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M.Sc. in Civil Engineering

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UNIVERSITY OF GAZİANTEP

GRADUATE SCHOOL OF

NATURAL & APPLIED SCIENCES

IMPROVING SOME GEOTECHNICAL PROPERTIES OF AN ORGANIC SOIL USING CRUSHED WASTE CONCRETE

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BY

OMAR ADNAN IBRAHEM

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Improving Some Geotechnical Properties of an Organic Soil Using Crushed Waste Concrete

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Supervisor

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by

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

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Omar Adnan IBRAHIM

ABSTRACT

IMPROVING SOME GEOTECHNICAL PROPERTIES OF AN ORGANIC SOIL USING CRUSHED WASTE CONCRETE

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Many urban areas are struggling with the high volume of solid wastes, particularly the construction and demolition materials. In this study, the crushed waste concrete (CWC) was used to improve some geotechnical properties of an organic soil. The CWC at the ratios of 10%, 20%, 30%, 40%, and 50% were added to the organic soil in order to conduct an intensive series of experimental tests. The laboratory tests includes the consistency limits, liquid limit by fall cone. Plastic limit and plasticity index modified compaction, unconfined compressive strength (UCS), and free swelling, consolidation and collapse in oedometer testing machine. The results showed that when the CWC percentages increased to 50%, there was decrease of about 30% and 60% in liquid limit and plasticity index of clay, respectively. Increase of about 35% in γ_{drymax} for the organic soil was noted when the CWC content was increased from 10% to 50%. A reduction of about 50% of w_{opt} for organic soil was shown by increasing the CWC percentage to 50%. The UCS values of the organic silt increases by around 25% by increasing the CWC percentage up to 50%. The swelling percentage increased by adding CWC up to 30%, and then decreased with the addition of CWC up to 50%. Increasing the CWC contents has a positive effect on the consolidation features of organic soil. CWC decreased the consolidation of organic soil by decreasing the compression index (C_c) and the time of consolidation for organic soil was decreased due to the increasing of the coefficient of consolidation (C_v) and coefficient of conductivity (k) for organic-CWC mixtures

Keywords: Stabilization, organic soil, crushed waste concrete.

ÖZET

ÖĞÜTÜLMÜŞ ATIK BETON KULLANILARAK ORGANİK BİR ZEMİNİN BAZI GEOTEKNİK ÖZELLİKLERİNİN İYİLEŞTİRİLMESİ

IBRAHIM, Omar Adnan
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Danışman: Prof. Dr. Ali Fırat ÇABALAR
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51 sayfa

özellikle inşaat ve yıkım malzeme atıkları başta olmak üzere yüksek miktardaki katı atıkların geri dönüşümü hususunda çalışmalar yapilmaktadır. Bu çalışmada, organik bir zeminin bazı geoteknik özelliklerini iyileştirmek için öğütülmüş atık beton (ÖAB) kullanılmıştır. Bir dizi deneysel testler yapmak amacıyla ÖAB organic zemine %10, %20, %30, %40 ve %50 oranlarında eklenmiştir. Oluşturulan karışımlara likit limit, plastik limit, kompaksiyon, serbest basınç deneyi, serbest şişme, konsolidasyon ve ödometre deneyleri uygulanmıştır. Sonuçlar, %50 ÖAB eklentisi ile, organik zeminin likit limit ve plastik limit değerinin sırasıyla %30 ve %60 oranlarında azaldığını göstermektedir. %10 dan %50'ye artan ÖAB eklentisi en büyük kuru yoğunluk ($\gamma_{kurumax}$) değerini %35 oranında arttırmıştır. %50 ÖAB eklentisi ile de optimum su muhtevası (w_{opt}) %50 oranında azaltırken serbest basınç dayanımını ise yaklaşık %25 oranında arttırmıştır. Karışımların serbest şişme oranı %30 ÖAB ilavesine kadar artarken, bu orandan sonra azalmıştır. ÖAB içeriğinin arttırılması organik zeminin konsolidasyon özellikleri üzerinde de iyileştirme gerçekleştirmiştir. ÖAB ilaveleri, organik zeminin sıkışma indisi (Cc) azaltarak zeminin konsolidasyonunu azaltmıştır ve konsolidasyon katsayısı (Cv) ve geçirimlilik katsayısının (k) arttırmasından dolayı da zeminin konsolidasyon süresi azaltmıştır.

Anahtar kelimeler: Stabilizasyon, organik zemin, öğütülmüş beton atığı.

To my wife, I am grateful to God for having wife like you. Your unconditional love and support made my every achievement possible.

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LIST OF SYMBOLS/ABBREVIATIONS

LL	Liquid Limit (%)
PL	Plastic Limit (%)
PI	Plasticity Index (%)
C_c	Compressibility Index
Cs	Swelling Index (%)
γ_{drymax}	Maximum Dry Unit Weight (kN/m^3)
w_{opt}	Optimum Water Content (%)
S	Swell Percentage (%)
K	Hydraulic Conductivity (cm/s)
c′	Effective Cohesion (kN/m2)
Φ	Angle of Internal Friction (°)
e_o	Initial Void Ratio
e_f	Final Void Ratio (at end of loading stage)
Gs	Specific Gravity
C_α	Secondary Compression Index
Cc	Compression Index

ABBREVIATIONS

OS	Organic Soil
CWC	Crushed Waste Concrete
UCS	Unconfined Compressive Strength
AASHTO	American Association of State Highway and Transportation Officials
ASTM	American Society for Testing and Materials
EDX	Energy Dispersive X-Ray
SEM	Scanning Electron Micrograph
OPC	Ordinary Portland Cement
XRD	X-Ray Diffraction
USCS	Unified Soil Classification System
WC	Water Content
QL	Quicklime
FA	Fly Ash

CHAPTER 1

INTRODUCTION

1.1 Introduction

In the last decades, the population of the world increased rapidly, it reached about 7 billion in 2011, (PRB, 2011). Therefore, this led to create many of overpopulation and to solve this problem needs to an expansion of existing cities, and development of infrastructure and construct new towns. These actions led to an accumulation of large quantities of solid waste concrete that adversely affect the urban environment. Many cities are now dealing with the high volume of solid wastes, the methodology of mechanical disposing and the reducing of solid wastes effect on the local and international environment.

Stabilization of Soil is the modification in the soil to boost their physical characteristic. Stabilization can be increasing soil shear strength and control shrink-swell properties of soil, this will be improving a sub-grade for supporting pavement and footing. Stabilization of Soil with the crushed solid waste concrete has not only used for the some of the geotechnical properties but also has adapted to be a useful method from the economic and environmental side. Recently, many types of research had been carried out in the ground improvement of different projects like road pavements and highway (Kamie et al., 2007;Ugai et al., 2009; Karakus, 2011) and in utilizing the wastes in soil stabilization methods (Jafari and Esna-ashari, 2012).

In this study, the crushed solid waste concrete was carried out to test its possible to change into useful materials such as organic soil stabilizers and partial alternatives to the fine contents of ordinary strength concrete. These solid wastes effect on the beautiful environment and impose financial costs on the administrations of cities and municipalities for the aim of disposal.

1.2 Problem statement

Organic soils classified as complicated soils, owing to the high compressibility, considerable secondary consolidation, deformations, and permeability. Since it is more compressible and weaker than inorganic soils, this soil can not offer appropriate conditions for all engineering projects. If such soil is present, we usually avoid them, excavate them, or added some materials with a specific percentage in order to get more appropriate properties.

1.3 Objectives

The primary aim of a research an investigation of using a waste concrete in improving some geotechnical properties of the organic soil in order to reduce economic and environmental concerns.

1.4 Outline

This study contains five chapters; Chapter 1 presents the background and the objective of this study. Chapter 2 involves some researches histories which are relevant to current research. The material characteristics and properties and the methods that carried out during the experimental work are included in Chapter 3. The 4th chapter discusses the results obtained by experimental works. Finally, Chapter 5 contains the conclusions gained from the various experiments in studying.

CHAPTER 2

LITERATURE REVIEW

2.1 Organic soil

The effects of the crushed wastes concrete on the stabilization of the organic soil were studied in a few articles over the last years. Limited references on the types of recycling that related to our study and organic soil references are listed down in this chapter.

The prevalent definition of organic material, any matter that have carbon is termed "organic". The organic soil is the soil contain the specific quantity of organic content that was created from plant remains. That means that it needs to be still in the decomposition process and fresh, so will having a peculiar texture, smell, and color (Huat et al., 2014). The organic substance in soils formed of living plants, animals and organisms. In particular, marine animals and plants contributing major amounts in the forming of organic material in the soil. Through the plants' transformation processes, organic matter like peat and coal are produced Larsson (1980). Stevenson (1994) pointed out that that the organic soil material holds the full organic matter in soils, containing the light portion, litter, water-soluble organics, and stabilized organic material given the difficulty of soil organic matter. Chikyala (2008) refers to ability of organic matter for classifying into two main kinds: non-living organic matter and living organic matter, the transition of plants and animals into organic soils principally through bacterial activities, and this process is concentrated by hot climate. For the organic forming, deposition rate should be faster than decomposition rate McDonald (1993) noted that the accumulation resultant of organic material takings about 500 years to accumulating 30 cm of organic soil. Organic soils are composed of residues cumulative animals and plant, in various stages of decomposition, in an environment that doesn't allow the materials to decay swiftly (Caldwell, 1977).

2.2 Geotechnical specifications of organics soils

2.2.1 Characterization index

The engineering characteristic of organic soils like water content (w_C), specific gravity (Gs), Attetberg limits (Liquid limit LL, Plastic limit PL, Plasticity index PI) are clarified here. w_C of soil can easily evaluated at laboratory by using water content test (ASTM D2216 or BS 1377: 1990), the process starts by dryings soil sample in furnace on 105◦C for 24 hours. For the peat soils, standard steps for the test previously mentioned leads to the burn the peat organic combinations, thus lead to finding several figure for moisture contents. Moreover, a depressed temperature keeps the organic matter, between 50 and 95◦C. Kabai and Farkas (1988) and Skempton and Petley (1970) studied this effect and found the deprivation of organic material at 105◦C is non-important, while at low temperatures drying holds a little free water amount. Zainorabidin and Bakar (2003) examined the influence of drying temperature for hemic peat soil and stated that for temperatures in the range between 100 and 200◦C the drying time is between 24 and 60 hours. For peat and organic soils, the LL is depended on the type of detritus of plant included, clay percentage and humidity amount in the soil. For temperate peat, the LL of fen peat differs between 200–600%, and for bog peat between 800–1500% according to (Hobbs, 1986). Skempton and Petley (1970) put the H3 of the von Post scale for LL as a convergent limit, and for the PL, H5 was used. At any status, according to Hobbs (1986), for calculating the PL of peat soil there is a slight point because the plasticity gives a few indications of their specifications. Commonly, the LL and PL of organic soil increase with increment the organic contents according to (Tremblay et al., 2002). Holtz and Krizek (1970) studied this soil and concluded the increasing the organic contents are causing decreasing the maximum dry density (γ_{drymax}) of compaction, whereas the optimum moisture content (w_{opt}) increase with increasing the organic content. The same results were also mentioned by Schmidt (1965). The Gs of a rise organic content soil general in a range of 1.0-2.0. For high organic content, the standard magnitude is 1.5 as (Huang et al., 2006). The Gs was increased with the mineral amount increasing; so, Gs of above than 2.0 are an indicator the height content of minerals of the soil according to (MacFarlane, 1969).

2.2.2 Strength of organic soil

Soil shear strength represented one of essential issues, effects on the engineering design for footing or any parts touch with soil. This factor was so important particularly during the pre- and post-construction stages, since it used to determine a slope stability, footing of the soil override the value of ultimate shear strength led to the soil fail, or soil deform as Huat et al (2014) both of the theory of elasticity and stress-strain relationship was used for developing the failure condition. Strain values of soil depended on many factors like soil composition, amount of applied load, void ratio, past stress history, and also the method of applied stress according to Anggraini (2006). Organic soil are encountered in some geographical zones, because of their high water content and organic solids it displays mechanical characterizations somewhat dissimilar than the usual behavior of inorganic soil according to Edil and Wang (2000). On the other hand, comprehension the shear strength and situation of stress in the field is so important in the design of structures on organic soils Edil and Wang (2000).As normal the shear strength parameter varies with both of consolidated soil and plasticity according (Larson, 1980; Edil and Wang, 2000). Arman (1969) discovered that the shear strength of the soil increases with the addition of fibrous organic material. (Mitchell and Soga 2005) They concluded that the strength can be increased if the fibers contained in the organic soil act as reinforcement. Mesri and Ajlouni (2007) showed that the friction angle magnitude for organic or peat soil is in the range of 40º to 60° compared to the less than 35° for soft clay. The high value of the friction angle does not represent the force of high shear of the soil because not all the fibers are solid due to its containment of water and gas. Despite the fiber organic soil contents effect on the friction that's stated by Edil and Dhowian (1981).

2.3 Oedometer properties of organic soil

2.3.1 Swelling characterization

Materials in nature are known for their apparent qualities and characteristics for the different conditions under which they are exposed. The soil is a natural material with varying engineering characteristics. One of the most engineering essential problems is the volume changes of the soil, because of its effect on the building and structures. The swelling soils have been characterized by volumetric changes of decreasing and increasing, (swell volume) increase with moisture content increment, and its size decreases (shrink) with a decrement of the moisture content. So both shrinkage, swelling affects hysteretic changes in soil volume as a function of (WC). Peng and Horn (2007).studied the variance in the curves of shrinkage and swelling of soil and the hysteresis of the void ratio as a function of moisture ratio for the 4 types of soils (Eutric Histosol, Histic Gleysol, Calcic Gleysol and Dystric Gleysol), and an explanation the anisotropy of soil shrinkage and swelling in two dimensions. They using model we had already developed to appropriate and for defining the endpoint of several shrinkages or swelling range. Two organic-rich soil appeared just structural and relatively shrinkages, while the two inorganic Gleysols covered all four shrinkage ranges. Of all the shrinkage ranges, relatively shrinkage participated to 60.2–96.8% of the whole volume decreasing. A standard soil swelling curve was formed of two distinct part, which was defined as virgin swelling and residual swelling with separate of the wet-side maximum curvature. A swelling virgin represented 81.2–91.9% of an overall soil volume increase. We found pronounced hysteresis during shrinkage and swelling. A single cycle of wetting and drying lost 10–78% of the soil volume. Shrinkage of the organic-rich soils was significant higher than that of inorganic Gleysols. Results of a study can be useful for the improving the understanding of soil structure change throughout the shrinkage and swelling period and can also apply to predict hydraulic characterization more exactly.

2.3.2 Consolidation characterization

The peculiarly low mineral composition, an abundance of water growing from an origin and forming peat, and the fact that peats are generally found very near the surface because these soils to have depressed density and a slightly porous fabric Hwang and Humphrey (2005). The organic soil has distinguished by high in-situ void ratio and thereafter high permeability (Fox and Edil 1996). Meyer and Bednarik (2008) starting to prepare a study for estimating the expecting soil reinforcement due to the consolidation load. This study represented the oedometer tests results of consolidation of soil from Ostrów Grabowski site in Szczecin Harbour. The specimens were taken from the site were loaded initially and unloaded and the again loaded. The fundamental parameter of tests was the elasticity modulus, increase prediction, due to consolidation; the result of the study shows clearly that under initial load the relation stress-strain indistinctly nonlinear while after loading again the relation tends to linear one.

Malinowsk and Szymański (2014) to Study the possibility of derivation of the consolidation of partial differential equations with non-linear flow characterization on organic soil model such as the organic soils. It has high compressibility, so that results in high permeability variations. Even with small stresses, organic soil has much deformed, road embankments, flood control levees, dikes, and dams are very often located on organic soil, so it is essential to model deformations under these constructions. So In this study, a non-linear theory has been presented for consolidation of organic soils considering the porosity differences, flow rate. Author suggests a new equation as a characterization of the non-linear flow characteristics in soft organic soils during stress variation.

2.3.3 Collapse characterization

Volumetric change is one of the most important problems that the footing engineers face in large areas of the world, especially in regions with continental and sub-continental climates. Volumetric change, especially the collapsed state, causes significant material losses as a result of serious damage to buildings, bridges, irrigation channels, roads, airports and other engineering structures. The organic soils have the highest possibility to collapse when the water content increase. The possible solutions or the available alternatives may be included (a) subtraction of collapsible soils, (b) compaction technics (c) avoidance of wetting, (d) chemical stabilization or grouting, (e) pre-wetting, (f) controlled wetting, (g) deep dynamic compaction, (h) pile or pier foundations, and (i) differential-settlement-resistant foundations (Houston et al. 2001). Ayadat and Hanna (2005) investigated experimentally the performance of stone columns condensed in geofabric reinforcement, installed in a collapsible soil layer and subjected to inundation. Stone columns possible to use in transmit footing loads to appropriate bearing strata under layer soil collapsible. According to the results of the experimental study, it can be conclude that unreinforced sand columns in collapsible soil did not contribute significant in performance of the soils.

2.4 Improvement of organic soil techniques

2.4.1 Improvement of organic soil using ordinary cement and fly ash

Organic soil generally considered as the problematic soil at all construction project, due to its high compressibility with a low shear strength (Huat 2004).With increased demand for industrial sector and the population intensity, it has become necessary to construct infrastructures requirements on the ground that rich in organic content or organic soil. The general constructions recommendation replacement of organic soil by appropriate filling materials, but if the peat depth is much, it may not be an economical option. Kolay and Aminur (2011) studied the effect of using the different stabilizing agents in improvement the physical characteristics of organic soil. The ordinary Portland cement (OPC), quicklime (QL), and class F fly ash (FA) were used as a stabilizer, and then added some amounts from each them as the as a proportion of dry soil mass, in the range of 5–20%; 5–20% and 2–8%, respectively for a curing duration from 7, 14, until 28 days. Author conclusion was the addition of chemical admixture, i.e., OPC, QL, and FA could be improving the physical characteristics of organic soils Duraisamy and Muniandy (2009) studied the effects of the cement column diameter on the compressibility of the fibrous organic soil and find the relationship between basic geotechnical characteristics of fibrous organic soil with index parameters like (wc), organic content, and (LL). The diameter of samples was 45 mm (area-ratio = 0.09) and 60 mm (area ratio = 0.16) respectively. The specimen of cement columns were cured for 7, 14 and 28 days, after which they were submitted to Rowe Cell consolidation test. The researcher concludes that the increase diameter of the cement column Lead to a decrease the both of compressibility index Cc and Ca. Kazemian and Huat (2009) studied the influence of cement columns' composition on the compressibility parameters of fibrous organic soil strengthened with cylinder cement columns. To prepare organic soil reinforced with cement, a single PVC tube was placed at center of soil samples. The tube was used to inspect the compressibility parameters, and for removing some amount of the organic soil from the cell and change it with dry (OPC) mixed with various quantities of organic soil, the cement-organic soil ratios tested being 10%, 20%, 30%, and 50% by the air dry weight of the organic soil base on BS 1377-1(7.3.4)) . The cement column's diameter was 45 mm. The area ratio of the column to sample was 0.09, then curing the specimens for 28 days in with natural water. The result indicates that increasing the cement proportion led to reduce the values of settlement and the compressibility of organic soil. And also appear the negative effect of the groundwater in the organic land on compressibility parameters of strengthened fibrous organic soil, in comparison of specimen curing in pure water.

2.4.2 Improvement of organic soil used the waste materials

The use of waste materials to improve or stabilize organic and/or peat soils has two advantages; (i) the environmental and economic benefit of materials disposal with negative environmental impact, and (ii) the engineering benefit of stabilizing or improving soil properties with geotechnical problems. Khalid and Mukri (2013) investigate the effect of using the waste paper sludge ash (WPSA) as a stabilizer material on fibrous strength of organic soil. The organic soil was mixed at five various proportions WPSA at 2%, 4%, 6%, 8% and 10% of dry weight of the sample for determining the optimum concentration of (WPSA) to stabilize organic soil at the maximum strength of compressive strength. This study indicates that the waste paper sludge ash (WPSA) have ability for organic soil stabilizing and giving an efficient result to enhance the organic soil strength for a long durations. Kolay and Taib (2011) research about the possibility of using the class F pond ash (PA) from a coal-fired which is obtained from the thermal power station in organic soils stabilization in organic soils stabilization. The researchers explored the effect of the different amount (i.e., 5, 10, 15 and 20%) of PA on the compaction and unconfined compressive strength (UCS) properties of organic soil. The results showed that with the increase in PA content, the (γ_{drymax}) of organic soil increases, while the (w_{opt}) decreases. The UCS values of the organic soils increase significantly with the increasing PA content and with curing periods. The results in the compressive strength of organic soils indicate that the PA has a potential to be used as a stabilizer for organic soil. Besides, the use of PA in soil stabilization helps in reduce the pond volume and achieve environment-friendly as well as sustainable development of natural resources. Rahgozar and Saberian (2016) doing an experimental investigations of influence of use shredded tire chips on stability and bearing capacity of the organic soils. Organic soil specimens from the Chaghakhor Wetland (Chaharmahal and Bakhtiari Province, Iran) were mixed with sand at a constant proportion (400 kg / m^3) and various ratios (0%, 5%, 10%, 15% and 20% by weight) of shredded tire chips. Each of (UCS), (c′), (Φ) were measured to all of these mixtures. The result appeared the add shredded tire chips significant improve the geotechnical properties of organic soil. Mixture with 10% shredded tire chips displayed the highest (UCS); the one with 15% tire chips showed the highest ductility; and adding 20% shredded tire chips gave the highest amount for the (Φ), (c').

CHAPTER 3

MATERIAL AND EXPERIMENTAL METHODOLOGY

3.1 Introduction

In the beginning, plan for experimental works was presenting to determining all the tests conducting for organic soil and organic soil-CWCs mixtures. Both of the soil and waste concrete samples have been prepared by the standards of American Society of Testing and Materials (ASTM). And we will get the engineering classification and characterization of the organic soil used in experiment research. This includes Compaction test, Atterberg limits, unconfined test, Swelling test, collapse test, organic content, specific gravity, particle size distribution, fiber content, water content, soil acidity of the organic soil. The experimental procedure was planned and counts on the test of soil sampled from Sakarya region, and waste concrete from Gaziantep region, Turkey. The former parts followed by characterization of the testing device and investigational procedures for each test. Instrumentation setup and the calibration also a clarification. All the experimenting supported out untreated soil the stabilized soil with various selected ratios that mentioned in Table 3.1

Table 3.1 Soil- mixture ratios that have been tested during the experimental study.

Materials	Mixing ratios (% by dry weight)					
CWCs	0	10	20	30	40	50

3.2 Materials of experimental Work

In this part, the specifications and properties of untreated soil and additives were studied and analyzed

3.2.1 Organic soil

Soil using to treat in study was collected from Sakarya -Turkey. Its color dark brown as shown in Figure 3.1. Table 3.2 appearing some engineering specifications gaining during research laboratory experiments accomplished on soil. Atterberg limit test was done by ASTM D4318-2000 standards to calculating (LL), (PL), and (PI).Soil classified as ASTM D2487-2000 as ML.The modified compaction test was accomplished to calculate w_{opt} and γ_{drymax} by ASTM D1557-98-2000.

Table 3.2 Some engineering propertied of the untreated soil

Untreated soil specifications	Results
(LL) %	68
(PL) %	45
(PI) %	23
Classification (USCS)	ML
Classification (AASHTO)	A-1-a
(γ_{dmax}) g/cm^3	11
w_{opt} %	30

Table 3.3 Chemical composition of untreated soil (in weight %)

Element	C	O	Na	Mg	Al	Si	S	K	Ca	Ti	Mn	Fe
Row soil	14.0	51.5	0.2	1.14	9.06	19.1	0.3	1.1	0.4	0.28	0.03	2.5

Figure 3.1 Soil used during experiment

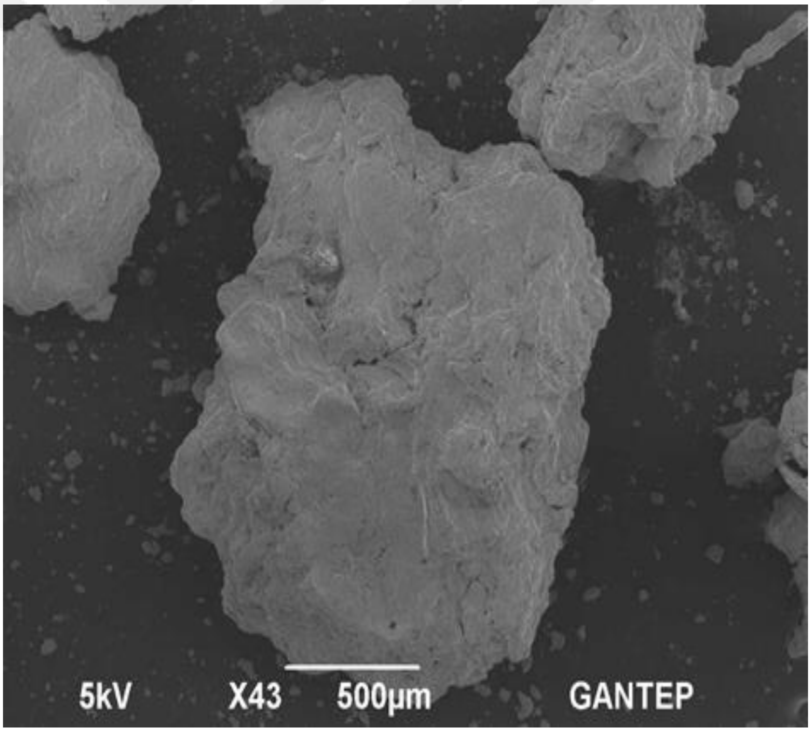

Figure 3.2 SEM picture of the soil.

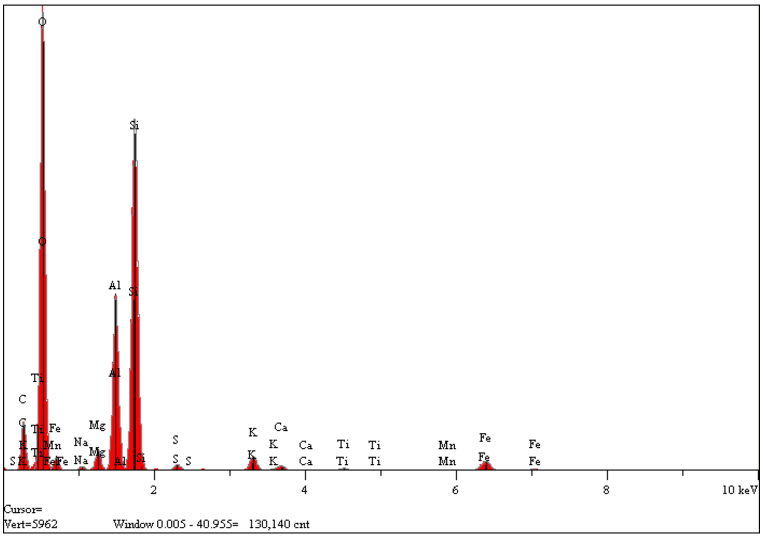

Figure 3.3 EDX analysis of the organic soil.

3.2.2 Solid waste materials (solid waste concrete)

The crushed waste concrete was used as additive materials, it was as crushed concrete paving slab and the Crushed concrete aggregates achieved from pavement of slabs are used in city. CWC with a size of less than 19 mm were unnaturally chosen for supplying uniform specimen for visional classification purpose these materials obtainable from municipal of Gaziantep City-Turkey as shown in Figure 3.5

Figure 3.4 Solid waste concrete in gaziantep

Table 3.4 Chemical composition of the crash of waste concrete (by dry weight %)

Elements	C	O	Na	Mg	Al	Si	K	Ca	Mn	Fe
CWC	12.93	54.16	0.16	0.46	1.40	2.42	0.22	27.45	0.06	0.70

Figure 3.5 Crushed of waste concrete used during the experiment (CWC).

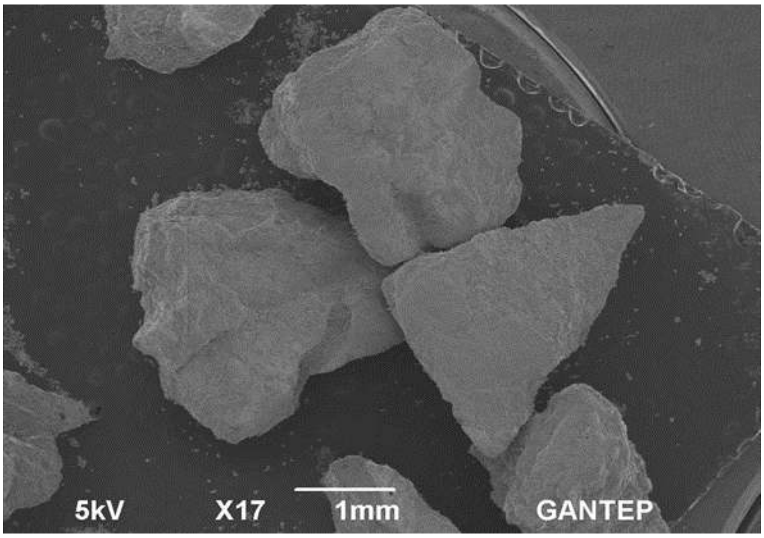

Figure 3.6 SEM Picture of the Crushed Waste Concrete (CWC).

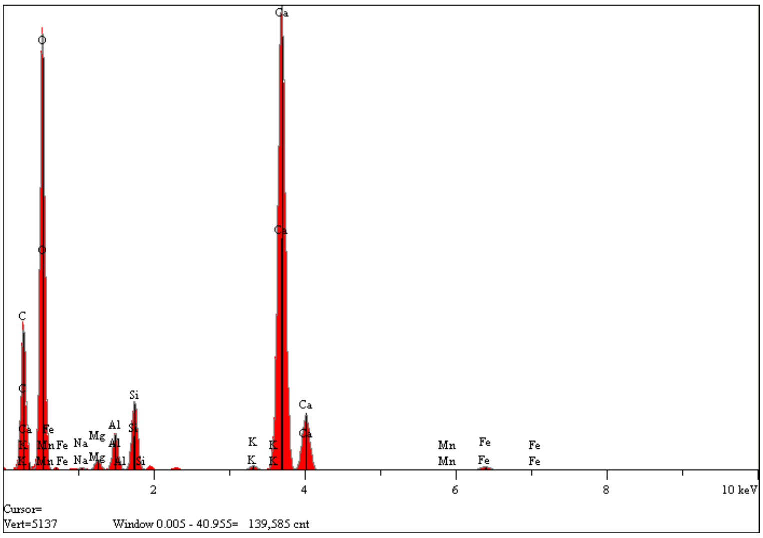

Figure 3.7 EDX analysis of crushed waste concrete (CWC).

3.3 Experimental methodology

All the organic soil used in the laboratory tests was oven dried at 60 c and then mixed with clean, dry, crushed waste concrete. The selected contents of the CWC were, 10%, 20%, 20%, 30%, 40% and 50% by dry weight of complete samples. Mixtures of organic soil and CWC were prepared in room conditions. CWC came in the big plastic bags. Then were clean, dried, and crushed until all materials passed through a 4.75mm (sieve no.4) and 0.425 mm (sieve no.40) according to (ASTM D2166) recommendations. This process was done to make the CWC suitable for all tests.

3.3.1 Geotechnical specifications of the organic Soil

3.3.1.1 Characterization of organic soil

The moment that the soils acquired, essential began process of material characterizing. Classification, estimation of index properties providing initiate point from which to initiate understand soil behavior. Characteristics analysis give a framing from which other soil from available literature or future soil specimen compare.

3.3.1.1.1 Water content

To calculate the moisture content for the tested soil. The requirement of British Standard (BS1377, Test 1(A)) the temperature of drying must be equal to 60Cº for peats, soils containing organic materials for avoiding the organic content oxidation. So because of that, this test was done according to B.S. Standard, The mass soil change of the sample measuring after the duration of drying, under a temperature of 60 Cº. The specified of the natural water content was 92%.

3.3.1.1.2 Organic content

This test done on organic soil. For calculating (OC), to this soil, determination used ignition technique in a muffle furnace (Figure 3.1) at 440o C until four hours, according to ASTM D2974-14. In test, oven dried soil sample kept till temperature of 440º C to limit that specimens mass did not appear any variation at further heating. Residual “ash” mineral contents of soil, with wasted mass constituting the organic matter (Figure 3.2). Organic contents can defined as proportion of original oven-dried mass. An organic contents calculation in this test was 20%.

Figure 3.8 Muffle furnace with organic soil sample

Figure 3.9 Organic soil samples (1) before oven (2) after oven.

3.2.1.1.3 Specific gravity

According to the ASTM D854, the laboratory experiments done on the tested soil (an organic soil) for getting a delicate value to the specific gravity. The test was done using distilled water. During test, the heat was applied to get rid of the entrapped air in the soil. In draining operation, slurry was frequently rapturous for making sure small air bubble able to proceed up and soil would not baton to glass. Average Gs values of organic soil 2.24.

3.2.1.1.4 Atterberg limits test

According to The BS1377 calculate the Atterberg limits to organic soil was done by using fall cone test (Figure 3.10) to identify a LL, and determinate the PL was done according to ASTM D4318 to. The Atterberg Limits give an adequate method for classifying and characterize the fine-grained soils. (PL) defined as the moisture content when the soil transmissions from plastic case to a semi-solid case. (LL) is represented the moisture content when the soil transmissions from a liquid case to plastic case. The variance between (LL) and (PL) named plasticity index (PI). According to test results the (LL) and (PL) range was 68% and 45% respectively. So that (PI) will be 23%. The various penetration values have been strategized alongside the water contents. The most acceptant way for measuring the (LL), is to be considered as water content at 20mm cone penetration. Su were then calculating by equation (3.1)

$$s_u = k\frac{mg}{d^2} \tag{3.1}$$

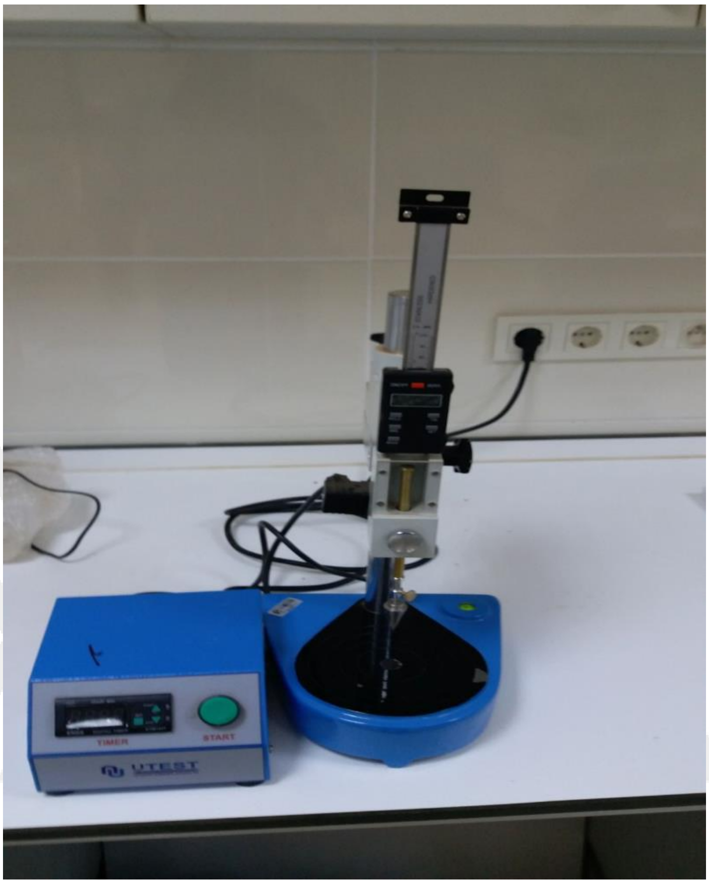

Figure 3.10 Fall cone test used during the experimental work

3.2.1.1.5 Compaction test

The compaction test can be defined as the technique of a re-arranging the soil particles by the decreasing the internal air voids by the impacting external energy. The modified proctor test was carried out on the all formerly mentioned ratios following ASTM D1557-2000 standards, as shown in (Figure 3.11). Dry soil and the dry soil with the admixture was first mixed in a suitable pan, the weight of soil and soil mix with the compaction mold and its base were weighted with an electronic balance. Then water was added to dry soil and dry mix (soil with crash west concrete) progressively with an interval of 10%, 20%, 30%, 40%, 50% respectively by dry weight of soil and dry mix and mix closely till the mix regularly became in color and textures. The mix of (natural soil with water and soil with crash concrete with water) placed in compaction mold as five same layers, and compacted each layer with 31 blows by A specially designed Procter hammer; as described by (Cabalar et al., 2014). The rate not exceeding 1.5 seconds per blow, to ensure that during the impact, the hammer covered all the surfaces, also, was ensured that the last layer thickness it should be on the top of the mold and extends through the collar. When finishing the compaction work of the five layers, the collar must be carefully separated from the mold and the extended layer cut off using a spatula. The weight of the remaining soil inside the mold has been recorded. For measuring the (wc), part of the specimen from top, middle, and bottom of compacted sample was put in the oven containers to be dried under at temperature of 60 for 48 hours. The dry density can be calculated by equation (3.2)

$$\gamma_d = \frac{\gamma_m}{1 + \left(\frac{w_c}{100}\right)} \tag{3.2}$$

Where;

γ_d is the dry density (gm/cm^3);
γ_m is the moist density (gm/cm^3); and
w_c is the water content (%).

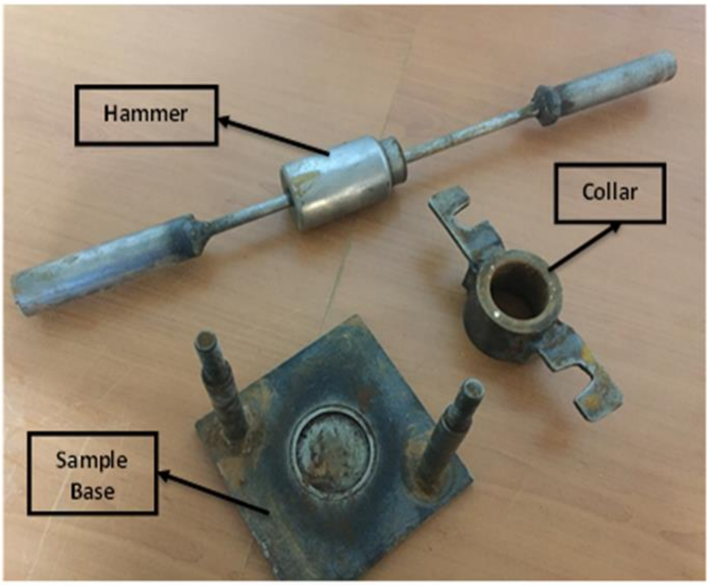

Figure 3.11 Compaction equipment was used during the experimental study

3.2.1.1.6 Unconfined compressive strength test (UCS)

Preparation of specimen to unconfined compressive strength test was identical to ASTM D2166-2000 by the same procedure of compaction test, the quantity of water used adopted the w_{opt} found from compaction test for each specimen. A cylindrical sample of 50 mm diameter and 100 mm height then compacted to all five layers, removed from the mold, and then placed into the standard unconfined compressive device as shown in (Figure 3.12). The load applied axially and the rate of axial strain equal to 0.5-2% per minute. Both gages have been set on the zero reading, after that, the machine of compression has been turned on, and readings started taken at a deformation interval of 0.20 mm. When the sample reached the maximum deformation point, the test device stopped. The unconfined compressive strength for each specimen was then plotted against the stain which calculated by equation (3.3).

$$\varepsilon = \frac{\Delta l}{l_{\circ}} \tag{3.3}$$

Where;

ε The axial strain;

Δl the deformation in length (mm); and

$L_{\circ}$ the initial length of sample (mm).

The unconfined compressive strength has been calculated by the formula (3.4)

$$q_u = \frac{p}{A} \tag{3.4}$$

Where;

q_u the unconfined compressive strength (kpa);

p the axial load (KN); and

A the cross-sectional area of the specimen which can be calculated by formula (3.5)

$$A = \frac{A_o}{1 - \varepsilon} \quad (3.5)$$

Where A_o is the initial area of the sample before deformation (mm^2).

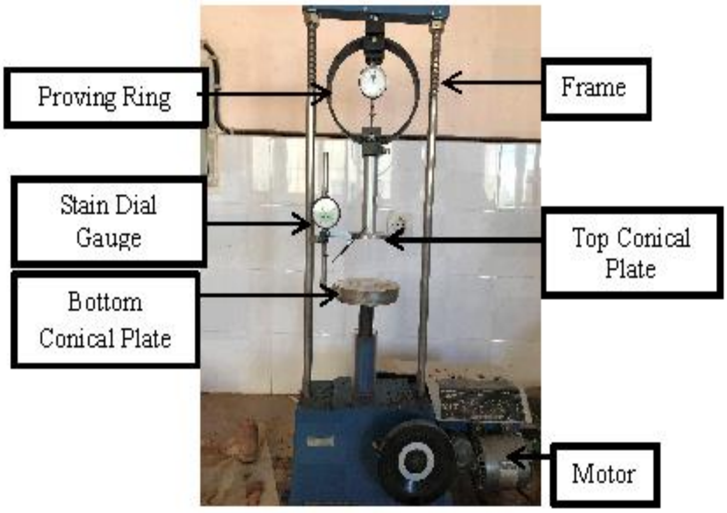

Figure 3.12 Unconfined compressive strength device.

3.2.1.1.8 Free swelling test and apparatus

Free swell test was carried out according to the ASTM D4546-14 methods and instruction. Swelling pressure test was performed by using the ELE consolidometer apparatus as shown in Figure 3.7. Swell tests were conducted in specimens by diameter is 75mm, and the thickness is 20mm. The organic soil and CWCs were sieved through a no. 10 (2mm) sieve, as shown in Figure 3.8. The samples were prepared on maximum values of dry densities and (w_{opt}) obtained from the compaction curves of organic soil and organic soil-crash of waste concrete mixtures. The compressed samples were placed in the ring of odometer statically by a steady rate equal to (0.02mm/sec or 0.05inch/min). The compaction of the specimens was done by using the CBR testing machine as shown in (Figure 3.9). Swell percentage (S%) and pressure of the swelling (Pmax) were determined for organic soil and organic soil –CWC mixtures. Swelling pressure is defined as the highest values of pressure, Pmax that was applied to the sample for preventing the deformation in the upward vertical position when the sample is saturated with water and supported by side restraints. 1kPa (20lb/ft2) was applied as

A seating pressure for each unsaturated sample, and the dial gauge was fixed on zero or other definite preliminary reading. And the seating pressure included both of the mass of the top porous stone and load plate. The specimen was situated in the midst of the two porous stones on its top and bottom surfaces and confined in a ring to avoid the lateral side deformation. The piston of the cell was in contact with the loading arm, whose displacement can be carefully measured with a dial gauge. The piston was also connected to the upper porous stone. After a recording of the initial reading of the dial gauge and finishing of immersing the sample in drinkable water. When the swelling in the sample is occurring because of its absorption of water weight was added to the loading ram, until the dial gage returned to the initial reading. The maximum allowable soil strain was ±0.02mm. Using the same previous steps; the swelling pressure was getting by the load applied for a corresponding time. The maximum swelling pressure (Pmax) was gained when the reading of the pointer did not change for 24h. The swelling percentage which can be defined as the maximum swelling percentage (S%), the ratio of the sample height after the free swell, and it's measured when the sample is saturated, to the initial sample height as shown in equation (3.6).

$$(S\,\%) = 100 * \Delta H / H0 \tag{3.6}$$

where ΔH represents the difference between the initial dial gauge reading before adding water, and the final dial gauge reading (after 24h), and H0 is the initial sample height at a seating pressure of 1kPa before water was added.

Figure 3.13 Pictures of organic soil and CWC size used in odometer test

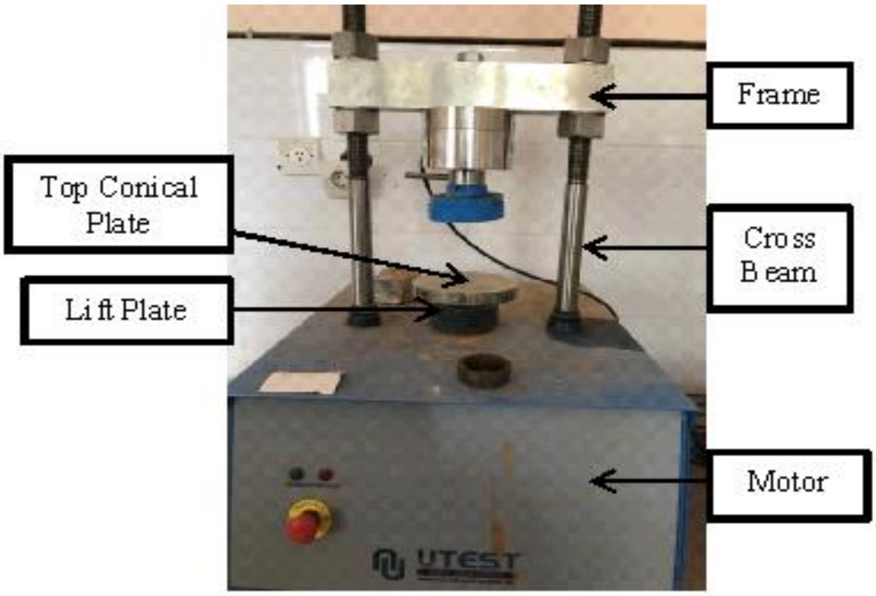

Figure 3.14 CBR devices for compaction the specimen of the consolidation, free swelling test, and collapse test during the experimental study

Figure 3.15 ELE consolidometer apparatus test device used during the test

3.2.1.1.9 Consolidation test and apparatus

The compressed samples were placed in the ring of odometer statically by a steady rate equal to (0.02mm/sec or 0.05inch/min). CBR testing machine did the compaction of the Specimen. The experiments were carried out in specimens by diameter is 75mm, and the thickness is 20mm. Both an organic soil and crash waste concrete were sieved on a no.10 (2mm) sieve, as shown in Figure 3.8. The specimens were prepared on the (γ_{drymax}) and (w_{opt}) contents attained from the compaction curves of organic soil and organic soil-crash of waste concrete mixtures. The experiments were carried out by use of an ELE consolidometer device and consisted of two stages. The first stage was done for identifying the consolidation parameters according to ASTM D 2435-2011a. The premiere reading was then taken. The first load applied on the samples was 25 kPa. The last reading was obtained when the reading of the pointer stopped changing. The loading was then doubled for each step gradually till the access a maximum loading of 800kPa. For each loading stage, the duration was determined according to when the reading on the dial gage stopped or after 24h of reading. Calculated of the Compressibility index, Cc was at this stage using Equation (3.7)

$$Cc = \frac{\Delta e}{\Delta log p} \qquad (3.7)$$

Each of hydraulic conductivity values of the 400 kN/m2 and 800 kN/m2 loads were estimated following Terzaghi's one-dimensional consolidation principle using equation (3.8)

$$k = C_{v}.\ Mv.\ \gamma_{w} \qquad (3.8)$$

$$M_{v} = \frac{a_{v}}{1+e_{o}} \qquad a_{v} = \frac{\Delta e}{\Delta p}$$

Where,

K represented hydraulic conductivity (in cm/s). And the Cv is the consolidation coefficient (in cm^2/s) specified by the method of Taylor (square root of time). The coefficient mv represented the change in volume and measured by (in cm2/gm), and γw unit weight of water measured by (in gm/cm^3). Principles of calculation of the k value are Known and acceptable (Sivapullaiah et al., 2000, Watabe et al., 2011). The Unloading part represents the beginning of the second stage, which is considered the inverse of the loading stage. It was done by recording the last reading of the last load, which is then considered the initial reading; take off the load and recording the final reading. In this stage, swelling index Cs was calculated in the rebound part of e-log p curve according to equation (3.9)

$$C_s = \frac{\Delta e}{\Delta \log p} \tag{3.9}$$

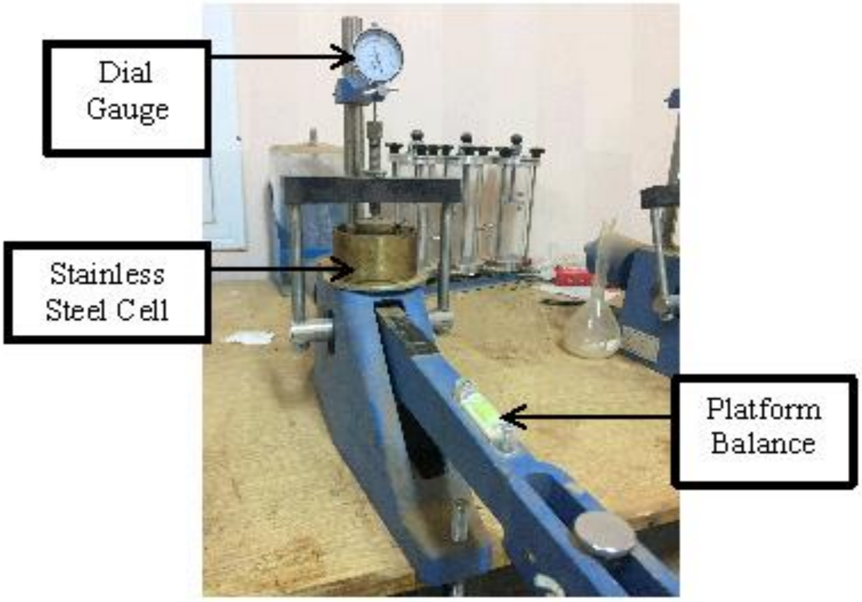

Figure 3.16 Consolidometer apparatus used during the experimental study

3.2.1.1.10 Collapse test and apparatus

The compressed samples were placed in the ring of odometer statically by a steady rate equal to (0.02mm/sec or 0.05inch/min). CBR testing machine did the compaction of the Specimen. The experiments were carried out in specimens by diameter is 75mm, and the thickness is 20mm. Both an organic soil and crash waste concrete were sieved on a no.10 (2mm) sieve, as shown in (Figure 3.12). The samples were prepared on the maximum values dry densities, (w_{opt}) obtained from compactions curves of organic soil and organic soil-crash of waste concrete mixtures. The tests were carried out by use of an ELE consolidometer device. ASTM D5333-92 is based on the method proposed by the American Society for Testing and Materials (ASTM D5333-92). An undisturbed sample is placed in the consolidometer cell after adjusting the surface of the model and measuring its usual moisture content and using air dry porous stone. The filter paper is located among the model and porous stone. The consolidometer cell is encased in Aluminum Foil and placed inside a nylon bag to prevent changing the moisture content of the model due to evaporation as shown in (Figure 3.13). The cell is then placed in the consolidometer device. 1kPa (20lb/ft2) was applied as A seating pressure for each unsaturated sample. To ensure full contact between the model and porous stone and then doubled the stresses every hour, and the dial gauge was fixed on zero or other definite preliminary reading. The readings are noted at the end of each stress and when the stress is reached (200 kPa). An hour later the reading is recorded, and distilled water is added to model from the bottom of the model only to ensure the elimination of the air bubbles. The readings are recorded up to 1440 minutes or according to the D2435 method after adding water. The loads are doubled every 24 hours, or when the landing stops, then the collapse index can calculate by the below equation

$$\mathrm{IC} = \frac{\Delta e}{1 \pm e0} 100 \tag{3.10}$$

Where;

IC: collapse index

e_o : Initial Void Ratio

Figure 3.17 Sample before test with covering to prevent humidity

CHAPTER 4

EXPERIMENT RESULT AND DISCUSSION

4.1 Introduction

This study deals with effects of CWC on the several problems of the organic soil like high compressibility, consolidation, swelling, and low shear strength. Despite there are many studies about the proper treatment of CWC in geotechnical and pavement applications as aggregates, there are little-known efforts to explore the effects of this material on the organic soil and the possibility of stabilizing the organic soil by this material. This chapter will deal with the analysis and discussion of all the data obtained from the experimental working at the laboratory.

4.2 Consistency limit and classification system

This test was done to identify and calculate the liquid limit (LL), plastic limit (PL) and the plasticity index (PI) of the untreated and treated soil specimens. Table 4.1, as well as Figures 4.1, shows the alteration in the Atterberg limits of the untrated soil and the stabilized soil mixtures. The L.L and PL were decreasing with the increasing of the ratio of CWC which has been added. The raw soil has a LL and PL of 68% and 45%, respectively. While at the % 30 CWC admixtures, the LL and the PL are 59 and 38, respectively Figure 4.1 shows the decreasing in the plasticity index with increasing of the CWC ratio.

The values of the plasticity limit slightly decreased with the increasing of CWC. The result of the change in the liquidity limit and plasticity limit values led to a significant decreasing values of the organic soil plasticity index. One suitable explanation for the decreasing of plasticity limits, when adding CWC to the organic soil is the physical compensation of a ratio of organic soil (by weight) with plasticity properties with non-

Plastic materials of a similar nature to sand or gravel.. Because of the gradual reducing in (LL) and (PI) of organic soil-CWC mixtures, the geotechnical classification of organic soil as OH (organic silt soil with high plasticity), changes at 50% CWC addition to the OL (organic silt soil with Low plasticity), as shown in Table 4.1. According to the Unified Soil Classification System (USCS) present soil is classified as an organic silt soil with high plasticity (OH). And According to Von Post Classification, the organic soil is classified as a three-dimensional decomposition of the von Post

Table 4.1 Effect the added of CWC on the consistency limits

Geotechnical properties		CWC%				
	Organic soil	10	20	30	40	50
Liquid limit (%)	68.0	63.0	61.5	59.0	53.0	48.0
Plastic limit (%)	45.0	41.0	40.0	38.0	37.5	38.5
Plasticity index (%)	23.0	22.0	21.5	21.0	15.5	9.5
Classification USCS	OH	OH	OH	OH	OH	OL

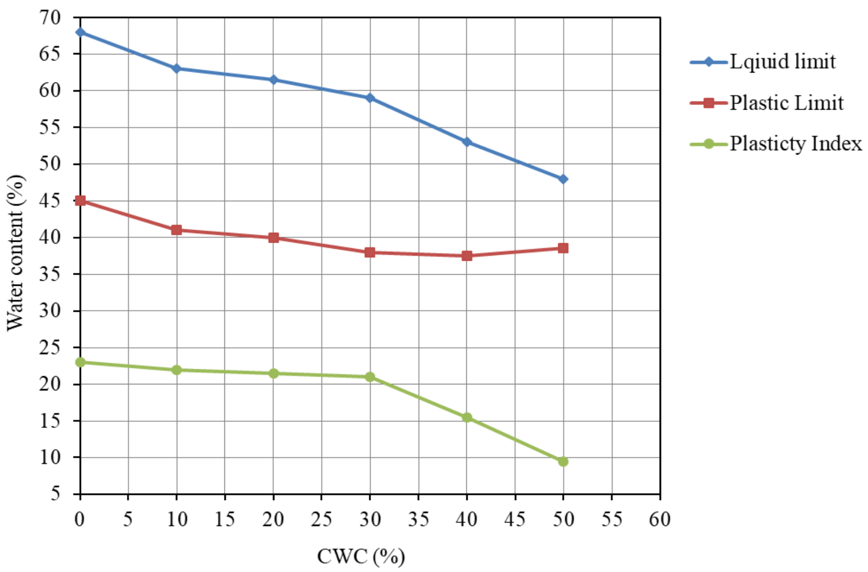

Figure 4.1 Relationships between consistency limits and crushed waste concrete content

4.3 Compaction characteristics

The test was done to investigate the variation in (w_{opt}) and the dry density after and before they added the CWC to soil as stabilizer material. Figure 4.2 shows the compaction behavior of soil with a deferent percentage of crushed waste concrete admixtures. It can be seen from Figure 4.3 that the optimum moisture content of the CWC-soil mixtures decreased from 30% for the zero additives to 22% for the %20 CWC and 16% for the %50 CWC. The adding of CWC does not have much effect on the optimum moisture content and the dry density, the results were very close to that of the untreated soil. The decreasing of the optimum moisture content because the CWC is a heavy, non-plastic material, The CWC has a rough surface and its ability to absorb the water less than the organic soil, Therefore, the (w_{opt}) decreased. Figure 4.4 showed that the (γ_{drymax}) increased gradually by adding the CWC in different amounts from 0% to 50%. This happened because of this CWC decreases the need for water, the amount of absorbed water obstructed the (Boobathiraja et al ;(2014)). This happened because of this CWC decreases the need for water, the amount of absorbed water obstructed the soil particles to close to each other. And therefore the density increased as it can be seen in Figures 4.2 to 4.4.

Table 4.2 Effect of the added of CWC on the compaction characterization

Geotechnical properties	CWC%					
	Organic soil	10	20	30	40	50
γ_{drymax} (kN/m³)	11.0	11.8	12.5	13.3	14	15
w_{op} (%)	30	28	22	17	16.5	16

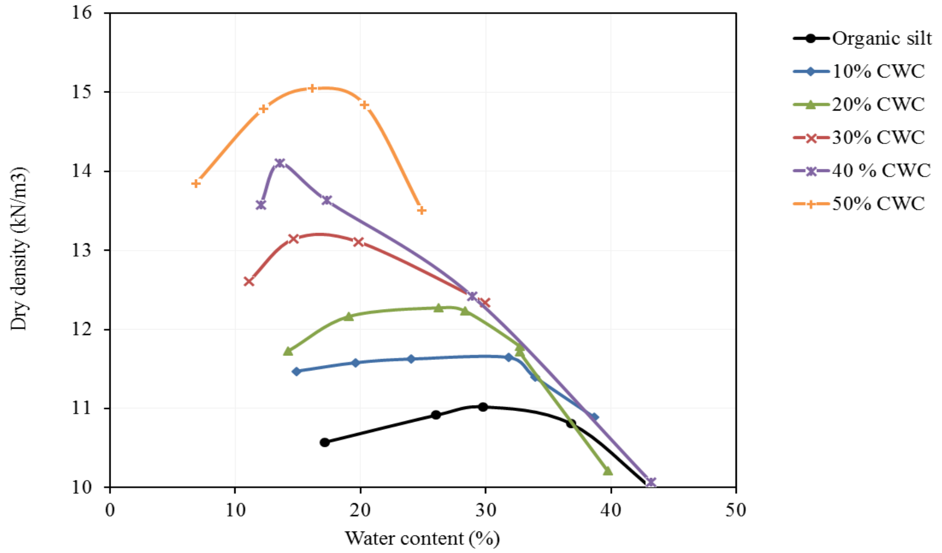

Figure 4.2 Variation of dry unit weight as a function of water content for the organic silt with CWC

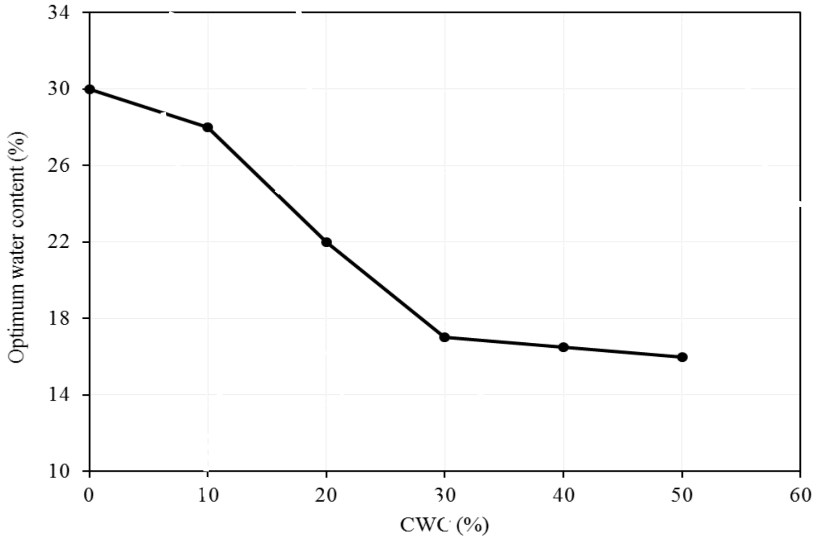

Figure 4.3 Variation of the w_{opt} with the CWC content

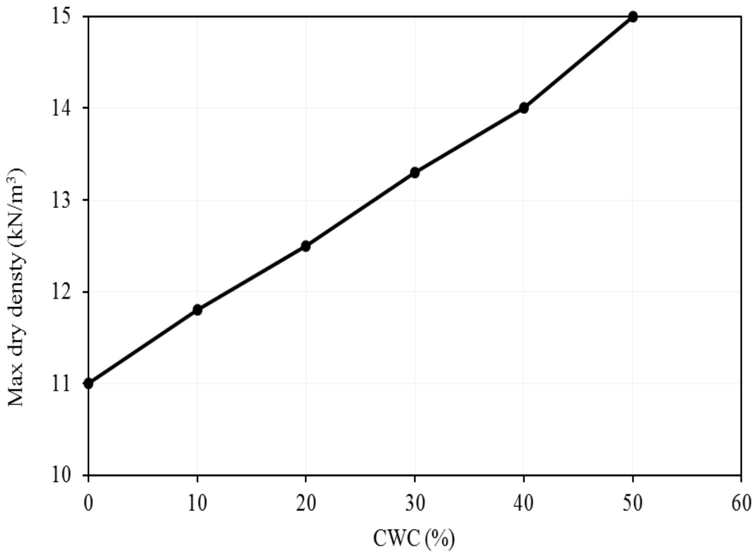

Figure 4.4 Variation of the γ_{drymax} with the CWC content

4.4 Strength characteristics of mixtures

4.4.1 Undrained shear strength

Relationship between undrained shear strength (Su) and water content (w_C) for organic soil and organic soil-CWC mixtures, for comparison, was given in Figure 4.5. The results showed that the (Su) of the natural soil gives the highest value at any specified (w_C). The organic soil-CWC mixtures are primarily controlled by the water content of the mixture, used to calculate the liquid limit by full cone test. The additions of CWC, which are non-plastic materials of a similar nature to non-cohesive materials such as sand, reduce the Su of natural clay with an increase in the proportion of CWC material.

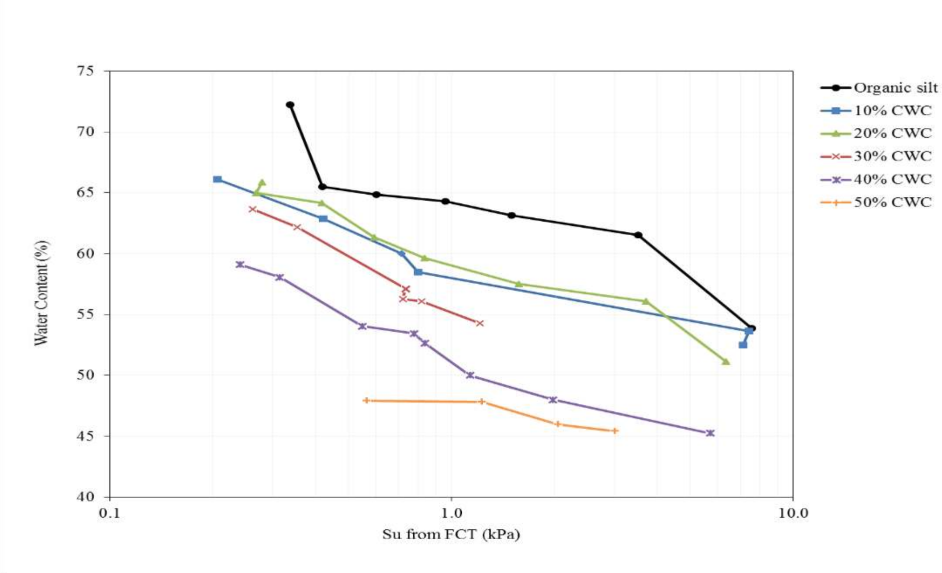

Figure 4.5 Variation of Su as function of WC to the organic soil with CWC

4.4.2 Unconfined compressive strength (UCS) test

The untreated soil, as well as the treated soil specimens with different percentage of CWC, was prepared for testing the (UCS) for the raw soil and mixtures. The test has been performed directly after the specimens are prepared, mixed, and compacted to their w_{opt} and γ_{drymax}. The outcome of the test each of the natural soil and all the mixtures of the soil-CWC test are shown in Figures 4.6. The results refer to the adding of CWC works on increasing the UCS values continuously increased as the amount of CWC increased as found by (Sing et al., (2008); Khalid et al (2013); Rahgozar and Saberian (2016)). As it has been noted, the UCS values of organic soil and organic soil-CWC mixtures were enhanced with similar increasing trends, comparing with UCS values of organic soil only, as shown in Figure 4.7. Figure 4.8 present the relation between the wopt and CWC, the redaction of WC by addition of CWC because replacing some of the clay of organic soil by crushed waste concrete and due to decreasing the absorption of water.

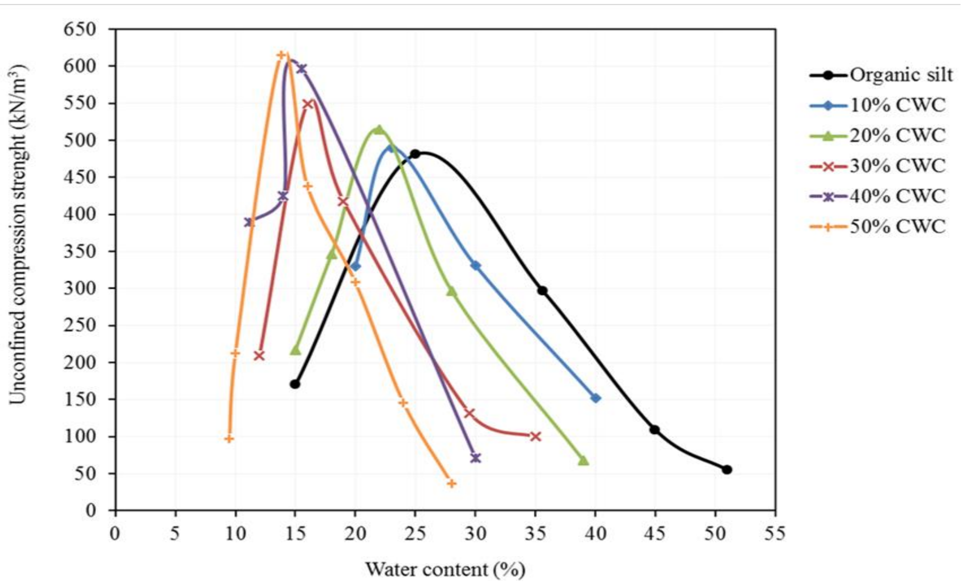

Figure 4.6 Variation of UCS as a function of water content for the organic soil with CWC

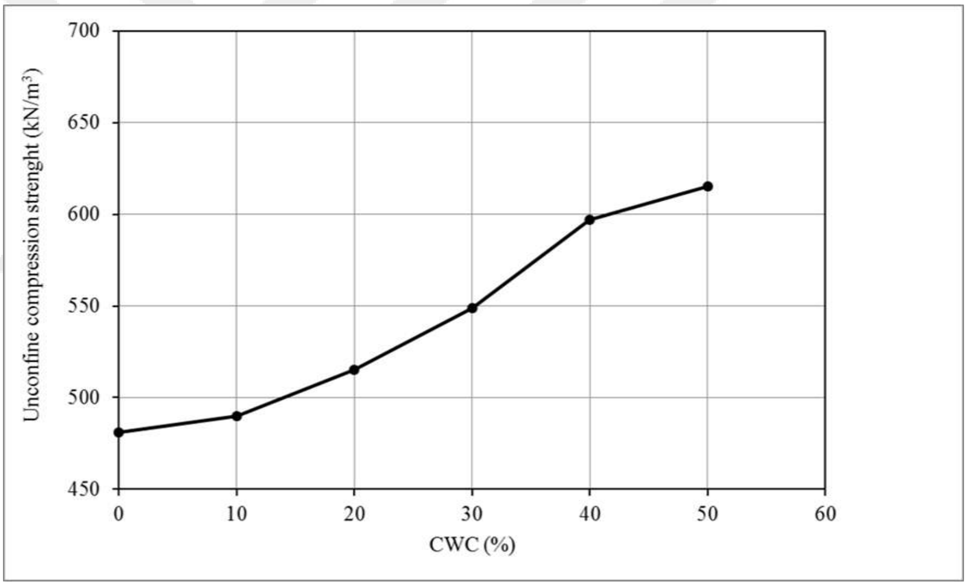

Figure 4.7 UCS Variation with the CWC contents

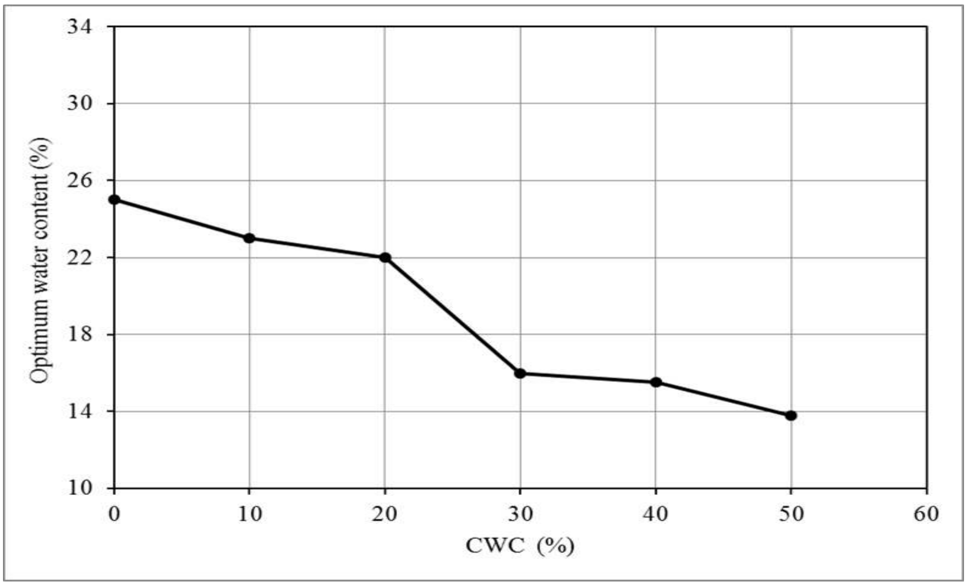

Figure 4.8 Variations of the w_{opt} of UCS test with the CWC content

4.5 Swelling characteristics of mixtures

The free swelling test had been performed for evaluating the swelling percentages for untreated and treated soil calculated at the (γ_{drymax}) and (w_{opt}). This magnitude was obtained by using the oedometer tests. Figure 4.9 shows that the swelling percentages increased when the CWC content increased in the oedometer test up to 30% CWC. This increase was due to the increase in (γ_{drymax}). After that, although the density continues to increase with the increase in the percentage of CWC, the swelling percentages begin to decrease because of the addition of heavy, non-plastic material, which obstructs the swelling process. Figure 4.10 and table 4.3 show the relation between the crushed waste concrete addition and swelling pressure, the increment of CWC led to increase the swelling pressure until 30% because the increasing of the density, then after 30% the swelling pressure began to reduce due to the increasing the CWC percentage which is considered inert and non-swelling materials .

Table 4.3 Effect the added of CWC on the swelling result

Geotechnical properties	CWC%					
	Organic soil	10	20	30	40	50
Maximum dry unit weight (kN/m³)	11.0	11.8	12.5	13.3	14.0	15.0
Optimum moisture content (%)	30	28	22	17	16.5	16
Free swelling percentages (%)	3.35	5.2	12.85	13.2	11.05	8.45
Constant pressure (KN/M^2)	175.0	312.5	375.0	775.0	562.5	350.0

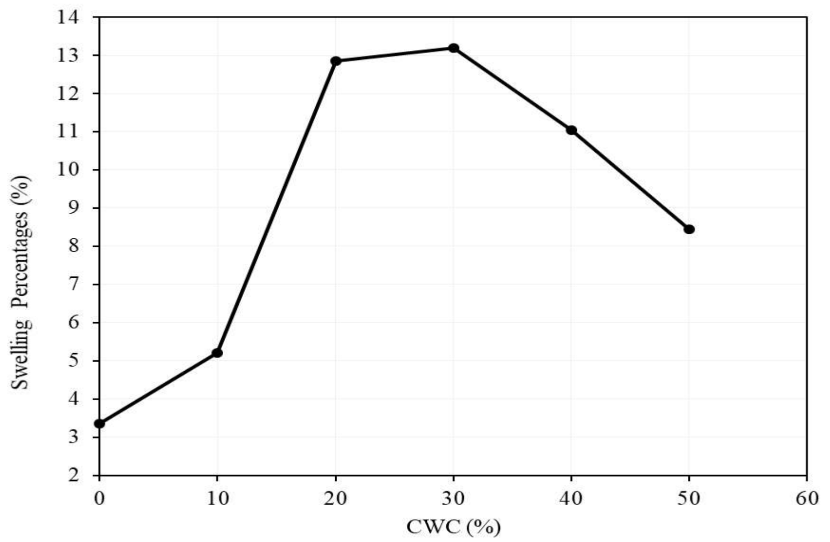

Figure 4.9 Variations of swelling percentages with the CWC contents

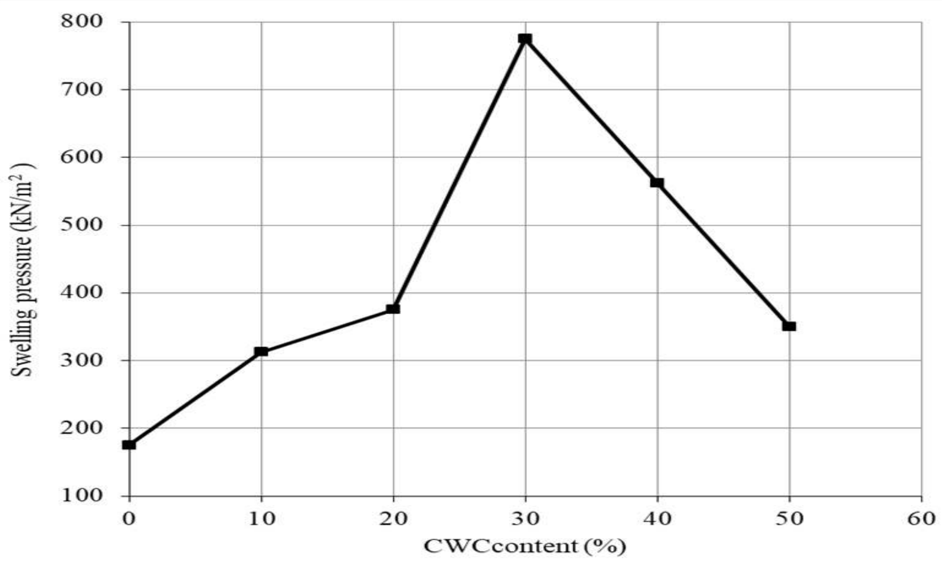

Figure 4.10 Variations of swelling pressure with CWC contents

4.6 Compressibility of organic soil-crushed concrete mixtures

Consolidation, especially the secondary is considered to be one of the main problems with organic soil. Substantial consolidation happens in the organic soil when it becomes saturated and the problem continues with time. The effects of mixing organic soil with crushed waste concrete on the consolidation characteristics were investigated. Figures 4.11 show the compression curves (e-log p) for the remolded soil of organic soil and organic soil -CWC mixtures. Table 4.4 reviews the results of all consolidation parameters, which were determined using a consolidation test, which may determine by the void ratio-log pressure curves. From the general shape of the (e-log p) curves of remolded organic soil -CWC mixtures, some differences from the organic soil curve can be noted. The addition of CWC decreases the (e0-ef), as shown in Figure 4.11 with the decreasing of (e0), as shown in Figure 4.12 which gives less compressible curves. The results may be considered logical as the additive material is incompressible material. The e0 decreasing with increasing of CWC content is a result of the increasing γdrymax values due to the addition of CWC material. The changes in soil structure and the rearrangement of soil particles due to the addition of CWC clearly affected the compressibility of the organic soil. Figures 4.13 and 4.14 respectively show the reduction of compression index (Cc) and swelling index (Cs) by due to increases in CWC for load increments from 100kN/m2 to 200kN/m2. The small increase in the (Cs) values may be explained by the effect of increasing the γdrymax values due to the addition of CWC material. The same behavior was seen for compressibility parameters (Cc and Cs) for load increments between 400kN/m2 and 800kN/m2, as shown in Figures 4.15 and 4.16. This change in consolidation parameters can be considered as an improvement of the consolidation characteristics of clay that leads to reduced settlement for structures built on this type of soil. The improvement is in the amount of consolidation represented by the reduction of Cc and the rate of consolidation represented by Cv. From the data in Figures 4.17, it is apparent that the increase in the coefficient of consolidation (Cv) was highlighted. In this Figure, the relationships between the coefficients of consolidation (Cv) and the variations of CWC for a pressure of 400 kN/m2 are shown. This increase in the coefficient of consolidation (Cv) is due to the change in soil structure and fabric, which has significant effects on the coefficient of conductivity of soil (k). Figure 4.18 illustrates the relationship between the coefficient of conductivity (k) and the variations of CWC for the pressure of 400kN/m2 in the oedometer test. In this Figure, there is a clear trend of (k) increasing with the increases in CWC content this is consistent with what was concluded by (Yulianto and Mochtar (2010); Duraisamy et al (2009)).

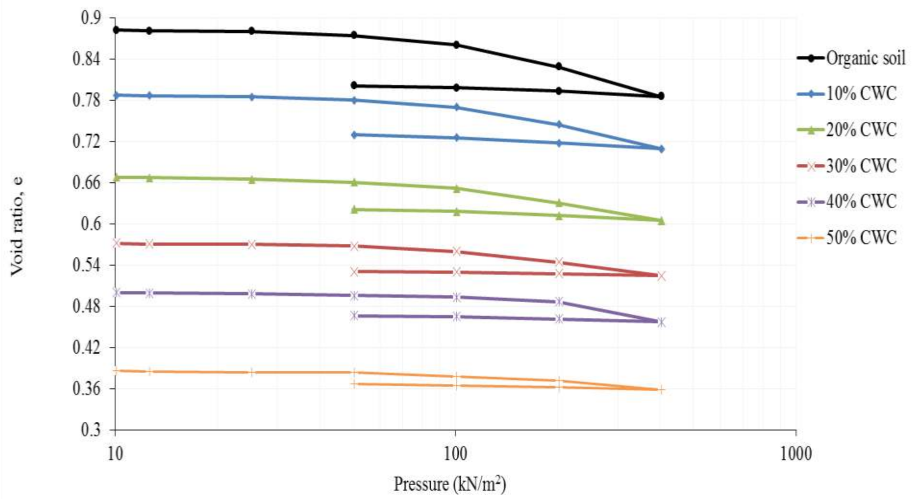

Figure 4.11 Compression curve (e-log p) for organic soil and organic soil− CWC mixtures

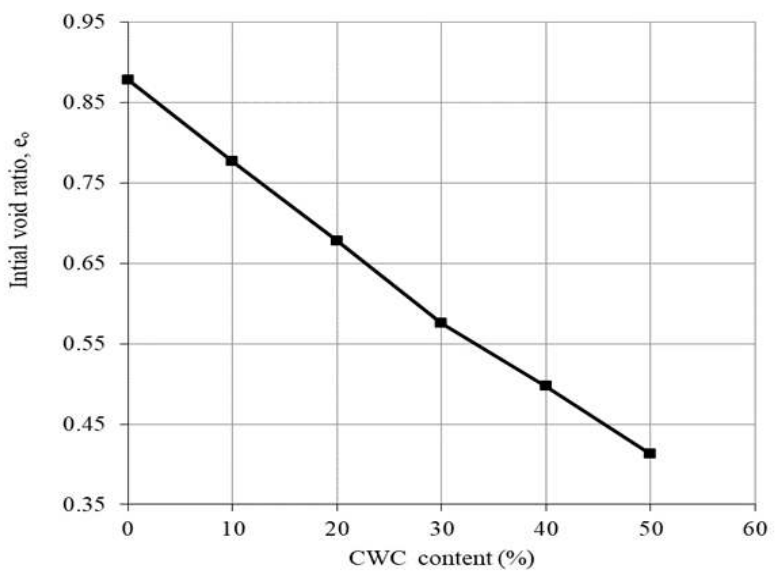

Figure 4.12 Relation between e_o the variation of CWC content

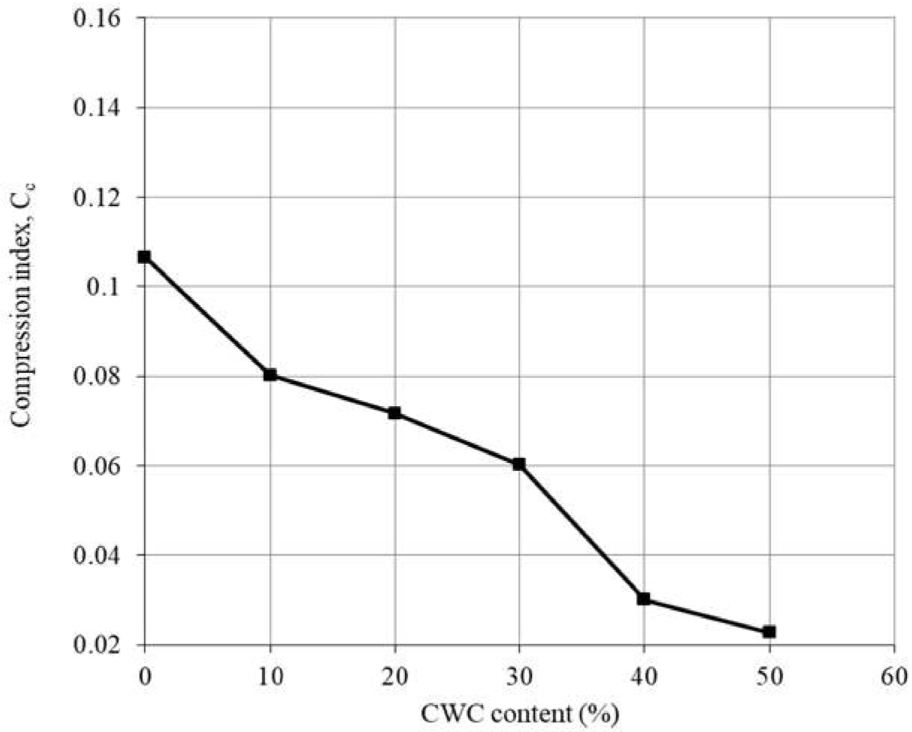

Figure 4.13 Relation between the compression index (C_c) and variation of CWC for pressure increment from 100 to 200 kN/m^2

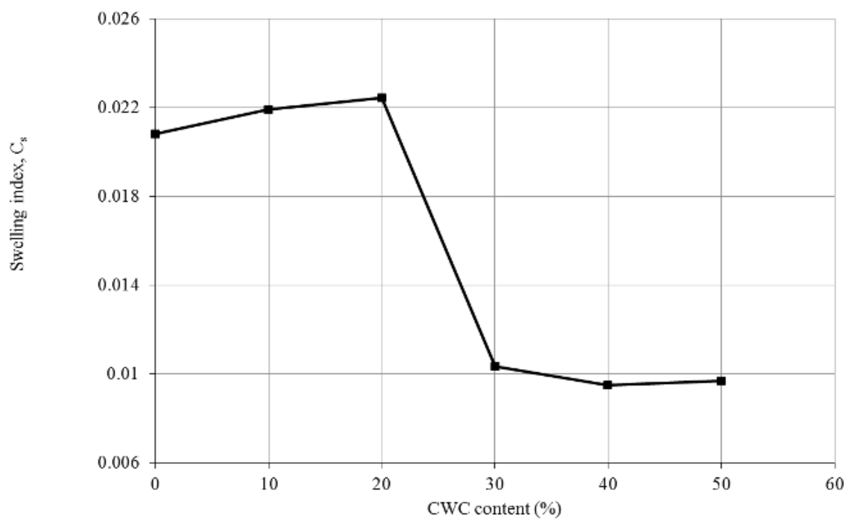

Figure 4.14 Relation between swelling index (Cs) and variation of CWC for pressure increased from 100 to 200 kN/m2

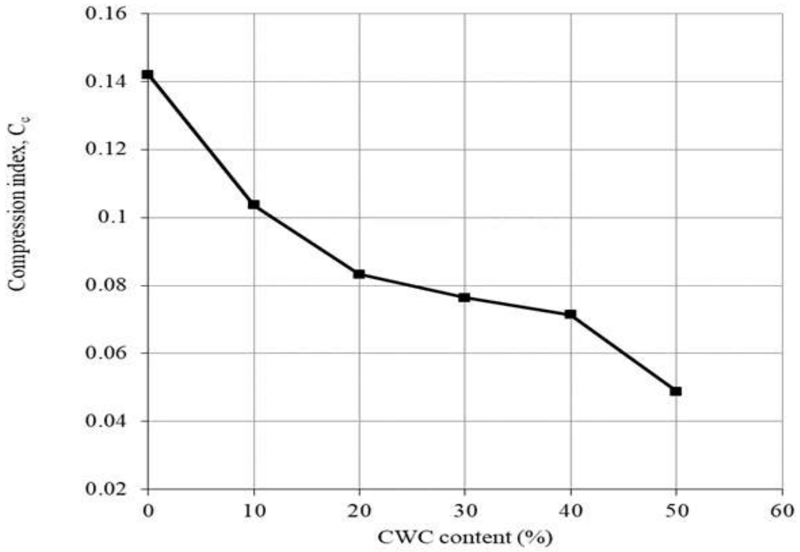

Figure 4.15 Relation between the compression index (Cc) and variation of CWC for pressure increased from 200 to 400 kN/m2

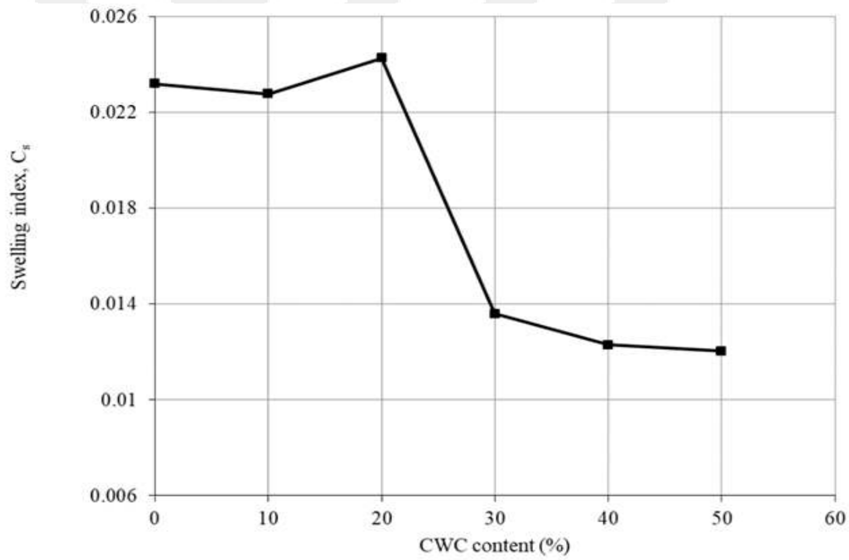

Figure 4.16 Relation between the swelling index (C_s) and variation of CWC for pressure increment from 200 to 400 kN/m^2

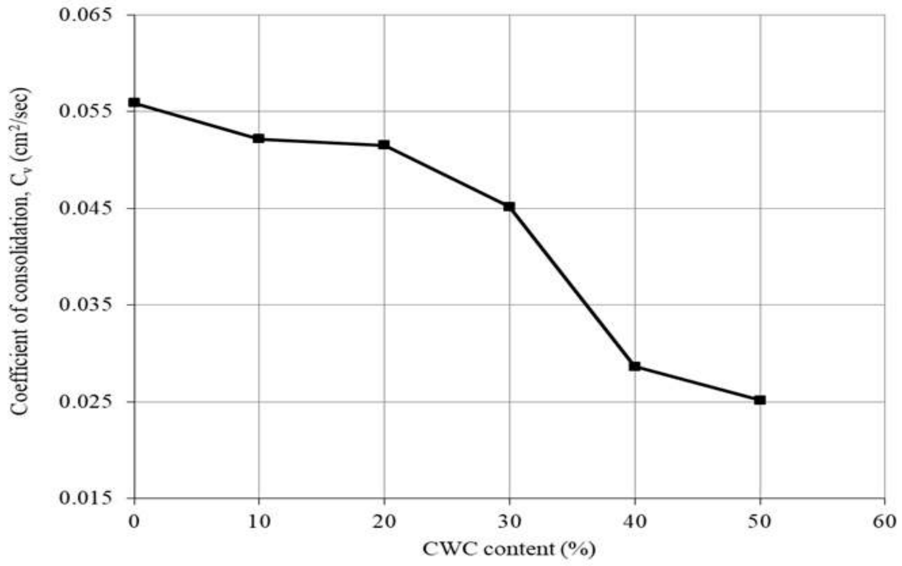

Figure 4.17 Relation between the coefficient of consolidation (C_v) and variation of CWC for pressure 400 kN/m^2

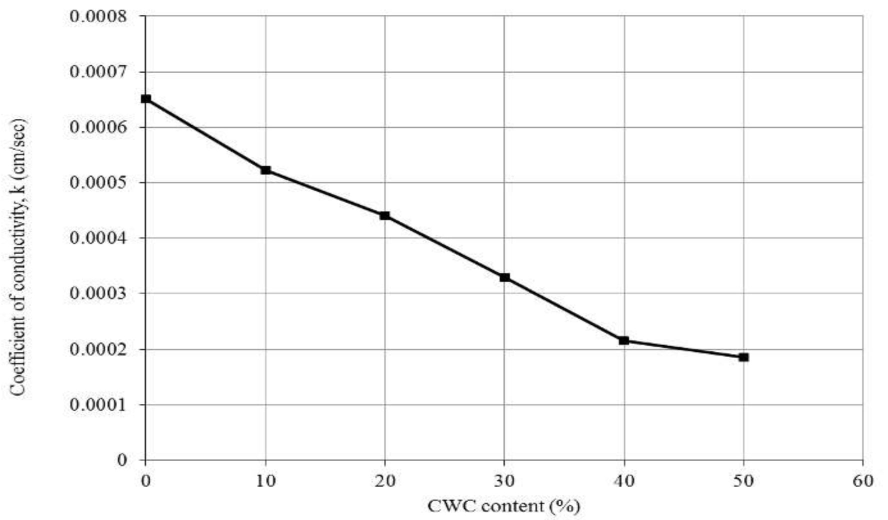

Figure 4.18 Relation between the coefficient of conductivity (k) and the variation of CWC for pressure 400 kN/m^2 in oedometer test

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter explains experimental summary works an attempt to conclude the main disadvantages for recycling the crushed sold waste concrete in soil stabilization method. These methods will give new economical methods in soil stabilization and assist the municipality in the disposal of solid waste resulting from construction work.

5.2 Conclusions

The conclusion are listed below depend on experimental work result:

1. LL had been reduced by increment the CWC ratio. The P.L had been decreased by adding CWC to the soil sample. (PI) slightly decreased by adding CWC because when adding CWC to the organic soil is the physical compensation of the organic soil ratio (by weight) with plasticity properties with non-plastic materials of a similar nature to sand or gravel.
2. The adding of CWC influenced the compaction behavior of the soil by increment (γ_{dmax}) and reduce the (w_{opt}). Because the CWC has a rough surface and its ability to absorb the water less than the organic soil.
3. The UCS increased by adding CWC for the soil sample. As it has been noted, the UCS values of organic soil and organic soil-CWC mixtures were enhanced with similar increasing trends, comparing with UCS values of organic soil only.
4. The fall cone test results of the organic soil treated with different proportions of CWC appeared reducing in LL and Su
5. Swelling percentages increased when the CWC content increased in the odometer test up to 30% CWC because of the addition of heavy, non-plastic material (CWC), which obstructs the swelling process after that, although the density

Continues to increase with the increase CWC proportion, swelling percentages begins to decrease.

6. Generally, increasing the CWC proportions have a favorable influence on consolidation features of organic soil because it is considered as uncompressible additive material.
7. CWC addition decreased the consolidation of organic soil by decreasing the compression index (C_c), this decreasing can be considered as an improvement of the consolidation characteristics of clay that leads to reduced settlement for structures built on this type of soil.
8. Consolidation time for organic soil was lessening due to the increasing each of (C_v) and (k) for an organic-CWC mixture. Because of change in soil structure and fabric, which has significant effects on the coefficient of conductivity of soil (k).

5.3 Recommendations

Investigation of the effects of CWC on soils may be a wide area in current and future geo-environmental research. Several recommendations can be extracted from the conclusion of study to discover the geotechnical properties of the soil-CWC mixture in extra deepness than this study. Thus, more scrupulousness may be considered regarding to the following items:

1. These studies were done using organic soil took from one site (Sakarya, Turkey). The use of the studied CWC with other problematic soils like Bentonite or Gypsum soils is strongly recommended.

2. The current study may be extended using other types of SWM by different percentages or mixtures of these materials.

3. Use other ratios of CWC that have not been used for studying the effects a larger amount on soil mechanical characteristic.

REFERENCES

Anggraini, V. (2006). Shear strength improvement of peat soil due to consolidation Ph.D. thesis, Universiti Teknologi Malaysia.

Anik, D., Boonstra, C., Mak, J. (1996). Handbook of sustainable building.James, London.

Arman, A. (1969). A definition of organic soils, an engineering identification, engineering research bulletin No. 101, Louisiana State University, division of engineering research for Louisiana department of Highways.

Arslan, H., Salgın, B., Coşgun, N. (2012). Construction and demolition waste management in Turkey. Intech open access publisher.

Ayadat, T., Hanna, A. M. (2005). Encapsulated stone columns as a soil improvement technique for collapsible soil. *Proceedings of the Institution of Civil Engineers-Ground Improvement*, **9**, 4, 137-147.

Azam, A.M., Cameron, D.A. (2013). Geotechnical properties of blends of recycled clay masonry and recycled concrete aggregates in unbound pavement construction. *Journal of Materials in Civil Engineering*. **25**, 788-798.

Boobathiraja, S., Balamurugan, P., Dhansheer, M., Adhikari, A. (2014). Study on strength of peat soil stabilized with cement and other pozzolanic materials. *International Journal of Civil Engineering Research*, **5**

Cabalar, A. F., Karabash, Z., Mustafa, W. S. (2014). Stabilizing a clay using tyre buffings and lime. *Road Materials and Pavement Design*, **15**, 4, 872-891.

Caldwell, R.E. (1977). The nature and use of a soil survey. soil and water science fact sheet SL-11. florida cooperative extension service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville.

Chikyala, S. R. (2008). Effects of calcium-based treatment on organic soil behavior, M.Sc. Thesis, University of Texas at Arlington.

Donovan, C.T. (1990). C.T. Donovan Associates Inc., P.O. Box 5665, Burlington, VT05402, 802, 658-9385.

Duraisamy, Y., Huat, B. B., Muniandy, R. (2009). Compressibility behavior of fibrous peat reinforced with cement columns. *Geotechnical and Geological Engineering*, **27**, 5, 619-629.

Edil, T. B., Dhowian, A. W. (1981). At-Rest Lateral Pressure of Soils, *Journal of Geotechnical Engineering,* **107**, 201–217.

Edil, T.B., Wang, X. (2000). Shear strength and Ko of peats and organic soils, Geotechnics of highwater content materials: ASTM Special technical publication, 1374, 209-225.

Esin, T., Cosgun, N. (2007). Study conducted to reduce construction waste generation in Turkey. *Building and Environment*. **42**, 4, 1667-1674.

Firat, S., Yllmaz, G., Cömert, A. T., Sümer, M. (2012**).** Utilization of marble dust, fly ash and waste sand (silt-quartz) in road sub-base filling materials. *KSCE Journal of Civil Engineering*, **16**, 7, 1143-1151.

Hobbs, N. B. (1986). Mire morphology and the properties and behaviour of some British and Foreign Peats. *Quarterly Journal of Engineering Geology*, **19**, 7–80.

Houston, S. L., Houston, W. N., Zapata, C. E., Lawrence, C. (2001). Geotechnical engineering practice for collapsible soils. In Unsaturated soil concepts and their application in geotechnical practice. *Springer, Dordrecht.*

Holtz, R. D., Krizek, R. J. (1970). Properties of slightly organic topsoils. *Journal of the Construction Division*, **96**, 1, 29-43.

Huang, P. T., Patel, M., Santagata, M., Bobet, A. (2006). Classification of organic soils, Report FHWA/IN/JTRP- 2006/35 for the Joint Transportation Research Program.

Huat, B. B. K., Prasad, A., Asadi, A., Kazemian, S. (2014). Geotechnics of organic soils and peat, Taylor & Francis Group, London.

Hwang, J., Humphrey, A., Bobet, A., Santagata, M. C. (2005). Stabilization and Improvement of Organic Soil, Final Report FHWA / IN / JTRP-2004 / 38.

Jafari, M., Esna-ashari, M. (2012). Effect of waste tire cord reinforcement on unconfined compressive strength of lime stabilized clayey soil under freeze–thaw condition. *Cold Regions Science and Technology*, **82**, 21-29.

Kabai, J., Farkas, K. (1988). Strength and deformation tests of Hungarian peats. In *Proc. 2nd Baltic CMSFE Conference* **48-54**.

Kalantari, B., Huat, B. B. (2008). Peat soil stabilization, using ordinary portland cement, polypropylene fibers, and air curing technique. *Electronic Journal of Geotechnical Engineering*, **13**, 8, 1-13.

Kamei, T., Kato, T., Shuku, T. (2007). Effective use for bassanite as soil improvement materials-recycling of waste plasterboard. *Geotechnical Society Electronic Journals*, **2**, 3, 245-252.

Karakuş, A. (2011). Investigating on possible use of Diyarbakir basalt waste in Stone Mastic Asphalt. *Construction and Building Materials*, **25**, 8, 3502-3507.

Khalid, N., Mukri, M., Kamarudin, F., Sidek, N., Arshad, M. F. (2013). Experimental studies on fibrous peat stabilized using waste paper sludge ash (WPSA). *Electronic Journal of Geotechnical Engineering*, ***18***.

Kolay, P. K., Aminur, M. R., Taib, S. N. L., Zain, M. M. (2011). Stabilization of tropical peat soil from Sarawak with different stabilizing agents, *Geotechnical and Geological Engineering*, **29**, 6, 1135.

Kolay, P. K., Sii, H. Y., Taib, S. N. L. (2011). Tropical peat soil stabilization using class F pond ash from coal fired power plant, *International Journal of Civil and Environmental Engineering*, **3**, 2, 79-83.

Larsson, R. (1980). Undrained shear strength in stability calculation of embankments and foundations on soft clays, *Canadian Geotechnical Journal*, **17**, 4, 591-602.

Lee, M.T. and Nicholson, P.G. (1997). An Engineering test program of MSW ash mixed with quarry tailings for use as a landfill construction material, Testing Soil Mixed with Waste or Recycled Materials, *Journal of ASTM International*. STP 1275, Mark A. Wasemiller, Keith B. Hoddinott, Eds, 205-218.

MacFarlane, I.C., Williams, G.P. (1974). Some Engineering Aspects of Peat Soils, Histosols: Their Characteristics, Classification, and Use. SSSA Special Publication Series , **6** , 79-93.

Magnan, J.P. (1980). Classification géotechnique des sols. A propos de classification LPC. Bulletin de Liaison des Laboratoires des Ponts et Chaussées, **105**, 49–52.

Maher, M. H., Gucunski, N., and Papp Jr, W. J. (1997). Recycled asphalt pavement as a base and sub-base material, Testing Soil Mixed with Waste or Recycled Materials, *Journal of ASTM International*. STP 1275, Mark A. Wasemiller, Keith B. Hoddinott, Eds, 42-53.

Malinowska, E. E., Bursa, B. A., Szymański, A. (2014). Derivation of consolidation partial differential equations with non-linear flow characteristics on organic soil example. *Annals of Warsaw University of Life Sciences, Land Reclamation*, ***46***, 4, 309-316.

McMahon, S. G. (1997). Valuable product from a construction and demolition facility, testing soil mixed with waste or recycled materials, *Journal of ASTM International*. STP **1275**.

McMainis, K. L. and Nataraj, M. (1997). Characterization of filter cake ash and applications for soil stabilization, Testing Soil Mixed with Waste or Recycled Materials, *Journal of ASTM International*, STP 1275, Mark A. Wasemiller, Keith B. Hoddinott, Eds, 219-231.

McDonald, M.R. (1993). Management of Organic Soils, Ministry of Agriculture and Food, February 1993.

Mesri, G., Stark, T. D., Ajlouni, M. A., Chen, C. S. (1997). Secondary compression of peat with or without surcharging, *Journal of Geotechnical and Geoenvironmental Engineering*, ***123***, 5, 411-421.

Miller, G. A., Azad, S., Dhar, B. (1997). The effect of kiln dust on the collapse potential of compacted shale, Testing Soil Mixed with Waste or Recycled Materials, *Journal of ASTM International*. STP 1275, Mark A. Wasemiller, Keith B. Hoddinott, Eds, 232-245.

Mitchell, James, K., Soga, K. (2005). Fundamentals of soil behavior3rd ed. Hoboken, New Jersey, John Wiley & Sons, Inc., Published simultaneously in Canada, 330-331.

Oglesby, C. H., Parker, H.W., Howell, G. A. (1989). Productivity improvement in construction. New York, NY: McGraw-Hill.

Okagbue, C., Ene, E. (2009). Some basic geotechnical properties of expansive soil modified using pyroclastic dust, *Engineering Geology*, **107**, 1, 61-65.

O'Mahony, M. M., and Milligan, G. W. E. (1991). Use of recycled materials in subbase layers, *Transportation Research Record*, 1310, 73-80.

Onur, B. (2009). Stabilization of expansive soils using waste marble dust (M.Sc. thesis). Civil Engineering Department. Middle East Technical University, Ankara, Turkey

Öztürk, M. (2005) Ministry of environment and forestry construction waste management. Ankara, Turkey: www.cevreorman. gov.tr [in Turkish].

Pappu A, Saxena M, Asolekar SR. (2007). Solid wastes generation in India and their recycling potential in building materials, *Building and Environment*, **42**, 6, 2311-2320.

Pasandín, A. R., and Pérez, I. (2013). Laboratory evaluation of hot-mix asphalt containing construction and demolition waste, *Construction and Building Materials*, **43**, 497–505.

Peng, X., Horn, R. (2007). Anisotropic shrinkage and swelling of some organic and inorganic soils, *European Journal of Soil Science*. **58**, 1, 98-107.

Population Reference Bureau. PRB. (.2011). at:https://assets.prb.org/pdf11/2011population-data-sheet_eng.pdf Accessed by October 2010.

Rahgozar, M. A., Saberian, M. (2016). Geotechnical properties of peat soil stabilized with shredded waste tyre chips. *Mires & Peat,* **18**.

Rama Subbarao, G. V., Siddartha, D., Muralikrishna, T., Sailaja, K. S., Sowmya, T. (2011). Industrial wastes in soil improvement, *ISRN Civil Engineering*, **15**.

Ravindrarajah, R. S., Bakoos, S. L. (1999). Recycled construction and demolition materials for use in road works and other local government activities: scoping report. University of Technology, Sydney, center for built infrastructure research.

Safiuddin, M., Jumaat, M. Z., Salam, M. A., Islam, M. S., Hashim, R. (2010). Utilization of solid wastes in construction materials, *International Journal of the Physical Sciences*, **5**, 13, 1952-1963.

Schmidt, N.O. (1965). Study of the isolation of organic matter as a variable affecting engineering properties of soil, Ph. D. thesis. University of Illinois.

Sing, W. L., Hashim, R., Ali, F. H. (2008). Behavior of stabilized peat soils in unconfmed compression tests, *American Journal of Engineering and Applied Sciences*, **1**, 4, 274-279.

Sivapullaiah, P. V., Sridharan, A., Stalin, V. K. (2000). Hydraulic conductivity of bentonite-sand mixtures, *Canadian Geotechnical Journal*, **37**, 2, 406-413.

Skempton, A.W., Petley, D.J. (1970). Ignition loss and other properties of peats and clays from Avonmouth, King‟s Lynn & Cranberry Moss.*Geotechniques,* **20,** 4. 343–356.

Tremblay, H., Duchesne, J., Locat, J., and Lerouil, S. (2002). Influence of the nature of organic compounds on fine soil stabilization with cement, *Canadian.Geotechnical. Journal.,* **39,** 3, 535–546.

Ugai, K., Ahmed, A. (2009). Evaluation of using gypsum waste plasterboard in ground improvement, *Proceeding of the Workshop on Recycling Waste Plasterboard* **, 9.**

Watabe, Y., Yamada, K., Saitoh, K., (2011). Hydraulic conductivity and mixtures of compressibility of Nagoya clay with sand or bentonite, *Geotechnique*. **1**, 3, 211-219.

Yeşilbaş, G. (2004). Stabilization of expansive soils using aggregate waste, rock powder and lime Ph.D. thesis, Middle East Technical University.

Yulianto, F. E., Mochtar, N. E. (2010). Mixing of rice husk ash (RHA) and lime for peat soil stabilization. In Proceedings of the First Makassar International Conference on Civil Engineering, March.

Zainorabidin, A., Bakar, I. (2003). Engineering properties of in situ and modified hemic peat soil in Western Johor, In: Huat BBK et al (eds) Proc 2nd int conference on advances in soft soil engineering and technology. University Putra Malaysia Press, Malaysia, 173–181.