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Investigating the Geotechnical Properties of Clay-Gravel Mixtures

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***Abstract*— *The suitability of soil for engineering purpose depends largely on their ability to remain in place and support whatever load that is placed upon it. Clays are detrimental to stability. Therefore, this study evaluated the influence of gravel on the geotechnical properties of clayey soil. The clayey soil samples were obtained from a dug pit from two different locations in Osogbo, Osun State and the gravels were collected locally. Three different gradations of gravel (2mm-6mm, 6mm-12mm, and 12mm-20mm) were mixed in a dry state in percentages of 5%, 10%, 15%, 20%, 30%, 40% and 50% with the two clayey soils collected respectively. Geotechnical properties including Index property test and Compaction were determined in accordance with BS 1377 and analyzed. The addition of gravel to the clayey soil led to an increase in Maximum Dry Density (MDD) and reduction in Optimum Moisture Content (OMC) as the concentration of gravel increases with size in the clay-gravel mixtures.*

***Keywords*— *Clayey soil, Clay-gravel mixtures, Gravel, Maximum Dry Density, Optimum Moisture Content.*

I. INTRODUCTION

Clay is predominant in most of the subgrade soil materials in Nigeria. The clay minerals attract and absorb water, thereby, making it highly susceptible to swelling and shrinkage respectively [1]. In Nigeria, some of these soils have been identified. They include the structurally unstable residual lateritic soils [2], the Black Cotton Soils (BCS) which occur widely in the North-Eastern part of Nigeria and the Sokoto soft clay shale (attapulgite) in North-Western Nigeria [1]. The problem soils in Lagos area are identified as peaty clays [3]. In Port-Harcourt area, they occur as clayey peat over the mud plains. Possible damages that can be caused by expansive soils includes; foundation cracks, severe structural damage, heaving, and cracking of sidewalks, roads etc.

For past several decades, mixing sand with an adequate amount of clay/bentonite has been a common practice for creating mixtures as construction materials used in a variety of engineering applications, such as hydraulic and waste containment [4]. The combination of mixing sand and bentonite can be able to provide a very low permeability because of the ability of bentonite to swell and then fill the voids between sand particles. Another benefit of the mixture is low compressibility which is provided by the sand framework [5]. Furthermore, the mixture has less susceptible to frost damage comparing with natural clays [6], with low shrinkage potential in terms of wetting or drying processes [7], which lead to better volume stability and higher strength. The sand-bentonite mixture seems to be an economical solution for the geo-environmental applications in places which are covered mostly by sandy soils.

The behaviour of compacted clay-sand and clay-gravel mixtures was studied by conducting undrained triaxial tests. They suggested critical sand/gravel contents, below which the shear strength and secant deformation modulus, of the mixed soil (as compared to those of the pure clay) remain almost unchanged, and beyond which they increase considerably. Also, the results revealed that adding sand/gravel to the clay increases pore water pressures during monotonic shearing. The clay-gravel mixtures, as opposed to the clay-sand mixtures, showed a slightly higher strength and lower pore water pressure during shearing [8].

II. MATERIALS AND METHOD

Two clayey soil samples were collected at a different location. One of the samples was collected at a dug pit for constructing a gantry located along Gbongan road, Ogo-Oluwa, Osogbo, Osun State. The other sample was collected at a dug well located at Oke-Baale, Osogbo, Osun state. The gravel was collected locally around Kasmo area, Oke-Baale, Osogbo. The Atterberg limits tests, specific gravity, and compaction tests were determined in accordance with standard [9]. The gravel was separated into grades 2-6mm, 6-12mm and 12-20mm at the laboratory and mixed in a dry state in percentages of 5%, 10%, 15%, 20%, 30%, 40% and 50% with the two clayey soils collected respectively. The clayey soil collected at Ogo-Oluwa was named as clayey soil A and the other collected at Oke-Baale was named as clayey soil B.

III. RESULTS AND DISCUSSION

The liquid limit for the clayey soil A and B was 49%and 58%, their plastic limit was 30.6% and 31.18%, and their linear shrinkage value was 9.3% and 10% respectively. Particle size analysis revealed that clayey soil B contains more fine grain soil than clayey soil A, with the percentage passing sieve size 0.075mm found to be 54%, which was higher than 52% of clayey soil A. For the clay-gravel mixtures, the Atterberg limits tests cannot be obtained by conventional laboratory test due to the existence of large particles (gravel). The two clayey soils A and B were classified in accordance with the America Association of State Highway Transportation Officials (AASHTO). Clayey soil A and B were classified as A-5-7 with a general subgrade rating of fair to poor. The particle size analysis showed that gravel addition to the clayey soil A and B changed the soil class from A-5-7 to A-2-7, with general subgrade rating of excellent to good. The soil class changed when 40% of gravel size 2-6mm, 30% of gravel size 6-12mm and 20% of gravel size 12-20mm were added respectively to each of the clayey soil A and B.

The result of compaction test shown in Tables I and II indicated that the value of the Maximum Dry Density (MDD) of all the clay-gravel mixtures increased with increase in the concentration of gravel size in clayey soil A and B. However, in terms of Optimum Moisture Content (OMC), the relationship becomes inversely to the increase in gravel percentage and as gravel size increases. The increase in MDD was due to the higher specific gravity of gravel and reduction in OMC was due to low water absorption rate of gravel.

TABLE I. Compaction test results of clay-gravel soil mixture A.

	Gravel size					
	2-6mm		6-12mm		12-20mm	
Percentage of gravel	**OMC %**	**MDD (g/cm^3)**	**OMC %**	**MDD (g/cm^3)**	**OMC %**	**MDD (g/cm^3)**
0	9.15	1.931	9.15	1.931	9.15	1.931
5	8.83	1.956	8.24	1.961	7.26	1.967
10	8.48	1.977	7.86	1.969	7.04	1.988
15	8.28	1.995	7.62	1.977	6.97	2.006
20	8.14	2.020	7.14	2.041	6.49	2.161
30	7.89	2.036	7.13	2.043	6.34	2.226
40	7.88	2.057	6.77	2.064	6.26	2.251
50	7.77	2.090	6.33	2.159	6.11	2.264

TABLE II. Compaction test results of clay-gravel soil mixture B.

	Gravel size					
	2-6mm		6-12mm		12-20mm	
Percentage of gravel	**OMC %**	**MDD (g/cm^3)**	**OMC %**	**MDD (g/cm^3)**	**OMC %**	**MDD (g/cm^3)**
0	10.45	1.825	10.45	1.825	10.45	1.825
5	10.22	1.840	10.12	1.864	9.93	1.871
10	9.87	1.896	9.78	1.903	9.64	1.912
15	9.86	1.910	9.60	1.945	9.35	1.946
20	9.80	1.936	9.29	2.003	9.28	2.101
30	9.54	1.990	9.20	2.009	9.40	2.199
40	9.42	2.075	9.10	2.124	8.68	2.205
50	9.21	2.104	9.02	2.178	8.55	2.282

IV. CONCLUSION

Study of the influence of gravel with grade sizes 2-6mm, 6-12mm and 12-20mm on the geotechnical properties of two clayey soils were carried out. The result of particle size analysis shows that the addition of gravel to the clayey soil changed the class of the clayey soil from A-5-7 to A-2-7. Also, addition of gravel to the clayey soil led to an increase in MDD and reduction in OMC as the concentration of gravel increases in the clay-gravel mixtures. Further increase in MDD with a reduction in OMC was observed as the gravel sizes increases.

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