AN EXPERIMENTAL STUDY ON SUBGRADE STABILIZATION WITH LIME AND STONE POWDER IN FLEXIBLE PAVEMENT

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Abstract: The performance of flexible pavement is determined by the functions of the component layers, particularly the subgrade. Subgrade is the compacted layer of soil providing the lateral support to the pavement. Our approach is to improve the properties of soil with the addition of admixtures like lime and stone dust with soil. Soil stabilization is one of the most suitable alternatives which are widely used in pavement construction. Soil stabilization and soil treatment give an innovative solution to improve the engineering properties of soil by improving the bearing capacity, durability of weak soils and other characteristics as per requirement. In this study, lime and stone powder has been selected as a stabilizer. The soil is tested in the laboratory by reinforcing it with different percentages of lime and stone dust, namely 5%, 10%, 15%, 20%, 25%, 30%. Atterberg limit and compaction tests were carried out on both unmodified and modified soil. California bearing ratio (CBR) test was performed to determine the strength properties of the soil, lime, stone powder mixtures.

Key words: Flexible Pavement, Subgrade Soil, Stabilization, Lime, Stone dust, CBR, Bearing Strength.

I. INTRODUCTION

Pavement:

The pavement is the part of the road that carries the traffic, and has a set of layers or material placed over the natural ground. The pavement layers spread the load of the vehicles so that it does not exceed the strength capacity of the subgrade.

Types of Pavements:

There are two types of pavements based on design considerations. They are,

1. Rigid Pavement,
2. Flexible Pavement.

Rigid Pavement:

1. A rigid pavement is constructed from cement concrete or reinforced concrete slabs. Grouted concrete roads are in the category of semi-rigid pavements.
2. The design of rigid pavement is based on providing structural cement concrete slabs of sufficient strength to resist the loads from traffic.
3. The rigid pavement has rigidity and high modulus of elasticity to distribute the load over a relatively wide area of soil.

**Structure of Rigid Pavement:**

![FIG.1.1.ComponentsofRigidPavement](image)

**Flexible Pavement:**

1. Flexible pavement can be defined as the one consisting of a mixture of asphaltic bituminous material and aggregates placed on a bed of compacted granular material of appropriate quality in layers over the subgrade.

2. Water bound macadam roads and stabilized soil roads with or without asphaltic toppings are examples of flexible pavements.

3. The design of flexible pavement is based on the principle that for a load of any magnitude, the intensity of the load diminishes as the load is transmitted downwards from the surface by virtue of spreading over an increasingly larger area, by carrying it deep enough into the ground through successive layers of granular material.

**Structure of Flexible Pavement:**

![FIG.1.2.ComponentsofFlexiblePavement](image)

II. LITERATURE REVIEW


The paper “effects of stone dust on lime stabilized granular soil” focuses on the variation of CBR value of stabilized granular soil on addition with lime and stone dust. The CBR value is an important factor which determines the strength of the pavement. The lateral load on the pavement distributed to the subgrade soil. So, subgrade soil should have high strength.
2. DOMMARAJUSOMESH et al. (2020).

The purpose of the paper “techno-economical design of flexible pavement based on the stabilization of soil using stonedust as additive” is to determine the properties of expansive soil developed by mixing stonedust to expansive soil in different proportions and observing the improvement in properties.

3. ANTENEHGEREMEWE et al. (2019).

The paper “performance studies on subgrade formation using lime and cement in road projects” determines how CBR Values affects the pavement thickness of Flexible Pavement. CBR value is inversely proportional to pavement thickness. The CBR value gives the total thickness requirement of the pavement above a subgrade and this thickness value would remain the same irrespective of the quality of materials used in component layers.


The paper “compaction and subgrade characteristics of clayey soil mixed with foundry sand and fly ash” determines the maximum dry density of clay-foundry sand mix decreased with addition of fly ash.

III. METHODOLOGY
Study Area

The red soil used in this study was collected from west Ibrahimpatnam, Andhra Pradesh, India.

Mixing Proportions

The mixing proportions of soil, lime, and stone powder are as follows:

<table>
<thead>
<tr>
<th>SOIL (%)</th>
<th>LIME (%)</th>
<th>STONE POWDER (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>90</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>80</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>70</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>60</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>50</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>40</td>
<td>30</td>
<td>30</td>
</tr>
</tbody>
</table>

IV. TESTS CONDUCTED

GRAINSIZE ANALYSIS – MECHANICAL METHOD:

Aim: To determine the grainsizedistributionofthe given coarse-grained soil by sieving.

Apparatus: Thermostatically controlled oven, Sieves and wire brush, Mechanical Sieve shaker, Rubber Pedestal & Mortar.

Theory:

The grainsizedistribution is universally used in engineering classification of the soils. In addition, the suitability criteria of soil used for road and airfield construction, dam and other embankment construction and the design of filters for earth dams are based partly on the resulting grain size analysis.

The grainsizedistributionismeant to determinethe relative proportion of the different grain sizes that constitute a given soil mass. This is accomplished by obtaining the quantity of material passing through the apertures of a given sized sieve but retained on a sieve of smaller sized apertures. The weight of the quantity of soil retained any particular sieve with reference to the overall weight of the soil sample taken for the analysis, expressed as a percentage, is termed as the percentage weight of the soil retained. The percentage of soil that passes through the sieve is termed as the...
percentage finer. For the purpose of determining the proportion of soil retained on or passing through the sieves of different apertures, the sieve analysis, the soil retained on 75micron sieve is used. The analysis performed on this soil is called the coarse analysis.

**Procedure:**

1. Keep the given representative sample of soil in the oven for 24 hours.
2. Pulverize the oven dried sample by using the mortar and pedestal and sieve it on the 4.75mm drive.
3. Take about 1kg of the fraction of the soil passing 4.75mm sieve and retained on 75mm sieve for the sieve analysis.

Take the following set of sieves and stack them one over the other in the order of arrangement shown (i.e. the sieve with the largest aperture at the top)

<table>
<thead>
<tr>
<th>Lid</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.75mm sieve</td>
</tr>
<tr>
<td>2.00mm sieve</td>
</tr>
<tr>
<td>1.00mm sieve</td>
</tr>
<tr>
<td>600-micron</td>
</tr>
<tr>
<td>300-micron</td>
</tr>
<tr>
<td>150-micron</td>
</tr>
<tr>
<td>75-micron</td>
</tr>
<tr>
<td>Pan</td>
</tr>
</tbody>
</table>

4. Place the soil in the top sieve, close the lid, transfer the set of sieves with the receiver pan at the bottom to a mechanical sieve and fit them. Sieve the soil for a period of 10 minutes.
5. Remove the stack of sieves from the shaker and obtain the weight of the material retained on each sieve.
6. Compute the percentage retained on each sieve by dividing the weight retained on each sieve by the original weight of the soil sample taken for the analysis.
7. Compute the percentage finer by starting with 100% and subtracting the percentage retained on each sieve as an accumulative procedure.
8. Draw a graph between the percentage finer, drawn to a natural scale on the Y-axis and the particlesize drawn to a logarithmic scale on the X-axis.

On the graph, the grain sizes corresponding to the different colours of soils are shown on the X-axis (drawn to a log scale) as shown:

<table>
<thead>
<tr>
<th>GRAVEL</th>
<th>SAND</th>
<th>SILT</th>
<th>CLAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRAIN</td>
<td>COARSE</td>
<td>MEDIUM</td>
<td>FINE</td>
</tr>
<tr>
<td>SIZE</td>
<td>4.75 – 2.00</td>
<td>2.00 – 0.425</td>
<td>0.425 – 0.075</td>
</tr>
</tbody>
</table>

Lid | 4.75mm sieve | 2.00mm sieve | 1.00mm sieve | 600-micron | 300-micron | 150-micron | 75-micron | Pan |
Comments:

From the given size distribution curve, grains sizes such as $D_{10}, D_{30},$ and $D_{60}$ may be obtained. Refer to the grainsize where the subscript $(10, 30, 60)$ denotes the percentage finer. Thus $D_{10} = 0.10$ mm indicates the diameter of the particle corresponding to 1 percent finer. Or, in other words, 10% of the sample has grains smaller than 0.10 mm.

For the above values, two quantities, namely the coefficient of uniformity, $C_U,$ and the coefficient of curvature, $C_C,$ may be computed by using the following formulae.

$$C_U = \frac{D_{60}}{D_{10}}.$$ 

$$C_C = \frac{(D_{30})^2}{(D_{60} \cdot D_{10})}.$$

These quantities enable to know whether the soils are well graded (W) i.e., it has a good representation of all particle sizes, or poorly graded (P) i.e., a good representation of all particle sizes does not exist.

For a well graded soil, $C_U > 4$ for gravels

For a well graded soil, $C_U > 6$ for sands

And the coefficient of curvature $C_C$ must be between 1 and 3 for both.

If the criteria are not met, the soil may be termed a poorly graded (P).

Formulae:

$$C_U = \frac{D_{60}}{D_{10}}.$$ 

$$C_C = \frac{(D_{30})^2}{(D_{60} \cdot D_{10})}.$$ 

Where,

$C_U =$ Coefficient of uniformity, $C_C =$ Coefficient of curvature, $D_{10}, D_{30}, D_{60} =$ Grain size at 10%, 30%, 60% finer.

<table>
<thead>
<tr>
<th>SI.No</th>
<th>ISSieve</th>
<th>Particle Size, D(mm)</th>
<th>Weight Retained (gm)</th>
<th>% Retained</th>
<th>Cumulative % Retained</th>
<th>Cumulative % Finer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>4.75</td>
<td>4.75</td>
<td>68</td>
<td>6.80</td>
<td>6.80</td>
<td>93.2</td>
</tr>
<tr>
<td>2.</td>
<td>2.00</td>
<td>2.00</td>
<td>84</td>
<td>8.40</td>
<td>15.2</td>
<td>84.8</td>
</tr>
<tr>
<td>3.</td>
<td>1.00</td>
<td>1.00</td>
<td>92</td>
<td>9.20</td>
<td>24.4</td>
<td>75.6</td>
</tr>
<tr>
<td>4.</td>
<td>0.60</td>
<td>0.60</td>
<td>161</td>
<td>16.1</td>
<td>40.5</td>
<td>59.5</td>
</tr>
<tr>
<td>5.</td>
<td>0.30</td>
<td>0.30</td>
<td>262</td>
<td>26.2</td>
<td>66.7</td>
<td>33.3</td>
</tr>
<tr>
<td>6.</td>
<td>0.15</td>
<td>0.15</td>
<td>193</td>
<td>19.3</td>
<td>86.0</td>
<td>14.0</td>
</tr>
<tr>
<td>7.</td>
<td>0.075</td>
<td>0.075</td>
<td>97</td>
<td>9.70</td>
<td>95.7</td>
<td>4.30</td>
</tr>
<tr>
<td>8.</td>
<td>Pan</td>
<td>-</td>
<td>43</td>
<td>4.30</td>
<td>100</td>
<td>0</td>
</tr>
</tbody>
</table>

Total Weight 1000 gm

Result:
Asper-IS:1498-1970 classification and identification of soils for general engineering purposes. Ccranges from 1 to 3 for well graded soil,

\[ C_U > 4 \text{ for gravels}, \quad C_U > 6 \text{ for sands}. \]

For the collected soil sample, \( C_U = 5.143 \text{ and } C_C = 1.032 \). Hence, the soil is well graded soil.

PLASTIC LIMIT TEST:

Need and Scope:

Soil is used for making bricks, tiles and soil cement blocks in addition to its use as foundation for structures.

Apparatus Required:

1. Porcelain dish,
2. Glass plate for rolling the specimen,
3. Airtight Containers,
4. Weighing Balance,
5. Thermostatically controlled Oven.

Theory:

The plastic limit of a soil is the moisture content at which soil begins to behave as a plastic material. At this water content (plastic limit), the soil will crumble when rolled into threads of 3.2 mm in diameter.

Procedure:

1. Take about 20 gm of thoroughly mixed portion of the material passing through 425 micron I.S. Sieve obtained in accordance with IS: 2720 (Part 1).
2. Mix it thoroughly with distilled water in the evaporating dish until soil mass becomes plastic enough to be easily moulded with fingers.
3. Allow it to season for sufficient time (for 24 hours) to allow water to permeate throughout the soil mass.
4. Take about 190 gms of this plastic soil mass and roll it between fingers and glass plate with just sufficient pressure to roll the mass into a threaded of uniform diameter throughout its length the rate of rolling shall be between 60 and 90 strokes per minute.
5. Continue rolling till you get a threaded of 3 mm diameter.
6. Knead the soil to get a uniform mass and re-roll.
7. Continue the process until the thread crumbles when the diameter is 3 mm.
8. Collect the pieces of the crumbled thread in an airtight container for moisture content determination.
9. Repeat the test at least three times and take the average of results. Calculated to the nearest whole number.
10. Compare the diameter of thread at intervals with the rod.
Formulae:

Plasticity Index, $I_p = W_L - W_P$


Observations and Calculations:

1. 100%Soil+5%Lime+5%StonePowder.

<table>
<thead>
<tr>
<th>Soil(%) + Lime(%) + StonePowder(%)</th>
<th>PlasticLimit, $W_P$(%)</th>
<th>PlasticityIndex, $I_p$(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 +0 +0</td>
<td>25.00</td>
<td>15.25</td>
</tr>
<tr>
<td>90 +5 +5</td>
<td>24.08</td>
<td>13.32</td>
</tr>
<tr>
<td>80 +10 +10</td>
<td>22.85</td>
<td>13.47</td>
</tr>
<tr>
<td>70 +15 +15</td>
<td>20.70</td>
<td>12.56</td>
</tr>
<tr>
<td>60 +20 +20</td>
<td>18.54</td>
<td>12.27</td>
</tr>
<tr>
<td>50 +25 +25</td>
<td>16.40</td>
<td>11.16</td>
</tr>
<tr>
<td>40 +30 +30</td>
<td>14.28</td>
<td>10.15</td>
</tr>
</tbody>
</table>

V. CONCLUSION

1. As per IS: 1498-1970 classification and identification of soils for general engineering purposes, $C_C$ ranges from 1 to 3 for well graded soil, $C_U > 4$ for gravels, $C_U > 6$ for sands. For the collected soil sample, $C_U = 5.143 < C_C = 1.032$. Hence, the soil is well-graded soil.

2. The collected soil sample has 44.689% of sand and 55.311% of silt. Hence the soil is combination of silt and sand.

3. Liquid Limit, $W_L = 40.25333\%$, Plasticity Index, $I_p = 14.785\%$. From the A-Line chart, the soil is Intermediate Compressible Silt.

4. Liquid Limit, $W_L$ is gradually decreases on increasing with the addition of different percentages of Lime and Stone Powder to the Soil. Liquid Limit, $W_L$ between 35% to 50% normally indicates an intermediate compressibility and intermediate shrinkage/swelling potential.

5. Plastic Limit, $W_P$ is gradually decreases on increasing with the addition of different percentages of Lime and Stone Powder to the Soil.

6. Plasticity Index, $I_p$ is initially increases and then decreases with the addition of different percentages of Lime and Stone Powder to the Soil. The decreasing in Plasticity Index, $I_p$ generally results in high shear strength.

7. The optimum moisture content, OMC(%) of soil initially decreases with the addition of 20% lime and 20% stone powder to the soil.

8. The CBR value of Soil initially increases with the addition of 20% Lime and 20% Stone Powder to the Soil, and then the CBR value gradually decreases with increasing percentages of Lime and Stone Powder.
9. The optimum percentage of lime and stone powder added to increase the strength of subgrade soil is 20% lime and 20% stone powder.

VI. REFERENCES.


9. IS:2720(PART5)–1985 METHODS OF TEST FOR SOILS, PART 5– DETERMINATION OF LIQUID LIMIT AND PLASTIC LIMIT.

10. IS:2720(PART7)–1980 METHODS OF TEST FOR SOILS, PART 7– DETERMINATION OF WATER CONTENT–DRY DENSITY RELATION USING LIGHT COMPACTION.