Soil Stabilisation Using Rice Husk Ash (RHA) in Marine Clay

By

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Civil Engineering Programme
University Technology of PETRONAS
In partial fulfillment of the requirement for the
Bachelor of Engineering (Hons)
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Approved by,

____
(Dr Tn Syed Baharom Azahar Syed Osman)

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

HAREZ B MOHD HIZAN

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Abstract

Marine clay has contributed many problems due to the reaction and behavior of the soil according to the different conditions for instances dry and wet period. Stabilisation of marine clay is studied by chemically using rice husk ash (RHA) as the stabilizers. Investigation includes the evaluation of such properties of the soil as compaction, strength, and other engineering properties of expansive soil as well as marine clay. Upon the determination of these parameters, the optimum amount of the stabilizers and the best curing period of time and temperature are studied. The test results showed that the unconfined compressive strength (UCS) increased about 75% after 7 days. However, the results indicated that if the curing period is less than 7 days, the UCS value of the RHA treated samples are higher than those of natural samples. This suggests that the pozzolans reaction between the clay soils and RHA had achieved optimum stabilisation at 8% of RHA content and 7 days curing time.

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CHAPTER 1: INTRODUCTION

1.1 Background of Research

Clay is a naturally occurring material, composed primarily of fine-grained minerals, which show plasticity through a variable range of water content (Howard *et. al*, 2007). Clays are distinguished from other fine-grained soils by various differences in composition. Silts, which are fine-grained soils which do not include clay minerals, tend to have larger particle sizes than clays, but there is some overlap in both particle size and other physical properties, and there are many naturally occurring deposits which include both silts and clays.

There are three or four main groups of clays: kaolinite, montmorillonite-smectite, illite, and chlorite. Chlorites are not always considered clay, sometimes being classified as a separate group within the phyllosilicates. There are approximately thirty different types of "pure" clays in these categories, but most "natural" clays are mixtures of these different types, along with other weathered minerals (Cited from Baiardo *et. al*, 2004).

Marine clay is a type of clay found in coastal regions around the world. Paul K. Mathew (2005) had mentioned that marine clay consists of bluish gray, red and yellow, clayey and silty soils that were deposited by rivers flowing into the ocean millions of years ago (Cited from Lazaro, R.C., & Moh, Z.C, 2006). Marine clays can be found in discontinuous layers often scattered with thin layers of sand. When clay is deposited in the ocean, the excess ions allow a loose, open structure that is open to water infiltration (Cited from O'Donnell *et. al*, 2004). Once stranded and dried by ancient, changing ocean levels, it becomes a geotechnical engineering challenge.

1.2 Problem Statement

Natural expansive soils are very common in some parts of the world. Annually, several million dollars are spent to repair the damages caused to infrastructures such as pavements, runways, residential buildings, and industrial building built on expansive soils (Norin *et. al*, 2006). The damages usually occur due to the heave of the clay. There has been a lot of work concerning the stabilisation of clay, which is mainly the weathering product of the surrounding volcanic rocks. The semi-arid climate and geology of certain area have caused the formation of calcareous expansive soils on the shore. In some areas, swelling has caused serious foundation problems.

S. Narasimha Rao, February (1997) said that marine clays had caused many problems because they shrink during dry periods of the year and swell during wet periods (Cited from Lazaro, R.C., & Moh, Z.C, 2006). Pressures exerted by marine clays upon swelling can crack and damage below-ground walls and ground floor slabs. Shrinking and swelling of soils underneath the foundation footing can reduce the bearing support, damaging foundation walls. The most troublesome areas occur on steeper slopes where the content of clay and silt is much higher than other soil types.

Some types of damage are more common than others and tend to occur at certain stages in the life of a house with some problems developing slowly at first and becoming more serious over time. In fact, many houses located within the marine clays often have problems. After sometime in the life of the structure, the soil will undergo foundation distress.

1.3 Objectives of Research

1) Study the effect of rice husk ash (RHA) on the strength properties of marine clay.

2) To study the optimum amount of RHA mixed with marine clay sample that produce the highest strength.

3) To study the effect of curing on the strength of marine clay.

1.4 Scope of Research

This project was in the form of laboratory works, data analysis and fabrication of laboratory apparatus. Both disturbed and undisturbed marine clay was taken as the soil sample and the properties of soil such as unit weight, porosity, permeability, consolidation, specific gravity, shear strength, particle size distribution and atterberg limits were used in the analysis of marine clay stabilisation. The soil stabilisation was carried out by using the cementitious and waste materials which is rice husk ash (RHA). In smaller scope, the micro structural behavior of the treated soil was studied through the X-ray diffraction, (XRD) scanning electron microscopy. Kamaruzzaman (2006) had mentioned that the XRD analysis of cement treated clay enables the identification of the formation of cementitious products, namely calcium silicate hydrate (CSH) and calcium aluminium silicate hydrate (CASH) (Cited from Muntohar, A.S., 2006a).

CHAPTER 2: LITERATURE REVIEW

2.1 Rice Husk Ash

2.1.1 Introduction

Rice husks are major agricultural by-product obtained from the food crop of paddy. Generally, it is considered a valueless product of rice milling process. About million tons of rice husks are generated annually in the world. Chemical analyses have shown that the ash i.e. rice husk ash (RHA), is a highly reactive pozzolanic material. Pozzolan is the material having high silica content with about 67-70% silica and about 4.9 and 0.95% aluminum and iron oxides, respectively (Cited from Oyetola and Abdullahi, 2006). Silica is substantially contained in amorphous form. The high amount of silica dioxide is suitable for use in lime pozzolanic mixes and Portland cement replacement (Cited from Farrell and Hebib, 1998). On this ground the contribution of rice husk ash to the engineering application needs further investigation.

Rice husk ash (RHA) is a pozzolanic material that could be potentially used in Malaysia, considering it is sufficiently produced and is widespread. When rice husk is allowed to burn under controlled temperature, higher pozzolanic properties than other leaf plants were observed. Silica is a main mineral of RHA.

This research concerned with the effect of adding the RHA to the expansive soil on its engineering properties. This includes the study on the swelling behavior of untreated and treated specimens.

The oxide composition of RHA is shown in Table 2. The combine percent composition of silica, Al2O3 and Fe2O3 is more than 70. This shows that, it is a good pozzolana that could help mobilize the CaOH in the soil for the formation of cementitious compounds.

Table 2.1: Chemical composition of RHA

Constituents	RHA (%)
SiO2	89.08
Al2O3	1.75
Fe2O3	0.78
CaO	1.29
MgO	0.64
Na2O	0.85
K2O	1.38
MnO	0.14
TiO2	0.00
P2O5	0.61
H20	1.33

2.2 Formation of Clay

Broadly, soft ground encompasses soft clay soils, soils having large fractions of fine silt, peat and loose sand deposits below ground water table (Cited from Kamon & Bergado, 1991). Soil being essentially particulate media, clay sediment formations is influenced by the nature of solid soil particles and their interactions with the surrounding pore fluid medium. Stress, time, and environment are dominant factors in soft clay formations.

2.2.1 Characteristics of Soft Clay

For a rational approach to find practical solutions to the geotechnical problems encountered in clays, it is necessary to determine the strength characteristic of such clays. The consistency of clay can be described by its unconfined compressive strength or by its undrained shear strength. Terzaghi (1967) had mentioned that clay is regarded as very soft if its unconfined compressive strength is less than 25kPa and as soft when the strength is in the range of 25 to 50 kPa (Cited from Das, B.M.,2002).

Soft clays can exhibit this order of undrained strength. As the sediments get compressed due to overburden the effective stress increases with a commensurate increase in the undrained strength. For the clays to exhibit strength in the range of 25-50 kPa without cementation, water contents have to be lower than their liquid limit water contents.

It is possible that clay may be soft from a shear strength point of view, but the compressibility could be low if the liquid limit water contents are relatively low. Mesri & Tavenas (1994) assessed that for water a content corresponding to their liquid limit, the undrained shear strength is only in the range of 1.5 to 2.5 kPa (Cited from O'Donnell *et. al*, 2004). Hence the additional strength contributed is by cementation bonds. As such the undrained strength would only become a viable parameter to designate clay as soft clay.

Table 2.2 contains the typical values of the undrained shear strength which represents the clay term including the visual identification.

Table 2.2: Typical Values

Term	Undrained Shear Strength	Visual Identification
Very soft	< 12.5	Exudes between fingers
Soft	12.5-25	Easily moulded with fingers and indented considerably with thumb
Firm	25-50	Can be moulded with moderate pressure of fingers and indented with moderate pressure
Stiff	50-100	Moulded with difficulty by fingers, can be indented by strong pressure of the thumb only a small amount
Very stiff	100-200	Can be indented to little more then a fingerprint with strong pressure of the thumb.

2.3 Soil Stabilisation

Geotechnically, soil improvement could either be by modification or stabilisation, or both. Soil stabilisation is the treatment of soils to enable their strength and durability to be improved such that they become totally suitable for construction beyond their original classification. Chemical soil stabilization is used in various civil engineering applications to improve engineering properties and behavior of soils. The most common stabilizing agents are rice husk ash (RHA) cement and lime, with fly ash also used as an agent. In most of the applications, improvement in the compression characteristics of soils is required.

Soil stabilisation involves determination of the type and amount of stabilizing agent required and verifying the quality of the resulting stabilized soil. Criteria such as previous experience, regulatory requirements, availability of materials, etc. are used to determine the type and amount of the stabilizing agent to be used for a particular application. In addition, a mixture design procedure is used for the selection of the stabilizing agent. The mixture design procedure consists of preparation of various mixture of the soil with varying amount and/or types of stabilizing agent and testing the mixtures. Tests are conducted on these mixtures to determine the compaction characteristics of the soil and also to determine the specific property of the soil to be improved, such as compressive strength. The quality of stabilized soil in the field is verified by procedures that are similar to those used for compacted soils. In most cases, this involves determining the water content and dry density of the soils. In addition, tests can be conducted to determine the specific property of the soil to be improved such as the compressive strength. Extensive literature is available on soil stabilisation including materials, testing, and design procedures (Brown, 1996).

Mixture design and quality control procedures require extensive testing of the soils. Properties and behavior of chemically stabilized soils are time dependent. Testing at various times subsequent to mixing the soil with the chemical agent is needed to characterize the soils thoroughly (Cited from Das, B.M., 2002).

2.3.1 Effect of Treatment with RHA

2.3.1.1 Compaction Characteristic

The variations of maximum dry densities (MDD) and optimum moisture content (OMC) with stabilizers contents are shown in figure 2.1. The MDD decreased while the OMC increased with increase in the RHA content.

The decrease in the MDD can be attributed to the replacement of soil and by the RHA in the mixture which have relatively lower specific gravity (2.25) compared to that of the soil which is 2.69 (Ola 1975; Osinubi and Katte 1997). It may also be attributed to coating of the soil by the RHA which result to large particles with larger voids and hence less density (Osula 1991). The decrease in the MDD may also be explained by considering the RHA as filler (with lower specific gravity) in the soil voids.

There was increase in OMC with increase RHA contents. The trend is in line with Ola (1975), Gidigasu (1976) and Osinubi (1999). The increase was due to the addition of RHA, which decreased the quantity of free silt and clay fraction and coarser materials with larger surface areas were formed (these processes need water to take place). This implies also that more water was needed in order to compact the soil-RHA mixtures (Cited from Musa Al-Hassan, 2008).

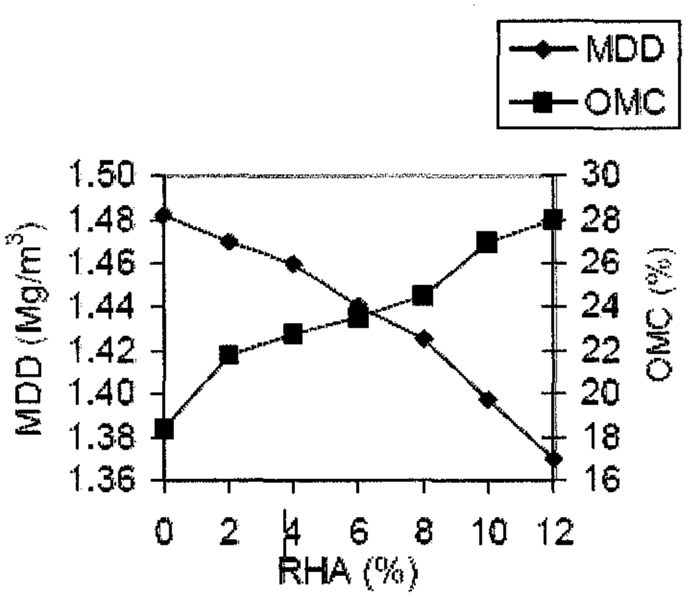

Figure 2.1: Variation of MDD and OMC with RHA content

2.3.1.2 Unconfined Compressive Strength

Unconfined compressive strength (UCS) is the most common and adaptable method of evaluating the strength of stabilized soil. It is the main test recommended for the determination of the required amount of additive to be used in stabilization of soil (Singh and Singh 1991). Variation of UCS with increase in RHA from 0% to 12% at British Standard Light energy level and for 7 days, 14 days and 28 days curing period were investigated and the results for the three curing periods are shown in figure 2.2. There was a sharp initial decrease in the UCS with addition of RHA to the natural soil when compared with the UCS value of 290kN/m2 recorded for the natural soil. This decrease may be due to earlier reason given in the case of CBR.

The UCS values increase with subsequent addition of RHA to its maximum at between 6-8% RHA after which it dropped from 10-12% RHA. The subsequent increase in the UCS is attributed to the formation of cementitious compounds between the CaOH present in the soil and RHA and the pozzolans present in the RHA. This decrease in the UCS values after the addition of 8% RHA may be due to the excess RHA introduced to the soil and therefore forming weak bonds between the soil and the cementitious compounds formed.

The maximum UCS value recorded was 293 and 295kN/m2 at 6 and 8% RHA contents respectively, after 28 days curing period. These values are slightly higher than the natural soil UCS of 290kN/m^2 (Cited from Musa Al-Hassan, 2008).

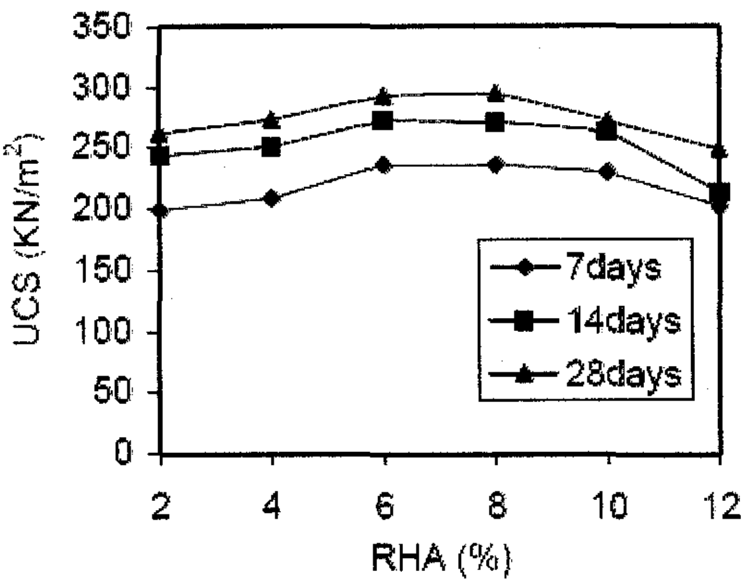

Figure 2.2: Variation of UCS with RHA content

2.3.1.3 California Bearing Ratio

As an indicator of compacted soil strength and bearing capacity, it is widely used in the design of base and sub-base material for pavement. It is also one of the common tests used to evaluate the strength of stabilized soils.

The variation of CBR with increase in RHA from 0 to 12% is shown in figure 2.3. For unsoaked samples, CBR values initially dropped with the addition of 2% RHA, after which the values rises to its peak at 6% RHA.

It slightly dropped at 8% RHA and remains constant to 12% RHA. The initial decrease in the CBR is due to the reduction in the silt and clay content of the soil, which reduces the cohesion of the samples. The increment in the CBR after 2% RHA can be attributed to the gradual formation of cementitious compounds between the RHA and CaOH contained in the soil. The gradual decrease in the CBR after 6% RHA may be due to excess RHA that was not mobilized in the reaction, which consequently occupies spaces within the sample and therefore reducing bond in the soil-RHA mixtures.

The trend of the soaked CBR was similar to the unsoaked CBR only that, even after the addition of 6% RHA, the CBR kept increasing. This trend shows that the presence of water (moisture) helps to further the formation of the cementitious compounds between the soil's CaOH and the pozzolanic RHA (Cited from Musa Al-Hassan, 2008).

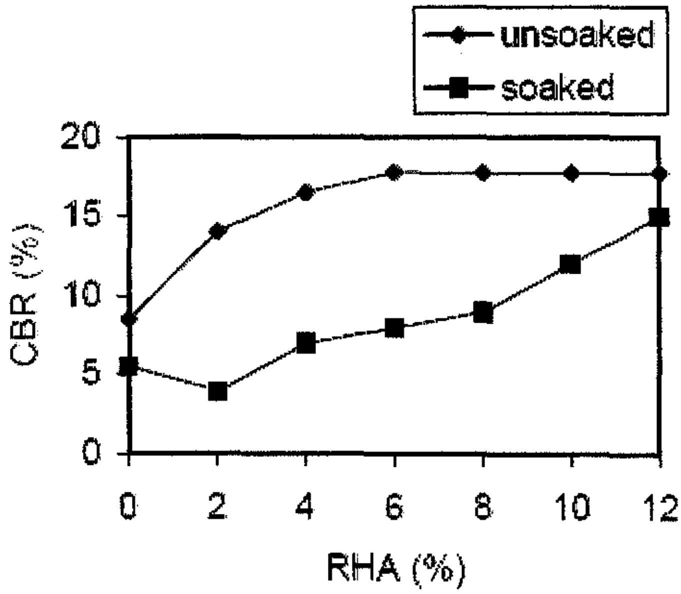

Figure 2.3: Variation of CBR with RHA content

CHAPTER 3: METHODOLOGY

3.1 Research Activities

During the research, several factors were taken into consideration such as the economical aspects and the mechanical properties of the stabilizers and soil samples. This is to ensure that the stabilizers are suitable to produce an effective result and be able to improve the engineering properties of the soil. The research activities are divided into several stages:

3.1.1 Selection of Location

As a base of this research, several journals, books and related articles are referred to in gaining deeper perceptive and understanding. Case study had been made to specify the suitable location for acquiring the soil sample. Marine Geologist at Technical Services Division, Minerals and Geoscience Department Malaysia, Ipoh, had suggested the location to be selected in Lumut, Perak.

3.1.2 Collecting Samples

Marine clay soil sample had been collected at the mangrove forest located in Lumut, Perak. Both disturbed and undisturbed samples were collected. The disturbed sample was taken half a meter deep from the top soil. The undisturbed sample was taken using the hand auger. This sampler typically consists of a short cylinder with a cutting edge attached to a rod and handle. The sampler is advanced by a combination of rotation and downward force.

Figure 3.1: Diagram of Hand Auger

3.2 Laboratory Works

The laboratory works have been divided into 2 parts. The first part was to determine the basic characteristics of the marine clay and RHA. The tests that have been conducted were dry sieving, pyknometer and standard proctor test. While for the second part, it was to determine the effect of the RHA on the strength of marine clay and also the ideal mix proportion of using RHA to stabilize the marine clay. The tests conducted for this part were unconfined compressive test and x-ray fluorescence spectrometry.

The samples in this laboratory testing were untreated and treated soils. Untreated soil was actually the raw sample of marine clay while the treated soils were various percentage of RHA (2-10%) mixed with marine clay. Following are the list of laboratory testing that will be conducted.

3.2.1 Oven-Drying (BS1377: Part 2:1990:3.2, and ASTM D2216)

The oven-drying method is the standard method for determining moisture content of soils. In this test, 3 samples of marine clay were carried out. The samples were freshly taken from the site and being oven-dried for 24 hours at temperature 110±5°C. The moisture content is calculated using following equation:

$$w = \frac{M_{CMS} - M_{CDS}}{M_{CDS} - M_{SC}} \times 100\% \quad \text{.............................Eqn 3.1}$$

where M_{CMS} is Mass of container with moist soil

M_{CDS} is mass of container with dry soil

M_{SC} is mass of container

3.2.2 Simple Dry Sieving (BS1377: Part 2:1990:9.3)

Dry sieving is the simplest of all methods of particle size analysis. For the dry sieve analysis test, 8 sets of samples have been carried out. The tests were for marine clay, rice husk ash (RHA) and mixture of marine clay-RHA (2 -10%).

Before conducting the tests, all the samples have been oven-dry for 24 hours. The sample is then shaken through a stack of sieves with openings of decreasing size from top to bottom. The mass of soil retained on each sieve is recorded after the sample is shaken. Particles that pass through a given sieve are said to be passing that sieve size. Particle that fail to pass through given sieve are said to be retained on that sieve. The individual weights are calculated as a percentage of the total weight.

3.2.3 Specific Gravity

In this test, 400gram of sample was placed into the pyknometer and added with distilled water until it full and ensures that there is no entrapped air bubble. 7 tests were made that are for untreated and treated samples. The specific gravity is calculated using equation below:

$$\rho_s = M_s / V_s \qquad \text{Eqn 3.2}$$

where ρ_s is density of the solid soil particles

M_s mass of the solid particles dried at a temperature of 105 °C

V_s Volume of the solid particles

3.2.4 Standard Proctor Test

This test is conducted to determine the optimum moisture content and maximum dry density of sample. 7 samples were carried out for untreated and treated samples. Each sample is mixed with varying amounts of water and then compacted in three equal layers by a hammer that delivers 27 blows to each layer. The hammer has a mass of 2.5 kg and has a drop of 30.5 mm.

3.2.5 Load Frame Method (BS 1377: Part 7:1990:7.2, and ASTM D2166)

The test is the definitive method for the determination of unconfined compressive strength of cylindrical specimens of soil. Axial compression is applied to the specimen at a constant rate of deformation.

Samples of untreated and treated soils were conducted for this test. Before being tested, samples of the mixtures of marine clay-RHA (2% to 10%) were compacted at optimum moisture content and cured for 1, 3 and 7 days.

3.2.6 X-ray Fluorescence Spectrometry

X-ray fluorescence (XRF) spectrometry provides one of the simplest, accurate and economic analytical methods for the determination of the chemical composition of many types of materials. It is non-destructive and reliable, requires no, or very little, sample preparation and is suitable for solid, liquid and powdered samples. It can be used for a wide range of elements, from beryllium (4) to uranium (92), and provides detection limits at the ppm level; it can also measure concentrations of up to 100%. For this testing, only qualified person can do the test thus the author does not perform the test since this involved x-ray. Small amount of RHA were given to the lab technologist.

3.3 Hazard Analysis

Safety measures and precaution steps in handling the laboratory work especially the stabilizers are presented in the table below.

3.3.1 Mixer

Basic Job Steps	Potential Accidents or Hazards	Recommended Safe Job Procedure
i. Filled the mixer bowl with sample.	o Expose to the dust	o Wear protective mask
ii. Place the agitator in the bowl, push it up on the agitator shaft and turn it clockwise.	o Blockade fingers	o Wear protective glove
iii. When the agitator mixing the sample.	o Expose to the dust o Expose to the rotating agitator	o Wear protective mask and safety goggle. o Have adequate distance with the agitator
iv. Switch off the power supply.	o Electrical shock	o Wear protective glove
v. Pulled down the bowl lift handle and move agitator. After that pulled out the bowl.	o Blockade fingers	o Wear protective glove

3.3.2 Unconfined Compression Test

Basic Job Steps	Potential Accidents or Hazards	Recommended Safe Job Procedure
i. Switch on the motor.	o Finger stuck	o Keep away finger when machine is running
ii. Lower the machine plate and remove the specimen.	o Finger stuck	o Keep away fingers
iii. Determine moisture content.	o Contact of the hot oven to skins	o Wear protective gloves

3.3.3 Universal Extruder

Basic Job Steps	Potential Accidents or Hazards	Recommended Safe Job Procedure
i. Choose the suitable frame and plate.	o The frame drop	o Wear protective shoes o Wear protective gloves
ii. Put the sample center of the extruder.	o The sample drop	o Wear protective shoes o Wear protective gloves
iii. Remove the sample from the extruder.	o The sample drop	o Wear protective shoes o Wear protective gloves
iv. Release the screw below to push down the extruder.	o The oil leaking	o Beware during release the screw

3.3.4 Sieve Shaker Set

Basic Job Steps	Potential Accidents or Hazards	Recommended Safe Job Procedure
i. Arrange the sieve sieves according their size. And put the soil sample inside the sieves.	o Expose to the dust	o Wear protective mask
ii. Tighten the locknut and set the timer	o Blockade fingers	o Wear protective gloves
iii. Switching on the machine. And wait until set up timing.	o Electrical shock o Expose to loud noise	o Wear protective gloves o Wear protective ear plug

3.3.5 Drying Oven

Basic Job Step	Potential Accidents or Hazards	Recommended Safe Job Procedure
i. Place sample in the oven.	o Contact of the hot oven to skins	o Wear protective gloves

3.3.6 Compaction Test

Basic Job Steps	Potential Accidents or Hazards	Recommended Safe Job Procedure
i. Locate centrally the mould at the base of compaction.	o The hammer drop	o Use scoop
ii. Fit the mould with screw	o The hammer drop	o Beware with your hand
iii. The compaction machine running.	o The hammer drop	o Wear protective shoes
iv. Add more soil sample in the mould.	o The hammer drop	o Use scoop
v. After finish the compaction, lock the safety key and remove the mould.		

CHAPTER 4 : RESULTS AND DISCUSSION

4.1 Introduction

In this project, several laboratories will be done in order to achieve the objectives stated. Currently, four tests had been carried out which are specific gravity, particle size distribution, compaction, and unconfined compressive test.

4.2 Specific Gravity

Table 4.1: Specific Gravity for Marine Clay and Mixture of Marine Clay + RHA (4-10%)

Samples	**Specific Gravity, Mg/m^3**
Marine Clay	2.729
Marine Clay + RHA (4%)	2.725
Marine Clay + RHA (6%)	2.723
Marine Clay + RHA (8%)	2.722
Marine Clay + RHA (10%)	2.720

Referring the Table above, it can be said that the sample is clayey and silty soil and the mixture of marine clay-RHA is also lies within the same range of 2.6-2.9. This is because RHA is a fine material and thus give effect to the specific gravity of marine clay. The detail calculations are represented in Table A.1 to Table 6 in Appendix A.

4.3 Particle Size Distribution

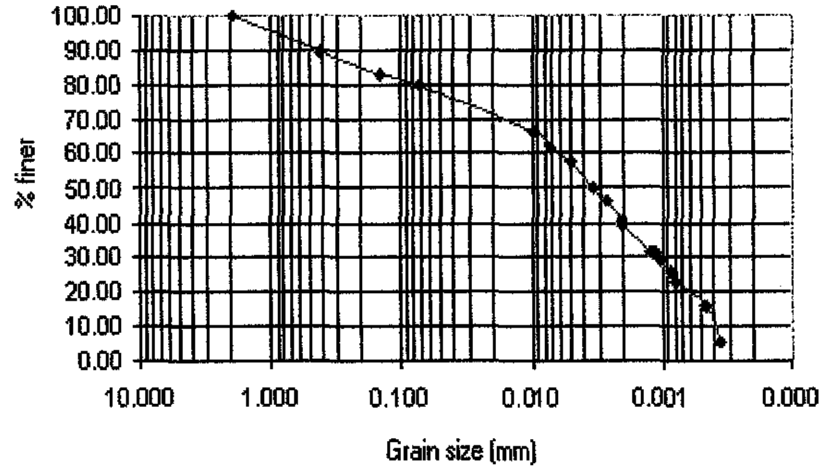

Figure 4.1: Particle Size Distribution Curve for Marine Clay

From figure 4.1 above, 3 parameters were determined, D_{10}, D_{30}, and D_{60}. These values are tabulated in the Table below:-

Table 4.2: The values of D_{60}, D_{30}, D_{10}, C_{u} and C_{z}

SAMPLE	D60	D30	D10	Cu	Cz
Marine Clay	0.006	0.001	0.0003	20.000	0.556

The sample which is the marine clay is proven to be in the clay and silty region. The particle size distribution curve shows that more than 50% of the sample lies below the size of 0.06mm. According to Unified Soil Classification System (ASTM D2487), marine clay is classified as poorly graded soil.

4.4 Compaction Test

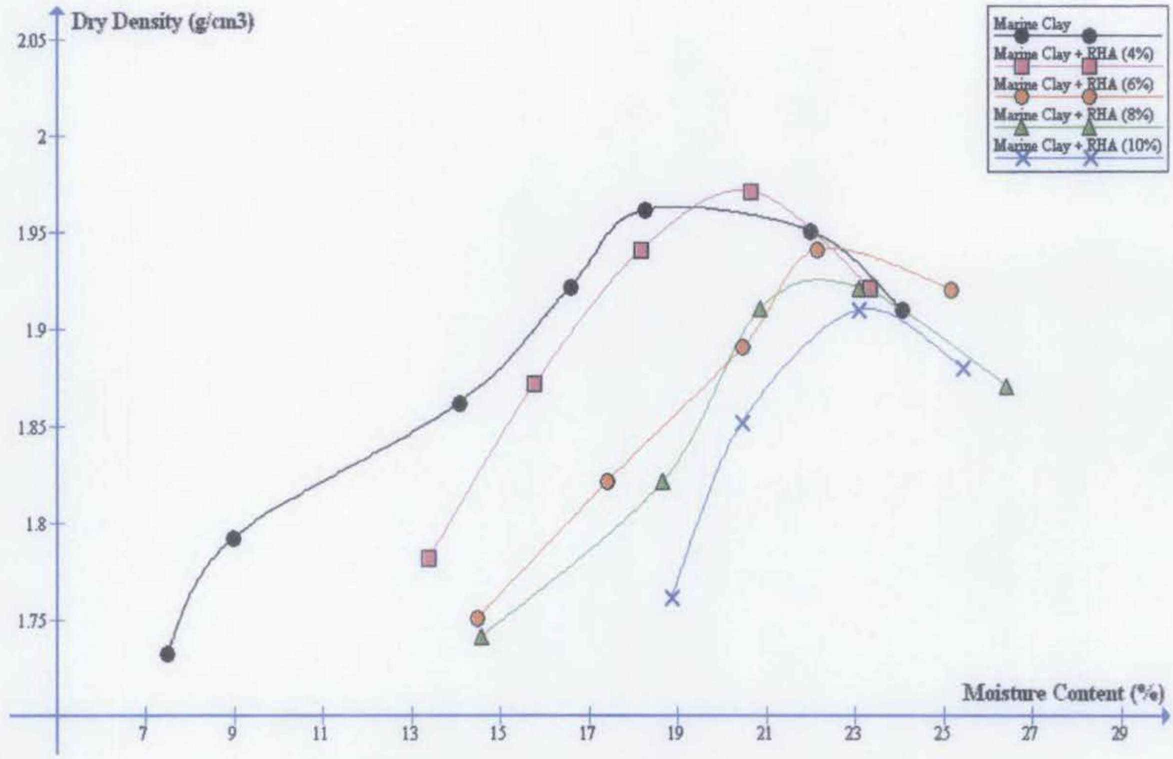

Figure 4.2: Compaction Curve for Marine Clay + RHA (4-10%)

From figure 4.2 above, it shows that the value of dry density increases with the increases of moisture content. Up to a certain point, the value of dry density will decrease with the increases of moisture content. This is because, when water is added to the soil during compaction, its acts as a softening agent on the soil particles. The soil particles slip over each other and move into a densely packed position. Beyond certain moisture content, any increase in the moisture content tends to reduce the dry unit weight. This phenomenon occurs because the water takes up the spaces that would have been occupied by the solid particles. The moisture content at which the maximum dry unit weight is attained is generally referred to as the optimum moisture content (Cited from Musa Al-Hassan, 2008).

The variations of maximum dry densities (MDD) and optimum moisture content (OMC) with stabilizers contents are shown in figure 4.3 and figure 4.4.

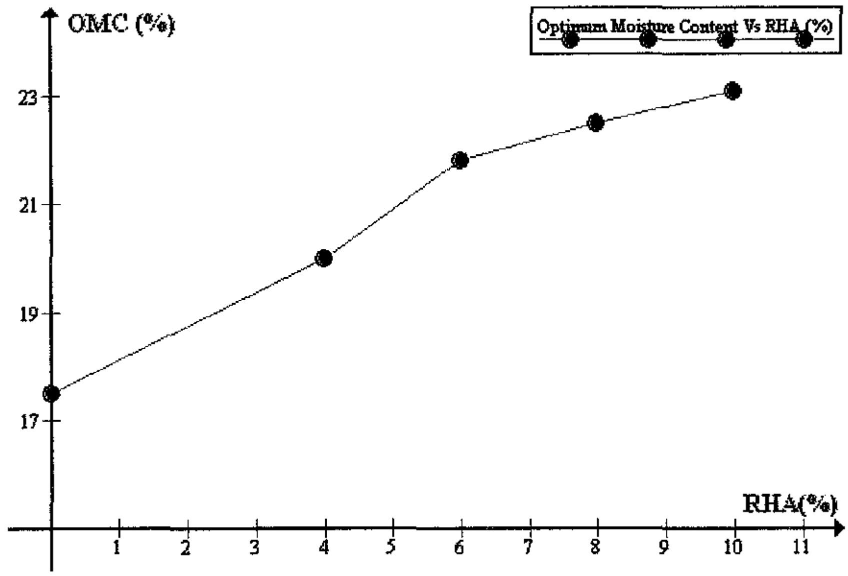

Figure 4.3: Optimum Moisture Content Vs RHA Addition (%)

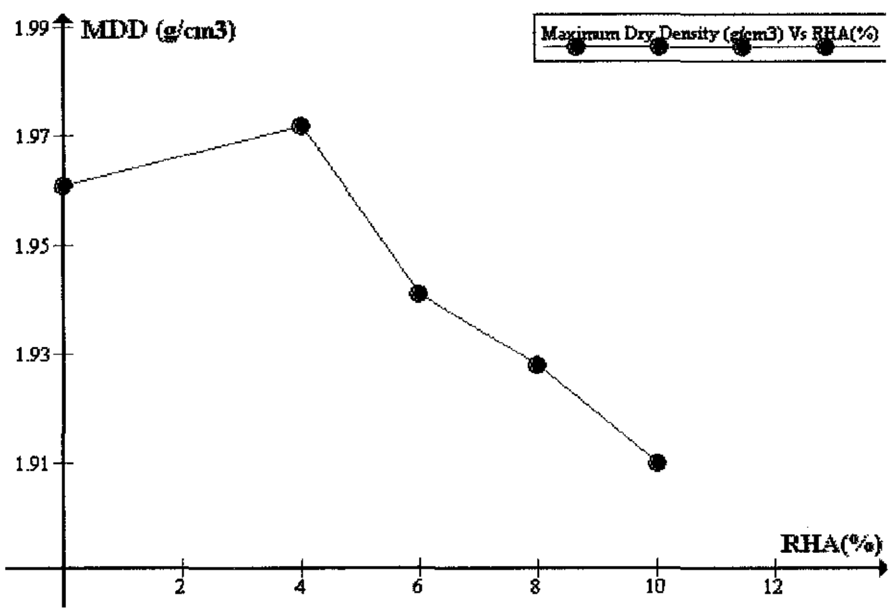

Figure 4.4: Maximum Dry Density Vs RHA Addition (%)

According to figures 4.3 and 4.4, the OMC increased while the MDD decreased with the addition of RHA content.

The decrease in the MDD is due to the partial replacement of soil by the RHA in the mixture which have relatively lower specific gravity (2.25) compared to that of the soil which is (2.729). The decrease in the MDD may also be explained by the particles of RHA which is a fine material filled the void between the particles of the marine clay.

By observing the graph, there was increase in OMC with addition of RHA contents. This can be explained by a process where the additional amounts of RHA decrease the quantity of free silt and clay fraction. Coarser materials with larger surface areas were formed. The OMC will increase because this process needs water in order to take place. This will also indicate that water is needed in order to compact the soil-RHA mixtures.

4.5 Unconfined Compressive Strength

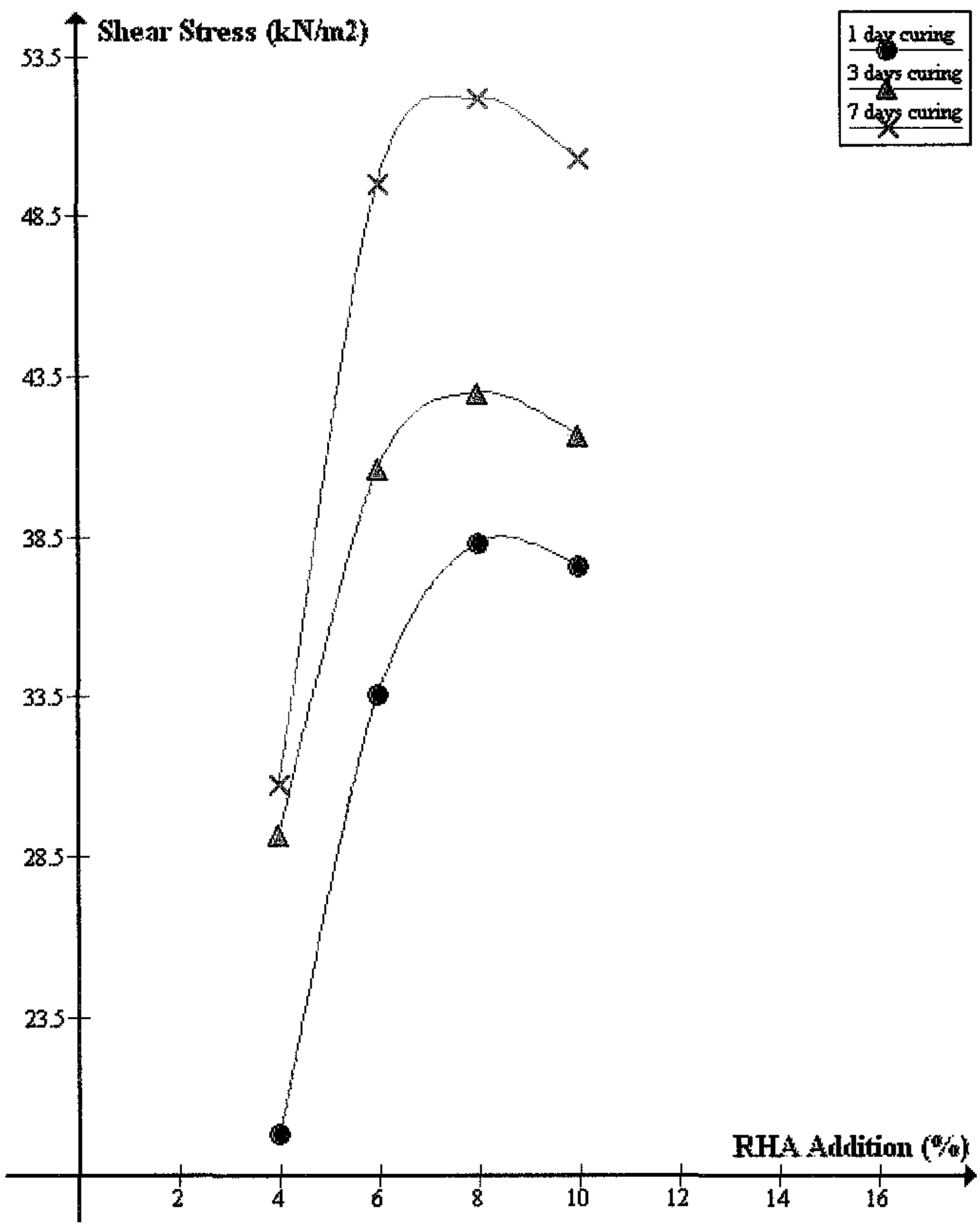

Figure 4.5: Shear Stress Vs RHA Addition (4-10%)

Figure 4.5 shows the effect of curing (1, 3 and 7 days) to the shear stress of the mixtures of Marine Clay-RHA (4-10%). From the graph, it shows that the longer period of curing, the higher the value of shear stress. It also indicates that when the amount of RHA is added, the value of shear stress also increases. But for Marine Clay-RHA (10%), the value of shear stress is decreased.

Variation of shear stress value with increase in RHA from 4% to 10% for 1 day, 3 days and 7 days curing period were investigated and the results for the three curing periods are shown in figure 4.5.

The shear stress values increase with subsequent addition of RHA to its maximum at 8% RHA after which it dropped at 10% RHA. The subsequent increase in the UCS is attributed to the formation of cementitious compounds between the mineral present in the clay and the pozzolans present in the RHA. Bonding between the cementitious compound and the soil improve the interlocking of the marine clay. This decrease in the UCS values after the addition of 8% RHA may be due to the excess RHA introduced to the soil and therefore forming weak bonds between the soil and the cementitious compounds formed.

The summary of the results for the unconfined compressive strength is presented in the Table 4.3 and the details of the results are tabulated in Table A.6 to Table 17 in Appendix A.

Table 4.3: Shear Stress for Cured Marine Clay-RHA (4-10%) at 1,3 and 7 days

Soil Sample	RHA addition, %	Shear Stress, kN/m^2		
		1 day	3 days	7 days
Marine Clay	0%	-	-	29.732
	4%	19.835	29.175	30.737
	6%	33.565	40.607	49.482
	8%	38.321	42.974	52.173
	10%	37.580	41.634	50.262

4.6 Atterberg Limits.

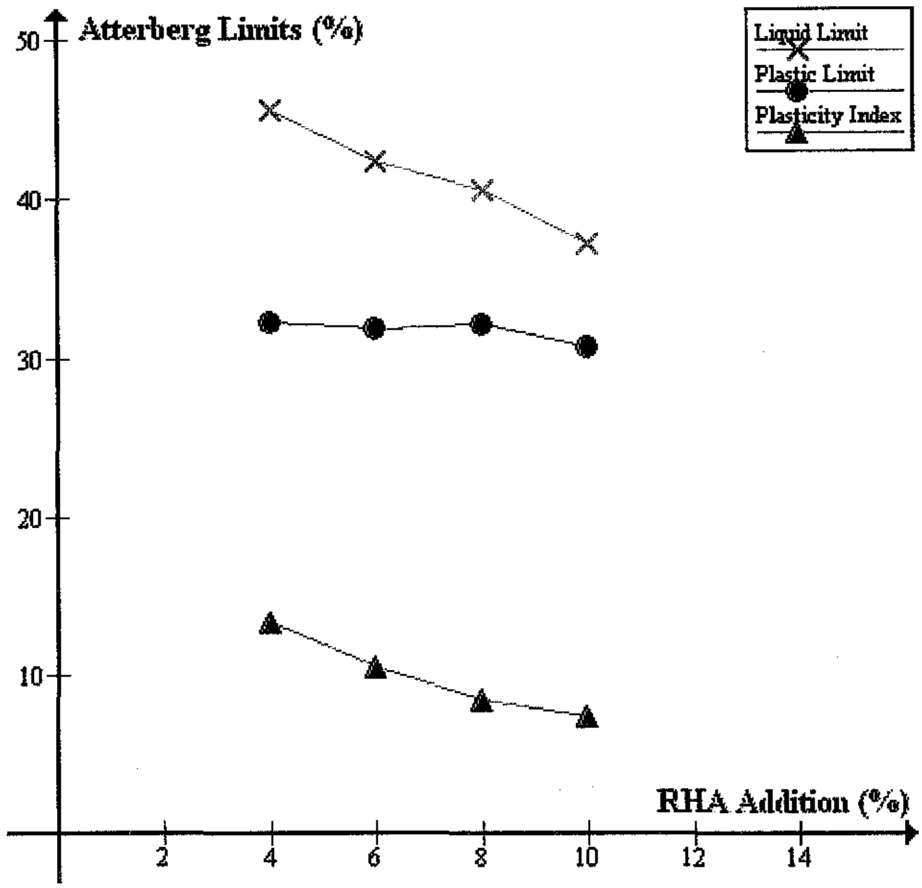

Figure 4.6: RHA Influence on Atterberg Limits of Marine Clay

Figure 4.6 shows the RHA influence on Atterberg limits of Marine Clay. According to the graph, RHA reduces the liquid limits while the plastic limits increased. As a result, the plasticity index reduced. This indicates that the swelling potential of the clay diminished with the addition of RHA.

Bell (1996) had mentioned that combination of marine clay and RHA reduced the swell considerably (Cited from Agus Setyo Muntohar (2006b). This is due to clods resulted from cementation process between RHA-soil. The clod tends to reduced permeability of the whole sample, thereby restricting the tendency of the soils to increase in volumetric strain. Besides that, the addition of RHA would fill in the intervoid of the soil particles. Concomitantly, the swelling pressure also decreased appreciably.

CHAPTER 5 : CONCLUSION AND RECCOMENDATION

The study has been successfully conducted to asses the geotechnical properties of clay soils improved with RHA wastes. From the results of this study, the following conclusion can be drawned:

i) The shear strength value was at their peak at 8%. The shear strength of the mix also increased with curing age.

ii) Since the optimum amount of 8% RHA subjected to 7 days curing period produced the highest strength, hence the ideal mix proportion to stabilize the marine clay is marine clay (92%) and RHA (8%) or 11.5:1 ratio.

iii) In term of compaction, the optimum moisture content (OMC) move to wet condition, and maximum dry density (MDD) generally decreased. It indicates the additive, especially RHA; absorb more water to attain its MDD.

The results of the study show little potentials of using RHA alone for soil improvement. It is therefore recommended that RHA should be used with cement or lime for the formation of secondary cementitious compound with the CaOH produced from the hydration of cement or when in use with lime (CaOH). Soil stabilisation is usually an alternative to the solution to a practical problem. In the case of clay soils, chemical improvement using RHA is commonly effective since it can be used to change the nature of the material. The innovative use of RHA has many benefits and as the construction works has become more aggressive on the coastal region in our country, more applications will almost certainly be raised. These require detail investigation, because the processes are complex, and the specialist needs to be involved at an early stage to ensure the success of the project.

REFERENCE

Baiardo *et. al*, (2004), "Soft Clay Behaviour Analysis and Assessment", A.A. Balkema Publishers.

Das, B.M., (2002), "Priciple of Geotechnical Engineering Fifth Edition", Bill Stenquist. Hanson, James L, Termaat,R.J., (2000), Soft Ground Technology. Americal Society of Civil Engineers.

Farrell and Hebib, 1998. Pulverised Fuel Ash Part 1: Origin and Properties. Current Practice sheet No. 116. Concrete Vol April. pg27.

Kamon & Bergado, 1991. Foundation on Expansive Soil, Development in Engineering 12. Elsevier Scientific Publishing Company, New York

Lazaro, R.C., & Moh, Z.C, (2006). Stabilisation of deltaic clays with lime-rice husk ash admixtures. The 2nd Southeast Asian Conference on Soil Engineering, Singapore.

Muntohar, A.S., 2006a, Effect of Lime and Rice Husk Ash on the Soft Clay, Regional Seminar at Islamic University of Indonesia, Yogyakarta, Indonesia

Muntohar, A.S., 2006b, Behavior of Engineering Properties on Blended with LRHA (Lime Rice Husk Ash), Research Report for Graduate, Muhammadiyah University of Yogyakarta, Indonesia

Musa Al-Hassan. April 2008, Potential of Rice Husk Ash for Soil Stabilisation, Department of Civil Engineering, Federal University of Technology Minna, Niger State, Nigeria.

O'Donnell *et. al*, 2004. Physical and Geotechnical Soil Properties, John Wiley & Sons Inc., New York, USA.

Oyetola and Abdullahi, 2006. Rice Hulls Rice; Production and Utilization.

ASTM D 2216: Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass

ASTM D 2974 - Standard Test Method for Moisture, Ash, and Organic Matter of Peat and Organic Soils

ASTM D 854 - Standard Test Method for Specific Gravity of Soil Solids by Water Pycnometer

ASTM D 422 - Standard Test Method for Particle-Size Analysis of Soils

ASTM D 2166 – Standard Test Method for Unconfined Compressive Strength of Cohesive Soil

ASTM 618 - Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolana for use as a Mineral Admixture in Concrete

APPENDIX A

Table A.1: Specific gravity test for Marine Clay

Specimen reference		Marine clay
Mass of jar + gas jar + plate + soil + water (m_3)	(g)	1758.91
Mass of jar + gas jar + plate + soil (m_2)	(g)	932.38
Mass of jar + gas jar + plate + water (m_4)	(g)	1507.33
Mass of jar + gas jar + plate (m_1)	(g)	534.22
Mass of soil ($m_2 - m_1$)	(g)	400.16
Mass of water in full jar ($m_4 - m_1$)	(g)	973.11
Mass of water used ($m_3 - m_2$)	(g)	826.53
Volume of soil particles ($m_4 - m_1$) – ($m_3 - m_2$)	ML	146.58
Particle density, ρs = $\frac{(m_2 - m_1)}{(m_4 - m1) - (m_3 - m_2)}$	Mg/m³	2.729
Average value, ρs	**Mg/m³**	**2.729**

Table A.2: Specific gravity test for Marine Clay + 4% RHA

Specimen reference		Marine Clay + RHA (4%)
Mass of jar + gas jar + plate + soil + water (m_3)	(g)	1760.67
Mass of jar + gas jar + plate + soil (m_2)	(g)	934.55
Mass of jar + gas jar + plate + water (m_4)	(g)	1507.33
Mass of jar + gas jar + plate (m_1)	(g)	534.35
Mass of soil ($m_2 - m_1$)	(g)	400.20
Mass of water in full jar ($m_4 - m_1$)	(g)	972.98
Mass of water used ($m_3 - m_2$)	(g)	826.12
Volume of soil particles ($m_4 - m_1$) – ($m_3 - m_2$)	ML	146.86
Particle density, ρs = $\frac{(m_2 - m_1)}{(m_4 - m1) - (m_3 - m_2)}$	Mg/m³	2.725
Average value, ρs	**Mg/m³**	**2.725**

Table A.3: Specific gravity test for Marine Clay + 6% RHA

Specimen reference		Marine Clay + RHA (6%)
Mass of jar + gas jar + plate + soil + water (m_3)	(g)	1760.34
Mass of jar + gas jar + plate + soil (m_2)	(g)	934.31
Mass of jar + gas jar + plate + water (m_4)	(g)	1507.33
Mass of jar + gas jar + plate (m_1)	(g)	534.47
Mass of soil $(m_2 - m_1)$	(g)	399.84
Mass of water in full jar $(m_4 - m_1)$	(g)	972.86
Mass of water used $(m_3 - m_2)$	(g)	826.03
Volume of soil particles $(m_4 - m_1) - (m_3 - m_2)$	ML	146.83
Particle density, $\rho s = \frac{(m_2 - m_1)}{(m_4 - m1) - (m_3 - m_2)}$	Mg/m^3	2.723
Average value, ρs	**Mg/m^3**	**2.723**

Table A.4: Specific gravity test for Marine Clay + 8% RHA

Specimen reference		Marine Clay + RHA (8%)
Mass of jar + gas jar + plate + soil + water (m_3)	(g)	1761.55
Mass of jar + gas jar + plate + soil (m_2)	(g)	935.01
Mass of jar + gas jar + plate + water (m_4)	(g)	1508.17
Mass of jar + gas jar + plate (m_1)	(g)	534.50
Mass of soil $(m_2 - m_1)$	(g)	400.50
Mass of water in full jar $(m_4 - m_1)$	(g)	973.67
Mass of water used $(m_3 - m_2)$	(g)	826.54
Volume of soil particles $(m_4 - m_1) - (m_3 - m_2)$	ML	147.03
Particle density, $\rho s = \frac{(m_2 - m_1)}{(m_4 - m1) - (m_3 - m_2)}$	Mg/m^3	2.722
Average value, ρs	**Mg/m^3**	**2.722**

Table A.5: Specific gravity test for Marine Clay + 10% RHA

Specimen reference		Marine Clay + RHA (10%)
Mass of jar + gas jar + plate + soil + water (m_3)	(g)	1759.39
Mass of jar + gas jar + plate + soil (m_2)	(g)	933.93
Mass of jar + gas jar + plate + water (m_4)	(g)	1506.48
Mass of jar + gas jar + plate (m_1)	(g)	533.98
Mass of soil ($m_2 - m_1$)	(g)	399.95
Mass of water in full jar ($m_4 - m_1$)	(g)	972.50
Mass of water used ($m_3 - m_2$)	(g)	825.46
Volume of soil particles ($m_4 - m_1$) – ($m_3 - m_2$)	ML	147.04
Particle density, ρs = $\frac{(m_2 - m_1)}{(m_4 - m1) - (m_3 - m_2)}$	Mg/m^3	2.720
Average value, ρs	**Mg/m^3**	**2.720**

Table A.6: Unconfined Compressive Test for Marine Clay at 7 days curing

Deformation Gauge Reading	Compression of Specimen	Strain, ε	Force Gauge Reading	Axial force P	Corrected area	Axial Stress	Shear Strength
0	0.0	0.000	0	0.00	1152.69	0.00	0.00
20	0.2	0.263	14	2.85	1152.69	2.477	1.239
40	0.4	0.526	35	7.14	1152.69	6.194	3.097
60	0.6	0.789	56	11.42	1152.69	9.911	4.555
80	0.8	1.053	91	18.56	1152.69	16.105	8.052
100	1.0	1.316	123	25.09	1152.69	21.768	10.884
120	1.2	1.579	150	30.60	1152.69	26.547	13.273
140	1.4	1.842	178	36.31	1152.69	31.503	15.751
160	1.6	2.105	202	41.20	1152.69	35.749	17.875
180	1.8	2.368	223	45.49	1152.69	39.466	19.733
200	2.0	2.632	244	49.77	1152.69	43.182	21.591
220	2.2	2.895	262	53.44	1152.69	46.368	23.184
240	2.4	3.158	280	5.711	1152.69	49.547	24.773
260	2.6	3.421	300	61.20	1152.69	53.093	26.547
280	2.8	3.684	320	65.28	1152.69	56.633	28.316
300	3.0	3.947	336	68.54	1152.69	59.464	**29.732**

Table A.7: Unconfined Compressive Test for Marine Clay + 4%RHA at 1 day curing

Deformation Gauge Reading	Compression of Specimen	Strain, ε	Force Gauge Reading	Axial force P	Corrected area	Axial Stress	Shear Strength
0	0.0	0.000	0	0	1151.92	0	0
20	0.2	0.263	22	4.488	1151.92	3.896	1.948
40	0.4	0.526	30	6.120	1151.92	5.313	2.657
60	0.6	0.789	42	8.568	1151.92	7.438	3.719
80	0.8	1.053	52	10.608	1151.92	9.209	4.605
100	1.0	1.316	59	12.036	1151.92	10.449	5.225
120	1.2	1.579	69	14.076	1151.92	12.220	6.110
140	1.4	1.842	75	15.300	1151.92	13.282	6.641
160	1.6	2.105	82	16.728	1151.92	14.522	7.261
180	1.8	2.368	90	18.360	1151.92	15.939	7.970
200	2.0	2.632	96	19.584	1151.92	17.001	8.504
220	2.2	2.895	102	20.808	1151.92	18.064	9.032
240	2.4	3.158	108	22.032	1151.92	19.126	95.63
260	2.6	3.421	113	23.052	1151.92	20.012	10.006
280	2.8	3.684	120	24.480	1151.92	21.251	10.626
300	3.0	3.947	125	25.500	1151.92	22.137	11.069
320	3.2	4.208	128	26.112	1151.92	22.668	11.334
340	3.4	4.471	132	26.928	1151.92	23.377	11.689
360	3.6	4.734	138	28.152	1151.92	24.439	12.220
380	3.8	4.997	143	29.172	1151.92	25.325	12.663
400	4.0	5.260	148	30.192	1151.92	26.210	13.105
420	4.2	5.523	152	31.008	1151.92	26.919	13.460
440	4.4	5.786	157	32.028	1151.92	27.804	13.902
460	4.6	6.049	160	32.640	1151.92	28.335	14.168
480	4.8	6.312	165	33.660	1151.92	29.221	14.611
500	5.0	6.575	170	34.680	1151.92	30.106	15.053
520	5.2	6.838	172	35.088	1151.92	30.460	15.230
540	5.4	7.101	176	35.904	1151.92	31.169	15.585
560	5.6	7.364	179	36.516	1151.92	31.700	15.850
580	5.8	7.627	183	37.332	1151.92	32.409	16.205
600	6.0	7.890	187	38.148	1151.92	33.117	16.559
620	6.2	8.153	190	38.760	1151.92	33.648	16.824
640	6.4	8.416	192	39.168	1151.92	34.002	17.001
660	6.6	8.679	197	40.188	1151.92	34.888	17.444
680	6.8	8.942	200	40.800	1151.92	35.419	17.710
700	7.0	9.205	203	41.412	1151.92	35.950	17.975
720	7.2	9.468	205	41.820	1151.92	36.305	18.153
740	7.4	9.731	208	42.432	1151.92	36.836	18.418
760	7.6	9.994	210	42.840	1151.92	37.190	18.595
780	7.8	10.257	212	43.248	1151.92	37.544	18.772
800	8.0	10.520	216	44.064	1151.92	38.253	19.127
820	8.2	10.783	217	44.268	1151.92	38.430	19.215
840	8.4	11.046	217	44.268	1151.92	38.430	19.215

860	8.6	11.309	220	44.880	1151.92	38.961	19.481
880	8.8	11.572	221	45.084	1151.92	39.138	19.569
900	9.0	11.835	222	45.288	1151.92	39.315	19.658
920	9.2	12.098	224	45.696	1151.92	39.669	19.835
940	9.4	12.361	224	45.696	1151.92	39.669	**19.835**

Table A.8: Unconfined Compressive Test for Marine Clay + 4%RHA at 3 days curing

Deformation Gauge Reading	Compression of Specimen	Strain, ε	Force Gauge Reading	Axial force P	Corrected area	Axial Stress	Shear Strength
0	0.0	0.000	0	0	1150.21	0	0
20	0.2	0.263	32	6.528	1150.21	5.675	2.838
40	0.4	0.526	45	9.180	1150.21	7.981	3.991
60	0.6	0.789	57	11.28	1150.21	10.090	5.055
80	0.8	1.053	68	13.872	1150.21	12.060	6.030
100	1.0	1.316	77	15.708	1150.21	13.657	6.829
120	1.2	1.579	86	17.544	1150.21	15.253	7.627
140	1.4	1.842	98	19.992	1150.21	17.381	8.691
160	1.6	2.105	108	22.032	1150.21	19.155	9.578
180	1.8	2.368	118	24.072	1150.21	20.928	10.464
200	2.0	2.632	126	25.704	1150.21	22.347	11.174
220	2.2	2.895	135	17.540	1150.21	15.249	7.625
240	2.4	3.158	143	29.172	1150.21	25.362	12.681
260	2.6	3.421	150	30.600	1150.21	26.604	13.302
280	2.8	3.684	157	32.028	1150.21	27.845	13.923
300	3.0	3.947	164	33.456	1150.21	29.087	14.544
320	3.2	4.208	170	34.680	1150.21	30.151	15.076
340	3.4	4.471	176	35.904	1150.21	31.215	15.608
360	3.6	4.734	182	37.128	1150.21	32.279	16.140
380	3.8	4.997	188	38.352	1150.21	33.343	16.672
400	4.0	5.260	194	39.576	1150.21	34.408	17.204
420	4.2	5.523	199	40.596	1150.21	35.294	17.647
440	4.4	5.786	205	41.820	1150.21	36.359	18.180
460	4.6	6.049	210	42.840	1150.21	37.245	18.623
480	4.8	6.312	213	43.452	1150.21	37.777	18.889
500	5.0	6.575	220	44.880	1150.21	39.019	19.510
520	5.2	6.838	223	45.492	1150.21	39.551	19.776
540	5.4	7.101	229	46.716	1150.21	40.615	20.308
560	5.6	7.364	233	47532	1150.21	41.325	20.663
580	5.8	7.627	238	48.552	1150.21	42.211	21.106
600	6.0	7.890	242	49.368	1150.21	42.921	21.461
620	6.2	8.153	246	50.184	1150.21	43.630	21.815
640	6.4	8.416	252	51.408	1150.21	44.694	22.347
660	6.6	8.679	256	52.224	1150.21	45.404	22.702
680	6.8	8.942	260	53.040	1150.21	46.113	23.057

700	7.0	9.205	264	53.856	1150.21	46.823	23.412
720	7.2	9.468	268	54.672	1150.21	47.532	23.766
740	7.4	9.731	272	55.488	1150.21	48.228	24.114
760	7.6	9.994	275	56.100	1150.21	48.774	24.387
780	7.8	10.257	278	56.712	1150.21	49.306	24.653
800	8.0	10.520	282	57.528	1150.21	50.015	25.008
820	8.2	10.783	285	58.140	1150.21	50.547	25.274
840	8.4	11.046	288	58.752	1150.21	51.079	25.540
860	8.6	11.309	292	59.568	1150.21	51.789	25.895
880	8.8	11.572	295	60.180	1150.21	52.321	26.161
900	9.0	11.835	298	60.792	1150.21	52.853	26.427
920	9.2	12.098	300	61.200	1150.21	63.208	31.604
940	9.4	12.361	303	61.812	1150.21	53.740	26.870
960	9.6	12.624	305	62.220	1150.21	54.094	27.047
980	9.8	12.887	307	62.628	1150.21	54.449	27.225
1000	10.0	13.150	310	63.240	1150.21	54.981	27.491
1020	10.2	13.413	312	63.648	1150.21	55.336	27.668
1040	10.4	13.686	314	64.056	1150.21	55.691	27.846
1060	10.6	13.939	315	64.260	1150.21	55.868	27.934
1080	10.8	14.202	317	64.668	1150.21	56.223	28.112
1100	11.0	14.465	320	65.280	1150.21	56.755	28.378
1120	11.2	14.728	321	65.484	1150.21	56.932	28.466
1140	11.4	14.991	322	65.688	1150.21	57.110	28.555
1160	11.6	15.254	324	66.096	1150.21	57.464	28.732
1180	11.8	15.517	325	66.300	1150.21	57.642	28.821
1200	12.0	15.780	326	66.504	1150.21	57.819	28.910
1220	12.2	16.043	328	66.912	1150.21	58.174	29.087
1240	12.4	16.306	329	67.116	1150.21	58.351	**29.175**

Table A.9: Unconfined Compressive Test for Marine Clay + 4%RHA at 7 days curing

Deformation Gauge Reading	Compression of Specimen	Strain, ε	Force Gauge Reading	Axial force P	Corrected area	Axial Stress	Shear Strength
0	0.0	0.000	0	0	1151.34	0	0
20	0.2	0.263	18	3.672	1151.34	31.89	1.595
40	0.4	0.526	35	7.140	1151.34	62.01	3.101
60	0.6	0.789	49	9.996	1151.34	86.82	4.341
80	0.8	1.053	64	13.056	1151.34	11.340	5.670
100	1.0	1.316	78	15.912	1151.34	13.820	6.910
120	1.2	1.579	93	18.972	1151.34	16.478	8.239
140	1.4	1.842	105	21.420	1151.34	18.604	9.302
160	1.6	2.105	118	24.072	1151.34	20.908	10.54
180	1.8	2.368	127	25.908	1151.34	22.502	12.51
200	2.0	2.632	136	27.744	1151.34	24.097	12.49

220	2.2	2.895	143	29.172	1151.34	25.337	12.669
240	2.4	3.158	151	30.804	1151.34	26.755	13.378
260	2.6	3.421	157	32.028	1151.34	27.818	13.909
280	2.8	3.684	162	33.048	1151.34	38.704	19.352
300	3.0	3.947	169	34.476	1151.34	29.944	14.972
320	3.2	4.208	174	35.496	1151.34	30.830	15.415
340	3.4	4.471	178	36.312	1151.34	31.539	15.770
360	3.6	4.734	185	37.740	1151.34	32.779	16.390
380	3.8	4.997	190	38.760	1151.34	33.665	16.833
400	4.0	5.260	195	39.780	1151.34	34.551	17.276
420	4.2	5.523	200	40.800	1151.34	35.437	17.719
440	4.4	5.786	205	41.820	1151.34	36.323	18.162
460	4.6	6.049	210	42.840	1151.34	37.209	18.605
480	4.8	6.312	214	43.656	1151.34	37.918	18.959
500	5.0	6.575	219	44.676	1151.34	38.803	19.402
520	5.2	6.838	222	45.288	1151.34	39.335	19.668
540	5.4	7.101	227	46.308	1151.34	40.221	20.111
560	5.6	7.364	230	46.920	1151.34	40.753	20.377
580	5.8	7.627	236	48.144	1151.34	41.816	20.908
600	6.0	7.890	240	48.960	1151.34	42.524	21.262
620	6.2	8.153	245	49.980	1151.34	43.410	21.705
640	6.4	8.416	249	50.796	1151.34	44.119	22.060
660	6.6	8.679	253	51.612	1151.34	44.828	22.414
680	6.8	8.942	258	52.632	1151.34	45.714	22.857
700	7.0	9.205	262	53.448	1151.34	46.422	23.211
720	7.2	9.468	266	54.264	1151.34	47.131	23.566
740	7.4	9.731	270	55.080	1151.34	47.840	23.920
760	7.6	9.994	274	55.896	1151.34	48.549	24.275
780	7.8	10.257	277	56.508	1151.34	49.080	24.540
800	8.0	10.520	280	57.120	1151.34	49.612	24.806
820	8.2	10.783	285	58.140	1151.34	50.498	25.249
840	8.4	11.046	289	58.956	1151.34	51.206	25.603
860	8.6	11.309	292	59.568	1151.34	51.738	25.869
880	8.8	11.572	296	60.384	1151.34	52.447	26.224
900	9.0	11.835	300	61.200	1151.34	53.155	26.578
920	9.2	12.098	303	61.812	1151.34	53.687	26.844
940	9.4	12.361	306	62.424	1151.34	54.219	27.110
960	9.6	12.624	309	63.036	1151.34	54.750	27.375
980	9.8	12.887	312	63.648	1151.34	55.282	27.641
1000	10.0	13.150	314	64.056	1151.34	55.636	27.818
1020	10.2	13.413	317	64.668	1151.34	56.168	28.084
1040	10.4	13.686	320	65.280	1151.34	56.699	28.350
1060	10.6	13.939	322	65.688	1151.34	57.054	28.527
1080	10.8	14.202	324	66.096	1151.34	57.408	28.704
1100	11.0	14.465	327	66.708	1151.34	57.939	28.970
1120	11.2	14.728	330	67.320	1151.34	58.471	29.236
1140	11.4	14.991	332	67.728	1151.34	58.825	29.413
1160	11.6	15.254	334	68.136	1151.34	59.180	29.590

1180	11.8	15.517	336	68.544	1151.34	59.534	29.767
1200	12.0	15.780	338	68.952	1151.34	59.888	29.944
1220	12.2	16.043	340	69.360	1151.34	60.243	30.122
1240	12.4	16.306	342	69.768	1151.34	60.597	30.299
1260	12.6	16.569	343	69.972	1151.34	60.774	30.387
1280	12.8	16.832	344	70.776	1151.34	61.473	**30.737**

Table A.10: Unconfined Compressive Test for Marine Clay+ 6%RHA at 1 day curing

Deformation Gauge Reading	Compression of Specimen	Strain, ε	Force Gauge Reading	Axial force P	Corrected area	Axial Stress	Shear Strength
0	0.0	0.000	0	0.00	1151.73	0.00	0.00
20	0.2	0.263	40	8.160	1151.73	7.085	3.543
40	0.4	0.526	68	13.872	1151.73	12.044	6.022
60	0.6	0.789	91	18.564	1151.73	16.118	8.059
80	0.8	1.053	110	22.440	1151.73	19.484	9.742
100	1.0	1.316	124	25.296	1151.73	21.963	10.982
120	1.2	1.579	141	28.764	1151.73	24.975	12.488
140	1.4	1.842	155	31.620	1151.73	27.454	13.727
160	1.6	2.105	167	34.068	1151.73	29.580	14.790
180	1.8	2.368	173	35.292	1151.73	30.643	15.322
200	2.0	2.632	186	37.944	1151.73	32.945	16.473
220	2.2	2.895	196	39.984	1151.73	34.716	17.358
240	2.4	3.158	207	42.228	1151.73	36.665	18.333
260	2.6	3.421	213	43.452	1151.73	37.723	18.862
280	2.8	3.684	222	45.288	1151.73	39.322	19.661
300	3.0	3.947	229	46.716	1151.73	40.562	20.281
320	3.2	4.208	240	48.960	1151.73	42.510	21.255
340	3.4	4.471	250	51.000	1151.73	44.281	22.141
360	3.6	4.734	255	52.020	1151.73	45.167	22.584
380	3.8	4.997	250	51.000	1151.73	44.281	22.141
400	4.0	5.260	257	52.428	1151.73	45.521	22.761
420	4.2	5.523	266	54.264	1151.73	47.115	23.558
440	4.4	5.786	274	55.896	1151.73	48.532	24.266
460	4.6	6.049	276	56.304	1151.73	48.886	24.443
480	4.8	6.312	283	57.732	1151.73	50.126	25.063
500	5.0	6.575	292	59.568	1151.73	51.720	25.860
520	5.2	6.838	300	61.200	1151.73	53.137	26.569
540	5.4	7.101	305	62.220	1151.73	54.023	27.012
560	5.6	7.364	312	63.648	1151.73	55.263	27.632
580	5.8	7.627	320	65.280	1151.73	56.680	28.340
600	6.0	7.890	321	65.448	1151.73	56.826	28.413
620	6.2	8.153	330	67.320	1151.73	58.451	29.226
640	6.4	8.416	337	68.748	1151.73	59.691	29.846
660	6.6	8.679	344	70.176	1151.73	60.931	30.466
680	6.8	8.942	344	70.776	1151.73	61.452	30.726
700	7.0	9.205	350	71.400	1151.73	61.994	30.997
720	7.2	9.468	356	72.624	1151.73	63.056	31.528
740	7.4	9.731	360	73.440	1151.73	63.765	31.883
760	7.6	9.994	365	74.460	1151.73	64.651	32.326
780	7.8	10.257	369	75.276	1151.73	65.359	32.680
800	8.0	10.520	372	75.888	1151.73	65.890	32.945
820	8.2	10.783	372	75.888	1151.73	65.890	32.945
840	8.4	11.046	375	76.500	1151.73	66.422	33.211
860	8.6	11.309	377	76.908	1151.73	66.776	33.388

880	8.8	11.572	379	77.316	1151.73	67.130	**33.565**

Table A.11: Unconfined Compressive Test for Marine Clay + 6%RHA at 3 days curing

Deformation Gauge Reading	Compression of Specimen	Strain, ε	Force Gauge Reading	Axial force P	Corrected area	Axial Stress	Shear Strength
0	0.0	0.000	0	0	1152.97	0	0
20	0.2	0.263	23	4.692	1152.97	4.069	2.035
40	0.4	0.526	50	10.200	1152.97	8.847	4.424
60	0.6	0.789	75	15.300	1152.97	13.270	6.635
80	0.8	1.053	95	19.380	1152.97	16.809	8.405
100	1.0	1.316	115	23.460	1152.97	20.347	10.174
120	1.2	1.579	136	27.744	1152.97	24.063	12.032
140	1.4	1.842	158	32.232	1152.97	27.956	13.978
160	1.6	2.105	176	35.904	1152.97	31.140	15.570
180	1.8	2.368	192	39.168	1152.97	33.971	16.986
200	2.0	2.632	205	41.820	1152.97	36.272	18.136
220	2.2	2.895	220	44.880	1152.97	38.926	19.463
240	2.4	3.158	231	47.124	1152.97	40.872	20.436
260	2.6	3.421	243	49.572	1152.97	42.995	21.498
280	2.8	3.684	253	51.612	1152.97	44.764	22.382
300	3.0	3.947	265	54.060	1152.97	46.887	23.444
320	3.2	4.208	274	55.896	1152.97	48.480	24.240
340	3.4	4.471	284	57.936	1152.97	50.249	25.125
360	3.6	4.734	293	59.772	1152.97	51.841	25.921
380	3.8	4.997	302	61.608	1152.97	53.434	26.717
400	4.0	5.260	311	63.444	1152.97	55.027	27.514
420	4.2	5.523	320	65.280	1152.97	57.486	28.743
440	4.4	5.786	328	66.912	1152.97	58.034	29.017
460	4.6	6.049	336	68.544	1152.97	59.450	29.725
480	4.8	6.312	344	70.176	1152.97	60.865	30.433
500	5.0	6.575	350	71.400	1152.97	61.927	30.964
520	5.2	6.838	358	73.032	1152.97	63.342	31.671
540	5.4	7.101	365	74.460	1152.97	64.581	32.291
560	5.6	7.364	372	75.888	1152.97	65.820	32.910
580	5.8	7.627	378	77.112	1152.97	66.881	33.441
600	6.0	7.890	385	78.540	1152.97	68.120	34.060
620	6.2	8.153	392	79.968	1152.97	69.358	34.679
640	6.4	8.416	399	81.396	1152.97	70.597	35.299
660	6.6	8.679	405	82.620	1152.97	71.658	35.829
680	6.8	8.942	412	84.048	1152.97	72.897	36.449
700	7.0	9.205	419	85.476	1152.97	74.135	37.068
720	7.2	9.468	425	86.700	1152.97	75.197	37.599
740	7.4	9.731	430	87.720	1152.97	76.082	38.041
760	7.6	9.994	435	88.740	1152.97	76.966	38.483

780	7.8	10.257	439	89.556	1152.97	77.674	38.837
800	8.0	10.520	442	90.168	1152.97	78.205	39.103
820	8.2	10.783	447	91.188	1152.97	79.090	39.545
840	8.4	11.046	450	91.800	1152.97	79.620	39.810
860	8.6	11.309	453	92.412	1152.97	80.151	40.076
880	8.8	11.572	455	92.820	1152.97	80.505	40.253
900	9.0	11.835	457	93.228	1152.97	80.859	40.430
920	9.2	12.098	458	93.432	1152.97	81.036	40.518
940	9.4	12.361	459	93.636	1152.97	81.213	40.607
960	9.6	12.624	459	93.636	1152.97	81.213	40.607
980	9.8	12.887	459	93.636	1152.97	81.213	**40.607**

Table A.12: Unconfined Compressive Test for Marine Clay+ 6%RHA at 7 days curing

Deformation Gauge Reading	Compression of Specimen	Strain, ε	Force Gauge Reading	Axial force P	Corrected area	Axial Stress	Shear Strength
0	0.0	0.000	0	0.00	1150.24	0.00	0.00
20	0.2	0.263	25	5.100	1150.24	4.434	2.217
40	0.4	0.526	67	13.668	1150.24	11.883	5.942
60	0.6	0.789	110	22.440	1150.24	19.509	9.755
80	0.8	1.053	146	29.784	1150.24	25.894	12.947
100	1.0	1.316	180	36.720	1150.24	31.924	15.962
120	1.2	1.579	212	43.248	1150.24	37.599	18.800
140	1.4	1.842	242	49.368	1150.24	42.920	21.460
160	1.6	2.105	270	55.080	1150.24	47.886	23.943
180	1.8	2.368	292	59.568	1150.24	51.787	25.894
200	2.0	2.632	311	63.444	1150.24	55.157	27.579
220	2.2	2.895	329	67.116	1150.24	58.350	29.175
240	2.4	3.158	346	70.584	1150.24	61.365	30.683
260	2.6	3.421	358	73.032	1150.24	63.493	31.747
280	2.8	3.684	372	75.888	1150.24	65.976	32.988
300	3.0	3.947	382	77.928	1150.24	67.749	33.875
320	3.2	4.208	393	80.172	1150.24	69.700	34.850
340	3.4	4.471	402	82.008	1150.24	71.296	35.648
360	3.6	4.734	411	83.844	1150.24	72.893	36.447
380	3.8	4.997	422	86.088	1150.24	74.844	37.422
400	4.0	5.260	431	87.924	1150.24	76.440	38.220
420	4.2	5.523	441	89.964	1150.24	78.213	39.107
440	4.4	5.786	441	89.964	1150.24	78.213	39.107
460	4.6	6.049	460	93.840	1150.24	81.583	40.792
480	4.8	6.312	468	95.472	1150.24	83.002	41.501
500	5.0	6.575	475	96.900	1150.24	84.243	42.122
520	5.2	6.838	480	97.920	1150.24	85.130	42.565
540	5.4	7.101	488	99.552	1150.24	86.549	43.275
560	5.6	7.364	495	100.980	1150.24	87.793	43.897
580	5.8	7.627	502	102.408	1150.24	89.032	44.516
600	6.0	7.890	509	103.836	1150.24	90.273	45.137

620	6.2	8.153	517	105.468	1150.24	91.633	45.817
640	6.4	8.416	522	106.488	1150.24	92.579	46.287
660	6.6	8.679	528	107.712	1150.24	93.643	46.822
680	6.8	8.942	535	109.140	1150.24	94.885	47.443
700	7.0	9.205	540	110.160	1150.24	95.771	47.886
720	7.2	9.468	545	111.180	1150.24	96.658	48.329
740	7.4	9.731	550	112.200	1150.24	97.545	48.823
760	7.6	9.994	555	113.220	1150.24	98.432	49.216
780	7.8	10.257	558	113.832	1150.24	98.964	**49.482**

Table A.13: Unconfined Compressive Test for Marine Clay + 8%RHA at 1 day curing

Deformation Gauge Reading	Compression of Specimen	Strain, ε	Force Gauge Reading	Axial force P	Corrected area	Axial Stress	Shear Strength
0	0.0	0.000	0	0.00	1152.54	0.00	0.00
20	0.2	0.263	24	4.896	1152.54	4.248	2.124
40	0.4	0.526	35	7.140	1152.54	6.195	3.098
60	0.6	0.789	56	11.424	1152.54	9.912	4.956
80	0.8	1.053	75	15.300	1152.54	13.275	6.638
100	1.0	1.316	90	18.360	1152.54	15.930	7.965
120	1.2	1.579	100	20.400	1152.54	17.700	8.850
140	1.4	1.842	113	23.052	1152.54	20.001	10.001
160	1.6	2.105	123	25.092	1152.54	21.771	10886
180	1.8	2.368	133	27.132	1152.54	23.541	11.7705
200	2.0	2.632	141	28.764	1152.54	24.957	12.4785
220	2.2	2.895	150	30.600	1152.54	26.550	13.275
240	2.4	3.158	157	32.028	1152.54	27.789	13.895
260	2.6	3.421	165	33.660	1152.54	29.205	14.603
280	2.8	3.684	170	34.680	1152.54	30.090	15.045
300	3.0	3.947	177	36.108	1152.54	31.329	15.665
320	3.2	4.208	183	37.332	1152.54	32.391	16.196
340	3.4	4.471	191	38.964	1152.54f	33.807	16.904
360	3.6	4.734	197	40.188	1152.54	34.869	17.435
380	3.8	4.997	204	41.616	1152.54	36.108	18.054
400	4.0	5.260	210	42.840	1152.54	37.170	18.585
420	4.2	5.523	218	44.472	1152.54	38.586	19.293
440	4.4	5.786	225	45.900	1152.54	39.825	19.913
460	4.6	6.049	232	47.328	1152.54	41.064	20.532
480	4.8	6.312	238	48.552	1152.54	42.126	21.063
500	5.0	6.575	244	49.776	1152.54	43.188	21.594
520	5.2	6.838	251	51.204	1152.54	44.427	22.214
540	5.4	7.101	257	52.428	1152.54	45.489	22.745
560	5.6	7.364	263	53.652	1152.54	46.551	23.276
580	5.8	7.627	270	55.080	1152.54	47.790	23.895
600	6.0	7.890	276	56.304	1152.54	48.852	24.426
620	6.2	8.153	283	57.732	1152.54	50.091	25.046
640	6.4	8.416	290	59.160	1152.54	51.330	25.665
660	6.6	8.679	295	60.180	1152.54	52.215	26.108
680	6.8	8.942	303	61.812	1152.54	53.631	26.816
700	7.0	9.205	310	62.340	1152.54	54.089	27.045
720	7.2	9.468	317	64.668	1152.54	56.109	28.055
740	7.4	9.731	324	66.096	1152.54	57.348	28.674
760	7.6	9.994	329	67.116	1152.54	58.233	29.117
780	7.8	10.257	335	68.340	1152.54	59.295	29.648
800	8.0	10.520	342	69.768	1152.54	60.534	30.267
820	8.2	10.783	347	70.788	1152.54	61.419	30.710
840	8.4	11.046	352	71.808	1152.54	62.304	31.152

860	8.6	11.309	358	73.032	1152.54	63.366	31.683
880	8.8	11.572	365	74.460	1152.54	64.605	32.303
900	9.0	11.835	370	75.480	1152.54	65.490	32.745
920	9.2	12.098	376	76.704	1152.54	66.552	33.276
940	9.4	12.361	382	77.928	1152.54	67.614	33.807
960	9.6	12.624	387	79.848	1152.54	69.280	34.640
980	9.8	12.887	393	80.172	1152.54	69.561	34.781
1000	10.0	12.150	399	81.396	1152.54	70.623	35.312
1020	10.2	13.413	404	82.416	1152.54	71.508	35.754
1040	10.4	13.676	409	83.436	1152.54	72.393	71.508
1060	10.6	13.939	413	84.252	1152.54	73.101	63.551
1080	10.8	14.202	418	85.272	1152.54	73.986	36.993
1100	11.0	14.465	421	85.884	1152.54	74.517	37259
1120	11.2	14.728	425	86.700	1152.54	75.225	37.613
1140	11.4	14.991	428	87.312	1152.54	75.756	37.878
1160	11.6	15.254	430	87.720	1152.54	76.110	38.055
1180	11.8	15.517	432	88.128	1152.54	76.464	38.232
1200	12.0	15.780	433	88.332	1152.54	76.641	38.321
1220	12.2	16.043	433	88.332	1152.54	76.641	**38.321**

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Table A.14: Unconfined Compressive Test for Marine Clay + 8%RHA at 3 days curing

Deformation Gauge Reading	Compression of Specimen	Strain, ε	Force Gauge Reading	Axial force P	Corrected area	Axial Stress	Shear Strength
0	0.0	0.000	0	0.00	1153.54	0.00	0.00
20	0.2	0.263	42	8.568	1153.54	7.428	3.714
40	0.4	0.526	70	14.280	1153.54	12.379	6.190
60	0.6	0.789	97	19.788	1153.54	17.154	8.590
80	0.8	1.053	128	26.112	1153.54	22.636	11.318
100	1.0	1.316	152	31.008	1153.54	26.881	13.441
120	1.2	1.579	177	36.108	1153.54	31.302	15.651
140	1.4	1.842	195	39.780	1153.54	34.485	17.243
160	1.6	2.105	211	43.044	1153.54	37.315	18.658
180	1.8	2.368	225	45.900	1153.54	39.791	18.996
200	2.0	2.632	240	48.960	1153.54	42.443	21.222
220	2.2	2.895	250	51.000	1153.54	44.212	22.106
240	2.4	3.158	260	53.040	1153.54	45.980	22.990
260	2.6	3.421	271	55.284	1153.54	47.926	23.963
280	2.8	3.684	280	57.120	1153.54	49.517	24.759
300	3.0	3.947	290	59.160	1153.54	51.286	25.643
320	3.2	4.208	309	63.036	1153.54	54.646	27.323
340	3.4	4.471	308	62.832	1153.54	54.469	27.235
360	3.6	4.734	316	64.464	1153.54	55.884	27.942
380	3.8	4.997	324	66.096	1153.54	57.298	28.649
400	4.0	5.260	332	67.728	1153.54	58.713	29.357
420	4.2	5.523	340	69.360	1153.54	60.123	30.062
440	4.4	5.786	346	70.584	1153.54	61.189	30.595

460	4.6	6.049	353	72.012	1153.54	62.427	31.214
480	4.8	6.312	358	73.032	1153.54	63.311	31.656
500	5.0	6.575	365	74.460	1153.54	64.549	32.275
520	5.2	6.838	372	75.888	1153.54	65.787	32.894
540	5.4	7.101	377	76.908	1153.54	66.671	33.336
560	5.6	7.364	383	78.132	1153.54	67.732	33.866
580	5.8	7.627	390	79.560	1153.54	68.970	34.485
600	6.0	7.890	395	80.580	1153.54	69.855	34.928
620	6.2	8.153	402	82.008	1153.54	71.092	35.546
640	6.4	8.416	409	83.436	1153.54	72.330	36.165
660	6.6	8.679	415	84.660	1153.54	73.391	36.696
680	6.8	8.942	421	85.884	1153.54	74.453	37.227
700	7.0	9.205	426	86.904	1153.54	75.337	37.669
720	7.2	9.468	433	88.332	1153.54	76.575	38.289
740	7.4	9.731	438	89.352	1153.54	77.459	38.730
760	7.6	9.994	445	90.780	1153.54	78.697	39.349
780	7.8	10.257	446	90.984	1153.54	78.874	39.437
800	8.0	10.520	453	92.412	1153.54	80.112	40.056
820	8.2	10.783	457	93.228	1153.54	80.819	40.410
840	8.4	11.046	462	94.248	1153.54	81.703	40.852
860	8.6	11.309	465	94.860	1153.54	82.234	40.017
880	8.8	11.572	470	95.880	1153.54	83.118	41.559
900	9.0	11.835	474	96.696	1153.54	83.825	41.913
920	9.2	12.098	475	96.900	1153.54	84.002	42.001
940	9.4	12.361	480	97.920	1153.54	84.887	42.444
960	9.6	12.624	482	98.328	1153.54	85.240	42.620
980	9.8	12.887	483	98.532	1153.54	85.417	42.709
1000	10.0	12.150	485	98.940	1153.54	85.771	42.886
1020	10.2	13.413	486	99.144	1153.54	85.948	42.974
1040	10.4	13.676	486	99.144	1153.54	85.948	**42.974**

Table A.15: Unconfined Compressive Test for Marine Clay + 8%RHA at 7 days curing

Deformation Gauge Reading	Compression of Specimen	Strain, ε	Force Gauge Reading	Axial force P	Corrected area	Axial Stress	Shear Strength
0	0.0	0.000	0	0	1153.47	0	0
20	0.2	0.263	28	5.712	1153.47	4.952	2.476
40	0.4	0.526	65	13.260	1153.47	11.496	5.748
60	0.6	0.789	95	19.380	1153.47	16.801	8.401
80	0.8	1.053	124	25.296	1153.47	21.930	10.965
100	1.0	1.316	150	30.600	1153.47	26.529	18.265
120	1.2	1.579	173	35.292	1153.47	30.596	15.298
140	1.4	1.842	193	39.372	1153.47	34.134	17.067
160	1.6	2.105	210	42.840	1153.47	37.140	18.570
180	1.8	2.368	228	46.512	1153.47	40.324	20.162

200	2.0	2.632	245	49.980	1153.47	43.330	21.665
220	2.2	2.895	258	52.632	1153.47	45.629	22.815
240	2.4	3.158	272	55.488	1153.47	48.105	24.053
260	2.6	3.421	284	57.936	1153.47	50.228	25.114
280	2.8	3.684	295	60.180	1153.47	52.173	26.087
300	3.0	3.947	305	62.220	1153.47	53.942	26.971
320	3.2	4.208	315	64.260	1153.47	55.710	27.855
340	3.4	4.471	328	66.912	1153.47	58.009	29.005
360	3.6	4.734	339	69.156	1153.47	59.955	29.978
380	3.8	4.997	350	71.400	1153.47	61.900	30.950
400	4.0	5.260	360	73.440	1153.47	63.669	31.835
420	4.2	5.523	372	75.888	1153.47	65.791	32.896
440	4.4	5.786	380	77.520	1153.47	67.206	33.603
460	4.6	6.049	390	79.560	1153.47	68.974	34.487
480	4.8	6.312	400	81.600	1153.47	70.743	35.372
500	5.0	6.575	410	83.640	1153.47	72.512	36.256
520	5.2	6.838	420	85.680	1153.47	74.280	37.140
540	5.4	7.101	428	87.312	1153.47	75.695	37.848
560	5.6	7.364	438	89.352	1153.47	77.464	38.732
580	5.8	7.627	448	91.392	1153.47	79.232	39.616
600	6.0	7.890	457	93.228	1153.47	80.824	40.412
620	6.2	8.153	467	95.268	1153.47	82.593	26.297
640	6.4	8.416	477	97.308	1153.47	84.361	42.181
660	6.6	8.679	487	99.348	1153.47	86.130	43.065
680	6.8	8.942	495	10.098	1153.47	87.545	43.773
700	7.0	9.205	503	102.612	1153.47	88.959	44.480
720	7.2	9.468	512	104.448	1153.47	90.551	45.276
740	7.4	9.731	520	106.080	1153.47	91.966	45.983
760	7.6	9.994	528	107.712	1153.47	93.381	46.691
780	7.8	10.257	536	109.344	1153.47	94.796	47.398
800	8.0	10.520	545	111.180	1153.47	96.387	46.835
820	8.2	10.783	555	113..20	1153.47	98.156	49.078
840	8.4	11.046	567	115.668	1153.47	100.278	50.139
860	8.6	11.309	578	117.912	1153.47	102.224	51.112
880	8.8	11.572	590	120.360	1153.47	104.346	**52.173**

Table A.16: Unconfined Compressive Test for Marine Clay + 10%RHA at 1 day curing

Deformation Gauge Reading	Compression of Specimen	Strain, ε	Force Gauge Reading	Axial force P	Corrected area	Axial Stress	Shear Strength
0	0.0	0.000	0	0	1107.41	0	0
20	0.2	0.263	30	6.120	1107.41	5.526	2.763
40	0.4	0.526	58	11.832	1107.41	10.684	5.342
60	0.6	0.789	84	17.136	1107.41	15.474	7.737
80	0.8	1.053	108	22.032	1107.41	19.895	9.948
100	1.0	1.316	132	26.928	1107.41	24.316	12.158
120	1.2	1.579	160	32.640	1107.41	29.474	14.737
140	1.4	1.842	190	38.760	1107.41	35.001	17.501
160	1.6	2.105	218	44.472	1107.41	40.159	20.080
180	1.8	2.368	241	49.164	1107.41	44.395	22198
200	2.0	2.632	262	53.448	1107.41	48.264	24.132
220	2.2	2.895	282	57.528	1107.41	51.948	25.974
240	2.4	3.158	298	60.792	1107.41	54.896	27.448
260	2.6	3.421	315	64.260	1107.41	58.027	29.014
280	2.8	3.684	328	66.912	1107.41	60.422	30.211
300	3.0	3.947	343	69.972	1107.41	63.185	31.593
320	3.2	4.208	357	72.828	1107.41	65.764	32.882
340	3.4	4.471	370	75.480	1107.41	68.159	34.080
360	3.6	4.734	383	78.132	1107.41	70.554	35.277
380	3.8	4.997	396	80.784	1107.41	72.949	36.475
400	4.0	5.260	408	83.232	1107.41	75.159	**37.580**

Table A.17: Unconfined Compressive Test for Marine Clay + 10%RHA at 3 days curing

Deformation Gauge Reading	Compression of Specimen	Strain, ε	Force Gauge Reading	Axial force P	Corrected area	Axial Stress	Shear Strength
0	0.0	0.000	0	0	1126.96	0	0
20	0.2	0.263	30	6.120	1126.96	5.431	2.716
40	0.4	0.526	72	14.688	1126.96	13.033	6.517
60	0.6	0.789	110	22.440	1126.96	19.912	9.956
80	0.8	1.053	150	30.600	1126.96	27.153	13.577
100	1.0	1.316	185	37.740	1126.96	33.488	16.744
120	1.2	1.579	218	44.472	1126.96	39.462	19.731
140	1.4	1.842	249	50.796	1126.96	45.073	22.537
160	1.6	2.105	275	56.100	1126.96	49.780	24.890
180	1.8	2.368	297	60.588	1126.96	53.684	26.842
200	2.0	2.632	320	65.280	1126.96	57.926	28.963
220	2.2	2.895	338	68.952	1126.96	61.184	30.592
240	2.4	3.158	353	72.012	1126.96	63.899	31.950
260	2.6	3.421	368	75.072	1126.96	66.615	33.308
280	2.8	3.684	381	77.724	1126.96	68.968	34.484
300	3.0	3.947	395	80.580	1126.96	71.502	35.751
320	3.2	4.208	407	83.028	1126.96	73.674	36.837
340	3.4	4.471	420	85.680	1126.96	76.028	38.014
360	3.6	4.734	432	88.128	1126.96	78.200	39.100
380	3.8	4.997	448	91.392	1126.96	81.096	40.548
400	4.0	5.260	460	93.840	1126.96	83.268	**41.634**

APPENDIX B

Figure B.1: Failure condition for marine clay-RHA at 7 days curing

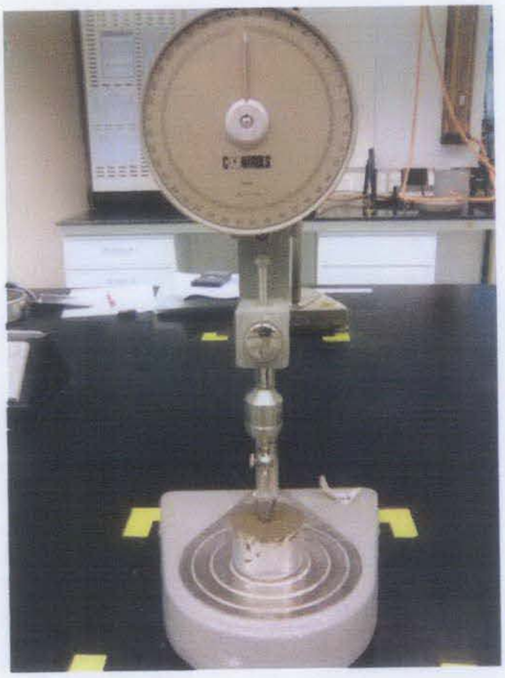

Figure B.2: Atterberg Limits (Liquid Limit Test)

Figure B.3: Atterberg Limits (Plastic Limit Test)

Figure B.4: Atterberg Limits (Plastic Limit Test)