FIELD STUDIES ON THE MARINE CLAY FOUNDATION SOIL BEDS TREATED WITH LIME, GBFS AND REINFORCEMENT TECHNIQUE

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ABSTRACT

Majority of the population in India are living in costal corridor, where the existing soils are weak and more deformative. It is becoming a great challenge for the civil engineers to design suitable foundation for the structures in these regions. The effect of GBFS, lime and geotextile as reinforcement & separator on the marine clay foundation soil bed in field has been investigated. A test track of 8m long and 2m wide was laid in the field for testing the treated and untreated conditions of the marine clay foundation soil beds. The ultimate load carrying capacity of the test tracks for untreated and treated conditions have been studied and also the degree of compaction of the test tract was found.

KEY WORDS:  Load carrying capacity, Field studies, Degree of compaction untreated and treated conditions of marine clay foundation soil beds.

1. INTRODUCTION

Soft marine clay is very sensitive to change the stress system, moisture content and system chemistry of the pore fluid. Geotechnical engineers feel a necessity to improve the behavior of these deposits using anyone of the available ground improvement techniques for the construction of foundations.

Behavior of Marine Clay

The marine clays are highly compressible soft clays and also it exhibits moderate swelling when comes in contact with moisture. This behaviour is due to the presence of clay minerals with expanding lattice structure. The marine clay is very hard when it is dry but loses its strength on wetting. The marine clay got cracks as shown in the plate 1 on drying and in the worst cases the width of the cracks is almost 250 mm to 500 mm and travel down to 1.00m beneath the ground level.

The consistency limits of the marine clay are as follows:
Liquid limit is 89%, plastic limit is 47%, shrinkage limit is 16% and specific gravity is 2.62 (Basak et.al:2009).

Plate 1: Marine Clay Showing Cracks
2. REVIEW OF LITERATURE

Marine clay

Marine clay normally possesses soft consistency marine clay deposits of Kakinada were used for the testing with the aim to investigate its Engineering properties (S. Narasimha Rao et.al:1996; Shridharan et.al:1989; Thiam-Soon Tan et.al:2002; Supakij Nontananandh et.al:2004; Basak et.al:2009, Gang Ren: 2010) and further, made suitable for foundation constructions over it.

Test Track Studies

It is a recognised fact that, whenever a new material or a technique is introduced in the pavement constriction, it becomes necessary to experiment it for its validity by constructing a test track, where the loading, traffic and other likely field conditions were simulated. Several test tracks studies (Reddy et.al, 1981 ; Rolt et.al,1987 ; Qubain, 2000 ; Prasada Raju, 2001 ; Prasad et.al, 2008 ; Prasad and Prasada Raju et.al (2009) have been carried out in many ways to characterise the pavement and to assess the effectiveness of remedial technique developed to deal with the problematic condition like freeze –thaw , expansive soil and other soft ground problems.

3. MATERIALS USED

Marine clay

The soil was collected from 0.50m to 1.00m depth from ground level at Kakinada Sea Ports limited, Kakinada, A.P, India and used for this investigation and it was classified as CH.

Geotextile

PP woven geotextile-GWF-40-220, manufactured by GARWARE –WALL ROPES LTD, Pune, India, was used in this investigation. The tensile strength of woven geotextile is 60.00 kN /m for warp and 45.00 kN / m for weft.

Lime (Ca(OH)₂)

Commercial grade lime mainly consisting of 58.67% of CaO and 7.4% Silica was used in the study. The quantity of lime was varied from 6% to 9% by dry weight of soil.

Granulated Blast Furnace Slag (GBFS)

Granulated blast furnace slag used for this study was brought from Vizag steel plant, Visakhapatnam, Andhra Pradesh, A.P, India. Various laboratory tests were conducted to determine the properties of GBFS as per IS code of practice. The strength of marine clay has been improved due to the presence of 11.6% CaO in the GBFS

Gravel

The gravel was collected from the Surampalem quarry, Peddapuram Mandal, East Godavari District, A.P, India. It was classified as well graded gravel and used as cushion on the untreated and treated marine clay foundation soil.

4. TEST TRACK PREPARATION FOR UNTREATED AND TREATED MARINE CLAY FOUNDATION SOIL BEDS

A track of size 4m long and 2.0m wide individually for untreated and treated conditions, was excavated to an average depth of 0.8m, out of which 0.5m was for laying the treated or untreated marine clay foundation soil over which a 0.30m thick gravel layer was laid as cushion for a model foundation soil bed for untreated and
Plate 2: Excavation of Trench

Plate 3: Mixing of Lime with Marine Clay

Plate 4: Mixing GBFS with Marine Clay + Lime mix

Plate 5: Prepared Lime Treated Marine Clay Foundation Soil

Plate 6: Author is Curing the Geotextile using Pegs Foundation Soil

Plate 7: Anchoring of Lime Treated Marine Clay
treated conditions as shown in plate 2 and 9. The geotextile was provided as reinforcement & separator in between the treated foundation soil and the gravel cushion as shown in the plate 7. The plate 7 represents the anchoring of geotextile.

5. IN SITU TESTS

General
Marine clay behaves very critically when it comes in contact with the moisture. Hence various field studies were carried out in the wet season with a view to study the relative performance of the adopted stabilization techniques.

5.1 Field Moisture Content and Core Density Test
The field dry density and field moisture content of the treated and untreated marine clay foundation soil with gravel cushion were determined by conducting core cutter test during all the stages of construction of the foundation soil bed as shown in the Plates 10 and the results were presented in the table 1.

5.2 Field Static Plate Load Tests
General
The following in-situ plate loads tests were conducted on two test tracks to assess the efficacy of the stabilized & reinforced track in improving the overall performance in comparison with the untreated test track for the foundation soil beds. Details of the tests were given in the following sections.
Static Plate Load Tests on Model Foundation Soil Bed

Static plate load tests were conducted on the untreated and treated & reinforced test tracks of marine clay model foundation soil beds under normal pressures using circular steel plate of diameter 0.30m. A loading frame was loaded with the help of soil bags as shown in Plate 11. The loading frame was arranged centrally over the test track as shown in the Fig 1 and Plate 11. A 0.30m diameter circular metal plate with extension rod was placed centrally over the prepared marine clay model foundation soil bed and a hydraulic jack of 50 kN capacity was centrally placed over the circular plate. The plate was attached to the loading frame with a loading cylinder for conducting the static plate load test.
Two dial gauges with a least count of 0.01mm were placed on the metal flat to measure the deformations. A load of 5kPa was applied as a seating load with the help of hydraulic jack and released. The static plate load tests were carried out to determine the ultimate load carrying capacity of the untreated and treated & reinforced marine clay foundation soil beds. Each pressure increment was placed till only for insignificant change in deformation was observed between consecutive load increments. The testing was further continued till the failure for knowing the ultimate load bearing capacity of the untreated and treated & reinforced marine clay foundation soil beds.

**In-situ Static Plate Load Tests Results of Model Foundation soil beds**

The In-situ static plate load tests were conducted on untreated and treated marine clay foundation soil bed with gravel cushion. The marine clay was treated with an optimum of 8% Ca(OH)\(_2\) + 20%GBFS and geotextile as reinforcement between the treated foundation soil and the gravel cushion for the preparation of marine clay foundation soil bed during the wet season. The results are presented in the Table 2 and Fig 2 to 4.

**Table 1 Core Cutter Density of In-situ Model Foundation Soil Beds.**

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight of the core sample</th>
<th>Vol. of the core sample</th>
<th>Field bulk density (kN/m(^3))</th>
<th>Water content (%)</th>
<th>Field dry density (kN/m(^3))</th>
<th>Lab dry density (kN/m(^3))</th>
<th>Degree of Compaction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>For Model Foundation Soil bed : untreated results</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil</td>
<td>3100</td>
<td>1410</td>
<td>21.990</td>
<td>21.00</td>
<td>13.17</td>
<td>13.77</td>
<td>95.64</td>
</tr>
<tr>
<td>Gravel</td>
<td>3250</td>
<td>23.04</td>
<td>16.50</td>
<td>19.89</td>
<td>99.44</td>
<td></td>
<td></td>
</tr>
<tr>
<td>For Model Foundation soil bed: treated results</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil</td>
<td>3200</td>
<td>1410</td>
<td>22.695</td>
<td>22.00</td>
<td>16.11</td>
<td>16.88</td>
<td>95.43</td>
</tr>
<tr>
<td>Gravel</td>
<td>3300</td>
<td>1410</td>
<td>23.404</td>
<td>14.50</td>
<td>19.75</td>
<td>19.89</td>
<td>99.29</td>
</tr>
</tbody>
</table>

The stabilized marine clay foundation soils bed has exhibited an In-situ ultimate load bearing capacity of 763.661kN/m\(^2\) with the deformation of 1.12mm for the treated condition and of 282.837kN/m\(^2\) load with the deformation of 1.32mm for the untreated condition.

**Table 2: Ultimate Load Carrying Capacity of Foundation Soil Beds**

<table>
<thead>
<tr>
<th>SL.No</th>
<th>Load Carrying Capacity for Untreated Condition kN/ m(^2)</th>
<th>Load Carrying Capacity for Treated Condition kN/ m(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In Lab</td>
<td>In Field</td>
</tr>
<tr>
<td>1</td>
<td>339.404</td>
<td>282.837</td>
</tr>
</tbody>
</table>

**Fig 2 : In-situ Static Plate Load Tests on Untreated and Treated Marine Clay Foundation Soil Beds**

- **Load (kN/m\(^2\)):**
  - Untreated: 282.837, 1.32, 226.269, 2.68, 339.404, 3.8, 367.688, 6.25
  - Treated: 622.241, 2.23, 763.661, 1.12, 820.228, 4.28

- **Settlements (mm):**
  - Untreated: 0.00, 1.32, 2.68, 3.8, 6.25
  - Treated: 0.00, 4.28, 6.36
DISCUSSIONS

It was noted that, at a depth 0.6m the natural soil strata was in fully saturated condition due to the heavy rains during the wet season and also at some places in the JNTU-CAMPUS the rain water was stagnated.

It was observed that the untreated and treated marine clay laboratory model foundation soil bed has exhibited the highest load carrying capacity when compared with the field models, because there was a confinement in the laboratory model tanks and no effect of natural water table as in case of field investigations.

CONCLUSIONS

The following conclusions are drawn based on the field studies carried out while comparing with the laboratory investigations.

- It was noticed that the ultimate in-situ load carrying capacity of the untreated and treated marine clay model foundations soil bed has exhibited less value than the laboratory marine clay model foundation soil beds as explained in the discussions.
- It was observed that the treated marine clay foundation soil bed has exhibited the justified load carrying capacity in wet season.

REFERENCES


