Investigation on Improving the Geotechnical Properties of Black cotton soil by Blending with Pumice.
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ABSTRACT

Soil stabilization is the process of improving the shear strength parameters of soil and thus increasing the bearing capacity of soil. It is required when the soil available for construction is not suitable to carry structural load. Soils exhibit generally undesirable engineering properties. Soil Stabilization is the alteration of soils to enhance their physical properties.

Stabilization can increase the shear strength of a soil and/or control the shrink-swell properties of a soil, thus improving the load bearing capacity of a sub-grade to support pavements and foundations. Soil stabilization is used to reduce permeability and compressibility of the soil mass in earth structures.

In this study, pumice has been used to stabilize black cotton soil due to its mineralogical content which will act to have a cementitious property and will undergoes pozzolanic reaction and able to alter the black cotton soil property to a certain degree. The natural pumice material excavated from quarry source and passing 4.75mm sieve was used as stabilizing material. On the process of testing of the soil-pumice mix, the pumice material was subjected to compaction effort which causes crushing of the pumice to a certain extent. Hence, all test results and conclusion were drawn based on partially crushed pumice material in the soil-pumice mix. The effect of pumice powder mixed with black cotton soil was not conducted and determined. Hence, further investigation shall be carried out to determine the outcomes of powdered pumice material (pulverized form) to its stabilization property after mixing with expansive clay soil.
In this regard an attempt has been made to evaluate the effect of pumice as a stabilizer on the geotechnical properties of black clay soil. Therefore, series of laboratory tests such as Atterberg limits, free swell index, compaction, soaked CBR and swelling pressure tests for different percentages of pumice mix were performed. The soil was stabilized with pumice in stepped concentration of 10%, 20%, 30%, 40%, 50%, and 60% by dry weight of the soil. Analysis of the results shows slight improvement on the geotechnical properties of pumice stabilized soil was seen. Pumice slightly reduces the index properties of black clay soil as well as the heaving tendency of the soil. Pumice is known to its light weight property due to that the MDD of the soil decreases as the ratio of pumice increased in the clay soil. Moreover, the CBR-Swell, free swell and one dimensional swelling pressure shows a decrease as the pumice ratio increases in the clay soil.

**Introduction**

Expansive soil changes its volume when the water content of the soil changes. Usually, the soil will shrink when water (or moisture) content is reduced and will swell when the water content increases. The degree of expansiveness depends on the content of the active clay mineral called Montmorillonite.

The stress caused by alternate heaving and shrinkage of the foundation soil creates stress on the structures. Usually, structures are not designed to withstand this stress or it is difficult to account quantitatively. As a result, the structures are damaged due to the additional stress.

Damage due to expansive soils could occur on any type of buildings, road and other civil engineering constructions that are not properly designed and/or constructed. However, light structures like one or two story buildings, warehouses retaining walls and buried facilities are more vulnerable to damages because these structures couldn’t exert a heavy pressure to counteract the uplift pressure from the expansive soils. Therefore, in this study more emphasis is given to reduce and minimize the effect of volume change and to increase the bearing capacity and shearing resistance of these soils by mechanical stabilization using pumice material. The pumice material source which was used in this stabilization study has been collected from Nazareth area. During this study pumice was used as a stabilizing agent to expansive clay soil. The pumice material which were used in the stabilization of black cotton soil was partially crushed due to the application of compaction effort during the process of testing. Hence, all test results as well as the conclusion of this study was reached based on a partially crushed pumice material. Therefore, further investigation shall be carried out in order to determine the effect of fully crushed pumice (pulverized form) on its behavior to stabilize expansive clay soil. The general objective of this research is to assess and determine the effect of pumice stabilization on black cotton soil with the addition of pumice material with an increments of 10% to
expansive black cotton soils which are collected from Koyefech and Mekanisa areas. In addition this study aimed at evaluating on the extent of the engineering property change of these expansive clay soil after the soil being stabilized with pumice material. The result of the study will come up with remedial measures for those construction which will be conducted on expansive soil areas of the country.

LABORATORY TEST RESULTS AND DISCUSSIONS

In this chapter laboratory test results are presented and their analysis is briefly discussed. The relevant engineering property of the soil is evaluated both for natural and stabilized soil samples separately. The tests include Atterberg limits, free swell, compaction, UCS, One dimensional swell potential and CBR. All the tests were conducted on black clay soil mixed with different percentage of pumice material.

Properties of Materials Used in the Study.

Native Expansive soil (Black cotton soil)

Soil samples were collected from NifasilkLafto Sub City around, Koyefech (E-0479583, N-0984817) and Mekanisa (E-0470218, N-0990702) areas where Black cotton soil is found. One test pit was excavated at each locations and disturbed samples were taken. Disturbed samples were air dried to constant moisture and sieved with different sieve sizes after pulverizing depending on the requirement of specific test procedures.

Laboratory tests were conducted on disturbed and remolded soil samples. Tests such as Atterberg limits, particle size analysis, linear shrinkage, free swell, moisture-density, CBR, remolded UCS and remolded swelling potential were conducted on disturbed samples.

Table 1 Summary of Lab. Test results of Natural Soil.

<table>
<thead>
<tr>
<th>Laboratory Test</th>
<th>Sample Locations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Koyefech</td>
</tr>
<tr>
<td>LL (%)</td>
<td>86</td>
</tr>
<tr>
<td>PI (%)</td>
<td>43</td>
</tr>
<tr>
<td>LS (%)</td>
<td>20</td>
</tr>
<tr>
<td>FS (%)</td>
<td>130</td>
</tr>
<tr>
<td>OMC (%)</td>
<td>30</td>
</tr>
<tr>
<td>MDD (g/cc)</td>
<td>1.32</td>
</tr>
<tr>
<td>CBR (%)</td>
<td>0</td>
</tr>
<tr>
<td>CBR Swell (%)</td>
<td>13.44</td>
</tr>
<tr>
<td>Swelling Potential (kPa)</td>
<td>400</td>
</tr>
</tbody>
</table>
From the summary of test results, the natural soil can be characterized as highly expansive and high plastic. Accordingly, both soil samples falls under the A-7-5 soil class based on AASHTO soil classification system.

**Pumice used for blending.**

Pumice material has been used in this study which was found from Nazareth which is 100km from Addis Ababa.

*Table 2 Summary of Lab. Test results of Pumice material.*

**Effect of Pumice on Atterberg limits Effect.**

The test was performed in accordance to AASHTO T-89 and T-90. The ratio of pumice in the soil varies from 10% to 60% by dry weight of the soil.
Effect of Pumice on Modified compaction

Modified proctor compaction test which simulates heavy compacting effort were used to obtain the moisture-dry density relationship of the specific soil samples accordance to AASHTO T-180 method in a 4 inches diameter mold.

MDD goes on decreasing irrespective of the increase in percentage addition of pumice. The maximum reduction of MDD for pumice treated soil is 17% and 32% for Koyefeche and Mekanissa soil sample respectively which was obtained for 60% of pumice stabilized clay soil. Generally the maximum dry density of soil decreases gradually with an increase of pumice content for both soil samples. This is due to comparatively low specific gravity and light weight behavior of pumice material. Pumice (with lower specific gravity) fills the soil voids and it contributes to a decrease in density.

The OMC of treated soil with pumice decreases from 30% to 22.4% and from 29% to 19% for Koyefeche and Mekanissa sample respectively with increased in pumice content from 0% to 60%. Generally the OMC of the soil decreases with an increase of pumice content for all soil samples.
collected from the corresponding study area. The decrease of optimum moisture content is caused by the decrease in water absorbing clay particles as the pumice content increases in the soil-pumice mix.

Fig. 2 MDD and OMC Values of Pumice treated expansive clay soil for both study areas.

Effect of Pumice on California Bearing Ratio (CBR).

CBR is a measure of shearing resistance of the material under controlled density and moisture conditions. The CBR test in study were done according to AASHTO T-193. One point CBR test have been done for all samples to determine the strength character of the black cotton soil alone and in the stabilized case. The density versus CBR were plotted and the CBR for 56 blows is determined from the graph of maximum dry density.

The variations of California Bearing Ratio (CBR) with different percentage of soil-pumice combinations are shown in Figure below.
Fig. 3 CBR Values of Pumice treated expansive clay soil.

The maximum California Bearing Ratio (CBR) value of 28% and 11% for Koyefech and Mekanissa respectively is found with the addition of 60% pumice contents under soaked condition. However,
the CBR-Swell shows a decrease as the content of pumice material is increases in the soil-pumice mix for both soil samples collected from the study areas.

**Fig.4 CBR Swell Values of Pumice treated expansive clay soil.**

**Effect of Pumice on one dimensional Swelling Pressure.**

One dimensional swell tests were performed on both unstabilized and pumice stabilized soil materials which are blended at different ratios for both study areas as mentioned above. The tests were carried according to ASTM Standard D4546.

**Fig.5 Swelling potential (one dimensional) Values of Pumice treated expansive clay soil.**

One dimensional swelling pressure as shown in the above figure decreases with increase in pumice content. The swelling pressure decreased from 400kPa at 0% pumice content for both soil sample to 100kPa and 125kPa at 60% pumice content for Koyefeche and Mekanissa soil samples respectively.

**Conclusions.**

Based on the test results obtained from the investigation of the selected soil treated with Pumice material the following conclusions can be drawn. In the conclusion part each stabilized clay material is compared with that of the pure expansive clay soil (non-stabilized state) and hence, all figures are expressed in percentage to show clearly the extent of pumice Stabilization.
1. Atterberg limit shows reduction as the ratio of pumice increases in the mechanical stabilization process. The liquid limit is reduced by 27% (from 100% to 73%) for Koyefeche soil sample and by 30% (from 100% to 70%) for soil sample collected from Mekanisa area. The plastic index also reduced by 37% (from 100% to 63%) for soil sample collected from Koyefeche area and by 32% (from 100% to 68%) for soil sample collected from Mekanisa area as the ratio of the pumice material increased. As a result of pumice material has a non-plastic nature a decrease in liquid limit and plastic index is observed as the pumice content increase in the soil-pumice mix.

2. The linear shrinkage of the soil samples collected from Koyefech area is reduced by 65% (from 100% to 35%) and by 47% (from 100% to 53%) for Mekanissa soil sample.

3. However, the compaction test result shows a reverse observation as the above. As the ratio of pumice increases in the soil mix for both study areas, the samples show a decrease in the maximum dry density. This is due to the fact that pumice has low density or due to its light weight behavior. Moreover, the void ratio also shows an increase as the ratio of pumice material added to the expansive clay soil increased, this phenomena is occurred due to the fact that pumice is produced when lava with a very high content of water and gases is discharged from a volcano. As the gas bubbles escape, the lava becomes frothy. When this lava cools and hardens, the result is a very light rock material filled with tiny bubbles of gas. Hence, more voids are available in the pumice, then as the ratio of pumice material added to the expansive clay soil increases the void space in the mix (soil to pumice) is increased and it is difficult to reduce the void space during remolding process (compaction).

4. Laboratory test was carried out to estimate the CBR value for soil samples collected from Koyefeche and Mekanisa Test pits. Accordingly, the test result shows small increment of CBR value for both soil samples collected from the corresponding areas which were treated with different incremental percentage of pumice material. However, the result shows that the increase in CBR value is small after the expansive clay soil is treated with pumice material.

5. On the other hand CBR-swell value for both samples shows a significant reduction as the ratio of pumice material increase. The CBR-Swell for Koyefeche soil sample reduced by 89% (from 100% to 11%) and that of Mekanisa soil sample reduced by 80% (from 100% to 20%). The free swell test result also reduced by 62% (from 100% to 38%) for Koyefeche soil sample and by 75% (from 100% to 25%) for Mekanissa soil sample. This reduction in CBR-Swell and free swell is caused by the minimization of clay particles which are capable of absorbing large quantities of water (such as Montmorillonite) and they partly replaced by non-water absorbing minerals. This result indicates that blending of pumice material to expansive clay soil minimize the heaving tendency which occurs due to seasonal moisture variations.

6. Furthermore, one dimensional swell test have been also carried on the soil samples collected from the corresponding study areas. One dimensional swelling pressure test result is reduced by
75% for Koyefech soil sample and by 69% for Mekanissa soil sample at 60% pumice content in the soil mix. It can be concluded that in line with the test result the change in volume/heave in black cotton soil decreases as the ratio of pumice material increases in the process of stabilization.

7. In general, all the above conclusions was reached using naturally occurring pumice material from quarry source preparing it with sieve size passing 4.75mm. This means no further processing was done on the pumice material to make it as a powder (pulverized) form. However, if the pumice material has been used in this study as a powder form, the reaction between the pulverized pumice and that of the black cotton soil will be fast and maximized and it will develop cementitious property early. Hence, the stabilization process will be better due to high pozzolanic reaction between the soil - pumice mix and a better result with a minimum pumice content will be expected.

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