University of Baghdad
College of Engineering
JOURNAL OF ENGINEERING

Journal of Engineering
journal homepage: www.joe.uobaghdad.edu.iq
Number 7 Volume 26 July 2020

Civil and Architectural Engineering

Evaluating the Uses of Concrete Demolishing Waste in improving the Geotechnical Properties of Expansive Soil

Safin Bahadin H. Saeed*
MSc. Student
College of Engineering – University of Sulaimani
Iraq- Sulaymaniyah
safin.hama@univsul.edu.iq

Kamal Ahmad Rashed
Assistant Professor
College of Engineering – University of Sulaimani
Iraq- Sulaymaniyah
kamal.rashed@univsul.edu.iq

ABSTRACT

Expansive soil is one of the most serious problems that face engineers during the execution of any infrastructure projects. Soil stabilization using chemical admixture is one of the most traditional and widespread methods of soil improvement. Nevertheless, soil improvement on site is one of the most economical solutions for many engineering applications. Using construction and demolishing waste in soil stabilization is still under research., The aim of this study is to identify the effect of using concrete demolishing waste (CDW) in soil stabilization. Serious tests were conducted to investigate the changes in the geotechnical properties of the natural soil stabilized with CDW. From the results, it is concluded that the swelling potential of the expansive soil reduced and dramatic increases in unconfined compressive strength (UCS) value up to 3 times of its original value was reported. The results indicate that CDW is an economical solution to be used in soil stabilization whereas it is a sustainable idea to recycle constructional wastes and solve the continued need for the more landfilling area.

Keywords Expansive soils, Soil stabilization, Concrete Demolishing waste, and Geotechnical properties.

تقييم استخدام نفايات الخرسانة في تحسين الخواص الجيوتقنية للتربة المنتفخة

سفين بهائدين حمه سعيد*
طالب ماجستير
كلية الهندسة – جامعة السليمانية

كمال احمد رشيد
طالب ماجستير
كلية الهندسة – جامعة السليمانية

الخلاصة

تعد التربة المنتفخة احد أخطر المشاكل التي تواجه المهندسين أثناء تنفيذ اي من مشاريع البنية التحتية. وأحد أكثر الطرق التقليدية انتشارًا لتحسين التربة، هي تحسين التربة باستخدام الخلطات الكيميائية، ويعد تحسين التربة في الموقع أحد أكثر الحلول اقتصاديةً

*Corresponding author
Peer review under the responsibility of University of Baghdad.
https://doi.org/10.31026/j.eng.2020.07.11

Article received: 17/1/2020
Article accepted:18/4/2020
Article published:1/7/2020

في العديد من التطبيقات الهندسية. ولا تزال الدراسات عن استخدام نفايات البناء ومخلفات هدمها في تثبيت التربة قيد البحث، وعليه فان هذه الدراسة تهدف الى تحديد تأثير استخدام نفايات هدم الخرسانة (CDW) في تحسين التربة، وقد أجريت الاختبارات لاستكشاف التغيرات في الخواص الجيوتقنية للتربة الطبيعية المستقرة باستخدامCDW. توصلت النتائج إلى تقليص احتمال حدوث انتفاخ في التربة الممتدة، فضلا عن احداث زيادات كبيرة في قيمة مقاومة الضغط غير المقيد (UCS) التي تصل إلى ثلاثة أضعاف القيمة الأصلية. وتشير النتائج كذلك إلى ان استخدام نفايات هدم الخرسانة (CDW) في تحسين التربة هو حل اقتصادي، كما انها في الوقت نفسه فكرة مستدامة لإعادة تدوير النفايات الإنشائية وتقليل الحاجة المستمرة إلى مساحات اضافية لدفن النفايات الخرسانية.

1. INTRODUCTION.

Nowadays buildings and infrastructures are constructed widely everywhere due to the continuous needs and population growth, sometimes it is hard to place infrastructures on suitable land due to the distribution of problematic soils, those with high plasticity and low strength which results in cracking and damaging the infrastructures. Expansive soils are those which have the ability to expand and swell as they get wet. This type of soil's clay minerals have the ability to absorb an excessive amount of water molecules and expand, in the opposite, they start to shrink as they dry, leaving an excessive amount of voids in the soil **(Cokca, 2001; Al-Rawas et al., 2005; Dang et al., 2016)**. Expansive soils cover a wide surface area in many countries al around the world **Sabatan, 2005; Huang and wu, 2007; Ahmed and Hamza, 2015)**. Expansive soil's Clay particles have a large specific area, the swelling occurs due to the poor bonding between the sheets that are forming the mineral particles **(Nalbantoglu and Gucbilmez, 2001; Fityus and Buzzi, 2009)**. The estimated annual loss of structural damages due to the effect of expansive soils is about 10^{th} billions of dollars all around the world **(Dang et al., 2016)**.
As a result, many different methods have been investigated including soil replacement, soil reinforcing, and soil stabilization. Soil stabilization is one of the most effective methods to solve the soil's problems **(Ali et al., 1992; Bell, 1996; Al-Rawas et al., 2005; Chen and Wang, 2006; Abdulrasool, 2015; Ahmed and Adkel, 2017)**. Soil improvement is the process of improving the quality of in-situ soil and makes it more functional as an engineering material. According to literature many traditional stabilizers such as Cement, lime and fly ash have been used by many researchers al around the word **(Ali et al., 1992; Bell, 1996; Al-Rawas et al., 2005; Chen and Wang, 2006)**. The stabilization agents create bonds between clay particles, reduce the excessive voids in the soil and reduces swelling potential. In past decades cement and lime have been used effectively to stabilize expansive soils all around the world. The result of these studies showed that the addition of cement and lime which was varied between 1 to 20 % has improved expansive soils and reduced the swelling potential effectively **(Bell, 1996; Al-Rawas et al., 2005; Chen and Wang, 2006)**. Improving the in-situ weak soil with suitable waste material could be an economical and effective method **(Hasan et al., 2016; Paul and Cyrus 2016; Ravikanth et al., 2017)**. Many researchers studied the effect of construction and demolishing (C&D) waste in pavements, but utilizing C&D wast for soil improvement is still under research. Every year around 1,183 million tones of C&D waste are generated worldwide **(Kerni et al., 2015)**. Recycling C&D waste material will diminish the excessive production of pollutant gases and CO_2 emission that has a direct effect on the global warming issue. Also, it will reduce the continuos need for extracting raw materials or transporting the materials long distances. Whereas it will cut the need for new landfills. The use of concrete demolishing waste (CDW) in geotechnical applications is a sustainable option to minimize C&D waste. Nevertheless, it will enhance the geotechnical characteristics of the soil. **(Agrela et al., 2012; Ransinchung et al., 2012; Sharma and Hymavathi 2016; Hidalgo et al.,**

2019) reported that on using CDW the plasticity index will reduce, whereas the unconfined compressive strength (UCS) and Californian bearing ratio (CBR) values are improved. This study focused on studying the efficacy of using Concrete Demolishing Waste (CDW) for stabilizing expansive soil.

2. MATERIAL AND METHODOLOGY

2.1 Soil.

The soil used in this study was obtained from a site (Qrga) near Sulaymaniyah city in Kurdistan-Iraq (see **Fig. 1**). The soil sample was collected carefully and representative soil samples were collected. Then the soil was oven-dried, cooled and pulverized to be used in the laboratory tests to investigate its geotechnical properties and study the effect of CDW. The soil is classified as a CH soil (clay with high plasticity) according to the unified soil classification system (USCS) and its geotechnical properties are given in **Table 1**.

2.2 Concrete Demolishing waste.

In general C&D waste come from dismantling of old building and infrastructures. This waste is increasing day by day. Recycling and reusing C&D waste is a sustainable solution to reduce landfill and this material is free of cost since it has to be disposed to the landfill area. The C&D waste used in this study is consists of crushed concrete obtained from the slab of a dismantled building (Residential house) in Sulaymaniyah city (see **Fig. 2**). The concrete demolishing waste obtained then crushed to powder (see **Fig. 3)** and sieved through sieve No. 40. Generally, it has a fine and white texture as shown in **Fig. 4.** It should be note that the additive has been crushed and turned in to fine particle in order to obtain relatively homogenous specimen and avoid segregation on mixing the admixture with the expansive soil since other researchers reported that the courser particle and the irregular shape of C&D waste may form small waterways within the specimen (**Hasan et al., 2016)**.

2.3 Sample preparation.

Different percentages of the obtained concrete demolishing waste (CDW) were mixed with the expansive soil, the prepared specimens were curried for 1, 7 and 28 days the optimum moisture content (OMC) and maximum dry density (MDD) were used for all specimens to deduce comparative data.

2.4 Laboratory Tests.

A series of laboratory tests were conducted for the natural and soil-admixture combination; the tests were conducted according to the ASTM standards. The tests consisted of:

1. Atterberg limits (ASTM D4318 – 14).
2. Linear shrinkage (ASTM C 356 – 10).
3. Swelling tests (one dimensional swell tests according to ASTM D4546 – 14).
3. Compaction test (ASTM D1557 – 12).
4. Unconfined Compressive strength test (ASTM D2166/D2166M16).
5. Californian bearing ratio test (ASTM D1883-16).

3. RESULTS AND DISCUSSION.

The hydrometer test was performed to determine the particle size distribution for the natural soil, the test was conducted according to **ASTM D422 -2007** and the grain size distribution of the soil illustrated in **Fig. 5**. From the test result, it can be seen that the clay and silt fractions of the natural soil are 54 % and 45 %, respectively. Therefore, and according to a unified soil classification system the soil is classified as expansive (CH) soil. (**Sharma and Hymavathi, 2016)** reported that crushed concrete is a pozzolanic material that reduces the plasticity index whereas it improves UCS and soaked CBR values.

3.1 Atterberg Limits.

The liquid limit (LL) and plastic limit (PL) of the natural soil were 60% and 28.5%, respectively. A significant reduction in liquid limit observed on adding CDW to the soil and the results are presented in **Fig. 6**. From this figure, it can be observed that the liquid limit sharply dropped to only 50%. in contrast the plastic limit of the soil slightly increased by adding CDW, (see **Fig. 6**). Hence the plasticity index of the soil improved too and the results are presented in **Fig. 6**. Linear shrinkage test was conducted for the natural soil and the result was 15.9%. Also, the Linear shrinkage test was performed for the soil-stabilizer mix as it can be seen in **Fig. 7**. From the results, it is obvious that the Linear shrinkage limit of the soil reduced to 10.3% on adding 18% of CDW as the results are presented in **Fig. 6**. The test results confirming that the Atterberg limits and linear shrinkage limit are significantly improved on adding CDW and the reason behind this improvement is the presence of sand particles in CDW which has less specific surface area compared to the clay particles from the natural soil and CDW also contains cement particles which reduce adsorbed double layer surrounding clay particle as stated by (**Varaprasad et al., 2019)**.

3.2 Swelling Tests.

Effect of CDW on swelling percent and swelling pressure of the selected expansive soil was determined based on different curing periods and various addition of CDW contents. The soil–admixtures combinations that are used in this study for conducting swell tests are soil:CDW, 98:2, 96:4, 94:6, 92:8, 90:10, 88:12, 86:14, 84:16, 82:18, 80:20 and 78:22. The samples were prepared and wrapped with several layers of cling film and tested after a curing period of 1, 7, and 28 days. The effect of adding CDW on swelling percent of soil is illustrated in **Fig. 8**. The swelling percent of the untreated soil was 14 % which on the addition of CDW reduced drastically at 12 % of CDW content and becomes 4.28 % after 28 days of curing. Further addition of CDW results in a slight reduction in swelling percent. The addition of CDW to soil resulted in a decrease in soil swelling pressure. The swelling pressure of the soil decreases with the addition of CDW content, at the binging the samples were compacted in the oedometer ring and the constant volume method were used to investigate the swelling pressure as shown in **Fig. 9**. an improvement of up to 55% in swelling pressure was obtained on adding 12% of CDW after 28 days of curing as shown in **Fig. 10**. Further addition of CDW results in a slight reduction in swelling pressure. Therefore 12% of CDW waste was selected as optimum to improve the swelling potential of the selected soil. This is attributed to increasing in coarser particle content in soil–CDW mix resulting in a decrease in surface activity and cement present in CDW obstructs the voids by taking water and pozzolana reduces the interparticle attraction between clay particles as stated by (**Sharma and Hymavathi, 2016**; **Varaprasad et al., 2019)**.

3.3 Compaction test.

The modified proctor test was employed for investigating the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) of soil and soil-admixture. 12% of CDW was selected as an optimum mix based on the results from swelling percent and swelling pressure tests. the soil-CDW combinations and their proportion for conducting the compaction tests were fixed as soil:CDW, 88:12 and the results are shown in **Fig. 11**. The addition of 12% CDW increased MDD from 1.8 to 1.81 gm/cm$^{3.}$ Also, OMC decreased from 17.5% to 16.3%. The reason for the decrease in OMC value is the existence of fine sand in CDW which generally possess lower specific surface area compared to clay.

3.4 Unconfined Compressive strength test.

The unconfined compressive strength (UCS) test was conducted to investigate the improvement in compressive strength of the soil stabilized with CDW. Different soil-admixture combinations such as: soil:CDW, 90:10, 88:12, 86:14, 84:16, 82:18, 80:20 and 78:22 were used. The samples were prepared and wrapped with several layers of cling film and tested after a curing period of 1, 7, and 28 days (see **Fig.12**). The UCS for untreated soil was 302 kPa. It was observed that the strength increases with the addition of CDW and strength increased with higher curing periods. The UCS value for stabilized samples with CDW and cured for 7days are 591.4 kPa for 10% CDW, 775.9 kPa for 12% CDW and 950.9 kPa for 20% CDW. The results of 28-days, UCS tests are: 735 kPa for 10% CDW, 962.68 kPa for 12% CDW and 1039.7 kPa for 20% CDW, the results are illustrated in **Figs. 13, 14 and 15**. This increase is due to the pozzolanic reaction between soil and CDW. Similar behavior was reported by (**Sharma and Hymavathi, 2016)**. From **Fig. 17,** it is clear that the strength of the soil dramatically increases by adding 12% of CDW in which the UCS value increased by 3.18 times of the original value after 28 days of curing period. The UCS value increased gradually after adding CDW in increments of (10, 12 up to 20%) as 2.43, 3.18, 3.27, 3.34, 3.43 and 3.44 times of it is original value and after 28 days of curing period. It was noted that continuously adding CDW up to 22% will change the soil behavior from flexible material to brittles material. **Fig. 18** shows a specimen failure mechanism. Also from **Fig. 16 and 17** it is clear that the higher percentage of CDW (22%) adverse the continuous strength gaining and this is due to the fact that the pore spaces inside the soil are totally filed up with CDW.

3.5 Californian bearing ratio test.

The California bearing ratio (CBR) test was conducted on soil and the soil-stabilizer mix (optimum mix) as soil:CDW; 88:12 which is selected based on swelling tests results. The addition of 12% CDW to soil increases the soaked CBR value for 7 days from 4.27% to 24.14 % as shown in **Fig. 19**. The increase in CBR is due to the presence of sand and cement particles in the CDW which create bonds and mobilizes the angle of internal friction resulting in an increase in strength.

4. CONCLUSION.

The aim of this study was to identify the effect of concrete demolishing waste (CDW) on the geotechnical properties of the selected expansive soil and the results concluded as:

1. Liquid limit, plasticity index and linear shrinkage limit of the treated soil decreased with the increase in CDW for all soil-admixture percentage since CDW is non-cohesive material.
2. The swelling potential (swelling percent and swelling pressure) of the stabilized soil improved, as swelling percent decreased to one-third of its original value also the swelling pressure reduced to half of its original value after adding 12% of CDW. Adding further CDW cased insignificant change in the swelling potential of the soil.
3. Adding 12% of CDW cased reduction in Maximum dry density and Optimum moisture content. The decreases are due to the presence of fine sand in CDW.
4. UCS increased with the addition of CDW, the increases in strength, is more and significant on adding 12% of CDW cured for 28 days. It is reported that the soil behavior changes from flexible to brittle materials on adding CDW in increment.
5. Soaked CBR value of the soil Soaked for 7 days increased up to 6 times compare to virgin soil after adding 12% of CDW.

In conclusion, CDW is an economical and environmentally sustainable solution to improve expansive soils, especially for low expansive soils and adverse the unacceptable geotechnical properties of the soils.

Table 1. Geotechnical properties of expansive soils

Characteristics		Specification
Specific gravity	2.74	ASTM D422-2007
Liquid limit (%)	60	ASTM D4318-14
Plastic limit (%)	28.5	ASTM D4318-14
Plasticity index (%)	31.5	ASTM D4318-14
Unified soil classification system	CH	USCS
Optimum moisture content (%)	17.5	ASTM D1557-12
Maximum dry density (g/cm^3)	1.8	ASTM D1557-12
Unconfined compressive strength UCS (kPa)	302	ASTM D2166/D2166M-16
Free swell (%)	14	ASTM D5446-08
Soaked California bearing ratio (%)	4.27	ASTM D8883-16

Figure 1. location where the soil sample is taken.
(https://www.google.com/maps/place/35%C2%B031'18.0%22N+45%C2%B028'26.0%22E/@35.5426548,45.4313849,10592m/data=!3m1!1e3!4m6!3m5!1s0x4000297601803e73:0x27b4628f0c24aec2!7e2!8m2!3d35.5216697!4d45.4738927)

Figure 2. Old demolished house where the CDW was taken.

Figure 3. Mechanism of crushing the concrete demolishing waste (CDW).

Figure 4. Concrete demolishing waste (CDW).

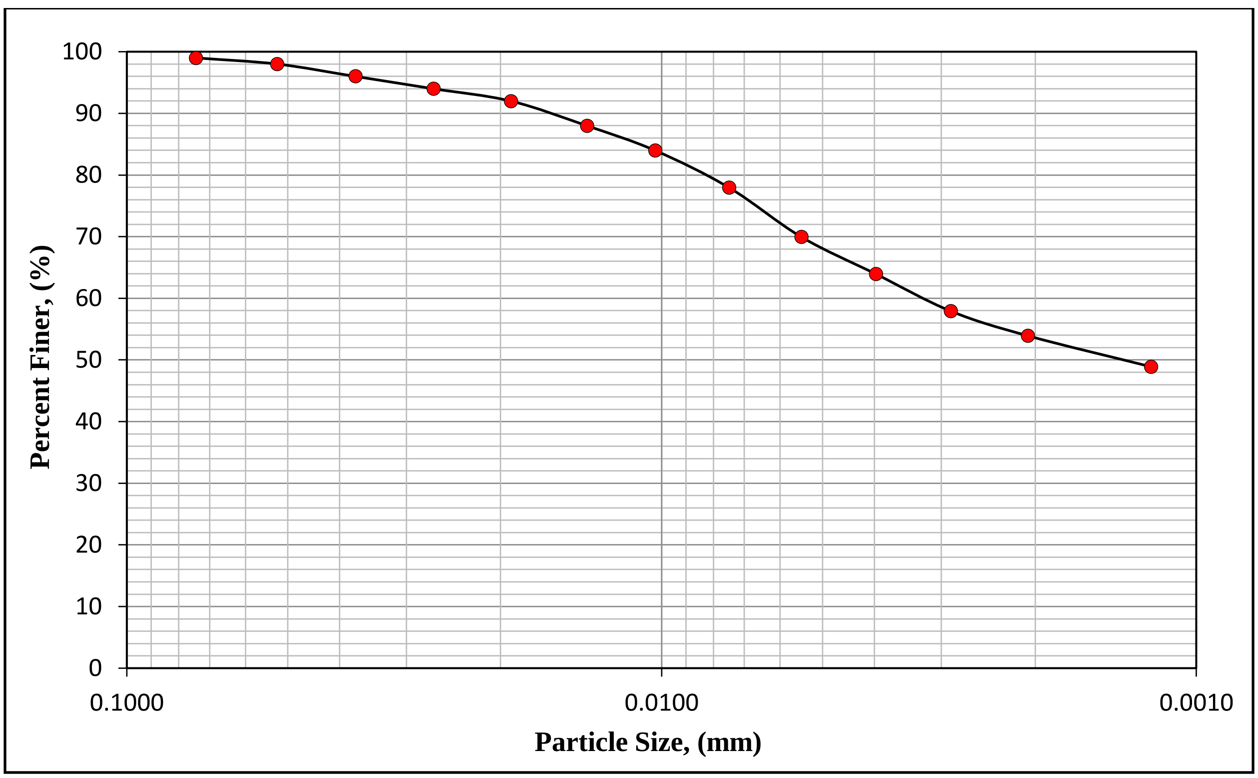

Figure 5. Particle size distribution for the selected expansive soil.

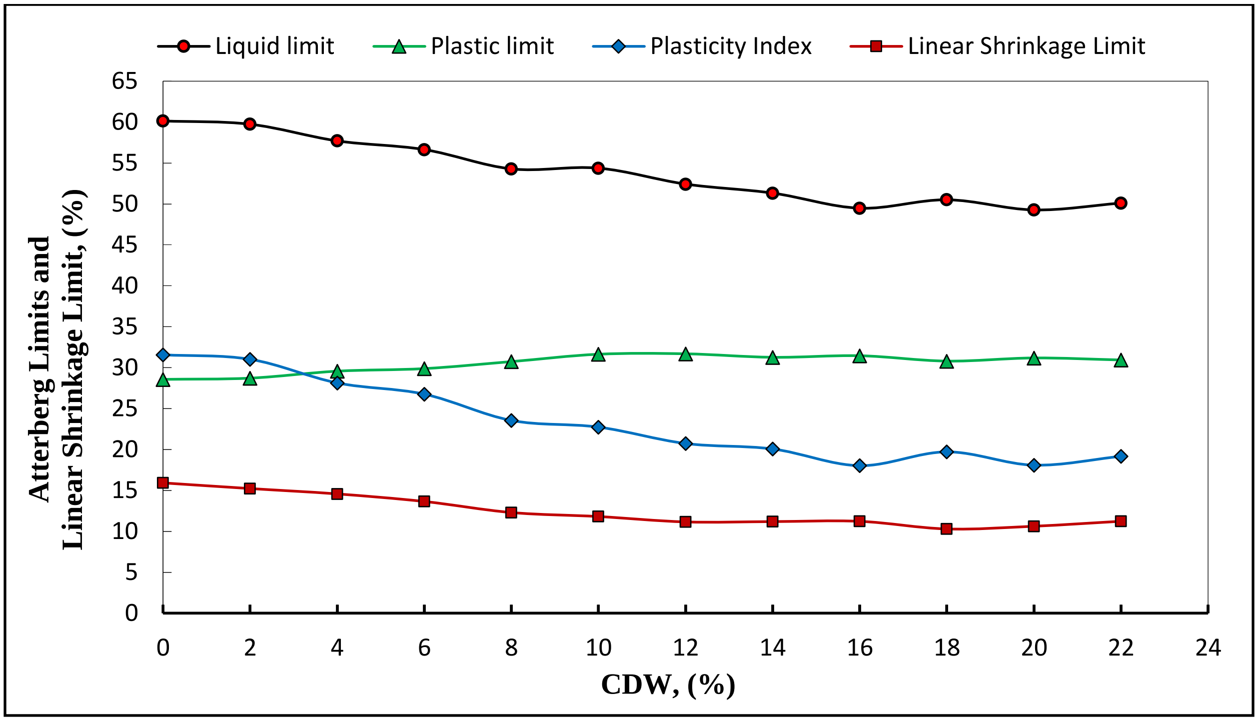

Figure 6. Atterberg Limits and Linear Shrinkage limit test results**.**

Figure 7. Linear Shrinkage test samples.

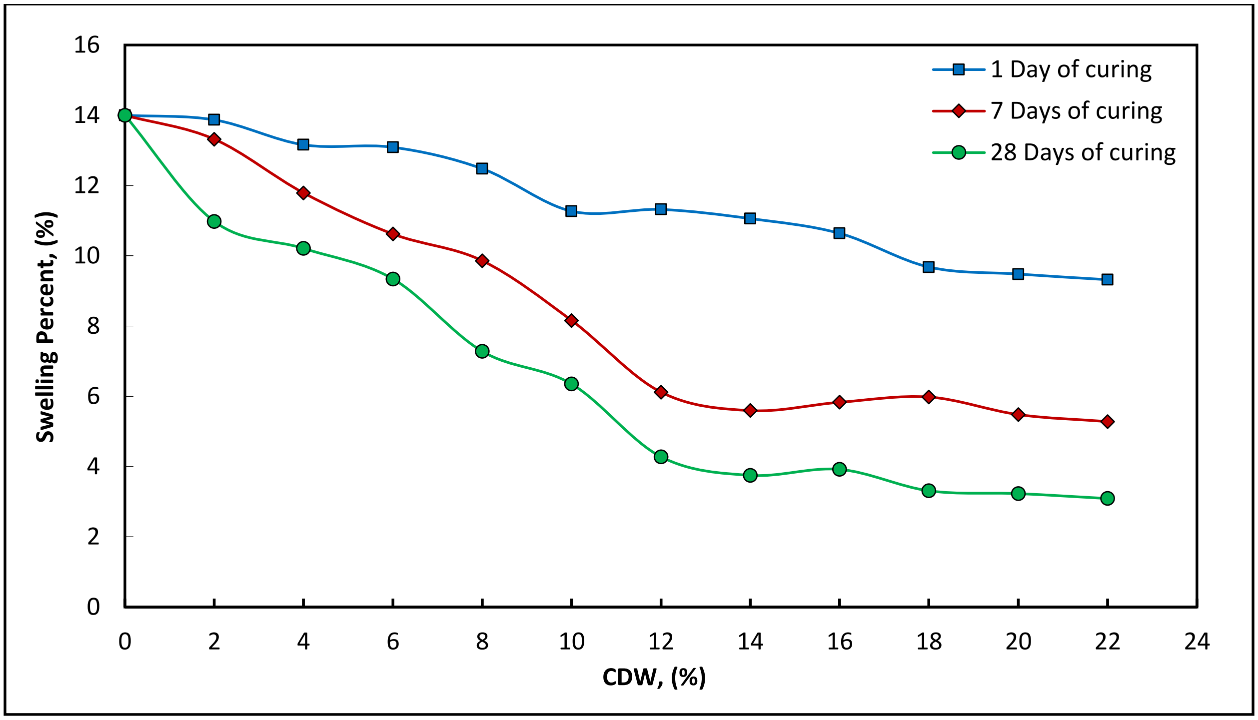

Figure 8. Effect of CDW on Swelling Percent of the Soil.

Figure 9. Odometer apparatuses (swelling pressure test).

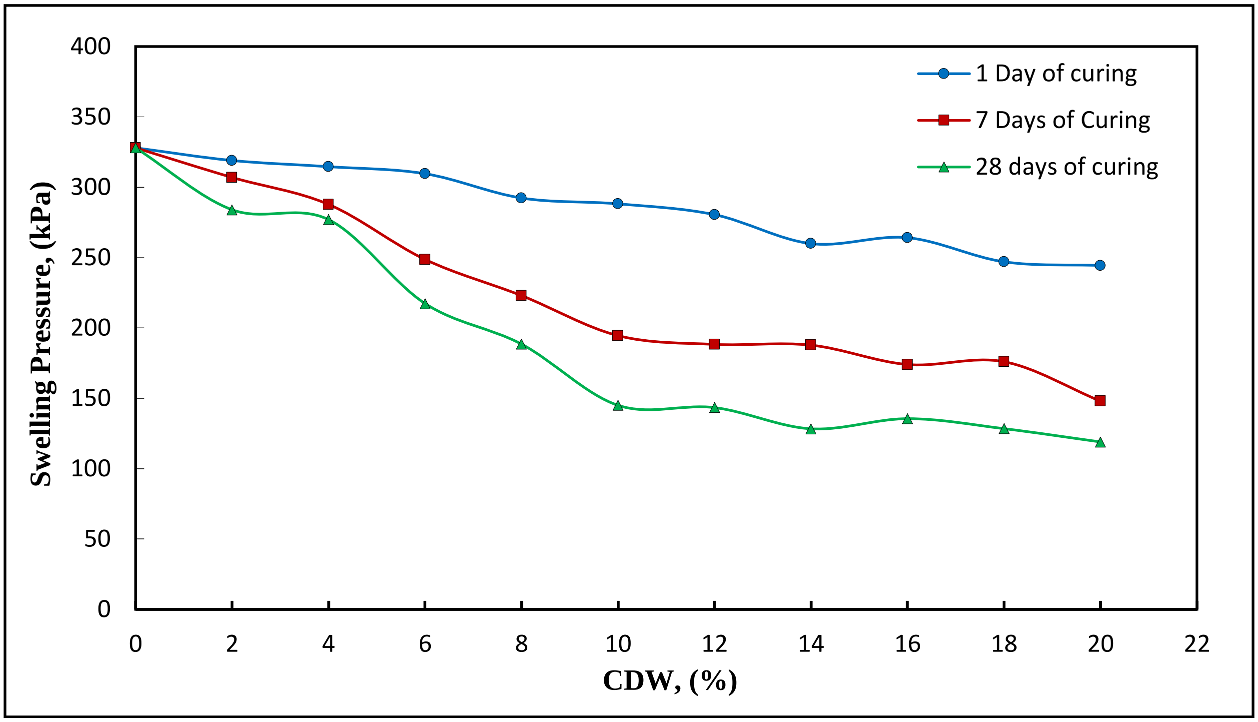

Figure 10. Effect of CDW on Swelling Pressure of the soil.

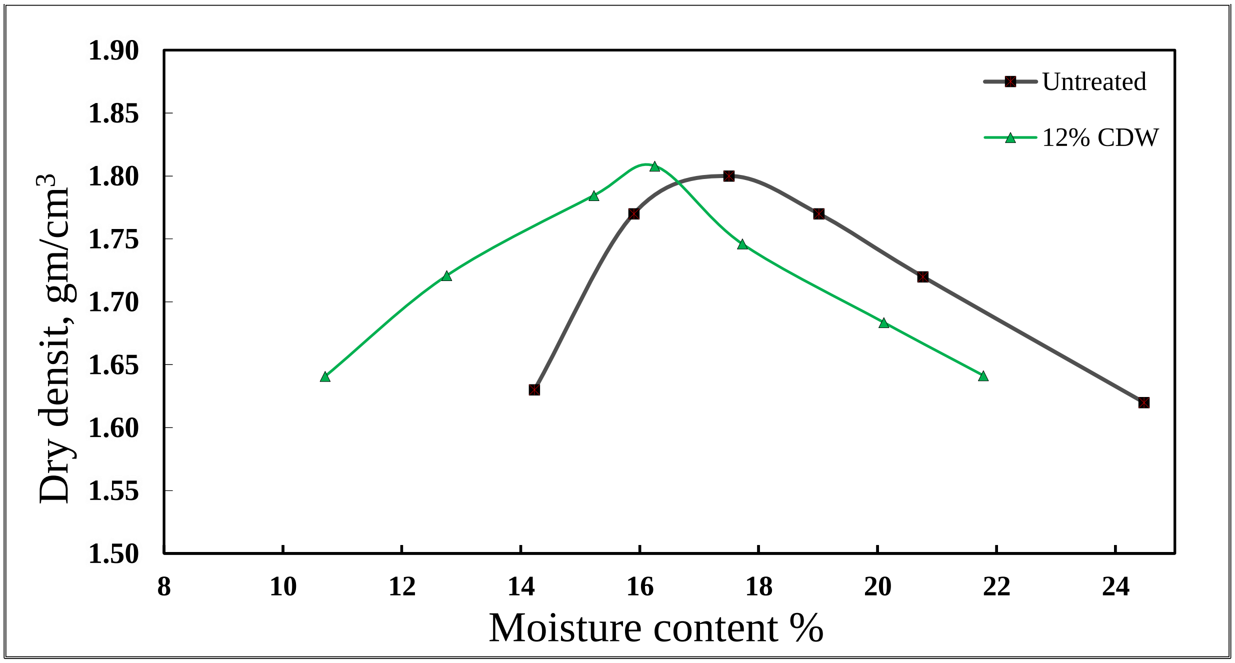

Figure 11. Compaction curves for natural soil and Soil-Stabilizer mix (12%CDW).

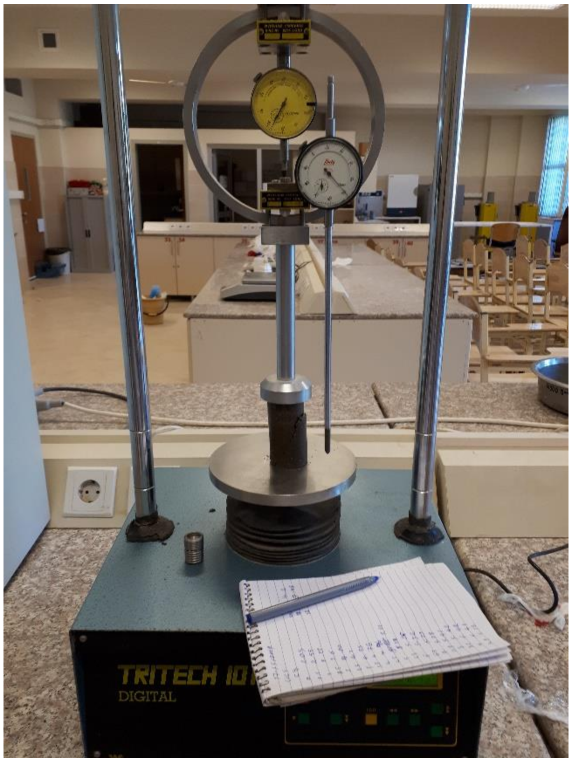

Figure 12. Unconfined Compressive Strength Test.

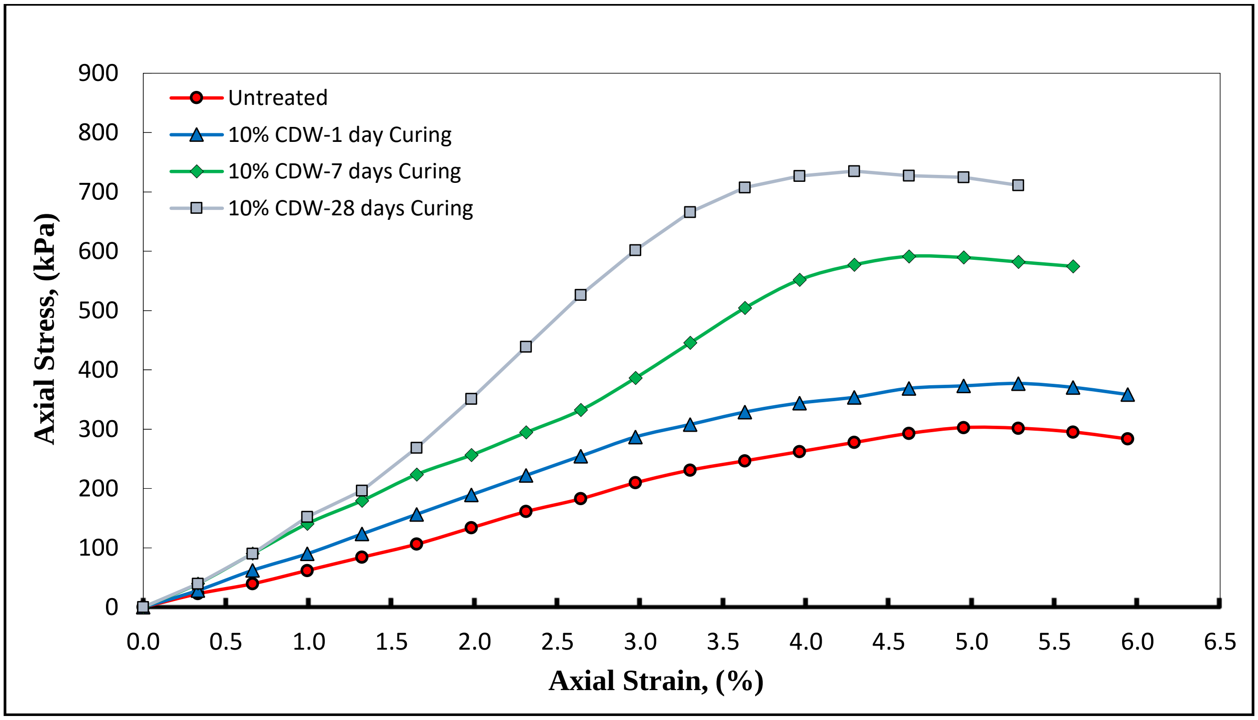

Figure 13. Variation of the UCS with 10% CDW, for 1, 7 and 28 days curing durations.

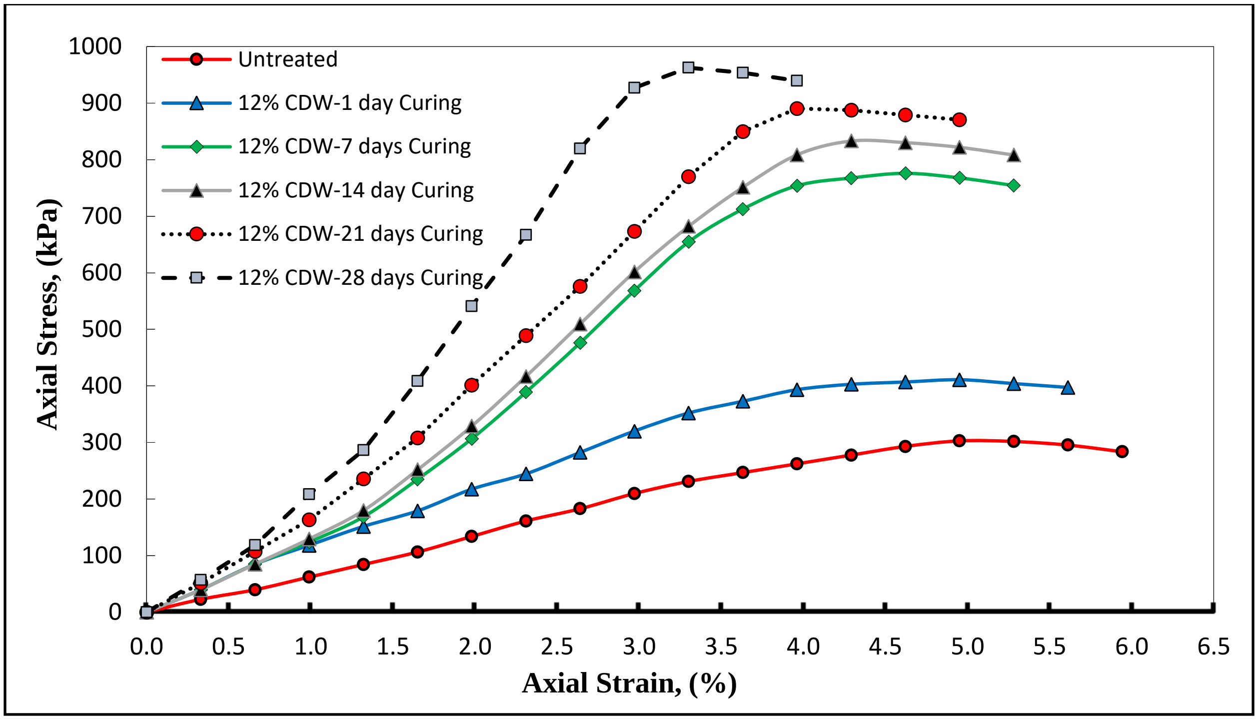

Figure 14. Variation of the UCS with 12% CDW, for 1, 7, 14, 21 and 28 days curing durations.

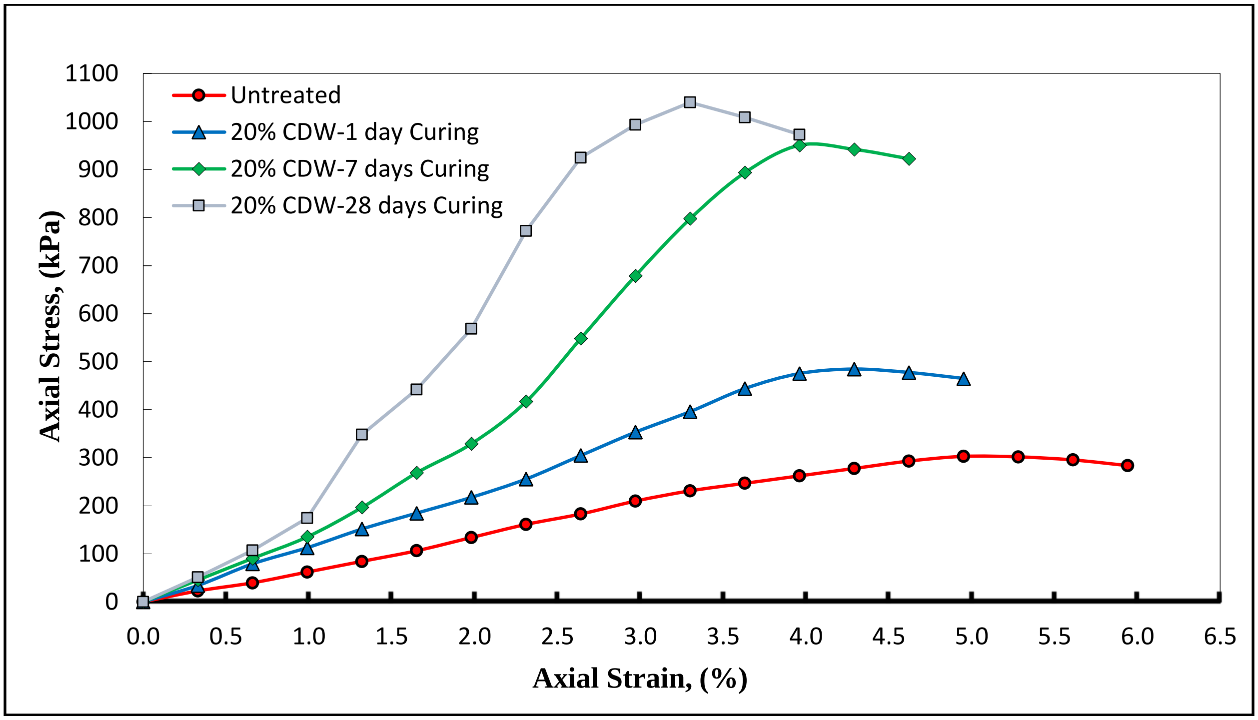

Figure 15. Variation of the UCS with 20% CDW, for 1, 7 and 28 days curing durations.

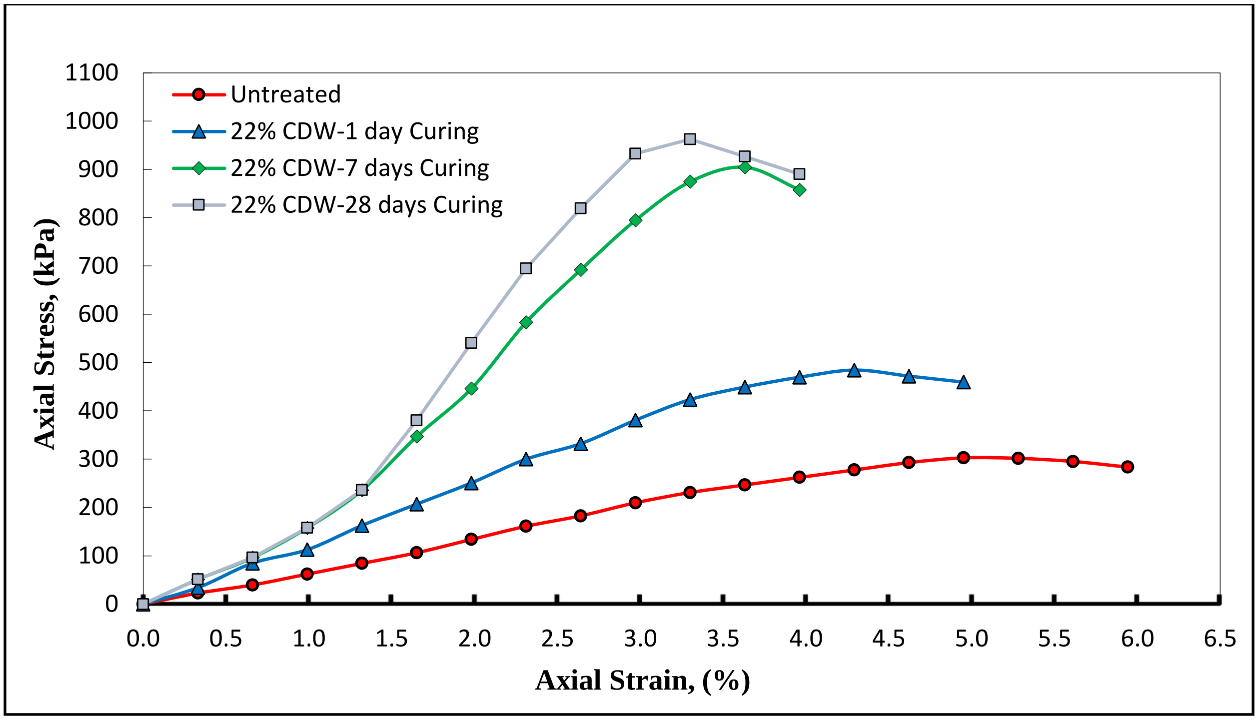

Figure 16. Variation of the UCS with 22% CDW, for 1, 7 and 28 days curing durations.

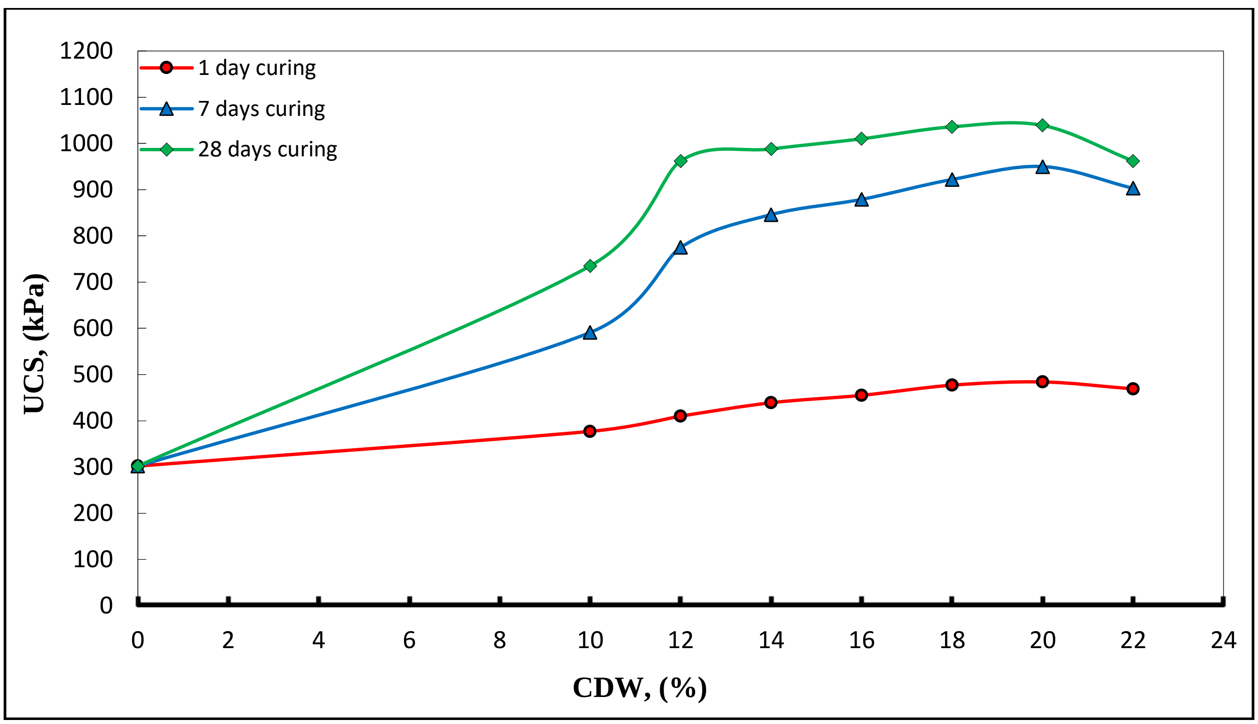

Figure 17. Variation of the UCS with CDW.

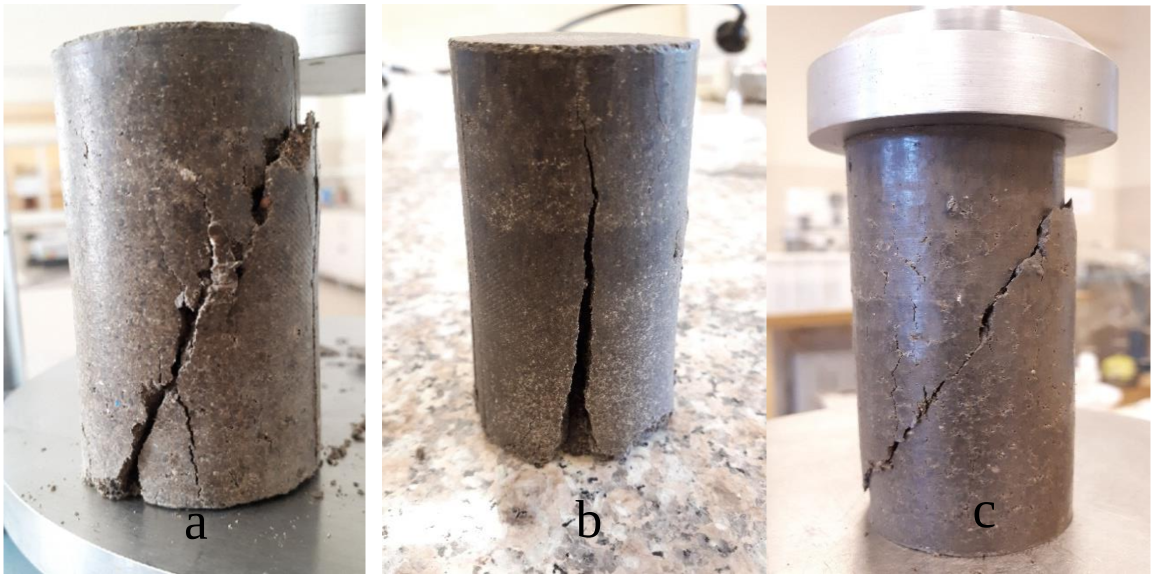

Figure 18. Specimen failure mechanism **a** Natural soil, **b** Treated soil with 12% CDW **c** Treated soil with 22% of CDW.

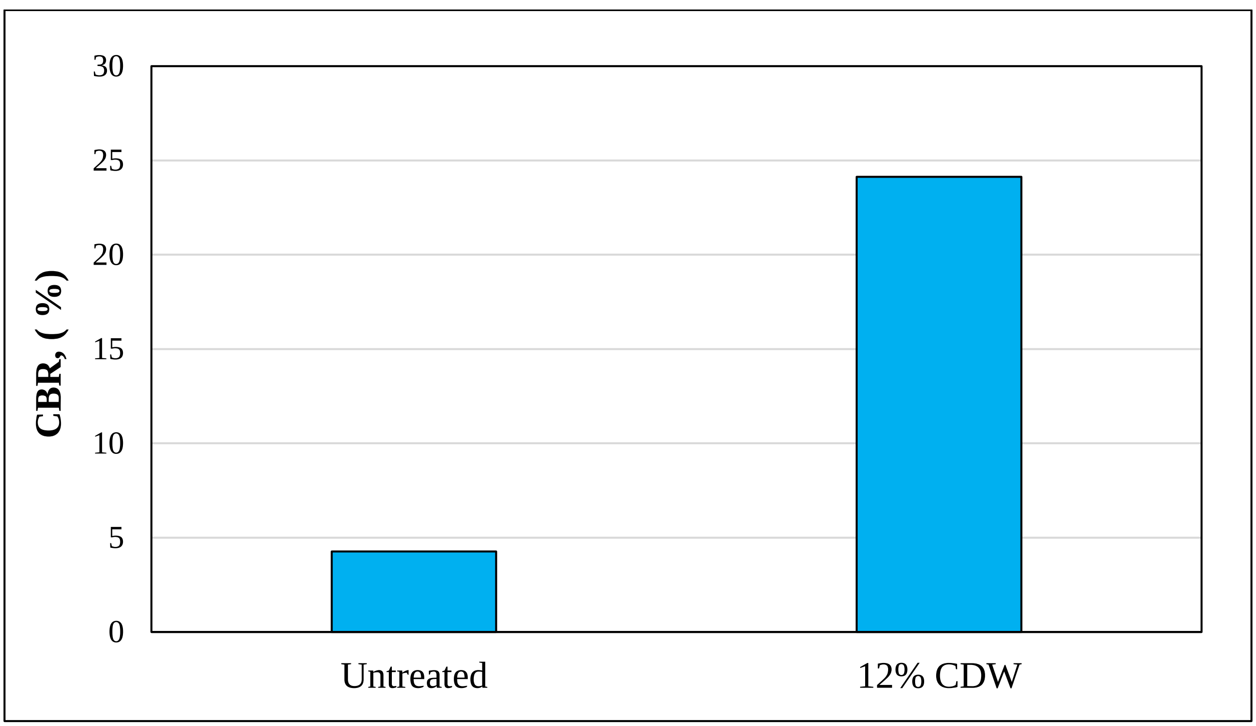

Figure 19. Variation of CBR value for untreated soil and stabilized soil with 12% CDW.

REFERENCES

- Abdulrasool, A.S., 2015. Strength Improvement of Clay Soil by Using Stone Powder. *Journal of Engineering*, *21*(5), pp.72-84.

- Agrela, F., Barbudo, A., Ramírez, A., Ayuso, J., Carvajal, M.D., and Jiménez, J.R., 2012. Construction of road sections using mixed recycled aggregates treated with cement in Malaga, Spain. *Resources, Conservation and Recycling*, *58*, pp.98-106.

- Ahmed, M.D. and Adkel, A.M., 2017. Stabilization of Clay Soil Using Tyre Ash. *Journal of Engineering*, *23*(6), pp.34-51.

- Ahmed, M.D. and Hamza, N.A., 2015. Effect of metakaolin on the geotechnical properties of expansive Soil. *Journal of Engineering*, *21*(12), pp.29-45.

- Ali, F.H., Adnan, A. and Choy, C.K., 1992. Geotechnical properties of a chemically stabilized soil from Malaysia with rice husk ash as an additive. *Geotechnical & Geological Engineering*, *10*(2), pp.117-134.

- Al-Rawas, A.A., Hago, A.W. and Al-Sarmi, H., 2005. Effect of lime, cement, and Sarooj (artificial pozzolan) on the swelling potential of an expansive soil from Oman. *Building and Environment*, *40*(5), pp.681-687.Ayub,

- Bell, F.G., 1996. Lime stabilization of clay minerals and soils. *Engineering Geology*, *42*(4), pp.223-237.

- Chen, H. and Wang, Q., 2006. The behaviour of organic matter in the process of soft soil stabilization using cement. *Bulletin of Engineering Geology and the Environment*, *65*(4), pp.445-448.

- Cokca, E., 2001. Use of class c fly ashes for the stabilization of expansive soil. *Journal of Geotechnical and Geoenvironmental Engineering*, *127*(7), pp.568-573.

- Dang, L.C., Fatahi, B. and Khabbaz, H., 2016. Behaviour of expansive soils stabilized with hydrated lime and bagasse fibers. *Procedia Engineering*, *143*, pp.658-665

- Fityus, S. and Buzzi, O., 2009. The place of expansive clays in the framework of unsaturated soil mechanics. *Applied Clay Science*, *43*(2), pp.150-155.

- Hasan, U., Chegenizadeh, A., Budihardjo, M.A. and Nikraz, H., 2016. Experimental evaluation of construction waste and ground granulated blast furnace slag as alternative soil stabilisers. *Geotechnical and Geological Engineering*, *34*(6), pp.1707-1722.

- Hidalgo, C., Carvajal, G. and Muñoz, F., 2019. Laboratory Evaluation of Finely Milled Brick Debris as a Soil Stabilizer. *Sustainability*, *11*(4), p.967.

- Huang, R. and Lizhou, W.U., 2007. Stability analysis of unsaturated expansive soil slope. *Earth Science Frontiers*, *14*(6), pp.129-133.
- Kerni, V., Sonthwal, V.K. and Jan, U., 2015. Review on stabilization of clayey soil using fines obtained from demolished concrete structures. *Int J Innov Res Sci Eng Technol*, *4*(5), pp.296-299.

- Nalbantoglu, Z. and Gucbilmez, E., 2001. Improvement of calcareous expansive soils in semi-arid environments. *Journal of arid environments*, *47*(4), pp.453-463.

- Paul, H. and Cyrus, S., 2016. Stabilisation of Weak Subgrade Soil Using Demolished Concrete Aggregate. In *Indian Geotech Conf* (pp. 1-5).

- Ransinchung, R.N.G.D., Kumar, P. and Sharma, P., 2012. Stabilization of clayey soil with fines from waste crushed concrete cubes for construction of pavements. In *Proceedings of the international conference on engineering and information technology (ICEIT), Toronto, Canada* (pp. 24-28).

- Ravikanth, Y., Tejaram, B., Pradesh, A., Rahul, B.G. and Pradesh, A., 2017. Stabilisation of Debris Material by Using Soil. *Int J Civ Eng Technol [Internet]*, *8*(4), pp.2125-31.

- Sabtan, A.A., 2005. Geotechnical properties of expansive clay shale in Tabuk, Saudi Arabia. *Journal of Asian Earth Sciences*, *25*(5), pp.747-757.

- Sharma, R.K. and Hymavathi, J., 2016. Effect of fly ash, construction demolition waste and lime on geotechnical characteristics of a clayey soil: a comparative study. *Environmental Earth Sciences*, *75*(5), p.377.

- Varaprasad, B.J.S., Reddy, J.J., Rajesh, T., Kumar, Y.Y. and Reddy, K.R.M., Soil Improvement by Fine Fraction Residue from Recycling Construction and Demolition Wast