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Research Article

Effect of sodium silicate and cement on the improvement of engineering properties of organic soil

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Abstract: The study is aimed at evaluating the effect of adding sodium silicate and cement to organic soil. Geotechnical properties of organic soil are determined before and after the addition of the stabilizing materials, which in this case are cement and sodium silicate. The results obtained after treatment were analyzed and evaluated to determine whether the strength values reached are adequate for strong subgrades for pavement, and airports construction. Organic soil samples used in this study were obtained from Kayseri Free Area in Turkey. Index properties and geotechnical properties of organic soil, which was identified as sample P, were determined and this formed the reference upon which strength improvements of each mix design sample were obtained. Optimum moisture content and maximum dry density of the soil and the various mixes were obtained using standard proctor test. Unconfined compressive tests (UCS), California bearing ratio (CBR), and Falling head permeability tests were used to determine geotechnical properties. UCS tests were conducted on air cured samples for 1, 7, and 28 days. Soaked and unsoaked CBR samples were tested after 1, 7 and 28 days. Hydraulic conductivity was determined using the falling head permeability test. From the experiments, sodium silicate and cement were seen to improve the strength of organic soil and provide acceptable subgrade strength and CBR values. CBR and UCS tests indicated that longer curing periods improved strength even more. Higher values were obtained for 7 days cured samples than for 1-day samples with the highest values being obtained for 28 days cured samples. Design mixes with higher cement and sodium silicate compositions gave the highest values of strength. In conclusion, sodium silicate and cement give positive results when it comes to stabilizing organic soil.

Keywords: Organic soil, sodium silicate, cement, UCS, CBR, hydraulic conductivity.

1. Introduction

With an increasing demand for infrastructural development, soil improvement has become a major area of focus to help curb the high demand for good and strong foundations which is becoming less with each passing day. Construction of safe and durable pavements, airports and railroads among others is also very critical in our modern world (Parsons & Milburn, 2003). Any effort to try and improve the engineering properties of problematic soils can be termed soil stabilization or soil improvement (Firoozi, Guney Olgun, Firoozi, & Baghini, 2017). This study concentrates on the stabilization of organic soil by adding materials to it, which are cement and sodium silicate.

Organic soils cover a large surface area in the world, approximating about 2% of the surface of the earth that is not covered by ice. Almost all states in the United States of America and all provinces in Canada have some regions covered with organic soil (Hatfield, Sauer, & Prueger, 2004). Most countries in Europe, including Switzerland, Netherlands, and Germany, have utilized most of their organic soils, with others still studying and continuing with stabilization and improvement strategies (Xu, Morris, Liu, & Holden, 2018). According to Akova, (Akova, 2011), organic soil coverage in Turkey is approximately 25% based on land with suitable organic soil that can be utilized for agriculture. As a result, engineers are always figuring out how to make these places appropriate for engineering. Improved technology has brought tremendous success in soil improvement techniques. There are modern soil testing laboratories that have aided in ensuring that weak soils are identified, improved, and tested accordingly to ensure safe and efficient construction and infrastructural development.

According to Ibrahim et al. (Ibrahim, Cabalar, & Abdulnafaa, 2018), soils that contain some undecomposed plant remains are termed organic soils. The main contributing factor to their formation is the presence of water and the most favorable climate for organic soil formation is a humid and cool forested area (Ma, Zhao, Long, Sang, & Xie, 2018) (Nowak & Kanty, 2019). The presence of remains from plants or plant roots makes organic soils highly compressible, and it increases their water content (ElMouchi, Siddiqua, Wijewickreme, & Polinder, 2021). These soils are associated with very low strength capacities and high settlements that result from consolidation (Dehghanbanadaki et al., 2017; Kazemian, Prasad, Huat, Ghiasi, & Ghareh, 2012) (Pan, Xie, Gen, & Wang, 2020). When the organic content in the soil exceeds 25%, the soil is usually referred to as organic soil. Soils with more than 75% organic matter are termed peats (Kazemian et al., 2012).

Sodium silicate has been investigated and found to be effective when it comes to the treatment of weak soils. Sodium silicate is usually found mostly in the form of white powder which can dissolve in water readily. It can also be found in the form of glass solids or colorless solids which form alkaline solutions when they come into contact with water (Moayedi, Asadi, Huat, Moayedi, & Kazemian, 2011). Sodium silicate is obtained from mixing water, caustic soda, silica, and very hot steam in a reacting chamber. It can also be obtained from sodium carbonate or sodium sulfate through different chemical reactions.

Cement has widely been used in the engineering sector as a construction material in making concrete, mortar, and plaster among others. Cement has also been among the most effective and widely used materials when it comes to the stabilization of soil. It has been applied across all ranges of weak soils such as clay soil, black cotton soils, and organic soils among others. Cement has been utilized mostly as a binder and it has been proven to improve the engineering properties of soils (Prusinski & Bhattacharja, 1998) (Binh & Quynh, 2021; Zhu, Zhang, Zhang, & Hui, 2018). With the cost of cement being quite high and other stabilizing materials being discovered, cement has been used in presence of other materials to lower the amount of cement required and help improve on other geotechnical properties that cement alone cannot effectively improve.

With many soil improvement studies focusing on clay soils and others on other treatment methods such as grouting, a considerable gap in organic soil treatment has been left. This research paper has focused on using different mixes of cement and sodium silicate to help improve subgrade materials that are composed of organic soil. The available literature has proven that cement and sodium silicate are suitable materials in treating organic soils even though they have been used in the presence of other materials and different forms. In most existing studies, these two components have been used in the presence of other materials or terms of a grout system. This research focused on the different dry mixes of the two materials plus organic soil and their effect on strength, soaked and unsoaked California Bearing Ratio (CBR) values, permeability, and moisture content. The improvement was evaluated in terms of Atterberg limits, Unconfined Compressive Strength, CBR values for both soaked as well as unsoaked state, and hydraulic conductivity (k).

2. Materials and methods

2.1. Material properties

2.1.1. Organic soil

Organic soil used for this study was obtained from the Kayseri Free Area in Kayseri, Turkey. From inspecting the soil visually, the color of organic soil was found to range from dark brown to black. Wet sieving was used in grain size analysis with sieve analysis and hydrometer test aiding in determining the grain size distribution. The distribution is presented in Figure 1. The natural moisture content of the soil was found to be 302.1% with a specific gravity of 1.88. To determine the amount of ash, organic soil was burned in a muffle furnace at 4400C. An average of 68.27% of ash content was obtained. The organic content of soil determined by subtracting ash content percentage from 100 was 31.73%. When the organic content in the soil exceeds 25%, the soil is usually referred to as organic soil. Soils with more than 75% organic matter are termed peats (Moayedi et al., 2011). In the determination of liquid limit, the cone penetrometer method was preferred since the Casagrande method is not effective for soils with low plasticity (Jain, Gandhi, Trivedi, & Shukla, 2021). Additionally, the cone penetrometer is a static method and therefore more effective. Maximum dry density (MDD) and optimum moisture content (OMC) were determined using the standard proctor test. The index properties of organic soil are given in Table 1.

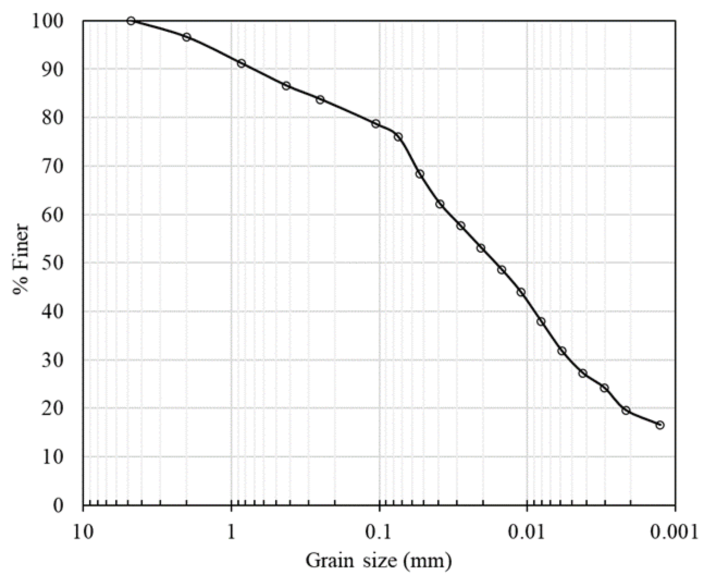

Figure 1. Grain size distribution of organic soil.

Table 1. Properties of organic soil.

Organic soil	Test standard	Test results
Organic content (OC), (%)	ASTM D2974	31.73
Ash content, (%)	ASTM D2974	68.27
Specific gravity (G_s)	ASTM D854	1.88
Natural moisture content (%)	ASTM D2216	302.1
Liquid limit (%), LL	ASTM D3441	138.6
Plastic limit (%), PL	ASTM D4318-17	89.1
Plasticity index (%), PI	-	49.5
Maximum dry unit weight (kN/m^3)	ASTM D698	6.21
Optimum water content (%)	ASTM D698	78.0

2.1.2. Sodium silicate

Sodium silicate was used as an additive to help curb the high moisture content problem (Wattez, Patapy, Frouin, Waligora, & Cyr, 2021). The sodium silicate presented in this paper was in a viscous liquid form. Two aqueous liquids that make sodium silicate are silicon dioxide and sodium oxide (Nigussie, 2011). Sodium silicate liquid has no color and no distinguishable smell. It has a slippery touch and when left in the open air, it dries and forms a glass-like material. Liquid sodium silicate is usually produced by mixing soda ash and silica of high purity levels under very high pressure with steam and very hot water usually in hearth furnaces.

2.1.3. Cement

Ordinary Portland Cement was used as the main binding agent. Cement is the most widely used material when it comes to soil stabilization. It is usually composed of; calcium oxide in percentages ranging from 60 – 67, aluminum oxide from 3% to 8%, silicon dioxide which ranges from 17% – 25%, iron oxide in percentages of 0.5 to 6, and other materials including soda, magnesium oxide, Sulphur trioxide and potash in proportions of less than 4% (Janz & Johansson, 2002).

2.2. Experimental methods

Samples were prepared by mixing different percentages of cement and sodium silicate with organic soil. The percentage by mass of dry organic soil was used to replace the soil. Four different samples were prepared with different cement and sodium silicate compositions. Three samples were used where applicable, and an average value was obtained. Tests on plain organic soil were also conducted where necessary to obtain the reference point, better comparisons, and easier track of behavioral change with different compositions. Sample compositions are presented in Table 2.

Table 2. Sample compositions.

No	Sample abbreviation	Sodium silicate, %	Cement, %	Organic soil, (OS)
1	P	N/A	N/A	OS
2	A	3	10	OS
3	B	3	20	OS
4	C	6	10	OS
5	D	6	20	OS

2.2.1. Compaction tests

For all the design mixes, standard compaction tests were conducted as per ASTM D698 to determine maximum dry density and optimum moisture content. Values of MDD and OMC obtained were subsequently used in unconfined compression tests and California bearing ratio tests. Organic soil was oven dried at 80^0C before the test commenced (Brendan & O'Kelly, 2005). Soil materials passing sieve No. 4 were used. A standard proctor mold of 4 inches diameter and 4.584 inches height was utilized for these tests. Compaction tests were conducted for all the samples prepared. Graphs of dry unit weight versus moisture content were drawn and the peak values were read to obtain the MDD and OMC.

2.2.2. UCS tests

This test is essential as it helps determine the bearing capacity of a given soil. To determine the strength gains of the stabilized soil, the UCS test is very crucial. For slopes and foundations where the rate of drainage is slow and loading takes place fast, UCS test results help to determine the stability for a short time. This test was performed as per ASTM D2166 standard (ASTM 2166, 2013). Samples were prepared with a height of 116.4 mm and 101.6 mm in diameter. The stabilized soil was tested to confirm the highest reached undrained shear strength and unconfined compressive strength after treatment.

During treatment and curing, the samples were sealed in plastic bags to prevent loss of moisture. Samples tested for UCS were treated for 1, 7, and 28 days with a rate of strain of 2.0 mm/minute.

2.2.3. CBR tests

The test is most of the time used to determine if certain soils and other underlying materials have adequate strength to serve as subgrade or subbase material in the construction of pavements, airports, and railroads, among others. CBR tests conducted followed the ASTM D1883 standards (D1883 ASTM, 2005). Dry and wet cured samples were tested after a curing period of 1, 7, and 28 days with 1.27 mm/min strain rate. Unsoaked samples were moisture sealed. Swelling on soaked samples was also determined. This test was conducted on the soil samples to see how cement and sodium silicate influenced CBR values and if the CBR values reached the acceptable level in accordance with road design standards. After the soil and the stabilizing materials have been prepared, tested, and results obtained, analysis was conducted to evaluate the validity of the results and to also determine how the stabilizing materials affect the behavior of the organic soil.

2.2.4. Falling head permeability tests

Organic soil being a fine-grained soil, the falling head permeability test method was used to determine its hydraulic conductivity. Permeability of soil is important to engineers and most specifically geotechnical engineers as it helps in predictions of compaction, erosion, water retention potential, and flooding among others. The permeability test was conducted as per the ASTM 2434 which gives the constant head standards that were adjusted to have a falling head rather than a constant head with the same equipment being utilized. Permeability of different soil mixes was also determined to have a comparison of how the different treatment materials affected permeability.

3. Experimental results and analysis

3.1. Compaction tests

Results from standard proctor tests conducted on all samples are presented in Table 3. Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) values were determined for all design mix samples. Sample P, which is organic soil with nothing added to it, can be seen to have an OMC of 78% and dry density of 6.21kN/m^3.

Sample A, which was designed to compose of 3% sodium silicate and 10% cement was found to have 76% optimum moisture content and 6.39kN/m3 dry density. Sample B with the same sodium silicate composition of 3% and 50% more cement than sample A has an OMC of 68% and MDD of 7.32kN/m^3. Sample C and D are composed of 50% more sodium silicate than sample A and B. The MDD and OMC of sample C, which had the same cement composition as sample A of 10% and 6% sodium silicate, was found to be 6.67kN/m^3 and 75% respectively. Sample D, which had the highest composition of both sodium silicate and cement of 6% and 20% respectively had the lowest OMC of 65% and highest MDD of 7.63kN//m^3.

Comparing samples 'A and C' and 'B and D', which had the same amount of cement but varying sodium silicate composition, it can be observed from Figure 2 that Sample C had slightly higher MDD values and slightly lower OMC values compared to sample A. Additionally, sample B had lower MDD values and higher OMC values compared to sample D. This shows that sodium silicate helps in increasing dry density and lowering optimum moisture content. This agrees with studies conducted by Kazemian et al., (2012), where sodium silicate in varying percentages of 1 to 5 were added to tropical organic soils. For some of the samples, moisture content was lowered from approximately 170% to less than 100%. Sodium silicate of 3% was found to be the most effective in lowering the moisture content of the organic soil.

Sample 'A and B', and 'C and D' had the same sodium silicate compositions but different cement compositions. Samples with a higher cement composition showed up to 15% reduction in OMC and approximately 14% increment in MDD. In the study by Kazemian et al., (2012), effects of adding cement to tropical organic soils were also examined. Cement percentages of 10 to 30 were used. The higher the cement content, the lower the moisture content and consequently the OMC. 30% cement content had the lowest moisture content and highest MDD.

Both cement and sodium silicate were seen to increase the MDD and lower the OMC. The effect of cement in lowering the OMC and increasing the MDD was observed to be much stronger than that of sodium silicate. Different organic soil stabilization studies have also come up with the same conclusion that cement has a much higher effect than other stabilizers including fly ash, phosphogypsum and calcium chloride among others (Degirmenci, Okucu, & Turabi, 2007; Kazemian et al., 2012).

Table 3. MDD and OMC for soil and mix.

Material designation	OMC (%)	γ_{dmax} (kN/m^3)
Sample P – organic soil	78.0	6.21
Sample A- Soil + 3% Na_2SiO_3+ 10% Cement	76.0	6.39
Sample B-Soil + 3% Na_2SiO_3+ 20% Cement	68.0	7.32
Sample C-Soil + 6% Na_2SiO_3+ 10% Cement	75.0	6.67
Sample D- Soil + 6% Na_2SiO_3+ 20% Cement	65.0	7.63

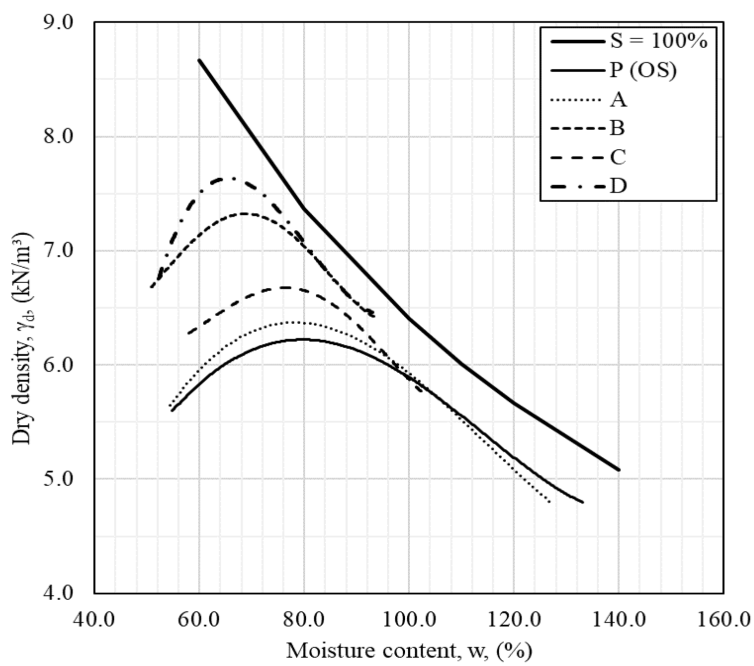

Figure 2. The MDD-OMC relationship for the different soil mixes.

3.2. UCS tests

The MDD and OMC obtained from compaction tests were utilized while preparing samples for Unconfined Compression Test (UCS). From this test, unconfined compressive strengths (q_u) of organic soil and the other soil mixtures were determined. 1-, 7-, and 28-days curing period was applied to all soil mixtures.

Samples B and D which had 20% cement showed higher q_u values than samples A and B which had 10% cement. Unconfined compressive strength of B and D were found to be approximately double the values obtained for A and C. Additionally, as the curing period increased, the unconfined compressive strength increased. The UCS test results are presented in Table 4, Figure 3, Figure 4, Figure 5, Figure 6, and Figure 7.

Table 4. UCS test results.

	P (untreated soil)	A - 3% Na2SiO3+ 10% Ce +OS	B- 3% Na2SiO3+ 20% Ce +OS	C- 6% Na2SiO3+ 10% Ce +OS	D- 6% Na2SiO3+ 20% Ce +OS
UCS - 1 D (kPa)	112.51	141.67	287.13	150.53	291.91
UCS - 7 D (kPa)	-	181.4	421.63	205.21	447.18
UCS - 28D (kPa)	-	200.1	529.47	235.61	647.04

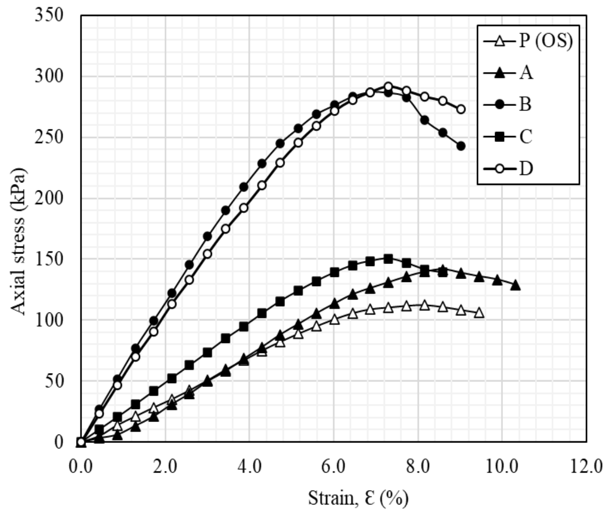

Figure 3. Stress vs. axial strain for all samples for 1 day.

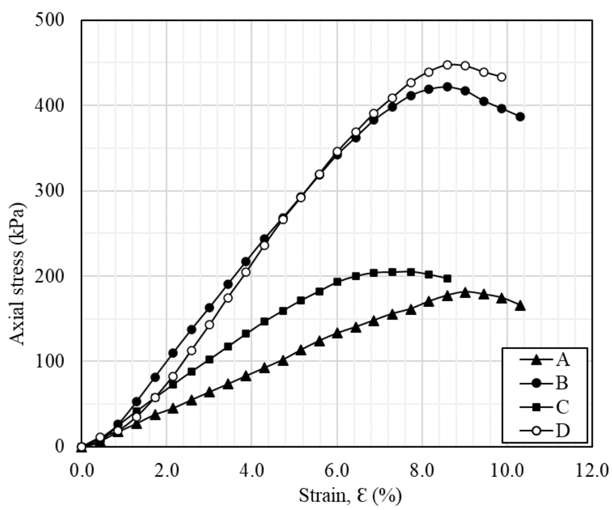

Figure 4. Stress vs. axial strain for all samples for 7 days.

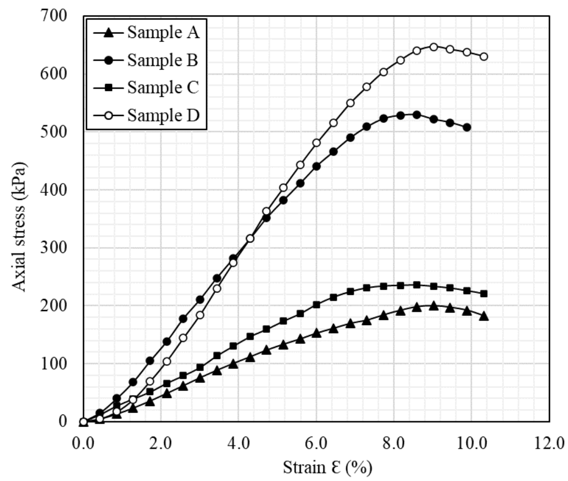

Figure 5. Stress vs. axial strain for all samples for 28 days.

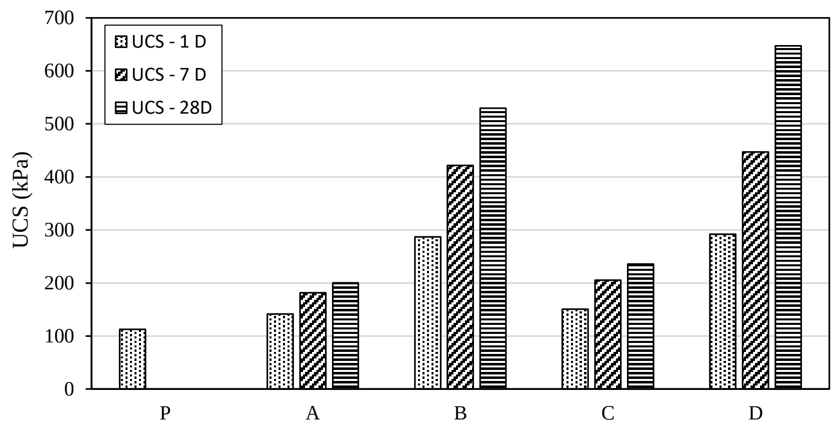

Figure 6. Influence of curing period on UCS values of different samples.

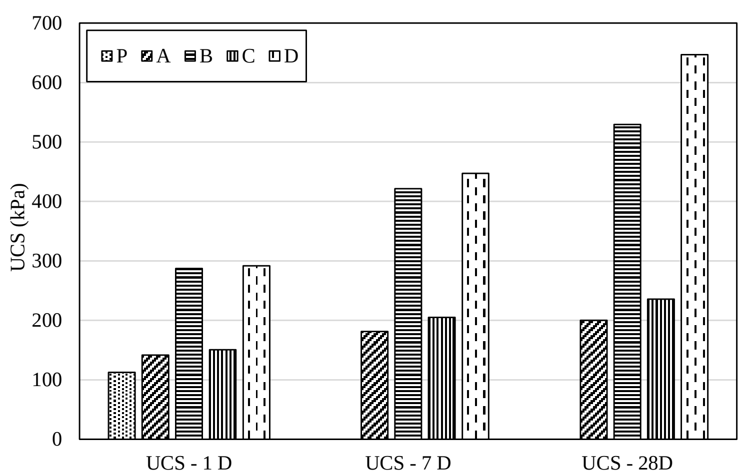

Figure 7. Comparison of UCS values for the different samples.

The untreated sample had a UCS value of 112.51 kPa which increased by approximately 26% when the sodium silicate was increased by 3% and approximately 160% when 20% cement was added. Increasing cement by 50% increased the UCS values by approximately 94%. Untreated soil had the lowest UCS values while organic soil with 20% cement and 6% sodium silicate had the highest UCS values.

Figures 3, 4, and 5 show the UCS values for 1 day, 7 days, and 28 days respectively. From the graphs, it can be seen that samples with high cement composition have the highest UCS values. Both sodium silicate and cement influence unconfined compressive strength. Doubling the amount of sodium silicate while maintaining the amount of cement showed an increase in UCS values. Similarly, doubling the amount of cement while maintaining the same amount for sodium silicate showed increments in UCS values. However, the influence of cement is much higher than that of sodium silicate. Chen and Wang (2006) also found that cement improved the strength of organic soil. Although their study involved addition of admixtures, strength values of >90 kPa for the treated soil mixture were observed. They concluded that organic matter had a greater role to play as it helped in retaining moisture needed for hydration process and therefore contributed significantly to the strength increase of soil-cement mixture.

An increase in the curing period was observed to also increase UCS values of all the samples. Binh and Quynh (Binh & Quynh, 2021) also found that an increase in the curing period had a positive influence on the UCS of soil. A study conducted by Lu, Cui, Wang, & Li, (2018) also highlighted the effect of curing period on strength gain. When the same amount of cement was added to the soil and different curing periods allowed, 28-day cured samples had more than 50% increase in strength than 7-day cured samples.

Samples A and C which had the same amount of cement had an increase of 28% and 36% when the curing period was increased from 1 to 7 days. Sample C, which had 50% more sodium silicate than the sample had a slightly higher UCS than sample B. Samples B and D with 20% cement showed approximately 50% increase in UCS when the curing period was increased from 1 to 7 days.

For all samples excluding sample D, UCS increased 50% more when the curing time was increased from 1 to 7 days than when it was increased from 7 to 28 days. Samples with 20% cement showed more increase when the curing period was increased. The increase in UCS with curing time is important as it signifies that there will be long-term performance of the pavements subgrade system and that strength is bound to increase with time (Parsons & Milburn, 2003; Zhang, Little, Grajales, You, & Kim, 2017).

From Figures 6 and 7 it can be depicted that curing time has a huge influence on unconfined compressive strength. Values obtained after a 28-day curing period were higher than values obtained between 7 days and 1 day. Correspondingly, 7 days cured samples had higher UCS values than 1-day cured samples which proves that curing time has a significant influence on the strength gain of stabilized soil (Latifi, Eisazadeh, Marto, & Meehan, 2017) (Ghadir & Ranjbar, 2018).

3.3. CBR tests

Soaked and unsoaked CBR tests were conducted and cured for 1 day, 7 days, and 28 days. For the preparation of all CBR samples, dry density values and optimum moisture content values obtained from the compaction test were applied. The swelling was also determined for all soaked CBR samples. CBR results are presented in Table 5.

For both soaked and unsoaked samples when the curing period was increased from 1 to 7 days, the CBR values increased more than 100%. From 7 to 28 days, the percent increase of CBR ranged from approximately 20% - 60%. It was depicted that the rate of CBR increase in the first 7 days was much higher than that of 7 to 28 days.

CBR values were observed to increase with an increase in the curing period as depicted in Figures 8 and 9. Unsoaked and soaked CBR values are highest at 28 days and lowest at 1 day for all samples. Sample D, which has the highest cement and sodium silicate, has the highest CBR values in all categories. Sample B, which has the same cement percentage as D and 50% of sample D's sodium silicate, helps demonstrate the effect of sodium silicate.

Table 5. Unsoaked and soaked CBR and swell values.

Material Designation	1 Day CBR (%)			7 Days CBR (%)			28 Days CBR (%)		
	Unsoaked	Soaked	Swell (%)	Unsoaked	Soaked	Swell (%)	Unsoaked	Soaked	Swell (%)
P - Untreated soil	6.10	3.20	1.41	-	-	-	-	-	-
A- 3% Na_2SiO_3 + 10% Ce +OS	21.44	10.07	1.02	31.46	24.73	1.20	41.28	34.95	1.23
B- 3% Na_2SiO_3 + 20% Ce +OS	33.75	22.13	0.96	72.93	55.43	0.65	89.43	74.73	0.45
C- 6% Na_2SiO_3 + 10% Ce +OS	15.25	10.07	1.10	34.2	20.99	0.98	49.60	38.54	0.91
D- 6% Na_2SiO_3 + 20% Ce +OS	49.20	44.87	0.73	86.54	56.58	0.44	104.17	80.65	0.21

Comparing sample, A for 1, 7, and 28 days, the unsoaked CBR values were approximately 100%, 29%, and 20% more than the soaked CBR values respectively. The percent increase of unsoaked values of sample B ranged from 20% to 45% when compared to soaked values, while those of sample C ranged from 26% - 50%. For sample D, soaked CBR samples were around 24% less than unsoaked samples.

Figure 10 gives a clear comparison between soaked and unsoaked CBR values. All treated samples gave CBR values that are deemed adequate for pavement construction. Unsoaked CBR samples have higher values when compared to soaked CBR. This is in agreement with Akula, Naik, & Little, (2021) who concluded that presence of excess water molecules in the pozzolanic reaction environment affects strength gain. Soaked CBR is conducted to demonstrate the presence and effect of water and water load on pavements (Kalantari, 2011).

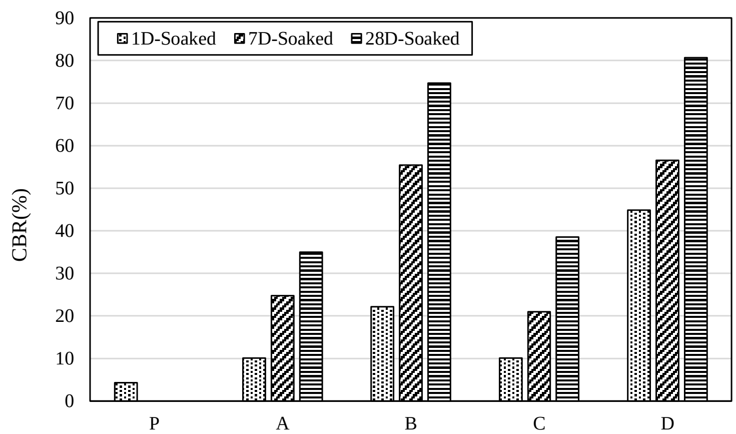

Figure 8. Soaked CBR for all samples for 1 day, 7 days and 28 days.

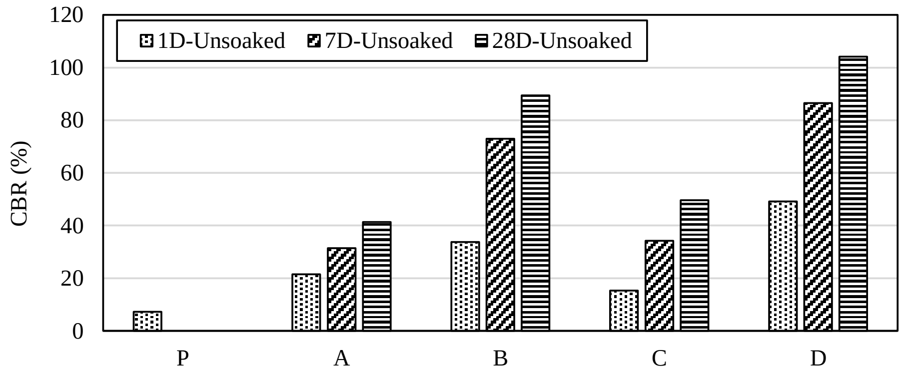

Figure 9. Unsoaked CBR for all samples for 1 day, 7 days and 28 days.

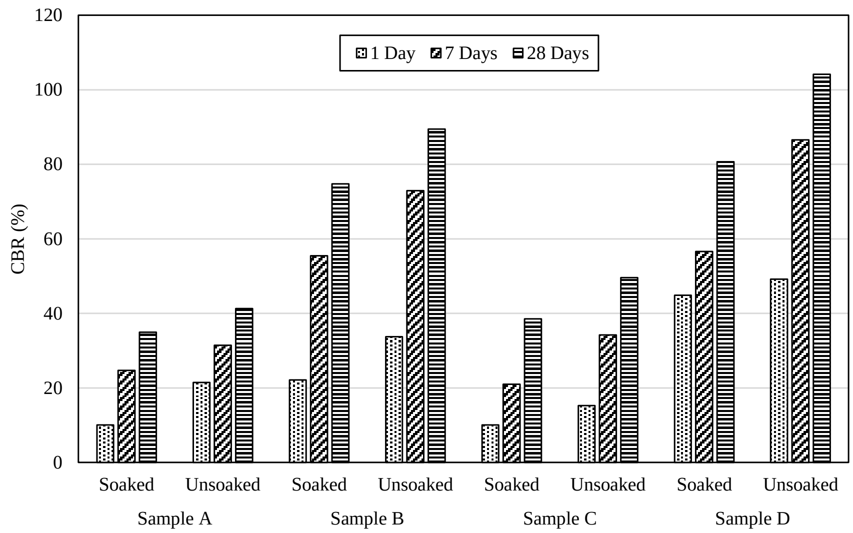

Figure 10. Soaked and unsoaked CBR for all samples for 1 day, 7 days, and 28 days.

3.4. Falling head permeability tests

All samples for these tests had a standard size of 10cm in diameter and 11.5 cm in height. All samples were tested two hours after preparation. They were all prepared using MDD and OMC values obtained from standard proctor tests. Hydraulic conductivity (k) values of the different samples are presented in Table 6 below.

Table 6. Hydraulic conductivity values.

Material designation	Hydraulic conductivity, k (cm/s)
P- organic soil	$5.24x10^{-6}$
A- 3% Na_2SiO_3 + 10% Ce +OS	$4.99x10^{-6}$
B- 3% Na_2SiO_3 + 20% Ce +OS	$5.79x10^{-7}$
C- 6% Na_2SiO_3 + 10% Ce +OS	$4.44x10^{-6}$
D- 6% Na_2SiO_3 + 20% Ce +OS	$3.89x10^{-7}$

Samples A and C which had 10% cement composition had 5% and 18% less hydraulic values when compared to untreated soil. The effect of sodium silicate can be evident as C had 50% more sodium silicate and the percent reduction is higher than that of sample A. Samples B and D had much lower permeability values as they had the highest cement composition of 20%.

All treated samples showed a decrease in permeability when compared to the untreated organic soil sample. In pavement construction, it is significant that permeability is kept to the very minimum as water has a negative effect on the durability and bearing capacity of the pavement (Lewis, Jared, Torres, & Mathews, 2006). Samples B and D which had 50% more cement composition than samples A and C are observed to have the least hydraulic conductivity values. This observation agrees with the available literature in that increase in cement reduces permeability (Diana, Hartono, & Muntohar, 2019).

Sample C which had the same amount of cement as sample A but 50% more sodium silicate also shows lower permeability than A. Additionally, both sample B and sample D had 20% cement composition but sample B had 50% less sodium silicate and lower permeability values were observed for D when compared to B. Addition of sodium silicate also reduces hydraulic conductivity values significantly (Avci, Deveci, & Gokce, 2021).

4. Conclusions and comments

From the study, the following conclusions were drawn.

1. Maximum dry density (MDD) values were seen to increase, and optimum moisture content (OMC) values decreased as the amount of cement and sodium silicate increased.
2. UCS values increased with the curing period as well as with an increase in the amount of sodium silicate and cement. Increasing cement by 50%, increased the UCS by approximately 95% while increasing sodium silicate by the same 50% increased the UCS by approximately 15%.
3. Unsoaked samples gave higher CBR values when compared to soaked samples. Overall, CBR values increased with an increase in the amount of stabilizing agent as well as with the treatment period.
4. Cement had a much stronger effect on improving the geotechnical properties of organic soil as compared to sodium silicate. Using cement and sodium silicate improved the overall strength of organic soil than if the two stabilizing agents had been used on their own.
5. Both cement and sodium silicate were seen to reduce the permeability of organic soil. Cement had a much stronger effect than sodium silicate. A 50% increase in cement was observed to reduce the permeability of soil by approximately 15%.
6. 6% sodium silicate and 20% cement composition were found to give the best stabilization results in terms of UCS, CBR, and permeability.
7. Cement and sodium silicate are effective materials for organic soil stabilization and subgrade strength improvements.

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