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Study the Effect of Waste Paper Sludge Ash and Granite Dust on the Geotechnical Properties of Fine Graind Soils

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by

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بسم الله الرحمن الرحيم

(يَرْفَعِ اللَّهُ الَّذِينَ آمَنُوا مِنْكُمْ وَالَّذِينَ أُوتُوا الْعِلْمَ دَرَجَاتٍ وَاللَّهُ بِمَا تَعْمَلُونَ خَبِيرٌ)

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SUPERVISOR CERTIFICATION

I certify that the proportion of this research entitled " **Study the Effect of Waste Paper Sludge Ash and Granite Dust on the Geotechnical Properties of Fine Graind Soils**" was accomplished by "Khudhur Jaber Hamzah" under supervision at the University of Babylon in fulfillment of partial requirements for the degree of High Diploma in Civil Engineering (Geotechnical Engineering).

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First, praise be to "Allah" who gave me the strength and health to work and enable me to finish this work.

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Finally, I would like to thank all my teachers in the Civil Engineering Department.

Khudhur Jaber Hamzah

ABSTRACT

This study aims, through experimental works, to develop a new and sustainable binder by blended two waste materials, namely waste paper slag ash (WPSA) and granite dust (GD) to stabilize fine-grained soil and reduce the environmental impacts resulting from improper disposal in addition to reducing the use of cement and lime in soil stabilization. The soil utilized in this research was obtained from a site near 80th Street in Babylon city. The effect of different binary mixtures on the Atterberg limits, compaction test, and unconfined compression streanth test after (3, 7, and 28) days of curing was investigated. Mixing ratio of WPSA/GD was adopted as(10:0, 7.5:2.5, 5:5, 2.5:7.5, and 0:10) by weight for soil stabilization.The results showed that the use of the mixture (WPG100) containing 10% GD alone led to a decrease in the LL, PL, and PI decrease by 1.22%,and when increase the percentage of (WPSA) in the mixture, it led to an increase in (LL) and (PL) while (PI) decreased by 9% for mixtures (WPG25,WPG50). Moreover, the maximum dry density of the treated soil with mixture (WPG100) increased noticeably from 1.68 g/cm^3 to 1.73 g/cm^3, however, it decreased significantly after the add of WPSA in the binder used from 1.68gm/cm3 to 1.54 g/cm^3 for the mixture (WPG0). As per the results of the unconfined compression test, it was shown that the use of the mixture (WPG0) that contains 10% WPSA gave the highest compressive strength, which is equivalent to 14 times that of the compressive strength of untreated soil at the age of 28 days. The strength then dropped with increasing the percentage of granite dust in the mixture.

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Symbol	definition	unite
C-S-H	Calcium –silicate-hydrate	-
C-A-H	Calcium- aluminate- hydrate	-
CL	Clay low plasticity soil	-
L.L	Liquid limit	%
P.L	Plastic limit	%
PI	Plasticity index	%

Abbreviations

Abb.	Description	unite
ASTM	American Socity for Testing and Materials	-
USCS	United Soil Classification System	-
MDD	Maximum dry density	g/cm^3
OWC	Optimum water content	%
OPC	Ordinary Portland cement	-
UCS	Unconfined compression strength	kPa
CBR	California bearing ratio	%
WPSA	Waste paper sludge ash	-
GD	Granite duste	-
WPG0	mixture contain(90 % soil) ,(0%GD) ,(100% WPSA)	-
WPG25	mixture contain(90 % soil) ,(25%GD) ,(75% WPSA)	-
WPG50	mixture contain(90 % soil) ,(50%GD) ,(50% WPSA)	-
WPG75	mixture contain(90 % soil) ,(75%GD) ,(25% WPSA)	-
WPG100	mixture contain(90 % soil) ,(100%GD) ,(0% WPSA)	-
GGBFS	Ground Granulated Blast Furnace Slags	-
CKD	Cement-kiln dust	-
MD	Marble dust	-
RHA	Rice husk ash	-
POFA	Palm oil fuel ash	-
HCFA	High calciume fly ash	-

Certification of Examining Committee

We certify as an Examining Committee that we have read this research entitled " **Evaluation of Geotechnical Properties of Fine Grained Soil Stabilised with High Calcium Binder"** and examined the studen**t " Khudhur Jaber Hamzah** " in its content and what related to it, and found it meets the standard of the research for the degree of Higher Diploma in Civil Engineering / Geotechnical Engineering .

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CHAPTER ONE

INTRODUCTION

1.1 General

One of the hard problems face the works in civil engineering is that when the soil is found to be weak fine grained soil. When the fine-grained soil has a high clay content, this results in swelling, high compressibility, low permeability, low shear strength and consequently low quality for construction If the water content is allowed to increase, this rise in moisture content is most likely due to rains, floods, leaky sewage lines, and reduced surface evaporation when an area is covered by a structure or pavement (chen,1981) . In Iraq, problems of weak soils have captured an area of interest of geologist and civil engineers as a large of Iraqi clay soils (around 35% of Iraq clay soils, essentially southern Iraq) (Ahmed, 2015). Soils with such properties bring dangerous problem to geotechnical engineering related with settlement and stability problems (Abbawi, 2010) which can caused large damage to structures and pavement if not adequately as an example broken and cracking of pavement, railways, roadways, highway embankment, basement, canals or reservoir liners. Therefore, when weak fine grained soils appear on the building site, treatment should be implemented which involve either altering the design to suitable the soils state or replacing the soils. change the design is not at all feasible while replacing weak soil is high-cost (Cristelo et al., 2013). As a result of these issues, various cost-effective and efficient approaches have been developed, one of which is soil stabilization. Stabilization can be accomplished in a number of methods, which are: mechanical method soil improvement via mechanical means where the soil is improved without adding another materials and physical method. Enhancing the soil by physical method is by exploiting the physical changes. Chemical method or so called chemical soil improvement involves the addition of stabilizing agents that can alter the soil's undesirable qualities. These approaches have been used to improve inherent soil properties such as increasing strength, decreasing compressibility, improving swelling or squeezing characteristics, and enhancing soil durability. Thus, it meets the engineering specification of the project site (Bergado, 1996). The chemical stability of weak soils is very significant for various civil engineering implementation for example pavement structures, foundation construction, canal and reservoir lining, roadway, water and sewage line, and irrigation networks to minimize the damages from weak soils stability and settlement (Ismail ,2002). Chemical stabilization is the most appropriate way for stabilizing fine-grained soils like silt or clay soils (Hashad and El-Mashad, 2014). The famous traditional binders used in this method are cement and lime. Their use in soil stabilization has been examined in numerous researcher (Miura et al., 2002). Lime and cement are effective, but their production involves many problem represented by high energy consumption, carbon dioxide (CO_2), emission, the exhaustion of natural raw material, and high cost (O'Rourke et al., 2009) due to its negative environmental impacts and the comparatively high costs of cement manufacture, studies have been encouraged to develop environmentally friendly and costs-effective alternatives to substitute or limit the usage of OPC in all fields of construction. The majority of these materials are by-products or waste material, for example, Ground Granulated Blast Furnace Slags (GGBFS), fly ash, bottom ash, waste paper slag ash (WPSA), cement-kiln dust (CKD), marble dust (MD), mill scale, ceramic dust (CD), lime kiln dust

(LKD), rice husk ash (RHA), Granit dust (GD), etc.) are used as additives for stabilizing the weak soils (Yadav et al, 2017)

1.2 The Aim and Objectives

The aim of this study is to study the influence of using two types of waste materials; Waste Paper Sludge Ash (WPSA) and Granite dust (GD) on some engineering and mechanical properties of a fine grained soil.

To achieve this aim the the sieve and hydrometer analysis, Atterberg limits, compaction test, and unconfined compression streanth test were set to evaluating the performance of different prepared mixtures proposed from WPSA and GD on the geotechnical properties of the stabilized soils in this research.

1.3 Layout of the study

The study involves five chapter :

Chapter one : This section gives a brief introduction and general scope, overview about the problems associated with fine grained soils. Moreover, the aim and objective of this research were also presented in this chapter.

Chapter tow : includes the literature review about chemical stabilization using the traditional stabilizers, employment of WPSA, and GD in soil stabilization.

Chapter three: Covers the methodology used in this research , select materials, and method of analysis the results.

Chapter four: includes the presentation, analysis and discussions of the tests results

Chapter five : conclusion of this study work, and the recommendations for the future researches.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter presents a comprehensive overview with a description of the major techniques utilized to stabilize soils .The concentration is on the impact of admixtures of lime, cement , byproduct, and waste materials as mixtures when blended with fine-grained soils. It also gives information on the significance of cement, lime , waste paper sludge ash (WPSA), granite dust (GD), Problems associated with the cement and benefit associated with alternatives.

2.2 Soil Stabilization

One of the most essential variables in foundation design is the ground or soil condition. Before beginning to design the foundations, civil engineers must first gather the required soils characteristics from soil investigation conducted at the selected site. As a result, civil engineers must be well-versed in soil characteristics and soil tests. Soil with properties of low strength and compressibility may be found all over the world. One of the most serious issues emerges as a result of its properties, which are challenges in bearing loads on such foundations. These issues prompted the developments of more costs effective and efficient solutions, one of which is soils stabilization (Kolias et.al., 2005).

Soil stabilization is the mechanical or chemical modification of one or more soil characteristics in order to produce a better soil material with the necessary engineering properties. The most typical benefits of stabilization are a lower plasticity index or swelling potential, as well as increased durability and strength due to better soil gradation (Guyer, J. P., 2011).

Soil stabilization is the operation of enhancing the strength characteristics of soil in order to rise its bearing capacity. It is necessary when the available soils for building is inadequate for carrying structural load. Soil stabilization is utilized in earth constructions to minimize compressibility and permeability of the soils while increasing shear strength. As a result, buildings have become less likely to settle. (Lambe, 1958). Soil stabilization can be achieved through a variety of techniques. All of these techniques are classified into two major types: mechanical and chemical stabilization.

2.2.1 Mechanical Stabilization

Mechanical stabilization is described as the operations of enhancing the soil's stability and shear strength without affecting the soil's chemical characteristics. Compaction, densification by mechanical energy application utilizing several types of rollers, and mixing or combining soil of two or more gradations to create a substance fulfilling the requisite specifications are the basic ways of mechanical stabilization (Guyer, J. P., 2011) and to achieve a proper grain size distribution, which results in greater particle contact and fewer voids in the soil (Sherwood, 1993). Mechanical stabilization can be used on silt and clay soils that is especially weak (Nordin, 2010).

2.2.2 Chemical Stabilization

Soil stabilization utilizing chemical admixtures is the oldest and wide spread approach of soil enhancement. Chemical stabilization is the process of combining soil with one or more chemical additive (slurry, powders, and liquid) to initiate a chemical reaction. As a results of which the soil has a better structure (Dayalan, 2016) to enhance or manage its strength, stability, swell, permeability, and durability, with addition the binder, it bounds the soil particles together by building up strength around the soil particles or and both reacting with the soil particles them selfs. The most common example of a binder that building up a strength around and also reacts with individual soil particles is hydrated lime and cement (Sherwood, 1993). The efficiency of these chemicals is based on the soils conditions, stabilizers characteristics, and building type. The selected of a certain additive based on cost, availability, benefit and its application feasibility. (Al-Rawas et al. 2002).

2.3 Mechanism of chemical soil stabilization

Soil chemical stabilization can be divided into four processes: cation exchange, flocculation, pozzolanic, and hydration. (Mallela et al., 2004).

2.3.1 Cation Exchange and Flocculation

When the lime is combined with clay soils, sodium and another cations that have become adsorbent on the clay mineral surfaces are interchanged for calcium. The skeleton component of the clay mineral is affected by the alteration in cation complex. Due to the existence of carbonic acid (H_2CO_3) in the soils, the calcium hydroxide is converted again in a short time after blending (Kezdi, 1979). Carbonic acid is formed in the soil as a result of the interaction between carbon dioxide from the air and free water. The reaction causes the lime to dissociate into Ca^{+2} and (OH), altering the surface electric force of the clay minerals (Bargado et al, 1996).

$$Ca(OH)2 \rightarrow Ca^{+2} + 2(OH) \qquad (2.1)$$

The flocculation and coagulation of soil grains into large aggregates, as well as a rise in the plastic limit, begin to modify the soil structure (Nichloson, 2015).

The soil skeleton changes as a result of cation interchange, which occurs when separated divalent calcium ions in the water replacing the monovalent alkaline ions that are ordinarily coupled to negatively charged clay grains (Assarson et al., 1974). Monovalent cations, on the other hand, may easily be replaced by higher-valence cations like calcium. Sodium can be replaced by a variety of cations in the following sequence (Na^{+}+ , k^{+}+, Ca^{++}, MG^{+++}, AL^{+++}), A calcium – soils stabilizer will give enough calcium ion for the divalent cations to be interchanged the larger charge density of trivalent ion result in a considerable lowering of the double-layer thickens during ion interchange. In general, the ions interchange operation is relatively quick (within a few time) (Grim and McGraw, 1962).

The cation exchange capacity of soil moisture is largely dependent on the pH of the soils and the kind of minerals in the soils, between the minerals, Montmorillonite have the greatest cation exchange capacities, while Kaolinite have the lowest (Assarson et al., 1974).

The decrease in plasticity is due to the flocculation and agglomeration of the soil, which results in a reduction in the soil surface area. The soil's swelling is reduced significantly as a result of the textural change.

2.3.2 Hydration:

After reacting the cement or lime with water, it might take up to a months to finish. The reaction of quicklime is exothermic (Equation 2.2). The quantity of water in the soil immediately lowers after mixing since it is consumed during hydration. The fundamental reason for improving soft soils with high water content is the drying process. The soil must have enough moisture to slake the quicklime and allow for ion exchange after evaporation (Bergado et al., 1996).

$$CaO + H2O \rightarrow Ca(OH)2 + Heat \qquad .... 2.2$$

When the reaction products of equation 2.2 dissolve in water, Ca+2 and OH- are released. (Equation 2.3). As a result, the pH of the solution will rise to a level where the SiO2 and Al2O3 found in the soils clay grains will dissolve. (Bergado et al., 1996).

$$Ca(OH)2 + H2O \rightarrow Ca^{++} + 2(OH)^{-} \qquad ....2.3$$

Five phases occur when cement is mixed with water; Cement grains dissolved at first, then the ion level in the water rise. Compounds are formed when ionic concentration reach a certain level. Once the ionic level is reached, the compounds solidify on the surfaces of an hydrated cement particles. Cement contains 4 components that are significant in increasing strength; 2 of them are (C3S and C2S), whereas the another two are (C3A and C4AF). Calcium silicate hydrate (C-S-H) is formed as a results of the reactions of C3S and C2S. C3A is very helpful in the early stages of strength development, however, the C4AF contributes slightly to strength since it hydrates fast, lowering the clinkering temperature.

2.3.3 The pozzolanic reaction:

Because they are responsible for the improvement of many soil characteristics, time dependent pozzolanic reaction plays an important function in soil treatment through these reactions, Ca(OH)*2* moves during the soil water to react with the silicate and aluminate in the soil. Only when the pH of the solution exceeds 10.5 the aluminate and silicate of the soil can be dissolved (Davidson et al., 1965). If this occurs, the dissolve

Ca^{+2} ion reaction with the dissolve (SiO_2) and (Al_2O_3) to generate C-S-H and C-A-H gel (Equations 2.4 & 2.5) .

$Ca^{+2}+ 2(OH)^{-}$ $+SIO_2 \rightarrow$ C-S-H ………….. 2.4

$Ca^{+2}+ 2(OH)^{-}$ $+ AL_2O_3 \rightarrow$ C-A-H ………… 2.5

Part of the soil water will be consumed throughout the pozzolanic process. As a result, engineering characteristics such as compressibility and strength, will be enhanced (Sherwood, 1993).

2.4 Traditional Stabilizing Binders

2.4.1Cement Stabilization

Cement is the most old type of binder of soils stabilization technique in 1960’s. It is classified as a major stabilizing agent or hydraulic binder, therefore, it can give the required stabilizing reaction on its own (Sherwood, 1993). To enhance the engineering characteristics of clayey soils, cement stabilization has been commonly utilize (Broms, 1999). Cement interaction is not only related to soils minerals, and the essential function is its interaction with water, which could be found in any soils (EuroSoilStab, 2002). That may be the cuss why cement is utilized to treat a large ranges of soil. There are several types of cement available today, the various types have different ratios of chemical components that are managed to help in resisting sulfate attacks, generating high early resistance, moderating hydration temperature, and etc. Typically, the type of cement utilized is selected by the type of soil to be treated and the required strength . Portland cement is a finely split substance produced by the intergrading of clinker (Prusinski and Bhattacharja, 1999). A cement grains is a heterogeneous material composed of (C_3S), (C_2S), (C_3A), and (C_4AF) (Lea, 1956). These four components are important compounds that lead to strength as stated by Bergado et al. (1996). Although Portland cement is effective in stabilizing coarse soil and fine grains soil, it performs best in fine clay soils with moderate or low plasticity. The adding of cement to clay causes two basic chemical reactions which regulate the soil cement stabilization process. the first hydration reactions of the water and cement and produce hydrated calcium silicate, hydrated calcium aluminate and Ca(OH)2, and the second pozzolanic reaction that occur in fine-grained soils, between the calcium hydroxide produced during hydration and soil aluminate and silicate. The hydrated products indicated above are major cementitious products formed and the $Ca(OH)_2$ is precipitated as a separated crystals solid stage. The clay can use the calcium in the crystalline and pores solutions to continued stabilizing the soil grains (Herzog and Mitchell, 1965). The cement grains binding the contiguous cement granules together through hardening and form a matrix of hard structure, that surround unmodified soil particles. The strong bases of cement compounds will then dissolve the soils silicate and aluminate. The hydrous silicate and aluminate will then progressively reaction with calcium ion freed during cement hydrolysis to establish insoluble compound which harden when cure and therefore stabilizing the soil. Many researches have been carried out to assess the usefulness of cement as a stabilizer. It has been discovered that cement can enhance the engineering characteristics of soils, such as particle size distribution, Atterberg limits, shear strength, compressibility, and durability (Jauberthie et al., 2010).

2.4.2 Lime Stabilization

Lime is one of the oldest and most often utilized additions for treating fine-grained soils. Lime, alone or in mix with other substances, can be utilized to improve a variety of different soils. Hydrated lime $Ca(OH)_2$ and Quicklime CaO are the two forms of lime that may be used in soil stabilization. When used in fine clay soils with low or medium plasticity, it achieves a significant improvement. Soil lime treatment helps infrastructure projects in several ways, reduce the LL and rise the PL results in an important decrease in plasticity index (PI). A lower plasticity index allows the treated soil to be more workable, as a result of chemical interaction between soil and lime, the moisture content decreases. This helps in the compaction of highly moist soils. Moreover, the addition of lime enhances the optimal water content while decreasing the maximum dry density, resulting in an immediately improvement in strength and a solid platform that allows for equipment movement (Muhunthan and Sariosseiri, 2008). These chemical processes take place in two stages, having both short and long term advantages. The initial stage of the chemical interaction includes rapid alters in soil texture and characteristics as a result of cation interchange. The liberated calcium of the lime exchange with the adsorption cations of the soil mineral, resulted in a decrease in the size of the diffused water layer around the clay grains. This decrease in the dispersed water layer allow the clay grains to go into close contact with others, resulting in flocculation and agglomeration. The second stage of the chemical process includes pozzolanic reaction inside the lime-soil combination, which results in increased strength with the time. Whenever lime and clay soil are mixed, the pH of the combination rises, and the liberated (SiO_2) and (Al_2O_3) reaction with the calcium from the lime to produce cementing materials, and hardens gradually over time. The pozzolanic reaction will continue as long time as there is enough calcium from the lime to react with the soluble (SiO_2) and (AL_2O_3), and the pH remain higher enough to keep the(SIO_2) and (AL_2O_3) in soluble (Little, 1995).

2.5 Environmental impact of cement production

Cement stabilization has long been used to enhance soil engineering characteristics. But their production is always related with many drawbacks and environmental disadvantages (Scrivener and Kirkpatrick, 2008). The cement production takes approximately 5.6 GJ of energy power and following the steel industry as the most intense power user, accounting for around 15% of global industrial power demand (Ruijven et al., 2016), consumes the raw materials about 1500 kg of quarry material for producing one ton of cement. Cement manufacture is responsible for around 7% of global CO2 emissions in which one ton of cement generates approximately one ton of CO2 (Gartner, 2004). After the transportation and electricity generating sectors, cement manufacturing is the third largest emitter of greenhouse emissions. The global cement output in 2015 was estimated to be approximately 4.6 billion tones . However, due to the fast growth of the building and construction industry throughout the world and a predicted rise in global population, cement output is estimated to cross over 9 billion tones by 2050 (Aprianti, 2017). Searchers have already been encouraged to develop new ecologically friendly and economy substances to replacing or limit the usage of OPC in the concrete manufacturing because of its harmful effects on the environment and higher cost of cement manufacture. Generally, these substances are by-products or waste materials (Sivrikaya et al., 2014).

2.6 Waste and by-product materials

The global expansion of manufacturing, factories, agriculture, and domestic activity has resulted in increased utilization of natural sources and the generation of large amounts of waste substance in recent years

(Thomas, 2015). Most of these waste substances have significant environmental consequences, prompting investigators to find ways to accomplish long-term development (Rafieizonooz et al., 2016). Furthermore, civil engineers have focused on meeting the land requirement for the treatment of these waste products (Pappu et al., 2007). Recycling solid waste materials might be an efficient strategy to minimize natural resource consumption and the harmful effects of these hazardous products on the environment. However, some by-product materials have high to calcium content for example WPSA, GGBFS. Such substances have the capability to operate as cementitious material, interacting with silicate via a pozzolanic interaction to produce cementitious components that are comparable to those produced by the OPC hydration operations (Sun et al., 2015). Another by-product substances, such as, silica fume, rice husk ash, palm oil fuel ash and pulverized fuel ash are dense in silica and alumina and interact pozzolanically with $Ca(OH)_2$ (Aprianti, 2017). Several research have been carried out to employ by-product materials to replace a part of cement in binder, which are subsequently utilized in a several of construction applications like building concrete, rigid pavements, and soil stabilization to saves money and protects the environment (Mina et al., 2019)

2.6.1 Waste Paper Sludge Ash (WPSA)

2.6.1.1 Manufacture and its associated benefit

Waste Paper Sludge Ash is a byproduct of the burning of wastepaper sludge in paper recycling plants. In the industrialized world, it is generated in hundreds of thousands of tons each year. For example, it was reported that WPSA is to be generated in more than 100000 tons per year, only with Aylesford Newsprint plant in Kent generating 50 000 tons per year on its own (Bujulu et al., 2007). The most common form of disposal is landfills, which prevents the area from being used for other useful purposes and may lead to pollution of ground water and soil. WPSA categorized as Type-C fly ash due to the total combination percentage composition for major constituent components such as silicon dioxide (SiO2), aluminina oxide (Al2O3) and iron oxide (Fe2O3) less than minimum of 50 (ASTM C618) and has cementitous and pozzolanic characteristics, resulted in self - cementing properties. Thus no activators like cement or lime are necessary. Because of its self-cementing properties, class-C fly ash provides a low-cost supply of high-quality soil stabilizing agent..

2.6.1.2 WPSA as soil stabilizer

many researches have been carried out to investigate the usage of WPSA in soil stabilization. Khalid et al., (2016) conducted a research to examine the compaction characteristics of a soft soil treated utilizing WPSA, by determining the dry density and moisture content of soft soil treated with WPSA utilizing various energy ways of compaction, and determining the Atterberg limit characteristics. A certain proportion of WPSA was utilized to stabilize the soils. The result showed that the plasticity index of soft soil treated with series percentages (4, 8, 12, and 16 percent) of WPSA were lowered in tandem with the increase in liquid and plastic limits results as shown in figure (2.1). Meanwhile, for modified and standard compaction, the result for stabilized soft soil revealed an increase in dry density after adding 4% WPSA followed by a decrease when the WPSA percentage in the mixture was increased. While the optimum water content decreased with the increase of the WPSA percentage in the mixture as shown in figure (2.2). However, 4 percent WPSA provided the optimal combination of optimal water content and highest dry density for soft soil stabilization by modified compaction. The results of this experiment revealed that WPSA improves the geotechnical characteristics of soft soils in a substantial and effective way.

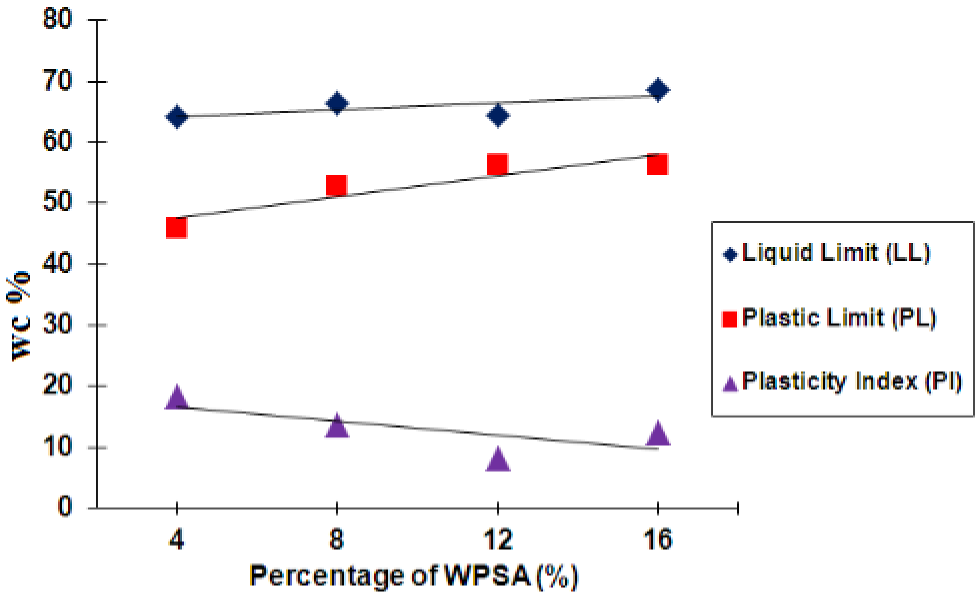
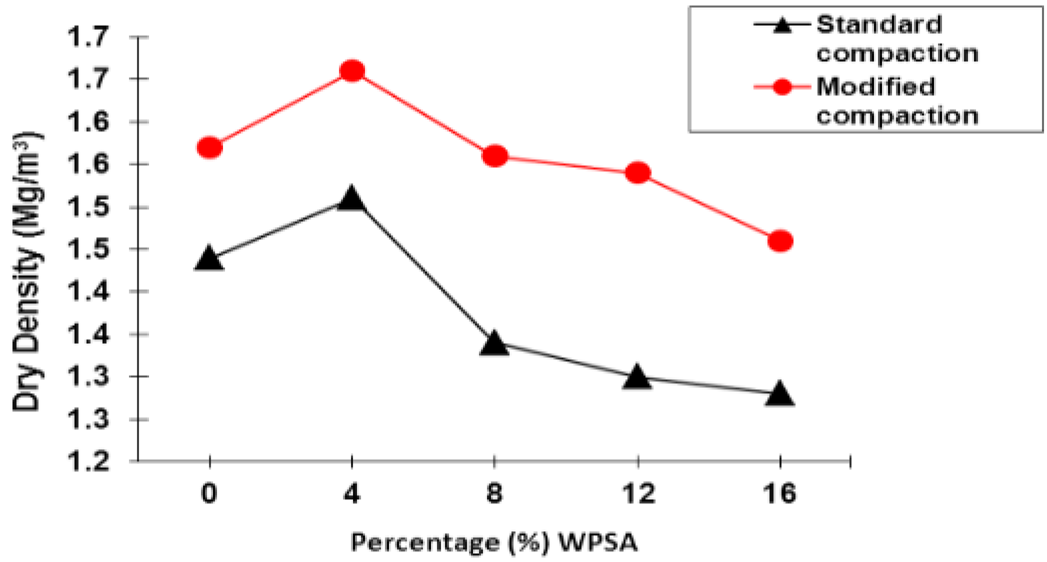


Figure (2.1) The Atterberg limits for soft soil treated with series percentage of of WPSA (Khalid et al., 2016)



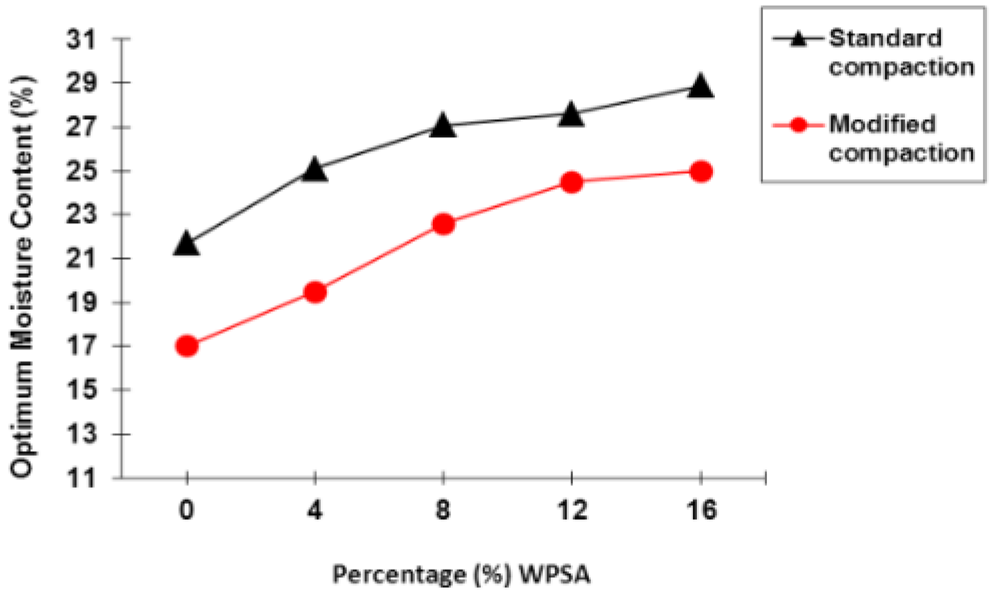
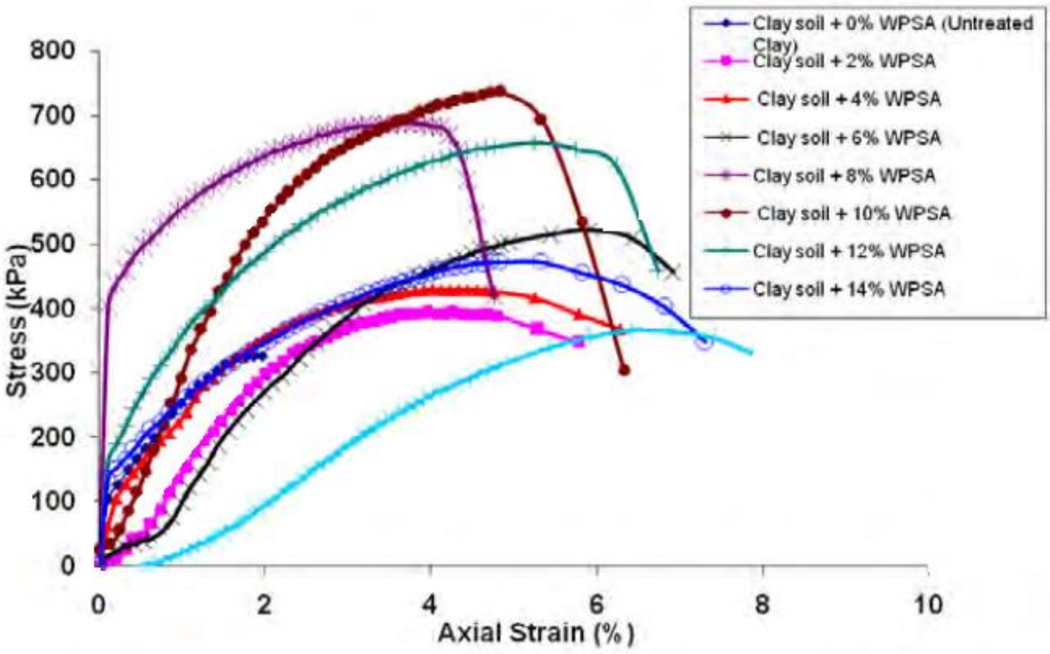


Figure (2.2) Compaction parameters for soft soil treated with series percentage of of WPSA (Khalid et al., 2016)

Mazidah et al., (2012) examined the use of WPSA as stabilizer for clay soil. The initial objective of this research was to find the best proportion of WPSA to use as an addition depended on compressive strength. The other purpose was to measure the strength improvement of clay soil treated at the optimal proportion of WPSA after curing for (0 ,14, and 28) days. To find the best amount ratio of WPSA to treat the clay soil, a series of various WPSA mixes (2, 4, 6, 8, 10, 12, and 14%) were combined with clay soil samples. The specimens were formed with varying percentages of WPSA at highest dry density and optimal water content. The specimens are examined using (UCS) test to establish the optimal ratio of WPSA at highest strength. The samples were blended with the optimal percentage of WPSA and readied for curing at 0 days, 14 days, and 28 days for the UCS test. The results revealed that the UCS increased from 392 kPa to 737 kPa when the WPSA increased from 2% to 10%. However, it displayed a decrease in compressive strength from 737 kPa to 366 kPa with an increase in WPSA from 10% to 14%. As shown in figure 2.3. The optimal WPSA concentration was around 10% to treated the soil at highest strength. When compared to treated clay soil, the (UCS) of clay soil treated with 10% WPSA raised during the curing period of 0, 14, and 28 days ,when compare with untreated clay soil, the compressive strength of clay treated with 10% WPSA increased by up to 50% for 0 days and 14 days, and by roughly 46 % for 28 days as shown in figure 2.4. This study demonstrates that WPSA may be used to stabilize clay soil and that WPSA is successful in enhancing clay soil strength over lengthy periods of time.



Figure(2.3) stress vesus axila strain for the specimens**(Mazidah et al., 2012**)

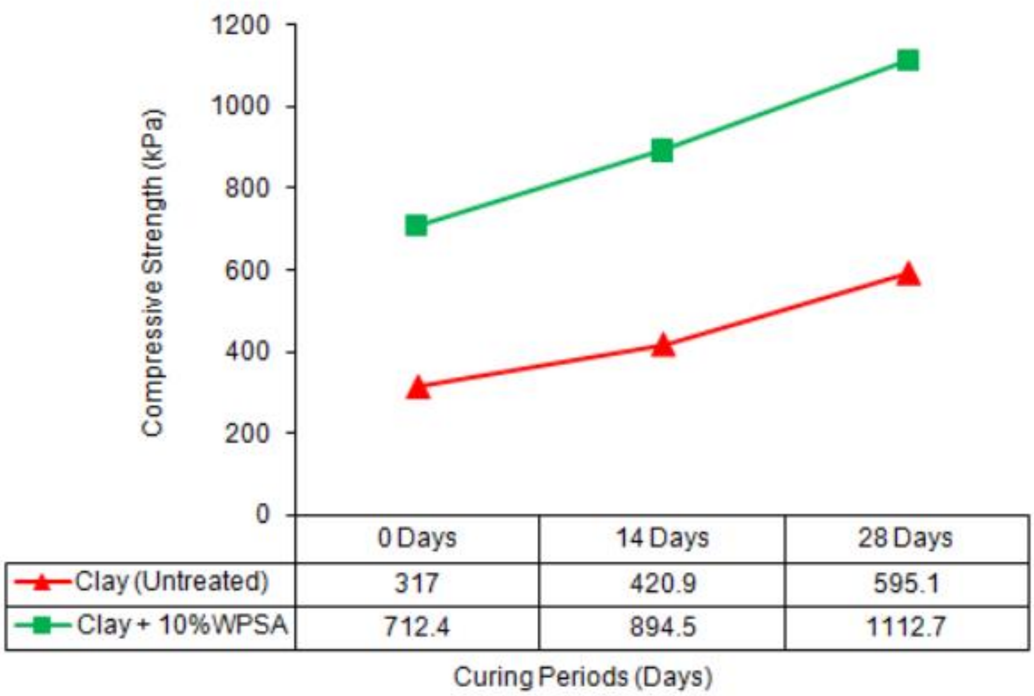


Figure (2.4) the (UCS) results at (0,14,28) days of curing **(Mazidah et al., 2012**)

Mavroulidou. (2018) utilized paper sludge ash instead of cement and lime as a stabilizing agent for clay soil depending on unconfined compressive strength (UCS) and plasticity properties, Lime and WPSA, in especially, improved the plasticity properties of soil (reduced (PI) indicating a decreased tendency of the soils to swell) owing to the high (PL) (particular for mixture stabilized with WPSA). In most cases, each soil's liquid limit (LL) was equal between lime and WPSA. In contrast, cement raised both LL and PI in the expansive clay combination . WPSA also significantly affected the texture of the soil, making it more coarser. Figure 2.5 (a, and b) illustrate suggestive UCS testing findings depended on samples with fixed moisture contents and the same compaction dry density independent of stabilizer type to evaluate the influence of the stabilizer alone. For all soils, WPSA-treated samples exhibit significantly greater UCS than cement-stabilized or, in particular, lime-stabilized ones.

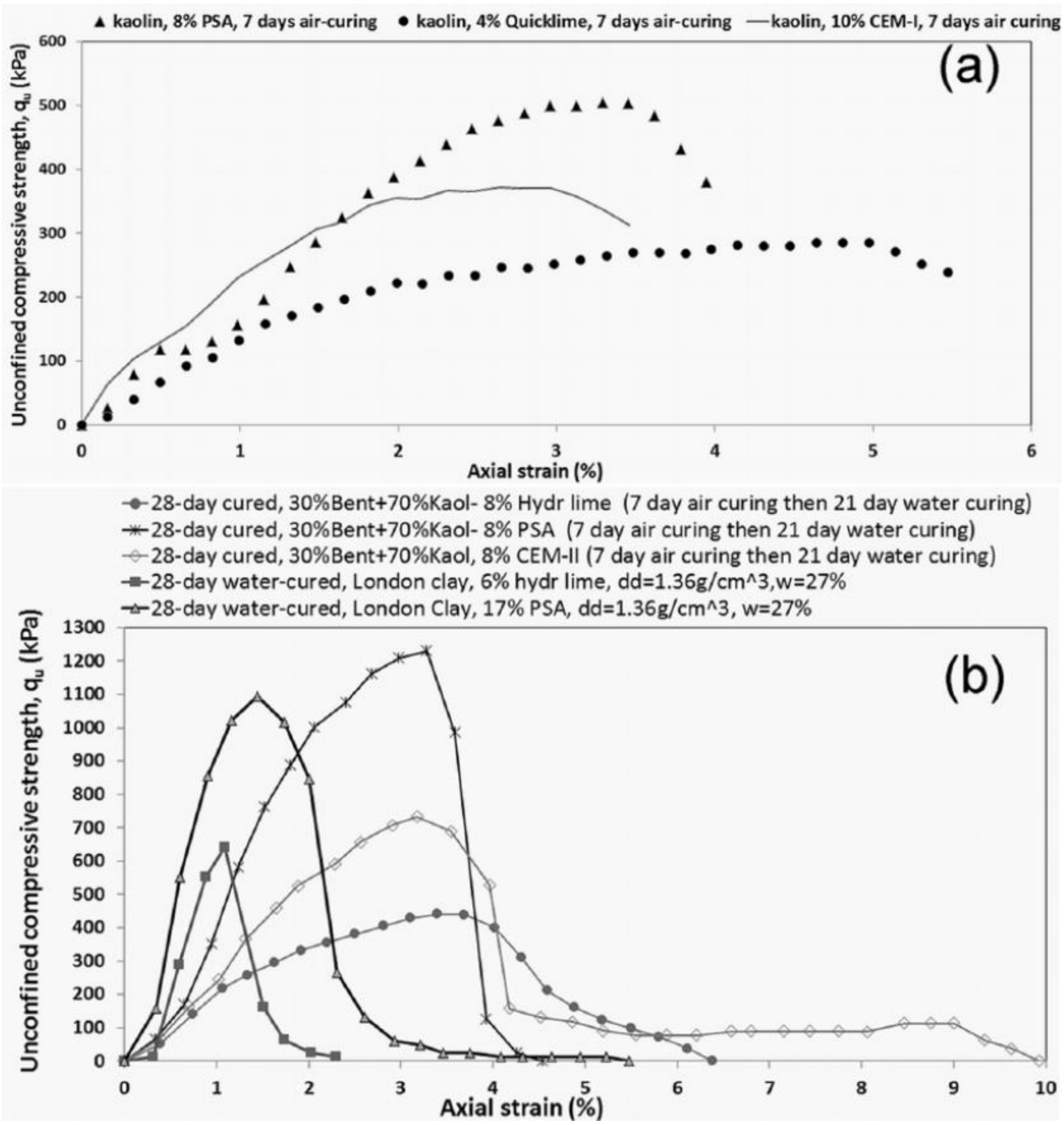


Figure 2.5 : unconfined compressive strength result (**Mavroulidou.** 2018)

Segui (2012) studied the properties of WPSA in order to assess the usefulness in its potential reuse as a component in hydraulic bonding. according to the results, the WPSA may be used as a hydraulic mineral additive, which is highly positive for the material's prospective usage in hydraulic binders. It would be ideal for use in road construction,particularly for soil stabilization, where lime is commonly used because to its beneficial qualities, such as drying and strengthening the compressive strength of soil.

Jafer et al. (2018) studied the engineering properties of stabilized soil using high calciume fly ash (HCFA) and (POFA), by creating several binary HCFA and POFA combinations. stage one to determine the ideal proportion of HCFA in the soil, researchers used 6 major percentage of HCFA (0, 3, 6, 9, 12, and 15) % by dry mass of the soil. The compaction parameter test revealed that highest dry density dropped from 1.56 Mg/m3 for unstabilized soils to 1.40 Mg/m3 when 15% HCFA was added, but OMC rise dramatically from 23% to 30.5 percent. With a rise in HCFA concentration, LL and PL rise while PI declined dramatically. According to the UCS test findings, 12 percent HCFA was the best proportion for achieving the maximum (UCS) of the stabilized soil throughout all curing durations. When the POFA was added to the mixture, the compaction parameters test revealed minor increases in MDD and decreases in OMC, but the PI continued to reduce. According to the UCS experiments, the best combination had a 9:3 ratio of HCFA and POFA, at 90 days, the strength of the soil stabilized with 12 percent (HCFA+POFA) increased from 200 kPa for virgin soils to 1059 kPa for treated soil; this growth is 5.7 times of compressive strength for compacted natural soil.

Shubbar et al.(2018) conducted research into the creation of a low-carbon binder made from a combination of cement (OPC) ,(GGBFS), and (HCFA); (35 % OPC + 35 % GGBS + 30 % HCFA) were combined to create a novel ternary mixed cementitious material. This binder can be used as a filler in road construction or as a cement substitute in mortar, concrete manufacture, and soils stabilization. Reducing the OPC concentration in the overall binder by 65 percent might help to reduce the negative environmental impact of the cement manufacturing process. The new mortar's compressive strength raised from 13.1 MPa at three days to 30.8 MPa at 56 days. The mortar's compressive strength value of 56 days is roughly 96 percent of the compressive strength of reference cement mortars (32.1 MPa).

Jafer et al. 2018 carried out a study to improvement of a novel ternary mixed cementitious bond (TBCB) derived from waste products, including 66% high calcium fly ash (HCFA), 17% (RHA) and 17% (POFA) reactivated with 5% gypsum (FGD) by total binders. This binders can be utilized to substitute cement in the stabilization of soils. The initial stage is to determine The mix proportion was optimized by utilizing HCFA alon as an addition to the soft soils. The compaction experiments were performed prior to the UCS testing. The MDD dropped and the OWC rose dramatically as the HCFA concentration increased. The UCS was observed to rise with increasing HCFA concentration and curing time. Then this (HCFA) optimal dose was applied in ternary blended (TBCB). The result showed that the (PI) was lowered from 20.2 to 13.0 and the (UCS) rose from 202 kPa to 944 kPa after 28 days of curing employing the (TBCB) non-FGD activate mixtures. FGD considerably contributed by rising the(UCS) to 1464 kPa at 180 day of treating, which exceeded that of the reference cement (1450 kPa), and by enhancing the soil consistency limit; where the PI reduced to 11.7 using TBCB relative to 14.5 utilizing the reference cement.

Bujulu, P.M.S.(2007) used WPSA as a binder to replace in stabilization of soft and problematic soils, The optimal lime-to-WPSA mix proportions and mixing moisture content have been found to provide the optimum stabilizing influence and specimens of high and consistent quality. It has also been demonstrated that the stabilizing benefits of lime-WPSA mixes are equivalent to that of lime-cement binder. However, it takes a longer period (about 75 days) for lime- WPSA combinations to acquire characteristic comparable to those of the 28-day-old lime- cement mixture.

2.6.2 Granite dust (GD)

2.6.2.1Manufacture, associated problems, and potential solutions

During the manufacture of granite tiles and slabs from raw rock, granite dust is created as a by-product every day. Approximately three thousand metric ton of (GD) is produced per day during cutting granite rock to the required shape (Eltwati et al., 2020). The GD provides a good source of silica (silicon dioxide), which is commonly utilized in the production of cement (Igwe and Adepehin, 2017). These wastes are dumped in neighboring pits or open fields by the granite cutting industry. This causes severe environmental contamination and the occupation of a large amount of land. As a result, using and recycling such waste materials as an additive in the enhancement of geotechnical characteristics of soils would considerably benefit the economy and the environment by reducing harmful impacts from stone quarries and stone plants.

2.6.2.2 GD as a soil stabilizer

The use of GD in soils stabilization helps in the reduction of its amounts. Several studies have been conducted to evaluate such use. An instance of that is a study carried out by **Igwe and Adepehin** (2017), the research explains the result of an examination on the impact of two substance; GD and dolerite dust (DD) on the characteristic of expansive soils. The outcome demonstrated that liquid and plastic limits of natural soil were both reduced. The addition of 20% (GD) resulted in a 6.7 percent drop in the plasticity index of the virgin soil, whereas the addition of 10% (DD) resulted in a 6.8% decrease in the plasticity index (PI) of the virgin soil as shown in figure 2.6. The value of MDD in natural soil was shown to be lowered when 10% (GD) and (DD) were added, but increased when 15% of the rock dusts were added. The MDD (1935 kg/m3) was obtained with the adding of 15% (GD), comparing to 1880 kg/m3 with the adding of 20% (DD) as shown in figure 2.7. With rising proportions of (GD) and (DD) in the modified clay the CBR values steadily increase, but with the addition of 20% (DD), CBR progressively decreases, whilst that of granite dust continues to rise steadily as shown in figure 2.8.

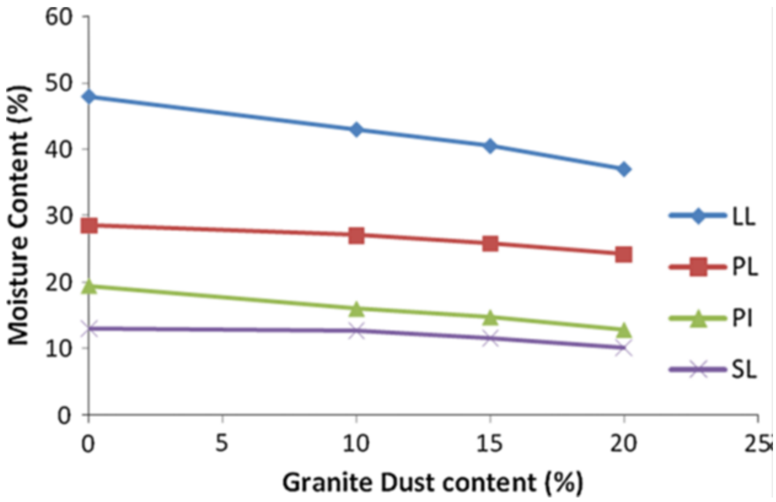


Figure (2.6) The Atterberg limits for soil treated with GD

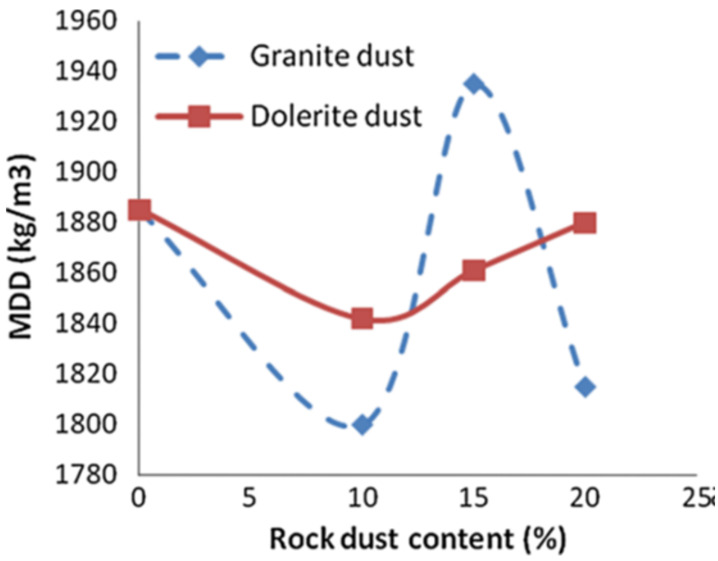


Figure (2.7) the compaction test result(Igwe and Adepehin 2017)

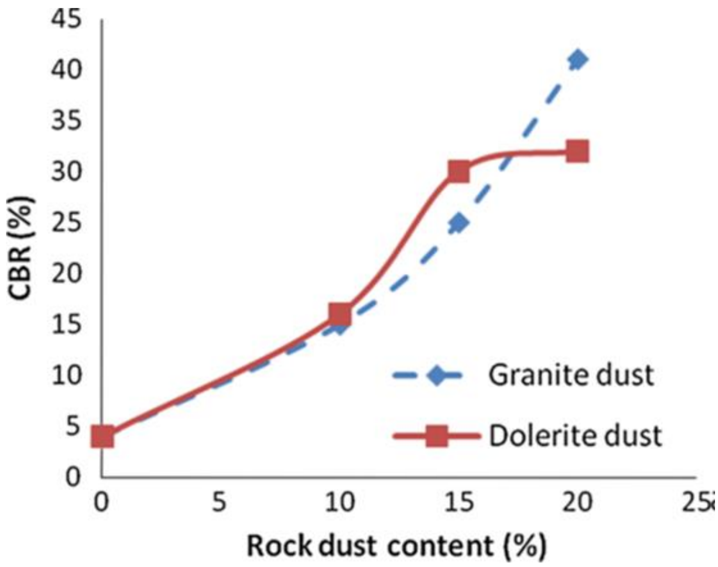


Figure (2.8) CBR test result(Igwe and Adepehin 2017)

Eltwati et. al.,(2020) conducted an investigation on the engineering properties of clay soils treated with GD. Soil was mixed with various amounts of GD, including 4, 8, 12, 16, and 20% of the total weight. The efficacy of the un-stabilized and stabilized soil was evaluated using compaction, direct shear, and CBR tests. The highest MDD of the soil specimen increased and the OMC decreased as the proportion of granite powder in the soil increased. The highest value of MDD was 1.86 g/cm3, which characterizes the stabilized soil with 8.0% GD. On the other side, the virgin soil has MDD of 1.61 g/cm3 as shown in figure 2.9. The CBR of the soil rised as the proportions of granite dust rised; the highest value of CBR recorded was 16.5 percent, which corresponds to the stabilized soil with 8.0% GD. The virgin soil had the lowest value reported (CBR was 3.65 percent) as shown in figure 2.10. As a result, the soil bearing capacity containing 8% GD is approximately 4.5 times that of virgin soil. It may be inferred that adding 8% granite dust powder to soil boosted its shear strength by about 2.8 times over virgin soil.

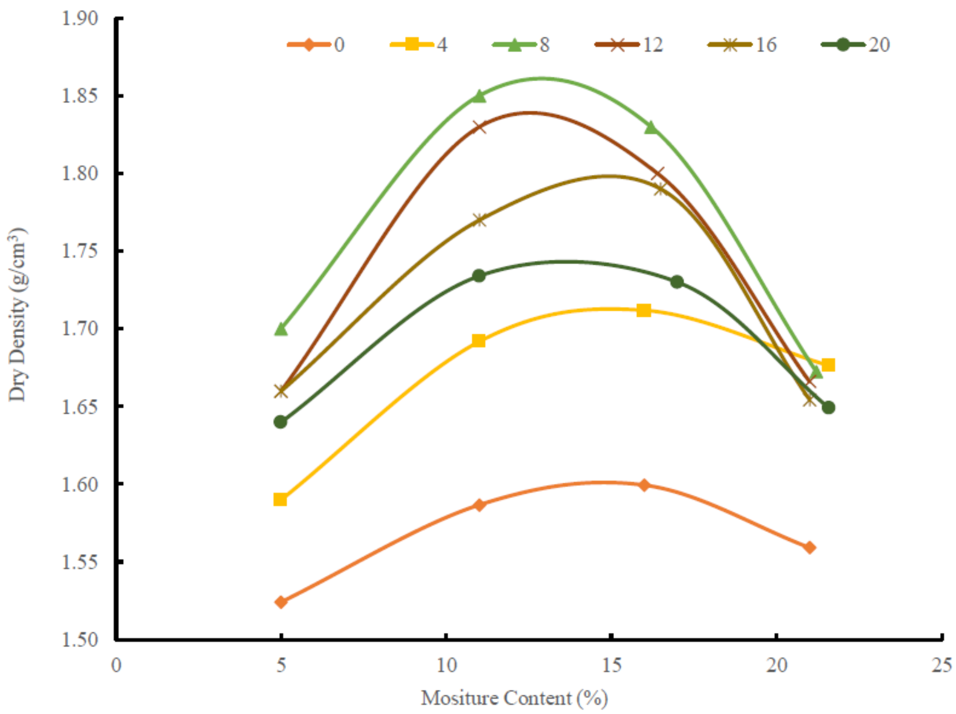


Figure (2.9) the compaction test result(Eltwati et. al., 2020)

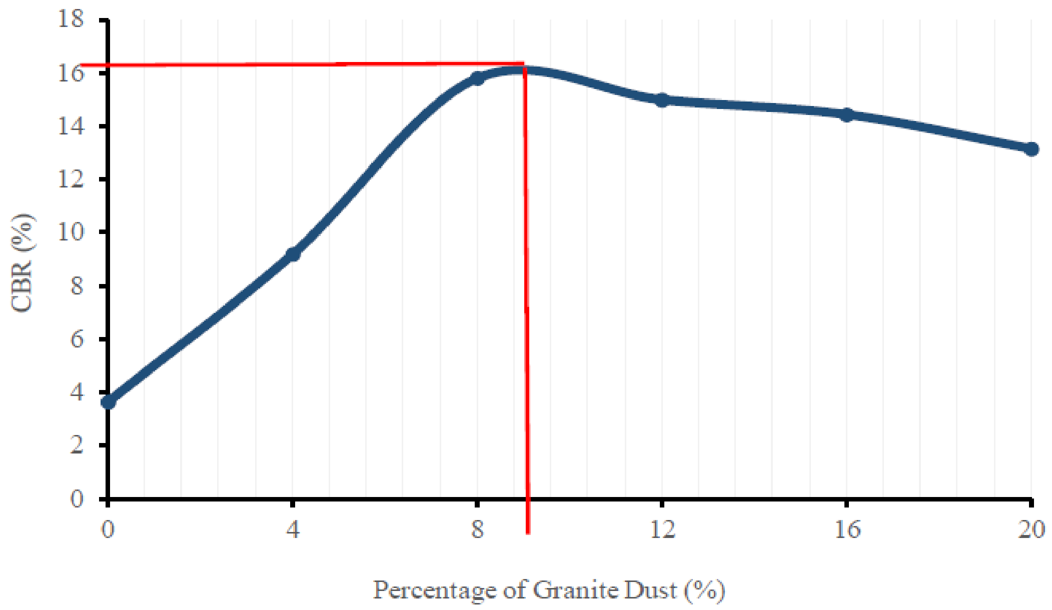


Figure (2.10) CBR test result (Eltwati et. al., 2020)

Mishra et. al., (2014) studied the impact of GD on the engineering characteristics of Black Cotton soils stabilized with 5% lime. Compaction feature and CBR tests were conducted on soil samples that contain 5% lime and 0, 10, 20, and 30% GD, respectively. The results showed that CBR value rose from 1.7 percent to 7.15 percent as shown in figure 2.11. The optimal water content decreased from 22 % to 14.3 % as shown in figure 2.12 a, and the highest dry density rose from 1.58 g/cm3 to 1.88 gm/cm3 as shown in figure 2.12 b. The conclusions gained from this research is that expansive clays, such as black cotton soil, may be treated by combining lime and GD to limit swelling and promote stability.

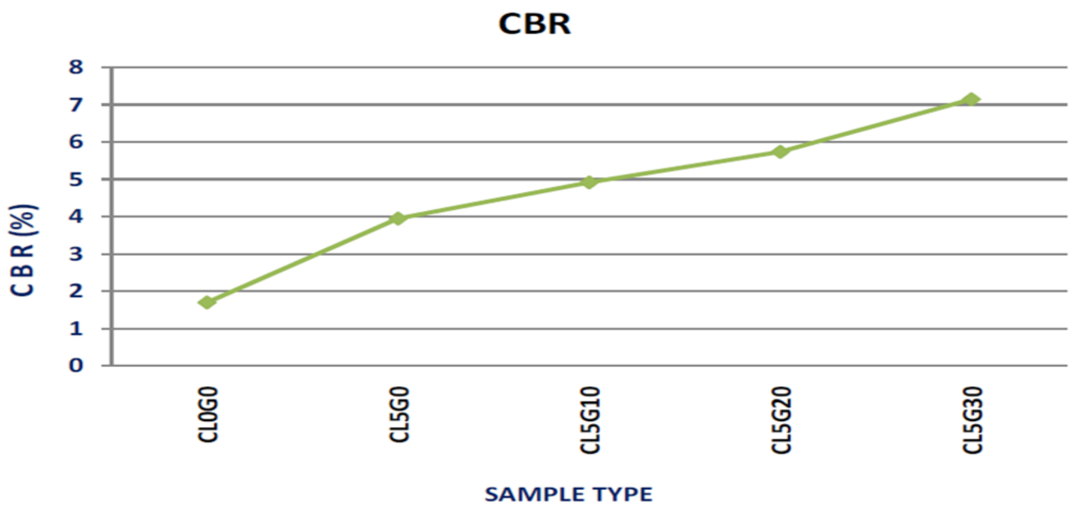
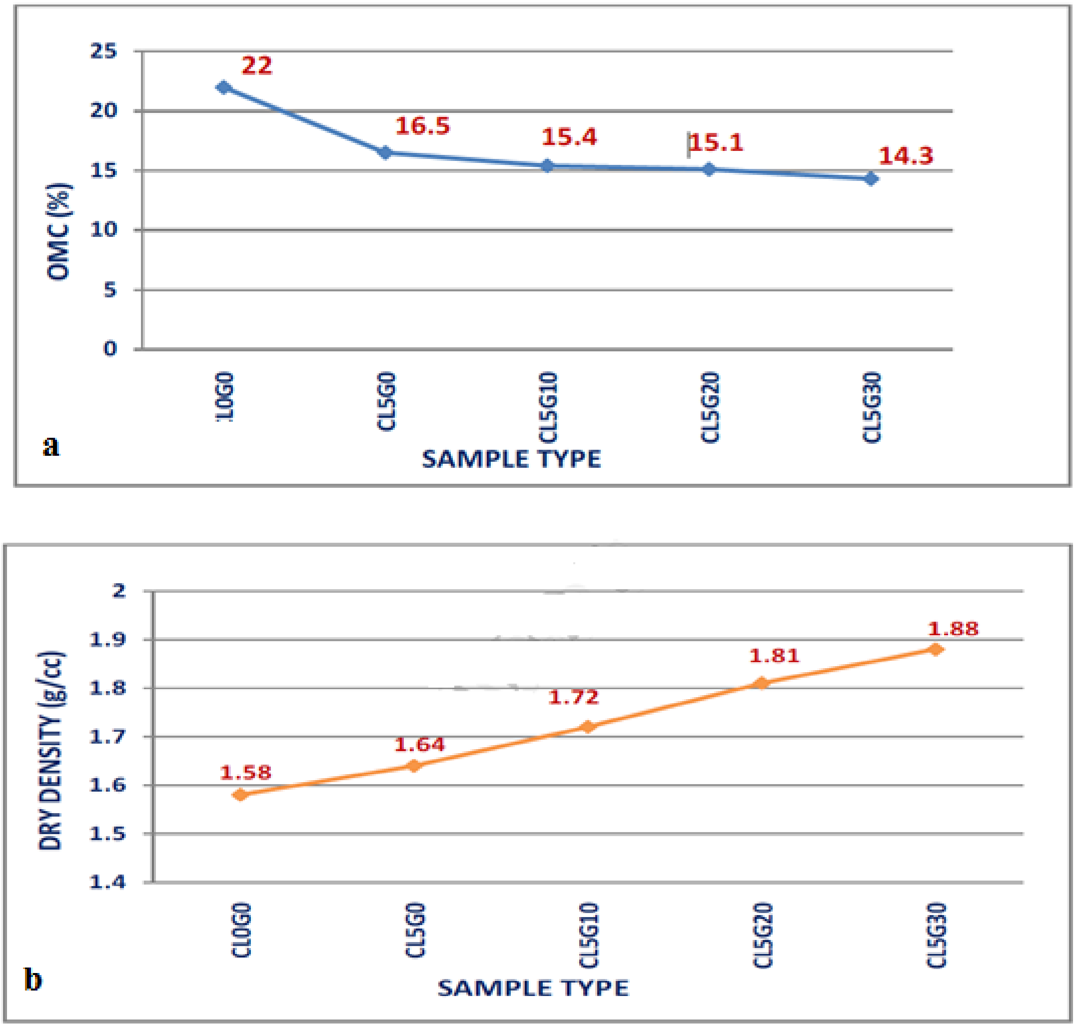


Figure (2.11) CBR test result



Figure(2.12) **the compaction test result (a, and b)(Mishra et. al., 2014)**

Sabat and Moharana, (2015) carried out an experiment to discuss the impact of compaction energy on the characteristics of fly ash (FA) – (GD) stabilized expansive soils. The optimal percentage of FA-GD for stabilization of expansive soils was found out. For that purpose, by addition of one part of FA and two parts of GD, at an increment of 6% up to 54% by replacement of expansive soil. The samples for UCS tests were prepared by compacting them with corresponding MDD and OMC for that purpose. The result showed increase in MDD occurred with increase in percentage of FA - GD and decrease in OMC due to increase in FA – GD percentage. The UCS reached highest value when percentage addition of FA-GD is 42%. UCS decreased when the percentage addition of FA-GD mix is more than 42%. Hence, for stabilization of expansive soil, 42% of FA-GD is taken as the optimum percentage. With rise in compaction energy, the MDD goes on increasing, OMC goes on decreasing and the UCS rise to 777 kN/m2 from 245 kN/m2 when the compaction energy increased to 2700 kJ/m3 from 592 kJ/m3.

Roohbakhshan and Kalantari, (2013) conducted a research to stabilize clay soils with lime and stone sludge (WSP). In this research, SP from slab stone manufacturing and stone washing factories was reused for clayey soil stabilization with lime. The proportions of lime and WSP utilized were 3, 6, 9, and 11% by the total weight of soil respectively. From the results with increased SP and lime concentration, the (LL) dropped while the (PL) rose. The plasticity index generally showed a downward trend. For all specimens, the optimal water content dropped as the lime and WSP contents increased. Also, when the lime content rose, the highest dry density dropped, but as the WSP concentration rises, the highest dry density rises too. The addition of WSP and lime increased the value of UCS until the WSP content reached 6%

and the lime content reached 7%, after which the value reduced as shown in figure 2.13

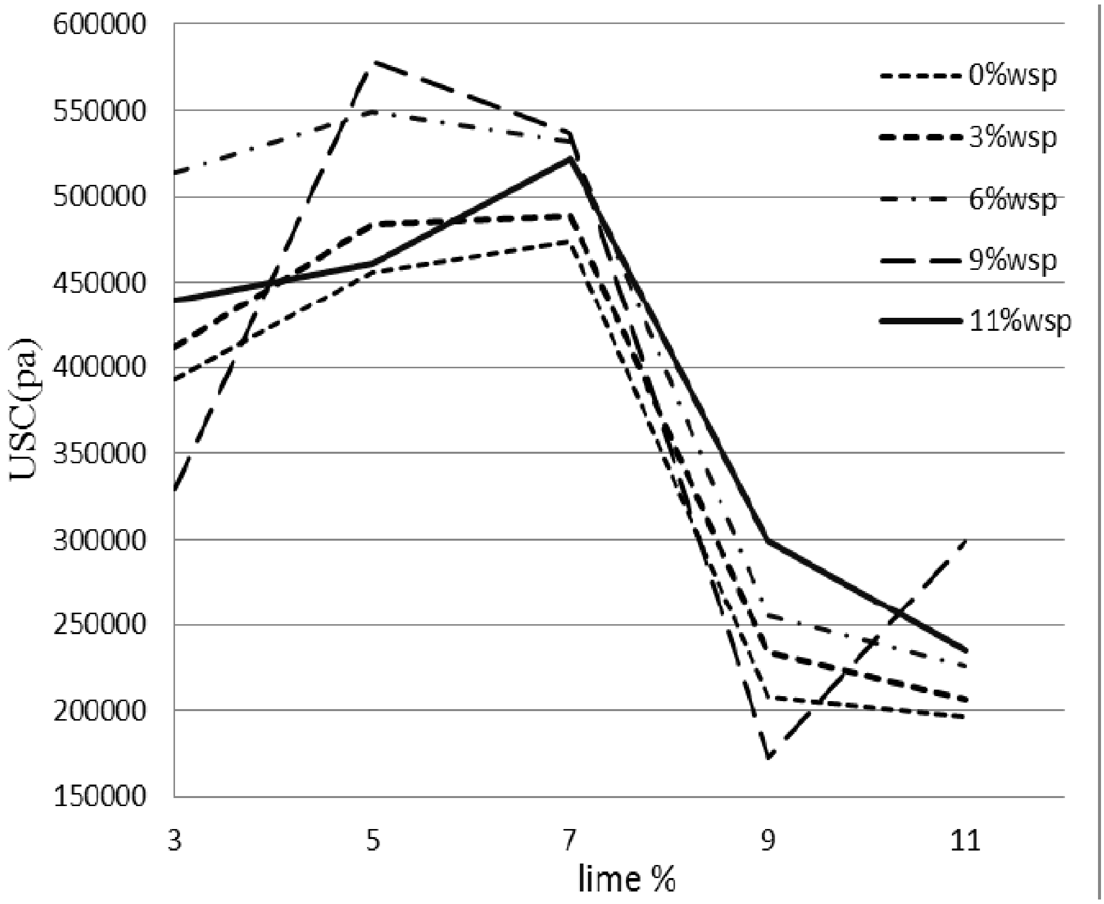


Figure (2.13) UCS test result (Roohbakhshan and Kalantari, 2013)

Yilmaz and Yurdakul, (2017) carried out an experiment to evaluation of Marble Dust (MD) for soil stabilization. The result showed that the UCS values of specimens indicated that the strength of each marble dust - silty soil specimen rises with the rise of the curing duration and the content of MD from 107.14kpa to 212kpa with the increment of MD from 0% to 40% from the total dry weight of soil with curing 7 days and to 255kpa with curing 28 days.

Sabat and Muni, (2015) studied the impact of Lime stone powder (LSP) on characteristic of an expansive soil. LSP added to soil by up to 12% at a rise of 3%. The evaluation of test results showed that there was a continuous reduction in (LL), (PI), (MDD), and swelling pressures while the (PL) continuous up to 12% addition of LSP. When the percentage of LSP added was 9 %, the UCS, and soaking CBR had the highest values.

Ahirwar, (2014) conducted a research to examine the performance of stabilized black cotton soil with calcium carbide residue (CCR) and stone dust (SD). The test results such as standard Proctors test, CBR, and UCS on black cotton soil, showed that adding an equal percentage of stone dust and CCR (10% - 10%) to the black cotton soil is more successful in regulating swelling behavior than adding stone dust and CCR alone.

2.7 Summary

By studying the previous research described in this chapter, we noticed the following:

- The use of granite dust in stabilization of fine grained soil led to a decrease in L.L P.L and P.I, an increase in the maximum dry density and an increase in CBR.
- The use of (WPSA) in the stabilization of fine grained soils led to an increase LL ,PL and a decrease in PI , decrease in the maximum dry density, increase in the (UCS) because it contains a high percentage of Cao and thus the formation of cement compounds that bind the soil grains

CHAPTER THREE

MARTIAL AND METHODOLOGY

3.1 Introduction

This chapter deals with the experimental works, materials used, in laboratory test procedure and tests program for evaluating the performance of different mixtures produced from WPSA and GD on the geotechnical properties of stable soil. First, the sieve analysis, hydrometer analysis and the Atterbreg limits were conducted to classify the soil and find its mechanical properties. Then Proctor test was carried out to get the optimal water content (OWC) and the highest density in the dry state (MDD) for each mixing ratio. The last mentioned compaction parameters are required to be used in preparing models for the unconfined compression test (UCS) to find the compressive strength. The research experimental program used in this study can be highlighted as shown in Figure 3.1.

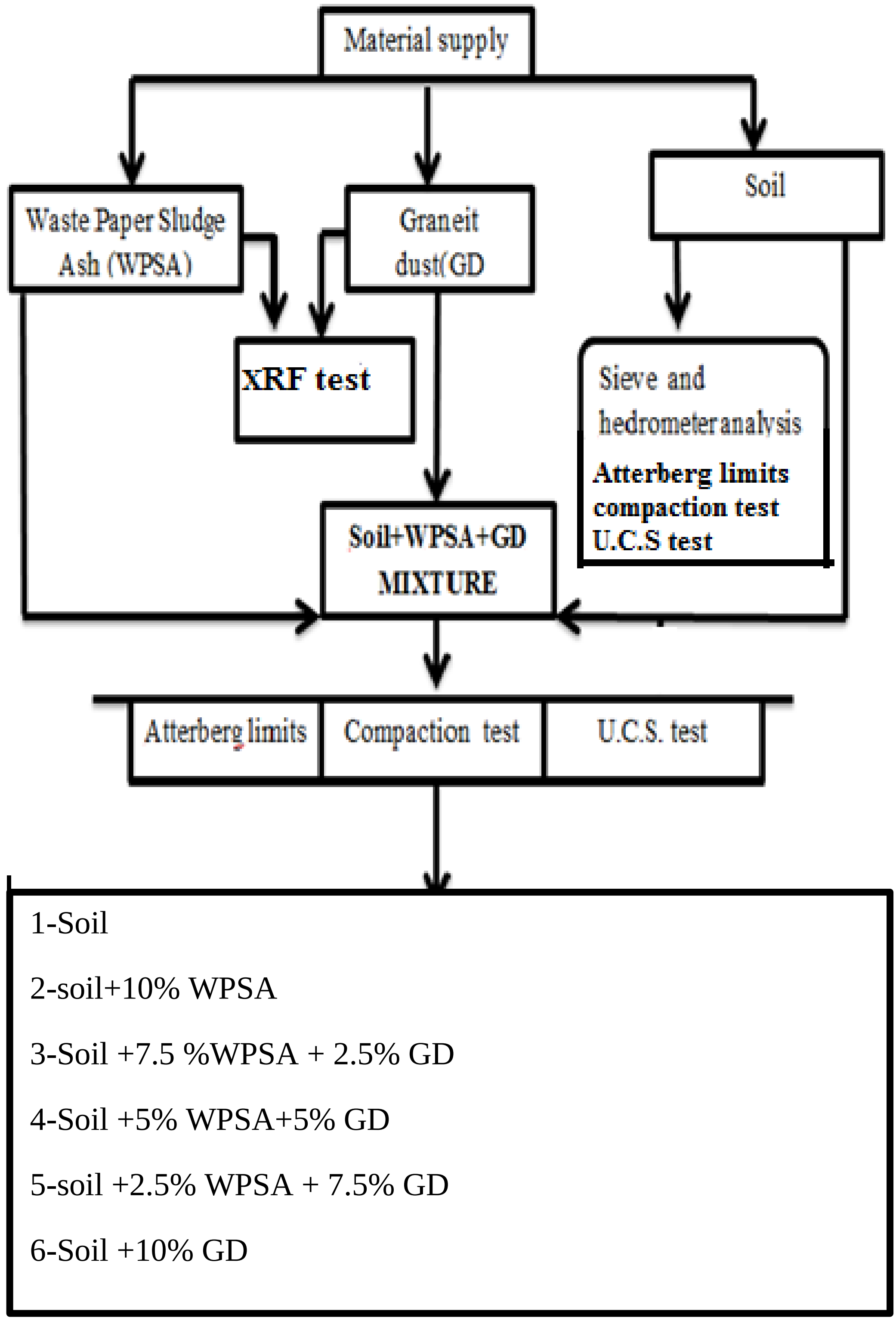


Figure (3.1) Flowchart for experiential work

3.2 Material

3.2.1 Soil

The soil utilized in this research was compiled from a site near 80th Street in Babylon city from a depth about 50 cm below the surface. The physical characteristic of the un-stabilized soil was inspected through conducting particle size distribution, Atterberg limit and compaction tests, however the unconfined compressive strength was used to show geotechnical properties, As shown in Table (3.1). the particles size distribution (obtained from sieve and hydrometer analysis) of the soil used in this research is shown in Figure (3.2). The soil is classified as CL according to the Unified Soils Classification System (USCS).

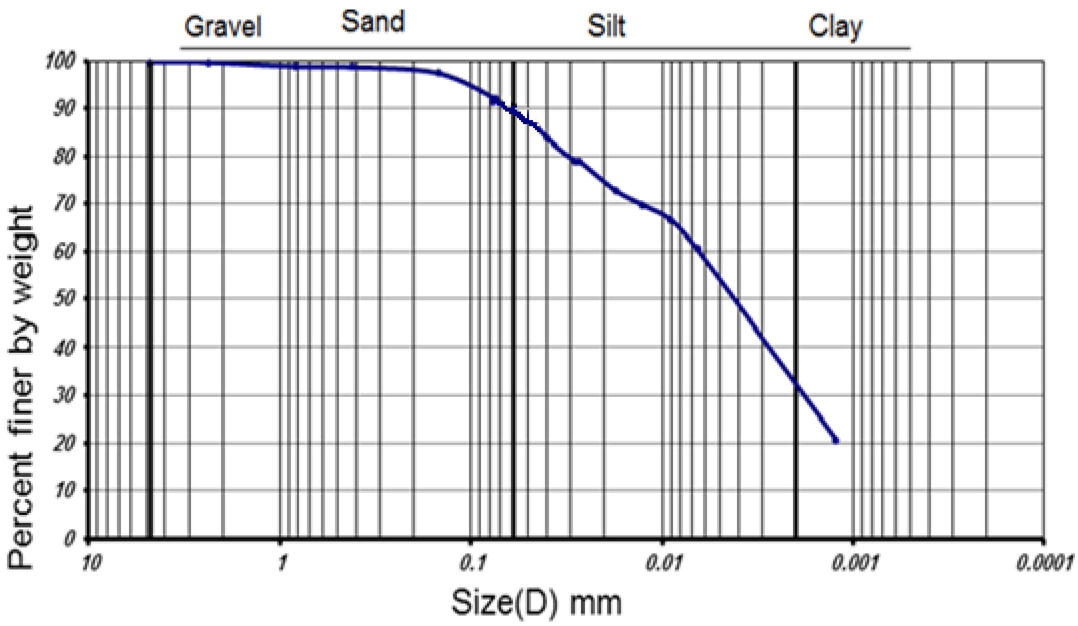


Figure (3.2) Curve of grain size distribution in untreated soil

Table 3.1 The physical and geotechnical characteristics of untreated soil utilize in the study

Characteristic	Test Standard	Value
(L.L)%	ASTM D4318	41
(P.L)%	ASTM D4318	19
(P.I)%	ASTM D4318	22
sand %	ASTM D422	11.5%
silt %	ASTM D422	55.5%
clay %	ASTM D422	33%
Classification (USCS)	ASTM D2487	CL
Maximum dry density (gm/cm3)	ASTM D698	1.68
Optimum water content (OMC) %	ASTM D698	20.5
Uncnfind compressive strength kpa for compacted specimen	ASTM D2166	124

3.2.2 Waste Paper Sludge Ash (WPSA)

generated from power plants using an incineration process at temperatures between 850 °C and 1100 °C by means of a fluidized bed combustion system. WPSA used in this study from Aylesford Newsprint plant in Kent. The chemical composition of WPSA used in this research are listed in the table 3.2 while the curve of grains size distribution for the WPSA is appeared in Figure (3.3)

Table 3.2: Main chemical compositions of WPSA determined by XRF.

Item	%
Cao %	66.76
SiO2%	25.12
Al2O3 %	2.38
Fe2O3 %	0.03
MgO %	2.57
Na2O %	1.718
K2O %	0.31
SO3 %	0.38

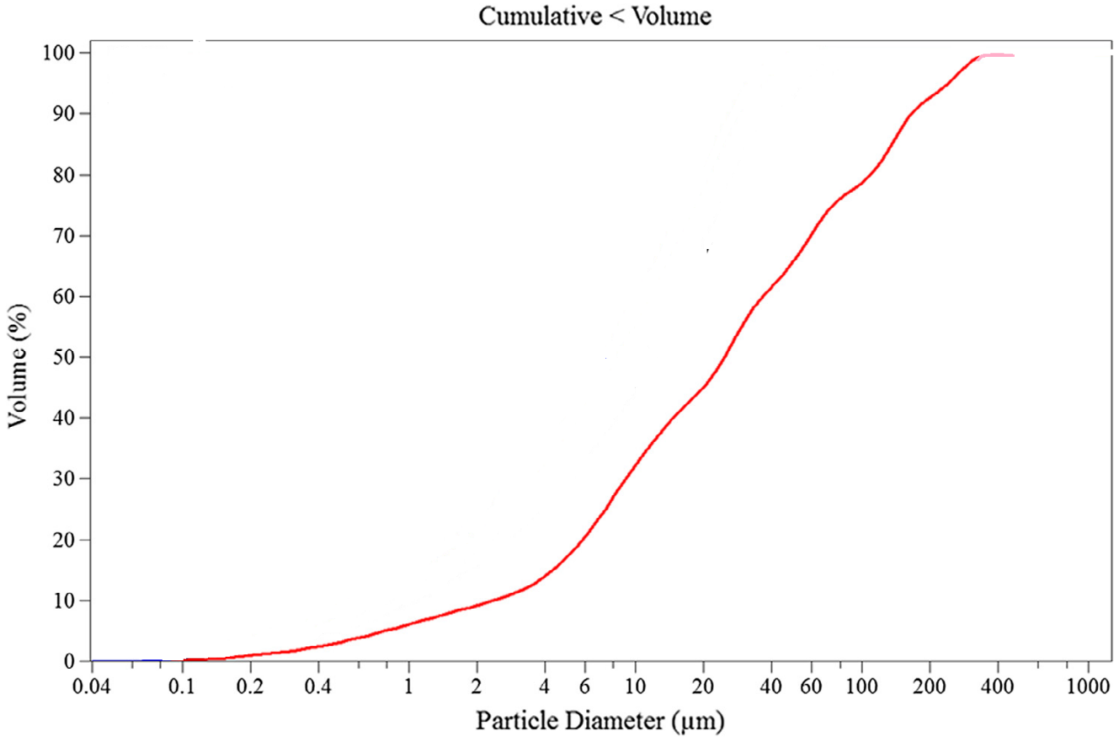


Figure (3.3) Cumulative particle size distribution of WPSA.

3.2.3 Granite Dust (GD)

During the manufacture of granite tiles and slabs from raw blocks, granite dust is created as a byproduct every day. The GD used in this research was brought from the granite slabs cutting and shaping factories in Babylon city . The chemical composition of GD used in this study are given in Table 3.3. While the curve of grains size distribution for the GD is appeared in Figure (3.4)

Table 3.3: Major chemical components of GD were determined using XRF test in National Laboratory Center in Baghdad

component	%
Cao %	1.13
Sio2%	41.45
Fe2o3 %	3.534
AL2O3 %	38.34
Tio2%	0.26
Mno%	0.066
K2o%	15.09
So3%	0.024

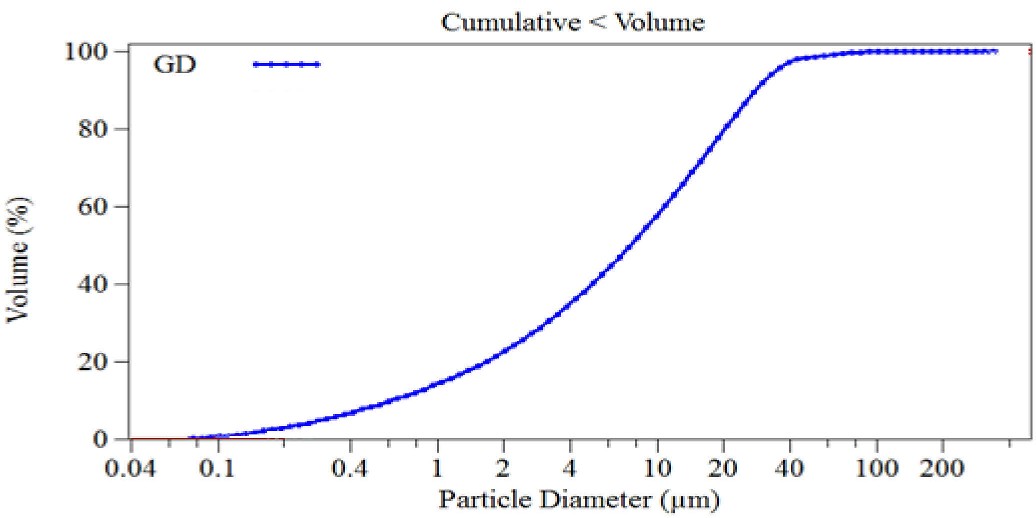


Fig.3.4 Cumulative particle size distribution of GD.

3.3 Methodology and Tests Adopted in this Study

3.3.1 Mixing proportion

The site's soil was initially allowed to air-dry for a few days before being used (not less than four days), then it was oven dried at 110 ± 5 °C. Using a plastic hammer, the soil lumps were crushed. The impacts of various binder mixes derived from the mixing of WPSA and GD on soil consistency limitations and compressive strength was examined. The binder proportion of the soils treated was set at 10% by the dry mass of natural soil. Table 3.4 shows the mixing proportions that were employed.

Table 3.4 Mixing percentages used in the research.

Mixture ID	Soil % from total mixture	WPSA % from total mixture	GD % from the total mixture
S	100	-	-
WPG0	90	10	0
WPG25	90	7.5	2.5
WPG50	90	5	5
WPG75	90	2.5	7.5
WPG100	90	0	10

3.3.1 sieve and hydrometer analyses

This test is carried out in accordance with ASTM (D 422) to estimate the proportions of various particle sizes present in the soil. The sieve analysis determines the particle size distribution of coarser, bigger particles; particles have diameter larger than 75 micrometer, whereas the hydrometer approach determines the distribution of the smaller grain. The distribution of grain sizes is essential in soil classification as shown in plates (3.1).

Plate (3.1) : Sieve and hydrometer analysis

3.3.2 Atterberg Limits

Atterbergs limits were calculated in accordance with ASTM D4318 test way for liquid limit. This experiment is done to find the plastic and liquid limitations of a fine particle size. according to Casagrande method The liquid limit (LL) has been randomly described as the moisture content, in percentage. The plastic limit (P.L) is the percentage of moisture in a soil that may no longest be distorted by drifting it at (3.20 millimeter) diameter thread that are not rumble. The PI is the different between the LL and PL in terms of numbers. soils engineering characteristics have already been connected to the plastic and liquid limits, and also the Atterberg limit can also be utilized to categorize fine particle soils as stated by Unified Soil Classification system. In this study the values of (L.L).(P.L),(PI) were found for all mixture in table 3.3, as shown in plates (3.2),(3.3).

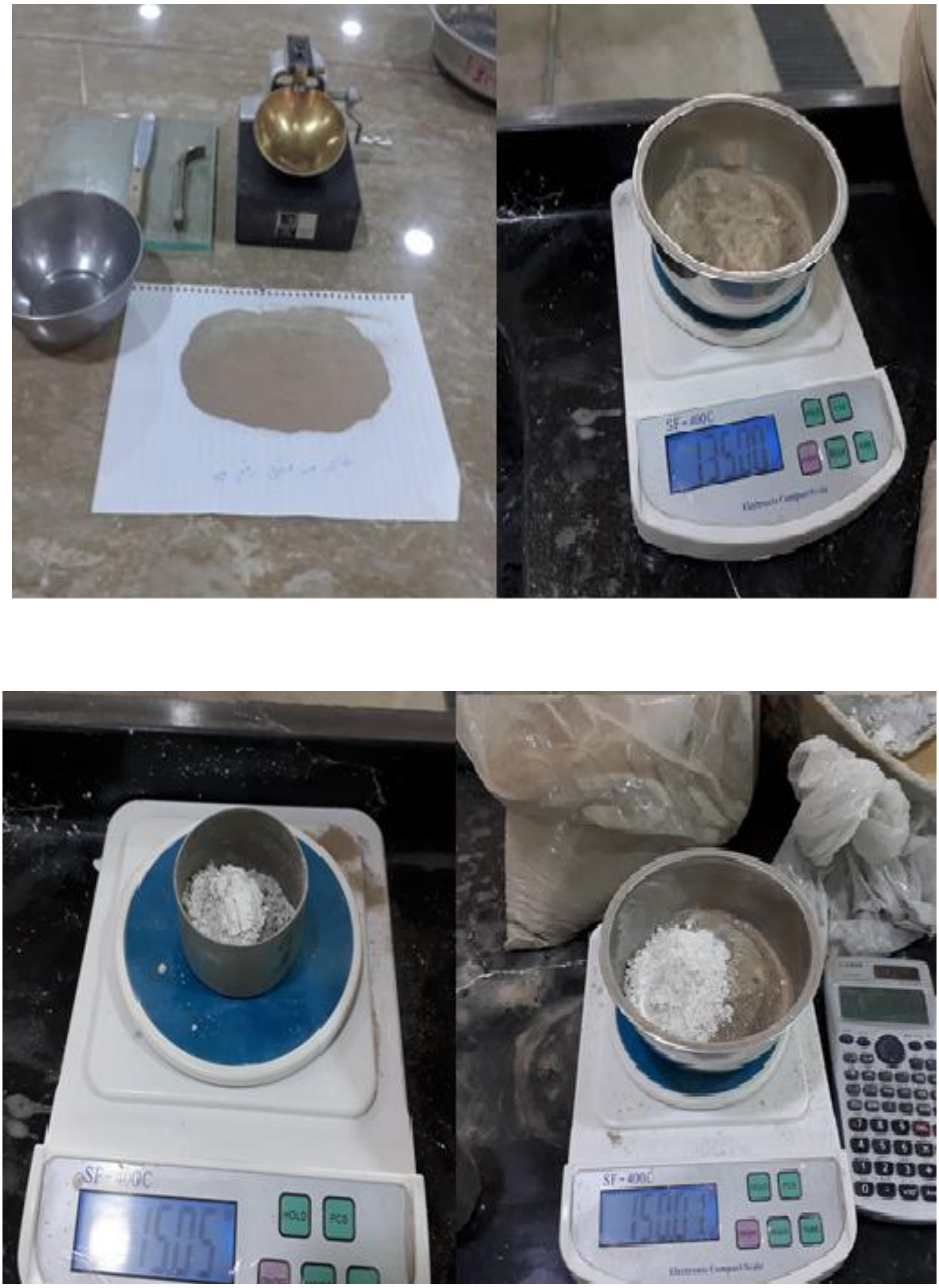


Plate (3.2) : Atterberg Limits Test

Plate (3.3) : Atterberg Limits Test

3.3.3 Compaction test

The compaction operation includes densification of the soils by removing air from the pores and drawing soil particles closer together. Among the most widely used and cost-effectiveness methods of improvement the soils is mechanical compaction. This test was utilized to find out the correlation between highest dry density (MDD) and optimal water contents (OWC) for virgin and modified soils. Most engineering characteristics, such as soil strength, stiffness, shrinkage resistance, and imperviousness, will improve as soil density is increased. In this research, the specimens preparation and data collected follow in the protector compaction basing on ASTM D(698Approximately) , two kilograms of dry soil, and soil with the binder (all combination in table 3.3) were combined with various water content (around five different percentages). For each percentage of moisture, 2.5 kg hammer is used to compact the soil by striking it from a distance into a soil filled molding. Three equal layer of soil are put in the mold., each of which is hammered 25 times. In this research the finding of(MMD) and (OWC) as shown in plates (3.4).

Plate 3.4: proctor test

3.3.4 Unconfined Compressive Strength (UCS)

The major objective of test is to assess the compressive strength, basing on the ASTM (D2166). In a basic compression tests, the unconfined comprssive strength is define as compressive pressure where an unconfined cylindrical spaceman of soil fails. Furthermore, in this test technique, the compressive strength is calculated as the greatest load per the unit area reached, or load on the unit area at 15 % axial strain, which come first throughout the test. In this research, for the (UCS) test, ASTM(D2166) was utilized to prepare the sample and gather the results. Briefly, the OWC and MDD calculated from the compaction test were used to prepare the soil or mixture for all Mixing proportion in table (3.3). Then the specimen was placed in a cylindrical fixed volume mold has been designed by Dr. hassnen mosa jafar with measurements of thirty eight millimeter in diameter and seventy six millimeter in height. Then, the mold containing the sample was pushed in hydraulic jack for a few minutes. The compressed specimens, after they were extracted from the mold , they were wrapped in cling film and placed in a sealed plastic bags to retain the moisture and left to curing for 3,7, and 28 days at room temperature. After curing, The specimen was placed in the machine and subjected to axial load testing, which was raised until failure was achieved. The axial stress was raised at a rate of one millimeter per minute throughout testing. as shown in plates (3.5),(3.6).

Plate (3.5) Unconfined compressive strength test

Plate (3.6) Unconfined compressive strength test

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This section summarizes the results of experiments that were conducted using different percentages of the composite (WPSA and GD) by dry weight mix with the soil as described in Chapter 3 to investigate the behavior of fine grained soil under the influence of these two different stabilizers.

4.2 Atterberge limits

Figure 4.1 shows the results of Atterberge limits test for un-stabilized soil and treated soil with various proportions of WPSA and GD binders. From this graph, it may be observed that the treated soil with unary binder (WPG100) reduced LL, PL,and PI, while the stabilized samples with other binders increased the LL ,PL and reduced the PI as appear in table 4.1.

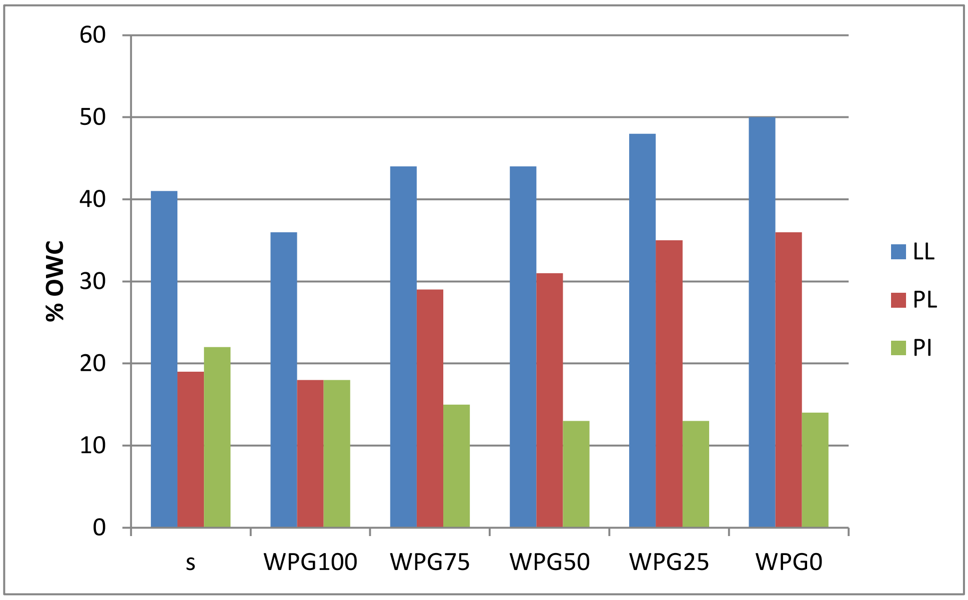


Figure (4.1) influence of various binary blending on LL, PL and PI of the stabilized soil

Table (4.1) Values of Atterberg limits for the soil stabilized with various binary blending of WPSA and GD

Mixture name	L.L %	P.L %	P.I
S	41	19	22
WPG100	36	18	18
WPG75	44	29	15
WPG50	44	31	13
WPG25	48	35	13
WPG0	50	36	14

4.3 Compaction test results

Figure 4.2 demonstrates the correlation between the dry density and water content for the untreated soil in compaction test.

From this figure, it can be observed that the max dry density was 1.68 g/cm^3 and its optimum water content was 20.5%.

After adding the waste materials as a binder with different proportions, the outcomes of compaction testing are presented in figures 4.3 and 4.4 a , and b . It can be seen that the treated soil with unary binder (WPG100) increased the MDD from 1.68 to 1.73 g/cm^3 and reduced OWC from 20.5 to 20%, whilst the treated soil with other binder reduced the MDD and raised the OWC. Furthermore table 4.2 illustrates the values of MDD and OWC for soil samples treated with different mixtures.

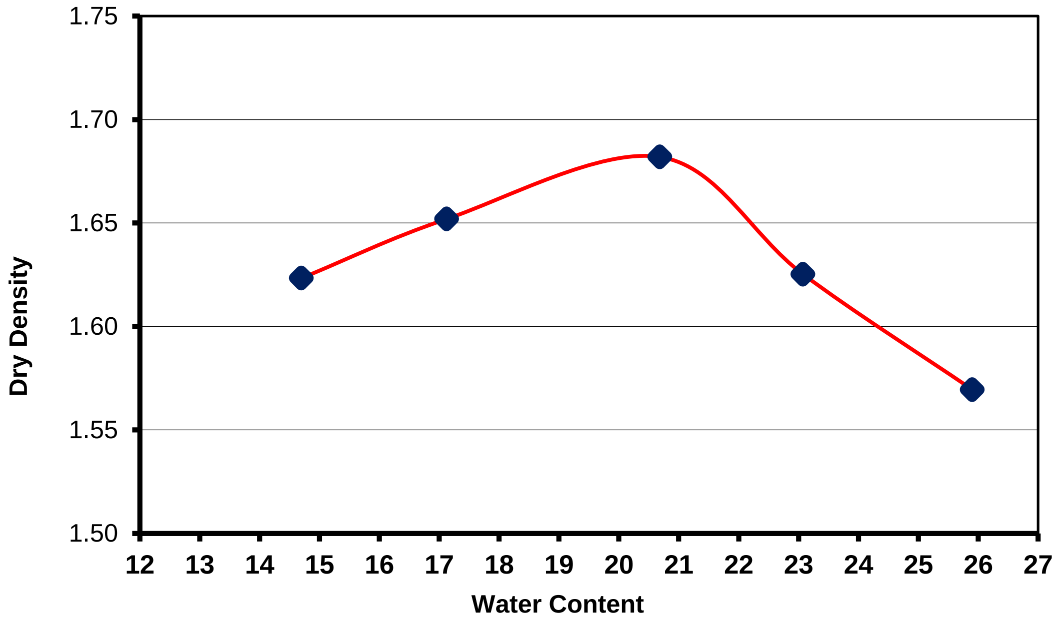
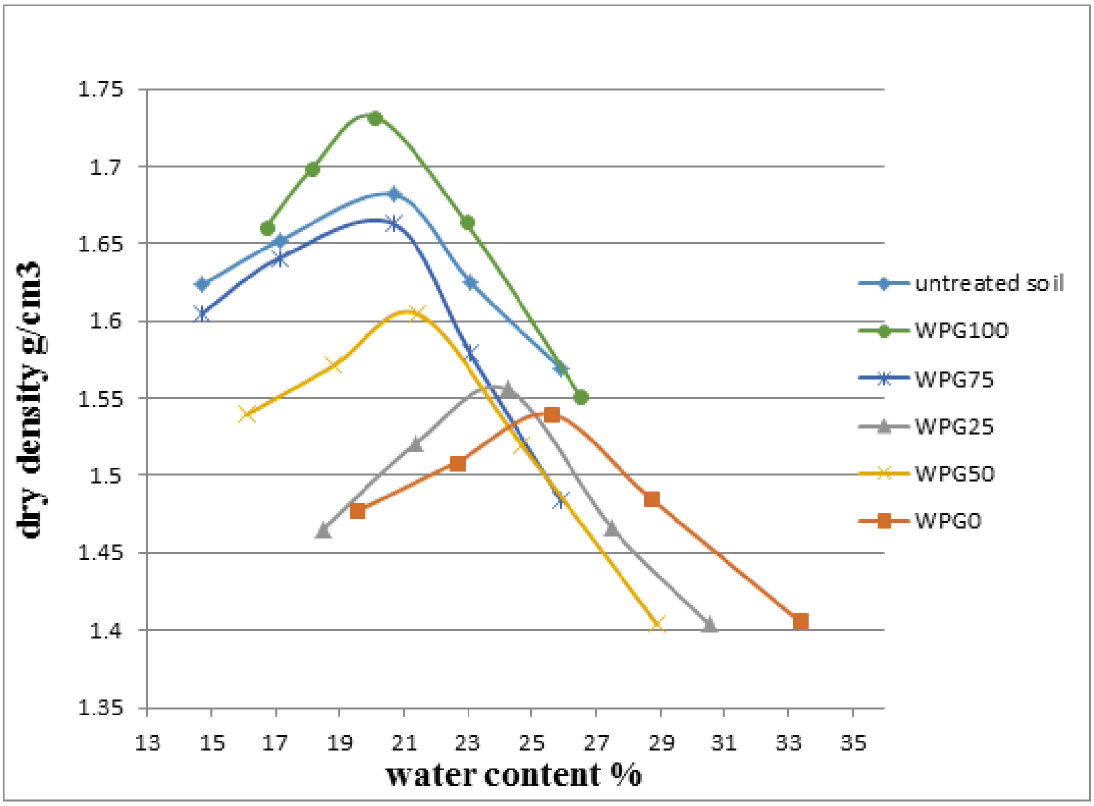
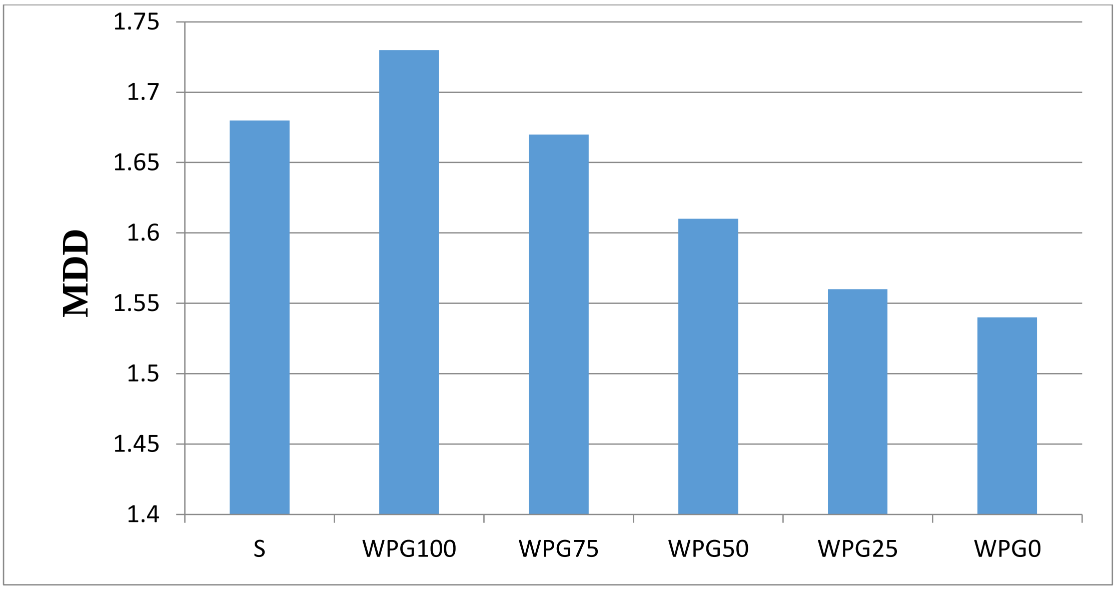


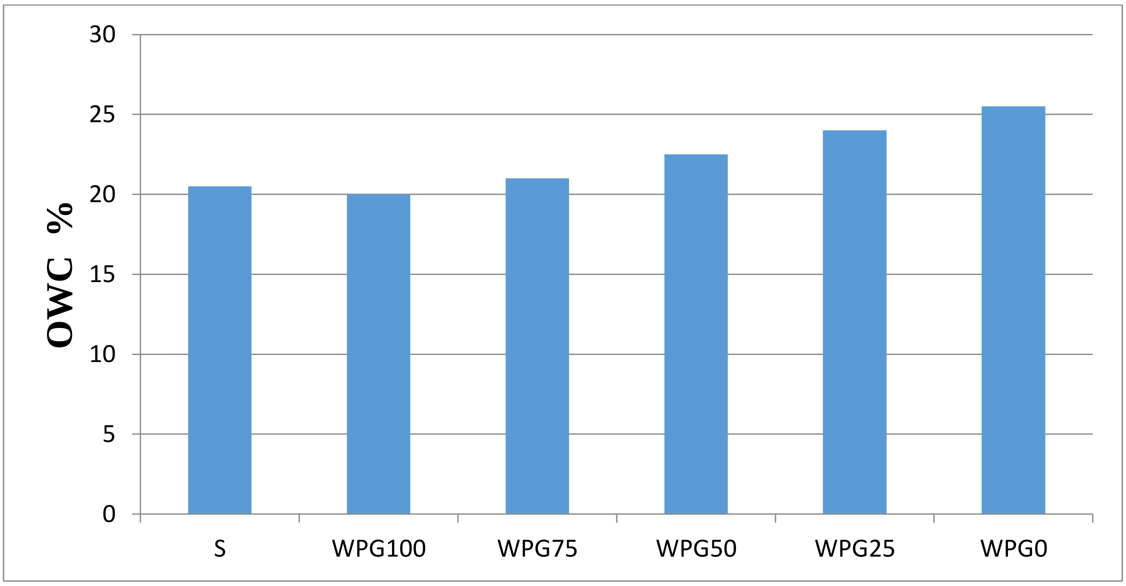
Figure (4.2) Result of compaction test of virigin soil



Figure(4.3) Dry density versus moisture content curves for the soil stabilized with different mixtures



(a)



(b)

Figure(4.4) Compaction parameters (MDD and OWC) for the soil treated with various mixtures

Table 4.2 :MDD and OWC values for the soil treated with various mixes of WPSA and GD

Mixture name	MDD (g/cm^3)	OWC %
S	1.68	20.5
WPG100	1.73	20
WPG75	1.67	21
WPG50	1.61	22.5
WPG25	1.56	24
WPG0	1.54	25.5

4.4 Unconfined compressive strength (UCS)

4.4.1 Stress –strain

Figure 4.5 Explain the correlation between stress and axial strain for specimens of untreated soil and soil treated with 10% binder produced from different proportions of the composite (WPSA and GD). It can be seen that the corresponding strain to crest axial stress for the untreated soil was 4.9 % at unconfined compressive strength of 124 kPa and can see that the behavior of untreated soil is ductile; offers more elastic behavior, and the sample took a long time to fail with greater buckling. After adding the waste materials as a binder with different proportions to the treated soil, the corresponding strain to peak axial stress decreased and the (UCS) rise with the increasing of WPSA portion in the mixture and the mixture (WPG0) have the highest unconfined compressive strength and minimum strain for all curing periods. The curve of stress- strain became more stepper compared to that of un-stabilized soil due to the hydration and pozzolanic reactions of WPSA. Additionally, the ductility of soil specimens have reduced gradually after the incorporation of the waste materials as binders in this study and the behavior turned to be brittle particularly for the longer periods of curing. Moreover, based on the stress-axial strain curves depicted in figure (4.5)(a,b,c), it is seen that WPSA has the dominant effect on the brittleness of the soil specimens compared to that of GD.

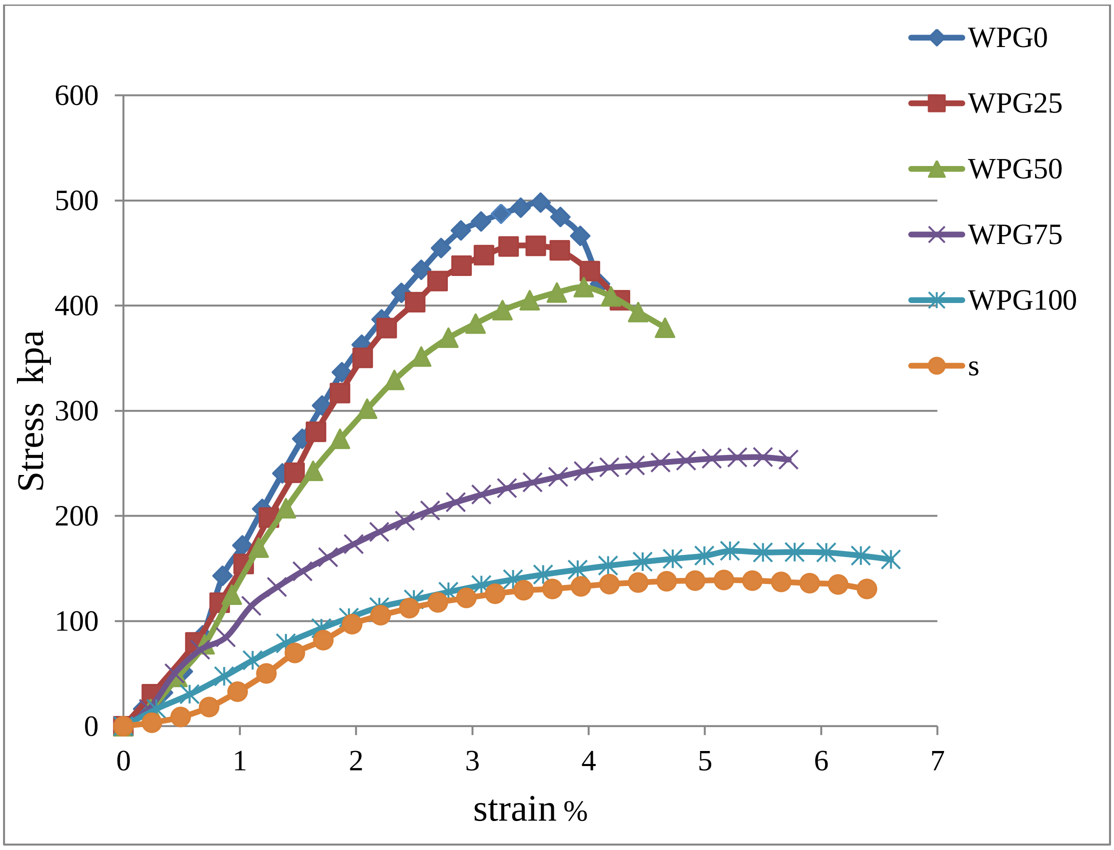


Figure (4.5) (a) Stress-axial stain diagrams of the soil stabilized with various proportions of WPSA and GD at three day

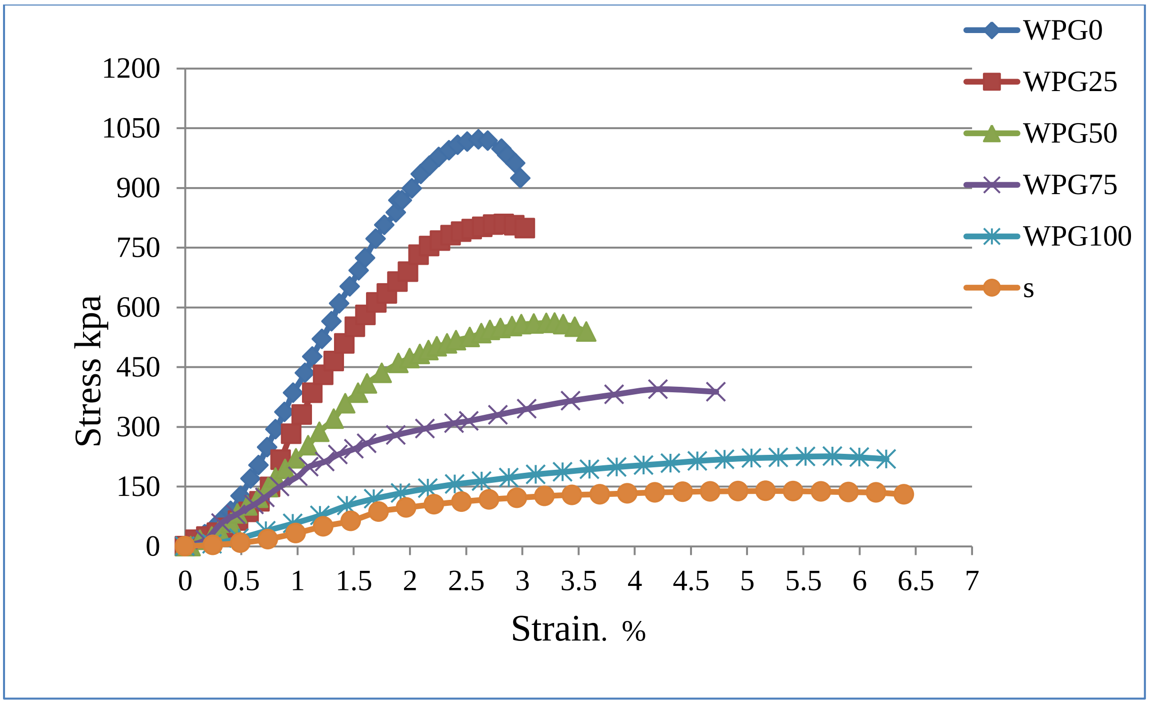


Figure (4.5) (b) Stress-axial stain diagrams of the soil stabilized with various proportions of WPSA and GD at curing period 7 days,

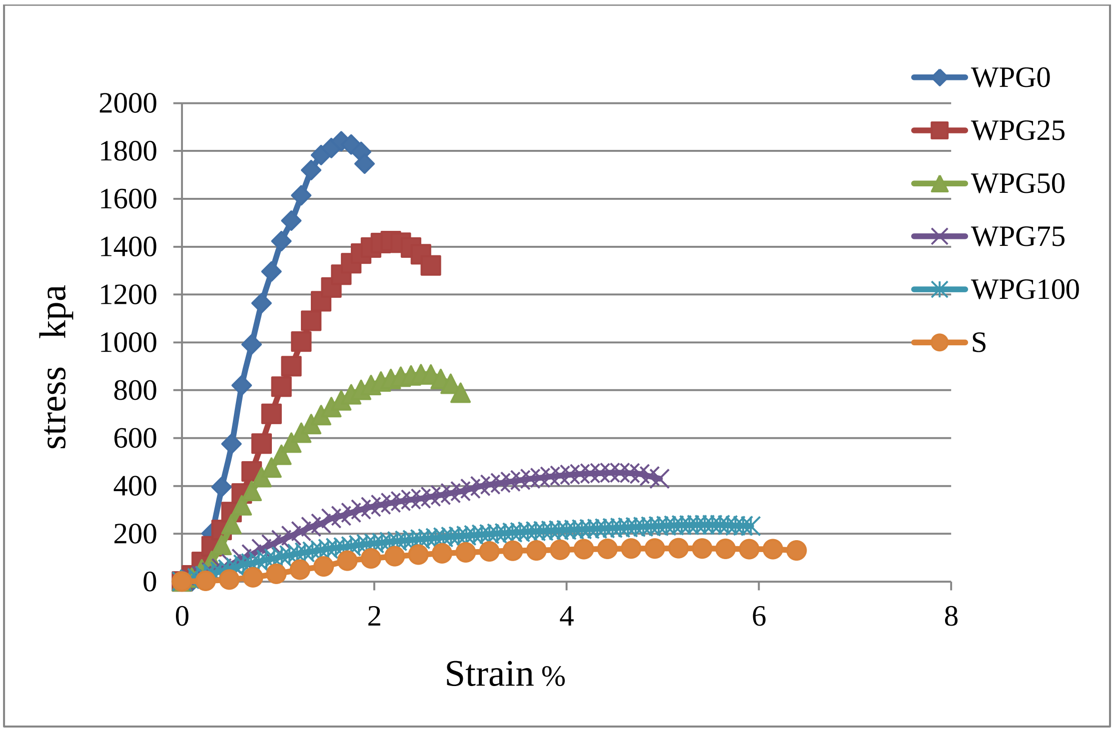


Figure (4.5) **(c)** Stress-axial stain diagrams of the soil stabilized with various proportions of WPSA and GD at curing period 28 days.

4.4.2 Effect of curing on UCS

Figure (4.6) shows the results of the average highest values of Unconfined compressive strengths for three samples of the un-stabilized soil and soil stabilized with various proportions of composites WPSA and GD after they were subjected to three different curing periods; 3, 7, and 28 days. Moreover, the aforementioned values are illustrated in Table 3.1.

It can be observed that the use of unary GD binder represented by 10% GD (WPG100) increased the unconfined compressive strength of the treated soils slightly from 124kPa to 237kPa at 28 day of curing ,while the use unary WPSA binder represented by 10% WPSA (WPG0) increased the UCS significantly from 124kPa to 1805 kPa at the curing age of 28 day.

Regarding the influence of the time for cure on the (UCS) of the specimen, it can be observed that for the mixture (WPG100) which contains 10 percent of GD, the unconfined compressive strength slightly developed througout the curing time from 166 kPa at the age of 3 days to 225 kPa at the age of 7 days then to 237 kPa at 28 day of curing compared to the significant rise in strength for the mixture (WPGO) which contains 10 percent WPSA, where the unconfined compressive strength progressed from 493 kPa at the age of 3 days to 1000 kPa at 7 days of age, and then to 1805 kPa . The highest compressive strength values for the stabilized soil were at the age of 28 days. This significant increases is due to the fact that WPSA has a high content of CaO.

The flocculation and agglomeration phenomena, as well as the cation exchanged that happened between the monovalent cation of the stabilized soil clay mineral and the divalent calcium ions of the WPSA, are accountable for the uncured samples early strength growth. The pozzolanic reactions that occurred between the WPSA and the silica and aluminate of the stabilized soil resulted in the growth of the strength of the stabilized soils as curing time. This reaction generates cementing material such as calcium-silica-hydrate and calcium-alumina-hydrate. (Jafer et al., 2018)

With respect to the other mixtures from the figure 4.6, it can be noticed that the (UCS) of stabilized soil rising with the increment of the percentage of WPSA in the binder for all ages of curing, as the mixtures (WPG75, WPG50, WPG25) gave the compressive strength (267, 400, and 456 kPa) respectively at 3 day age of curing and these values increased with the increase in the period of curing reached (293, 554.5, 728 kPa) respectively at 7 days and (450, 960, 1267 kPa) respectively at age 28 days , due to the increase of the pozzolanic reactions with time.

Therefore, the mixtures (WPG75, WPG50) have good outcome in terms of (UCS) and Atterberg limits compared to the rest of the mixtures and therefore can be used in soil improvement according to the desired soil strength, as these mixtures contain a percentage of WPSA and GD, thus we can recycle these wastes safely and economically.

Table 4.3: The compressive strength values of the soil treated with various proportions WPSA and GD at various curing periods .

Mixture name	UCS (kPa) at 3days	UCS (kPa) at 7days	UCS (kPa) at 28days
S	124		
WPG100	166	225	237
WPG75	267	393	450
WPG50	400	554.5	960
WPG25	456	728	1267
WPG0	493	1000	1805

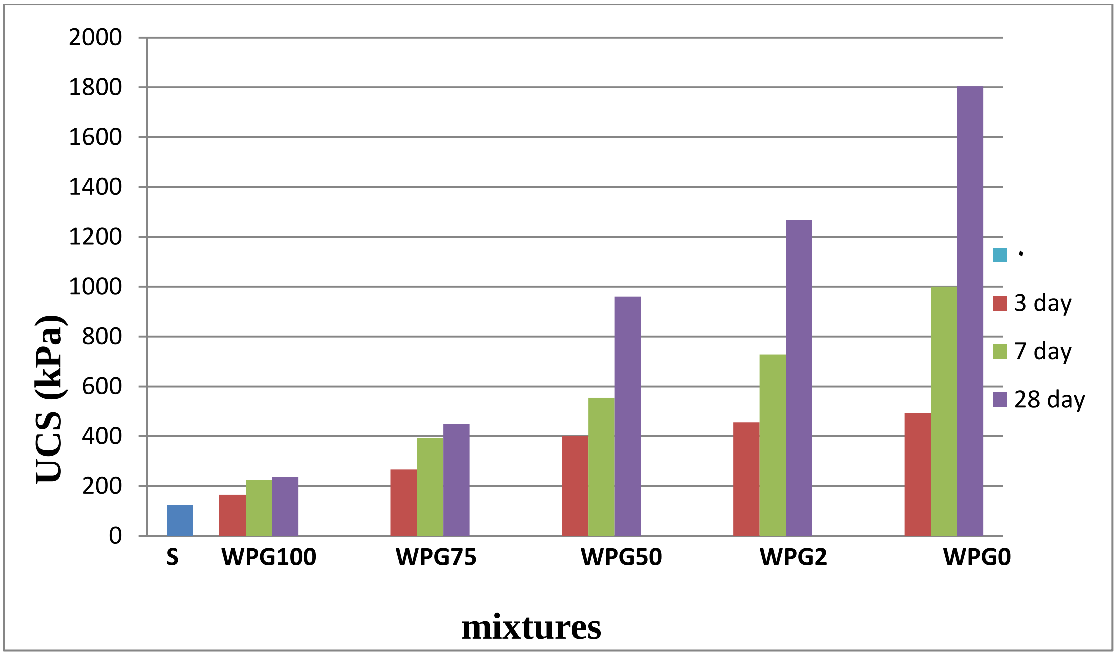


Figure (4.6) the (UCS) of the soil stabilized with various proportions of WPSA and GD at various curing periods.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

This research aims to develop a binder for soil stabilization by reuse two of waste materials; WPSA and GD in stabilizing fine-grained soil and improving some of its engineering properties by mixing them with untreated soil at a rate of 10 % of the dry mass. The properties of treated and untreated soil were evaluated through a procedure of several practical tests.

By analyzing the results obtained, the following was concluded

1- The outcomes of Atterberg Limits showed that the utilization of GD alone led to a reduced in the LL, PL, and PI of the treated soil, while the use of WPSA alone or when mixed with GD led to an increase in the LL and PL, and a reduction in the plasticity index of the treated soil, the lowest PI was obtained by using mixtures WPG25, and WPG50 in which both of the aforementioned mixtures reduced the plasticity index by 9%

2- The results showed that when use WPSA alone led to a significant reduction in the MDD and noticeable rise in OWC, but when using a binder of GD with WPSA, gradual rise in the MDD and decrease in OWC content were obtained. It was observed that the highest MdD was 1.73 g/cm^3) with OMC of 20% which obtained by using GD alone (WPG100).

3- Regarding soil strength, the results of compressive strength (UCS) test showed the following:

- When use the mixture (WPG100) which contains GD alone as a binder, a slight increase in the compressive strength from 124 kPa for the virgin soil to 237 kPa was gained, while when increasing the WPSA portion in the binder, noticeable developments were occurred in the compressive strength of the stabilized soil. The mixture WPG50 had a UCS of 960 kPa that makes the soil strength about 7.7 times of that for untreated soil.

- The highest compressive strength value (1805kPa) was obtained when using the mixture (WPG0) that contains 100% WPSA and it was 14.55 times the UCS of untreated soil.
- The compressive strength increased with the increase in the curing period, particularly for mixtures that contain a high percentage of WPSA, as it was noticed that the compressive strength of the mixture (WPG0) at the age of curing 3 days has (UCS) 3.97 times of the compressive strength of untreated soil that which increased by 14.55 times at age of curing 28 days. The mixture (WPG100) had a compressive strength at the age (3, 28) days (1.38,1.91) times of the compressive strength of untreated soil respectively.

Finally, it can be concluded that WPSA and GD as waste materials can be used successfully as stabilizers to improve the geotechnical properties of fine grained soils.

5.2 Recommendation

Based on the results of current study, the following future works can be recommended:

1- Studying the effect of the use of waste materials in this study on the swelling indices of the fine grained soils.

2- As the WPSA has the predominant effect on the stabilized soil strength when compared with effect of GD, it is recommended to use another waste material with the combination of WPSA such as sewage sludge ash, cane sugar ash, etc. to evaluate the effect of the newly developed binder on the geotechnical and engineering properties of the soil.

3- As WPSA showed high water consumption, the studying of its effect on the high natural water content soft soils is recommended.

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الخلاصة

تهدف هذه الدراسة ، من خلال الأعمال التجريبية ، إلى تطوير مادة رابطة جديدة ومستدامة من خلال مزج مادتين من النفايات ، وهما نفايات رماد نفايات الورق (WPSA) وغبار الجرانيت (GD) لتثبيت التربة ناعمة الحبيبات وتقليل الآثار البيئية الناتجة عن التخلص غير السليم لها بالإضافة إلى تقليل استخدام الأسمنت والنورة في تثبيت التربة. تم الحصول على التربة المستخدمة في هذا البحث من موقع بالقرب من شارع ثمانين في مدينة بابل. تمت دراسة تأثير المخاليط الثنائية المختلفة على حدود القوام واختبار بروكتر القياسيي واختبار الضغط غير المقيد بعد (3 ، 7 ، 28) يومًا من المعالجة. تم اعتماد نسبة خلط WPSA / GD على النحو التالي (10: 0 ، 7.5: 2.5 ، 5: 5 ، 2.5: 7.5 ، 0:10) بالوزن لتثبيت التربة ، وأظهرت النتائج أن استخدام الخليط (WPG100) الذي يحتوي على نسبة 10٪ GD إلى انخفاض في LL و PL اما PI انخفضت بنسبة 1.22٪ ، وعند زيادة نسبة (WPSA) في الخليط أدى إلى زيادة في (LL) و (PL) بينما ((PI) انخفض بنسبة 9٪ للخلائط (WPG25) و (WPG50) علاوة على ذلك ، زادت الكثافة الجافة العضمى للتربة المعالجة بالخليط (WPG100) بشكل ملحوظ من 1.68 جم / سم 3 إلى 1.73 جم / سم 3 ، إلا أنها انخفضت بشكل ملحوظ بعد إضافة WPSA في المادة الرابطة المستخدمة من 1.68 غم / سم 3 إلى 1.54 غم/ سم 3 للخليط (WPG0) ووفقًا لنتائج اختبار الضغط غير المقيد ، فقد تبين أن استخدام الخليط (WPG0) الذي يحتوي على 10٪ WPSA أعطى أعلى مقاومة للضغط ، والتي تعادل 14 ضعف مقاومة ضغط التربة غير المعالجة بعمر28 يومًا. ثم تنخفض قوة الانضغاط مع زيادة نسبة غبار الجرانيت في الخليط

جمهورية العراق

وزارة التعليم العالي والبحث العلمي

جامعة بابل

كلية الهندسة

قسم الهندسة المدنية

دراسة تاثير رماد خبث الورق وغبار الكرانيت على الخصائص الجيوتقنية للترب الناعمة الحبيبات

بحث

مقدم الى كلية الهندسة جامعة بابل

كجزء من متطلبات نيل درجة الدبلوم العالي في الهندسة /

الهندسة المدنية / التربة والاساسات

من قبل

خضر جابر حمزة عوين

اشراف

أ.م.د حسنين موسى جعفر

1443 2021