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Investigating the Effectiveness of Various Techniques for Soil Improvement

A Report Submitted to
Mewar University, Chittorgarh Towards the Partial Fulfillment of the Degree of Bachelor of Technology
Civil Engineering

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Abstract:- Existence of unsuitable soil for supporting structures in construction sites, lack of space and economic motivations are primary main reasons for using soil improvement techniques with poor subgrade soil conditions rather than deep foundation. Soil at a construction site may not always be totally suitable for supporting structures in its natural state. In such a case, the soil needs to be improved to increase its bearing capacity and decrease the expected settlement.

This topic gives an overview of techniques that are commonly used to improve the performance, reduce the post construction settlement, and enhance the shear strength of the soil system, increase the bearing capacity of the soil, and improve the stability of dams and embankments.

Then, this study concluded that there is an urgent need to study the technique of removal and replacement for improving soil behavior taking into consideration geotechnical requirements (i.e. bearing capacity and settlement) and cost to achieve the optimum thickness of replacement layers and the most suitable material corresponding to minimum total cost of foundation works.

Keywords:- *Investigation**,** Various Techniques, Soil Improvement**.***

I. INTRODUCTION

Soil is exclusively used as a basic construction material from the existence of earth structures such as dams, embankments, levees, etc. Where the natural topography is undulated and needs to accommodate a building, highway or any other civil engineering development, soil is generally the material used for filling in low locations.

It is essential the in-place soil should possess certain properties to withstand the forces caused by structures. Soil should have adequate strength, should be capable to resist settlement or heave, should possess permeability and should be durable and safe against deterioration.

Soil engineering is a subject of great importance to highway engineers. In highway engineering, consideration should be given to the action of soil when used as construction materials in its natural condition as it may in case of bridge pier founded on a natural deposit.

Expansion soil is in the group of problematic soils encountered by geotechnical engineers. They are confined to the semi-arid region of the tropical and temperature climate zones and are abundant where the annual evaporation exceeds the precipitation and can be found anywhere in the world.

The silt clay available for construction cannot meet the strength and in-compressibility requirements imposed by their use in sub-grade and that is the reason why a difficult work exists in civil engineering when a sub-grade (underlying soil) is found to be clayey.

Soil stabilization techniques, such as the addition of binders, have been introduced in order to improve the mechanical and chemical characteristics of its engineering performance. In addition, the utilization of stabilizing agents in roadwork and in sub-grade with poor soil condition improves other qualities such as cohesion, thereby contributing to the strengthening of the structure or embankment. This can eventually lead to a remarkable reduction in road building costs. Different additives like cement, lime or other minerals such as fly ash, rice husk ash have been used for this purpose. It is also well known that stabilizing soil with local natural and industrial resources have a significant effect on the improvement of soil properties. Lime and fly ash in particular have been used as an appropriate additive in soil stabilization in a variety of geotechnical constructions such as highways, foundation bases and embankments. The importance of utilization of lime and fly ash in soil treatment has been recognized in Western of Australia and Australia as well. This method is applied in the wide range of civil engineering projects including road woks and pavement specifically.

The inefficient properties of soil are currently of critical concern in engineering projects. In some cases, improving the characteristics of unsuitable soils by stabilization is a fundamental step prior to construction. Soil stabilization is performed by adding a binder to the soil in order to improve its engineering performance. Research has illustrated that additives lead to improvements in the workability and mechanical behavior of soil after it has been stabilized. In addition, if stabilized soil is to be used as a wearing surface, then it must be capable of withstanding the abrasive effect of traffic.

In some areas, the natural soil are of unfavorable character and require modification through the use of suitable mineral constituents such as gravel or crushed stone or clay binder might be required. At times, additives such as bituminous materials, Portland cement, salt or lime and rice-husk ash are used for effective stabilization (improvement) of the soil.

The primary use of stabilized soil mixture at the present time is in base and sub-base construction. A stabilized base or sub-base may provide supports for relatively wearing surface that will be subjected to light or moderate amount to traffic or it may function as a base for a light-type pavement that will be subjected to a very heavy volume to traffic

Therefore, in this investigation, lime and rice husk ash as local natural and industrial resources were applied for chemical stabilization. These additives improve the mechanical properties of soil such as compaction, strength, swelling, the plasticity index and compressibility. One of the most frequent chemical stabilization methods used is lime stabilization. Rice-husk ash as an additive may also be added in order to further improve the properties of the stabilized soil. In lime stabilization, the lime reacts with the water contained within the soil and attracts the soil particles to one another.

II. LITERATURE REVIEW

Clay soil is susceptible to high swell potential which could be detrimental to construction works. Fly ash or pozzolanic material, which are regarded as wastes may be used in soil improvements. Recent research based on pozzolanic activity found that rice-husk ash is a potential material for improvement (Muntohar 1997 and 1999).

The addition of traces of chemicals in the stabilization of expansive (silt clay) soil has been a common practice. A number of guidelines for determining the suitability of soil for any type of stabilization have been suggested by researchers on the basis of the stabilization of the major soil components.

However, hydrated lime has been found to be the most effective in reducing the swelling properties of the expansive soil (silt clay). In region where lime is scarce, cement has been found suitable alternative. The Highway Research Board of America (HRBA) has suggested limits to be met by soil that can be economically stabilized with Portland cement. These criteria include values less than 40 %liquid limit and 18% plasticity index. If these criteria are not met, it is difficult to work with such soil.

Silt clay soil is known to have undesirable properties when wet and one of the ways of making it useful for road construction is to render it workable by treating with lime or use lime as an additive during stabilization with cement which also regarded as an effective ways of stabilizing soil.

It is important to emphasize the treatment of the soil (silt clay) with lime is basically soil modification which is the improvement of physical properties of the soil in question in order to make it workable, whereas stabilization is the improvement of soil strength properties (Osinibi K.J Civil Engineering Dept. ABU Zaria).

The same Rice-Husk Ash or Fly Ash was discovered to have a good percentage of calcium oxide (CaO) silicate and alumina which are the major constituents of the cement, which they react to form cements materials. It brings about increase in soil strength and decrease in permeability, the void in the soil is closely filled together. This is achieved by the action of the chemical present.

Therefore, based on the above the “ash” stability mechanism of silt clay soil was adopted. Also, when the mechanically stability of a soil cannot be obtained by the parent material, it cement and lime, bituminous material or special additives. But lime is the most applied to road stabilization especially when the moisture content of the subgrade is very high. The process of “soil stabilization” entails the sampling and analysis combined with a good soil classification. Also, it is process whereby unsuitable soil in terms of strength is improved in order to meet the standard requirements of stability and strength for use in the highway construction.

It also involves a series of basic and standardized laboratory test to determine the soil properties. The choice of stabilization method depends on the laboratory tests, availability stabilizers traffic condition as well as the overall economy.

- *Techniques in Soil Improvement*

Soil stabilization is a process whereby the properties and characteristics are altered so as to improve its engineering properties as in the case of dam, road, field pavement etc.

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Stabilization is also done to improve the strength of the soil and shrink/arrest the swelling potential, thus improving the load bearing capacity and the overall performance of the in-situ soils.

Soil improvement techniques can be classified into various ways, according to the nature of the process involved, the materials added and the desired results. On the basis, we have the mechanical, chemical, lime rice-husk ash methods.

III. METHODOLOGY

The material for this particular investigation which is "silt clay" was obtained from the site. A proportion of lime and rice-husk ash were used in percentages (2%, 4%, 6%, 8% and 10%) for evaluation of soil. The following laboratory test were carried out: natural moisture content, specific gravity, compaction, shear box, sieve analysis, atterberg limit test, linear shrinkage.

IV. PRESENTATION AND ANALYIS OF RESULT

The American Association of State Highways and Transport Officials (AASHTO) classification system was adopted for the classification of the soil sample.

Table 1 Soil Classfication

SOIL SAMPLE	GROUP
SILTY CLAY	A-6

Table 2 Natural Mositure Content Test

SOIL SAMPLE	MOSITURE CONTENT
SILTY SOIL	86.53

Table 3 Specific Gravity Test

(%)	SPECFIC GRAVITY (GS)		
	PARENT	LIME	R.H.A
0	2.27	-	-
2	-	2.31	2.30
4	-	2.63	1.94
6	-	2.60	2.70
8	-	2.42	2.09
10	-	2.50	1.96

Table 4 Particle Size Distribution

B.S NO	Weight retained (g)	Cumulative wt. retained	Percentage wt. retained %	Total passing %
7	0.00	0.00	0.00	100
10	0.68	0.68	0.136	99.32
14	0.67	1.35	0.134	98.65
18	0.69	2.04	0.138	97.96
25	0.68	2.72	0.136	97.28
36	0.67	3.39	0.134	96.61
52	0.69	4.08	0.138	95.92
60	0.70	4.78	0.140	95.22
100	4.92	9.70	0.984	90.30
150	9.86	19.56	1.972	80.44
200	0.75	20.31	0.15	79.69
PAN	0.00	20.31	0.00	79.69

Table 5 Compaction Test Result

ADDITVES	%	MDD (g/cm^3)	OMC %
PARENT	0	1.75	19.4
LIME	2	1.69	18.34
	4	1.63	18.75
	6	1.68	19.50
	8	1.68	18.13
	10	1.64	20.0
R.H.A	2	3.10	12.40
	4	2.77	12.32
	6	2.50	12.31
	8	1.84	19.33
	10	1.63	20.30

Table 6 Atterberg Limit Test Results

ADDITIVES	%	LL %	P.L %	P.I %	L.S %
PARENT	0	33.5	15.78	17.72	1.40
LIME	2	37.0	27.95	9.05	2.10
	4	38.0	31.92	6.08	2.85
	6	37.0	35.27	2.00	3.21

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	8	42.0	41.0	1.00	3.57
	10	42.0	41.0	1.00	5.71
RHA	2	22.20	15.46	6.84	3.57
	4	26.10	20.06	6.04	4.29
	6	37.20	22.69	16.51	7.14
	8	37.49	22.32	15.17	8.75
	10	38.13	25.71	12.47	5.76

Table 7 Shear Box Test Result

ADDITIVES	**%**	**C (KN/m^3)**	**0 (^{0})**
PARENT	0	14.80	37.50
	2	26.90	28.00
	4	39.00	15.00
	6	40.30	16.70
	8	52.00	23.00
	10	59.00	23.00
RHA	2	0.00	40.20
	4	10.12	30.30
	6	17.20	30.35
	8	26.00	29.40
	10	31.00	28.00

Table 8 General Summary of Test Results

%	NMC	GS	ATTERBERG				SHEAR BOX		COMPACTION		CLASSIFI-CATION	ADDITIVES	LOCATION
			LL	PL	PI	LS	C (KN/M^2)	Ø (^{0})	MDD (g/cm^3)	OMC (%)	A-6		KABALA COSTAIN KADUNA
0	86.53	2.27	33.4	15.78	17.72	1.4	14.80	37.5	1.75	19.4			
2	-	2.31	37	27.95	9.05	2.10	26.90	28.0	1.69	18.34		LIME	
4	-	2.63	38	31.92	6.08	2.85	39.00	15.0	1.63	18.75			
6	-	2.60	37	35.27	2.00	3.21	40.30	16.7	1.68	19.50			
8	-	2.42	42	41	1.0	3.57	52.00	23.0	1.68	18.13			
	-												
10	-	2.50	42	41	1.0	5.71	59.00	23.0	1.64	20.0			
2	-	2.30	22.0	15.46	6.84	3.57	0.00	40.20	3.10	12.40		RHA	
4	-	1.94	26.10	20.06	6.04	4.29	10.12	30.30	2.77	12.32			
6	-	2.70	37.20	20.69	16.51	7.14	17.20	30.35	2.50	12.31			
8	-	2.09	37.49	22.32	15.17	8.57	26.00	29.40	1.84	19.33			
10	-	1.96	38.13	25.71	12.47	5.76	31.00	28.00	1.63	20.3			

For analysis of results conducted on silty-clay, the N.M.C has a higher value of 86.53%. this is as the result of the four (4) location where the soil sample was obtained in a water logged area. The value obtained also shows that the sample is composed of a very high percentage of clay. The value of G.S of soil for parent material was found to be 2.27 between 2%-6% lime, in the value of the G.S (i.e. 2.31 – 2.60) was recorded but at 8%, there was a decrease (i.e. 2.42).

At 2% R.H.A, the G.S was found to be 2.30. A decrease however was recorded at 4%, 6% and 10%. Table 4.1.5 indicated that lime stabilized with R.H.A.

Using the AASHTO classification system, the sample (i.e. silty clay) was classified as A-6. The sample under this classification are very poor to be used a sub-grade material. However, on stabilizing with lime and rice husk ash, the classification changed to A-2-4 and A-2-6 respectively. This shows that the properties of the sample has been improved upon.

For the Atterberg limit test, the L.L of 33.5%, P.L = 15.87% and P.I = 17.72% was obtained for parent material.

For lime stabilized soil, the L.L ranges between 37%-42%, P.L between 27.95%-41%, P.I between 9.05%-1.0% and L.S between 2.10%-571% respectively.

For soil stabilized using R.H.A, the L.L ranges between 22.20%-38.13%, P.L between 15.46%-25.71%, P.I between 6.87%-12.47% and L.S between 3.57%-5,76% respectively.

For the L.L value, the geotechnical properties of the soil has been improved with the addition of lime (between 2%-6%) when compared to the percent material as shown in table 4.1.6. similarly, for the sample stabilized with R.H.A, there was also improvement in the properties between 2%-4% R.H.A.

From these and as mentioned above, the soil properties have been improved upon such that the samples are suitable for use as sub-grade material.

As regard to the compaction test conducted, the M.D.D and O.M.C recorded for parent material are 1.7g/cm^3 and 19.4 respectively. A drop-in value was recorded at 4 % increase in lime and also at 10%. A maximum value of 1.6g/cm^3 was recorded at 6% and 8% respectively at O.M.C of 19.50% and 18.23%.

In the case of R.H.A stabilized soils, increase in O.M.C and M.D.D was recorded with increase in additive, the only exception was at 10% were a decrease of 1.63g/cm^3 was recorded. Tables 4.1.5, shows that lime stabilized soil have higher M.D.D when compared to R.H.A stabilized soil.

The direct shear test conducted for parent material shows the value of C and $\emptyset$ as 14.80KN/m^3 and 37.5^0 respectively. For lime stabilized soil an appreciable rise was recorded for the C which ranges between 26.90KN/m^3 – 59.00KN/m^3 respectively and for the $\emptyset$, the value ranges between 28.0^0 - 23.0^0 respectively. On the other hand, soil stabilized using R.H.A increase with increase in additive for value of C and $\emptyset$

The natural moisture content of the silty clay sample a determined from the result of test was found to be 86.53%. the sample (under the AASHTO classification) was classified as A-6 for the parent material.

Between the ranges of 2%-10% for lime, the sample classification improved from A-2-4 to A-2-6. Similarly, for the R.H.A (between 2%-10%), it also shows the same above improvement as that of lime.

The parent material been improved upon changes from poor to good under the AASHTO general rating for sub-grade.

From the analysis of the results, it can be deduced that lime stabilized soil provided better properties when compared to that of the R.H.A.

Therefore, both lime and R.H.A can be used to improve in the geotechnical properties of silty-clay material.

V. CONCLUSION

The natural moisture content of the silty clay sample as determined from the result of test was found to be 86.53%. The sample (under AASHTO classification)was classified as A-6 for the parent material. Between the ranges of 2% -10% for lime, the sample classification improved from A-2-4 to A-2-6. Similarly, for the R.H.A (between 2% - 10%), it shows the same above improvement as that of lime.

The parent material been improved upon changes from poor to good under the AASHTO general rating for subgrade. From the analysis of results, it can be deduced that lime stabilized soil provided better properties when compared to that of R.H.A.

Therefore, both lime and R.H.A can be used to improve in the geotechnical properties of silty-clay materials.

RECOMMENDATION

According to the result of various test conducted on silty-clay soil sample in the laboratory, using different percentage of lime stabilized soils provide better properties and are more suitable as sub-grade material.

Although rice-husk ash can equally be used but are of lesser properties when compared to lime. In relation to cost implication, rice -husk ash is cheaper and can easily be obtained.

DECLARATION

In accordance with the requirements for the degree of **B. Tech** Programme in **Civil Engineering,** in Faculty of Engineering and Technology, I present this report on ***"INVESTIGATING THE EFFECTIVENESS OF VARIOUS TECHNIQUES FOR SOIL IMPROVEMENT"***. I OLUWASEUN AYOBAMI IBRAHIM declare that the work presented in the report is my own work except as acknowledged in the text and foot notes.

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19th August, 2023	**Oluwaseun A. Ibrahim**

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