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

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ABSTRACT. Many urban areas are now struggling with the high volume of solid wastes, especially the construction and demolition materials. In this study, the crushed waste concrete (CWC), which is considered as one of the biggest components of solid waste, was used to improve some geotechnical properties of an organic soil. The CWC at the ratios of 5%, 10%, 15%, and 20% were added to organic soil in order to conduct an intensive series of experimental tests. The laboratory tests included the consistency limits by fall cone, modified compaction, unconfined compressive strength (UCS), and swelling percentage. The results show that when the CWC percentages were increased to 50%, there were decreases 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 noticed 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 increase 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%.

Keywords: soil stabilization, organic soil, crushed waste concrete

1. INTRODUCTION AND PREVIOUS STUDIES

Organic soil is one of the most difficult soils with engineering problems. Due to the presence of organic soils in large areas and depths, geotechnical engineers are forced to deal with them and use them for construction. The low shear strength, low hydraulic conductivity, high consolidation and settlement are the most common problems faced in the organic soil, which do not make it very suitable option compared to inorganic soil. Therefore, they are classified as the hardest soil for engineering purposes [1, 2]. The using of organic soils or peat to construct the roadways can be hard and problematic due to the low shear strength and high compressibility [3]. Some unexpected results from the engineering and geotechnical point of view may be observed, when conducting laboratory experiments on organic soils and peat. Den Haan [4] showed that both the effective strength parameters and the undrained shear strength of different types of organic soils and peat increase with increasing the water content or decreasing the unit weight. The possible explanation for the apparently counter behaviour of organic soils and peat is due to the fibre content, which generally increases with increasing of water content and decreasing of unit weight. Hashim and Islam [5] concluded that peat and organic soil displays unique geotechnical properties in comparison with those of inorganic soils such as clay and sandy soils which are fabricated of only soil particles.

Geotechnical engineers have to deal with organic soils or peat for improving engineering properties of these types of soils. Improving organic soils or peat needs to be used in a comprehensive and in-depth study because of the increased volatility of the engineering properties of those of the soil when increasing the content of organic matter. For instance, organic soils are known to be more difficult to stabilize by chemical additive than inorganic soils [6, 7]. Despite those evidences, some investigators use the liquid chemical to stabilize organic soil and the results shows suitable improvement regarding of strength of organic soil [8]. The stabilization of organic soils or peat by cement or fly ash is considered as the most famous methods of stabilizing organic soils or peat [9-16].

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. A limited number of papers in the literature were found on the use of waste materials in order to improve the properties of organic soils or peat. Kolay [17] used pond ash (PA), obtained from a coal fired thermal power station, to stabilize tropical peat soil collected from Sarawak, Malaysia. The researchers explored the effect of different amount (i.e., 5, 10, 15 and 20%) of PA on the compaction and unconfined compressive strength (UCS) properties of peat soil. The results showed that with the increase in PA content, the maximum dry density (MDD) of peat soil increases, while the optimum moisture content (OMC) decreases. The UCS values of the peat soils increases significantly with the increase of PA content and with curing periods. This result on compressive strength of tropical peat soils indicates that the PA has a potential to be used as a stabilizer for tropical peat soil. Besides, the use of PA in soil stabilization helps in reducing the pond volume and achieving environment friendly as well as a sustainable development of natural resources.

In the presented study, the crushed waste concrete was used at the ratios of 10%, 20%, 30%, 40%, and 50% in order to improve the geotechnical properties of organic silt. No attempt has been made to investigate the use of crushed waste concrete to stabilize the organic soils and/or peat, although numerous investigations have been conducted the effects of using cement and fly ash to improve organic soils.

2. MATERIALS AND METHODS

2.1 Materials of Study

2.1.1 Organic Soil

An experimental procedure was employed to test the soil sampled from Sakarya region, Turkey. Visual inspection on the soil indicated that the soil was dark brown to black in colour. The SEM (at scale 1″=500 μm) of organic soil used in the study is shown in Figure 1. Table 1 gives the chemical composition of organic soil. The index, chemical, and geotechnical properties of organic soil are shown in Table 2.

2.1.2 Crushed Waste Concrete (CWC)

Crushed waste concrete was obtained from the paving slabs used in the Gaziantep city. The CWC with a size of less than 4.75 mm were artificially sieved to provide uniform specimens for the conducted tests program. The CWC was bringing from the municipal of Gaziantep City-Turkey. The SEM (at scale 1″=500 μm) of CWC used in the study is shown in Figure 1. Table 1 gives the chemical composition of CWC used in the study as additive.

2.2 Experimental Methods

All the organic soil used in the laboratory tests was dried in a conventional oven and then mixed with dry CWC. The selected contents of the CWC were 10%, 20%, 30%, 40% and 50% by dry weight of the sample. The mixtures of organic soil and CWC were prepared at room conditions. In order to examine the effect of CWC on the index, geotechnical, and chemical properties of peat soil, an experimental tests program have been conducted. The index tests include water content, particle size analysis, consistency limits, and specific gravity. The fall cone test, used to determine the liquid limits of organic soil and organic soil-CWC mixtures was used to estimate the undrained shear strength of organic soil and organic soil-CWC mixtures. Hansbo [28] gave the following equation (1) that can used to determine the undrained shear strength s_u for organic soil and organic soil-CWC mixtures:

$$s_u = k\frac{mg}{d^2} \tag{1}$$

Where, m is the cone mass (g), d depth of cone penetration in the sample (cm), and k is a constant, which changes based on the angle of the cone and is found to be 0.85 for the 30° British cone [29] . The chemical tests contain the organic content, fiber content, ash content, and soil acidity. Undrained shear strength was found from the full cone test. Shear strength is found out by unconfined compressive strength according to ASTM D2166 [18], based on the maximum dry density and optimum moisture content of organic soil and organic soil-CWC mixtures. Table 1 gives the standards of tests adopted in this study. To obtain an accurate description of the soil used in the study, they were classified by three different systems, two of which specialize in the classification of organic soils.

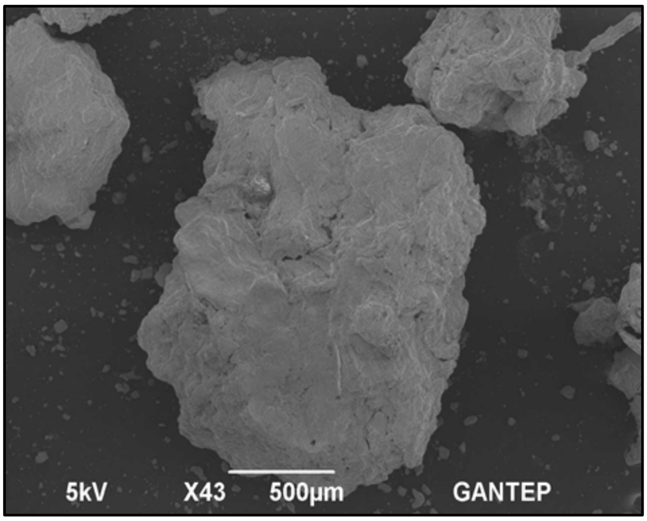

Figure 1. SEM Picture of Organic Soil

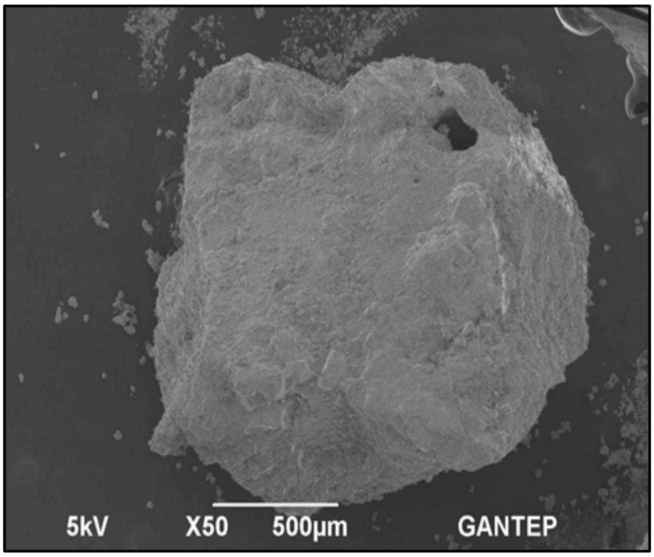

Figure 2. SEM Picture of CWC

Table1. Chemical Composition of Organic Soil and CWC Using the Energy. Dispersive X-Ray (EDX) Analysis

Element	Unit	Organic soil	CWC
		Concentration	Concentration
C	wt.%	14.057	12.934
O	wt.%	51.548	54.166
Na	wt.%	0.295	0.165
Mg	wt.%	1.144	0.468
Al	wt.%	9.068	1.402
Si	wt.%	19.127	2.420
S	wt.%	0.394	---
K	wt.%	1.127	0.227
Ca	wt.%	0.411	27.453
Ti	wt.%	0.287	---
Mn	wt.%	0.032	0.060
Fe	wt.%	2.511	0.707
		Total= 100.000	Total=100.000

Table2. Engineering Properties and Standard of Tests of Organic Soil Used in The

Properties	Standards	Values
Moisture content (%)	BS1377, Test 1(A)	
Specific gravity	ASTM D854 [20]	2.24
Liquid Limit (%)	BS 1337 [19]	68
Plastic limit (%)	ASTM D4318	45
Plasticity index (%)		23
Sand (%)	ASTM D422 [22]	25
Silt (%)	ASTM D422 [22]	67
Clay (%)	ASTM D422 [22]	8
Fibre content (%)	ASTM D1997	22.31
Ash content (%)	ASTM D2974	77
Acidity pH (%)	ASTM D2976	6.7
Organic content (%)	ASTM D2974	
ASTM classification	ASTM D5715	Sapric, High Ash, slightly
Unified soil classification		Organic silt soil with high
Von Post classification		H3
Maximum dry density ,γ_{dmax}	ASTM D1557-12	11
Optimum moisture content,	ASTM D1557-12	30

3. RESULTS AND DISCUSSION

3.1 Consistency Limits Tests, Classification, and undrained shear strength Results

Table 3 displays the consistency limits values (Atterberg limits) for organic soil and organic soil-CWC mixtures. Figure 3 illustrates the relation between the percentages of CWC addition and consistency limits. The data in Figure 3 and Table 3 show that there is decrease in liquid limits with increasing of CWC addition. 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 decrease in the values of the organic soil plasticity index. One suitable explanation for the decreasing of plasticity limits, when adding CWC to 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. Table 3 also shows the classification of organic soil and organic soil-CWC mixtures, according to the unified soil classification system (USCS). Because of the gradual reduction in liquid limits and plasticity index 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).

The relationship between undrained shear strength su and water content for organic soil and organic soil-CWC mixtures, for comparison was given by Figure 4. The results showed that the undrained shear strength of the natural clay give the highest value at any specified water content. The organic soil-CWC mixtures are primarily controlled by the water content of 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.

3.2 Unconfined Compression Strength Test Results (UCS)

The density and water content of each UCS sample were calculated and showed in Table 3 and Figure 5. The optimum water content and maximum dry unit weight values of the specimens conducted for UCS are decreased with increases in CWC content as shown in Figures 6 and 7. The dry unit weight and Gs values of the CWC only were higher than those of the organic soils only. Therefore, the dry unit weight of the mixture increased. Figure 8 gives the variation of UCS as a function of water content for organic soil and organic soil-CWC mixtures. The peak compressive strength values of the specimens continuously increased as the amount of CWC increased as shown in Figure 9. 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.

3.3 Free Swelling Test Results

Table 3. Summary of Study Results

Geotechnical properties	CWC%					
	Organic soil	10	20	30	40	50
Liquid limit (%)	68	63	61.5	59	53	48
Plastic limit (%)	45	41	40	38	37.5	38.5
Plasticity index (%)	23	22	21.5	21	15.5	9.5
Classification USCS	OH	OH	OH	OH	OH	OL
Maximum dry unit weight [a](kN/m^3)	11.0	11.8	12.5	13.3	14	15
Optimum moisture content [b] (%)	30	28	22	17	16.5	16
Unconfined compression strength (kN/m^3)	481	490	515	549	597	615
Optimum water content [c] (%)	25	23	22	16	15.5	13.8
Free swelling percentages	3.35	5.2	12.85	13.2	11.05	8.45

a: density calculated by specimens of UCS before testing,
b: water content by specimens of UCS before testing,
c: water content by specimens of UCS after testing

Table 3 and Figure 10 show 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 to the maximum dry density. After that, although the density continues to increase with the increase in the proportion of CWC, the swelling percentages begins to decrease because of the addition of heavy, non-plastic material, which obstructs the swelling process.

4. CONCLUSIONS

This study aims to investigate the possibility to improve the geotechnical properties of organic soil using crushed waste concrete, some notable points can be concluded from the study results. The liquid limits and plasticity index of organic soil decrease as the CWC percentages increase. These decreases are reflected in the soil classification and strength. The increasing of the CWC content increased the maximum dry density of organic soil and causes increased swelling percentages to certain limit, then start to decrease. The strength of organic soil, as represented by UCS values, increased with increasing CWC percentages.

REFERENCES

[1] Coduto DP. Geotechnical Engineering Principles and Practices. 2nd ed. Upper Saddle River, NJ07458. Prentice Hall. 1999.
[2] Hwang J et al. Stabilization and Improvement of Organic Soil. Final Report FHWA / IN / JTRP-2004 / 38, 2005

[3] Edil TB. Construction over peats and organic soils. In Conference on Recent Advances in Soft Soil Engineering 1997 Mar, pp. 5-7.

[4] Den Haan EJ. An overview of the mechanical behavior of peats and organic soils and some appropriate construction techniques. In Proc. of the Conf. on Recent Advances in Soft Soil Engineering 1997 Mar Vol. 1, pp. 17-45

[5] Hashim R, Islam MS. Properties of stabilized peat by soil-cement column method. Electronic Journal of Geotechnical Engineering. 2008; 13:pp.1-9

[6] Hampton MB, Edil TB. Strength gain of organic ground with cement-type binders. In Soil improvement for big digs 1998 (pp. 135-148). ASCE.

[7] Janz M, Johansson SE. The function of different binding agents in deep stabilization. Swedish deep stabilization research centre, report. 2002; 9:1-35.

[8] Ali, F. (2012). Stabilization of residual soils using liquid chemical. Electronic Journal of Geotechnical Engineering, 17(BUNDLE B), pp. 115-126.

[9] Huat BB, Maail S, Mohamed TA. Effect of chemical admixtures on the engineering properties of tropical peat soils. American Journal of Applied Sciences. 2005; 2(7):pp.1113-20.

[10] Kalantari B, Huat BB. Peat soil stabilization, using ordinary portland cement, polypropylene fibers, and air curing technique. Elect. J. Geotech. Eng., Bund. J. 2008:pp.1-3.

[11] Kalantari B, Huat BK. Load-Bearing Capacity Improvement for Peat Soil. European journal of scientific research. 2009; 32(2):pp.252-9.

[12] Kalantari B, Huat BB, Prasad A. Effect of polypropylene fibers on the California Bearing Ratio of air cured stabilized tropical peat soil. Am. J. Engg. & Applied Sci. 2010; 3(1):pp.1-6.

[13] Kazemian S, Huat BB, Prasad A, Barghchi M. Effect of peat media on stabilization of peat by traditional binders. International Journal of Physical Sciences. 2011 Feb 4; 6(3):pp.476-81.

[14] Tastan EO, Edil TB, Benson CH, Aydilek AH. Stabilization of organic soils with fly ash. Journal of geotechnical and Geoenvironmental Engineering. 2011 Jan 8; 137(9):pp.819-33.

[15] Sing WL, Hashim R, Ali F. Unconfined compressive strength characteristics of stabilized peat. Scientific Research and Essays. 2011 May 31; 6(9):pp.1915-21.

[16] Kolay PK, Aminur MR, Taib SN, Zain MM. Stabilization of tropical peat soil from Sarawak with different stabilizing agents. Geotechnical and geological engineering. 2011 Nov 1; 29(6):p.1135.

[17] Kolay PK, Sii HY, Taib SN. Tropical peat soil stabilization using class F pond ash from coal fired power plant. International Journal of Civil and Environmental Engineering. 2011; 3(2):pp.79-83.

[18] ASTM D. 2166 (2000) Standard test method for unconfined compressive strength of cohesive soil. Annual book of ASTM Standards, American Society for Testing and Materials, Philadelphia. 2003;4(08).

[19] BS 1377. Part 1–4., “Soils for civil engineering purposes,” British Standards Institution. London, UK, 1990.

[20] ASTM. American Society for Testing and Materials. (2014). Standard Test Methods for Specific Gravity of Soil Solids by Water Pycnometer, D854-2014 West Conshohocken, PA.

[21] ASTM. American Society for Testing and Materials. (2010). Standard test methods for liquid limit, plastic limit, and plasticity index of soils. D4318-2010 West Conshohocken, PA.
[22] ASTM. American Society for Testing and Materials. (2007). Standard Test Method for Particle-Size Analysis of Soils, D422-2007 West Conshohocken, PA.
[23] ASTM American Society for Testing and Materials. (2014). Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils, D1997-2014 West Conshohocken, PA.
[24] ASTM. American Society for Testing and Materials. (2014). Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils, D2974-2014 West Conshohocken, PA.
[25] ASTM. American Society for Testing and Materials. D2976. (2013). Standard Test Method for pH of Peat Materials, D2976-2013 West Conshohocken, PA.
[26] ASTM. American Society for Testing and Materials. (2014). Standard Test Method for Estimating the Degree of Humification of Peat and Other Organic Soils (Visual/Manual Method), D5715-2014 West Conshohocken, PA.
[27] ASTM. American Society for Testing and Materials. (2012). Standard test methods for laboratory compaction characteristics of soil using modified effort. D1557-2012West Conshohocken, PA.
[28] Hansbo S. A new approach to the determination of the shear strength of clay by the fall-cone test. Royal Swedish Geotechnical Institute; 1957.
[29] Wood DM. Some fall cone tests. Geotechnique. 1985 Mar; 35(1).

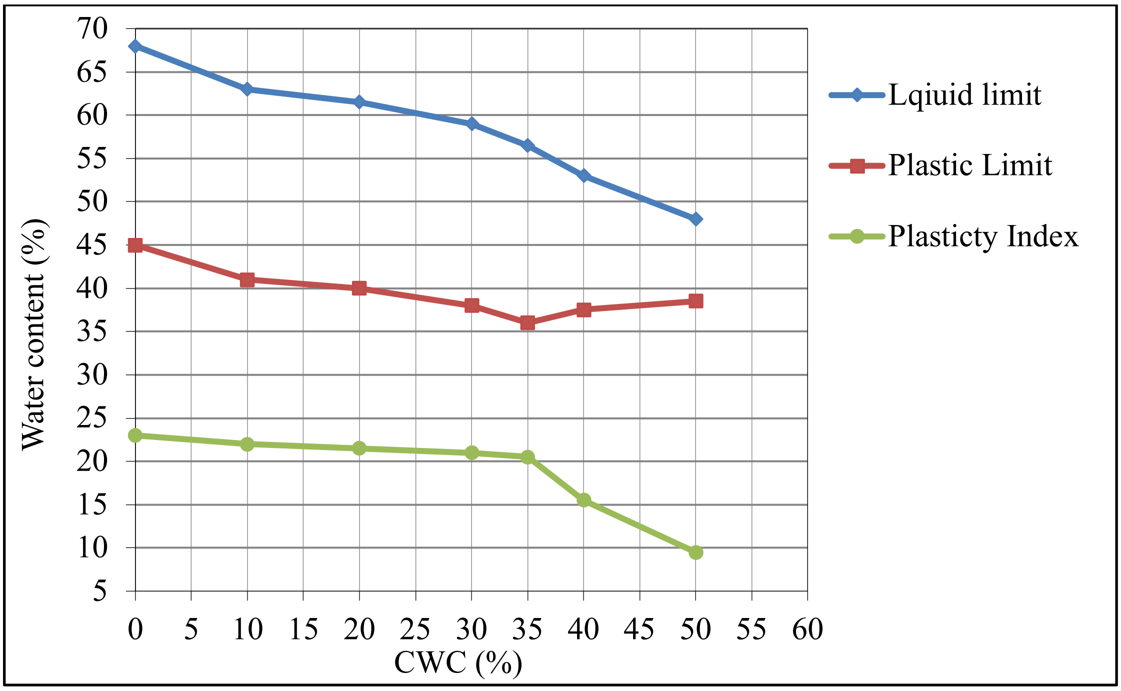

Figure 3. Relationships between consistency limits and cwc content

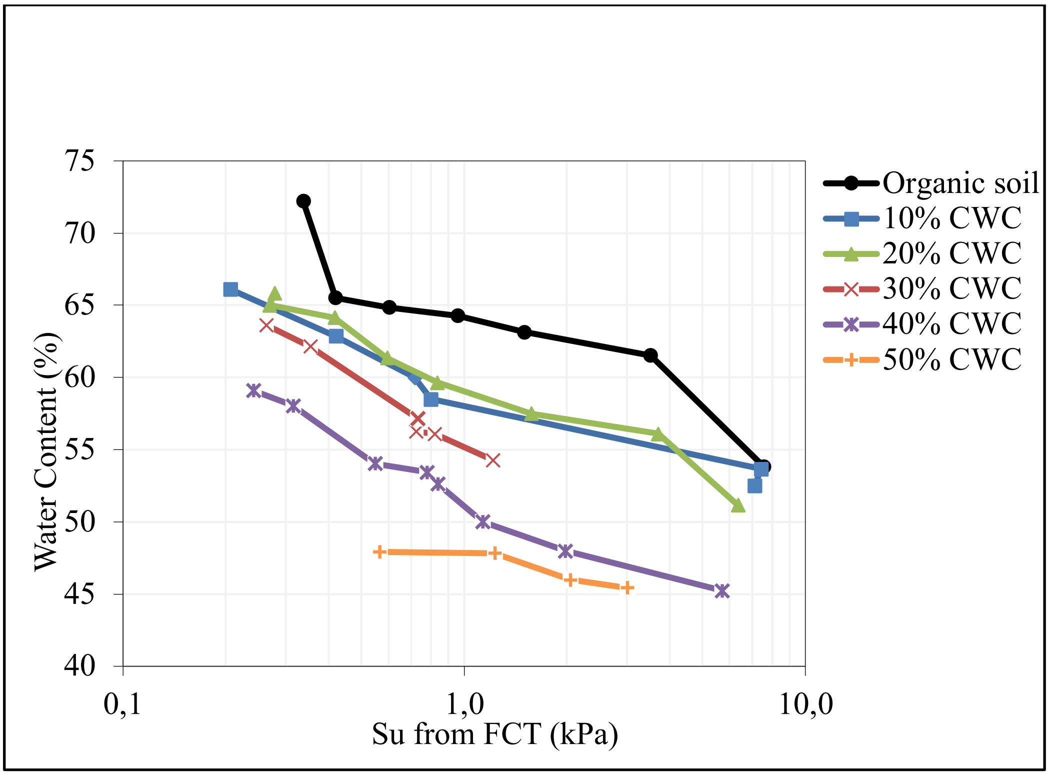

Figure 4. Variation of undrained shear strength as a function of water content for the organic silt with cwc

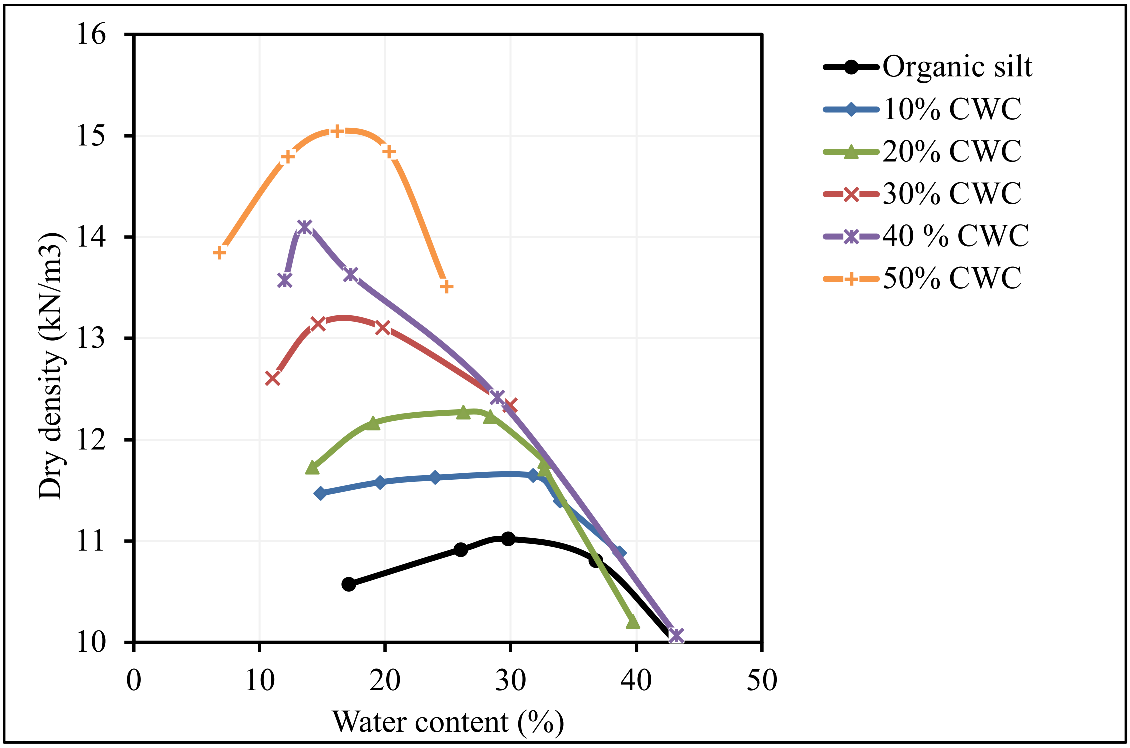

Figure 5. Variation of dry unit weight as a function of water content for the organic soil with cwc

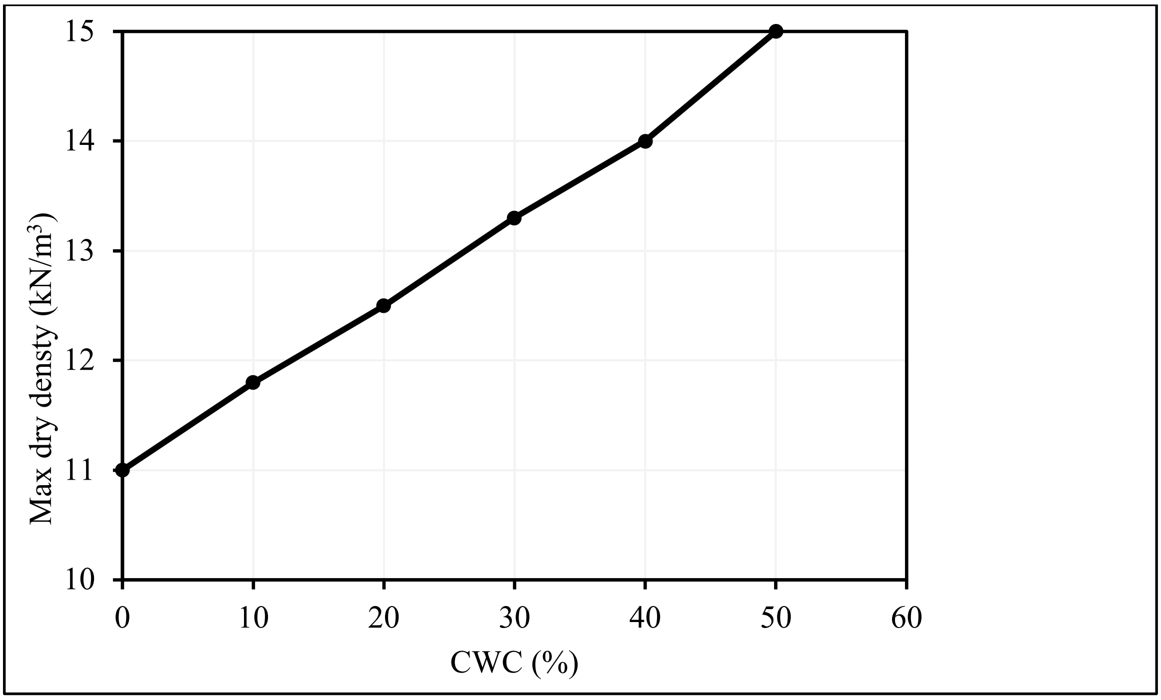

Figure 6. Variation of the γ_{drymax} with the cwc content

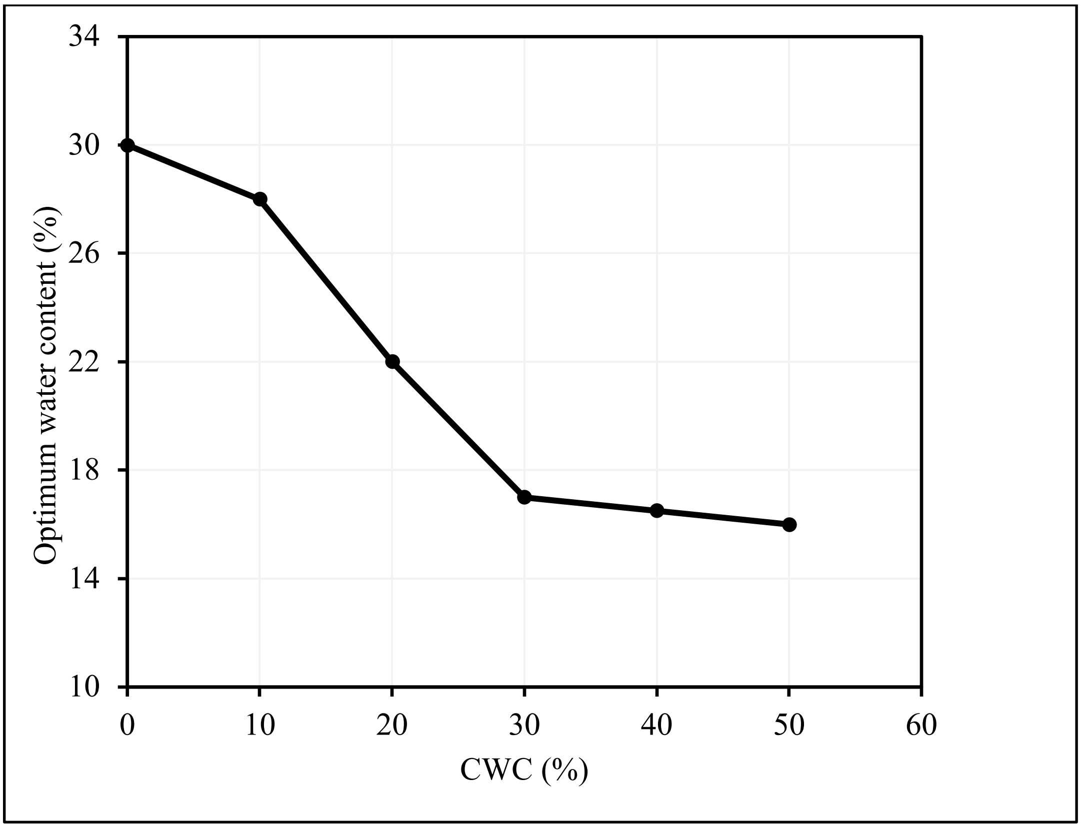

Figure 7. Variation of the w_{opt} of compaction test with the CWC content

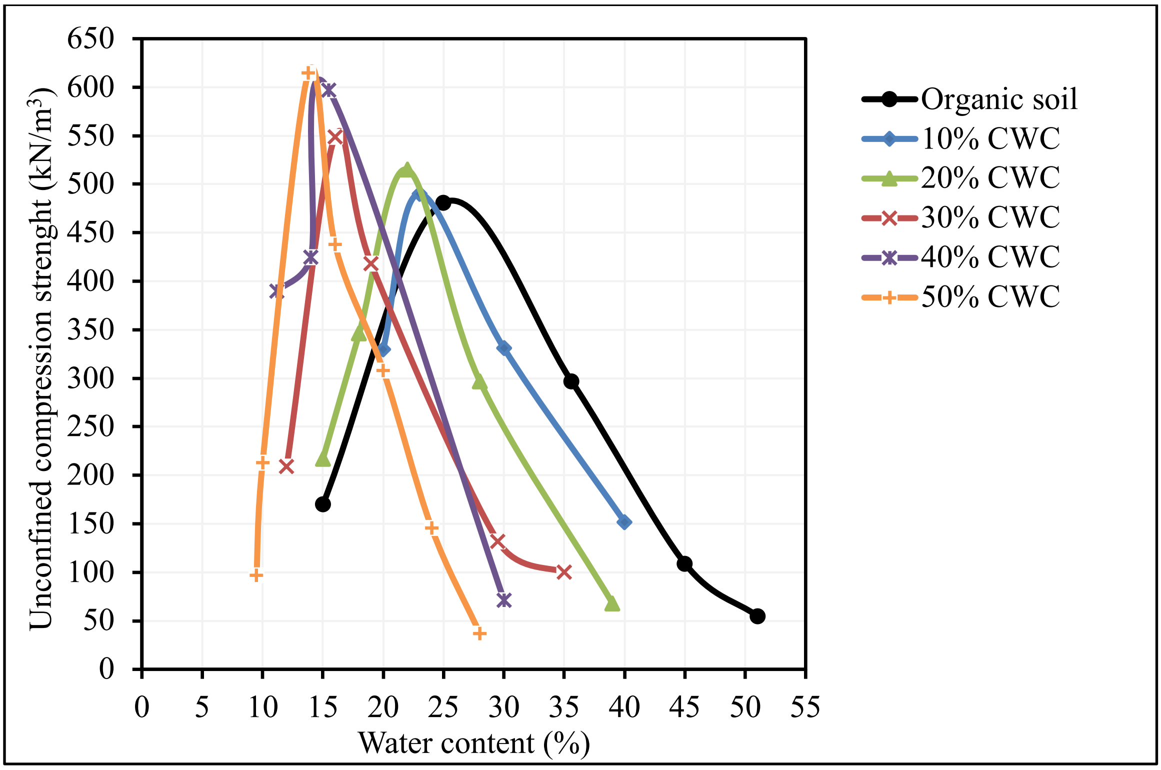

Figure 8. Variation of UCS as a function of water content for the organic soil with CWC

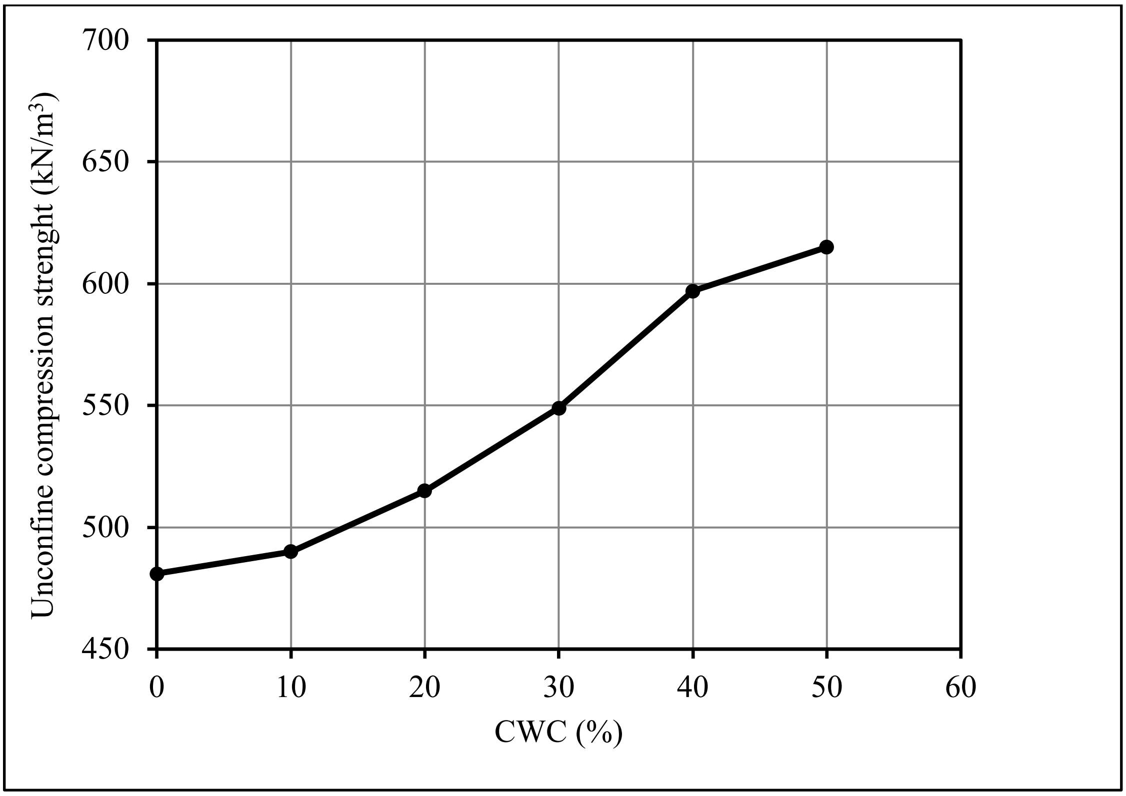

Figure 9.Variations of unconfined compressive strength with the CWC contents

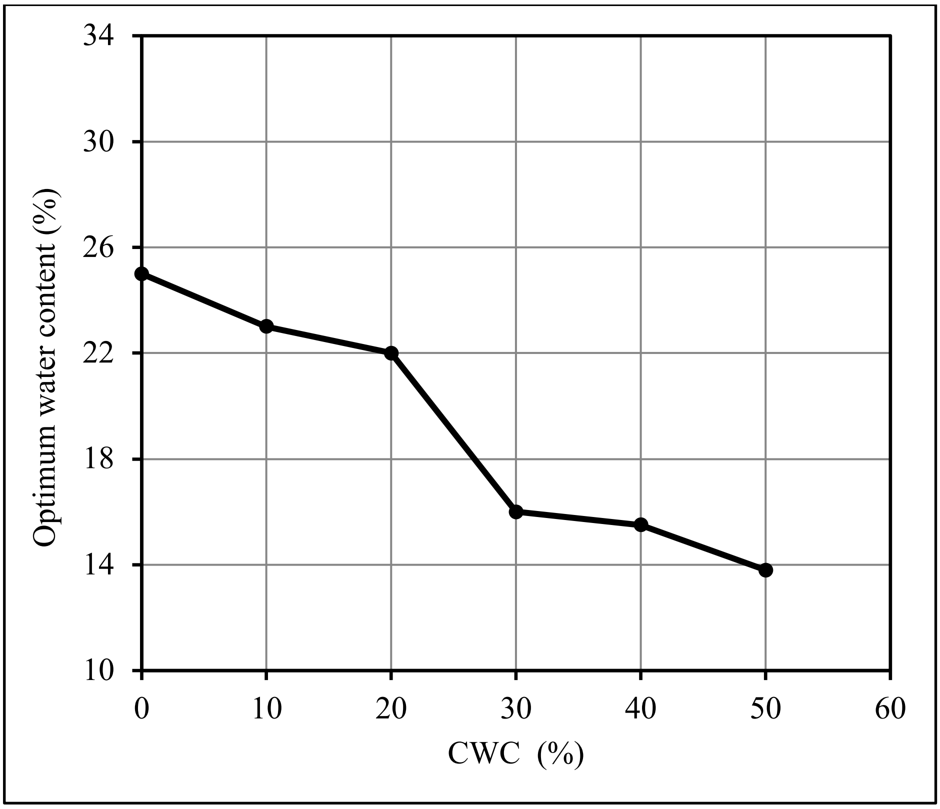

Figure 10.Variations of swelling percentages with the CWC contents