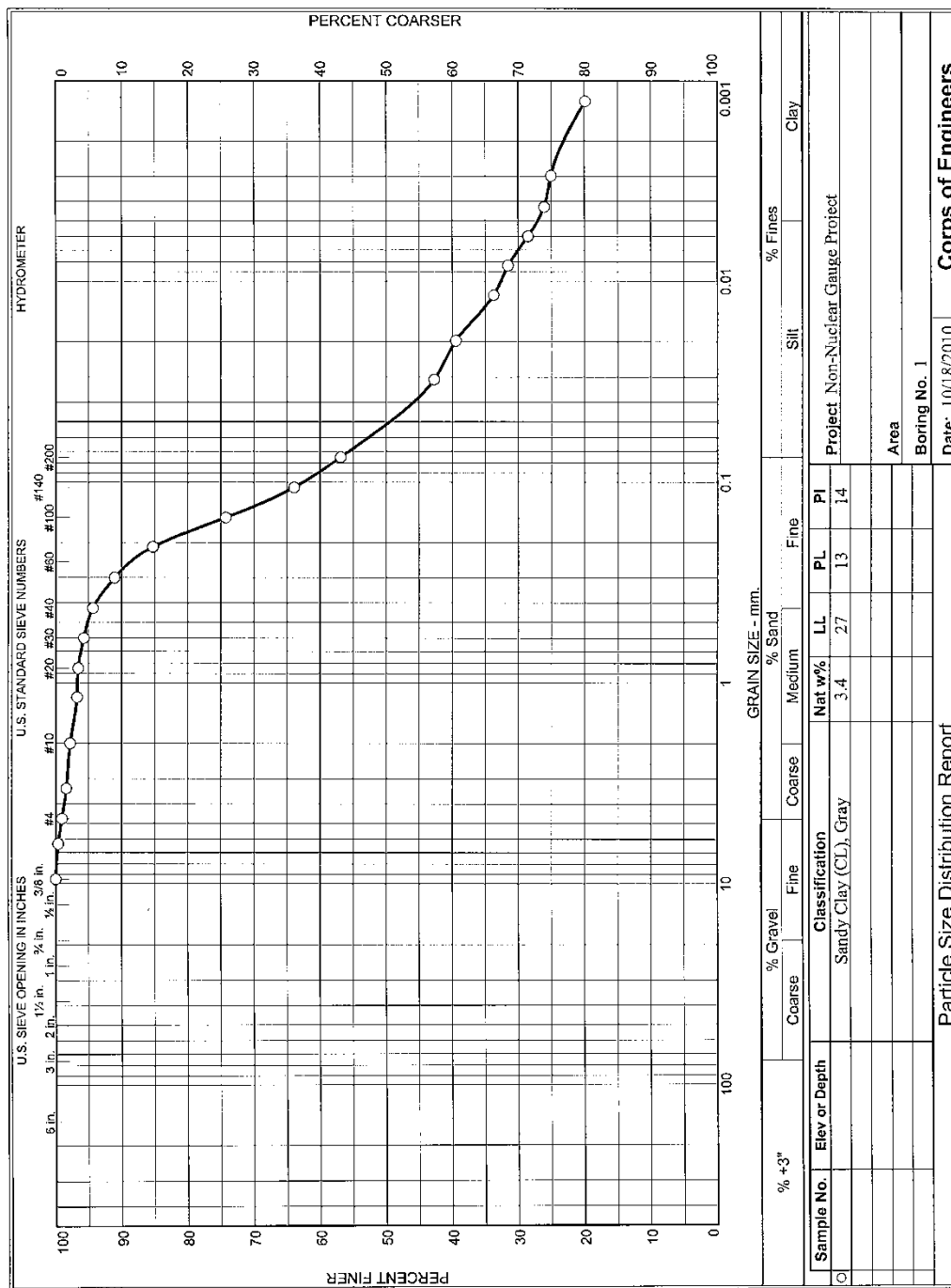


Figure 28. USCS classification breakdown for fine-grained soils based on textural analysis.

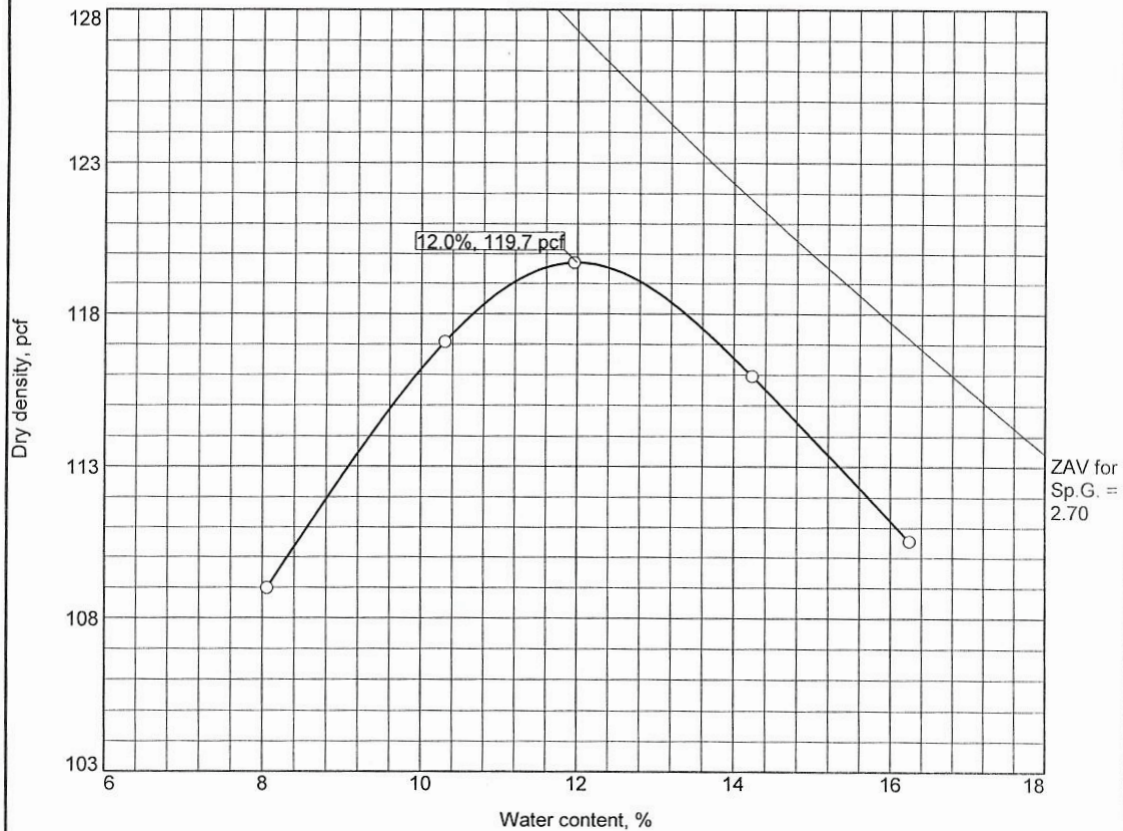


Appendix B: Soil Characterization Data

B.1 CL-1



COMPACTION TEST REPORT



Test specification: ASTM D 698-07 Method B Standard

Elev/ Depth	Classification		Nat. Moist.	Sp.G.	LL	PI	% > 3/8 in.	% < No.200
	USCS	AASHTO						
			2.39	2.70 Est.	27	14		

TEST RESULTS		MATERIAL DESCRIPTION
Maximum dry density = 119.7 pcf Optimum moisture = 12.0 %		Clay (CL), Gray
Project No. Md3510 Client: Mariely Mejias Project: Non-Nuclear Gauge Project ○ Source of Sample: Stock Pile #1		Remarks: Esatimated Gravity 2.70, Compacted using CBR Molds.
Corps of Engineers Engineer Research Development Center		

Figure

Tested By: CEC

SPECIFIC GRAVITY OF SOILS
ASTM D 854
FLASK SET # 1

WORK ORDER NO. MD1812

Date: 4/18/12

Project: Non-Nuclear Gauge

Method A: _____ Method B: X

Boring:	CL1			
Location:				
Sample No.:				
Flask No.:	12	16		
Weight dry soil after test, g, (M_s):	84.49	85.19		
Test temp., °C:	19.5	19.5		
Average calibrated weight of flask, g, (M_p):	167.30	173.12		
Average calibrated volume of flask, ml, (V_p):	499.41	499.32		
Weight of flask, water, & soil @ test temp., g, ($M_{pws,t}$):	718.68	724.94		
Density of water @ test temp., g/ml, (Table 1, ($P_{w,t}$)):	0.99831	0.99831		
Temp. coefficient, (Table 1 (K)):	1.00010	1.00010		
$M_{pw,t}$ =	685.86	671.59		
G_t =	2.67	2.68		
$G_{20}^{\circ C}$ =	2.67	2.68		
Average $G_{20}^{\circ C}$ =	2.67			

Formulas: Weight of flask & water @ test temp., g = $M_{pw,t} = M_p + (V_p \times P_{w,t})$ Specific gravity of soil @ test temp. = $G_t = M_s / (M_{pw,t} - (M_{pws,t} - M_s))$ Specific gravity of soil @ 20°C = $K \times G_t$ Visual Classification: Clay (CL), BrownPercent passing No. 4 sieve: 100Was any soil or material excluded from the specimen? Yes _____ No X

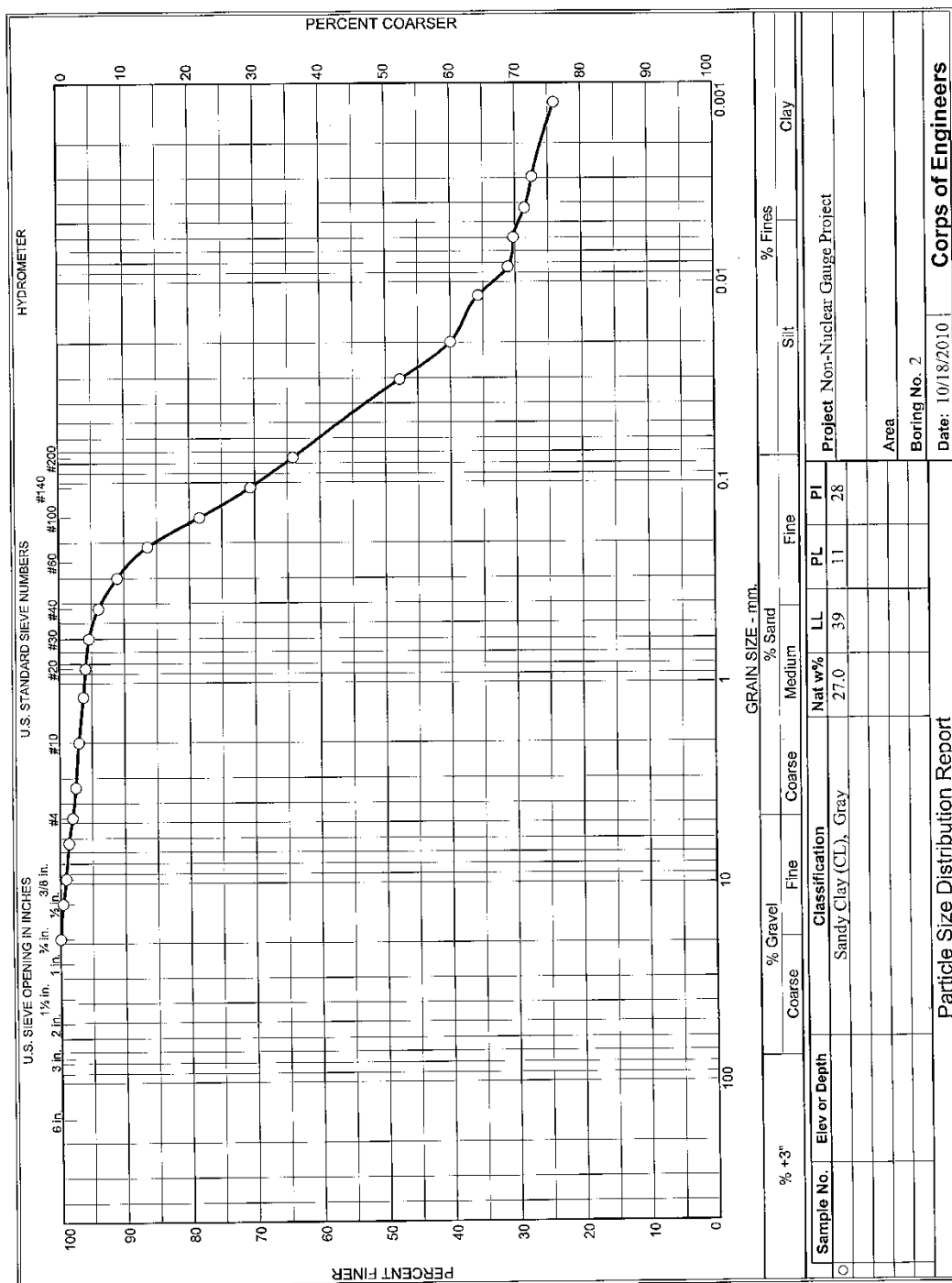
Description of soil or material excluded: _____

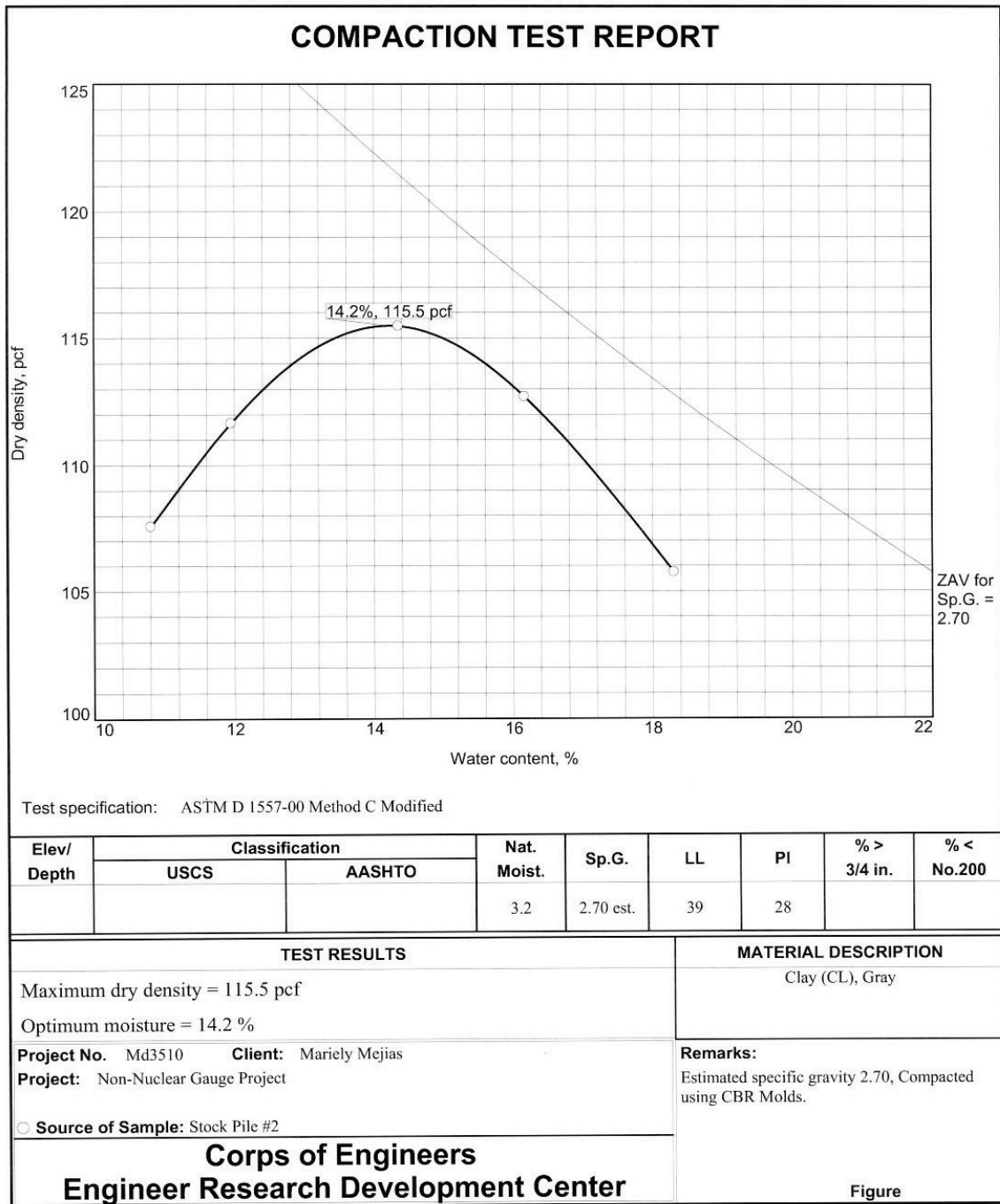
Remarks: _____

Technician: ATComputed by: ATChecked by: LRC

Revised 8/8/11

B.2 CL-2





Tested By: CEC

Checked By: LRC

SPECIFIC GRAVITY OF SOILS
ASTM D 854
FLASK SET # 1

WORK ORDER NO. MD1812Date: 4/18/12Project: Non-Nuclear GaugeMethod A: _____ Method B: X

Boring:	CL2			
Location:				
Sample No.:				
Flask No.:	20	25		
Weight dry soil after test, g, (M_s):	76.18	72.56		
Test temp., °C:	19.5	19.4		
Average calibrated weight of flask, g, (M_p):	171.39	166.90		
Average calibrated volume of flask, ml, (V_p):	499.32	499.31		
Weight of flask, water, & soil @ test temp., g, ($M_{pws,t}$):	718.00	713.20		
Density of water @ test temp., g/ml, (Table 1, ($P_{w,t}$)):	0.99834	0.99833		
Temp. coefficient, (Table 1 (K)):	1.00010	1.00012		
$M_{pw,t}$ =	669.85	667.87		
G_t =	2.72	2.71		
$G_{20}^{\circ C}$ =	2.72	2.71		
Average $G_{20}^{\circ C}$ =	2.72			

Formulas: Weight of flask & water @ test temp., g = $M_{pw,t} = M_p + (V_p \times P_{w,t})$ Specific gravity of soil @ test temp. = $G_t = M_s / (M_{pw,t} - (M_{pws,t} - M_s))$ Specific gravity of soil @ 20°C = $K \times G_t$ Visual Classification: Clay (CL), BrownPercent passing No. 4 sieve: 100

Was any soil or material excluded from the specimen?

Yes _____

No X

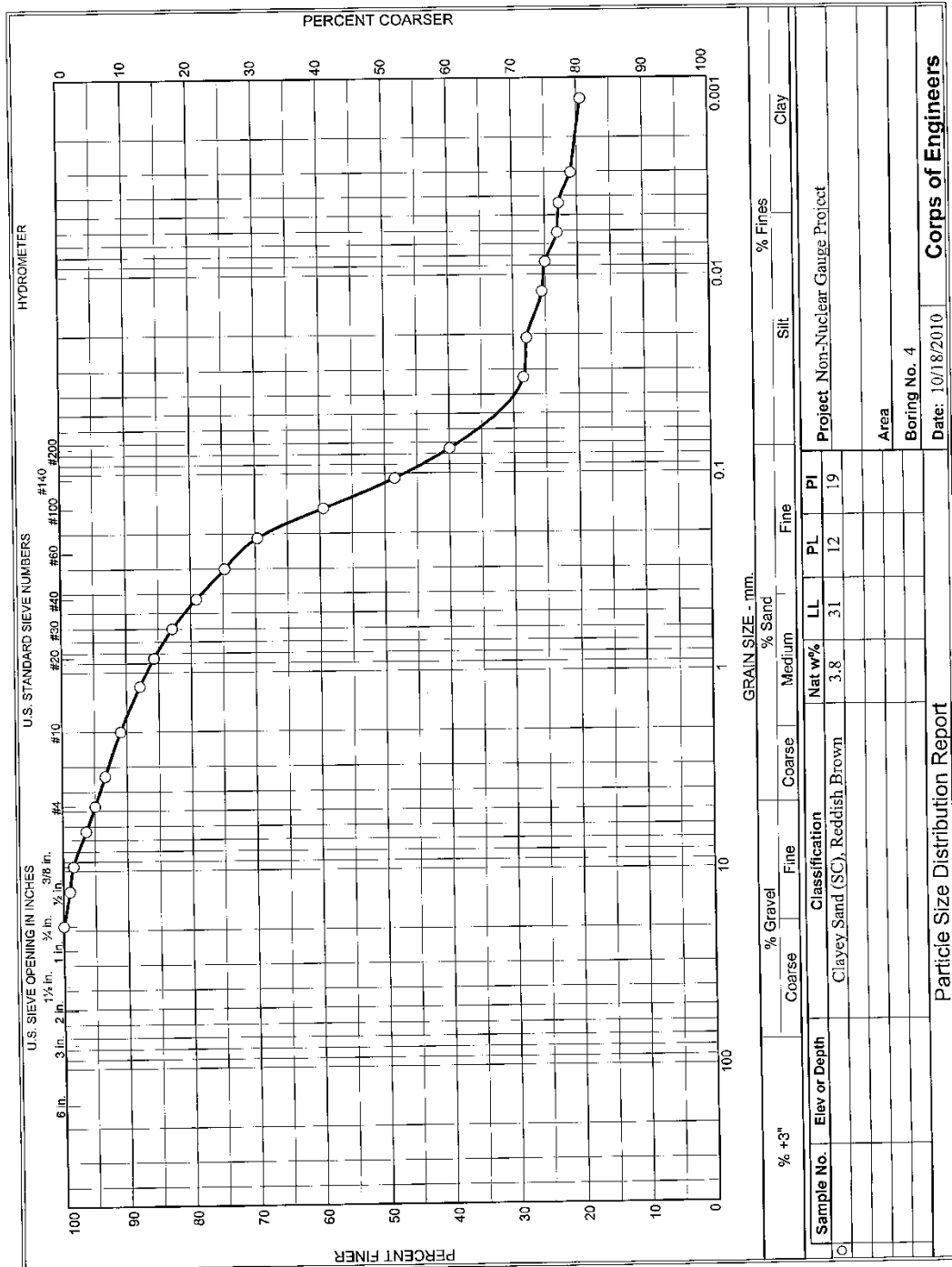
Description of soil or material excluded: _____

Remarks: _____

Technician: ATComputed by: ATChecked by: LRC

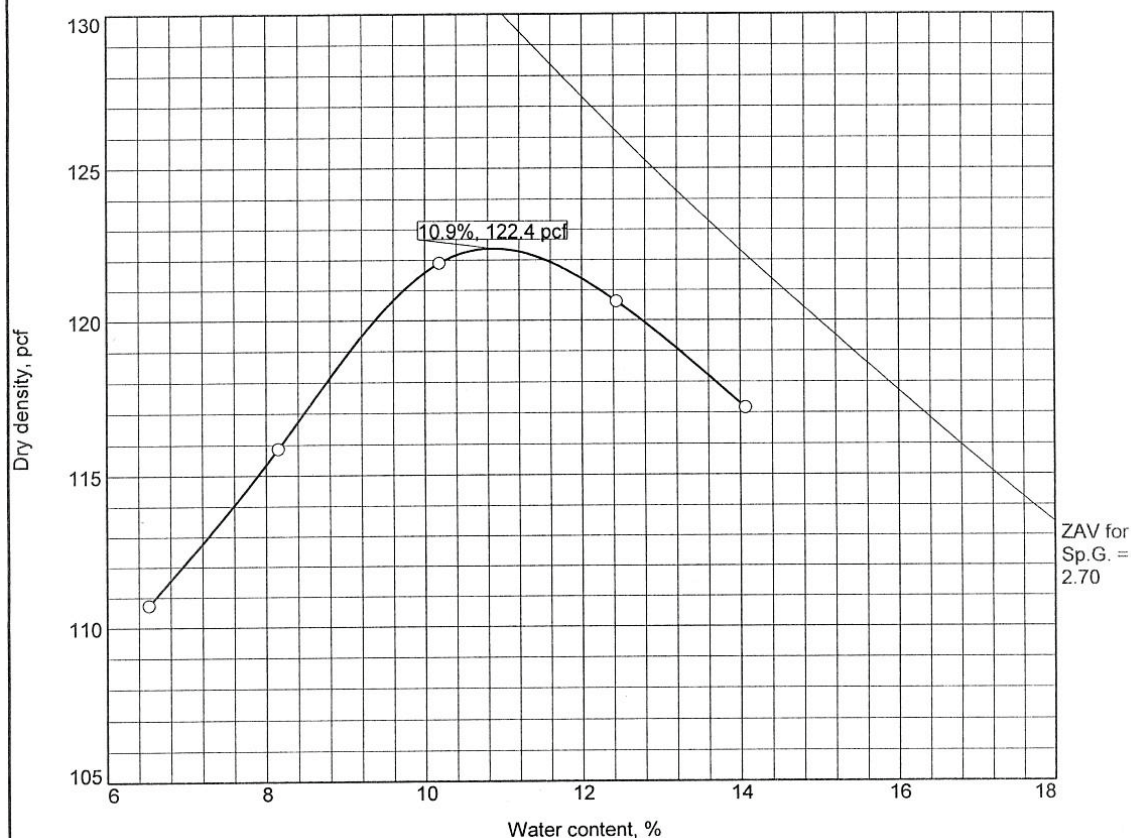
Revised 8/8/11

B.3 SC-1



ENG FORM 2087
1 MAY 63

COMPACTION TEST REPORT



Test specification: ASTM D 698-07 Method B Standard

Elev/ Depth	Classification		Nat. Moist.	Sp.G.	LL	PI	% > 3/8 in.	% < No.200
	USCS	AASHTO						
			2.2	2.70 est.	31	19		

TEST RESULTS		MATERIAL DESCRIPTION
Maximum dry density = 122.4 pcf Optimum moisture = 10.9 %		Clay (CL), Reddish Brown
Project No. Md3510 Client: Mariely Mejias Project: Non-Nuclear Gauge Project ☐ Source of Sample: Stock Pile #4		Remarks: Estamated Gravity
Corps of Engineers Engineer Research Development Center		

Figure

Figure

Tested By: CEC

SPECIFIC GRAVITY OF SOILS

ASTM D 854

FLASK SET # 2

WORK ORDER NO. MD1812

Date: 04/18/12

Project: Non-Nuclear Gauge

Method A: _____ Method B: X

Boring:	SC1			
Location:				
Sample No.:				
Flask No.:	20	24		
Weight dry soil after test, g, (M_s):	87.24	90.86		
Test temp., °C:	20.4	20.4		
Average calibrated weight of flask, g, (M_p):	176.62	174.24		
Average calibrated volume of flask, ml, (V_p):	499.46	489.37		
Weight of flask, water, & soil @ test temp., g, ($M_{pws,t}$):	730.17	729.98		
Density of water @ test temp., g/ml, (Table 1, ($P_{w,t}$)):	0.99812	0.99812		
Temp. coefficient, (Table 1 (K)):	0.99992	0.99992		
$M_{pw,t}$ =	875.14	672.87		
G_t =	2.71	2.71		
$G_{20^\circ C}$ =	2.71	2.71		
Average $G_{20^\circ C}$ =	2.71			

Formulas: Weight of flask & water @ test temp., g = $M_{pw,t} = M_p + (V_p \times P_{w,t})$ Specific gravity of soil @ test temp. = $G_t = M_s / (M_{pw,t} - (M_{pws,t} - M_s))$ Specific gravity of soil @ 20°C = $K \times G_t$ Visual Classification: Clayey Sand (SC), Reddish BrownPercent passing No. 4 sieve: 100Was any soil or material excluded from the specimen? Yes _____ No X

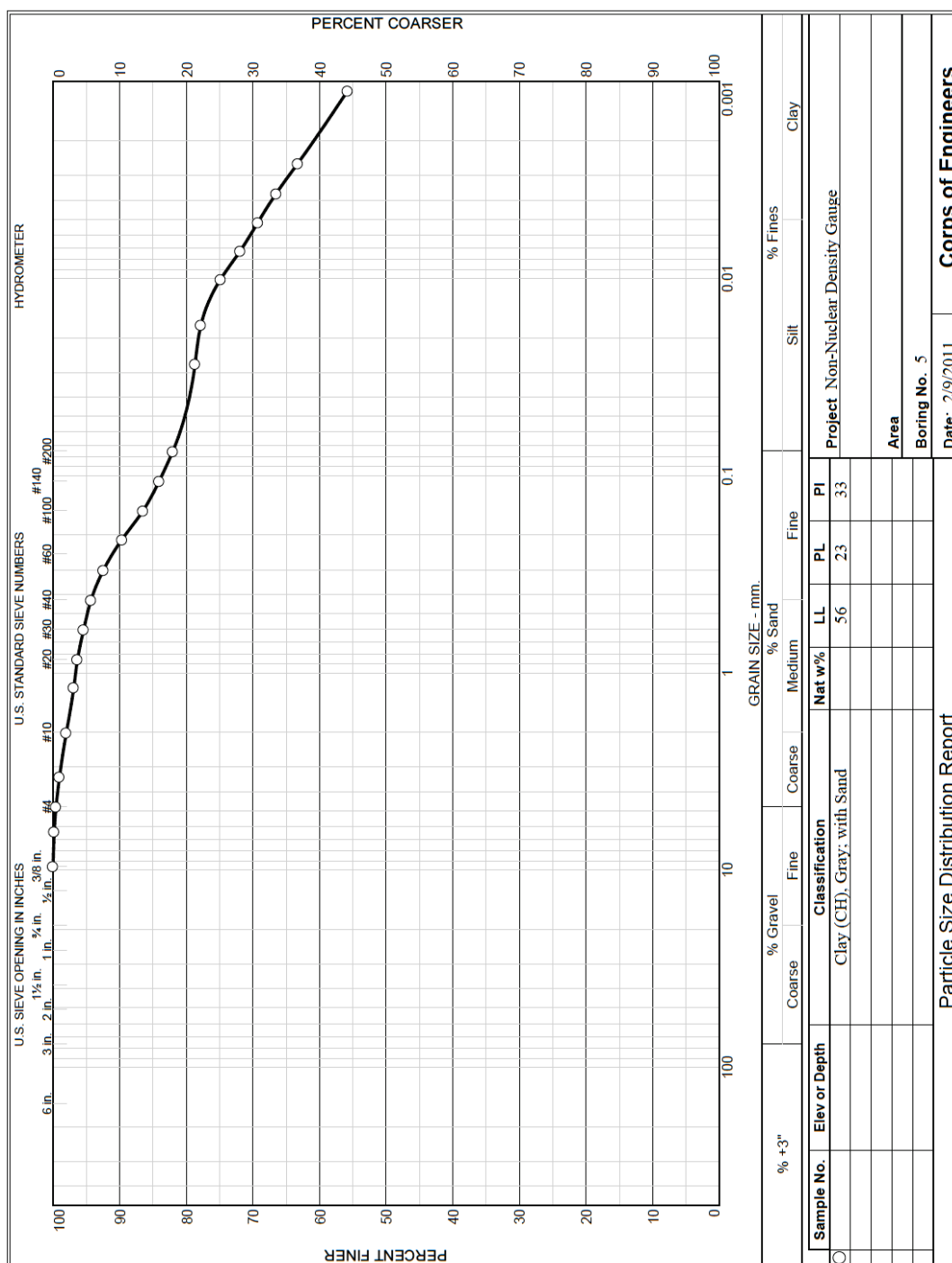
Description of soil or material excluded: _____

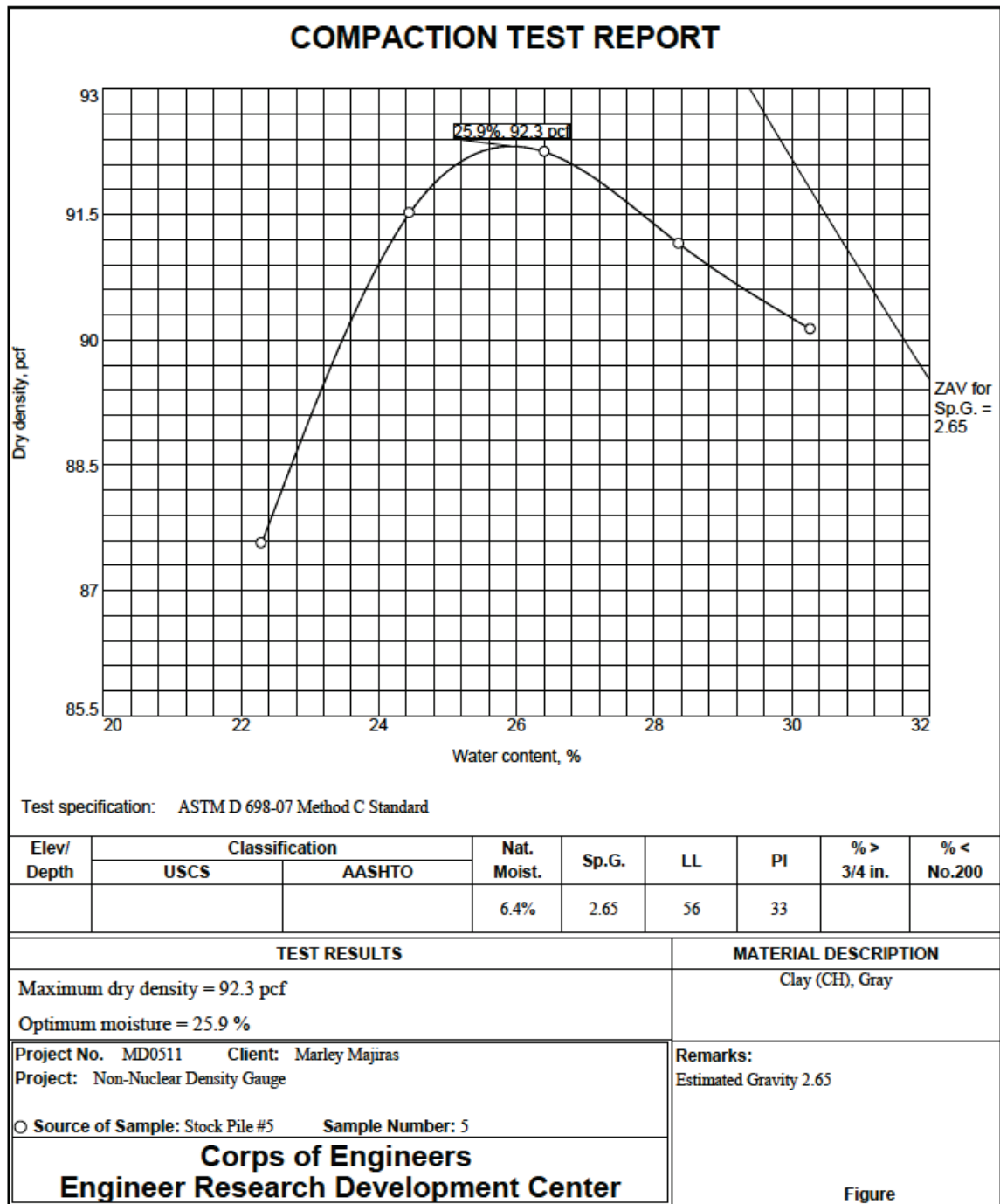
Remarks: _____

Technician: ATComputed by: ATChecked by: LRC

Revised 8/8/11

B.4 CH-2





Tested By: CEC Checked By: LRC

SPECIFIC GRAVITY OF SOILS
ASTM D 854
FLASK SET # 1

WORK ORDER NO. MD1812

Date: 4/18/12

Project: Non-Nuclear Gauge

Method A: _____ Method B: X

Boring:	CH2			
Location:				
Sample No.:				
Flask No.:	44	48		
Weight dry soil after test, g, (M_s):	84.21	73.31		
Test temp., °C:	19.4	19.4		
Average calibrated weight of flask, g, (M_p):	168.89	174.58		
Average calibrated volume of flask, ml, (V_p):	499.34	499.33		
Weight of flask, water, & soil @ test temp., g, ($M_{pws,t}$):	721.02	719.89		
Density of water @ test temp., g/ml, (Table 1, ($P_{w,t}$)):	0.99833	0.99833		
Temp. coefficient, (Table 1 (K)):	1.00012	1.00012		
$M_{pw,t}$ =	667.36	673.07		
G_t =	2.75	2.77		
$G_{20}^{\circ C}$ =	2.76	2.77		
Average $G_{20}^{\circ C}$ =	2.76			

Formulas: Weight of flask & water @ test temp., g = $M_{pw,t} = M_p + (V_p \times P_{w,t})$ Specific gravity of soil @ test temp. = $G_t = M_s / (M_{pw,t} - (M_{pws,t} - M_s))$ Specific gravity of soil @ 20°C = $K \times G_t$

Visual Classification: Clay (CH), Gray

Percent passing No. 4 sieve: 100

Was any soil or material excluded from the specimen? Yes _____ No X

Description of soil or material excluded: _____

Remarks: _____

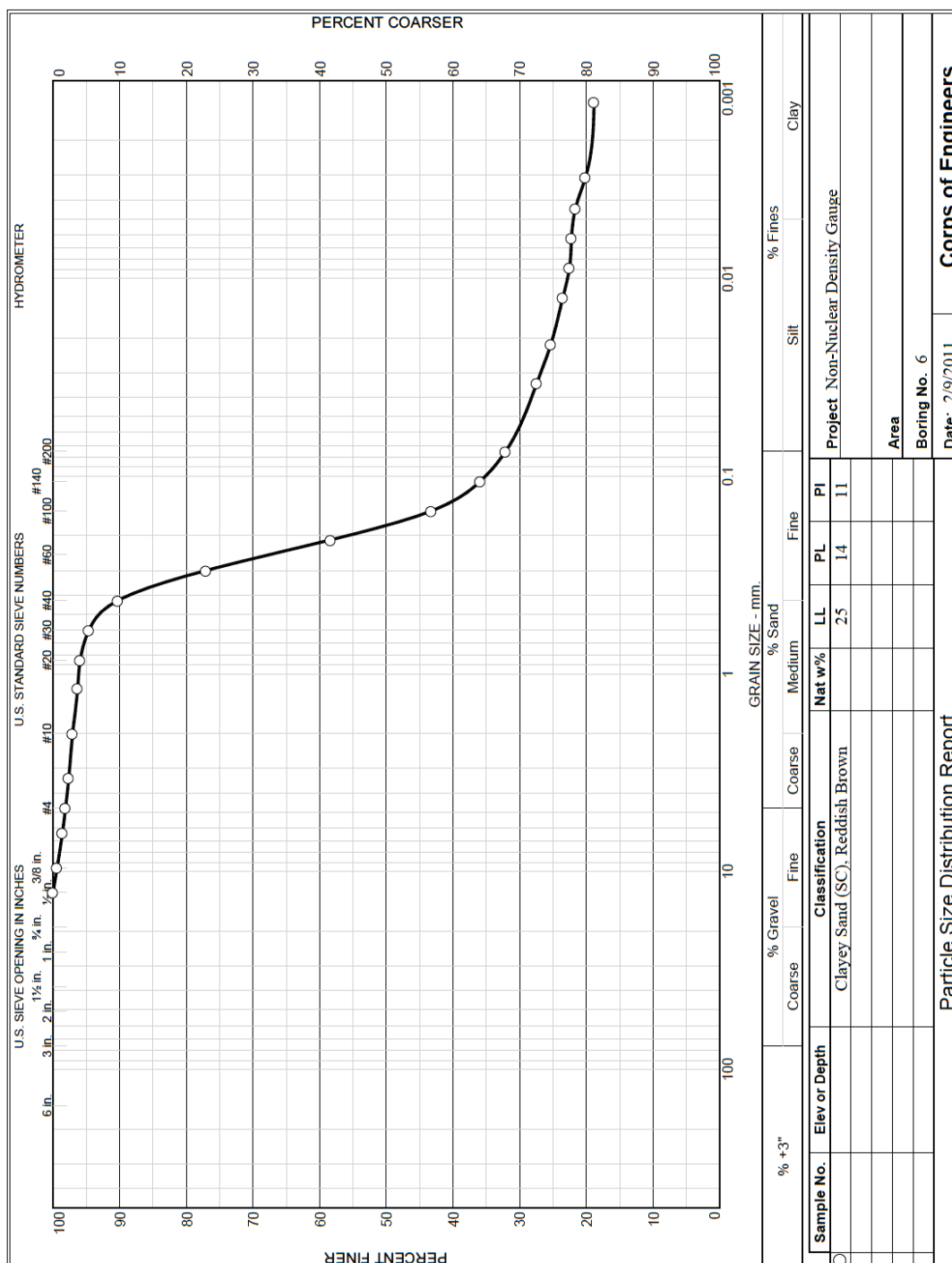
Technician: AT

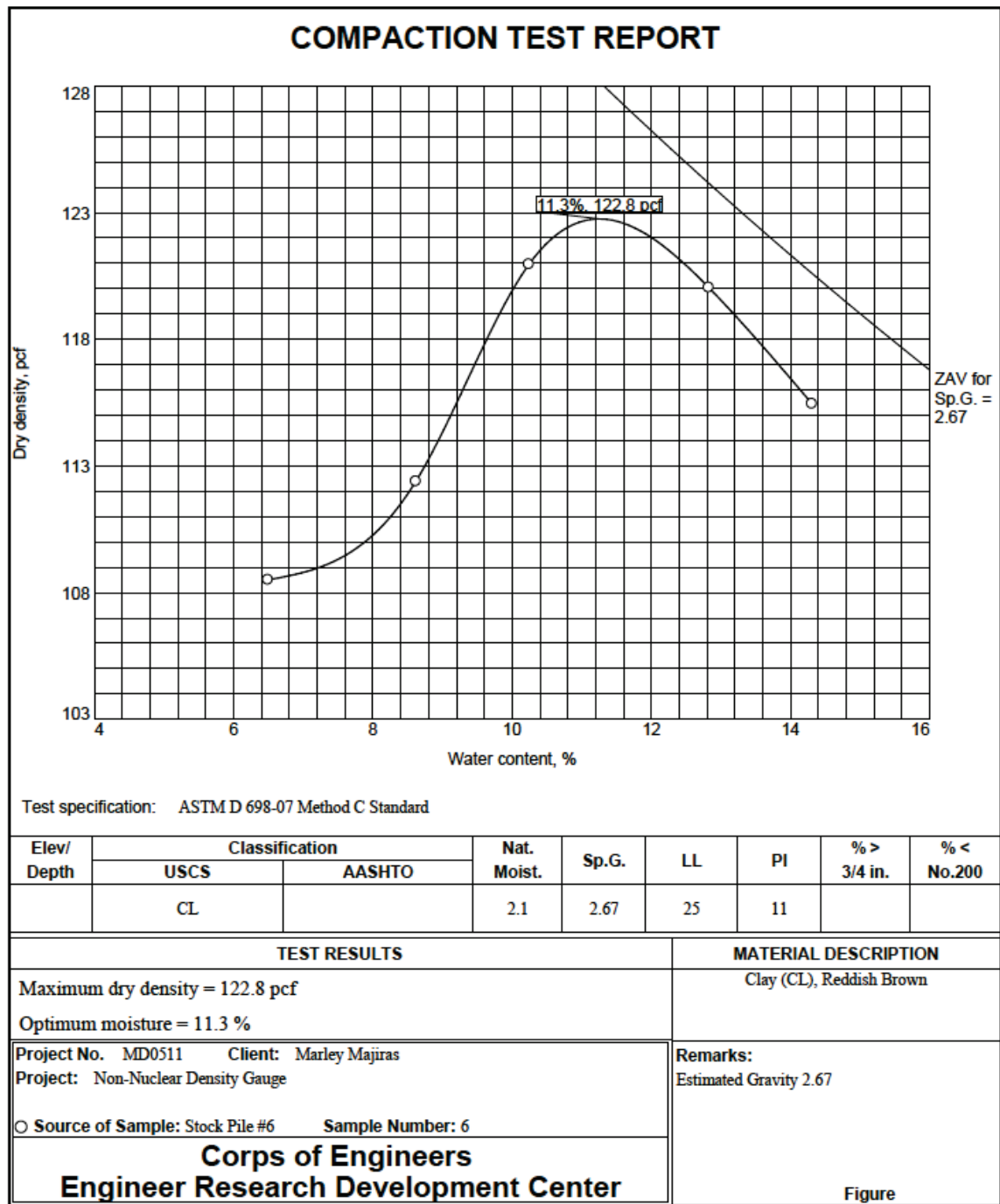
Computed by: AT

Checked by: LRC

Revised 8/8/11

B.5 SC-2





Tested By: CECILDD Checked By: LRC

SPECIFIC GRAVITY OF SOILS

ASTM D 854

FLASK SET # 2

WORK ORDER NO. MD1812

Date: 04/18/12

Project: Non-Nuclear Gauge

Method A: _____ Method B: X

Boring:	SC2			
Location:				
Sample No.:				
Flask No.:	28	35		
Weight dry soil after test, g, (M_s):	80.08	76.35		
Test temp., °C:	20.4	20.0		
Average calibrated weight of flask, g, (M_p):	180.07	168.28		
Average calibrated volume of flask, ml, (V_p):	499.42	489.48		
Weight of flask, water, & soil @ test temp., g, ($M_{pws,t}$):	728.90	714.75		
Density of water @ test temp., g/ml, (Table 1, ($P_{w,t}$)):	0.99842	0.99920		
Temp. coefficient, (Table 1 (K)):	0.99992	0.99999		
$M_{pw,t}$ =	678.55	668.86		
G_t =	2.68	2.68		
$G_{20}^{\circ C}$ =	2.69	2.68		
Average $G_{20}^{\circ C}$ =	2.69			

Formulas: Weight of flask & water @ test temp., g = $M_{pw,t} = M_p + (V_p \times P_{w,t})$ Specific gravity of soil @ test temp. = $G_t = M_s / (M_{pw,t} - (M_{pws,t} - M_s))$ Specific gravity of soil @ 20°C = $K \times G_t$

Visual Classification: Clayey Sand (SC), Reddish Brown

Percent passing No. 4 sieve: 100

Was any soil or material excluded from the specimen? Yes _____ No X

Description of soil or material excluded: _____

Remarks: _____

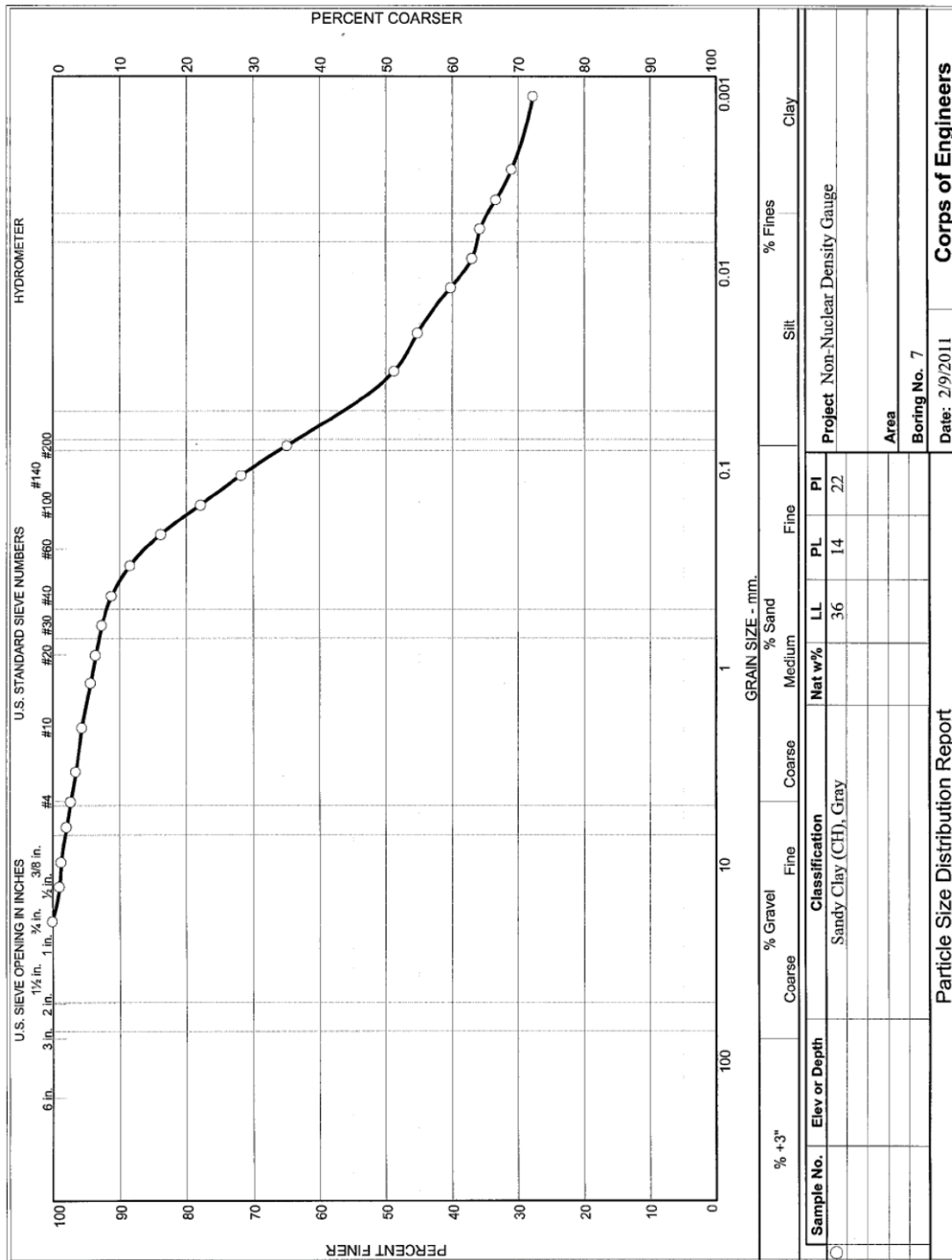
Technician: AT

Computed by: AT

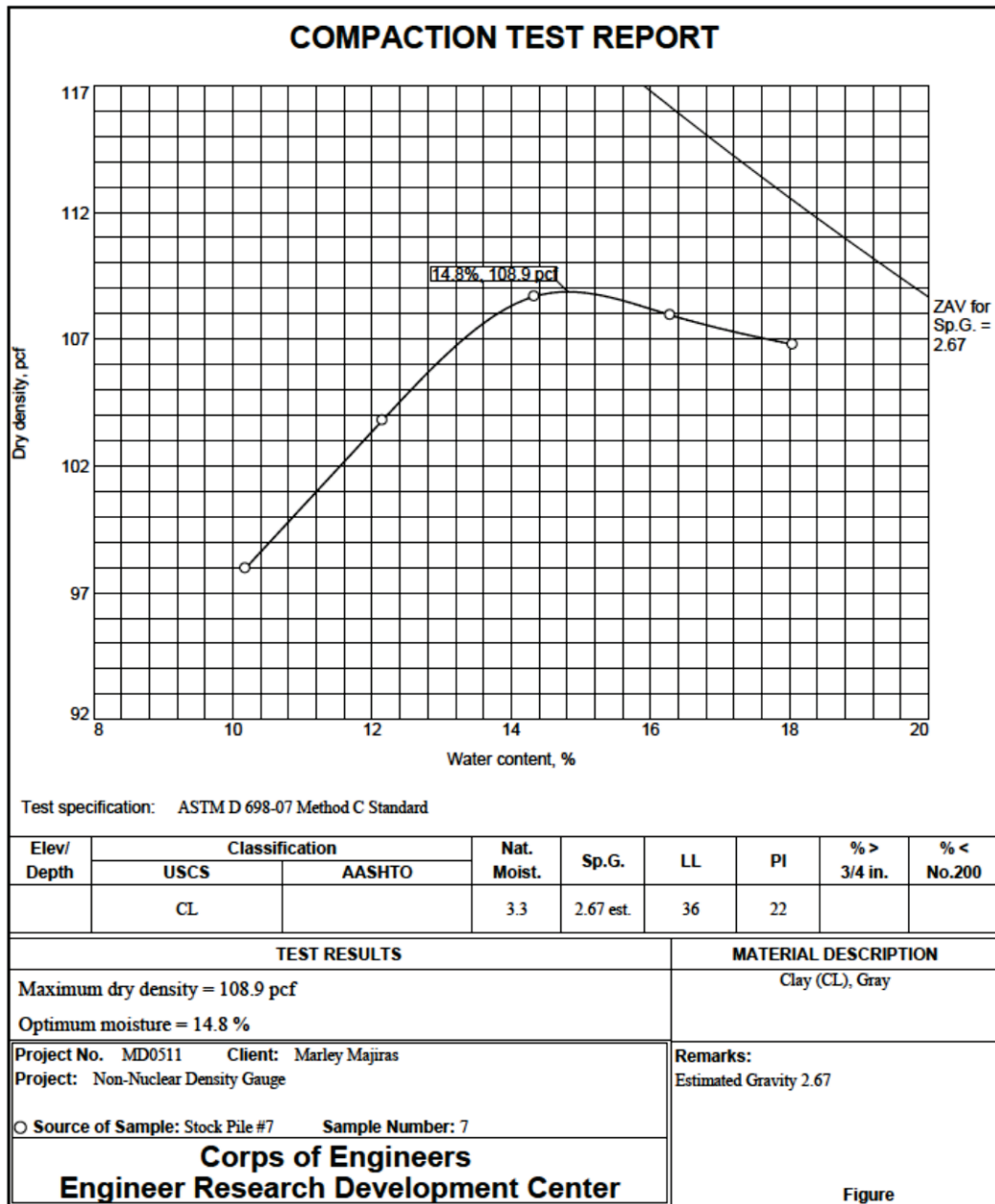
Checked by: LRC

Revised 8/8/11

B.6 CH-3



ENG FORM 2087
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Tested By: CEC\LDD Checked By: LRC

SPECIFIC GRAVITY OF SOILS

ASTM D 854

FLASK SET # 1

WORK ORDER NO. MD1812

Date: 4/18/12

Project: Non-Nuclear Gauge

Method A: _____ Method B: X

Boring:	CH3			
Location:				
Sample No.:				
Flask No.:	53	56		
Weight dry soil after test, g, (M_s):	85.54	87.44		
Test temp., °C:	19.4	19.4		
Average calibrated weight of flask, g, (M_p):	168.37	171.52		
Average calibrated volume of flask, ml, (V_p):	489.45	498.43		
Weight of flask, water, & soil @ test temp., g, ($M_{pws,t}$):	720.98	725.25		
Density of water @ test temp., g/ml, (Table 1, ($P_{w,t}$)):	0.99833	0.99833		
Temp. coefficient, (Table 1 (K)):	1.00012	1.00012		
$M_{pw,t}$ =	686.98	678.11		
G_t =	2.71	2.71		
$G_{20}^{\circ C}$ =	2.71	2.71		
Average $G_{20}^{\circ C}$ =	2.71			

Formulas: Weight of flask & water @ test temp., g = $M_{pw,t} = M_p + (V_p \times P_{w,t})$ Specific gravity of soil @ test temp. = $G_t = M_s / (M_{pw,t} - (M_{pws,t} - M_s))$ Specific gravity of soil @ 20°C = $K \times G_t$

Visual Classification: Clay (CH), Gray

Percent passing No. 4 sieve: 100

Was any soil or material excluded from the specimen? Yes _____ No X

Description of soil or material excluded: _____

Remarks: _____

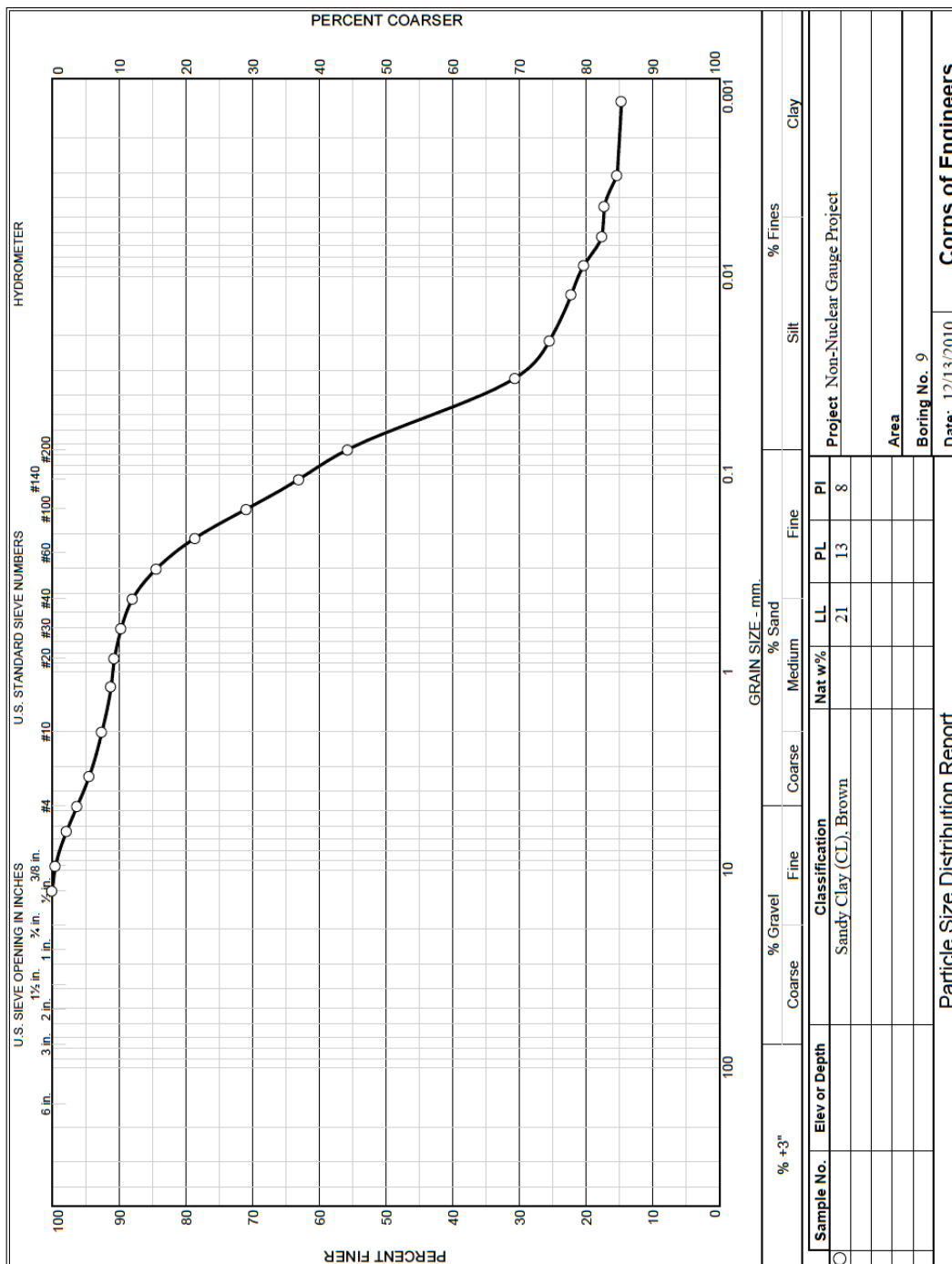
Technician: AT

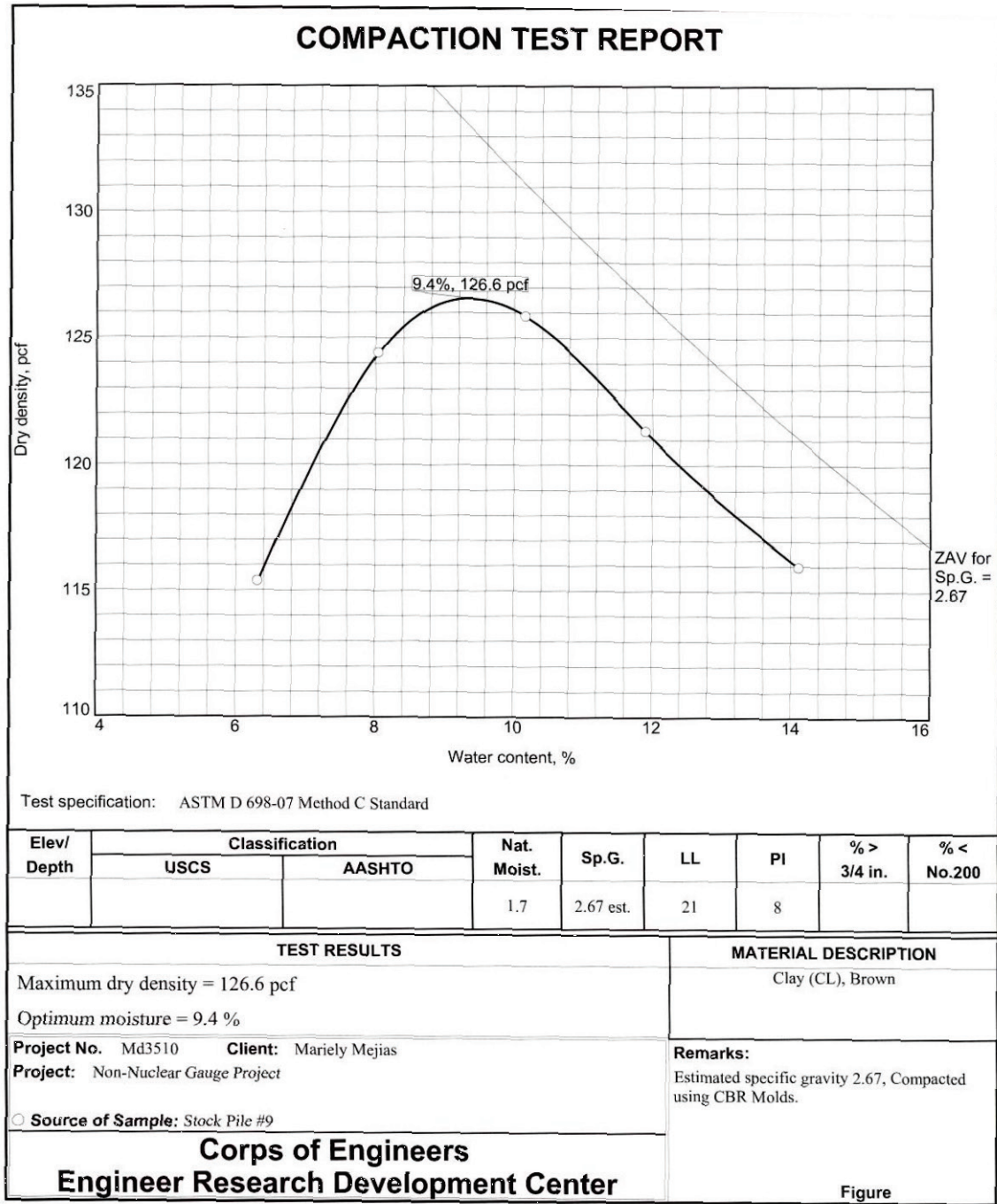
Computed by: AT

Checked by: LRC

Revised 8/8/11

B.7 CL-3





Tested By: CEC

Checked By: LRC

SPECIFIC GRAVITY OF SOILS

ASTM D 854

FLASK SET # 1

WORK ORDER NO. MD1812

Date: 4/18/12

Project: Non-Nuclear Gauge

Method A: _____ Method B: X

Boring:	CL3			
Location:				
Sample No.:				
Flask No.:	28	32		
Weight dry soil after test, g, (M_s):	93.71	92.86		
Test temp., °C:	19.4	19.4		
Average calibrated weight of flask, g, (M_p):	168.39	169.96		
Average calibrated volume of flask, ml, (V_p):	489.39	498.42		
Weight of flask, water, & soil @ test temp., g, ($M_{pws,t}$):	727.00	726.91		
Density of water @ test temp., g/ml, (Table 1, ($P_{w,t}$)):	0.99833	0.99833		
Temp. coefficient, (Table 1 (K)):	1.00012	1.00012		
$M_{pw,t}$ =	667.86	668.48		
G_t =	2.71	2.70		
$G_{20}^{\circ C}$ =	2.71	2.70		
Average $G_{20}^{\circ C}$ =	2.70			

Formulas: Weight of flask & water @ test temp., g = $M_{pw,t} = M_p + (V_p \times P_{w,t})$ Specific gravity of soil @ test temp. = $G_t = M_s / (M_{pw,t} - (M_{pws,t} - M_s))$ Specific gravity of soil @ 20°C = $K \times G_t$

Visual Classification: Clay (CL), Brown

Percent passing No. 4 sieve: 100

Was any soil or material excluded from the specimen? Yes _____ No X

Description of soil or material excluded: _____

Remarks: _____

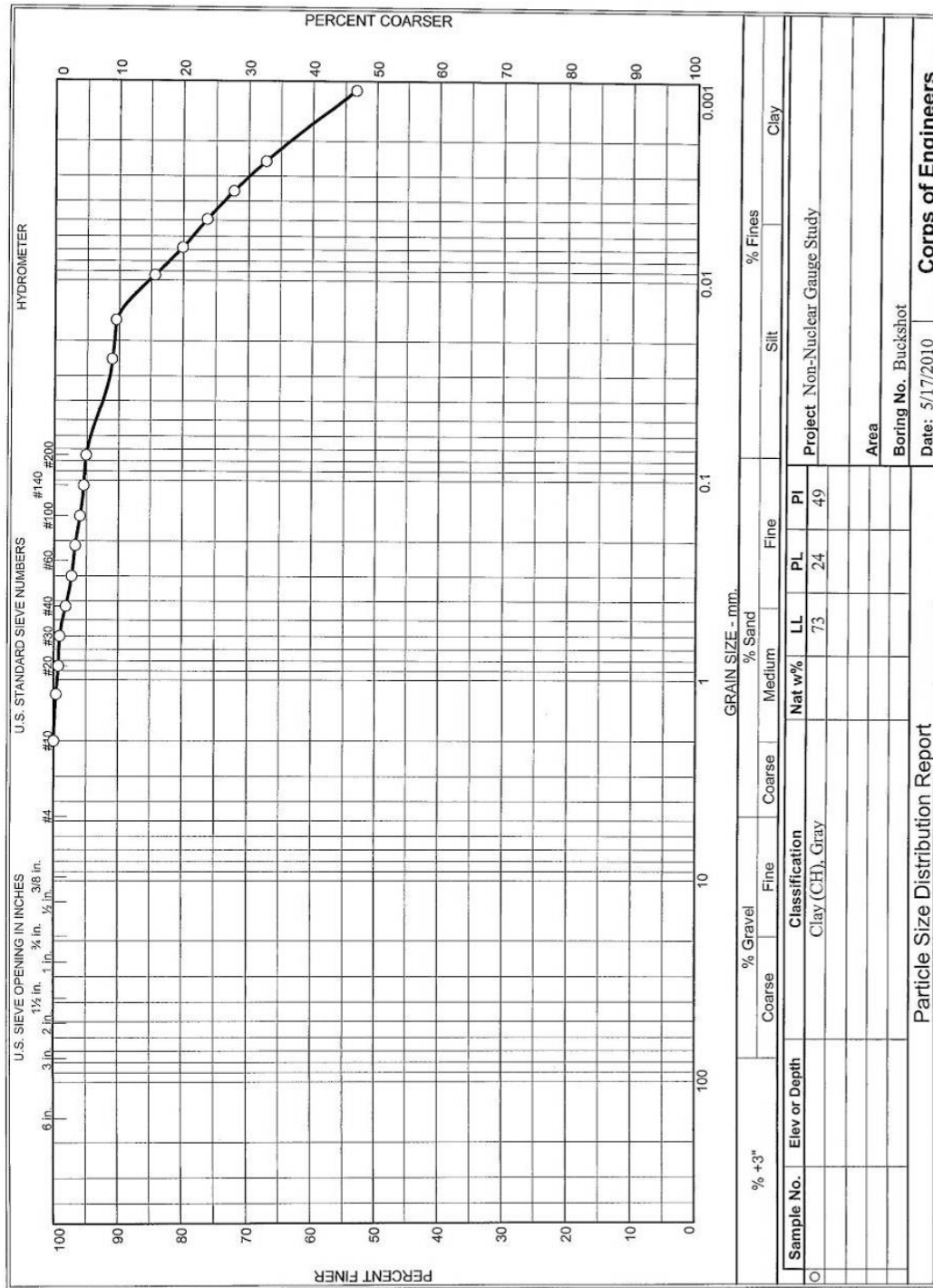
Technician: AT

Computed by: AT

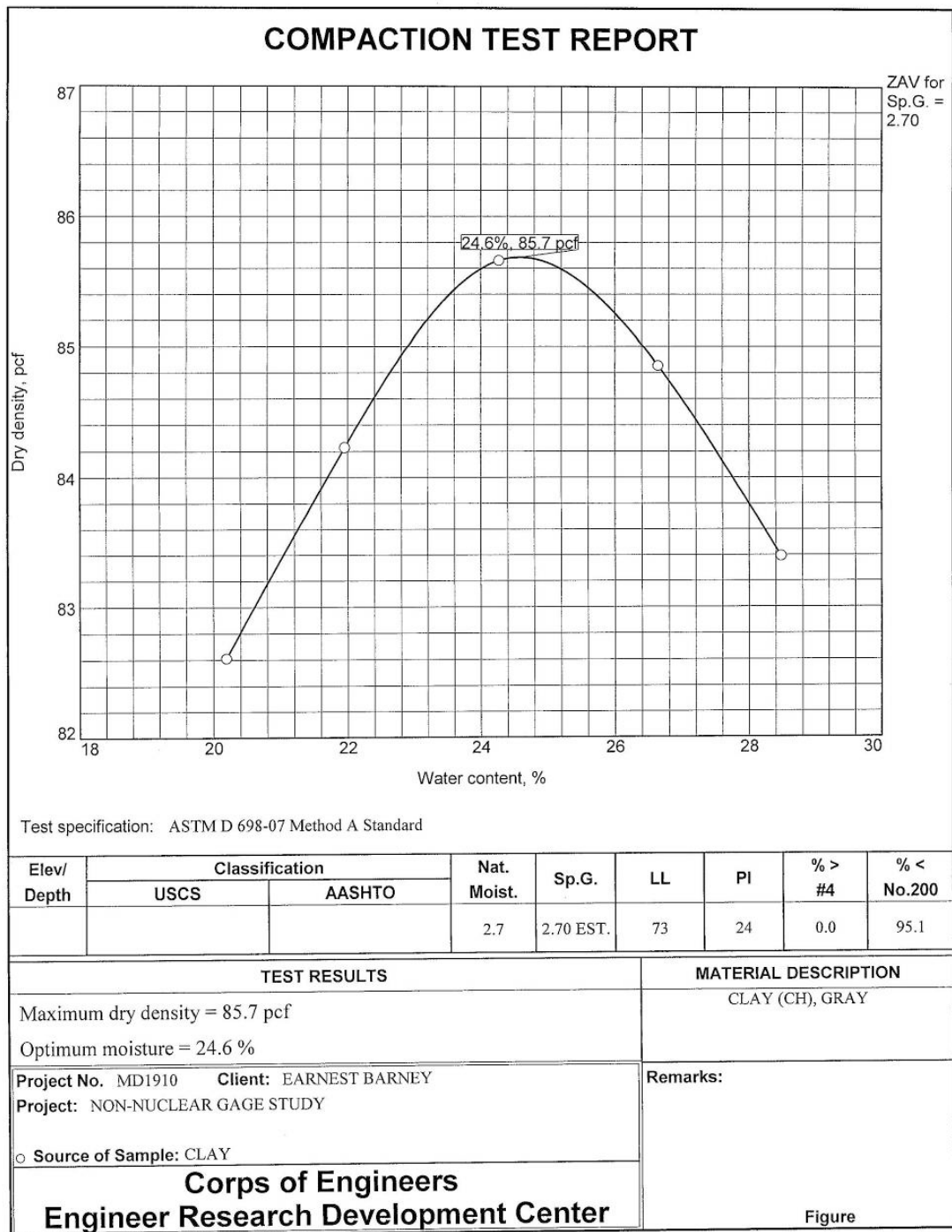
Checked by: LRC

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B.8 CH-ERDC



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 Tested By: CEC

SPECIFIC GRAVITY OF SOILS

ASTM D 854

FLASK SET # 2

WORK ORDER NO. MD1812

Date: 4/25/12

Project: Non-Nuclear Gauge

Method A: _____ Method B: X

Boring:	CH-ERDC			
Location:				
Sample No.:				
Flask No.:	12	16		
Weight dry soil after test, g, (M_s):	76.77	70.35		
Test temp., °C:	20.5	20.5		
Average calibrated weight of flask, g, (M_p):	174.66	178.14		
Average calibrated volume of flask, ml, (V_p):	499.56	489.29		
Weight of flask, water, & soil @ test temp., g, ($M_{pws,t}$):	722.14	722.43		
Density of water @ test temp., g/ml, (Table 1, ($P_{w,t}$)):	0.99810	0.99810		
Temp. coefficient, (Table 1 (K)):	0.99989	0.99989		
$M_{pw,t}$ =	673.27	677.48		
G_t =	2.75	2.77		
$G_{20^\circ C}$ =	2.75	2.77		
Average $G_{20^\circ C}$ =	2.76			

Formulas: Weight of flask & water @ test temp., g = $M_{pw,t} = M_p + (V_p \times P_{w,t})$ Specific gravity of soil @ test temp. = $G_t = M_s / (M_{pw,t} - (M_{pws,t} - M_s))$ Specific gravity of soil @ 20°C = $K \times G_t$ Visual Classification: Clay (CH), GrayPercent passing No. 4 sieve: 100Was any soil or material excluded from the specimen? Yes _____ No X

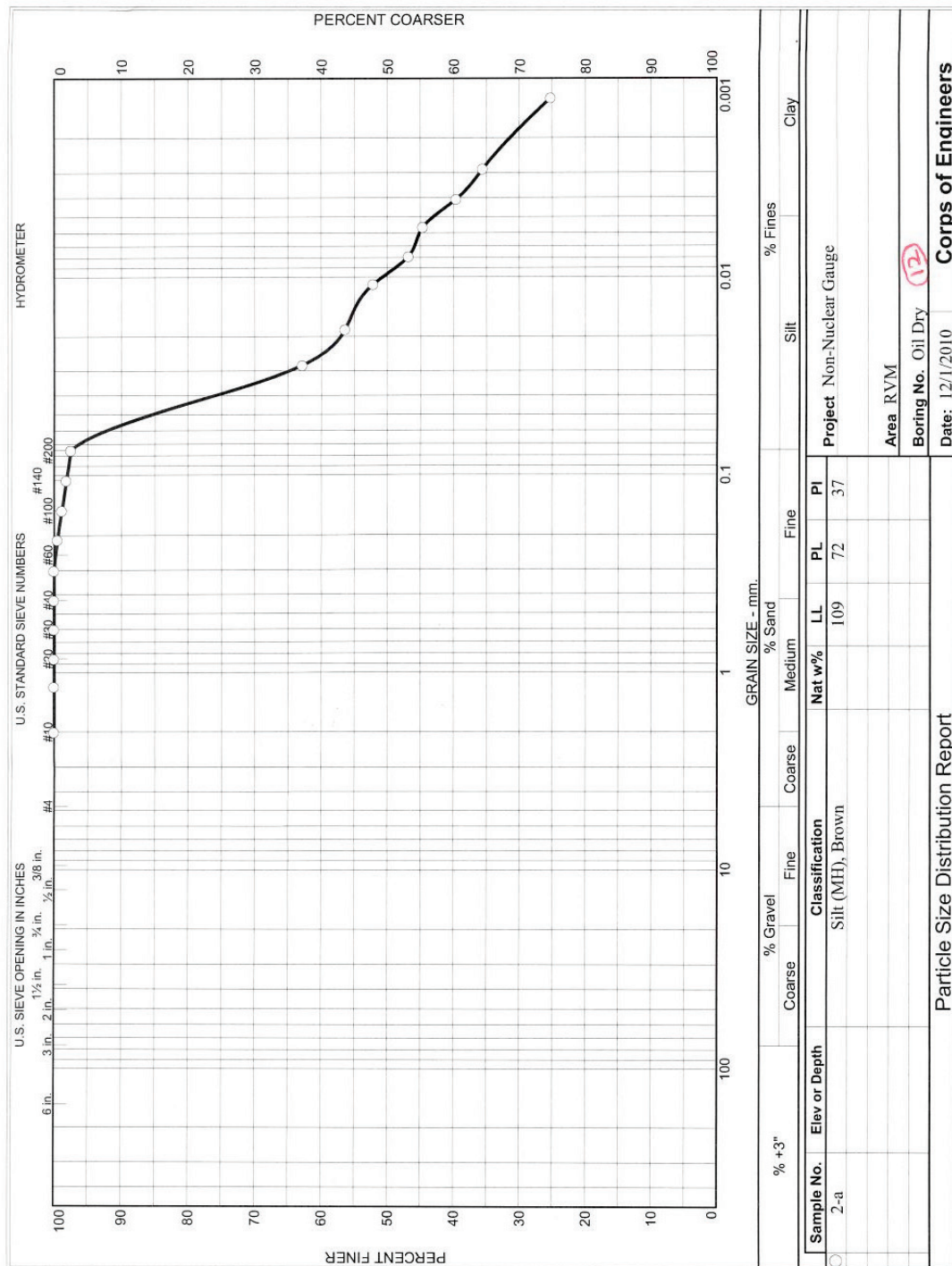
Description of soil or material excluded: _____

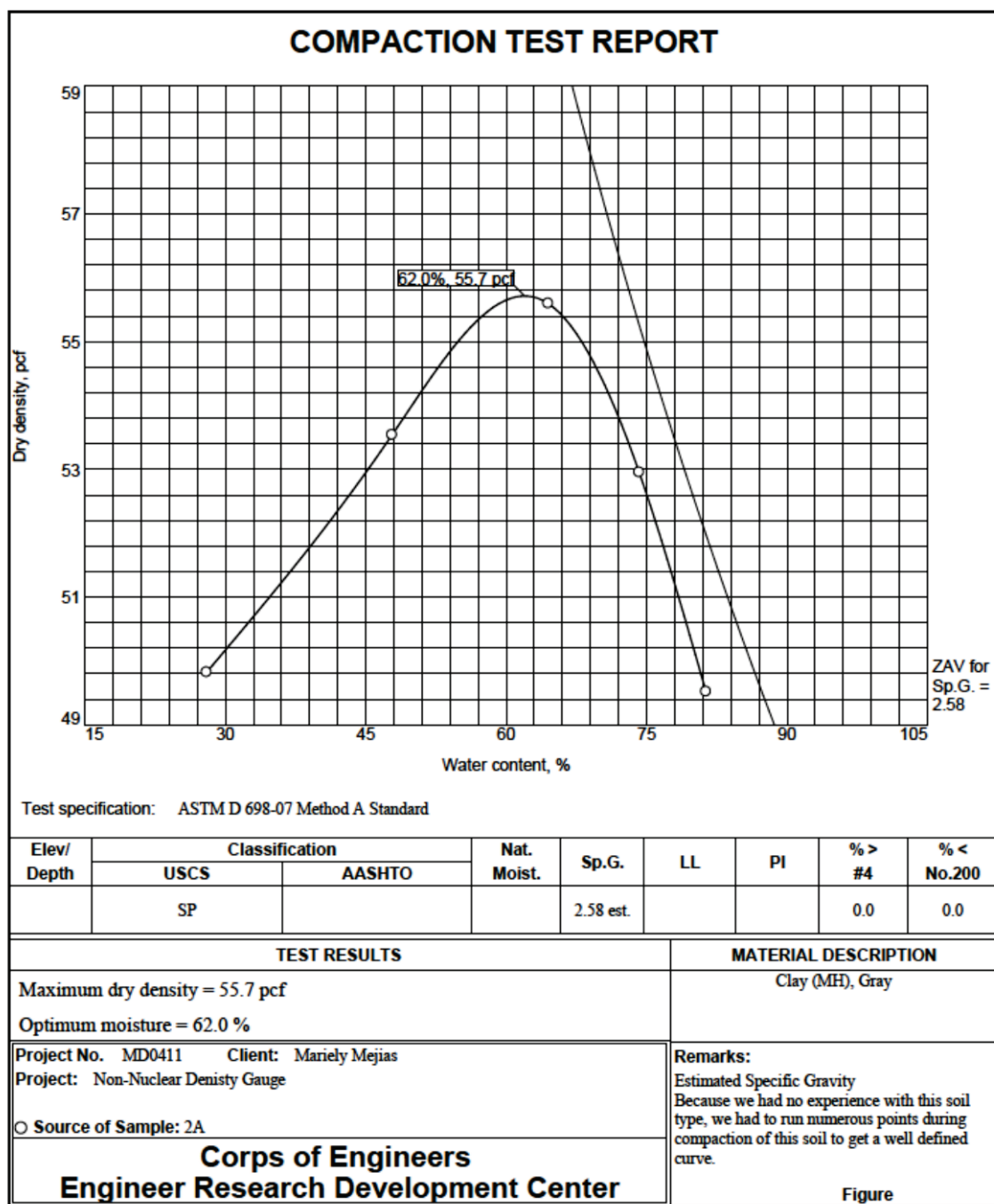
Remarks: _____

Technician: ATComputed by: ATChecked by: LRC

Revised 8/8/11

B.9 MH





Tested By: CEC Checked By: LRC

SPECIFIC GRAVITY OF SOILS
ASTM D 854
FLASK SET # 1

WORK ORDER NO. MD1812Date: 4/18/12Project: Non-Nuclear GaugeMethod A: _____ Method B: X

Boring:	MH			
Location:				
Sample No.:				
Flask No.:	28	32		
Weight dry soil after test, g, (M_s):	43.72	41.09		
Test temp., °C:	19.5	19.6		
Average calibrated weight of flask, g, (M_p):	169.33	169.90		
Average calibrated volume of flask, ml, (V_p):	499.39	499.42		
Weight of flask, water, & soil @ test temp., g, ($M_{pws,t}$):	694.64	693.63		
Density of water @ test temp., g/ml, (Table 1, ($P_{w,t}$)):	0.99831	0.99829		
Temp. coefficient, (Table 1 (K)):	1.00010	1.00008		
$M_{pw,t} =$	667.87	668.46		
$G_t =$	2.58	2.58		
$G_{20^\circ C} =$	2.58	2.58		
Average $G_{20^\circ C} =$	2.58			

Formulas: Weight of flask & water @ test temp., g = $M_{pw,t} = M_p + (V_p \times P_{w,t})$ Specific gravity of soil @ test temp. = $G_t = M_s / (M_{pw,t} - (M_{pws,t} - M_s))$ Specific gravity of soil @ 20°C = $K \times G_t$ Visual Classification: Silt (MH), GrayPercent passing No. 4 sieve: 100Was any soil or material excluded from the specimen? Yes _____ No X

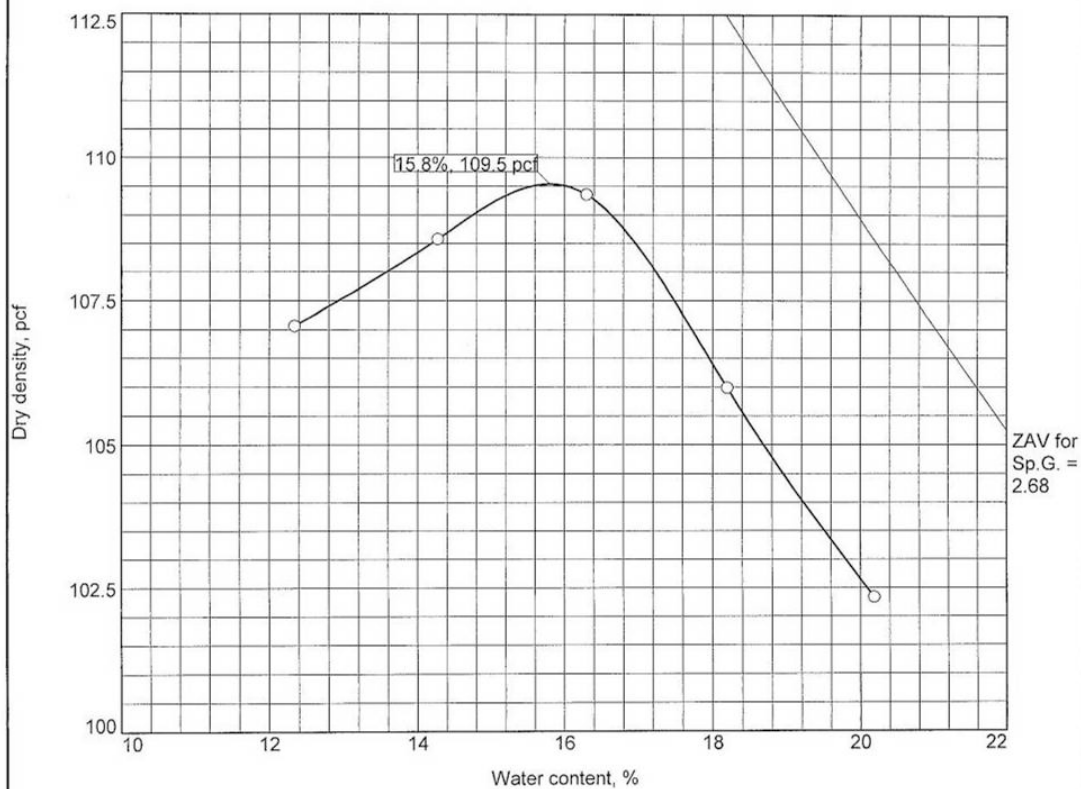
Description of soil or material excluded: _____

Remarks: _____

Technician: ATComputed by: ATChecked by: LRC

Revised 8/8/11

COMPACTION TEST REPORT



Test specification: ASTM D 698-00a Method A Standard

Elev/ Depth	Classification		Nat. Moist.	Sp.G.	LL	PI	% > #4	% < No.200
	USCS	AASHTO						
			1.0	2.68 EST.	NP		1.2	87.7

TEST RESULTS		MATERIAL DESCRIPTION
Maximum dry density = 109.5 pcf Optimum moisture = 15.8 %		SILT (ML), BROWN
Project No. MD1910 Client: EARNEST BARNEY Project: NON-NUCLEAR GAGE STUDY ☐ Source of Sample: SILT		Remarks:
Corps of Engineers Engineer Research Development Center		
		Figure

Figure

Tested By: CEC

SPECIFIC GRAVITY OF SOILS
ASTM D 854
FLASK SET # 2

WORK ORDER NO. MD1812

Date: 04/18/12

Project: Non-Nuclear Gauge

Method A: _____ Method B: X

Boring:	ML (Silt)			
Location:				
Sample No.:				
Flask No.:	53	57		
Weight dry soil after test, g, (M_s):	76.23	81.27		
Test temp., °C:	20.3	20.2		
Average calibrated weight of flask, g, (M_p):	180.46	171.24		
Average calibrated volume of flask, ml, (V_p):	499.36	499.28		
Weight of flask, water, & soil @ test temp., g, ($M_{pws,t}$):	727.51	721.23		
Density of water @ test temp., g/ml, (Table 1, ($P_{w,t}$)):	0.99814	0.99816		
Temp. coefficient, (Table 1 (K)):	0.99994	0.99996		
$M_{pw,t}$ =	878.91	669.60		
G_t =	2.76	2.74		
$G_{20}^{\circ C}$ =	2.76	2.74		
Average $G_{20}^{\circ C}$ =	2.75			

Formulas: Weight of flask & water @ test temp., g = $M_{pw,t} = M_p + (V_p \times P_{w,t})$ Specific gravity of soil @ test temp. = $G_t = M_s / (M_{pw,t} - (M_{pws,t} - M_s))$ Specific gravity of soil @ 20°C = $K \times G_t$ Visual Classification: Silt (ML), BrownPercent passing No. 4 sieve: 100Was any soil or material excluded from the specimen? Yes _____ No X

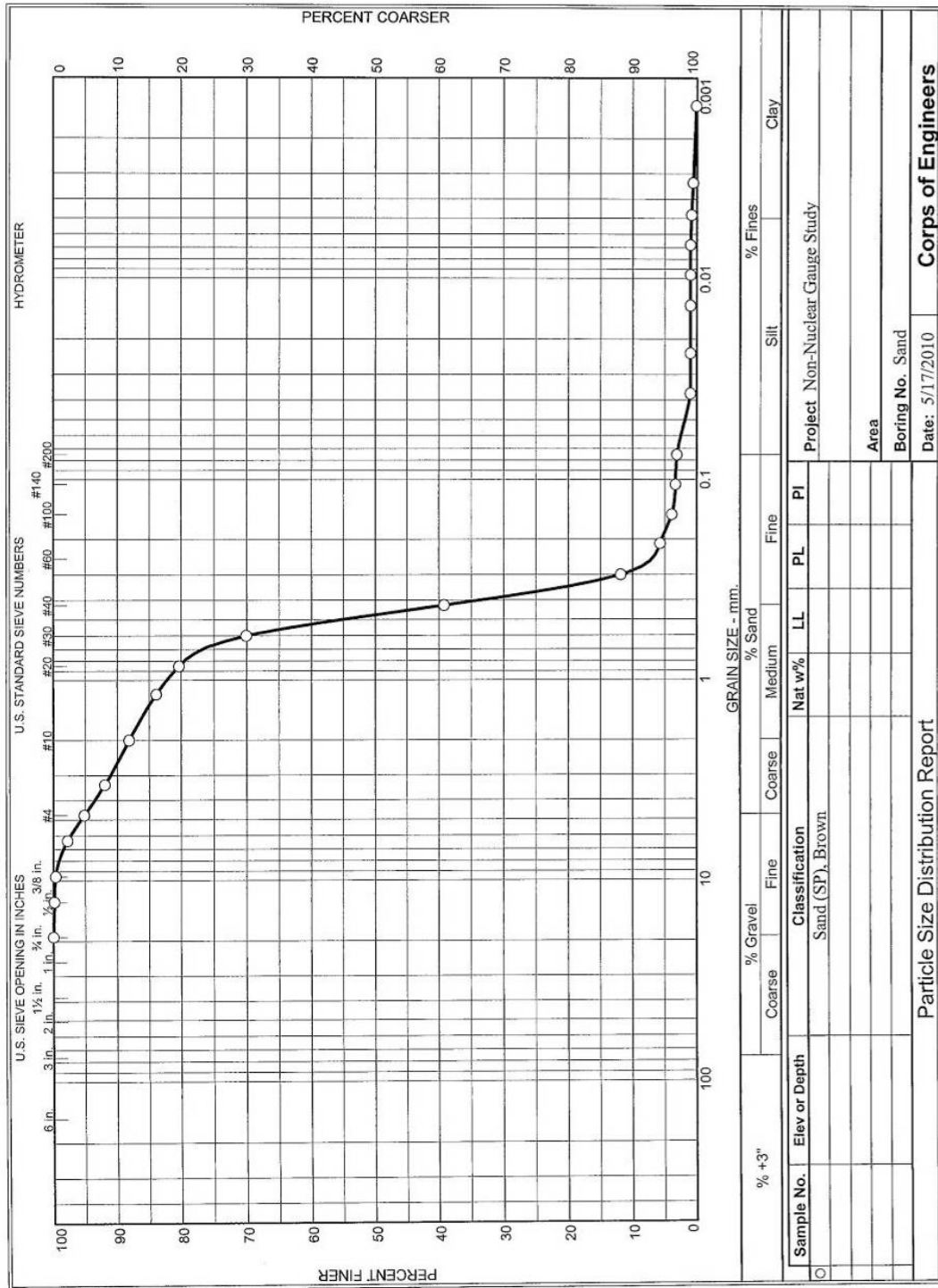
Description of soil or material excluded: _____

Remarks: _____

Technician: ATComputed by: ATChecked by: LRC

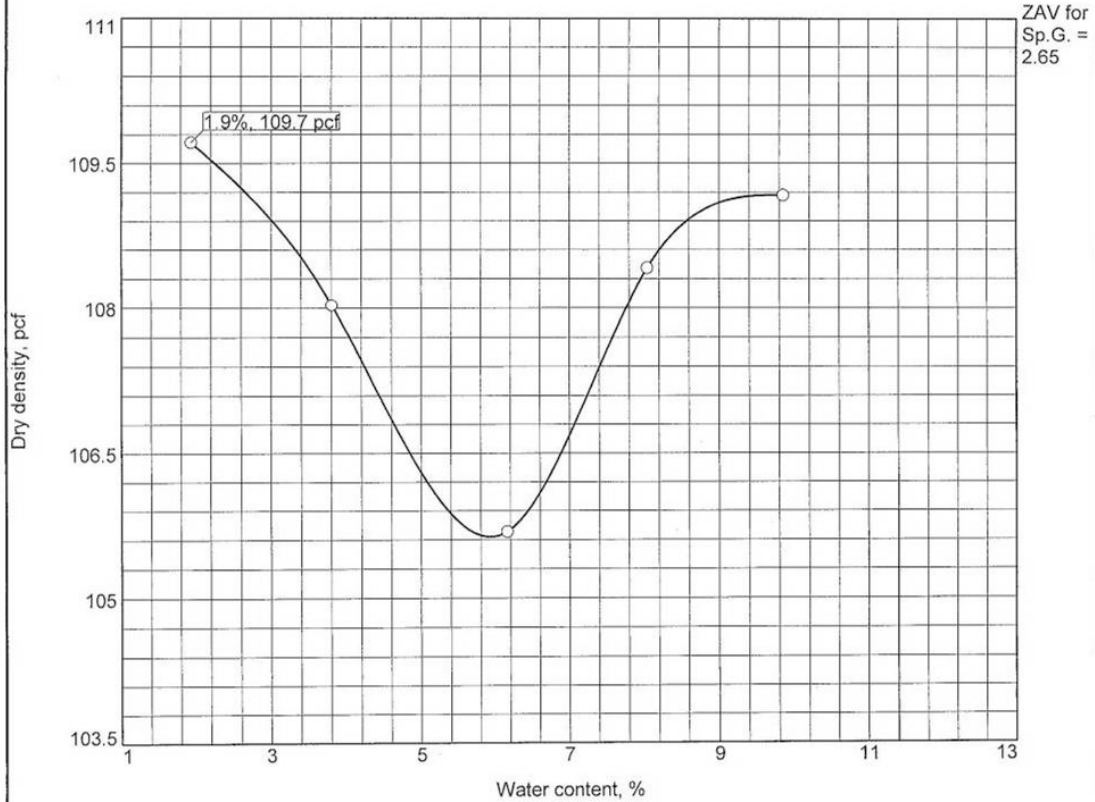
Revised 8/8/11

B.11 SP



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COMPACTION TEST REPORT



Test specification: ASTM D 698-00a Method A Standard

Elev/ Depth	Classification		Nat. Moist.	Sp.G.	LL	PI	% > #4	% < No.200
	USCS	AASHTO						
	SP		0.4	2.65	NP		4.9	3.1

TEST RESULTS		MATERIAL DESCRIPTION
Maximum dry density = 109.7 pcf Optimum moisture = 1.9 %		SAND (SP), BROWN
Project No. MD1910 Client: EARNEST BARNEY Project: NON-NUCLEAR GAGE STUDY		Remarks: SOIL SHIFTED DURING COMPACTION GRAVITY EST.
○ Source of Sample: SAND		
Corps of Engineers Engineer Research Development Center		
		Figure

Tested By: CEC _____

SPECIFIC GRAVITY OF SOILS
ASTM D 854
FLASK SET # 1

WORK ORDER NO. MD1812Date: 4/18/12Project: Non-Nuclear GaugeMethod A: _____ Method B: X

Boring:	SP			
Location:				
Sample No.:				
Flask No.:	37	40		
Weight dry soil after test, g, (M_s):	100.89	108.88		
Test temp., °C:	19.6	19.6		
Average calibrated weight of flask, g, (M_p):	177.20	174.27		
Average calibrated volume of flask, ml, (V_p):	489.34	498.44		
Weight of flask, water, & soil @ test temp., g, ($M_{pws,t}$):	738.84	740.96		
Density of water @ test temp., g/ml, (Table 1, ($P_{w,t}$)):	0.99828	0.99829		
Temp. coefficient, (Table 1 (K)):	1.00005	1.00008		
$M_{pw,t}$ =	675.66	672.85		
G_t =	2.67	2.67		
$G_{20^\circ C}$ =	2.67	2.67		
Average $G_{20^\circ C}$ =	2.67			

Formulas: Weight of flask & water @ test temp., g = $M_{pw,t} = M_p + (V_p \times P_{w,t})$ Specific gravity of soil @ test temp. = $G_t = M_s / (M_{pw,t} - (M_{pws,t} - M_s))$ Specific gravity of soil @ 20°C = $K \times G_t$ Visual Classification: Sand (SP), BrownPercent passing No. 4 sieve: 100Was any soil or material excluded from the specimen? Yes _____ No X

Description of soil or material excluded: _____

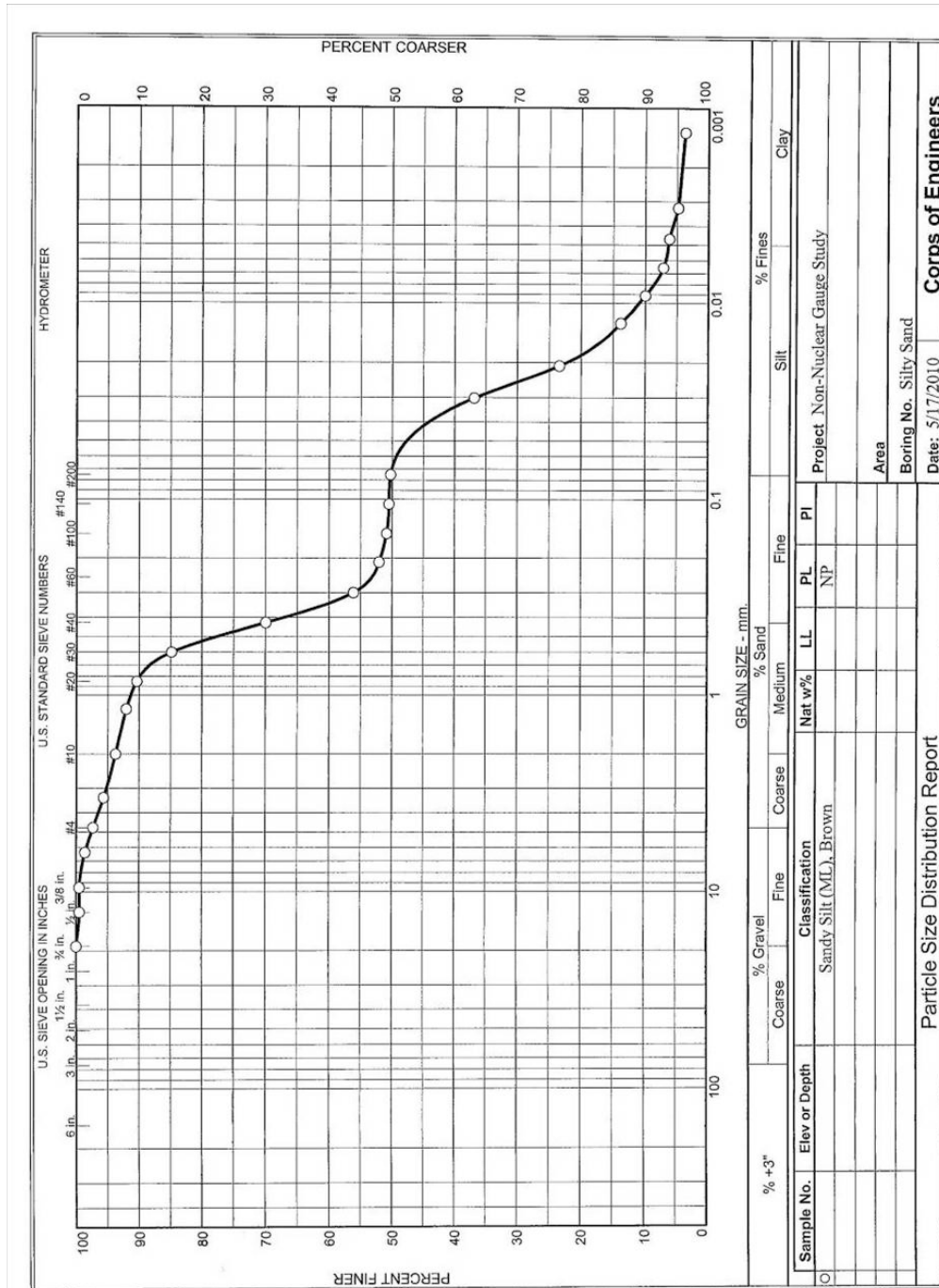
Remarks: _____

Technician: ATComputed by: ATChecked by: LRC

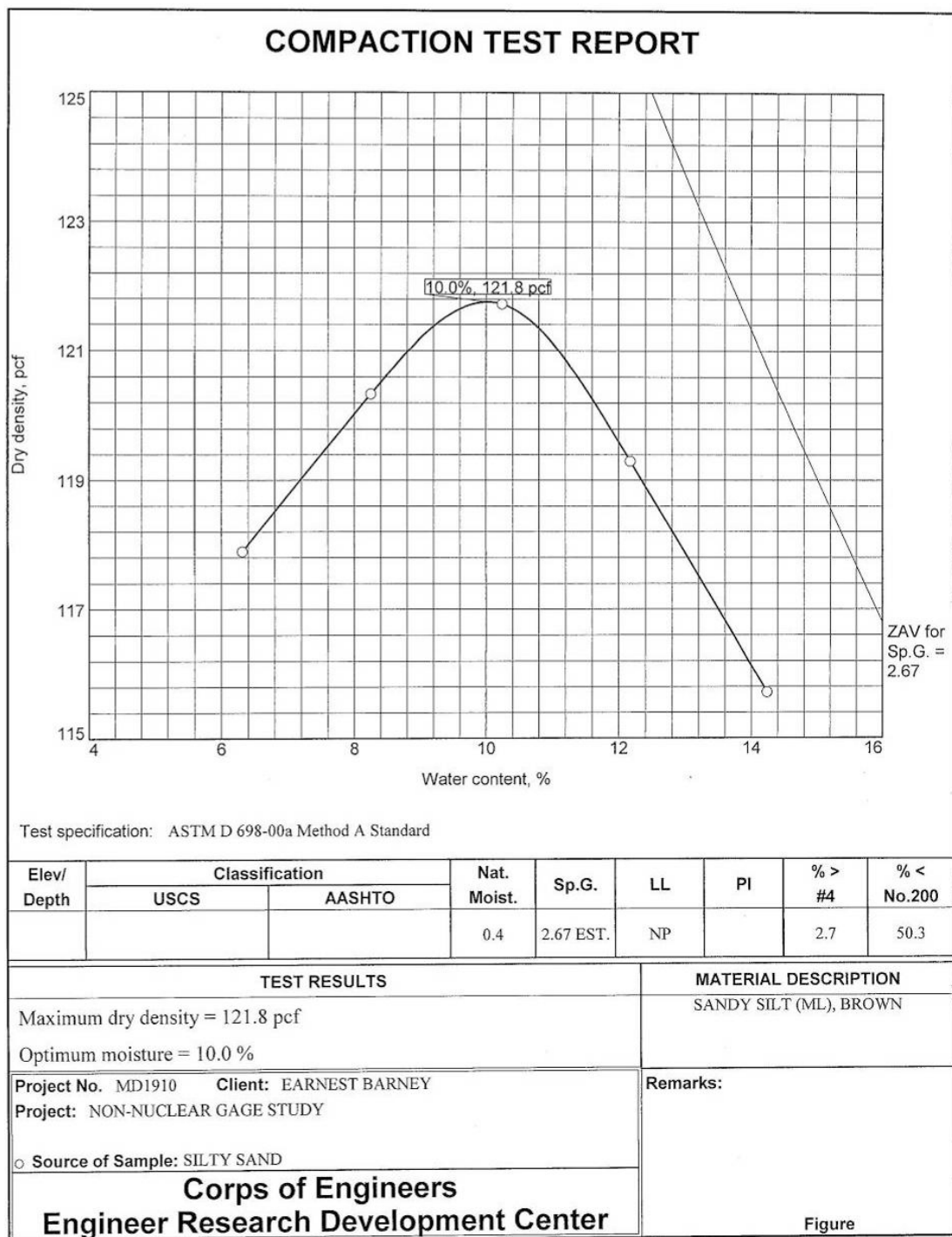
Revised 8/8/11

B.12 SM

Note: This soil was classified as Sandy-Silt (ML) by the MTC.



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Tested By: CEC _____

SPECIFIC GRAVITY OF SOILS
ASTM D 854
FLASK SET # 1

WORK ORDER NO. MD1812Date: 4/18/12Project: Non-Nuclear GaugeMethod A: _____ Method B: X

Boring:	ML (SM)		
Location:			
Sample No.:			
Flask No.:	12	16	
Weight dry soil after test, g, (M_s):	94.04	98.34	
Test temp., °C:	19.7	19.7	
Average calibrated weight of flask, g, (M_p):	167.30	175.12	
Average calibrated volume of flask, ml, (V_p):	499.41	498.32	
Weight of flask, water, & soil @ test temp., g, ($M_{pws,t}$):	725.22	733.71	
Density of water @ test temp., g/ml, (Table 1, ($P_{w,t}$)):	0.99827	0.99827	
Temp. coefficient, (Table 1 (K)):	1.00006	1.00006	
$M_{pw,t}$:	685.94	671.57	
G_t :	2.71	2.72	
$G_{20}^{\circ C}$:	2.71	2.72	
Average $G_{20}^{\circ C}$:	2.71		

Formulas: Weight of flask & water @ test temp., g = $M_{pw,t} = M_p + (V_p \times P_{w,t})$ Specific gravity of soil @ test temp. = $G_t = M_s / (M_{pw,t} - (M_{pws,t} - M_s))$ Specific gravity of soil @ 20°C = $K \times G_t$ Visual Classification: Silty Sand (SM), BrownPercent passing No. 4 sieve: 100Was any soil or material excluded from the specimen? Yes _____ No X

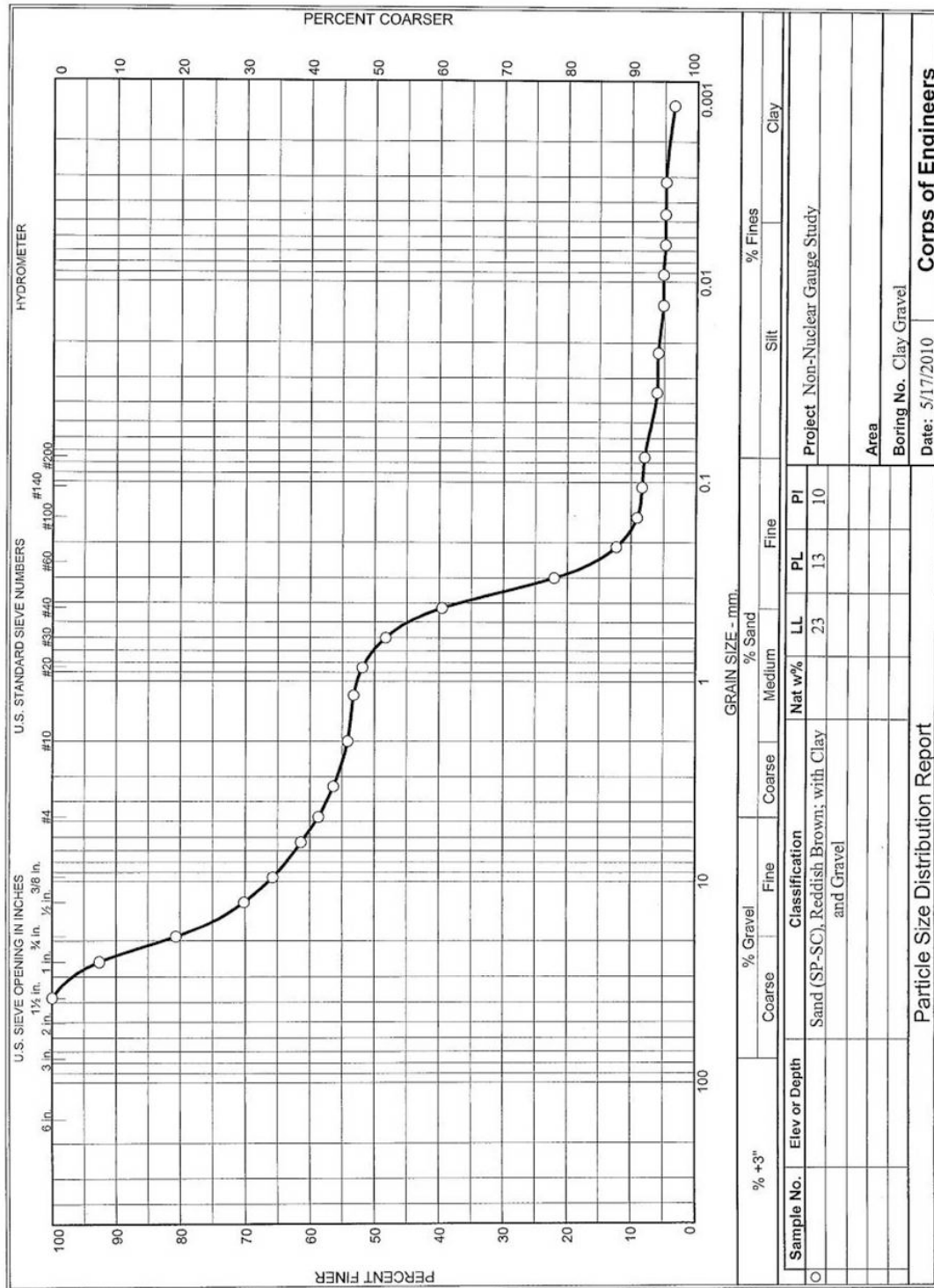
Description of soil or material excluded: _____

Remarks: _____

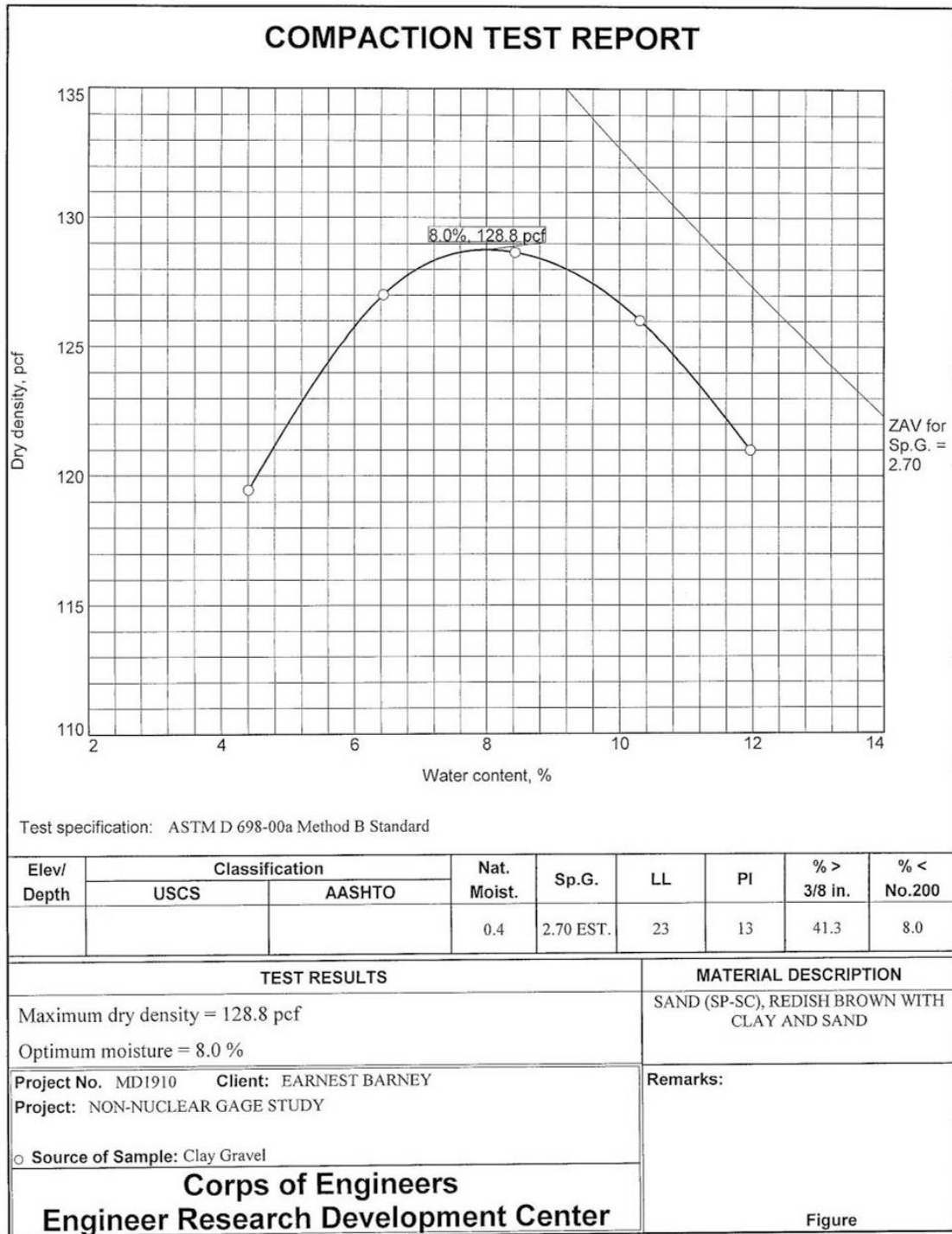
Technician: ATComputed by: ATChecked by: LRC

Revised 8/8/11

B.13 SP-SC



ENG FORM 2087
1 MAY 63



Tested By: CEC

SPECIFIC GRAVITY OF SOILS

ASTM D 854

FLASK SET # 1

WORK ORDER NO. MD1812

Date: 4/18/12

Project: Non-Nuclear Gauge

Method A: _____ Method B: X

Boring:	SP-SC			
Location:				
Sample No.:				
Flask No.:	20	25		
Weight dry soil after test, g, (M_s):	96.41	97.77		
Test temp., °C:	19.5	19.6		
Average calibrated weight of flask, g, (M_p):	171.35	166.90		
Average calibrated volume of flask, ml, (V_p):	499.32	498.31		
Weight of flask, water, & soil @ test temp., g, ($M_{pws,t}$):	730.42	728.40		
Density of water @ test temp., g/ml, (Table 1, ($P_{w,t}$)):	0.99831	0.99829		
Temp. coefficient, (Table 1 (K)):	1.00010	1.00008		
$M_{pw,t}$ =	689.85	667.35		
G_t =	2.69	2.66		
$G_{20}^{\circ C}$ =	2.68	2.66		
Average $G_{20}^{\circ C}$ =	2.68			

Formulas: Weight of flask & water @ test temp., g = $M_{pw,t} = M_p + (V_p \times P_{w,t})$ Specific gravity of soil @ test temp. = $G_t = M_s / (M_{pw,t} - (M_{pws,t} - M_s))$ Specific gravity of soil @ 20°C = $K \times G_t$

Visual Classification: Clayey Sand (SC), Reddish Brown

Percent passing No. 4 sieve: 100

Was any soil or material excluded from the specimen?

Yes _____

No X _____

Description of soil or material excluded:

Remarks: _____

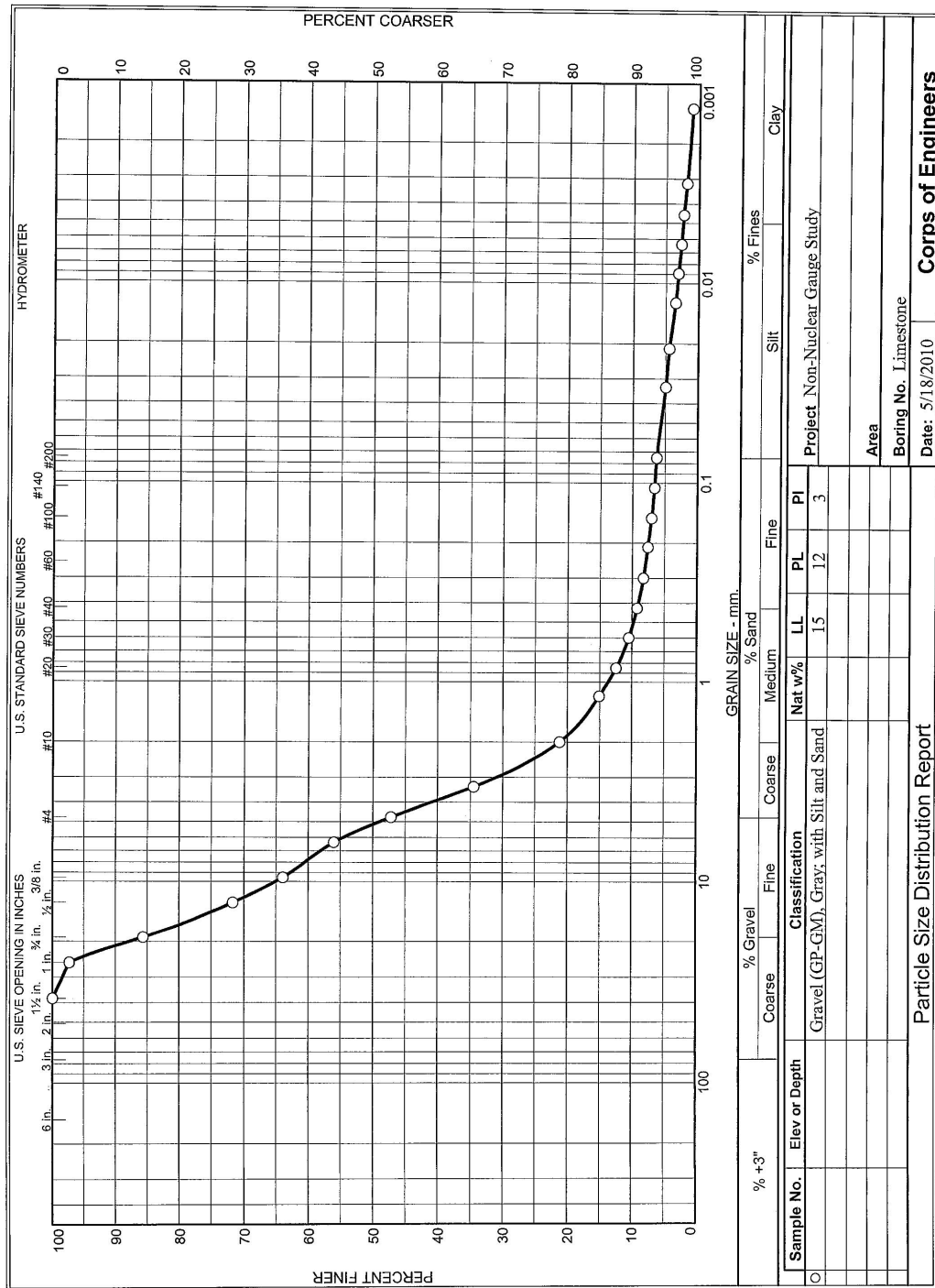
Technician: AT

Computed by: AT

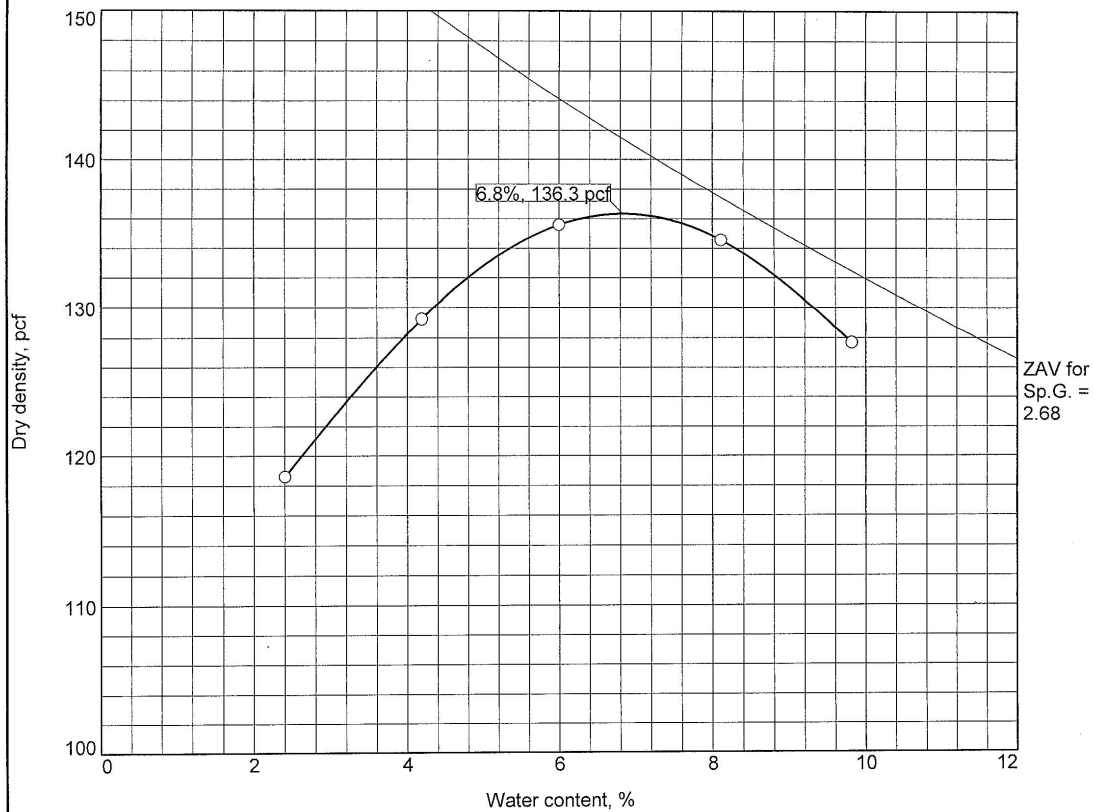
Checked by: LRC

Revised 8/8/11

B.14 Limestone



COMPACTION TEST REPORT



Test specification: ASTM D 698-07 Method B Standard

Elev/ Depth	Classification		Nat. Moist.	Sp.G.	LL	PI	% > 3/8 in.	% < No.200
	USCS	AASHTO						
			0.2	2.68 EST.	15	12	52.8	6.3

TEST RESULTS		MATERIAL DESCRIPTION
Maximum dry density = 136.3 pcf Optimum moisture = 6.8 %		GRAVEL (GW), GRAY WITH SAND
Project No. MD1910 Client: EARNEST BARNEY Project: NON-NUCLEAR GAGE STUDY ○ Source of Sample: CRUSH LIMESTONE		Remarks:
Corps of Engineers Engineer Research Development Center		

Tested By: CEC _____

LIQUID AND PLASTIC LIMIT TEST DATA

5/11/2010

Client: Ernest Berney

Project: Non-Nuclear gage study

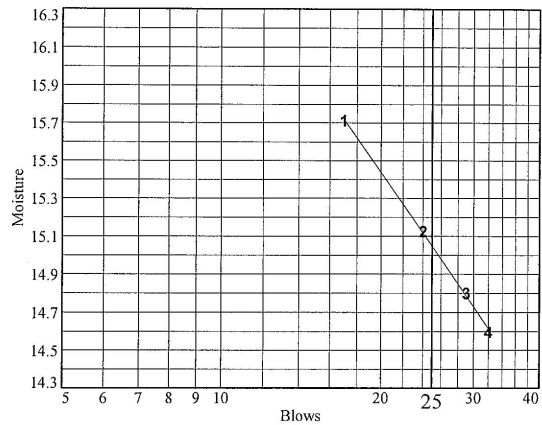
Project Number: MD1910A

Location: Limestone

Material Description: Silt (ML), Gray

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare	31.21	32.52	37.35	33.34		
Dry+Tare	29.23	30.44	34.69	31.06		
Tare	16.63	16.69	16.72	15.44		
# Blows	17	24	29	32		
Moisture	15.7	15.1	14.8	14.6		



Liquid Limit= 15
 Plastic Limit= 12
 Plasticity Index= 3

Plastic Limit Data

Run No.	1	2	3	4	
Wet+Tare	30.28	28.85			
Dry+Tare	28.70	27.45			
Tare	14.91	15.39			
Moisture	11.5	11.6			

CEERD-GS-E

LIQUID AND PLASTIC LIMIT TEST DATA

5/11/2010

Client: Ernest Berney

Project: Non-Nuclear gage study

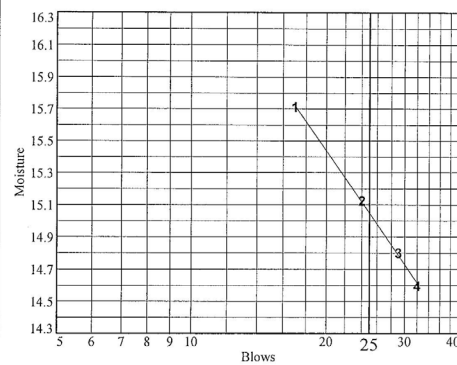
Project Number: MD1910A

Location: Limestone

Material Description: Silt (ML), Gray

Liquid Limit Data

Run No.	1	2	3	4	5	6
Wet+Tare	31.21	32.52	37.35	33.34		
Dry+Tare	29.23	30.44	34.69	31.06		
Tare	16.63	16.69	16.72	15.44		
# Blows	17	24	29	32		
Moisture	15.7	15.1	14.8	14.6		



Liquid Limit= 15
 Plastic Limit= 12
 Plasticity Index= 3

Plastic Limit Data

Run No.	1	2	3	4	
Wet+Tare	30.28	28.85			
Dry+Tare	28.70	27.45			
Tare	14.91	15.39			
Moisture	11.5	11.6			

CEERD-GS-E

Appendix C: Summary of Grain Size Data

Table 9. Average of percent passing each sieve from 3 replicates for all soils and techniques evaluated.

ASTM													
Sieve Number	Percent Passing Average												
	Sand	SM	GC	Lime	SC-1	SC-2	CH (ERDC)	CH-2	CH-3	ML	CL-1	CL-2	CL-3
1"	100.0	100.0	97.6	98.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1/2"	99.7	100.0	88.1	80.4	98.1	100.0	99.6	99.5	99.2	98.6	100.0	100.0	98.4
4	96.1	85.9	82.7	56.2	94.7	98.8	99.4	98.2	96.1	98.3	96.8	99.0	95.4
10	87.1	81.4	80.3	34.2	90.7	97.6	98.9	96.2	94.3	97.5	95.3	97.8	91.8
20	80.4	76.4	77.1	20.2	85.9	96.5	98.3	94.7	92.7	96.6	94.1	96.5	89.9
40	57.0	62.6	51.5	14.0	79.3	90.5	96.9	90.8	89.8	95.5	91.1	94.0	87.1
100	10.4	51.2	11.3	8.8	58.2	42.5	89.7	77.2	76.1	92.3	67.1	76.0	68.9
200	6.8	51.0	10.0	6.8	39.9	32.1	85.3	70.9	62.9	91.7	49.5	61.0	53.5
RSAC-Wet													
Sieve Number	Percent Passing Average												
	Sand	SM	GC	Lime	SC-1	SC-2	CH (ERDC)	CH-2	CH-3	ML	CL-1	CL-2	CL-3
1"	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1/2"	100.0	99.7	92.9	89.9	99.4	100.0	100.0	100.0	98.0	100.0	99.9	100.0	100.0
4	96.3	88.2	88.5	66.3	96.2	99.1	99.7	98.6	96.7	99.9	99.0	98.7	97.7
10	87.3	83.8	86.1	41.9	90.8	98.0	97.5	96.4	95.3	98.7	98.3	97.7	95.3
20	80.9	78.5	83.0	26.6	83.2	96.6	85.5	89.6	92.0	95.8	97.2	96.4	93.0
40	54.7	62.8	56.7	16.8	65.2	86.8	65.9	75.6	85.3	90.2	94.5	93.6	89.4
100	10.1	51.6	18.2	12.6	34.5	29.4	51.1	39.8	56.4	81.9	62.7	71.8	60.6
200	4.9	45.5	15.8	10.7	30.8	22.5	46.5	25.5	28.9	67.3	41.9	50.1	21.7
RSAC-Dry													
Sieve Number	Percent Passing Average												
	Sand	SM	GC	Lime	SC-1	SC-2	CH (ERDC)	CH-2	CH-3	ML	CL-1	CL-2	CL-3
1"	100.0	100.0	96.9	100.0	100.0	100.0	100.0	96.3	100.0	100.0	100.0	100.0	100.0
1/2"	100.0	100.0	90.3	83.5	98.8	100.0	100.0	96.3	99.1	100.0	100.0	100.0	99.7
4	96.4	85.2	85.8	58.6	95.7	99.2	99.9	95.8	97.9	99.8	99.5	98.9	96.3
10	87.1	80.4	83.1	33.9	93.4	98.8	99.9	95.5	97.1	98.9	98.3	97.5	94.2
20	76.8	73.2	72.8	16.8	88.7	98.1	95.7	94.0	95.1	93.7	95.7	93.9	90.9
40	40.6	52.5	38.1	9.7	80.1	93.4	68.8	79.3	88.4	81.8	91.2	88.5	86.1
100	3.6	38.1	4.3	2.3	36.2	21.7	20.3	16.9	38.9	68.1	49.4	40.1	52.5
200	0.7	16.3	1.9	0.3	2.9	2.1	1.6	1.7	3.7	36.7	5.9	5.0	5.3

Figure 29. Comparison of percent passing each sieve between RSAK techniques and ASTM procedure for all soils tested.

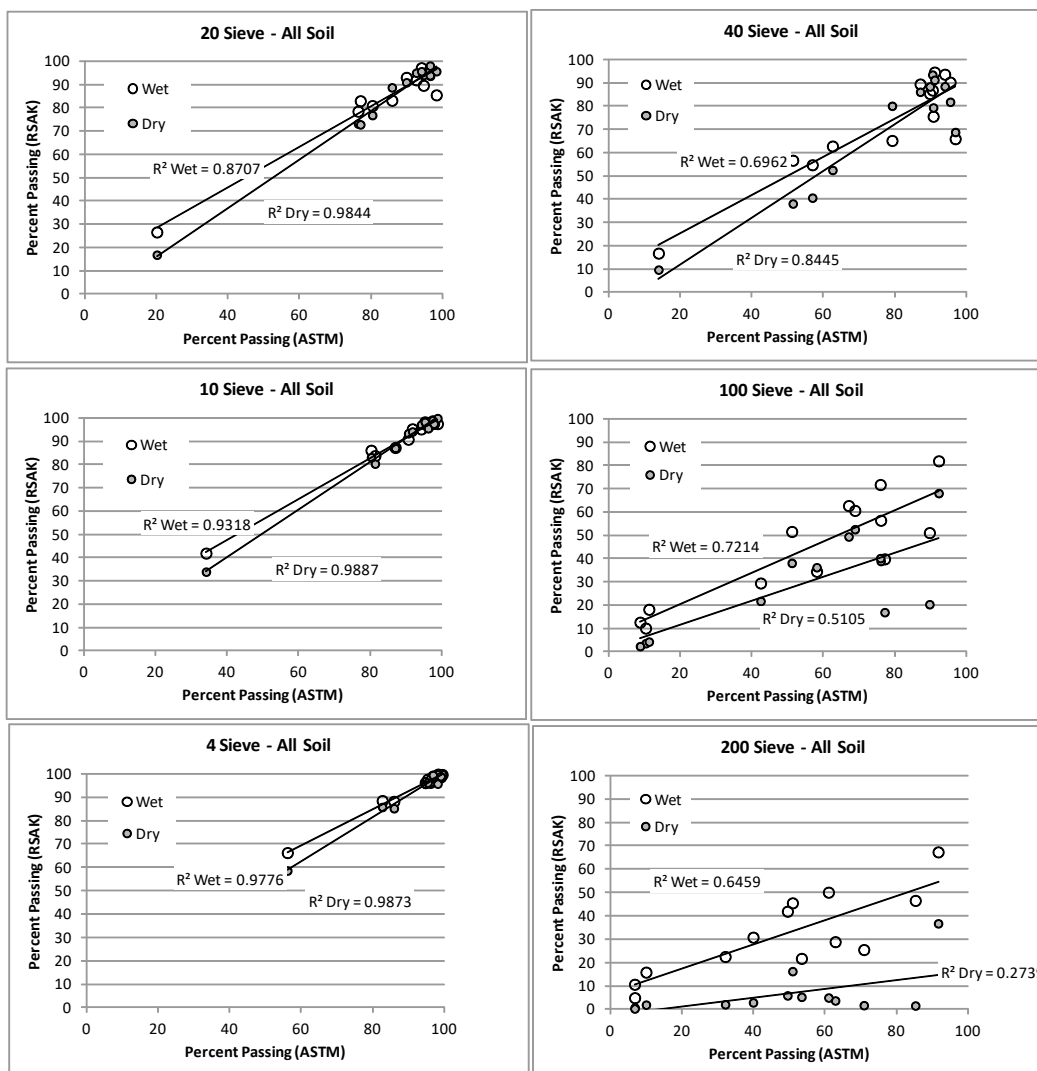
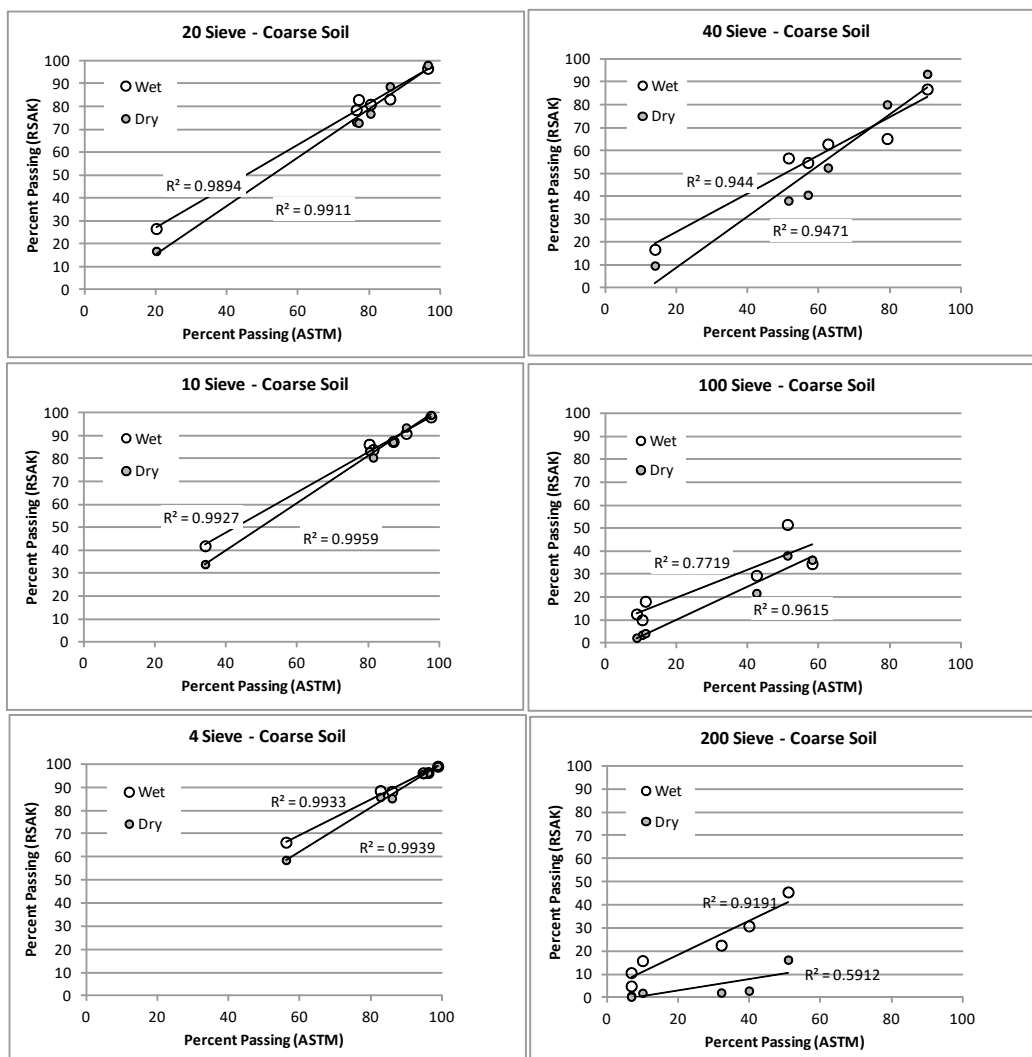


Figure 30. Comparison of percent passing each sieve between RSAK and ASTM procedure for soils classified as coarse grained (<50% fines).



Appendix D: Army Soils Kit LIN-V92959

The following is the document detailing the specific components of the Army field soils kit. This kit also includes all necessary surveying and drafting equipment to perform the ground and site preparation that are not applicable to the soil engineering and classification determination. The figures listed in Chapter 2 illustrate only those portions of the Army Soils Kit that are necessary to perform the classification and engineering definitions.

D101.16: 6635-98-CL-E02-HR
SC 6635-98-CL-E02-HR

HAND RECEIPT CATALOG COVERING CONTENT OF:

Sets, Kits and Component List

TEST SET, SOIL

**(NSN 6635-00-641-3643)
(LIN V92959)**

**(NSN 6635-00-926-1250)
FOR MAP USE**

HEADQUARTERS, DEPARTMENT OF THE ARMY

19 APRIL 1982

sa

Hand Receipt
SC 6635-98-CL-E02-HR

HEADQUARTERS
DEPARTMENT OF THE ARMY
Washington, D.C., 19 April 1982

Hand Receipt Catalog Covering Content Of:

Sets, Kits, and Outfits Components List

TEST SET, SOIL
(NSN 6635-00-641-3643)
(LIN V92959)
(NSN 6635-00-926-1250 FOR MAP USE)

REPORTING OF ERRORS

You can help improve this publication. If you find any mistakes, please let us know. Mail your letter, DA Form 2028 (Recommended Changes to Publications and Blank Forms) to: Commander, US Army Tank Automotive Command, ATTN: DRSTA-MB, Warren, MI 48090. A reply will be furnished direct to you.

Section I Introduction Page
II HAND RECEIPT 1

SECTION I INTRODUCTION

1.Scope. This hand receipt catalog provides a listing on a preprinted DA Form 2062 (Hand Receipt) of accountable sets, kits, and outfits items related to Test Set, Soil.

2.General. Section II of this catalog is an overprinted DA Form 2062 consisting of a listing of sets, kits, and outfit items extracted from SC 6635-98-CL-E02. The listing consists of exactly the same items and in the same sequence as the components list listing. The overprinted DA Form 2062 will aid the property accountability officers in preparation of hand receipts required by PAM 710-2-1. Those NSNs identified by an "X" in the ARC on the hand

receipt pages need not be counted under the inventory provision of PAM 710-2-1. Items will be ordered as required. Local reproduction of the overprinted DA Form 2062 is authorized. Extra copies of the HR catalog are available through:

Commander
US Army AG Publications Center
2800 Eastern Boulevard
Baltimore, Maryland 21220

3.Explanation of Blocks and Columns. Refer to Chap 5, PAM 710-2-1.

HAND RECEIPT/ANNEX NUMBER <i>For use of this form, see DA Pam 710-2-1. The proponent agency is ODCSLOG.</i>		FROM	TO	HAND RECEIPT NUMBER								
FOR ANNEX/CR ONLY	END ITEM STOCK NUMBER	END ITEM DESCRIPTION	PUBLICATION NUMBER	PUBLICATION DATE	QUANTITY							
	6635-00-641-3643	TEST SET SOIL	SC 6635-98-CL-E02-HR	19 APR 82								
STOCK NUMBER a.	ITEM DESCRIPTION b.	* c.	SEC d.	U e.	QTY AUTH f.	# g.	QUANTITY					
							A	B	C	D	E	F
3820-01-115-9858	ADAPTER, AUGER, BIT: 1 in. dia shaft	D	U	EA	1							
6635-01-088-6391	ADAPTER, PENETROMETER: attach CL-700	D	U	EA	1							
3820-01-116-3847	AUGER, EARTH, PORTABLE: 3.5 h.p.	D	U	EA	1							
5120-00-223-8553	AUGER, POSTHOLE, HAND: bucket blade, 6 in. dia, stem	D	M	EA	1							
8105-01-093-6894	BAG, TEXTILE: Drill Cloth, string closure fastening	X	U	EA	30							
8105-00-290-4579	BAG, TEXTILE: cotton duck, unlined, 32 in. nom o/a h	X	U	EA	15							
6140-01-088-0535	BATTERY FILLER, SYRINGE: rubber bulb	X	U	EA	2							
3820-01-116-3760	BIT, AUGER: 4 in. dia, 3 ft lg	D	U	EA	1							
8125-01-016-4559	BOTTLE, SNAD CONE: 1 gallon plastic bottle, threaded	X	U	EA	4							
6640-00-641-3499	BOTTLE, SPECIFIC GRAVITY: calibrated at 20 deg C	X	U	EA	2							
8020-00-260-1306	BRUSH, VARNISH: 1 in. nom stock w.	X	U	EA	2							
8020-00-260-1304	BRUSH, VARNISH: 2 in. nom stock w.	X	U	EA	2							
7920-00-282-9246	BRUSH, WIRE, SCRATCH: 10.50 in. max o/a lg, steel	X	U	EA	3							
6810-00-815-4727	CALCIUM CARBIDE, REAGENT: granular form; 1 lb per pkg	X	U	LB	12							
7420-01-083-9311	CALCULATING MACHINE: 10 digit, ac or battery operated	D	W	EA	1							
8110-00-178-8292	CAN, FRICTION TOP: 1 gallon capacity, rnd steel cover	X	U	EA	5							

* WHEN USED AS A
 HAND RECEIPT, enter Hand Receipt Annex Number
 HAND RECEIPT FOR QUARTERS FURNITURE, enter Condition Codes
 HAND RECEIPT ANNEX/COMPONENTS RECEIPT, enter Accounting Requirements Code (ARC)

DA FORM 2062 JAN 82 EDITION OF JAN 68 IS OBSOLETE.
 Current as of 19 April 1982

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SC 6635-98-CL-E02-HR

TEST SET SOIL

STOCK NUMBER a.	ITEM DESCRIPTION b.	* c.	SEC d.	U e.	QTY AUTH f.	# g.	QUANTITY					
							A	B	C	D	E	F
6635-01-106-7755	CHEST, SOIL TEST SET: (BEARING RATIO EQUIPMENT)	D	U	EA	2							
6635-01-106-2732	CHEST, SOIL TEST SET: (SOIL SAMPLING EQUIPMENT)	D	U	EA	1							
6635-00-371-9686	CHEST, SOIL TEST SET: rectangular shape	D	U	EA	1							
5110-00-585-8428	CHISEL, BUTT, WOODWORKING: tang type, plastic handle	D	M	EA	1							
8305-00-223-1270	CLOTH, DUCK: cotton, no. 4 olive drab; mildew	X	U	YD	5							
6635-00-371-9689	COLLAR SAMPLING: tubing, seamless, case harden	X	U	EA	1							
6635-00-355-6318	COMPACTION CYLINDER, SOIL: steel, 4 in. id, (98773)	X	U	EA	5							
6635-00-371-9692	COMPACTION CYLINDER, SOIL: steel, 6 in. id	D	U	EA	20							
6635-01-108-9580	COVER, TEST SIEVE: brass, 8 in. cyl shape, handle	X	U	EA	1							
6635-01-088-6392	CUP, SOIL DISPERSION: four stationary baffles	X	U	EA	1							
6675-00-244-0445	CURVE, DRAFTING, IRREGULAR: french pattern 28	X	U	EA	1							
6640-00-883-8516	CYLINDER, GRADUATED, LABORATORY: glass 100 ml, w/pour	X	U	EA	2							
5340-00-135-4385	DISC, SOIL, SAMPLER: cast iron, cadmium plated	X	U	EA	2							
6640-00-421-5000	DISH, EVAPORATING: porcelain, bowl shaped rnd bottom	X	U	EA	10							
6640-00-421-6500	DISH, MOISTURE DETERMINATION: aluminum, 50 mm dia	X	U	EA	36							
6640-00-811-4431	DISH, MOISTURE DETERMINATION: aluminum, 90 mm dia	X	U	EA	24							
3820-01-115-9868	EXTENSION, AUGER BIT: 3 ft lg	D	U	EA	6							
5110-00-239-7556	FILE, HAND: American pattern; Three sq type, 8 in. lg	D	M	EA	1							
5110-00-241-9138	FILE, HAND: Mill; single smooth cut face, 10 in. lg	D	M	EA	1							
6635-00-933-0559	GROOVING TOOL, SOIL TEST: cadmium plated steel	X	U	EA	1							
4930-00-222-2680	GUN, FLUID, DIRECT DELIVERY: flexible metallic hose	X	U	EA	1							

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PAGE 2 OF 8 PAGES

HAND RECEIPT/ANNEX NUMBER For use of this form, see DA PAM 710-2-1. The proponent agency is ODCSLOG.		FROM	TO	HAND RECEIPT NUMBER							
FOR ANNEX/CR ONLY	END ITEM STOCK NUMBER	END ITEM DESCRIPTION	PUBLICATION NUMBER	PUBLICATION DATE	QUANTITY						
	6635-00-641-3643	TEST SET SOIL	SC 6635-98-CL-E02-HR	19 APR 82							
STOCK NUMBER a	ITEM DESCRIPTION b	* c	SEC d	U e	QTY AUTH f	QUANTITY g					
						A	B	C	D	E	F
6635-00-559-3147	HOLDER, INDICATOR DIAL: adjustable, w/permanent	X	U	EA	4						
6630-00-514-5535	HYDROMETER, GRADUATED SCALE: density scale, glass	D	U	EA	1						
5210-00-243-9649	INDICATOR DIAL: adjustable dial setting, plunger	D	M	EA	4						
5120-00-188-1788	JACK, HYDRAULIC, HAND: 20 tons load capacity	N	M	EA	2						
7340-00-291-0625	KNIFE, STEAK, SCIMITAR: carbon steel, 10 in. lg blade	X	U	EA	2						
7530-00-286-6165	LABEL: paper, gummed, water soluble	X	U	BX	5						
5210-00-277-2430	LEVEL AND PLUMB: aluminum, double face, nonadjustable	C	M	EA	1						
6675-00-880-1820	LEVEL, SURVEYING: locators, hand, rnd cross sect. 6 in	X	U	EA	1						
6630-01-083-5537	METER pH: portable, battery operated	D	U	EA	1						
6640-01-106-7753	MIXER, ELECTRIC LABORATORY: 110 v, ac or dc current	D	U	EA	1						
6640-00-531-6347	MORTAR AND PESTLE: porcelain, unglazed grinding	X	U	EA	1						
6640-00-811-4429	OVEN, LABORATORY: gravity convection, steel door	D	U	EA	1						
7240-00-137-1609	PAIL, UTILITY: plastic, 3 gallon capacity	X	U	EA	20						
6635-00-786-8032	PAN, CEMENT: steel, 19 gauge	X	U	EA	4						
7330-00-655-5257	PAN, PLODDING: aluminum, 3 quart	X	U	EA	10						
6635-00-526-9119	PAN, TEST SIEVE: brass, rnd, 8 in. dia;	X	U	EA	1						

* WHEN USED AS A
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PAGE 3 OF 8 PAGES

DA FORM 2062
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SC 6635-98-CL-E02-HR TEST SET SOIL

STOCK NUMBER a	ITEM DESCRIPTION b	* c	SEC d	U e	QTY AUTH f	QUANTITY g					
						A	B	C	D	E	F
6640-00-252-5200	PAPER, FILTER: quantitative; 100 per box	X	U	HD	1						
7530-00-260-0618	PAPER, GRAPH: cross sect ruling tracing	X	U	PG	1						
7530-00-205-3676	PAPER, GRAPH: semilogarithmic ruling	X	U	PG	1						
7510-00-264-4612	PENCIL: yellow, extra thk lead, 12 per pkg	X	U	DZ	1						
6635-00-986-4980	PENETROMETER: cres, pocket, soils classification	X	U	EA	1						
6640-00-641-3055	PESTLE LABORATORY: 2 piece, rubber tipped, w/wood	X	U	EA	1						
4710-00-595-0449	PIPE, METALLIC: seamless or welded, external thd ends	X	U	EA	3						
6635-00-371-9695	PLATE, BASE, PERFORATED: California bearing test	D	U	EA	20						
6635-00-786-8033	PLATE, FIELD DENSITY, SOIL TEST: cast aluminum alloy	X	U	EA	1						
5120-00-239-8251	PLIERS: lineman's side cutter, 8 in. lg	D	M	EA	1						
7240-00-248-9620	SAFETY CAN: red, 3 gallon capacity	X	U	EA	1						
6670-00-494-3845	SCALE, BEAM INDICATING: sp gr determination	D	U	EA	1						
6670-00-494-3604	SCALE, BEAM INDICATING: 1,610 gm, 3 weight beams	N	U	EA	1						
6670-00-514-4117	SCALE, BEAM INDICATING: 21,100 gm 2 weight beams	D	U	EA	1						
6675-00-238-3498	SCALE, DRAFTING: wood and plastic	X	U	EA	1						
7330-00-153-9760	SCOOP, KITCHEN: cres 7.8 in. lg	X	U	EA	2						
5120-00-222-8852	SCREWDRIVER, FLAT TIP: plastic handle; 4 in. lg blade	D	M	EA	1						
5120-00-293-0315	SCREWDRIVER, FLAT TIP: plastic handle; 6 in. lg blade	D	M	EA	1						
6635-00-225-7102	SHAKING MACHINE, TESTING SIEVE LABORATORY: hand	D	U	EA	1						
6635-00-641-3586	SIEVE, TEST: rnd, brass frame, Size No. 200	X	U	EA	2						
6635-00-641-3584	SIEVE, TEST: rnd, brass frame, Size No. 100	X	U	EA	2						

Reverse of DA Form 2062

Current as of 17 April 1982

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HAND RECEIPT/ANNEX NUMBER For use of this form, see DA PAM 710-2-1. The proponent agency is ODCSLOG.		FROM	TO	HAND RECEIPT NUMBER								
FOR ANNEX/ONLY	END ITEM STOCK NUMBER	END ITEM DESCRIPTION	PUBLICATION NUMBER	PUBLICATION DATE	QUANTITY							
	6635-00-641-3643	TEST SET SOIL	SC 6635-98-CL-E02-HR	19 APR 82								
STOCK NUMBER a.	ITEM DESCRIPTION b.	* c.	SEC d.	U e.	QTY AUTH f.	QUANTITY g.	A	B	C	D	E	F
6635-00-526-6187	SIEVE, TEST: rnd, brass frame, Size No. 80	X	U	EA	1							
6635-00-641-3583	SIEVE, TEST: rnd, brass frame, Size No. 60	X	U	EA	1							
6635-00-641-7367	SIEVE, TEST: rnd, brass frame, Size No. 50, 297 micr	X	U	EA	1							
6635-00-641-3582	SIEVE, TEST: rnd, brass frame, Size No. 40, 420 micr	X	U	EA	2							
6635-00-641-7353	SIEVE, TEST: rnd, brass frame, Size No. 30, 590 micr	X	U	EA	1							
6635-00-641-7354	SIEVE, TEST: rnd, brass frame, Size No. 20	X	U	EA	1							
6635-00-641-7355	SIEVE, TEST: rnd, brass frame, Size No. 16	X	U	EA	1							
6635-00-641-3591	SIEVE, TEST: rnd, brass frame, Size No. 10	X	U	EA	1							
6635-00-641-7364	SIEVE, TEST: rnd, brass frame, Size No. 8	X	U	EA	1							
6635-01-105-6844	SIEVE, TEST: rnd, brass frame, Size No. 200	X	U	EA	2							
6635-01-105-6843	SIEVE, TEST: rnd, brass frame, Size No. 40	X	U	EA	2							
6635-00-641-7357	SIEVE, TEST: rnd, brass frame, Size No. 4	X	U	EA	3							
6635-00-641-7358	SIEVE, TEST: rnd, brass frame, Size No. 3	X	U	EA	1							
6635-00-641-7361	SIEVE, TEST: rnd, brass frame, Size 3/4 in.	X	U	EA	1							
6635-00-641-7350	SIEVE, TEST: rnd, brass frame, Size 1 in.	X	U	EA	1							
6635-00-641-3596	SIEVE, TEST: rnd, brass frame, Size 1-1/2 in	X	U	EA	1							

* WHEN USED AS A
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 HAND RECEIPT ANNEX/COMPONENTS RECEIPT, enter Accounting Requirements Code (ARC)

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JAN 82EDITION OF JAN 88 IS OBSOLETE.
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SC 6635-98-CL-E02-HR

TEST SET SOIL

STOCK NUMBER a.	ITEM DESCRIPTION b.	* c.	SEC d.	U e.	QTY AUTH f.	QUANTITY g.	A	B	C	D	E	F
6635-00-514-4149	SIEVE, TEST: rnd, brass frame, Size No. 2 in.	X	U	EA	1							
7520-00-868-4754	SLIDE RULE: Single face, plastic body	X	U	EA	1							
6810-00-597-5287	SODIUM HEXAMETAPHOSPHATE, TECHINCAL: granular or flake	X	U	LB	12							
6810-00-270-8177	SODIUM HYDROXIDE, TECHINICAL: flake or powder form	X	U	CN	1							
6640-00-171-5198	SPATULA LABORATORY: cres blade, wood handle	X	U	EA	2							
7340-00-240-7080	SPOON, FOOD SERVICE: 15.25 in. lg	X	U	EA	2							
6645-00-250-4680	STOPWATCH: pocket type	X	U	EA	1							
5210-00-282-2150	STRAIGHT EDGE: steel std, 24 in. lg	D	M	EA	1							
6635-00-371-9698	SUPPORT, TRIPOD, DIAL: indicator clamp, California	X	U	EA	1							
8135-00-292-2345	TAG, SHIPPING: rectangular, cloth, white; (81348)	X	U	MX	100							
6635-00-514-4013	TAMPER, COMPACTION, SOIL TESTING: w/rammer, 2 in. dia	X	U	EA	2							
5210-00-221-1888	TAPE, MEASURING: 100 ft measuring capacity, handcrank	D	M	EA	1							
5210-00-245-0301	TAPE, MEASURING: 78.75 in. measuring capacity, null	D	M	EA	2							
6635-00-641-3496	TESTING MACHINE, SOIL LIQUID LIMIT: brass cup	D	U	EA	1							
6630-00-226-0920	TEST PAPER AND COLOR CHART: hydrogen ion	X	U	EA	1							
6635-00-411-3727	TEST SET, SOIL, FIELD: California bearing ratio	D	U	SE	1							
6635-00-411-3728	TEST SET, SOIL, LABORATORY: California bearing ratio	D	U	SE	1							
6635-00-976-3463	TEST SET, SOIL: MOISTURE DETERMINATION	D	U	EA	1							
6635-00-542-1284	TEST SET, SOIL TRAFFICABILITY: c/o the following:											
6635-00-679-5760	CARRYING CASE, TEST SET, SOIL TRAFFICABILITY	D	U	EA	1							
5120-00-240-5300	KEY, SOCKET, HEAD SCREW: hex	D	M	EA	1							

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HAND RECEIPT/ANNEX NUMBER For use of this form, see DA PAM 710-2-1. The proponent agency is ODCSLOG.			FROM	TO	HAND RECEIPT NUMBER									
FOR ANNEX/CR ONLY	END ITEM STOCK NUMBER	END ITEM DESCRIPTION	PUBLICATION NUMBER	PUBLICATION DATE	QUANTITY									
	6635-00-641-3643	TEST SET SOIL	SC 6635-98-CL-E02-HR	19 APR 82										
STOCK NUMBER a.		ITEM DESCRIPTION b.	* c.	SEC d.	UI e.	QTY f.	Q.JANITY g. A B C D E							
6635-00-679-5761		PENETROMETER: soil, cir base	D	U	EA	1								
6635-00-679-5762		REMODELING SET, SOIL COMPACTION	D	U	EA	1								
6635-00-679-5764		SAMPLER, SOIL	D	U	EA	1								
5120-00-287-2504		SCREWDRIVER, FLAT TIP: plastic handle, 5 in. lg	D	M	EA	1								
5120-00-187-7124		WRENCH, OPEN END: steel	D	M	EA	2								
5120-00-277-1483		WRENCH PIPE: iron, 6 in. lg	D	M	EA	1								
5120-00-288-8746		WRENCH, SPANNER: steel	D	M	EA	1								
6635-00-807-3717		TESTER, SOIL DENSITY, SAND METHOD: brass or steel	X	U	EA	3								
6685-01-088-0548		THERMOMETER, SELF-INDICATING, LIQUID IN GLASS:	X	U	EA	1								
6640-00-444-8000		TONGS, LABORATORY: crucible, double bent, (96906)	X	U	EA	1								
5140-01-018-2719		TOOL BOX, PORTABLE: 2 tray	D	M	EA	1								
7210-00-243-1019		TOWEL, HAND: cotton, huck weave	X	M	EA	12								
6675-00-190-5867		TRIANGLE, DRAFTING: plastic, right angle; 30 deg-60	X	U	EA	1								
6675-00-190-5862		TRIANGLE, DRAFTING: plastic, right angle; 45 deg, 8 in	X	U	EA	1								
5120-00-223-9477		TROWEL: pointer unit	D	M	EA	2								
4020-00-243-3155		TWINE, FIBROUS: cotton, cable lay												

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JAN 82

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SC 6635-98-CL-E02-HR

TEST SET SOIL

[illegible]

Revised of DA Form 2042

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By Order of the Secretary of the Army:

Official:

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Brigadier General, United States Army
The Adjutant General

E. C. MEYER
General, United States Army
Chief of Staff

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1. REPORT DATE (DD-MM-YYYY) January 2018		2. REPORT TYPE Final		3. DATES COVERED (From - To)	
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				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Ernest S. Berney IV, Naveen B. Ganesh, and David R. Daily				5d. PROJECT NUMBER 354894	
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13. SUPPLEMENTARY NOTES					
14. ABSTRACT ERDC research on crater formation from detonation of improvised explosive devices identified the significance of soil type on crater shape and size. Military Explosive Ordinance Disposal (EOD) teams required an expedient means of classifying soil from small field samples, according to the Unified Soil Classification System, to help identify characteristics of buried explosives. The existing Rapid Soils Analysis Kit (RSAK), developed at ERDC, was modified to shrink its cube volume, improve its accuracy, and adapt it to the EOD mission. As such the RSAK was changed from a dry, pulverization-based (D-RSAK) system to a wet, wash-based (W-RSAK) system similar to that used in a commercial laboratory to improve accuracy of determining fines content. Modifications were focused on increasing speed and accuracy from the original D-RSAK. This report presents comparisons of classification results on 14 different soil types by both the traditional laboratory, dry-based and wet-based systems to demonstrate the strengths and weaknesses of the new W-RSAK procedure. The kit in its current configuration with the wet process was demonstrated to significantly improve classification estimations. Revised software to process the data obtained from the W-RSAK equipment was developed using Matlab and Android platforms to enable deployment on multiple software platforms.					
15. SUBJECT TERMS		Field construction Soil testing Field instrumentation Soils – sampling Ordnance disposal units – Equipment - Evaluation		Rapid site assessment California bearing ratio Soil density Scientific apparatus and instruments - Evaluation	
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