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# BEARING CAPACITY EVALUATION OF LATERITIC SOIL STABILIZED WITH SAND FOR USE AS SUBGRADE

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**ABSTRACT**

*A pilot scale study was conducted to examine the bearing capacity evaluation of lateritic soil stabilized with sand for use as subgrade in Omu-Aran. Road project are very expensive because they require a lot of earthworks. At times, the soil in place has an insufficient bearing capacity, hence the need to look for good soil whose characteristics are defined in the specifications. When such material is not near the completion period very long. This work consisted of testing an approach that could improve the bearing capacity of a laterite found on a site by adding sand to it.*

*Results reveal that regardless of the amount of compaction applied to the samples under study, the addition of 40% to 60% sand to a sample of laterite significantly improves its bearing capacity, which reduces work cost and execution time.*

**Key words**: bearing capacity, Evaluation, Lateritic, Soil, Sand, Subgrade.

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## 1. INTRODUCTION

One of the major needs of a developing or already develop country is a standard communication system and this system can be developed by constructing sufficient infrastructure such as roads, tunnels, bridges, and many other civil engineering works. A rapid growth has occurred in the transportation sector of all countries. The standard and performance of a constructed road critically depends on essential parameters such as the quality of the subgrade material, the materials used in different layers of the pavement and traffic, so selection of suitable subgrade materials having the best quality becomes a question for getting the best performance and longevity of the constructed roads we need.

Since my area of case study, Omu-Aran has a vast of soft soils that are highly compressible with low bearing capacity. So it is essential to improve the subgrade material and consequently reduce the construction cost of the project by reducing their layer thickness. A large number of investigations made their investigation to improve the characteristics of such types of low strength soils not only by adding different alternative materials but also various chemicals (Bhasin et al. 1985; Richardson, 1996; Ghosh and Subbarao, 2007; Sharma et al. 2013). Years before now, admixtures such as lime, cement and cement kiln are used to influence and improve the qualities of readily available local soils.

Lateritic soil is the abundant and available tropical soil group covering over 50% of the tropics (Bawa, 1957; Uehard, 1982). Lateritic soil is always problematic for engineering structures due to its swelling and behaviors. It will shrink when dried in summer and swell when wet in winter season. Lateritic are mostly yellowish to reddish brown in color depending on the relative proportions of iron and aluminum sesquixides. They have also been described by Buchanan (1807) and Alexander and Cady (1962) as soil materials which are highly weathered, rich in secondary oxides (or sesquixides) of iron and/ or aluminum, nearly void of bases and/or primary silicates but may contain large amount of kaolinite (also Querioz de Carvalho, 1991) and quartz, may exist either hard (as superficial “cuirases” or lateritic rock) or capable of hardening upon exposure to wetting and drying.

The structures on these soils experience large-scale damages. Expansive soil result to cracking in the soil without any warning. These cracke are something very large and cause rigorous damage to the structures. Roads running through expansive soil regions are subjected to severe distress resulting in poor performance and increased maintenance cost. Also, cohesive soil having plasticity index more than 6 is required to be treated and stabilized before use for construction according to the specification of Ministry of Road Transport & Highway, Nigerian.

To prevent the structure from such damages, stabilization of soil is required with the stabilizing materials like fly ash, lime, sand, bitumen, cement, rice husk ash etc. The engineering properties of cohesive soil can significantly be improved with these stabilization agents. The attempt of stabilizing the soil with use of sand being practiced for a while now.

## 2. LITERATURE REVIEW

The material behaviors of sand on lateritic soil was first investigated fist by Coulomb in the $18^{th}$ century and studies of the mechanical behavior of pure clays were reported approximately 150 years later. Studies of these soils continued over the years as clean sands and pure clays define distinct boundaries of a wide spectrum of natural soils and thus set limits on expected performance. Most of the studies concerning the stress-strain and shear strength behavior of granular soils mainly inspected the response of clean sands. However, filed observations show that granular soil may contain a considerable amount o clay and/or silt. Therefore, these fines are expected to influence the engineering behavior of cohesive soils.

Lateritic soils are often used unmodified as subgrade for roads carrying light traffic hence it is thought that a little improvement might make them acceptable as bases for medium trafficked roads. The occurrence of laterites and lateritic soils is wide-spread in Africa and they occur widely in the western, Midwestern eastern, Benue Plateau and other parts of Nigeria. In most of these areas, sand and sandy soils can be found and consequently can be used as a component in the sand-soil mixture where such mixtures are found suitable.

In America, this method of stabilization was used extensively in the early thirties and forties. In many tropical countries, more than quarters of the total road mileage consists of earth or unimproved roads and laterite-sand mixtures can often be used with advantage in the construction of such roads since these mixture tend to ease the problem of corrugation, pot-holing among others. In some developing countries like Nigeria, this method of soil-improvement in which one type of soil is added to a parent soil or aggregate to improve its strength and stability is often referred to as mechanical stabilization is also widely used.

In Nigeria, sand is used as aggregates in the construction industry, test samples in geotechnical and soil science laboratories, experimental porous medium in hydro geological studies and for other uses. The use of sand for construction purpose grew significantly with the drive for increased paved road of sand network and housing schemes. So far in Nigeria, very little has been done on standardizing the properties of sands. Geotechnical and hydraulic testing of sand is required for various applications in a developing country like Nigeria. Some developed countries such as USA and Canada have standard sand for laboratory experiments, such as Ottawa silica sand in lllinois (USA) with fully characterized parameters. There is therefore need to characterized and assess the baseline properties for some southwestern Nigeria sands that could serve as a tool for investigations in soil mechanics and hydrogeological applications.

Standard sand is natural sand, which is siliceous and has content of at least 98% particularly its finest fractions. It is clean, the particles are generally isometric and rounded in shape. It is dried, screened and prepared in a modern workshop which offers every guarantee in terms of quality and consistency. The study area is located in Omu-Aran, Kwara State (80 7’28.672”N, 50 4’ 41.5632”E) in the Northern part of Nigeria.

## 3. AIMS AND OBJECTIVES

- The aim of the present study is to evaluate the f=different improved characteristics of the lateritic soil when mixed with sand and their cost effective mix proportion.
- The main objectives of this study are to determine how the properties of the laterites can be improved sufficiently by mixing them with sand to make acceptable for surfacing earth roads and to determine the extent of the improvement in the properties of the sand-laterite mixture and their suitable for bases for roads carrying medium density traffic.
- This study has been undertaken to explore the possibility of stabilizing laterite with the combination of sand. The bais engineering properties of the composite material (laterite: sand) and their compaction and strength characteristics will be studied. The results will be discussed to bring out the possibility of using the composite in the construction of sub-grade for roads.
- This study is based on investigation that is being carried out to determine the influence of sand on the strength and compressibility of lateritic soils in its naturally occurring state.
- Field observation show that the predominant content of the admixture will mainly be sand. However, the sand occurs with different amounts of clay, silt and grave. The sand is expected to influence the engineering behavior of the cohesive soil. Knowledge of the influence of sand on strength and compressibility parameters of the soils if fundamental in the interpretation of their properties for engineering design.

# 4. METHODOLOGY

A quick method of determining moisture density is known as the "Hand Test". Pick up a handful of soil and Squeeze it in one hand. Open the hand. If the soil is powdery and will not retain the shape made when hand folded, it is too dry. If it shatters when dropped, it is too dry. If the soil is moldable and breaks into only a couple of pieces when dropped, it has the right amount of moisture for proper compaction. If the soil is plastic in your hand, leaves small traces of moisture on your fingers and stays in piece when dropped, it has too much moisture for compaction.

# 5. CHARACTERIZATION TEST

## 5.1. SIEVE ANALYSIS TEST

Grading (sieve analysis) test will be performed on a sample of aggregate in a laboratory. A typical sieve analysis involves a nested column of sieves with wire mesh cloth (screen). A representative known weighed sample will be poured into the sieve which has the largest screen openings. Each lower sieve in the column has smaller openings than the one above. At the base will be a round pan, called the receiver. The column will be placed in a mechanical shaker.

The shaker shakes the column, usually for a fixed amount of time. After the shaking is complete the material on each sieve will be weighed. The weight of the sample of each sieve will then be divided by the total weight to give percentage retained on each sieve. The size of the average particle on each sieve will then be analyzed to get a cut-off point or specific size range, which will then ne recorded. The result of this test will be used to describe the properties of the aggregate and to see if it is appropriate for various civil engineering purpose such as selecting the appropriate aggregate for asphalt mixes as well suitable for sub-grade construction. The result of this test will be provided in a graphical from to identify the type of graduation of the aggregate. The complete procedure for this test is outlined in the American Society for Testing and Material (ASTM) C 136 and the American Association and State Highway and Transportation Official (AASHTO) T 27. A suitable sieves size for the aggregate underneath the nest of siebes to collect the aggregate that passes through the smallest. The entire nest will then be agitated, and the material whose diameter is smaller than the mesh opening pass through the sieves. After the aggregate reaches the pan, the amount of material retained in each sieves will then be weighed.

## 5.2. SPECIFIC GRAVITY TEST

Specific gravity is the ratio of the density of a substance to the mass of the mass of a substance to the mass of a reference substance for the same given volume. Apparent specific gravity is the ratio of the weight of a volume of the substance to the weight of an equal volume of the reference substance. The reference substance is nearly always water at its densest ($4^0$C) for liquids; for gasses it is air at room temperature ($21^0$C). Nonetheless, the temperature and pressure must be specified for both the sample and the reference. Pressure is nearly always 1 atm (101.325 kPa). Temperatures for both sample and reference vary from industry to industry.

Specific gravity test will be performed on a sample of aggregate in a laboratory. A typical specific gravity analysis involves a pycnometer of volumetric flask having a capacity of 500mL for 100mL, thermometer sensitive to a degree Celsius and a balance sensitive to 0.01g. a representative known weighed sample will be used for this test and the representative known weighed soil will be carefully put into the pyrometer avoiding losing any of the soil in case the oven dry weight was determined, distilled water will be added to the flask until it is ¾ full. Then the entrapped air will be removed either by subjecting the contents to a partial vacuum of air pressure not more than 100mm of mercury or by gently boiling the contents for a fixed time frame of about 12mins while occasionally rolling the pyrometer to assist in the removal of air . Samples heated will be cooled to about twenty degrees Celsius. The pycnometer will be filled with water after removal of air to bring the temperature of the total content to twenty degrees Celsius plus/minus five and within five degrees of temperature Ti by any suitable means. The pycnometer will be cleaned and dried with a clean dry cloth and the weight in grams of the pycnometer and the contents, Wb, and the temperature in degrees, c, Tx of the contents will be determined.

Assuming the test will be will be performed on a sample having its natural moisture, the dry weight of the material by evaporating off the water in accordance to California test 226 in an oven maintained at 110 degrees Celsius plus/minus 5 degrees Celsius or at a lower temperature explained under section f-2 will be determined, until the material reaches a constants mass. The sample will be cooled to room temperature and the weight in grams determined and recorded Wo.

## 5.3. NATURAL MOIISTURE CONTENT TEST

Natural Moisture content test was be performed on a defined amount of sample

## 5.4. ATTERBERGS LIMIT TEST

Atterberg limits test was be performed a known amount of sample.

## 5.5. COMPACTION TEST

Compaction test will be carried out in the laboratory on a known amount of sample.

## 5.6. CALIFORNIA BEARING RATIO (CBR) TEST

The California Bearing Ratio (CBR) is a measure of the supporting value of the subgrade. It is not unique and other tests such as the Tri-axiaal tests are used occasionally. It is just the most commonly used in pavement Design. The CBR test should be used with soil at the calculated equilibrium moisture although in the United States it is usual for samples to be soaked for 4 day prior to testing.

The CBR test for soil will be effectively carried out since the equipment is available otherwise the table below could have been used to estimate the CBR.

**Table.4** Estimated CBR Values

| Type of soil | Plasticity index (%) | CBR (%) Depth of formation below water table | |
|---|---|---|---|
| | | More than 600mm | 600mm or less |
| Heavy clay | 70 | 2 | 1* |
| | 60 | 2 | 1.5* |
| | 50 | 2.5 | 2 |
| | 40 | 3 | 2 |
| Silty clay | 30 | 5 | 3 |
| Sandy clay | 20 | 6 | 4 |
| | 10 | 7 | 5 |
| Silt | - | 2 | 1* |
| Sand (poorly graded) | non-plastic | 20 | 10 |
| Sand (well graded) | non-plastic | 40 | 15 |
| Well graded sandy gravel | non-plastic | 60 | 20 |

The CBR should be carried out in accordance BS 13772

# 6. RESULTS AND ANALYSIS

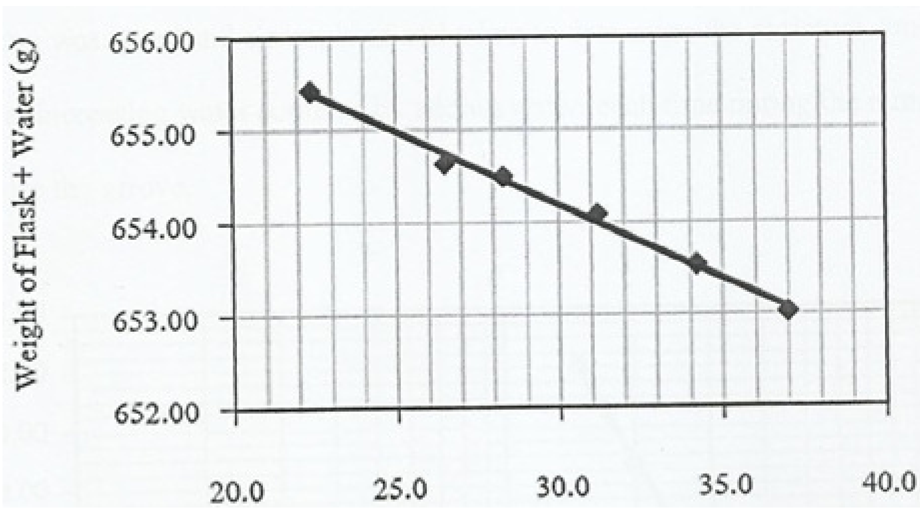
## 6.1. SIEVE ANALYISS (Compiled with ASTM D 422-63)

### *6.1.1. Grain size Distribution Cure*

Sieve analysis test results was given in Appendix A which shows the percent finer or percent passing of sieve in each size. The figure above shows a grain size distribution curve for laterite soil sample as percent finer by weight with the particle size decreasing from left to right on the horizontal axis.

For this lateritie soil samples, percent passing sieve no. 4 are 37.90% and 76.76% respectively. The basic properties from Attergbergs limit test is as follows: LL=46.52%and PI=29.04%. According to unified classification system the soil can be classified as clayey sand, SC which has percent of gravel 23.24% or it can be classified as clayey sand with gravel. For AASHTO soil classification, can be identified soil as A-7-6 which is clayey soil. Group index can be defined as 5that is indicated quality of this laterite soil. Thus this laterite is suitable for highway subgrade material.

## 6.2. SPECIFIC GRAVITY TEST (Complied with ASTM D 854-58)




Temperature(C)

The definition of specific gravity is the ratio of the weigh in air of a given volume of a soil at a state temperature to the weight in air of equal volume of distilled water at a stated temperature. The specific gravity of soils determined by means of pycnometer (ASTM D 854-58). The result of test given in appendix b has 2.68 on average specific gravity.

## 6.3. ATTERBERG LITS TEST (Compiled with ASTM D 4318)

Attergberg's Limit test (ASTMD 4318) was performed to determine to determine liquid limit, plastic limit and the plasticity of specimens in order to condition by water Content. The result of liquid limit and plastic limit test are summarized in the Spreadsheet as in Appendix A.

Liquid limit test was performed with 4 different water contents. The casagrande Method was used to set speed and number of bounces of the cup of the hard bas4e Counted. The rotation was continued until the groove in the soil flows and closed over

A specified length. The number of blows of the cup was note and a sample of soil taken To determine the moisture content. The test was repeated at increasing water contents By adding water, each time noting the number of blows required to close the grove.

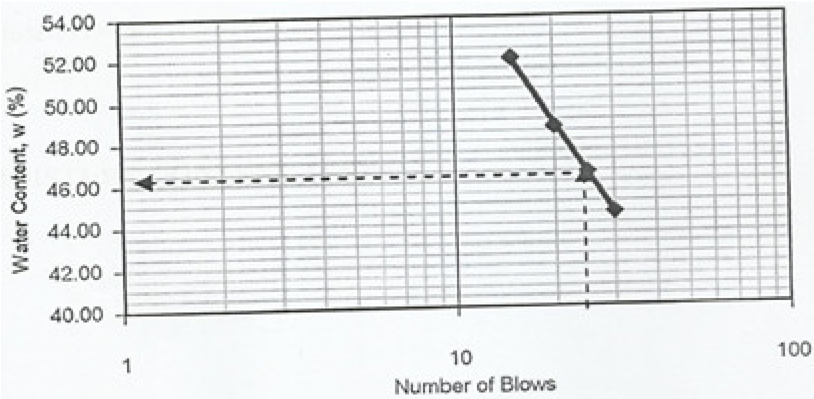



**Figure 9** Flow curve of liquid limit (LL) determination of laterite soil

After testing, m the water content of the soil on an arithmetic scale in percent, and corresponding number of blows on a logarithmic scale are plotted. The relevant point are connected and this line yielded the liquid limit intersection with the vertical of the 25 number of blows .the figure abobe shows the average liquid limit (LL) of 46.52% at 25number of blows.

Plastic limit test was performed with two different water contents that defined the moisture content, in percent, at which the soil crumbles, when rolled into 3.22mm in diameter to determine the water content of a section of the thread. The average plastic limit (PL) for these specimens is 17.48%.

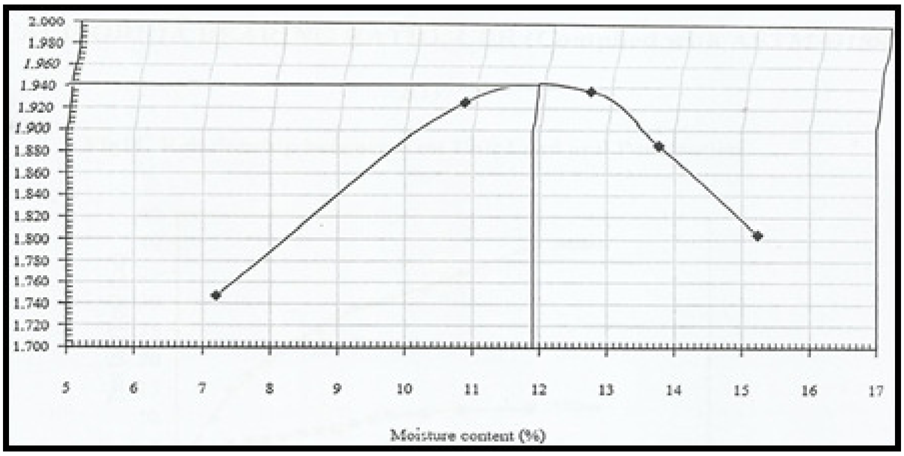
Liquid Limit, LL=46.52%

Plastic Limit, PL=17.48%

Plastic Index, PI=29.04%

## 6.4. MOISTURE CONTENT TEST

### *6.4.1. Relationship between Dry Unit Weight and Moisture Content*




Max. Dry Unit weight = 1.945ton/m3, Optimum Moisture Content=11.90%

## 6.5. CALIFORNIA BEARING RATIO, (complied with ASTM d 1883-87)

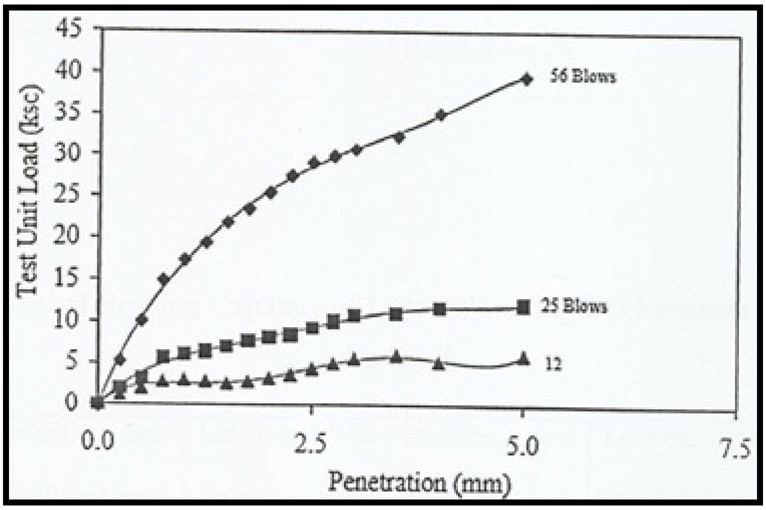



**Figure 11**. Relationship between Test Unit Load and Penetration

**Table.5.** Summarized basic Properties of the Lafterite soil Sample

| Characteristics | Description |
|---|---|
| Percent passing sieve No.200 | 37.90 |
| Liquid limit (%) | 46.52 |
| Plastic limit (%) | 17.48 |
| Plasticity index (%) | 29.04 |
| Unified classification | Sc |
| AASHTO classification | A-7-6 |
| Group index | 5 |
| Maximum Dry Density (Mg/m3) | 1.945 |
| Optimum moisture content (%) | 11.90 |
| Unconfined compressive strength (ksc) | 2.01 |
| Modulus of Elasticity (Ksc) | 38.44 |
| Califoenia Gravity | 2.68 |
| Color | Reddish-brown |

**Table.6** Summary of bearing Capacity of Latertie at Different percentage stabilization with sand

| | Latertic soil Stabilized with 0%sand | Latertic soil stabilized with 20% sand | Lateritic soil stabilized with 40%sand | Lateritic Soil stabilized with 60% sand | Lateritic soil stabilized with 80%sand |
|---|---|---|---|---|---|
| C. B. R (%) | 57.17 | 69.52 | 82.23 | 74.97 | 60.50 |

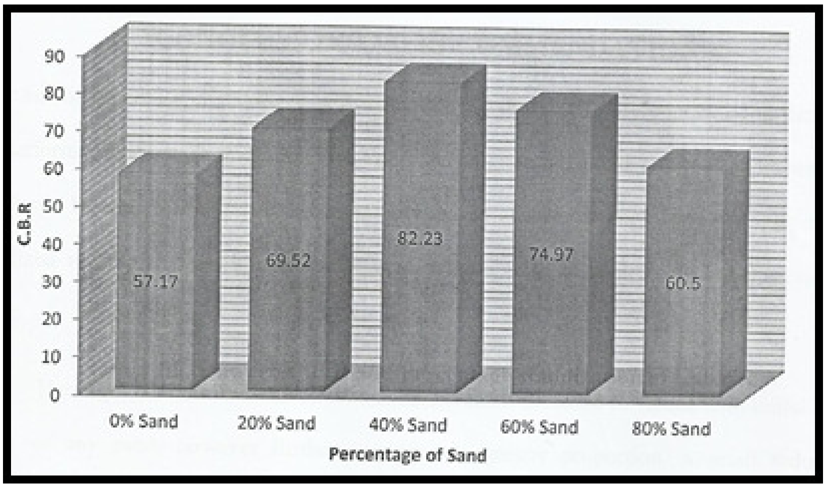



**Figure.12** Relationship between C.B.R and percentage stabilization of Laterite with sand

## 7. CONCLUSION

The test of Laterite soil stabilized with sand in the Laboratory were conducted to demonstrate its performance of soil-sand samples. The test properties test, California Bearing Ratio test and permeability test to ensure the engineering properties of soil stabilized with sand. Base from the results in these tests, the following conclusions can be made:

- The Liquid Limit of all alluvial soils indicated decrease in values with initial addition of any sand, however further increases in greater proportion, a small reduction is observed of such values. But plastic limit of all the soil does not show any significant change with increases of sand percentages within the range of the test. As results plasticity index shows a lesser values of sand content as Liquid Limit.
- In compaction characteristics, MDD value of all the two type of alluvial soil show a significant increases in the value of MDD with addition of any of the three type of sands used. Conversely OMC value all such alluvial soil indicated a gradual decreased with increasing in the values of sand percentages added, irrespective of sand percentage of the sand used. This is the indication of lesser demand of water for achieving the desired density in the field.
- In strength properties, the CBR values indicated a very large amount without addition of the sand used in the test. However better result is observed for mixing 20% of fine sand, and such value in unsoaked condition become nearly doubled for addition of40% fine sand compared to that of tested soils and may be identified as cost effective mix. Proportion because for reducing the thickness of difference layers of flexible pavement due to better improvement in the CBR value.

## 8. RECOMODATION

Application of this soil stabilization in other location with other soils, weather conditions etc may produce significantly differently result. Engineering experienced in soil stabilization should be involved in any further studies or applications of this nature, especially during placement, mixing and compaction of the base course of road pavement. Soil stabilization can provide the judgment necessary to ensure successful project. In some types of soils, these testing's programs may need to be repeated to ensure that the results are reliable and suited to the particular site.

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