Comparison of Stone and Sand Ceramic Dust Column on Bearing Capacity and Settlement of Soil

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Abstract— the demand for improvement of construction sites with poor/weak soils has triggered research in the area of ground improvement. As a result many methods of improvement of weak soils have been employed over a period of time. Now a day’s abundant amount of waste is generated in India in the form of Ceramic dust, Fly ash, Rubber waste, Construction and Demolition waste etc. Much of this waste has been thrown to landfill, without considering its potential for reuse, recycling or valuation. Through the literatures it has been found that Ceramic Dust can also act as a major material in improving bearing capacity. Hence the present study aim at potential use of Ceramic Dust waste in ground improvement to save construction cost. Experimental set up is created for carrying out test on stone and Sand Ceramic Dust column by applying load through mechanical jack and load carrying capacity as well as settlement is measured. The Ceramic Dust is used as replacement material in Sand column in the range of 5%, 10%, 15% and 20% of total weight of column. After performing experiment a noticeable amount of increment in bearing capacity has been observed in case of Sand Ceramic Dust column of 15% and 20%.

Key words: Stone Column, Sand Ceramic Dust Column, ML Type Soil, Bearing Capacity, Settlement

I. INTRODUCTION

This necessitated the use of land, which has weak strata, wherein the geotechnical engineers are challenged by presence of different problematic soils with varied engineering characteristics. Many of these areas are covered with thick soft marine clay deposit, with very low shear strength and high compressibility. Ambily et. al (2007) Stone column, one of the most commonly used soil improvement technique, has been utilized worldwide to increase the bearing capacity of soft soils and reduce the settlement of superstructures constructed on them. Subsurface soils whose undrained shear strength range from 7 to 50 kPa or loose Sandy soils including silty or clayey Sands represent a potential class of soils requiring improvement by stone columns. IS 15284 (Part 1):2003. Tandel et.al (2012) has made effort to study the effect of wrapping geotextile on Sand column and concluded that the load carrying capacity can be increased by all round reinforcement by geotextile. Kousik et.al (2011) attempts to study on unreinforced and geogrid reinforced Sand bed over stone column improved soft clay and concluded that the presence of stone column in soft soil improves load carrying capacity and reduces settlement. Mukul et.al (2012) has studied on load deformation behavior of floating stone column in soft clay and concluded that with the provision of stone column bearing capacity can be increased by 3.5 times. Gandhi et.al (2004) has studied on theoretical and experimental evaluation of stone column in soft clay and concluded that when column area alone is loaded, failure is due to bulging while when entire area is loaded behavior is linear. Hence based on the literatures referred an effort has been made to replace the stone column material by Sand Ceramic Dust to study its impact on bearing capacity and settlement of soil. The availability of land for the development of commercial, housing, industrial and transportation, infrastructure etc. are scarce particularly in urban areas.

A. Scope of Study:

In the present study an attempt has been made to study the effect of the stone and Sand Ceramic Dust column on bearing capacity and settlement of soil. Additive material used in Sand column is Ceramic Dust. Laboratory model tests on Stone and Sand Ceramic Dust columns have been carried out to study its impact on bearing capacity and settlement. The Ceramic Dust used in Sand column is varied in range of 5%, 10%, 15% and 20% of total weight of column material.

II. EXPERIMENTAL STUDY

A. Materials Used:

Soil (ML type), for making the soil bed is collected from Chandkheda region of Ahmedabad and its properties were determined and are listed in Table 1. Gravels are used for making stone column having size between 2-10mm. Sand used for making Sand Ceramic Dust column is collected from local trader in which particles passing from 4.75 mm are used

I) Properties of Soil for Preparation of Bed:

The soil used for preparation of bed is procured from Chandkheda region of Ahmedabad and properties of the soil is shown below.

<table>
<thead>
<tr>
<th>Properties</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Gravity</td>
<td>2.7</td>
</tr>
<tr>
<td>Liquid Limit</td>
<td>28%</td>
</tr>
<tr>
<td>Plastic Limit</td>
<td>25.12%</td>
</tr>
<tr>
<td>Plasticity Index</td>
<td>2.88%</td>
</tr>
<tr>
<td>Optimum Moisture Content</td>
<td>13.6%</td>
</tr>
<tr>
<td>Maximum Dry Density</td>
<td>18.75 KN/m³</td>
</tr>
<tr>
<td>ISC Classifications</td>
<td>Silt with low plasticity (ML)</td>
</tr>
<tr>
<td>Direct box shear test</td>
<td>C= 2.5 KN/m² Φ= 20°</td>
</tr>
</tbody>
</table>

Table 1: Properties of Soil Used For Preparation of Bed

2) Properties of Sand:

The Sand used for preparation of Sand Ceramic Dust column is brought from local trader of Ahmedabad and properties of same are shown below.

<table>
<thead>
<tr>
<th>Properties</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Gravity</td>
<td>2.61</td>
</tr>
<tr>
<td>Grain Size Distribution</td>
<td>Cu= 2.93 Cc= 0.87</td>
</tr>
</tbody>
</table>

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Relative Density
\[
\begin{align*}
\rho_{\text{max}} &= 18.93 \text{ KN/m}^2 \\
\rho_{\text{min}} &= 17.07 \text{ KN/m}^3 \\
I_d &= 31.53\%
\end{align*}
\]

Direct Box Shear Test
\[ C= 0 \text{ and } \Phi = 30^\circ \]

Table 2: Properties of Sand

3) Properties of Gravel:
The gravel used for preparation of stone column is brought from local trader of Ahmedabad and properties of same are shown below.

<table>
<thead>
<tr>
<th>Properties</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Gravity</td>
<td>2.56</td>
</tr>
<tr>
<td>Grain Size Distribution</td>
<td>Cu= 1.05 Cc= 1.69</td>
</tr>
</tbody>
</table>
| Relative Density            | $\rho_{\text{max}} = 17.50 \text{ KN/m}^3$  \\
|                             | $\rho_{\text{min}} = 14.46 \text{ KN/m}^3$  \\
|                             | $I_d = 36.43\%$ |

Table 3: Properties of Gravel

4) Index and Engineering Properties of Ceramic Dust:
The additive in the form of Ceramic Dust used for making Sand Ceramic Dust column is procured from Marbito vitrified tiles Himmatnagar.

<table>
<thead>
<tr>
<th>Properties</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Gravity</td>
<td>G= 2.61</td>
</tr>
</tbody>
</table>
| Standard Proctor Test       | OMC= 15.8%     \\
|                             | MDD= 15.50 \text{ KN/m}^3 |
| Direct Box Shear Test       | $C= 0.5 \text{ kN/m}^2$  \\
|                             | $\Phi = 31^\circ$ |

Table 4: Index and Engineering Properties of Ceramic Dust

B. Experimental Setup:
For carrying out test experimental setup is created in Geotechnical Laboratory of L.D. college of Engineering Ahmedabad. The model tests were performed on a stone and Sand Ceramic Dust column installed at the centre of a soil bed (ML type) prepared on a square tank and the footing load was applied to the stone and Sand Ceramic Dust column using a loading plate having a size 140 X 140 mm respectively. A loading set up created for study is shown in Figure 1. In the entire tests, the thickness of the soil (ML type) bed is kept constant as 400 mm. Concrete tanks of square size 350 X 350 mm and 500 mm deep with a wall thickness of 40 mm were used. The column used is designed as a rigid column having a diameter (d) of 50 mm and length (L) 400 mm. The test is conducted up to a maximum settlement of 15mm. The load and settlement is measured by means of proving ring and settlement respectively.

C. Preparation of Bed:
The soil (ML type) that is used for the testing is obtained from Chandkheda region of Ahmedabad. For preparation of bed inside tank the soil (ML type) is mixed thoroughly at moisture content of 22.40% and is compacted in 3 layers to achieve dry density of 15KN/m3. A PVC pipe of 50 mm external diameter was placed at the centre of the tank. Around this pipe, the bed is formed. The soil bed thus formed is left for 24 hours. The PVC pipe is then removed completely from the bed without causing any disturbance to the bed. Then the Ceramic dust required to form the Sand Ceramic Dust column is carefully charged into the hole in three layers. The composite soil with stone and Sand Ceramic Dust column is constructed and left for 24 hours to develop proper bonding between the column and the bed. Then the loading is applied by means of mechanical jack. The load and settlement is measured with the help of proving ring and dial gauges.

D. Construction of Stone Column and Sand Ceramic Dust Column:
A thin open-ended seamless PVC pipe of 50 mm outer diameter and wall thickness 2 mm is placed at the center of the tank. Slight grease is applied on outer surface of the pipe for easy withdrawal without any significant disturbance to the surrounding soil. Stones were charged into the hole in three layers at a relative density of 35%. In similar ways Sand Ceramic Dust column is charged into hole at relative density of 35%. The pipe is then raised in stages ensuring a minimum of 5mm penetration below the top level of placed material. To achieve uniform density, compaction is given with circular steel tamper. The light compaction effort is adopted to ensure that there is no significant lateral bulging of column creating disturbance to surrounding soil (ML type).

E. Test Procedures:
After preparing the stone column, the load deformation behavior of the stone and Sand Ceramic Dust column is studied by applying vertical load in a loading frame. For testing a loading plate of 140X 140 mm is placed over the stone column and Sand Ceramic Dust column. Load is applied at a constant rate till there is settlement of 15 mm.

III. RESULTS AND DISCUSSION
After performing the experiments the load settlement behavior is studied through plot between load and settlement. The ultimate load is obtained by drawing two tangents and the point of intersection of this tangent represents ultimate load. For all samples the load settlement behavior is shown below.
A. Load vs. Settlement Graphs for Various Samples

1) Soil without Reinforcement:

Fig. 3: Load vs. Settlement Characteristics of Soil without Reinforcement

2) Stone Column:

Fig. 4: Load vs. Settlement Characteristics of Stone Column

3) Sand Column:

Fig. 5: Load vs. Settlement Characteristics of Sand Column

4) Sand Column with 5% Ceramic Dust:

Fig. 6: Load vs. Settlement Characteristics of Sand Column with 5% Ceramic Dust

5) Sand Column with 10% Ceramic Dust:

Fig. 7: Load vs. Settlement Characteristics of Sand Column with 10% Ceramic Dust

6) Sand Column with 15% Ceramic Dust:

Fig. 8: Load vs. Settlement Characteristics of Sand Column with 15% Ceramic Dust

7) Sand Column with 20% Ceramic Dust:

Fig. 9: Load vs. Settlement Characteristics of Sand Column with 20% Ceramic Dust
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<table>
<thead>
<tr>
<th>S.No</th>
<th>Sample</th>
<th>Ultimate Load (kN)</th>
<th>Ultimate Bearing Capacity (kN/m²)</th>
<th>Increment of Load (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Soil without reinforcement</td>
<td>1.1</td>
<td>56.12</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>Stone column</td>
<td>1.71</td>
<td>87.24</td>
<td>55.45</td>
</tr>
<tr>
<td>3</td>
<td>Sand Column</td>
<td>1.42</td>
<td>72.44</td>
<td>29.09</td>
</tr>
<tr>
<td>4</td>
<td>Sand column with 5% Ceramic Dust</td>
<td>1.52</td>
<td>77.55</td>
<td>38.18</td>
</tr>
<tr>
<td>5</td>
<td>Sand column with 10% Ceramic Dust</td>
<td>1.78</td>
<td>90.81</td>
<td>61.81</td>
</tr>
<tr>
<td>6</td>
<td>Sand column with 15% Ceramic Dust</td>
<td>1.93</td>
<td>98.46</td>
<td>75.45</td>
</tr>
<tr>
<td>7</td>
<td>Sand column with 20% Ceramic Dust</td>
<td>2.14</td>
<td>109.18</td>
<td>94.54</td>
</tr>
</tbody>
</table>

Table 5: Comparison of Bearing Capacity of Stone Column And Sand Ceramic Dust Column

Fig. 10: Variation of Percentage Load Increment for Different Samples

From the above load settlement graph it has been observed that the ultimate load capacity increases significantly when Sand is replaced by 15% and 20% of Ceramic Dust by total mass while as it achieves 6.36% higher load as compared to stone column when Sand is replaced by 10% of Ceramic Dust by total mass. The ultimate load achieved in case when Sand is replaced by 5% Ceramic Dust is higher by 9.09% than Sand column but is lesser than of stone column by 17.27%. However the ultimate load is higher in case of stone column as compared to soil (ML) without any treatment. The ultimate load increases with increase in percentage of Fly ash and hence increases bearing capacity. The increase in the value of ultimate load in case of Ceramic Dust column may be due to Ceramic Dust acting as a cementing agent. In all the cases a common observation is that initially with application of load, settlement takes place at slower rate as compare to load applied at later stages.

IV. CONCLUSIONS

Following conclusions are drawn from the experimental analysis of stone column and Sand Ceramic Dust Column:

1) The ultimate load capacity of ML soil with stone column reinforcement is found to be 55.45% higher as compared to ML soil without reinforcement.
2) When the ML soil is treated with Sand column the ultimate load is found to be 29.09% higher as compared to ML soil without reinforcement but it is 26.36% lower than stone column reinforcement.
3) The ultimate load is found to be 17.27% low in case of 5% of Sand material replaced by Ceramic Dust while in case when 10% of Sand material is replaced by Ceramic Dust, ultimate load is higher by 6.36% as compared to stone column reinforcement.
4) The ultimate load is found to be higher by 75.45% and 94.54% in case of 15% and 20% Sand replacement by Ceramic Dust as compared to stone column reinforcement.
5) The ultimate load capacity is highest in case of 20% of Sand material by weight is replaced by Ceramic Dust due to Ceramic Dust acting as cementing agent and percentage increment is 94.54%.
6) The ultimate load capacity increases with increase in percentage of Ceramic Dust in Sand Ceramic Dust Column.

REFERENCES