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ORIGINAL RESEARCH ARTICLE

EVALUATING THE STRENGTH CHARACTERISTICS OF CLAY- GRAVEL MIXTURES

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ABSTRACT

Shear strength is one of the most important soil properties in almost all geotechnical engineering problems. Therefore, this study was aimed at investigating the effect of gravel on the shear strength of clayey soil. Two clayey soil samples were obtained from a dug pit from different locations in Osogbo, Osun State and the gravels were collected locally. Three different gradations of gravel (2-6mm, 6-12mm, and 12-20 mm) were mixed in a dry state in percentages of 5, 10, 15, 20, 30, 40 and 50% with the collected clay soil respectively. Initially, some physical properties of clayey soil and the gravel, which include specific gravity, particle size analysis, liquid limit and plastic limit, were determined in accordance with BS 1377-3:2018. Consequently, the California Bearing Ratio (CBR) and Consolidated - Undrained (CU) triaxial compression tests at three different confining pressures of 50, 100 and 150 kN/m^2, with a loading rate of 0.5 mm/min were carried out on the clay-gravel mixtures in accordance with BS 1377 (1990). The results from the CBR test indicated that the CBR value of the clay-gravel mixtures was higher than that of pure clay. The result of shear strength showed that the cohesion and effective angle of internal friction increases as the concentration of gravel increases from 0 to 50%. As the gravel size was increased from 6-12mm, effective cohesion reduces and angle of internal friction increases. It concluded that locally available gravel can be used to improve the strength properties of clayey soil for engineering construction.

1.0 Introduction

According to Njoka et al. (2015) clay is a naturally occurring material that composed of layered structures of fine-grained materials which exhibit the property of plasticity at appropriate moisture content. It is chemically and structurally analogous to other phyllosilicates but contain varying amounts of water and allow more substitution of their cations. The clay material is formed from chemical weathering processes on the earth's surface, and it contributes about 40% of the fine grained sedimentary rocks (Ombaka, 2016). Clayey soils have lower strength, lower permeability, higher compressibility, higher cracking potential and are apparently less susceptible to liquefaction. Tijani et al. (2017) stated that it is necessary to obtain information on the properties of soils for engineering construction purposes so as to make improvement if it does not substantiate with internationally established standards.

Mixing of clayey soils with granular materials (e.g. sand and gravel) is one of the methods to reduce the swell and shrinkage potential as well as improved strength. These soils with dominant part of clay are called mixed clayey soils (Soltani and Soroush, 2007). Jafari and Shafiee (2004) carried out consolidated undrained compression triaxial tests on mixtures of kaolin, sand/gravel and observed that the angle of shearing resistance at the critical state increases as the aggregate contents in the mixture increase. The study also observed that, during undrained loading, higher pore water pressures are induced in the mixtures with higher aggregate contents.

Soltani and Soroush (2007) studied the behaviour of compacted clay-sand and clay-gravel mixtures by conducting undrained triaxial tests. The study suggested that 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.

Ayininuola et al. (2018) investigated the influence of gravel on the geotechnical properties of clayey soil. The influence of gravel with grade sizes 2-6 mm, 6-12 mm and 12-20 mm 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, 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 in the clay-gravel mixtures. Further increase in MDD with a reduction in OMC was also observed as the gravel sizes increases.

Vallejo and Mawby (2000) revealed that the shear strength of clay-aggregate composites depends upon the relative concentrations of the aggregates and the clay by weight in such a way that if the content of the granular material in the composite is greater than 75%, the shear strength is controlled by the aggregate alone. In another study, Kumar and Wood (1999) noted that for clay contents above 35%, it is the clay matrix alone, which controls the mechanical behaviour of the mixture and the gravel only begins to influence the behaviour when the granular fraction reaches about 45%.

Iannacchione and Vallejo (2000) reviewed 31 technical papers (comprised field case studies, laboratory investigations, and theoretical analysis) containing analysis of shear strength for clays and sands with varying mixtures of rock particles. The study concluded that the shear strength gradually increases with increase in percentages of floating particles in unsaturated clays. The present study, thus, aimed at evaluating the shear strength characteristics and California bearing ratio of clayey soil mixed with three different grades of gravel. The clayey soil-gravel mixtures were prepared by means of standard Proctor compaction tests and the shear strength behaviour of the prepared samples was evaluated under Consolidated-Undrained (CU) triaxial test condition. Results of the study will reveal the suitability of locally available gravel to improve the strength properties of clayey soil for engineering construction.

2. Materials And Method

Two clayey soil samples were collected at different locations. One at a dug pit for constructing a gantry located at 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. California bearing ratio, and consolidated undrained triaxial, compaction tests,were determined in accordance with BS 1377-3 (2018).The gravel was separated into grades ranging from 2-6 mm, 6-12 mm and 12-20 mm in the laboratory. The gravel was 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 labeled as clayey soil A and the other collected at Oke-Baale was labeled as clayey soil B.

3. Results And Discussions

The liquid limits for the clayey soils A and B were 49 and 58% respectively. The plastic limit was respectively found to be 30.6 and 31.18%, and the linear shrinkage was recorded as 9.3 and 10% respectively. Particle size analysis revealed that clayey soil B contains more fine grain soil than clayey in soil A, with the percentage passing sieve size 0.075mm found to be 54%, which was higher than 52% of clayey soil A. The two clayey soils (A and B) were classified in accordance with the American Association of State Highway Transportation Officials (AASHTO). Clayey soils A and B were classified as A-5-7 with a general subgrade rating of fair to poor. The results of geotechnical properties are similar to those obtained by Kumar and Muir (1999) who observed a sharp change in response when the clay content falls below about 40% and a change in character of response at clay contents below about 40% and for clay contents above about 35%, only the clay matrix controls the mechanical behaviour of the mixture.

The results of the California Bearing Ratio (CBR) shown in Tables 1 and 2 revealed that the value of the CBR of all the clay-gravel mixtures increased with increase in the concentration and sizes of gravels in clayey soils A and B from 0% to 50%. The increase was attributed to the presence of larger granular particles in the clay-gravel mixture, which will require a larger magnitude of forces at 2.5 and 5.0 mm penetration for CBR measurement. This is in agreement with the work of Ayininuola et al. (2018) who reported that gravel addition to the clayey soil 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 6-12 mm and 20% of gravel size 12-20mm were added respectively to each of the clayey soil A and B

Table1. Average CBR in percentage values of clay-gravel soil samples A

Percentage of gravel	Size of gravel(mm)		
	2 – 6mm	6 – 12mm	12 – 20mm
0	65.00	65.0	65.0
5	66.5	67.5	68.8
10	68.0	69.0	70.5
15	70.5	72.0	74.6
20	71.2	74.6	78.2
30	74.4	78.2	81.6
40	76.0	80.0	85.7
50	78.0	82.0	87.0

Table 2. Average CBR in percentage values of clay-gravel soil samples B

Percentage of gravel	Size of gravel(mm)		
	2 – 6 mm	6 – 12 mm	12 – 20 mm
0	68.0	68.0	68.0
5	70.0	72.0	74.0
10	72.0	73.0	76.0
15	73.2	75.0	77.2
20	75.0	77.0	79.6
30	76.9	79.0	82.1
40	77.5	81.0	85.0
50	78.7	84.0	88.0

The shear strength parameters (effective cohesion c' and angle of internal friction φ') for the clay-gravel mixtures with gravel size 12-20mm cannot be obtained on the triaxial machine due to the presence of larger particle sizes than the values specified in the BS 1377-3 (2018 and reported also by Bakhtiar et al. (2019); this could be solved by conducting sieve analysis before use. The variation of internal friction angle and the cohesion for clay-gravel mixtures for clayey soil A and B are shown in Tables 3 and 4 for gravel size 2mm-6mm and 6mm-12mm respectively. An increase in shear strength of gravel content of approximately 50% was observed. This is undoubtedly in response to the significant inter-particle interaction occurring within this concentration. A corresponding reduction in the cohesion of the soil as the gravel size was increased from 6-12mm in the clay-gravel mixtures was apparent as the clay-gravel mixtures became more granular.

Table 3. The result of shear strength parameters c' and φ' for clay-gravel soil A

	Size of gravel			
Percentage of gravel	C' (kN/m^2) 2-6 mm	φ' (0) 2-6 mm	c' (kN/m^2) 6-12 mm	φ' (0) 6-12 mm
0	22.0	10.0	24.0	10.0
5	24.0	12.0	30.0	14.0
10	26.0	14.0	32.0	18.0
15	28.0	16.0	34.0	20.0
20	30.0	18.0	36.0	22.0
30	32.0	20.0	40.0	24.0
40	34.0	30.0	40.0	32.0
50	38.0	35.0	39.0	38.0

Table 4. The result of shear strength parameters c' and φ' for clay-gravel soil B

	Size of gravel			
Percentage of gravel	c' (kN/m^2) 2 – 6mm	φ' (0) 2– 6mm	c' (kN/m^2) 6-12mm	φ' (0) 6 – 12mm
0	30.0	18.0	30.0	18.0
5	32.0	19.0	31.0	20.0
10	34.0	20.0	32.0	22.0
15	36.0	21.0	33.0	26.0
20	38.0	23.0	34.0	28.0
30	40.0	25.0	35.0	32.0
40	41.0	27.0	36.0	38.0
50	41.0	30.0	37.0	42.0

4. Conclusions

The effects of gravel on the geotechnical and strength properties of clayey soils were evaluated using three different grades of gravel. The clayey soil-gravel mixtures were prepared by means of standard Proctor compaction tests and the shear strength behaviour of the prepared samples was evaluated under Consolidated-Undrained (CU) triaxial test condition. The results revealed that, an addition of gravel to clayey soil contributes to the improvement in both its geotechnical and strength properties. The strength of the clay-gravel mixtures was influenced when the percentage of the gravel of sizes 6 – 12 mm, and 2 – 6 mm were 30 and 40% respectively. It was concluded that locally available gravels could be used to improve the strength properties of clayey soil for engineering construction.

References

Ayininuola, GM., Salami, MO. and Salami, LO. 2018. Investigating the Geotechnical Properties of Clay-Gravel Mixtures. International Research Journal of Advanced Engineering and Science, 4(1): 40-41.

Bakhtiar, AO., Aminaton, M., Nor, ZMY., Tan, CS. and Faizal, P. 2019. The Grading Effect of Coarse Sand on Consolidated Undrained Strength Behaviour of Sand Matrix Soils. International Journal of Recent Technology and Engineering (IJRTE), 7 (5): 88 – 92.

BS 1377-3 2018. Methods of test for soils for civil engineering purposes. Chemical and electro-chemical testing. British Standards Institution, July 2020, London. pp. 1-7

Iannacchione, AT. and Vallejo, LE. 2000. Shear Strength Evaluation of Clay-Rock Mixtures. Slope Stability 2000, Proceedings of Sessions of Geo-Denver 2000 Denver, Colorado, August 5-8, Geotechnical Special Publication No. 101, Editors; Griffiths DV., Fenton GA. and Martin TR., Reston, VA: American Society of Civil Engineers, 209-223.

Jafari, MK. and Shafiee, A. 2004. Mechanical behaviour of compacted composite clays. Canadian Geotechnical Journal, 41 (6): 1152-1167.

Kumar, GV and Muir, WD. 1999. Fall cone and compression tests on clay–gravel mixtures. Geotechnique, 49(6): 727–739.

Njoka, EN., Ombaka, O., Gichumbi, JM., Kibaara, DI. and Nderi, OM. 2015. Characterization of clay from Tharaka Nithi Country in Kenya for industrial and agricultural applications. African Journal of Environmental Science and Technology, 9 (3): 228-243.

Ombaka, O. 2016. Characterization and classification of clay minerals for potential applications in Rugi Ward, Kenya. African Journal of Environmental Science and Technology, 10 (11): 415-431.

Soltani, JH. and Soroush, A. 2007. The behaviour of mixed clayey soils under monotonic loading. International Journal of Science and Technology-Amirkabir (CMM), 18(67): 21-29

Tijani, MA., Akinleye, MT. and Jaiyeoba, KF. 2017. Engineering Properties of Laterites Obtained in Ede, Southwestern Nigeria. International Journal of Engineering and Advanced Technology, 7(1):160 – 162.

Vallejo, LE. and Mawby, R. 2000. Porosity influence on the shear strength of granular material-clay mixtures. Engineering Geology, 58: 125–136

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