Stabilization On Expansive Soil For Civil Engineering Projects

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Abstract: The selection of the suitable soil type for construction is a challenging job for civil engineers as the expansive soils are not suitable for the construction of houses, commercial buildings and mainly for highway projects as its engineering behaviors in reaction with water may considerably reduce the strength and thus damages to the civil engineering structures. Keeping this under consideration, the soil samples were excavated from five different locations and taken for their geological assessment by performing the various physical tests such as Specific gravity test; Sieve analysis, Hydrometer analysis; free swell index test; Atterberg limits and Compaction test for the unstabilized expansive soil samples in IOT Laboratory, Ambo University, Ambo, Ethiopia. In the current study, the additives and techniques have been applied using the lime as a special ingredient for stabilizing the expansive soil, particularly, which has been focused with respect to improving the efficiency of their physical properties. Eventually, it was concluded that the application of lime helps for improving the physical properties of the expansive soil.

Index Terms: Black Cotton Soil, Expansive soil, Free Swell Index, Lime, Plasticity Index, Textural Class, Weaker Cations

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1. INTRODUCTION

As the Soil is the essential sediments or other accumulation of minerals, and it's a valuable component in an ecosystem, the addition of some binders with soil enhances a moral support so that soil particles get in contact to raise the water holding capacity and to build the pressure resistant and thus improving its physical and chemical characteristics [5, 6]. About 5% of the global area occupies with Black Cotton Soil (BCS) and mainly found in Sudan, South Africa, Ethiopia and Tanzania. The low shrinkage limit and high optimum moisture content and highly sensitive to moisture changes are the nature of BCS and hence its undesirable factors to be modified using some suitable stabilization mechanisms [4], [9]. Pavements are in particular susceptible to damage by expansive soils because they are light weight and extended over large areas [10]. The reduction in the strength and damage of the structure is mainly due to the changes in the physical properties and behavior of soil is due to the reaction with water. Stabilization of soil involves the methods used for modifying the property of a soil to develop its engineering performance [4]. Its value helps to some extent in identifying and classifying soils. A better idea about suitability of the soil as a construction material; the higher value of specific gravity gives more strength for highways work and foundations. Soil stabilization is a technique that uses other materials to improve the durability of soil by increasing its strength and resistance to water [7], [8]. Though there are several methods that have been used to recognize the presence of expansive soils a need of fast and relatively cheaper methods continues to be a necessary under taking. The most commonly used stabilizer for the expansive soils are; bitumen; lime, and cement.

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According to the Pioneer Researchers, the stabilization of this soil with bitumen: lime or cement is effective [2], [3]. Regrettably, the costs of these stabilizers are high making them economically unattractive. Recent trend in research works in the field of geotechnical engineering and construction materials focuses for the cheap materials and the locally easily available ingredients as the best stabilizing agents [5],[9].

2 MATERIALS AND METHODS

The soil samples from five different locations were collected during the period March – April 2018 with shovels at depths varying from three to four meters below the grade. The samples were jam-packed in five different bags, carefully tagged for identification purpose and transported to Materials Testing Laboratory, Civil Engineering Department, Institute of Technology, Awaro campus, Ambo University, Ambo, Oromia region, Ethiopia. The soil samples collected were kept for air – drying using the number of trays (labeled with the location names) at the civil engineering laboratory. All the soil samples were tested (Figure-1) for the identification of the type of soil by doing the Sieve analysis and Hydrometer analysis, determination of specific gravity (G), Free Swell Index (FSI), and Plasticity Index (PI) using the standard procedures, and the maximum dry density as well as the maximum water content by performing the compaction test. The stabilization of the expansive soil was done using the lime as a special ingredient and the results were compared with the natural soil.

3 RESULTS AND DISCUSSION

The sample result for sieve analysis on sample-1 is shown in Table-1. The test results on sieve analysis for the other samples will be discussed. The particle size curve produced under the hydrometer (sedimentation analysis) for soil sample -5 shows 60% of soil grains passing through 0.02 mm which is indication that clay percentage is dominating more in the soil sample. The gradation (mechanical composition) of each sample is presented in Table-2 where the sample-5 collected from Awaro campus was taken for the hydrometer analysis and found to be 60% of clay and the silt amount is of only 8.4% as shown in Table-3. The plasticity index of soil samples shown in Table-4 varies between 26.25 and 55.40. Soil PI closer to 17 indicate that the soil is medium to Expansive potential; PI closer to 25 is High expansive, PI closer to 30 is highly expansive and PI close to 40 is Very high expansive potential. Compaction tests are done in the laboratory with the aim of determining the moisture density relationships of soils. The Table-6 and 7 shows the soil compaction test results for the samples 3 and 5. The optimum moisture content and the maximum dry density were found to be 24.5 % and 1.320gm/cc respectively for soil sample -3. Similarly, the optimum moisture content and the maximum dry density were found to be 24.3 % and 1.343gm/cc respectively for soil sample-5. According to Brajesh Mishra, 2015, it was evidently proved that the optimum moisture content of samples 3 and 5 are in the range of 20 – 35% as well as the maximum dry density of the samples ranging between 1300 – 1800 kg/m^3 indicate that the soil samples are purely Black cotton soil with more clay content and hence highly expansive [1]. The outcome of the preliminary test for the identification of the natural soil and the determination of its characteristics were summarized in Table-8. The hydrometer analysis done for the sample-5 collected from Awaro campus with an elapsed time interval (0.5, 1, 2, 5,10,15,30 and 60 minutes) under a constant temperature of solution is presented in Table – 3 and the particle size curve. The current test on soil samples show that the plasticity index for soil samples 2, 3 and 5 are very high. As seen in Table 20, the plasticity index range from 26.25% - 55.40% as well as the free swell index of soil samples range from 43% to 93%. The results of all the soil samples in the study area are greater than 20% and hence the soil has high and very high plasticity. As shown in Table-5, from the test results obtained in the prior study on the original soil samples, it was evidently clear that only the soil sample-5 is of with extreme clay percentage and therefore, the stabilization mechanism was done only for that sample using the locally available stabilizing agents. The addition of lime to soil sample-5 has produced a corresponding decline in with the plasticity index of the soil. The addition of 5%, 10%, 15% and 50% lime to the soil sample -5, the plasticity index has been considerably reduced with 35%, 28%, 15.34% and 2% respectively. Thus the addition of lime to sample -5 with 5%, 10%, 15% and 50% lime have shown a considerable reduction in free swell index with 83%, 62.5%, 50% and 22.58% respectively. According to Olugbenga O. Amu et.al., as a result of the cations exchange which occurs when Ca^{2+} ions from the lime replace weaker cations in the soil , when Ca^{2+} ions from the lime replace weaker cations in the soil , the reduction in the swelling potential occurs,, and also causing the agglomeration of the particles and a better covering of the porous structures [9]. From the compaction test carried out on soil sample -5 with the lime increments as 5%, 10% and 15% have shown a better improvement with the maximum dry density of soil sample as 1.358gm/cc, 1.398gm/cc and 1.483gm/cc with its corresponding moisture content of 15.5%, 16.5% and 14.8% respectively. The results of the other trails will be discussed. From the compaction test carried out on soil sample -5 with the lime increments as 5%, 10% and 15% have shown a better improvement with the maximum dry density of soil sample as 1.358gm/cc, 1.398gm/cc and 1.483gm/cc with its corresponding moisture content of 15.5%, 16.5% and 14.8% respectively. It was evidently proved that the addition of lime in different percentage to the soil sample -5 originally with the maximum dry density of 1.324gm/cc with its moisture content of 23.5%, have been changed with the positive improvement. According to Brajesh Mishra et al., the boost in potency of lime-stabilized materials in compression as well as in tension is endorsed to the reactions between lime and clay particles and this statement is matching with the results obtained in the stabilized soil sample -5 using lime [1]. The free swell index (FSI) of soil sample-5 with 5%, 10%, 15% and 50% lime is given in Table-10.

2.3 Compaction test using Lime Increments

All tables and figures will be processed as images. You need to embed the images in the paper itself. Please don't send the images as separate files. The compaction test was conducted on soil sample -5 with the addition of lime in different percentage as 5%, 10% and 15% and the results for Trail-1 was shown in Table-9. The results of the other trails will be discussed.

TABLE 1

RESULT OF SIEVE ANALYSIS FOR SAMPLE -1 FROM ST. MICHAEL CHURCH, AMBO TOWN

S.No.	Sieve Size (mm)	Soil Retained (gm)	Soil retained in %	Cumulative Soil Retained (%)	% Finer
1	4.75	5	0.5	0.5	99.5
2	2.36	50	5	5.5	94.5
3	1.18	580	58	63.5	36.5
4	0.6	94	9.4	72.9	27.1
5	0.425	21	2.1	75	25
6	0.3	25	2.5	77.5	22.5
7	0.15	9	0.9	78.4	21.6
8.	0.075	4	0.4	78.8	21.2
9.	B.P	212	21.2	100	0

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TABLE 2

MECHANICAL COMPOSITION OF SOIL SAMPLES

Location no	Sand	Clay	Silt	Textural Class
1	78.3	21.2		SCL
2	48.5	51		C
3	36.85	63		C
4	75.8	21.7		SCL
5	31.6	51	17.4	C

TABLE 3

HYDROMETER ANALYSIS FOR SAMPLE -5 FROM AWARO CAMPUS, AMBO TOWN

S.No.	Time, t(min)	D= 0.0116 (√He /t)	% finer
(1)	(2)	(9)	(10)
1	0.5	0.050	78.4
2	1	0.037	73.6
3	2	0.027	68.8
4	5	0.018	59.2
5	10	0.013	56

6	15	0.011	51.2
7	30	0.011	51.2
8	45	0.011	51.2
9	60	0.011	51.2
10	120	0.011	51.2

TABLE 4

RESULTS ON PLASTICITY INDEX FOR SOIL SAMPLES

Sample No.	Plasticity Index (I_P)
1	26.25
2	44.98
3	46.80
4	28.30
5	55.40

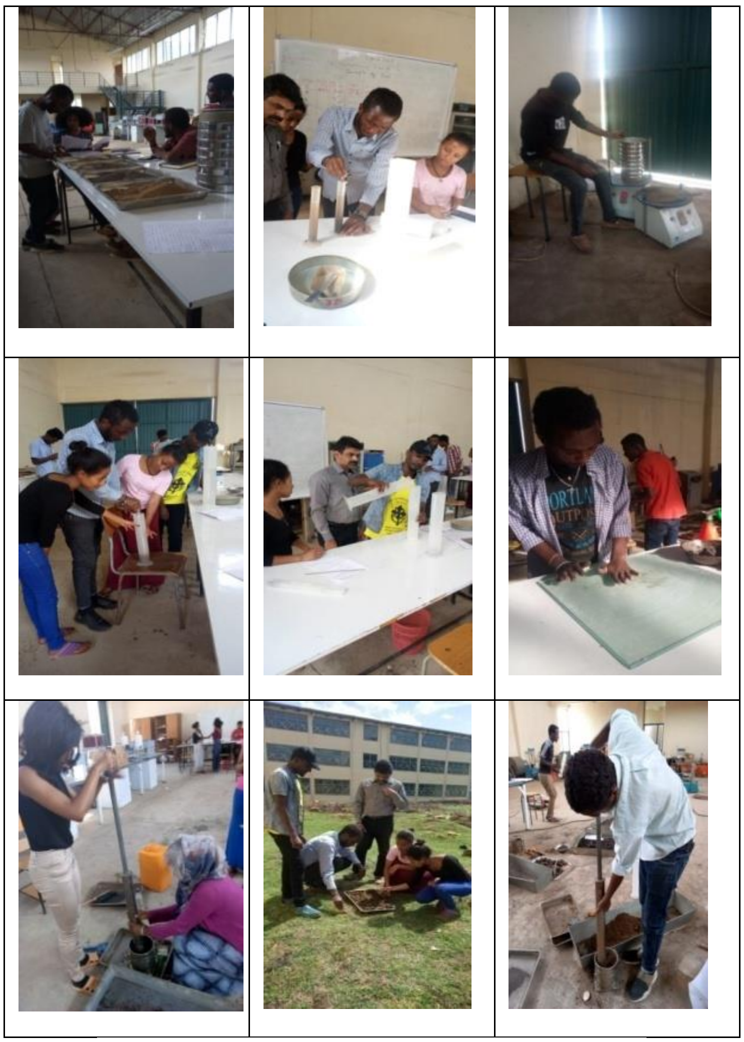

Figure-1 *Preparation of soil samples and Testing*

TABLE 5

SUMMARY TABLE FOR FSI, PI AND PERCENTAGE PASSING THROUGH 75µ

S. No.	FSI	I_P	Sieve < 75µ
Sample 1	43	26.25	21.2
Sample 2	73	44.98	51
Sample 3	76	46.80	63
Sample 4	40	28.30	21.7
Sample 5	93	55.40	68

TABLE 6

RESULTS OF COMPACTION TEST FOR SAMPLE-3

Compaction Test for BCS Sample 3						
Wt. of empty mold (gm)	4843	4843	4843	4843	4843	4843
Wt. of mold + dry soil (gm)	7669	7669	7669	7669	7669	7669
Wt. of mold + moist soil (gm)	7695	7803	7924	8053	8203	8164
Wt. of dry soil (gm)	2826	2826	2826	2826	2826	2826
Wt. of moist soil (gm)	2852	2960	3081	3210	3360	3321
Moisture Content (%)	8	12	16	20	24	28
Wet unit weight (gm./cc)	1.391	1.443	1.503	1.565	1.639	1.620
Dry unit weight (gm./cc)						

TABLE 7

RESULTS OF COMPACTION TEST FOR SAMPLE-5

Wt. of empty mold (gm)	4843	4843	4843	4843	4843	4843
Wt. of mold + dry soil (gm)	7755	7755	7755	7755	7755	7755
Wt. of mold + moist soil gm	7543	7698	7833	8011	8269	8188
Wt. of dry soil (gm)	2912	2912	2912	2912	2912	2912
Wt. of moist soil (gm)	2700	2855	2990	3168	3426	3345
Moisture Content (%)	8	12	16	20	24	28
Wet unit weight gm./cc	1.317	1.393	1.459	1.545	1.671	1.632
Dry unit weight gm./cc	1.219	1.244	1.257	1.288	1.348	1.275

TABLE 8

RESULTS OF INDEX PROPERTIES UNSTABILIZED BLACK COTTON SOIL

Samples	S – 1	S - 2	S - 3	S - 4	S - 5
Color	Brown	Black	Black	Brown	Black
Liquid limit (%)	71.43	89.8	96.82	64.73	97.5
Plastic limit (%)	45.15	44.82	50	36.43	42.12
Plasticity Index (%)	26.25	44.98	46.82	28.3	55.38
Free Swell (%)	43	73	76	40	93
Specific Gravity	2.34	2.62	2.64	2.38	2.66
Maximum Dry Density (gm/cc)			1.324		1.345
Optimum Moisture Content (%)			23.5		24.1

TABLE 9

COMPACTION TEST RESULT ON SOIL SAMPLE - 5 USING 5% LIME

Compaction Test For BCS + 5% lime				
Observation	1	2	3	4
Mold weight(gm)	4843	4843	4843	4843

Wt. of mold + dry soil (gm)	7926	7926	7926	7926
Wt. of mold + moist soil (gm)	7793	7948	8071	8166
Wt. of dry soil (gm)	3083	3083	3083	3083
Wt. of moist soil (gm)	2950	3105	3228	3323
Moisture Content (%)	8	12	16	20
Wet unit weight (gm./cc)	1.43	1.51	1.57	1.62
Dry unit weight (gm./cc)	1.33	1.35	1.35	1.35

TABLE 10

RESULT ON FREE SWELL INDEX (FSI) OF SOIL SAMPLE -5 USING 5 – 50% LIME

% Lime added	Reading after 24 Hours		Free Swell Index (%)
	Water	Kerosene	
5%	21	11.5	83
10%	19.5	12	62.5
15%	19.5	13	50
50%	19.0	15.5	22.58

4 CONCLUSION

a) The results of sieve analysis for the soil samples shows that the soil samples are not uniform, and the most of the samples are poorly graded. Upon the output of the examination as far as this, (Plasticity index, sieve analysis, hydrometer analysis, specific gravity and compaction test) shows that the soil samples in the study area are not uniform, as some of the soil samples are having more clay content, more compactness, and plastic, hence the menace of unsuitability for the construction.

b) The specific gravity of the soil samples were determined using the density bottle of 200 cc shows that the range varies between 2.34 and 2.66.

c) Since the swelling potential of the black cotton soil is mainly due to the plasticity index, the particle size and the other engineering physio-chemical properties, this study was mostly needed.

d) In the present study, although the black cotton soils were found in Bus station, Golf fifa, and Awaro campus, the soil sample from Awaro campus with extreme clay contents is taken for the analysis on their index, grain size and engineering properties with some specific locally available stabilizing agents.

e) The physical properties of the soils are found to be improved noticeably with the addition of lime as a stabilizer.

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REFERENCES

[1] Brajesh Mishra, "A Study on Engineering Behavior of Black Cotton Soil and its Stabilization by Use of Lime", International Journal of Science and Research (IJSR), 2015, vol. 4, No. 11, pp. 290 – 294, 2015.

[2] O. Kunnedy, O.O. Fidelis, and N. Daniel, "Geophysical use of quarry dust as admixture as applied to soil stabilization and modification – A Review", ARPN Journal of Earth Science, vol. 1, No. 1, pp. 6 – 8, 2012.

[3] Olugbenga Oludolapo Amu, Oluwole Fakunle Bamisaye and Iyiola Akanmu Komolafe, "The suitability and lime stabilization requirement of some lateritic soil samples as pavement", International Journal of Pure and Applied Science and Technology, vol. 2, No.1, pp. 29-46, 2011.

[4] R. Pankaj, Modak, B. Prakash, D. Nangare, Sanjay Nagrale, Ravindra Nalawade and V. S. Chavhan, "Stabilisation of Black Cotton Soil Using Admixtures", International Journal of Engineering and Innovative Technology (IJEIT), vol. 1, No. 5, pp. 1-3, 2012.

[5] T. Subash, P. Vincent, and K. Sathya Prabha, "Stabilization Mechanism for Soil by using Lime and Rice Husk Ash as Binding Agents in Erosion Prone Zone – A Case Study", International Journal of Civil Engineering and Technology (IJCIET), vol. 8, No. 4, pp. 1479 -93, 2017.

[6] T. Subash, A. Dhanasekaran and K. Sathya Prabha, "Assessment of Soil Nature and Control Mechanism for

Rill Erosion in a Hilly Slope Area at Ambo Town, Oromia Region, Ethiopia", International Journal of Pharm Bio Science, Vo. 9, No. 2, pp. 204-212, 2018.

[7] T. Subash, P. Vincent, S. Karuppasamy and B. K. Kushnappa, "Analysis of Nutrient Index of Soil for a Green Environment", Asian Journal of Chemistry, vol. 29, No. 10, pp. 2311-15, 2017.

[8] T. Subash, P. Vincent and N. Nalanth, "Geotechnical assessment of Soil in Erosion Prone Zone", International Journal of Civil Engineering and Technology (IJCIET), vol. 7, No. 6, pp. 227-40, 2016.

[9] T. Suresh, Y. Balakrishna and K. Nitesh, "Improving the Properties of Black Cotton Soil using Terrazyme as a Admixture", International Journal of Engineering and Techniques, vol. 3, No. 1, pp. 96-105, 2017.

[10] Vidya Pathak, and Prof. Swapnil Joshi, "Utilization of Sea Salt in Black Cotton Soil: A Literature Review", International Journal of Innovative Research in Science and Engineering, vol. 3, No. 2, pp. 312-319, 2017.