A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
OF ÇANKIRI KARATEKİN UNIVERSITY

INFLUENCE OF SOIL CLASSIFICATION BASED ON PHYSICAL AND GEOTECHNICAL PROPERTIES

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF MASTER OF SCIENCE
IN
CIVIL ENGINEERING

BY

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ÇANKIRI

2023

INFLUENCE OF SOIL CLASSIFICATION BASED ON PHYSICAL AND GEOTECHNICAL PROPERTIES

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February 2023

We certify that we have read this thesis and that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science

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ABSTRACT

INFLUENCE OF SOIL CLASSIFICATION BASED ON PHYSICAL AND GEOTECHNICAL PROPERTIES

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Soil properties estimate is very serious and major in structure and related on the physical, chemical, and engineering properties employed for soil covers that are influenced by the stresses from the loads enjoined on it. The geotechnical analysis is extending to contain discovering the location and analysis of soil and its relation with physical, chemical, and engineering properties soil to realize soil attitude in the situation of definite constructions on it. Geotechnical estimation contains the analysis of geometric possessions, and the stress impact on the soil as unification, confrontation, and compressibility.

2023, 71 pages

Keywords: Soil, Physical properties, Geotechnical properties, Organic matter, Chemical properties

ÖZET

FİZİKSEL VE JEOTEKNİK ÖZELLİKLERE DAYALI ZEMİN SINIFLANDIRMASININ ETKİSİ

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İnşaat Mühendisliği, Yüksek Lisans

Tez Danışmanı: Doç. Dr. Cihan DOĞRUÖZ

Ocak 2023

Zemin özellikleri tahmini çok ciddi ve yapı olarak önemlidir ve üzerine uygulanan yüklerden kaynaklanan gerilmelerden etkilenen zemin örtüleri için kullanılan fiziksel, kimyasal ve mühendislik özellikleri ile ilgilidir. Jeoteknik analiz, üzerinde belirli yapılar olması durumunda zemin tutumunu gerçekleştirmek için zeminin konumunu ve analizini ve bunun fiziksel, kimyasal ve mühendislik özellikleri ile ilişkisini keşfetmeyi içerecek şekilde genişliyor. Jeoteknik tahmin, geometrik özelliklerin analizini ve birleşme, yüzleşme ve sıkıştırılabilirlik olarak zemin üzerindeki gerilme etkisini içerir.

2023, 71 sayfa

Anahtar Kelimeler: Zemin, Fiziksel özellikler, Jeoteknik özellikler, Organik madde, Kimyasal özellikler

PREFACE AND ACKNOWLEDGEMENTS

I would like to thank my thesis advisor, Assoc. Prof. Dr. Cihan DOĞRUÖZ, for his patience, guidance, and understanding.

Balsam Khalid Hussein HUSSEIN
Çankırı-2023

Dedication

To my biggest supporter,

Who keeps saying "lam proud of you"

In my failures before my success

To my dad

"Everything I am, or ever will be, I owe it to my mom"

My success is because of her duaa, and my failures are because of me

To my mom

Someone who matches you without giving up.

Thank you for your caring &loving and well wishes

They are greatly appreciated

To my partner "Mohammed"

Life's greatest blessing. A group that dreams, laughs, plays, and loves together.

Those whom you can always count on. Always present not only in the good times.

The most precious gift

To (Yousef, Sarah, and Younis)

In this world, she is my world

Piece of my heart you taught me that fear is not an option

A piece of heaven "Tara"

CONTENTS

LIST OF SYMBOLS

%	Percentage
$\gamma_{d\,max.}$	Optimum water content
γ_d	Dry unit weight
γ_{wet}	Wet unit weight
Cm	Centimeter
gm	Gigameter
GS	Specific gravity
k	Erodibility coefficients
kg	Kilogram
m	Meter
P	Pressure
t	Time
v	Volume

LIST OF ABBREVIATIONS

AASHTO	American association of state highway and transportation officials
ASTM	American society for testing and materials
BSCS	British soil classification system
DR	Dispersion ratio
EC	Electrical condactivity
GMDA	Guwahati metropolitan development authority
ISSS	International society of soil science
IUSS	International union of soil sciences
JICA	Japan international cooperation agency
LL	Liquid limits
OC	Organic carbon
OM	Organic matter
PI	Plasticity index
PL	Plastic limit
SAR	Sodium adsorption ratio
UCS	Unconfined compression test
USCS	Unified soil classification system
USDA	United states department of agriculture

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1. INTRODUCTION

Numerous structures are built with insufficient foundations for the existing soil conditions (Yilmaz and Yavuzer 2005). Due to the scarcity of appropriate ground that is geographically accessible, homes are frequently constructed on marginal terrain with necessary bearing ability to sustain the large weight of a construction (Yilmaz and Bagcı 2005). With the expansion of urban areas, it is sometimes required to construct structures and other construction on locations with critical circumstances (Yilmaz 2007). For this reason, thorough study is often required for soil foundations (Yilmaz 2008).

The particle size spreading and geotechnical qualities of basis soils are crucial for the construction of building foundations. The source of the basis soils should also be considered, since it is feasible to anticipate a specific performance of a certain deposit kind through geotechnical studies (Yilmaz 2009) if the topic is well understood. Diverse types and ages of foundation soils are extremely varied, frequently non-uniform, and insufficiently investigated further (Bell and Maud 1995). (Franks and Woods 1993) discussed the geotechnical features of several types of foundation soils and identified the following probable geotechnical issues/challenges.

Soft or more specifically muddy soils by (Que *et al.* 2008) presents some difficult to sample and evaluate geotechnical features of the soft soils. To control the physical symbols of the soils, laboratory and field experiments were conducted. The data were statistically examined so that predictive equations for the geotechnical characteristics of soft soils could be produced. The numerical strength of the relationship mark revealed that mechanical symbols may be derived from physical symbols controlled by regular analysis utilising these equations.

The sediments covered by (Khadge 2002);

The region was subjected to a simulated disturbance experiment, which altered the drained shear intensity and natural water content (W.C %) of the residues. In sediment layer 0–5 cm from the disturbance region, an rise in W.C % and a substantial reduction in shear strength were recorded, but no significant changes were observed outside the disturbance area. The presence of 10–20% radiolarian testing and water-absorbing montmorillonite led to high levels of porosity and water content. The noticeable reduction of undrained shear strength of sediments exposed to physical disturbance would impact the sediment's bearing capacity and consequently impede the nodule collector's mobility. Other index parameters such as wet bulk density, and specific gravity were identical inside and outside the disturbed zone, mostly due to comparable particle size and clay mineralogy. (Lee *et al.* 2011) examine marine sediments. the geotechnical properties of deposits are investigated. To determine the controlling sediment characteristics, chemical composition, and mineralogy, geotechnical indication checks, XRD, and SEM pictures were acquired.

Based on correlations with index qualities, well-recognised empirical relationships used to estimate engineering limitations do not applicable to thesedeposits, which demonstrate more compressible than predicted founded on empirical relationships. Settlements will be of utmost importance if gas manufacture is tried by remove pressure, since this method will result in the detachment of hydrates and a rise in actual stress. (Miller *et al.* 2012) investigated soil genesis and reforestation success, similar to prior research on soil genesis. The quantity of resolving, which is revealing of the weathering method, and the better potency of the clean brown sandstone behaviours indicate that this solid is more suitable than other mine waste materials for the outside of recovered mine locations. Despite the fact that the shale dealings had the second highest tree productivity and the greatest descending, the geology of the Appalachian coal basin would limit the material's utility as a uppersoil replace; but, the combination of brown sandstones and shale may provide a better long-term intermediate. This would combine the shale spoils' increased subsidence, Ca, Mg, K, CEC, and clay with the brown sandstone spoils' larger N and P.

In 2013, (Brevik 2013) studied soil parameters, and compared the emerging soils to the adjacent natural soils. This research focuses on three of the various vegetation zones found within the pit. Using established procedures, soil samples were collected, characterised, and tested. While soil development over only 41 years is minimal, there are substantial soil variations between the examined vegetative zones. Variations in topographically regulated availability to water and density, which effect botanical progress and litter buildup, are related to soil variances. A study of the developed soils surrounding the pit indicates that the pit's soils still require a substantial quantity of improvement previously they attain stability with the normal surroundings.

The analysis has uncovered the following probable geotechnical issues/challenges.

- Stability issues on cut slopes resulting from the orientation of relict links, particularly those originating from volcanic stuns.
- Possible constancy issues on usual slopes resulting from excavation into intrinsically unstable slopes or natural processes on slopes above construction locations. For instance, boulder fields, steep cliffs, and drainage systems including metastable coiluvial deposits that can be remobilized by high rainfall are examples of the latter scenario.
- Challenges in accessing colluvial or alluvial deposits having a large proportion of boulders, resulting in building difficulties for piled foundations (or possibly saprolites containing corestones). Additionally, significant weathering and very uneven 'rockhead' levels may provide obstacles.
- Reclamation of dense layers of soft sea mud.

The present research targets to:

- This research attentive on the geotechnical link of the soils and their classification.
- This research determined on the geotechnical association of the soils their properties for use as subgrade of roadway.

- Studying the properties of composted clay minerals to be used as absorbent in ion exchange techniques.
- This research defines the geotechnical stuffs of basis soils of numerous types.

The principal detached of this investigation is to control the geotechnical assets of the soils; secondly, to classify them according to some of the most commonly used soil organisation systems; and thirdly, to found potential interrelationships between the numerous organisation systems.

2. LITERATURE REVIEW

2.1 Introduction

The features and nature of the soil are essential to human existence. Various soil classification methods have been established worldwide due to diverse interests.

Soil categorization methods are used to forecast soil behavior and make available facts to geologists and government agencies. The initial stage in soil classification is identification.

The premise that soils with identical characteristics might be grouped presupposes the existence of correlations among the different characteristics of soil. As relationships are only convergent, rating methods can only offer a rough sign of applicability and attitude. This restriction should be recognized if arrangement methods are to be used intelligently. This is specially relevant when a rating method based on the analysis of damaged samples is employed to expect soil mass-dependent features (Buol *et al.* 2011).

As per (García-Gaines and Frankenstein 2015), soil categorization methods can be separated into two primary categories: one for engineering resolutions and one for soil knowledge. The objective of soil rating is to classify soils.

According to (Cline 1949), geoscientists and engineers utilize soil categorization methods to define soils, control their possible behavior, and comprehend the restrictions of the soils encountered during building projects.

In 2016, (Tingle *et al.* 2016) postulated in their work that even the finest categorization method would never be able to provide all the data required for all practical study. Therefore, it is vital to create relationships between various soil categorization methods and to provide all professional stakeholders with general guidance on critical material attributes. Providing a mapping tool to convert readily between soil categorization methods can improve communication through multidisciplinary or global activities.

2.2 Control of Soil Structure

The following are the general methods for improving and maintaining soil structure (Ramanathan 1994):

- Tillage activities must be conducted within optimal moisture conditions for the least amount of aggregate degradation
- The use of zero or minimal tillage practices to ensure proper aeration and limit the loss of O.M.
- Keep the soil protected with remains to shield aggregates from the effect of raindrops, and contribute O.M.
- The combination of yield leftovers and composts into the soil for aggregate stabilization.
- The combination of legumes into yield alternation using phosphatic fertilizers.
- Green fertilization and protecting harvest are valuable O.M origin.
- Employment of O.M and fertilizers for agricultural production.

Several soils have distinct structural issues that necessitate correct soil control techniques for improved soil structure (Brady and Weil 2004).

- These soils have limited water retention and nutrient retention issues. To enhance the building of any soils, adding O.M sincerely. Adding pond sediments, clay soil, or even compaction can rise the number of small-sized pores, strengthening the soil's ability to retain water and nutrients.
- These soils have restricted drainage and aeration as a result of low aggregation. Although adding organic matter is beneficial for enhancing aggregation, the quantity required is substantial. Consequently, crop rotation and phosphate composts are beneficial.

- Puddled condition: In regions with persistent waterlogging, the soil aggregates break down, resulting in a puddled state. Drainage is a possible solution to this issue.
- Dispersed state Sodic soils present the issue of dispersion. Using gypsum in conjunction with green enriching, or yield residue assimilation effectively enhances the soil structure and ameliorates these soils.
- Reduced organic matter concentration is responsible for low aggregate stability in dry and semi-arid soils. The inclusion of organic materials can enhance the stability of aggregates. Mulching may also be beneficial since it facilitates microorganisms' decomposition of organic matter.

2.3 Effects of Soil Structure and Texture on Porosity

The soil's grain and constituents have the greatest impact on the soil's porosity and the distribution of pore sizes. The O.M indirectly influences total porosity, pore size distribution, bulk density, and controlling elements such as Plowing, and irrigation that impact soil construction. It has previously been stated that rough soils have a lower overall porosity than fine soils, while their pores are bigger. Clayey soils have a highly variable porosity because they exhibit swelling and shrinkage.

The fine textured include a greater percentage of micropores. These soils are hence more water-retentive and often poorly drained. The ranges of total porosity for sandy, loamy, and clayey soils are 30-45%, 40-55, and 45-60%, individually.

In sandy texture, the majority of pores are moderately large and closely equivalent in size; Unlike sandy soils, where water levels tend to rise as suction rises, clay soils' pores are more evenly spaced, leading to a steady decline in water levels (Figure 2.1) (Foth 1978).

The volume of pores of middle size is significant, but the micropores are uninfluenced by soil Unification; hence, the soil wetness holding for Consolidated and accumulated soils may be practically comparable in high-suction variety (Hillel 2012) (Figure 2.2).

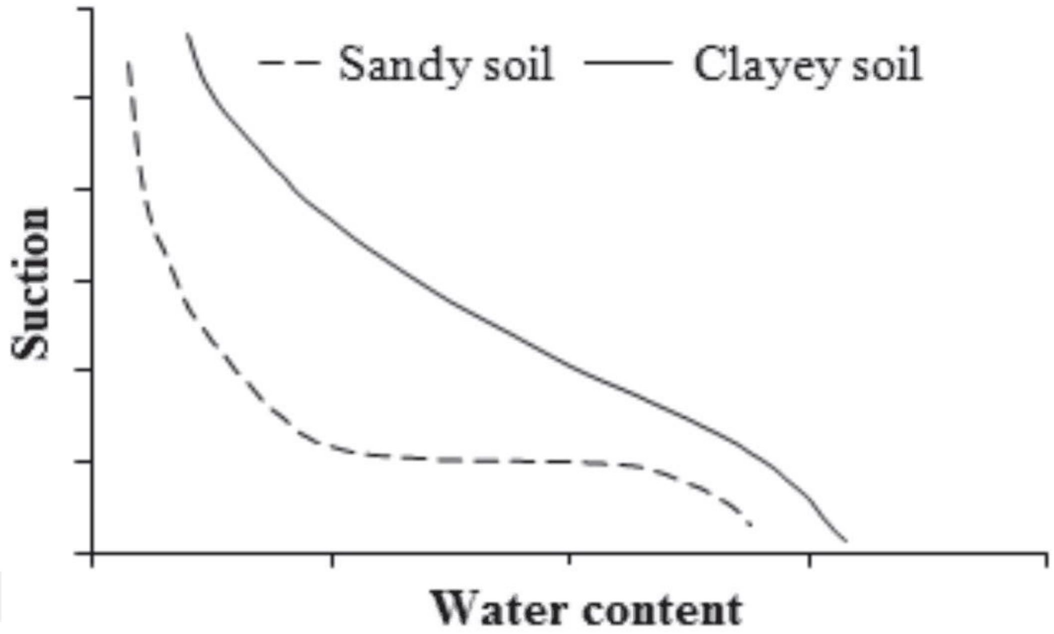

Figure 2.1 Diagram design of the impact of soil texture on water retention

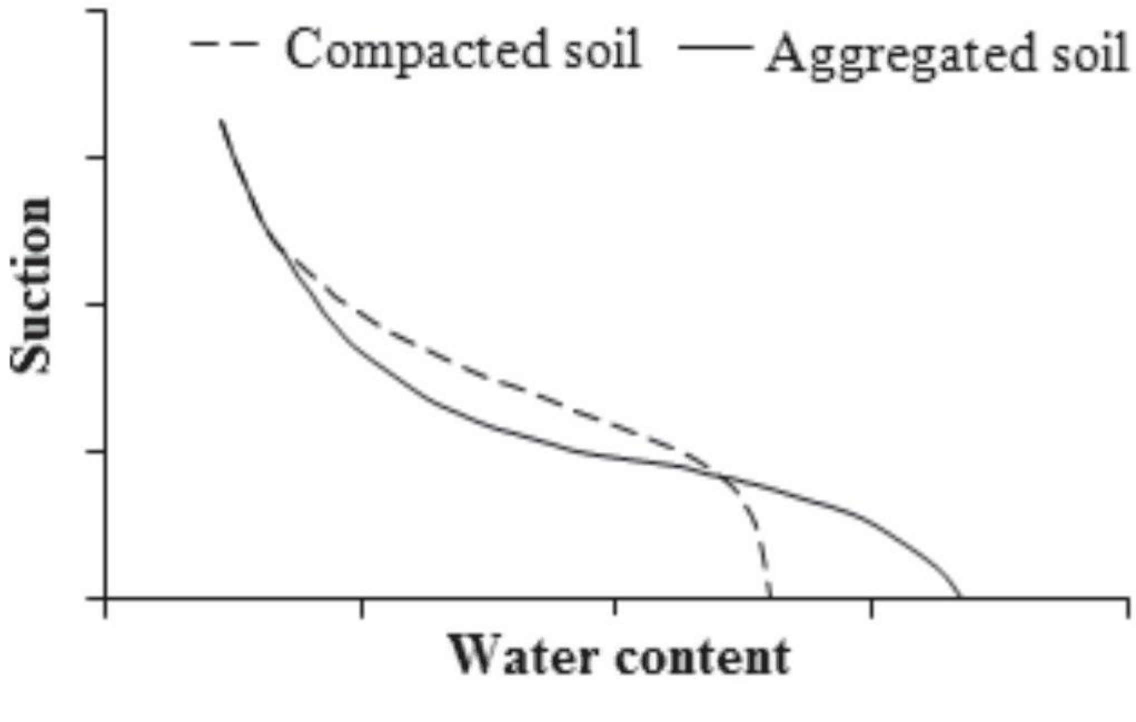

Figure 2.2 Soil water retention diagram showing the impact of structure

2.4 Soil Physical Properties

Physical properties show a crucial part in assessing the appropriateness of soil for agronomic, and engineering applications. Water retention, nutrient availability, root saturation, and temperature and air circulation are all directly influenced by the soil's physical characteristics. The following sections cover the physical features of soil that are most significant to its usage as a average for plant development (Kohnke and Barber 1968).

The soil's physical qualities, like as texture, porosity, ρ, and wetness content, govern the arrangement of soil air to a great extent. Sandy soils have little total porosity but massive pore size, while clayey soils have great complete porosity nonetheless small pore size. Soils with larger pores facilitate a faster interchange of gases than those with smaller pores; hence, soil air composition in sandy soils may not change. Due to reduced aeration, puddled or flooded soils have a greater concentration of carbon dioxide. The reduction in macropore volume caused by compaction results in an rise in CO2 and a reduction in O_2. The reduction in gas dispersion caused by an rise in soil moisture raises the CO_2 concentration in damp soils. Gases such as H_2S, CH_4, and NH_3 may collect in saturated soils and have a negative impact on plant. Since topsoil spreads straight with the ambiance, it contains comparatively more O_2 than the subsurface (Lal and Shukla 2004).

2.5 Soil Texture

Typically, the quantity of amorphous material, including organic materials, in the solid stage of mineral soil is negligible. Mineral elements are not perfectly round but vary greatly in form; hence, they are usually separated into three groups depending on a given size variety based on their similar diameter. As soil splits, main elements, or textural portions, are the groupings of mineral particles with different particle sizes. The texture of soil relates to the predominant amount variety of mineral elements determined (Lal and Shukla 2004).

2.6 Classification of Particles Soil

Soil particles with a diameter of fewer than 2 millimeters are included in the categorization and termed standard soil analysis material. Some soils include big particles that impede tillage processes but may not significantly donate to critical soil qualities. Gravel (2-4 mm), pebbles (4-76 mm), cobbles (76-250 mm), stones (250-600 mm), and boulders (>600 mm) are the several categories for particles larger than 2 millimeters in size. There are numerous categorization methods for soil particles, but the ISSS, renamed the IUSS, and the USDA are the most prevalent (Table 2.1). Table 2.2 lists some essential characteristics of sand, silt, and clay elements.

In adding, sand and silt elements are composed of basic minerals like quartz, whereas clay elements are mostly composed of minor metals like kaolinite, illite, and hydrated iron and aluminum oxides. Clay is a surface- effective portion with a great level of chemical and physical behaviours, whereas sand and silt fractions are largely inert and display these activities to a lower degree. The soil's skeleton consists of sand and silt, while the clay makes up the soil's "body". All three sections, as well as the interstitial pore space, comprise the soil matrix.

Table 2.1 Techniques of arrangement of soil elements via their sizes

International Society of Soil Science (ISSS)		United States Department of Agriculture (USDA)	
Particle	Diameter (mm)	Particle	Diameter (mm)
Coarse sand	2.0-0.2	Very coarse sand	2.0-1.0
Fine sand	0.2-0.02	Coarse sand	1.0-0.5
Silt	0.02-0.002	Medium sand	0.5-0.25
Clay	<0.002	Fine sand	0.25-0.10
		Very fine sand	0.10-0.05
		Silt	0.05-0.002
		Clay	< 0.002

Table 2.2 Significant properties of sand, silt and clay elements

Particle	Properties
Sand	Visible to naked eye, generally spherical or cubical in shape, feel gritty, low water and nutrients holding capacity, loose when dry, very low plasticity and stickiness when wet.
Silt	Not visible to naked eye, seen through an ordinary microscope, generally spherical or cubical in shape, low to medium in capacity to hold water and nutrients, feel smooth, some plasticity and stickiness when wet.
Clay	Visible only through an electron microscope, platy in shape, high water and nutrients holding capacity, hard when dry, high degree of plasticity and stickiness when wet, exhibit swelling and shrinkage behavior.

2.7 Soil Geotechnical Characteristics

Numerous geotechnical characteristics of soils have varying effects on constructions. They are also interdependent (Roy and Bhalla 2017). The following attributes are discussed:

2.7.1 Specific gravity

Gravity individual is the relation of the quantity of soil solids to the quantity of water in an identical volume. It is a main soil key attach directly related to mineralogy or chemical arrangement (Oyediran and Durojaiye 2011) and replicates the history of weathering (Tuncer and Lohnes 1977). It is essential in relations of the qualitative behavior of the soil (Raj 2008) and helps in categorizing soil minerals; for instance, iron metals have greater specific gravity than silicas (Bowles 1992). It indicates the soil's appropriateness as a building solid; a greater value of specific gravity results in stronger roads and foundations (Prakash 1979). The typical specific gravity standards are listed in Table 2.3.

Table 2.3 Definitions of typical specific gravity (Bowles 1992)

Type of soil	Specific gravity
Sand	2.65-2.67
Silty sand	2.67-2.70
Inorganic clay	2.70-2.80
Soil with mica or iron	2.75-3.00
Organic soil	1.00-2.60

An increase in specific gravity was observed to enhance shear strength parameters (Roy and Das 2014, Roy 2016).

2.7.2 Solidity indicator

The standard of compacted of lands is assessed in proportion to the extreme dehydrated solidity for a definite compacted action. For compaction of rough soils, however, a separate index is utilized. relying on the form, size, and intensity of soil particles, rough soils can exist in two ultimate compaction positions: the loosest and the most compact. Using a relative density or density index measure, you may compare any middle condition of compaction to these two intense levels (Kaniraj 1988). Density index measures the compaction and stability of a stratum (Table 2.4).

Table 2.4 The soil parameters based on relative density

Relative density (%)	Soil compactness	Angle of shearing resistance (°)
0-15	Very loose	<28
15-35	Loose	28-30
35-65	Medium	30-36
65-85	Dense	36-41
85-100	Very dense	>41

According to (Apparao and Rao 1995), the comparative density of sandy deposits is arbitrary. It indicates the relation of the real decline in capacity of voids in sandy soil to the utmost feasible decline in volume of voids, while, the extent to which the sand under consideration may be densified beyond its native condition. Its measurement aids in complying rough grained soils and assessing the safe behaviour capability of sandy soils.

2.7.3 Consistency levels

The water content of slight grained soil significantly influences its stability. A progressive decrease in the wetness of a slight grained soil mud leads the soil to change starting a liquid to plastic, to a semi-solid, and finally to a solid form. The water content during these changes in a condition varies amongst soil types. Atterberg parameters are the moisture that resemble to these variations in situation. The moisture consistent to the change from one situation to the next are referred to as the liquid parameters, the plastic parameters, and the shrinkage parameters (Kaniraj 1988).

The liquid parameters of a soil is the moisture, given as a fraction of the oven-dried soil weight, at the transition point between the liquid and plastic situation of consistency. The soil's shear strength is negligibly modest. The plastic parameters of a soil is the moisture, given as a percentage of the oven-dried soil weight, at the transition point among the plastic and half -solid situation of consistency.

The plastic limit for many soils falls inside a limited numerical series. Sand does not have a plastic stage; however, particularly fine sand demonstrates little plasticity. The plastic control is a critical soil property. At this point of moisture, roadways are easily navigable. With soils at their plastic control, excavation and agricultural cultivation may be accomplished with minimal attempt. When a soil's moisture drops amid the liquid and plastic limits, it is considered to be in the plastic range. As described by the plasticity index, the range of the plastic state is supplied by the difference between the liquid control and the plastic control. As a important soil property (Raj 2008), the elasticity indication is utilized in soil categorisation and numerous relationships with extra soil features. Atterberg's classification of soils based on the elasticity index reveals connections between the plasticity index, amount of plasticity, soil type, and amount of cohesiveness (Table 2.5) (Prakash 1979).

In 1953, (Skempton 1953) noted that the soil's flexibility index improves linearly by the proportion of clay-sized particles.

In 2012, (Laskar and Pal 2012) discovered that soil flexibility varies on grain size. With an rise in sand content, the soil's plasticity index drops, possibly owing to a reduction in intermolecular attraction force. Due to a drop in soil attraction force, the soil's liquid limit and plasticity index fall. However, when the clay concentration rises, so does the intermolecular attraction force and the liquid limit (Table 2.5).

Table 2.5 Categories of soils established on plasticity indication (Prakash 1979)

Plasticity index (%)	Soil type	Degree of plasticity	Degree of cohesiveness
0	Sand	Non-Plastic	Non-Cohesive
<7	Silt	Fewer Plastics	Weakly Cohesive
7-17	Silt clay	Medium-sized Plastic	Cohesive
>17	Clay	High Plastic	Cohesive

Maximum moisture expressed as a percentage of oven-dried mass at which further dehydration would not cause a decrease in usable land area is known as the shrinkage control.

The land quantity was first created from land. The greater the amount of shrinking, the finer the soil particles. Soils containing the clay mineral montmorillonite shrink more. As a result of the uneven shrinkage of these soils over the summer, surface fissures form. In addition, these soils absorb extra water through the monsoon and swell.

Expanding and contracting soils are classified as expansive soils. Black cotton soils in India are members of this category (Raj 2008).

According to (Prakash 1979), the shrinkage limit value is employed to comprehend cohesive soils' swelling and shrinking features. It is used to calculate shrinkage factors, which aids in the construction of buildings built of soil or resting on the soil. It explains the soil's usefulness as a building material for foundations, roadways, barriers, and reservoirs. It helps find out how the soil is doing.

According to (Ersoy *et al.* 2013), the consistency of extremely slight clayey soils is an essential quality and a valuable measurement. Plasticity and cohesiveness are indicators of soil consistency and workability. However, these soil properties show an significant part in numerous plans, like as the building of the clay core in an earth fill weir, the building of a layer of little permeability covering a contaminated solid sediment, the project of grounds, holding walls, and slab bridges, and the determination of the slope stability of the soil.

In 2015, (Agbede *et al.* 2015) did the research at Nigeria's University of Ibadan (UI). Under investigation was a two-story structure with a basement that included offices. This structure is situated on a level, small terrain by a top level of weak clayey lands and an essential layer of sandy, silty clay soil. Due to the expanding earth supporting the building's base, fissures were noticed. The foundational soil is rich in clay with a great plasticity indication.

2.7.4 Element size investigation

The proportion of diverse ranges of soil atoms larger than 75 microns is measured by sieve testing, whereas the percentage of particles less than 75 microns is determined by hydrometer. Element size Investigation is managed to plot particle size dispersal curves. The particle size dispersal bend (stage curve) depicts the spreading of particles of varying sizes within the soil mass (Mallo and Umbugadu 2012). It indicates the soil's gradation, it is potential to determine whether the soil is well or badly classified. In systematic soil equilibrium, the primary premise is to mixture a limited chosen soils so that the design mix achieves the required grain size distribution. For proportioning the selected soils, it is necessary to know the grain size investigation of each soil (Prakash 1979).

Apparao and Rao (1995) underlined the importance of grain size analysis in the soil classification system. Particle size research curves are used to create sieves for earth weirs and evaluate soil suitability for construction of roads, runways, and other infrastructure. Sieves and the assessment of absorptivity, capillarity, and frost sensitivity all have some practical bearing on the atomic level of sands and silts, as does the use of larger sieves (Raj 2008). Important and useful data may be gleaned from grain size distribution curves, such as I the percentage of larger or smaller components above a certain mass and the consistency or series in particle-size dispersion.

In 1992, (Bowles 1992) discovered that grain size is one of the acceptability standards for soils used in building highways, airfields, levees, dams, and other barriers. Although particle-size analysis can forecast soil-water flow, permeability measurements are more frequently employed. From the particle size study, it is possible to forecast the susceptibility of soil to frost action, which is a crucial factor in colder climes. Very small soil atoms are definitely transported in interruption, and subdrainage methods quickly get clogged with residues if they are not covered by a filter of adequately graded gritty matters. Particle-size analysis may be used to estimate the correct gradation of this filter material. The atom size of the sieve material must be greater than that of the soil to be covered so that the filter's pores may allow water to pass through while collecting the smaller soil particles in suspension.

According to (Dafalla 2013), the morphology of sand, whether curved, subrounded, or rounded, influences the shear intensity of the soil. Angular grains offer better interlocking and shear resistance. Degree and particle size of the sand influence its shear. Poorly categorized substances allow for less grain-to-grain interaction than properly arranged ones. When contemplating combinations of clays and sands, the porosity and availability of clay voids inside the sand are crucial.

2.7.5 Compaction

Compaction of the soil is one of the strategies for improving the land. The soil grains are reorganized more compactly by investing compaction energy in soil.

The compaction of soil enhances its shear strength and decreases its compressibility and permeability (Kaniraj 1988). (Murthy 2002) explains that when an earth dam is adequately compacted, the material's shear strength increases, and the dam becomes more stable. As the soil becomes more compact, its permeability decreases. The reduction in the dam's permeability reduces the water loss through seepage. Due to the rise in the density of the materials, the dam's settlement also lowers.

Prakash (1979) provide evidence that compacting soil increases density, shear strength, and bearing capacity while decreasing void ratio, porosity, permeability, and settlements. The findings may be used to ensure the safety of earthen structures including dams, embankments, roads, and airport runways. Soil compaction is done within a certain moisture range, which is determined by the results of a laboratory proctor compaction test. The maximum dry density measured in the laboratory also controls the compaction energy employed in the field. (Michelin *et al.* 2015) utilized strong dynamic compaction to compact the foundation subsoil of Bursa, Turkey's Carrefour Hypermarket and Trade Center. To strengthen the foundation subsoils' carrying capacity and manage the total and differential settlements beneath the foundations, the subsoils must be stabilized.

GMDA and JICA sponsored a massive water supply project (208 MLD) for the central Guwahati area in India. The mechanical compaction of foundation dirt with a road roller was deemed appropriate for foundation building (Gogoi and Laskar 2015).

2.7.6 Consolidation

Compression occurs when a soil layer is subjected to pressure stress due to building movement. Movement of atoms, leakage of water, particle severe, and flexible alterations induce the compression. The aesthetic, the function, and the damage caused by a compromised structure are the three main factors that motivate the study of its compromise. As a result of the settlement, the existence of fractures or tilt in a structure can detract from its aesthetic appeal. A structure's compromise can harm utilities such as cranes, sewers, pumps, and electrical cables. Additional settling can lead to structural failure and the collapse of a building. Settlement combines time-independent (e.g., instantaneous pressure) and time-dependent (called unification) compression (Raj 2008).

Agreeing to (Prakash 1979) the primary purpose of a unification test is to collect soil data required to anticipate the rate and quantity of settling of structures built on clay owing to the clay's volume change.

For foundations resting on clay, the following information is obtained:

- Overall compromise of establishment below some given weight,
- Time necessary for overall compromise because of essential unification,
- Dominion for some given weight and period,
- Time desired for some fraction of overall compromise or unification
- Tension because which the soil has formerly been unification/crushed.

In 1985, (Abeele 1985) highlighted that dewatering or lowering the water table is likely the most well-known cause of large settlements. When submerged, individual particles of soil are very buoyant. When water is removed, buoyancy disappears, and the increase in pressure that results from this process causes unity to form even if no additional force is being applied. To add insult to injury, vibrations may have a densifying effect on soils, which can eventually cause settling. When the frequency of the vibration equals the natural frequency of the soil, the impacts might be severe.

Due to earthquakes, soils frequently disintegrate and settle catastrophically. Devastating landslides are a common consequence of such situations. Among the three soil phases, only the solid phase controls the resistance to compression and shear. In damp soil, water is incompressible, yet it cannot withstand shear stresses as a liquid. The air contained in unsaturated soils cannot support shear or compression stresses.

In 1982, (Head 1992) said that compression would be generated mostly by water evaporating from soil cavities in wet soil. Under an externally imposed stress, the medium's permeability plays a significant role in expelling water from voids. Due to the extraordinarily poor permeability of clay, void contraction is sluggish. Unification is the compression of saturated, weak-permeability stratum beneath rigid pressure. Compressibility (how much its capacity is reduced by tension) and absorptivity (how well it absorbs fluid) are what set the unification rate. Temperature enhances the pace of unification but does not influence the overall quantity of unification (Koçak and Köksal 2010).

In 2015, (Yardım and Mustafaraj 2015) also observed that tremors from nearby roads and railroads, as well as earthquakes and erratic fluctuations in ground water flat caused by stream foundation displacement, led to the need for compensation.

In 2011, (Naik *et al.* 2011) performed a cost benefit analysis on a South Goa, India, institutional building that has cracks in its plinth beams. Some foundations were uncovered two meters below the surface of the unconsolidated filled-in soil. This differential settlement was seen at the building's front left corner, situated on the filled-in ground. Differential settling resulted in fractures in the plinth beam and Foundation Concrete.

2.7.7 Permeability

The capacity, spreading, and flow of water in soil significantly impact its qualities and behavior. As groundwater conditions are commonly encountered in building projects, the engineer should be familiar with fluid flow fundamentals.

About the water table, soil mass is separated into two zones: I below the water table (a saturated zone with 100 percent) and (ii) immediately overhead the water table (named the capillary area with an amount of saturation less than 100 percent) (Raj 2008). In the planning of different civil engineering repairs, like crossing wall planning of earth weirs, data from field permeability tests are required to determine the pumping capacity for dewatering excavations and to derive aquifer constants (Raj 2008).

The permeability of soils has a dramatic influence on the stability of foundations, the seepage loss via reservoir embankments, the drainage of subgrades, the excavation of open cuts in water-bearing sand, and the rate of water flow into wells (Murthy 2002).

In 1979, (Prakash 1979) demonstrated that water percolating through soil exerts significant seepage pressures that directly impact the safety of hydraulic constructions. A compressible clay layer's permeability determines its settling rate under load. How much water gets through and beneath an earthen dam is determined by the structure's and the dam's permeability. The degree of soil permeability is determined by the typical rate of water drainage via wells and carefully excavated installation pits. Indirectly, the shear strength of soils depends on permeability since it controls the dissipation of pore pressure.

The U.S. Office addresses soils as I Impervious: k (coefficient of permeability) less than 10-6 cm/sec, (ii) Semi previous: k between 10-6 and 10-4 cm/sec, and (iii) Previous: k more than 10-4 cm/sec (iii) Previous: k in excess of 10-4 cm/sec.

The fill (a soft, silty clay with differing quantities of sand, gravel, and O.M), clay (a medium-to-stiff, silty clay), and gravel/cobble (a coarse, stony material) were all detected at different depths at the established construction site in Taiwan (Chen and Jensen 2013). As a result, there was some variation in the permeability. It was more cost-effective for the buildings to be supported by shallow footings and slab-on-grade floors because of the use of continual drainage devices drilled into the floor slab to reduce the groundwater table.

2.7.8 Shear potency

The shear resistance of soil is a function of friction, particle interlocking, and maybe cementation or bonding at particle contacts. Cohesion and the friction angle define the soil shear strength parameters. The shear strength of soil is determined by the effective stress, drainage conditions, particle density, strain rate, and strain direction. Consequently, the shear Potency is influenced by the reliability of the substances, their mineralogy, grain size spreading, particle size, and characteristics such as covers, cracks, and strengthening (Jansen 1988). The shear potency characteristics of gritty soil have a direct relationship with the maximum particle size, coefficient of homogeneity, density, applied normal stress, and gravel and fines content of the sample.

The shear strength parameters can be attributed to the frictional strengths exerted by the elements as they move and overlap through shearing (Yagiz 2001).

Soil with elements with a great sharpness tends to fight movement and, as a result, has a greater shear strength than soil with less angular particles (Ranjan and Rao 2007).

Different studies (Raj 2008, Prekash 1979, Kaniraj 1988) indicated that a soil's shear strength governs its capacity to withstand loading from a structure, support its overburden, and maintain a slope in equilibrium. Shear strength is crucial for foundation design, earth and rock fill dam design, highway and airport construction, slope and cut stability, and lateral earth pressure concerns. Numerous elements, such as the soil's varied nature, the water table's position, the drainage ability, the kind and form of building, the stress history, time, chemical activity, or climatic situations, contribute to its complexity.

According to (Prekash 1979), confining forces significantly alter soils' behavior in deep basics. Likewise, the confining pressures in high-rise earth dams are very large. Only the triaxial test can mimic these restricting forces. For short- duration constancy of basics, weirs, and inclines, shear force limitations corresponding to uncombined unexhausted or combined unexhausted situations are utilized, whereas shear limits matching to combined exhausted surroundings provide more consistent outcomes for long-term stability.

In 2013, (Akayuli *et al.* 2013) found that sandy soil has a higher resilience than clayey soil, and (Skempton 1953) determined that clay content generally increases cohesiveness in their investigation. As additional clay is added to sandy materials, the clay particles begin to fill the vacuum spaces between the sand particles and promote interlocking behavior in the sand. Therefore, clayey sand soils are anticipated to have little solidity, while solidity rises with rising clay intensity.

In 2013, (Dafalla 2013) found that mineralogy can significantly affect clays' shear strength capability. A chemical or physicochemical link may cause cementation between particles. In expansive soils, swelling and shrinkage have polar opposite effects on shear strength. Fully inflated clay typically possesses a low shear strength; however, dry shrinking clay can create a greater cohesiveness and position of inside resistance. According to the study's results, achieving the desired shear strength can be facilitated by selecting the proper mixture and/or employing the proper proportion of clay. When the clay content of a very damp sand-clay combination is high, the cohesiveness and angle of internal friction reduction dramatically. As said by (Murthy 2002, Abd El Maksoud 2006), cohesion in slight-grained soils is mostly caused by the intermolecular link between the adsorbed water around each grain.

According to (Laskar and Pal 2012), clayey soils with high plasticity have more cohesiveness and a smaller angle of shearing resistance. In contrast, soil cohesiveness reduces as sand-like soil particle size rises. During two case studies of Iran's embankment dams. (Mallo and Umbugadu 2012) determined that for big dams, the internal friction angle plays a more important role in stability analysis than the cohesion parameter.

Properties of the soil

The features and properties of the soil are essential to human existence. Several fields (geology, agriculture, and engineering) need a systematized classification of soil that describes its physical qualities. Numerous soil categorization systems have been established worldwide due to diverse interests.

According to (García-Gaines and Frankenstein 2015), soil categorization methods may be separated into two primary categories for engineering reasons and for soil research. The objective of soil classification is to classify soils with comparable qualities or characteristics. Soil categorization systems are used to forecast soil behavior and offer information to geologists, engineers, builders, agricultural extension agents, community planners, and government organizations, according to (Cline 1949). Geoscientists and engineers utilize soil categorization systems to define soils, determine their possible behavior, and comprehend the constraints of the soils encountered during building projects. This information is crucial when developing airfields, roads, buildings, dams, bridges, and other infrastructure.

The initial stage in soil classification is identification. For a classification system to be useful, it must facilitate identification by inspection or testing, and tests should be as easy as feasible.

In this regard, according to (Buol *et al.* 2011), tests that need distressed samples are preferable: not only do they reduce the requirement for undisturbed sampling or field testing, but the characteristics they evaluate are independent of the soil mass's structure. Consequently, grain size, mineral composition, organic matter content, and soil flexibility are favored over parameters such as moisture content, density, and shear strength as the basis for a categorization system.

The function of Soil Geotechnical Properties in Civil Engineering

Such civil engineering buildings as structures, bridges, highways, tunnels, dams and towers are founded either below or on the earth's surface. For their constancy, the foundation soil must be adequate. Its qualities must be evaluated to control if the soil is appropriate for use as a foundation or building material (Prakash 1979).

According to many studies (Roy and Das 2014, Roy 2016), evaluating the geotechnical qualities of the subsoil at the project site is required to provide meaningful input data for the design and construction of the proposed buildings' foundations (Kaniraj 1988).

According to researchers (Apparao and Rao 1995), suitable design and building of civil engineering buildings prevent environmental effects, structural failure, and post-construction issues. For the design of structures and the preparation of building methods, surface and subsurface characteristics data are necessary. It is more cost effective to do subsurface research before designing a structure to support high, powerful loads and a deep zone of influence.

Detail study is essential for complicated projects requiring large constructions such as bridges, dams, and multi-story buildings. The objective of in-depth examinations is to establish the engineering characteristics of the soils for various layers (Skempton 1953). When a structure's foundation is placed on compressible soil, settling occurs. From a design perspective, it is vital to understand the pace at which soil compression occurs.

The features of the soil, such as its plasticity, compressibility, or strength, constantly influence the construction design. Lack of understanding of the soil's qualities might result in building blunders. Soil suitability for a certain purpose must be determined by its technical features, not by eye examination or superficial similarities to other soils.

The load up capacity of soil is dependent on the soil kind. Normally speaking, slight-grained soils have a lower load-bearing capability than rough-grained soils. Plasticity index and liquid limit are two crucial parameters that aid engineers in determining the consistency or plasticity of clay. Though shear strength is constant at liquid limits changes at plastic limits for all clays (Ersoy *et al.* 2013), this is not the case for plastic limits.

The impact of permeability on civil engineering constructions. According to (Thermann *et al.* 2006), even among geotechnical soil properties, the shear force of soils is crucial since it is one of the most essential metrics for analyzing and addressing solidity difficulties. This study addresses connections between various geotechnical qualities and their effects on constructions in light of these considerations. (Bowles 1979) states that soil geotechnical assessment is crucial and is based on the physical, organic, and engineering features employed for surface covers and under surface that are impacted by pressures from weights applied to it.

Exploration of the site and investigation of groundwater and its interaction with soil are being added to the scope of geotechnical research to comprehend the soil's behavior in the presence of particular buildings.

Geotechnical evaluation entails the investigation of geometric qualities, soil stress as unification, resistance, and compressibility. Physical and technical qualities are affected by the chemical composition of soil and water.

All geotechnical studies may be acquired via fieldwork at the engineering structure and sample testing to determine the most appropriate drilling approach (Burnett 1975). The bearing capacity of soil determines the amount of dynamic and static loads that may be supported without failing. The analysis of soil compressibility properties is crucial for constructing any engineering structure.

Previous study

Soil classification systems give a standard vocabulary to communicate the main properties of soils simply and may be used to anticipate soil behavior and provide information to experts, community planners, and government organizations. Although it may be ideal for an analyst to apply the majority of available soil categorization schemes when characterizing soils for a specific project, cost and time constraints may prevent him from doing so. The alternative is to depend on documented relationships across soil categorization methods, understanding that each classification scheme has strengths and shortcomings (Oborie and Akpofure 2020).

The relationships between the USCS, BSCS, AASHTO, and USDA for soil samples analyzed in the research region have been identified. However, the USDA categorization approach has limited relevance in site characterization for civil engineering projects since, unlike the others, it is based only on the grain size distribution and makes no reference to the atterberg soil limits. According to the data, the correlation between USCS and BSCS is stronger than between USCS and USDA.

According to (Nwankwoala and Warmate 2014), the soil deposits within the depths investigated are characterized by a near-surface layer of a firm to stiff sandy clay. A layer of medium-density sand lies beneath. The water table was 11 meters below the earth's surface. Borings and cone resistance soundings have shown that the thickness of this deposit varies from 7 to 9 meters. The clay has an average CPT value of 10kg/cm^2, is typically red in color, and has an intermediate compressibility with mv values greater than 0.15 m^2/mn. This layer is recommended for design purposes with a cohesiveness of 50 kpa, an angle of internal friction of zero, and a saturated unit weight of 18 kn/m^3. A layer of mostly well-sorted, somewhat compact sand lies beneath the lower clay. About 11 meters of the sand deposits were confirmed. A layer of sand with a mean angle of internal friction of 31 degrees and zero percent cohesiveness is ideal for most design applications.

These results suggest that a layer of clay with a cu of around 50 kN/m^2 lies under the surface soil. Beneath this layer is a sand bed with a phi of 310–320 and a low density. Bearing capacity characteristics at 1.5m are modest (132 kn/m^2), reflecting the profile of the subsurface's permissible bearing capacity. Using a loading of 150 kN/m^2, we were able to anticipate a settling of 10 mm. The following foundation options should be considered in the region based on the findings of this study: I shallow foundation (ii) placement of a raft foundation for heavier construction/facilities.

The geotechnical characteristics of Minna, North-Central Nigeria, were determined by BS 1377 (1997) and head of (1990) techniques of soil testing for Civil engineers (Amadi *et al.* 2015). The outcome revealed that the analyzed soil samples are classed as sandy clay, which is incompressible, readily compactible, and has excellent drainage. The examined soil samples from the research region reveal a cohesive nature with a low moisture level and a high granular content, making them appropriate for road building except for position 5. These essential geotechnical study results may be utilized by civil engineers in the planning and building roads in Minna and the surrounding area for optimal durability and efficacy. Before beginning any construction project, such as a road, it is recommended to do engineering confirmation tests. Location 5's failing lateritic soil must be stabilized using cement, sand, or 1/2- and 3/4-inch crushed stone (gravel) to fulfill the sub-base or base course requirements.

2.8 Summary

Researchers discovered that various geotechnical features of soils had distinct effects on buildings. The greater the Gs, the larger the soil's load-bearing capability. The density indication is utilized to compress rough-grained soils. Stability limitations show the qualities of slight-grained soils; hence, slight-grained soils can be utilized for the building of a little permeability level for solid waste disposal. Gradation of soils is indicated by particle size, which aids in building ways, weirs, banks, filters, etc. Compaction increases the soil's impact ability. Soil unification characteristics reveal the settling of buildings. Permeability provides information on the solidity of grounds, leakage through banks, and so on. Shear strength is the supreme crucial geotechnical feature of soils, contributing to the solidity of constructions on or under the earth's surface. The interplay between various geotechnical qualities of soils can aid in constructing foundations for various civil engineering structures.

Physical qualities significantly affect the behavior of soil for farming and engineering applications. The structure and texture of the soil impact the overall porosity and range dispersal of pores, which affect the soil's water, heat, and air linkages. The texture is a fixed quality of soil, although management approaches may alter structure. To prevent soil structure deterioration, performing tillage activities when soil moisture levels are optimal is vital. Physical, chemical, and biological elements can be managed to ensure optimal soil physical situations for plant development. Soil value for plants and other organisms is affected by airing and heat. Airing and temperature in soil are greatly influenced by its moisture content. Together with the soil's air, it regulates the ground's temperature. The soil's consistency, flexibility, compaction, and other properties assist in determining its resistance to loading pressures from traffic, cultivation, or building foundations.

3. MATERIALS AND METHODS

3.1 Overview

The experimental work of this research was an effort to examine the effect of physical and geotechnical properties on soil characteristics. The physical properties include Specific Gravity, Density Index, bulk density, texture, structure, porosity, and moisture content. Geotechnical characteristics include of things like consistency limits, particle size analysis, compaction, permeability, and shear strength. The chapter is devoted to describe the materials, equipment, and the procedure used in the experimental work.

3.2 Materials

3.2.1 Soil

The testing procedure used soil taken from a farm. This soil is a natural soil with organic content (10%). The soil was cleaned, crushed and transported to the soil mechanics laboratory, where the experimental program is implemented.

3.2.2 Soil samples preparation

Disturbed natural organic soil samples were used in this work, taken from a depth of about (0.5 to 1.5 m). The soil excavated from this depth was a natural organic soil with organic content of (10 %). The disturbed samples were packed and carried to the Soil workshop. First, the soil was loose using the crushing machine as shown in Figure 3.1.

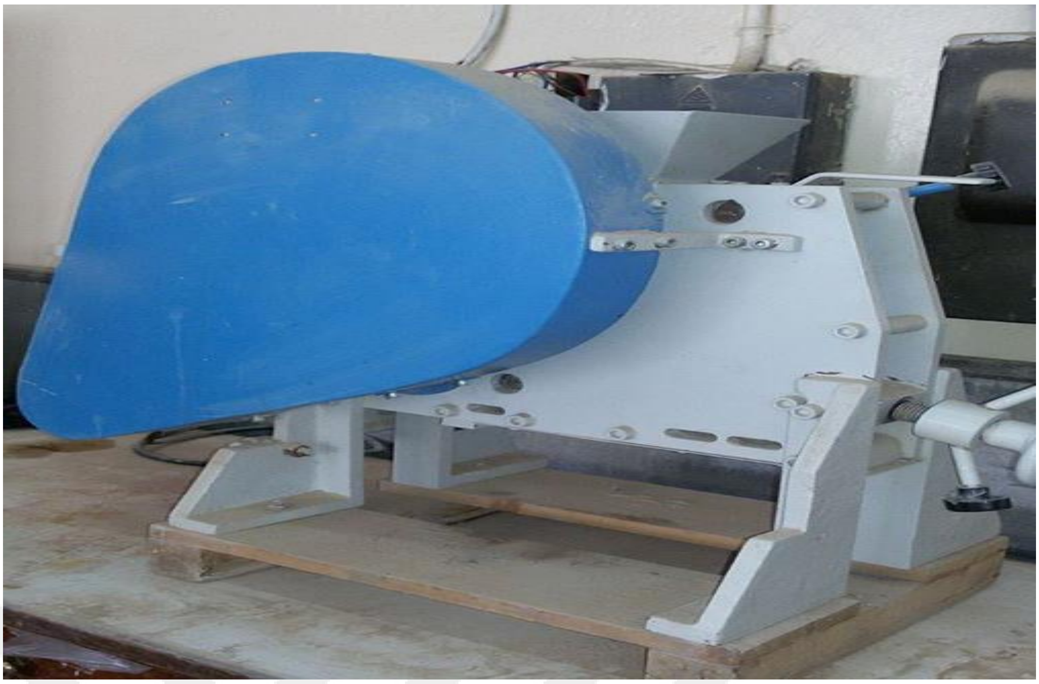

Figure 3.1 Crushing machine used in soil sample preparations

Physical tests were conducted in the laboratory for determining the Specific Gravity (Gs), Atterberg Limits and dry unit weight versus W.C (%) relationship. After that the samples were taken for the examinations procedure, which study by using (Unconfined Compression Test and One Dimensional Compression Tests).

3.3 Equipment

- Direct shear apparatus
- Conventional unification apparatus with a ring
- Crushing machine
- Sieve and hydrometer apparatus
- Water pycnometer
- Filter paper.
- Glass ware: (Pipette, Beakers, Volumetric flask).

The flow chart of the test program is shown in Figure 3.2.

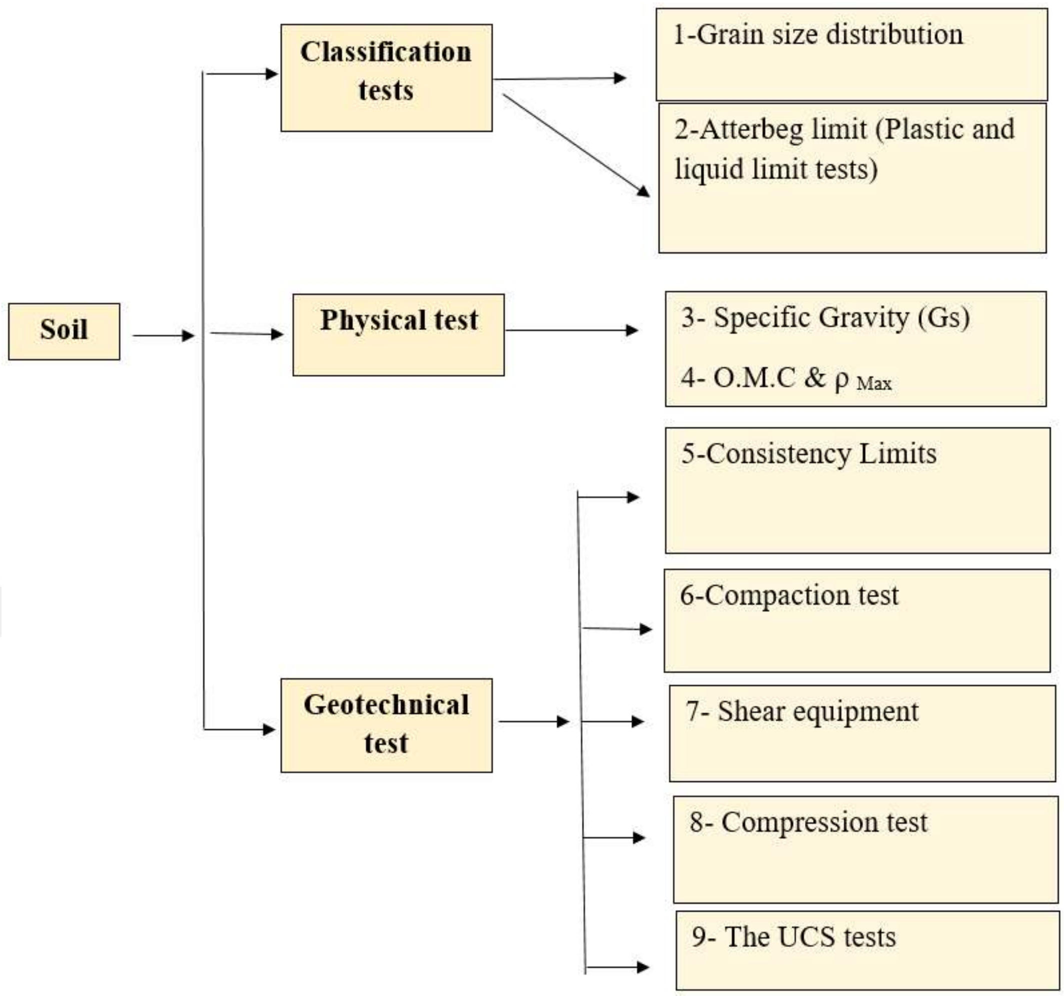

Figure 3.2 Flow chart of testing program

The flow chart of the experimental design is shown in Figure 3.3.

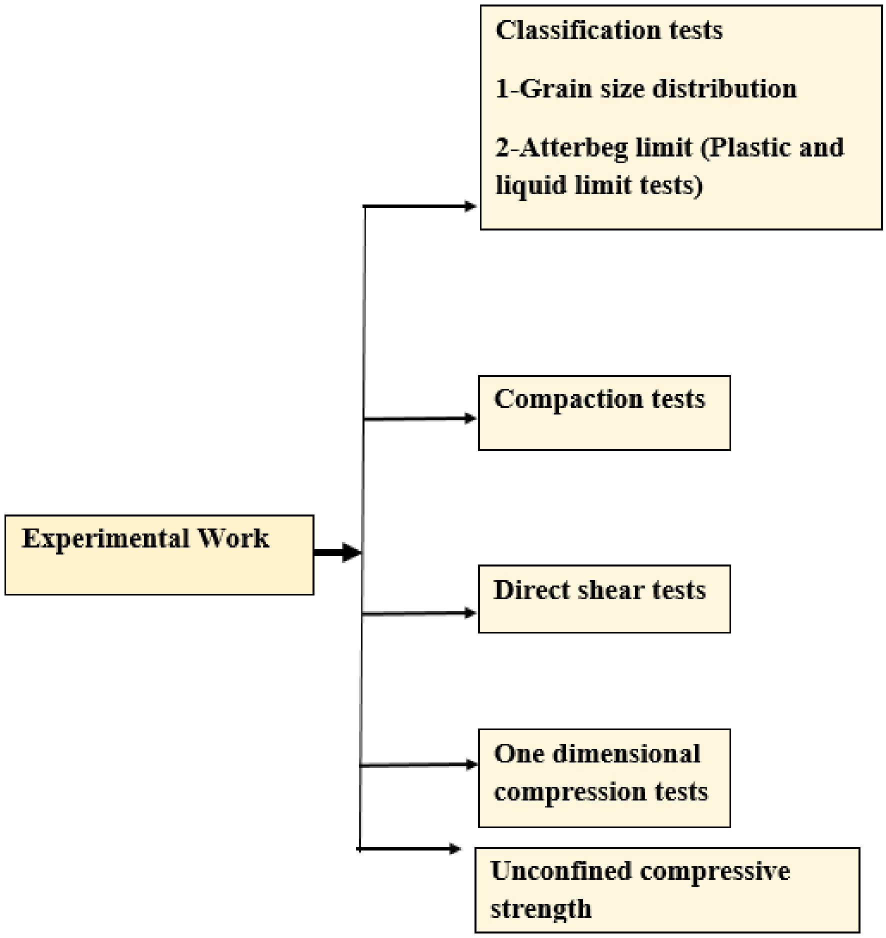

Figure 3.3 Flow chart of the experimental design

3.4 Classification Tests

Classification and identification tests are executed on the soil including grain size analysis, and Atterberg controls (plastic controls, liquid controls).

3.4.1 Grain size distribution

Grain Size Distribution of the investigated samples was determined by standard hydrometer method. The soil consists of (2%) sand, (55%) silt, and (43%) clay. As shown in Figure 3.4.

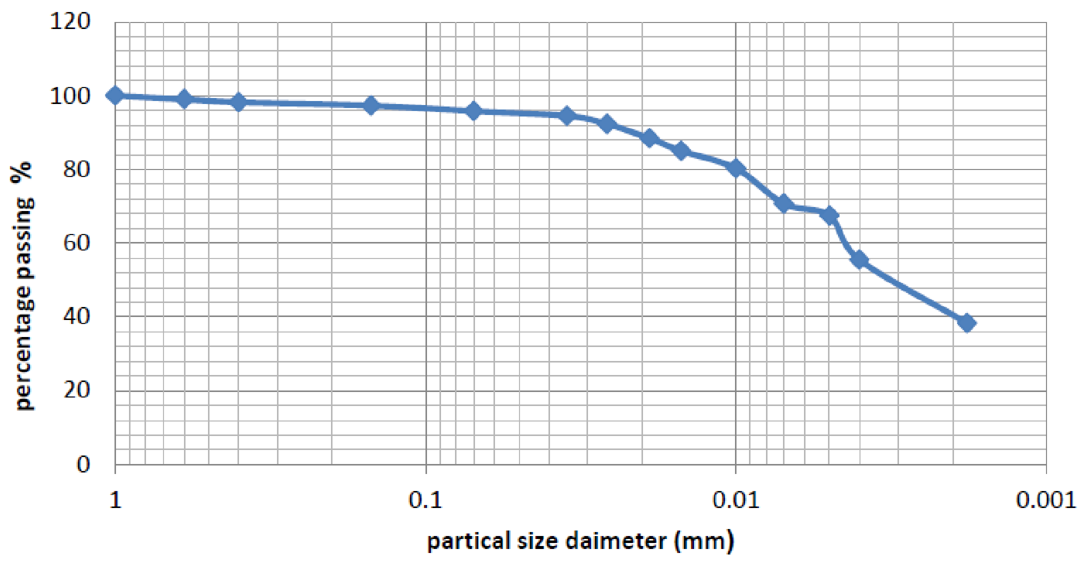

Figure 3.4 Grain size analysis for soil

3.4.2 Atterberg limits for soil

Liquid limit test is approved out in agreement with BS 1377, using the cone penetration method. The plastic limit was determined in accordance with BS 1377. The liquid and plastic controls of soil are (51.45%) and (28%) individually. In accordance with ASTM D 2487-06, soil is categorized as high plasticity clay (CH).

3.5 Physical Tests

There are several attributes to be taken for physical properties; these physical tests include specific gravity and ρ_{Max} versus W.C (%) correlation, which are illustrated in the following:

3.5.1 Specific gravity (Gs)

The specific gravity of the soil solids was evaluated using a water pycnometer in accordance with ASTM D 854-00. The Gs of soil solids was match to (2.825)

3.5.2 P_{Max} versus W.C (%) correlation

Standard proctor compaction test is carried out according to ASTM D 698-78. The results of the compaction test are plotted in Figure 3.5. The optimum W.C (%) for soil is (22.21%), while the ρ_{Max} is (15.48) kN/m^3 Table 3.1 shows the summary of physical and classification tests.

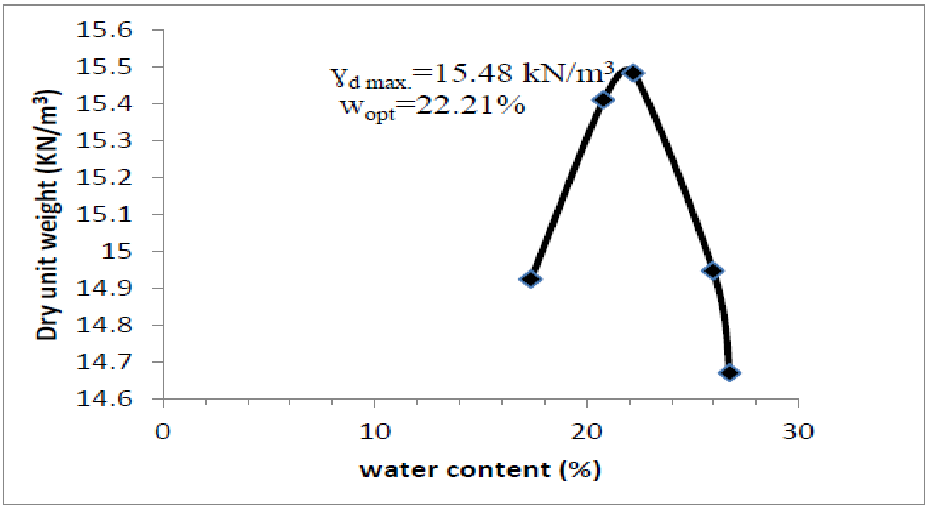

Figure 3.5 Dry unit weight vs soil moisture content

Table 3.1 The outcome of soil's physical and classifying features

Properties	**Value**	**Standard**
Specific Gravity (Gs)	2.825	**(ASTM D854, 2006)**
Liquid Limit (L.L.)%	51.45	**BS1377: 1975**
Plastic Limit (P.L)%	28	**BS1377: 1975**
Plasticity Index(P.I)%	23.45	
Standard compaction test	(15.48) kN/m^3	**ASTM D698-78**
Maximum dry ynit		
weight		
Optimum moisture content (%) (o.m.c)	22.21%	
Unified soil classification system (USCS)	CH*	**ASTM D 2166-06**

*CH: Clay of high plasticity

3.6 Consistency Limits (Plastic and Liquid Limits for Prepared Samples)

The plastic limit was controlled in agreement with BS 1377. Liquid limit test was approved out in agreement with BS 1377, using the cone penetration method.

3.7 Compaction Tests

The compaction test was showed on samples. The standard compaction force specified by ASTM D 698-78. Figure 3.6 shows the soil samples compacted.

Figure 3.6 The soil samples compacted

3.8 Direct Shear Tests

The purpose of this test is to control the shear strength limitations soil samples. Using the direct shear equipment, a chain of shear tests are showed agreeing to the ASTM D 3080-72. For horizontal deformation, a calibrated showing ring with a capacity of 2 kN and a precision dial gauge with a resolution of 0.002 mm are used. The strain rate selected for this test is 1mm/min. All examples were produced in a 60 x 60 x 20 mm direct shear box under three different normal stresses (39.51, 66.76, and 121.26 kPa).

The shear strength investigation for soil samples. The tasters were created by determining the taster weight that corresponds to 90% of the ρ_{Max} and has the optimal W.C (%), per Equation (3.1), Equation (3.2), Equation (3.3), Equation (3.4) and Equation (3.5).

$$\gamma_d = \gamma_{d\,max.} * 90\% \tag{3.1}$$

$$\gamma_d = \frac{\gamma_{wet}}{1+O.W.C} \tag{3.2}$$

$$\gamma_{wet} = (\gamma_{d\,max.} * 0.9) * (1 + O.W.C) \tag{3.3}$$

$$\gamma_{wet} = \frac{w}{v} * 9.81 \tag{3.4}$$

$$\gamma_{wet} = \frac{w}{v} * 9.81 = (\gamma_{d\,max.} * 0.9) * (1 + O.W.C) \tag{3.5}$$

Where v=72 cm^3 as in Equation (3.6)

$$w = (6.606 * \ \gamma_{d\,max.}) * (1 + O.W.C) \tag{3.6}$$

The weight was compacted in shear box at one layer. Figure 3.7 shows the soil in shear box.

Figure 3.7 The soil samples in shear box

3.9 One Dimensional Compression Tests

The one dimensional compression test was achieved via the traditional technique suggested by ASTM D 2435–80.

Samplings were confirmed in the conventional unification apparatus with a ring size of (75) mm in diameter and (20) mm in height. To avoid friction between the ring and soil specimen, grease is used to coat the inner face of ring.

The one dimensional compression tests investigation includes soil samples. The samples were set by calculating the model weight matching to 90% from ρ_{Max} that contains O.W.C (%), according to Equation (3.7).

$$w = (8.1101 * \gamma_{d\,max.}) * (1 + O.W.C) \tag{3.7}$$

These calculated weight was compacted in consolidometer ring at one layer. Figure 3.8 shows the soil samples in the ring of the unification apparatus.

Figure 3.8 The soil testers in the ring of the unification apparatus

3.10 Unconfined Compression Test (UCS)

The goal of this test is to assess the soil's strength and its stability. The UCS tests were conducted according ASTM D 2166-06.

The soils were compressed at O.W.C (%) in the mold and pushed in shelby tube sampler. A soil specimen having 76.5 mm height and 35 mm diameter was prepared and left in plastic wrapper, then kept it in bucket to prevent any water evaporation, as revealed in Figure 3.9.

Figure 3.9 Taster of unconfined compressive strength in a bucket

Soil Classification

By means of any the USCS ASTM D 2435–80 or AASHTO Category Arrangement, soils are classed to offer a usual terminology and a basic reference to their engineering performance (AASHTO M 145). Use of either technique to categorise soil relies on the size of the bulk of soil elements.

1. USCS: Unified Soil Classification System Each soil in the USCS

AASHO: the **AASHTO** technique classifies soil into seven broad classes, A-1 through A-7 (Table 3.2). Laboratory studies are necessary to categorise the soil. The following approach may be used to categorise the soil after the particle size curve (particle size vs. % passing) has been produced. Table 3.2 displays a contrast between the two systems.

Table 3.2 Contrast of the AASHTO system with the USCS

Soil groups in AASHTO system	Comparable soil groups in USCS		
	Most probable	**Possible**	**Possible but improbable**
A-l-a	GW,GP	SW, SP	GM.SM
A-l-b	SW,SP, GM.SM	GP	
A-3	SP		SW.GP
A-2-4	GM, SM	GC'.SC	GW.GP, SW.SP
A-2-5	GM.SM		GW.GP, SW.SP
A-2-6	GC, SM	GM.SM	GW.GP, SW.SP
A-2-7	GM.GC.SM, SC		GW.GP, SW.SP
A-4	ML.OL	CL.SM.SC	GM.GC
A-5	OH, MH, ML, OL		SM.GM
A-6	CL	ML. OL.SC	GC.CM.CM
A-7-5	OH. Mil	ML, OL.CII	GM.CM.GC. SC
A-7-6	CH, CL	ML. OL.SC	OH, MH, GC, GC. SM

3.11 Measuring Soil Moisture and Dry Density

The moistness content of soil samples was analyzed to identify any differences in moisture content. Oven-dried samples were used to calculate the soil's moisture content. In agreement through the ASTM standard, soil samples were deposited in aluminium containers and dried at 110 °C for 24 hours. The aluminium containers were weighed three times: while empty, before drying, and after drying. Therefore, the difference in weight between the boxes before and after drying was interpreted as the soil moisture. The W.C (%)and dry density (gm/cm^3) was calculated by the following Equation (3.8), Equation (3.9) and Equation (3.10):

$$W\% = \frac{Mw}{Ms} * 100 \quad (3.8)$$

- MW = Mass of hole water (gm)
- MS = Mass of soil matters (gm)

$$\rho_{wet} = \frac{M_{ws}}{V} \quad (3.9)$$

- M= moist mass of soil in template (gm)
- V= volume of template (cm^3)

$$\rho_d = \frac{\rho_{wet}}{1+\frac{W}{100}} \quad (3.10)$$

Measuring Soil Aggregate Stability

Aggregate stability was evaluated based on (Mutter 2018). The soil used in this research was dehydrated, cracked into tiny pieces, and filtered by a 4.75 mm sieve. Next, 25 g of soil was put in a graduated cylinder and 50 ml of distilled water was inserted to the soil sample (1:2 soil: water ratio). The combination was hand- stirred for one minute, afterward allowed for two hours to allow sand and silt to settle. After 2 hours of sedimentation, the residual soil solution was exposed to several tests, including pH, EC, SAR, and the DR as an indicator of soil aggregate solidity. The DR technique indicates the ratio of clay particles dispersed in soil solution (2m) to the original soil sample's total percentage of clay. Using the gravimetric approach, ten millimetres of the postponement was moved to a weighted glass and placed in an furnace to control the distributed soil components in interruption (Figure 3.10).

The following Equation (3.11) was used to compute the gravimetric (DR, %):

$$\text{Gravimetric (DR,\%)} = \frac{\text{Clay in suspension (gm)}}{\text{Clay in bare Soil Suspension (gm)}} \times 100 \quad (3.11)$$

The suspended soil components in both the crusted and bare soil samples were calculated using a field portable turbidity metre.

The following Equation (3.12) was used to obtain the turbid metric DR (%):

$$\text{Turbidity (DR,\%)} = \frac{\text{NTU of Suspension}}{\text{NTU of Suspension of bare Soil}} \times 100 \quad (3.12)$$

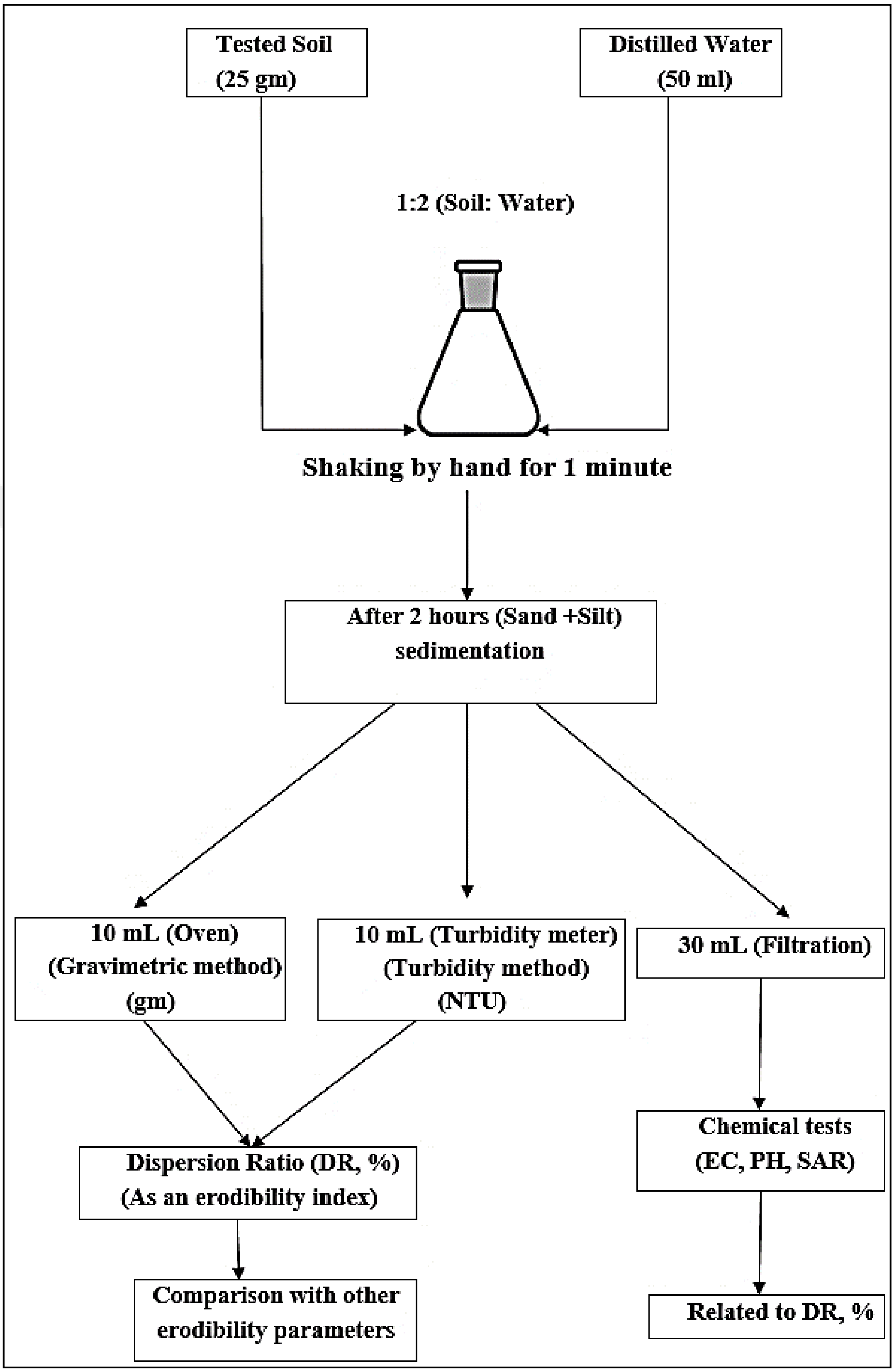

Figure 3.10 The dispersion ratio (DR, %) Determination

Bulk density test

The top of the soils were sampled for bulk density. The soils were collected to a depth of 1 m because they displayed substantial soil creation to at least that depth and since the majority of O.M in most soils is found in the top meter (Mutter 2018). The bulk density (kg/m^3) was measured by drying tasters of known volume for 24 hours at 105°C and then measuring the volume's oven-dry mass.

Soil Texture

As soil divides, main elements, or textural portions, sand, silt, and clay are the groupings of mineral particles with differing particle sizes. Soil texture is both qualitatively and quantitatively dictated by the size distribution of the soil's major mineral constituents. When rubbed between the thumb and finger, it gives an idea of the soil's texture, such as how rough it is or how smooth it is. In quantitative terms, soil grain is the comparative quantity of sand, silt, and clay matter.

There is a lot of overlap between the concepts of soil grain and soil mechanical organization. It is a relatively unchanging characteristic that affects almost every other soil variable. Grain has a significant impact on land management techniques and land use capabilities.

Classification of Soil Particles by Soil Texture

Soil grains with a diameter of less than 2 millimetres are included in the categorization and termed standard soil analysis material. Large particles found in certain soils may be a nuisance during tillage processes without necessarily adding anything useful to the soil's overall health. Gravel (2-4 mm), pebbles (4-76 mm), cobbles (76-250 mm), stones (250-600 mm), and boulders (>600 mm) are the different categories for particles larger than 2 millimeters.

There are numerous categorization schemes for soil particles, but **ISSS**, renamed the **IUSS**, and the USDA are the most prevalent (Table 3.3). In Table 3.4, we see that the most important features of sand, silt, and clay particles are summarized. Sand and silt elements in additive are made mostly of primary metals, whereas clay elements are made up of of secondary metals. While the sand and silt fractions are very inert and exhibit only mild levels of chemical and physical surface activity, the clay fraction is highly active. Clay, in contrast to sand and silt, may be thought of as the soil's organs and tissues. All three fractions, as well as the interstitial pore space, comprise the pattern of soil.

Table 3.3 Approaches of categorization of soil particle sizes as per their classification

International Society of Soil Science (ISSS)		**United States Department of Agriculture (USDA)**	
Particle	**Diameter (mm)**	**Particle**	**Diameter (mm)**
Coarse sand	2.0-0.2	Very coarse sand	2.0-1.0
Fine sand	0.2-0.02	Coarse sand	1.0-0.5
Silt	0.02-0.002	Medium sand	0.5-0.25
Clay	<0.002	Fine sand	0.25-0.10
		Very fine sand	0.10-0.05
		Silt Clay	0.05-0.002
			<0.002

Table 3.4 Revealed the value of silt, clay, and sand

Particle Properties	
Sand	Easily observable, often round or cube-shaped, coarse to the touch, poor at retaining moisture and nutrients, sloppy when dry, and very floppy and gummy when wet.
Silt	Not perceivable without the use of a microscope, they are typically spherical or cuboid in form, have a low to medium capacity to store water and nutrients, have a smooth texture, and exhibit considerable flexibility and stickiness when wet.
Clay	Swelling and contracting behavior, only detectable with an electron microscope; platy form; high water and nutrient retaining capacity; hard when dry; high plasticity and stickiness when wet.

3.12 Laboratory Analysis

The purpose of these examinations is to describe the soil. Few soil sorting systems have been utilized for this purpose, and these arrangements can be reformed into two categories: the multipurpose arrangements denoted by the triangular textural soil sorting scheme of the USDA and the USCS. The classifications of the AASHTO indicate the second kind, which is orientated by the specification for use as road subgrade.

Grain size dispersal: Using the Sieve Analysis Way and the Hydrometer Way, the particle size distribution was determined. The Sieve testing was used for aggregates with a sieve diameter larger than 80 m, but the Hydrometer Analysis technique was utilized for slight-grained soils transient a sieve size of 75 m.

In the current study, the liquidity limits were evaluated using the dispersal cone technique, while the plasticity limits were obtained using the roll way. The "Oven dry technique" was used to determine the moisture content of soils. It involves drying specimens in an oven at 105°C for 24 hours, then comparing the weight before and after the drying period.

Proctor Test: Compaction experiments were done in the laboratory using a modified Proctor analysis to assess the sum of compaction needed via the soil and, more importantly, the optimal W.C (%) associated with it. Concluded these experiments, the W.C (%)—dry density curves were schemed. These curves, which are unique to every material, provide, as easting and northing values, the ρ_{Max} and the O.M.C at their maxima.

Soil Arrangement: Primarily established on grain size analyses and Atterberg rations, the multifunctional soils classifying schemes aid engineers in describing the texture and consistency of soils (USDA) (USCS). In reality, the USDA Textural Category Scheme is established on distribution of grain sizes, but the USCS concurrently refers to pore size distribution, O.M, and consistency factors indicated by Atterberg limits.

4. RESULTS AND DISCUSSION

4.1 Overview

In present chapter, show the outcomes obtained in the experimental work. This chapter includes the presentation and discussion of the experimental program results, the chemical and physical properties of organic soil, and one dimensional and unconfined compressive strength tests. The results of liquid and plastic limits, compaction, shear strength, one dimensional compression and unconfined compressive strength tests are presented.

4.2 Presentation and Discussion of the Experimental Results

4.2.1 Physical properties

The physical properties which were investigated in this study include the specific gravity for soil samples. The standards of specific gravity of organic soil for various percentages of organic materials (0, 2, 5, 8, 12, 20) % by dry weight of soil are revealed in Table 4.1. This Table 4.1 includes also the values of specific gravity for organic soils after decomposition of organic material. The obtained results are calculated from equation, depending on the standards of specific gravity of natural soil equal to (2.63), organic material (1.67),

Table 4.1 Values of specific gravity for soil samples

O.M percent	**Specific gravity (G_s)**
5	2.721
10	2.624
15	2.534
20	2.45

4.2.2 Specific gravity results

As mentioned in chapter three the specific gravity of soil samples were established by the pycnometer test according to (ASTM D854) with values of (2.825). According to the experimental program, different percentages of organic soils were resulting a new mixture with different specific gravity. Equation (4.1) is used to determine the new value of specific gravity (Skempton and Petley 1970).

$$G = \frac{G_S G_P}{(G_S - G_P)P + G_P} \quad (4.1)$$

Where:

- G= mean specific gravity of organic soil sample
- Gs= mean specific gravity of soil particles
- GP= mean specific gravity of new solid
- P= quantity of additional material by dry weight

4.3 Consistency Limits of Organic Soil

4.3.1 Influence of organic material on plastic limit and liquid limit

Consistency limits were controlled in the lab for the organic soil with various percents of O.M. It was establish that liquid limit and plastic limit rise linearly with the rise in the O.M while the plasticity index almost remain constant with the rise of O.M as shown in Figure 4.1, This can be recognized to the great capacity of O.M for water absorption.

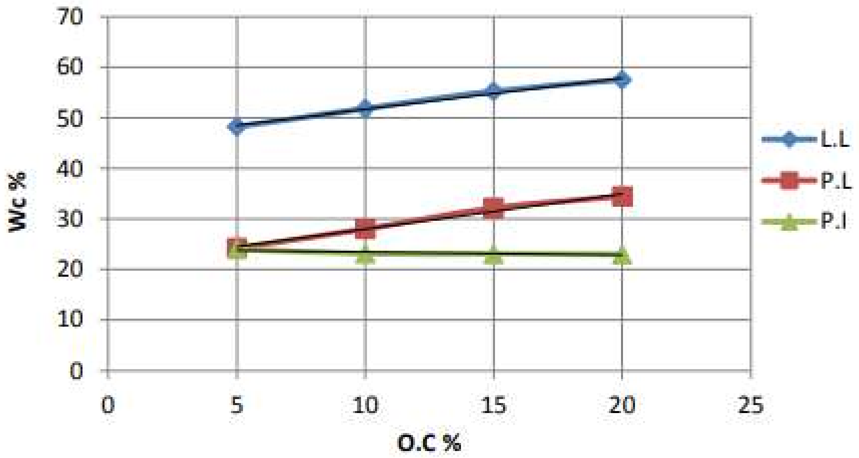

Figure 4.1 Difference of liquid limit, plastic limit and plasticity indication with ratio of O.M

The outcomes of the plastic limit, liquid limit experiments and plasticity indication are revealed in Figure 4.1.

The outcomes display that, the liquid limit, plastic limit rise linearly with the rise in the O.Ms for samples. These outcomes are recognized to the great capacity of O.M to suck water absorption.

4.4 Compaction Tests

4.4.1 Effect of organic material on compaction characteristic

Variations of dry unite weight with W.C (%) for organic soil with (5%, 10%, 15% and 20%) O.M is show in Figure 4.2. It can be noticed that the ρ max of the organic soil reduces as the O.M increases, while the optimum moisture content (O.M.C) increases as shown in Figure 4.3 and Figure 4.4 respectively. This can be recognised to that the specific gravity of organic material which is smaller relative to the specific gravity of soil solids leading to reduction in dry unite weight, then for the O.M.C improved with the rise of O.M. These results agree with the previous literatures (Al-Abbass and Ozguner 1985).

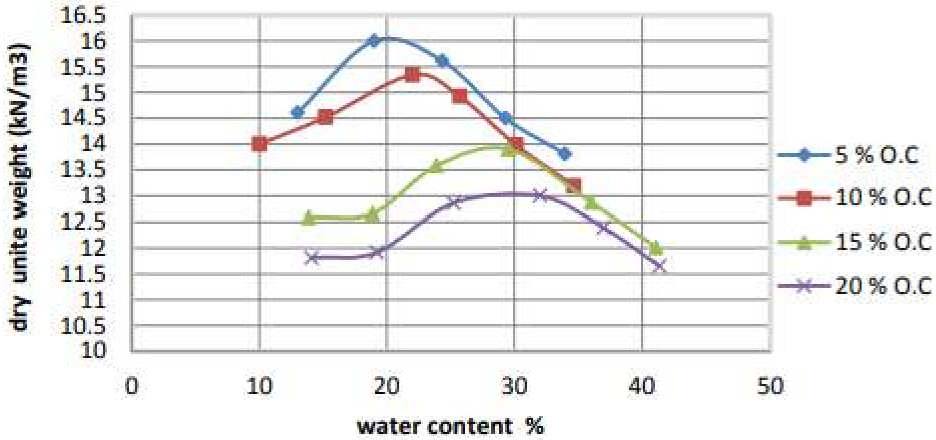

Figure 4.2 Compaction curves for diverse O.M

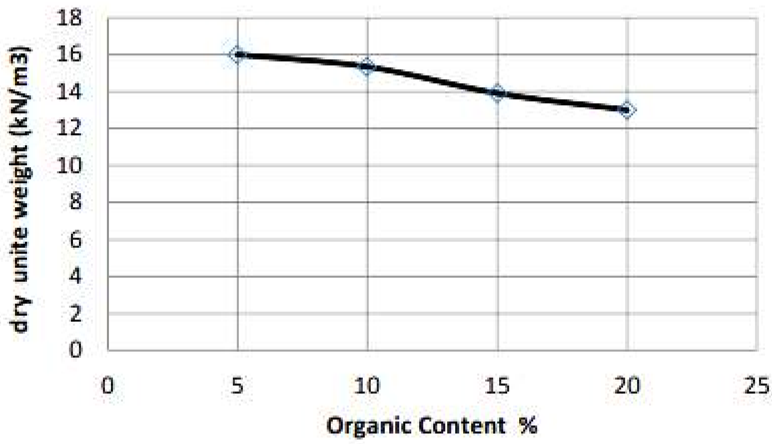

Figure 4.3 Variation of max dry unite weight with percentage of organic contents

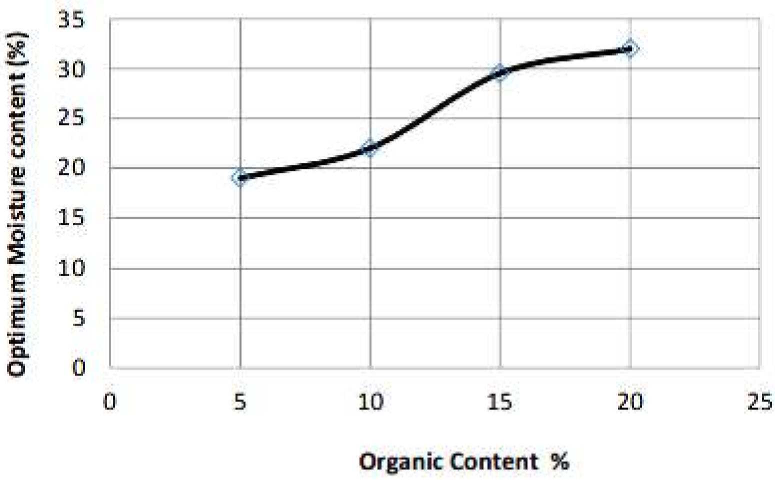

Figure 4.4 Difference of optimum W.C (%) with percentage of O.M

The consequences of the compaction tests are revealed in Figure 4.2, Figure 4.3, and Figure 4.4 respectively. The consequences point to that, as the O.M is improved, the maximum dry density (ρ_{max}) reductions and the O.M.C rises.

The reduction in ρ_{max} may be related to the rise in O.M. but the rises in O.M.C denote to great capacity of O.M to suck water absorption.

Figure 4.3 and Figure 4.4 displays the difference of ρ max and O.M.C for samples. The ρ max reductions with the rise in the O.M for samples. This may related to the fiber which acts as a binder between soil particles and a hinder to the compacting process. These outcomes approve with the (Al-Abbass and Ozguner 1985).

A summary of these results is given in Table 4.2.

Table 4.2 Value of ρ_{max} and O.M.C for organic soil

Organic material percent	ρ_{MAX} (KN/m^3)	O.M.C (%)
5%	16	19
10%	15.34	22
15%	13.9	29.54
20%	13.1	32

4.5 Strength Tests (Shear Strength Parameters)

Shear assessment is used to forecast the attitude of shear strength factors, angle of internal friction (ø˚) and cohesion (c) for tasters.

Shear stress against horizontal strain is schemed for both test below three certain normal pressures (39.51, 66.76, and 121.26) kPa.

4.5.1 Unconfined compressive strength (UCS) assessment

To estimate the strength development of the soils, the undrained shear strength was measured using the unconfined compressive strength (UCS) test which denoted the greatest public technique for assessing the strength of a stabilized soil.

UCS tests were performed on diverse samples of natural organic soils with (0%, 5%, 10%, 15% and 20% organic content). All the unconfined compressive tests were carried out on specimens with 1.05 O.M.C and 95 % ρ_{max} of the natural remolded organic soils obtained from stander Procter compaction test.

4.5.1.1 Influence of organic content on unconfined compressive strength (UCS)

Figure 4.5 plays the connection amid the UCS and O.M in the soil. It can be realized that increasing the O.M causing a reduction in the UCS, brief of the consequences attained from these trials is given in Table 4.3.

Table 4.3 Summary of UCS tests results for O.M %

Organic Content %	Unconfined compressive strength (q_u) Kpa
0	160.799
5	141.43
10	113.58
15	89.07
20	75.77

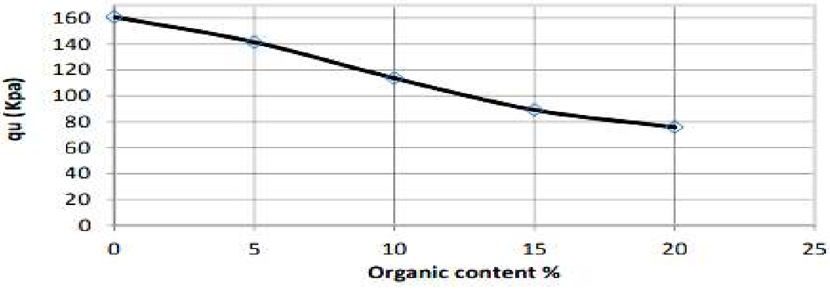

Figure 4.5 Variation of UCS (qu) with different O.M

4.6 One Dimensional Compression Checks

These checks are showed to study the influence of O.M on the compressibility parameters (compression index Cc, rebound index Cr, coefficient of consolidation Cv, and coefficient of secondary compression Cα).

4.6.1 Influence of O.M on compressibility characteristics

4.6.1.1 Impact of O.M on compression index (cc) and Rebound Index (cr)

Compression Indication is the difference of the void ratio (e) as a purpose of the variation of effective stress (p) marked on the logarithmic scale. The compression behavior of organic soils is shown in Figure 4.6, Table 4.4 show the summary of compression tests results. The rates of compression index increased with the rise of O.M as shown in Figure 4.7. This performance can be recognized to the fact that, the adding of O.M improved the void ratio which leads to rise the compressibility. These results agree with the previous studies (Andersland and Al-Khafaji 1980, Brady 1984, Al-Saoudi *et al.* 2013).

The rebound index was established from the chart demonstrating the difference of void ratio (e) as a role of the effective stress (p) marked on the logarithmic scale for receiving - refilling sequence. The rebound index increased with the rise in O.M for organic soil samples with O.M less than 15 % then after started to reduction as shown in Figure 4.8. This may be referred to that organic soil with high O.M (more than 15 %) is highly compressibility with low ductility, where organic material upon loading may not easily retain deformation.

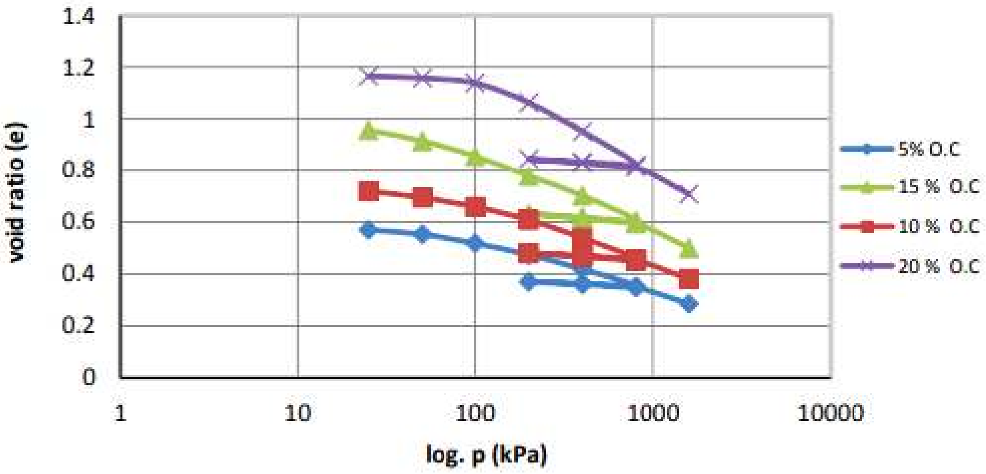

Figure 4.6 Void ratio against logarithm of consolidation pressure for diverse O.M.

Table 4.4 Summary of compression tests outcomes for organic samples

Properties	O.C. %			
	5	10	15	20
γ_d (kN/m^3)	15	15.34	13.9	13
e^o	0.58	0.72	0.96	1.18
W.C (%)	19	22	29.54	32
C_c	0.2065	0.2359	0.3127	0.3459
C_r	0.0295	0.038	0.0486	0.0405

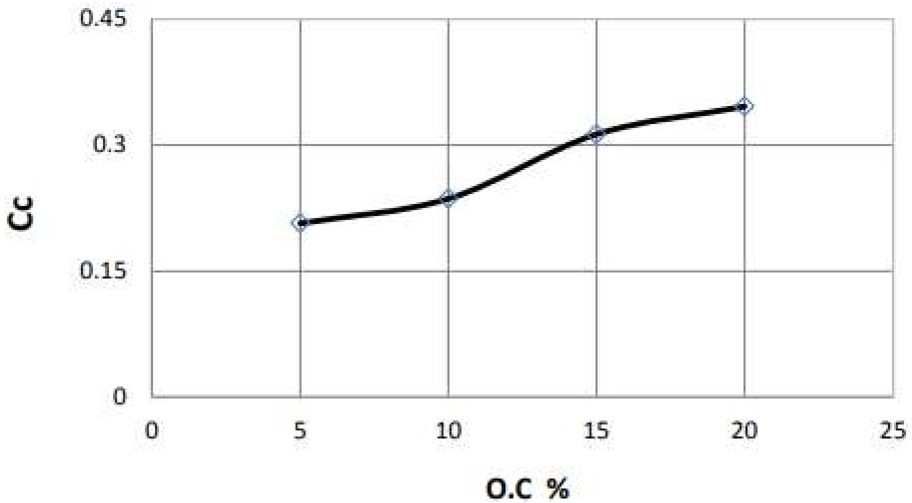

Figure 4.7 Influence of O.M on compression index for organic soil

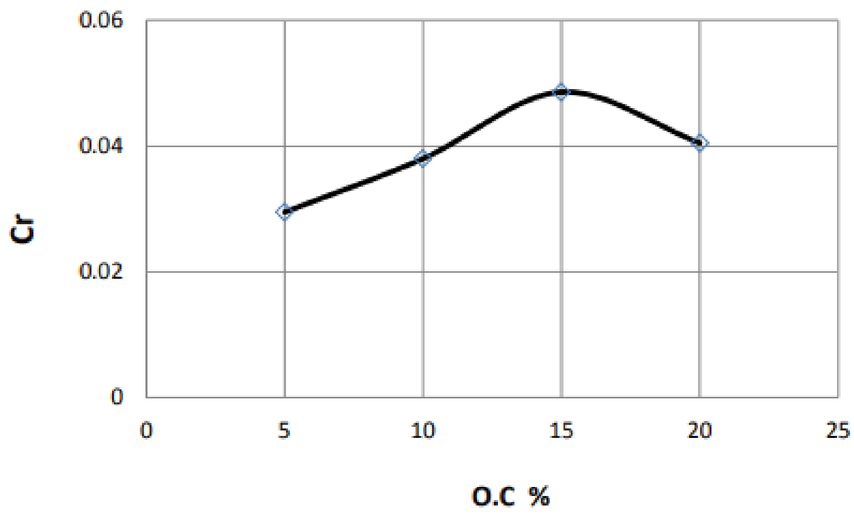

Figure 4.8 Effect of O.M on rebound index for organic soil

4.6.1.2 Effect of O.M on coefficient of consolidation (C_v)

Square root time technique is used to control the coefficient of consolidation for tested organic soils. The outcomes for all samples at different O.M are reviewed in Table 4.5. The amounts of (cv) ranged from (2.47–12.245) m^2/yr. The values of (cv) rise with the rise of unification pressure for all percentages of O.M. As shown in Figure 4.9.

The rise in coefficient of consolidation (cv) for organic soil samples may be referred to the rise of void ratio with increasing of O.M. The rise in void ratio causes rise in permeability which increased the value of (cv).

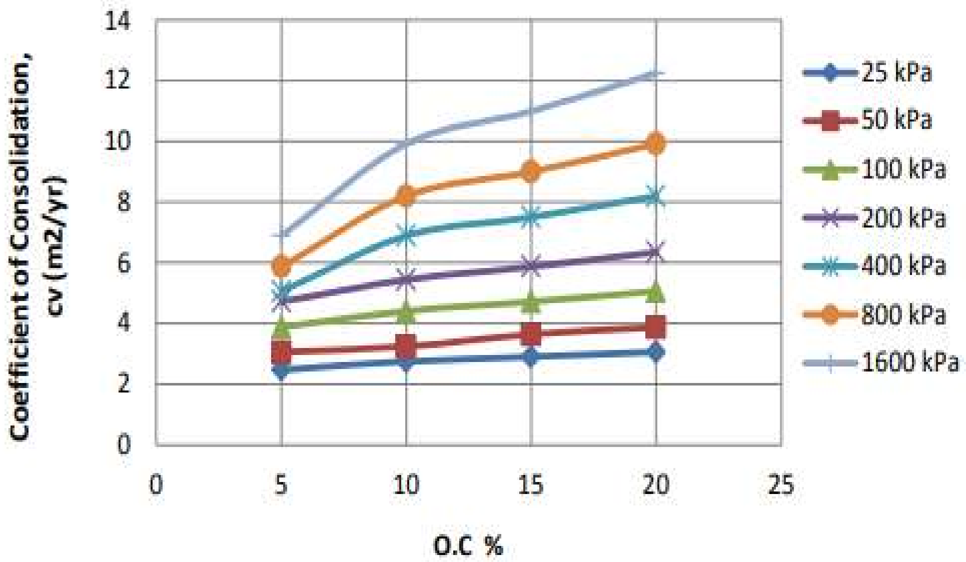

Figure 4.9 Effect of O.M on coefficients of consolidation for diverse consolidation pressures for O.C %

Table 4.5 Quantity of C_v (m^2/yr) for O.M models

P (KPa)	O.M. %			
	5	10	15	20
25	2.47	2.747	2.898	3.061
50	3.06	3.238	3.643	3.874
100	3.874	4.408	4.717	5.06
200	4.717	5.44	5.868	6.347
400	5.06	6.887	7.499	8.197
800	5.868	8.197	8.996	9.918
1600	6.887	9.918	10.99	12.245

4.6.1.3 Effect of O.M on coefficient of secondary compression (C_α)

The indication of secondary compression is relative to the logarithm of time and the slope of main main. Coefficient of secondary compression for organic soils is considered to be the incline of axial stress vs. logarithm of time curve for period after transitory 24 hours which will be asymptotic later the dial gage analysis becomes stable below a unification pressure (1600) kPa.

Figure 4.10 show the variation of coefficient of secondary compression (C_α) with the O.M, the values of (C_α) rise with the rise in O.M indicating continued compression after primary unification completed.

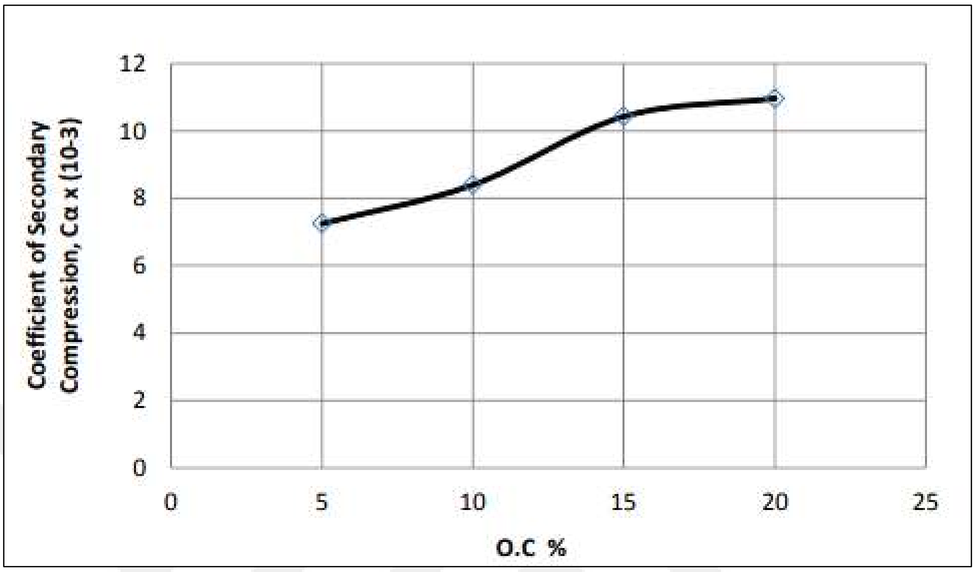

Figure 4.10 Effect of O.M on coefficients of secondary compression for organic samples

4.7 Effect Aggregation Stability on Soil-Water Erodibility

Soil aggregate stability measurement one of the most important approaches to assess water erodibility

Figure 4.11 (A) shows a clear relationships between the aggregate stability measured as dispersion ratio DR (%) by gravimetric method of the crusted and bare soil with the kd.

The figure designates that whenever the dispersion ratio reduction in the soil, the erodibility coefficients (kd) of soil reduced which income that soils are below better steadiness situations. More O.M seems as the best additive in reduction together dispersion ratio and erodibility coefficients (kd) of soil mixture, due to the O.M act as a binding material to improving soil particle connections as well as the organic binding agents contributed in stabilizing aggregates

Figure 4.11 (B) shows the relationships between the dispersion ratio DR (%) by turbidity method of the soil samples with the kd.

The DR seems a reduction in O.M soil, same as above results. It is clearly indicated that the Turbidity DR (%) can be effectively used as a steady indication of the soil control position.

Also, this point is in attached beside (Nwankwoala and Warmate 2014) who establish that turbidity capacities often can be connected and used as a additional for gravimetric solids quantity in the measuring Aggregate Stability.

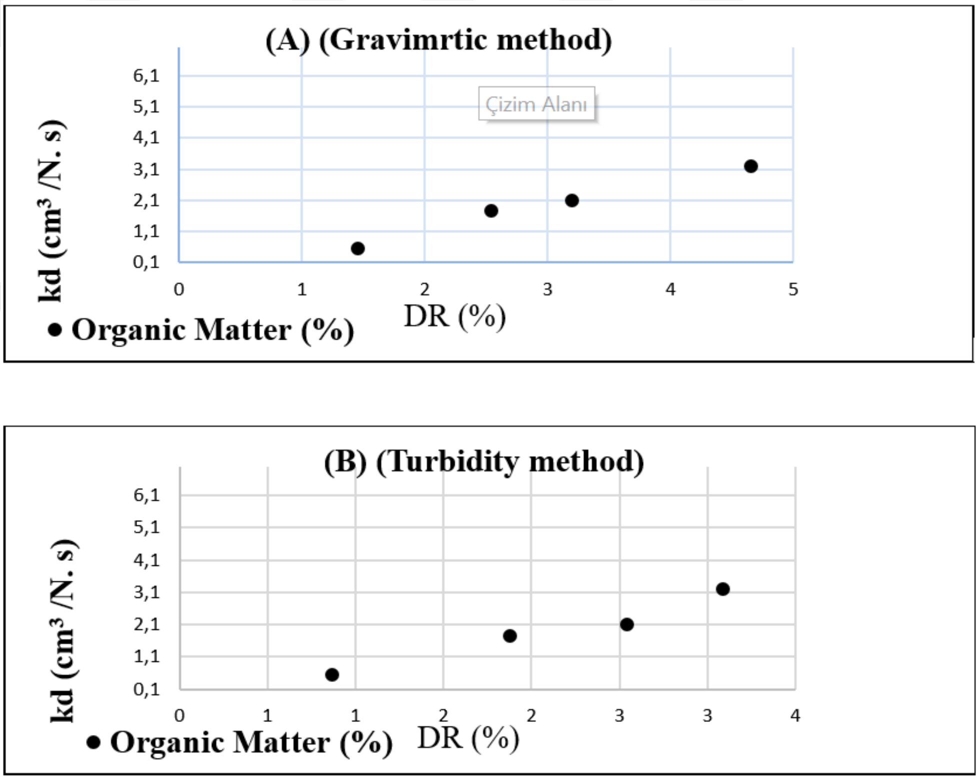

Figure 4.11 Relationships between Dispersion ratio (DR), measured by two method (Gravimetric method and Turbidity technique), and the k_d

Lastly, the influence of O.M (%) on the turbidity DR, %. Water interruption are summarized in Table 4.6, and compare these results with an erodibility classification derived by (Mutter 2018).

Figure 4.12 indicates that there is a great relationship amid the DR and the erodibility coefficients (kd), and at any time the dispersion ratio (DR, %) growth in soil, the erodibility coefficients (kd) rise. After these figures, turbidity DR method standards played to be weakly larger than those gravimetric methods (Oborie and Akpofure 2020).

These outcome may mention the utility of the turbidity DR in measuring the strength of soils, which is in agreement with the results of (Nwankwoala and Warmate 2014).

Table 4.6 Effect of the two biocrust and bare soil on the Turbidity Dispersion Ratio (DR, %)

Sample O.M (%)	DR % (Turbidity method)	Soil Stability or Erodibility Class	Turbidity DR, (%)
5	7.9	Unstable/ Erodible	>7
10	4.085	Moderately Stable/Moderately Erodible	2-7
15	2.91	Moderately Stable/Moderately Erodible	2-7
20	1.19	Very Stable/ Non- Erodible	<2

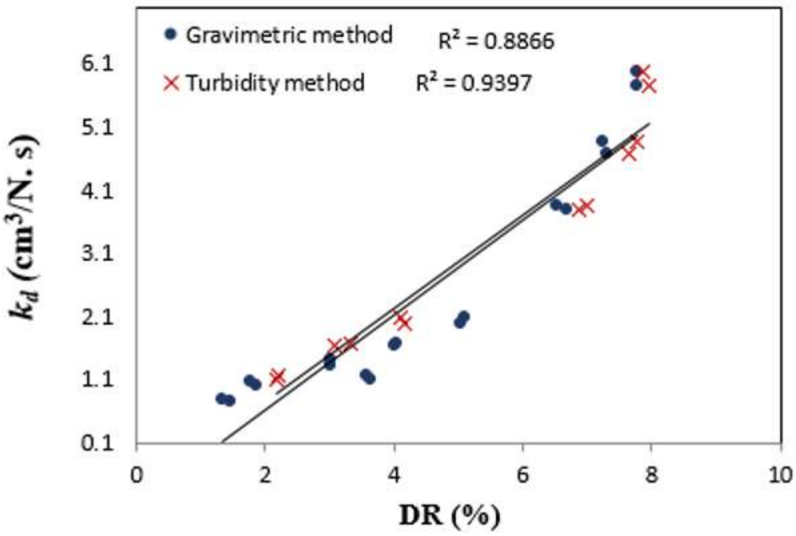

Figure 4.12 Comparison between two methods for measuring dispersion ratio (DR)

4.8 Relation Between Dispersion Ratio and SAR

Figure 4.13 show the link between the SAR and DR, % of soil samples.

The soil samples have sharply reduced the SAR. The decreases in SAR and hence in DR are basically associated to the rise of divalent and trivalent cations necessary in clay flocculation on the account of sodium (Amadi *et al.* 2015). The main physical processes related by great sodium intensities and hence SAR is soil dispersion. Calcium and magnesium, secreted by O.M, may usually keep soil flocculated by binding clay particles.

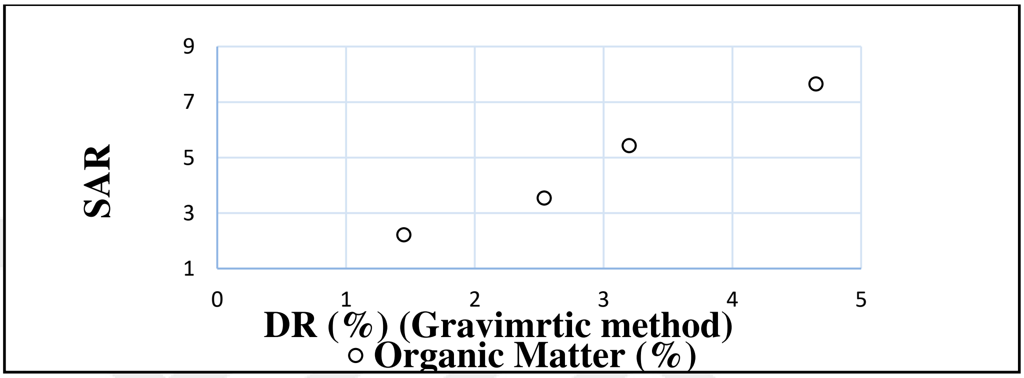

Figure 4.13 The connection between the SAR and DR, % of diverse organic soil

4.9 Influence of O.M (%) of Soil Wetness

To deal in the variation in W.C (%) levels and bulk densities at different O.M (%) are stated in Table 4.7.

A slightly increased in W.C (%) of O.M (%). This was due to the rise the water retention at the soil surface (Belnap 2001).

Table 4.7 The W.C (%) and bulk density (g/cm^3) for different O.M (%)

O.M (%)	W.C (%)	Bulk ρ (g/cm^3)
5	10.6	1.51
10	14	1.56
15	18	1.52
20	23.8	1.58

4.10 Influence of Soil O.M on τ_c and k_d

With a view to examine the attitude of erodibility parameters (kd and τc) versus O.M (OM),

Figure 4.14 and Figure 4.15 reports the relationship between k_d and τ_c versus OM for soil samples.

Note that the O.M was 5 % at initial and reached up to 20%.

The O.M reduction soil erodibility via the effect of soil aggregation. A identical result by ASTM D 3080-72 show that the prevalence of O.M (OM) of any kind appears to be involved in determining soil eroded in the area. Eroding could rise because of rise of thin elements, which are additional simply eroded, or it may reduction because of rising OM. Despite the influence of O.M is extracted mostly in the upper soil, they are critical as they are like to a type of skin on the upper soil defensive soil from water destruction.

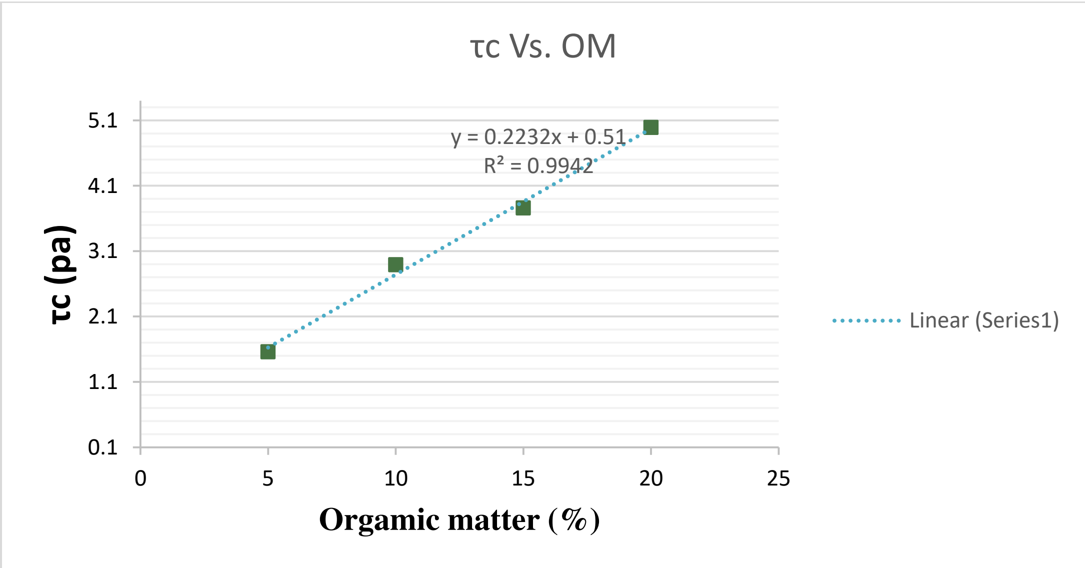

Figure 4.14 Influence of different O.M (%) on τ_c

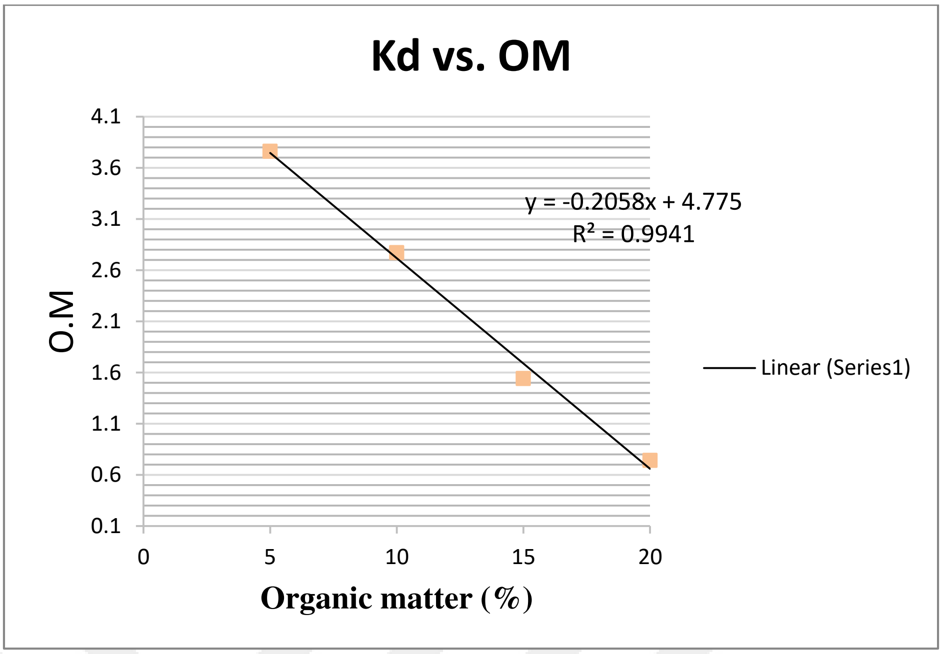

Figure 4.15 Influence of different O.M (%) on k_d

Organic Carbon (OC) is another important factor often affecting soil penetration resistance (Figure 4.16) (Figure 4.17).

As predictable and similarly to IN, a decline in limitation kd was monitored as OC rising, whereas the τc growthed. After soils were gained, the OC was 2.9 % and extended up to 11.6 %.

In unconsolidated sands, the attachment of soil particles O.M (%) participated to rising the soil strength and resistance, as in Equation (4.2)

$$\text{O.M}(\%) = 1.724 * \text{ Total Organic Carbon } (\%) \tag{4.2}$$

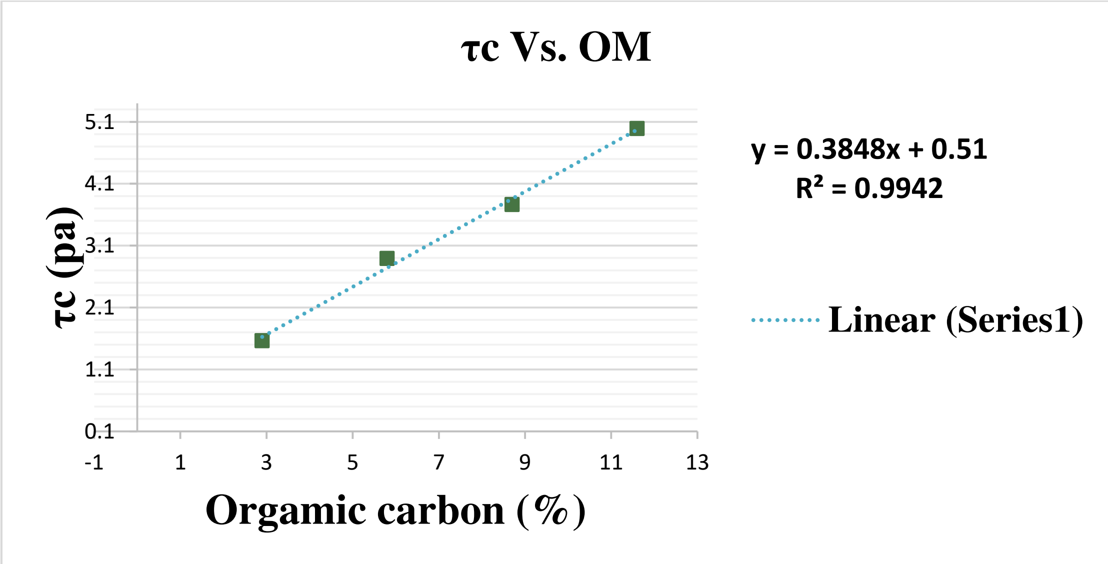

Figure 4.16 Influence of different O.M (%) on τ_c

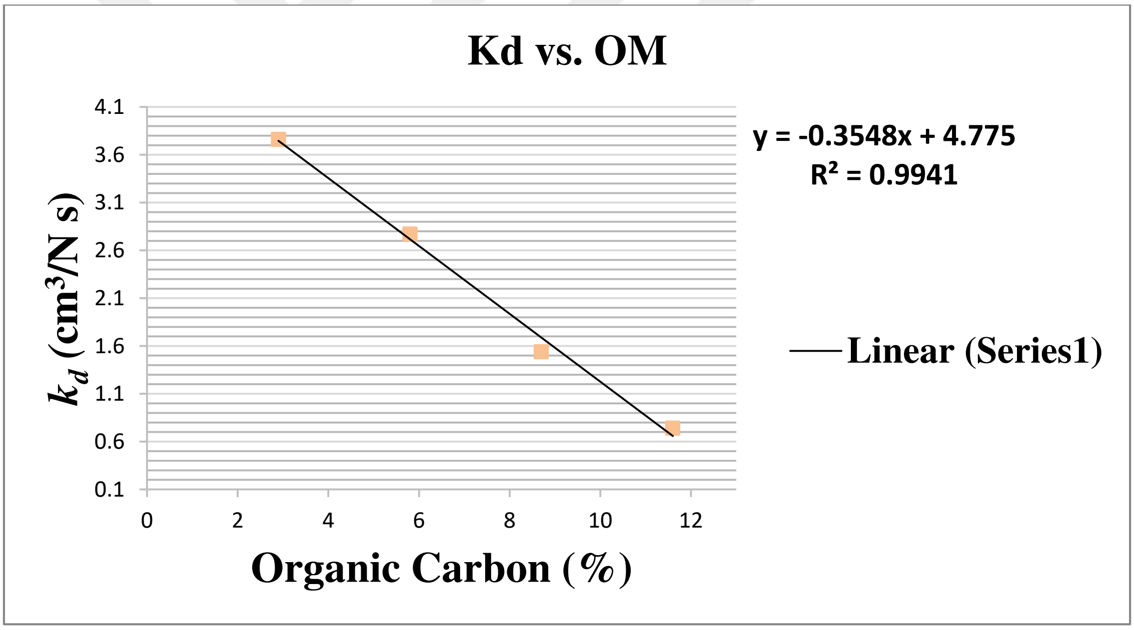

Figure 4.17 Influence of different O.M (%) on k_d

5. CONCLUSIONS AND RECOMMENDATION

5.1 Inference and Recommendation

- The liquid, plastic levels and plasticity indication rise with the rise in the O.M for soil samples.
- The greatest density reductions and the O.W.C rises by the rise in the O.M for soil samples.
- The amount of cohesion for O.M soil samples rise with the rise in the O.M up to 6.92%.
- The rise in the organic content from (0-20) % leads to rise the angle of internal friction (Ø˚) values by about 2.355 decayed samples.
- The rise in the O. M from (0-20) % leads to rise the compression index (Cc) values by about 1.6 for decayed samples.
- The rise in the O.M from (0-20) % leads to rise the coefficient of consolidation (Cv) values by about 25.49 for decayed samples.
- The rise in the O.M from (0-20) % leads to rise the secondary compression (Cα) values by 2.694 for decayed samples

5.2 Recommendations for Future Works

A set of recommendations for future research

- The influence of another O.M on the engineering property of clay in both cases before and after decomposition of organic material.
- Theoretical studies to predict the secondary compression settlement for long time durations for decomposed samples can be implemented.
- Effect of curing time on the organic soil treated with chemical material.

REFERENCES

Abd El Maksoud, M. A. 2006. Laboratory determining of soil strength parameters in calcareous soils and their effect on chiseling draft predictıon. In Energy Efficiency and Agricultural Engineering International Conference, 2006.

Abeele, W. V. 1985. Consolidation and shear failure leading to subsidence and settlement. Part I (No. LA-10261-MS). Los Alamos National Laboratory, 11(1).

Agbede, O. A., Jatau, N. D., Oluokun, G. O. and Akinniyi, B. D. 2015. Geotechnical investigation into the causes of cracks in building: A case study of Dr. Egbogha building, university of Ibadan, Nigeria. International Journal of Engineering Science Invention, 4(11): 18-22.

Akayuli, C., Ofosu, B., Nyako, S. O. and Opuni, K. O. 2013. The influence of observed clay content on shear strength and compressibility of residual sandy soils. DSpace, 3(4), 2538-2542.

Al-Abbass, F. and Ozguner, U. 1985. Decentralized model reference adaptive system using a variable structure control. In 1985 24th IEEE Conference on Decision and Control (pp. 1473-1478). IEEE.

Al-Saoudi, N. K., Al-Khafaji, A. N. and Al-Mosawi, M. J. 2013. Challenging problems of gypseous soils in Iraq. In Proceedings of the 18th International Conference on Soil Mechanics and Geotechnical Engineering, 479-482.

Amadi, A. N., Akande, W. G., Okunlola, I. A., Jimoh, M. O. and Francis, D. G. 2015. Assessment of the geotechnical properties of lateritic soils in Minna, North Central Nigeria for road design and construction. FUTMinna Institutional Repository, 15(1).

Andersland, O. B. and Al-Khafaji, A. A. W. 1980. Organic material and soil compressibility. Journal of the Geotechnical Engineering Division, 106(7): 749-758.

Apparao, K. V. S. and Rao, V. C. S. 1995. Soil testing laboratory manual and question bank. Taylor & Francis, 153 page, London.

Bell, F. G. and Maud, R. R. 1995. Expansive clays and construction, especially of low-rise structures: a viewpoint from Natal, South Africa. Environmental & Engineering Geoscience, 1(1): 41-59.

Belnap, J. 2001. Biological soil crusts: structure, function, and management. Springer, 150: 241-261.

Bowles, J. E. 1979. Physical and geotechnical properties of soils. McGraw-Hill, 448 page, New York.

Bowles, J. E. 1992. Engineering properties of soils and their measurement. McGraw-Hill, 481 page, New York.

Brady, N. C. and Weil, R. R. 2004. Elements of the nature and properties of soils. Pearson Education, 4(1): 1-9.

Brady, R. H. 1984. Neogene stratigraphy of the Avawatz Mountains between the Garlock and Death Valley fault zones, southern Death Valley, California: Implications as to late Cenozoic tectonism. Sedimentary Geology, 38(1-4): 127-157.

Brevik, E. C. 2013. Forty years of soil formation in a South Georgia, USA borrow pit. Soil Horizons, 54(1): 20-29.

Buol, S. W., Southard, R. J., Graham, R. C. and McDaniel, P. A. 2011. Soil genesis and classification. John Wiley & Sons, 560 page, New York.

Burnett, A. D. 1975. Engıneering geology and site investigation. Part 2: Field studies. Ground Engineering, 8(4).

Chen, B. S. and Jensen, R. E. 2013. Case studies of dewatering and foundation design: Retail warehouses in Taiwan. In Proceedings of the International Conference on Case Histories in Geotechnical Engineering, Chicago, IL, USA (Vol. 29).

Cline, M. G. 1949. Basic principles of soil classification. Soil Science, 67(2), 81-92.

Dafalla, M. A. 2013. Effects of clay and moisture content on direct shear tests for clay-sand mixtures. Advances in Materials Science and Engineering, 13(1).

Ersoy, H., Karsli, M. B., Cellek, S., Kul, B., Baykan, I. and Parsons, R. L. 2013. Estimation of the soil strength parameters in Tertiary volcanic regolith (NE Turkey) using analytical hierarchy process. Journal of Earth System Science, 122(6): 1545-1555.

Foth, H. D. 1978. Fundamentals of soil science. Soil Science, 125(4): 272.

Franks, C. A. M. and Woods, N. W. 1993. Engineering geology of North Lantau, Hong Kong. Quarterly Journal of Engineering Geology and Hydrogeology, 26(2): 81-98.

García-Gaines, R. A. and Frankenstein, S. 2015. USCS and the USDA soil classification system: Development of a mapping scheme. ERDC Knowledge Core, 15-27.

García-Gaines, R. A. and Frankenstein, S. 2015. USCS and the USDA soil classification system: Development of a mapping scheme. ERDC, 1-46.

Gogoi, J. C. and Laskar, A. A. 2015, Mechanical compaction-a simple ground improvement technique: A case study. Discovery, 40(185): 377-383.

Head, K. H. 1992. Manual of soil laboratory testing. Volume 1. Soil classification and compaction tests. Pentech Press Limited, 388 page, London.

Hillel, D. 2012. Soil and water: physical principles and processes. Elsevier, 304 page, Amsterdam.

Jansen, R. B. 1988. Advanced dam engineering for design, construction, and rehabilitation. Springer Science & Business Media, 292–320.

Kaniraj, S. R. 1988. Design aids in soil mechanics and foundation engineering. McGraw-Hill, 698 page, New York.

Khadge, N. H. 2002. Geotechnical properties of siliceous sediments from the Central Indian Basin. Current Science, 338-343.

Koçak, A. and Köksal, T. 2010. An example for determining the cause of damage in historical buildings: Little hagia sophia (Church of St. Sergius and Bacchus)–Istanbul, Turkey. Engineering Failure Analysis, 17(4): 926-937.

Kohnke, H. E. L. M. U. T. and Barber, S. A. 1968. Tillage techniques on Indiana prairie soil. In Proceedings of the Indiana Academy of Science, 7(8): 418-428.

Lal, R. and Shukla, M. K. 2004. Principles of soil physics. CRC Press, 736 page, New York

Laskar, A. and Pal, S. K. 2012. Geotechnical characteristics of two different soils and their mixture and relationships between parameters. EJGE, 17: 2821-2832.

Lee, C., Yun, T. S., Lee, J. S., Bahk, J. J. and Santamarina, J. C. 2011. Geotechnical characterization of marine sediments in the Ulleung Basin, East Sea. Engineering Geology, 117(1-2): 151-158.

Mallo, S. J. and Umbugadu, A. A. 2012. Geotechnical study of the properties of soils: a case study of Nassarawa-Eggon town and environs, northern Nigeria. Continental Journal of Earth Sciences, 7(1): 40-47.

Michelin, A., Khatchadourian, A., Durgunoglu, H. T. and Akcakal, O. 2015. A case study on soil improvement with dynamic compaction and dynamic replacement. ICE Virtual Library, 15(11).

Miller, J., Barton, C., Agouridis, C., Fogel, A., Dowdy, T. and Angel, P. 2012. Evaluating soil genesis and reforestation success on a surface coal mine in Appalachia. Soil Science Society of America Journal, 76(3): 950-960.

Murthy, V. N. S. 2002. Geotechnical engineering: principles and practices of soil mechanics and foundation engineering. CRC press, 1056 page, Florida.

Mutter, G. M. 2018. The use of portable turbidity meters in developing an erodibility classification system for Iraqi soils. IJSRSET, 4(1): 1-11.

Naik, S., Naik, N. P., Kandolkar, S. S. and Mandrekar, R. L. 2011. Settlement structure—A case study. In Proceedings of the Indian Geotechnical Conference, Kochi, 1031-1034.

Nwankwoala, H. O. and Warmate, T. 2014. Geotechnical assessment of foundation conditions of a site in Ubima, Ikwerre local government area, Rivers State, Nigeria. International Journal of Engineering Research and Development (IJERD), 9(8): 50-63.

Oborie, E. and Akpofure, E. 2020. Geotechnical Investigation of Subsoils for Foundation Design in Port Harcourt, Nigeria. Geoscience and Remote Sensing, 3(1): 17-28.

Oyediran, I. A. and Durojaiye, H. F. 2011. Variability in the geotechnical properties of some residual clay soils from southwestern Nigeria. International Journal of Scientific & Engineering Research, 2(9): 1-6.

Prakash, S. 1979. Engineering soil testing. Nem Chand, 88 page, Wisconsin.

Que, J., Wang, Q., Chen, J., Shi, B. and Meng, Q. 2008. Geotechnical properties of the soft soil in Guangzhou College City. Bulletin of Engineering Geology and the Environment, 67(4): 479-483.

Raj, P. P. 2008. Soil mechanics and foundation engineering. Pearson Education India, 840 page, New Delhi.

Ramanathan, K. M. 1994. Text book of soil science. Journal of the Indian Society of Soil Science, 42(4), 670-670.

Ranjan, G. and Rao, A. S. R. 2007. Basic and applied soil mechanics. New Age International, 774 page, New Delhi.

Roy, S. 2016. Assessment of soaked California bearing ratio value using geotechnical properties of soils. Resources and Environment, 6(4): 80-87.

Roy, S. and Bhalla, S. K. 2017. Role of geotechnical properties of soil on civil engineering structures. Resources and Environment, 7(4): 103-109.

Roy, S. and Dass, G. 2014. Statistical models for the prediction of shear strength parameters at Sirsa, India. International Journal of Civil and Structural Engineering, 4(4): 483.

Skempton, A. W. 1953. The colloidal activity of clays. Selected Papers on Soil Mechanics, 106-118.

Skempton, A. W. and Petley, D. J. 1970. Ignition loss and other properties of peats and clays from Avonmouth, King's Lynn and Cranberry Moss. Géotechnique, 20(4): 343-356.

Thermann, K., Gau, C. and Tiedemann, J. 2006. Shear strength parameters from direct shear tests–influencing factors and their significance. In The Geological Society of London, 484: 1-14.

Tingle, J. S., Tingle, S. L. and Harrelson, D. W. 2016. Translating the language of soils: Developing a soil classification system for international engineering projects. GeoStrata Magazine Archive, 20(1): 48-52.

Tuncer, E. R. and Lohnes, R. A. 1977. An engineering classification for certain basalt-derived lateritic soils. Engineering Geology, 11(4): 319-339.

Yagiz, S. 2001. Brief note on the influence of shape and percentage of gravel on the shear strength of sand and gravel mixtures. Bulletin of Engineering Geology and the Environment, 60(4): 321-323.

Yardım, Y. and Mustafaraj, E. 2015. Effects of soil settlement and deformed geometry on a historical structure. Natural hazards and Earth System Sciences, 15(5): 1051-1059.

Yilmaz, I. 2007. The effect of swelling clays on a water transport canal between Köklüce HPP and Erbaa HPP (Turkey). Bulletin of Engineering Geology and the Environment, 66(4): 467-472.

Yilmaz, I. 2008. A case study for mapping of spatial distribution of free surface heave in alluvial soils (Yalova, Turkey) by using GIS software. Computers & Geosciences, 34(8): 993-1004.

Yilmaz, I. 2009. Swell potential and shear strength estimation of clays. Applied Clay Science, 46(4): 376-384.

Yilmaz, I. and Bagci, A. 2006. Soil liquefaction susceptibility and hazard mapping in the residential area of Kütahya (Turkey). Environmental Geology, 49(5): 708-719.

Yilmaz, I. and Yavuzer, D. 2005. Liquefaction potential and susceptibility mapping in the city of Yalova, Turkey. Environmental Geology, 47(2): 175-184.

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