

**FINAL REPORT
ENGINEERING PROPERTIES AND UTILIZATION
OF
ASH RESIDUE FROM MUNICIPAL SOLID
WASTE INCINERATORS IN
ROADWAY CONSTRUCTION**



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DISCLAIMER

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EXECUTIVE SUMMARY

Scope

The purpose of this investigation was to determine the engineering properties and study the chemical characterization of ash residue from Municipal Solid Waste Incinerator. This is a prelude to the use of ash residue in roadway construction. Thus, there are two interrelated principal objectives of this project:

- ▶ To achieve chemical fixation/stabilization of the ash residue through various chemical stabilizing agents used independently and/or in combination with cement-based and lime-based mixtures for chemical fixation.
- ▶ To study and evaluate the geotechnical properties of stabilized and unstabilized ash residue, with a view to its use in roadway construction.

The determination of geotechnical/engineering properties of the ash residue was conducted according to the American Society for Testing and Materials (ASTM) Standards as referenced in the ASTM Standard Handbook and in many soil or geotechnical engineering laboratory manuals. One purpose of conducting these tests is to compare the results obtained to that of known properties of common soil types and evaluate the ash residue for potential use(s).

Chemical characterization and analysis were performed according to the United States Environmental Protection Agency's (USEPA) Toxicity Characteristics Leaching Procedure Test(TCLP). The TCLP is designed to determine the mobility of both organic and inorganic contaminants present in the wastes. It is also meant to simulate the leaching of organic and inorganic contents in a landfill condition.

Results

Engineering/Geotechnical Properties.

The engineering properties of unstabilized ash residue suggested that ash is a material that is relatively stable and can be readily compacted to a very dense condition.

It could be classified as a well-graded sandy soil - SW in the Unified Soil Classification System (ASTM D-2487), and as a granular material - A-1 in the AASHTO classification system (ASTM D-3282; AASHTO M145). The compaction test showed that ash residue exhibits characteristics similar to a dense uniform sand with a maximum dry density of 18 kN/m^3 . The range of the coefficient of permeability - k falls within the range of fine sand (k -value ranges from $2.6 \times 10^{-4} \text{ cm/sec}$ to $4.32 \times 10^{-4} \text{ cm/sec}$), and the angle of friction - ϕ was within the range of sandy soil. These results suggest that ash is an excellent to good material for a subgrade use. Based on characteristics pertinent to Road and Runway Foundation published by the Corps of Engineers, the sand or gravelly sand that is well graded is a good material for foundation.

Similar engineering/geotechnical property tests were performed on stabilized ash residue. In general, all stabilization effort improves the engineering properties, sometimes, dramatically, when compared with the unstabilized sample.

Chemical Characterization & Stabilization.

The result of the chemical stabilization showed that ash residue contains heavy metal concentration at levels that are below the regulatory limits established by the USEPA. However, TCLP is meant to simulate leaching ability of these metals, and not to quantify the total heavy metal content. From an engineering application perspective, establishing correlation between particle size (as measured by gradation) and heavy metal concentration becomes important. The particle size (s) with higher heavy metal content can thus be screened out if the material is found to have good engineering properties. Therefore, the initial focus was on establishing correlation between particle size and heavy metal content. Results of chemical characterization are summarized below:

- There is a wide variation of heavy metal concentration level in particle sizes of the ash residue. The variability is contrary to the popular belief that concentration level increases as the specific surface area of the particle increases. That is, the smaller the particle size, the larger the specific surface area, and therefore the greater

should be the concentration level of its organic and inorganic content.

- ▶ In addition, heavy metal leaching was evaluated as a factor of leaching time to see the variation in leaching of heavy metal over time. The reason being that the USEPA recommended leaching time of 18 hours is arbitrary and since each element has different time at which it reaches equilibrium, it follows that maximum leachability of elements has to be controlled by the time at which equilibrium is reached. This investigation showed that there is a variation in the concentration level of heavy metal with leaching time.

Conclusions and Recommendations

The findings and conclusions of this investigation on the engineering utilization of ash residue from municipal waste incinerator can be summarized by the following:

1. Ash residue contains heavy metals regulated under the Resource Conservation and Recovery Act (RCRA) provision, however, none of the heavy metals exceeded the concentration level as regulated by the USEPA.
2. Unstabilized Municipal Solid Waste Incinerator Ash Residue has good to excellent geotechnical engineering property, and based on the Unified Soil Classification and AASHTO, it can possibly be used as a foundation material, as a subbase material, and because of its pozzolanic nature, it can also be used as a concrete and asphalt admixture.
3. Stabilization of ash residue improves its geotechnical properties above that of unstabilized sample, while reducing further the heavy metal leachability from the ash residue.
4. Physical stabilization with cement and lime and chemical stabilization with chemical

fixing agents - Sodium Sulfide and Sodium Phosphate improved the shear strength and permeability of the ash residue. Chemical stabilization exhibits similar behavior on the ash residue as lime stabilized ash.

5. Stabilization effort affects the leachability of the heavy metal content in the ash residue, because some stabilizing agent contained traces of heavy metal, and therefore in combination with ash residue produced an increase in some metals in the stabilized ash sample as compared with the unstabilized ash sample. However, the heavy metal concentrations were all below the USEPA regulatory limit.
6. There are definite differences in the concentration level of heavy metals leached out because of variation in leaching time. For instance, Barium consistently has a higher concentration level leached out at 12-hour than at 18-hour leaching time (18-hour being the USEPA stipulated leaching time for TCLP) over its various particle size.

From the above findings, it appears that ash residue can be used somewhat in roadway construction. However, the focus of this investigation is on the ash residue alone, and to some extent in combination with concrete and lime, but was not evaluated in combination with other construction material. The behavior of such a "composite" material might be different from the result of this investigation.

Based on the findings of this investigation, it is recommended that:

- i. A field application, evaluation and verification of ash residue as subbase material be performed. This will evaluate the field design; constructability; performance; long-term chemical leaching characteristics; evaluation of the existing test methods; and acceptance procedures (or their modification). This will be necessary to properly assess the suitability and practicability of using ash residue in roadway

construction.

- ii. For the disposal of unstabilized ash residue, the effect of ash residue with leachate from the landfill, and the potential migration of such mix from the disposal site, coupled with the risk associated with these exposure levels need further investigation.

CHAPTER I: INTRODUCTION

OBJECTIVES

The use of incineration as an MSW management option is on the increase nationally and internationally which results in more ash residue being generated. What to do with the ash residue is a major concern. Earlier studies have shown that ash residue is toxic (5), therefore it is environmentally unsafe. Therefore for ash to be effectively used, its toxicity level has to be reduced to an acceptable level without affecting the engineering/geotechnical properties of ash residue. Thus, there are two interrelated principal objectives of this project:

- ◆ To achieve chemical fixation/stabilization of the ash residue through chemical stabilization agents and/or in combination with cement-based and lime-based mixtures.
- ◆ To study and evaluate engineering properties of stabilized and unstabilized ash residue, with a view to its utilization in an engineering endeavor, namely in roadway construction.

SCOPE

The composition of the incoming waste stream determines the physical and chemical composition of ash residue produced as a by-product of the incineration process. Therefore, difference in localities and seasons might affect the composition of the raw material (here, solid waste), and may be chemical and geotechnical properties of the ash residue, also the ash residue was collected at different intervals and seasons. The scope of work was divided into two stages. In the first stage, chemical characterization of the as-received and stabilized ash residue was performed to determine its heavy metal content and its toxicity as determined by the Resource Conservation and Recovery Act(RCRA). In the second stage, geotechnical properties of as-received and stabilized ash residue was studied.

The heavy metals regulated under the RCRA provision were the ones tested for in chemical characteristics study. These were:

- ▶ Arsenic
- ▶ Barium
- ▶ Cadmium
- ▶ Chromium
- ▶ Lead
- ▶ Selenium
- ▶ Silver

The concentration level of each of these metals was then compared with the EPA regulatory limit, any concentration level that was above the regulatory limit, makes the ash residue to be classified as a hazardous material.

- The geotechnical properties tested for are:
 1. Particle size distribution, used for classification purposes
 2. Moisture Content & Maximum Dry Density
 3. Coefficient of Permeability
 4. Shear Strength
 5. California Bearing Ratio(CBR)

REPORT

This report documents the result of the tests performed, it provides an interpretation of the results and their influence on the use of ash residue in roadway construction. Conclusions and recommendations about what is needed to be done to transfer these research findings into field application were also given.

CHAPTER II: LITERATURE REVIEW

2.1: Geotechnical Properties of Ash Residue

Poran and Ahtichi-Ali (1990) extensively investigated the engineering properties of Solid Waste Incinerator Fly Ash (SWIF) to find a use for this material as a compact fill and subbase material. They found that the density of the compacted ash was lower than that of most conventional fills, which would be an advantage if the embankment was placed on soils with low bearing capacity. They reported a coefficient of permeability of 0.159 cm/s to 0.010 cm/s for this material and found it to be between results normally obtained for medium to fine sands. From their triaxial and CBR test results, they reported a cohesion and angle of friction values of 65 kPa and 43° , respectively and a California Bearing Ratio (CBR) value of 44. These results concluded that SWIF has geotechnical properties similar to soils used for subbase construction in roadways.

Poran and Ahtichi-ali also reported that their test results on stabilization of SWIF with lime was less effective compared to the results on stabilization with cement. Low permeability, high shear strength and good workability was reported for cement stabilization, and was recommended as an effective subbase and base course for pavement construction.

Tay and Goh (1993) studied the physical and chemical properties of Municipal Solid Waste Incinerator Fly Ash (MSWIF) to find a potential use for this material in construction related applications. They reported that the lower compacted density of MSWIF compared with conventional earthfill material was advantageous when used as a fill or in embankments constructed over soft and compressible ground, because this would result

in smaller foundation settlements. This conclusion agrees with the study conducted by Poran and Ahtichi-Ali for using this material as a fill material. They reported a specific gravity of the MSWIF to be 1.7 which is about 35% lower than that of sand. They concluded that this may be due to the high carbon content or that most of MSWIF was hollow. They also reported a permeability value of 1.5×10^{-5} cm/s which is in the same order of magnitude as that of fine sand. This was concluded to be an advantage over clay soils if used as a fill material. They reported that the free drainage nature of MSWIF in comparison to clay soils would enhance the rate of consolidation of MSWIF, resulting in a major portion of the foundation settlement to occur during construction.

Tay and Goh recommended the addition of MSWIF to clay samples, as this mixture showed improvements in engineering properties such as shear strength, permeability and compression. They reported improvements in shear strength value of cement and lime treated clay samples on addition of MSWIF.

A study conducted by Javier Y. Zepada (1994) on utilization of MSWIF for geotechnical application showed that ash is a granular material with irregular shape and high frictional strength. From chemical analysis, he concluded that the material was hazardous due to high concentration of heavy metals. He reported that low dry density and specific gravity values of MSWIF makes it a good material for use in fills and embankments. Further, he observed no major improvement in engineering properties of MSWIF when stabilized with lime. However, he concluded that stabilization with lime or cement could significantly reduce the leaching of heavy metals as it reduced the coefficient of permeability of the ash.

Buddhima Indraratna (1992) carried out detailed laboratory investigation to evaluate the construction potential of Mae Moh fly ash. He reported that if used in an embankment, the pozzolonic reactivity of ash residue would improve its internal stability over time. He also reported that if used as a fill material over compressible soils, settlements beneath a fly ash embankment could be effectively controlled due to the low specific gravity of ash residue. In addition, with proper curing of samples, CBR values as high as 250% could be obtained, showing the suitability of compacted fly ash in the construction of roads and airfields.

Aziz and Ramaswamy (1992) conducted a study on ash residues from Singapore to assess the feasibility of using MSWIF in road construction. They reported a specific gravity of 2.3-2.6 and a pH value of 9-10 for this material. They reported that ash residues could be used in dense bituminous mixes for road surfacing as a replacement for granitic aggregates in applications where high-quality aggregate is not required. They also reported that an admixture containing 50% - 70% of incinerator residue along with as low as 2.5 to 5% lime, would be an economical stabilization percentage for road subgrade soils.

A summary of the geotechnical properties obtained for the aforementioned research work is provided in Table 2.1, page 10. The wide variation in these results may be due to the variation in solid waste entering the incinerator, difference in combustion process and the testing procedures and technology used.

Table 2.1: Summary of Geotechnical Properties from Prior Research Effort

Engineering Property	St. Petersburg ¹	Brooklyn ²	Tuas ³	Miami ⁴	Mae Moh ⁵	Ontario ⁶	Alberta ⁷
Std. Compaction Test							
MDD, kN/m ³	17.2	13.5	12.4	13.55	13.35	11.6	11.6
OMC, %	16.5	23	34	29.1	15.5	28	18-34
Permeability, m/s	3.454×10^{-6}	10^{-5}	1.5×10^{-6}	8.89×10^{-6}	4.7×10^{-7}	$10^{-6} - 10^{-9}$	$0.05-6 \times 10^{-6}$
Triaxial Compression							
Cohesion, Kpa	40	65	0	0	700	NA	28
Angle of internal friction	45	43	45	47.5	35	35	33

1. - Used for this study 2. - Poran and Ahtichi Ali 3. - Goh and Tay

4. - Javier Y. Zepeda 5, 6, 7, - Buddhirama Indraratna

2.2: Chemical Properties of Ash Residue

Goh and Tay (1993) used a self prepared procedure for obtaining the leachate samples of Singapore Incinerator residue, to study the heavy metal concentrations. They used an atomic absorption spectrophotometer (Perkin-Elmer spectrophotometer 2280) with graphite furnace (Perkin-Elmer HGA 400) for finding the various inorganic chemical concentrations. They conducted their leachate procedure for a total period of 90 days and collected samples at different time intervals. They reported an initial pH value of 9.4 for the fly ash which further decreased to 7.2 after 28 days (identical to the potable water used for leaching). They reported that the concentrations of chemicals such as calcium, potassium and sodium were in the detectable limits but further reduced to lower levels for the samples collected after 28 days. They reported very low concentrations of heavy metals such as silica, ferrous, magnesium, zinc, and copper.

They also reported that the concentrations of chromium and cadmium of 0.2 mg/L and 0.03 mg/L, respectively, exceeded the World Health Organization (WHO) standards. However, they found concentration of these chemicals to be below the WHO limits after 28 days.

Goh and Tay reported an increase in heavy metal concentrations on stabilizing the ash with lime and cement. However, they concluded that this is due to the large amounts of cement and lime used in their tests. Based on their test results they concluded that lime and cement were two effective stabilizers if used in the right proportion.

Bagchi and Sopcich (1989) conducted bulk chemical, water leach and EP toxicity tests on four bottom ash samples obtained from the Sheboygan Incinerator. From the results of their bulk chemical and water leach tests, they reported high concentrations of aluminum, boron, cadmium, lead, and sulphate. Further, they commented that from their past experience and research (Dames and Moore, 1985), one could conclude that the field leachate concentrations of chemicals would be higher than the concentrations observed in the laboratory. Summarizing their results from the three tests conducted, they concluded that MSW incinerator ash could at times be classified as a hazardous material and is likely to contain mobile components, which if improperly managed could impact groundwater.

McKinley, Warren, Lahoti and Kandipati (1992) extensively investigated the chemical properties of municipal incinerator fly ash using - X-ray diffraction, scanning electron microscope (SEM), inductively coupled plasma atomic adsorption (ICPA) and

atomic adsorption (AA) analysis. To classify the ash, they used two processing schemes, one involving stabilization with cement in a 1:1 ratio and the other by leaching and subsequent precipitation of metals such as lead, cadmium and zinc that could be quickly and effectively accomplished in hydrochloric acid solutions. They reported successful preliminary experiments involving recovery of lead and cadmium by cementation in the presence of zinc dust. They also reported that further investigations were underway to minimize the use of zinc in these experiments and to finding a method to recover the used zinc.

Hammernik and Frantz conducted a comparative study of the amounts of heavy metals leaching from fly ash in mass-burn and refuse-derived incinerator facility. They reported that their EPTOX and TCLP tests on these fly ashes showed significant variations in the amounts of leachable aluminum, cadmium, lead magnesium, manganese and zinc. They reported that levels of leachable cadmium and lead exceeded the toxicity limits in MSW fly ashes and recommended use of safety equipment while handling this material. They also reported a study conducted by Taylor, who concluded that the concentration of trace elements was higher in MSW fly ash than in coal ash. However, he also concluded that the general concentrations of the major elements in MSW were within the ranges reported for coal ash.

CHAPTER III: MATERIALS & METHODS

I. MATERIALS

3.1 Incinerator Ash Residue

The incinerator residue was obtained from the Pinellas County Department of Solid Waste Operations, St. Petersburg, Florida. This refuse-to-energy facility was built to handle 2,100 tons of Municipal Solid Waste(MSW) per day. The combustion of solid waste in the incinerator reduces the volume of MSW by 90 percent and the weight by 70 percent, resulting in a significant extension of landfill life. This facility is one of the largest facilities in the state and has been in operation since 1983. The composition of its solid waste is given below:

Yard Waste.....	22%	Corrugated Cardboard.....	9%
Other Paper.....	14.3%	Construction & Demolition.....	12.9%
Newspaper.....	5.8%	Glass.....	2.4%
All Plastics.....	8%	Aluminium.....	0.3%
Ferrous.....	2.9%	*Other.....	22.4%

* Other includes food wastes, wood, textile, furniture and ceramics.

Source: Pinellas County Department of Solid Waste Operations

The ash residue sample was picked up in plastic drums from the facility and was kept covered throughout the testing and analysis period, to prevent the sample from absorbing or losing moisture. The sample was moist, flaky and dark grey in color. The as-received ash sample was pre-screened by the plant operator to be consistent in particle

size, even though small pieces of ferrous metals and glass were found in the ash residue.

The ash residue sample was sieved in the laboratory using the ASTM designated sieve number 4. The material retained was discarded and the material passing through was used for all testing, after which, it was oven dried at 100°C before being used for the experiment.

3.2 Cement

The cement that was used for physical stabilization was Type I, Portland cement (Broco Products, Brooksville, Florida). The quality of the cement complies with ASTM specification C-150 and Federal Specification SS-C1960 Type I. The cement was stored in a moisture resistant bag throughout the testing period.

3.3 Lime

The Lime was a High Calcium Chemical Hydrated Lime (Dravo Lime Company, Saginaw, Alabama), and was used for physical stabilization of the ash residue. It was also stored in a moisture resistant bag.

3.4 Sodium Phosphate and Sodium Sulfide

Chemical fixation of the ash residue was performed by using sodium Phosphate and sodium sulfide as fixing agents. These two were obtained in a crystalized reagent form of $\text{Na}_2\text{S} \cdot 9\text{H}_2\text{O}$ - Sodium sulfide and $\text{Na}_3\text{PO}_4 \cdot 10\text{H}_2\text{O}$ - Sodium Phosphate (Fisher Scientific, Norcross, Georgia). These two were stored in their original plastic bottle until the time and

day that the fixation was to be conducted.

METHODS

3.5 Engineering Properties

All tests were performed on the as-received ash residue sample, which is unstabilized and the stabilized ash residue sample. The tests performed for determining the geotechnical characteristics of the samples and the standard reference are given in table 3.1 below.

Table 3.1: Tests and the Standard Reference

Engineering Property	Standard Reference
Particle Size Distribution	Mechanical Sieve, ASTM D422
Specific Gravity	Specific Gravity Test, ASTM D854
Optimum Moisture Content/ Maximum Dry Density	Standard Proctor Compaction Test/ ASTM D-698-78; AASHTO T-99
Coefficient of Permeability	Falling Head Permeameter
Shear Strength	Triaxial Compression, ASTM 4767-78
California Bearing Ratio(CBR)	CBR test, ASTM D18883-87

ASTM - The American Society for Testing and Materials

3.6 Chemical Characteristics

The key to the use of ash residue in any engineering endeavor lies in the knowledge of the potential mobility of the toxic elements, since ash residue is known to

contain heavy metals. Accurate characterization of leachable contaminants in ash residue prior to its use is very important. The United States Environmental Protection Agency's (USEPA) current leaching test is known as the Toxicity Characteristics Leaching Procedure(TCLP) Test (Method 1311 - USEPA, see Appendix A for a copy of the methodology). The TCLP is designed to determine the mobility of both organic and inorganic analytes present in liquid, solid, and multiphasic wastes. The end product of TCLP procedure is a leachate extraction - an analyte. The procedure involves contacting loose ash residue(after sieving through sieve #4) with a leaching medium - TCLP fluid #1, pH = 4.9 (Miller Analytical Services, Bristol, PA) on a mechanical shaker - a 12 vessel rotary agitator apparatus (Associated Design and Manufacturing Company, Alexandria, Virginia) that rotates the extraction vessel in an end-over-end fashion at 30+/-2rpm for 18-hours. The leachate is then separated from the residue by using a Zero-Headspace Extractor Vessel (Associated Design and Manufacturing Company, Alexandria, Virginia) followed by filtration. (see appendix A for the full procedure).

The extracted leachate or analyte was delivered to the Florida Department of Environmental Protection's (DEP) Chemistry laboratory on the day of collection. DEP chemistry laboratory prepared the extracts, labelled it, assigned it a number, and have it stored. Chemical analyses for metals on the TCLP extracts was then performed at a later date. DEP laboratory provided analytical support for the chemical characterization of the unstabilized and stabilized samples using the plasma emission spectroscopy. DEP laboratory is a USEPA certified laboratory that provides chemical testing and analysis for state, federal, and local agencies as well as for private organizations. It is a well

recognized analytical laboratory. This association provided a USEPA certifiable, and verifiable chemical analysis support for the research effort.

CHAPTER IV: CHEMICAL ANALYSIS

4.1 INTRODUCTION

Ash residue from Municipal Waste Incinerators is known to contain heavy metals, and therefore, it is a toxic material. Previous chemical analysis by various researchers 1,2,3, has attempted to predict the environmental impact of leachates extracted from ash residue. In order for the ash residue to be widely accepted for use as a construction material, the nature of its heavy metal content has to be understood.

From a civil engineering applications point of view, establishing correlation(if any) between particle size of ash residue and the heavy metal concentration level becomes relevant, because it will enable the screening out of a particle size, with a higher concentration level of heavy metal. Therefore, chemical analysis was performed to identify this correlation. In addition, chemical analysis was performed on physically-stabilized ash residue. In order to verify the importance of leaching time on concentration level, different leaching time was used to supplement the 18-hr required leaching time by the USEPA method 1311. This is important because some elements in solid wastes dissolve quickly but concentration decreases with time, while others dissolve slowly and steadily on leaching, and also the times required to reach peak and equilibrium concentration are not the same for different elements. The above factors might give an erroneous concentration level of heavy metal leached at 18-hour, while at longer (or lesser) leaching time, the concentration level might change.

4.2 EXPERIMENTAL PROCEDURE

Ash residue was sieved through sieve #4, the material retained on the sieve were discarded, while the ones that passed through were used for the experiment (see section 7.1.3 in Appendix A). The sample was then oven dried for 24-hours, and a moisture content of the sample were determined and recorded. A preliminary TCLP evaluation was performed on the sample to determine (i) the percent of solids in the samples, and (ii) the appropriate extraction fluid (see section 7.1.4 in Appendix A).

The preliminary evaluation indicated that the sample was mostly solid and TCLP fluid #1, with a pH = 4.9 was the appropriate fluid for this ash residue. For the unstabilized ash residue, 100-g of the sample was used, and slowly mixed with the appropriate amount of extraction fluid #1, as determined in 7.2.11 in Appendix A in an extraction vessel - 3745-ZHE Zero Headspace Extractor (Associated Design & Manufacturing Co, Alexandria, Virginia). The extractor vessel was tightly sealed with Teflon tape (Associated Design & Manufacturing Co, Alexandria, Virginia), and secured in the 12-vessel mechanical with timer rotary agitator (Associated Design & Manufacturing Co, Alexandria, Virginia), and rotated at 30 rpm for 18-hours. The temperature of the room was maintained at 22⁰C during the extraction period.

After the 18-hour timed agitation, the sample was separated into its components- liquids and solids by filtering throughg a 1.5 liter filtration device - 3750-HWF (Associated Design & Manufacturing Co, Alexandria, Virginia), and borosilicate glass fiber filter under vaccum. The filtered liquid is known as the analyte or the TCLP extract.

The TCLP extract was then taken to the Florida Department of Environmental Protection (FDEP) Chemistry laboratory the same day the TCLP extract was obtained. On arrival at the FDEP laboratory, acid digestion was done on the extract and then stored under refrigeration until analyzed.

For unstabilized sample, the focus was on the differences in heavy metal concentration and particle size, hence, the sample were sieved, and samples were obtained from the ones retained on each sieve, these samples were then subjected to the experimental procedure outlined above.

For the stabilized sample, 100-g of ash residue was mixed with the desired percentage(ranging from 5% to 15% by weight) of the physical stabilizing agent - lime and cement before adding the desired amount of TCLP extraction fluid #1. In addition, similar extraction procedure was performed on the physical stabilizing agent - lime and cement, to determine the level of heavy metal concentration in their respective extracts.

In order to study the effect of extraction time (i.e the time in the agitator), samples from different sieves were subjected to various extraction time ranging from 12-hour to 36-hour period on the rotary agitator.

4.3 RESULTS

4.3.1 Unstabilized Ash Residue

Ash residue is known to contain heavy metals, therefore in order for it to be widely accepted for use, the nature of the heavy metal content has to be understood. From a civil engineering point of view, establishing correlation (if any) between the particle size and

heavy metal concentration becomes important. If ash residue has good engineering properties (or can be made to have), the specific particle size(s) (if those sizes contain a higher level of heavy metal) can be separated and screened out prior to using ash residue. Hence, the initial focus was not on finding out the heavy metal content of ash residue, since this has been done by many researchers in the past, but on establishing correlation between particle size and heavy metal content. The result of the heavy metal composition in unstabilized ash residue is presented in Table 4.1.

Table 4.1 : Heavy Metal Concentration of unstabilized ash residue by Particle Size distribution

Sieve #	Size(mm)	Arsenic	Barium	Cadmium	Chromium	Lead	Selenium	Silver
4	4.75	0.1	0.07	0.05	0.1	0.4	0.1	0.03
8	2.36	0.1	0.07	0.13	0.1	0.75	0.1	0.03
20	850 μ m	0.1	0.05	0.13	0.1	0.89	0.07	0.03
30	600 μ m	0.1	0.05	0.14	0.1	1.32	ND	0.03
40	425 μ m	0.1	0.05	0.17	0.1	1.24	0.1	0.03
50	300 μ m	0.1	0.05	0.18	0.1	0.93	ND	0.03
60	250 μ m	0.1	0.06	0.17	0.1	0.81	0.05	0.03
100	150 μ m	0.1	0.05	0.23	0.1	0.7	0.1	0.03
200	75 μ m	0.1	0.04	0.21	0.1	0.16	0.08	0.03
Pan		0.1	0.03	0.11	0.1	0.1	0.1	0.03
Reg. Lmt		5.0	100	1.0	5.0	5.0	1.0	5.0

All Concentration levels are in mg/l

4.3.2 Stabilized Ash Residue

Ash residue was stabilized with the physical stabilizing agent - Lime and Cement. The physical stabilization was mainly to improve the geotechnical properties of ash residue, having achieved that, the effect of the physical stabilizing agent on the leachability of heavy metal in the ash residue, and the background level contribution of these agents to

the heavy metal content of the stabilized samples was investigated. The curing time for the samples were fixed for four(4) days. Table 4.2 shows the result of heavy metal concentration for stabilized ash residue.

Table 4.2: Heavy Metal Concentration for Stabilized Ash Residue

Sample ID	Arsenic	Barium	Cadmium	Chromium	Lead	Selenium	Silver
R5LSA5A	0.1	0.413	0.02	0.1	0.1	0.2	0.12
R5LSA5B	0.1	0.262	0.02	0.1	0.1	0.2	0.12
R5LSA10A	0.1	2.36	0.02	0.1	0.53	0.2	0.12
R5LSA10B	0.1	2.12 ^a	0.02	0.1	1.11 ^a	0.2	0.12
R5LSA15A	0.1	2.38	0.02	0.1	0.79	0.2	0.12
R5LSA15B	0.1	2.41	0.02	0.1	1.23	0.2	0.12
R5ASH1	0.1	0.245	0.36	0.1	0.1	0.2	0.12
R5LIME	0.1	3.73	0.02	0.1	0.1	0.2	0.12
R6CSA5A	0.1	0.131	0.02	0.15	0.1	0.2	0.12
R6CSA5B	0.1	0.123	0.02	0.1	0.1	0.2	0.12
R6CSA10A	0.1	0.316	0.02	0.3	0.1	0.2	0.12
R6CSA10B	0.1	0.302	0.02	0.31	0.1	0.2	0.12
R6CSA15A	0.1	0.869	0.02	0.34	0.1	0.2	0.12
R5CSA15B	0.1	0.706	0.02	0.28	0.1	0.2	0.12
R6CMNT	0.1	1.22	0.02	1.08	0.1	0.2	0.12

all concentration levels are in mg/l

Notes to Table 4.2:

- (a) value reported represents the mean of more than two(2) determinations
 - all reported values of 0.1 means that value reported are below the minimum detection limit

Sample ID explanation

- * The third digit, which is either letter L or C represents the stabilizing agent; L - Lime and C - Cement
- * The sixth digit , which is number 5, 10, or 15 represents the percentage(by weight) of the stabilizing agents in the stabilized samples.
- * The last digit, which is either A or B is the designation of the laboratory at which the chemical analysis was performed. A is for FDEP chemistry laboratory, and B is for the Oak Ridge National laboratory in Oakridge, Tennessee.
- * R5ASH1 represents the unstabilized ash residue.
- * R5LIME represents the lime stabilizing agent, this is to give background metal content for lime
- * R6CMNT is for the cement stabilizing agent, and is also to give background metal content for cement.

4.3.3 Effect of Leaching time on Heavy Metal Leaching

As explained in section 4.1, in evaluating the long time environmental consequence of ash utilization, leaching ability over various extraction time is one of the main criteria for evaluation, especially, in light of the bio-availability and bio-accumulation of the leached heavy metals in plants and the ecosystem, in general.

The 18-hour leaching time is the prescribed and recommended leaching time by the USEPA Method 1311. However, this leaching time is arbitrary, therefore, heavy metal leaching was evaluated for time periods of 12-hour, 18-hour, 24-hour, and 36-hour, and the results are presented in tables 4.3 through 4.6 below.

Table 4.3: Leachability versus 12-hour Leaching Time

Sieve #	Arsenic	Barium	Cadmium	Chromium	Lead	Selenium	Silver
4	0.01	0.33	0.31	0.01	0.09	0.03	0.003
8	0.01	0.31	0.36	0.01	0.08	0.03	0.003
20	0.01	0.25	0.45	0.01	0.09	0.03	0.003
30	0.01	0.24	0.23	0.01	0.04	0.03	0.003
50	0.01	0.25	0.05	0.01	0.01	0.03	0.003
100	0.01	0.19	0.02	0.02	0.01	0.03	0.003
200	0.01	0.17	0.02	0.02	0.01	0.03	0.003
pan	0.01	0.13	0.01	0.06	0.01	0.03	0.003

Table 4.4: Leachability versus 18-hour Leaching Time

Sieve #	Arsenic	Barium	Cadmium	Chromium	Lead	Selenium	Silver
4	0.01	0.32	0.26	0.01	0.02	0.03	0.003
8	0.01	0.30	0.25	0.01	0.03	0.03	0.003
20	0.01	0.23	0.33	0.01	0.09	0.03	0.003
30	0.01	0.23	0.15	0.01	0.01	0.03	0.003
50	0.01	0.21	0.02	0.01	0.01	0.03	0.003
100	0.02	0.20	0.02	0.01	0.01	0.03	0.003
200	0.01	0.17	0.02	0.02	0.01	0.03	0.003
pan	0.01	0.13	0.01	0.06	0.01	0.03	0.003

Table 4.5: Leachability versus 24-hour Leaching Time

Sieve #	Arsenic	Barium	Cadmium	Chromium	Lead	Selenium	Silver
4	0.01	0.30	0.19	0.01	0.01	0.03	0.003
8	0.01	0.26	0.15	0.01	0.01	0.03	0.003
20	0.01	0.22	0.18	0.01	0.05	0.03	0.003
30	0.01	0.20	0.09	0.01	0.01	0.03	0.003
50	0.02	0.20	0.04	0.01	0.01	0.03	0.003
100	0.01	0.25	0.03	0.01	0.01	0.03	0.003
200	0.01	0.16	0.02	0.01	0.01	0.03	0.003
pan	0.01	0.13	0.01	0.05	0.01	0.03	0.003

Table 4.6: Leachability versus 36-hour Leaching Time

Sieve #	Arsenic	Barium	Cadmium	Chromium	Lead	Selenium	Silver
4	0.01	0.30	0.05	0.01	0.02	0.03	0.003
8	0.01	0.29	0.05	0.01	0.03	0.03	0.003
20	0.01	0.23	0.09	0.01	0.09	0.03	0.003
30	0.01	0.19	0.05	0.01	0.01	0.03	0.003
50	0.02	0.19	0.03	0.01	0.01	0.03	0.003
100	0.01	0.18	0.02	0.01	0.01	0.03	0.003
200	0.01	0.15	0.01	0.01	0.01	0.03	0.003
pan	0.01	0.12	0.01	0.03	0.01	0.03	0.003

Note for tables 4.3 through 4.6:

- The reported values have been rounded up to two digits
- All reported values are in mg/l

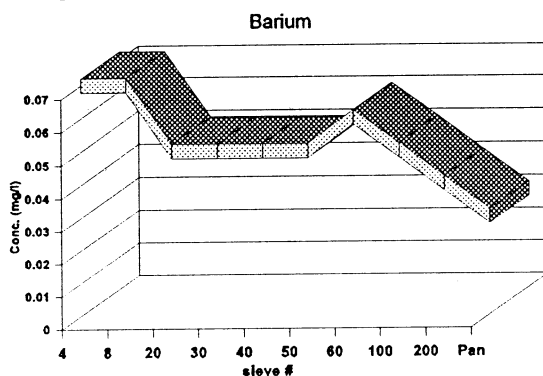
4.4 DISCUSSION AND SUMMARY

The chemical analysis of ash residue examined in this investigation showed that none of the heavy metals exceeded the regulatory limits established by the USEPA using EPA method 1311, for both unstabilized and stabilized ash residue samples.

4.4.1 Heavy metal leaching versus particle size

Table 4.1 showed that four of the seven heavy metals (Arsenic, Chromium, Selenium, and Zinc) maintain a stable concentration level irrespective of the particle size,

Fig. 4.1: Conc. level vs Particle Size



while the other three metals shows some variability in concentration level with particle size distribution. Concentration of Barium decreases as the particle size decreases; however, there is no such proportional relationship between Cadmium and Lead concentration level and particle size distribution. As indicated in the graph, Barium level tends to decrease as the particle size decreases, that is, as the particle becomes finer, the concentration level of Barium decreases, with the highest concentration level of .07mg/l at sieve #4.

Fig. 4.3: Conc. level vs. Particle size

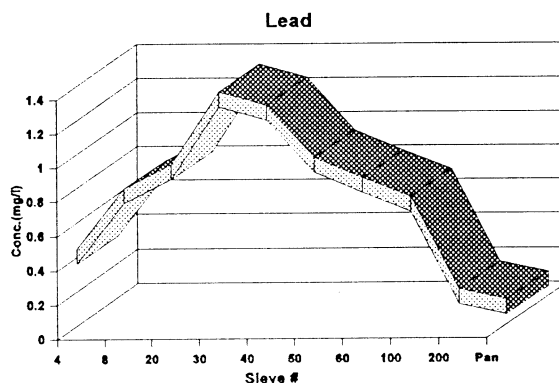
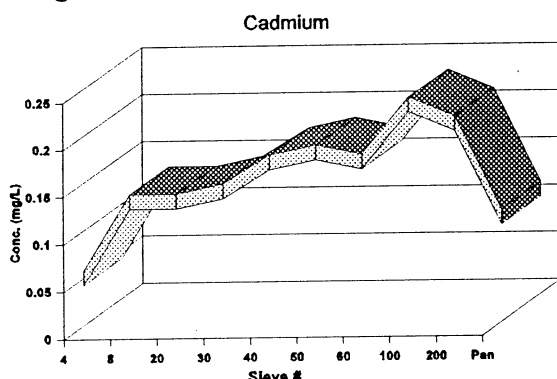


Fig. 4.2: Conc. level vs. Particle size



Lead and Cadmium exhibited a different variation, in that the concentration level shows a gradual increase until certain particle size and then decreases gradually. Lead has a maximum concentration of 1.32mg/L at sieve number 30, while

cadmium reaches its maximum concentration level 0.23mg/L at sieve number 100. The normal relationship of having a higher concentration level of heavy metals as the specific surface area of particles increase is not so, and hence represents one of the inconsistencies in the chemical composition of ash residue from MSW incinerator. As the particle size decreases, specific surface area increases, and therefore concentration level of organic and inorganic content should increase, overall, that tendency does not hold. One thing that is common to all the metals analyze, especially the ones that show variability, is that the larger the particle size, the less the concentration level(except Barium, which reaches a maximum concentration at the larger particle size).

4.4.2 Heavy Metal leaching versus Leaching Time.

The highest concentration for Barium, Lead, and Cadmium occurred at the 12-hour leaching time, therefore the concentration level recorded at the 18-hour as recommended by the EPA Method 1311 does not give an accurate indication of the amount of heavy metals that are leaching out. In which case, the concentration level would have pass its

maximum equilibrium by the 18-hour leaching time. Other observations are:

- ▶ For Lead, (figure 4.4) there is a slight difference in concentration level at 12-hour and at 18-hour leaching time, but it is not as dramatic as in Barium and Chromium. The highest concentration, at all the leaching times, is at sieve number 20, and it gradually decreases to below the detection limit over time and as particle size decreases.

Fig. 4.4: Conc. versus Leaching Time

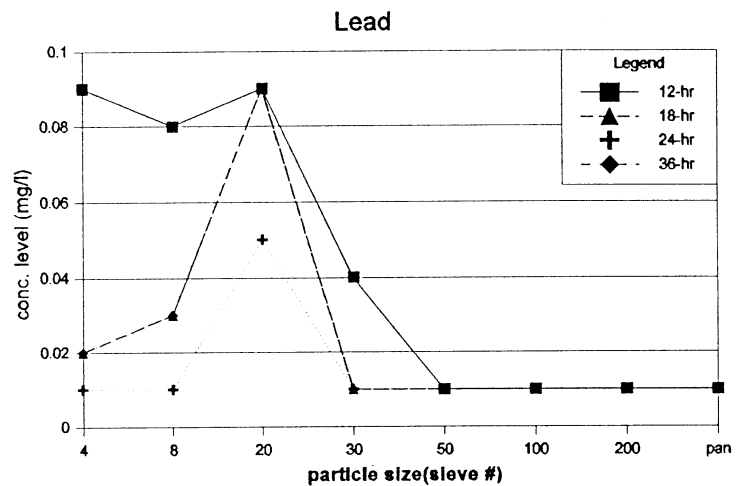
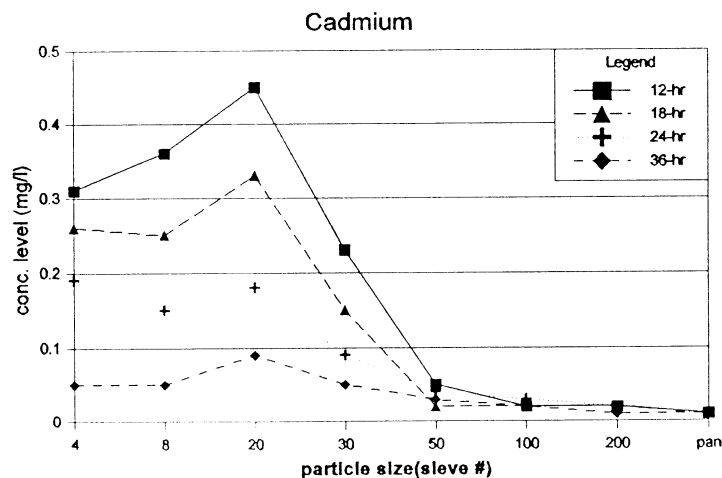


Fig. 4.5: Conc. versus Leaching Time



- ▶ Cadmium (figure 4.5) shows the same trend as lead, with the highest concentration also occurring at sieve number 20 across the different leaching time, and gradually decreases as the particle size decreases.
- ▶ Barium consistently has a higher leachability at 12-hour leaching time than at the 18-hour over different particle size. The larger the particle size, the higher the concentration level, and as the particle size decreases so does the concentration level.

Fig. 4.6: Conc. versus Leaching Time

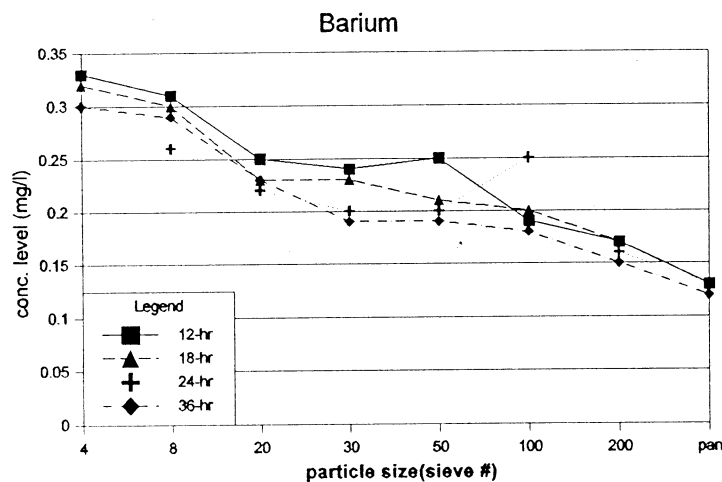
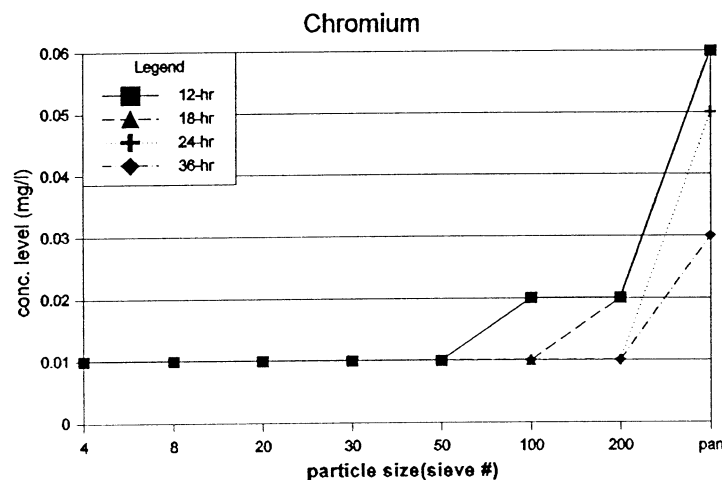


Fig. 4.7: Conc. versus Leaching Time



- Chromium (figure 4.7) follows the same pattern as Barium, in that the highest concentration occurred at the 12-hour leaching time over the particle sizes. However, concentration level of chromium increases as the particle size decreases over the different leaching period.

4.4.3 Leachability of Stabilized Ash Residue

The leachability of Stabilized Ash residue as reported in table 4.2 showed that the stabilizing agent - lime and cement have some heavy metal content, and for some heavy metals, at levels above the detectable limit. The intention was to obtain background heavy metal concentration level in lime and cement, and to compare it with the stabilized ash residue samples, especially in situations where there are increases in concentration level of heavy metals in stabilized ash residue samples. The following observations can be made on the effect of stabilization on ash residue:

- Barium concentration increases as the percentage of lime and concrete in the mix increases, at levels that are consistently above the unstabilized ash sample. It should be noted that lime and cement have a high concentration level of Barium, however, the increase in lime and cement stabilized ash is not proportional to these levels. The lowest concentration is at 5% mix ratio(by weight) for both lime and cement, however, cement stabilization produces the lower concentration (across different mix ratio) than lime. For lime, the lowest concentration occurred at 5%, increases at 10% and basically remains the same to 15% (fig. 4.8).
- Stabilization reduces the leachability of Cadmium into the environment, it also stabilizes it and makes its concentration level consistent. Lime and Cement have the same effect on Cadmium, they both produce the same amount of leachability (0.02mg/l concentration level throughout the mixing proportion).

Fig.4.8: Stabilization vs. Leachability

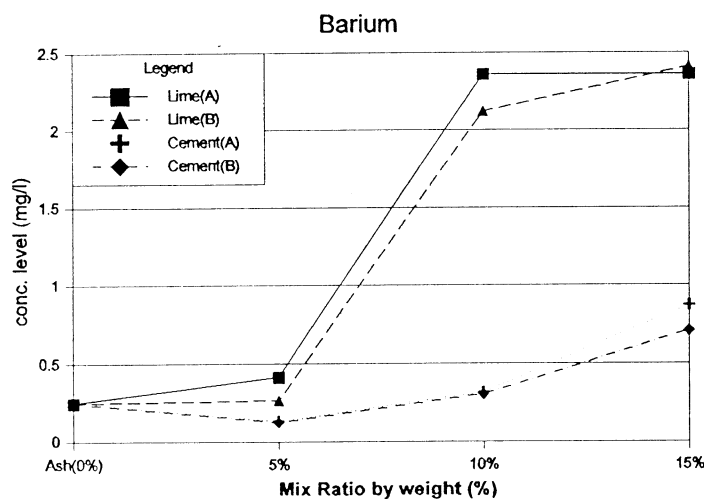
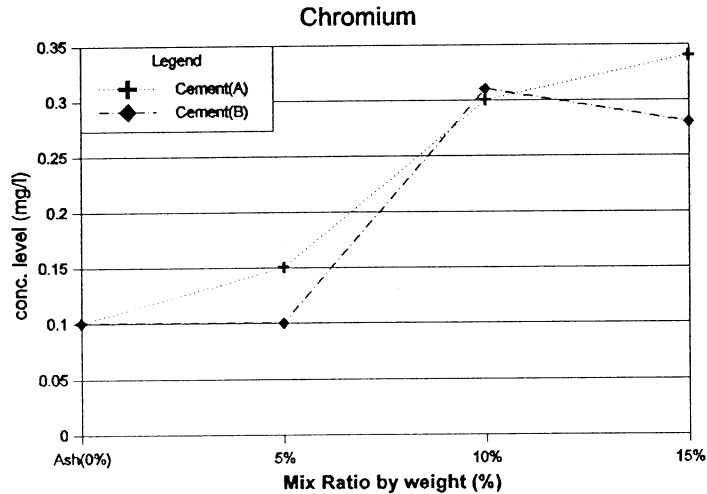
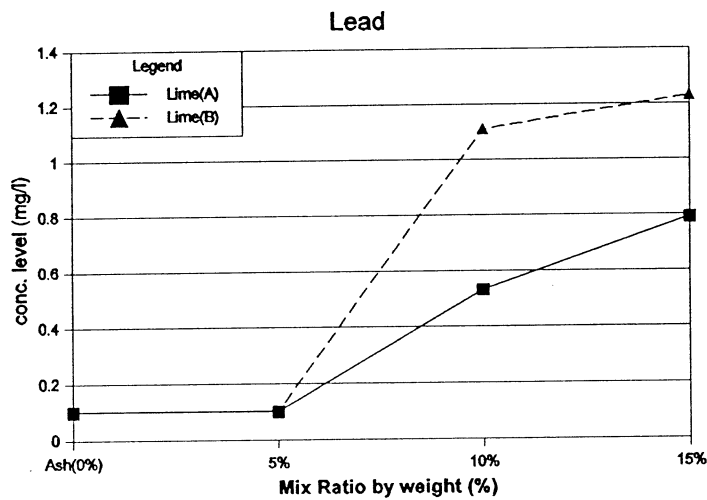


Fig.4.9: Stabilization vs. Leachability



- ▶ The effect of stabilization varies on Chromium depending on the stabilizing agent. Lime maintains the concentration level of Chromium to be consistently below the detection limit. However, stabilization by cement increases the leachability of Chromium, this might be due to the high concentration of Chromium in the cement - 1.08mg/l as compared to 0.1mg/l for lime. The maximum effect is achieved at a lower mix ratio of cement to ash, and remains the same for 10% and 15% mix ratios.

Fig 4.10:Stabilization vs. Leachability



- Cement stabilization reduces lead leachability below the detection limit while an increase in lime stabilization increases the lead leachability,(fig. 4.10) even though lead concentration level in lime stabilized samples is below the detection limit. Lime stabilized ash also has higher concentration level of heavy metals than the unstabilized ash residue.

4.5 CONCLUSION

Stabilization of ash residue, in general, reduces leachability of heavy metals, especially in Arsenic, and Cadmium to consistently below the detection limit, while it increases the leachability of lead and Chromium. While lime stabilization increases the leachability of lead and consistently keeping chromium below the detection limit, cement stabilization keeps lead consistently below detection limit and increases chromium leachability. Though, cement has a higher level of chromium in its original state.

CHAPTER V: ENGINEERING/GEOTECHNICAL PROPERTIES

5.1 INTRODUCTION

The determination of engineering/geotechnical properties of the ash residue sample was conducted according to the American Society of Testing and Materials (ASTM) standards as documented in the ASTM Handbooks. The purpose of conducting these tests, besides knowing these engineering properties, is to compare the results with the known properties of common soil types, and then to evaluate the ash sample for possible use in roadway construction.

The test for engineering properties were conducted on both the stabilized and the unstabilized ash residue samples. Two types of stabilization were performed on the ash residue samples, physical stabilization with lime and cement, and chemical fixation with Sodium phosphate and Sodium sulfide. Physical stabilization with lime and cement was cured for four(4) days. For chemical fixation, after mixing for one(1) hour to achieve a uniform and blended mix between the chemical fixing agent and the ash residue, the blended mix was then left to cure for twenty-four(24) hours prior to testing.

5.2 EXPERIMENTAL PROCEDURE

5.2.1 CLASSIFICATION AND INDEX PROPERTIES OF ASH RESIDUE

◆ Sieve and Hydrometer Analysis of Ash Residue

Mechanical sieve analysis was performed according to ASTM D422 and AASHTO T-88 procedures, respectively⁹. Two samples of the ash residue were individually sieved and average values were obtained. In both cases one kilogram sample of

ash residue was oven dried for 24 hours and the sieves were properly cleaned before use. Figure 5.1 shows the setup for used in studying the grain size distribution of the ash residue. It was observed that the ash residue contained approximately 29% gravel size particles i.e. greater than 4.76-mm sieve and less than 3% fine size particles, i.e. particles smaller than 76- μ m sieve. The coefficient of curvature (C_c) and coefficient of uniformity(C_u) were calculated using the values of $D_{10} = 0.3$, $D_{30}=1.0$ and $D_{60}=3.5$, obtained from sieve analysis. Atterberg limits tests could not be conducted due to the non plastic behavior of the ash residue.

Hydrometer analysis was performed according to the specifications of ASTM D422 and AASHTO T88-90 procedures⁹. A mixture of 50-gm of sample passing through No. 200 sieve and 4% Na_3PO_4 was prepared for conducting the test. Two tests were conducted with 1-hour and 24-hour standing periods for the soil mixture, and hydrometer readings were taken at regular time intervals for a total period of 96-hours. It was observed that the hydrometer reading remained constant after an elapsed time of 1-hour in both tests. Hence, the percent finer for the ash residue sample remained the same below a diameter of 0.0093-mm.

The results of sieve analysis and hydrometer analysis were used to classify the ash residue as follows:

1. According to the AASHTO classification system, the classification is A-1-b (gravel and sand), which suggests an excellent-to-good material for subgrade use.

2. According to the United Soil Classification System (USCS), the classification is SM (poorly graded silt sand).

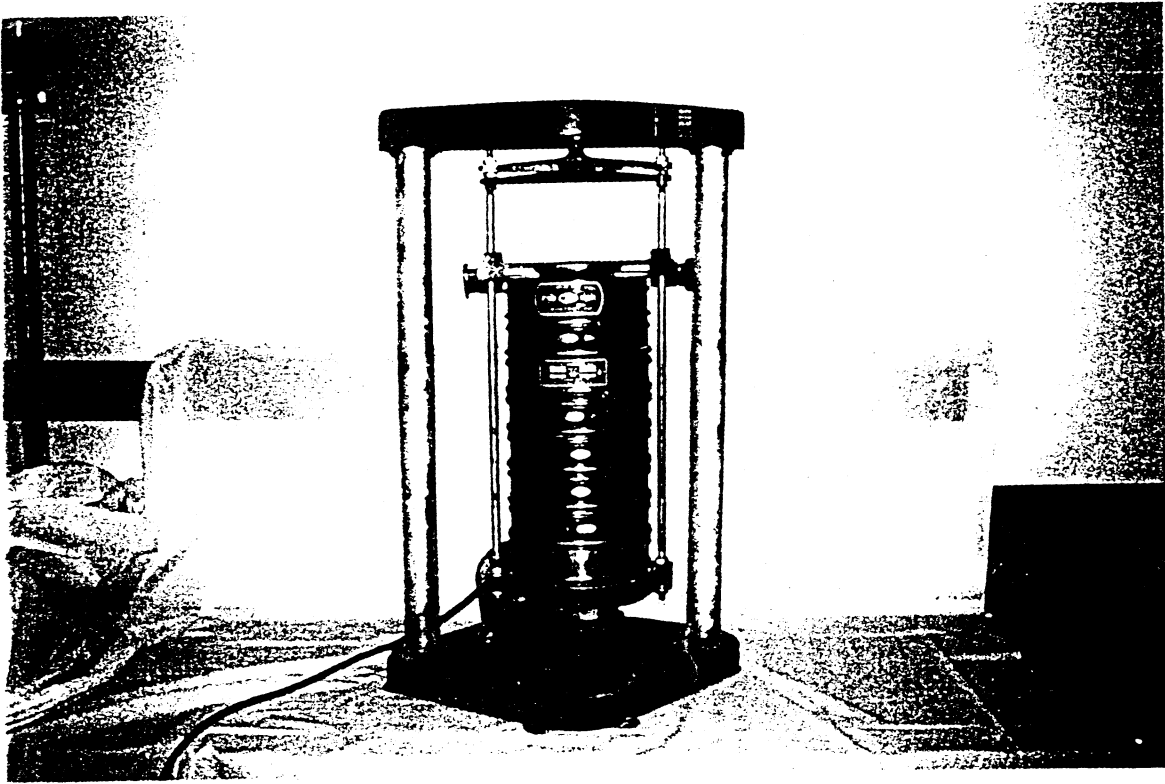


Figure 5.1 : Setup used for conducting Mechanical Sieve Analysis Test.

◆ Specific Gravity of Ash Residue

This was performed according to the ASTM D854 procedure⁹. The specific gravity of ash was found to be 2.70. This is an average of two sample tests conducted.

The specific gravity value obtained falls in the range of 2.67 -2.70, wherein the sample is classified as silty sand. Javier Y. Zepeda reported a specific gravity(Gs) value of 2.3 for Miami MSWIA, with a different grain size distribution. Poran and Ahtichi-Ali reported a value of 2.51 for MSWIAS from New York and indicated that the low value is attributed to the fact that high proportion of their ash particles were hollow. Tay and Goh reported a Gs of 2.45 for MSWIF from Singapore with 86% of fly ash particles being silty-sized and the remaining 14% sand-sized particles. The dissimilarities in the aforementioned research can be attributed to the composition of the raw material of ash - solid wastes. Table 5.1 gives the values of specific gravity and grain size distribution for St. Petersburg's MSW ash and previous research reports.

Table 5.1 Physical Properties of Incinerator Ash.

Property	Petersburg	Miami ²	New York ³	Singapore ⁴	Silty-Sand
Specific Gr.	2.7	2.3	2.51	2.45	2.67-2.7
C _u	11.67	11.42	49	4.76	
C _c	0.95	0.66	10	1.44	

2. Javier Y. Zepeda

3. Poran abd Ahtichi-Ali

4. Toy and Gay

5.2.2 Standard Proctor Test

Many of the engineering properties of ash residue, such as shrink and swell potential, compressive strength, and CBR value, permeability, and compressibility are dependent on the moisture and density at which it is compacted. Generally a high level of compaction enhances these important soil parameters of the ash. Therefore, achieving the desired degree of relative compaction necessary to meet specified or desired properties of ash is of great importance.

To obtain the optimum moisture content and maximum dry density values of the ash sample, Standard Proctor Test was performed according to the ASTM D698-78 procedure. A 944 cm³ volume mold was used for the test. The sample was compacted in three layers with 25 blows/layer using the standard 24.5 N x 0.305- m drop rammer. The sample was oven dried for 24-hours and then sieved through the No. 4 sieve before being compacted. The test was started at 10% moisture content and an increment of 2% moisture content was maintained until two more samples were obtained after reaching the maximum density. An average of seven(7) samples were used for each test. Wet samples of the ash residue at every increment of moisture content were collected in small cans and kept in the oven for 24 hours. The dry weight readings were collected the following day to calculate the moisture content.

5.2.3 Falling Head Permeameter Test

The Falling Head method was performed to determine the permeability of the ash residue. A standard compaction mold permeameter was used to compact the sample. The

sample was prepared according to the standard proctor ASTM D 698-78 procedure⁹. Two samples were compacted at optimum moisture content obtained from the standard proctor test. The sample was then soaked for 24 hours. After soaking, the mold was fitted to the permeameter device and the test was performed consistent with the falling head method. Figure 5.2 shows a setup of the falling head permeameter used in the testing. Six readings for the elapsed time of test were obtained and an average of those readings was used for calculating the coefficient of permeability. The coefficient of permeability was obtained by using the formula given below:

$$k = (aL/At) * \ln(h_1/h_2) \text{ cm/s}$$

where:

a = cross-sectional area of burette, cm^2

A = cross-sectional area of soil sample, cm^2

h_1 = hydraulic head across sample at beginning of test ($t=0$), sec.

h_2 = hydraulic head across sample at end of test ($t=t_{\text{test}}$), sec.

L = length of soil sample, cm

t = elapsed time of test, seconds

$\ln$ = logarithm to base 2.718...

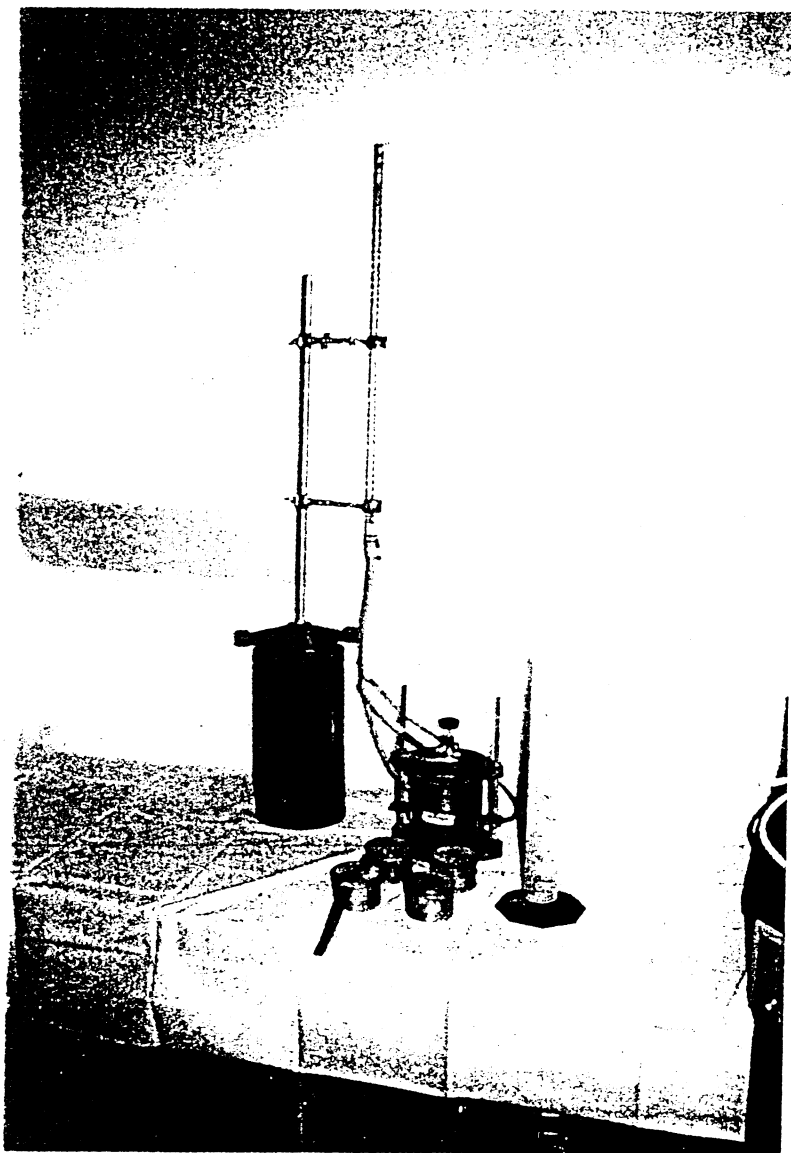


Figure 5.2: Setup of Falling Head Permeameter used for testing

5.2.4 Triaxial Compression Test

Shear strength parameters were obtained using consolidated undrained (CU) triaxial compression tests. Tests were performed according to ASTM 4767-88 procedure with unsaturated samples compacted to maximum dry density at optimum moisture content. A triaxial mold of volume 0.0327-m³ was used to prepare the samples. A 2.8-inch (70-mmm) triaxial membrane was used during the experiment. Since the volume of the mold differed from one used during the standard proctor test, the energy relation was used to compute the number of blows/layer for the mold used. The sample was compacted in three layers, the calculations used to obtain the number of blows/layer are shown below

Compaction energy for a standard proctor test =

$$\begin{aligned} &= \frac{3 \text{ layers} \& 25 \text{ blows/layer} \cdot 5.5 \text{ lb} \cdot 1 \text{ ft/lb}}{0.3333} \\ &= 12,375 \frac{\text{ft-lb}}{\text{ft}^3} \end{aligned}$$

Triaxial Mold Volume:

Diameter = 7.3cm., Height=18.5 cm.

Volume = $\pi r^2 h$ = 32692 cm³ = 0.013327 ft³.

(Conversion: 0.02832m³=35.314 ft³)

Since, the energy with which the triaxial sample needs to be compacted is the same as the compaction energy provided for a standard proctor test, the number of blows required were calculated as shown below:

$$12,375 \frac{\text{ft-lb}}{\text{ft}^3} = \frac{3 \text{ layers} \cdot \text{No. of blows/layer} \cdot 5.5 \text{ lb} \cdot 1 \text{ ft/lb}}{0.013327 \text{ ft}^3}$$

No. of blows/layer = 9.99525 $\approx$ 10 blows/layer

Series of tests were conducted at three different confined pressures in order to determine the shear strength values of apparent cohesion - C, and internal failure angle - ϕ at conditions which are likely to exist in construction applications such as in roadway construction. The setup used during the testing program is shown in Figure 5.3. The normal stresses δ_1 , δ_3 were obtained using the confined pressure and deviator stress values obtained from the equipment. Three mohr's circles were plotted on the same graph sheet for the three confined pressures and a best tangential line was drawn. The slope of the line gave the internal friction angle and the point where the tangential line cut the abscissa (Y-axis) gave the cohesion value. The calculations for the normal stresses and shear strength values are shown below:

$$\delta_n = \frac{\delta_1 + \delta_3}{2} + \frac{\delta_1 - \delta_3}{2} \cos 2\alpha$$

where, δ_n = Normal Stress (kPa)

$$\delta_2 = \delta_3 + \delta_2$$

δ_2 = Deviator Stress (kPa)

δ_3 = Confined Pressure (kPa)

$\alpha = (90+\phi)/2$ Further, a range for the shear stress can be calculated by the

formula: $\tau = \delta_n \tan \phi + C$

where τ = Shear Stress (kPa) ; ϕ = angle of friction(obtained from graph)

δ_n = Normal Stress(from graph) ; C = cohesion (from graph)

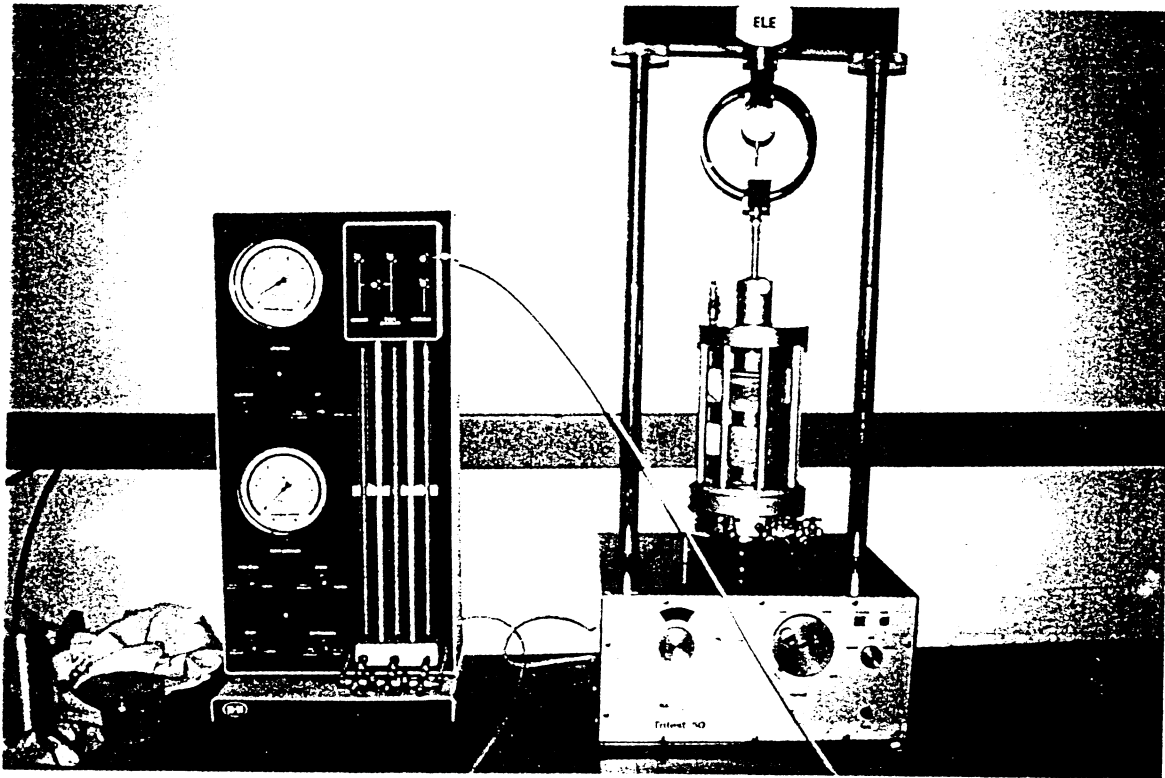


Figure 5.3: Setup used for conducting Triaxial Shear Test

5.2.5 California Bearing Ratio(CBR) Test

California bearing ratio test was conducted in order to evaluate the relative quality of ash residue as a subgrade, subbase and base material for pavement construction. The test was performed in accordance with ASTM D1883-87 procedure⁹. A mold of volume 87.63-in³ with a 2-in. high spacer disk at the bottom was used for preparing the samples. The samples were compacted in 5-layers with 56 blows/layer using a 10-lb. hammer. A surcharge of 10-lb. was used while conducting the penetration test to simulate the required overburden pressure that would exist during pavement construction. A Rainhart compression machine with a penetration rate of 1.3-mm/min. was used for the penetration test. A setup of the compaction and compression machine is shown in Figure 5.4. A 12-kg sample of ash residue was mixed at OMC to prepare two CBR molds of soil. A penetration test was conducted on the first mold immediately, except for lime stabilization. The second mold was soaked in water for 4 days to study the swell readings which would simulate a high water table condition. Samples for determination of water content were taken at required stages to obtain moisture contents at the top, middle, and bottom of the mold, and to calculate the percentage water absorbed by the sample. At the end of the soaking period, the sample was drained for 15 minutes and penetration and load readings were obtained. A percent change in value for the soaked and unsoaked samples was obtained to study the variation of CBR ratio under two different conditions. Finally, the CBR number was obtained as the ratio of unit stress of tested samples required to effect a certain depth of standard compacted specimen of soil at some water content and density, to the standard unit stress required to obtain the same depth of penetration on

a standard sample of crushed stone. CBR test on unstabilized ash sample gave CBR values of 49% and 25% for soaked and unsoaked samples, respectively. The CBR ratio in equation form is:

$$CBR\ Ratio = \left(\frac{Total\ Unit\ Stress}{Standard\ Unit\ Stress} \right) * 100$$

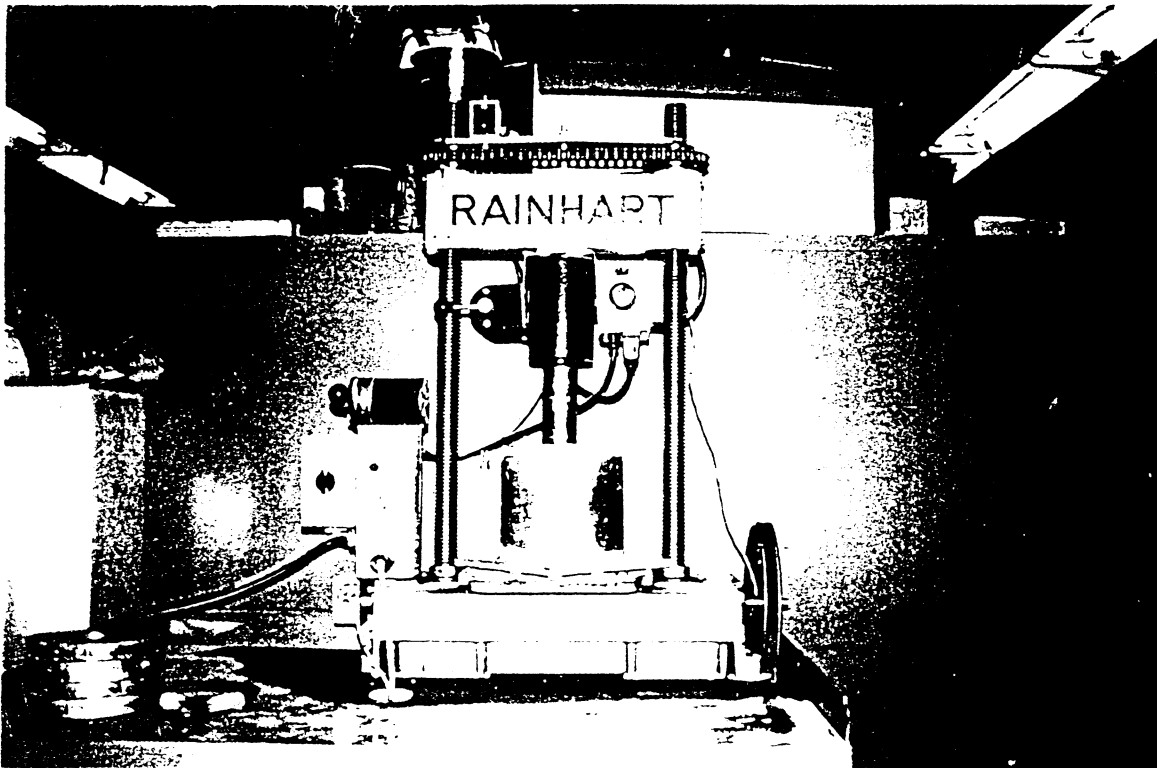


Figure 5.4: Rainhart Compression Machine used for CBR Tests

5.2.6 Stabilization of Ash Residue

- Cement and Lime Stabilization

The American Society for Testing Materials (ASTM) defines ash residue as a pozzolan, a siliceous or siliceous aluminous material. Ash residue in itself possesses little cementitious property, but, in a finely divided form and in the presence of moisture and at room temperature, reacts with calcium hydroxide to form compounds possessing cementitious properties. The pozzolanic reaction of stabilized ash residue depends mainly on such factors as amount of stabilizer (lime or cement), carbon content of ash residue and time of reaction. Lime or cement stabilization is expected to increase shear strength and reduce permeability of the ash residue, based on the similarities in its physical properties to coal fly ash. For using ash residue in constructing a compacted fill or road sub-base, reduction in its permeability after stabilizing may be a vital factor³. Hence, series of tests were conducted with cement-and lime-stabilized ash residue using five common mix ratios or 5, 10, 15, 25 and 50 percent. However, CBR tests for 25 and 50 percent were not conducted as an improving trend of CBR ratio was observed with the percent increase in stabilization.

- ◆ Lime Stabilization

Lime is a product obtained from the combustion of Calcite (CaCO_3) at a temperature of about 800°C , and will react with medium- and fine-grained soils to produce increased workability and strength. Commercially there are various types of lime available. Calcitic quicklime (CaO) and dolomite quick lime ($\text{CaO} + \text{MgO}$) are

produced by calcining calcitic and dolomitic limestone, respectively. Several reactions take place rapidly and produce immediate changes in the lime-ash mix permeability and workability. The pozzolonic reaction results in various cementing agents which tend to improve the mixture's strength and durability³.

Based on the above facts, standard proctor test, falling head permeability test, triaxial compression test and CBR test were conducted on samples of ash residue passing through No. 4 sieve after stabilizing the samples with lime at ratios of 5, 10, 15, 25, and 50 percent by weight. In the case of CBR tests for unsoaked samples, a decreasing trend of CBR value with the increase in lime stabilization was observed. However, by increasing the curing period (3, 7 and 28 days were studied) there was a corresponding increase in CBR values.

◆ Cement Stabilization:

The Portland Cement Association recommends the use of cement as a suitable material to stabilize ash residue. Portland cement type I which was used for this study is an energy-rich anhydrous tricalcium silicate (Ca_3S) with excess free lime. The cement has a large surface area of about $3000 \text{ cm}_2/\text{g}$, after hydration. This large surface area is the reason for the cementing action of the cement plate by adhesion to the adjacent surfaces. The predominant cementing compound in hydrated portland cement is calcium silicate, termed tobermorite³.

Standard proctor test, falling head permeability test, triaxial compression test and CBR test were conducted on samples of ash residue passing through No. 4 sieve after stabilizing the samples with cement at ratios of 5, 10, 15, 25, and 50 percent by weight. For the CBR test for 5 percent stabilization, extreme hardness of the sample causing difficulty in extracting the sample was noticed. Hence, CBR tests for higher stabilization percentage were not conducted. The procedures followed for the above mentioned tests were similar to the procedure used in testing unstabilized ash residue.

◆ Chemical Stabilization with Sodium Phosphate and Sodium Sulfide

The use of sodium phosphate and sodium sulfide as chemical fixing agents for heavy metal stabilization, was one of the reason for studying the effect of the chemical agents on the geotechnical properties of ash residue. Standard proctor test, falling head permeability test, triaxial compression test and CBR test were conducted on samples of ash residue passing through No. 4 sieve after stabilizing the samples with sodium phosphate and sodium sulfide at ratios of 5, 10, and 15 percent by weight. The procedures followed for the above mentioned tests were similar to the procedure used in testing unstabilized ash residue. It was observed during testing sodium phosphate stabilized ash samples, that sodium phosphate chemical behaved as a dispersing agent, thereby, drastically reducing the CBR values.

5.3 RESULTS

Grain size distribution curve is shown below in figure 5.5. The curve and the sieve analysis were used in classifying the ash residue as A-1-b, under AASHTO classification system. The results of geotechnical properties testing are summarized below in Table 5.2, copy of all tests are provided in Appendix B.

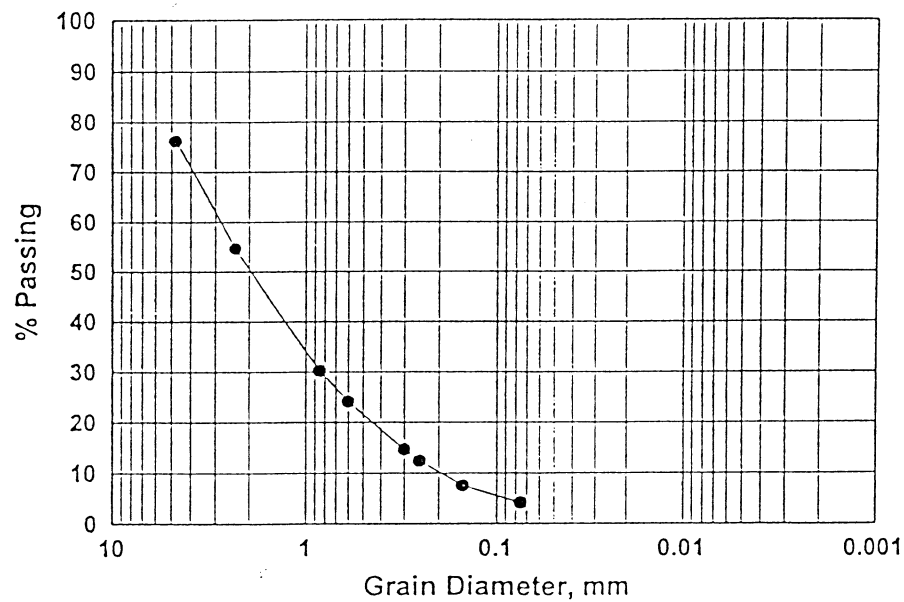


Figure 5.5: Grain Size Distribution Curve for the MSW Incinerator Ash Residue

Table 5.2: SUMMARY OF GEOTHECNICAL PROPERTIES OF STABILIZED AND UNSTABILIZED ASH RESIDUE

	OMC (%)	DRY DENSITY (kN/M ³)	PERMEABILITY (cm/sec)	SHEAR "C" (kPa)	SHEAR "φ" (degrees)	CONFINED PRESSURE TRIAXIAL (kPa)	CBR SOAKED (%)	CBR UNSOAKED (%)
UNSTABILIZED	16.5	17.2	2.588 x 10 ⁻⁴	40	45	10 30 50	18	49.5
5% LIME	17	17.4	4.55 x 10 ⁻⁵	40	48	10 20 30	44	34
10% LIME	20.3	16.55	5.28 x 10 ⁻⁶	65	50	10 20 30	41	8
15% LIME	22.8	19.3	2.87 x 10 ⁻⁶	65	45	10 20 30	22	3
25% LIME	19.6	16.0	9.87 x 10 ⁻⁷	80	45	10 20 30	ND	ND
50% LIME	24.5	14.5	7.96 x 10 ⁻⁷	100	36	10 20 30	ND	ND
5% CEMENT	17.0	16.8	3.24 x 10 ⁻⁴	60	48	10 20 30	179	55
10% CEMENT	18.4	16.62	2.39 x 10 ⁻⁴	60	48	10 20 30	ND	ND
15% CEMENT	18.25	17.4	6.57 x 10 ⁻⁵	70	51	10 20 30	ND	ND
25% CEMENT	16.6	18.1	4.915 x 10 ⁻⁵	60	50	10 20 30	ND	ND
50% CEMENT	18.0	17.7	9.47 x 10 ⁻⁶	65	45	10 20 30	ND	ND
5% SODIUM PHOSPHATE	16.2	17.8	1.06 x 10 ⁻⁵	50	51	10 20 30	3	ND
10% SODIUM PHOSPHATE	17.9	16.9	8.57 x 10 ⁻⁶	60	51	10 20 30	3	ND
15% SODIUM PHOSPHATE	21.5	15.4	5.65 x 10 ⁻⁶	65	49	10 20 30	2.3	ND
5% SODIUM SULFIDE	18.5	17.1	2.35 X 10 ⁻⁶	45	37	10 20 30	ND	ND
10% SODIUM SULFIDE	18.0	17.1	4.05 X 10 ⁻⁶	50	39	10 20 30	ND	ND
15% SODIUM SULFIDE	17.9	16.7	1.20 X 10 ⁻⁵	60	38	10 20 30	ND	ND

N.D = TEST NOT PERFORMED

5.4 DISCUSSION AND SUMMARY

Sieve analysis, specific gravity, standard compaction, coefficient of permeability, triaxial shear and California bearing ratio tests were performed on the ash residue sample obtained from the Pinellas County incinerator to study its geotechnical properties. The test procedures used in the laboratory are provided in Chapter 4. Based on the sieve analysis, the ash residue sample was classified as A-1-b, under the AASHTO classification system. A specific gravity of 2.7 was obtained for the ash residue. The results obtained from the aforementioned tests for unstabilized ash residue are provided in Appendix B. Also test results on cement, lime, sodium phosphate and sodium sulfide stabilized samples are provided in Appendix B.

The engineering properties for unstabilized ash residue were compared to the lime and cement stabilized ash residue. Physical stabilization of ash residue with cement and lime should result in decrease of the Dry Density, and an increase in shear strength. Increase in strength is caused by the cementing action. Ash residue is high in silica and alumina, therefore the addition of lime or cement, speeds the pozzolanic action. Pozzolanic action is the formation of cementitious silicates and aluminates and results in an increase of strength, especially over a long period of curing.

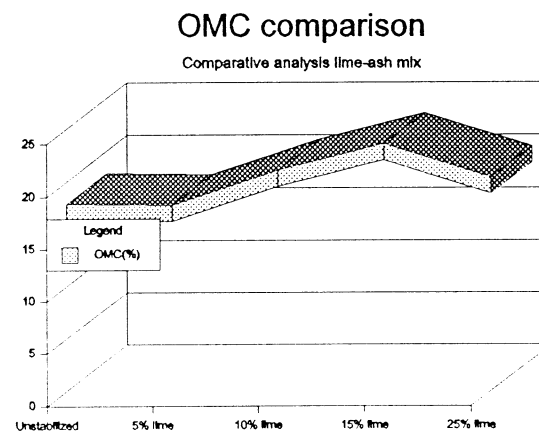
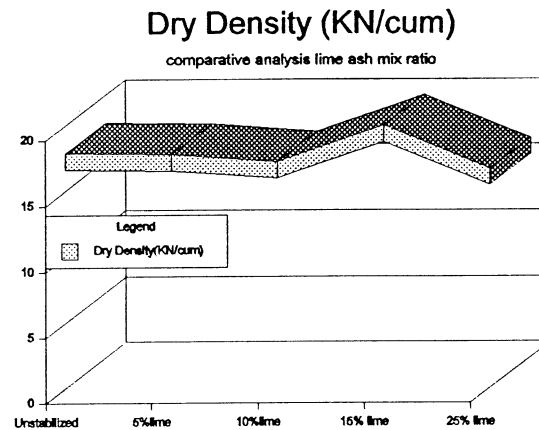
5.4.1: Engineering Properties Testing - Lime Stabilized ash residue.

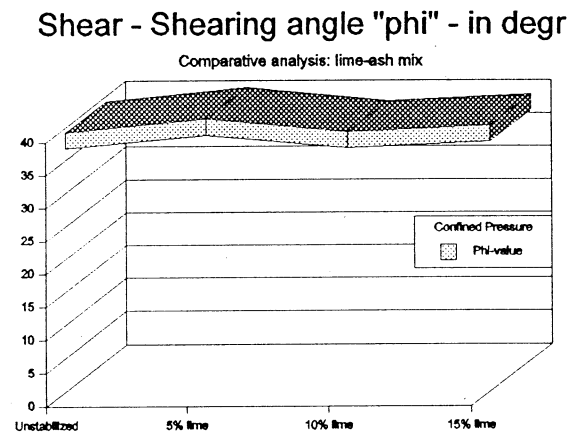
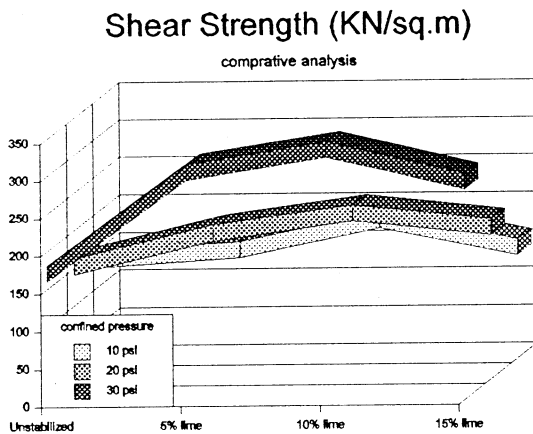
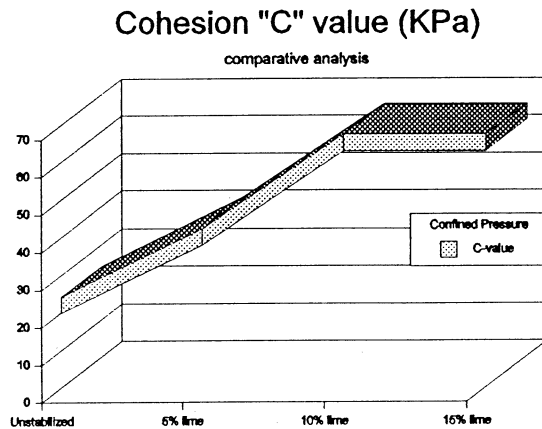
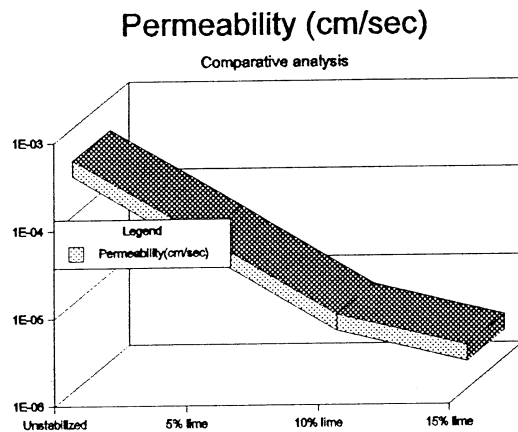
Lime stabilization initially results in slightly decreased dry density, afterwards, the dry density increases above the unstabilized ash residue to 19.3 KN/m^3 at 15% (by weight) lime to ash residue mixture. Other properties seem to improve as the ratio of lime to ash

residue increases, except shear strength.

Shear strength increases to 10% mix ratio of lime to ash residue and then declines, suggesting that *10% is the optimum mix ratio*. These changes are due to several reactions that are taking place between lime and ash residue, these are:

- ▶ The mixture of lime with ash residue results in a greater concentration of calcium ion than is actually needed, since both lime and ash residue contain calcium. The effect of this is the flocculation of the ash residue particles.
- ▶ The reaction of lime with ash residue components to form new chemicals. The two principal components of ash residue that reacts with lime are alumina and silica. This is a long term reaction and results in greater strength if lime-ash residue mixture is cured for a long period of time.

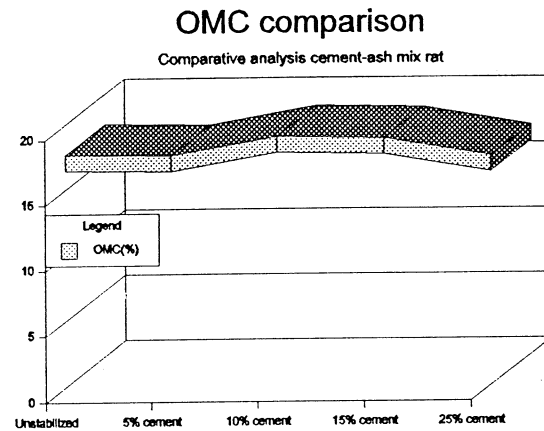
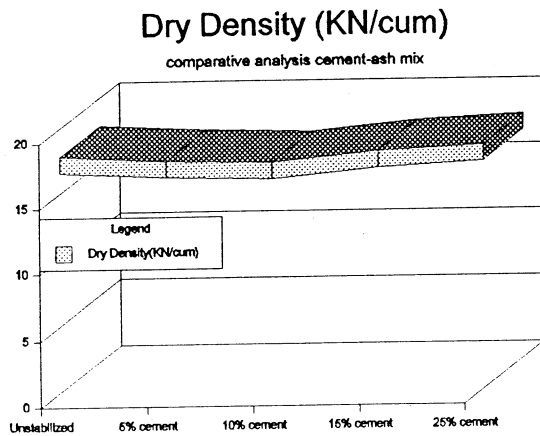




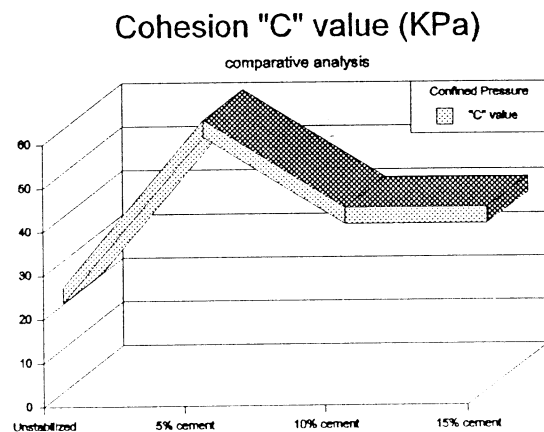
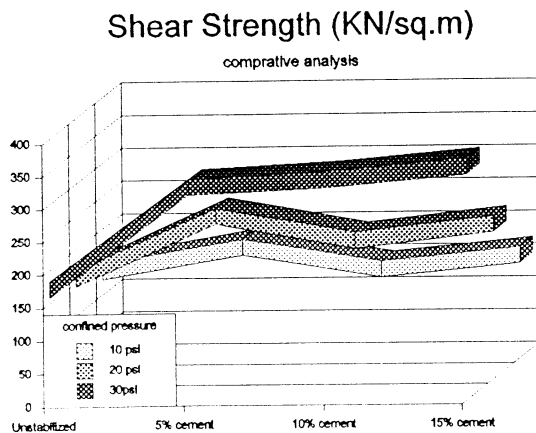
5.4.2: Engineering Properties testing - Cement Stabilized ash residue

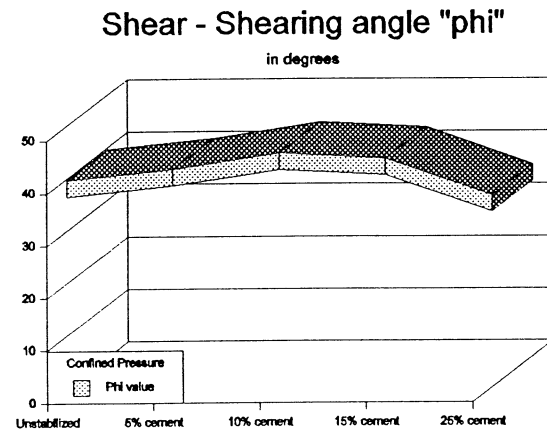
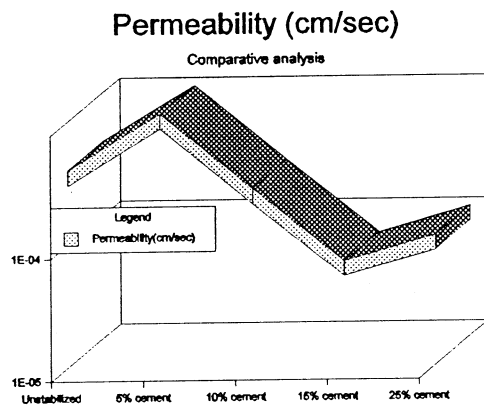
Factors affecting the properties of Ash-Cement mix include:

- ▶ quantity of the cement in the mix
- ▶ degree of mixing
- ▶ time of curing
- ▶ dry density of the compacted mix.



Dry density appears constant, while all other properties increase with the quantity of cement in the mix. Cement-Ash residue mix results in slightly decreased density when compared to the unstabilized ash, however, this is not significant in the sense that the mix, if cured in the presence of moisture (this variable is not tracked) will hydrate much as it does in concrete.

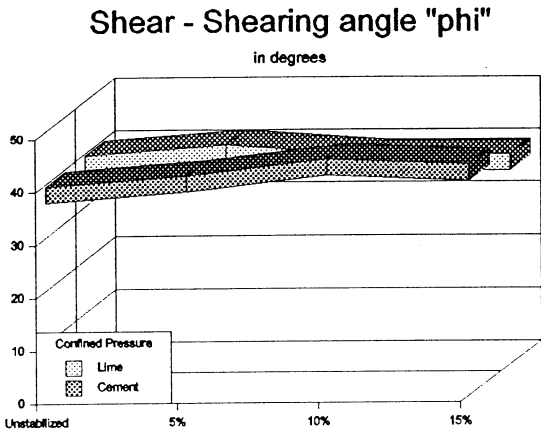
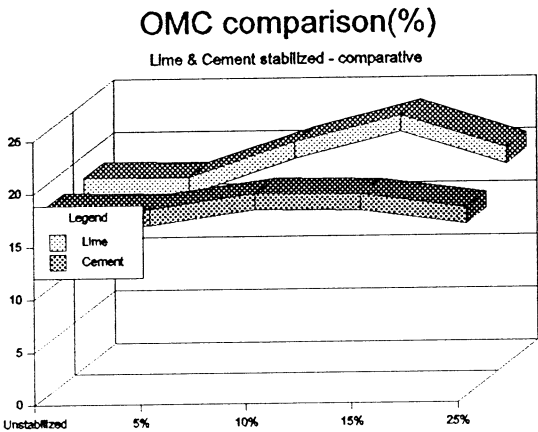




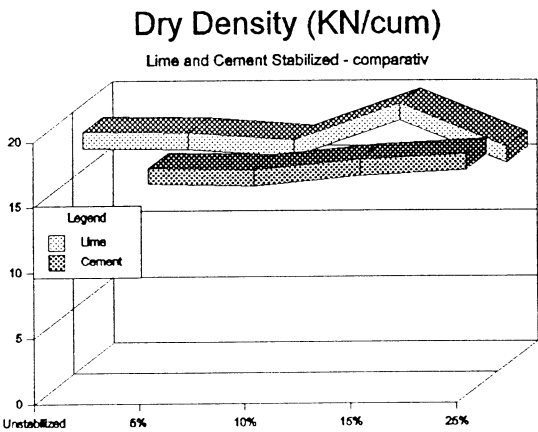
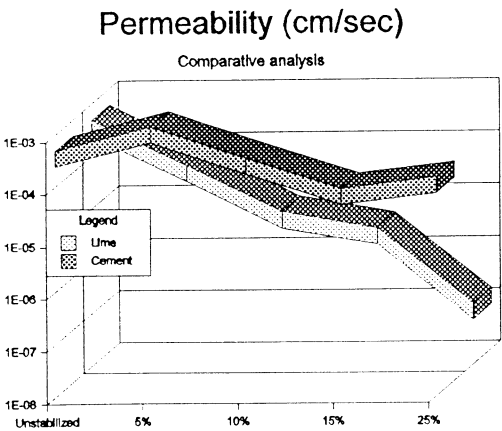
The cement-ash mix results in a hardened material, the more the cement in the mix, the harder the material. The mix can be used as a base course sometimes, such as in low cost roads of all types. The most important factor will be the period of time the compacted cement-ash is allowed to cure. Portland Cement Association has considerable amount of information on using concrete as hardening admixture. The mix ratio recommended for soil particles that have a dry density between 105lb/ft³(16.49KN/m³) and 115lb/ft³(18KN/m³) is between 9-11% by weight of cement to soil particles. This is within the range of this ash-cement mix ratio.

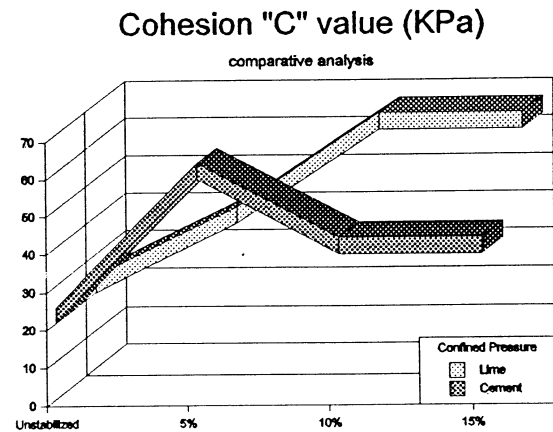
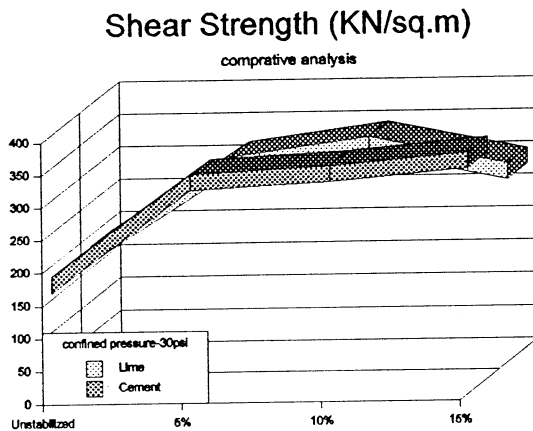
5.4.3: Engineering Properties Testing - Lime and Cement Stabilized ash residue

There is an improvement in the properties of lime stabilized ash residue over the



cement stabilized ash residue, in general terms. The shear strength is basically the same, however, the rate of strength gain during curing should improve for lime stabilized ash residue. Cement-Ash mixes should gain strength rapidly during the curing process, while the lime-ash mix should show increased strength over a relative long period of time.





5.4.4: Comparison of Results for Chemical and Physical Stabilization

From the graphs shown in pages 60 - 66, the following can be deduced on the identified geotechnical properties:

► Optimum Moisture Content (OMC)

- * There is an increase in OMC as the percentage mix ratio increases for sodium phosphate. Sodium sulfide has the highest OMC at 5% mix ratio and then decreases as the percentage of the sodium sulfide increases.
- * Lime and Sodium Phosphate are almost identical to each other in their OMC behavior, while to some extent, cement stabilized ash and sodium sulfide stabilized ash mimic one another. Cement has its highest OMC at 10% mix, and then its behavior is similar to sodium sulfide.

► Dry Density:

- * There is a gradual decrease in dry density as the percentage mix ratio

increases for sodium phosphate, but there is no significant improvement in the dry density as the percentage mix increases for sodium sulfide, and is almost unchanged from the unstabilized ash sample's dry density.

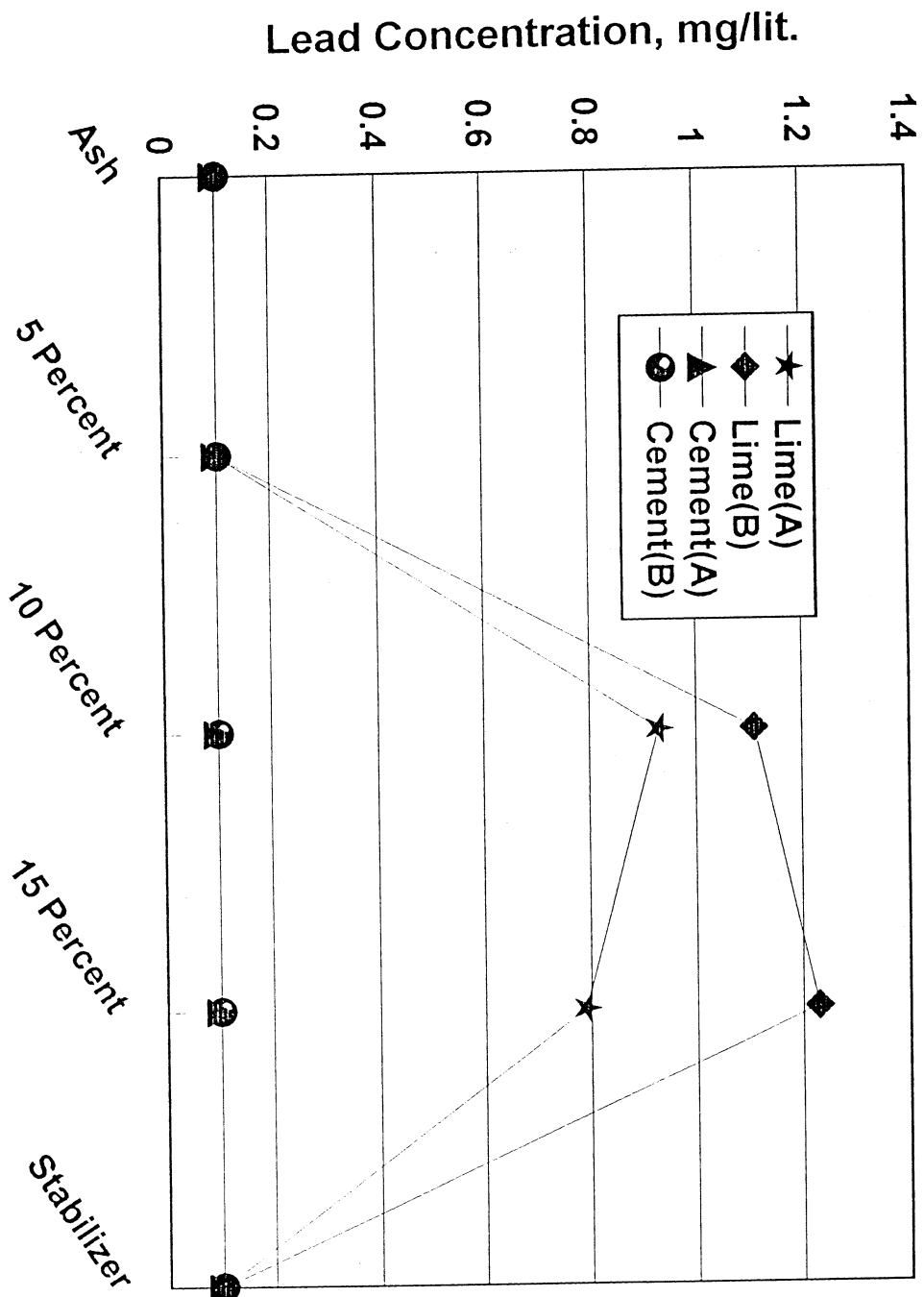
► Permeability:

- * There is a gradual improvement in permeability for all the stabilized samples, when compared with the unstabilized samples, except for cement stabilized sample. The behavior of chemical stabilization on permeability and shear strength (since these two are the primary engineering properties that will influence the application of ash in roadway construction) was one of the biggest concerns prior to conducting the study. The result showed that all chemical stabilization effort have positive impact on the permeability and on the shear strength.

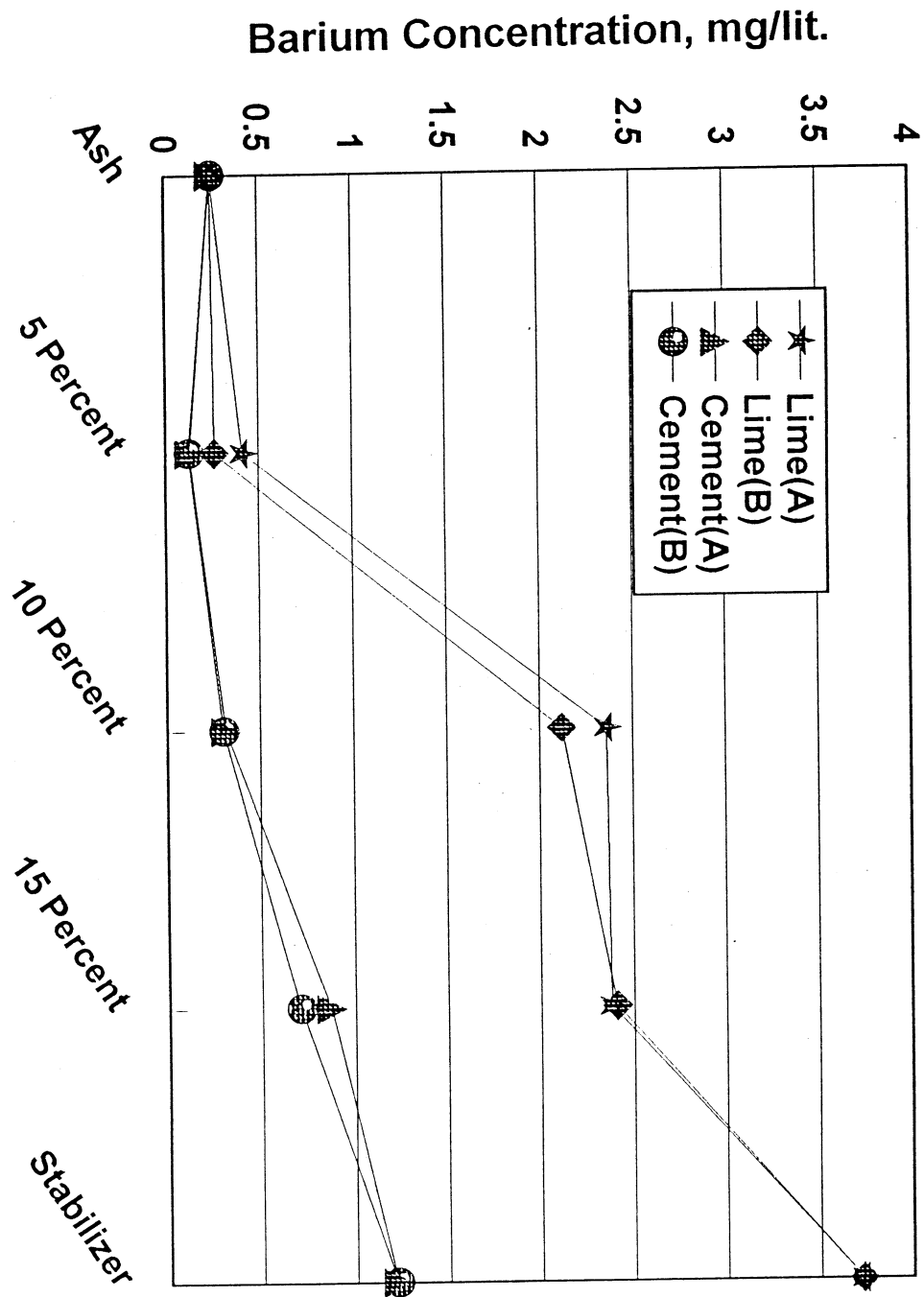
► Shear Strength

- * At 10psi confined pressure, there is an increase in shear strength as the percentage mix increases. However, at 30psi confined pressure, both sodium phosphate and sodium sulfide reaches their maximum shear strength at 10% mix ratio and then declines drastically for subsequent mix ratio.

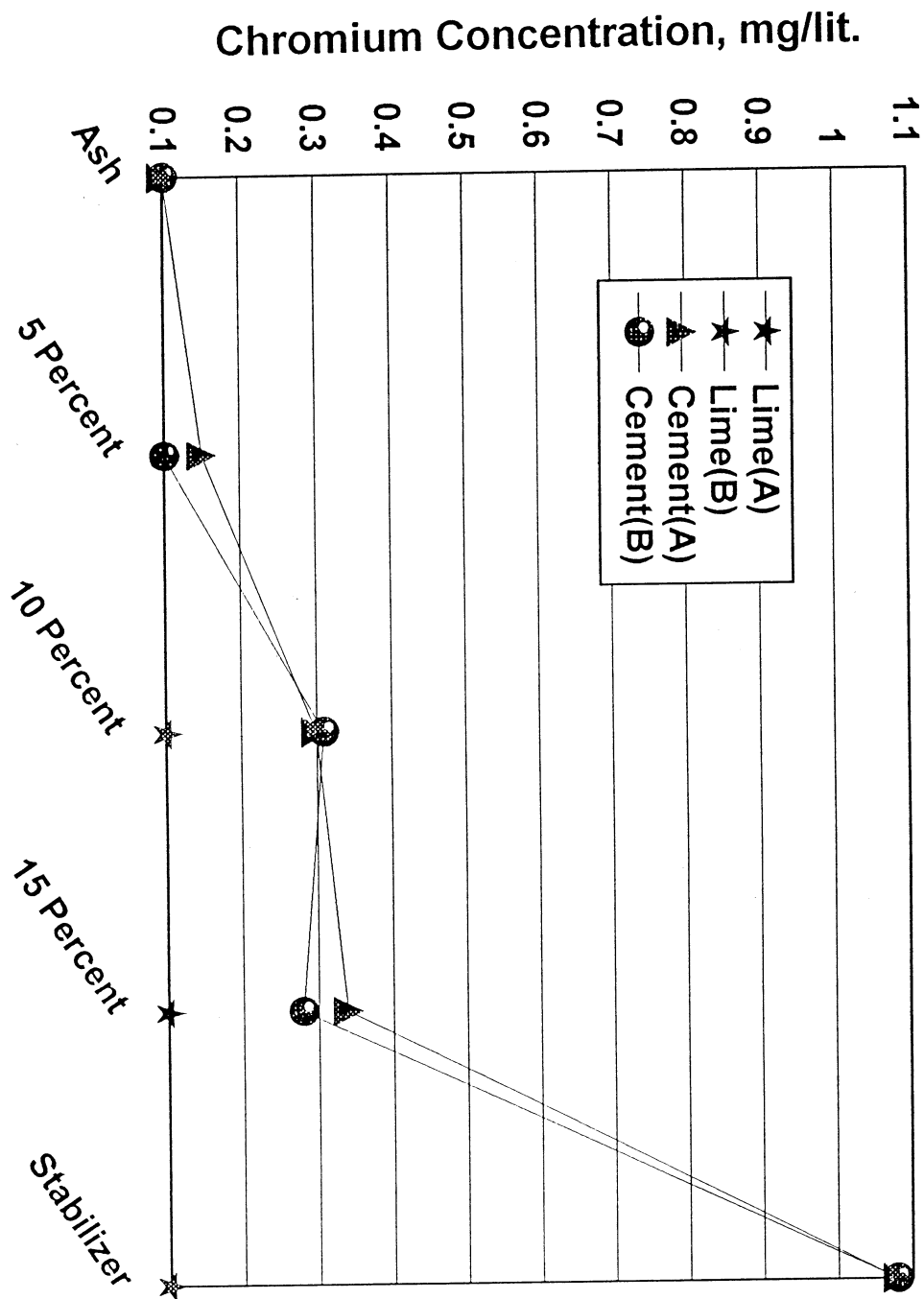
Analysis of Lead Concentration



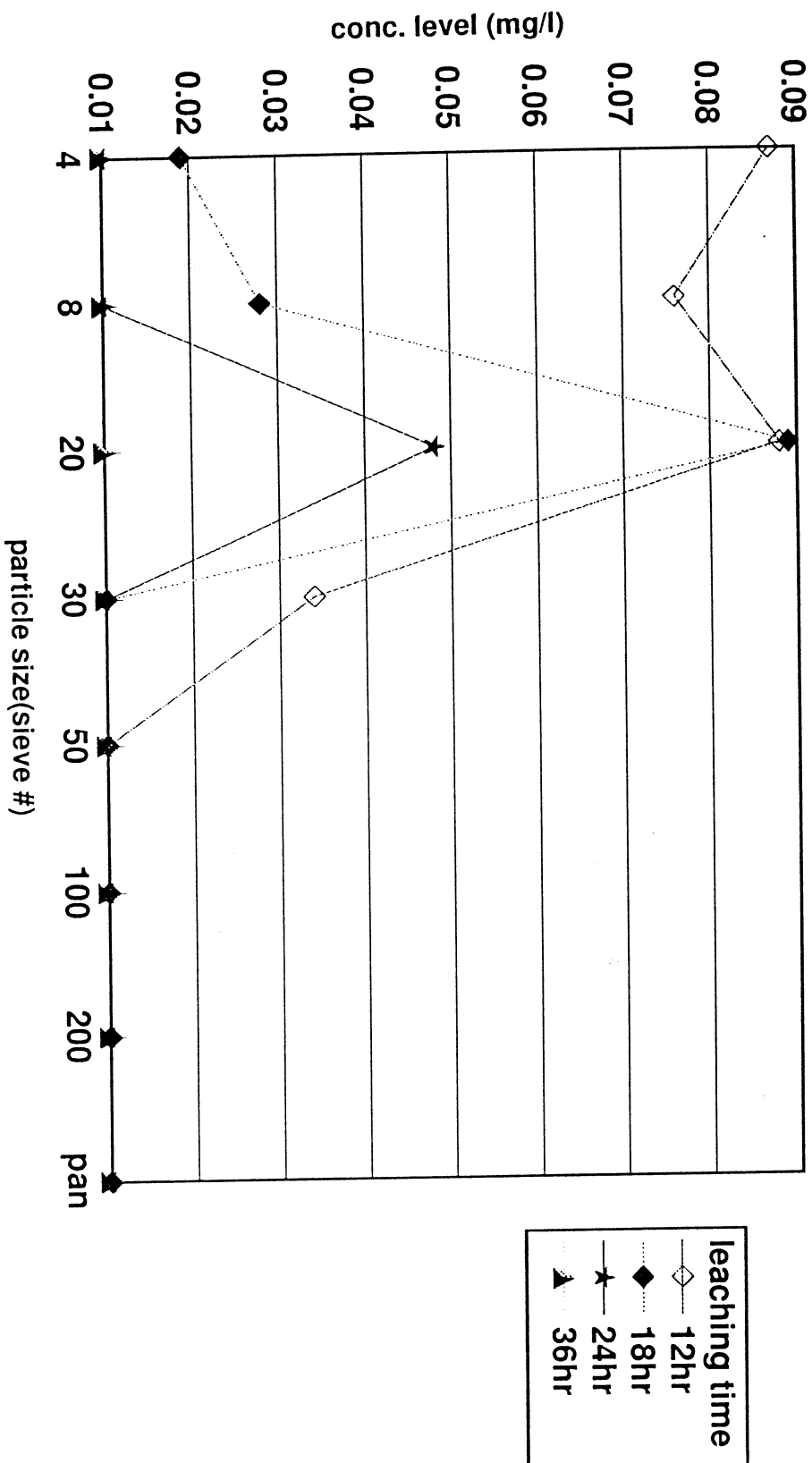
Analysis of Barium Concentration



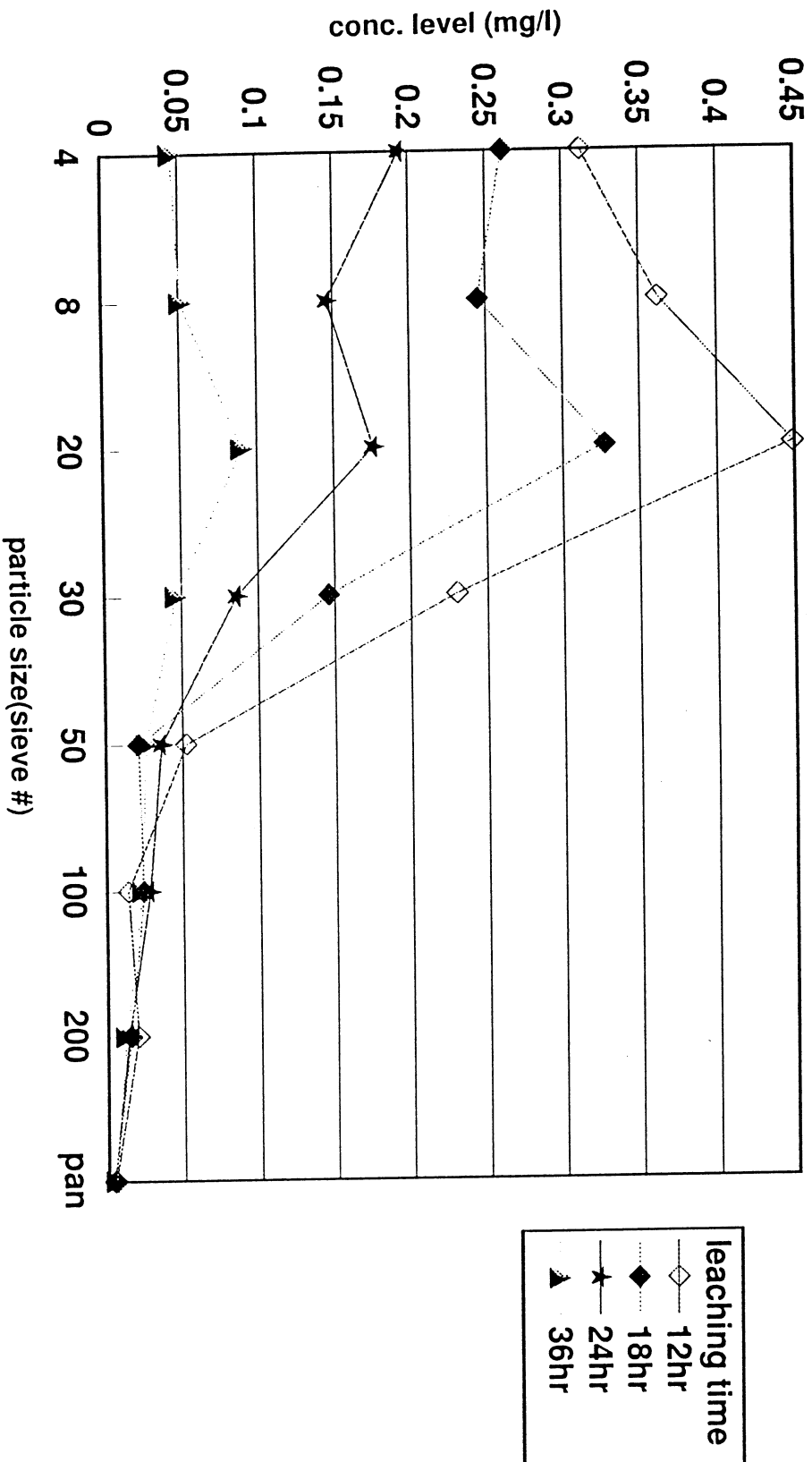
Analysis of Chromium Concentration



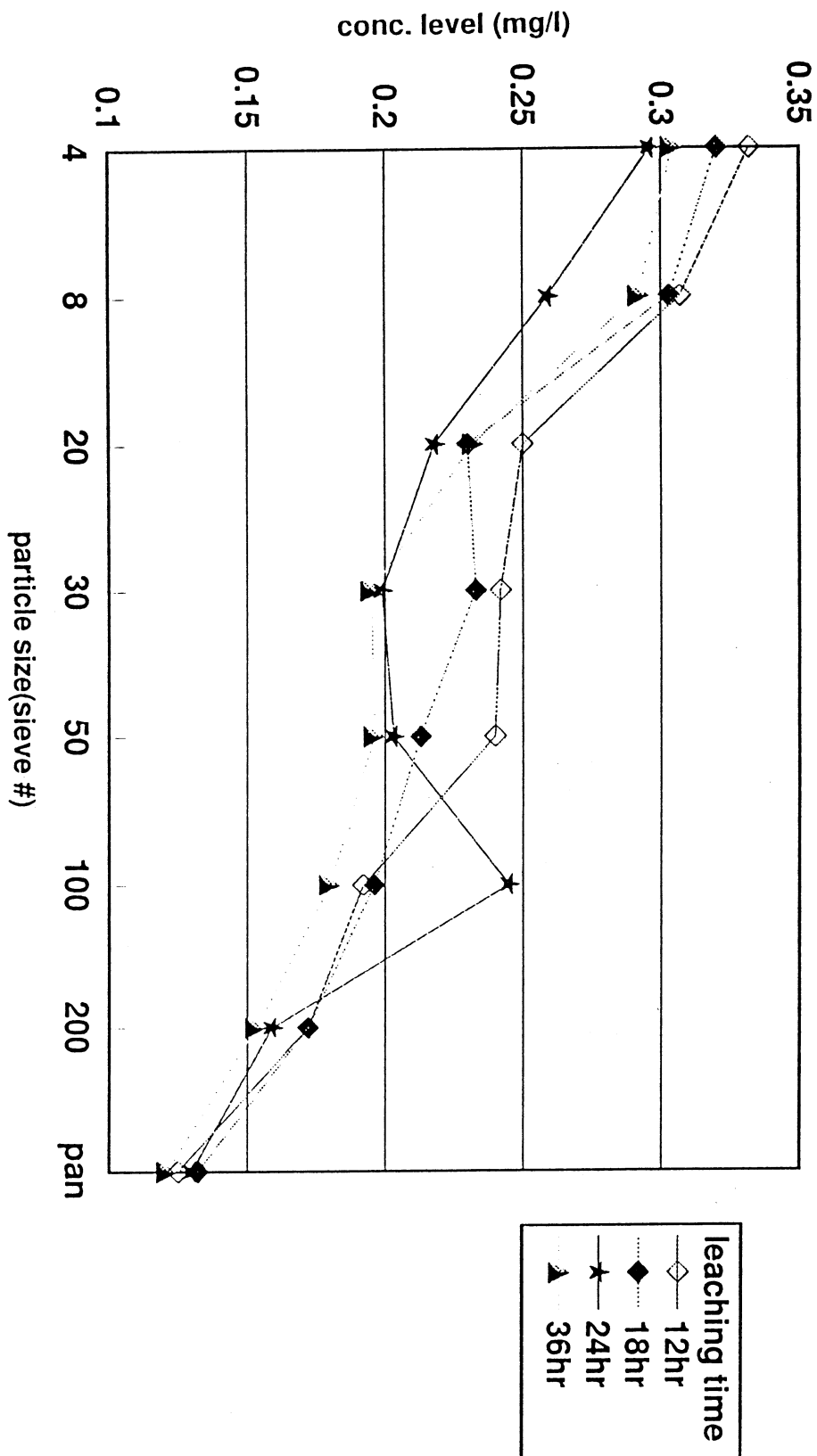
Lead Variation of Concentration versus leaching time



Cadmium **Variation of Concentration level** **versus leaching time**

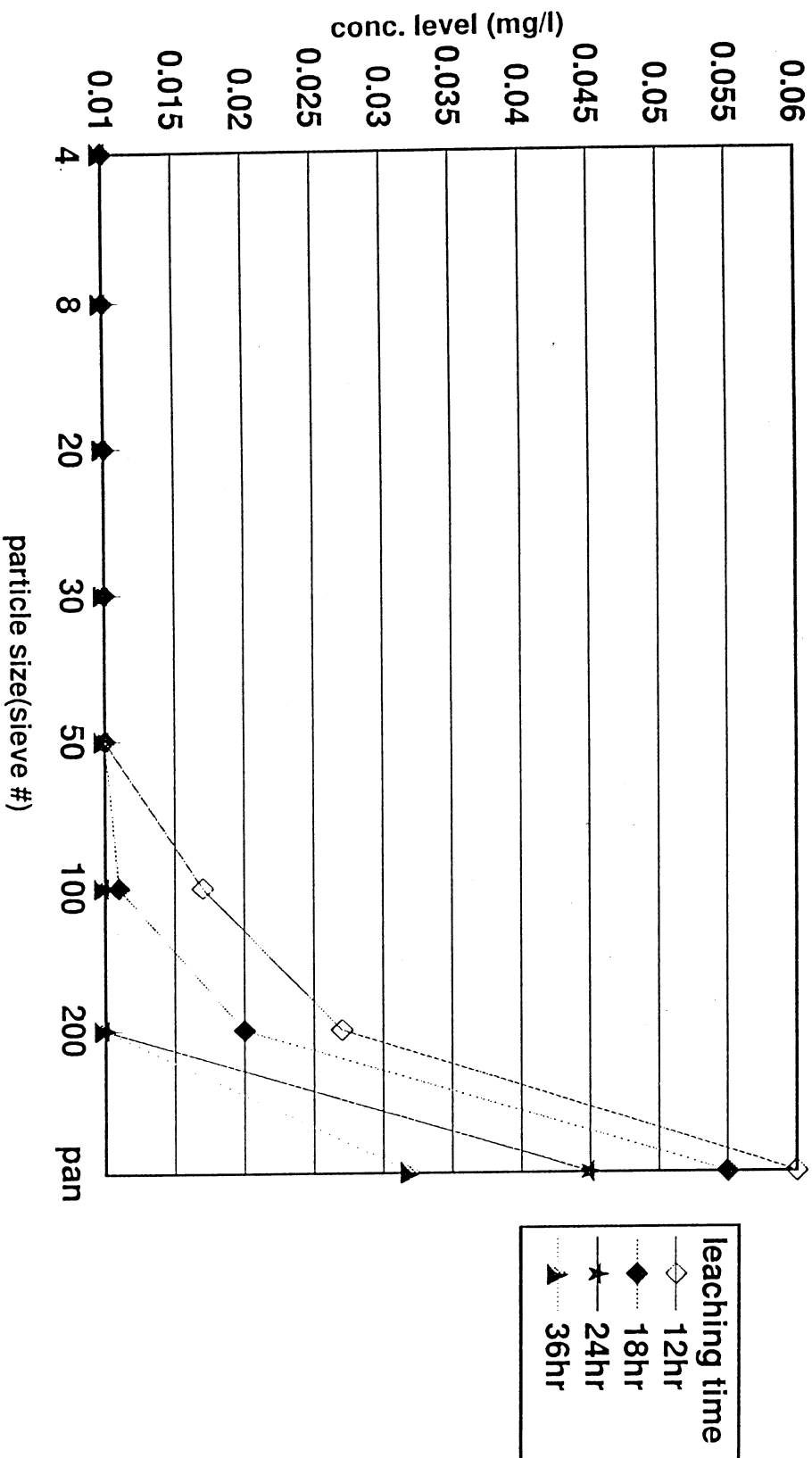


Barium Variation of Concentration level versus leaching time



Chromium

Variation of Concentration level versus leaching time



CHAPTER VI : CONCLUSION AND RECOMMENDATION

The reuse of "waste" in engineering is being recognized as a partial solution to the United States' mounting waste problem. But the reuse of "waste" needs to be carefully evaluated in terms of its impact on the environment. Ash residue being a "waste" product was evaluated for potential application in roadway construction. Application of ash residue should be approached from a system point of view, starting from its production. The "quality" of the ash residue produced depends on the solid waste processed and the technology used in processing it.

Ash residue is readily available and constitutes between 13.5% to 26% by weight (see the attached copy of the survey - Appendix C) of solid waste processed, and with eight(8) facilities in Florida, the raw material - ash residue can be accessed at a relatively cheaper price.

Chemical Characterization study showed that this ash residue sample is non-hazardous as defined by the United States Environmental Protection Agency's TCLP, Method 1311 protocol, though it contained heavy metal. Stabilization through Physical and Chemical fixation, reduced the leachability of heavy metals contained in the ash residue. The study also revealed that leachability of certain heavy metals depend on the leaching time. In addition, the study showed that there is a wide variation in heavy metal concentration in different particle sizes of this ash residue sample. This variation is contrary to popular belief that the concentration level increases as the specific surface area of a particle increases: the smaller the particle size, the larger the specific surface area, and hence the larger should be the organic and inorganic content.

Geotechnical properties of the ash residue sample were improved upon by the stabilization effort. The results of permeability and shear strength showed that the optimum mix ratio is 10% for both sodium sulfide and sodium phosphate. In addition, chemical fixation exhibits similar characteristics as the lime stabilized ash residue; because of this, lime stabilization is recommended with the optimum mix ratio of 10% of lime to ash residue.

Recommendation

This study has been conducted in the laboratory under controlled conditions and situations. The variation of leachability as the leaching time changes raises a fundamental question as to the bio-accumulation of the heavy metal content in the environment; bio-accumulation in the sense that metals can not be destroyed. Therefore, plants can serve as a reservoir for the heavy metals as they are being leached out gradually over time. TCLP is designed to determine the mobility of both organic and inorganic contaminants present in wastes, but it does not measure the total heavy metal content of the waste.

Therefore, it is recommended that an application based field verification be performed. The objectives of this field application are:

- to study the long-term chemical stability of the ash residue in light of bio-accumulation and bio-availability in the environment;
- to evaluate the applicability of existing test methods as they apply to ash composite material, and based on that evaluation, recommend either the acceptance(with

- modifications) of the existing test methods, or develop new test methods;
- to establish design criteria, constructability and performance for ash residue application.

Without the above information, Florida Department of Transportation cannot properly assess the suitability and practicability of using ash in roadway construction. In addition the data collected can be used to perform risk assessment involved in the utilization of ash residue. This risk assessment will be necessary in order to expedite the approval of ash residue - in terms of environmental consideration.

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APPENDIX A

**TOXICITY CHARACTERISTICS
AND
LEACHING PROCEDURE TEST(TCLP)
USEPA METHOD 1311 PROCEDURE**

METHOD 1311

TOXICITY CHARACTERISTIC LEACHING PROCEDURE

1.0 SCOPE AND APPLICATION

1.1 The TCLP is designed to determine the mobility of both organic and inorganic analytes present in liquid, solid, and multiphasic wastes.

1.2 If a total analysis of the waste demonstrates that individual analytes are not present in the waste, or that they are present but at such low concentrations that the appropriate regulatory levels could not possibly be exceeded, the TCLP need not be run.

1.3 If an analysis of any one of the liquid fractions of the TCLP extract indicates that a regulated compound is present at such high concentrations that, even after accounting for dilution from the other fractions of the extract, the concentration would be above the regulatory level for that compound, then the waste is hazardous and it is not necessary to analyze the remaining fractions of the extract.

1.4 If an analysis of extract obtained using a bottle extractor shows that the concentration of any regulated volatile analyte exceeds the regulatory level for that compound, then the waste is hazardous and extraction using the ZHE is not necessary. However, extract from a bottle extractor cannot be used to demonstrate that the concentration of volatile compounds is below the regulatory level.

2.0 SUMMARY OF METHOD

2.1 For liquid wastes (*i.e.*, those containing less than 0.5% dry solid material), the waste, after filtration through a 0.6 to 0.8 μm glass fiber filter, is defined as the TCLP extract.

2.2 For wastes containing greater than or equal to 0.5% solids, the liquid, if any, is separated from the solid phase and stored for later analysis; the particle size of the solid phase is reduced, if necessary. The solid phase is extracted with an amount of extraction fluid equal to 20 times the weight of the solid phase. The extraction fluid employed is a function of the alkalinity of the solid phase of the waste. A special extractor vessel is used when testing for volatile analytes (see Table 1 for a list of volatile compounds). Following extraction, the liquid extract is separated from the solid phase by filtration through a 0.6 to 0.8 μm glass fiber filter.

2.3 If compatible (*i.e.*, multiple phases will not form on combination), the initial liquid phase of the waste is added to the liquid extract, and these are analyzed together. If incompatible, the liquids are analyzed separately and the results are mathematically combined to yield a volume-weighted average concentration.

to hold the sample and the extraction fluid is needed. Headspace is allowed in this vessel.

The extraction bottles may be constructed from various materials, depending on the analytes to be analyzed and the nature of the waste (see Section 4.3.3). It is recommended that borosilicate glass bottles be used instead of other types of glass, especially when inorganics are of concern. Plastic bottles, other than polytetrafluoroethylene, shall not be used if organics are to be investigated. Bottles are available from a number of laboratory suppliers. When this type of extraction vessel is used, the filtration device discussed in Section 4.3.2 is used for initial liquid/solid separation and final extract filtration.

4.3 Filtration Devices: It is recommended that all filtrations be performed in a hood.

4.3.1 Zero-Headspace Extractor Vessel (ZHE): When the waste is evaluated for volatiles, the zero-headspace extraction vessel described in Section 4.2.1 is used for filtration. The device shall be capable of supporting and keeping in place the glass fiber filter and be able to withstand the pressure needed to accomplish separation (50 psi).

Note: When it is suspected that the glass fiber filter has been ruptured, an in-line glass fiber filter may be used to filter the material within the ZHE.

4.3.2 Filter Holder: When the waste is evaluated for other than volatile analytes, any filter holder capable of supporting a glass fiber filter and able to withstand the pressure needed to accomplish separation may be used. Suitable filter holders range from simple vacuum units to relatively complex systems capable of exerting pressures of up to 50 psi or more. The type of filter holder used depends on the properties of the material to be filtered (see Section 4.3.3). These devices shall have a minimum internal volume of 300 mL and be equipped to accommodate a minimum filter size of 47 mm (filter holders having an internal capacity of 1.5 L or greater, and equipped to accommodate a 142 mm diameter filter, are recommended). Vacuum filtration can only be used for wastes with low solids content (<10%) and for highly granular, liquid-containing wastes. All other types of wastes should be filtered using positive pressure filtration. Suitable filter holders known to EPA are shown in Table 4.

4.3.3 Materials of Construction: Extraction vessels and filtration devices shall be made of inert materials which will not leach or absorb waste components. Glass, polytetrafluoroethylene (PTFE), or type 316 stainless steel equipment may be used when evaluating the mobility of both organic and inorganic components. Devices made of high density polyethylene (HDPE), polypropylene (PP), or polyvinyl chloride (PVC) may be used only when evaluating the mobility of metals. Borosilicate glass bottles are recommended for use over other types of glass bottles, especially when inorganics are analytes of concern.

4.4 Filters: Filters shall be made of borosilicate glass fiber, shall contain no binder materials, and shall have an effective pore size of 0.6 to

5.0 REAGENTS

5.1 Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available. Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

5.2 Reagent water. All references to reagent water in this method refer to one of the following, as appropriate:

5.2.1 Inorganic Analytes: Water which is generated by any method which would achieve the performance standards for ASTM Type II water. The analyte(s) of concern must be no higher than the highest of either (1) the detection limit, or (2) five percent of the regulatory level for that analyte, or (3) five percent of the measured concentration in the sample.

5.2.2 Volatile Analytes: Water in which an interferant is not observed at the method detection limit of the compounds of interest. Organic-free water can be generated by passing tap water through a carbon filter bed containing about 1 lb. of activated carbon. A water purification system may be used to generate organic-free deionized water. Organic-free water may also be prepared by boiling water for 15 minutes. Subsequently, while maintaining the temperature at 90°C, bubble a contaminant-free inert gas through the water for 1 hour. The analyte(s) of concern must be no higher than the highest of either (1) the detection limit, or (2) five percent of the regulatory level for that analyte, or (3) five percent of the measured concentration in the sample.

5.2.3 Semivolatile Analytes: Water in which an interferant is not observed at the method detection limit of the compounds of interest. Organic-free water can be generated by passing tap water through a carbon filter bed containing about 1 lb. of activated carbon. A water purification system may be used to generate organic-free deionized water. The analyte(s) of concern must be no higher than the highest of either (1) the detection limit, or (2) five percent of the regulatory level for that analyte, or (3) five percent of the measured concentration in the sample.

5.3 Hydrochloric acid (1N), HCl, made from ACS reagent grade.

5.4 Nitric acid (1N), HNO₃, made from ACS reagent grade.

5.5 Sodium hydroxide (1N), NaOH, made from ACS reagent grade.

5.6 Glacial acetic acid, CH₃CH₂OOH, ACS reagent grade.

5.7 Extraction fluid.

5.7.1 Extraction fluid # 1: Add 5.7 mL glacial CH₃CH₂OOH to 500 mL of reagent water (See Section 5.2), add 64.3 mL of 1N NaOH, and

7.0 PROCEDURE

7.1 Preliminary Evaluations

Perform preliminary TCLP evaluations on a minimum 100 gram aliquot of waste. This aliquot may not actually undergo TCLP extraction. These preliminary evaluations include: (1) determination of the percent solids (Section 7.1.1); (2) determination of whether the waste contains insignificant solids and is, therefore, its own extract after filtration (Section 7.1.2); (3) determination of whether the solid portion of the waste requires particle size reduction (Section 7.1.3); and (4) determination of which of the two extraction fluids are to be used for the nonvolatile TCLP extraction of the waste (Section 7.1.4).

7.1.1 Preliminary determination of percent solids: Percent solids is defined as that fraction of a waste sample (as a percentage of the total sample) from which no liquid may be forced out by an applied pressure, as described below.

7.1.1.1 If the waste will obviously yield no liquid when subjected to pressure filtration (i.e., is 100% solids) proceed to Section 7.1.3.

7.1.1.2 If the sample is liquid or multiphasic, liquid/solid separation to make a preliminary determination of percent solids is required. This involves the filtration device described in Section 4.3.2 and is outlined in Sections 7.1.1.3 through 7.1.1.9.

7.1.1.3 Pre-weigh the filter and the container that will receive the filtrate.

7.1.1.4 Assemble the filter holder and filter following the manufacturer's instructions. Place the filter on the support screen and secure.

7.1.1.5 Weigh out a subsample of the waste (100 gram minimum) and record the weight.

7.1.1.6 Allow slurries to stand to permit the solid phase to settle. Wastes that settle slowly may be centrifuged prior to filtration. Centrifugation is to be used only as an aid to filtration. If used, the liquid should be decanted and filtered followed by filtration of the solid portion of the waste through the same filtration system.

7.1.1.7 Quantitatively transfer the waste sample to the filter holder (liquid and solid phases). Spread the waste sample evenly over the surface of the filter. If filtration of the waste at 4°C reduces the amount of expressed liquid over what would be expressed at room temperature then allow the sample to warm up to room temperature in the device before filtering.

Note: If waste material (>1% of original sample weight) has obviously adhered to the container used to transfer the sample to the filtration apparatus,

7.1.2.1 Remove the solid phase and filter from the filtration apparatus.

7.1.2.2 Dry the filter and solid phase at $100 \pm 20^{\circ}\text{C}$ until two successive weighing yield the same value within $\pm 1\%$. Record the final weight.

Note: Caution should be taken to ensure that the subject solid will not flash upon heating. It is recommended that the drying oven be vented to a hood or other appropriate device.

7.1.2.3 Calculate the percent dry solids as follows:

$$\text{Percent dry solids} = \frac{(\text{Wt. of dry waste + filter}) - \text{tared wt. of filter}}{\text{Initial wt. of waste (Section 7.1.1.5 or 7.1.1.7)}} \times 100$$

7.1.2.4 If the percent dry solids is less than 0.5%, then proceed to Section 7.2.9 if the nonvolatile TCLP is to be performed, and to Section 7.3 if the volatile TCLP is to be performed. If the percent dry solids is greater than or equal to 0.5%, and if the nonvolatile TCLP is to be performed, return to the beginning of this Section (7.1) and, with a fresh portion of waste, determine whether particle size reduction is necessary (Section 7.1.3) and determine the appropriate extraction fluid (Section 7.1.4). If only the volatile TCLP is to be performed, see the note in Section 7.1.4.

7.1.3 Determination of whether the waste requires particle size reduction (particle size is reduced during this step): Using the solid portion of the waste, evaluate the solid for particle size. Particle size reduction is required, unless the solid has a surface area per gram of material equal to or greater than 3.1 cm^2 , or is smaller than 1 cm in its narrowest dimension (i.e., is capable of passing through a 9.5 mm (0.375 inch) standard sieve). If the surface area is smaller or the particle size larger than described above, prepare the solid portion of the waste for extraction by crushing, cutting, or grinding the waste to a surface area or particle size as described above. If the solids are prepared for organic volatiles extraction, special precautions must be taken (see Section 7.3.6).

Note: Surface area criteria are meant for filamentous (e.g., paper, cloth, and similar) waste materials. Actual measurement of surface area is not required, nor is it recommended. For materials that do not obviously meet the criteria, sample specific methods would need to be developed and employed to measure the surface area. Such methodology is currently not available.

7.1.4 Determination of appropriate extraction fluid: If the solid content of the waste is greater than or equal to 0.5% and if the sample will be extracted for nonvolatile constituents (Section 7.2),

7.2.1 If the waste will obviously yield no liquid when subjected to pressure filtration (i.e., is 100% solid, see Section 7.1.1), weigh out a subsample of the waste (100 gram minimum) and proceed to Section 7.2.9.

7.2.2 If the sample is liquid or multiphasic, liquid/solid separation is required. This involves the filtration device described in Section 4.3.2 and is outlined in Sections 7.2.3 to 7.2.8.

7.2.3 Pre-weigh the container that will receive the filtrate.

7.2.4 Assemble the filter holder and filter following the manufacturer's instructions. Place the filter on the support screen and secure. Acid wash the filter if evaluating the mobility of metals (see Section 4.4).

Note: Acid washed filters may be used for all nonvolatile extractions even when metals are not of concern.

7.2.5 Weigh out a subsample of the waste (100 gram minimum) and record the weight. If the waste contains <0.5% dry solids (Section 7.1.2), the liquid portion of the waste, after filtration, is defined as the TCLP extract. Therefore, enough of the sample should be filtered so that the amount of filtered liquid will support all of the analyses required of the TCLP extract. For wastes containing >0.5% dry solids (Sections 7.1.1 or 7.1.2), use the percent solids information obtained in Section 7.1.1 to determine the optimum sample size (100 gram minimum) for filtration. Enough solids should be generated by filtration to support the analyses to be performed on the TCLP extract.

7.2.6 Allow slurries to stand to permit the solid phase to settle. Wastes that settle slowly may be centrifuged prior to filtration. Use centrifugation only as an aid to filtration. If the waste is centrifuged, the liquid should be decanted and filtered followed by filtration of the solid portion of the waste through the same filtration system.

7.2.7 Quantitatively transfer the waste sample (liquid and solid phases) to the filter holder (see Section 4.3.2). Spread the waste sample evenly over the surface of the filter. If filtration of the waste at 4°C reduces the amount of expressed liquid over what would be expressed at room temperature, then allow the sample to warm up to room temperature in the device before filtering.

Note: If waste material (>1% of the original sample weight) has obviously adhered to the container used to transfer the sample to the filtration apparatus, determine the weight of this residue and subtract it from the sample weight determined in Section 7.2.5, to determine the weight of the waste sample that will be filtered.

Gradually apply vacuum or gentle pressure of 1-10 psi, until air or pressurizing gas moves through the filter. If this point is not reached under 10 psi, and if no additional liquid has passed through the filter in any 2 minute interval, slowly increase the pressure in 10 psi increments to a maximum of 50 psi. After each incremental increase of 10 psi, if the

Slowly add this amount of appropriate extraction fluid (see Section 7.1.4) to the extractor vessel. Close the extractor bottle tightly (it is recommended that Teflon tape be used to ensure a tight seal), secure in rotary agitation device, and rotate at 30 ± 2 rpm for 18 ± 2 hours. Ambient temperature (i.e., temperature of room in which extraction takes place) shall be maintained at $22 \pm 3^\circ\text{C}$ during the extraction period.

Note: As agitation continues, pressure may build up within the extractor bottle for some types of wastes (e.g., limed or calcium carbonate containing waste may evolve gases such as carbon dioxide). To relieve excess pressure, the extractor bottle may be periodically opened (e.g., after 15 minutes, 30 minutes, and 1 hour) and vented into a hood.

7.2.12 Following the 18 ± 2 hour extraction, separate the material in the extractor vessel into its component liquid and solid phases by filtering through a new glass fiber filter, as outlined in Section 7.2.7. For final filtration of the TCLP extract, the glass fiber filter may be changed, if necessary, to facilitate filtration. Filter(s) shall be acid-washed (see Section 4.4) if evaluating the mobility of metals.

7.2.13 Prepare the TCLP extract as follows:

7.2.13.1 If the waste contained no initial liquid phase, the filtered liquid material obtained from Section 7.2.12 is defined as the TCLP extract. Proceed to Section 7.2.14.

7.2.13.2 If compatible (e.g., multiple phases will not result on combination), combine the filtered liquid resulting from Section 7.2.12 with the initial liquid phase of the waste obtained in Section 7.2.7. This combined liquid is defined as the TCLP extract. Proceed to Section 7.2.14.

7.2.13.3 If the initial liquid phase of the waste, as obtained from Section 7.2.7, is not or may not be compatible with the filtered liquid resulting from Section 7.2.12, do not combine these liquids. Analyze these liquids, collectively defined as the TCLP extract, and combine the results mathematically, as described in Section 7.2.14.

7.2.14. Following collection of the TCLP extract, the pH of the extract should be recorded. Immediately aliquot and preserve the extract for analysis. Metals aliquots must be acidified with nitric acid to $\text{pH} < 2$. If precipitation is observed upon addition of nitric acid to a small aliquot of the extract, then the remaining portion of the extract for metals analyses shall not be acidified and the extract shall be analyzed as soon as possible. All other aliquots must be stored under refrigeration (4°C) until analyzed. The TCLP extract shall be prepared and analyzed according to appropriate analytical methods. TCLP extracts to be analyzed for metals shall be acid digested except in those instances where digestion causes loss of metallic analytes. If an analysis of the undigested extract shows that the concentration of any regulated metallic analyte exceeds the regulatory level, then the waste is hazardous and digestion of the extract is not necessary. However, data on undigested

fluid). Adjust the piston within the ZHE body to a height that will minimize the distance the piston will have to move once the ZHE is charged with sample (based upon sample size requirements determined from Section 7.3, Section 7.1.1 and/or 7.1.2). Secure the gas inlet/outlet flange (bottom flange) onto the ZHE body in accordance with the manufacturer's instructions. Secure the glass fiber filter between the support screens and set aside. Set liquid inlet/outlet flange (top flange) aside.

7.3.3 If the waste is 100% solid (see Section 7.1.1), weigh out a subsample (25 gram maximum) of the waste, record weight, and proceed to Section 7.3.5.

7.3.4 If the waste contains < 0.5% dry solids (Section 7.1.2), the liquid portion of waste, after filtration, is defined as the TCLP extract. Filter enough of the sample so that the amount of filtered liquid will support all of the volatile analyses required. For wastes containing $\geq 0.5\%$ dry solids (Sections 7.1.1 and/or 7.1.2), use the percent solids information obtained in Section 7.1.1 to determine the optimum sample size to charge into the ZHE. The recommended sample size is as follows:

7.3.4.1 For wastes containing < 0.5% solids (see Section 7.1.1), weigh out a 500 gram subsample of waste and record the weight.

7.3.4.2 For wastes containing $\geq 0.5\%$ solids (see Section 7.1.1), determine the amount of waste to charge into the ZHE as follows:

$$\text{Weight of waste to charge ZHE} = \frac{25}{\text{percent solids (Section 7.1.1)}} \times 100$$

Weigh out a subsample of the waste of the appropriate size and record the weight.

7.3.5 If particle size reduction of the solid portion of the waste was required in Section 7.1.3, proceed to Section 7.3.6. If particle size reduction was not required in Section 7.1.3, proceed to Section 7.3.7.

7.3.6 Prepare the waste for extraction by crushing, cutting, or grinding the solid portion of the waste to a surface area or particle size as described in Section 7.1.3. Wastes and appropriate reduction equipment should be refrigerated, if possible, to 4°C prior to particle size reduction. The means used to effect particle size reduction must not generate heat in and of itself. If reduction of the solid phase of the waste is necessary, exposure of the waste to the atmosphere should be avoided to the extent possible.

Note: Sieving of the waste is not recommended due to the possibility that volatiles may be lost. The use of an appropriately graduated ruler is recommended as an acceptable alternative. Surface area requirements are

Note: Some wastes, such as oily wastes and some paint wastes, will obviously contain some material that appears to be a liquid. Even after applying pressure filtration, this material will not filter. If this is the case, the material within the filtration device is defined as a solid and is carried through the TCLP extraction as a solid.

If the original waste contained <0.5% dry solids (see Section 7.1.2), this filtrate is defined as the TCLP extract and is analyzed directly. Proceed to Section 7.3.15.

7.3.11 The liquid phase may now be either analyzed immediately (See Sections 7.3.13 through 7.3.15) or stored at 4°C under minimal headspace conditions until time of analysis. Determine the weight of extraction fluid #1 to add to the ZHE as follows:

$$\text{Weight of extraction fluid} = \frac{20 \times \text{percent solids (Section 7.1.1)} \times \text{weight of waste filtered (Section 7.3.4 or 7.3.8)}}{100}$$

7.3.12 The following Sections detail how to add the appropriate amount of extraction fluid to the solid material within the ZHE and agitation of the ZHE vessel. Extraction fluid #1 is used in all cases (See Section 5.7).

7.3.12.1 With the ZHE in the vertical position, attach a line from the extraction fluid reservoir to the liquid inlet/outlet valve. The line used shall contain fresh extraction fluid and should be preflushed with fluid to eliminate any air pockets in the line. Release gas pressure on the ZHE piston (from the gas inlet/outlet valve), open the liquid inlet/outlet valve, and begin transferring extraction fluid (by pumping or similar means) into the ZHE. Continue pumping extraction fluid into the ZHE until the appropriate amount of fluid has been introduced into the device.

7.3.12.2 After the extraction fluid has been added, immediately close the liquid inlet/outlet valve and disconnect the extraction fluid line. Check the ZHE to ensure that all valves are in their closed positions. Manually rotate the device in an end-over-end fashion 2 or 3 times. Reposition the ZHE in the vertical position with the liquid inlet/outlet valve on top. Pressurize the ZHE to 5-10 psi (if necessary) and slowly open the liquid inlet/outlet valve to bleed out any headspace (into a hood) that may have been introduced due to the addition of extraction fluid. This bleeding shall be done quickly and shall be stopped at the first appearance of liquid from the valve. Re-pressurize the ZHE with 5-10 psi and check all ZHE fittings to ensure that they are closed.

7.3.12.3 Place the ZHE in the rotary agitation apparatus (if it is not already there) and rotate at 30 ± 2 rpm for 18 ± 2 hours. Ambient temperature (i.e., temperature of room in

7.3.16 Compare the analyte concentrations in the TCLP extract with the levels identified in the appropriate regulations. Refer to Section 8.0 for quality assurance requirements.

8.0 QUALITY CONTROL

8.1 Refer to Chapter One for all required quality control procedures. A minimum of one blank (using the same extraction fluid as used for the samples) for every 20 extractions that have been conducted in an extraction vessel.

8.2 A matrix spike shall be performed for each waste type (e.g., wastewater treatment sludge, contaminated soil, etc.) unless the result exceeds the regulatory level and the data are being used solely to demonstrate that the waste property exceeds the regulatory level. As a minimum, follow the matrix spike addition guidance provided in each analytical method.

8.2.1 Matrix spikes are to be added after filtration of the TCLP extract and before preservation. Matrix spikes should not be added prior to TCLP extraction of the sample.

8.2.2 In most cases, matrix spikes should be added at a concentration equivalent to the corresponding regulatory level. If the analyte concentration is less than one half the regulatory level, the spike concentration may be as low as one half of the analyte concentration, but may not be not less than five times the method detection limit. In order to avoid differences in matrix effects, the matrix spikes must be added to the same nominal volume of TCLP extract as that which was analyzed for the unspiked sample.

8.2.3 The purpose of the matrix spike is to monitor the performance of the analytical methods used, and to determine whether matrix interferences exist. Use of other internal calibration methods, modification of the analytical methods, or use of alternate analytical methods may be needed to accurately measure the analyte concentration in the TCLP extract when the recovery of the matrix spike is below the expected analytical method performance.

8.3 All quality control measures described in the appropriate analytical methods shall be followed.

8.4 Samples must undergo TCLP extraction within the following time periods:

Filter type	0.7 μ m glass fiber vs. 0.45 μ m vs. polycarbonate
Bottle type	borosilicate vs. flint glass

Of the seven method variations examined, acidity of the extraction fluid had the greatest impact on the results. Four of 13 metals from an API separator sludge/electroplating waste (API/EW) mixture and two of three metals from an ammonia lime still bottom waste were extracted at higher levels by the more acidic buffer. Because of the sensitivity to pH changes, the method requires that the extraction fluids be prepared so that the final pH is within ± 0.05 units as specified.

9.1.2 Volatile Organic Compounds - The following conditions were used when leaching a waste for VOC analysis:

Varying Conditions	
Liquid/Solid ratio	19:1 vs. 21:1
Headspace	0% vs. 5%
Buffer #1 acidity	60 meq vs. 80 meq
Method of storing extract	Syringe vs. Tedlar [®] bag
Aliquotting	yes vs. no
Pressure behind piston	0 psi vs. 20 psi

None of the parameters had a significant effect on the results of the ruggedness test.

9.2 Precision. Many TCLP precision (reproducibility) studies have been performed, and have shown that, in general, the precision of the TCLP is comparable to or exceeds that of the EP toxicity test and that method precision is adequate. One of the more significant contributions to poor precision appears to be related to sample homogeneity and inter-laboratory variation (due to the nature of waste materials).

9.2.1 Metals - The results of a multi-laboratory study are shown in Table 6, and indicate that a single analysis of a waste may not be adequate for waste characterization and identification requirements.

9.2.2 Semi-Volatile Organic Compounds - The results of two studies are shown in Tables 7 and 8. Single laboratory precision was excellent with greater than 90 percent of the results exhibiting an RSD less than 25 percent. Over 85 percent of all individual compounds in the multi-laboratory study fell in the RSD range of 20 - 120 percent. Both studies concluded that the TCLP provides adequate precision. It was also determined that the high acetate content of the extraction fluid did not

Table 1.
Volatile Analytes^{1,2}

Compound	CAS No.
Acetone	67-64-1
Benzene	71-43-2
n-Butyl alcohol	71-36-3
Carbon disulfide	75-15-0
Carbon tetrachloride	56-23-5
Chlorobenzene	108-90-7
Chloroform	67-66-3
1,2-Dichloroethane	107-06-2
1,1-Dichloroethylene	75-35-4
Ethyl acetate	141-78-6
Ethyl benzene	100-41-4
Ethyl ether	60-29-7
Isobutanol	78-83-1
Methanol	67-56-1
Methylene chloride	75-09-2
Methyl ethyl ketone	78-93-3
Methyl isobutyl ketone	108-10-1
Tetrachloroethylene	127-18-4
Toluene	108-88-3
1,1,1,-Trichloroethane	71-55-6
Trichloroethylene	79-01-6
Trichlorofluoromethane	75-69-4
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1
Vinyl chloride	75-01-4
Xylene	1330-20-7

¹ When testing for any or all of these analytes, the zero-headspace extractor vessel shall be used instead of the bottle extractor.

² Benzene, carbon tetrachloride, chlorobenzene, chloroform, 1,2-dichloroethane, 1,1-dichloroethylene, methyl ethyl ketone, tetrachloroethylene, and vinyl chloride are toxicity characteristic constituents.

Table 3.
Suitable Zero-Headspace Extractor Vessels¹

Company	Location	Model No.
Analytical Testing & Consulting Services, Inc.	Warrington, PA (215) 343-4490	C102, Mechanical Pressure Device
Associated Design and Manufacturing Company	Alexandria, VA (703) 549-5999	3745-ZHE, Gas Pressure Device
Lars Lande Manufacturing ²	Whitmore Lake, MI (313) 449-4116	ZHE-11, Gas Pressure Device
Millipore Corporation	Bedford, MA (800) 225-3384	YT30090HW, Gas Pressure Device
Environmental Machine and Design, Inc.	Lynchburg, VA (804) 845-6424	VOLA-TOX1, Gas Pressure Device
Gelman Science	Ann Arbor, MI (800) 521-1520	15400 Gas Pressure Device

¹ Any device that meets the specifications listed in Section 4.2.1 of the method is suitable.

² This device uses a 110 mm filter.

Table 5.
Suitable Filter Media¹

Company	Location	Model	Pore Size (μm)
Millipore Corporation	Bedford, MA (800) 225-3384	AP40	0.7
Nucleopore Corporation	Pleasanton, CA (415) 463-2530	211625	0.7
Whatman Laboratory Products, Inc.	Clifton, NJ (201) 773-5800	GFF	0.7
Micro Filtration Systems	Dublin, CA (800) 334-7132 (415) 828-6010	GF75	0.7
Gelman Science	Ann Arbor, MI (800) 521-1520	66256 (90mm) 66257 (142mm)	0.7

¹ Any filter that meets the specifications in Section 4.4 of the Method is suitable.

Table 7. Single-Laboratory Semi-Volatiles, Precision

Waste	Compound	Extraction Fluid	$\bar{X}$	S	%RSD
Ammonia Lime Still Bottoms	Phenol	#1	19000	2230	11.6
		#2	19400	929	4.8
	2-Methylphenol	#1	2000	297	14.9
		#2	1860	52.9	2.8
	4-Methylphenol	#1	7940	1380	17.4
		#2	7490	200	2.7
	2,4-Dimethylphenol	#1	321	46.8	14.6
		#2	307	45.8	14.9
	Naphthalene	#1	3920	413	10.5
		#2	3827	176	4.6
	2-Methylnaphthalene	#1	290	44.8	15.5
		#2	273	19.3	7.1
	Dibenzofuran	#1	187	22.7	12.1
		#2	187	7.2	3.9
	Acenaphthylene	#1	703	89.2	12.7
		#2	663	20.1	3.0
	Fluorene	#1	151	17.6	11.7
		#2	156	2.1	1.3
	Phenanthrene	#1	241	22.7	9.4
		#2	243	7.9	3.3
	Anthracene	#1	33.2	6.19	18.6
		#2	34.6	1.55	4.5
	Fluoranthrene	#1	25.3	1.8	7.1
		#2	26.0	1.8	7.1
API/EW Mixture	Phenol	#1	40.7	13.5	33.0
		#2	19.0	1.76	9.3
	2,4-Dimethylphenol	#1	33.0	9.35	28.3
		#2	43.3	8.61	19.9
	Naphthalene	#1	185	29.4	15.8
		#2	165	24.8	15.0
	2-Methylnaphthalene	#1	265	61.2	23.1
		#2	200	18.9	9.5
%RSD Range = 1 - 33					
Mean %RSD = 12					

Note: Units = $\mu\text{g/L}$

Extractions were performed in triplicate

All results were at least 2x the detection limit

Extraction Fluid #1 = pH 4.9

#2 = pH 2.9

Table 9. Multi-Laboratory (11 Labs) VOCs, Precision

Waste	Compound	$\bar{X}$	S	%RSD
Mine Tailings	Vinyl chloride	6.36	6.36	100
	Methylene chloride	12.1	11.8	98
	Carbon disulfide	5.57	2.83	51
	1,1-Dichloroethene	21.9	27.7	127
	1,1-Dichloroethane	31.4	25.4	81
	Chloroform	46.6	29.2	63
	1,2-Dichloroethane	47.8	33.6	70
	2-Butanone	43.5	36.9	85
	1,1,1-Trichloroethane	20.9	20.9	100
	Carbon tetrachloride	12.0	8.2	68
	Trichloroethene	24.7	21.2	86
	1,1,2-Trichloroethene	19.6	10.9	56
	Benzene	37.9	28.7	76
	1,1,2,2-Tetrachloroethane	34.9	25.6	73
	Toluene	29.3	11.2	38
	Chlorobenzene	35.6	19.3	54
	Ethylbenzene	4.27	2.80	66
	Trichlorofluoromethane	3.82	4.40	115
	Acrylonitrile	76.7	110.8	144
Ammonia Lime Still Bottoms	Vinyl chloride	5.00	4.71	94
	Methylene chloride	14.3	13.1	92
	Carbon disulfide	3.37	2.07	61
	1,1-Dichloroethene	52.1	38.8	75
	1,1-Dichloroethane	52.8	25.6	49
	Chloroform	64.7	28.4	44
	1,2-Dichloroethane	43.1	31.5	73
	2-Butanone	59.0	39.6	67
	1,1,1-Trichloroethane	53.6	40.9	76
	Carbon tetrachloride	7.10	6.1	86
	Trichloroethene	57.3	34.2	60
	1,1,2-Trichloroethene	6.7	4.7	70
	Benzene	61.3	26.8	44
	1,1,2,2-Tetrachloroethane	3.16	2.1	66
	Toluene	69.0	18.5	27
	Chlorobenzene	71.8	12.0	17
	Ethylbenzene	3.70	2.2	58
	Trichlorofluoromethane	4.05	4.8	119
	Acrylonitrile	29.4	34.8	118
%RSD Range = 17 - 144				
Mean %RSD = 75				

Note: Units = $\mu\text{g/L}$

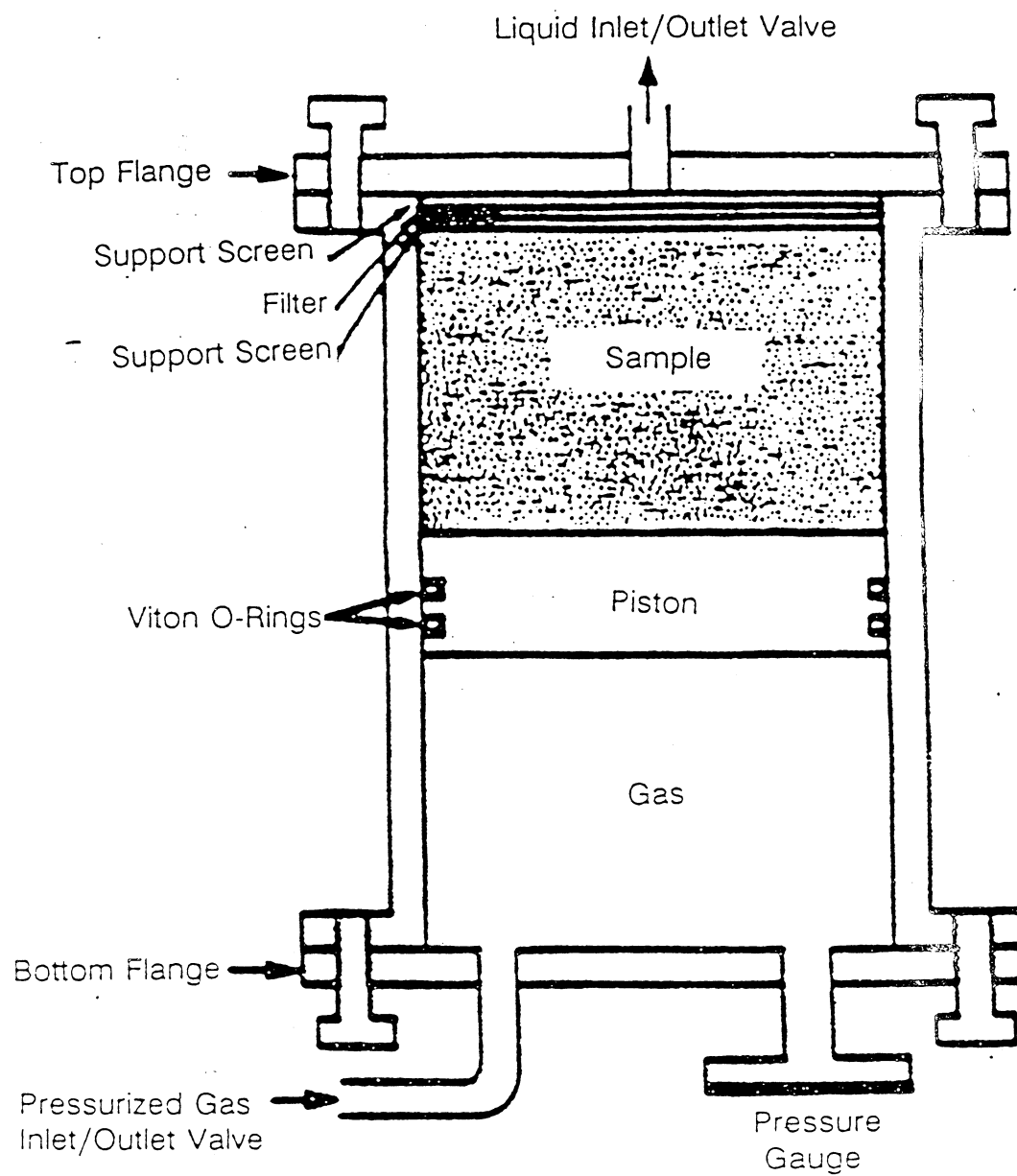
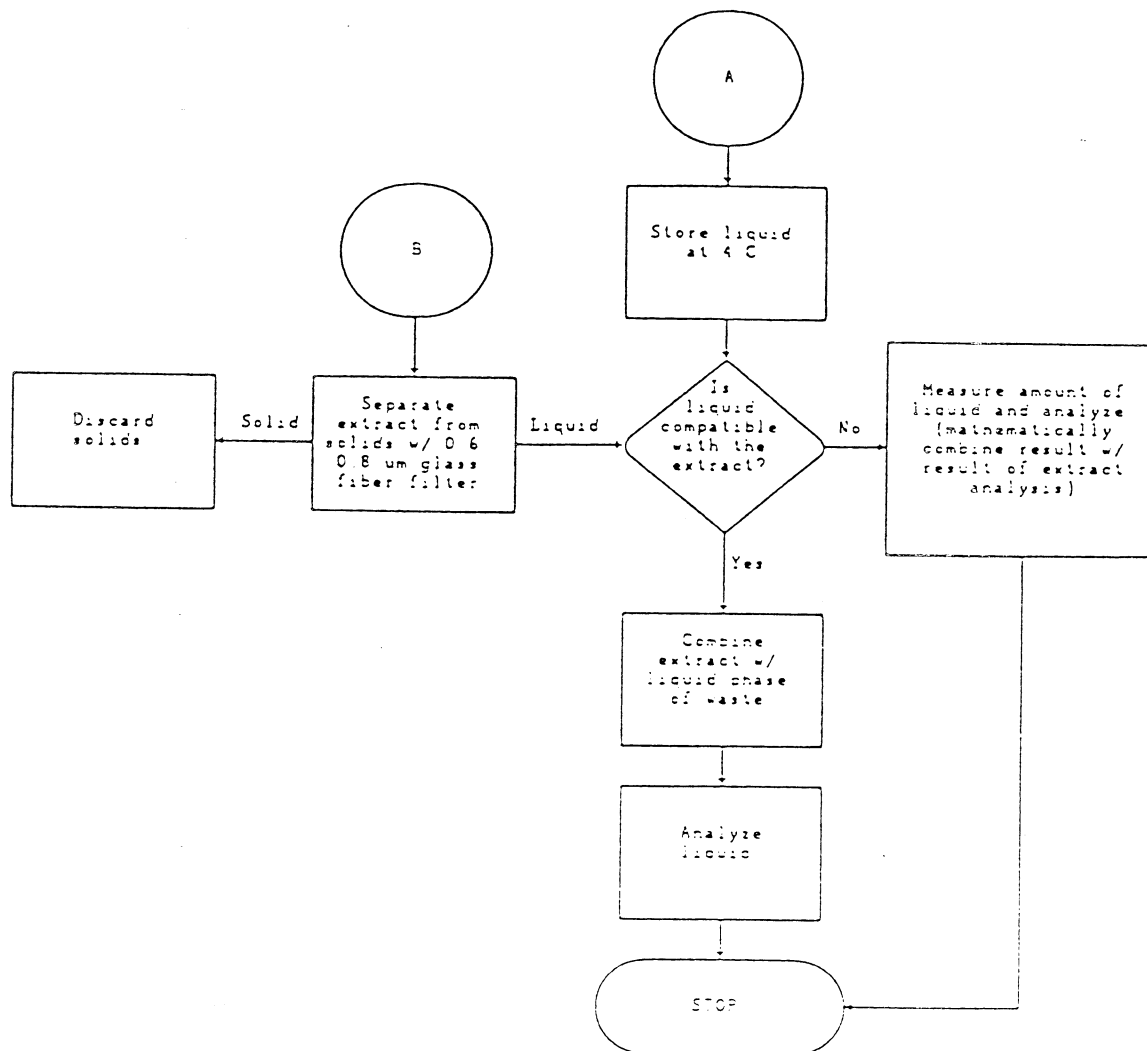


Figure 2. Zero-Headspace Extractor (ZHE)

METHOD 1311 (CONTINUED)

TOXICITY CHARACTERISTIC LEACHATE PROCEDURE



APPENDIX B

GEOTECHNICAL PROPERTIES OF UNSTABILIZED AND STABILIZED ASH RESIDUE

GEOTECHNICAL PROPERTIES

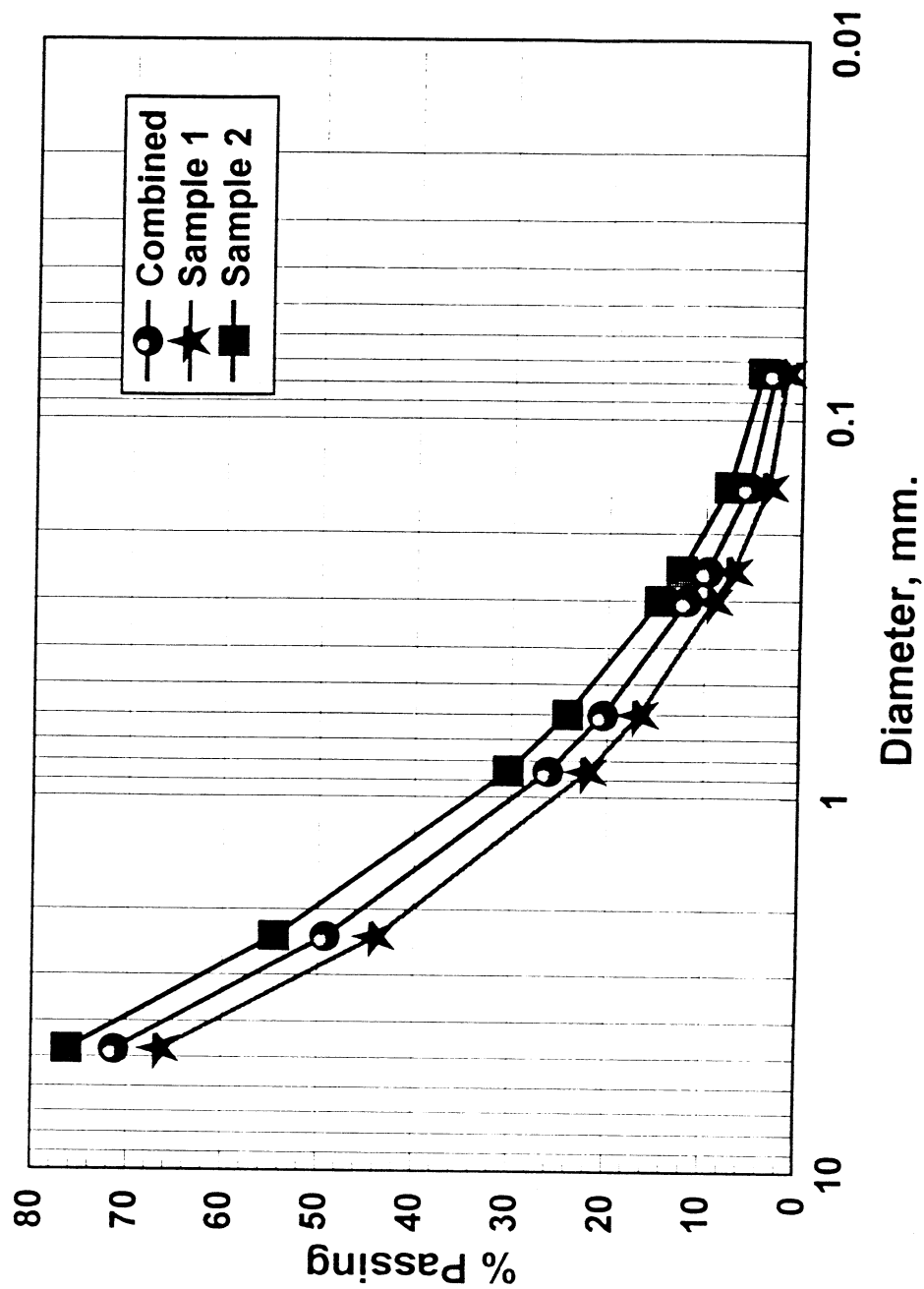
UNSTABILIZED ASH RESIDUE

**GRAIN SIZE ANALYSIS - MECHANICAL
UNSTABILIZED SAMPLES -I, II**

MATERIAL :- MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT :- SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE
Test performed : ASTM D422 (GRAIN SIZE ANALYSIS)

Sieve #	Dia. (mm)	Sample 1		Sample 2		Wt. (gm)	% Retained	% Passing
		Wt. (gm)	Percent (1)	Wt.(gm)	Percent (2)			
4	4.75	336.10	33.61	234.80	23.40	570.90	28.72	71.28
8	2.36	224.90	22.40	213.50	21.30	438.40	22.06	49.22
20	0.85	219.80	21.90	240.80	24.08	460.60	23.17	26.05
30	0.60	53.00	5.30	60.10	6.01	113.10	5.69	20.36
50	0.30	76.30	7.63	93.60	9.36	169.90	8.55	11.81
60	0.25	19.40	1.94	22.10	2.21	41.50	2.09	9.72
100	0.15	35.50	3.55	47.90	4.79	83.40	4.20	5.52
200	0.08	18.43	1.84	33.70	3.37	52.13	2.62	2.90
PAN		16.57	1.66	41.10	4.11	57.67	2.90	
Total		1000.00	99.83	987.60	98.63	1987.60	100.00	

Grain Size Distribution Curve - Mechanical Method



SPECIFIC GRAVITY TEST

UNSTABILIZED SAMPLE - I, II

MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE

TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE

Test Performed : ASTM 854 (Specific Gravity)

* All weights in Grams

Test No.	1	2
Vol. of Flask	500	500
Method of Air Removal	Vacuum	Vacuum
Mass Fla. + Water + Ash = M_{bws}	738.3	752.26
Temperature (° C)	25.6	26.1
Mass Fla. + Water = M_{bw}	664.1	677.4
Dish No.	1	2
Mass Dish + Dry Sample	403.6	415
Mass of Dish	286.5	295.4
Mass of Dry Sample	117.1	119.06
$M_w = M_s + M_{bw} - M_{bws}$	42.9	44.2
Alpha	0.9987	0.9991
Specific Gravity, G_s	2.71	2.69

Remarks = $2.71/2.69 = 1.007 < 1.02$ O.K

Average Specific Gravity Of Ash Residue (G_s) = $(2.71 + 2.69)/2 = 2.7$

GRAIN SIZE ANALYSIS - HYDROMETER METHOD

Project: MSW Incinerator Fly Ash
 Location of Project: Soils Laboratory
 Description of Soil: Fly Ash (Passing No.200 sieve), Soaked for 24 hr.
 Tested by: Krishna M. Kuchibhotla
 Date of Testing: 9-Oct-95

G_s of solids = 2.7
 a (Table 6-2) = 0.99
 Dispersing agent NaPO_3 (Calgon)
 Wt of soil, W_s (g) = 50
 Zero correction = 3.5
 Meniscus correction 1
 Amount = 4% in 125 ml
 (Found from control sample)

Date	Time of reading t	Elapsed time min	Temp °C	Temp Correction Factor C_T	Actual Hyd reading R_a	Corrected Hyd reading R_c	% Finer	Hyd Corr for meniscus R	L from Table 6-5	L/t	K from Table 6-4	D mm
10/9/95	14:32											
	14:34	2	20.5	0.1	55	51.6	102.17	56	7.3	3.6500	0.01335	0.0255
	14:36	4	20.5	0.1	47	43.6	86.33	48	8.6	2.1500	0.01335	0.0196
	14:40	8	20.5	0.1	41	37.6	74.45	42	9.6	1.2000	0.01335	0.0146
	14:48	16	20.5	0.1	33	29.6	58.61	34	10.9	0.6813	0.01335	0.0110
	15:02	30	20.5	0.1	10	6.6	13.07	11	14.7	0.4900	0.01335	0.0093
	15:32	60	20.5	0.1	10	6.6	13.07	11	14.7	0.2450	0.01335	0.0066
	16:32	120	21	0.2	10	6.7	13.27	11	14.7	0.1225	0.0133	0.0047
	18:32	240	21	0.2	10	6.7	13.27	11	14.7	0.0613	0.0133	0.0033
	21:18	406	21	0.2	10	6.7	13.27	11	14.7	0.0362	0.0133	0.0025
10/10/95	9:18	1126	19	-0.3	10	6.2	12.28	11	14.7	0.0131	0.0136	0.0016
	21:18	1846	19	-0.3	10	6.2	12.28	11	14.7	0.0080	0.0136	0.0012
10/11/95	9:18	2566	19	-0.3	10	6.2	12.28	11	14.7	0.0057	0.0136	0.0010

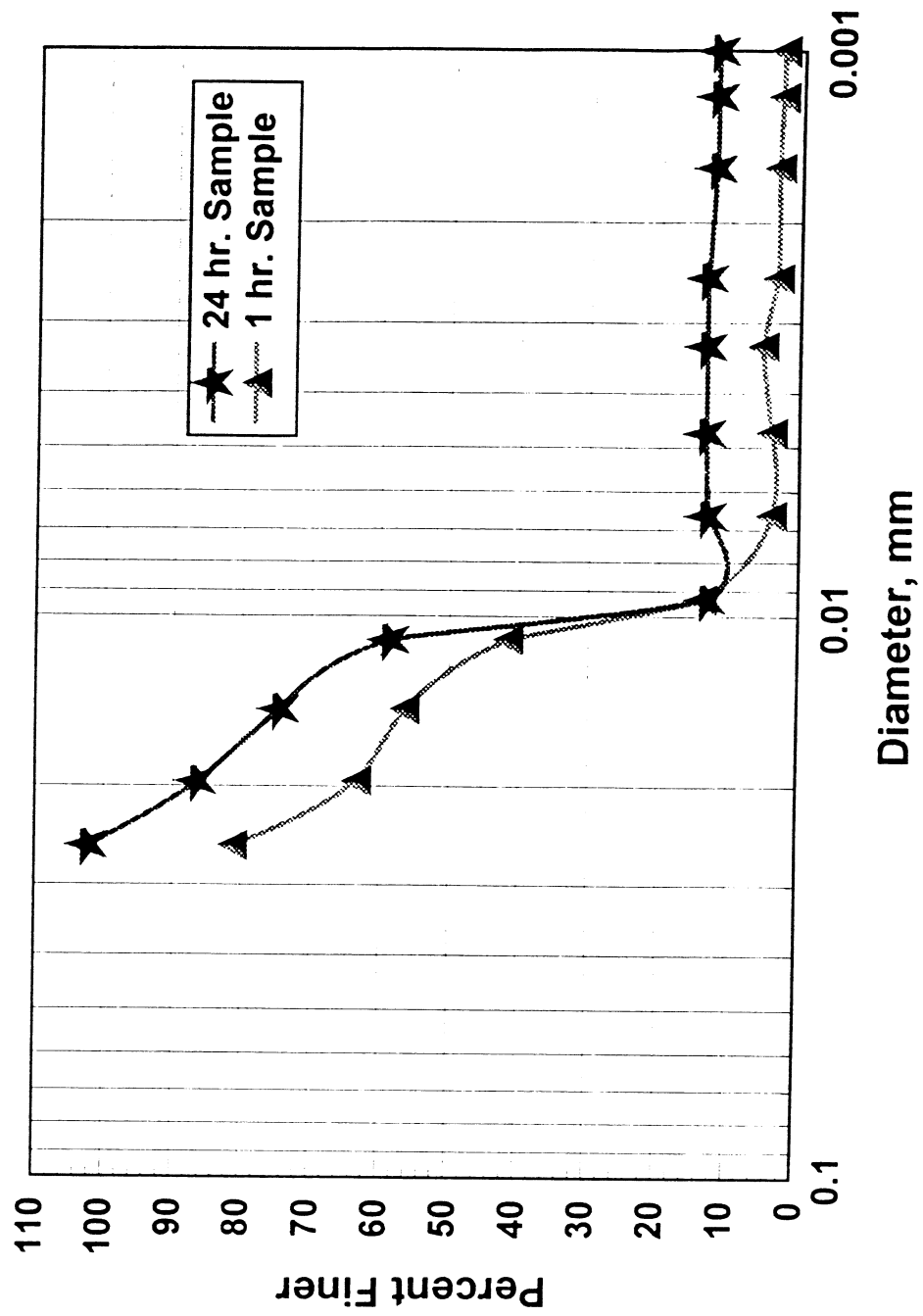
GRAIN SIZE ANALYSIS - HYDROMETER METHOD

Project: MSW Incinerator Fly Ash
 Location of Project: Soils Labaoratory
 Description of Soil: Fly Ash (Passing No.200 sieve), Soaked for 1 hr.
 Tested by: Krishna M. Kuchibhotla
 Date of Testing: 7-Nov-95

G_s of solids = 2.7
 a (Table 6-2) = 0.99
 Dispersing agent $NaPO_3$ (Calgon)
 Wt of soil, W_s (g) = 50
 Zero correction = 3.5
 Meniscus correction 1
 Amount = 4% in 125 ml
 (Found from control sample)

Date	Time of reading t	Elapsed time min	Temp $^{\circ}C$	Temp Correction Factor C_T	Actual Hyd reading R_a	Corrected Hyd reading R_c	% Finer	Hyd Corr for meniscus R	L from Table 6-5	L/t	K from Table 6-4	D mm
10/7/95	11:46	0	0	0	0	0	0	0	0	0	0	0
	11:48	2	18	-0.5	45	41	81.18	46	8.8	4.4000	0.0138	0.0289
	11:50	4	18	-0.5	36	32	63.36	37	10.4	2.6000	0.0138	0.0223
	11:54	8	18	-0.5	32.5	28.5	56.43	33.5	11	1.3750	0.0138	0.0162
	12:02	15	18	-0.5	25	21	41.58	26	12.2	0.8133	0.0138	0.0124
	12:16	30	18	-0.5	11	7	13.86	12	14.5	0.4833	0.0138	0.0096
	12:46	60	18	-0.5	6	2	3.96	7	15.3	0.2550	0.0138	0.0070
	13:46	120	18	-0.5	6	2	3.96	7	15.3	0.1275	0.0138	0.0049
	15:46	240	21	0.2	6	2.7	5.346	7	15.3	0.0638	0.0133	0.0034
	18:32	406	21	0.2	5	1.7	3.366	6	15.5	0.0382	0.0133	0.0026
10/8/95	10:48	1382	21	0.2	5	1.7	3.366	6	15.5	0.0112	0.0133	0.0014
10/9/95	8:52	1791	20	0	5	1.5	2.97	6	15.5	0.0087	0.0134	0.0012
	15:12	3086	20	0	5	1.5	2.97	6	15.5	0.0050	0.0134	0.0009

Grain Size Distribution Curve - Hydrometer Method



STANDARD COMPACTION TEST

UNSTABILIZED SAMPLE - I

MATERIAL :- MUNICIPAL SOLID WASTE ASH RESIDUE

TEST PERFORMED AT:- SOILS LABORATORY- FAMU/FSU ENGINEERING COLLEGE

TEST PERFORMED : Standard Proctor

Blows/Layer = 25 No. of Layers = 3 Wt. of Hammer = 24.5 N

Mold Dimensions: Diam. = 10.14 cm

Ht = 11.67cm

Vol. = 0.0009424 m³.

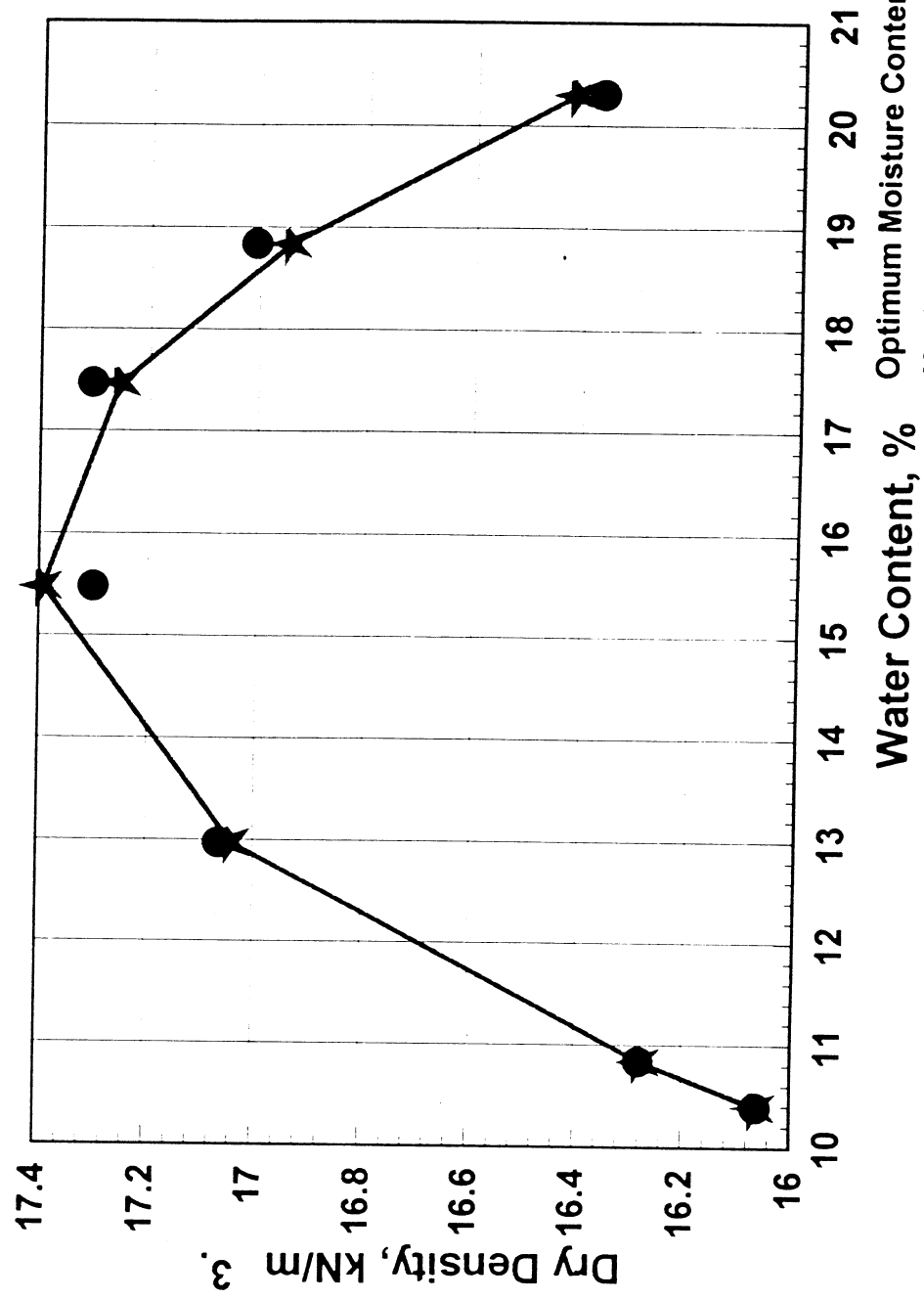
WATER CONTENT DETERMINATION

Sample No.	1		2			3			4			5			6			7		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Moisture Can No.																				
Wt. of can + wet soil	24.2	29.4	29.9	27	32.2	30.3	27.6	28.3	35.1	34.3	39.3	34.6	31	40.1						
Wt. of can + dry soil	22.8	27.3	27.6	25.1	29.3	27.7	25.1	25.9	31.1	30.5	34.3	30.5	27.3	34.7						
Wt. of water	1.4	2	2.3	1.9	2.9	2.6	2.5	2.4	4	3.8	5	4.1	3.7	5.4						
Wt. of can	11.8	11.6	11.8	11.9	11.9	12	11.7	11.9	11.2	12	11.8	11.7	11.8	11.5						
Wt. of dry soil	11	15.7	15.8	13.2	17.4	15.7	13.4	14	19.9	18.5	22.5	18.8	15.5	23.2						
Water Content, w%	12.7	12.7	14.5	14.4	16.66	16.56	18.65	17.1	20.1	20.5	22.2	21.8	23.87	23.27						

DENSITY DETERMINATION

Assumed w%	14																			
Actual Water Content	12.7	14.447	16.61	17.9	20	22	24	26												
Wt. of soil + mold	3823.5	3915.6	3991.5	4004.4	4045.5	4097.8	4150.7	4203.6												
Wt. of mold	2045.5	2045.5	2045.5	2045.5	2045.5	2045.5	2045.5	2045.5												
Wt. of soil in mold	1778	1870.1	1946	1958.9	2045.5	2045.5	2045.5	2045.5												
Wet Density, kN/m ³	18.45	19.4	20.2	20.335	20.335	20.335	20.335	20.335												
Dry Density, kN/m ³	16.3	16.96	17.32	17.26	17.26	17.26	17.26	17.26												

Compaction Curve - Unstabilized Sample - I.



STANDARD COMPACTION TEST - II

UNSTABILIZED SAMPLE - II

MATERIAL :- MUNICIPAL SOLID WASTE ASH RESIDUE

TEST PERFORMED AT:-SOILS LABORATORY- FAMU/FSU ENGINEERING COLLEGE

TEST PERFORMED : Standard Proctor

Blows/Layer = 25 No. of Layers = 3 Wt.of Hammer = 24.5 N

Mold Dimensions: Diam. = 10.14 cm

Ht = 11.67cm

Vol. = 0.0009424 m³.

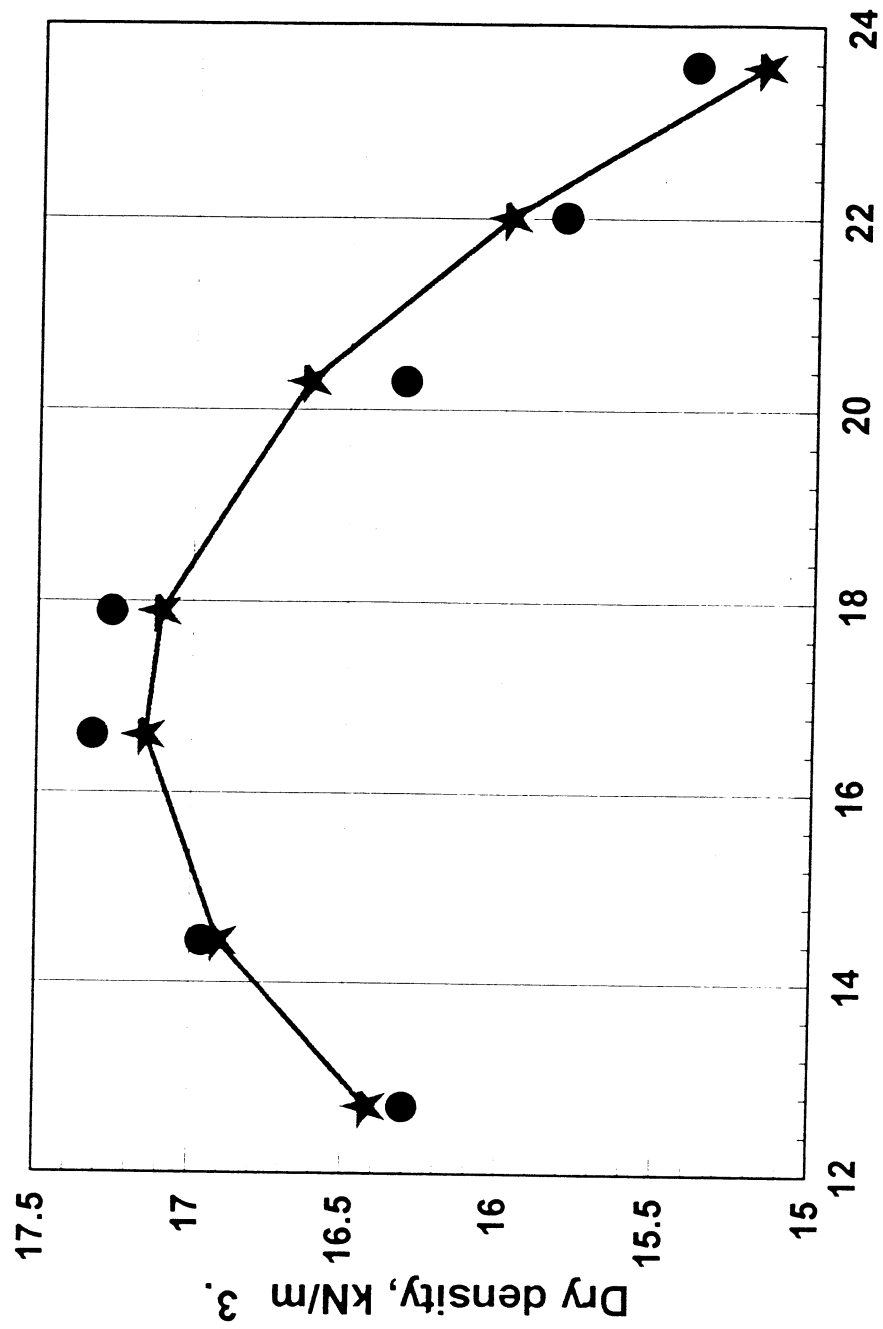
WATER CONTENT DETERMINATION

Sample No.	1		2		3		4		5		6		7		8	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Moisture Can No.	31.4	27	39.9	30.8	33	30.4	36.4	33.2	36.8	36.2	58.7	48	34.5	37.4	34.8	32
Wt. of can + wet soil	29.5	25.58	38.01	28.8	30.61	28.26	33.22	30.23	33.35	32.51	52.82	42.06	30.57	33.12	30.55	28.15
Wt. of can + dry soil	1.9	1.42	1.89	2	2.39	2.14	3.18	2.97	3.45	3.69	5.88	5.94	3.93	4.28	4.25	3.85
Wt. of water	11.2	11.93	20.6	11.9	12.3	11.7	11.77	11.84	13.5	11.5	20.9	11.8	11.4	11.9	11.9	11.3
Wt. of can	18.28	13.65	17.41	16.9	18.31	16.58	21.45	18.39	19.85	21.01	31.92	30.26	19.17	21.22	18.65	16.85
Wt. of dry soil	10.39	10.4	10.85	11.83	13.05	12.9	14.82	16.15	17.38	17.56	18.42	19.26	20.5	20.1	22.78	22.84
Water Content, w%																

DENSITY DETERMINATION

Assumed w%	12		14		16		18		20		22		24		26	
	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42
Actual Water Content	10.395	10.84	12.975	15.485	17.47	18.84	20.3	22.81	24.3	26.7	29.1	31.5	33.9	36.3	38.7	41.1
Wt. of soil + mold	3753.8	3783.7	3902.6	3966.1	4003.7	3992.4	3942.3	3910.7	3879.1	3847.5	3815.9	3784.3	3752.7	3721.1	3689.5	3657.9
Wt. of mold	2045.5	2045.5	2045.5	2045.5	2045.5	2045.5	2045.5	2045.5	2045.5	2045.5	2045.5	2045.5	2045.5	2045.5	2045.5	2045.5
Wt. of soil in mold	1708.2	1738.1	1857	1924.5	1958.1	1946.8	1896.7	1865.1	1833.5	1801.9	1770.3	1738.7	1707.1	1675.5	1643.9	1612.3
Wet Density, kN/m ³	17.73	18.04	19.28	19.98	20.33	20.21	19.69	19.36	19.01	18.66	18.31	17.96	17.61	17.26	16.91	16.56
Dry Density, kN/m ³	16.06	16.28	17.06	17.30	17.30	17.01	16.37	15.77	15.42	15.07	14.72	14.37	14.02	13.67	13.32	12.97

Compaction Curve - Unstabilized Sample - II.



Optimum Moisture Content = 16.5%
Maximum Dry Density = 17.2 kN/m³.

COEFFICIENT OF PERMEABILITY - FALLING HEAD METHOD**UNSTABILIZED SAMPLE - I****MATERIAL :- MUNICIPAL SOLID WASTE ASH RESIDUE****TEST PERFORMED AT :- SOILS LABORATORY-FAMU/FSU ENGINEERING COLLEGE****WATER CONTENT DETERMINATION:**

Moisture can #:	1	2
Wt. of can + wet soil (g)	27.5	28.3
Wt. of can + dry soil (g)	25.1	25.9
Wt. of water(g)	2.4	2.4
Wt. of can (g)	11.7	11.9
wt. of dry soil (g)	13.4	14
Water content, w%:	17.9	17.1

USING COMPACTION PERMEAMETER AND STANDARD PROCTOR AASHTO T99

Blows per layer: 25	Mold dia.(cm):	10.14
No. of layers: 3	Area (cm ²):	81.1
Wt. of hammer: 24.5 N	Ht. (cm):	11.6
	Vol. (m ³):	0.0009424

PERMEABILITY TEST DATA:

Area of standpipe: 1.71 cm²
 Kt/K20 1

Test #	h1 (cm)	h2 (cm)	Time (sec)	Temp(°C)
1	71	45	252	20
2	71	45	245	20
3	71	45	265	20
4	71	45	260	20
5	71	45	252	20
6	71	45	275	20
Average:			258.17	

$$Kt = (a \times L/A \times t) \ln (h_1/h_2)$$

$$Kt = (1.71 \times 11.6/81.1 \times 258.17) \ln (71/45) = 4.32 \times 10^{-4} \text{ cm/sec.}$$

$$\text{Coefficient of Permeability, } K, \text{ at } 20^\circ\text{C} = 4.32 \times 10^{-4} \text{ cm/sec.}$$

COEFFICIENT OF PERMEABILITY - FALLING HEAD METHOD**UNSTABILIZED SAMPLE - II**

MATERIAL :- MUNICIPAL SOLID WASTE ASH RESIDUE

TEST PERFORMED AT :- SOILS LABORATORY-FAMU/FSU ENGINEERING COLLEGE

WATER CONTENT DETERMINATION:

Moisture can #:	1
Wt. of can + wet soil (g)	37.73
Wt. of can + dry soil (g)	34.1
Wt. of water(g)	3.63
Wt. of can (g)	11.92
Wt. of dry soil (g)	22.18
Water content, w%:	16.37

USING COMPACTION PERMEAMETER AND STANDARD PROCTOR AASHTO T99

Blows per layer: 25	Mold dia.(cm):	10.14
No. of layers: 3	Area (cm ²):	81.1
Wt. of hammer: 24.5 N	Ht. (cm):	11.6
	Vol. (m ³):	0.0009424

PERMEABILITY TEST DATA:Area of standpipe: 1.71 cm²

Kt/K20: 1

Test #	h1 (cm)	h2 (cm)	Time (sec)	Temp (°C)
1	70.3	58.7	180	20
2	70.3	58.7	165	20
3	70.3	58.7	172	20
4	70.3	58.7	172	20
5	70.3	58.7	168	20
6	70.3	58.7	168	20
Average:			170.428	

$$K = (a \times L/A \times t) \ln (h_1/h_2)$$

$$K = (1.71 \times 11.6/81.1 \times 170.43) \ln (70.3/58.7) = 2.588 \times 10^{-4} \text{ cm/sec.}$$

$$\text{Coefficient of Permeability, } K, \text{ at } 20^\circ\text{C} = 2.588 \times 10^{-4} \text{ cm/sec.}$$

TRIAXIAL SHEAR TEST
UNSTABILIZED SAMPLE - I, 30 PSI.
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE
Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.033	0.084	0.002	0.228	20	0.165	43.08	38.21
0.071	0.180	0.005	0.490	40	0.329	43.20	76.21
0.115	0.292	0.008	0.793	60	0.494	43.33	113.97
0.160	0.406	0.011	1.103	80	0.658	43.47	151.48
0.210	0.533	0.014	1.448	100	0.823	43.62	188.69
0.270	0.686	0.019	1.862	120	0.988	43.80	225.48
0.335	0.851	0.023	2.310	140	1.152	44.00	261.86
0.420	1.067	0.029	2.897	160	1.317	44.27	297.47
0.535	1.359	0.037	3.690	180	1.481	44.63	331.92
0.615	1.562	0.042	4.241	190	1.564	44.89	348.36
0.710	1.803	0.049	4.897	200	1.646	45.20	364.18

Sample Description:-

Moist unit weight of specimen: 2.0335 gm/cm³

Dry unit weight of specimen: 1.726 gm/cm³

Moisture content of specimen: 17 %

Initial average length of specimen: 14.5 cm

Initial average diameter of specimen: 7.4 cm

Initial area of specimen: 42.9866 cm²

Proving ring calibration factor:

1 kN = 121.5

2 kN = 241.8

3kN = 362.9

TRIAxIAL SHEAR TEST

UNSTABILIZED SAMPLE - I, 50 PSI.

MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE

TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE

Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.011	0.028	0.001	0.063	20	0.165	43.01	38.27
0.024	0.061	0.001	0.137	40	0.329	43.05	76.48
0.039	0.099	0.002	0.223	60	0.494	43.08	114.62
0.070	0.178	0.004	0.400	100	0.823	43.16	190.70
0.086	0.218	0.005	0.491	120	0.988	43.20	228.63
0.150	0.381	0.009	0.857	190	1.564	43.36	360.67
0.170	0.432	0.010	0.971	210	1.728	43.41	398.17
0.214	0.544	0.012	1.223	250	2.058	43.52	472.81
0.308	0.782	0.018	1.760	330	2.716	43.76	620.72
0.437	1.110	0.025	2.497	420	3.457	44.09	784.07
0.469	1.191	0.027	2.680	440	3.621	44.17	819.87
0.630	1.600	0.036	3.600	520	4.280	44.59	959.78
0.856	2.174	0.049	4.891	580	4.774	45.20	1056.18
0.986	2.504	0.056	5.634	587	4.831	45.55	1060.58
1.046	2.657	0.060	5.977	580	4.774	45.72	1044.12
1.085	2.756	0.062	6.200	570	4.691	45.83	1023.69

Sample Description:-

Moist unit weight of specimen: 2.0335 gm/cm³

Dry unit weight of specimen: 1.726 gm/cm³

Moisture content of specimen: 17 %

Initial average length of specimen: 17.5 cm

Initial average diameter of specimen: 7.4 cm

Initial area of specimen: 42.9866 cm²

Proving ring calibration factor:

1 kN = 121.5

2 kN = 241.8

3kN = 362.9

SUMMARY OF RESULTS FOR 10, 30, 50 PSI TESTS ON SAMPLE -I

TRIAXIAL SHEAR TEST

UNSTABILIZED SAMPLE - I.

MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE

TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE

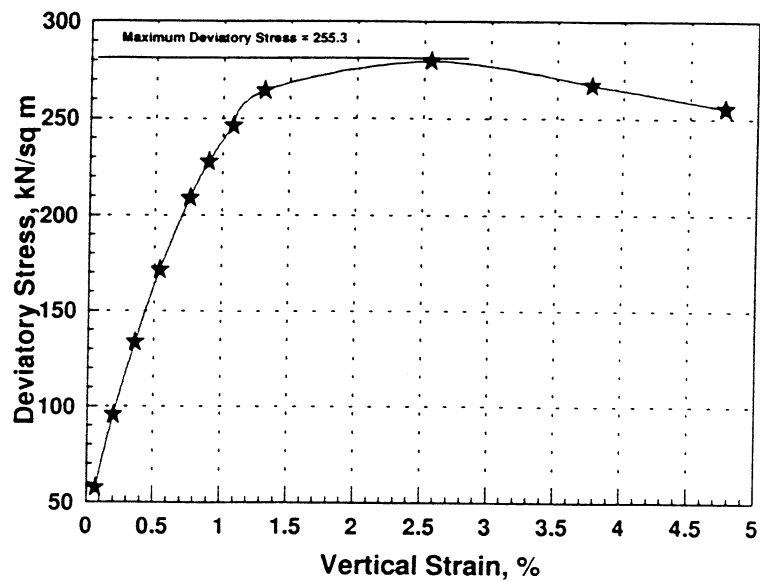
Test Performed : Consolidated Drained

S No.	Confined Press. psi	Confined Press. kN/sq.m	Deviatory Stress. kN/sq. m	Deviatory + Confined Stress kN/sq.m
1	10	68.95	255	323.95
2	30	206.85	365	571.85
3	50	344.75	1023	1367.75

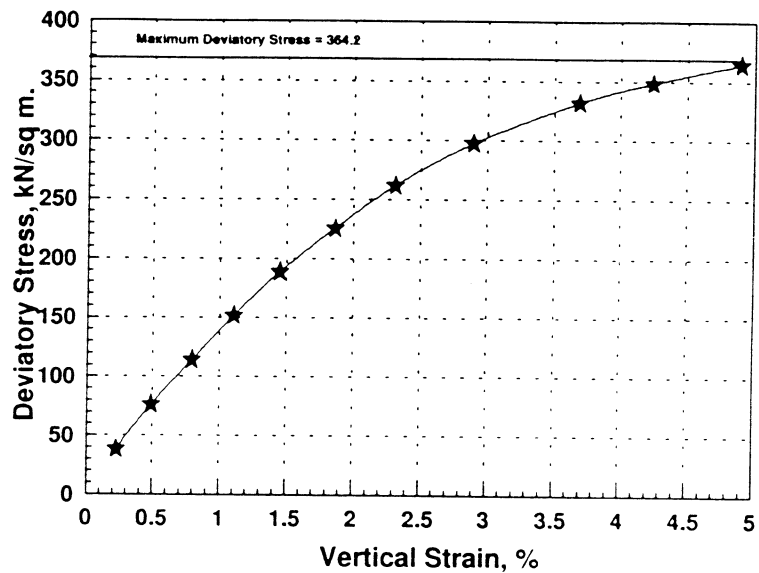
Conversion Factor Used:

$$1 \text{ kN/sq. m} = 6.895 \text{ psi.}$$

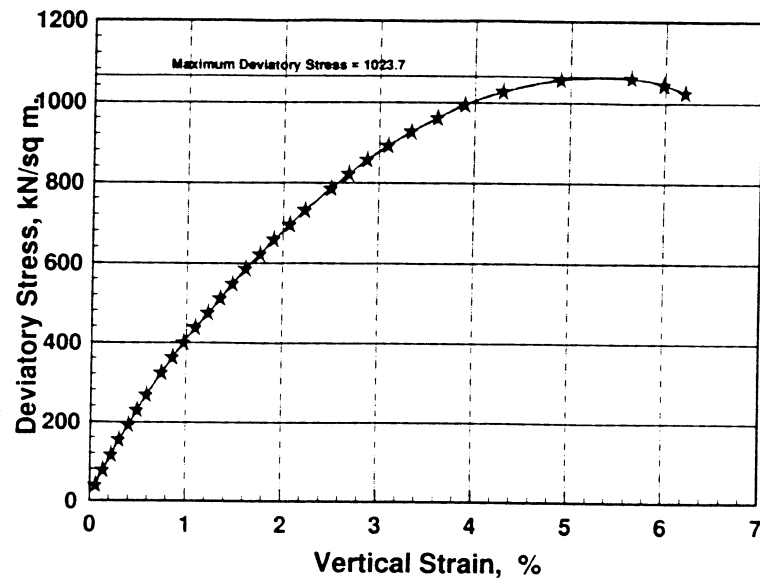
Triaxial Shear Test - Unstabilized Sample - I, 10 psi



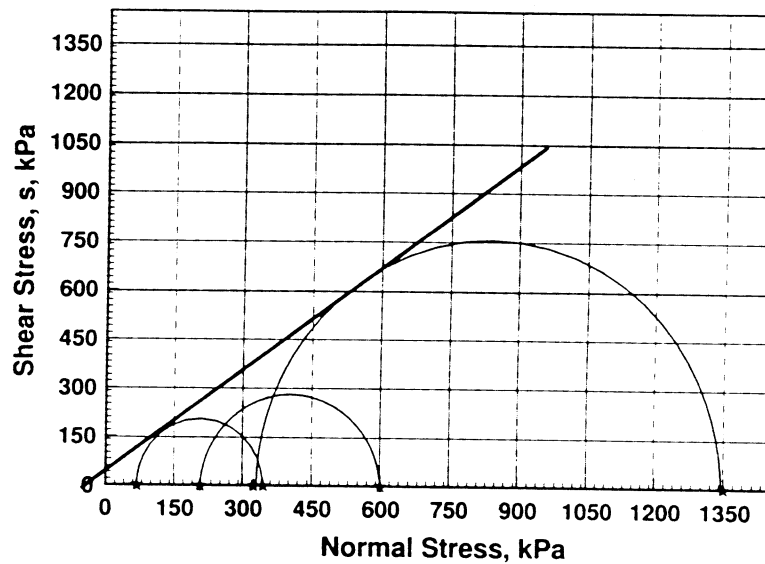
Triaxial Shear Test - Unstabilized Sample - I, 30 psi



Triaxial Shear Test - Unstabilized Sample - I, 50 psi



Mohr's Circle Plot - Unstabilized Sample - I.



Cohesion = 40 k Pa.
Angle Of Internal Friction = 45 deg.

TRIAxIAL SHEAR TEST

UNSTABILIZED SAMPLE - II, 20 PSI.

MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE

TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE

Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.013	0.033	0.001	0.084	20	0.16	43.02	38.26
0.026	0.066	0.002	0.168	40	0.33	43.06	76.46
0.047	0.119	0.003	0.303	70	0.58	43.12	133.62
0.061	0.155	0.004	0.394	90	0.74	43.16	171.64
0.085	0.216	0.005	0.548	120	0.99	43.22	228.50
0.103	0.262	0.007	0.665	140	1.15	43.27	266.27
0.121	0.307	0.008	0.781	160	1.32	43.32	303.95
0.145	0.368	0.009	0.935	180	1.48	43.39	341.41
0.172	0.437	0.011	1.110	200	1.65	43.47	378.68
0.210	0.533	0.014	1.355	220	1.81	43.58	415.52
0.235	0.597	0.015	1.516	230	1.89	43.65	433.69
0.305	0.775	0.020	1.968	250	2.06	43.85	469.24
0.380	0.965	0.025	2.452	256	2.11	44.07	478.14

Sample Description

Moist unit weight of specimen: 2.054 gm/cm³

Dry unit weight of specimen: 1.784 gm/cm³

Moisture content of specimen: 16 %

Initial average length of specimen: 15.5 cm

Initial average diameter of specimen: 7.4 cm

Initial area of specimen: 42.9866 cm²

Proving ring calibration factor:

1 kN = 121.5

2 kN = 241.8

3kN = 362.9

TRIAxIAL SHEAR TEST

UNSTABILIZED SAMPLE - II, 30 PSI.

MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE

TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE

Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.016	0.041	0.001	0.098	30	0.25	43.03	57.38
0.027	0.069	0.002	0.166	50	0.41	43.06	95.57
0.043	0.109	0.003	0.264	80	0.66	43.10	152.77
0.055	0.140	0.003	0.337	100	0.82	43.13	190.82
0.072	0.183	0.004	0.442	130	1.07	43.18	247.81
0.084	0.213	0.005	0.515	150	1.23	43.21	285.72
0.095	0.241	0.006	0.583	170	1.40	43.24	323.59
0.113	0.287	0.007	0.693	200	1.65	43.29	380.28
0.154	0.391	0.009	0.945	260	2.14	43.40	493.11
0.178	0.452	0.011	1.092	290	2.39	43.46	549.19
0.233	0.592	0.014	1.429	350	2.88	43.61	660.55
0.270	0.686	0.017	1.656	380	3.13	43.71	715.52
0.298	0.757	0.018	1.828	400	3.29	43.79	751.86
0.376	0.955	0.023	2.307	440	3.62	44.00	823.02
0.427	1.085	0.026	2.620	460	3.79	44.14	857.67
0.470	1.194	0.029	2.883	470	3.87	44.26	873.94

Sample Description:

Moist unit weight of specimen: 2.054 gm/cm³

Dry unit weight of specimen: 1.784 gm/cm³

Moisture content of specimen: 16 %

Initial average length of specimen: 16.3 cm

Initial average diameter of specimen: 7.398 cm

Initial area of specimen: 42.9866 cm²

Proving ring calibration factor:

1 kN = 121.5

2 kN = 241.8

3kN = 362.9

4 kN = 483.8

SUMMARY OF RESULTS FOR 10, 20, 30 PSI TESTS ON SAMPLE -II

TRIAXIAL SHEAR TEST

UNSTABILIZED SAMPLE - II

MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE

TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE

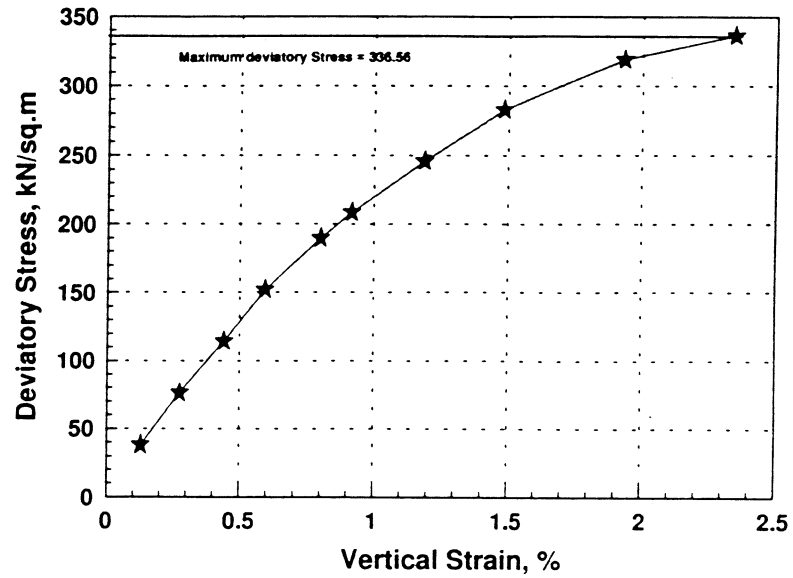
Test Performed : Consolidated Drained

S No.	Confined Press. psi	Confined Press. kN/sq.m	Deviatory Stress. kN/sq. m	Deviatory + Confined Stress kN/sq.m
1	10	68.95	336.55	405.5
2	20	137.9	478.13	616.03
3	30	206.85	873.94	1080.79

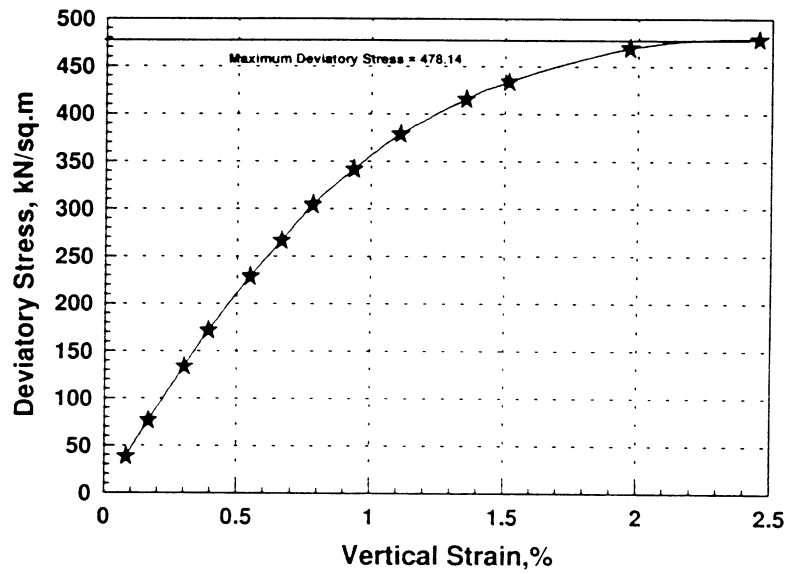
Conversion Factor Used:

1 kN/sq. m = 6.895 psi.

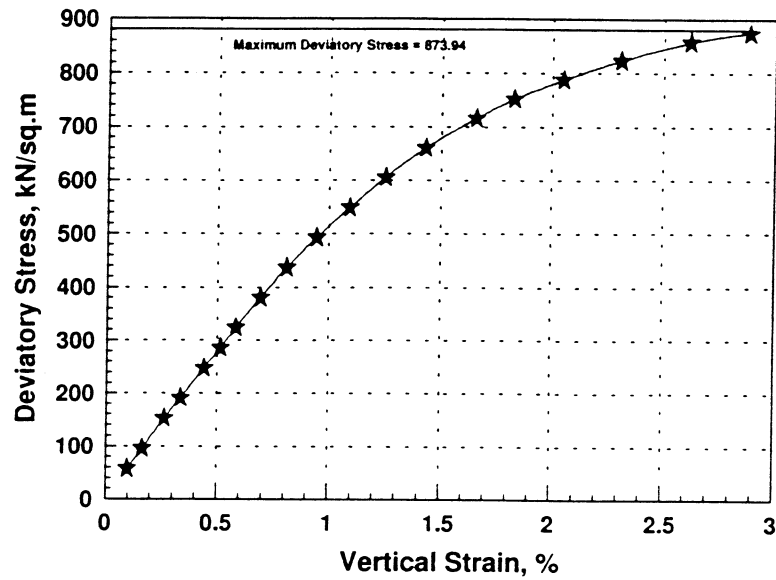
Triaxial Shear Test - Unstabilized Sample - II, 10psi



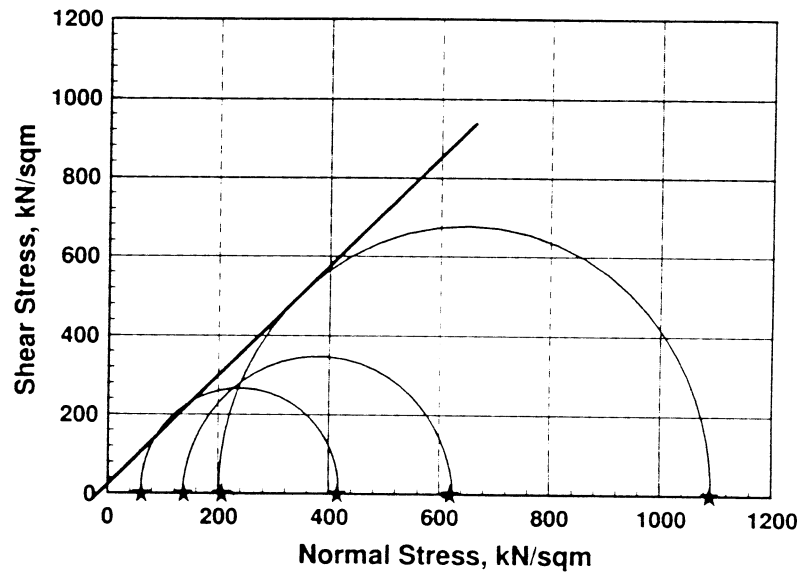
Triaxial Shear Test - Unstabilized Sample - II, 20 psi



Triaxial Shear Test - Unstabilized Sample - II, 30 psi



Mohr's Circle Plot - Unstabilized Sample - II



Cohesion = 35 kPa
Angle Of Internal Friction = 50 degrees

CALIFORNIA BEARING RATIO
UNSTABILIZED, UNSOAKED
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST CONDUCTED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE

Test Performed : ASTM D 1883-87, AASHTO T 193-81
 Compression Machine with Penetration Rate of 1.3 mm/min
 Mold Dimensions:
 Diam. = 6 in. No. of Layers: 5
 Ht. = 7 in. No. of Blows/Layer: 56
 Spacer Disk:
 Diam. = 6 in. Wt. of Hammer = 10 lb.
 Ht. = 2 in. Surcharge Wt. = 10 lb.

MOLD SAMPLE DATA

Mold No.	Unsoaked	Soaked
Surcharge(lbs)	10.00	10.00
Initial mass of wet soil + mold	8605.00	8625.00
Final mass wet soil and mold	xxx	8685.69
Mass of mold	4249.90	4195.10
Initial mass of wet soil	4325.10	4429.90
Initial wet density	2.07	2.12
Mass of water absorbed	xxx	60.69
% water absorbed	xxx	1.37

xxx - not applicable

WATER CONTENT DETERMINATION

Moisture Can No.	1	2	Top 1/3		Middle 1/3		Bottom 1/3	
Wt. of can + wet soil	36.30	42.10	33.00	37.30	44.30	43.80	31.80	29.80
Wt. of can + dry soil	32.70	39.10	30.20	34.00	41.50	40.90	29.10	27.30
Wt. of water	3.60	3.00	2.80	3.30	2.80	2.90	2.70	2.50
Wt. of can	12.00	20.90	12.00	12.00	21.30	21.00	12.00	11.70
Wt. of dry soil	20.70	18.20	18.20	22.00	20.20	19.90	17.10	15.60
Water Content, w%	17.39	16.48	15.38	15.00	13.86	14.57	15.79	16.03
Average =		16.94	Average = 15.19		Average = 14.22		Average = 15.91	

CBR TEST LOAD DATA

Deflection Reading	Dial Reading	Penetrate inches	Load Reading	Force kN	Stress kN/sq. m	Pressure q, in.
0.00	0.00	0.00	0.00	0.00	0.00	
25.00	0.03	110.00	0.91	467.88		
50.00	0.05	330.00	2.72	1403.64		
75.00	0.08	575.00	4.73	2445.74		
100.00	0.10	797.00	6.56	3390.01		
125.00	0.13	913.00	7.51	3883.41		
150.00	0.15	1103.00	9.08	4691.57		
175.00	0.18	1270.00	10.45	5401.90		
200.00	0.20	1405.00	11.56	5976.12		
225.00	0.23	1542.00	12.69	6558.84		
250.00	0.25	1680.00	13.83	7145.82		
275.00	0.28	1813.00	14.92	7711.53		
300.00	0.30	1942.00	15.98	8260.23		
325.00	0.33	2072.00	17.05	8813.18		
350.00	0.35	2203.00	18.13	9370.38		
375.00	0.38	2325.00	19.14	9889.30		

CALIFORNIA BEARING RATIO
UNSTABILIZED, SOAKED (4 DAYS)
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST CONDUCTED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE

Test Performed : ASTM D 1883-87, AASHTO T 193-81
 Compression Machine with Penetration Rate of 1.3 mm/min
 Mold Dimensions:
 Diam. = 6 in.
 Ht. = 7 in.
 No. of Layers: 5
 No. of Blows/Layer: 56
 Wt. of Hammer = 10 lb.
 Spacer Disk:
 Diam. = 6 in.
 Ht. = 2 in.
 Surcharge Wt. = 10 lb.

WATER CONTENT DETERMINATION

	Top 1/3			Middle 1/3			Bottom 1/3		
	1	2	3	4	5	6	7	8	
Moisture Can No.									
Wt. of can + wet soil	36.30	42.10	36.40	38.70	45.10	45.70	29.80	32.90	
Wt. of can + dry soil	32.70	39.10	32.30	34.30	42.00	42.50	27.40	30.40	
Wt. of water	3.60	3.00	4.10	4.40	3.10	3.20	2.40	2.50	
Wt. of can	12.00	20.90	12.00	12.00	21.50	21.20	12.00	11.50	
Wt. of dry soil	20.70	18.20	20.30	22.30	20.50	21.30	15.40	18.90	
Water Content, w%	17.39	16.48	20.20	19.73	15.12	15.02	15.58	13.23	
Average =	16.94			19.96			15.07		
	Average =			Average =			Average =		

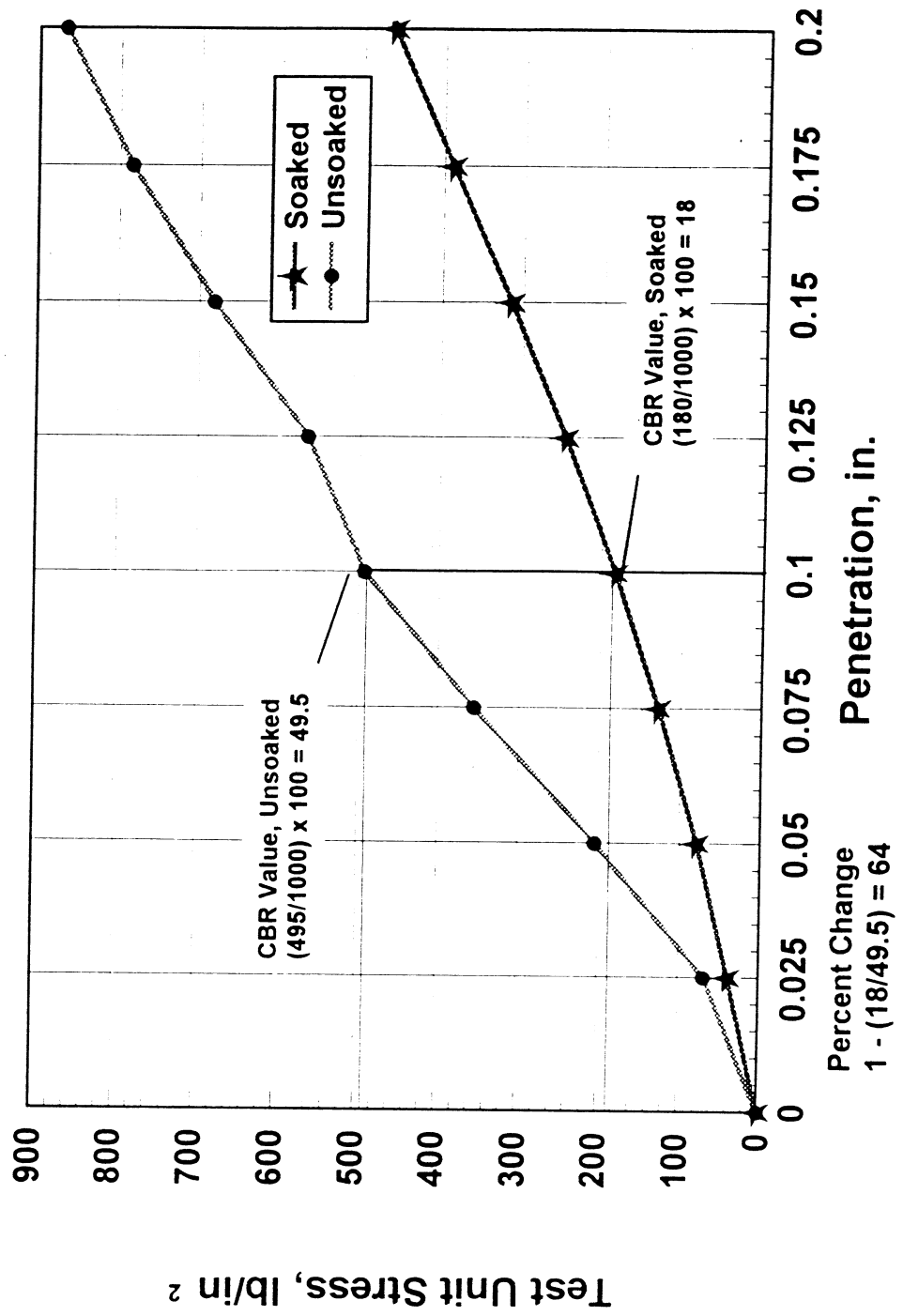
CBR TEST LOAD DATA

Deflection Dial	Penetrate mm	Load Reading	Force kN	Stress kN/sq. m	Stress lb/sq. in.
0.00	0.00	0.00	0.00	0.00	0.00
25.00	0.64	62.00	0.51	263.71	38.25
50.00	1.27	127.00	1.05	540.19	78.35
75.00	1.91	205.00	1.69	871.96	126.48
100.00	2.54	295.00	2.43	1254.77	182.00
125.00	3.18	398.00	3.28	1692.88	245.55
150.00	3.81	510.00	4.20	2169.27	314.65
175.00	4.45	628.00	5.17	2671.18	387.45
200.00	5.08	749.00	6.16	3185.84	462.10
225.00	5.72	875.00	7.20	3721.78	539.84
250.00	6.35	1004.00	8.26	4270.48	619.42
275.00	6.99	1137.00	9.36	4836.19	701.48
300.00	7.62	1267.00	10.43	5389.14	781.68
325.00	8.26	1403.00	11.55	5967.61	865.59
350.00	8.89	1535.00	12.63	6529.07	947.03
375.00	9.53	1672.00	13.76	7111.79	1031.55
400.00	10.16	1806.00	14.86	7681.76	1114.22

SWELL DATA

Start Time and Date	Elapsed Time	Dial Reading	%
17-Sep	12:30 0h		0
	13:30 1h		2
	14:30 2h		3
	16:30 4h		5
	22:30 10h		11
18-Sep	16:30 21h		22
	21:00 33h		23.5
	9:00 45h		27
20-Sep	9:00 69h		33
21-Sep	9:00 93h		41
			0.91

CBR Graph - Unstabilized, Soaked and Unsoaked



GEOTECHNICAL PROPERTIES

CEMENT STABILIZED ASH RESIDUE

SUMMARY OF RESULTS FOR 10, 20, 30 PSI TESTS OF 50% CEMENT STABILIZATION

TRIAxIAL SHEAR TEST

MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE

TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE

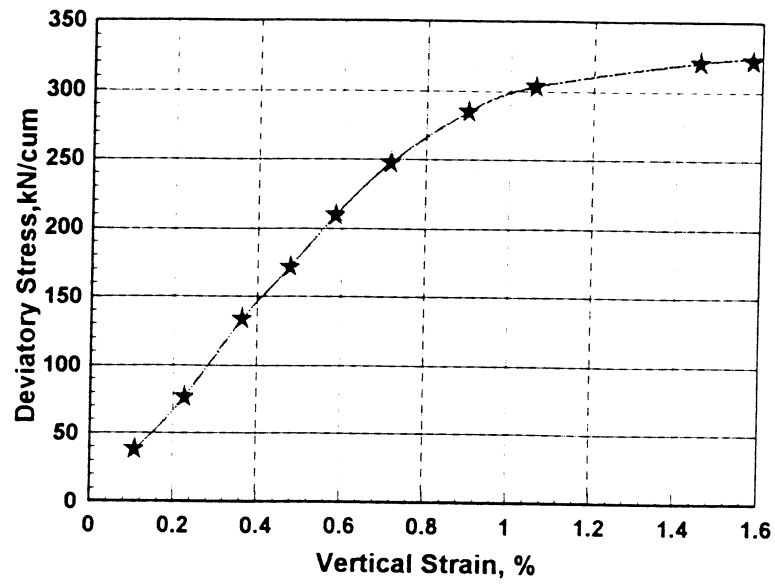
Test Performed : Consolidated Drained

S No.	Confined Press. psi $\sigma(3)$	Confined Press. kN/sq.m $\sigma(3)$	Deviatory Stress. kN/sq. m $\Delta\sigma$	Deviatory + Confined Stress kN/sq.m $\sigma(1) = \sigma(3) + \Delta\sigma$
1	10	68.95	322.24	391.19
2	20	137.9	524.92	662.82
3	30	206.85	674.33	881.18

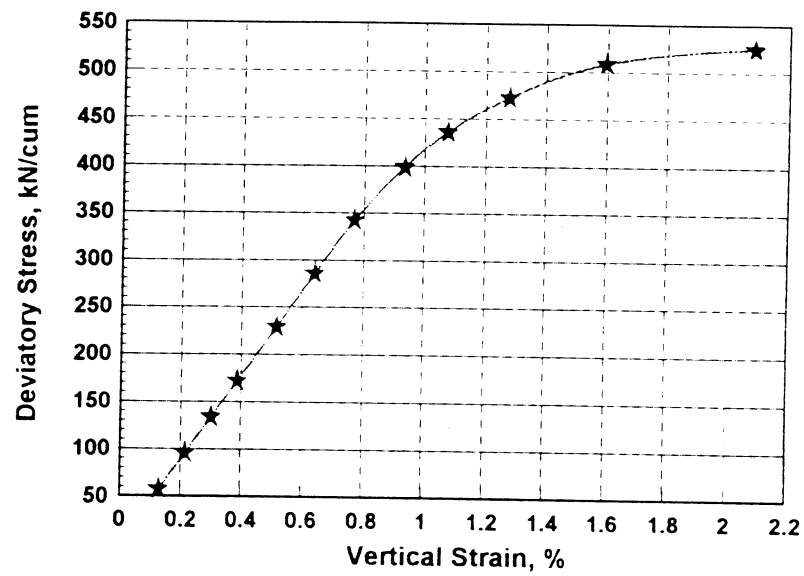
Conversion Factor Used:

$$6.895 \text{ kN/sq. m} = 1 \text{ psi.}$$

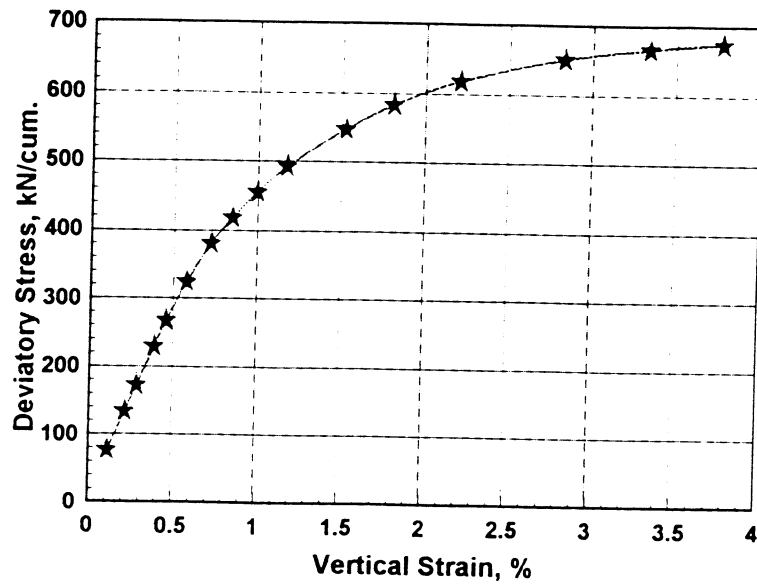
Triaxial Shear Test - 50% Cement Stabilization, 10psi



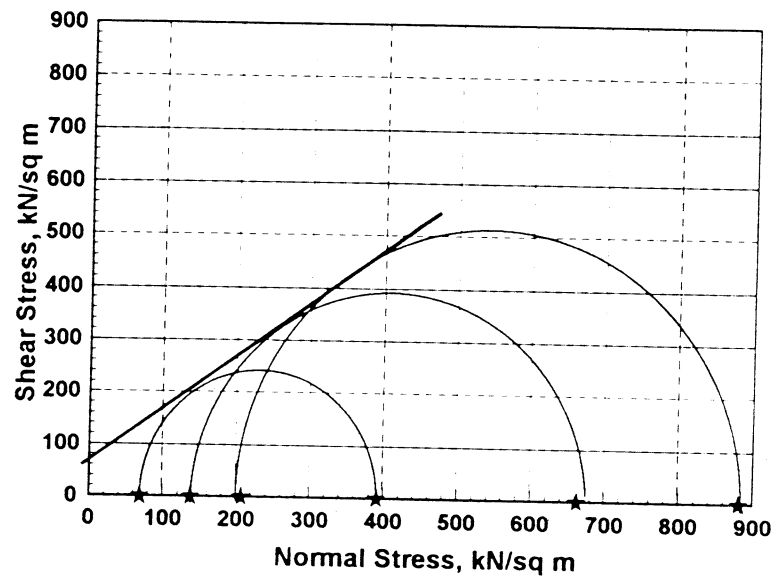
Triaxial Shear Test - 50% Cement Stabilization, 20 psi



Triaxial Shear Test - 50 % Cement Stabilization, 30 psi



Mohr's Circle Plot - 50% Cement Stabilization



C (Cohesion) = 65 kN/cum
 Phi (Angle of Internal Friction) = 45 degrees

CALIFORNIA BEARING RATIO
5% CEMENT, UNSOAKED
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST CONDUCTED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE

Test Performed : ASTM D 1883-87, AASHTO T 193-81
 Compression Machine with Penetration Rate of 1.3 mm/min
 Mold Dimensions: Diam. = 6 in. No. of Layers: 5
 Ht. = 7 in. No. of Blows/Layer: 56
 Spacer Disk: Diam. = 6 in. Wt. of Hammer = 10 lb.
 Ht. = 2 in. Surcharge Wt. = 10 lb.

MOISTURE CONTENT DETERMINATION

Moisture Can No.	1	2	Top 1/3		Middle 1/3		Bottom 1/3	
Wt. of can + wet soil	36.50	45.30	11	12	21	22	25	26
Wt. of can + dry soil	33.34	41.90	41.82	47.03	30.22	32.14	32.71	34.86
Wt. of water	3.16	3.40	39.10	43.61	28.06	29.42	30.24	32.11
Wt. of can	12.00	20.90	2.72	3.42	2.16	2.72	2.47	2.75
Wt. of dry soil	21.34	21.00	20.66	21.16	13.50	11.53	13.55	13.45
Water Content, w%	14.81	16.19	18.44	22.45	14.56	17.89	16.69	18.66
Average =	15.50		Average = 14.99		Average = 15.02		Average = 14.77	

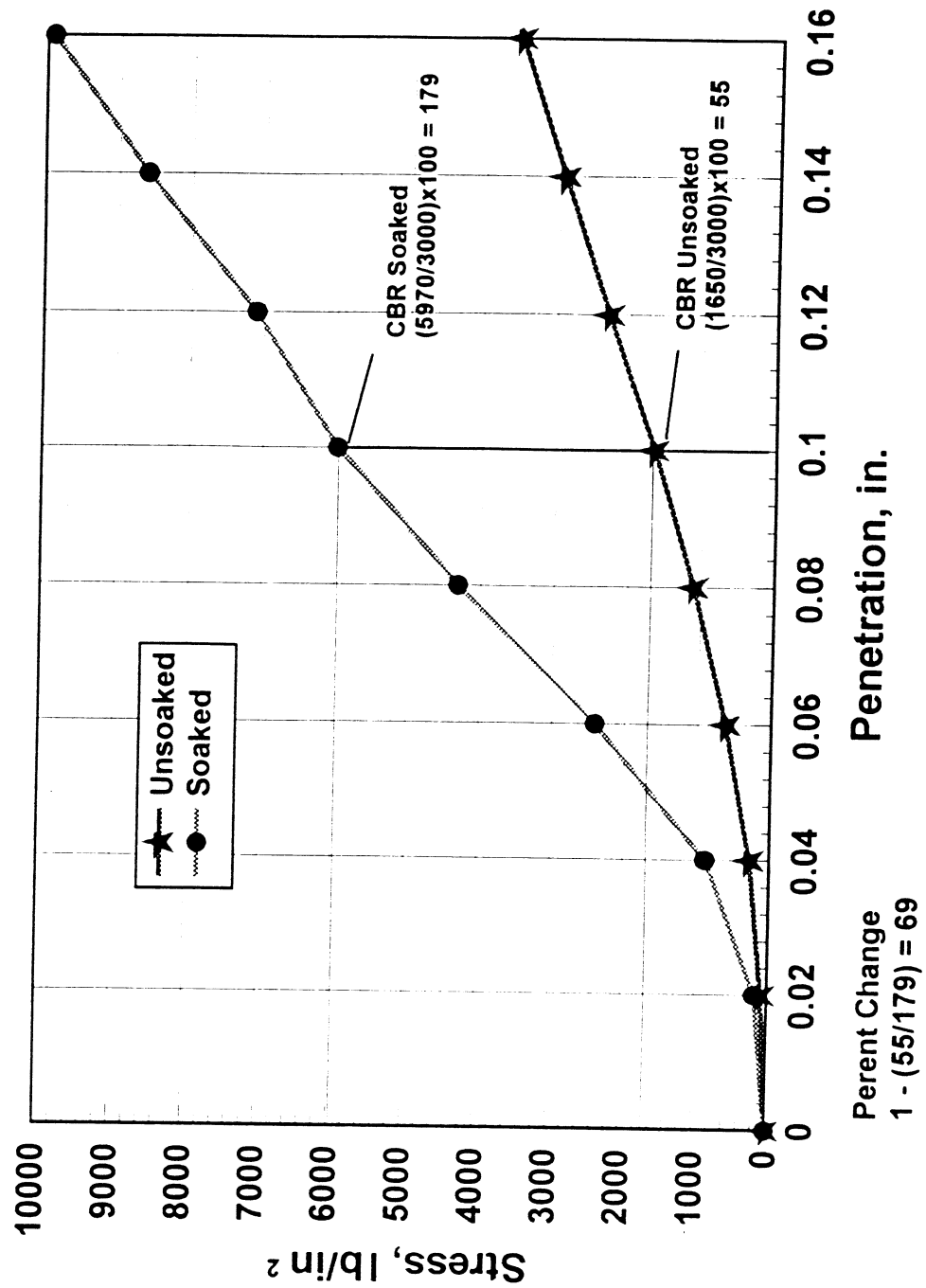
CBR TEST LOAD DATA

Penetrate in.	Stress lb/sq. in.
0.00	0
0.02	90
0.04	270
0.06	610
0.08	1090
0.10	1650
0.12	2280
0.14	2910
0.16	3540

MOLD SAMPLE DATA

Mold No.	Unsoaked	Soaked
Surcharge(lbs)	10.00	10.00
Initial mass of wet soil + mold	8655.20	8655.00
Final mass wet soil and mold	xxx	8659.00
Mass of mold	4196.70	4248.80
Initial mass of wet soil	4458.50	4406.20
Initial wet density	2.14	2.11
Mass of water absorbed	xxx	4.00
% water absorbed	xxx	0.09
xxx - not applicable		

CBR Graph, 5% Cement Soaked and Unsoaked



STANDARD COMPACTION TEST
5% Cement Stabilization
MATERIAL: MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT: SOILS LABORATORY- FAMU/FSU ENGINEERING COLLEGE

Test Performed : Standard Proctor
Blows/Layer = 25 No. of Layers = 3 Wt. of Hammer = 24.5 N
Mold Dimensions: Diam. = 10.14 cm
Ht = 11.67cm
Vol. = 0.0009424 m³

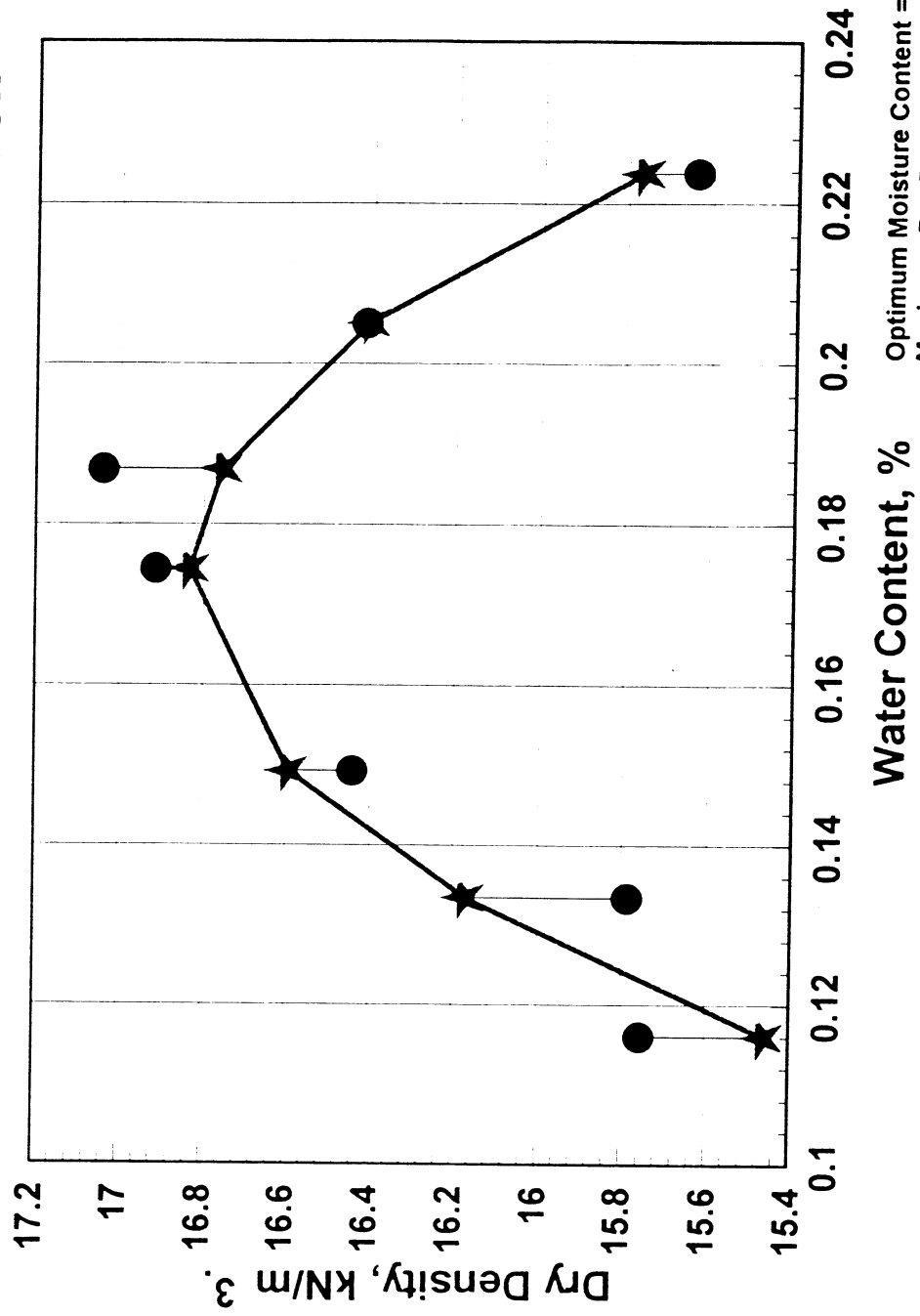
WATER CONTENT DETERMINATION

Sample No.	1		2		3		4		5		6		7	
Moisture Can No.	1	2	3	4	5	6	7	8						
Wt. of can + wet soil	63.40	61.50	32.30	33.30	43.00	45.70	33.80	34.80	47.00	49.80	48.50	51.60	44.40	42.50
Wt. of can + dry soil	59.03	57.27	29.83	30.85	40.18	42.49	30.63	31.28	42.85	45.29	43.89	46.37	38.40	37.30
Wt. of Water	4.37	4.23	2.47	2.45	2.82	3.21	3.17	3.52	4.15	4.51	4.61	5.23	6.00	5.20
Wt. of Can	21.10	21.10	11.90	11.90	21.30	21.00	12.00	11.60	20.70	21.10	21.30	21.00	12.10	13.60
Wt. of dry soil	37.93	36.17	17.93	18.95	18.88	21.49	18.63	19.68	22.15	24.19	22.59	25.37	26.30	23.70
Water Content, w%	11.52	11.69	13.78	12.93	14.94	14.94	17.02	17.89	18.74	18.64	20.41	20.61	22.81	21.94

DENSITY DETERMINATION

Assumed w%	14	16	18	20	22	24	26
Actual Water Content	11.61	13.35	14.94	17.45	18.69	20.51	22.38
Wt. of soil + Mold	3697.60	3727.50	3824.30	3917.50	3952.10	3909.60	3847.30
Wt. of Mold	2004.00	2004.00	2004.00	2004.00	2004.00	2004.00	2004.00
Wt. of soil in mold	1693.60	1723.50	1820.30	1913.50	1948.10	1905.60	1843.30
Wet Density, kN/m ³	17.58	17.89	18.90	19.86	20.22	19.78	19.14
Dry Density, kN/m ³	15.75	15.78	16.44	16.91	17.04	16.42	15.64

Compaction Curve - 5% Cement Stabilization



STANDARD COMPACTION TEST
10% Cement Stabilization
MATERIAL: MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT:-SOILS LABORATORY- FAMU/FSU ENGINEERING COLLEGE

Test Performed : Standard Proctor
Blows/Layer = 25 No. of Layers = 3 Wt.of Hammer = 24.5 N
Mold Dimensions:
Diam. = 10.14 cm
Ht = 11.67cm
Vol. = 0.0009424 m³

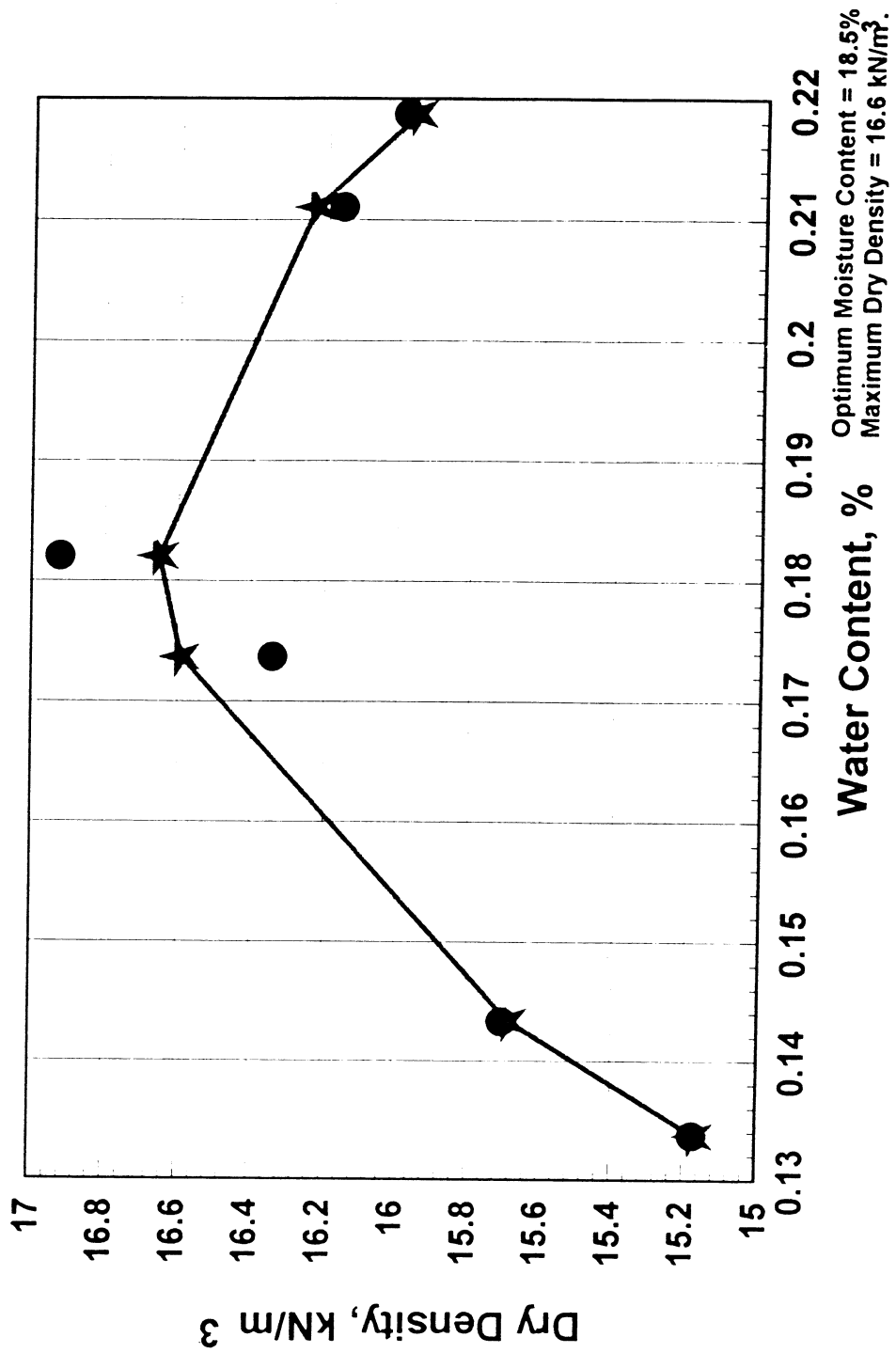
WATER CONTENT DETERMINATION

Sample No.	1		2		3		4		5		6	
Moisture Can No.	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00	12.00
Wt. of can + wet soil	42.70	38.60	27.60	30.40	46.00	46.10	34.70	32.30	47.70	48.50	57.20	51.90
Wt. of can + dry soil	40.20	36.50	25.70	28.00	42.30	42.40	31.20	29.10	43.00	43.70	50.70	46.40
Wt. of Water	2.50	2.10	1.90	2.40	3.70	3.70	3.50	3.20	4.70	4.80	6.50	5.50
Wt. of Can	21.00	21.20	11.90	11.90	21.20	20.90	11.90	11.60	20.60	21.10	21.40	20.90
Wt. of dry soil	19.20	15.30	13.80	16.10	21.10	21.50	19.30	17.50	22.40	22.60	29.30	25.50
Water Content, w %	13.02	13.73	13.77	14.91	17.54	17.21	18.13	18.29	20.98	21.24	22.18	21.57

DENSITY DETERMINATION

Assumed w %	16	18	20	22	24	26
Actual Water Content	13.37	14.34	17.37	18.21	21.11	21.88
Wt fo soil + Mold	3687.80	3760.10	3878.30	3957.90	3916.00	3907.40
Wt. of Mold	2030.90	2030.90	2030.90	2030.90	2030.90	2030.90
Wt.of soil in mold	1656.90	1729.20	1847.40	1927.00	1885.10	1876.50
Wet Density, kN/m ³	17.20	17.95	19.18	20.00	19.57	19.48
Dry Density, kN/m ³	15.17	15.70	16.34	16.92	16.16	15.98

Compaction Curve - 10% Cement stabilization



STANDARD COMPACTION TEST
15% Cement Stabilization
MATERIAL: MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT: SOILS LABORATORY- FAMU/FSU ENGINEERING COLLEGE

Test Performed : Standard Proctor
Blows/Layer = 25 No. of Layers = 3 Wt. of Hammer = 24.5 N
Mold Dimensions:
Diam. = 10.14 cm
Ht = 11.67cm
Vol. = 0.0009424 m³

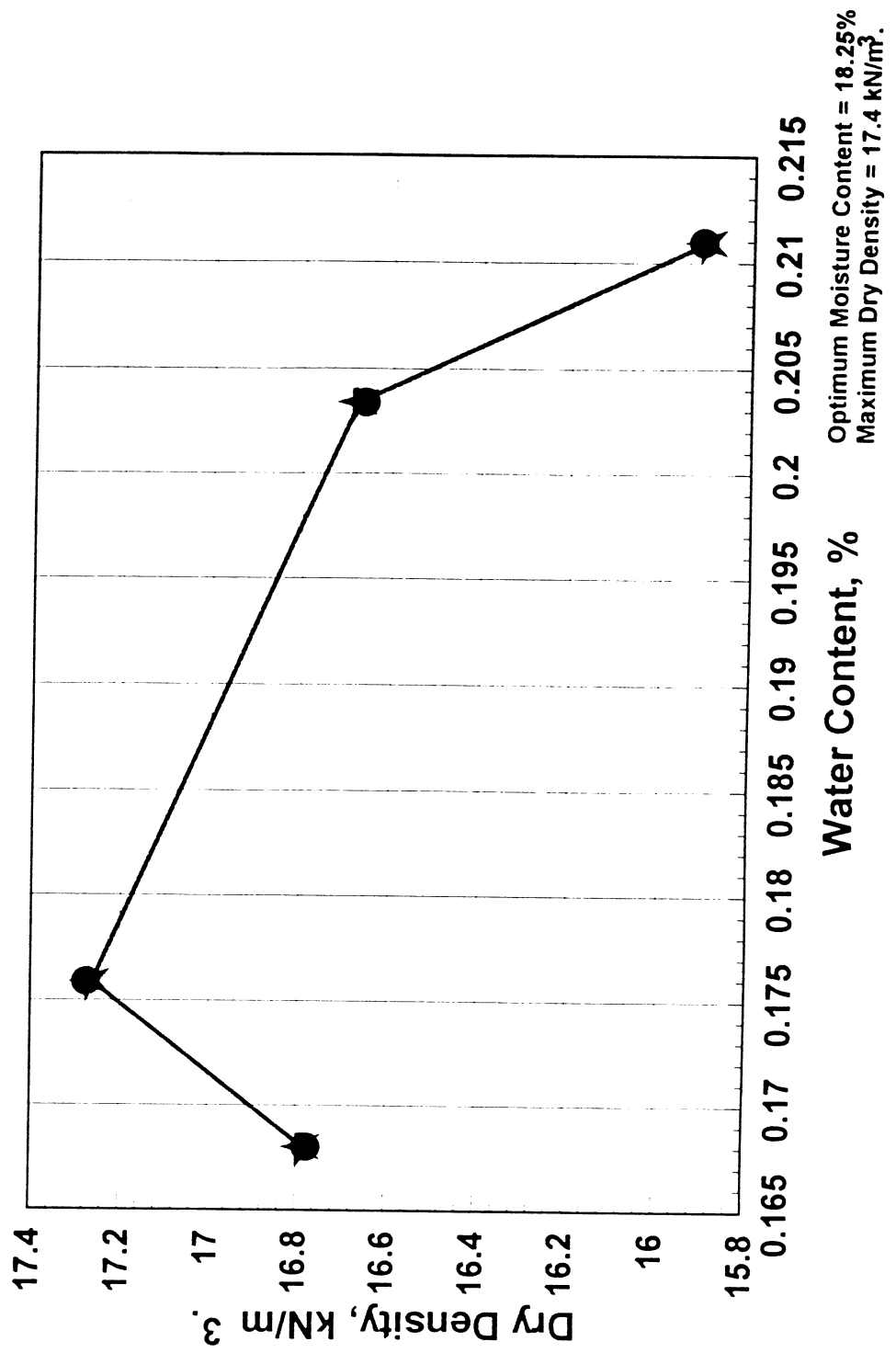
WATER CONTENT DETERMINATION

Sample No.	1		2		3		4	
Moisture Can No.	1	2	3	4	5	6	7	8
Wt. of can + wet soil	33.00	33.70	32.30	31.30	36.20	32.10	36.80	40.70
Wt. of can + dry soil	30.30	30.70	29.50	28.70	32.10	28.60	32.40	35.70
Wt. of water	2.70	3.00	2.80	2.60	4.10	3.50	4.40	5.00
Wt. of can	13.70	13.40	13.60	13.90	11.70	11.60	11.80	11.70
Wt. of dry soil	16.60	17.30	15.90	14.80	20.40	17.00	20.60	24.00
Water Content, w%	16.27	17.34	17.61	17.57	20.10	20.59	21.36	20.83

DENSITY DETERMINATION

Assumed w%	18	20	22	24
Actual Water Content	16.80	17.59	20.34	21.10
Wt. of soil + mold	3890.70	3960.10	3934.80	3859.40
Wt. of mold	2003.30	2003.30	2003.30	2003.30
Wt. of soil in mold	1887.40	1956.80	1931.50	1856.10
Wet Density, kN/m ³	19.59	20.31	20.05	19.27
Dry Density, kN/m ³	16.77	17.28	16.66	15.91

Compaction Curve - 15% Cement Stabilization



STANDARD COMPACTION TEST
25% Cement Stabilization

MATERIAL: MUNICIPAL SOLID WASTE ASH RESIDUE
 TEST PERFORMED AT: SOILS LABORATORY- FAMU/FSU ENGINEERING COLLEGE

Test Performed : Standard Proctor

Blows/Layer = 25 No. of Layers = 3 Wt.of Hammer = 24.5 N

Mold Dimensions: Diam. = 10.14 cm

Ht = 11.67cm

Vol. = 0.0009424 m³

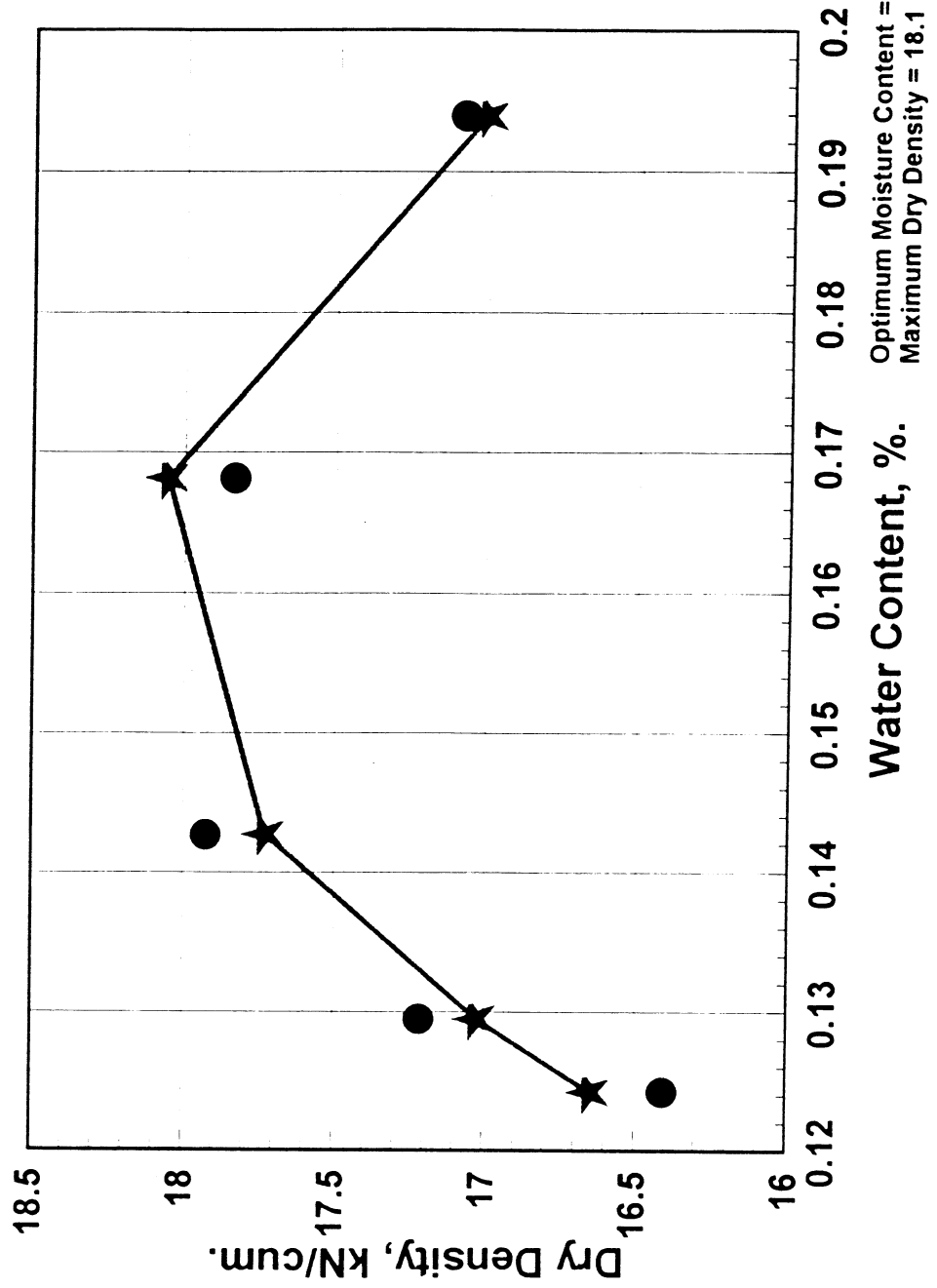
WATER CONTENT DETERMINATION

Sample No.	1		2		3		4		5		6	
Moisture Can No.	1	2	3	4	5	6	7	8	9	10	11	12
Wt. of can + wet soil	27.5	28.1	31.2	30.5	36.3	28.3	37.8	37.1	37.77	43.7	57.45	42.74
Wt. of can + dry soil	26.34	26.92	29.53	29.09	33.9	26.86	34.84	34.36	34.26	39.91	50.71	38.45
Wt. of water	1.16	1.18	1.67	1.41	2.4	1.44	2.96	2.74	3.51	3.79	6.74	4.29
Wt. of can	16.6	17.8	17.8	17	17.8	16.3	18	17.3	16.9	19.5	17.5	17.5
Wt. of dry soil	9.74	9.12	11.73	12.09	16.1	10.56	16.84	17.06	17.36	20.41	33.21	20.95
Water Content, w %	11.91	12.94	14.24	11.66	14.91	13.64	17.58	16.06	20.22	18.57	20.30	20.48

DENSITY DETERMINATION

Assumed w %	14		16		18		20		22		24	
Actual Water Content	12.42		12.95		14.27		16.82		19.39		20.39	
Wt. of soil + mold	3822.2		3918.2		4018.3		4052.3		4010.2		3992.3	
Wt. of mold	2045.5		2045.5		2045.5		2045.5		2045.5		2045.5	
Wt. of soil in mold	1776.7		1872.7		1972.8		2006.8		1964.7		1946.8	
Wet Density, kN/cum	18.44		19.44		20.48		20.83		20.40		20.21	
Dry Density, kN/cum	16.41		17.21		17.92		17.83		17.08		16.79	

Compaction Curve- 25% Cement Stabilization.



STANDARD COMPACTION TEST
50% Cement Stabilization
MATERIAL: MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT: SOILS LABORATORY- FAMU/FSU ENGINEERING COLLEGE

Test Performed : Standard Proctor
 Blows/Layer = 25 No. of Layers = 3 Wt. of Hammer = 24.5 N
 Mold Dimensions:
 Diam. = 10.14 cm
 Ht = 11.67cm
 Vol. = 0.0009424 m³

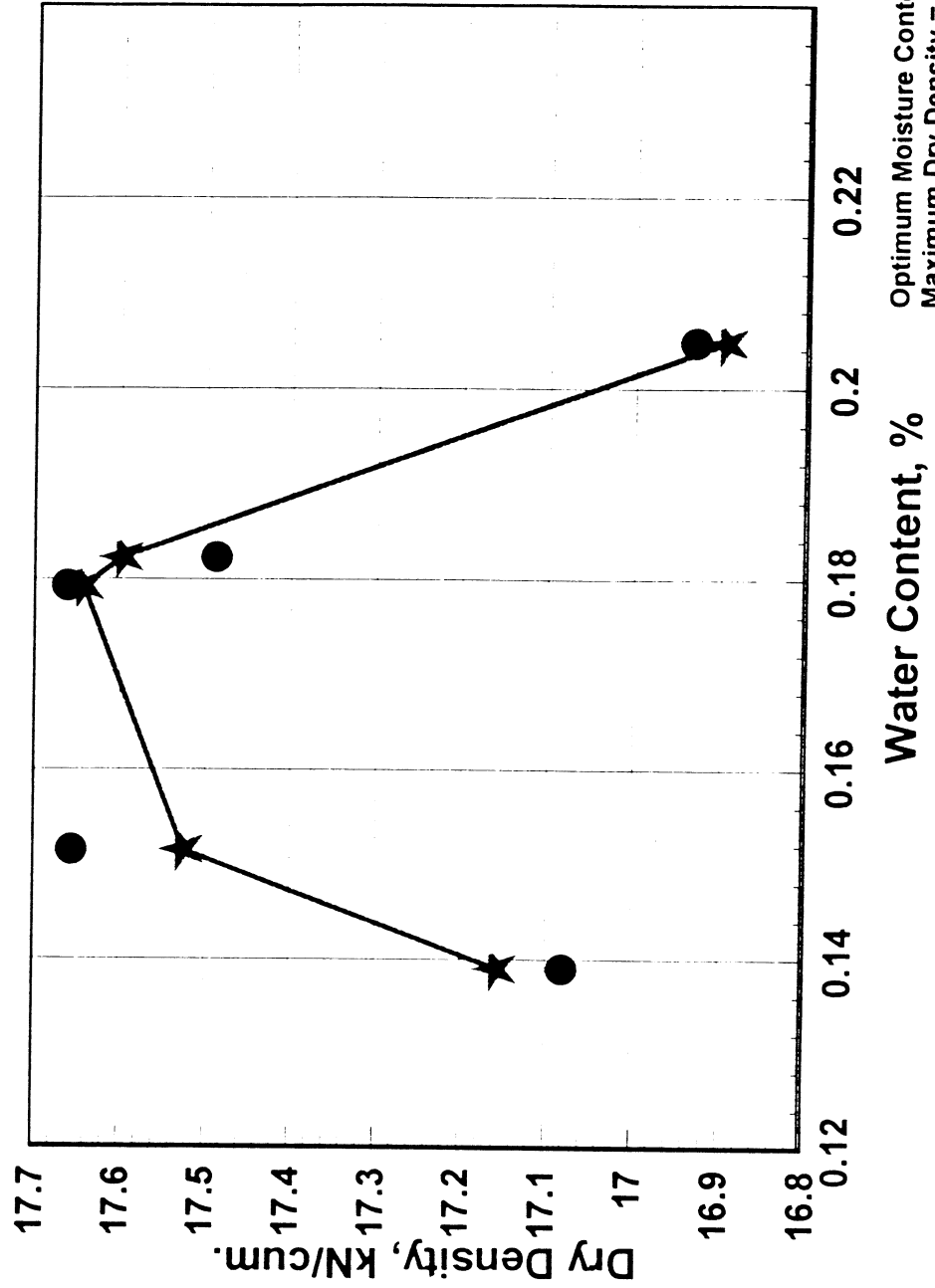
WATER CONTENT DETERMINATION

Sample No.	1		2		3		4		5	
Moisture Can No.	1	2	3	4	5	6	7	8	9	10
Wt. of can + wet soil	25.3	31	31.8	34.7	33.98	44.12	45.4	50.1	42.4	44
Wt. of can + dry soil	23.7	28.6	29.1	31.7	30.7	39.1	40.3	44.1	37.3	38.4
Wt. of water	1.6	2.4	2.7	3	3.28	5.02	5.1	6	5.1	5.6
Wt. of can	11.8	11.9	11.2	12	12	11.7	11.8	11.8	11.8	11.7
Wt. of dry soil	11.9	16.7	17.9	19.7	18.7	27.4	28.5	32.3	25.5	26.7
Water Content, w%	13.45	14.37	15.08	15.23	17.54	18.32	17.89	18.58	20.00	20.97

DENSITY DETERMINATION

Assumed w%	14	16	18	20	22
Actual Water Content	13.91	15.16	17.93	18.24	20.49
Wt. of soil + mold	3916	4000	4048	4034	4007
Wt. of mold	2042	2042	2042	2042	2042
Wt. of soil in mold	1874	1959	2006	1992	1965
Wet Density, kN/m ³	19.46	20.33	20.83	20.68	20.40
Dry Density, kN/m ³	17.08	17.66	17.66	17.49	16.93

Compaction Curve - 50% Cement Stabilization.



COEFFICIENT OF PERMEABILITY - FALLING HEAD METHOD**5% CEMENT STABILIZATION**

MATERIAL :- MUNICIPAL SOLID WASTE ASH RESIDUE

TEST PERFORMED AT :- SOILS LAB.-FAMU/FSU ENGINEERING COLLEGE

WATER CONTENT DETERMINATION:

Moisture can #:	1.00	2.00
Wt. of can + wet soil (g)	33.80	34.80
Wt. of can + dry soil (g)	30.63	31.28
Wt. of water(g)	3.17	3.52
Wt. of can (g)	12.00	11.60
wt. of dry soil (g)	18.63	19.68
Water content, w%:	17.00	18.00

USING COMPACTION PERMEAMETER AND STANDARD PROCTOR AASHTO T9

Blows per layer: 25	Mold dia.(cm):	10.14
No. of layers: 3	Area (cm ²):	81.1
Wt. of hammer: 24.5 N	Ht. (cm):	11.6
	Vol. (m ³):	0.0009424

PERMEABILITY TEST DATA:

Standpipe: 100 ml burette

Area of standpipe: 1.71 cm²
 Kt/K20 1

Test #	h1 (cm)	h2 (cm)	Time (sec)	Temp (°C)
1	63.5	48	212	20
2	63.5	48	210	20
3	63.5	48	211	20
4	63.5	48	214	20
5	63.5	48	209	20
6	63.5	48	211	20
Average:			211.17	

$$Kt = (a \times L/A \times t) \ln (h_1/h_2) =$$

$$Kt = (1.71 \times 11.6/81.1 \times 211.17) \ln (63.5/48) = 3.24 \times 10^{-4}$$

$$\text{Coefficient of Permeability, } K, \text{ at } 20^\circ\text{C} = 3.24 \times 10^{-4} \text{ cm/sec}$$

COEFFICIENT OF PERMEABILITY - FALLING HEAD METHOD**10% CEMENT STABILIZATION****MATERIAL :- MUNICIPAL SOLID WASTE ASH RESIDUE****TEST PERFORMED AT:-SOILS LAB-FAMU/FSU ENGINEERING COLLEGE****WATER CONTENT DETERMINATION:**

Moisture can #:	1	2
Wt. of can + wet soil (g)	34.7	32.3
Wt. of can + dry soil (g)	31.2	29.1
Wt. of water(g)	3.5	3.2
Wt. of can (g)	11.9	11.6
wt. of dry soil (g)	19.3	17.5
Water content, w%:	18.1	18.3

USING COMPACTION PERMEAMETER AND STANDARD PROCTOR AASHTO T99

Blows per layer: 25	Mold dia.(cm):	10.14
No. of layers: 3	Area (cm ²):	81.1
Wt. of hammer: 24.5 N	Ht. (cm):	11.6
	Vol. (m ³):	0.0009424

PERMEABILITY TEST DATA:

Standpipe: 100 ml burette

Area of standpipe: 1.71 cm²

Kt/K20 1

Test #	h1 (cm)	h2 (cm)	Time (sec)	Temp (°C)
1	63.5	52.5	187	20
2	63.5	52.5	190	20
3	63.5	52.5	193	20
4	63.5	52.5	195	20
5	63.5	52.5	200	20
6	63.5	52.5	204	20
Average:			194.83	

$$Kt = (a \times L/A \times t) \ln (h_1/h_2) =$$

$$Kt = (1.71 \times 11.6/81.1 \times 194.83) \ln (63.5/52.5) = 2.39 \times 10^{-4} \text{ cm/sec}$$

$$\text{Coefficient of Permeability, } K, \text{ at } 20^\circ\text{C} = 2.39 \times 10^{-4} \text{ cm/sec}$$

COEFFICIENT OF PERMEABILITY - FALLING HEAD METHOD**15% CEMENT STABILIZATION**

MATERIAL :- MUNICIPAL SOLID WASTE ASH RESIDUE

TEST PERFORMED AT :- SOILS LAB-FAMU/FSU ENGINEERING COLLEGE

WATER CONTENT DETERMINATION:

Moisture can #:	1	2
Wt. of can + wet soil (g)	32.30	31.30
Wt. of can + dry soil (g)	29.50	28.70
Wt. of water(g)	2.80	2.60
Wt. of can (g)	13.60	13.90
wt. of dry soil (g)	15.90	14.80
Water content, w%:	17.90	18.10

USING COMPACTION PERMEAMETER AND STANDARD PROCTOR AASHTO T9

Blows per layer: 25	Mold dia.(cm):	10.14
No. of layers: 3	Area (cm ²):	81.1
Wt. of hammer: 24.5 N	Ht. (cm):	11.6
	Vol. (m ³):	0.0009424

PERMEABILITY TEST DATA:

Standpipe: 100 ml burette

Area of standpipe: 1.71 cm²

Kt/K20 1

Test #	h1 (cm)	h2 (cm)	Time (sec)	Temp (°C)
1	63.5	62.4	470	20
2	63.5	62.4	452	20
3	63.5	62.4	530	20
4	63.5	62.4	512	20
5	63.5	62.4	552	20
6	63.5	62.4	475	20
Average:			498.5	

$$Kt = (a \times L/A \times t) \ln (h_1/h_2) =$$

$$Kt = (1.71 \times 11.6/81.1 \times 194.83) \ln (63.5/62.4) = 6.57 \times 10^{-6} \text{ cm/sec}$$

$$\text{Coefficient of Permeability, } K, \text{ at } 20^\circ\text{C} = 6.57 \times 10^{-6} \text{ cm/sec}$$

COEFFICIENT OF PERMEABILITY - FALLING HEAD METHOD**25% CEMENT STABILIZATION**

MATERIAL :- MUNICIPAL SOLID WASTE ASH RESIDUE

TEST PERFORMED AT :- SOILS LAB.-FAMU/FSU ENGINEERING COLLEGE

WATER CONTENT DETERMINATION:

Moisture can #:	1	2
Wt. of can + wet soil (g)	27.6	37.4
Wt. of can + dry soil (g)	25.58	33.7
Wt. of water(g)	2.02	3.7
Wt. of can (g)	12.4	11.7
wt. of dry soil (g)	13.18	22
Water content, w%:	15.33	16.82

USING COMPACTION PERMEAMETER AND STANDARD PROCTOR AASHTO T99

Blows per layer: 25	Mold dia.(cm):	10.14
No. of layers: 3	Area (cm ²):	81.1
Wt. of hammer: 24.5 N	Ht. (cm):	11.6
	Vol. (m ³):	0.000942

PERMEABILITY TEST DATA:

Standpipe: 100 ml burette

Area of standpipe: 1.71 cm²
 Kt/K20 1

Test #	h1 (cm)	h2 (cm)	Time (sec)	Temp (°C)
1	72.7	66	480	20
2	72.7	66	472	20
3	72.7	66	477	20
4	72.7	66	486	20
5	72.7	66	484	20
6	72.7	66	488	20
Average:			481.1667	

$$K = (a \times L/A \times t) \ln (h_1/h_2) =$$

$$K = (1.71 \times 11.6/81.1 \times 481.17) \ln (72.7/66) = 4.915 \times 10^{-5}$$

$$\text{Coefficient of Permeability, } K, \text{ at } 20^\circ\text{C} = 4.915 \times 10^{-5}$$

COEFFICIENT OF PERMEABILITY - FALLING HEAD METHOD**50% CEMENT STABILIZATION****MATERIAL :- MUNICIPAL SOLID WASTE ASH RESIDUE****TEST PERFORMED AT :- SOILS LAB.-FAMU/FSU ENGINEERING COLLEGE****WATER CONTENT DETERMINATION:**

Moisture can #:	1	2
Wt. of can + wet soil (g)	49.2	45.8
Wt. of can + dry soil (g)	44.25	41.1
Wt. of water(g)	4.95	4.7
Wt. of can (g)	12	11.8
wt. of dry soil (g)	32.25	29.3
Water content, w%:	15.35	16.04

USING COMPACTION PERMEAMETER AND STANDARD PROCTOR AASHTO T99

Blows per layer: 25	Mold dia.(cm):	10.14
No. of layers: 3	Area (cm ²):	81.1
Wt. of hammer: 24.5 N	Ht. (cm):	11.6
	Vol. (m ³):	0.000942

PERMEABILITY TEST DATA:

Standpipe: 100 ml burette

Area of standpipe: 1.71 cm²

Kt/K20 1

Test #	h1 (cm)	h2 (cm)	Time (sec)	Temp (°C)
1	68.2	66.6	610	20
2	68.2	66.6	612	20
3	68.2	66.6	614	20
4	68.2	66.6	622	20
5	68.2	66.6	618	20
6	68.2	66.6	626	20
Average:			617	

$$K = (a \times L/A \times t) \ln (h_1/h_2) =$$

$$K = (1.71 \times 11.6/81.1 \times 617) \ln (68.2/66.6) = 9.41 \times 10^{-6}$$

$$\text{Coefficient of Permeability, } K, \text{ at } 20^\circ\text{C} = 9.41 \times 10^{-6}$$

TRIAxIAL SHEAR TEST
5% CEMENT STABILIZATION, 10 PSI.
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE
Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.009	0.023	0.001	0.055	10	0.082	43.01	19.14
0.013	0.033	0.001	0.080	20	0.165	43.02	38.26
0.022	0.056	0.001	0.135	30	0.247	43.04	57.36
0.040	0.102	0.002	0.245	50	0.412	43.16	95.35
0.066	0.168	0.004	0.405	80	0.658	43.16	152.55
0.082	0.208	0.005	0.503	100	0.823	43.20	190.50
0.106	0.269	0.007	0.650	130	1.070	43.27	247.29
0.127	0.323	0.008	0.779	150	1.235	43.32	284.96
0.150	0.381	0.009	0.920	170	1.399	43.39	322.50
0.188	0.478	0.012	1.153	190	1.564	43.49	359.59
0.263	0.668	0.016	1.613	210	1.728	43.69	395.59
0.358	0.909	0.022	2.196	220	1.811	43.95	411.97
0.379	0.963	0.023	2.325	222	1.827	44.01	415.17

Sample Description:-

Moist unit weight of specimen: 2.062 gm/cm³
Dry unit weight of specimen: 1.738 gm/cm³
Moisture content of specimen: 18.6 %
Initial average length of specimen: 16.3 cm
Initial average diameter of specimen: 7.4 cm
Initial area of specimen: 42.9866 cm²

Proving ring calibration factor:

1 kN = 121.5
2 kN = 241.8
3kN = 362.9
4 kN = 483.8

TRIAXIAL SHEAR TEST
5% CEMENT STABILIZED, 20 PSI.
 MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
 TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE
 Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.008	0.020	0.000	0.046	30	0.247	43.01	57.41
0.018	0.046	0.001	0.104	50	0.412	43.03	95.63
0.039	0.099	0.002	0.225	80	0.658	43.08	152.83
0.060	0.152	0.003	0.347	110	0.905	43.18	209.69
0.076	0.193	0.004	0.439	130	1.070	43.18	247.81
0.092	0.234	0.005	0.532	150	1.235	43.22	285.67
0.119	0.302	0.007	0.688	180	1.481	43.28	342.27
0.140	0.356	0.008	0.809	200	1.646	43.34	379.83
0.165	0.419	0.010	0.954	220	1.811	43.40	417.21
0.209	0.531	0.012	1.208	250	2.058	43.51	472.88
0.252	0.640	0.015	1.457	270	2.222	43.62	509.43
0.306	0.777	0.018	1.769	290	2.387	43.76	545.43
0.372	0.945	0.022	2.150	310	2.551	43.93	580.78
0.434	1.102	0.025	2.509	320	2.634	44.09	597.32
0.515	1.308	0.030	2.977	330	2.716	44.31	613.03
0.655	1.664	0.038	3.786	338	2.782	44.68	622.65

Sample Description:-

Moist unit weight of specimen: 2.062 gm/cm³

Dry unit weight of specimen: 1.725 gm/cm³

Moisture content of specimen: 18.4 %

Initial average length of specimen: 17.3 cm

Initial average diameter of specimen: 7.4 cm

Initial area of specimen: 42.9866 cm²

Proving ring calibration factor:

1 kN = 121.5

2 kN = 241.8

3kN = 362.9

TRIAxIAL SHEAR TEST
5% CEMENT STABILIZED, 30 PSI.
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE
Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.014	0.036	0.001	0.085	30	0.247	43.02	57.39
0.035	0.089	0.002	0.212	70	0.576	43.08	133.74
0.050	0.127	0.003	0.303	100	0.823	43.12	190.89
0.072	0.183	0.004	0.436	140	1.152	43.24	266.51
0.095	0.241	0.006	0.576	180	1.481	43.24	342.65
0.120	0.305	0.007	0.727	220	1.811	43.30	418.16
0.148	0.376	0.009	0.897	250	2.058	43.38	474.37
0.183	0.465	0.011	1.109	280	2.305	43.47	530.16
0.226	0.574	0.014	1.370	310	2.551	43.58	585.41
0.274	0.696	0.017	1.661	340	2.798	43.71	640.17
0.338	0.859	0.020	2.048	370	3.045	43.89	693.91
0.430	1.092	0.026	2.606	400	3.292	44.14	745.90
0.506	1.285	0.031	3.067	420	3.457	44.35	779.49
0.569	1.445	0.034	3.448	430	3.539	44.52	794.91
0.643	1.633	0.039	3.897	438	3.605	44.73	805.94

Sample Description:-

Moist unit weight of specimen: 2.062 gm/cm³

Dry unit weight of specimen: 1.738 gm/cm³

Moisture content of specimen: 18.6 %

Initial average length of specimen: 16.5 cm

Initial average diameter of specimen: 7.4 cm

Initial area of specimen: 42.9866 cm²

Proving ring calibration factor:

1 kN = 121.5

2 kN = 241.8

3kN = 362.9

4kN = 483.8

SUMMARY OF RESULTS FOR 10, 20, 30 PSI TESTS OF 5% CEMENT STABILIZATION

TRIAXIAL SHEAR TEST

MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE

TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE

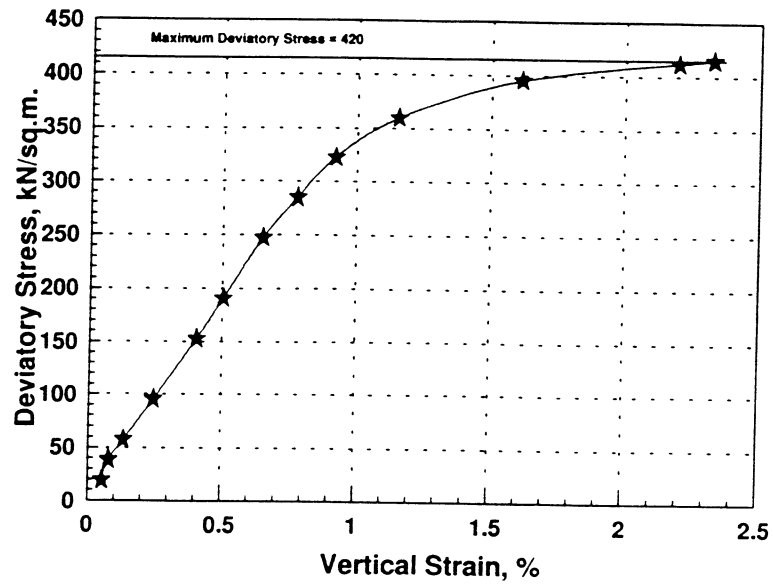
Test Performed : Consolidated Drained

S No.	Confined Press. psi $\sigma(3)$	Confined Press. kN/sq.m $\sigma(3)$	Deviatory Stress. kN/sq. m $\Delta\sigma$	Deviatory + Confined Stress kN/sq.m $\sigma(1) = \sigma(3) + \Delta\sigma$
1	10	68.95	415.17	484.12
2	20	137.9	622.65	760.55
3	30	206.85	805.93	1012.78

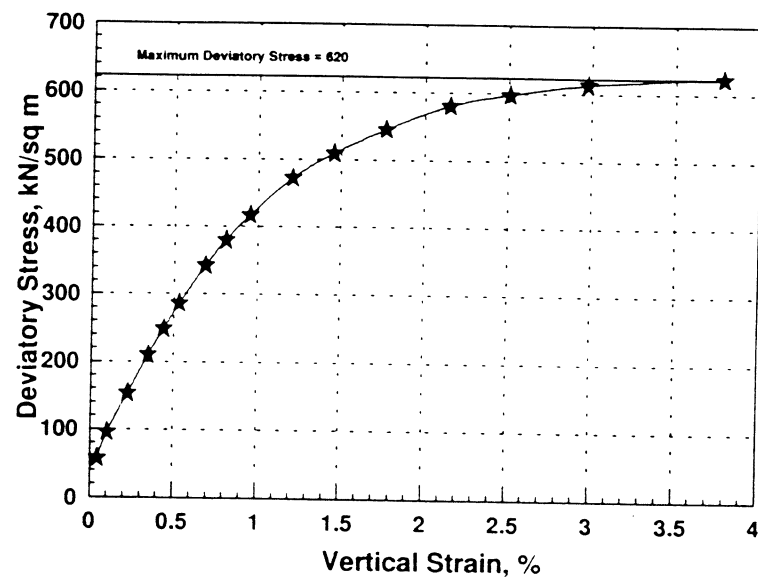
Conversion Factor Used:

$$6.895 \text{ kN/sq. m} = 1 \text{ psi.}$$

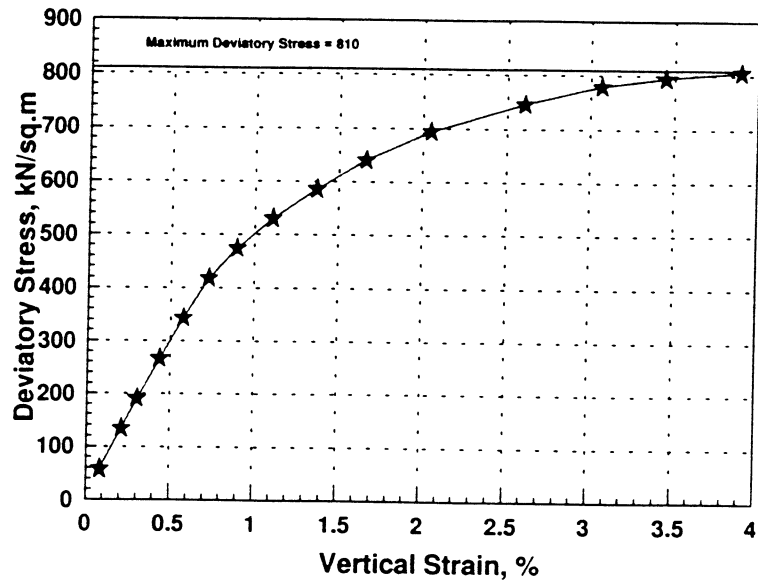
Triaxial Shear Test - 5% Cement Stabilization, 10 psi



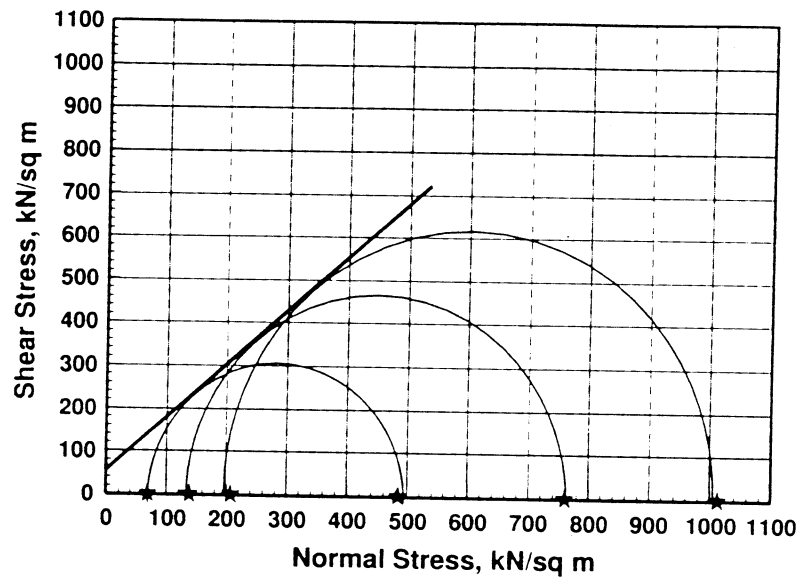
Triaxial Shear Test - 5% Cement Stabilization, 20 psi



Triaxial Shear Test - 5% Cement Stabilization , 30 psi



Mohr's Circle Plot - 5% Cement Stabilization



C (Cohesion) = 60 k Pa.

Phi (Angle Of Internal Friction) = 48 degrees.

TRIAXIAL SHEAR TEST
10% CEMENT STABILIZATION, 10 PSI.
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE
Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.015	0.038	0.001	0.092	20	0.165	43.026	38.258
0.035	0.089	0.002	0.215	40	0.329	43.079	76.422
0.055	0.140	0.003	0.337	60	0.494	43.132	114.492
0.072	0.183	0.004	0.442	80	0.658	43.225	152.327
0.090	0.229	0.006	0.552	100	0.823	43.225	190.408
0.108	0.274	0.007	0.663	120	0.988	43.273	228.236
0.128	0.325	0.008	0.785	140	1.152	43.327	265.947
0.155	0.394	0.010	0.951	160	1.317	43.399	303.432
0.193	0.490	0.012	1.184	180	1.481	43.502	340.557
0.225	0.572	0.014	1.380	190	1.564	43.588	358.763
0.290	0.737	0.018	1.779	200	1.646	43.765	376.118

Sample Description:-

Moist unit weight of specimen: 2.gm/cm³
Dry unit weight of specimen: 1.692 gm/cm³
Moisture content of specimen: 18.6 %
Initial average length of specimen: 16.3 cm
Initial average diameter of specimen: 7.4 cm
Initial area of specimen: 42.9866 cm²

Proving ring calibration factor:

1 kN = 121.5
2 kN = 241.8
3kN = 362.9
4 kN = 483.8

TRIAXIAL SHEAR TEST
10% CEMENT STABILIZATION, 20 PSI.
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE
Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.012	0.030	0.001	0.073	20	0.165	43.018	38.265
0.025	0.064	0.002	0.152	40	0.329	43.052	76.470
0.042	0.107	0.003	0.255	60	0.494	43.096	114.587
0.058	0.147	0.004	0.352	80	0.658	43.180	152.485
0.074	0.188	0.004	0.448	100	0.823	43.180	190.607
0.093	0.236	0.006	0.564	120	0.988	43.230	228.464
0.113	0.287	0.007	0.685	140	1.152	43.283	266.216
0.142	0.361	0.009	0.861	160	1.317	43.360	303.708
0.177	0.450	0.011	1.073	180	1.481	43.453	340.941
0.205	0.521	0.012	1.242	190	1.564	43.527	359.265
0.244	0.620	0.015	1.479	200	1.646	43.632	377.268
0.297	0.754	0.018	1.800	210	1.728	43.775	394.840
0.371	0.942	0.022	2.248	218	1.794	43.975	408.010

Sample Description:-

Moist unit weight of specimen: 2.0 gm/cm³
Dry unit weight of specimen: 1.692 gm/cm³
Moisture content of specimen: 18.2 %
Initial average length of specimen: 17.3 cm
Initial average diameter of specimen: 7.4 cm
Initial area of specimen: 42.9866 cm²

Proving ring calibration factor:

1 kN = 121.5
2 kN = 241.8
3 kN = 362.9

TRIAXIAL SHEAR TEST

10% CEMENT STABILIZATION, 30 PSI.

MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE

TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE

Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.011	0.028	0.001	0.071	30	0.247	43.017	57.399
0.020	0.051	0.001	0.129	50	0.412	43.042	95.609
0.037	0.094	0.002	0.239	90	0.741	43.112	171.819
0.045	0.114	0.003	0.290	110	0.905	43.112	210.001
0.054	0.137	0.003	0.348	130	1.070	43.137	248.038
0.070	0.178	0.005	0.452	170	1.399	43.182	324.021
0.078	0.198	0.005	0.503	190	1.564	43.204	361.954
0.100	0.254	0.006	0.645	240	1.975	43.266	456.553
0.124	0.315	0.008	0.800	290	2.387	43.333	550.808
0.149	0.378	0.010	0.961	330	2.716	43.404	625.763
0.162	0.411	0.010	1.045	350	2.881	43.441	663.125
0.199	0.505	0.013	1.284	390	3.210	43.546	737.129
0.224	0.569	0.014	1.445	410	3.374	43.617	773.664
0.271	0.688	0.017	1.748	440	3.621	43.752	827.719
0.319	0.810	0.021	2.058	460	3.786	43.890	862.615
0.418	1.062	0.027	2.697	475	3.909	44.178	884.935
Sample Description:-							

Moist unit weight of specimen: 2.0gm/cm³

Dry unit weight of specimen: 1.692 gm/cm³

Moisture content of specimen: 18.2 %

Initial average length of specimen: 17.3 cm

Initial average diameter of specimen: 7.4 cm

Initial area of specimen: 42.9866 cm²

Proving ring calibration factor:

1 kN = 121.5

2 kN = 241.8

3kN = 362.9

SUMMARY OF RESULTS FOR 10, 20, 30 PSI TESTS OF 10% CEMENT STABILIZATION

TRIAXIAL SHEAR TEST

MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE

TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE

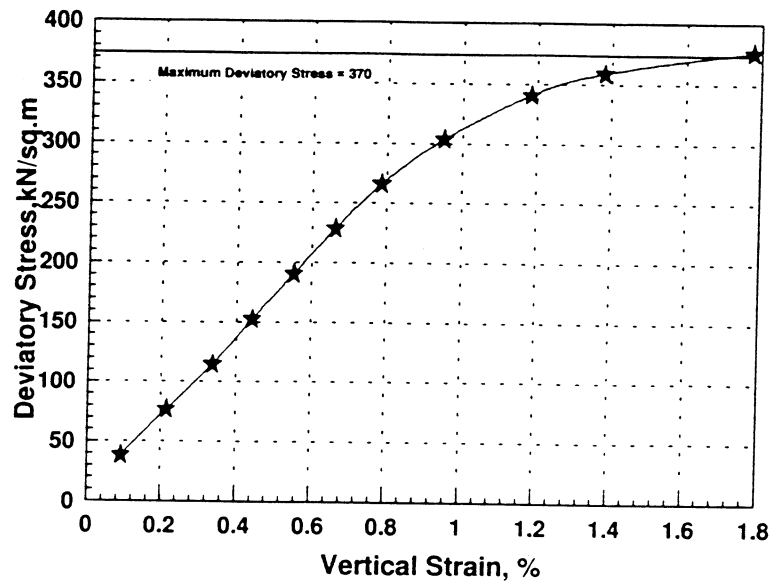
Test Performed : Consolidated Drained

S No.	Confined Press. psi $\sigma(3)$	Confined Press. kN/sq.m $\sigma(3)$	Deviatory Stress. kN/sq. m $\Delta\sigma$	Deviatory + Confined Stress kN/sq.m $\sigma(1) = \sigma(3) + \Delta\sigma$
1	10	68.95	376.12	445.07
2	20	137.9	408	545.9
3	30	206.85	884.94	1091.79

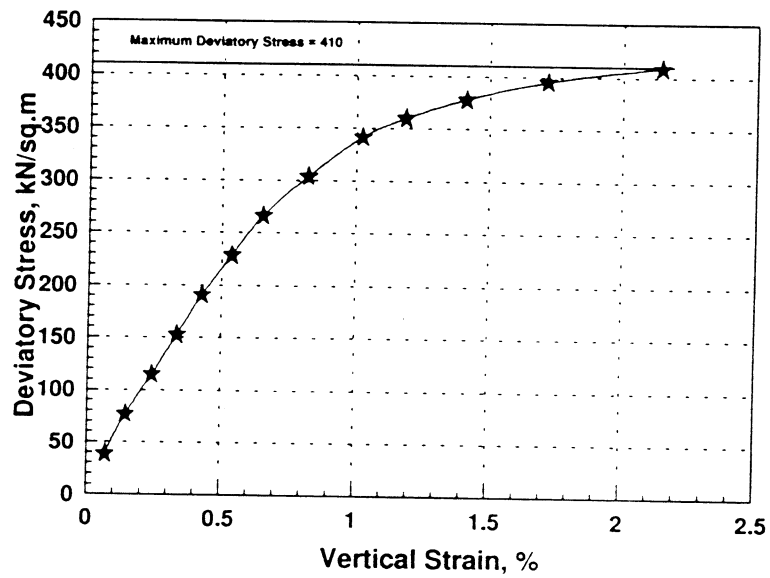
Conversion Factor Used:

$$6.895 \text{ kN/sq. m} = 1 \text{ psi.}$$

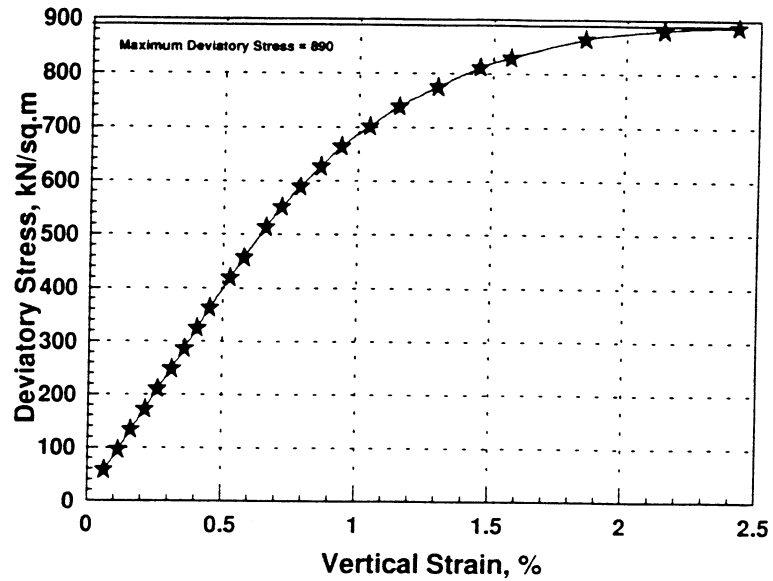
Triaxial Shear Test - 10% Cement Stabilization, 10psi



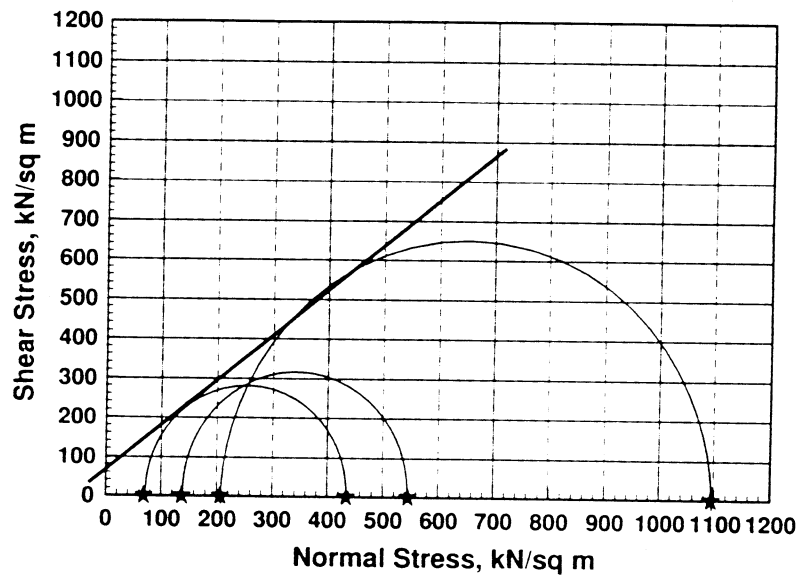
Triaxial Shear Test - 10% Cement Stabilization, 20 psi



Triaxial Shear Test - 10% Cement Stabilization, 30 psi



Mohr's Circle Plot - 10% Cement Stabilization



Cohesion = 60 kPa
Angle of Internal Friction = 48 degrees

TRIAXIAL SHEAR TEST
15% CEMENT STABILIZATION, 10 PSI.
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE
Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.020	0.051	0.001	0.117	20	0.165	43.037	38.248
0.043	0.109	0.003	0.251	40	0.329	43.095	76.394
0.060	0.152	0.004	0.351	60	0.494	43.138	114.476
0.080	0.203	0.005	0.468	80	0.658	43.237	152.286
0.099	0.251	0.006	0.579	100	0.823	43.237	190.357
0.122	0.310	0.007	0.713	120	0.988	43.295	228.119
0.153	0.389	0.009	0.895	140	1.152	43.375	265.653
0.203	0.516	0.012	1.187	160	1.317	43.503	302.708
0.310	0.787	0.018	1.813	180	1.481	43.780	338.390
0.402	1.021	0.024	2.351	190	1.564	44.021	355.232
0.509	1.293	0.030	2.977	193	1.588	44.305	358.529

Sample Description:-

Moist unit weight of specimen: 2.005gm/cm³
Dry unit weight of specimen: 1.666 gm/cm³
Moisture content of specimen: 20 %
Initial average length of specimen: 16.3 cm
Initial average diameter of specimen: 7.4 cm
Initial area of specimen: 42.9866 cm²

Proving ring calibration factor:

1 kN = 121.5
2 kN = 241.8
3kN = 362.9
4 kN = 483.8

TRIAXIAL SHEAR TEST
15% CEMENT STABILIZATION, 20 PSI.
 MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
 TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE
 Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.015	0.038	0.001	0.096	30	0.247	43.028	57.384
0.025	0.064	0.002	0.160	60	0.494	43.056	114.695
0.039	0.099	0.003	0.250	90	0.741	43.094	171.888
0.059	0.150	0.004	0.378	120	0.988	43.194	228.654
0.075	0.191	0.005	0.481	140	1.152	43.194	266.763
0.097	0.246	0.006	0.622	160	1.317	43.256	304.440
0.124	0.315	0.008	0.795	180	1.481	43.331	341.899
0.164	0.417	0.011	1.051	200	1.646	43.443	378.905
0.225	0.572	0.014	1.442	220	1.811	43.616	415.149
0.268	0.681	0.017	1.718	230	1.893	43.738	432.805
0.392	0.996	0.025	2.513	250	2.058	44.095	466.636
0.405	1.029	0.026	2.596	260	2.140	44.132	484.886
0.674	1.712	0.043	4.321	268	2.206	44.928	490.958

Sample Description:-

Moist unit weight of specimen: 2.0 gm/cm³
 Dry unit weight of specimen: 1.692 gm/cm³
 Moisture content of specimen: 18.2 %
 Initial average length of specimen: 17.3 cm
 Initial average diameter of specimen: 7.4 cm
 Initial area of specimen: 42.9866 cm²

Proving ring calibration factor:
 1 kN = 121.5
 2 kN = 241.8
 3kN = 362.9

TRIAXIAL SHEAR TEST
15% CEMENT STABILIZATION, 30 PSI.
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE
Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.011	0.028	0.001	0.076	30	0.247	43.019	57.396
0.020	0.051	0.001	0.139	50	0.412	43.046	95.600
0.035	0.089	0.002	0.243	80	0.658	43.091	152.800
0.045	0.114	0.003	0.313	100	0.823	43.166	190.668
0.060	0.152	0.004	0.417	130	1.070	43.166	247.868
0.078	0.198	0.005	0.542	170	1.399	43.221	323.728
0.092	0.234	0.006	0.639	200	1.646	43.263	380.485
0.106	0.269	0.007	0.736	230	1.893	43.305	437.129
0.123	0.312	0.009	0.854	260	2.140	43.357	493.558
0.152	0.386	0.011	1.056	310	2.551	43.445	587.278
0.173	0.439	0.012	1.201	340	2.798	43.509	643.162
0.190	0.483	0.013	1.319	360	2.963	43.561	680.181
0.244	0.620	0.017	1.694	410	3.374	43.728	771.707
0.324	0.823	0.023	2.250	450	3.704	43.976	842.209
0.456	1.158	0.032	3.167	480	3.951	44.392	889.932
0.578	1.468	0.040	4.014	492	4.049	44.784	904.199

Sample Description:-

Moist unit weight of specimen: 2.005.gm/cm³

Dry unit weight of specimen: 1.666 gm/cm³

Moisture content of specimen: 20 %

Initial average length of specimen: 17.3 cm

Initial average diameter of specimen: 7.4 cm

Initial area of specimen: 42.9866 cm²

Proving ring calibration factor:

1 kN = 121.5

2 kN = 241.8

3kN = 362.9

SUMMARY OF RESULTS FOR 10, 20, 30 PSI TESTS OF 15% CEMENT STABILIZATION

TRIAXIAL SHEAR TEST

MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE

TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE

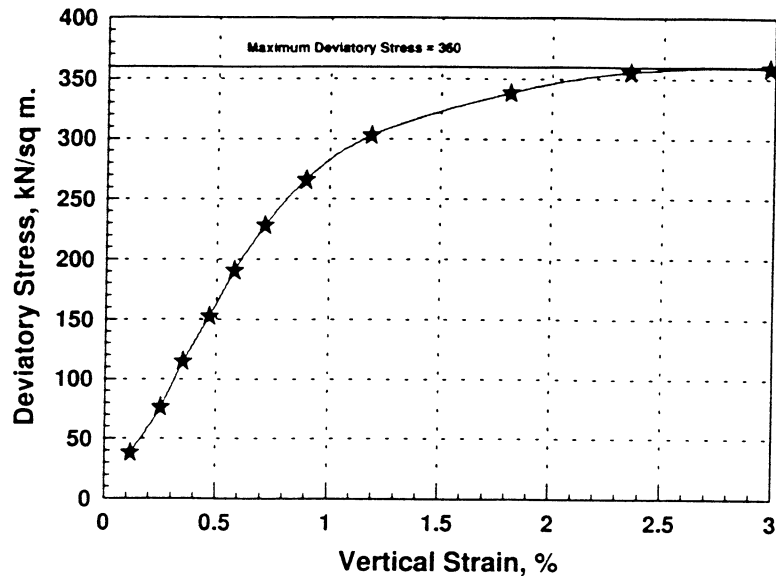
Test Performed : Consolidated Drained

S No.	Confined Press. psi $\sigma(3)$	Confined Press. kN/sq.m $\sigma(3)$	Deviatory Stress. kN/sq. m $\Delta\sigma$	Deviatory + Confined Stress kN/sq.m $\sigma(1) = \sigma(3) + \Delta\sigma$
1	10	68.95	358.52	427.47
2	20	137.9	490.95	628.85
3	30	206.85	904.17	1111.02

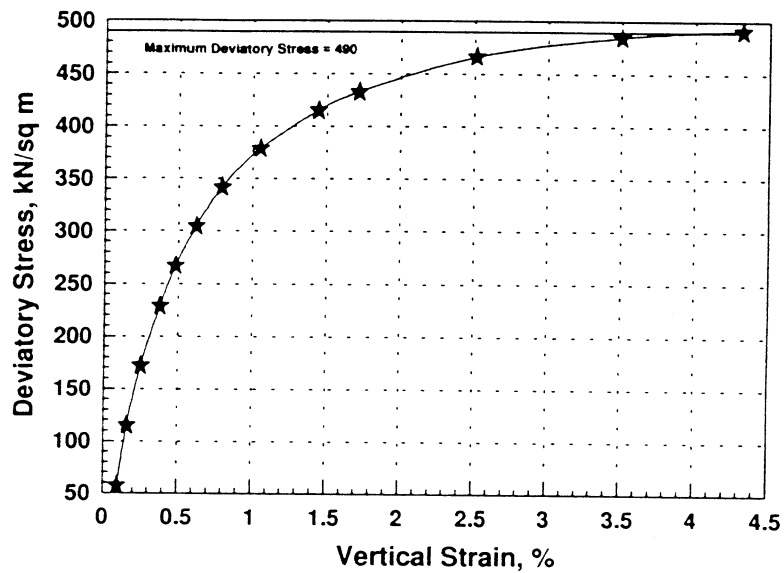
Conversion Factor Used:

$$6.895 \text{ kN/sq. m} = 1 \text{ psi.}$$

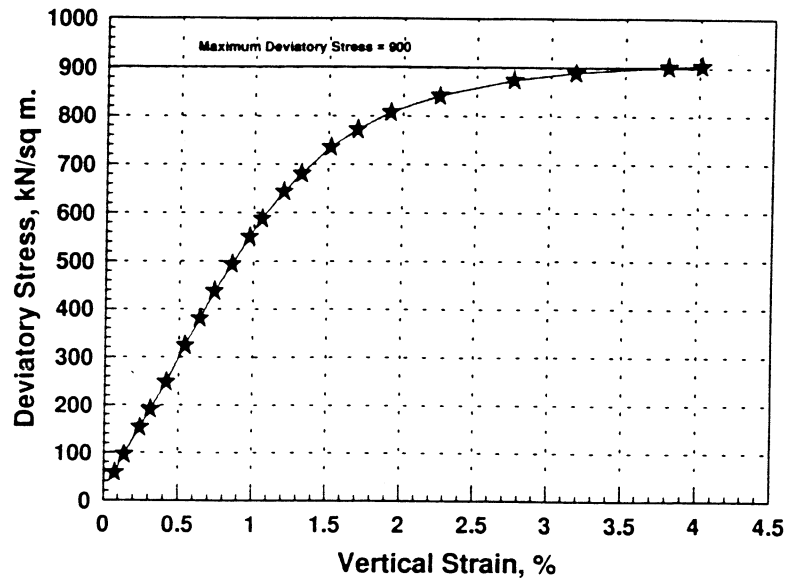
Triaxial Shear Test - 15% Cement Stabilization, 10 psi



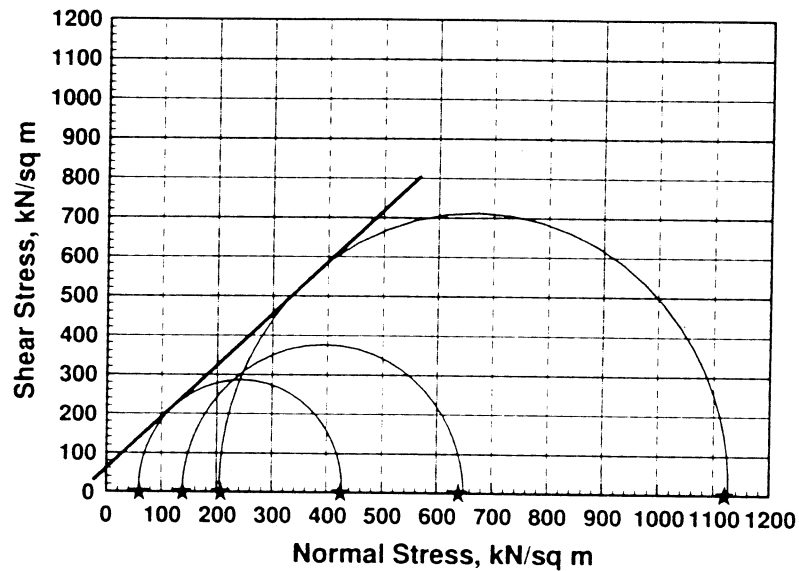
Triaxial Shear Test - 15% Cement Stabilization, 20 psi



Triaxial Plot - 15% Cement Stabilization, 30 psi



Mohr's Circle Plot - 15 % Cement Stabilization



Cohesion = 70 kPa.

Angle of Internal Friction = 51 degrees.

TRIAXIAL SHEAR TEST
25% CEMENT STABILIZATION, 10 PSI.
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE
Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.027	0.069	0.002	0.17	20	0.16	43.06	38.23
0.055	0.140	0.004	0.35	40	0.33	43.14	76.32
0.083	0.211	0.005	0.53	60	0.49	43.22	114.27
0.119	0.302	0.008	0.76	80	0.66	43.38	151.78
0.142	0.361	0.009	0.91	90	0.74	43.38	170.75
0.185	0.470	0.012	1.19	110	0.91	43.50	208.11
0.229	0.582	0.015	1.47	130	1.07	43.63	245.25
0.256	0.650	0.016	1.64	140	1.15	43.70	263.65
0.29	0.737	0.019	1.86	150	1.23	43.80	281.86
0.419	1.064	0.027	2.69	160	1.32	44.17	298.12
0.508	1.290	0.033	3.26	164	1.35	44.43	303.78
Sample Discription :							

Moist unit weight of specimen: 2.047gm/cm³ Proving ring calibration factor:
Dry unit weight of specimen: 1.792 gm/cm³ 1 kN = 121.5
Moisture content of specimen: 19.6 % 2 kN = 241.8
Initial average length of specimen: 15.6 cm 3kN = 362.9
Initial average diameter of specimen: 7.4 cm 4 kN = 483.8
Initial area of specimen: 42.9866 cm²

TRIAXIAL SHEAR TEST
25% CEMENT STABILIZATION, 20 PSI.
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE
Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.019	0.048	0.001	0.13	20	0.16	43.04	38.24
0.035	0.089	0.002	0.24	50	0.41	43.09	95.50
0.055	0.140	0.004	0.37	80	0.66	43.15	152.60
0.078	0.198	0.005	0.53	110	0.91	43.26	209.27
0.094	0.239	0.006	0.64	130	1.07	43.26	247.31
0.11	0.279	0.007	0.75	150	1.23	43.31	285.05
0.136	0.345	0.009	0.93	180	1.48	43.39	341.45
0.163	0.414	0.011	1.11	200	1.65	43.47	378.68
0.202	0.513	0.014	1.37	220	1.81	43.59	415.44
0.237	0.602	0.016	1.61	230	1.89	43.69	433.27
0.32	0.813	0.022	2.18	240	1.98	43.94	449.51
0.368	0.935	0.025	2.50	260	2.14	44.09	485.35
0.422	1.072	0.029	2.87	265	2.18	44.26	492.82

Sample Discription :

Moist unit weight of specimen: 2.047gm/cm³

Dry unit weight of specimen: 1.792 gm/cm³

Moisture content of specimen: 19.6 %

Initial average length of specimen: 14.7 cm

Initial average diameter of specimen: 7.4 cm

Initial area of specimen: 42.9866 cm²

Proving ring calibration factor:

1 kN = 121.5

2 kN = 241.8

3kN = 362.9

4 kN = 483.8

TRIAXIAL SHEAR TEST
25% CEMENT STABILIZATION, 30 PSI.
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE
Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.016	0.041	0.001	0.11	20	0.16	43.03	38.25
0.036	0.091	0.002	0.24	50	0.41	43.09	95.50
0.045	0.114	0.003	0.30	90	0.74	43.12	171.80
0.057	0.145	0.004	0.38	110	0.91	43.15	209.81
0.082	0.208	0.005	0.55	160	1.32	43.22	304.67
0.093	0.236	0.006	0.62	180	1.48	43.25	342.50
0.11	0.279	0.007	0.73	210	1.73	43.30	399.13
0.15	0.381	0.010	1.00	270	2.22	43.42	511.79
0.171	0.434	0.011	1.14	300	2.47	43.48	567.85
0.206	0.523	0.014	1.37	340	2.80	43.59	642.04
0.227	0.577	0.015	1.51	360	2.96	43.65	678.84
0.268	0.681	0.018	1.79	390	3.21	43.77	733.37
0.305	0.775	0.020	2.03	410	3.37	43.88	769.05
0.363	0.922	0.024	2.42	430	3.54	44.05	803.38
0.45	1.143	0.030	3.00	450	3.70	44.32	835.75
Sample Discription :							

Moist unit weight of specimen: 2.047gm/cm³ Proving ring calibration factor:

Dry unit weight of specimen: 1.792 gm/cm³ 1 kN = 121.5

Moisture content of specimen: 19.6 % 2 kN = 241.8

Initial average length of specimen: 15 cm 3kN = 362.9

Initial average diameter of specimen: 7.4 cm 4 kN = 483.8

Initial area of specimen: 42.9866 cm²

SUMMARY OF RESULTS FOR 10, 20, 30 PSI TESTS OF 25% CEMENT STABILIZATION

TRIAxIAL SHEAR TEST

MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE

TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE

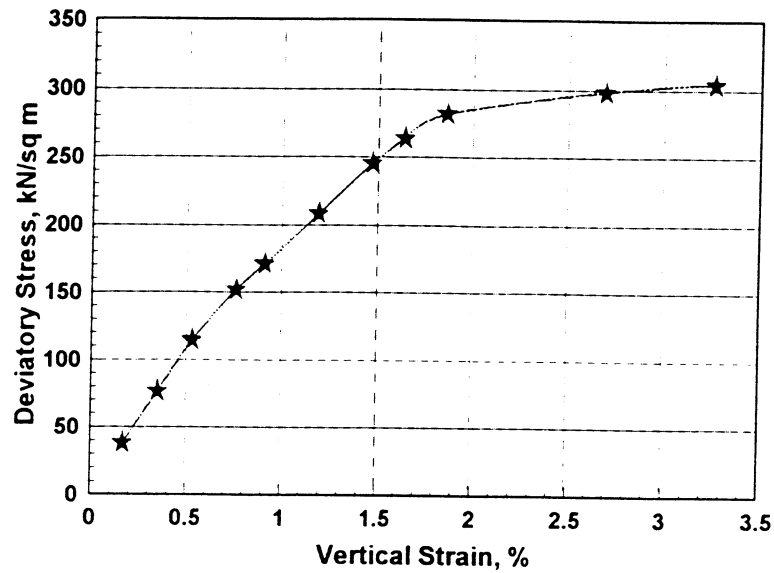
Test Performed : Consolidated Drained

S No.	Confined Press. psi $\sigma(3)$	Confined Press. kN/sq.m $\sigma(3)$	Deviatory Stress. kN/sq. m $\Delta\sigma$	Deviatory + Confined Stress kN/sq.m $\sigma(1) = \sigma(3) + \Delta\sigma$
1	10	68.95	303.78	372.73
2	20	137.9	492.82	630.72
3	30	206.85	835.75	1042.6

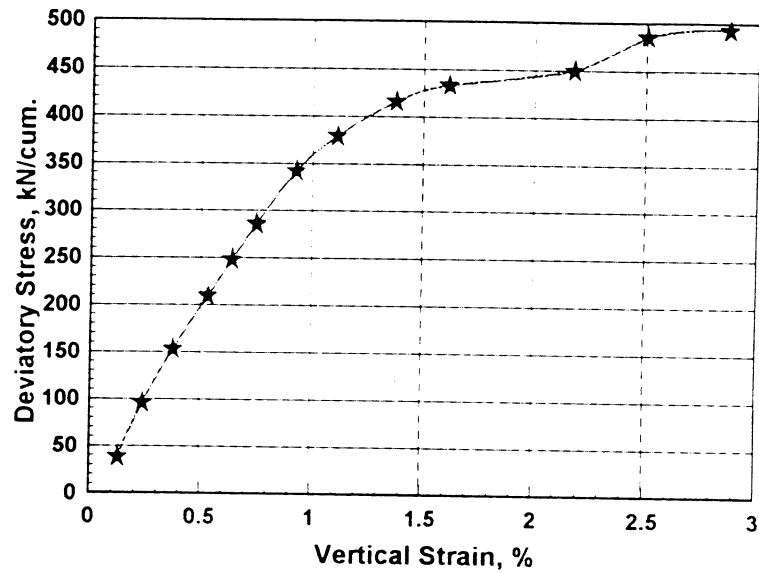
Conversion Factor Used:

$$6.895 \text{ kN/sq. m} = 1 \text{ psi.}$$

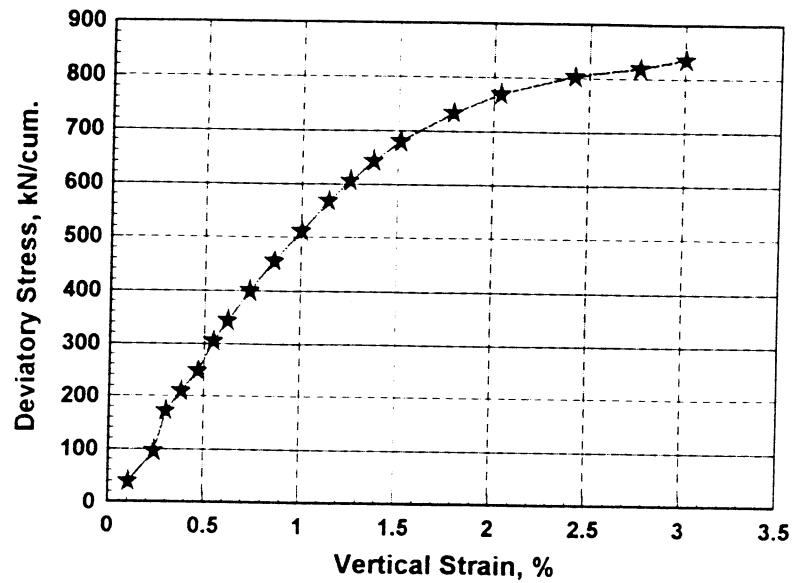
Triaxial Shear Test - 25% Cement Stabilization, 10psi



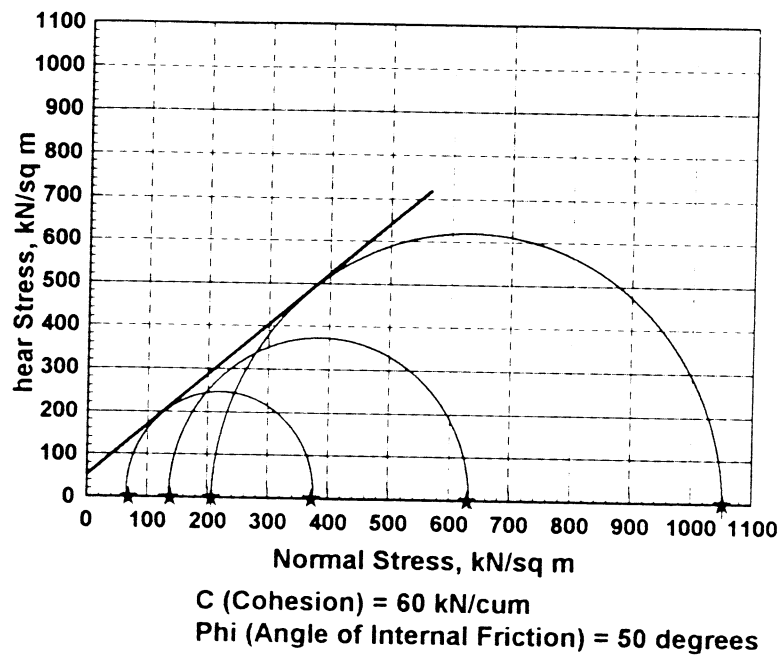
Triaxial Shear Test - 25% Cement Stabilization, 20psi



Triaxial Results - 25% Cement Stabilization, 30psi



Mohr's Circle Plot - 25% Cement Stabilization



TRIAXIAL SHEAR TEST
50% CEMENT STABILIZATION, 10 PSI.
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE
Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.018	0.05	0.001	0.11	20	0.16	43.03	38.25
0.038	0.10	0.002	0.23	40	0.33	43.08	76.41
0.061	0.15	0.004	0.36	70	0.58	43.14	133.54
0.08	0.20	0.005	0.48	90	0.74	43.24	171.31
0.098	0.25	0.006	0.58	110	0.91	43.24	209.38
0.12	0.30	0.007	0.71	130	1.07	43.30	247.13
0.151	0.38	0.009	0.90	150	1.23	43.38	284.62
0.178	0.45	0.011	1.06	160	1.32	43.45	303.10
0.244	0.62	0.015	1.45	170	1.40	43.62	320.76
0.265	0.67	0.016	1.58	171	1.41	43.68	322.24

Sample Discription :

Moist unit weight of specimen: 2.083gm/cm³

Dry unit weight of specimen: 1.77 gm/cm³

Moisture content of specimen: 19.6 %

Initial average length of specimen: 16.8cm

Initial average diameter of specimen: 7.4 cm

Initial area of specimen: 42.9866 cm²

Proving ring calibration factor:

1 kN = 121.5

2 kN = 241.8

3kN = 362.9

4 kN = 483.8

TRIAXIAL SHEAR TEST
50% CEMENT STABILIZATION, 20 PSI.
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE
Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.021	0.053	0.001	0.129	30	0.25	43.04	57.37
0.035	0.089	0.002	0.215	50	0.41	43.08	95.53
0.049	0.124	0.003	0.301	70	0.58	43.12	133.62
0.063	0.160	0.004	0.387	90	0.74	43.21	171.43
0.084	0.213	0.005	0.515	120	0.99	43.21	228.57
0.104	0.264	0.006	0.638	150	1.23	43.26	285.37
0.125	0.318	0.008	0.767	180	1.48	43.32	342.00
0.152	0.386	0.009	0.933	210	1.73	43.39	398.33
0.175	0.445	0.011	1.074	230	1.89	43.45	435.64
0.208	0.528	0.013	1.276	250	2.06	43.54	472.56
0.26	0.660	0.016	1.595	270	2.22	43.68	508.71
0.34	0.864	0.021	2.086	280	2.30	43.90	524.92
Sample Description:-							

Moist unit weight of specimen: 2.083 gm/cm³
Dry unit weight of specimen: 1.77 gm/cm³
Moisture content of specimen: 18.2 %
Initial average length of specimen: 16.3 cm
Initial average diameter of specimen: 7.4 cm
Initial area of specimen: 42.9866 cm²

Proving ring calibration factor:
1 kN = 121.5
2 kN = 241.8
3kN = 362.9

TRIAXIAL SHEAR TEST
50% CEMENT STABILIZATION, 30 PSI.
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE
Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.02	0.051	0.001	0.114	40	0.33	43.04	76.50
0.038	0.097	0.002	0.217	70	0.58	43.08	133.73
0.05	0.127	0.003	0.286	90	0.74	43.11	171.83
0.068	0.173	0.004	0.389	120	0.99	#REF!	#REF!
0.101	0.257	0.006	0.577	170	1.40	43.24	323.61
0.126	0.320	0.007	0.720	200	1.65	43.30	380.17
0.148	0.376	0.008	0.846	220	1.81	43.35	417.66
0.205	0.521	0.012	1.171	260	2.14	43.50	491.98
0.266	0.676	0.015	1.520	290	2.39	43.65	546.81
0.316	0.803	0.018	1.806	310	2.55	43.78	582.83
0.495	1.257	0.028	2.829	350	2.88	44.24	651.17
0.584	1.483	0.033	3.337	360	2.96	44.47	666.27
0.66	1.676	0.038	3.771	366	3.01	44.67	674.34
Sample Description:-							

Moist unit weight of specimen: 2.083.gm/cm³ Proving ring calibration factor:
Dry unit weight of specimen: 1.77 gm/cm³ 1 kN = 121.5
Moisture content of specimen: 20 % 2 kN = 241.8
Initial average length of specimen: 17.5 cm 3kN = 362.9
Initial average diameter of specimen: 7.4 cm
Initial area of specimen: 42.9866 cm²

GEOTECHNICAL PROPERTIES

LIME STABILIZED ASH RESIDUE

STANDARD COMPACTION TEST

5% Lime Stabilization

MATERIAL: MUNICIPAL SOLID WASTE ASH RESIDUE

TEST PERFORMED AT: SOILS LABORATORY- FAMU/FSU ENGINEERING COLLEGE

Test Performed : Standard Proctor

Blows/Layer = 25 No. of Layers = 3 Wt. of Hammer = 24.5 N

Mold Dimensions: Diam. = 10.14 cm

Ht = 11.67cm

Vol. = 0.0009424 m³

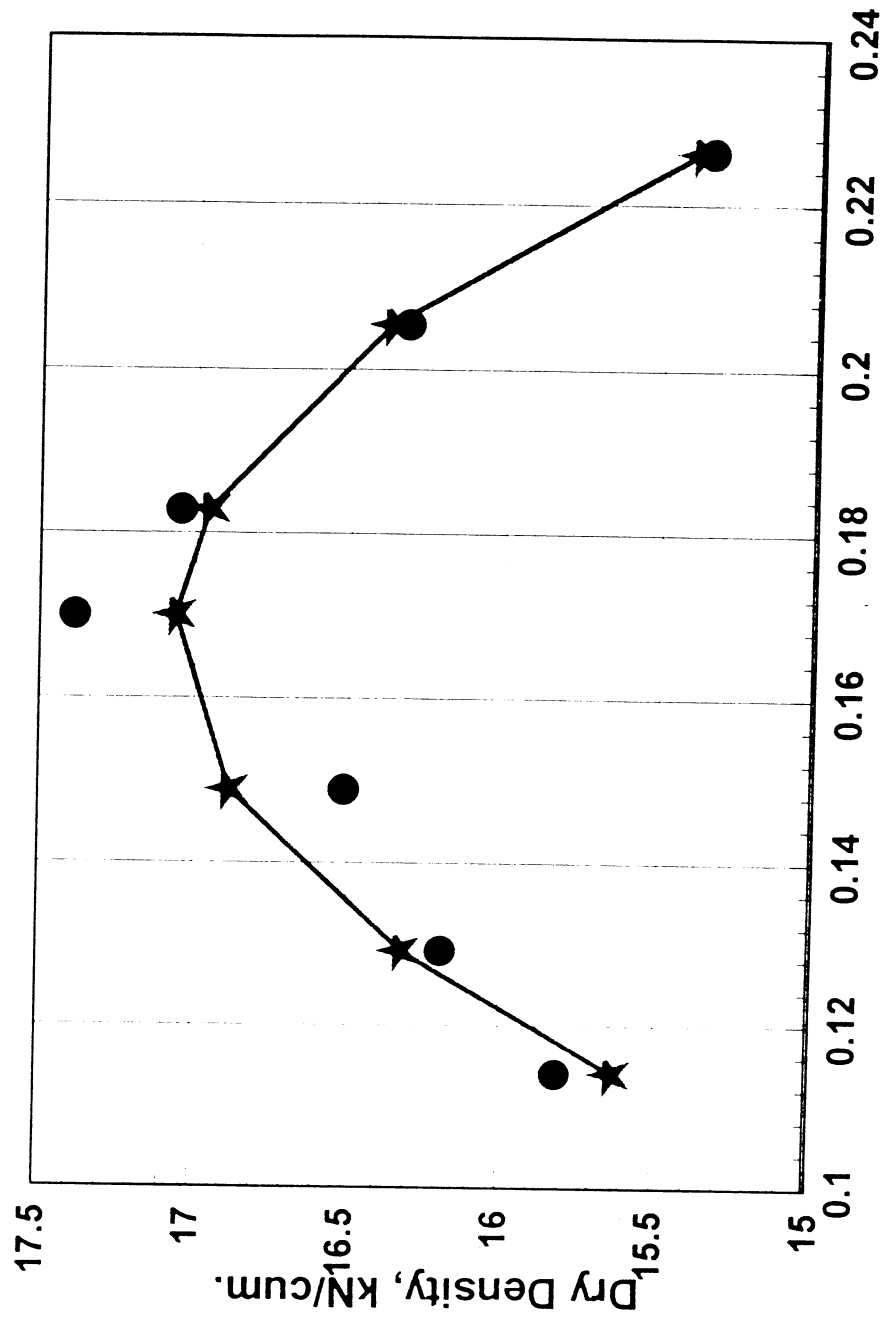
WATER CONTENT DETERMINATION

Sample No.	1		2		3		4		5		6		7	
Moisture Can No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Wt. of can + wet soil	36.1	30.3	57.4	57.5	41.5	39.7	62.9	61.2	61.8	48	69.7	64.6	51.7	69.7
Wt. of can + dry soil	33.84	28.35	53.28	54.4	37.72	36.04	56.82	55.36	55.49	42.36	61.23	57.26	44.52	60.5
Wt. of Water	2.26	1.95	4.12	4.3	3.78	3.66	6.08	5.84	6.31	5.64	8.47	7.34	7.18	9.2
Wt. of Can	13.65	11.58	21.38	21.15	11.9	11.88	21.22	20.9	20.97	11.54	20.61	21.02	11.87	20.98
Wt. of dry soil	20.19	16.77	31.9	33.25	25.82	24.16	35.6	34.46	34.52	30.82	40.62	36.24	32.65	39.52
Water Content, w%	11.19	11.63	12.92	12.93	14.64	15.15	17.08	16.95	18.28	18.30	20.85	20.25	21.99	23.28

DENSITY DETERMINATION

Assumed w%	12	14	16	18	20	22	24
Actual Water Content	11.41	12.92	14.89	17.01	18.29	20.55	22.64
Wt. of soil + mold	3730.5	3794.6	3860.8	3993.3	3976.2	3928.9	3847.3
Wt. of mold	2033.4	2033.4	2033.4	2033.4	2033.4	2033.4	2033.4
Wt. of soil in mold	1697.1	1761.2	1827.4	1959.9	1942.8	1895.5	1813.9
Wet Density, kN/m ³	17.62	18.28	18.97	20.35	20.17	19.68	18.83
Dry Density, kN/m ³	15.81	16.19	16.51	17.39	17.05	16.32	15.35

Compaction Curve - 5% Lime Stabilization.



Optimum Moisture Content = 17.0 %
Maximum Dry Density = 17.4 kN/cum.

STANDARD COMPACTION TEST
10% Lime Stabilization
MATERIAL: MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT: SOILS LABORATORY- FAMU/FSU ENGINEERING COLLEGE

Test Performed : Standard Proctor
Blows/Layer = 25 No. of Layers = 3 Wt. of Hammer = 24.5 N
Mold Dimensions: Diam. = 10.14 cm
Ht = 11.67cm
Vol. = 0.0009424 m³

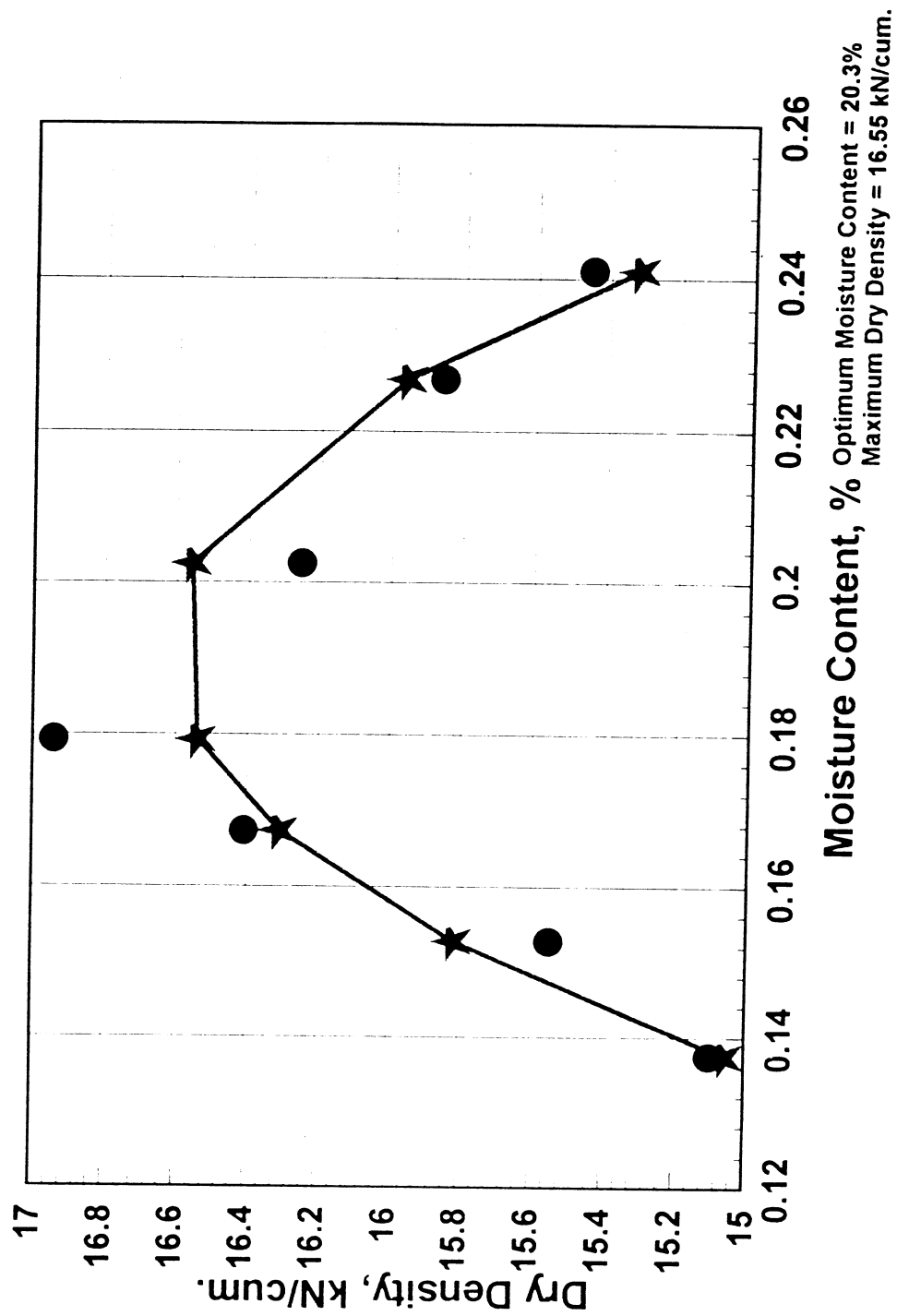
WATER CONTENT DETERMINATION

Sample No.	1		2		3		4		5		6		7	
Moisture Can No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Wt. of can + wet soil	39.5	38.3	50.7	55.5	44.9	43	61.2	55.7	69.4	51.3	61.6	72.5	62.1	79.5
Wt. of can + dry soil	36.28	35.17	46.82	50.94	40.22	38.49	55.2	50.34	61.17	44.66	53.98	63.03	52.36	68.11
Wt. of Water	3.22	3.13	3.88	4.56	4.68	4.51	6	5.36	8.23	6.64	7.62	9.47	9.74	11.39
Wt. of Can	13.65	11.58	21.38	21.15	11.9	11.88	21.22	20.9	20.97	11.54	20.61	21.02	11.87	20.98
Wt. of dry soil	22.63	23.59	25.44	29.79	28.32	26.61	33.98	29.44	40.2	33.12	33.37	42.01	40.49	47.13
Water Content, w%	14.23	13.27	15.25	15.31	16.53	16.95	17.66	18.21	20.47	20.05	22.83	22.54	24.06	24.17

DENSITY DETERMINATION

Assumed w%	16	18	20	22	24	26	28
Actual Water Content	13.75	15.28	16.74	17.93	20.26	22.69	24.11
Wt. of soil + mold	3687.8	3760.1	3878.3	3957.9	3916	3907.4	3880.4
Wt. of Mold	2033.4	2033.4	2033.4	2033.4	2033.4	2033.4	2033.4
Wt. of soil in mold	1654.4	1726.7	1844.9	1924.5	1882.6	1874	1847
Wet Density, kN/m ³	17.17	17.92	19.15	19.98	19.54	19.45	19.17
Dry Density, kN/m ³	15.10	15.55	16.41	16.94	16.25	15.86	15.45

Compaction Curve - 10% Lime Stabilization.



STANDARD COMPACTION TEST
15% Lime Stabilization
MATERIAL: MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT: SOILS LABORATORY- FAMU/FSU ENGINEERING COLLEGE

Test Performed : Standard Proctor
Blows/Layer = 25 No. of Layers = 3 Wt. of Hammer = 24.5 N
Mold Dimensions:
Diam. = 10.14 cm
Ht = 11.67cm
Vol. = 0.0009424 m³

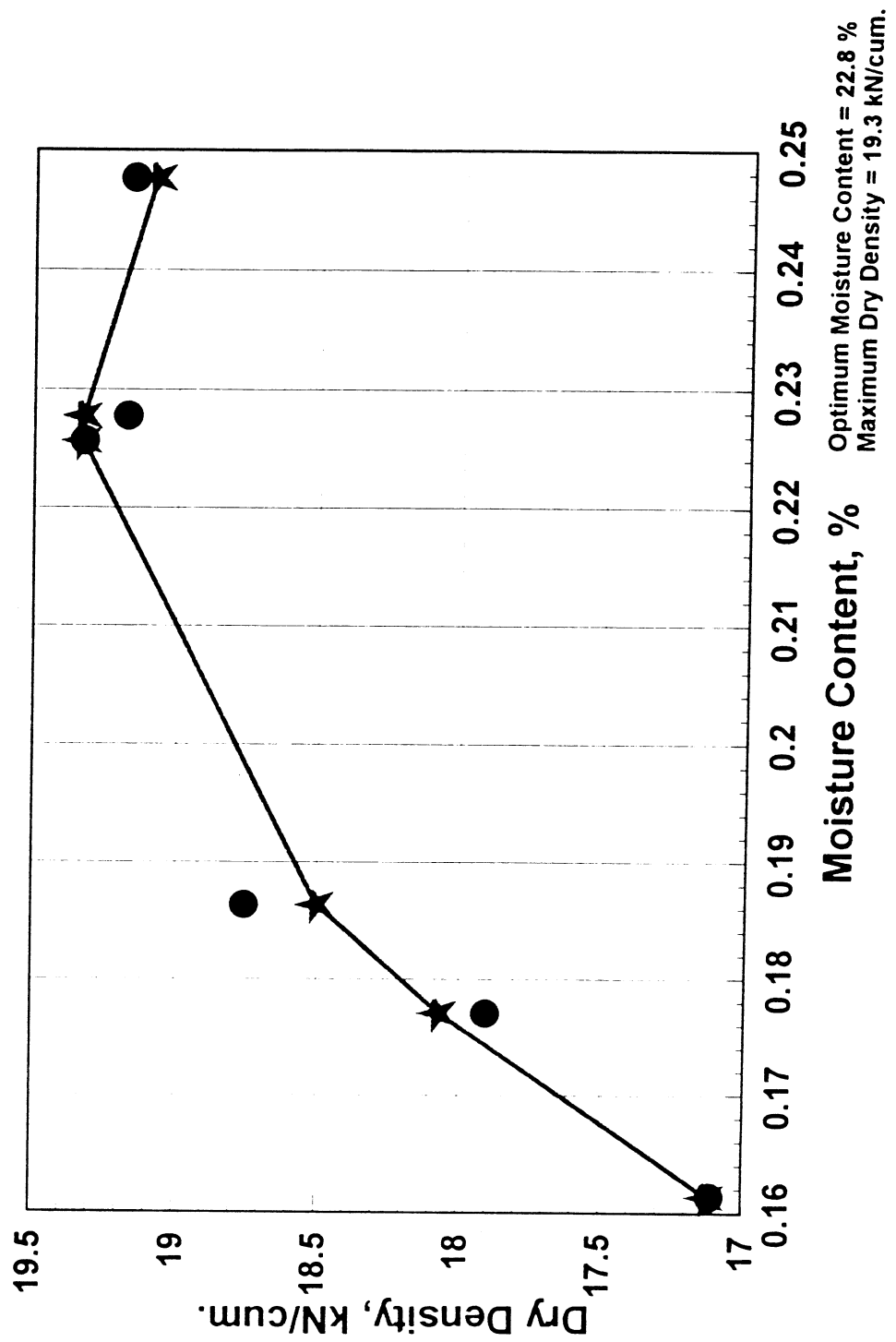
WATER CONTENT DETERMINATION

Sample No.	1		2		3		4		5		6	
Moisture Can No.	1	2	3	4	5	6	7	8	9	10	11	12
Wt. of can + wet soil	46.5	43.5	60	63	44.5	47.4	65.4	74.2	77.6	56.8	85.4	95
Wt. of can + dry soil	41.94	39.06	54.1	56.8	39.47	41.72	57.68	63.9	67.11	48.4	72.58	80.28
Wt. of Water	4.56	4.44	5.9	6.2	5.03	5.68	7.72	10.3	10.49	8.4	12.82	14.72
Wt. of Can	13.64	11.59	21.36	21.17	11.9	11.88	21.24	20.9	21.01	11.57	20.64	21.07
Wt. of dry soil	28.3	27.47	32.74	35.63	27.57	29.84	36.44	43	46.1	36.83	51.94	59.21
Water Content, w%	16.11	16.16	18.02	17.40	18.24	19.03	21.19	23.95	22.75	22.81	24.68	24.86

DENSITY DETERMINATION

Assumed w%	18	20	22	24	26	28
Actual Water Content	16.14	17.71	18.64	22.57	22.78	24.77
Wt. of soil + mold	3684.3	3761.1	3843.4	3899.1	3884.7	3883.2
Wt. of mold	2033.3	2033.3	2033.3	2033.3	2033.3	2033.3
Wt. of soil in mold	1651	1727.8	1810.1	1865.8	1851.4	1849.9
Wet Density, kN/m ³	17.14	17.94	18.79	19.37	19.22	19.20
Dry Density, kN/m ³	14.76	15.24	15.84	15.80	15.65	15.39

Compaction Curve - 15 % Lime Stabilization



STANDARD COMPACTION TEST

25% Lime Stabilization

MATERIAL: MUNICIPAL SOLID WASTE ASH RESIDUE

TEST PERFORMED AT: SOILS LABORATORY- FAMU/FSU ENGINEERING COLLEGE

Test Performed : Standard Proctor

Blows/Layer = 25 No. of Layers = 3

Wt. of Hammer = 24.5 N

Mold Dimensions: Diam. = 10.14 cm

Ht = 11.67cm

Vol. = 0.0009424 m³

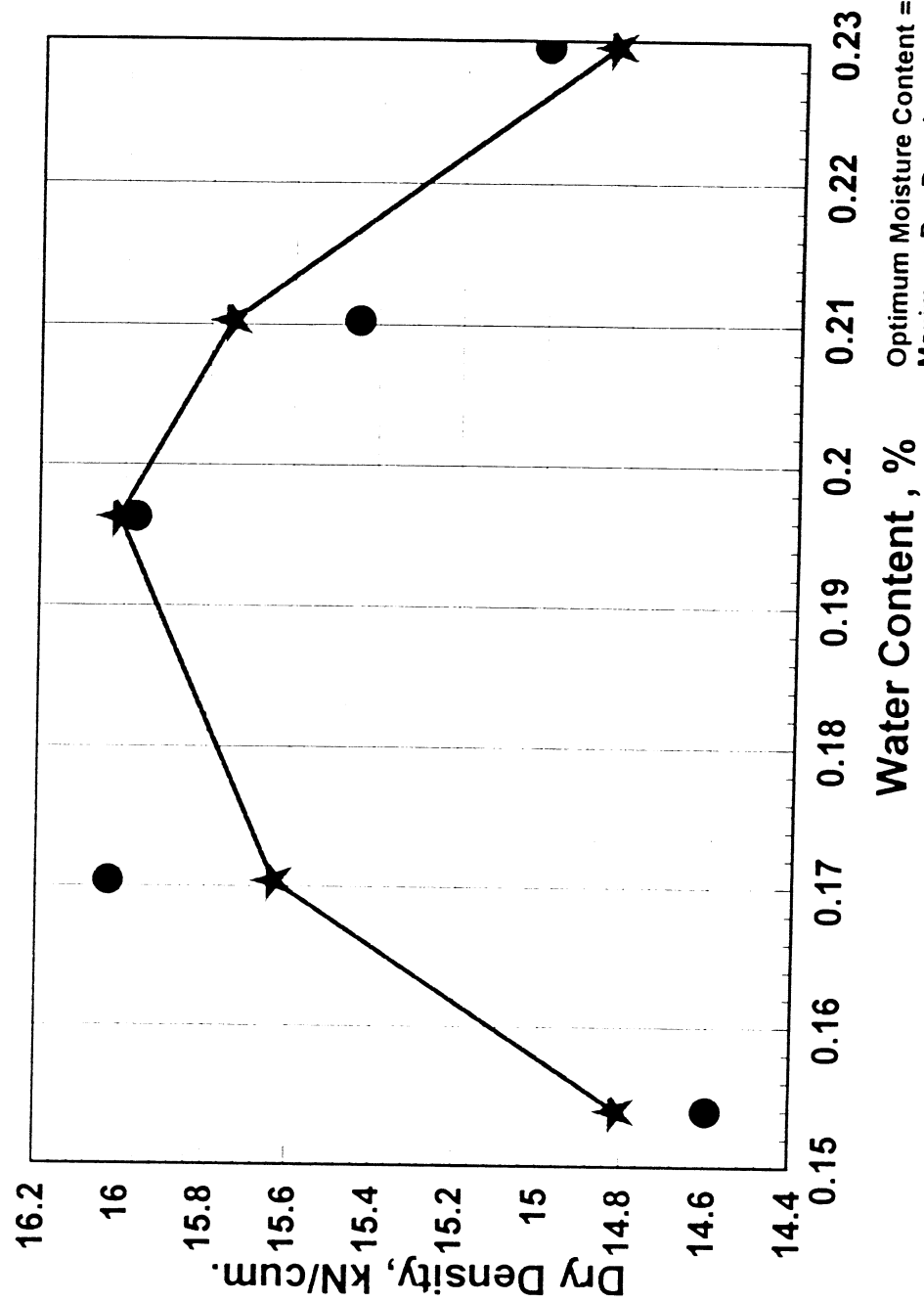
WATER CONTENT DETERMINATION

Sample No.	1		2		3		4		5	
Moisture Can No.	1	2	3	4	5	6	7	8	9	10
Wt. of can + wet soil	26.8	26.7	26.8	33.6	26.8	34.8	46.4	50.9	54	66.2
Wt. of can + dry soil	24.8	24.7	24.6	30.4	24.3	31.1	40.2	44.2	46.1	56.1
Wt. of water	2	2	2.2	3.2	2.5	3.7	6.2	6.7	7.9	10.1
Wt. of can	11.72	11.8	11.72	11.58	11.75	11.97	11.24	11.76	11.87	11.87
Wt. of dry soil	13.08	12.9	12.88	18.82	12.55	19.13	28.96	32.44	34.23	44.23
Water Content, w%	15.29	15.50	17.08	17.00	19.92	19.34	21.41	20.65	23.08	22.84

DENSITY DETERMINATION

Assumed w%	20	22	24	26	28
Actual Water Content	15.40	17.04	19.63	21.03	22.96
Wt. of soil + mold	3665.2	3849.6	3883.3	3843.4	3820.2
Wt. of mold	2042.6	2042.6	2042.6	2042.6	2042.6
Wt. of soil in mold	1622.6	1807	1840.7	1800.8	1777.6
Wet Density, kN/m ³	16.84	18.76	19.11	18.69	18.45
Dry Density, kN/m ³	14.60	16.03	15.97	15.45	15.01

Compaction Curve - 25% Lime Stabilization.



STANDARD COMPACTION TEST

50% Lime Stabilization

MATERIAL: MUNICIPAL SOLID WASTE ASH RESIDUE

TEST PERFORMED AT: SOILS LABORATORY- FAMU/FSU ENGINEERING COLLEGE

Test Performed : Standard Proctor

Blows/Layer = 25 No. of Layers = 3

Wt. of Hammer = 24.5 N

Mold Dimensions: Diam. = 10.14 cm

Ht = 11.67cm

Vol. = 0.0009424 m³

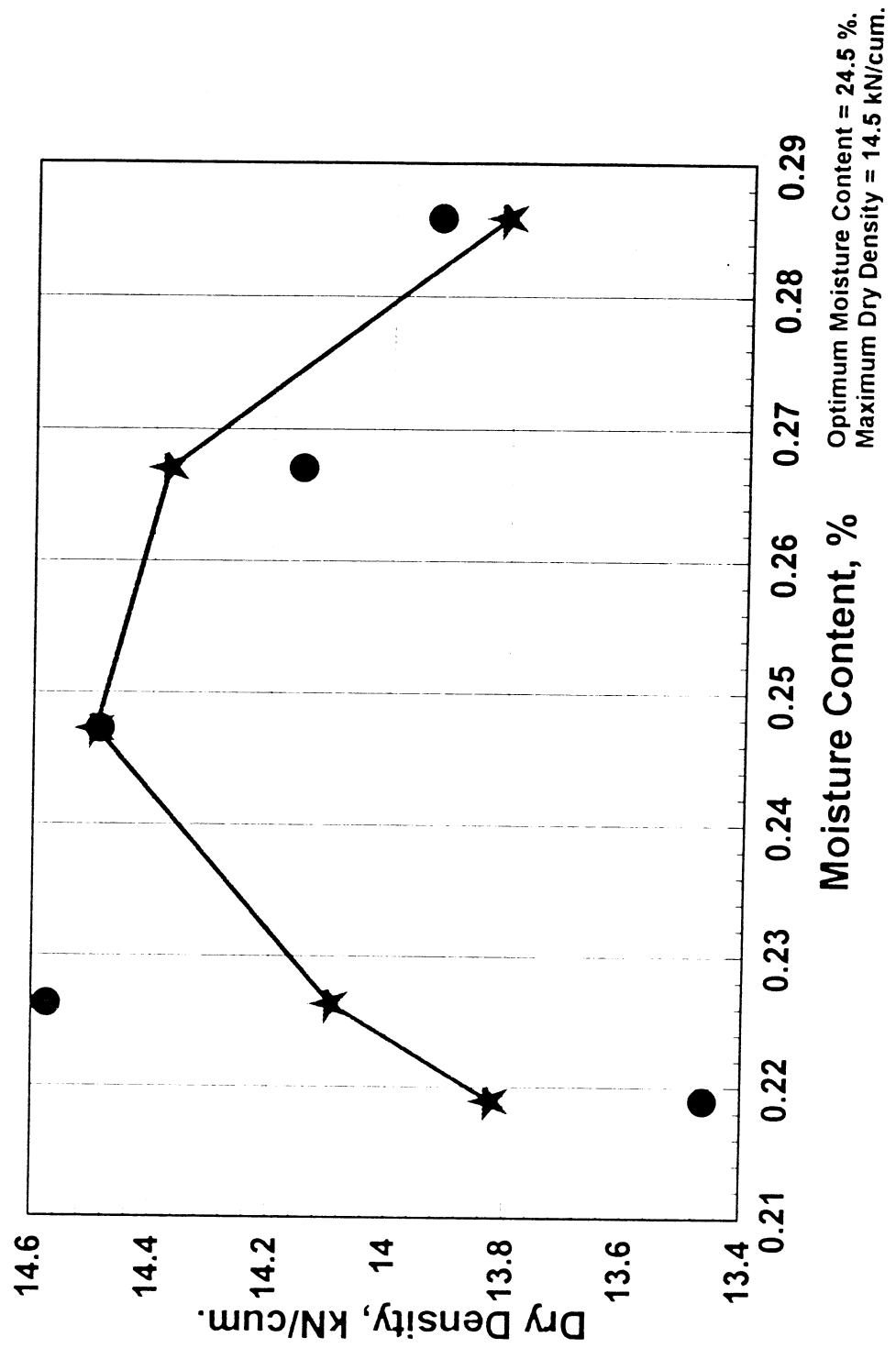
WATER CONTENT DETERMINATION

Sample No.	1			2			3			4			5		
Moisture Can No.	1	2	3	4	5	6	7	8	9	10					
Wt. of can + wet soil	28.7	39.3	39.1	37.2	39.1	39.7	39	45.7	41.5	41.2					
Wt. of can + dry soil	25.75	34.2	34.09	32.43	33.71	34.17	33.21	38.47	34.8	34.79					
Wt. of water	2.95	5.1	5.01	4.77	5.39	5.53	5.79	7.23	6.7	6.41					
Wt. of can	11.72	11.8	11.72	11.58	11.75	11.97	11.24	11.76	11.87	11.87					
Wt. of dry soil	14.03	22.4	22.37	20.85	21.96	22.2	21.97	26.71	22.93	22.92					
Water Content, w%	21.03	22.77	22.40	22.88	24.54	24.91	26.35	27.07	29.22	27.97					

DENSITY DETERMINATION

Assumed w%	24					28		30		32
Actual Water Content	21.90					24.73		26.71		28.59
Wt. of soil + mold	3623.5					3783.3		3769.8		3767.2
Wt. of mold	2042.6					2042.6		2042.6		2042.6
Wt. of soil in mold	1580.9					1740.7		1727.2		1724.6
Wet Density, kN/m ³	16.41					18.07		17.93		17.90
Dry Density, kN/m ³	13.46					14.49		14.15		13.92

Compaction Curve - 50% Lime Stabilization.



COEFFICIENT OF PERMEABILITY - FALLING HEAD METHOD**5% LIME STABILIZATION**

MATERIAL :- MUNICIPAL SOLID WASTE ASH RESIDUE

TEST PERFORMED AT :- SOILS LAB.-FAMU/FSU ENGINEERING COLLEGE

WATER CONTENT DETERMINATION:

Moisture can #:	1	2
Wt. of can + wet soil (g)	62.9	61.2
Wt. of can + dry soil (g)	56.83	55.36
Wt. of water(g)	6.08	5.84
Wt. of can (g)	21.22	20.9
wt. of dry soil (g)	35.6	34.46
Water content, w%:	17	16.9

USING COMPACTION PERMEAMETER AND STANDARD PROCTOR AASHTO T99

Blows per layer: 25	Mold dia.(cm):	10.14
No. of layers: 3	Area (cm ²):	81.1
Wt. of hammer: 24.5 N	Ht. (cm):	11.6
	Vol. (m ³):	0.000942

PERMEABILITY TEST DATA:

Standpipe: 100 ml burette

Area of standpipe: 1.71 cm²

Kt/K20 0.976

Test #	h1 (cm)	h2 (cm)	Time (sec)	Temp (°C)
1	77.35	74.5	200	21
2	77.35	74.5	195	21
3	77.35	74.5	205	21
4	77.35	74.5	198	21
5	77.35	74.5	206	21
6	77.35	74.5	208	21
Average:			202	

$$Kt = (a \times L/A \times t) \ln (h_1/h_2) =$$

$$Kt = (1.71 \times 11.6/81.1 \times 202) \ln (77.35/74.5) = 4.55 \times 10^{-5} \text{ cm/sec}$$

$$\text{Coefficient of Permeability, K at } 20^\circ\text{C} = 4.44 \times 10^{-5} \text{ cm/sec}$$

COEFFICIENT OF PERMEABILITY - FALLING HEAD METHOD**10% LIME STABILIZATION**

MATERIAL :- MUNICIPAL SOLID WASTE ASH RESIDUE

TEST PERFORMED AT :- SOILS LAB.-FAMU/FSU ENGINEERING COLLEGE

WATER CONTENT DETERMINATION:

Moisture can #:	1	2
Wt. of can + wet soil (g)	69.4	51.3
Wt. of can + dry soil (g)	61.17	44.66
Wt. of water(g)	8.23	6.64
Wt. of can (g)	20.97	11.54
wt. of dry soil (g)	40.2	33.37
Water content, w%:	20.47	20.05

USING COMPACTION PERMEAMETER AND STANDARD PROCTOR AASHTO T99

Blows per layer: 25	Mold dia.(cm	10.14
No. of layers: 3	Area (cm ²):	81.1
Wt. of hammer: 24.5 N	Ht. (cm):	11.6
	Vol. (m ³):	0.000942

PERMEABILITY TEST DATA:

Standpipe: 100 ml burette

Area of standpipe: 1.71 cm²

nt/n20 = 0.9095

Test #	h1 (cm)	h2 (cm)	Time (sec)	Temp (°C)
1	70.1	69.1	602	24
2	70.1	69.1	594	24
3	70.1	69.1	612	24
4	70.1	69.1	586	24
5	70.1	69.1	633	24
6	70.1	69.1	602	24
Average:			604.8333	

$$Kt = (a \times L/A \times t) \ln (h_1/h_2) =$$

$$Kt = (1.71 \times 11.6/81.1 \times 604.83) \ln (70.1/69.1) \quad 5.81 \times 10^{-6} \text{ cm/sec}$$

$$\text{Coefficient of Permeability, } K \text{ at } 20^\circ\text{C} = 5.28 \times 10^{-6} \text{ cm/sec}$$

COEFFICIENT OF PERMEABILITY - FALLING HEAD METHOD**15% LIME STABILIZATION**

MATERIAL :- MUNICIPAL SOLID WASTE ASH RESIDUE

TEST PERFORMED AT :- SOILS LAB.-FAMU/FSU ENGINEERING COLLEGE

WATER CONTENT DETERMINATION:

Moisture can #:	1	2
Wt. of can + wet soil (g)	65.4	74.2
Wt. of can + dry soil (g)	57.68	63.9
Wt. of water(g)	7.72	10.3
Wt. of can (g)	21.24	20.9
wt. of dry soil (g)	36.44	43
Water content, w%:	21.19	23.95

USING COMPACTION PERMEAMETER AND STANDARD PROCTOR AASHTO T99

Blows per layer: 25	Mold dia.(cm)	10.14
No. of layers: 3	Area (cm ²):	81.1
Wt. of hammer: 24.5 N	Ht. (cm):	11.6
	Vol. (m ³):	0.000942

PERMEABILITY TEST DATA:

Standpipe: 100 ml burette

Area of standpipe: 1.71 cm²

nt/n20 = 0.90945

Test #	h1 (cm)	h2 (cm)	Time (sec)	Temp (°C)
1	70.1	68	2320	24
2	70.1	68	2396	24
3	70.1	68	2356	24
Average:			2357.333	

$$Kt = (a \times L/A \times t) \ln (h_1/h_2) =$$

$$Kt = (1.71 \times 11.6/81.1 \times 2357.3) \ln (70.1/68) \quad 3.155 \times 10^{-6} \text{ cm/sec}$$

$$\text{Coefficient of Permeability, } K, \text{ at } 20^\circ\text{C} = 2.87 \times 10^{-6} \text{ cm/sec}$$

COEFFICIENT OF PERMEABILITY - FALLING HEAD METHOD**25% LIME STABILIZATION**

MATERIAL :- MUNICIPAL SOLID WASTE ASH RESIDUE

TEST PERFORMED AT :- SOILS LAB.-FAMU/FSU ENGINEERING COLLEGE

WATER CONTENT DETERMINATION:

Moisture can #:	1	2
Wt. of can + wet soil (g)	26.8	34.8
Wt. of can + dry soil (g)	24.3	31.1
Wt. of water(g)	2.5	3.7
Wt. of can (g)	11.75	11.97
wt. of dry soil (g)	12.55	19.13
Water content, w%:	19.92	19.34

USING COMPACTION PERMEAMETER AND STANDARD PROCTOR AASHTO T99

Blows per layer: 25	Mold dia.(cm):	10.14
No. of layers: 3	Area (cm ²):	81.1
Wt. of hammer: 24.5 N	Ht. (cm):	11.6
	Vol. (m ³):	0.000942

PERMEABILITY TEST DATA:

Standpipe: 100 ml burette

Area of standpipe: 1.71 cm²
 Kt/K20 0.93

Test #	h1 (cm)	h2 (cm)	Time (sec)	Temp (°C)
1	70.1	69	3608	23
2	70.1	69	3704	23
Average:			3656	

$$K = (a \times L/A \times t) \ln (h_1/h_2) =$$

$$K = (1.71 \times 11.6/81.1 \times 3656) \ln (70.1/69) \quad 1.058 \times 10^{-6} \text{ cm/sec}$$

$$\text{Coefficient of Permeability, } K \text{ at } 20^\circ\text{C} = 9.8 \times 10^{-7} \text{ cm/sec}$$

COEFFICIENT OF PERMEABILITY - FALLING HEAD METHOD**50% LIME STABILIZATION**

MATERIAL :- MUNICIPAL SOLID WASTE ASH RESIDUE

TEST PERFORMED AT :- SOILS LAB.-FAMU/FSU ENGINEERING COLLEGE

WATER CONTENT DETERMINATION:

Moisture can #:	1	2
Wt. of can + wet soil (g)	39.1	37.2
Wt. of can + dry soil (g)	34.09	32.43
Wt. of water(g)	5.01	4.77
Wt. of can (g)	11.72	11.58
wt. of dry soil (g)	22.37	20.85
Water content, w%:	22.40	22.88

USING COMPACTION PERMEAMETER AND STANDARD PROCTOR AASHTO T99

Blows per layer: 25	Mold dia.(cm):	10.14
No. of layers: 3	Area (cm ²):	81.1
Wt. of hammer: 24.5 N	Ht. (cm):	11.6
	Vol. (m ³):	0.000942

PERMEABILITY TEST DATA:

Standpipe: 100 ml burette

Area of standpipe: 1.71 cm²
 Kt/K20 0.89

Test #	h1 (cm)	h2 (cm)	Time (sec)	Temp (°C)
1	71.2	70	4609	25
2	71.2	70	4684	25
Average:			4646.5	

$$K = (a \times L/A \times t) \ln (h_1/h_2) =$$

$$K = (1.71 \times 11.6/81.1 \times 4646.5) \ln (71.2/70) \quad 8.947 \times 10^{-6} \text{ cm/sec}$$

$$\text{Coefficient of Permeability, } K \text{ at } 20^\circ\text{C} = 7.96 \times 10^{-6} \text{ cm/sec}$$

TRIAXIAL SHEAR TEST
5% LIME STABILIZATION, 10 PSI.
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE
Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.008	0.020	0.001	0.07	10	0.08	43.02	19.13
0.018	0.046	0.002	0.16	20	0.16	43.05	38.23
0.028	0.071	0.002	0.24	30	0.25	43.09	57.30
0.047	0.119	0.004	0.41	50	0.41	43.16	95.34
0.054	0.137	0.005	0.47	60	0.49	43.19	114.34
0.061	0.155	0.005	0.53	70	0.58	43.21	133.32
0.076	0.193	0.007	0.66	90	0.74	43.27	171.19
0.094	0.239	0.008	0.81	110	0.91	43.34	208.91
0.111	0.282	0.010	0.96	130	1.07	43.40	246.52
0.134	0.340	0.012	1.16	150	1.23	43.49	283.88
0.163	0.414	0.014	1.41	170	1.40	43.60	320.92
0.187	0.475	0.016	1.61	180	1.48	43.69	339.08
0.217	0.551	0.019	1.87	190	1.56	43.81	356.98
0.288	0.732	0.025	2.48	200	1.65	44.08	373.42
0.32	0.813	0.028	2.76	205	1.69	44.21	381.68
Sample Discription :-							

Moist unit weight of specimen: 2.075 gm/cm³ Proving ring calibration factor:

Dry unit weight of specimen: 1.773 gm/cm³
Moisture content of specimen: 17.0 %
Initial average length of specimen: 11.6 cm
Initial average diameter of specimen: 7.398 cm
Initial area of specimen: 42.9866 cm²

1 kN = 121.5
2 kN = 241.8
3kN = 362.9
4 kN = 483.8

TRIAXIAL SHEAR TEST
5% LIME STABILIZATION, 20 PSI.
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE
Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.006	0.015	0.000	0.04	10	0.08	43.00	19.14
0.016	0.041	0.001	0.10	30	0.25	43.03	57.38
0.027	0.069	0.002	0.16	50	0.41	43.06	95.58
0.04	0.102	0.002	0.24	70	0.58	43.09	133.70
0.052	0.132	0.003	0.32	90	0.74	43.12	171.77
0.064	0.163	0.004	0.39	110	0.91	43.16	209.79
0.078	0.198	0.005	0.48	130	1.07	43.19	247.72
0.093	0.236	0.006	0.57	150	1.23	43.23	285.57
0.108	0.274	0.007	0.66	170	1.40	43.27	323.35
0.13	0.330	0.008	0.79	190	1.56	43.33	360.90
0.144	0.366	0.009	0.88	200	1.65	43.37	379.57
0.162	0.411	0.010	0.99	210	1.73	43.42	398.11
0.212	0.538	0.013	1.29	230	1.89	43.55	434.68
0.292	0.742	0.018	1.78	250	2.06	43.77	470.14
0.375	0.953	0.023	2.29	260	2.14	43.99	486.43
Sample Discription:-							

Moist unit weight of specimen: 2.075 gm/cm³ Proving ring calibration factor:
Dry unit weight of specimen: 1.773 gm/cm³ 1 kN = 121.5
Moisture content of specimen: 17.0 % 2 kN = 241.8
Initial average length of specimen: 16.4 cm 3kN = 362.9
Initial average diameter of specimen: 7.398 cm 4 kN = 483.8
Initial area of specimen: 42.9866 cm²

TRIAXIAL SHEAR TEST
5% LIME STABILIZATION, 30 PSI.
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE
Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.019	0.048	0.001	0.12	20	0.16	43.04	38.25
0.07	0.178	0.005	0.45	50	0.41	43.18	95.30
0.081	0.206	0.005	0.52	80	0.66	43.21	152.37
0.093	0.236	0.006	0.60	100	0.82	43.25	190.32
0.122	0.310	0.008	0.79	140	1.15	43.33	265.94
0.16	0.406	0.010	1.03	180	1.48	43.43	341.08
0.186	0.472	0.012	1.20	200	1.65	43.51	378.34
0.251	0.638	0.016	1.62	240	1.98	43.69	452.08
0.29	0.737	0.019	1.87	260	2.14	43.81	488.50
0.334	0.848	0.022	2.15	280	2.30	43.93	524.55
0.382	0.970	0.025	2.46	300	2.47	44.07	560.24
0.495	1.257	0.032	3.19	340	2.80	44.40	630.19
0.56	1.422	0.036	3.61	360	2.96	44.60	664.37
0.725	1.842	0.047	4.68	400	3.29	45.10	730.04
0.905	2.299	0.058	5.84	430	3.54	45.65	775.23
1.13	2.870	0.073	7.29	450	3.70	46.37	798.78

Sample Discription:-

Moist unit weight of specimen: 2.075 gm/cm³ Proving ring calibration factor:

Dry unit weight of specimen: 1.773 gm/cm³
 Moisture content of specimen: 17.0 %
 Initial average length of specimen: 15.5 cm
 Initial average diameter of specimen: 7.398 cm
 Initial area of specimen: 42.9866 cm²

1 kN = 121.5
 2 kN = 241.8
 3kN = 362.9
 4 kN = 483.8

SUMMARY OF RESULTS FOR 10, 20, 30 PSI TESTS OF 5% LIME STABILIZATION

TRIAXIAL SHEAR TEST

MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE

TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE

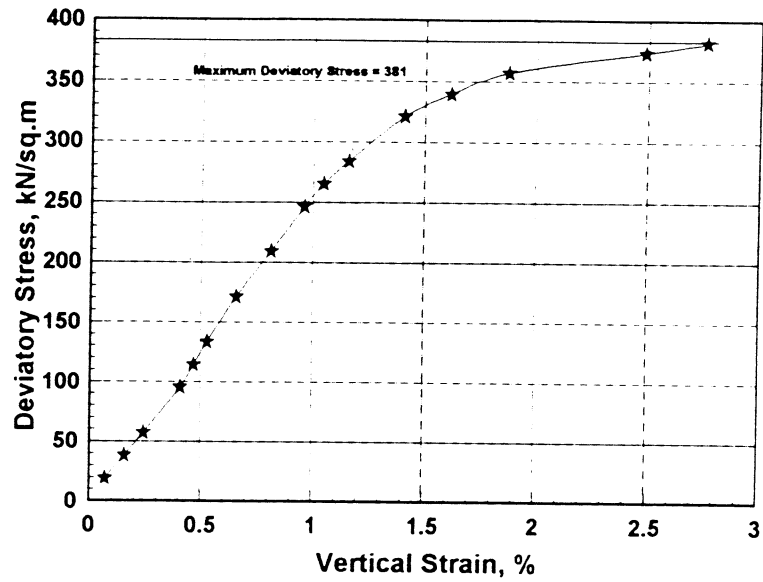
Test Performed : Consolidated Drained

S No.	Confined Press. $\sigma(3)$ psi	Confined Press. $\sigma(3)$ kN/sq.m	Deviatory Stress. $\Delta\sigma$ kN/sq. m	Deviatory + Confined Stress $\sigma(1) = \sigma(3) + \Delta\sigma$ kN/sq.m
1	10	68.95	381.67	450.62
2	20	137.9	486.43	624.33
3	30	206.85	798.78	1005.63

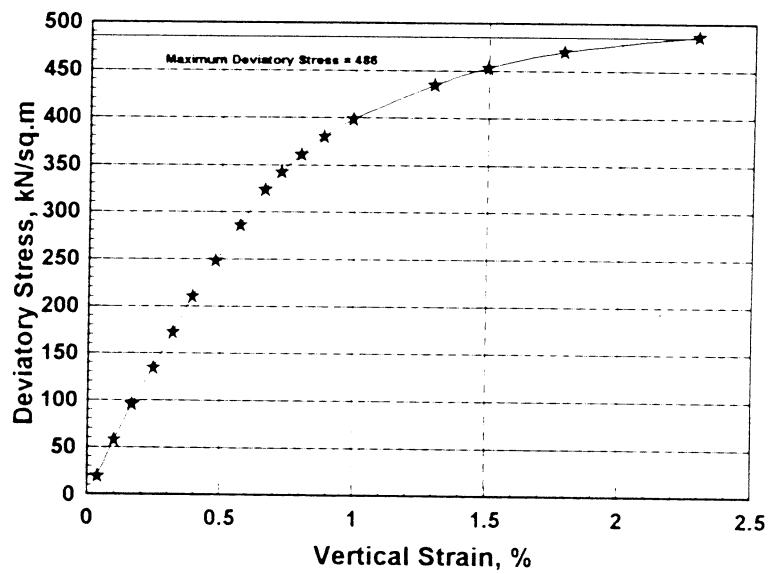
CO nversion Factor Used:

$$6.895 \text{ kN/sq. m} = 1 \text{ psi.}$$

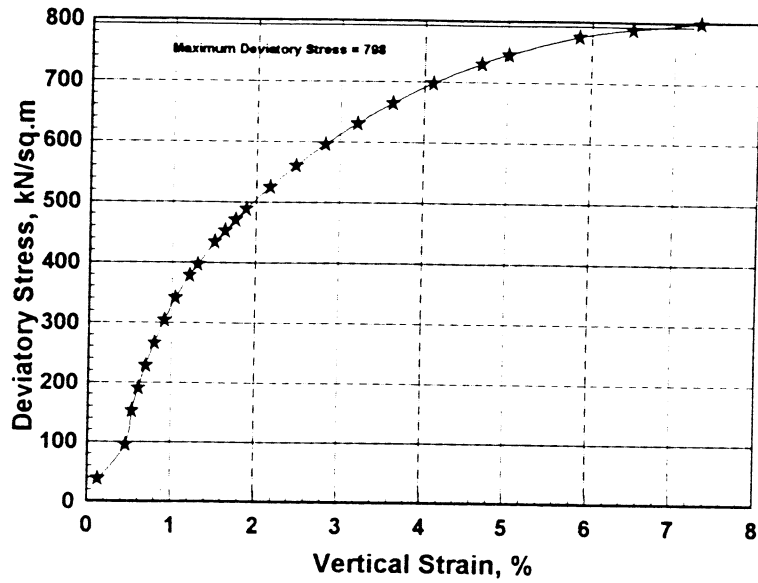
Triaxial Shear Test - 5% Lime Stabilization , 10 psi



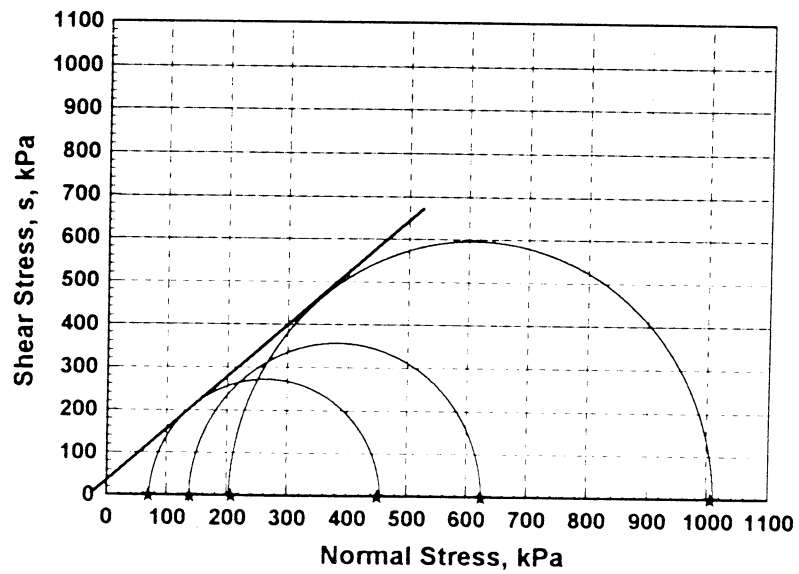
Triaxial Shear Test- 5% Lime Stabilization, 20 psi.



Triaxial Shear Test- 5% Lime Stabilization, 30 psi



Mohr's Circle Plot, 5% Lime Stabilization



C (Cohesion) = 40 k Pa.

Phi (Angle Of Internal Friction) = 48 deg.

TRIAXIAL SHEAR TEST
10% LIME STABILIZATION, 10 PSI.
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE
Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.008	0.020	0.000	0.05	20	0.16	43.01	38.27
0.02	0.051	0.001	0.12	40	0.33	43.04	76.49
0.04	0.102	0.002	0.25	60	0.49	43.09	114.60
0.06	0.152	0.004	0.37	80	0.66	43.15	152.61
0.082	0.208	0.005	0.51	100	0.82	43.21	190.50
0.094	0.239	0.006	0.58	110	0.91	43.24	209.39
0.12	0.305	0.007	0.74	130	1.07	43.31	247.06
0.138	0.351	0.009	0.85	140	1.15	43.36	265.77
0.17	0.432	0.010	1.05	160	1.32	43.44	303.13
0.209	0.531	0.013	1.29	180	1.48	43.55	340.19
0.231	0.587	0.014	1.43	190	1.56	43.61	358.60
0.277	0.704	0.017	1.71	200	1.65	43.73	376.38
0.293	0.744	0.018	1.81	210	1.73	43.78	394.81
0.357	0.907	0.022	2.20	220	1.81	43.96	411.94
0.41	1.041	0.025	2.53	222	1.83	44.10	414.30
Sample Discription :-							

Moist unit weight of specimen: 2.037 gm/cm³ Proving ring calibration factor:
Dry unit weight of specimen: 1.727 gm/cm³
Moisture content of specimen: 20.3 %
Initial average length of specimen: 16.2 cm
Initial average diameter of specimen: 7.398 cm
Initial area of specimen: 42.9866 cm²

1 kN = 121.5
2 kN = 241.8
3kN = 362.9
4 kN = 483.8

TRIAxIAL SHEAR TEST
10% LIME STABILIZATION, 20 PSI.
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE
Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.01	0.025	0.001	0.06	20	0.16	43.01	38.27
0.022	0.056	0.001	0.13	40	0.33	43.04	76.48
0.043	0.109	0.003	0.26	70	0.58	43.10	133.67
0.058	0.147	0.004	0.36	90	0.74	43.14	171.71
0.073	0.185	0.004	0.45	110	0.91	43.18	209.67
0.092	0.234	0.006	0.56	130	1.07	43.23	247.50
0.131	0.333	0.008	0.80	170	1.40	43.33	322.88
0.16	0.406	0.010	0.98	190	1.56	43.41	360.21
0.21	0.533	0.013	1.29	210	1.73	43.55	396.90
0.237	0.602	0.015	1.45	230	1.89	43.62	433.97
0.255	0.648	0.016	1.56	240	1.98	43.67	452.33
0.32	0.813	0.020	1.96	260	2.14	43.85	488.04
0.355	0.902	0.022	2.18	270	2.22	43.94	505.70
0.41	1.041	0.025	2.52	280	2.30	44.10	522.62
0.485	1.232	0.030	2.98	290	2.39	44.30	538.73
Sample Discription :-							

Moist unit weight of specimen: 2.037 gm/cm³ Proving ring calibration factor:
Dry unit weight of specimen: 1.727 gm/cm³ 1 kN = 121.5
Moisture content of specimen: 20.3 % 2 kN = 241.8
Initial average length of specimen: 16.3 cm 3kN = 362.9
Initial average diameter of specimen: 7.398 cm 4 kN = 483.8
Initial area of specimen: 42.9866 cm²

TRIAXIAL SHEAR TEST
10% LIME STABILIZATION, 30 PSI.
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE
Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.013	0.033	0.001	0.08	20	0.16	43.02	38.26
0.025	0.064	0.001	0.15	40	0.33	43.05	76.47
0.038	0.097	0.002	0.22	60	0.49	43.08	114.62
0.049	0.124	0.003	0.29	80	0.66	43.11	152.73
0.061	0.155	0.004	0.36	100	0.82	43.14	190.78
0.087	0.221	0.005	0.51	140	1.15	43.21	266.68
0.114	0.290	0.007	0.67	180	1.48	43.28	342.33
0.129	0.328	0.008	0.76	200	1.65	43.32	380.03
0.163	0.414	0.010	0.96	240	1.98	43.40	455.11
0.207	0.526	0.012	1.22	280	2.30	43.52	529.58
0.232	0.589	0.014	1.36	300	2.47	43.58	566.56
0.294	0.747	0.017	1.73	340	2.80	43.74	639.72
0.388	0.986	0.023	2.28	380	3.13	43.99	710.96
0.462	1.173	0.027	2.72	400	3.29	44.19	745.05
0.51	1.295	0.030	3.00	410	3.37	44.32	761.46
0.59	1.499	0.035	3.47	416	3.42	44.53	768.85

Sample Discription :-

Moist unit weight of specimen: 2.037 gm/cm³ Proving ring calibration factor:

Dry unit weight of specimen: 1.727 gm/cm³

Moisture content of specimen: 20.3 %

Initial average length of specimen: 17.0 cm

Initial average diameter of specimen: 7.398 cm

Initial area of specimen: 42.9866 cm²

1 kN = 121.5

2 kN = 241.8

3kN = 362.9

4 kN = 483.8

SUMMARY OF RESULTS FOR 10, 20, 30 PSI TESTS OF 10% LIME STABILIZATION

TRIAXIAL SHEAR TEST

MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE

TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE

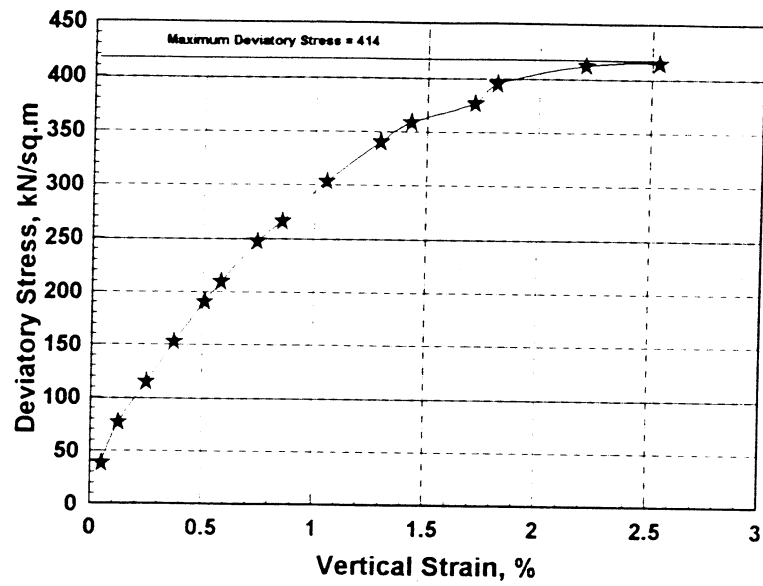
Test Performed : Consolidated Drained

S No.	Confined Press. $\sigma(3)$ psi	Confined Press. $\sigma(3)$ kN/sq.m	Deviatory Stress. $\Delta\sigma$ kN/sq. m	Deviatory + Confined Stress $\sigma(1) = \sigma(3) + \Delta\sigma$ kN/sq.m
1	10	68.95	414.296	483.246
2	20	137.9	538.73	676.63
3	30	206.85	768.86	975.71

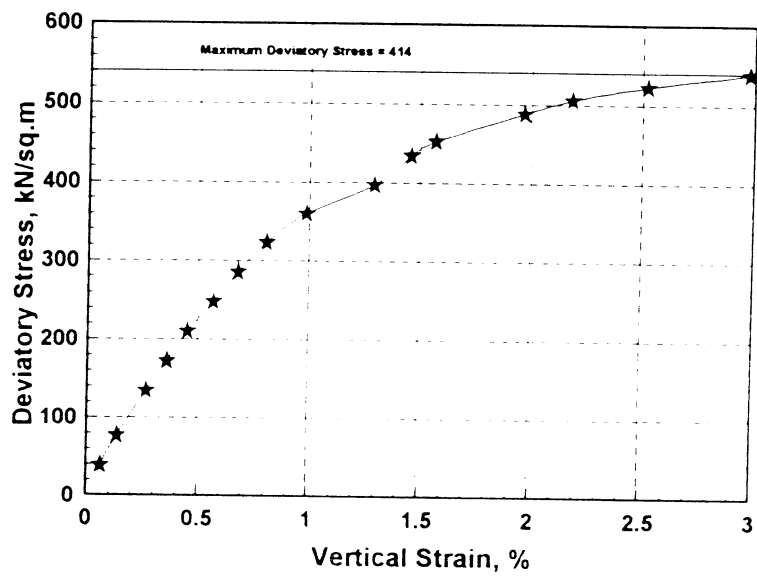
Conversion Factor Used:

$$6.895 \text{ kN/sq. m} = 1 \text{ psi.}$$

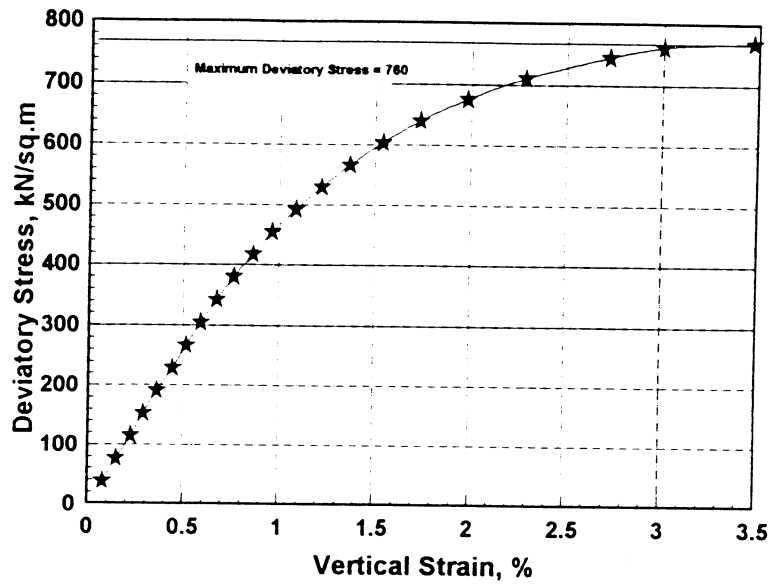
Triaxial Shear Test - 10 % Lime Stabilization, 10psi



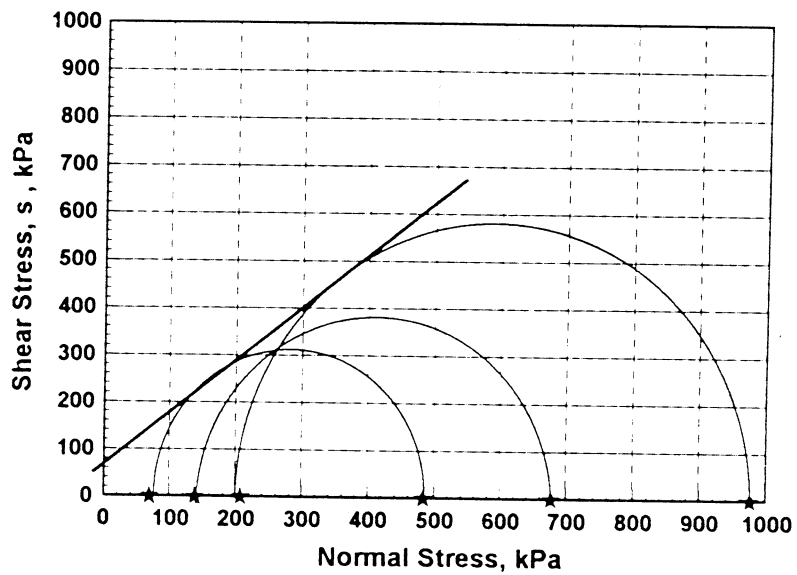
Triaxial Shear Test - 10 % Lime Stabilization, 20 psi



Triaxial Shear Test - 10 % Lime Stabilization, 30 psi



Mohr's Circle Plot - 10 % Lime Stabilization



C (Cohesion) = 65 k Pa.

Phi (Angle Of Internal Friction) = 50 deg.

TRIAXIAL SHEAR TEST
15% LIME STABILIZATION, 10 PSI.
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE
Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.012	0.030	0.001	0.07	10	0.08	43.02	19.13
0.042	0.107	0.002	0.25	30	0.25	43.09	57.30
0.07	0.178	0.004	0.41	50	0.41	43.16	95.34
0.102	0.259	0.006	0.60	70	0.58	43.25	133.22
0.14	0.356	0.008	0.82	90	0.74	43.34	170.90
0.182	0.462	0.011	1.07	110	0.91	43.45	208.36
0.24	0.610	0.014	1.41	130	1.07	43.60	245.39
0.315	0.800	0.019	1.85	150	1.23	43.80	281.88
0.355	0.902	0.021	2.09	160	1.32	43.90	299.95
0.415	1.054	0.024	2.44	170	1.40	44.06	317.55
0.47	1.194	0.028	2.76	175	1.44	44.21	325.80
Sample discription :-							

Moist unit weight of specimen: 1.975 gm/cm³ Proving ring calibration factor:
Dry unit weight of specimen: 1.970 gm/cm³ 1 kN = 121.5
Moisture content of specimen: 22.8 % 2 kN = 241.8
Initial average length of specimen: 17.0 cm 3kN = 362.9
Initial average diameter of specimen: 7.398 cm 4 kN = 483.8
Initial area of specimen: 42.9866 cm²

TRIAXIAL SHEAR TEST
15% LIME STABILIZATION, 20 PSI.
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE
Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.018	0.046	0.001	0.11	20	0.16	43.03	38.25
0.035	0.089	0.002	0.21	40	0.33	43.08	76.42
0.053	0.135	0.003	0.32	60	0.49	43.13	114.51
0.073	0.185	0.004	0.45	80	0.66	43.18	152.49
0.093	0.236	0.006	0.57	100	0.82	43.23	190.38
0.112	0.284	0.007	0.68	120	0.99	43.28	228.19
0.14	0.356	0.009	0.85	140	1.15	43.36	265.76
0.195	0.495	0.012	1.19	180	1.48	43.50	340.54
0.228	0.579	0.014	1.39	200	1.65	43.59	377.61
0.248	0.630	0.015	1.51	210	1.73	43.65	396.00
0.29	0.737	0.018	1.77	230	1.89	43.76	432.58
0.345	0.876	0.021	2.10	250	2.06	43.91	468.59
0.38	0.965	0.023	2.32	260	2.14	44.01	486.28
0.43	1.092	0.026	2.62	270	2.22	44.14	503.40
0.52	1.321	0.032	3.17	280	2.30	44.39	519.11
Sample Discription							

Moist unit weight of specimen: 1.975 gm/cm³ Proving ring calibration factor:
Dry unit weight of specimen: 1.970 gm/cm³ 1 kN = 121.5
Moisture content of specimen: 22.8 % 2 kN = 241.8
Initial average length of specimen: 16.4 cm 3kN = 362.9
Initial average diameter of specimen: 7.398 cm 4 kN = 483.8
Initial area of specimen: 42.9866 cm²

TRIAXIAL SHEAR TEST
15% LIME STABILIZATION, 30 PSI.
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE
Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.011	0.028	0.001	0.07	20	0.16	43.02	38.27
0.021	0.053	0.001	0.14	40	0.33	43.05	76.48
0.032	0.081	0.002	0.21	60	0.49	43.08	114.63
0.053	0.135	0.004	0.35	100	0.82	43.14	190.79
0.064	0.163	0.004	0.43	120	0.99	43.17	228.78
0.087	0.221	0.006	0.58	160	1.32	43.24	304.57
0.099	0.251	0.007	0.66	180	1.48	43.27	342.36
0.112	0.284	0.007	0.75	200	1.65	43.31	380.07
0.162	0.411	0.011	1.08	260	2.14	43.46	492.43
0.1863	0.473	0.012	1.24	280	2.30	43.53	529.45
0.207	0.526	0.014	1.38	300	2.47	43.59	566.47
0.31	0.787	0.021	2.07	360	2.96	43.89	675.03
0.364	0.925	0.024	2.43	380	3.13	44.06	709.91
0.44	1.118	0.029	2.93	400	3.29	44.29	743.40
0.575	1.461	0.038	3.83	420	3.46	44.70	773.33

Sample Discription:-

Moist unit weight of specimen: 1.975 gm/cm³ Proving ring calibration factor:
Dry unit weight of specimen: 1.970 gm/cm³ 1 kN = 121.5
Moisture content of specimen: 22.8 % 2 kN = 241.8
Initial average length of specimen: 15.0 cm 3kN = 362.9
Initial average diameter of specimen: 7.398 cm 4 kN = 483.8
Initial area of specimen: 42.9866 cm²

SUMMARY OF RESULTS FOR 10, 20, 30 PSI TESTS OF 15% LIME STABILIZATION

TRIAxIAL SHEAR TEST

MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE

TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE

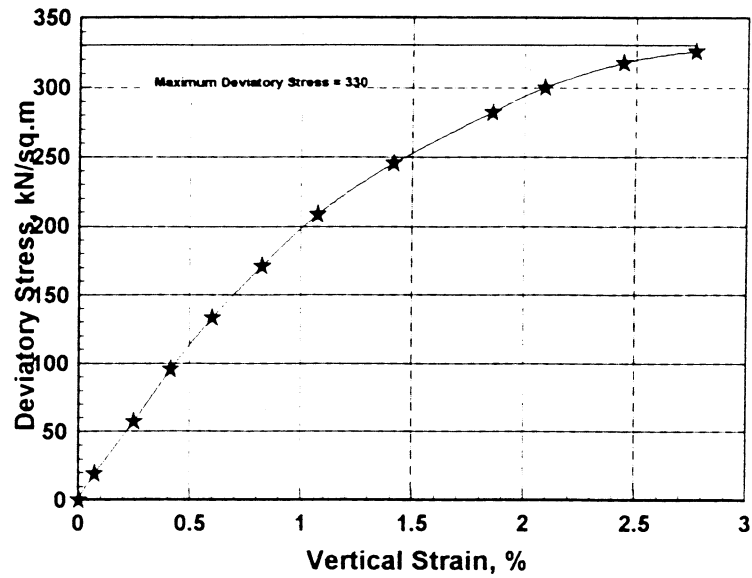
Test Performed : Consolidated Drained

S No.	Confined Press. $\sigma(3)$ psi	Confined Press. $\sigma(3)$ kN/sq.m	Deviatory Stress. $\Delta\sigma$ kN/sq. m	Deviatory + Confined Stress $\sigma(1) = \sigma(3) + \Delta\sigma$ kN/sq.m
1	10	68.95	414.296	483.246
2	20	137.9	519.1	657
3	30	206.85	773.32	980.17

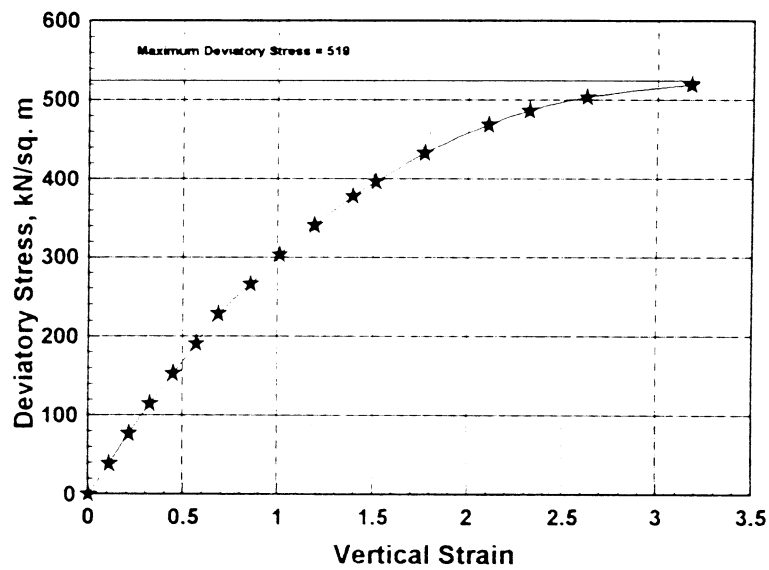
Conversion Factor Used:

$$6.895 \text{ kN/sq. m} = 1 \text{ psi.}$$

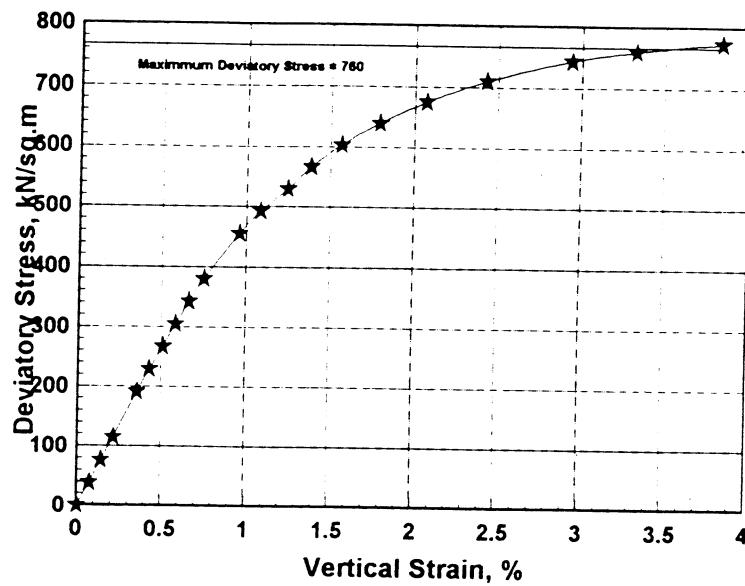
Triaxial Shear Test - 15% Lime Stabilization, 10 psi.



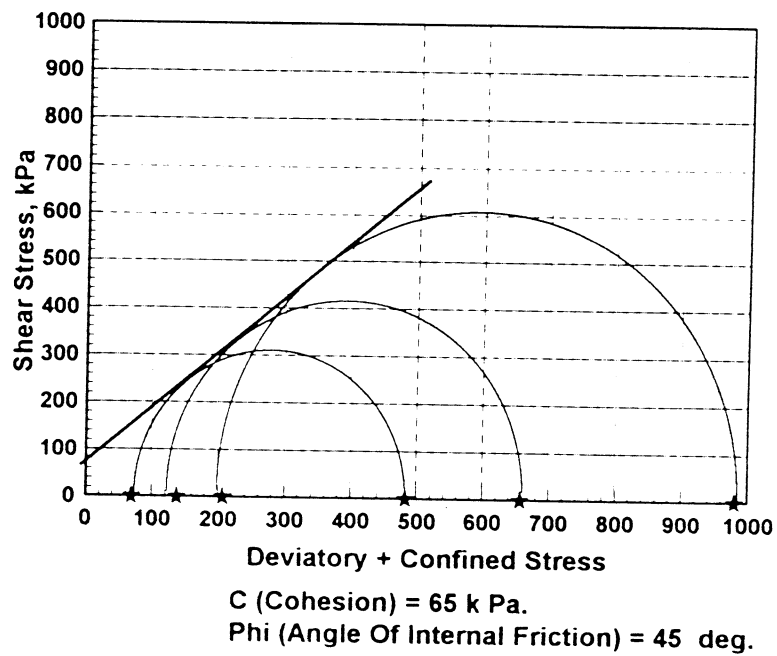
Triaxial Shear Test - 15% Lime Stabilization, 20 psi



Triaxial Shear Test- 15% Lime Stabilization, 30 psi



Mohr's Circle Plot - 15% Lime Stabilization



TRIAXIAL SHEAR TEST
25% LIME STABILIZATION, 10 PSI.
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE
Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.007	0.018	0.000	0.05	10	0.08	43.01	19.14
0.022	0.056	0.001	0.15	30	0.25	43.05	57.35
0.038	0.097	0.003	0.26	50	0.41	43.10	95.49
0.057	0.145	0.004	0.39	70	0.58	43.15	133.51
0.081	0.206	0.005	0.55	90	0.74	43.22	171.38
0.112	0.284	0.008	0.76	110	0.91	43.31	209.02
0.15	0.381	0.010	1.01	130	1.07	43.43	246.38
0.197	0.500	0.013	1.33	140	1.15	43.57	264.48
0.229	0.582	0.015	1.55	160	1.32	43.66	301.60
0.309	0.785	0.021	2.09	170	1.40	43.90	318.70
0.45	1.143	0.030	3.04	177	1.46	44.33	328.59

Sample Discription :-

Moist unit weight of specimen: 1.975 gm/cm³ Proving ring calibration factor:
Dry unit weight of specimen: 1.970 gm/cm³ 1 kN = 121.5
Moisture content of specimen: 19.6 % 2 kN = 241.8
Initial average length of specimen: 14.8 cm 3kN = 362.9
Initial average diameter of specimen: 7.398 cm 4 kN = 483.8
Initial area of specimen: 42.9866 cm²

TRIAXIAL SHEAR TEST
25% LIME STABILIZATION, 20 PSI.
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE
Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.015	0.038	0.001	0.09	20	0.16	43.03	38.26
0.033	0.084	0.002	0.21	40	0.33	43.08	76.43
0.051	0.130	0.003	0.32	60	0.49	43.12	114.51
0.07	0.178	0.004	0.44	80	0.66	43.18	152.50
0.09	0.229	0.006	0.57	100	0.82	43.23	190.38
0.111	0.282	0.007	0.70	120	0.99	43.29	228.15
0.133	0.338	0.008	0.84	140	1.15	43.35	265.81
0.159	0.404	0.010	1.00	160	1.32	43.42	303.28
0.185	0.470	0.012	1.16	180	1.48	43.49	340.63
0.215	0.546	0.014	1.35	200	1.65	43.58	377.75
0.25	0.635	0.016	1.57	220	1.81	43.67	414.60
0.294	0.747	0.018	1.85	240	1.98	43.80	451.02
0.343	0.871	0.022	2.16	260	2.14	43.93	487.07
0.42	1.067	0.026	2.64	280	2.30	44.15	521.94
0.53	1.346	0.033	3.33	300	2.47	44.47	555.25
Sample Discription							

Moist unit weight of specimen: 1.975 gm/cm³ Proving ring calibration factor:
Dry unit weight of specimen: 1.970 gm/cm³ 1 kN = 121.5
Moisture content of specimen: 19.6% 2 kN = 241.8
Initial average length of specimen: 15.9cm 3kN = 362.9
Initial average diameter of specimen: 7.398 cm 4 kN = 483.8
Initial area of specimen: 42.9866 cm²

TRIAxIAL SHEAR TEST
25% LIME STABILIZATION, 30 PSI.
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE
Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.02	0.051	0.001	0.12	30	0.25	43.04	57.37
0.043	0.109	0.003	0.26	60	0.49	43.10	114.58
0.069	0.175	0.004	0.42	90	0.74	43.17	171.59
0.099	0.251	0.006	0.60	120	0.99	43.25	228.37
0.13	0.330	0.008	0.79	150	1.23	43.33	284.92
0.154	0.391	0.009	0.94	170	1.40	43.39	322.43
0.182	0.462	0.011	1.11	190	1.56	43.47	359.75
0.213	0.541	0.013	1.30	210	1.73	43.55	396.86
0.25	0.635	0.015	1.52	230	1.89	43.65	433.66
0.293	0.744	0.018	1.79	250	2.06	43.77	470.11
0.336	0.853	0.020	2.05	270	2.22	43.89	506.37
0.388	0.986	0.024	2.37	290	2.39	44.03	542.11
0.532	1.351	0.032	3.24	330	2.72	44.43	611.34
0.595	1.511	0.036	3.63	340	2.80	44.60	627.36
0.685	1.740	0.042	4.18	350	2.88	44.86	642.14
Sample Discription:-							

Moist unit weight of specimen: 1.975 gm/cm³ Proving ring calibration factor:

Dry unit weight of specimen: 1.970 gm/cm³
Moisture content of specimen: 19.6 %
Initial average length of specimen: 15.0 cm
Initial average diameter of specimen: 7.398 cm
Initial area of specimen: 42.9866 cm²

1 kN = 121.5
2 kN = 241.8
3kN = 362.9
4 kN = 483.8

SUMMARY OF RESULTS FOR 10, 20, 30 PSI TESTS OF 25% LIME STABILIZATION

TRIAXIAL SHEAR TEST

MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE

TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE

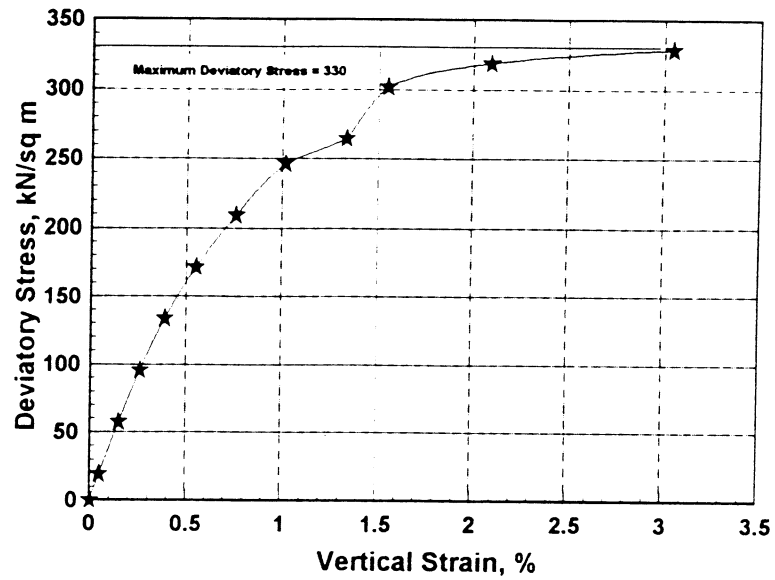
Test Performed : Consolidated Drained

S No.	Confined Press. $\sigma(3)$ psi	Confined Press. $\sigma(3)$ kN/sq.m	Deviatory Stress. $\Delta\sigma$ kN/sq. m	Deviatory + Confined Stress $\sigma(1) = \sigma(3) + \Delta\sigma$ kN/sq.m
1	10	68.95	328.59	397.54
2	20	137.9	555.25	693.15
3	30	206.85	642.74	849.59

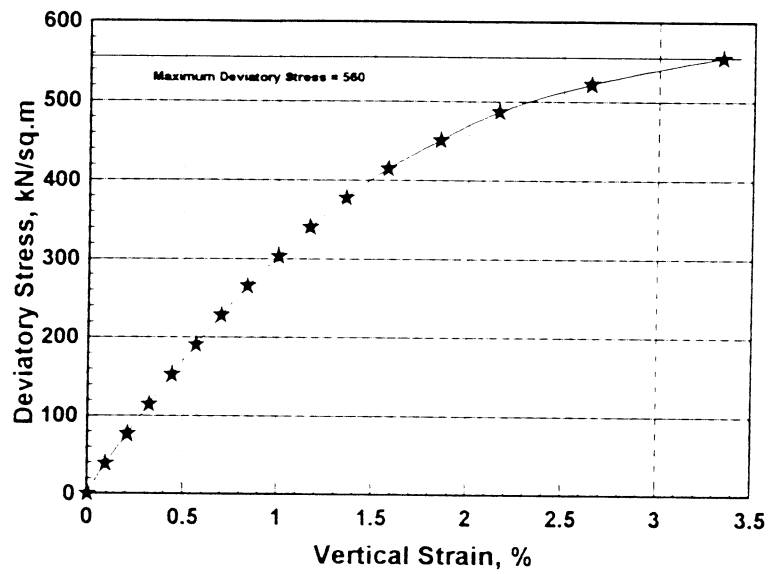
Conversion Factor Used:

$$6.895 \text{ kN/sq. m} = 1 \text{ psi.}$$

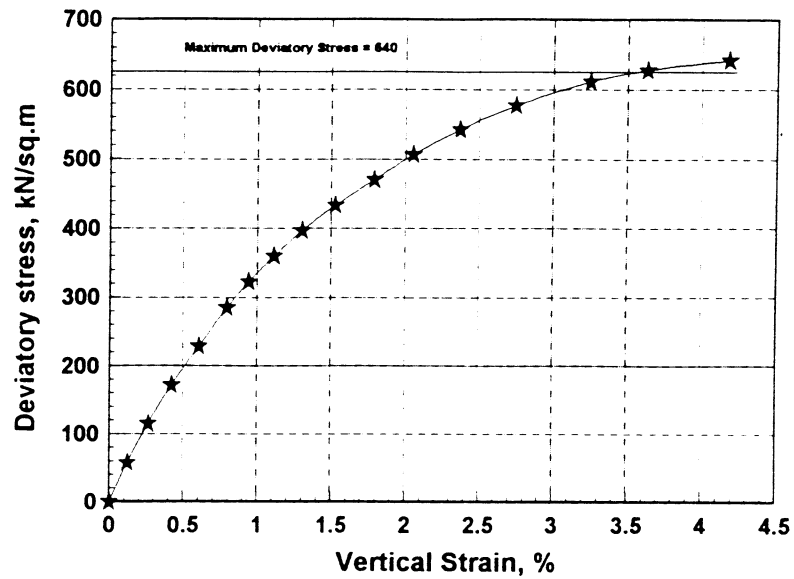
Triaxial Shear Test - 25% Lime Stabilization, 10 psi



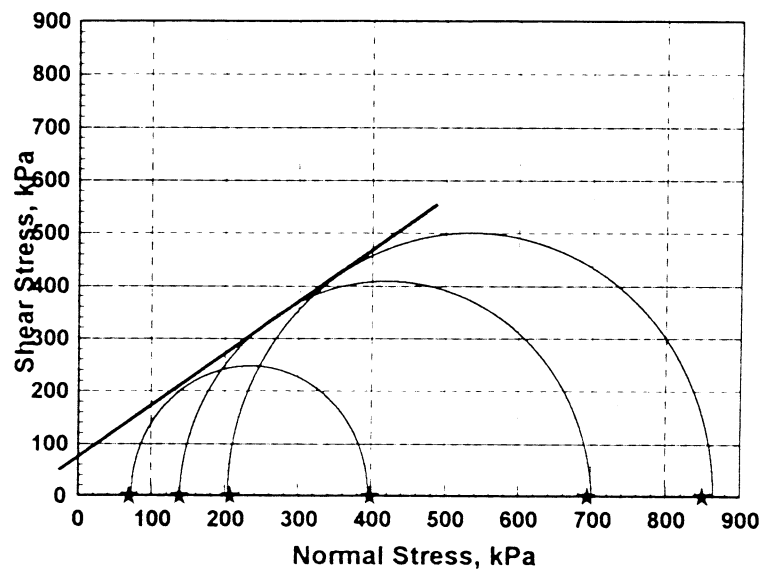
Triaxial Test Results - 25 Lime Stabilization, 20psi



Triaxial Shear Test - 25% Lime Stabilization, 30 psi



Mohr's Circle Plot - 25% Lime Stabilization



TRIAXIAL SHEAR TEST
50% LIME STABILIZATION, 10 PSI.
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE
Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.015	0.038	0.001	0.09	10	0.08	43.03	19.13
0.034	0.086	0.002	0.20	20	0.16	43.07	38.22
0.087	0.221	0.005	0.52	40	0.33	43.21	76.19
0.172	0.437	0.010	1.02	60	0.49	43.43	113.70
0.269	0.683	0.016	1.60	80	0.66	43.69	150.72
0.322	0.818	0.019	1.92	90	0.74	43.83	169.02
0.377	0.958	0.022	2.24	100	0.82	43.97	187.17
0.486	1.234	0.029	2.89	120	0.99	44.27	223.11
0.541	1.374	0.032	3.22	130	1.07	44.42	240.89
0.73	1.854	0.043	4.35	148	1.22	44.94	271.06

Sample Discription :-

Moist unit weight of specimen: 1.787 gm/cm³ Proving ring calibration factor:
Dry unit weight of specimen: 1.457 gm/cm³ 1 kN = 121.5
Moisture content of specimen: 24.5 % 2 kN = 241.8
Initial average length of specimen: 16.8 cm 3kN = 362.9
Initial average diameter of specimen: 7.398 cm 4 kN = 483.8
Initial area of specimen: 42.9866 cm²

TRIAXIAL SHEAR TEST
50% LIME STABILIZATION, 20 PSI.
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE
Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.007	0.018	0.000	0.05	10	0.08	43.01	19.14
0.025	0.064	0.002	0.17	20	0.16	43.06	38.23
0.073	0.185	0.005	0.50	40	0.33	43.20	76.20
0.131	0.333	0.009	0.90	60	0.49	43.38	113.84
0.193	0.490	0.013	1.33	80	0.66	43.57	151.13
0.23	0.584	0.016	1.59	100	0.82	43.68	188.43
0.271	0.688	0.019	1.87	120	0.99	43.81	225.46
0.335	0.851	0.023	2.31	140	1.15	44.00	261.86
0.402	1.021	0.028	2.77	160	1.32	44.21	297.85
0.448	1.138	0.031	3.09	170	1.40	44.36	315.43
0.543	1.379	0.037	3.74	190	1.56	44.66	350.16
0.605	1.537	0.042	4.17	200	1.65	44.86	366.95
0.72	1.829	0.050	4.97	210	1.73	45.23	382.11
0.875	2.223	0.060	6.03	220	1.81	45.75	395.81

Sample Discription

Moist unit weight of specimen: 1.787 gm/cm³ Proving ring calibration factor:
1 kN = 121.5
Dry unit weight of specimen: 1.457 gm/cm³
2 kN = 241.8
Moisture content of specimen: 24.5%
3kN = 362.9
Initial average length of specimen: 14.5cm
4 kN = 483.8
Initial average diameter of specimen: 7.398 cm
Initial area of specimen: 42.9866 cm²

TRIAxIAL SHEAR TEST**50% LIME STABILIZATION, 30 PSI.****MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE****TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE****Test Performed : Consolidated Drained**

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.005	0.013	0.000	0.03	10	0.08	43.00	19.14
0.017	0.043	0.001	0.10	20	0.16	43.03	38.26
0.041	0.104	0.002	0.24	40	0.33	43.09	76.40
0.071	0.180	0.004	0.41	60	0.49	43.16	114.41
0.099	0.251	0.006	0.57	80	0.66	43.23	152.30
0.131	0.333	0.008	0.76	100	0.82	43.31	190.02
0.147	0.373	0.008	0.85	110	0.91	43.35	208.82
0.219	0.556	0.013	1.27	150	1.23	43.54	283.56
0.259	0.658	0.015	1.50	170	1.40	43.64	320.62
0.296	0.752	0.017	1.71	190	1.56	43.73	357.56
0.344	0.874	0.020	1.99	200	1.65	43.86	375.32
0.404	1.026	0.023	2.34	230	1.89	44.01	430.09
0.44	1.118	0.025	2.54	240	1.98	44.11	447.83
0.475	1.207	0.027	2.75	246	2.02	44.20	458.07

Sample Discription:-Moist unit weight of specimen: 1.787 gm/cm³ Proving ring calibration factor:Dry unit weight of specimen: 1.457 gm/cm³

Moisture content of specimen: 24.5%

Initial average length of specimen: 17.3 cm

Initial average diameter of specimen: 7.398 cm

Initial area of specimen: 42.9866 cm²

1 kN = 121.5

2 kN = 241.8

3kN = 362.9

4 kN = 483.8

SUMMARY OF RESULTS FOR 10, 20, 30 PSI TESTS OF 50% LIME STABILIZATION

TRIAxIAL SHEAR TEST

MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE

TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE

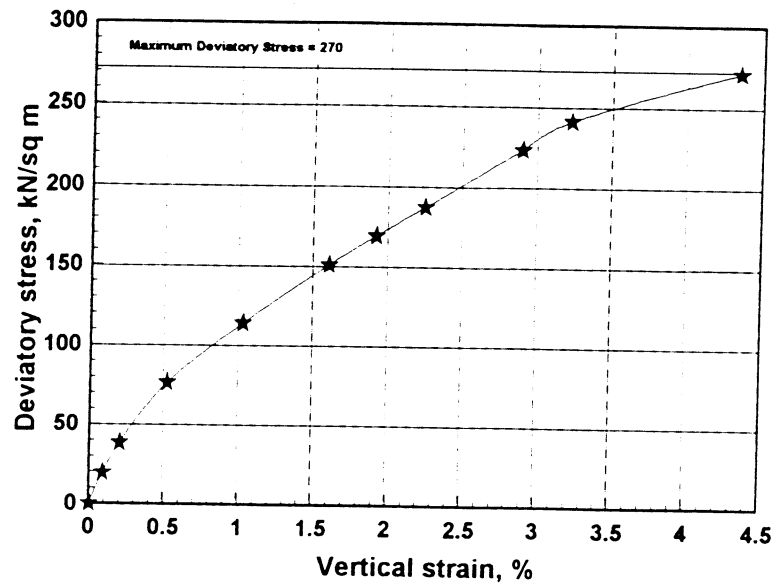
Test Performed : Consolidated Drained

S No.	Confined Press. $\sigma(3)$ psi	Confined Press. $\sigma(3)$ kN/sq.m	Deviatory Stress. $\Delta\sigma$ kN/sq. m	Deviatory + Confined Stress $\sigma(1) = \sigma(3) + \Delta\sigma$ kN/sq.m
1	10	68.95	271.06	340.01
2	20	137.9	395.85	533.75
3	30	206.85	458.073	664.923

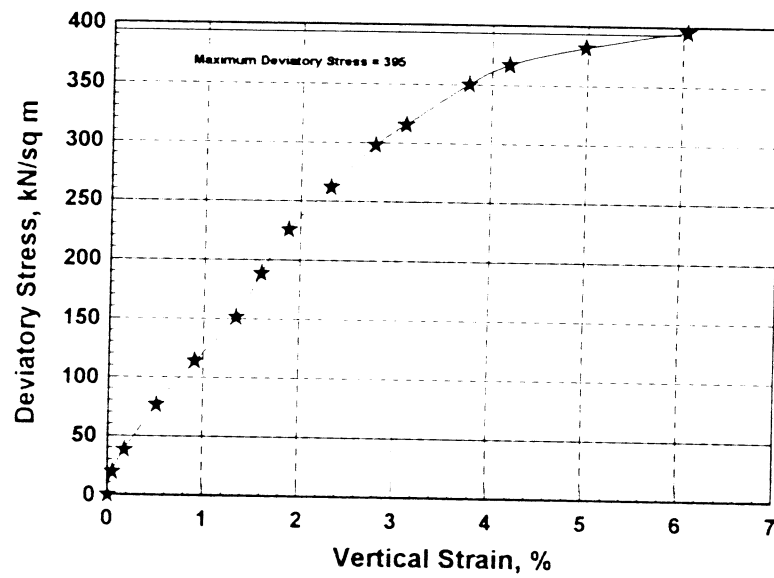
Conversion Factor Used:

$$6.895 \text{ kN/sq. m} = 1 \text{ psi.}$$

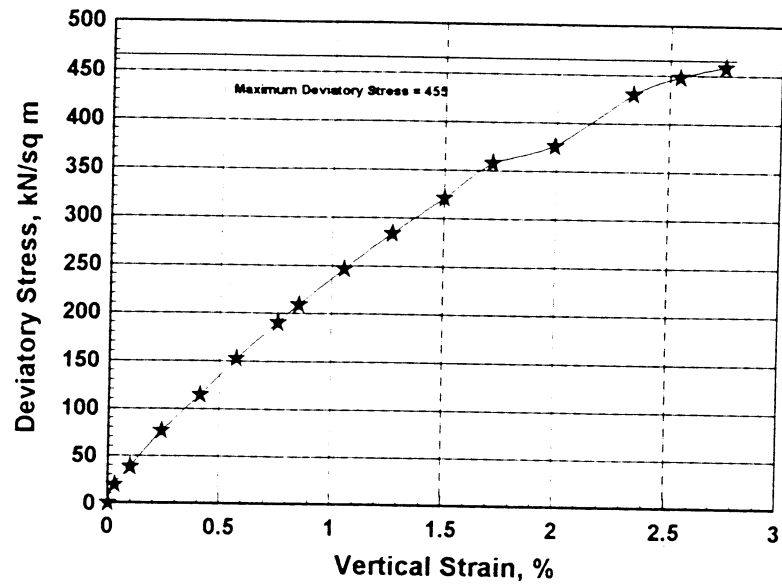
Triaxial Shear Test - 50% Lime Stabilization, 10psi



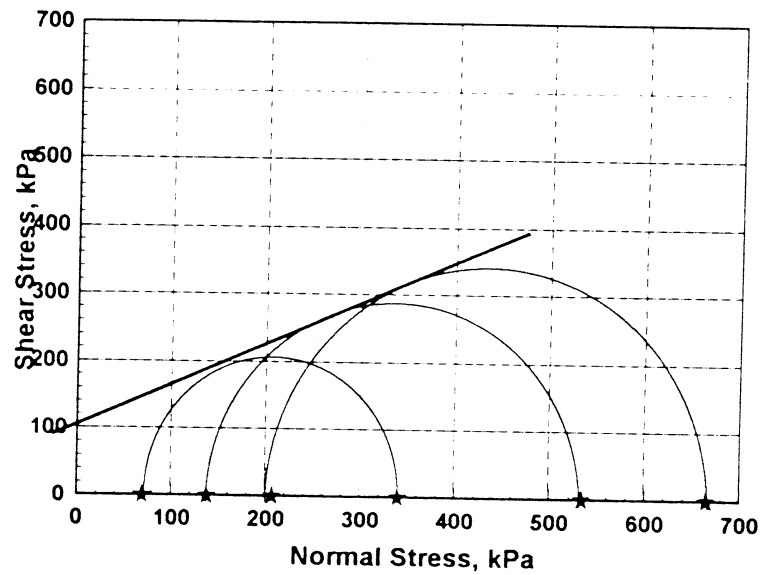
Triaxial Shear Test - 50% Lime Stabilization, 20 psi



Triaxial Shear Test - 50% Lime Stabilization, 30 psi



Mohr's Circle Plot - 50% Lime Stabilization



C(Cohesion) = 100 kPa

Phi(Angle of Internal Friction) = 36 degrees

CALIFORNIA BEARING RATIO
5% LIME, UNSOAKED
 MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
 TEST CONDUCTED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE

Test Performed : ASTM D 1883-87, AASHTO T 193-81
 Compression Machine with Penetration Rate of 1.3 mm/min
 Mold Dimensions: No. of Layers: 5
 Diam. = 6 in.
 Ht. = 7 in.
 Spacer Disk: Diam. = 6 in.
 Ht. = 2 in.
 Surcharge Wt. = 10 lb.

MOISTURE CONTENT DETERMINATION

Moisture Can No.	1	2
Wt. of can + wet soil	34.70	30.40
Wt. of can + dry soil	31.66	28.10
Wt. of water	3.04	2.30
Wt. of can	12.00	13.50
Wt. of dry soil	19.66	14.60
Water Content, w%	15.46	15.75
Average =		15.61

Note: Top, middle and bottom moisture contents were not taken due to the extreme hardness of the sample.

MOLD SAMPLE DATA

Mold No.		Unsoaked	Soaked
Surcharge(lbs)		10.00	10.00
Initial mass of wet soil + mold		10822.00	8627.00
Final mass wet soil and mold		xxx	8630.00
Mass of mold		6437.00	4197.30
Initial mass of wet soil		4385.00	4429.70
Initial wet density		2.10	2.12
Mass of water absorbed		xxx	3.00
% water absorbed		xxx	0.07
xxx - not applicable			

CBR TEST LOAD DATA

Penetrate in.	Stress lb/sq.in.
0.00	0.00
0.02	70.00
0.04	190.00
0.06	420.00
0.08	750.00
0.10	1020.00
0.12	1560.00
0.14	2070.00
0.16	2520.00

CALIFORNIA BEARING RATIO
5% LIME, SOAKED (4 DAYS)
 MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
 TEST CONDUCTED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE

Test Performed : ASTM D 1883-87, AASHTO T 193-81
 Compression Machine with Penetration Rate of 1.3 mm/min
 Mold Dimensions: Diam. = 6 in. No. of Layers: 5
 Ht. = 7 in. No. of Blows/Layer: 56
 Spacer Disk: Diam. = 6 in. Wt. of Hammer = 10 lb.
 Ht. = 2 in. Surcharge Wt. = 10 lb.

MOISTURE CONTENT DETERMINATION

Moisture Can No.	Top 1/3		Middle 1/3		Bottom 1/3			
	1	2	5	6	10	11	25	26
Wt. of can + wet soil	37.00	39.70	36.10	28.72	34.55	36.20	28.50	26.39
Wt. of can + dry soil	33.50	36.97	32.60	26.00	31.50	33.60	26.36	24.50
Wt. of water	3.50	2.73	3.50	2.72	3.05	2.60	2.14	1.89
Wt. of can	11.91	20.94	11.98	11.96	11.75	20.64	13.52	13.42
Wt. of dry soil	21.59	16.03	20.62	14.04	19.75	12.96	12.84	11.08
Water Content, w%	16.21	17.03	16.97	19.37	15.44	20.06	16.67	17.06
Average =	16.62		Average = 18.17		Average = 17.75		Average = 16.86	

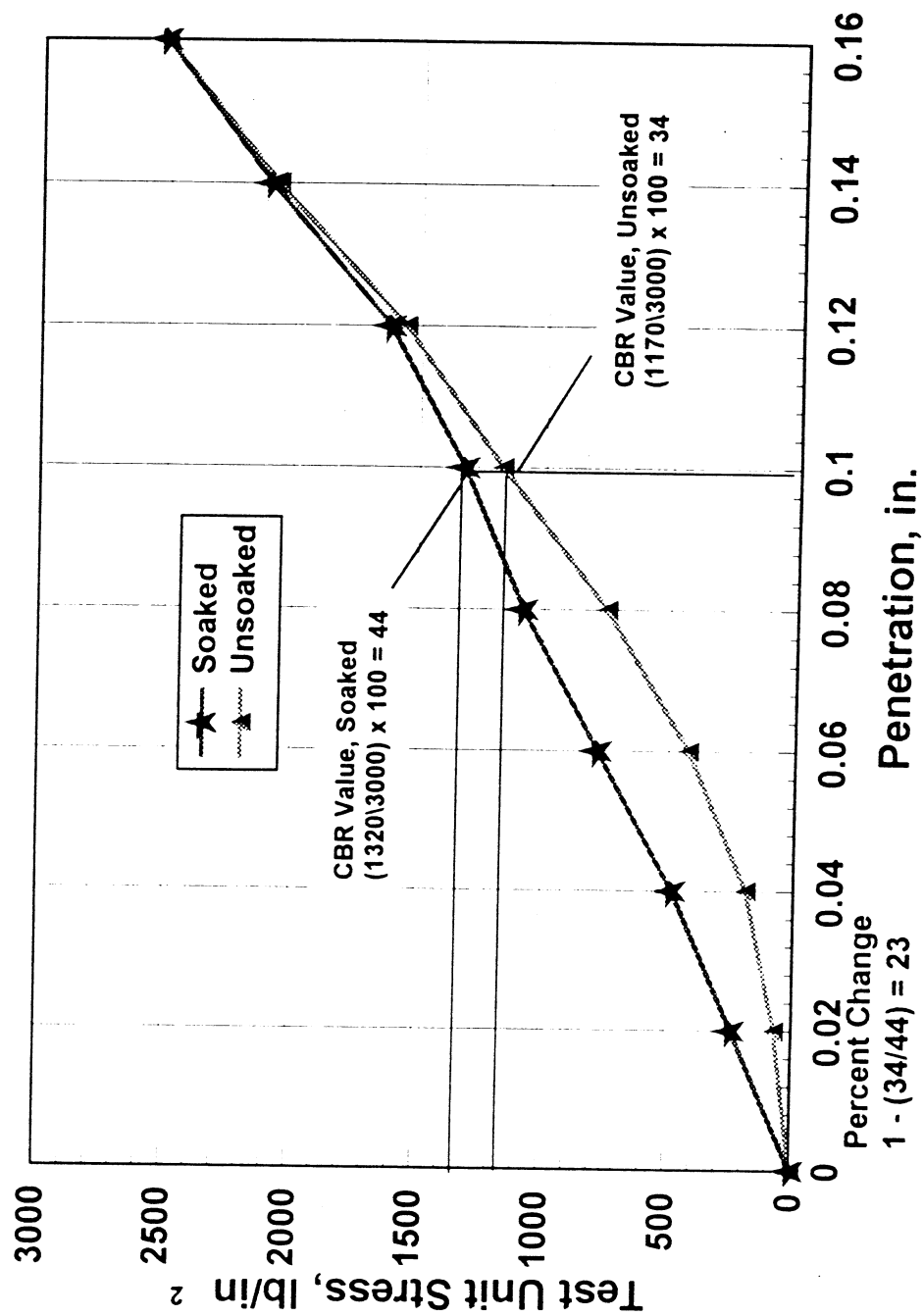
CBR TEST LOAD DATA

Penetrate in.	Stress lb/sq in.
0.00	0.00
0.02	240.00
0.04	480.00
0.06	780.00
0.08	1080.00
0.10	1320.00

SWELL DATA

Start Time and Date	Elapsed Time	Dial Reading	%
28-Sep 10:30	0h	0	0.00
11:30	1h	2	0.04
12:30	2h	3	0.07
14:30	4h	4	0.09
20:30	10h	6	0.13
29-Sep 9:30	21h	11	0.24
21:30	33h	16	0.35
30-Sep 9:00	45h	24	0.53
1-Oct 9:00	69h	33	0.73
2-Oct 9:00	93h	41	0.91

CBR Graph, 5% Lime Soaked and Unsoaked



CALIFORNIA BEARING RATIO
5% LIME, CURED (3,7,28 DAYS)
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST CONDUCTED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE

Test Performed : ASTM D 1883-87, AASHTO T 193-81
 Compression Machine with Penetration Rate of 1.3 mm/min
 Mold Dimensions: Diam. = 6 in. No. of Layers: 5
 Ht. = 7 in. No. of Blows/Layer: 56
 Spacer Disk: Diam. = 6 in. Wt. of Hammer = 10 lb.
 Ht. = 2 in. Surcharge Wt. = 10 lb.

MOISTURE CONTENT DETERMINATION

Moisture Can No.	3 Day			7 Day			28 Day		
	22	25	22	25	25	25	3	9	
Wt. of can + wet soil	29.99	31.55	29.99	31.55	33.68	36.33			
Wt. of can + dry soil	27.32	28.99	27.32	28.99	30.60	32.80			
Wt. of water	2.67	2.56	2.67	2.56	3.08	3.53			
Wt. of can	11.71	13.66	11.71	13.66	12.08	12.06			
Wt. of dry soil	15.61	15.33	15.61	15.33	18.52	20.74			
Water Content, w%	17.10	16.70	17.10	16.70	16.63	17.02			
	Average = 16.90			Average = 16.90			Average = 16.83		

Note: Top, middle and bottom moisture contents were not taken due to the extreme hardness of the sample.

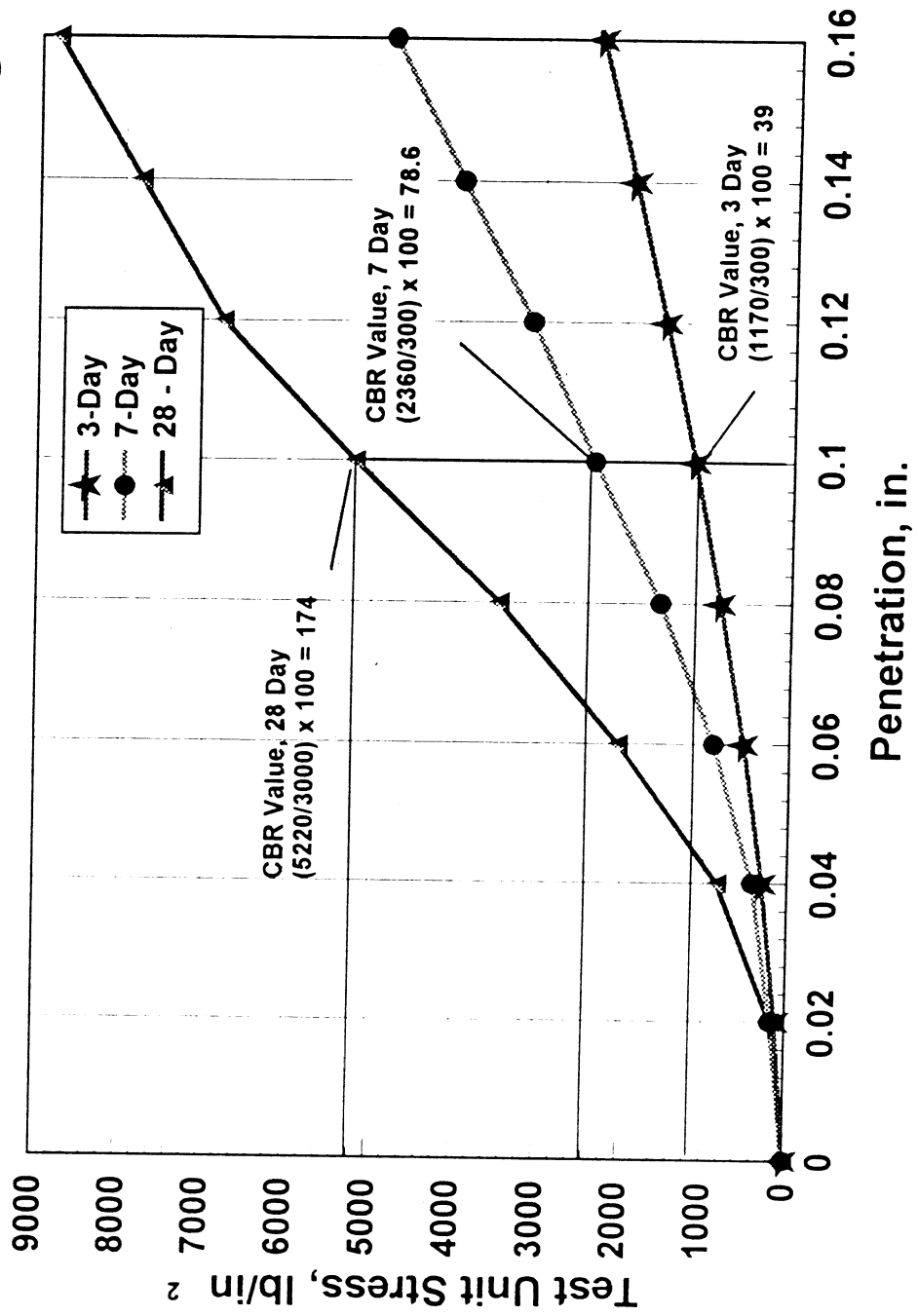
CBR TEST LOAD DATA

Penetration in.	3 Day Stress lb/sq.in.	7 Day Stress lb/sq.in.	28 Day Stress lb/sq.in.
0.00	0	0	0
0.02	120	180	180
0.04	300	420	840
0.06	540	900	2040
0.08	840	1560	3480
0.10	1170	2280	5220
0.12	1530	3120	
0.14	1920	3960	
0.16	2340	4800	

MOLD SAMPLE DATA

No. of Days	3-Day	7-Day	28-Day
Surcharge(lbs)	10.00	10.00	10.00
Initial mass of wet soil + mold	8595.00	8545.00	10817.00
Final mass wet soil and mold	xxx	xxx	xxx
Mass of mold	7320.00	7293.00	6426.00
Initial mass of wet soil	1275.00	1252.00	4391.00
Initial wet density	0.61	0.60	2.10
Mass of water absorbed	xxx	xxx	xxx
% water absorbed	xxx	xxx	xxx
xxx - not applicable			

CBR Graph, 5% Lime 3, 7 & 28 Day Curing



CALIFORNIA BEARING RATIO
10% LIME, SOAKED (4 DAYS)

MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
 TEST CONDUCTED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE

Test Performed : ASTM D 1883-87, AASHTO T 193-81

Compression Machine with Penetration Rate of 1.3 mm/min

Mold Dimensions:

Diam. = 6 in.

Ht. = 7 in.

No. of Layers: 5

Spacer Disk:

Diam. = 6 in.

Ht. = 2 in.

No. of Blows/Layer: 56

Wt. of Hammer = 10 lb.

Surcharge Wt. = 10 lb.

MOISTURE CONTENT DETERMINATION

Moisture Can No.	Top 1/3			Middle 1/3			Bottom 1/3				
	1	2	5	6	21	22	25	26			
Wt. of can + wet soil	25.48	43.77	34.01	32.00	32.29	28.72	29.36	30.99			
Wt. of can + dry soil	23.40	40.14	30.20	28.70	29.40	26.00	26.90	28.10			
Wt. of water	2.08	3.63	3.81	3.30	2.89	2.72	2.46	2.89			
Wt. of can	11.97	20.96	11.98	11.97	13.47	11.60	13.52	13.42			
Wt. of dry soil	11.43	19.18	18.22	16.73	15.93	14.40	13.38	14.68			
Water Content, w%	18.20	18.93	20.91	19.73	18.14	18.89	18.39	19.69			
Average =		18.56	Average =		20.32	Average =		18.52	Average =		19.04

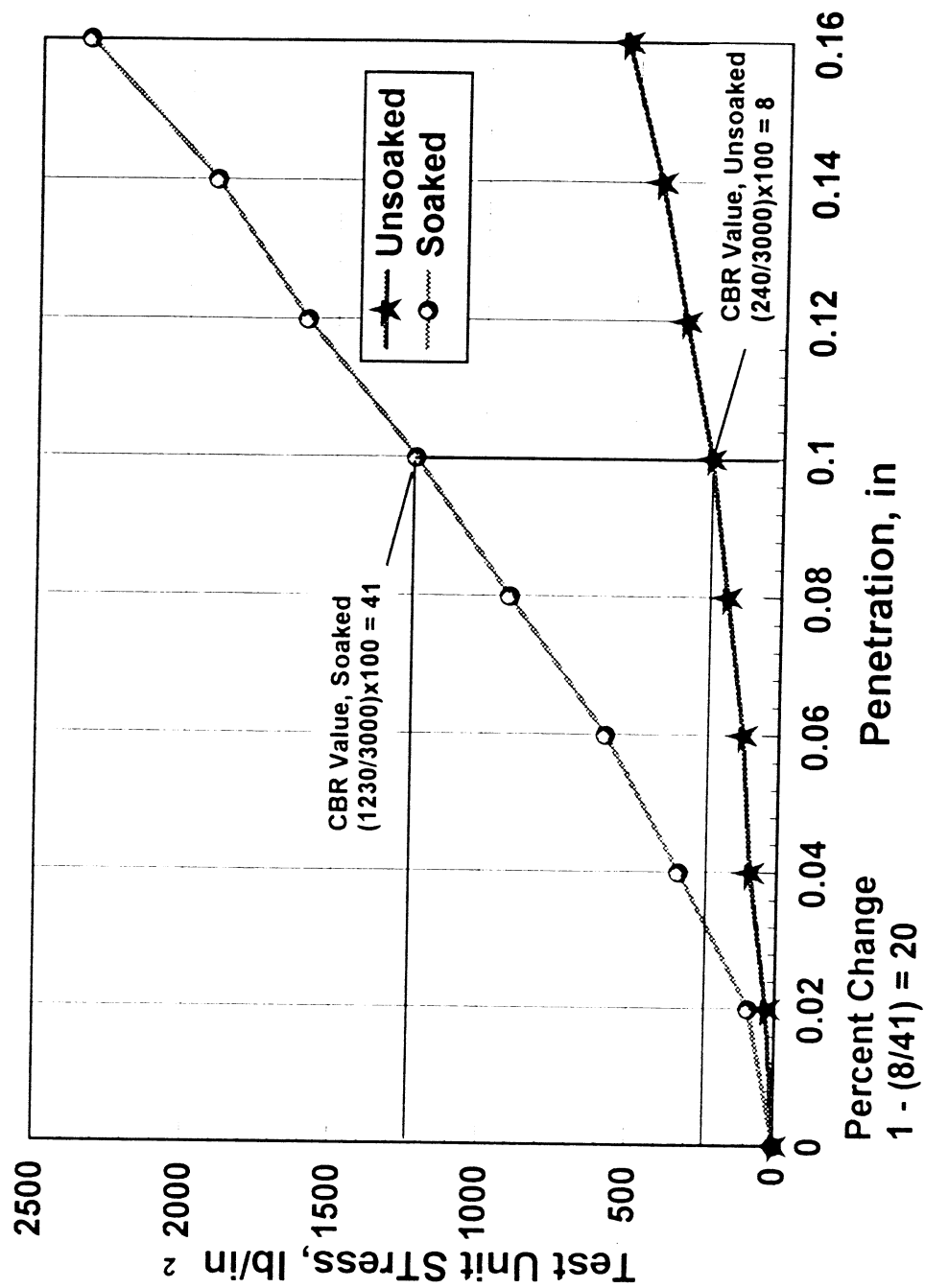
CBR TEST LOAD DATA

Penetrate in.	Stress lb/sq.in.
0.00	0.00
0.02	90.00
0.04	330.00
0.06	580.00
0.08	910.00
0.10	1230.00
0.12	1600.00
0.14	1910.00
0.16	2340.00

SWELL DATA

Start Time and Date	Elapsed Time	Dial Reading	%
2-Oct 10:00	0h	11	0.24
11:00	1h	13	0.29
12:00	2h	15	0.33
14:00	4h	21	0.46
20:00	10h	28	0.62
3-Oct 7:00	21h	52	1.15
19:00	33h	69	1.52
4-Oct 7:00	45h	83	1.83
5-Oct 7:00	69h	90	1.99
6-Oct 7:00	93h	94	2.08

CBR Graph - 10% Lime Soaked & Unsoaked



CALIFORNIA BEARING RATIO
10% LIME, CURED (3, 7 and 28 DAYS)
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST CONDUCTED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE

Test Performed : ASTM D 1883-87, AASHTO T 193-81
 Compression Machine with Penetration Rate of 1.3 mm/min
 Mold Dimensions: Diam. = 6 in. No. of Layers: 5
 Ht. = 7 in. No. of Blows/Layer: 56
 Spacer Disk: Diam. = 6 in. Wt. of Hammer = 10 lb.
 Ht. = 2 in. Surcharge Wt. = 10 lb.

MOISTURE CONTENT DETERMINATION

Moisture Can No.	3 Day		7 Day		28 Day	
	22	25	3	4	22	25
Wt. of can + wet soil	29.99	29.10	31.70	33.70	29.99	29.10
Wt. of can + dry soil	27.11	26.62	28.70	30.40	27.11	26.62
Wt. of water	2.88	2.48	3.00	3.30	2.88	2.48
Wt. of can	11.74	13.66	11.90	13.60	11.74	13.66
Wt. of dry soil	15.37	12.96	16.80	16.80	15.37	12.96
Water Content, w%	18.74	19.14	17.86	19.64	18.74	19.14
Average =		18.94	Average =		18.75	Average = 18.94

Note: Top, middle and bottom moisture contents were not taken due to the extreme hardness of the sample.

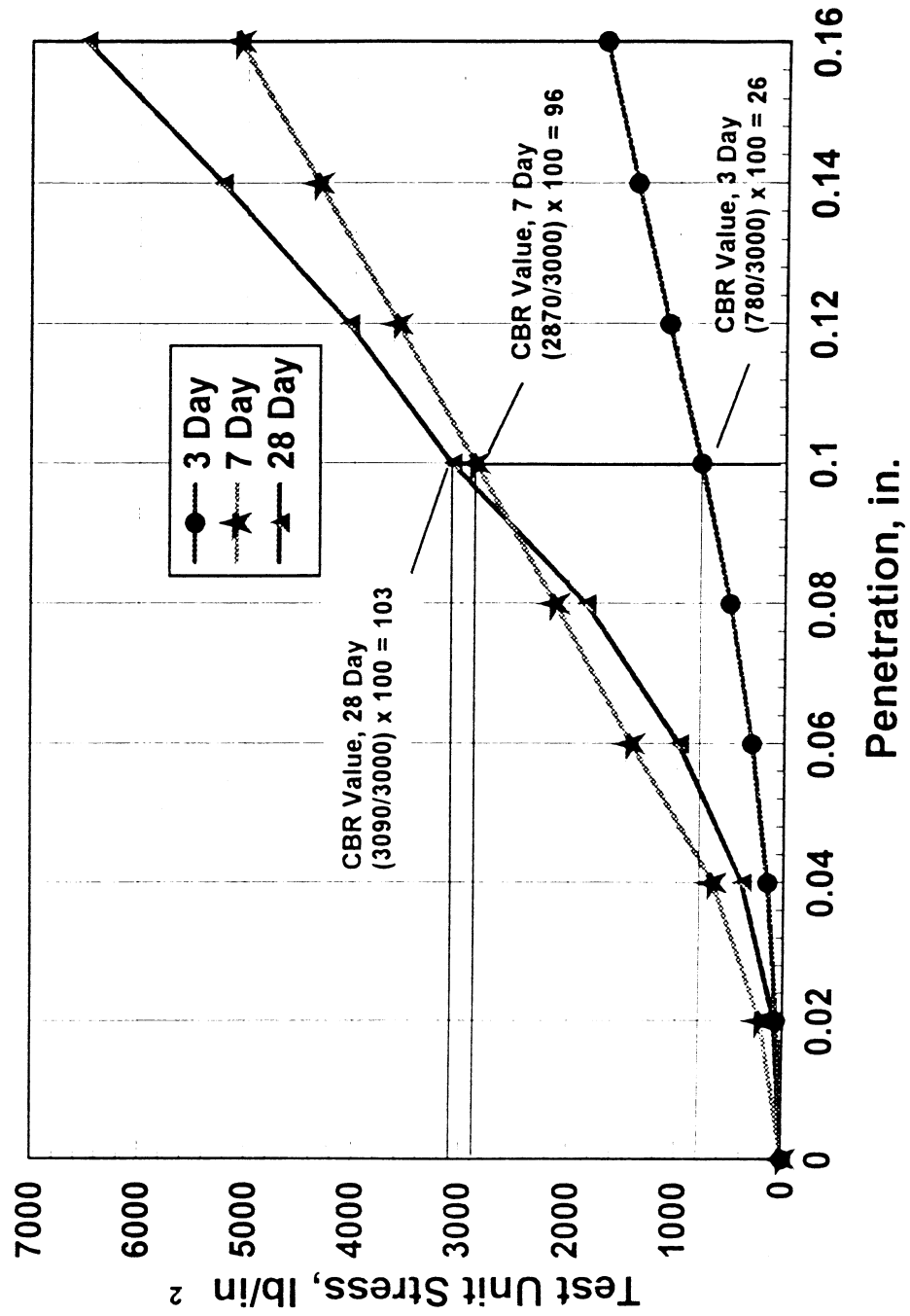
CBR TEST LOAD DATA

Penetrate in.	3 Day		7 Day		28 Day	
	Stress lb/sq.in.	Stress lb/sq.in.	Stress lb/sq.in.	Stress lb/sq.in.	Stress lb/sq.in.	Stress lb/sq.in.
0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.02	60.00	120.00	120.00	80.00	80.00	80.00
0.04	150.00	480.00	480.00	390.00	390.00	390.00
0.06	300.00	1020.00	1020.00	980.00	980.00	980.00
0.08	510.00	1740.00	1740.00	1840.00	1840.00	1840.00
0.10	780.00	2400.00	2400.00	3090.00	3090.00	3090.00
0.12	1080.00	3120.00	3120.00	4050.00	4050.00	4050.00
0.14	1380.00	3840.00	3840.00	5230.00	5230.00	5230.00
0.16	1680.00	4530.00	4530.00	6500.00	6500.00	6500.00

MOLD SAMPLE DATA

No. of Days		3 Day	7 Day	28 Day
Surcharge(lbs)		10.00	10.00	10.00
Initial mass of wet soil + mold		11640.00	8533.00	11670.00
Final mass wet soil and mold		xxx	xxx	xxx
Mass of mold		7342.00	4260.00	7348.00
Initial mass of wet soil		4298.00	4273.00	4322.00
Initial wet density		2.06	2.05	2.07
Mass of water absorbed		xxx	xxx	xxx
% water absorbed		xxx	xxx	xxx
xxx - not applicable				

CBR Graph - 10% Lime 3, 7 & 28 Day Curing



CALIFORNIA BEARING RATIO

15% LIME, UNSOAKED

MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE

TEST CONDUCTED AT : SOILS LABORATORY : FAMU/FSU ENGINEERING COLLEGE

Test Performed : ASTM D 1883-87, AASHTO T 193-81

Compression Machine with Penetration Rate of 1.3 mm/min

Mold Dimensions:

Diam. = 6 in.

Ht. = 7 in.

No. of Layers: 5

No. of Blows/Layer: 56

Wt. of Hammer = 10 lb.

Spacer Disk:

Diam. = 6 in.

Ht. = 2 in.

Surcharge Wt. = 10 lb.

MOISTURE CONTENT DETERMINATION

Moisture Can No.	1	2	3	4	Top 1/3		Middle 1/3		Bottom 1/3	
Wt. of can + wet soil	29.50	38.20	25.80	34.30	9	10	11	12		
Wt. of can + dry soil	26.32	35.16	23.34	30.79	30.90	28.70	43.30	45.70		
Wt. of water	3.18	3.04	2.46	3.51	27.52	25.75	39.30	41.39		
Wt. of can	12.00	21.00	12.00	13.60	3.38	2.95	4.00	4.31		
Wt. of dry soil	14.32	14.16	11.34	17.19	12.00	11.80	20.70	21.10		
Water Content, w%	22.21	21.47	21.69	20.42	15.52	13.95	18.60	20.29		
Average =	21.84	Average =	21.06	Average =	21.46	Average =	21.37			

CBR TEST LOAD DATA

Penetrate in.	Stress lb/sq. in.
0.00	0.00
0.02	20.00
0.04	30.00
0.06	45.00
0.08	60.00
0.10	75.00
0.12	90.00
0.14	105.00
0.16	120.00

MOLD SAMPLE DATA

Mold No.	Unsoaked	Soaked
Surcharge(lbs)	10.00	10.00
Initial mass of wet soil + mold	8423.00	8327.00
Final mass wet soil and mold	xxx	8385.00
Mass of mold	4249.10	4196.90
Initial mass of wet soil	4173.90	4130.10
Initial wet density	2.00	1.98
Mass of water absorbed	xxx	58.00
% water absorbed	xxx	1.40

xxx - not applicable

CALIFORNIA BEARING RATIO

15% LIME, SOAKED (4 DAYS)

MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE

TEST CONDUCTED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE

Test Performed : ASTM D 1883-87, AASHTO T 193-81

Compression Machine with Penetration Rate of 1.3 mm/min

Mold Dimensions:

Diam. = 6 in.

Ht. = 7 in.

No. of Layers: 5

No. of Blows/Layer: 56

Spacer Disk:

Diam. = 6 in.

Ht. = 2 in.

Wt. of Hammer = 10 lb.

Surcharge Wt. = 10 lb.

MOISTURE CONTENT DETERMINATION

Moisture Can No.	1	2	Top 1/3		Middle 1/3		Bottom 1/3	
Wt. of can + wet soil	29.50	38.20	5	6	9	10	21	22
Wt. of can + dry soil	26.32	35.16	28.24	27.72	32.97	31.14	31.32	32.25
Wt. of water	3.18	3.04	3.74	2.89	2.89	2.76	28.23	28.61
Wt. of can	12.00	21.00	11.97	11.97	11.92	11.78	13.42	11.48
Wt. of dry soil	14.32	14.16	16.27	12.86	17.24	15.82	14.81	17.13
Water Content, w%	22.21	21.47	22.99	22.47	22.10	22.38	20.86	21.25
Average =	21.84	Average =	22.73	Average =	22.24	Average =	21.06	

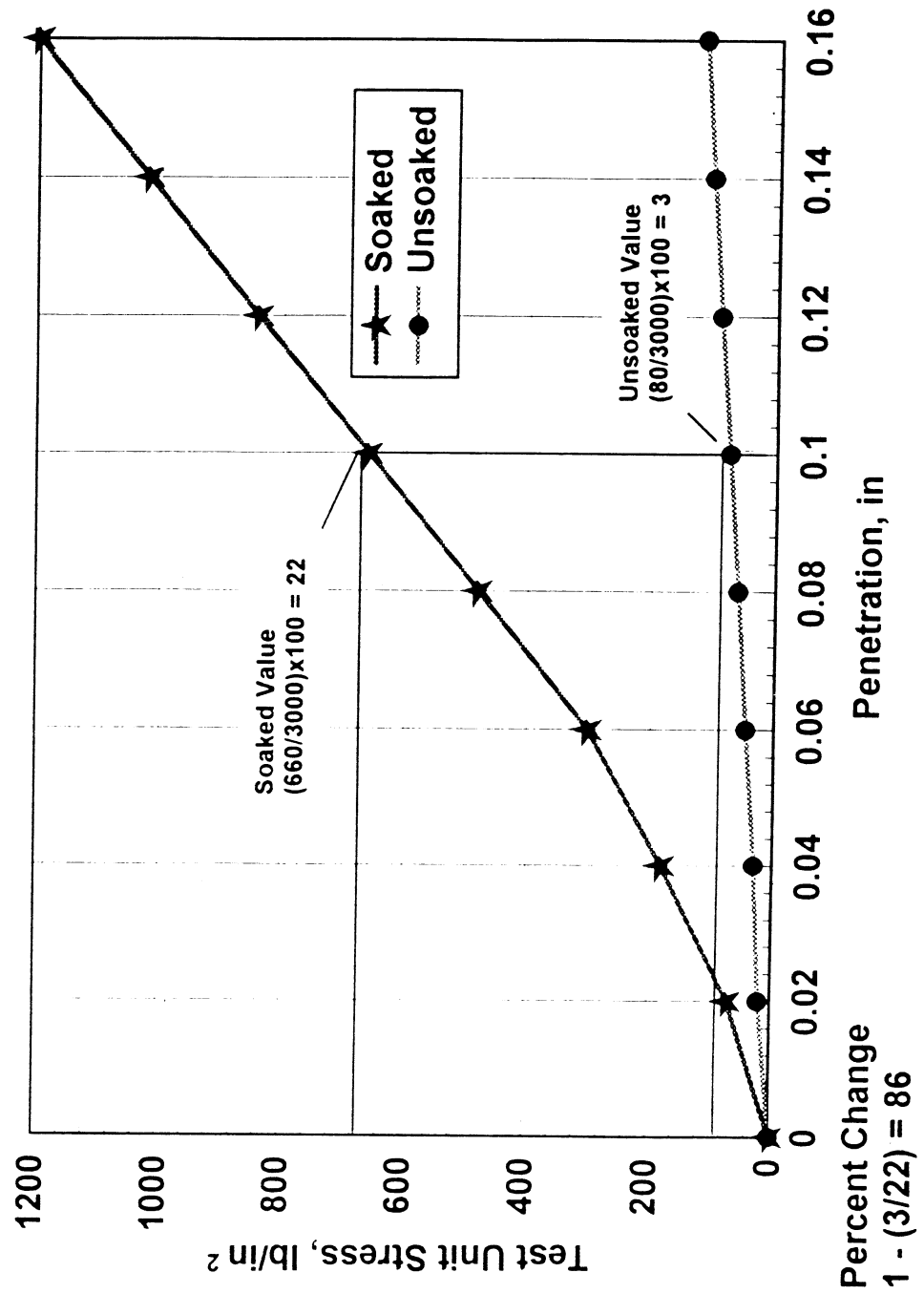
CBR TEST LOAD DATA

Penetrate in.	Stress lb/sq.in.
0.00	0.00
0.02	70.00
0.04	180.00
0.06	300.00
0.08	480.00
0.10	660.00
0.12	840.00
0.14	1020.00
0.16	1200.00

SWELL DATA

Start Time and Date	Elapsed Time	Dial Reading	%
9-Oct 10:00	0h	0	0.00
11:00	1h	25	0.55
12:00	2h	30	0.66
14:00	4h	40	0.88
20:00	10h	54	1.19
10-Oct 7:00	21h	72	1.59
19:00	33h	96	2.12
11-Oct 7:00	45h	120	2.65
12-Oct 7:00	69h	126	2.78
13-Oct 7:00	93h	130	2.87

CBR Graph - 15% Lime Soaked and Unsoaked



CALIFORNIA BEARING RATIO
15% LIME, CURED (3.7 and 28 DAYS)
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST CONDUCTED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE

Test Performed : ASTM D 1883-87, AASHTO T 193-81
 Compression Machine with Penetration Rate of 1.3 mm/min
 Mold Dimensions: Diam. = 6 in. No. of Layers: 5
 Ht. = 7 in. No. of Blows/Layer: 56
 Spacer Disk: Diam. = 6 in. Wt. of Hammer = 10 lb.
 Ht. = 2 in. Surcharge Wt. = 10 lb.

MOISTURE CONTENT DETERMINATION

Moisture Can No.	21	26	7 Day	28 Day
Wt. of can + wet soil	30.30	29.75	36.02	26
Wt. of can + dry soil	27.20	26.90	32.20	29.75
Wt. of water	3.10	2.85	4.12	26.90
Wt. of can	13.66	13.48	12.03	2.85
Wt. of dry soil	13.54	13.42	22.07	13.66
Water Content, w%	22.90	21.24	18.67	13.42
Average =	22.07	Average =	18.75	22.07

Note: Top, middle and bottom moisture contents were not taken due to the extreme hardness of the sample.

CBR TEST LOAD DATA

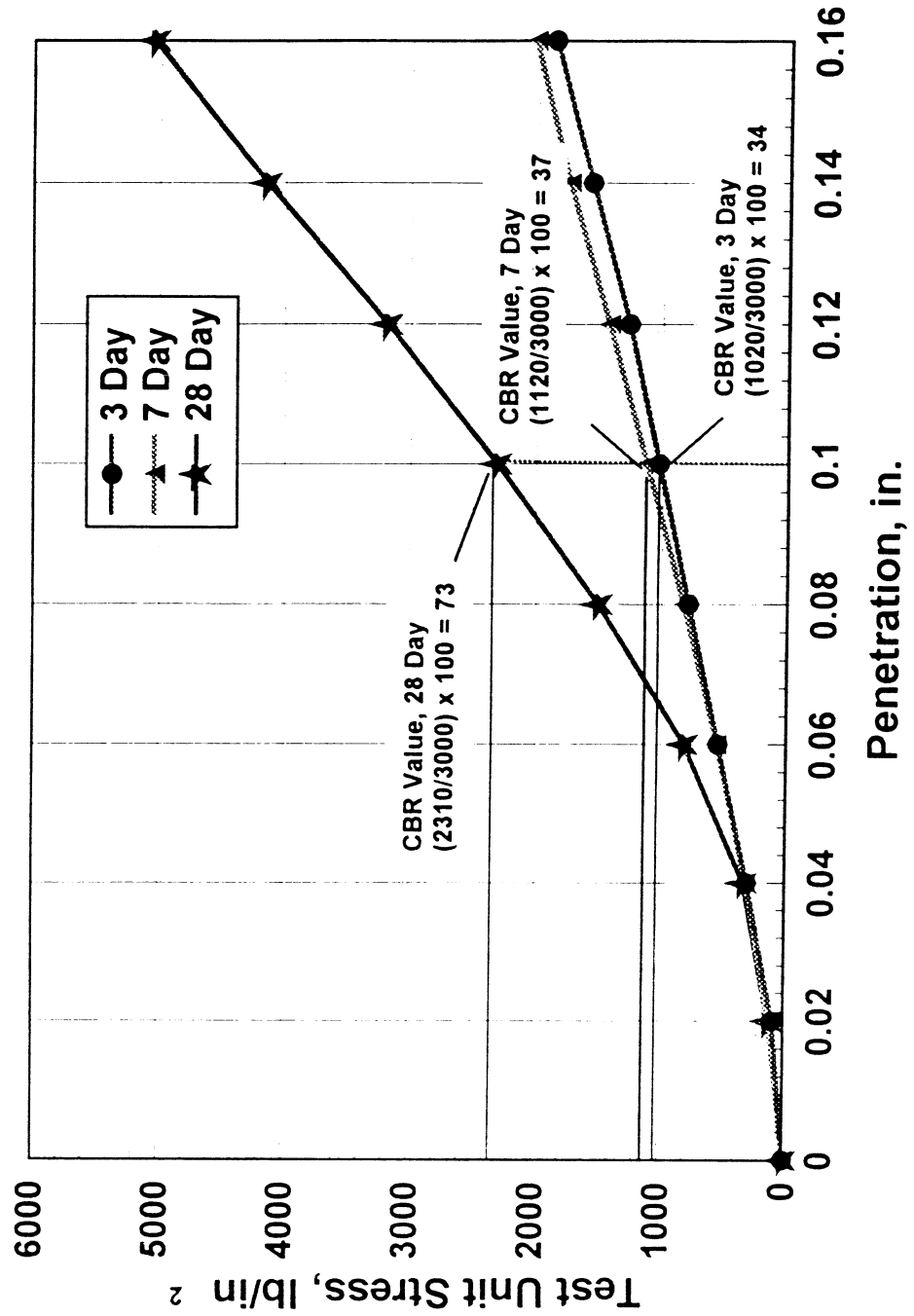
Penetrate in.	3 Day Stress lb/sq.in.	7 Day Stress lb/sq.in.	28 Day Stress lb/sq.in.
0.00	0	0	0
0.02	90	120	120
0.04	300	310	330
0.06	540	550	810
0.08	780	820	1500
0.10	1020	1120	2310
0.12	1260	1420	3180
0.14	1560	1740	4140
0.16	1860	2020	5040

MOLD SAMPLE DATA

Mold No.	3 Day	7 Day	28 Day
Surcharge(lbs)	10.00	10.00	10.00
Initial mass of wet soil + mold	11497.00	8489.00	11473.00
Final mass wet soil and mold	xxx	xxx	xxx
Mass of mold	7317.00	4210.00	7292.00
Initial mass of wet soil	4180.00	4279.00	4181.00
Initial wet density	2.00	2.05	2.00
Mass of water absorbed	xxx	xxx	xxx
% water absorbed	xxx	xxx	xxx

xxx - not applicable

CBR Graph - 15% Lime 3, 7 & 28 Day Curing



GEOTECHNICAL PROPERTIES

**CHEMICAL FIXATION/STABILIZED
ASH RESIDUE**

STANDARD COMPACTION TEST
5% Sodium Phosphate Stabilization
 MATERIAL: MUNICIPAL SOLID WASTE ASH RESIDUE
 TEST PERFORMED AT: SOILS LABORATORY- FAMU/FSU ENGINEERING COLLEGE

Test Performed : Standard Proctor
 Blows/Layer = 25 No. of Layers = 3 Wt. of Hammer = 24.5 N
 Mold Dimensions:
 Diam. = 10.14 cm
 Ht = 11.67cm
 Vol. = 0.0009424 m³

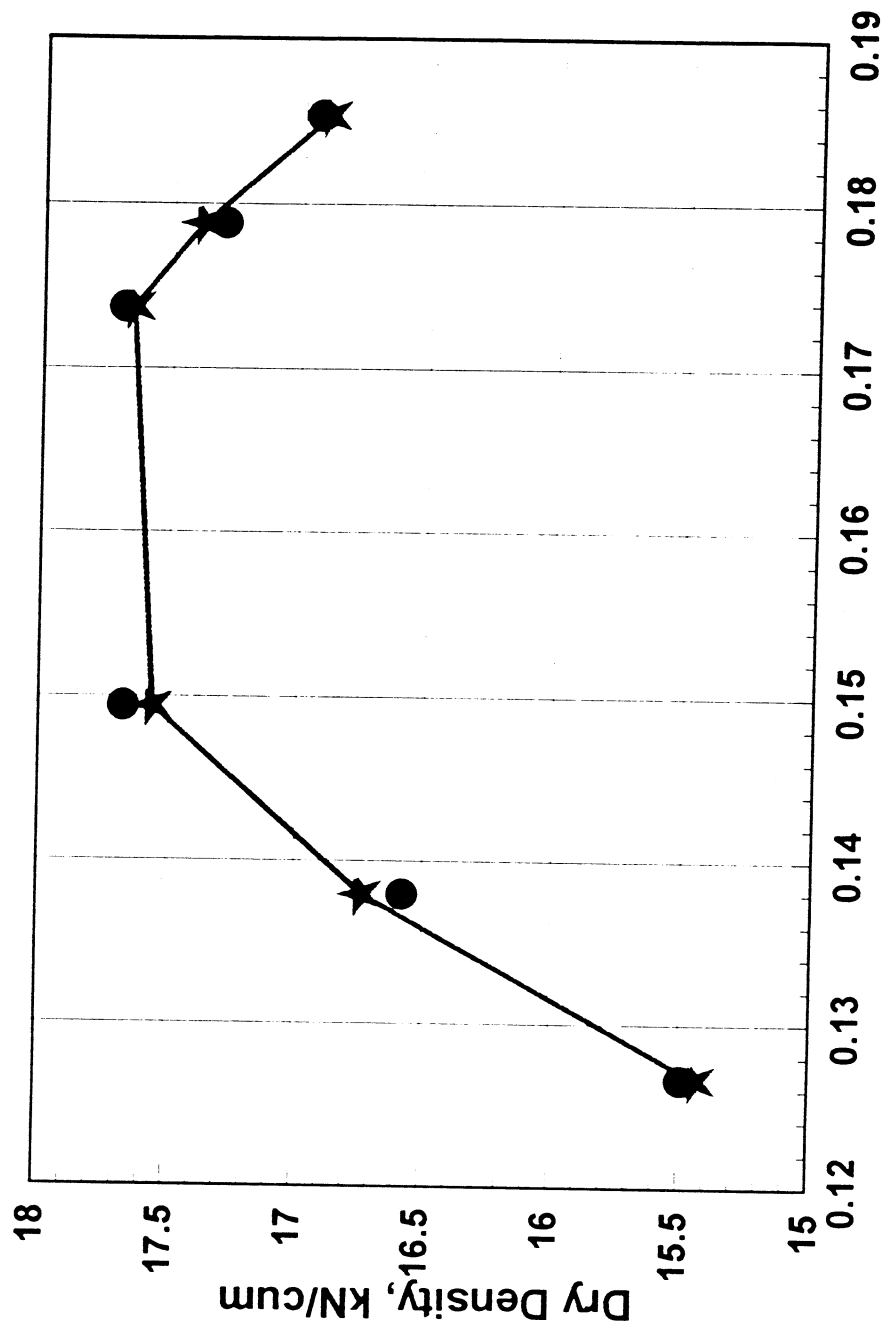
WATER CONTENT DETERMINATION

Sample No.	1		2		3		4		5		6	
Moisture Can No.	1	2	3	4	5	6	7	8	9	10	11	12
Wt. of can + wet soil	36.3	46.3	43.8	41.9	58	47.3	28.7	49.4	61.9	61	70.1	62.8
Wt. of can + dry soil	33.6	43.4	40	38.2	53.2	42.7	26.2	45.1	55.6	55.1	62.5	56.2
Wt. of water	2.7	2.9	3.8	3.7	4.8	4.6	2.5	4.3	6.3	5.9	7.6	6.6
Wt. of can	11.9	20.9	11.9	11.9	21.1	11.9	11.6	20.7	21.1	21.4	20.9	21.1
Wt. of dry soil	21.7	22.5	28.1	26.3	32.1	30.8	14.6	24.4	34.5	33.7	41.6	35.1
Water Content, w%	12.44	12.89	13.52	14.07	14.95	14.94	17.12	17.62	18.26	17.51	18.27	18.80

DENSITY DETERMINATION

Assumed w%	10	12	14	16	18	20
Actual Water Content	12.67	13.80	14.94	17.37	17.88	18.54
Wt. of soil + mold	3688.2	3824.2	3964	4007.4	3971.8	3940.9
Wt. of mold	2007.3	2007.3	2007.3	2007.3	2007.3	2007.3
Wt. of soil in mold	1680.9	1816.9	1956.7	2000.1	1964.5	1933.6
Wet Density, kN/m ³	17.45	18.86	20.31	20.76	20.39	20.07
Dry Density, kN/m ³	15.49	16.57	17.67	17.69	17.30	16.93

Compaction Curve - 5% Sodium Phosphate Stabilization



Optimum Moisture Content = 16.2 %
Maximum Dry Density = 17.8 kN/cum.

STANDARD COMPACTION TEST
10% Sodium Phosphate Stabilization
MATERIAL: MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT: SOILS LABORATORY- FAMU/FSU ENGINEERING COLLEGE

Test Performed : Standard Proctor
Blows/Layer = 25 No. of Layers = 3 Wt. of Hammer = 24.5 N
Mold Dimensions:
Diam. = 10.14 cm
Ht = 11.67cm
Vol. = 0.0009424 m³

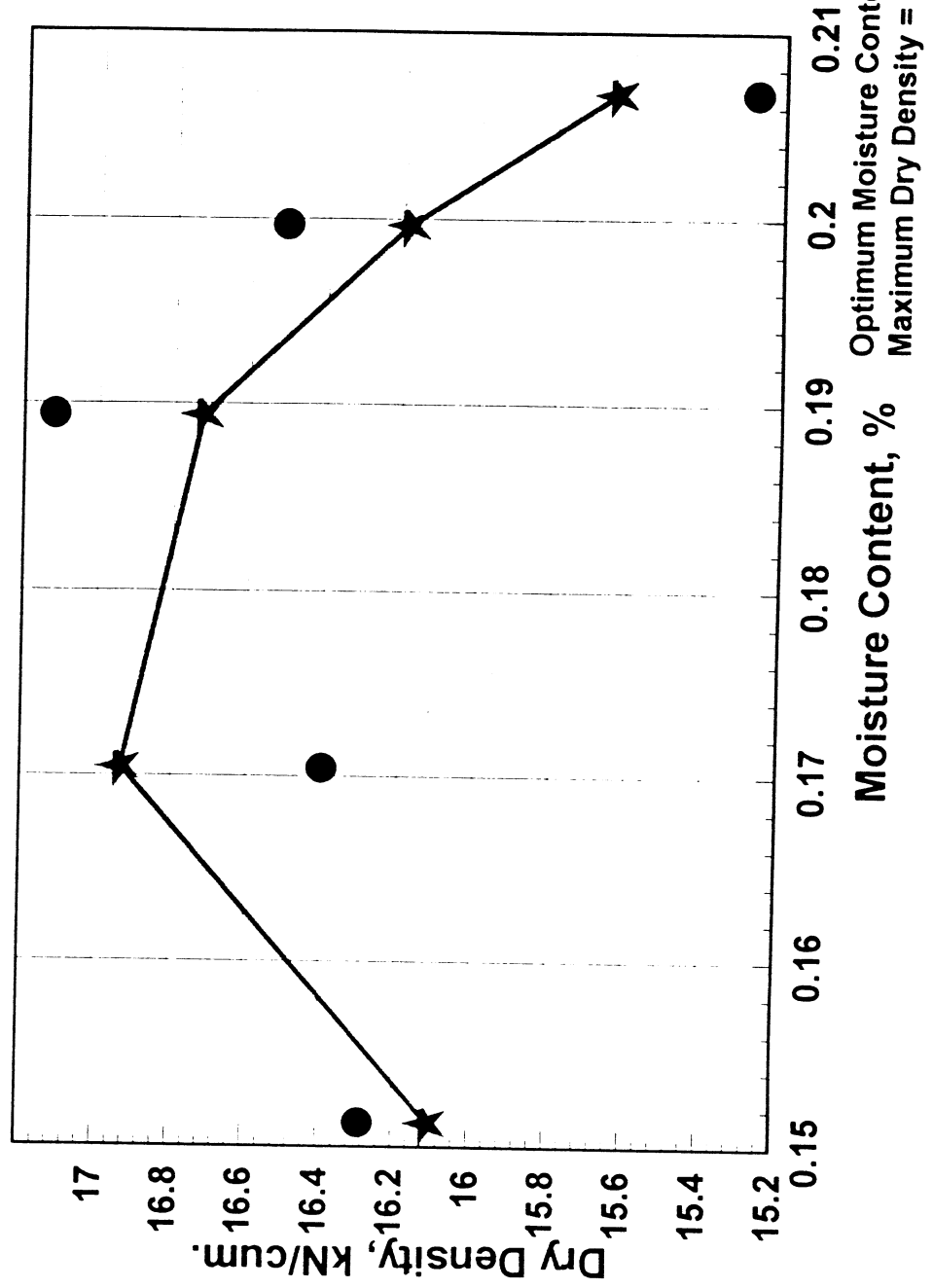
WATER CONTENT DETERMINATION

Sample No.	1		2		3		4		5	
Moisture Can No.	1	2	3	4	5	6	7	8	9	10
Wt. of can + wet soil	48.4	55	24.5	38.7	31.2	30.9	53.9	50.7	35.4	44.8
Wt. of can + dry soil	44.8	50.6	22.6	36.2	28.1	27.9	48.5	45.7	31.6	38.8
Wt. of water	3.6	4.4	1.9	2.5	3.1	3	5.4	5	3.8	6
Wt. of can	21.1	21.4	11.9	20.9	11.9	11.9	21.2	20.9	11.9	11.6
Wt. of dry soil	23.7	29.2	10.7	15.3	16.2	16	27.3	24.8	19.7	27.2
Water Content, w%	15.19	15.07	17.76	16.34	19.14	18.75	19.78	20.16	19.29	22.06

DENSITY DETERMINATION

Assumed w%	10	12	14	16	18
Actual Water Content	15.13	17.05	18.94	19.97	20.67
Wt. of soil + mold	3809.8	3852.5	3964.9	3911.2	3778.9
Wt. of mold	2003.4	2003.4	2003.4	2003.4	2003.4
Wt. of soil in mold	1806.4	1849.1	1961.5	1907.8	1775.5
Wet Density, kN/m ³	18.75	19.20	20.36	19.80	18.43
Dry Density, kN/m ³	16.29	16.40	17.12	16.51	15.27

Compaction Curve - 10% Sodium Phosphate Stabilization



STANDARD COMPACTION TEST
15% Sodium Phosphate Stabilization
MATERIAL: MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT: SOILS LABORATORY- FAMU/FSU ENGINEERING COLLEGE

Test Performed : Standard Proctor
Blows/Layer = 25 No. of Layers = 3 Wt. of Hammer = 24.5 N
Mold Dimensions: Diam. = 10.14 cm
Ht = 11.67cm
Vol. = 0.0009424 m³

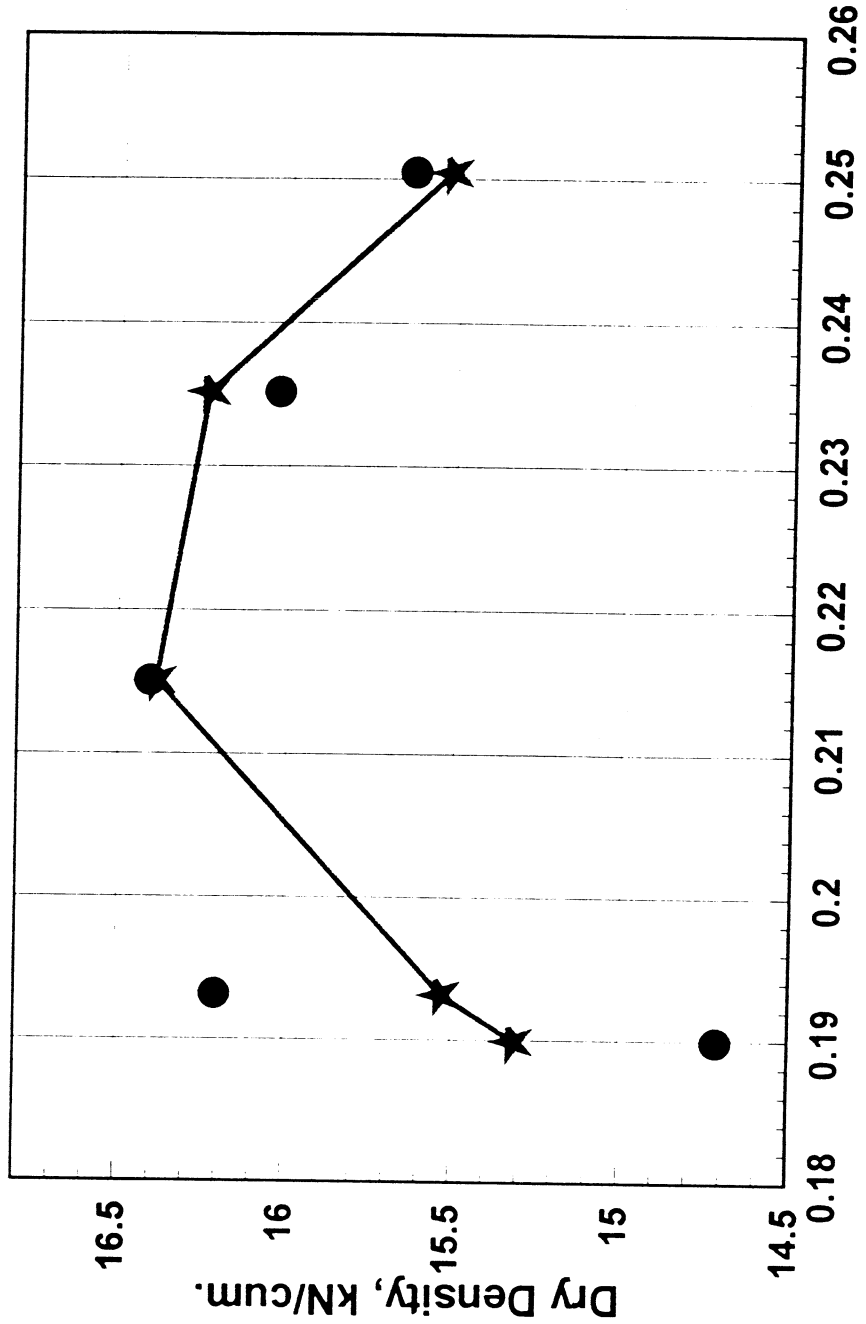
WATER CONTENT DETERMINATION

Sample No.	1		2		3		4		5	
Moisture Can No.	1	2	3	4	5	6	7	8	9	10
Wt. of can + wet soil	26.8	36.3	28.2	27.3	46.3	44.1	40.6	45.5	67.7	61.4
Wt. of can + dry soil	24.31	33.96	25.6	24.77	41.95	39.94	35.25	39.03	58.01	53.53
Wt. of water	2.49	2.34	2.6	2.53	4.35	4.16	5.35	6.47	9.69	7.87
Wt. of can	11.9	20.9	11.9	11.9	21.4	20.9	12	12.1	20.6	21
Wt. of dry soil	12.41	13.06	13.7	12.87	20.55	19.04	23.25	26.93	37.41	32.53
Water Content, w%	20.06	17.92	18.98	19.66	21.17	21.85	23.01	24.03	25.90	24.19

DENSITY DETERMINATION

Assumed w%	10	12	14	16	18
Actual Water Content	18.99	19.32	21.51	23.52	25.05
Wt. of soil + mold	3719.1	3895.5	3953.2	3940.3	3886.9
Wt. of mold	2033	2033	2033	2033	2003.4
Wt. of soil in mold	1686.1	1862.5	1920.2	1907.3	1883.5
Wet Density, kN/m ³	17.50	19.33	19.93	19.80	19.55
Dry Density, kN/m ³	14.71	16.20	16.41	16.03	15.64

Compaction Curve 15% Sodium Phosphate Stabilization



Optimum Moisture Content, % = 21.5
Maximum Dry Density, kN/cum = 15.4

COEFFICIENT OF PERMEABILITY - FALLING HEAD METHOD**5% SODIUM PHOSPHATE STABILIZATION****MATERIAL :- MUNICIPAL SOLID WASTE ASH RESIDUE****TEST PERFORMED AT :- SOILS LAB.-FAMU/FSU ENGINEERING COLLEGE****WATER CONTENT DETERMINATION:**

Moisture can #:	1	2
Wt. of can + wet soil (g)	48	48.1
Wt. of can + dry soil (g)	43.7	43.9
Wt. of water(g)	4.3	4.2
Wt. of can (g)	20.8	20.8
wt. of dry soil (g)	22.9	23.1
Water content, w%:	18.77	18.18

USING COMPACTION PERMEAMETER AND STANDARD PROCTOR AASHTO T99

Blows per layer: 25	Mold dia.(cm):	10.14
No. of layers: 3	Area (cm ²):	81.1
Wt. of hammer: 24.5 N	Ht. (cm):	11.6
	Vol. (m ³):	0.0009424

PERMEABILITY TEST DATA:

Standpipe: 100 ml burette

Area of standpipe, a = 1.71 cm²

nt/n20 = 1

Test #	h1 (cm)	h2 (cm)	Time (sec)	Temp (°C)
1	68.5	65.7	960	20
2	68.5	65.7	962	20
3	68.5	65.7	965	20
Average:			962.33333	

$$Kt = (a \times L/A \times t) \ln (h_1/h_2) =$$

$$Kt = (1.71 \times 11.6/81.1 \times 962.33) \ln (68.5/65.7) = 1.06 \times 10^{-5} \text{ cm/sec}$$

$$\text{Coefficient of Permeability, } K, \text{ at } 20^\circ\text{C} = 1.06 \times 10^{-5} \text{ cm/sec}$$

COEFFICIENT OF PERMEABILITY - FALLING HEAD METHOD
10% SODIUM PHOSPHATE STABILIZATION

MATERIAL :- MUNICIPAL SOLID WASTE ASH RESIDUE

TEST PERFORMED AT :- SOILS LAB.-FAMU/FSU ENGINEERING COLLEGE

WATER CONTENT DETERMINATION:

Moisture can #:	1	2
Wt. of can + wet soil (g)	60.9	52.1
Wt. of can + dry soil (g)	53.1	46.2
Wt. of water(g)	7.8	5.9
Wt. of can (g)	21	20.9
wt. of dry soil (g)	32.1	25.3
Water content, w%:	24.2	23.3

USING COMPACTION PERMEAMETER AND STAND. PROCTOR AASHTO T9

Blows per layer: 25	Mold dia.(cm):	10.14
No. of layers: 3	Area (cm ²):	81.1
Wt. of hammer: 24.5 N	Ht. (cm):	11.6
	Vol. (m ³):	0.000942

PERMEABILITY TEST DATA:

Standpipe: 100 ml burette

Area of standpipe, a = 1.71 cm²

nt/n20 = 1

Test #	h1 (cm)	h2 (cm)	Time (sec)	Temp (°C)
1	68.4	65.6	1200	20
2	68.4	65.6	1206	20
3	68.4	65.6	1213	20
Average:			1206.333	

$$Kt = (a \times L/A \times t) \ln (h1/h2) =$$

$$Kt = (1.71 \times 11.6/81.1 \times 1206.33) \ln (68.4/65.6) \quad 8.47 \times 10^{-6} \text{ cm/sec}$$

$$\text{Coefficient of Permeability, K, at } 20^{\circ}\text{C} = 8.47 \times 10^{-6} \text{ cm/sec}$$

COEFFICIENT OF PERMEABILITY - FALLING HEAD METHOD
15% SODIUM PHOSPHATE STABILIZATION

MATERIAL :- MUNICIPAL SOLID WASTE ASH RESIDUE

TEST PERFORMED AT :- SOILS LAB.-FAMU/FSU ENGINEERING COLLEGE

WATER CONTENT DETERMINATION:

Moisture can #:	1	2
Wt. of can + wet soil (g)	33.32	43.34
Wt. of can + dry soil (g)	29.1	38.9
Wt. of water(g)	4.22	4.44
Wt. of can (g)	11.98	20.99
wt. of dry soil (g)	17.12	17.91
Water content, w%:	24.6	24.79

USING COMPACTION PERMEAMETER AND STAND. PROCTOR AASHTO T99

Blows per layer: 25	Mold dia.(cm):	10.14
No. of layers: 3	Area (cm ²):	81.1
Wt. of hammer: 24.5 N	Ht. (cm):	11.6
	Vol. (m ³):	0.0009424

PERMEABILITY TEST DATA:

Standpipe: 100 ml burette

Area of standpipe, a = 1.71 cm²

nt/n20 = 1

Test #	h1 (cm)	h2 (cm)	Time (sec)	Temp (°C)
1	68.5	65.7	1804	20
2	68.5	65.7	1806	20
3	68.5	65.7	1810	20
		Average:	1806.67	

$$Kt = (a \times L/A \times t) \ln (h_1/h_2) =$$

$$Kt = (1.71 \times 11.6/81.1 \times 1806.67) \ln (68.5/65.7) = 5.65 \times 10^{-6} \text{ cm/sec}$$

$$\text{Coefficient of Permeability, } K, \text{ at } 20^\circ\text{C} = 5.65 \times 10^{-6} \text{ cm/sec}$$

TRIAXIAL SHEAR TEST
5% SODIUM PHOSPHATE STABILIZATION, 10 PSI.
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE
Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.021	0.053	0.001	0.13	20	0.16	43.04	38.24
0.044	0.112	0.003	0.28	40	0.33	43.11	76.38
0.066	0.168	0.004	0.41	60	0.49	43.16	114.41
0.087	0.221	0.005	0.54	80	0.66	43.22	152.34
0.115	0.292	0.007	0.72	100	0.82	43.30	190.09
0.142	0.361	0.009	0.89	120	0.99	43.37	227.72
0.172	0.437	0.011	1.08	140	1.15	43.45	265.17
0.21	0.533	0.013	1.31	160	1.32	43.56	302.32
0.249	0.632	0.016	1.56	180	1.48	43.67	339.27
0.308	0.782	0.019	1.93	200	1.65	43.83	375.56
0.42	1.067	0.026	2.63	220	1.81	44.15	410.17
0.51	1.295	0.032	3.19	224	1.84	44.40	415.21
Sample Discription :-							

Moist unit weight of specimen: 2.076 gm/cm³ Proving ring calibration factor:
 Dry unit weight of specimen: 1.768 gm/cm³ 1 kN = 121.5
 Moisture content of specimen: 20.3 % 2 kN = 241.8
 Initial average length of specimen: 16cm 3kN = 362.9
 Initial average diameter of specimen: 7.398 cm 4 kN = 483.8
 Initial area of specimen: 42.9866 cm²

TRIAxIAL SHEAR TEST
5% SODIUM PHOSPHATE STABILIZATION, 20 PSI.
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE
Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.02	0.051	0.001	0.13	30	0.25	43.04	57.37
0.038	0.097	0.002	0.25	60	0.49	43.09	114.60
0.057	0.145	0.004	0.37	90	0.74	43.15	171.69
0.084	0.213	0.005	0.54	130	1.07	43.22	247.56
0.111	0.282	0.007	0.72	170	1.40	43.30	323.16
0.136	0.345	0.009	0.88	200	1.65	43.37	379.57
0.167	0.424	0.011	1.08	230	1.89	43.45	435.63
0.204	0.518	0.013	1.32	260	2.14	43.56	491.26
0.253	0.643	0.016	1.63	290	2.39	43.70	546.19
0.318	0.808	0.021	2.05	320	2.63	43.89	600.12
0.383	0.973	0.025	2.47	340	2.80	44.08	634.90
0.433	1.100	0.028	2.79	350	2.88	44.22	651.41
0.542	1.377	0.035	3.50	360	2.96	44.54	665.17
Sample Discription :-							

Moist unit weight of specimen: 2.076 gm/cm³ Proving ring calibration factor: 1 kN = 121.5
Dry unit weight of specimen: 1.768 gm/cm³ 2 kN = 241.8
Moisture content of specimen: 20.3 % 3kN = 362.9
Initial average length of specimen: 15.5 cm 4 kN = 483.8
Initial average diameter of specimen: 7.398 cm
Initial area of specimen: 42.9866 cm²

TRIAxIAL SHEAR TEST
5% SODIUM PHOSPHATE STABILIZATION, 30 PSI.
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE
Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.022	0.056	0.001	0.14	40	0.33	43.05	76.48
0.048	0.122	0.003	0.30	80	0.66	43.12	152.71
0.078	0.198	0.005	0.49	120	0.99	43.20	228.62
0.101	0.257	0.006	0.64	150	1.23	43.26	285.36
0.131	0.333	0.008	0.83	190	1.56	43.35	360.77
0.168	0.427	0.011	1.06	230	1.89	43.45	435.69
0.197	0.500	0.012	1.25	260	2.14	43.53	491.60
0.24	0.610	0.015	1.52	300	2.47	43.65	565.67
0.273	0.693	0.017	1.73	330	2.72	43.74	620.92
0.311	0.790	0.020	1.97	360	2.96	43.85	675.71
0.339	0.861	0.021	2.15	390	3.21	43.93	730.69
0.396	1.006	0.025	2.51	420	3.46	44.09	784.00
0.434	1.102	0.027	2.75	440	3.62	44.20	819.31
0.465	1.181	0.029	2.94	455	3.74	44.29	845.53
Sample Discription :-							

Moist unit weight of specimen: 2.076 gm/cm³ Proving ring calibration factor:
 Dry unit weight of specimen: 1.768 gm/cm³ 1 kN = 121.5
 Moisture content of specimen: 20.3 % 2 kN = 241.8
 Initial average length of specimen: 15.8 cm 3kN = 362.9
 Initial average diameter of specimen: 7.398 cm 4 kN = 483.8
 Initial area of specimen: 42.9866 cm²

SUMMARY OF RESULTS FOR 10, 20, 30 PSI TESTS OF 5% SODIUM PHOSPHATE STABILIZATION

TRIAxIAL SHEAR TEST

MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE

TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE

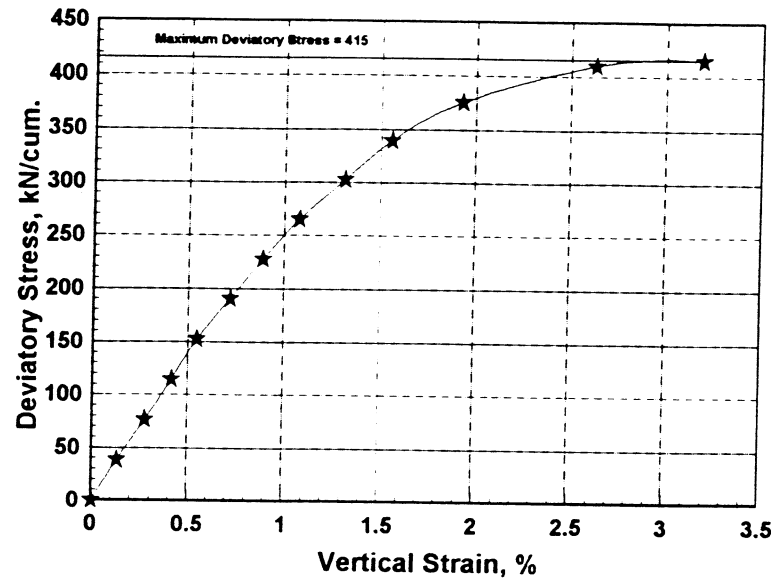
Test Performed : Consolidated Drained

S No.	Confined Press. $\sigma(3)$ psi	Confined Press. $\sigma(3)$ kN/sq.m	Deviatory Stress. $\Delta\sigma$ kN/sq. m	Deviatory + Confined Stress $\sigma(1) = \sigma(3) + \Delta\sigma$ kN/sq.m
1	10	68.95	415.21	484.16
2	20	137.9	665.17	803.07
3	30	206.85	845.52	1052.37

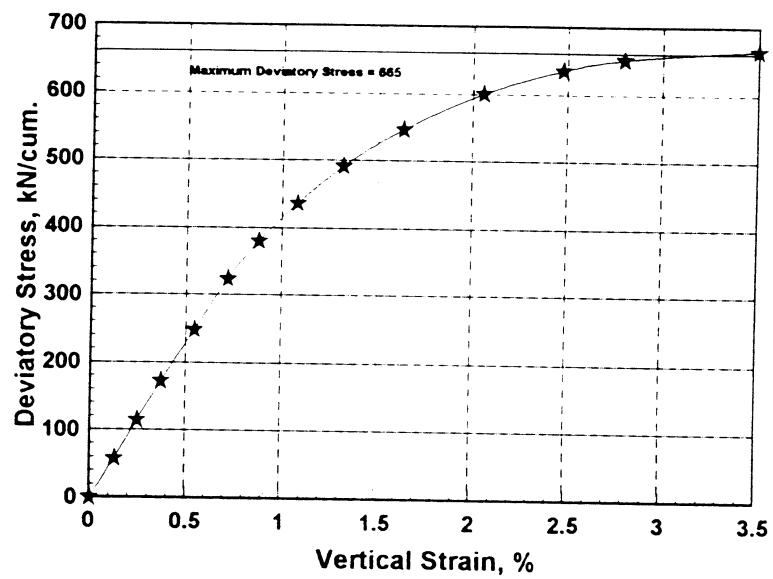
Conversion Factor Used:

$$6.895 \text{ kN/sq. m} = 1 \text{ psi.}$$

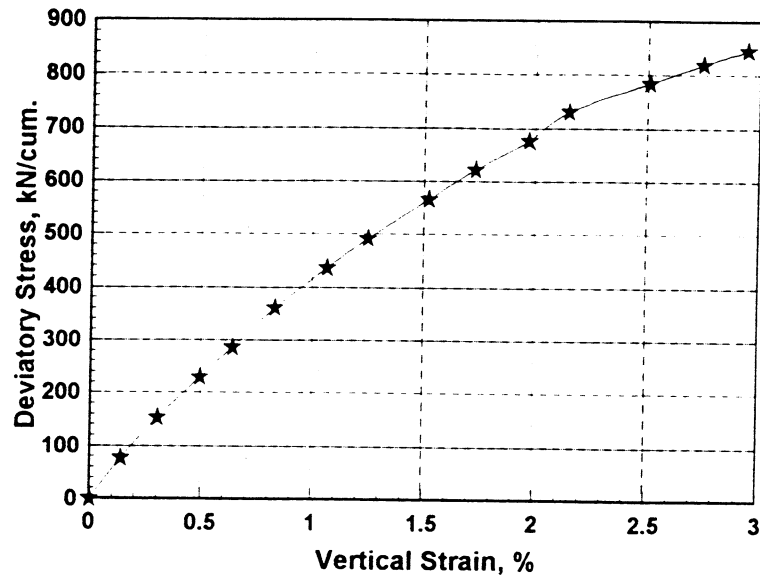
Triaxial Shear Test - 5% Sodium Phosphate, 10 psi



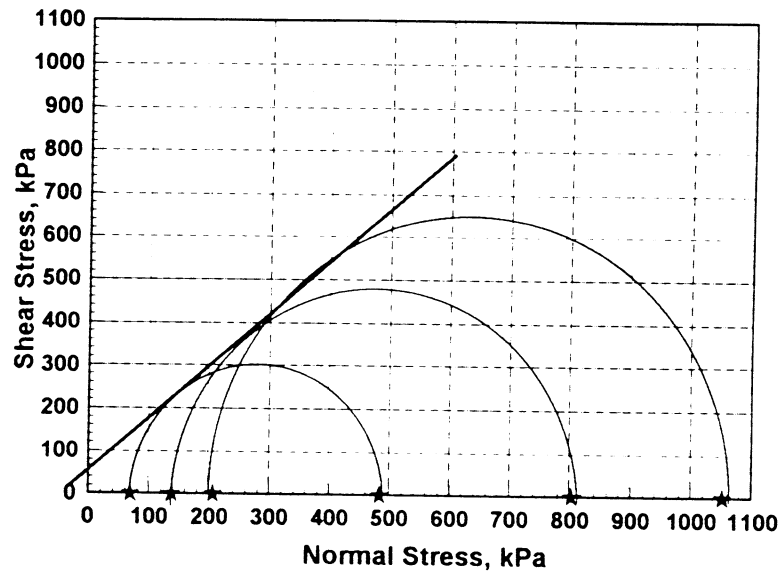
Triaxial Shear Test - 5% Sodium Phosphate, 20 psi



Triaxial Shear Test - 5 % Sodium Phosphate, 30 psi



Mohr's Circle Plot - 5 % Sodium Phosphate



C (Cohesion) = 50 kPa
 Phi (Angle of Internal Friction) = 51 deg.

TRIAXIAL SHEAR TEST
10% SODIUM PHOSPHATE STABILIZATION, 10 PSI.
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE
Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.018	0.046	0.001	0.11	20	0.16	43.03	38.25
0.036	0.091	0.002	0.22	40	0.33	43.08	76.42
0.055	0.140	0.003	0.34	60	0.49	43.13	114.49
0.075	0.191	0.005	0.46	80	0.66	43.19	152.47
0.098	0.249	0.006	0.60	100	0.82	43.25	190.31
0.125	0.318	0.008	0.77	120	0.99	43.32	228.00
0.154	0.391	0.009	0.94	140	1.15	43.40	265.52
0.189	0.480	0.012	1.16	160	1.32	43.49	302.79
0.234	0.594	0.014	1.44	180	1.48	43.61	339.69
0.31	0.787	0.019	1.90	200	1.65	43.82	375.65
0.41	1.041	0.025	2.52	209	1.72	44.10	390.10
<u>Sample Discription :-</u>							

Moist unit weight of specimen: 2.036 gm/cm³ Proving ring calibration factor:

Dry unit weight of specimen: 1.71 gm/cm³
 Moisture content of specimen: 17.9 %
 Initial average length of specimen: 16.3 cm
 Initial average diameter of specimen: 7.398 cm
 Initial area of specimen: 42.9866 cm²

1 kN = 121.5
 2 kN = 241.8
 3kN = 362.9
 4 kN = 483.8

TRIAXIAL SHEAR TEST
10% SODIUM PHOSPHATE STABILIZATION, 20 PSI.
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE
Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.019	0.048	0.001	0.13	30	0.25	43.04	57.37
0.042	0.107	0.003	0.28	70	0.58	43.11	133.65
0.062	0.157	0.004	0.42	100	0.82	43.17	190.67
0.084	0.213	0.006	0.56	130	1.07	43.23	247.50
0.107	0.272	0.007	0.72	160	1.32	43.30	304.14
0.132	0.335	0.009	0.89	190	1.56	43.37	360.56
0.162	0.411	0.011	1.09	220	1.81	43.46	416.64
0.185	0.470	0.012	1.24	240	1.98	43.53	453.81
0.212	0.538	0.014	1.42	260	2.14	43.61	490.73
0.245	0.622	0.016	1.64	280	2.30	43.71	527.29
0.286	0.726	0.019	1.92	300	2.47	43.83	563.37
0.313	0.795	0.021	2.10	310	2.55	43.91	581.07
0.35	0.889	0.023	2.35	320	2.63	44.02	598.30
0.485	1.232	0.033	3.26	338	2.78	44.43	626.09
Sample Discription :-							

Moist unit weight of specimen: 2.036 gm/cm³ Proving ring calibration factor:
 Dry unit weight of specimen: 1.71 gm/cm³ 1 kN = 121.5
 Moisture content of specimen: 17.9 % 2 kN = 241.8
 Initial average length of specimen: 14.9 cm 3kN = 362.9
 Initial average diameter of specimen: 7.398 cm 4 kN = 483.8
 Initial area of specimen: 42.9866 cm²

TRIAXIAL SHEAR TEST
10% SODIUM PHOSPHATE STABILIZATION, 30 PSI.
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE
Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.026	0.066	0.002	0.17	50	0.41	43.06	95.57
0.049	0.124	0.003	0.33	90	0.74	43.13	171.76
0.082	0.208	0.005	0.55	140	1.15	43.22	266.59
0.11	0.279	0.007	0.73	180	1.48	43.30	342.11
0.125	0.318	0.008	0.83	200	1.65	43.35	379.74
0.149	0.378	0.010	0.99	230	1.89	43.42	436.00
0.175	0.445	0.012	1.17	260	2.14	43.49	492.00
0.205	0.521	0.014	1.37	290	2.39	43.58	547.66
0.246	0.625	0.016	1.64	330	2.72	43.70	621.47
0.284	0.721	0.019	1.89	360	2.96	43.82	676.23
0.33	0.838	0.022	2.20	390	3.21	43.95	730.29
0.367	0.932	0.024	2.45	410	3.37	44.06	765.80
0.415	1.054	0.028	2.77	430	3.54	44.21	800.52
0.473	1.201	0.032	3.15	449	3.70	44.39	832.57
Sample Discription :-							

Moist unit weight of specimen: 2.036 gm/cm³ Proving ring calibration factor:
Dry unit weight of specimen: 1.71 gm/cm³ 1 kN = 121.5
Moisture content of specimen: 17.9 % 2 kN = 241.8
Initial average length of specimen: 15.8 cm 3kN = 362.9
Initial average diameter of specimen: 7.398 cm 4 kN = 483.8
Initial area of specimen: 42.9866 cm²

SUMMARY OF RESULTS FOR 10, 20, 30 PSI TESTS OF 10% SODIUM PHOSPHATE STABILIZATION

TRIAXIAL SHEAR TEST

MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE

TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE

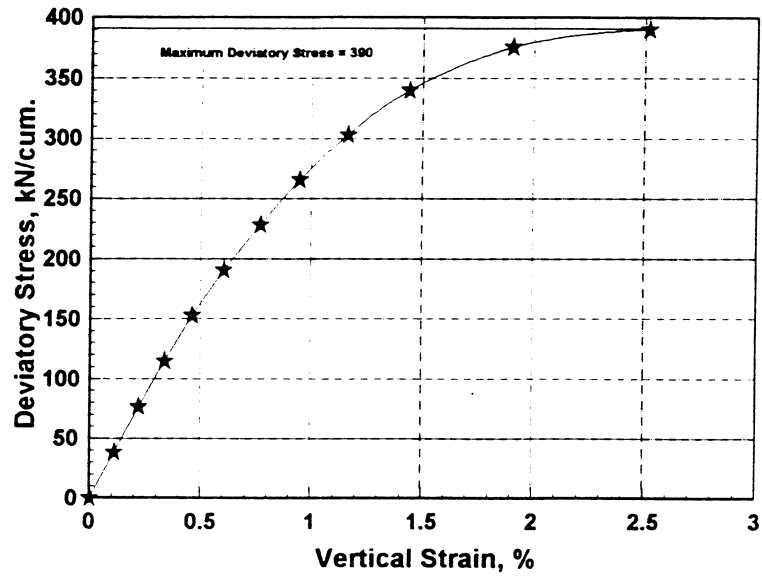
Test Performed : Consolidated Drained

S No.	Confined Press. $\sigma(3)$ psi	Confined Press. $\sigma(3)$ kN/sq.m	Deviatory Stress. $\Delta\sigma$ kN/sq. m	Deviatory + Confined Stress $\sigma(1) = \sigma(3) + \Delta\sigma$ kN/sq.m
1	10	68.95	390.09	459.04
2	20	137.9	626.09	763.99
3	30	206.85	832.57	1039.42

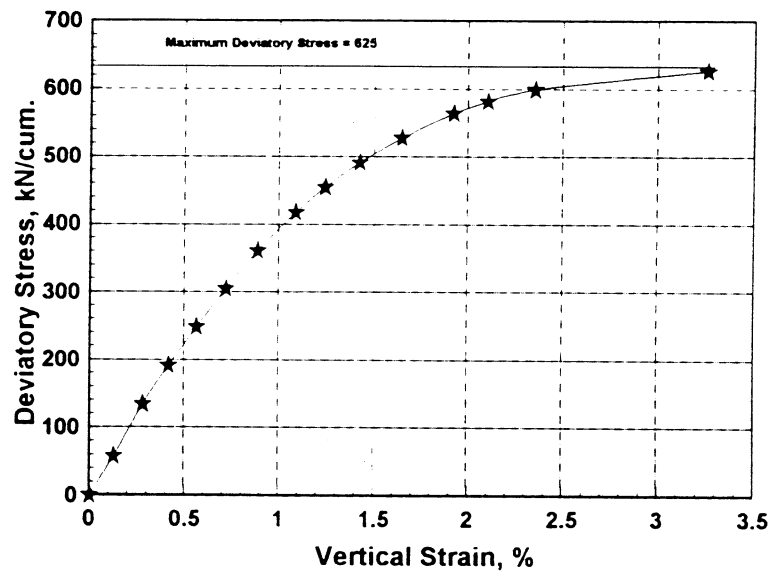
Conversion Factor Used:

$$6.895 \text{ kN/sq. m} = 1 \text{ psi.}$$

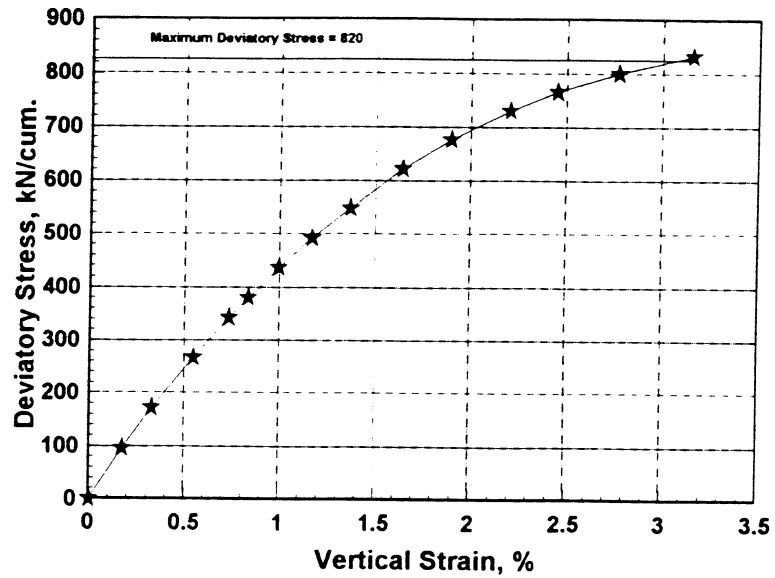
Triaxial Shear Test - 10 % Sodium Phosphate, 10 psi



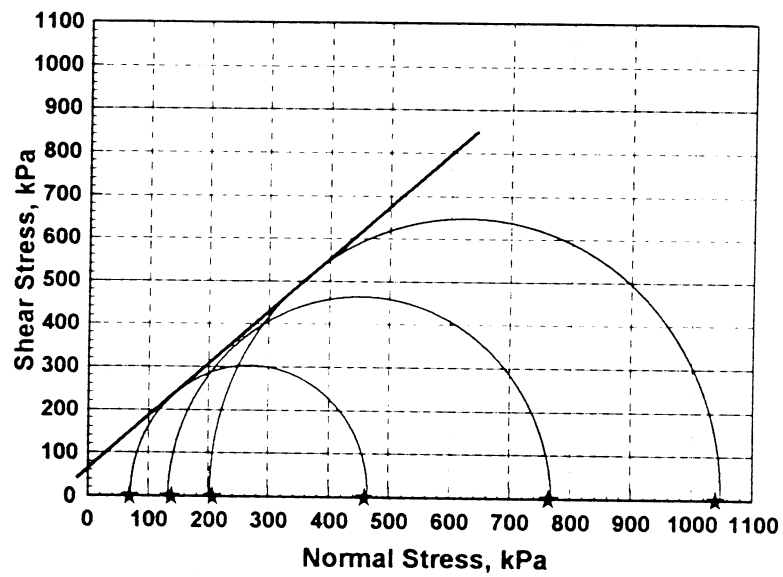
Triaxial Shear Test - 10% Sodium Phosphate, 20 psi



Triaxial Shear Test - 10% Sodium Phosphate, 30 psi



Mohr's Circle Plot - 10% Sodium Phosphate



Cohesion, $C = 60$ kPa
Angle of Internal Friction = 51 deg.

TRIAXIAL SHEAR TEST
15% SODIUM PHOSPHATE STABILIZATION, 10 PSI.
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE
Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.032	0.081	0.002	0.19	30	0.25	43.07	57.33
0.055	0.140	0.003	0.33	50	0.41	43.13	95.42
0.11	0.279	0.007	0.65	90	0.74	43.27	171.19
0.158	0.401	0.009	0.94	120	0.99	43.39	227.60
0.197	0.500	0.012	1.17	140	1.15	43.50	264.91
0.241	0.612	0.014	1.43	160	1.32	43.61	301.95
0.293	0.744	0.017	1.74	180	1.48	43.75	338.63
0.381	0.968	0.023	2.27	200	1.65	43.98	374.25
0.482	1.224	0.029	2.87	210	1.73	44.26	390.54

Sample Discription:

Moist unit weight of specimen: 1.993 gm/cm³ Proving ring calibration factor:
 Dry unit weight of specimen: 1.64 gm/cm³ 1 kN = 121.5
 Moisture content of specimen: 21.5 % 2 kN = 241.8
 Initial average length of specimen: 16.8 cm 3kN = 362.9
 Initial average diameter of specimen: 7.398 cm 4 kN = 483.8
 Initial area of specimen: 42.9866 cm²

TRIAXIAL SHEAR TEST
15% SODIUM PHOSPHATE STABILIZATION, 20 PSI.
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE
Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.019	0.048	0.001	0.13	30	0.25	43.04	57.37
0.039	0.099	0.003	0.26	60	0.49	43.10	114.58
0.06	0.152	0.004	0.40	90	0.74	43.16	171.63
0.092	0.234	0.006	0.61	130	1.07	43.25	247.38
0.108	0.274	0.007	0.72	150	1.23	43.30	285.13
0.136	0.345	0.009	0.91	180	1.48	43.38	341.51
0.159	0.404	0.011	1.06	200	1.65	43.45	378.87
0.186	0.472	0.012	1.24	220	1.81	43.53	416.00
0.234	0.594	0.016	1.56	250	2.06	43.67	471.20
0.275	0.699	0.018	1.83	270	2.22	43.79	507.48
0.325	0.826	0.022	2.17	290	2.39	43.94	543.22
0.444	1.128	0.030	2.96	320	2.63	44.30	594.55
0.546	1.387	0.036	3.64	330	2.72	44.61	608.84
0.569	1.445	0.038	3.79	333	2.74	44.68	613.39
Sample Discription:							

Moist unit weight of specimen: 1.993 gm/cm³ Proving ring calibration factor:
 Dry unit weight of specimen: 1.64 gm/cm³ 1 kN = 121.5
 Moisture content of specimen: 21.3 % 2 kN = 241.8
 Initial average length of specimen: 15 cm 3kN = 362.9
 Initial average diameter of specimen: 7.398 cm 4 kN = 483.8
 Initial area of specimen: 42.9866 cm²

TRIAXIAL SHEAR TEST
15% SODIUM PHOSPHATE STABILIZATION, 30 PSI.
MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE
Test Performed : Consolidated Drained

Specimen Def. in.	Specimen Def. cm.	Vertical Strain	Vertical strain %.	Proving ring dial div	Piston load kN	Corrected Area. sq. cm	Deviatory Stress kN/sq.m
0.016	0.041	0.001	0.10	40	0.33	43.03	76.51
0.034	0.086	0.002	0.20	70	0.58	43.07	133.75
0.051	0.130	0.003	0.30	100	0.82	43.12	190.88
0.07	0.178	0.004	0.42	130	1.07	43.17	247.87
0.09	0.229	0.005	0.54	160	1.32	43.22	304.70
0.114	0.290	0.007	0.68	190	1.56	43.28	361.32
0.136	0.345	0.008	0.81	220	1.81	43.34	417.81
0.165	0.419	0.010	0.98	250	2.06	43.41	473.96
0.197	0.500	0.012	1.17	280	2.30	43.50	529.82
0.235	0.597	0.014	1.40	310	2.55	43.60	585.24
0.3	0.762	0.018	1.79	350	2.88	43.77	658.16
0.348	0.884	0.021	2.07	370	3.05	43.90	693.75
0.39	0.991	0.023	2.32	390	3.21	44.01	729.38
0.476	1.209	0.028	2.83	420	3.46	44.24	781.37
Sample Discription:							

Moist unit weight of specimen: 1.993 gm/cm³ Proving ring calibration factor:
 Dry unit weight of specimen: 1.64 gm/cm³ 1 kN = 121.5
 Moisture content of specimen: 21.5 % 2 kN = 241.8
 Initial average length of specimen: 16.8 cm 3kN = 362.9
 Initial average diameter of specimen: 7.398 cm 4 kN = 483.8
 Initial area of specimen: 42.9866 cm²

SUMMARY OF RESULTS FOR 10, 20, 30 PSI TESTS OF 15% SODIUM PHOSPHATE STABILIZATION

TRIAXIAL SHEAR TEST

MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE

TEST PERFORMED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE

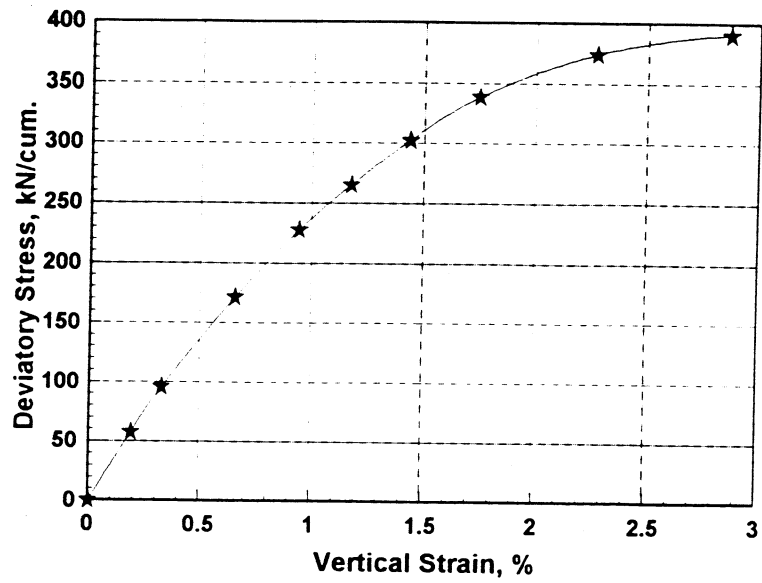
Test Performed : Consolidated Drained

S No.	Confined Press. $\sigma(3)$ psi	Confined Press. $\sigma(3)$ kN/sq.m	Deviatory Stress. $\Delta\sigma$ kN/sq. m	Deviatory + Confined Stress $\sigma(1) = \sigma(3) + \Delta\sigma$ kN/sq.m
1	10	68.95	390.54	459.49
2	20	137.9	613.4	751.3
3	30	206.85	778.63	985.48

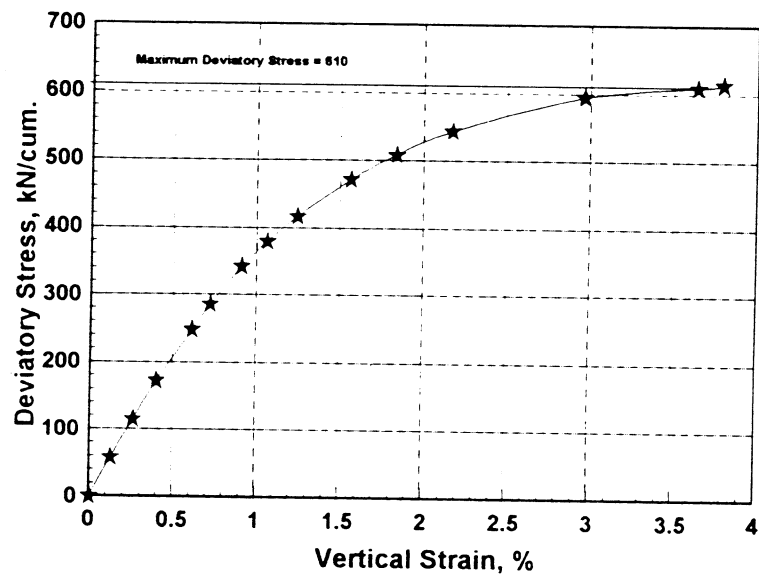
Conversion Factor Used:

$$6.895 \text{ kN/sq. m} = 1 \text{ psi.}$$

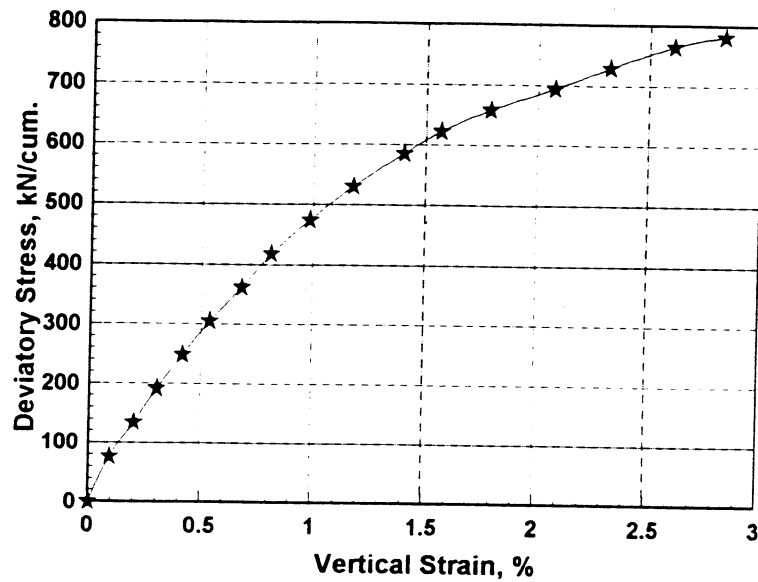
Triaxial Shear Test - 15% Sodium Phosphate, 10psi



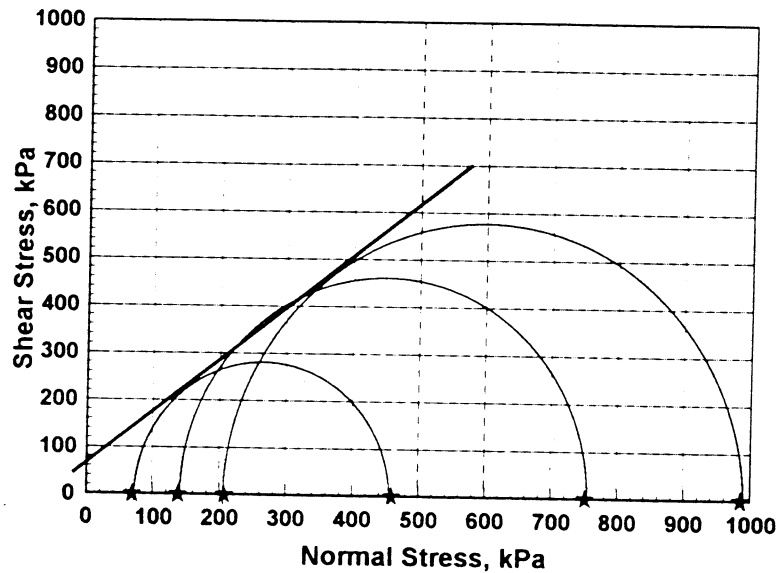
Triaxial Shear Test - 15% Sodium Phosphate, 20psi



Triaxial Shear Test - 15% Sodium Phosphate, 30 psi



Mohr's Circle Plot - 15 % Sodium Phosphate



C (Cohesion) = 65 kPa

Phi (Angle of Internal Friction) = 49 deg.

CALIFORNIA BEARING RATIO
5% SODIUM PHOSPHATE, SOAKED (4 DAYS)

MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
 TEST CONDUCTED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE

Test Performed : ASTM D 1883-87, AASHTO T 193-81

Compression Machine with Penetration Rate of 1.3 mm/min

Mold Dimensions:

Diam. = 6 in.

No. of Layers: 5

Ht. = 7 in.

No. of Blows/Layer: 56

Diam. = 6 in.

Wt. of Hammer = 10 lb.

Ht. = 2 in.

Surcharge Wt. = 10 lb.

Spacer Disk:

Penetrate in.	Stress lb/sq.in.
0.00	0.00
0.02	30.00
0.04	40.00
0.06	60.00
0.08	70.00
0.10	90.00
0.12	120.00
0.14	150.00
0.16	180.00

Start Time and Date	Elapsed Time	Dial Reading	%
18-Oct	10:00	0	0.00
	11:00	5	0.11
	12:00	9	0.20
	14:00	25	0.55
	20:00	55	1.21
19-Oct	7:00	132	2.91
	19:00	190	4.19
20-Oct	7:00	192	4.24
21-Oct	7:00	192	4.24
22-Oct	7:00	192	4.24

Moisture Can No.	Top 1/3			Middle 1/3		Bottom 1/3	
	11	12	5	6	21	22	25
Wt. of can + wet soil	46.10	40.10	36.34	30.32	40.53	38.06	26
Wt. of can + dry soil	42.20	37.30	33.00	27.30	36.80	34.60	37.73
Wt. of water	3.90	2.80	3.34	3.02	3.73	3.46	34.20
Wt. of can	20.70	21.10	12.05	12.04	13.51	11.55	3.53
Wt. of dry soil	21.50	16.20	20.95	15.26	23.29	23.05	13.44
Water Content, w%	18.14	17.28	15.94	19.79	16.02	15.01	20.76
Average =	17.71		Average =	17.87	Average =	15.51	17.00
						Average =	16.47

CALIFORNIA BEARING RATIO
5% Sodium Phosphate, Cured (7 DAYS)

MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
 TEST CONDUCTED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE

Test Performed : ASTM D 1883-87, AASHTO T 193-81

Compression Machine with Penetration Rate of 1.3 mm/min

Mold Dimensions: Diam. = 6 in. No. of Layers: 5

Ht. = 7 in. No. of Blows/Layer: 56

Spacer Disk: Diam. = 6 in. Wt. of Hammer = 10 lb.

Ht. = 2 in. Surcharge Wt. = 10 lb.

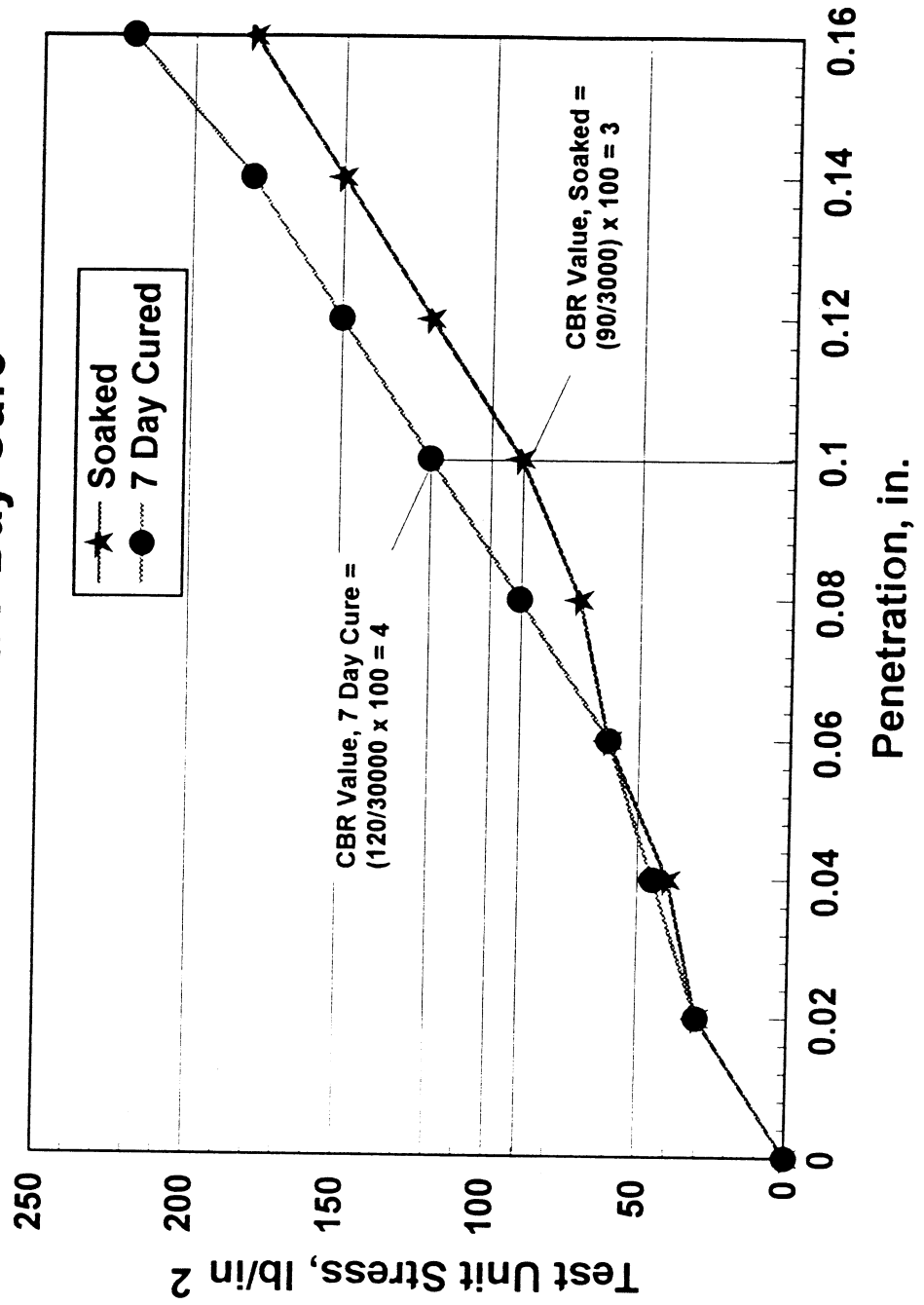
Penetrate in.	Stress lb/sq.in.
0.00	0.00
0.02	30.00
0.04	45.00
0.06	60.00
0.08	90.00
0.10	120.00
0.12	150.00
0.14	180.00
0.16	220.00

Mold No.	Unsoaked	Soaked
Surcharge(lbs)	10.00	10.00
Initial mass of wet soil + mold	8011.00	8098.00
Final mass wet soil and mold	xxx	8169.00
Mass of mold	3542.80	3540.00
Initial mass of wet soil	4468.20	4558.00
Initial wet density	2.14	2.18
Mass of water absorbed	xxx	71.00
% water absorbed	xxx	1.56

xxx - not applicable

Moisture Can No.	Top 1/3			Middle 1/3			Bottom 1/3		
	11	12	3	4	5	6	21	22	
Wt. of can + wet soil	46.10	40.10	33.93	30.07	34.98	35.10	36.50	33.18	
Wt. of can + dry soil	42.20	37.30	30.66	27.60	31.42	31.77	33.02	29.89	
Wt. of water	3.90	2.80	3.27	2.47	3.56	3.33	3.48	3.29	
Wt. of can	20.70	21.10	12.00	13.68	12.09	12.21	13.61	11.65	
Wt. of dry soil	21.50	16.20	18.66	13.92	19.33	19.56	19.41	18.24	
Water Content, w%	18.14	17.28	17.52	17.74	18.42	17.02	17.93	18.04	
Average =	17.71	Average =	17.63	Average =	17.72	Average =	17.98		

CBR Graph - 5% Sodium Phosphate, Soaked and 7 Day Cure



CALIFORNIA BEARING RATIO

10% SODIUM PHOSPHATE, SOAKED (4 DAYS)

MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE

TEST CONDUCTED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE

Test Performed : ASTM D 1883-87, AASHTO T 193-81

Compression Machine with Penetration Rate of 1.3 mm/min

Mold Dimensions:

Diam. = 6 in.

Ht. = 7 in.

No. of Layers: 5

No. of Blows/Layer: 56

Wt. of Hammer = 10 lb.

Surcharge Wt. = 10 lb.

Spacer Disk:

Diam. = 6 in.

Ht. = 2 in.

Penetrate in.	Stress lb/sq.in.
0.00	0.00
0.02	20.00
0.04	30.00
0.06	50.00
0.08	60.00
0.10	90.00
0.12	100.00
0.14	120.00
0.16	150.00

Start Time and Date	Elapsed Time	Dial Reading	%
24-Oct 17:00	0h	0	0.00
	1h	12	0.26
	2h	22	0.49
	4h	32	0.71
25-Oct 3:00	10h	50	1.10
	21h	160	3.53
26-Oct 2:00	33h	240	5.30
	45h	241	5.32
27-Oct 14:00	69h	241	5.32
28-Oct 14:00	93h	241	5.32

Moisture Can No.	11	12	Top 1/3 5	Mid 1/3 2	Bot 1/3 6
Wt. of can + wet soil	42.10	39.40	38.20	51.80	34.40
Wt. of can + dry soil	38.22	36.14	34.29	47.10	31.16
Wt. of water	3.88	3.26	3.91	4.70	3.24
Wt. of can	20.69	21.10	12.20	21.10	12.20
Wt. of dry soil	17.53	15.04	22.09	26.00	18.96
Water Content, w%	22.13	21.68	17.70	18.08	17.09
Average =		21.90	Average =		
			17.62		

CALIFORNIA BEARING RATIO
 10% SODIUM PHOSPHATE, CURED (7 DAYS)
 MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE
 TEST CONDUCTED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE

Test Performed : ASTM D 1883-87, AASHTO T 193-81

Compression Machine with Penetration Rate of 1.3 mm/min

Mold Dimensions:

Diam. = 6 in.

No. of Layers: 5

Ht. = 7 in.

No. of Blows/Layer: 56

Spacer Disk:

Diam. = 6 in.

Wt. of Hammer = 10 lb.

Ht. = 2 in.

Surcharge Wt. = 10 lb.

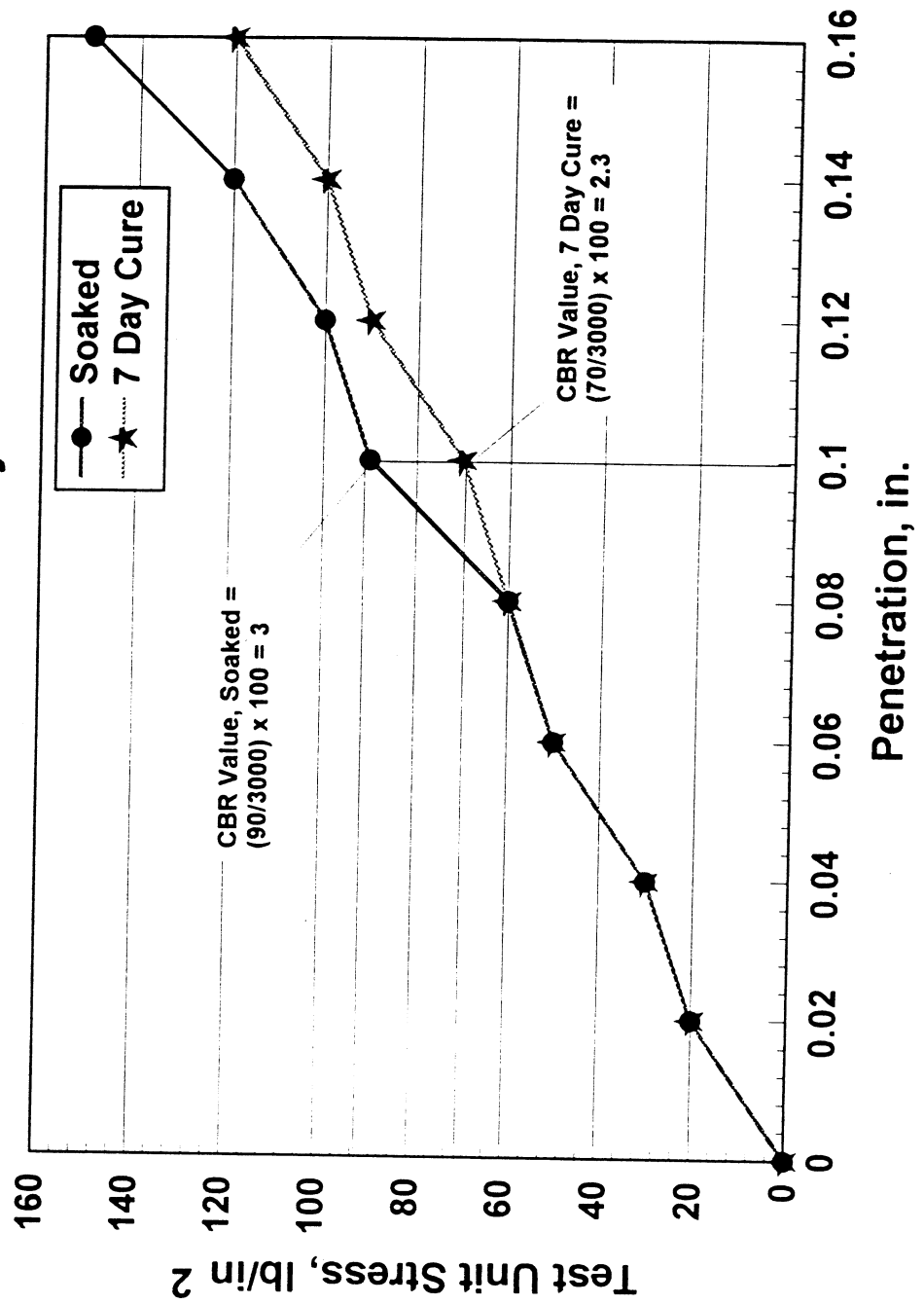
Penetrate in.	Stress lb/sq.in.
0.00	0.00
0.02	20.00
0.04	30.00
0.06	50.00
0.08	60.00
0.10	70.00
0.12	90.00
0.14	100.00
0.16	120.00

Mold No.	Unsoaked	Soaked
Surcharge(lbs)	10.00	10.00
Initial mass of wet soil + mold	11660.00	7923.00
Final mass wet soil and mold	xxx	7999.00
Mass of mold	7206.00	3558.00
Initial mass of wet soil	4454.00	4365.00
Initial wet density	2.13	2.09
Mass of water absorbed	xxx	76.00
% water absorbed	xxx	1.74

xxx - not applicable

Moisture Can No.	11	12	Top 1/3	Mid 1/3	Bot 1/3
Wt. of can + wet soil	42.10	39.40	21	22	25
Wt. of can + dry soil	38.22	36.14	31.35	35.20	34.65
Wt. of water	3.88	3.26	28.94	31.83	31.77
Wt. of can	20.69	21.10	2.41	3.37	2.88
Wt. of dry soil	17.53	15.04	13.63	11.65	13.59
Water Content, w%	22.13	21.68	15.74	20.18	18.18
Average =	21.90	21.60	16.70	15.84	16.09

CBR Graph - 10% Sodium Phosphate Soaked and 7 Day Cure



CALIFORNIA BEARING RATIO

15% SODIUM PHOSPHATE, SOAKED (4 DAYS)

MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE

TEST CONDUCTED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE

Test Performed : ASTM D 1883-87, AASHTO T 193-81

Compression Machine with Penetration Rate of 1.3 mm/min

Mold Dimensions: Diam. = 6 in.

Ht. = 7 in.

No. of Layers: 5

No. of Blows/Layer: 56

Wt. of Hammer = 10 lb.

Surcharge Wt. = 10 lb.

Spacer Disk:

Diam. = 6 in.

Ht. = 2 in.

Penetrate in.	Stress lb/sq.in.
0.00	0.00
0.02	10.00
0.04	15.00
0.06	20.00
0.08	30.00
0.10	40.00
0.12	50.00
0.14	60.00
0.16	65.00

Start Time and Date	Elapsed Time	Dial Reading	%	Dial Reading	%
27-Oct 10:00	0h	0	0.00	0	0.00
11:00	1h	80	1.77	40	0.88
12:00	2h	157	3.47	60	1.32
14:00	4h	170	3.75	64	1.41
20:00	10h	192	4.24	71	1.57
28-Oct 7:00	21h	201	4.44	76	1.68
19:00	33h	258	5.70	83	1.83
29-Oct 7:00	45h	329	7.26	95	2.10
30-Oct 7:00	69h	329	7.26	95	2.10
31-Oct 7:00	93h	329	7.26	95	2.10

Moisture Can No.	11	12	Top 1/3 2	Mid 1/3 11	Bot 1/3 12
Wt. of can + wet soil	38.98	40.98	58.30	54.67	48.71
Wt. of can + dry soil	35.88	37.49	51.79	48.98	44.19
Wt. of water	3.10	3.49	6.51	5.69	4.52
Wt. of can	20.91	20.40	21.23	20.80	21.16
Wt. of dry soil	14.97	17.09	30.56	28.18	23.03
Water Content, w%	20.71	20.42	21.30	20.19	19.63
Average =		20.56	Average =		
			20.37		

CALIFORNIA BEARING RATIO

15% SODIUM PHOSPHATE, CURED (7 DAYS)

MATERIAL : MUNICIPAL SOLID WASTE ASH RESIDUE

TEST CONDUCTED AT : SOILS LABORATORY - FAMU/FSU ENGINEERING COLLEGE

Test Performed : ASTM D 1883-87, AASHTO T 193-81

Compression Machine with Penetration Rate of 1.3 mm/min

Mold Dimensions:

Diam. = 6 in.

No. of Layers: 5

Ht. = 7 in.

No. of Blows/Layer: 56

Spacer Disk:

Diam. = 6 in.

Wt. of Hammer = 10 lb.

Ht. = 2 in.

Surcharge Wt. = 10 lb.

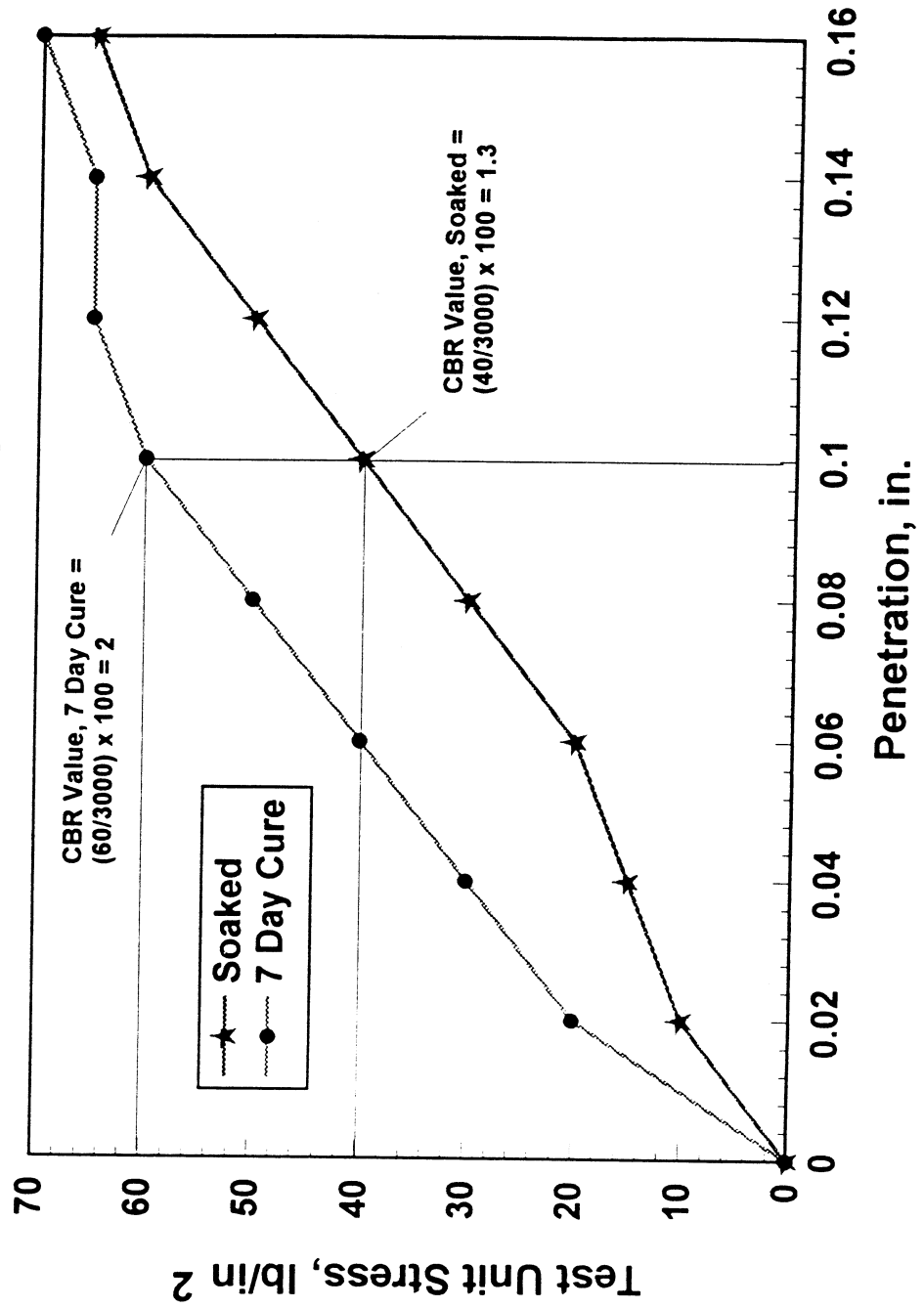
Penetration in.	Stress lb/sq.in.
0.00	0.00
0.02	20.00
0.04	30.00
0.06	40.00
0.08	50.00
0.10	60.00
0.12	65.00
0.14	65.00
0.16	70.00

Mold No.	Unsoaked	Soaked
Surcharge(lbs)	10.00	10.00
Initial mass of wet soil + mold	11446.00	11500.00
Final mass wet soil and mold	xxx	11592.00
Mass of mold	7181.00	7334.00
Initial mass of wet soil	4265.00	4166.00
Initial wet density	2.04	2.00
Mass of water absorbed	xxx	92.00
% water absorbed	xxx	2.21

xxx - not applicable

Moisture Can No.	11	12	Top 1/3 1	Mid 1/3 2	Bot 1/3 3
Wt. of can + wet soil	38.98	40.98	38.20	39.40	49.10
Wt. of can + dry soil	35.88	37.49	34.14	34.92	44.56
Wt. of water	3.10	3.49	4.06	4.48	4.54
Wt. of can	20.91	20.40	12.20	11.80	21.00
Wt. of dry soil	14.97	17.09	21.94	23.12	23.56
Water Content, w%	20.71	20.42	18.51	19.38	19.27
Average =		20.56	Average =		
			19.05		

CBR Graph - 15% Sodium Phosphate, Soaked & 7 Day Cure



APPENDIX C

SURVEY ON THE GENERATION OF ASH RESIDUE IN FLORIDA

1. Name of Facility :

DADE COUNTY Resources Recovery.

2. Technology : ☐ Mass Burn ☒ Refuse Derived Fuel ☐ Pyrolysis

3 (a) Amount of Solid waste processed :

76,000 (tons/yr or

_____ tons/month

(b) Ash amount generated (in % of waste processed generated :

13.5 %

OR

131,490 (tons/yr or month

4. Current Ash disposal/Utilization practices:

ASH FILL

5. Will you be willing to submit for testing samples of Ash residue from your facility. (The site of the sample will be reported anonymously)

☒ YES

☐ NO

We will need about a drum of sample, we can either come to pick it up or you can have it shipped COD.

1. Name of Facility :

Wheelabrator South Broward

2. Technology : ☒ Mass Burn ☐ Refuse Derived Fuel ☐ Pyrolysis

3 (a) Amount of Solid waste processed :

750K tons/yr or

_____ tons/month

(b) Ash amount generated (in % of waste processed generated :

5 % volumetric
26% weight

OR

_____ tons/yr or month

4. Current Ash disposal/Utilization practices:

- Double lined landfill

5. Will you be willing to submit for testing samples of Ash residue from your facility. (The site of the sample will be reported anonymously)

_____ YES

X NO

We will need about a drum of sample, we can either come to pick it up or you can have it shipped COD.