MICRO STRUCTURAL MODIFICATION AND STABILIZATION OF DISPERSIVE SOILS USING BAGASSE ASH

[1]ABENEAZER ALEMAYEHU KOSHIMA, [2]ELEYAS ASSEFA, [3]YITAYOU ESHETE

Addis Ababa Science and Technology Department of Civil Engineering
College of Architecture and Civil Engineering
E-mail: koshimaabeneazer@gmail.com

Abstract - Dispersive subgrade soils are one of the known causes of road failure. Replacement of dispersive soils with natural construction materials is an expensive and sometimes not economically viable solution. On the other hand, commonly used chemical stabilizations of dispersive soils are either costly or not environmentally friendly. This work investigates the use of SCBA as a stabilizer for dispersive soils. The results show that increasing the amount of SCBA up to 20% and the curing period to 21 days reduces the high plastic properties of dispersive soils and improves the Atterberg limits of these soils. Besides, SCBA stabilization enhances the strength and reduces the dispersive potentials of dispersive subgrade soils. SCBA stabilization also modifies and enhances the microstructure of dispersive soils.

Keywords - Dispersive Soils, SCBA Stabilization, Subgrade Improvement, Soil Engineering, Road Integrity, Atterberg Limits, CBR Enhancement, Soil Modification, Microstructural Analysis, Sustainable Stabilization

I. INTRODUCTION

Transportation is the flow of people and goods from one location to another to accomplish basic needs or tasks. Road transportation is the most popular and fundamental system that supports the economic growth of a nation by contributing an essential role in different sectors (Eichengreen and Gupta, 2011; Mushir and Hailemariam, 2015). The performance of roads depends on the nature of subgrade soils (Paige-Green, 2008; Singh et al., 2016).

Dispersive subgrade soils are one of the known causes of road failure. Dispersive clay particles are easily detached and eroded by rainwater due to having a small mass and very small particle size. As a result, these soils have extremely low erosion resistance (Pa, 1991). In contrast, normal clays have aggregated structures with high inter-particular attractions and water. Normal clay soils have a sufficient balance of electrochemical forces of attraction among particles, which is very strong, cohesive, and non-dispersive (Ismail et al., 2008).

Dispersive clay soils predominantly contain sodium cations (Vakili et al., 2018). These soils have an imbalance of electrochemical forces due to having one positive charge from sodium ions instead of two positive charges from magnesium and calcium ions, as seen in normal clay soils. This imbalance causes particles to be repulsive to each other (Abbaslou et al., 2016). As a result, these soils are susceptible to erosion by water with low ion concentrations (Vakili et al., 2013).

Dispersive soils are not suitable subgrade materials for constructing pavement structures, and these soils can cause serious engineering challenges if they are not identified and treated appropriately (Singh et al., 2018). However, dispersive clay soils sometimes create fewer problems than expected since eroding water might balance the ionic compositions of the soil (Edgar, 1991).
Soil replacement is one of the techniques used to mitigate problems caused by dispersive soils, but it is very expensive and sometimes not economically viable. On the other hand, chemical treatment methods add chemical additives like fly ash, gypsum, alum, and lime to stabilize dispersive soils.

Vakili et al. (2013) studied the stabilization of dispersive clays using pozzolan. Their study shows a reduction in dispersivity potential, which significantly altered upon the percentage of selected admixtures and curing time. The addition of pozzolan followed by curing reduced the sample's dispersivity potential. The pozzolan stabilization led to a decrease in the index of plasticity and sodium percentage, as well as an increase in electrical conductivity and unconfined compressive strength. The pozzolan replaced sodium ions with calcium and aluminum ions, which have higher valences and reduce the thickness of the double layer. The study also indicates that an increase in curing days could improve the unconfined compressive strength.

Moravej et al. (2015) studied the use of microbial calcite for the bio-stabilization of dispersive clays. Bacillus sphericus bacteria were used in the study. Curing time and bacterial cell density were the target

variables, and the results showed that the sample's dispersivity decreases as bacterial cell density and curing time increase. However, this technique requires strong biological knowledge and is complex for engineers.

Gidday et al. (2020) applied lime to improve the characteristics of dispersive subgrade soils. The results indicate an increase in the CBR values and unconfined compressive strength. Additionally, the dispersive properties decreased with increasing lime content and varying curing conditions. The study shows that the optimum lime content should be 7% to 9% to provide high quality and strength for the subgrade rating. However, this amount of lime, relative to soil mass, is expensive compared to other industrial wastes that could potentially serve as stabilizers.

In this study, we used SCBA for microstructural modification and stabilization of the Gidole-Wozeka road, which has failed due to dispersive subgrade soil. The Gidole-Wozeka road project passes through the western escarpment of the southern segment of the Ethiopian central rift. We will study the effects of SCBA on the index and engineering properties, as well as the microstructure of the soil, using various laboratory equipment.

II. METHODOLOGY

XRF tests on SCBA were performed to determine the pozzolanic properties of SCBA, and the specific gravity of SCBA was determined. Index properties tests, including grain size analysis, Atterberg limits tests, and specific gravity tests, were performed to analyze the effect of SCBA and curing on dispersive subgrade soil. Index property tests were conducted for both natural and treated subgrade soil with varying percentages of SCBA (0%, 5%, 10%, 15%, and 20%) and curing periods of 0, 7, 14, and 21 days.

On the other hand, chemical tests of SAR and PS were performed to determine the dispersive potential of natural and treated subgrade soils. Strength tests, including modified compaction, California Bearing Ratio (CBR), and unconfined compression strength (UCS) tests, were performed with varying percentages of SCBA (0%, 5%, 10%, 15%, and 20%) and curing periods of 0, 7, 14, and 21 days to analyze the effect of SCBA and curing on dispersive subgrade soil. SEM was also used to study the microstructural changes after the stabilization of subgrade soil.

III. RESULT

Table 1 presents laboratory test results of AASHTO, LL (Liquid Limit), MDD (Maximum Dry Density), OMC (Optimum Moisture Content), PI (Plastic Index), PL (Plastic Limit), CBR (California Bearing Ratio), GI (Group Index), Gs (Specific Gravity), and qu (Unconfined Compressive Strength) test results. Figure 1 shows the SEM result.

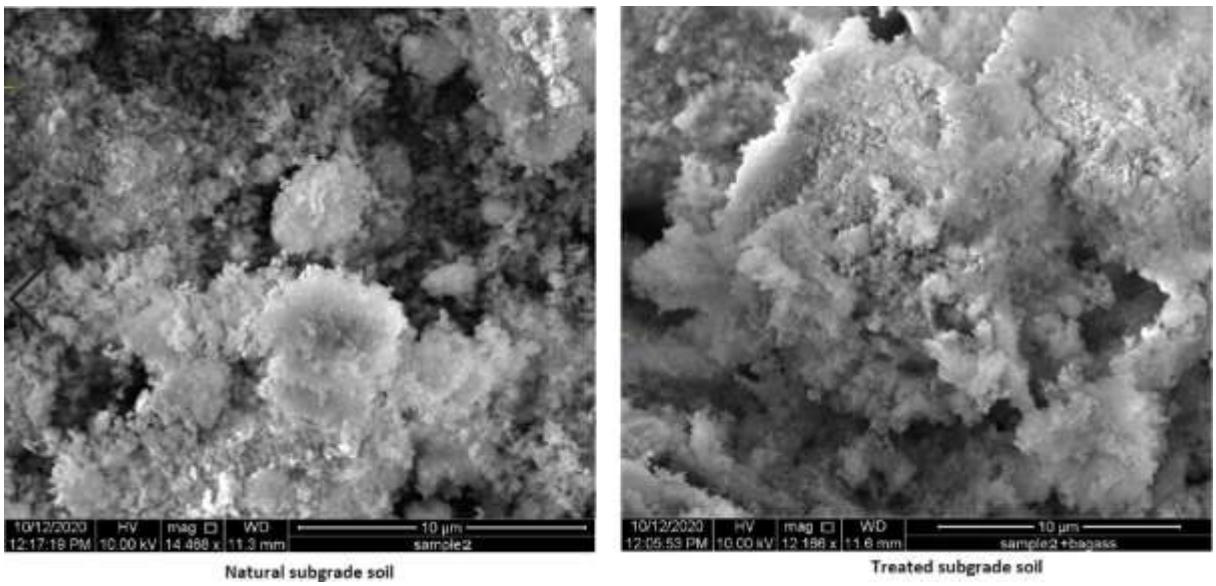

Figure1: SEM test result

SCBA(%)	Curingday	%pass#200	LL	PL	PI	GI	AASHTO	Gs	MDD	OMC	CBR	qu
0	0	67.05	46.16	27.5	18.66	10	A-7-6	2.85	1.77	17.92	1.98	41.34
	7	67.05	46.83	27.42	19.4	11	A-7-6	2.85	1.78	17.67	2.31	43.12
	14	67.05	46.46	27.78	18.69	10	A-7-6	2.85	1.8	17.14	2.64	43.96
	21	67.05	46.39	27.38	19.01	11	A-7-6	2.85	1.82	16.78	2.97	45.47
5	7	56.7	44.07	29.05	15.03	6	A-7-6	2.83	1.85	15.84	5.16	84.44
	14	47.3	42.57	32.48	10.09	2	A-5	2.82	1.88	15.54	8.24	99.3

	21	41.5	41.25	34.34	6.91	1	A-5	2.78	1.9	14.91	9.67	113.81
10	7	49.8	43.79	31.31	12.47	4	A-7-5	2.78	1.87	15.29	7.8	91.56
	14	40.2	41.82	32.48	9.34	1	A-5	2.76	1.9	14.88	11.86	133.06
	21	33.5	39.12	35.04	4.08	0	A-2-4	2.74	1.93	14.55	15.08	160.93
15	7	46.4	41.31	32.22	9.09	2	A-5	2.74	1.89	15.04	10.65	120.65
	14	38.1	39.39	34.72	4.67	0	A-4	2.68	1.92	14.62	14.26	150.55
	21	32.7	38.51	35	3.51	0	A-2-4	2.67	1.95	14.12	16.07	171.08
20	7	42.7	40.21	33.33	6.88	1	A-4	2.66	1.93	14.23	15.71	164.79
	14	34.1	38.49	35	3.49	0	A-2-4	2.66	1.96	13.86	17.05	181.42
	21	28.4	36.85	36.57	0.28	0	A-2-4	2.65	1.99	13.31	18.2	203.42

Table1: Overall laboratory test results summary of treated sub grade soils

IV. DISCUSSION

As shown in Table 1, SCBA and curing period have impacts on index properties of dispersive subgrade soils. SCBA and curing period could increase soil particle sizes, improve the Atterberg limits, and reduce the high plastic property of dispersive soils. Besides, it enhances the subgrade soil index. SCBA and curing period have impacts on the strength properties of dispersive subgrade soils. As the result shows (see Table 1), the treated subgrade soils have high MDD and low OMC compared to the natural subgrade soils, which means that SCBA stabilization with curing periods can improve the strength of dispersive subgrade soils. The results also show the CBR values increased above 15% and improved the soil's consistency to stiff with increasing the SCBA amounts up to 20% and the curing period to 21 days, which indicates the treated subgrade soils are very good. SCBA could also reduce the dispersion potential and alter the microstructure of dispersive soils. It forms numerous well-defined patterns on the soil surface that minimize the dispersed nature of the subgrade soils (see Figure 1).

REFERENCES

[1] H Abbaslou, H Hadifard, and A Poorgohardi. Characterization of dispersive problematic soils and engineering improvements: a review. Comput. Mater. Civ. Eng, 1:65–68, 2016.

[2] H Nelson Edgar. Soil mechanics note no. 13: Dispersive clays. Soil Conservation Service, United States Department of Agriculture, Washington, DC, pages 11–12, 1991.

[3] Barry Eichengreen and Poonam Gupta. The service sector as India's road to economic growth. Technical report, National Bureau of Economic Research, 2011.

[4] Bisrat Gissila Gidday and Satyendra Mittal. Improving the characteristics of dispersive subgrade soils using lime. Heliyon, 6(2): e03384, 2020.

[5] Fauzilah Ismail, Zainab Mohamed, and Mazidah Mukri. A study on the mechanism of internal erosion resistance to soil slope instability. Electronic Journal of Geotechnical Engineering, 13(A): 1–12, 2008.

[6] S Moravej, E Nikooee, G Habibagahi, and A Niazi. Bio-stabilisation of dispersive soils. 2015.

[7] Ali Mushir and Meaza Hailemariam. Geographical analysis of road transportation in Ethiopia. Ethiopian Journal of Environmental Studies and Management, 8: 846–845, 2015.

[8] Chester Pa. 1 no. copies i. 1991.

[9] P Paige-Green. Dealing with road subgrade problems in southern Africa. In The 12th International Conference of International Association for Computer Methods and Advances in Geomechanics (IACMAG) (India, 1-6 October 2008), pages 4345–53, 2008.

[10] B Singh, P Gahlot, and DGM Purohit. Dispersive soils: characterization, problems and remedies. Int. Res. J. Eng. Technol, 5(6): 2478–2484, 2018.

[11] Daljeet Singh, JN Jha, and KS Gill. Strength evaluation of soil subgrade using in-situ tests. Civil Engineering and Architecture, 4(6): 201–212, 2016.

[12] AH Vakili, MR Selamat, H Moayedi, and H Amani. Stabilization of dispersive soils by pozzolan. In Forensic Engineering 2012: Gateway to a Safer Tomorrow, pages 726–735, 2013.

[13] Amir Hossein Vakili, Mohammad Kaedi, Mehdi Mokhberi, Mohamad Razip bin Selamat, and Mahdi Salimi. Treatment of highly dispersive clay by lignosulfonate addition and electroosmosis application. Applied Clay Science, 152: 1–8, 2018.

★★★