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# Revised Rapid Soils Analysis Kit (RSAK) – Wet Methodology

Ernest S. Berney IV, Naveen B. Ganesh, and David R. Daily

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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 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.

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## Contents

Abs	tract .		ii
Fig	ures a	Ind Tables	v
Pre	face		vii
Uni	t Conv	version Factors	viii
1	Intro	duction	1
	1.1	Background	1
	1.2	Objectives	1
	1.3	Scope	2
2	Curre	ent State of Expedient Soil Classification	3
	2.1	Typical geotechnical testing	3
	2.2	Army test set, soil	4
	2.3	Rapid Soils Analysis Kit	5
	2.4	Other classification kits	6
3	Meth	nodology of New RSAK	9
	3.1	Overview	9
	3.2	Equipment	9
	3.3	Procedure	
	3.4	Software	15
4	Expe	rimentation	20
	4.1	Soils tested	20
	4.2	Experimental procedure	21
5	Data	Analysis	25
	5.1	Particle size distribution	25
	5.2	Atterberg limits	26
	5.3	Compaction indices	27
	5.4	USCS classification	28
6	Conc	clusions and Recommendations	30
	6.1	Conclusions	30
	6.2	Recommendations	30
	6.3	Areas for future study	30
		6.3.1 Expedient liquid limit test	
		6.3.2 Reduction in kit volume	
Ref	erence	es	32
Арр	endix	A: Expanded Expedient Soil Classification	34

Appendix B: Soil Characterization Data	37
Appendix C: Summary of Grain Size Data	80
Appendix D: Army Soils Kit LIN-V92959	83

**Report Documentation Page** 

# **Figures and Tables**

### Figures

Figure 1. Standard Army soils field kit (drying oven not shown).	4
Figure 2. Army soils kit drying oven in comparison to RSAK drying apparatus.	4
Figure 3. Components of the D-RSAK system	5
Figure 4. Components of the W-RSAK system.	6
Figure 5. Dynatest gravel roads test kit	7
Figure 6. Wash and decanting process for removing fines (minus #200 sieve) material using the Cornell quick wash procedure.	8
Figure 7. Dry-based Rapid Soils Analysis Kit (D-RSAK) as packaged for the JRAC program	9
Figure 8. Wet-based Rapid Soils Analysis Kit as developed for the CALDERA program	10
Figure 9. Wet-based RSAK (W-RSAK) packaged in a single 1620 Pelican Case	12
Figure 10. Procedural differences between wet and dry RSAK methods.	13
Figure 11. Illustration of procedural steps in conducting a wet RSAK experiment	14
Figure 12. Introductory screen to begin RSAK data input in Matlab executable.	16
Figure 13. Determination of initial moisture content of soil	16
Figure 14. Drying of washed soil to prepare for sieve analysis	17
Figure 15. Input of sieve weights empty and after soil has been introduced	17
Figure 16. Determination of plastic limit by weighting rolled threads	18
Figure 17. Final input screen in RSAK to determine texture and output final USCS classification and index properties.	18
Figure 18. Data analysis window demonstrating grains size distribution curve.	18
Figure 19. Data analysis window displaying modified proctor density curve.	19
Figure 20. Data analysis window displaying modified proctor CBR curve.	19
Figure 21. Three replicates of Limestone soil ready for washing for ASTM grain size determination.	22
Figure 22. Clay gravel dried and after washing over #200 sieve (note large ASTM sample size used versus a typical 500-g RSAK sample)	22
Figure 23. Washing fines in deep #200 sieve for ASTM procedure	23
Figure 24. Oven drying limestone soil samples in large oven for at least 16 hr.	23
Figure 25. Average Coefficient of Determination between ASTM and RSAK sieve methodologies by sieve opening size for all soils tested.	25
Figure 26. Simplified soil classification chart for CALDERA.	34
Figure 27. USCS classification breakdown for coarse-grained soils.	35
Figure 28. USCS classification breakdown for fine-grained soils based on textural analysis	36
Figure 29. Comparison of percent passing each sieve between RSAK techniques and ASTM procedure for all soils tested.	81
Figure 30. Comparison of percent passing each sieve between RSAK and ASTM procedure for soils classified as coarse grained (<50% fines)	82

#### **Tables**

Table 1. Parts list for the wet-based Rapid Soils Analysis Kit	10
Table 2. Modifications made from the original dry-based RSAK to the wet-based RSAK	11
Table 3. Summary of soil properties tested	20
Table 4. Standard laboratory tests conducted for soil classification.	21
Table 5. Atterberg limit comparison between laboratory and RSAK methods	26
Table 6. RSQ summary from Atterberg limit comparison	26
Table 7. Comparison of optimum moisture content and maximum dry density between           laboratory and RSAK methods.	27
Table 8. Comparison between USCS soil classifications between Laboratory, ASTM, and RSAK methods	29
Table 9. Average of percent passing each sieve from 3 replicates for all soils and         techniques evaluated.	80

### **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	Ву	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 realtime 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.



The size and weight of the Army Soil Test Kit make it impractical for most field exercises. Very few of these test kits exist in the Army inventory, and they are typically not moved once set up. Likewise, their permanent locations are at great distances from the operational needs of the soldier and, hence, they are not often used. Soil analysis is often ignored due to an inability to have test equipment on site, or lack of time to conduct the experiments necessary to obtain the required classifications following traditional ASTM guidelines.

#### 2.3 Rapid Soils Analysis Kit

To provide a means of determining soil classification in a compact deployable kit, the ERDC dry-based Rapid Soils Analysis Kit (Berney and Wahl 2008) (D-RSAK) (Figure 3) was developed as part of the Joint Rapid Airfield Construction (JRAC) Program (Anderton et al. 2008). The intent of the technology was to provide soldiers a means of determining the soil classification, in-situ moisture content and the moisture-density curves, and California Bearing Ratio strength curves within a 60-min time frame to establish quality control parameters and enable construction to begin. Physically, the D-RSAK represents a scaled-down version of the Army field soils using standardized equipment to provide numerical data that, when integrated with ERDC developed software, leads to a USCS classification. Detailed descriptions of the D-RSAK in its JRAC configuration as first presented to NGIC and the subsequent redesign are discussed in Chapter 3.



Figure 3. Components of the D-RSAK system.

For comparison, Figure 4 illustrates the components of the new wet-based W-RSAK system that removes many of the bulkier items from the D-RSAK to further improve transport logistics.



Figure 4. Components of the W-RSAK system.

#### 2.4 Other classification kits

Other than the D-RSAK, there is currently only one commercial product and one formalized procedure available to obtain a series of physical properties of soils in the field known as The South African Gravel Roads Test Kit (Paige-Green 2011) manufactured by Dynatest Pavement Engineering (Figure 5Figure 5). The manufacturer states in the sales literature that this kit:

"...allows materials grading, cohesion (liquid limit and linear shrinkage), compacted strength and aggregate strength of the borrow material to be determined."

This kit is designed primarily for measuring the properties of coarsegrained materials and assessing their strength and suitability as road surface material. The tests themselves take much longer (12 to 24 hr or longer to capture liquid limit and bar linear shrinkage) to conduct than the D-RSAK, and any drying of the soil is accomplished using solar power, which can delay results depending on location.



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	Stirring spoons	2
1", 1/2", #10, #20, #40, #100, #200		Coffee Grinder	1
Sampling trowel	1	1620 Pelican Case	1
Plastic Bowl	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 waterbased 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 coarsegrained 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.

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

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

#### WET mode steps

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

#### DRY mode steps

- 1. Collect a 200 to 500-gram field soil sample
- 2. Dry the field sample with a burner
- 3. Separate out coarse and fine soil from the dried sample
- 4. Pulverize fine soil to remove clumps
- 5. Sieve the dried soil through the brass sieves
- 6. Collect all soil passing the #40 sieve
- 7. Perform the plastic limit test
- 8. Determine the soil texture
- 9. Soil classification is returned



5. Sieve coarse sample



6. Prepare soil for plastic limit test



Example of proper thread



7. Perform plastic limit



8. Establish soil texture





Stirring sample for 20 sec.



4. Redry washed sample



Weigh each sieve full



Ignite burner Pour fuel into stove

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

Illustration of soil on sieve

14

In the D-RSAK, after drying, the intial 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 aggregae, 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).

CALDERA+					
ile Tools Help					
C:\Program Files (x86)\Caldera+\	Soil_Classify_main_GUI.exe				
Error in Soil_Classif	Classify main GUI	Constant of Linese		X `	
84)					
Error in gui_mainfcn					
Error in Soil_Classif					
	Step 1:	Calculate Moisture Content			
Error in					
@(hObject,eventdata)\$		Wash Technique for Silt and Clay Removal			
ck',hObject,eventdata					
	Step 3:	Sieve Analysis			
Error while evaluatin					
	Step 4.	Obtain Dried Soil Sample for Plastic Limit Test			
		Defense Directio Linck Text			
		Peloim Plastic Limit Test			
		Portat GIII Class			
	The second se				

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		
	Pot + Dried Soil Weight (g)	Percent Change (%)
Weight the Pot Empty: 206.16 9	461.5 g	
Place about 200-400 grams of moist soil in pan.	459	0.97344
Weight the Pot with Moist Soil: 462.98 9		
Place pan and soil on open flame burner and stir for one minute.		
Reweigh the Pot with Dry Soit: 461.5 9		
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	-	~

Wash Technique to Remove Silt and Clay From Soil Sample-		
	Pot + Dried Soil Weight (g)	Percent Change (%)
Weight the Pot Empty: 206.16 9	434.01 g	
Pour the dry soil sample from the pan into the bowl and rinse	430 425	1.4645 1.826
Weight the Pot with Wet Soit: 479.98 9	420 419	1.826 0.3652
Place pot and soil on open flame burner and stir for one minute		
Reweigh the pot with dry soil: 434.01 9		
Continue drying soil in 1 minute increments until the program stops asking for weight. Continue Drying Process		
Remove the hot soil pot from the burner and let it cool		
Close		

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



Waish the Sieves				Instructions
veign die Gieves				instructions
	Empty	Full		Pour the dried soil sample into the sieve stack being careful to brush all
1" Sieve	533.08	533.08	9	soil from the pan
1/2" Sieve	515.92	515.92	g	Shake the sieve stack side to side vigorously for approximately 2 minutes
#4 Sieve	502.99	504.37	9	Weigh the sieves full and discard soil when completed
#10 Sieve	479.12	481.08	9	
#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	
	Close			

Perform moisture content calculation to compute Plastic Limit		
	Pot + Dried Soil Weight (g)	Percent Change (%)
Weight the Pot Empty: 100 g	110 g	
Place the moist threads into the pan	109.8	1.6667 0.83333
Weight the Pot with Moist Soil: 112 g		
Place pot and soil on open flame burner and stir for one minute		
Reweigh the Pot with Dry Soit: 110 9		
Continue drying soil in 1 minute increments until the program stops asking for weight.		
Continue Drying Process		
Plastic Limit of the Soit 23.7 %		
Close	-	-
l l		

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







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).

					Grain size					
Soil		Atterberg Limits		(percent by weight)			MDD	омс		
ID	Description	LL	PL	PI	Fines	Sand	Gravel	(pcf)	(%)	Gs
	Sandy Clay									
CL-1	(CL)	27	13	14	56.9	42.1	1	119.5	12.0	2.67
	Sandy Clay									
CL-2	(CL)	39	11	28	64.1	34.0	1.9	115.5	14.2	2.72
	Clayey Sand									
SC-1	(SC)	31	12	19	40.0	55.0	5	122.3	10.9	2.71
	Clay with sand									
CH-2	(CH)	56	23	33	82.0	17.6	0.4	92.3	25.9	2.76
~~~~	Clayey Sand	05			00.4		1.0	100.0	11.0	0.00
SC-2	(SC)	25	14	11	32.1	66.0	1.9	122.8	11.3	2.69
011.0	Sandy Clay	20	4.4	00	C1 O	20.4	0.7	100.0	110	0.74
CH-3	(UH) Caradu Olau	30	14	22	64.9	32.4	2.1	108.9	14.8	2.71
		21	12	0	55 /	40 F	20	126.6	0.4	2.70
	(UL)	21	13	0	55.4	40.5	3.0	120.0	9.4	2.10
		72	24	10	05 1	10	0	<b>95</b> 7	24.6	2.76
LINDO		15	24	43	33.I	4.5	0	05.1	24.0	2.70
мн	Silt (MH)	109	72	37	97 5	25	0	55 7	62.0	2 58
		200		01	0110	2.0	<u> </u>	0011	02.0	2.00
ML	Silt (ML)	No Pla	asticity		87.8	11	1.2	109.5	15.8	2.75
SP	Sand (SP)	No Pla	asticity		3.1	92	4.9	109.7	1.9	2.67
SM	Sandy Silt (ML)	No Pla	asticity		50.3	47	2.7	121.8	10.0	2.71
	Sand with Clay									
SP-	and Gravel (SP-									
SC	SC)	23	13	10	8.0	50.7	41.3	128.8	8.0	2.68
Lima		15	10	2	G	4.1	50	126.2	6.9	0.69
∟ime	Gravel (GP-GM)	15	12	3	ю	41	53	136.3	0.X	2.68

Table 3	Summary	ofsoil	nronerties	tested
Table 3.	Summary	01 5011	properties	iesieu.

#### 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.

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

Table 4. Standard laboratory tests conducted for soil 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<sup>2</sup> (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.

Soil	Laboratory			RSAK		
Туре	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 5. Atterberg limit comparis	on between laborator	y and RSAK methods.
-----------------------------------	----------------------	---------------------

Table 6. RSQ summary from Atterberg limit comparison.

RSQ for Atterberg Limits							
	Wet-I	RSAK	Dry-R	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		
Plastcity 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.

	Maximum Dry Density			Opt	imum Mois	ture Conter	nt	
Soil			Predicted				Predicted	
Туре	Laboratory	ASTM	Wet	Dry	Laboratory	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

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

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 moisturedensity 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.

	Classification					
Soil						
Туре	Laboratory	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)	СН	СН	SC	SP		
CH-2	СН	СН	SC	SP		
CH-3	СН	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		

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

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

Determine % Passing #200

Field Vaterial 40 Sieve Wet 40 Sieve	ML no to low	Cation of S MH Iow to	Soil Fin	es <sub>СН</sub>	
Vlaterial ≪40 Sieve Wet ≪40 Sieve	ML no to low	MH low to	oil Types CL	СН	
<40 Sieve Wet <40 Sieve	no to low	low to			
<40 Sieve		med	med to high	very high	low
Sticky	low	low to med	med	high	spongy
<40 Sieve Sticky	< 1"	1" to 2"	3" to 8"	8" to 10"	
<40 Sieve Sticky	slow to rapid	no to slow	no to slow	no	
Damp	handle freely		handle roughly		
40 (<200) Sieve	unpleasant		smooth		
40 Sieve	stains, but rinses easily		stain must be rubbed of		-
<40 Sieve	slightly gritty sound		very little sound, if any		
	remains dull			shines	
	discolors quickly, >5% s		lt .		
	>10% silt				
	30 Second	ls	1 Hour		
	Sticky       40 Sieve       Sticky       Damp       40 (<200)	A0 Sieve     < 1"	No Sieve     < 1"	No Sieve     < 1"	No Sieve     < 1"

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

# **Appendix B: Soil Characterization Data**

# B.1 CL-1



ENG 1 MAY 63 2087



SPECIFIC GRA ASTM FLASK WORK ORDER NO. <u>MD1812</u> Project: <u>Non-Nuclear Gauge</u>	VITY OF SOILS D 854 SET # 1 Date: <u>4/18/12</u>
Method A:	Method B: X
Boring: Location: Sample No.:	CL1
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 <sub>p</sub> ):	
Average calibrated volume of flask, ml, (Vp): Weight of flask water & soil @ test temp. g. (M _ ):	718 68 724 94
Density of water $\emptyset$ test temp. $q/ml$ (Table 1 (P. )):	The shear the second se
Town coefficient (Table 1, $(K)$ ):	
Temp. coefficient, (Table T $(K)$ ).	<u>~</u>
M <sub>pw,t</sub> = G <sub>t</sub> =	
G <sub>20</sub> ° <sub>C</sub> =	[]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]
Average G <sub>20</sub> ° <sub>C</sub> =	2.67
Formulas: Weight of flask & water @ test tem Specific gravity of soil @ test temp. = 0 Specific gravity of soil @ 3	
Visual Classification: <u>Clay (CL), Brown</u> Percent passing No. 4 sieve: <u>100</u> Was any soil or material excluded from the specimen? Description of soil or material excluded:	Yes No <u>X</u>
 Remarks:	
Technician: AT Computed by:	AT Checked by: LRC
	Revised 8/8/11

B.2 CL-2



ENG FORM 2087



Checked By: LRC

SPECIFIC GRAV	ITY OF SC	DILS		
FLASK S	D 854 SET # 1			
WORK ORDER NO. MD1812			Date:	4/18/12
Project: Non-Nuclear Gauge				
Method A:	Method B:	Х		
Boring:	CL	.2		
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 <sub>p</sub> ):	<u> [] M P P</u>	//199/99/		
Average calibrated volume of flask, ml, (Vp):	<u>[ 1499] 74</u>	[[4987]		
Weight of flask, water, & soil @ test temp., g, (M <sub>pws,t</sub> ):	718.00	713.20		
Density of water @ test temp., g/ml, (Table 1, (P <sub>w,t</sub> )):	<u> </u>	<u> </u>		
Temp. coefficient, (Table 1 (K)) :	NOOD	////////		
F				
M <sub>pw,t</sub> =	[[49]24	[]]]][]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]]		
G <sub>t</sub> =	LINN			
G <sub>20</sub> ° <sub>C</sub> =	//1494	/////		
Average G <sub>20</sub> ° <sub>C</sub> =	2.7	2		
_				
Formulas: Weight of flask & water @ test temp	o., g = M <sub>pw,t</sub>	$= M_p + (V_p)$	X P <sub>w,t</sub> )	
Specific gravity of soil @ test temp. = G	$t = M_s / (M_{pw})$	,t - (M <sub>pws,t</sub> -	M <sub>s</sub> ))	
Specific gravity of soil @ 2	0°C = K X	Gt		
Visual Classification: Clay (CL), Brown				
Percent passing No. 4 sieve: 100	Vee		N.	V
Was any soil or material excluded from the specimen?	Yes		NO	X
Remarks:				
Technician AT O I II	٨T	~	h a alva al I	1.00
recnnician: AI Computed by:	AI	C	пескей ру:	LKC
		Revised 8/	8/11	

ERDC TR-18-1



# ENG 1 MAY 63 2087



SPECIFIC GRA	VITY OF SC	DILS		
ASTM	D 854			
	SEI#2		Data	04/18/12
Project: Non-Nuclear Gauge			Date.	04/10/12
The transaction of the second se				
Method A:	Method B:	Х		
Boring	sc	1		
Location:		/1		
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 <sub>p</sub> ):	//////	////////		
Average calibrated volume of flask, ml, (Vp):	////////	/ 1494 74		
Weight of flask, water, & soil @ test temp., g, (M <sub>pws,t</sub> ):	730.17	729.98		
Density of water @ test temp., g/ml, (Table 1, (P <sub>w,t</sub> )):	<u>                                     </u>	<u>                                     </u>		
Temp. coefficient, (Table 1 (K)) :	/ & & & & & & & & & & & & & & & & & & &	/ 1/.96992		
M <sub>pw,t</sub> =	<u> </u>	<u>[[]]]%</u>	ЩЦ	
G <sub>t</sub> =	////X	HAA		
$G_{20}C_{c} =$	///////	//////		
Average G <sub>20</sub> ° <sub>C</sub> =	2.7	71		
E I Mainht of flools 9 water @ toot torr		- • • • • •		
Formulas: Weight of flask & water @ test tem	$p_{.}, g = w_{pw,t}$	$= IVI_p + (V_p)$	$X P_{w,t}$	
Specific gravity of soli @ test temp. = 0	$pt = IVI_s / (IVI_{pw})$	,t - (IVI <sub>pws,t</sub> -	IVI <sub>s</sub> ))	
Specific gravity of soil @ 2	$20^{\circ}C = K X$	G <sub>t</sub>		
Visual Classification: Clavey Sand (SC) Reddish Brown				
Percent passing No. 4 sieve: 100				
Was any soil or material excluded from the specimen?	Yes		No	Х
Description of soil or material excluded:	•			
Remarks <sup>.</sup>				
Technician: AT Computed by:	AT	С	hecked by:	LRC
			0/4.4	
	1	Revised 8/	5/11	

B.4 CH-2



ENG 1 MAY 63 2087



Checked By: LRC

SPECIFIC GRAV	VITY OF SC	DILS		
ASTM	D 854			
	SEI # 1		Date:	1/18/12
Project: Non-Nuclear Gauge			Dale.	4/10/12
holi halioa oddgo				
Method A:	Method B:	Х		
Boring	CH	-12		
Location:	01	12		
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 <sub>n</sub> ):	1/168/89	//xAA	/////	
Average calibrated volume of flask, ml, (Vp):	1/489/34	1/498/53		
Weight of flask, water, & soil @ test temp., g, (M <sub>pws.t</sub> ):	721.02	719.89		
Density of water @ test temp., g/ml, (Table 1, (P <sub>w.t</sub> )):	1 K /SB /SB	/ /\/.96\$3/3	//////	
Temp_coefficient_(Table 1 (K))		11/1668/5		
	11.1.2.14	117777		
M <sub>pw,t</sub> =	// 68/39	//&1/2/2/		
G <sub>t</sub> =	111/1.15	11/250	/////	
$G_{20}^{\circ}C =$	/// / / / / /	11/14.10		
Average G <sub>20°C</sub> =	2.7	76		
				<b>i</b>
Formulas: Weight of flask & water @ test tem	p., g = M <sub>pw.</sub>	$_{t} = M_{p} + (V_{p})$	X P <sub>w.t</sub> )	
Specific gravity of soil @ test temp. = G	$St = M_s / (M_{pw})$	<sub>v.t</sub> - (M <sub>pws.t</sub> -	M <sub>s</sub> ))	
Specific gravity of soil @ 2	20°C = K X	Gt		
		- (		
Visual Classification: Clay (CH), Gray				
Percent passing No. 4 sieve: 100				
Was any soil or material excluded from the specimen?	Yes		No	Х
Description of soil or material excluded:				
Remarks:				
Technician: AT Computed by:	AT	С	hecked by:	LRC
		Device - 1 04	0/4.4	
		Revised 8/	8/11	

B.5 SC-2



ENG FORM 2087



Tested By: CEC\LDD

Checked By: LRC

SPECIFIC GRA	VITY OF SC	DILS		
ASTM	D 854			
FLASK	SET # 2		Dete	04/10/10
Project: Non-Nuclear Gauge			Date.	04/16/12
Method A:	Method B:	Х		
Boring	SC	22		
Location:	30	2		
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 <sub>p</sub> ):	//////	/////23		
Average calibrated volume of flask, ml, (Vp):	T [ A99.42	[ [ A\$\$ #3		
Weight of flask, water, & soil @ test temp., g, (M <sub>pws,t</sub> ):	728.90	714.75		
Density of water @ test temp., g/ml, (Table 1, (P <sub>w,t</sub> )):	1 \$ \$ \$ 17	/ / / / / / / / /		
Temp. coefficient, (Table 1 (K)) :	/ 15/15/19/12	/ 1.96999		
M <sub>pw,t</sub> =	[[\$14:54]	[[44]24]		
G <sub>t</sub> =	1/12/99	////		
G <sub>20</sub> ° <sub>C</sub> =	///7489	//////		
Average G <sub>20</sub> ° <sub>C</sub> =	2.6	69		
		M . 0/	V D \	
Formulas: Weight of flask & water @ test tem	$p_{i}, g = M_{pw,f}$	$t = IM_p + (V_p)$	XP <sub>w,t</sub> )	
Specific gravity of soil @ test temp. = 0	$it = M_s/(M_{pw})$	<sub>/,t</sub> - (IVI <sub>pws,t</sub> -	M <sub>s</sub> ))	
Specific gravity of soil @ 2	20°C = K X	Gt		
Visual Classification: Clayov Sand (SC) Boddish Brown				
Percent passing No. 4 sieve: 100				
Was any soil or material excluded from the specimen?	Yes		No	Х
Description of soil or material excluded:	•			
Pomarka				
Technician: AT Computed by:	AT	С	hecked by:	LRC
			0///	
		Revised 8/	8/11	

B.6 CH-3



ENG FORM 2087



Tested By: <u>CEC\LDD</u> Checked By: <u>LRC</u>

B.7 CL-3



ENG 1 MAY 63 2087



Checked By: LRC

SPECIFIC GRA	VITY OF SC	DILS		
ASTM	D 854			
FLASK	SET#1		Data	1/10/10
Project: Non-Nuclear Gauge			Date:	4/10/12
Toject. Non-Nuclear Gauge				
Method A:	Method B:	Х		
Boring	CI	3		
Location	01	.5		
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 <sub>p</sub> ):	//////////	//x64,490	/////	
Average calibrated volume of flask, ml, (Vp):	1/49/29	1 1490 F7	11111	
Weight of flask, water, & soil @ test temp., g, (M <sub>pws,t</sub> ):	727.00	726.91		
Density of water @ test temp., g/ml, (Table 1, (P <sub>w,t</sub> )):	/ K/S\$\$}\$	/ ///////	/////	
Temp. coefficient, (Table 1 (K)) :	//.566/2	Theben	1////	
M <sub>pw,t</sub> =	////////	/ /\$K\$ #\$		
G <sub>t</sub> =	TTAA	//////		
G <sub>20</sub> ° <sub>C</sub> =	//////	//////		
Average G <sub>20</sub> ° <sub>C</sub> =	2.7	70		
Formulas: Weight of flask & water @ test tem	p., g = M <sub>pw,t</sub>	$= M_p + (V_p)$	XP <sub>w,t</sub> )	
Specific gravity of soil @ test temp. = G	$St = M_s / (M_{pw})$	,t - (M <sub>pws,t</sub> -	M <sub>s</sub> ))	
Specific gravity of soil @ 2	20°C = K X	Gt		
Visual Classification: Clay (CL), Brown				
Percent passing No. 4 sieve: 100	Vee		Na	V
Description of soil or material excluded from the specimen?	res		INO	<u>×</u>
Remarks:				
Technician: AT Computed by	۸T	~	hookod bu	L PC
Computed by:	AI	C C	necked by:	LRU
		Revised 8/	8/11	

# **B.8 CH-ERDC**



ENG FORM 2087



SPECIFIC GRA	VITY OF SC D 854	DILS		
FLASK	SET # 2			
WORK ORDER NO. MD1812			Date:	4/25/12
Project: <u>Non-Nuclear Gauge</u>				
Method A:	Method B:	Х		
Boring:	CH-E	RDC		
Location:				
Sample No.:				
Flask No.:	12	16		
Weight dry soil after test, g, (M <sub>s</sub> ) :	76.77	70.35		
Test temp., °C:	20.5	20.5		
Average calibrated weight of flask, g, (M <sub>p</sub> ):	[[]]]	[[]]		
Average calibrated volume of flask, ml, (Vp):	[ [ ASY 50]	1 149 24		<i><u> </u></i>
Weight of flask, water, & soil @ test temp., g, (M <sub>pws,t</sub> ):	722.14	722.43		
Density of water @ test temp., g/ml, (Table 1, (P <sub>w,t</sub> )):	11111	1 1499919		
Temp. coefficient, (Table 1 (K)) :	/ \$ \$ \$ \$ \$	/ <u> </u>		
M <sub>pw,t</sub> =	[[\$1]4]	[[kt/k]		
G <sub>t</sub> =	/////////	//////		
G <sub>20</sub> ° <sub>C</sub> =	///#198	/////		
Average G <sub>20</sub> ° <sub>C</sub> =	2.7	76		
Formulas: Weight of flask & water @ test tem	p., g = M <sub>pw,t</sub>	$t = M_p + (V_p)$	XP <sub>w,t</sub> )	
Specific gravity of soil @ test temp. = G	$\Theta t = M_s / (M_{pw})$	,t - (M <sub>pws,t</sub> -	M <sub>s</sub> ))	
Specific gravity of soil @ 2	20°C = K X	Gt		
		-		
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	С	hecked by:	LRC
		Revised 8/	, 8/11	

**B.9** MH



ENG FORM 2087



Checked By: LRC
SPECIFIC GRA	VITY OF SO	ILS		
ASTM	D 854			
FLASK	SET # 1			
WORK ORDER NO. MD1812	-		Date:	4/18/12
Project: Non-Nuclear Gauge				
Method A:	Method B:	x		
Boring:	MH	4		
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 <sub>p</sub> ):	//1%25%	//x64,490	/////	
Average calibrated volume of flask, ml, (Vp):	<i>[ A\$</i> 938	1 / 498 AZ		
Weight of flask, water, & soil @ test temp., g, (M <sub>pws,t</sub> ):	694.64	693.63		
Density of water @ test temp., g/ml, (Table 1, (P <sub>w,t</sub> )):	/ KARASA	[K/\$\$\$}}	//////	
Temp, coefficient, (Table 1 (K));	/ Koles	15666	11111	
	///////			
M <sub>pw,t</sub> =	//k#/\$X	/ /\$K\$ #\$		
G <sub>t</sub> =	111/158	11/239	//////	
$G_{20}^{\circ}C =$	111 hts	11/158	11111	
Average $G_{20}^{\circ}C_{C}$ =	2.5	8		
Formulas: Weight of flask & water @ test tem	np., $g = M_{pw,t}$	$= M_p + (V_p)$	X P <sub>w,t</sub> )	
Specific gravity of soil @ test temp. = 0	$Gt = M_s / (M_{pw})$	t - (M <sub>pws.t</sub> -	(M <sub>s</sub> ))	
Specific gravity of soil @	20°C = K X (	G,		
		l.		
Visual Classification: Silt (MH), Gray				
Percent passing No. 4 sieve: 100				
Was any soil or material excluded from the specimen?	Yes		No	Х
Description of soil or material excluded:				
Remarks <sup>.</sup>				
Nomano.				
Technician: AT Computed by:	AT	С	hecked by:	LRC
		Revised 8/	8/11	

**B.10 ML** 



ENG 1 MAY 63 2087



SPECIFIC GRA	VITY OF SC	DILS		
FLASK	SET # 2			
WORK ORDER NO. MD1812			Date:	04/18/12
Project: Non-Nuclear Gauge	-			
Method A:	Method B:	Х		
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 <sub>p</sub> ):	////	///////		
Average calibrated volume of flask, ml, (Vp):	11 AAAAA	1149479	/////	
Weight of flask, water, & soil @ test temp., g, (M <sub>pws,t</sub> ):	727.51	721.23		
Density of water @ test temp., g/ml, (Table 1, (P <sub>w.t</sub> )):	[]\$\$\$K\$	/ / / / / / / / /	1/////	
Temp. coefficient. (Table 1 (K))	1 desta	These	1////	
	///////	111111		
M <sub>pw,t</sub> =	//xk/s/	/ / / / / / /	//////	V/////
G, =	TTAR	TTHA		
$G_{20}^{\circ}C_{\circ} =$	11/11	TTKK	11111	
Average $G_{20}^{\circ}$ =	2	75		
Formulas: Weight of flask & water @ test ten	np., g = M <sub>nw</sub>	$= M_n + (V_n)$	X P.,	
Specific gravity of soil @ test temp. = 0	$Gt = M_a/(M_{ex})$		M_))	
Specific gravity of soil @	20°C = K X	G.		
opeone gravity of son @	20 0 - 11 1	<b>U</b> t		
Visual Classification: Silt (ML), Brown				
Percent passing No. 4 sieve: 100				
Was any soil or material excluded from the specimen?	Yes		No	Х
Description of soil or material excluded:				
Demoder				
Remarks:				
	ΔΤ	С	hecked by:	LRC
Lechnician: AI Computed by:	<b>A</b> 1			
Technician: AT Computed by:		-	,	



### B.11 SP



SPECIFIC GR	AVITY OF SC	DILS		
AST	M D 854			
FLAS	K SET # 1		Dete	4/40/40
WORK ORDER NO. MD1812	_		Date	4/18/12
Floject. Non-Nuclear Gauge				
Method A:	Method B:	Х		
Boring		D		
Location:	. 3			
Sample No	.:			
Flask No	.: 37	40		
Weight dry soil after test, g, (M <sub>s</sub> )	: 100.89	108.88		
Test temp., °C	2: 19.6	19.6		
Average calibrated weight of flask, g, $(M_p$		1/10/4/47		
Average calibrated volume of flask, ml, (Vp	): <b>[ [ ABY 34</b> ]	[[4\$\$ A¥		
Weight of flask, water, & soil @ test temp., g, (M <sub>pws,t</sub>	): 738.84	740.96		
Density of water @ test temp., g/ml, (Table 1, (P <sub>w,t</sub> )	):	///////////////////////////////////////		
Temp. coefficient, (Table 1 (K))	: 1.0000	///////////////////////////////////////		
M <sub>pw,t</sub>	= ////////	///////////////////////////////////////		
G <sub>t</sub>	=	////#		
G <sub>20</sub> ° <sub>C</sub>	=	/////		
Average G <sub>20</sub> ° <sub>C</sub>	= 2.6	67		
				<b>·</b>
Formulas: Weight of flask & water @ test te	mp., $g = M_{pw,t}$	$= M_p + (V_p)$	X P <sub>w,t</sub> )	
Specific gravity of soil @ test temp. =	$Gt = M_s / (M_{pw})$	<sub>,t</sub> - (M <sub>pws,t</sub> -	(M <sub>s</sub> ))	
Specific gravity of soil @	Ø 20°C = K X	Gt		
Visual Classification: Sand (SP), Brown				
Percent passing No. 4 sieve: 100	Vec		No	V
Description of soil or material excluded	Tes			<u> </u>
Remarks:				
Technician: AT Computed by	<i>ι</i> : ΔΤ	0	hecked by	LRC
			neoneu by	
		Daviaged 0/	0/11	
Technician: AT Computed by	/: <u>AT</u>	C Revised 8/	hecked by	LRC

## B.12 SM

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



ENG 1 MAY 63 2087



SPECIFIC GRA		DILS		
ASTM	D 854			
FLASK	SET # 1			
WORK ORDER NO. MD1812			Date:	4/18/12
Project: Non-Nuclear Gauge				
Method A:	Method B:	Х		
Boring:	ML (	SM)		
Location:				
Sample No.:				
Flask No.:	12	16		
Weight dry soil after test, g, (M <sub>s</sub> ) :	94.04	98.34		
Test temp., °C:	19.7	19.7		
Average calibrated weight of flask, g, (M <sub>p</sub> ):	114114	1/11/14/14		
Average calibrated volume of flask, ml, (Vp):	<u> </u>	[]498/57		
Weight of flask, water, & soil @ test temp., g, (M <sub>pws,t</sub> ):	725.22	733.71		
Density of water @ test temp., g/ml, (Table 1, (P <sub>w,t</sub> )):	/ ///////	[N:99\$]]		
Temp. coefficient, (Table 1 (K)) :	1.6666	///////////////////////////////////////		
M <sub>pw,t</sub> =	////	///////////////////////////////////////		
G <sub>t</sub> =	TTAN	/////		
G <sub>20</sub> ° <sub>C</sub> =	///////	11/154		
Average G <sub>20</sub> ° <sub>C</sub> =	2.7	'1		
Formulas: Weight of flask & water @ test ten	np., g = M <sub>pw,t</sub>	$= M_p + (V_p)$	X P <sub>w,t</sub> )	
Specific gravity of soil @ test temp. = 0	$Gt = M_s / (M_{pw})$	.t - (M <sub>pws,t</sub> -	M <sub>s</sub> ))	
Specific gravity of soil @	20°C = K X	Gt		
Visual Classification: Silty Sand (SM), Brown				
Percent passing No. 4 sieve: 100				
Was any soil or material excluded from the specimen?	Yes		No	Х
Description of soil or material excluded:				
Remarks <sup>.</sup>				
Technician: AT Computed by:	AT	С	hecked by:	LRC
		Deviced Of	0/4.4	
		Revised 8/	8/11	

ERDC TR-18-1



ENG 1 MAY 63 2087



SPECIFIC GRAV	ITY OF SC	DILS		
ASTM I FLASK S	D 854 SFT # 1			
WORK ORDER NO. MD1812			Date:	4/18/12
Project: Non-Nuclear Gauge				
Method A:	Method B:	Х		
Boring:	SP-	SC		
Location:				
Sample No.:				
Flask No.:	20	25		
Weight dry soil after test, g, (M <sub>s</sub> ) :	96.41	97.77		
Test temp., °C:	19.5	19.6		
Average calibrated weight of flask, g, (M <sub>p</sub> ):	///////////////////////////////////////	// 166/90		
Average calibrated volume of flask, ml, (Vp):	[ 149324	[]499574		
Weight of flask, water, & soil @ test temp., g, (M <sub>pws,t</sub> ):	730.42	728.40		
Density of water @ test temp., g/ml, (Table 1, (P <sub>w,t</sub> )):	/ N/9\$\$}\$}	/\!\%		
Temp. coefficient, (Table 1 (K)) :	1.56540	/1/26/28		
M <sub>pw,t</sub> =	/ 644.34	//64//64		
G <sub>t</sub> =	////	////2%9		
G <sub>20</sub> ° <sub>C</sub> =	///2/68	/////%	//////	
Average G <sub>20</sub> ° <sub>C</sub> =	2.6	58		
E				
Formulas: Weight of flask & water @ test temp	o., g = M <sub>pw,t</sub>	$= M_p + (V_p)$	X P <sub>w,t</sub> )	
Specific gravity of soil @ test temp. = G	$t = M_s / (M_{pw})$	,t - (M <sub>pws,t</sub> -	M <sub>s</sub> ))	
Specific gravity of soil @ 2	0°C = K X	Gt		
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	С	hecked by:	LRC
		Revised 9/	R/11	
		Neviseu 6/	ווזכ	

# **B.14** Limestone



FNG FORM 2087



,		LIQUID	AND PLASTIC LI	MIT TEST DATA		5/11/2010
Client: Err Project: N Project Nu	nest Berney on-Nuclear gage stu Imber: MD1910A	dy				
Location:	Limestone					
Material D	escription: Silt (ML	.), Gray				
			Liquid Limit E	Data		
		100H-1		and a second	and the second	
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		
16.3 16.1 15.9 15.7 15.5 15.3 15.1 14.9 14.7 14.5 14.3					Liqu Plast Plasticit	id Limit= <u>15</u> ic Limit= <u>12</u> by Index= <u>3</u>
<b>ر</b>	6 / 8 9 10	Blows	25 30 40 Plastic Limit D	Pata		an a
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				Ĩ
			CEERD-GS-	E		×

,		LIQUID	AND PLASTIC LI	MIT TEST DATA		5/11/2010
Client: Erne	est Berney					
Project: No	n-Nuclear gage stu	dy				
Project Nun	nber: MD1910A					
Location: L	imestone					
Material De	scription: Silt (MI	) Grav				
inatorial De	Sonption: Sht (MI	2), Olay	Liquid Limit F	ala		and the second second
		1				
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		
# Disus	16.63	16.69	16.72	15.44		-
# DIOWS	15.7	24	29	32		
woisture	15.7	15.1	14.8	14.6		L;
16.3					Liqu	id Limit= 15
16.1					Place	ic Limit= 12
15.9					Plastici	hy Index= 3
					Flastici	ly muex-
15.7		1				
15.5						
ture						
si 15.3						
15.1			2			
14.9			3			
14.7						
14.5			4			
14.5						
14.3	5 7 8 9 10	20	25 30 40			
		Blows				
			Plastic Limit D	ata		
Run No	1	2	3	4		
Wet+Tare	30.28	28.85				
Dry+Tare	28 70	20.05			the selection of the se	
Tare	14.91	15 39				
Moisture	11.5	11.6				
moloturo	11.5	11.0		I		
			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						Percen	t Passing A	verage	°		°		
Number	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
	RSAK-V	Vet											
Sieve						Percen	t Passing A	verage					
Number	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
	RSAK-D	ry											
Sieve						Percen	t Passing A	verage					
Number	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. in the

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# DIVI.16:6635-98-CL-EVEME 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

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 Automoive Command, ATTN: DRSTA-MB, Warren, MI 48090. A reply will be furnished direct to you.

Section 1 Introduction II HAND RECEIPT

Page

#### **SECTION I INTRODUCTION**

i

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 11 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 pre-paration 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 ere 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.

	10							HAP	ID RECE	IPT NU	MBER		
For use of this form, see DA PA The proponent agency is ODCS	M 710-2-1. 20G.												
FOR END ITEM STOCK NUMBER	END ITEM DESCRIPTION TEST SET SOIL	PUBLICATION NUMBER SC 6635-98-CL	-E02-	HR		РUВЦК 19	APR	B2	ou	ANTITY			
				SFC		OTY	8.		QUAN	TTY			
STOCK NUMBER	ITEM DESCRIPTION		e.	d.	<i>e</i> .	AUTH J.			c	D	E	۴	
3820-01-115-9858	ADAPTER, AUGER, BIT: 1 in. dia shaft	DAPTER, AUGER, BIT: 1 in. dia shaft											
6635-01-088-6391	ADAPTER, PENETROMETER: attach CL-700	DAPTER, PENETROMETER: attach CL-700											
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 cl	osure 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						$\vdash$	
8020-00-260-1306	BRUSH, VARNISH: 1 in. nom stock w.		X	U	EA	2						$\vdash$	
8020-00-260-1364	BRUSH, VARNISH: 2 in. nom stock w.		x	U	EA	2						┡	
7920-00-282-9246	BRUSH, WIRE, SCRATHC: 10.50 in. max	o/a lg, steel	X	U	EA	3						$\vdash$	
6810-00-815-4727	CALCIUM CARBIDE, REAGENT: granular f	orm; 1 1b per pkg	x	U	LB	12						L	
7420-01-083-9311	CALCULATING MACHINE: 10 digit, ac or	CALCULATING MACHINE: 10 digit, ac or battery operate									L	L	
8110-00-178-8292	CAN, FRICTION TOP: 1 gallon capacity	, rnd steel cover	x	U	EA	5						L	
WHEN USED AS A     HAND RECEIPT, enter Hand Re	rceipt Annex Number												
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Current as of 19 April 1982

	SC 6635-98-CL-E02-HR TEST SET SUIL			_							_
STOCK NUMBER	ITEM DESCRIPTION		SEC	UI	AUTH	8.		QUA	YINY		-
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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	L	<u> </u>				
5110-00-585-8428	CHISEL, BUTT, WOODWORKING: tang type, plastic handle	D	М	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	ย	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 1g;	D	U	EA	6						
5110-00-239-7556	FILE, HAND: American pattern; Three sq type, 8 in.1g	D	м	EA	1						
5110-00-241-9138	FILE, HAND: Mill; single smooth cut face, 10 in. 1g	D	м	EA	1						
6635-00-933-0559	SROOVING 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						
Revenue of DA Form 2062	Current as of 19 April 1702							AGE _	O#	8	PAGE

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6635	5-00-559-3147	HOLD	ER, 1	INDIC	ATOR I	DIAL:	adjust	able,	w/perma	nent	x	U	EA	4						
6630	-00-514-5535	HYDR	OMETS	ER, G	RADUA	TED SC	CALE: d	ensit	scale,	glass	D	U	EA	1						
5210	)-00-243-9649	INDI	CATOP	R DIA	AL: ad,	justab	ole dia	l set	ting, pl	unger	D	м	EA	4						
5120	0-00-188-1788	JACK	, HYD	DRAUL	.1С, Н	AND: 2	20 tons	load	capacit	у	N	M	EA	2						
7340	-00-291-0625	KNIF	E, S1	TEAK,	SCIM	ITAR:	carbon	stee	1, 10 in	. 1g blad	×	U	EA	2						
7530	0-00-286-6165	LABE	L: pa	aper,	, gumm	ed, wa	ater so	luble			x	U	BX	5						
5210	0-00-277-2430	LEVE	LAN	D PLU	JMB: a	luminu	um, dou	ble f	ace, non	adjustabl	2	м	EA	۱						
6675	-00-880-1820	LEVE	iL, SU	URVEY	ING:	locato	ors, ha	nd, r	nd cross	sect.6 i	x	U	EA	1						
6630	0-01-083-5537	METE	R pH:	: por	table	, batt	tery op	erate	t		D	U	EA	1						
6640	-01-106-7753	MIXE	R, EL	LECTR	RIC LA	BORATO	ORY: 11	0 v, i	ac or dc	current	D	U	£A	1						
6640	-00-531-6347	MORT	AR AN	ND PE	STLE:	porce	elain,	ungla	zed grin	ding	x	U	EA	1						
6640	-00-811-4429	OVEN	, LAE	BORAT	ORY:	gravit	ty conv	ectio	n, steel	door	D	U	EA	1						
7240	-00-137-1609	PAIL	, UTI	ILITY	: pla	stic,	3 gall	on ca	pacity		X	U	EA	20						
6635	-00-786-8032	PAN,	CEME	ENT:	steel	, 19 g	jauge				x	U	EA	4						
7330	-00-655-5257	PAN,	PAN, PUDDING: aluminum, 3 guart							x	U	EA	10							
6635	-00-526-9119	PAN, TEST SIEVE: brass, rnd, 8 in. dia;								x	IJ	EA	h							
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STOCK NUMBER	ITEM DESCRIPTION	*	SEC	u	AUTH	8		004			
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6640-00-252-5200	PAPER, FILTER: quantitative; 100 per box	X	U	HU	-			_			
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. 1g	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. 1g 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						
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6635	-00-526-6187	SIEV	E, TE	ST: rnd	l, brass	frame,	Size	No. 80		x	U	EA	1					$\Box$	
6635	j-00-641-3583	SIEV	E, TE	ST: rnd	l, brass	frame,	Size	No. 60		X	U	EA	1						
6635	j-00-641-7367	SIEV	E, TE	ST: rnd	l, brass	frame,	Size	No. 50,	297 micr	x	U	EA	1						
6635	-00-641-3582	SIEV	E, TE	ST: rnd	l, brass	frame,	Size	No. 40,	420 micr	x	U	EA	2						
6635	-00-641-7353	SIEV	E, TE	ST: rnd	. brass	frame,	Size	No. 30,	590 micr	X	U	EA	1						
6635	-00-641-7354	SIEV	E, TE	ST: rnd	l, brass	frame,	Size	No. 20		x	U	EA	1						
6635	-00-641-7355	SIEV	E, TE	ST: rnd	l, brass	frame,	Size	No. 16		x	υ	EA	1						
6635	-00-641-3591	SIEV	E, TE	ST: rnd	, brass	frame,	Size	No. 10		x	U	EA	1						
6635	-00-641-7364	SIEV	E, TE	ST: rnd	, brass	frame,	Size	No. 8		x	U	EA	1						
6635	-01-105-6844	SIEV	E, TE	ST: rnd	, brass	frame,	Size	No. 200		x	U	EA	2						
6635	-01-105-6843	SIEV	E, TE	ST: rnd	, brass	frame,	Size	No. 40		x	U	EA	2						
6635	-00-641-7357	SIEVE	E, TE	ST: rnd	, brass	frame,	Size I	No. 4		x	U	EA	3						
6635	-00-641-7358	SIEVE	E, TE	ST: rnd	, brass	frame,	Size I	No. 3		x	U	EA	1						
6635	-00-641-7361	SIEVE	E, TE	ST: rnd	, brass	frame,	Size 3	3/4 in.		x	U	EA	1						
6635	-00-641-7350	SIEVE	E, TE	ST: rnd	, brass	frame,	Size	1 in.		X	U	EA	1						
6635	6635-00-641-3596 SIEVE, TEST: rnd, brass frame. Size 1-1/2 in								x	U	EA	1							
* WHEN	WHEN USED AS A     HAND RECEIPT, enter Hand Recipit Annex Number     HAND RECEIPT FOR QUARTERS FURNITURE, enter Condition Codes     HAND RECEIPT ANNEX/COMPONENTS RECEIPT, enter Accounting Requirements Code (ARC)																		

DA FORM 2062

SC 6635-98-CL-E02-HR

TEST SET SOIL

STOCK NUMBER	ITEM DESCRIPTION		SEC		OTY	8.					
	b.	* 6	d.	e.	ſ.	•	•	C	D	E	F
6635-00-514-4149	SIEVE, TEST: rnd, brass frame, Size No. 2 in.	x	U	EA	1						
7520-00-868-4734	SLIDE RULE: Single face, plastic body	x	U	EA	1						
6810-00-597-5287	SODIUM HEXAMETAPHOSPHATE, TECHINCAL: granular or flak	еX	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. 1g	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	МХ	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	м	EA	1						
5210-00-245-0301	TAPE, MEASURING: 78.75 in. measuring capacity, pull	D	м	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	м	EA	1						

Reverse of DA Form 2062

Current as of 19 April 1982

PAGE 6 OF 8 PAGES

EDITION OF JAN 58 IS OBSOLETE. Current as of 19 April 1982

HAND RECEIPT/ANNEX N						H/	AND REC	EIPT N	UMBER			
For use of this form, see DA PA The proponent agency is ODCS	M 710-2-1. 1 0G											
FOR END ITEM STOCK NUMBER	END ITEM DESCRIPTION	PUBLICATION NUMBER				PUBL	CATION	DATE	OK	JANTITY		
ONLY 0035-00-041-3043	TEST SET SOIL	SC 6635-98-0	L-E02	2-HR	'	19	APR	82	1			
STOCK NUMBER	ITEM DESCRIPTION	• /	*	SEC	u	AUTH	1	T.	0.00	ATTEN T	<u> </u>	τ.
6635-00-679-5761	DENETROMETER: soil, cir ba		r n	<i>a.</i>	- FA	Ľ,	ŕ	H	C I	+°	ť	ŀ
6635-00-679-5762	REMOLDING SET, SOIL COMPACT	TION	D	U	EA	1	$\vdash$		-	$\vdash$	$\vdash$	$\vdash$
6635-00-679-5764	SAMPLER, SOIL	101.	D	U	EA	1		$\square$				
5120-00-287-2504	SCREWDRIVER, FLAT TIP: plas	stic handle, 5 in. 1g	D	M	EA	1					$\square$	
5120-00-187-7124	WRENCH, OPEN END: steel		D	M	EA	2					$\Box$	
5120-00-277-1483	WRENCH PIPE: fron, 6 in. is	J	D	M	EA	1		Ē.			$\Box$	
5120-00-288-8746	WRENCH, SPANNER: steel		D	M	EA	1					$\Box$	
6635-00-807-3717	TESTER, SOIL DENSITY, SAND METH	OD: brass or steel	x	U	EA	3					$\Box$	
6685-01-088-0548	THERMOMETER, SELF-INDICATING, L	IQUID IN GLASS:	X	U	EA	1	$\Box$				$\Box$	
6640-00-444-8000	TONGS, LABORATORY: crucible, do	uble bent, (96906)	x	U	EA	1	$\Box$	$\Box$		$\Box$	$\Box'$	
5140-01-018-2719	TOOL BOX, PORTABLE: 2 tray		D	м	EA	1					$\Box$	
7210-00-243-1019	TOWEL, HAND: cotton, huck weave	·	X	м	EA	12	$\Box$				$\Box'$	
6675-00-190-5867	TRIANGLE, DRAFTING: plastic, ri	ght angle; 30 deg-60	X	U	EA	1		$\Box$			$\Box'$	
6675-00-190-5862	TRIANGLE, DRAFTING: plastic, ri	ght angle; 45 deg,8in	X	U	EA	1	$\Box$				$\Box$	
5120-00-223-9477	TROWEL: pointer unit		D	м	EA	2	$\Box$	$\Box$			$\Box$	
4020-00-243-3155	TWINE, FIBROUS: cotton, cable 1	ay			$\Box$	$\Box$	$\Box$	$\Box$	$\Box$	$\Box$	$\Box$	
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)     PAGE 7 OF 9 PAGES												

DA FORM 2062

EDITION OF JAN SE IS OBSOLETE. Current as of 19 April 1982

SC 6635-98-CL-E02-HR TEST SET SOIL

U AI/H & OUANTITY QUANTITY STOCK NUMBER ITEM DESCRIPTION SEC \* 6. **b**. F 40 D U EA WEIGHT, CALIFORNIA BEARING TEST LEAD: 5 1b. 6635-00-371-9702 D M EA 1 5120-00-264-3796 WRENCH, ADJUSTABLE: single head 2 D M EA 5120-00-277-1477 WRENCH PIPE: adjustable jaw

Revenue of DA Form 2062

MGE 8 OF 8 MGES

By Order of the Secretary of the Army:



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Official: ROBERT M. JOYCE Brigadier General, United States Army The Adjutant General E. C. MEYER General, United States Army Chief of Staff

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				5c.	PROGRAM ELEMENT NUMBER						
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<b>14. ABSTRACT</b> ERDC research on cr shape and size. Milit samples, according to Soils Analysis Kit (R mission. As such the similar to that used in increasing speed and types by both the trace RSAK procedure. The estimations. Revised platforms to enable d <b>15. SUBJECT TERMS</b>	ater formation from de ary Explosive Ordinar o the Unified Soil Class SAK), developed at E RSAK was changed to a commercial laborator accuracy from the ori- litional laboratory, dry the kit in its current con software to process the eployment on multiple Field const	etonation of improvised ace Disposal (EOD) tea sification System, to he RDC, was modified to rom a dry, pulverization ory to improve accurate ginal D-RSAK. This re- based and wet-based s figuration with the wet are data obtained from the software platforms.	d explosive device ams required an ex elp identify charac shrink its cube vo on-based (D-RSAk ey of determining f eport presents com systems to demons process was demon he W-RSAK equip	s identified the pedient means teristics of buri lume, improve () system to a v fines content. M parisons of class trate the streng ponstrated to sign poment was dever	significance of soil type on crater of classifying soil from small field ied explosives. The existing Rapid its accuracy, and adapt it to the EOD wet, wash-based (W-RSAK) system Modifications were focused on ssification results on 14 different soil ths and weaknesses of the new W- nificantly improve classification eloped using Matlab and Android						
Soils – classification	Soil testin Field inst	g rumentation	California bearing ratio Soil density								
Moisture content     Soils – sampling     Scientific apparatus and instruments - Evaluation											
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