INVESTIGATION ON THE EFFECT OF DIFFERENT MOISTURE CONTENTS ON AGGREGATED SOIL STRUCTURE AND STRENGTH

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ABSTRACT

Water content in soil depends on the soil porosity because each soil has its own characteristic soil-water retention. This study was done to compare the effects of different moisture content on aggregated soil structure as well as to investigate the effect of different moisture content on soil strength in aggregated soil. Type S22 kaolin powder was used to create the aggregated soil samples in the laboratory. Separate aggregated soil samples were created for moisture contents of 43%, 45% and 47% in order to evaluate the effect of moisture content difference on the aggregated samples. Environmental Scanning Electron Microscope (ESEM) was used to obtain images of the aggregated soil structure and Unconfined Compression Test (UCT) was performed on each sample to determine the strength of the aggregated soil. Based on the ESEM results, all the samples show double porosity features due to the compression of soil aggregates but the sample with water content of 45% gave the best aggregated soil structure. Based on the UCT results, the sample with 47% water content showed the maximum strength.

ABSTRAK

Kandungan air dalam tanah bergantung kepada keliangan tanah kerana setiap tanah mempunyai ciri mempertahankan tanah-air sendiri. Kajian ini dilakukan untuk membandingkan kesan kandungan lembapan yang berbeza pada struktur tanah agregat dan juga untuk mengkaji kesan kandungan lembapan yang berbeza pada kekuatan tanah dalam tanah diagregatkan. Jenis S22 serbuk kaolin telah digunakan untuk membuat sampel tanah diagregatkan dalam makmal. Berasingan sampel tanah diagregatkan dicipta untuk kandungan lembapan sebanyak 43%, 45% dan 47% untuk menilai kesan perbezaan kandungan kelembapan pada sampel agregat. Mengimbas Alam Sekitar Mikroskop Elektron telah digunakan untuk mendapatkan imej struktur tanah agregat dan Tidak Terkurung Ujian Mampatan telah dijalankan ke atas setiap sampel untuk menentukan kekuatan tanah diagregatkan. Berdasarkan keputusan ESEM, semua sampel menunjukkan ciri-ciri keliangan berganda disebabkan oleh mampatan agregat tanah tetapi sampel dengan kandungan air 45% memberikan struktur tanah yang terbaik diagregatkan. Berdasarkan keputusan UCT, sampel dengan kandungan air 47% menunjukkan kekuatan maksimum.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Soil usually contains several types of grains. The particles usually found in the voids between the grains are cereal grains of rock and mineral fragments mixed with water as well as air. The location and condition of the soil can change the composition of air and water. If water or the air is not available in the soil, the soil will be perfectly dry or fully saturated, respectively. The composition will be different at each point even if the size and shape of the solid granular contents rarely change at a given point. Soil act also as engineered particulate materials. Engineered particulate materials are not solid materials such as concrete or steel solid. The importance of design, composition, particle size, and the internal structure of the soil or the fabric is very important to understand.

Soil form the majority of the land. In general, the top layer of soil experiences physical weathering and chemical weathering. Generally, rotund shape is characteristic of sand grains. Clays and silty clays formed by wind blown areas have pure silt. Chemical or weathering of rocks usually also produce clay grains and clay particles which have an unstable form. There are large differences in the behavior of engineered clay and sand such as in compressibility, permeability, swelling or shrinking potential. This distinction is important because it is influenced by the size and shape of soil particles. Some soil either naturally or engineered shows two different sets of pore. It occurs due to the aggregated nature of the land, or the existence of worm holes and cracks as root holes. It is also associated with fractured rock formations. This characteristics is called double porosity. Besides showing the two scales of porosity, vacancies of space in the natural earth often are filled with more than one liquid phase which implies the need for a variety of modeling approaches (Khalili, 2008).

The features of porosity in the soil is important because it has a big influence on the nature the soil retain water. So, it great importance in the understanding the water storage in soil and soil strength variations in the infrastructure engineering by studied Bagherieh et al. (2009).

1.2 PROBLEM STATEMENT

Arrangement of pores and cracks or porosity of the soil is the arrangement of solid materials such as organic matter and soil particles. The pores and porosity are formed from the bonding of solid materials and aggregates. The quantity, composition and distribution of the pores determine water holding capacity, infiltration, respiration, permeability and root penetration.

The rate at which occurs is determined by the structure and layout of the two, the ability to make them happen and how things happen are also porosity, permeability, aggregation and soil strength used to help assess the ability of any land for good performance or otherwise. The ventilation, drainage, water storage capacity and wilting point of the plant depend on characteristic porosity whereas the infiltration, bonding, drainage and breathing depend on characteristic permeability. Strength and resilience of soil structure is dependent characteristic strength.

This research is necessary to ascertain whether variable moisture content has an impact on aggregated soil structure and strength. Furthermore, not many researchers have studied about the behavior and characteristics of double-porosity soil.

1.3 OBJECTIVES OF THE STUDY

The following is the objectives of this research are:

1) To compare the effect of different moisture contents on aggregated soil structure
2) To investigate the effect of different moisture contents on aggregated soil strength

1.4 SCOPE OF STUDY

The study method used in this research is experiments conducted in the geotechnical laboratory. The soil used for the purpose of this study is kaolin. The kaolin used is of type S22. The dry kaolin was mixed with different amount of water content. The percentage of moisture contents used in this study are 43%, 45% and 47%. The characteristics studied are soil structure and soil compression. The tests performed for this research are Environmental Scanning Electron Microscope (ESEM) and Unconfined Compression Test (UCT). ESEM was used for imaging soil structure while UCT was used for determining soil strength.

1.5 SIGNIFICANCE OF STUDY

Result from this study help to identify the optimum moisture content and to know the best value of moisture content for aggregated S22 kaolin. By identifying the most suitable moisture content, the soil will be at its the strongest and can hold the most pressure. Besides that, this study is important to know the effect on aggregated soil structure when different moisture contents are applied. When using the ESEM, the behavior, shape and characteristic pore size of the aggregated soil sample can be seen.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

One of the most variable characteristics of soil is water content. It is necessary for plants because the soil serves as a reservoir for the water. The water content is not only essential for plant growth, but sufficient key nutrients for plant growth are also found in the soil solution. So, it is important for the soil system. Most important reactions in the soil occurs in the context of soil such as fertilization, cation exchange, organic matter decomposition and weathering. Therefore, it is evident that soil moisture is very important.

2.2 MOISTURE CONTENT

The moisture content is the amount of water contained in the material. The water content is usually found in soil, rocks, ceramics and if it is on the soil, it is called soil moisture. Moisture can be present as adsorbed moisture on the inner surface and the capillary condensed water in small pores. When the relative humidity lower the water adsorbed moisture and when the relative humidity is higher, many to liquid water and it depends on the size of the soil pores.

The natural moisture content in the soil is usually determined by the soil itself humidity levels. The natural moisture content is very important in the study of soil mechanics. In addition, to determine the bearing capacity and settlement, the natural moisture content is used. This ratio is normally expressed as percentages. The natural moisture content will provide an idea about the soil conditions on the ground.

2.2.1 Moisture Contents in Aggregated Soil

In a survey of ecology, hydrology and agronomy, determine the amount of water in the soil is a necessity arises frequently. It seeks to understand the relationship of mechanical, chemical, soil, biological, and hydrological (Hillel, 1982). Very important factors to consider such as the properties of the soil liquid phase comprising water and how water through the pore because it affects the mechanical properties of the soil.

Water mass relative to the mass of dry soil particles are defined wet and it is often known as the gravimetric water content. Typically, depending on the porosity of the soil wetness. Therefore, the clay has a high porosity and usually have a water content greater than sandy soils. Water content is reduced if the soil is compacted and produce basal spacing between the pores will be less. Unsaturated condition definitions refer to most soil water content is less than the porosity.

2.2.2 The Influence of Soil Water Content

The ability of soil to hold the water is well connected to the surface area or volume of pore space, hence the capacity to retain water in relation to the structure and texture. Lands with subtle texture has a maximum capacity withstand maximum total water, but water is available the maximum withheld, on the ground with the texture being. Showed that the soil water is available at several closely linked to the dust content and very fine sand.

Fine-textured soils hold water on the entire interval of more energy compared to coarse textured soil. It is possible to fine-textured soils have a colloidal material, pore space and surface absorb more. Coarse textured soil has little ability to resist water than fine-textured soils. Therefore, crops grown on sandy soils generally easier dryness of the soil-textured loam or clay soil

In addition, organic matter also affects substantially the rate of soil water content. The soil organic material has pores that are far more numerous than the mineral particles of the soil absorption surface area means even more to the higher rates of soil organic matter alarmingly high rate and soil water availability.

Besides the nature of the soil, the climate and vegetation have a significant influence on the amount of water that can be absorb with efficiency grows in the ground. Temperature and air change is climate change and the effect on the efficiency of water usage and the determination of soil water can be lost through the evaporation surface. Will conduct resistance in drought conditions and growth rate is the growth factor means. Moisture in the soil depends on the abundance of rainfall, soil's ability to retain water, mainly evapotranspiration, organic matter content and high water table.

2.3 DOUBLE POROSITY

Based on research by Bagherieh et al. (2009) double porosity exists in porous media. He concluded that every soil either natural or engineered shows two different sets of pore. It occurs due to the aggregate nature of the land, or the existence of worm holes and cracks as root holes. It is also associated with fractured rock formations. These are characteristics of double porosity. The features of porosity in the soil is important because it has a big influence on the nature the soil retain water. So, it great importance in the understanding the water storage in soil and soil strength variations in the infrastructure engineering by studied Bagherieh et al. (2009).

2.3.1 Types of Aggregated Soil

The primary soil particles that are integrated with each other are stronger than the surrounding particles. Soil aggregates are formed through the combined action of fragmentation and aggregation processes. The unity among some particles, are caused by attractive and disruptive forces acting on the particles in the soil.

Separation of land into classes or groups each having similar characteristics and behavior of the same potential is soil classification. The classification of mechanical properties such as stiffness, permeability, and strength is one of the engineering purposes. The size, density, stability, structure, and its impact on the transport of fluids, solutes, colloids, and heat is essential for the physical aspects of the aggregate.

Generally, silicate clay, organic matter, oxides, and mineral volcanic ash are only very small particles to form aggregates. There are various mechanisms of soil aggregation. The mechanism of accumulation of soil is soil microorganisms produce substances that act as binding agents and cementing soil particles together, have filamentous fungus, called hyphae, which extend into the soil and bind soil particles together. Besides, the roots also produce sugar into the soil which helps bind minerals and oxides also act as glue and join the particles together. The process of aggregation is common to many highly weathered tropical soils and very prevalent. Finally, the soil particles can naturally attract to each other by electrostatic forces.

2.4 SOIL STRUCTURE

The soil structure is the arrangement and organization of primary and secondary particles in the soil mass. The soil structure will now control the amount of water and air in the soil. Adequate ventilation and oxygen needed for respiration by plant roots and seeds germinate. The water and the air in the soil depends on the activity of bacteria.

Soil particles may be present either as individual grains or as aggregates. the particles are bound together into granules or particles of the compound is the aggregate. single individual grains are present in sandy or silty soil, while part of the majority of the particles, they are present in the sand in the clay. Individual solid particles, while they have the character of porous or sponge is not solid aggregate. Most of the land is a mixture of single and compound grain particles.

The great influence in situ properties such as vertical and horizontal permeability will vary in alternating layers of fine and coarse soils, the presence of cracks affect several aspects of strength, the presence of layers or lenses of different strength are characteristic of the structure. It can affect the stability and the presence of cement or bonding strength and stiffness influence.

Soil, which is said to be dominated by a single grain structure less, while those who own the majority of secondary particles is said to be consolidated, sand or crumb structure. Range of particle sizes encountered in the soil is very large. From rock to dimensional control over 200mm to clay particles less than 0.002mm (2μm). Some clays contain particles less than 1 μm in size behave as colloids, which is not settled in the water due solely to gravity.

The textural classification system developed by U.S. Department of Agriculture (USDA) showed by Figure1. Generally, the soil has four different groups of different size particles :

Gravel = 60 – 2.0mm

Sand = 2.0 – 0.6mm

Silt = 0.06 – 0.002mm

Clay = <0.002mm

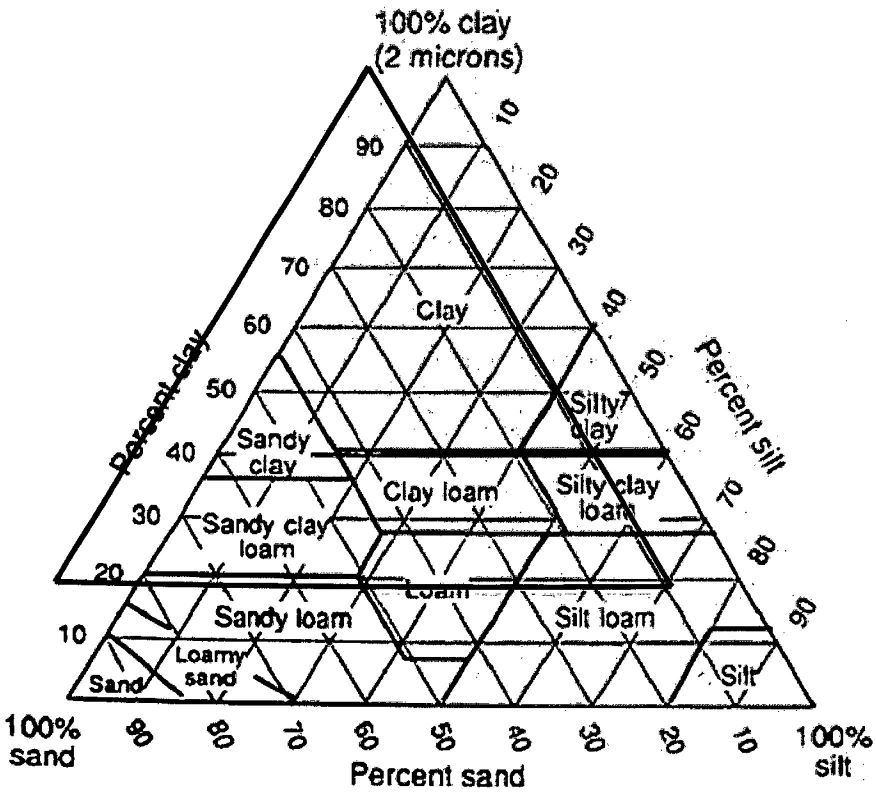

Figure 2.1: U.S. Department of Agriculture textural classification (Soil Survey Staff, 1975)

2.4.1 Effect of Water/Moisture Contents on Single Porosity Soil Structure

Configure the pore space of soil structure can be measured in terms of water retention and conduction properties, which govern the pore size distribution pattern and shape. (Daraghmeh, 2007)

The texture of soil refer to the composition of the sand, silt, and gravel combined with the large content material. Sand and silt are the result of the physical effects of the weather and the clay comes from the chemical effect due to the weather. Clay content has significant effects on soil properties caused by the accumulation of high capacity for nutrients and water. Due to this high accumulation capacity, the clay against water and wind erosion better than the muddy soil and sandy soils. In addition, it also has plastic when moistened, and can hold water easily, and it also has a good flow of good land. (Aziz, 2007)

2.5 SOIL STRENGTH

The strength of the soil is the soil's ability to resist forces without failure, either by breaking or cracking. Soil strength is very important and must be considered especially for agricultural purposes. The soil has an upper and a lower limit that is ideal and it has a detrimental effect if the strength exceeds either of these extremes. If the soil is too weak, it cannot withstand the forces of water and wind. On the other hand, if the soil is too strong, organisms such as earthworms and plant roots, cannot penetrate the soil.

Shear strength and friction angle are two important soil strength indices which have not been given due attention, particularly in a country dominated by structurally weak and expanding soils (Roopnarine et al., 2011).

The strength of cohesion between particles depends on various physical properties, chemical and biological. Among the most important of these is an attractive intermolecular forces between water and solid-air surface tension of water, cementation by precipitating solute, entanglement by roots and hyphae of fungi, and a variety of chemical phenomena. Unity land forces depends strongly on the water content and other conditions.

Friction angle of the soil, which is a measure of the ability of soil to hold the unit shear stress, is derived from the measurement of the shear strength of the soil. It is the measured angle between the normal (confining pressure) and the resultant force in the soil column reached when failure occurs only in response to shear stress.

Peak soil friction angle refers to the initial angle attained from the initial shearing phase, while the residual friction angle refers to the angle obtained following the initial failure of the soil sample.

2.5.1 Effect of Water/Moisture Content on Single Porosity Soil Strength

Clay type and content strength of influence through their role in cohesion. The cohesion significantly modified by water content. The cohesion will be decreased if the water content increases. This is due to the increased water content causes a greater separation of clay particles and thus will result in softening the soil cement.

Compact the soil can be used as an example to find out the strength of soil, moisture content and how management can interact with soil and water content. A more severe compaction process occurs with traffic on wet soil than dry soil. On dry land, the resistance is greater to change the structure because it has a higher strength.

The force of compaction produces a critical moisture content curve shows the effect of compaction increases with increasing content of moist until the point at which the soil becomes so wet that compaction is reduced. Critical moisture content for compactive happens at the peak of the curve because the moisture content is the most undesirable to distribute soil. Because of the critical moisture of any land depends on many factors includes the organic content and the soil texture.

2.6 PAST STUDIES ON AGGREGATED SOIL STRUCTURE

Daraghmeh (2007) investigated soil structure stability and near-saturated hydraulic characteristics under reduced and conventional tillage. The whole aim the research was to obtain the temporal variation soil structure attributes under reduced and conventional management systems. From the result, different aggregate size distribution under tillage practices and pre-treatments could be detected and there was a higher proportion of the large aggregates (> 2 mm). The larger aggregates may probably be more sensitive to the natural processes and thus were more susceptible to drying and wet structural degradation because of the smaller aggregates.

Macfarlane (1957) investigated structural effects due to secondary compression of kaolinite. The concept furnished the assumption that secondary compression will develop at a rate proportional to the amount of undeveloped secondary compression. From the result, at the same pressure and at the same void ratio, the slopes of the kaolinite clay samples with the distilled water pore solution was greater than slopes of the secondary compression curves for the samples with the di-sodium phosphate pore solution.

Azad (2008) investigated mechanical behaviour of unsaturated aggregated soils. The research is aimed at studying the mechanical behaviour of unsaturated, aggregated soil with respect to soil structure effects. From the result, the virgin compression curve of aggregated soils is on the right side of the normal consolidation line of the corresponding reconstituted soil. The results of unsaturated test revealed that the apparent proconsolidation stress increases with suction for both reconstituted and aggregated soil. The rate of increases is higher for aggregated soils.

Wei (2012) investigated soil aggregated pore structure and their relationship to bacteria spatial distribution using x-ray computed microtomography. The research was conducted to understand soil aggregate structure difference under contrasting land use and management, to investigated bacteria redistribution and transport pattern and its relation to aggregate pore characteristics and aim to effectively utilize soil aggregate μCT imaging. From the results, E.coli redistribution within soil aggregated display a significant different spatial an air-dry aggregated.

Based on the research by Ciric et al. (2012), they investigated the soil dry aggregate size distribution: effects of soil type and land use. The research was conducted to obtain the effects of different soil types and land uses on structure parameter and to relate them to selected soil properties. Five of soil types was performed to investigation and soil aggregated was collected from three different location and three different land uses (forest, cropland and meadow). The results showed that a highly significant impact of soil type on all ASCs and structure indices. Long term cultivation leads to the deterioration of soil structure and the formation of clods. Forest soils have significantly better structure than soils under meadows and croplans.

2.7 PAST STUDIES ON AGGREGATED SOIL STRENGTH

Utomo and Dexter (1980) observed soil friability. This study investigated the effect of wetting, drying, freezing and thawing cycles on Urrbrae soil fragility. From the investigation, the formation of micro-cracks due to internal wetting and drying cycles as well as the freezing and thawing cycles was observed. These can reduce the tensile strength of the soil aggregates. Formation of big aggregates fracture happens more intensively than small aggregates due to the fact that aggregate strength decrease with occurs move quickly in larger aggregates.

Barzegar (1995) investigated the factors affecting soil strength and structural stability and their interrelationship in salt-affected soils. The research was conducted to obtain to investigate the influence of clay particles on soil densification and mellowing, the mellowing of compacted soils and soil aggregates as influenced by solution composition, the disaggregation of soils subjected to different sodicities and salinities and its relationship to soil strength and dispersible clay and the effect of organic matter and clay type on aggregation of salt-affected soils. From the results, most important factor affecting soil strength was suspended clay particles after wet sieving and soil strength was affected not only by sodicity but also by salinity.

Nearing (1995) investigated the compressive strength for an aggregated and partially saturated soil .This study was undertaken to test the hypothesis that the saturation of interaggregate pores in aggregated soils controls the level of effective stress and, subsequently, soil strength relationships. Unconfined compressive strength was measured for five different aggregate size groups across a range of soil water suction levels. Results indicated that axial stress at failure for the soil was linearly related to the product of soil water suction and the saturation level of the interaggregate soil pores. The experimental results support the hypothesis that interaggregate pore water controls the effective confining stress level, and hence compressive strength, for aggregated soil.

Based on the research by Ostaz et al. (1997), they investigated the strength of individual soil aggregates against crushing forces and the characteristic influence of aggregates . The research was conducted to obtain the relative strength of individual soil aggregates of varying sizes and shapes to oppose destructive forces. Aggregate soil individually placed between the flat surface remains clean and the flat plate was connected to a pocket penetrometer and crushed under the pressure applied. The results showed that the mechanical strength of the aggregate used is directly related to the aggregate shape and size. When increasing the size of an aggregate, applied pressure was required to crush a higher aggregate.

2.8 CONTRIBUTION OF RESEARCH

The results from this study will help to recognize the most appropriate moisture content for aggregated soil. By identifying the appropriate moisture content, the soil can been sured to be the strongest and can hold the most pressure. Besides that, this study is important to know the effect on aggregated soil structure containing different moisture contents and to know value of optimum moisture content which can cause the aggregated structure to collapse. When using the ESEM, the behavior, shape and characteristic pore size of the soil structure will be seen. And finally, the test results will be about double porosity in soil structure and this investigation has never been studied by others.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This study briefs on the methodology is the process to collect information and data for the purpose to achieve the aim and objectives which are to compare of the effect of different moisture contents on aggregated soil structure and to investigate the effect of different moisture contents on aggregated soil strength.

The overall process is illustrated in Figure 3.1. The dry kaolin mixing with water content (43%, 45% and 47%) before forming the mixture into kaolin granules. In order to achieve a dry unit weight of 11kN/m, the amount of the kaolin granules was needed. These kaolin granules has been moved to UCT mold and compressed to a target sample of 76 mm and diameter 36 mm for testing.

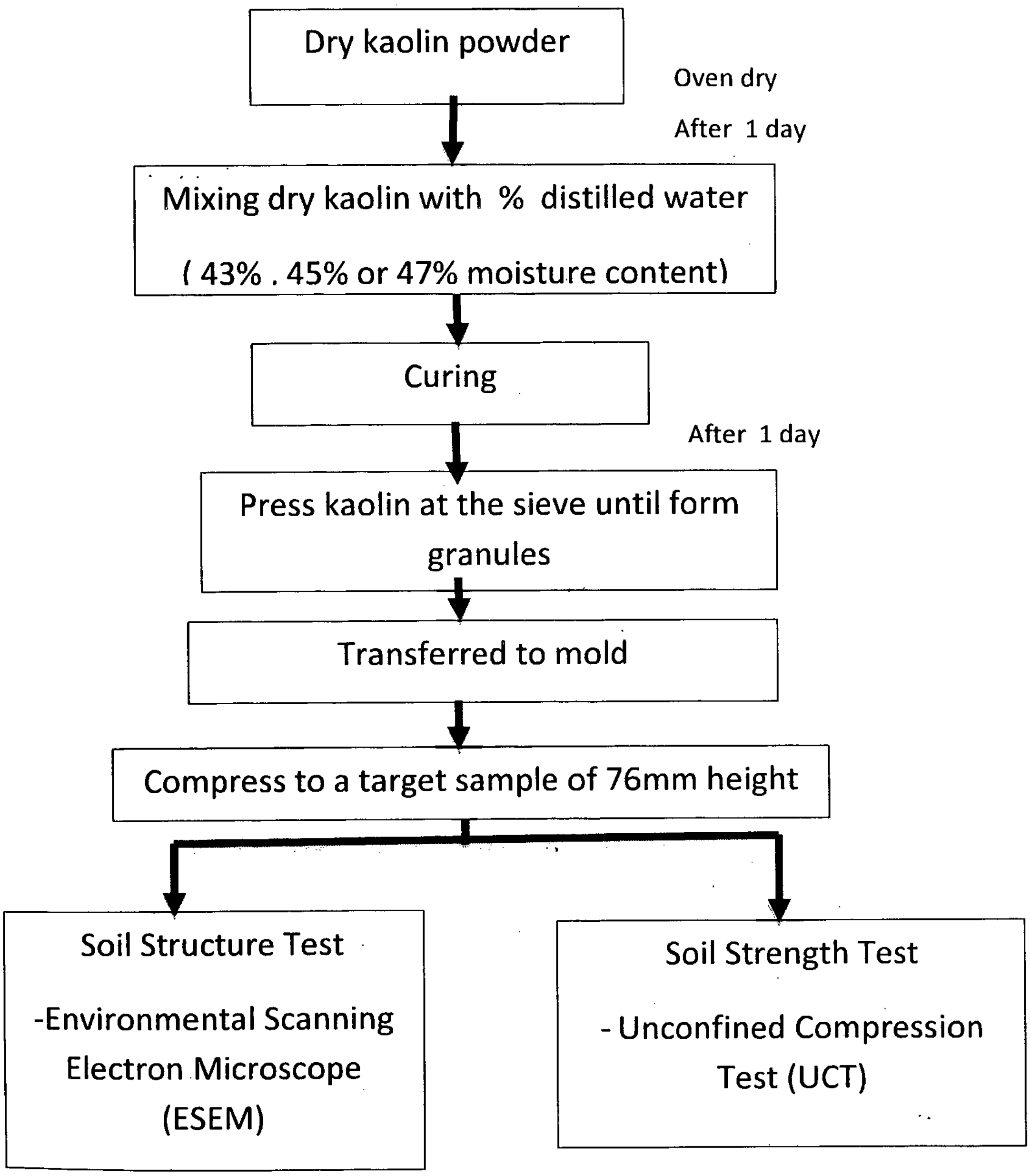

Figure 3.1 : Flowchart of research study

3.2 MATERIALS AND EQUIPMENT

3.2.1 Kaolin

In Integrated Soil Classification system if the soil particles finer than 2 μm are generally termed as clay particles. Typically, clay particles have a plate-like shape, formed by mineral crystal structure and contains the majority of the land mass of the particle is known as the clay. The type of clay used in this study is dry kaolinite. The kaolinite is a white non-swelling clay which has been formed by weathering. Table 1 shows type of kaolin, size and properties of kaolin.

Table 3.1: The size of clay mineral (Notman, 2011)

Group	Minerals Included	Size	Properties
Kaolin	Kaolinite Halloysite	~ 1μm	Non-swelling, low plasticity, low cohesion
Illite	Illite Partially degraded micas	~0.1μm	Expansive, medium plasticity, low permeability
Smectite	Montmorillonite Bentonite	≤ 0.01μm	Highly expansive, very plastic, extremely low permeability.

3.2.2 Sieve

Before do test for determining its physical properties and the engineering behavior of the soil, The size of soil particles can be measured by two methods. The method is by visual estimation or by use of a set of sieves. Using a set of sieves, the grain size can be accurately measured up to grade silt according to the Unified Soil Classification System and it has been acknowledged by most geologists. When does the sieve test, the sieves sorted by size would make it easier to determine the grain size of the class and give a measure of the scatter.

The size of the average particles on each sieve is then analyzed to obtain intersection or specific sizes and test results are used to describe the properties of the soil. The test results are provided in graphical form to identify the type of soil gradation. Table 3.2 is a chart Wentworth grain size. Complete procedure for this test is given in the American Society for Testing and Materials (ASTM) C 136.