STABILIZATION OF LATERITIC SOIL USING IRON ORE TAILINGS FOR PAVEMENT CONSTRUCTION

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ABSTRACT

In India, laterite soil is widespread covering over 10% of the total geographical area. However, lateritic soil containing a significant proportion of clay may expand when water is present and shrink when water present is very little. Hence, it should be stabilized to meet an engineering requirement. Soil stabilization is the alteration of soils to enhance their physical properties. Stabilization can increase the shear strength of a soil and control the shrink-swell properties of a soil, thus improving the load bearing capacity of a sub-grade to support pavements. Generally, cement and lime are used as stabilizers for lateritic soil, which are uneconomical. So, many researches and studies are made on the stabilization of lateritic soil by adding admixtures other than cement and lime to make it economical. Some studies has made an attempt to utilize the industrial wastes such as iron ore tailings for stabilization of lateritic soil. However, the physical, mineralogical and chemical composition of the mine tailing renders it a suitable material for use in civil engineering applications. By mixing optimum proportions of Iron ore tailings to lateritic soil, the physical properties of soil samples are studied by conducting the laboratory tests such as Sieve analysis, Specific gravity, Atterberg limits, Light compaction test, California Bearing Ratio test and Unconfined Compressive Strength test. 

Keywords: Stabilization Of Lateritic Soil, Iron Ore Tailings, Load Bearing Capacity, Chemical Composition, Laboratory Tests.

I. INTRODUCTION

The tropical soils such as Lateritic soils are not suitable for pavement constructions due to their shrinkage and swelling properties. Its poor workability, low strength, high compressibility and insufficient bearing capacity leads to the road failure. However, due to their widespread in the geographical area it as to be utilized for construction purposes, but in their stabilized state.

Soil stabilization can be achieved by adding admixtures in the suitable proportions. Generally, cement and lime are used as stabilizers for lateritic soil, which are uneconomical. To make the stabilization process economical industrial wastes are used. By using these wastes it not only make the construction economical, but also reduces the expenses for disposal and protects the environment keeping these materials from being dumped into Landfills, thereby saving already depleting landfill space. In this study we are using the Iron ore tailings for lateritic soil stabilization to improve the Load bearing capacity for Pavement construction.

1.1 STABILISATION

Soil stabilization is a process by which the physical properties of a soil are transformed to provide permanent strength gains before construction. Stabilizing a soil implies the modification of the properties of a soil-water-air system in order to obtain lasting properties, which are compatible with a particular application.

The parameters involved are:

- Properties of the soil to be stabilized
- Planned improvements
- Project economy
- Construction techniques
1.2 PROBLEM STATEMENTS

- Laterite soils are occasionally associated with geotechnical problems such as road deformation, erosion, settlement, dam seepage, slope instability, leachate permeation through hydraulic barriers, etc.
- Numerous soil improvement techniques were being applied to overcome these problems, including mixing the laterite soil with cements, limes, bitumen, chemicals, pozzolans, etc.
- These additives may not be locally available and cheap, and could significantly increase the cost of construction.
- Different percentages of fines, sand and gravel in laterite soils exhibit different engineering characteristics and behavior, making it difficult to obtain suitable and appropriate gradation for specific construction purposes.

1.3 OBJECTIVES AND SCOPES

- To study the morphological and chemical composition of iron ore tailings for utilizing in soil stabilization.
- To study the effect of iron ore tailings on index properties and consistency limits.
- To study the effect of iron ore tailings on shear strength properties.
- To study the effect of iron ore tailings on compaction properties.

II. LITERATURE REVIEW

<table>
<thead>
<tr>
<th>SL.NO.</th>
<th>REFERENCE</th>
<th>PUBLICATIONS/JOURNAL</th>
<th>MATERIALS/ADDITIONS</th>
<th>TESTS</th>
<th>INFERENCE</th>
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<tr>
<td>1.</td>
<td>K.Ishola, T.S.Ijimdiya, P.Yohanna, K.J.Osinubi</td>
<td>Journal of Engineering</td>
<td>Lateritic Soil with Iron ore Tailings</td>
<td>Compaction Test, Shear strength Test</td>
<td>An optimal blend of 8% IOT improved the shear strength of the soil and can be used for geotechnical engineering applications such as roads and embankments.</td>
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<td>2.</td>
<td>Chithaiah E, Nagraj Bacha</td>
<td>International Journal of Engineering Research and Technology</td>
<td>Lateritic Soil mixed with Black Cotton Soil</td>
<td>Compaction Test, Permeability Test</td>
<td>Mixed Soil LS 75%, BCS 25% was found suitable for subgrade for pavement.</td>
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<tr>
<td>No.</td>
<td>Authors</td>
<td>Journal/Conference</td>
<td>Test Methods</td>
<td>Remarks</td>
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<td>3.</td>
<td>A.K. Lawer, S.I.K. Ampadu, F. Owusu-Nimo</td>
<td>SN Applied Sciences, A Springer Nature Journal</td>
<td>Unconfined compression Strength Test, CBR Test</td>
<td>Based on CBR values as well as economic and environmental benefits, 0.2% fibre content is recommended to reinforce the weak lateritic soil for subgrade layer of low volume roads.</td>
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<td>4.</td>
<td>P Yohanna, R O Sani, K Ishola, T S Ijimdiya, A O Eberemu, K J Osinubi</td>
<td>IOP Conference series: Material Science and Engineering</td>
<td>Atterberg limits test, Compaction test</td>
<td>Treatment of LTS and BCS with 8-10% IOT improved the soil properties and can be used for pedestrian walkways.</td>
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<td>5.</td>
<td>Aminaton Marto, Nima Latifi, Houman Sohaei</td>
<td>Electronic Journal of Geotechnical Engineering (EJGE)</td>
<td>Unconfined Compressive Test, Direct Shear Test</td>
<td>The Unconfined Compressive Strength improves with the increase of curing time and mainly occurs in first 7 days. However, 9% of SS299 can be said to be the optimum amount of stabiliser required for Laterite soil.</td>
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<td>6.</td>
<td>Deepak Nayak, Purushotham G. Sarvade, Yash H. Patel, Ekaagra Yadav</td>
<td>International Journal of Engineering and Advanced Technology, (IJEAT)</td>
<td>Unconfined Compressive Strength Test, CBR Test</td>
<td>Lateritic soil with 26% Quarry dust and 4% Lime give higher strength of UCS and CBR value.</td>
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<td>7.</td>
<td>J.E. Sani, P. Yohanna, I.A. Chukwujama</td>
<td>Journal of King Saud University - Engineering Sciences, Science Direct</td>
<td>UCS test, Compaction Test, Tensile strength Test, Elongation Test</td>
<td>Optimum blend of 6% RHA/0.75% SF by dry weight of soil treated with lateritic soil can be used for sub-base material.</td>
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<td>8.</td>
<td>Opeyemi E. Oluwatuyi, Bamidele O. Adeola, Elijah A. Alhassan, Emeka S. Nnochiri, Abayomi</td>
<td>Elsevier/ Science Direct</td>
<td>Atterberg limits, Compaction Test, CBR Test, UCS Test</td>
<td>An 8% by soil weight of milled eggshell and cement mixture in ratio 1:1 stabilised lateritic soil could be used as a potential sub-base material for highway construction.</td>
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<td>Paper Number</td>
<td>Authors</td>
<td>Journal and Conference</td>
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<td>9</td>
<td>O O Komolafe, K J Osinubi</td>
<td>IOP Conference series: Material Science and Engineering</td>
<td>Lateritic soil with Cement-OPEFBA</td>
<td>An Optimum blend of 8% cement 2% OPEFBA treatment of lateritic soil is recommended as a base course material in light-traffic volume road pavement construction.</td>
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<td>10</td>
<td>N A Wahab, A S A Rashid, M J Roshan, N H A Rizal, N Z M Yunus, M A Hezmi, M Y M Tadza</td>
<td>IOP Conference series: Material Science and Engineering</td>
<td>Lateritic soil with OPC</td>
<td>It was found that the OMC increase from 28% to 34% while the MDD increase from 1.39g/cc to 1.47g/cc with the rise in the percentage of cement. Hence, the optimum moisture content (OMC) increased with cement content, implying that the more cement added, the more water is necessary.</td>
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<td>11</td>
<td>Abhinav V Lotankuar, Ankita D Usare, Omkar A Rane, Nagaraj H Koppa</td>
<td>International Journal of Engineering Research and Technology, (IJERT)</td>
<td>Lateritic soil with Terrazyme</td>
<td>Due to the heavy rainfall in konkan belt pavement surface are getting alligator cracks on surface. Hence by using Terrazyme in sub base of pavement which improves the property up to 40 to 60 % in CBR.</td>
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<td>12</td>
<td>Zubair Saing, Lawalenna Samang, Tri Harianto, Johannes Patanduk</td>
<td>International Journal of Applied Engineering Research, Research India Publications</td>
<td>Lateritic Soil with Lime</td>
<td>The result showed that, stabilization of 10% lime for 28 days curing time yields the strength and bearing capacity of the soil</td>
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<td>13.</td>
<td>S I Adedokun, J R Oluremi</td>
<td>International Journal of Engineering</td>
<td>Lateritic soil with agricultural waste products (such as Saw Dust Ash (SDA), Coconut Husk Ash (CHA), Corn Cob Ash (CCA), Rice Husk Ash (RHA), Bagasse Ash (BA), Locust Bean Pod Ash (LPBA))</td>
<td>Compaction Tests, CBR Test, UCS Test,</td>
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<td>three times higher than soil before stabilization. Subgrade modulus increased significantly with increasing of lime content and curing time. Comparing the relation of subgrade modulus and CBR values for common soil and sediment soil with cement stabilization, it was found that performance of laterite soil with lime stabilization is better than sediment soil with cement stabilization and approaching of common soil. It is concluded that laterite soil with lime stabilization has potential as a road foundation.</td>
<td>The maximum dry density of soil increased from 0 to 4% substitutions of SDA, CHA and CCA while it decreased with the addition of ashes from other wastes. CBR and UCS generally increased with increasing amount of the stabilizers whereas soil permeability and swell potential decreased as the ash content increased. Ash produced from these wastes can be used to improve the geotechnical properties of soil, to synthesize a stable</td>
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<td>No.</td>
<td>Authors</td>
<td>Journal</td>
<td>Soil Type</td>
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<td>14</td>
<td>Mojeed Mutiu Ayobami, Taiwo Rudwan Ademola,</td>
<td>International Journal of Innovative Science and Research Technology,</td>
<td>Lateritic soil with Blast furnace slag</td>
<td>UCS test, Atterberg limit test, Compaction limit test, CBR test</td>
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<td>Adegoke Adesola Habeeb</td>
<td>(IJISRT)</td>
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<td>The result obtained shows that the atterberg limit test, compaction test and the CBR test test the</td>
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<td>properties of the lateritic soil of sample A and B improves at 6% and 8% addition of blast furnace slag</td>
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<td>respectively. Also the UCS improve at 8% and 2% addition of blast furnace slag for sample A and B</td>
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<td>respectively. (Sample A and B – are the soil samples at depth 0.7-1.0m at two different locations)</td>
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<td>15</td>
<td>Emeka Segun Nnochiri, Olumide Moses</td>
<td>Civil Engineering Journal,(CEJ)</td>
<td>Lateritic soil with Groundnut Husk Ash(GHA)</td>
<td>Compaction Test, Atterberg Limits, CBR test, UCS test</td>
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<td>Ogundipe</td>
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<td>The results showed that the addition of GHA enhanced the strength of the soil sample. The MDD reduced</td>
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<td>from 1960 kg/m³ to 1760 kg/m³ at 10% GHA by weight of soil. The OMC increased from 12.70% to 14.95%,</td>
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<td>also at 10% GHA by weight of soil. The unsoaked CBR values increased from 24.42% to 72.88% finally,</td>
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<td>the UCS values increased from 510.25 kN/m² to 1186.46 kN/m² for both CBR and UCS, the values were</td>
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<td>at 10% GHA by weight of soil. It was therefore concluded that GHA performs satisfactorily as a cheap</td>
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<td>stabilizing</td>
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III. MATERIALS

3.1 LATERITIC SOIL

Lateritic soil is one of the soil, rich with vital nutrients and is widely used. The word Laterite is derived from the Latin word which means Brick. Laterite soil is a soil and rock type rich in iron and aluminium and is commonly considered to formed in hot and wet tropical areas. Almost all lateritic soil are of rusty-red color because of high iron oxide content. They develop by intensive and long lasting weathering of the underlying parent rock. Laterite soil is reddish to yellow in colour with a lower content of Potassium, Phosphorous, Nitrogen, Lime and Magnesia with 90% to 100% of Aluminium, Iron, Titanium and Manganese oxides.

Laterite soils are occasionally associated with geotechnical problems such as road deformation, erosion, settlement, dam seepage, slope instability, leachate permeation through hydraulic barriers, etc. Laterite soils will be collected from burrow pits on site at a depth of about 1.0 m below the natural ground surface. This is to avoid the dense organic matter contents present at surface. Then, it will be taken to the geotechnical laboratory to conduct experiments. The soil sample should be air dried and sieved into different grades, i.e. fines (<0.063 mm), sand (0.063 mm to 2.00 mm) and gravel (>2.00 mm to 4.75 mm). These different grades will be mixed to give reconstituted samples.

3.2 IRON ORE TAILINGS

Iron ore tailings (IOTs) are a form of solid mineral waste produced during the beneficiation process of iron ore concentrate. Among all kinds of mining solid waste, IOTs are one of the most common solid wastes in the world due to their high output and low utilization ratio.

Iron ore tailings will be thrown into the Kudremukh reservoir by KIOCL (Kudremukh Iron Ore Company Limited), a public miner and exporter of iron ore pellets. The KIOCL firm, which is one of our country's fastest-growing iron ore mining companies used to dump roughly 200 million metric tonnes of iron ore into the Lakya Dam. KIOCL was mined at Kudremukh for more than 25 years before it was shut down in 2005.

Iron Ore Tailings Chemical Composition,

<table>
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<tr>
<th>Minerals</th>
<th>Fe₂O</th>
<th>SiO₂</th>
<th>CaO</th>
<th>Al₂O₃</th>
<th>MgO</th>
<th>TiO₂</th>
</tr>
</thead>
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<tr>
<td>Composition (%)</td>
<td>47.70</td>
<td>45.64</td>
<td>0.607</td>
<td>3.26</td>
<td>0.393</td>
<td>0.240</td>
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</tbody>
</table>

Some of the business suggested that the Iron ore tailings are used to make value-added goods like tiles and bricks. Keeping these in mind, Iron ore Tailings are brought from Lakya Dam of Kudremukh. These Iron ore Tailings are mixed with Lateritic soil in different proportions and is taken to geotechnical laboratory to conduct tests.
IV. EXPERIMENTAL METHODS

4.1 Preparation of specimens
Lateritic soil is mixed with the 0%, 10%, 20% and 30% of IOT to conduct various Geotechnical Laboratory tests.

4.2 Sieve Analysis
A sieve analysis (or gradation test) is a practice or procedure used in civil engineering to assess the particle size distribution (also called gradation) of a granular material by allowing the material to pass through a series of sieves (4.75, 2.36, 1.18, 0.60, 0.425, 0.30, 0.15, 0.075mm) of progressively smaller mesh size and weighing the amount of material that is stopped by each sieve as a fraction of the whole mass.
IS: 2720-Part 4, Grain size Analysis, BIS, 1975

4.3 Specific Gravity
Specific gravity of soil solids is defined as the weight of soil solids to weight of equal volume of water. In effect, it tells how much heavier (or lighter) the material is than water. This test method covers the determination of the specific gravity of soil solids that pass 4.75 mm sieve.

4.4 Moisture Content
Natural moisture content is used in determining the bearing capacity and settlement. The natural moisture content will give an idea of the state of soil in the field. Water content of a soil mass is defined as the ratio of mass of water in the voids to the mass of solids.
IS: 2720-Part 2, Determination of Water content, BIS, 1973

4.5 Atterberg Limits
Consistency of fine-grained soils may be defined as the relative ease with which a soil can be remoulded. Consistency limits may be categorized into three limits called Atterberg limits.
They are Liquid limit, Plastic limit and Shrinkage limit:
- Liquid limit is the moisture content that defines where the soil changes from a plastic to a viscous fluid state.
- Plastic limit of fine-grained soil is the water content of the soil below which it ceases to be plastic. It begins to crumble when rolled into threads of 3mm dia.
- The value of shrinkage limit is used for understanding the swelling and shrinkage properties of cohesive soils. It is used for calculating the shrinkage factors which helps in the design problems of the structures made up of the soils or/and resting on soil. It gives an idea about the suitability of the soil as a construction material in foundations, roads, embankments and dams.
IS: 2720-Part 5, Determination of Liquid and Plastic Limits, BIS, 1970
IS: 2720-Part 6, Determination of Shrinkage factors, BIS, 1972

4.6 Compaction Test
Compaction is the application of mechanical energy to a soil so as to rearrange its particles and reduce the void ratio.
The objectives of compaction are:
To increase soil shear strength and therefore its bearing capacity.
To reduce subsequent settlement under working loads.
To reduce soil permeability making it more difficult for water to flow through.

The percent compaction for the field density test is calculated by dividing the dry density of the soil by the maximum dry density from the proctor test.

**4.7 CBR Test**

CBR (California Bearing Ratio) is the ratio expressed in percentage of force per unit area required to penetrate a soil mass with a standard circular plunger of 50 mm diameter at the rate of 1.25 mm/min to that required for corresponding penetration in a standard material. The ratio is usually determined for penetration of 2.5 and 5 mm. When the ratio at 5 mm is consistently higher than that at 2.5 mm, the ratio at 5 mm is used.

CBR Testing is primarily undertaken to provide data for road pavement design. It was first developed by the California State Highway Department. It is a penetration test which is used to evaluate the subgrade strength primarily of roads, pavements and foundations.

**4.8 UCS Test**

Unconfined Compressive Strength (UCS) stands for the maximum axial compressive stress that a cohesive soil specimen can bear under zero confining stress. Unconfined compression test is one of the fastest and cheapest methods of measuring shear strength of clayey soil.

**5. CONCLUSION**

Based on the study of reviewed papers, we can conclude that the various admixtures used for soil stabilization showed promising aspects in stabilizing the lateritic soil of certain geological properties of soil. These stabilizers or admixtures generally alter the mineralogy of soil resulting in highly stable soil substances having improved inherent properties such as strength and stiffness. To make the stabilization process economical we are using iron ore Tailings, the industrial waste for Stabilization of Lateritic soil. The main aim of our project is to improve the load bearing capacity of soil by mixing optimum proportions of IOTs to Lateritic soil.

**VI. REFERENCES**


