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Shear Strength of Compacted Foundry Sand Treated With Bentonite Using West African Standard Energy

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Abstract: *This research project investigates the effect of Bentonite content on the Shear Strength of Foundry Sand – Bentonite mixture using West African Standard compaction efforts. The Foundry Sand and Bentonite were mixed to form clay – sand mixtures with varying Bentonite contents of 2, 4, 6, 8 and 10%. Tests such as Particle Size Distribution, Atterberg limits, Specific Gravity, Compaction and Direct Shear Box were carried out to determine the index and strength properties of the Foundry sand and the various treated mixes. The results of the classification test show that Foundry Sand is non-plastic and falls under A-3 and SM using AASHTO and USCS classification systems respectively. The compaction characteristics trended in reverse directions as the Bentonite content increases. While the maximum dry density is decreasing, the optimum moisture content increased. The shear strength and internal friction angle of the Foundry Sand – Bentonite mixtures were measured to be lower than that of the untreated Foundry sand while the increase of cohesion with increasing Bentonite content is an indicator of the presence of cohesive material in the mixtures. Although the presence of clay has impacted on the index properties and cohesion of foundry sand, more research to determine shear strength which include additional clay content to foundry sand should be carried out to have more results in a wider range.*

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I. Introduction

The shear strength of a soil is perhaps the most important of its engineering properties. This is because all stability analysis in the field of geotechnical engineering, whether they relate to foundation, slopes of cuts or earth dams, natural slopes of hillsides and other structures built on soil depend upon the engineering properties of the soil and the shearing resistance offered by the soil along the probable surfaces of slippage (Venkatramaiah, 2006).

Geotechnical engineering projects such as stability of slopes of cuts or earth dams, foundations or embankments, requires suitable soil to satisfy the purpose of the project. Depending on the purpose for which the soil is intended to be used for, the shear strength of the soil is the most important engineering property that needs to be assessed and checked for. Although the shear strength of a soil cannot be tabulated in the codes of practice because a soil can significantly exhibit different shear strengths under different fields and engineering conditions, reference will be made to the guides stated in the codes regarding the determination of shear strength of foundry sand treated with bentonite using West African Standard compacting energy level (Venkatramaiah, 2006).

Most of civil engineering projects are associated with locating borrow pits, suitable materials, haulage or specifications that require high quality soil necessitates the initiation of researches in to the possibility of using locally available industrial waste (foundry sand) as a replacement for sand in construction works. This work will focus on the proper utilization of this industrial waste. Laboratory test will be carried out to determine the shear strength of foundry sand treated with bentonite using West African Standard compacting energy level. With this, if the operation is perfectly executed and the shear strength of foundry sand satisfies the desired strength requirements, then it can successfully be used in engineering projects.

The main aim of this study is to determine the shear strength of foundry sand treated with bentonite using West African Standard compacting energy level.

This research study will be limited to the use of foundry sand and bentonite mixture to determine compaction and strength behavior of the mixture under unconfined West African Standard stress. Tests were carried out on the soil sample in accordance with the provisions of BS1377 (1990), BS1924 (1990), ASTM D4318 using West African Standard (WAS) compacting effort. This work focuses on the shear strength of the compacted foundry sand treated with bentonite at various percentages of 0, 2, 4, 6, 8 and 10% by dry weight of the soil. Foundry sand and bentonite mixtures are compacted using the optimum moisture content (OMC) for the various percentages and the shear strength was determined for each percentage of bentonite content.

II. Materials And Method

2.1 Material

2.1.1 ***Foundry Sand***

Foundry sand is high quality silica sand that is a byproduct from the production of both ferrous and non-ferrous metal castings. The soil sample used for this research work is Foundry Sand. It is dark brown in color and was obtained from the Defense Industries Corporation of Nigeria (DICON), Kaduna (Latitude 10º 30'N and Longitude 7º 27'E), Nigeria. The various tests for the Engineering properties of soil was performed in accordance with BS 1377 (1990) for the natural foundry sand and BS 1924 (1990) for the soil treated with bentonite.

2.1.2 Bentonite Clay

Bentonite clay which is a binder material, in this research it is added to the Foundry Sand in 2%, 4%, 6%, 8% and 10% by weight of the Foundry Sand. It was obtained from Sabon-gari market in Kano, Nigeria.

2.2 Method

The methods adopted for determining the changes in Engineering properties of Foundry Sand when treated with Bentonite by the various laboratory tests (sieve analysis, atterberg limit, specific gravity, maximum dry density, optimum moisture contentand shear strength) are all in accordance with specifications in BS 1377 (1990) and BS 1924 (1990). The compacting effort used is the West African Standard (WAS).

III. Result And Discussion

3.1 Result of Sieve Analysis

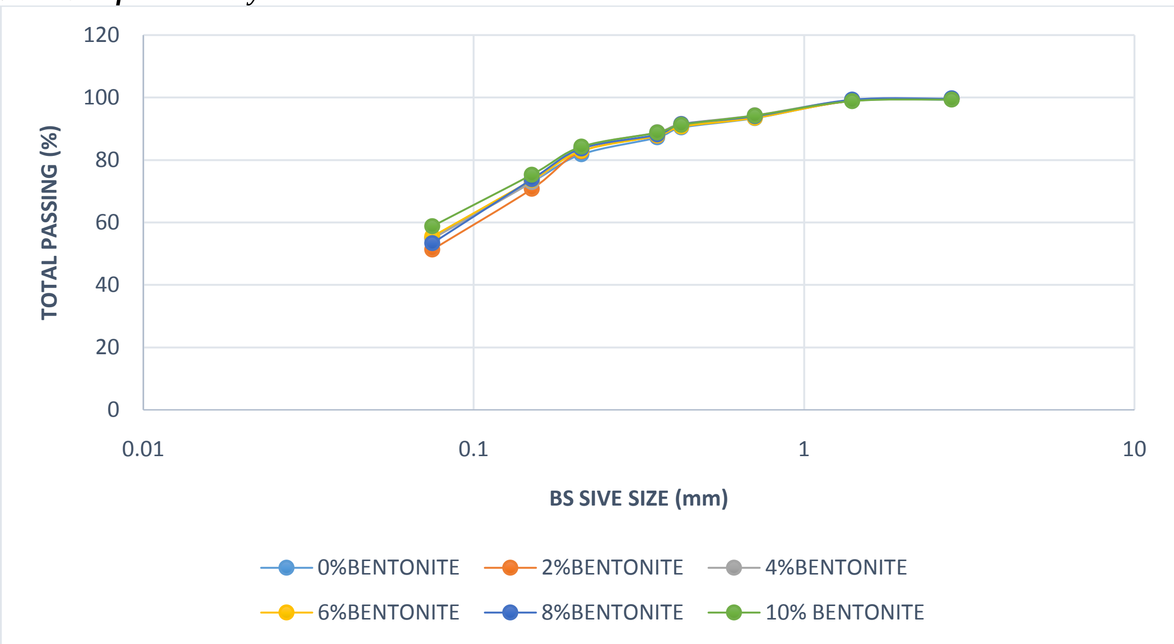

Fig. 3.1: Particle size distribution curves for foundry sand – Bentonite mixtures

The foundry sand and the clay – sand mixtures were classified as SM (coarse grain material) under USCS. Under AASHTO classification, the general classification was A-3 (granular material) and it ranges from excellent to good material for a subgrade.

3.2 *Result of Atterberg Limits*

Table 3.1: Results of Atterberg Limit test

Property	Bentonite Content (%)					
	0	2	4	6	8	10
Liquid Limit, (%)	21	30	30.7	32	34	35
Plastic Limit, (%)	-	-	-	-	-	-
Plasticity index, (%)	Non – plastic					
Linear Shrinkage, (%)	1.2	2.32	2.56	3.15	3.94	4.1

The foundry sand and the clay – sand mixtures were found to be non-plastic with increasing Liquid limits and linear shrinkage. The incremental trend of liquid limit could be attributed to the large amount of water absorbed by the fines of the bentonite while that of linear shrinkage could be due to the swelling and expanding ability of the bentonite clay that lost moisture on drying.

3.3 Result of Specific Gravity Test

Table 3.2: Results of Specific Gravity test

Property		**Bentonite Content (%)**					
		0	2	4	6	8	10
Specific Gravity		2.57	2.55	2.51	2.41	2.38	2.32

The specific gravity of the grains of bentonite is 2.34 while that of untreated foundry sand was found to be 2.57 and thus, the clay – sand mixture with higher amounts of Bentonite resulted in a decreasing trend of specific gravity.

3.4 *Result of Compaction Test*

Table 3.3: Results of Compaction test

Property	**Bentonite Content (%)**					
	0	2	4	6	8	10
Maximum Dry Density (Mg/m^3)	1.69	1.68	1.65	1.64	1.63	1.60
Optimum Moisture Content (%)	15.94	16.10	16.28	16.67	19.90	20.48

The results show a decrease in MDD from 1.69 Mg/m^3 for the untreated foundry sand to 1.60 Mg/m^3 for soil treated with 10% bentonite while the OMC increases from 15.94% for the untreated foundry sand to 20.48% at 10% bentonite. According to Ishaya (2014), the reduction in MDD is as a result of fine particles of bentonite with lower specific gravity occupying larger spaces in the mix and thus leading to a corresponding drop in dry density.

3.5 *Result of Shear Strength*

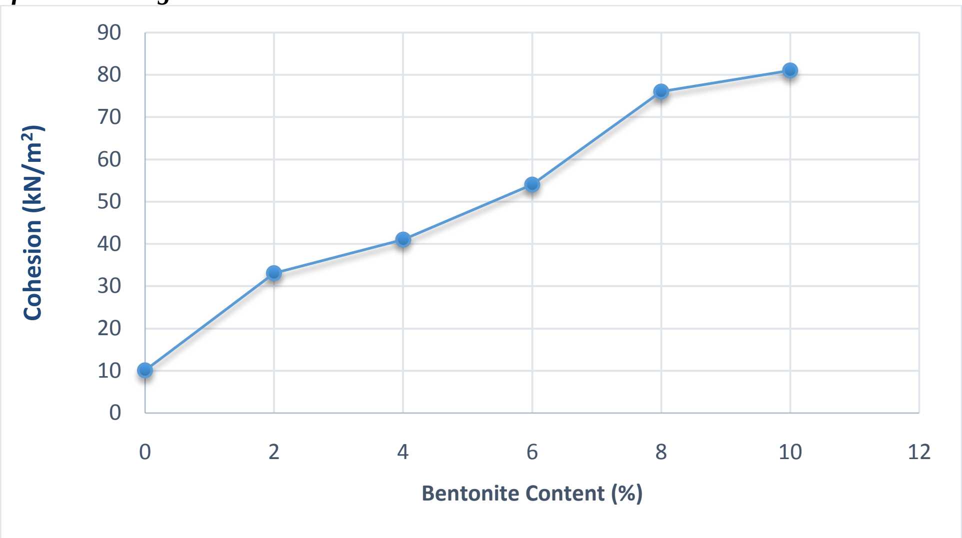

Fig. 3.2: Variation of cohesion of foundry sand with Bentonite content

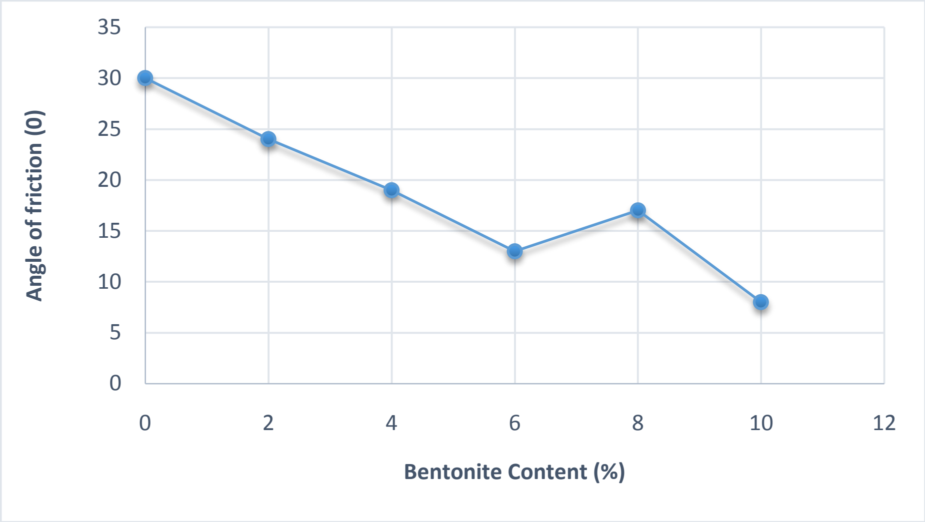

Fig. 3.3: Variation of internal friction angle of foundry sand with Bentonite content

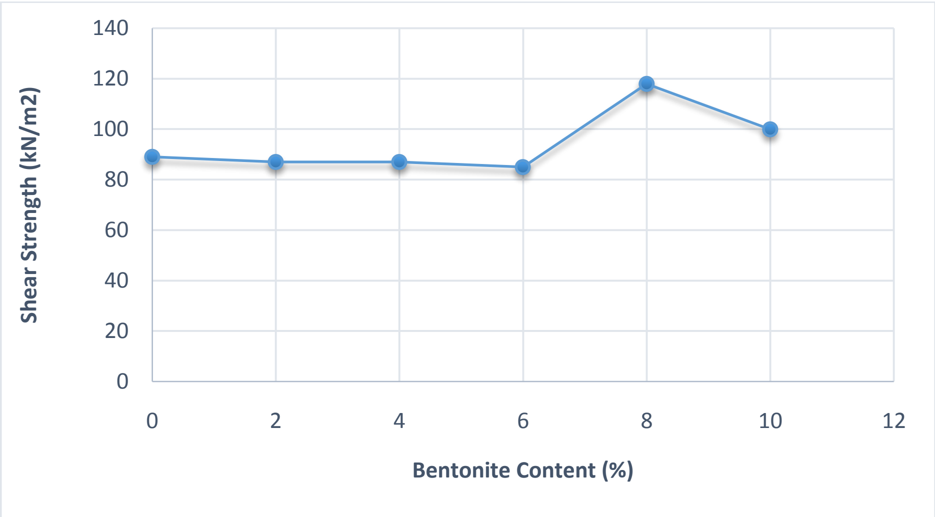

Fig. 3.4: Variation of Shear Strength Bentonite content (Applied Normal stress = 136kN/m^2)

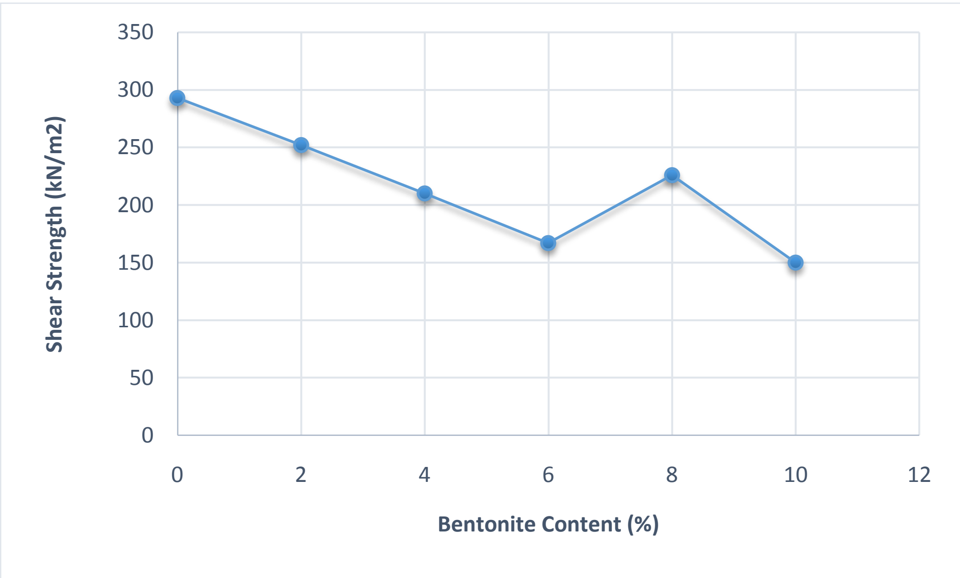

Fig. 3.5: Variation of Shear Strength with Bentonite content (Applied Normal stress = 491kN/m^2)

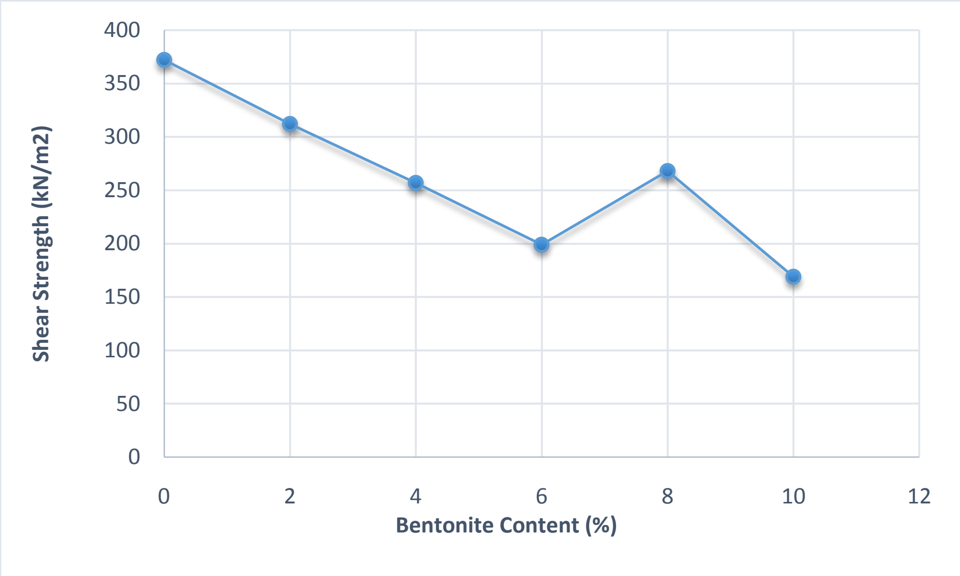

Fig. 3.6: Variation of Shear Strength with Bentonite content (Applied Normal stress = 627kN/m^2)

From figure 3.2, the cohesion of the clay – sand mixture is increasing as a result of the cohesive structure of bentonite than foundry sand which increase the cohesion of the mixture. According to Utku (2015) and FHWA (2004), the cohesive strength of green sands treated with clays is greater than that of untreated green sands and chemically bonded sands because of higher cohesion that exist in clays, the results obtained agree with these findings. However, the internal friction angle and shear strength follow a similar trend of decreasing with Bentonite content although slight increase was reported between 6-8%. Expectedly, the shear strengths of the various mixes increased with applied normal stresses used in the direct shear test.

IV. Conclusion and recommendation

4.1 Conclusion

This study was carried out to investigate the Shear Strength of foundry sand and foundry sand - bentonite mixture compacted with West African Standard (WAS). The untreated foundry sand was treated with bentonite as the additive in stepped concentrations of 2, 4, 6, 8 and 10% of bentonite content and by dry weight of the foundry sand. The experimental results shows;

- The soil falls under A-3 as classified in AASHTO classification; also it falls under SM in USCS classification.
- The untreated foundry sand has a liquid limit of 21% and is non-plastic. The liquid limit increases with increase in Bentonite content.
- The linear shrinkage generally increased with increase in bentonite clay content.
- The specific gravity decreased with increase in bentonite content from 2.57 for untreated foundry sand to 2.32 at 10% bentonite treatment.
- The compaction characteristics of the untreated foundry sand was altered with the addition of bentonite. The MDD decreased from 1.69 Mg/m^3 for the untreated foundry sand to 1.60 Mg/m^3 at 10% bentonite content, while the corresponding OMC increased from 15.94% for the untreated foundry sand to 20.48% at 10% bentonite content.
- The cohesion increases from 10kN/m^2 for the untreated foundry sand to 81kN/m^2 for 10% Bentonite content.
- The Angle of internal friction decreases from 30^0 for the untreated foundry sand to 8^0 for the 10% Bentonite content.
- The shear strength of foundry sand and the foundry sand with Bentonite treatment decreases with increase in Bentonite for Normal stress of 136kN/m^2 with the highest strength of 118kN/m^2 at 8%.
- The shear strength of foundry sand and the foundry sand with Bentonite treatment decreases with increase in Bentonite for Normal stress of 491kN/m^2 with the highest strength of 293kN/m^2 at 0%.
- The shear strength of foundry sand and the foundry sand with Bentonite treatment decreases with increase in Bentonite for Normal stress of 627kN/m^2 with the highest strength of 372kN/m^2 at 0%.

4.2 Recommendations

Based on the results of the investigation carried out using the optimum moisture content earlier determined, an optimum shear strength of 372kN/m^2 was obtained at a Normal stress of 627kN/m^2 when the foundry sand is not treated with Bentonite and compacted with West African standard compactive effort. The minimum allowable 200kN/m^2 strength performance for waste repositories is being exceeded by the untreated foundry sand and hence it is recommended as hydraulic barriers in waste containment applications.

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