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Modification of Clay Using A-3 Soil

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ABSTRACT

Clay soil classified as A-7-6 according to AASHTO soil classification system and CH according to unified soil classification system was collected from Niger State Polytechnic Zungeru in Niger State. The clay was modified with A-3 soil sieved out from river sand. The clay was replaced with A-3 soil at 0, 10, 20, 30 to 100% by weight of the clay soil. Grain size analysis tests and Atterberg limit tests were carried out on each of the clay-A-3 soil mixtures to evaluate the effect of A-3 soil on the clay soil. Results showed that the liquid limit of the clay reduced from 59.3% at 0% A-3 soil replacement to 23.4% at 80% A-3 soil replacement. The plasticity index reduced from 32.5% at 0% A-3 soil replacement to 6.6% at 60% A-3 soil replacement. These represent 60% reduction in liquid limit and 80% reduction in plasticity index. A-3 soil is therefore an appropriate material for modification of clayey soils and 60% A-3 soil replacement is the maximum required for effective modification of clay soils.

Keywords:*modification, A-3 soil, flocculation, Aggregation.*

1. INTRODUCTION

It is common in geotechnical practice to encounter lateritic soils which satisfies all requirements for use as sub-base course, or even base course for low trafficked roads according to Nigerian General Specification for Roads and Bridge Works (1992) but is deficient in Atterberg limits of its fines. This is attributed to the nature of the clay present in such type of laterite. Soils that fall under this group may be highly plastic. Placement of these materials during road construction is usually difficult as the plastic clay keep sticking to the rolling drum of the compactor. Sections that are successfully compacted, loose strength drastically with ingress of water due to softening of the clay soil which can result in to instant failure of the road structure. Also, the criteria placed by the Highway Research Board of America (1943) for highly plastic clay soils to be economically stabilized, include that, less than 50% passing sieve 0.075mm, less than 40% liquid limit and less than 18% plasticity index. Soils with index properties above these limits would be modify to reduce these values. Modification of clay will reduce its Atterberg limits and hence put the lateritic soil in an AASHTO classification group that will make it suitable for use as sub-base course or even base course material.

A-3 soils subgroup in AASHTO soil classification system is placed in a lone column without subdivisions like A-1 and A-2. A-3 soils are uniformly fine and non plastic sand which make its use in any component of road structure to be very minimal and almost completely neglected in AASHTO soil classification scheme. It is therefore pertinent to put this class of soil in to any possible engineering use.

Soil modification is the improvement of the physical properties of the soil in order to increase its workability. Materials commonly used for modification are cement, lime and some other pozzolanic admixtures like fly ashes, rice husk ashes, sugarcane Bagasse ashes, e.t.c. According to Ola (1983), modification by these chemicals is caused by flocculation and aggregation of the clay particles which reduces its double layer. This is based on the physico-chemical reaction which reduces the repulsive forces and increases the effective grain size due to agglomeration of the clay particles. The agglomeration will eventually turn clay particles to silt sized particles which cause reduction in the liquid limit. The author studied a lateritic clay soil and observed increase in liquid limit from 36% at 0% lime to 42% at 10% lime while the plastic limit was observed to increase from 18% at 0% lime to 41% at 10% lime. The cumulative effect of these two is the reduction in plasticity index from 18% at 0% lime to 1% at 10% lime. These trend was observed by Osinubi and Gadzama (2008), Osinubi and Katte (1999). Ola (1983b) studied lime stabilization of some Nigerian black cotton soils where lime content of 0, 2, 4 to 10% was used. Findings revealed continue reduction in liquid limit, continues increase in plastic limit and continues decrease in plasticity index. Osinubi and Alhassan (2008) worked on the lime modification of clay using Bagasse ash as pozollana. The researcher used 0, 1, 2 – 4% lime each admixed with 0, 1, 2 – 8% Bagasse ash by dry weight of the soil. The result shows particle size distribution curve shifting from region of fine grained soil to the region of course grained soil as percentage lime and Bagasse ash increases. There was continuous decrease in liquid limit and increase in plastic limit with increase in lime and Bagasse ash. These trends combined to cause reduction in plasticity index with increase in lime and Bagasse ash. Bagasse ash was used to modify shika lateritic clay soil Osinubi and Gadzama (2008). The Bagasse ash was used at 0, 2% - 10% by weight of the clay soil. Results showed increase in liquid limit and plastic limit and subsequently decreases in plasticity index as Bagasse ash content is increased. However, all these materials used for modification are either expensive or very difficult to source in large quantity hence the requirement to look for cheaper and easy-to-source material for modification of clay soils.

Goodarzi and Salimi (2015) treated dispersive clayey soil with granulated blast furnace slag (GBFS) and basic oxygen furnace slag (BOFS). The slags were added from 2.5 to 30% by weight of the dispersive clay. The index properties result showed continuous reduction in plasticity index from 350.5% to 200% for treatment with GBFS and to 100% for treatment with BOFS. Muazu (2006) studied the effect of sand on the Atterberg limits of four different lateritic soils. The author used 0%, 2%, 4% - 8% sand by weight of lateritic soil. The results revealed continuous reduction in liquid limit, plastic limit and plasticity index as the sand increases up to 8% sand. The researcher did not reduce the sand to predominantly silty sand and cannot evaluate the Atterberg limits beyond 8% sand. Joel and Agbede (2008) studied the possibility of using Igumale sand and lime to stabilize Igumale shale. The author used 0%, 10%, 20% to 50% sand each admixed with 0%, 2%, 4% to 14% lime by weight of dry Igumale shale. Results at 0% lime showed reduction in plasticity index from 45% at 0% sand to 30% at 50% sand. This research does not consider the soil properties beyond 50% sand.

This work is therefore intended towards replacing clay with A-3 soil from 0% to 100% to modify the clay soil.

2. METARIALS AND METHODOLOGY

2.1. *Materials*

The materials used for this study are clay soil collected from Niger State Polytechnic, Zungeru, Niger State. The A-3 soil used for the study was obtained from River Chanchaga in Minna, Niger State. The A-3 soil was collected by sieving the river sand through sieve 0.425mm.

2.2. *Methodology*

The clay soil was properly dried and pulverised before it is being put in to use. The A-3 soil was used to replace the clay soil at 0%, 10%, 20% to 100% by weight of the dried clay soil. Index properties test was conducted on the natural clay soil and silt soils according to the methods highlighted in BS 1377 (1990) while same was done on each of the mixed samples according to the methods highlighted in BS 1924 (1990). Variation in Atterberg limits with percentage A-3 soil replacement were calculated and plotted. The variation in percentage liquid limit and percentage plasticity index with percentage silt replacement was also calculated and plotted.

3. RESULTS AND DISCUSSIONS

3.1. *Grain size analysis*

The result of the grain size analysis is shown in figure 1. The result showed curves moving from well graded nature at 0% A-3 soil replacement to highly uniformly graded nature at 100% A-3 soil replacement. This is because of the uniformly graded A-3 soil used for replacement of well graded clay soil as shown in figure 1.

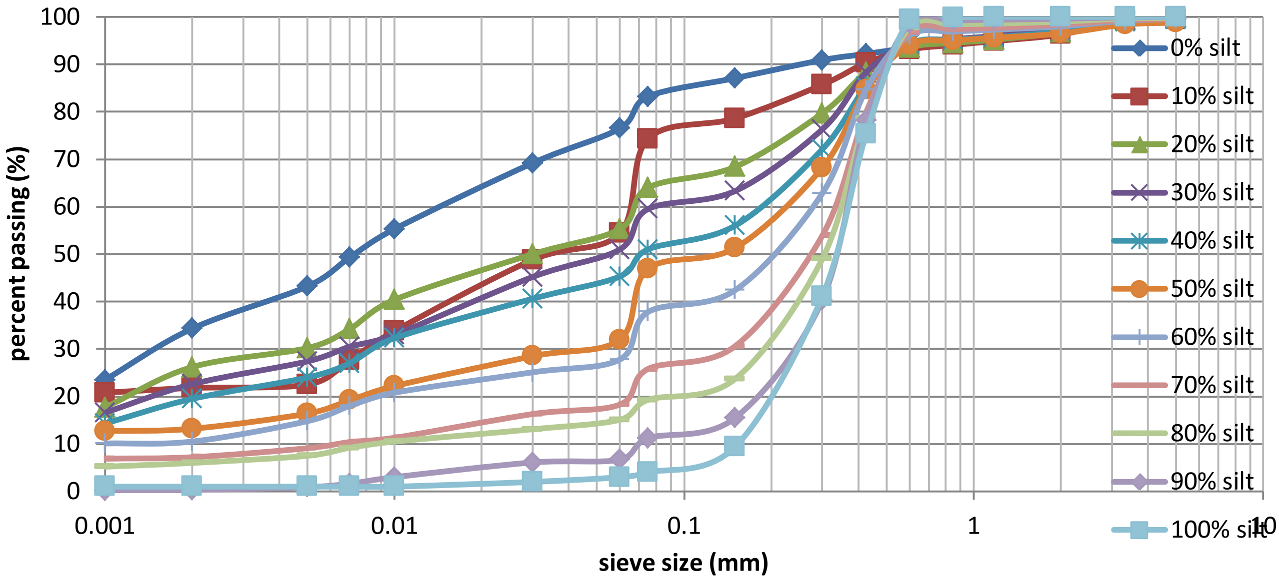

Figure 1: Grain size analysis of the clay soil at various silt replacement

This can probably cause reduction in strength of remoulded clay soils replaced with high composition of A-3 soil.

The result also showed grained size curves moving from the region of fine grained soil towards the region of course grained soils. This agrees with the findings by Osinubi and Alhassan (2008).

3.2 Atterberg limits

The result of the variation in liquid limit, Plastic limit and plasticity index with A-3 soil replacement is shown in figure 2. The liquid limit decreases from 59.3% at 0% A-3 soil replacement to 23.4% at 80% A-3 soil replacement after which the value increased to 28.8% at 100% A-3 soil replacement. The plastic limit behaved similarly with reduction from 26.8% at 0% A-3 soil replacement to 18% at 50% A-3 soil replacement after which the value increased to 20.3% at 60% A-3 soil replacement. This trend is in agreement with Muazu (2006) and Joel and Agbede (2008). The mixture became non plastic beyond this replacement.

The resultant plasticity index reduces from 32.5% at 0% A-3 soil replacement to 6.6% at 60% A-3 soil replacement after which the mixture becomes non plastic. These results are in disagreementwith studies carried out using lime and cement for modifications (Osinubi, 1999). This is because the results of lime and cement modification of clays are commonly characterised by average increase in both the liquid limit and plastic limit with resultant decrease in plasticity index. Unlike lime, cement and some other pozzolanic admixtures that pass through chemical reactions in the process of modifying clay soils, A-3 soil is inactive and do not undergo these reactions.Therefore, the trend observed in this study emanates from the physical process of which A-3 soil particles covers the surfaces of the active clay particles and reduces interaction between

clay to clay particles thus reducing the plastic action of the clay particles.

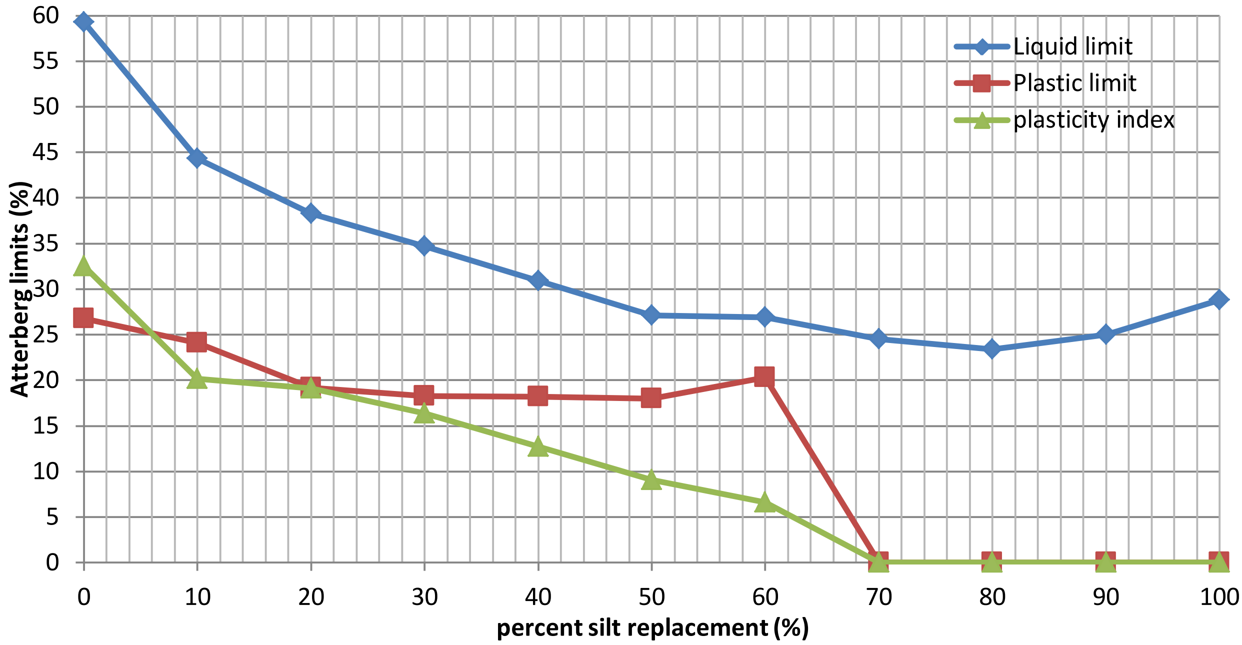

Figure 2: Variation of Atterberg Limits with increase in non-plastic silt replacement

At lower composition of A-3 soil particles, few active clay particles are covered with the A-3 soil which leaves more active clay particles to exhibit plastic action. However, increase in A-3 soil tends to cover more active clay particles and further reduction in both the liquid limit and the plastic limit with resultant decrease in plasticity index.

A point is reached when the whole active clay particles contained in the soil sample are covered with A-3 soil. Increase in A-3 soil beyond this point results in to slight increase in liquid limit with completely non plasticity of the fines contained in the soil. The reduction in Atterberg Limits with

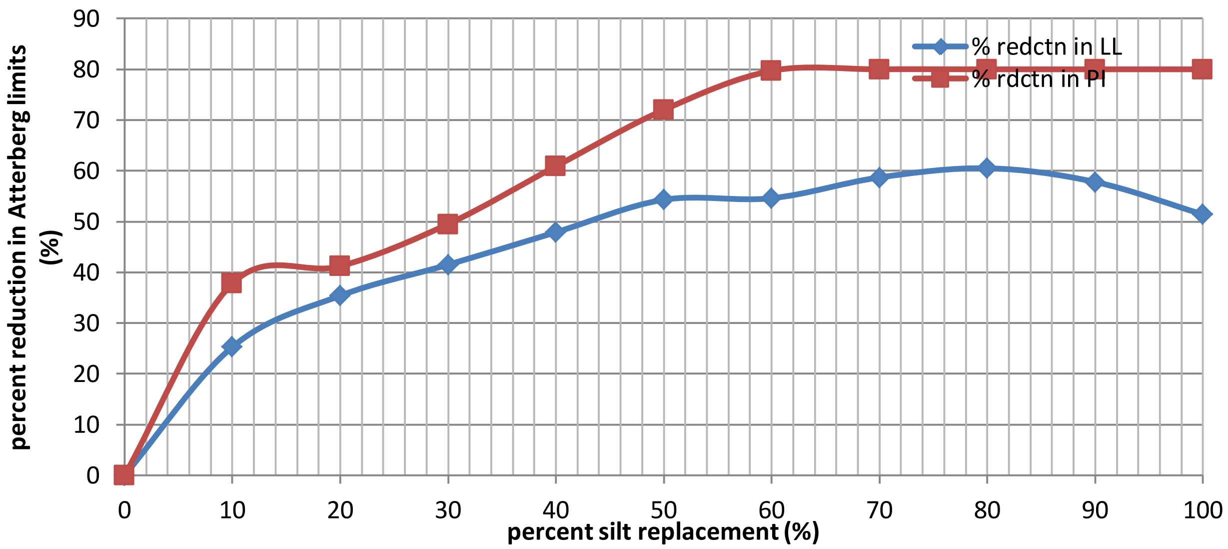

Figure 3: Percentage reduction in Atterberg Limit with percentage silt replacement

increase in A-3 soil replacement represented by percentage reduction on the bases of the maximum Atterberg limit values of the clay is shown in figure 3. This percentage Atterberg limit reduction will help to determine the amount of A-3 soil required to modifying a gravely lateritic soil which is deficient in only the Atterberg limits. The result of the index properties of the clay soil replaced with varied A-3 soil as well as its classifications using the Unified Soil Classification System (USCS) and the American Association of State Highways and Transportation Officers system (AASHTO) classifications is shown below:

Table 1: Summary of index properties and subsequent soil classification with silt replacement

percentage silt Replacement (%)	Percent passing sieves (%) 5.0mm	2.0mm	0.425mm	0.075mm	Liquid Limit (%)	Plasticity Index (%)	Soil Classification AASHTO	USCS
0	99.5	96.5	92.2	83.2	59.3	32.5	A-7-6	CH
10	99.4	96.3	90.3	74.3	44.3	20.2	A-7-6	CL
20	99.8	96.7	88.3	64.0	38.3	19.1	A-6	CL
30	99.5	97.4	88.3	59.5	34.7	16.4	A-6	CL
40	99.4	96.9	85.3	51.0	30.9	12.7	A-6	CL
50	98.8	96.5	84.7	46.9	27.1	9.1	A-4	SC
60	99.6	98.0	84.7	37.8	26.9	6.6	A-4	SM-SC
70	99.5	98.4	79.9	25.8	24.5	NP	A-2-4	SM
80	99.8	99.0	78.6	19.3	23.4	NP	A-2-4	SM
90	100	99.6	78.2	11.2	25.0	NP	A-2-4	SM
100	100	100	75.3	4.0	28.8	NP	A-3	SP

The soil classification presented on the table above showed clay of high plasticity at 0% A-3 soil through clay of low plasticity from 10% to 40% A-3 soil. The classification becomes clay sand at 50% A-3 soil and silty sand to clay sand at 60% A-3 soil. Beyond this percentage A-3 soil, the clay soil becomes non plastic. Therefore, 60% A-3 soil is the maximum value required for effective modification of clay soils.

4. CONCLUSION

From the result of the investigation carried out in this study, the following conclusions can be drawn:

1. The clay used in this study classified as A-7-6 under AASHTO classification system and as CH under unified soil classification system.
2. The particle sizes moved from the region of fine grained soil to that of course grained soil with increase in percentage A-3 soil replacement.
3. The index properties decreased continuously from 0% A-3 soil to 60% A-3 soil replacement after which the clay becomes completely non plastic. Therefore, 60% A-3 soil replacement is the maximum required for effective modification of clay soils.
4. Maximum of 60% reduction in liquid limit was achieved at 80% A-3 soil replacement while maximum of 80% reduction in plasticity index was achieved at 60% A-3 soil replacement.

5. RECOMMENDATIONS

1. A maximum of 60% A-3 soil replacement is recommended for effective modification of plastic clays. Beyond this level of replacement, the whole mixture becomes non plastic.

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