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A Study on Load Carrying Capacity of Soft Clays Provided with Granular Pile of Different Material

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Abstract: Soft grounds are usually associated with substantial difficulties since these soils are sensitive to deformation and possess very small shear strength, which may lead to structural damages. Out of several techniques available for improving the soft clay strata, stone columns are ideally suited for structures with wide spread loads with higher permissible settlements. The beneficial effects of stone column installation in weak deposits are manifested in the form of increased load carrying capacity, a significant reduction in total and differential settlements, accelerating process of consolidation, reduction of liquefaction risks, improving the slope stability of embankments and natural slopes. In the present study, in order to preserve the naturally available materials, it has been thought off to utilize some locally available waste materials for the formation of stone columns which is popularly known as granular piles. Laboratory tests were conducted to determine the load carrying capacity of granular piles installed in soft soils by varying the percentages of Recycled aggregate in place of natural aggregate and marble floor dust in place of sand. Tests were also conducted with natural aggregate for comparison purpose. To understand the influence of cementing agents (cement, lime, and gypsum), tests were also conducted by adding the cementing agents to the granular pile material. The test results showed significant increase about 28 folds in the load carrying capacity of soft soil reinforced with granular pile mixed with cementing agents upon curing period when compared to the only granular pile. The addition of cementing agents to the granular pile could also reduce the settlements significantly.

Keywords: Load carrying capacity, softclays, granular pile, cementing agents ,

Introduction

Geotechnical design and execution of civil engineering structures on/in soft to very soft soils are usually associated with substantial difficulties. Since this type of soils are sensitive to deformations and possesses very small shear strength, they may lead to structural damages during the execution as well as throughout the life of the projects, especially in urban areas. This can be due to: Excessive settlements or tilting of newly constructed building structures, Entrainment settlement of old structures near newly erected structures, An adverse effect of excavations on nearby structures, etc. different ground improvement techniques available for soft soil improvement is Dewatering-Open ditches, Open sumps, and ditches, Wellpoint systems, Vacuum dewatering and Dewatering by electro-osmosis.Preloading- Surcharge preloading, Preloading with Radial Drainage, Sand Drains, Prefabricated Vertical Drains(PVD), Vacuum Preloading.The above techniques require long time for the soil to get consolidated Stone columns, also known as granular piles are popular as a technique of ground improvement not only in cohesive soils but also in cohesionless soil deposits (GopalRanjan, 1989; Rao, 1993). These piles are finding their wide application in India and abroad to support area loads such as embankment, oil storage tanks, warehouses, large oil-stock yards, fertilizer plant storage facilities and buildings with framed structures. This technique could be the most appropriate choice of ground improvement for most of the soils due to the technical feasibility, low energy utilization, cost effectiveness especially in developing countries like India**.** The practice of installing natural aggregate material as granular piles in such clays is highly appreciated. Unfortunately, the vast construction across the world is consuming a heavy amount of natural materials (natural aggregate). Simultaneously, due to a high increase in a volume of demolished concrete which has overcome their age limit of use like old buildings, concrete pavements, bridge structures is causing dumping problem and pollution. To preserve natural materials and utilizing demolished concrete waste in a proper manner to avoid dumping problem some technique has to be thought off. Also, other dumped waste materials, rock floor, was thought to study its geotechnical parameters and an effort has to be presented to utilize for replacement of fine aggregate.

Objectives

The main objective of the study proposed here is to

1. A study on load carrying capacity of soft clays provided with granular piles of different materials
2. To study and compare the load-settlement curves by adding different cementing agents.
3. To study the possible failure mechanisms of treated soft soil

Materials Used

Soil: The soft soil used in the present study is Clay soil, obtained hyderabad, Collected at a depth of 1.5m from ground level. The properties of soft soil are given in Table1

Sand And Clayey Sand: For the present investigation, the sand and clayey gravel w**ere** collected from MREC Campus. The properties of sand and clayey gravel are presented in Table 2 respectively.

Aggregate: Natural crushed stone Aggregate of size between 5-10 mm, confirmingWBM-III standards was used, whereas the Re-cycle aggregate was collected from college demolished waste disposal area, MREC CAMPUS. The properties of aggregates are shown in Table 3

Cement, Lime, And Gypsum: The cement used in the present study islocally available with the following chemical composition. Locally available Quicklime and gypsum are purchased from Agrochemicals from Hyderabad.

Geo-textile: Polyester woven multifilament geo-textile, manufactured by **charm nonwovens**, lakdikapol Hyderabad India, was used in this investigation. The inherent characteristics of polyester – high tensile strength and modulus, low elongation, low creep and high long-term design strength - makes these products ideal for soil reinforcement applications. The fabric develops excellent frictional interaction with a wide variety of soils and granular materials.

Marble dust: marble dust of granite was collected from Hyderabad.The properties of marble dust is presented in Table .

TABLE I:PROPERTIES OF SOIL

S.No	***Properties***	***Value***
1	Specific gravity	2.69
2	Grain-size Analysis (%)	
	Gravel Sand Silt Clay	0% 39% 31% 30%
3	Liquid Limit(%)	52
4	Plastic Limit(%)	26
5	Plasticity Index(%)	26
5	IS Soil Classification	CH
6	Free Swell Index(%)	150
7	Compaction properties Optimum moisture content (%) Maximum dry density (g/cm^3)	18% 1.76
8	Consolidation Cc (cm^2/kg) Cv (m^2/yr)	0.28 1.069
9	Permeability K (cm^2/sec)	6.8 x10^{-8}

TABLE II:PROPERTIES OF SAND AND CLAYEY SAND

SNo.	***Properties***	***Value***
1	Specific gravity	2.67
2	Gravel % Sand % Silt % Clay %	24 45 8 23
3	Liquid Limit(%)	42
4	Plastic Limit(%)	24
5	Plasticity Index(%)	18
6	Soil classification	SC
7	Maximum dry density(g/cc)	1.72
8	Free Swell Index(%)	30

TABLE III: PROPERTIES OF AGGREGATE

Properties	***Natural aggregate***	***Recycled Aggregate***
Bulk Density	1.49	1.27
Specific gravity	2.78	2.55
Fineness modulus	7.06	7.15
Water absorption	1.20	5.70
Flakiness index	22	16
Elongation index	18	22
Aggregate impact value	18.20	20.45
Aggregate Crushing value	18.01	25.47

TABLE IV: PROPERTIES OF MARBLE DUST

S.No	***Properties***	***Value***
1	Specific gravity	2.63
2	Grain-size Analysis (%) Gravel Sand Silt Clay	 0% 0% 78% 22%
3	Plasticity %	NP

Methodology

Experimental Procedure

The experimental study involves pilot tests in C.B.R mould. A series of plate load tests on unreinforced and reinforced soft clay with granular pile with different materials over-lain by sand cushion was done to compare results

Pilot Load Tests

The pilot tests on the load carrying capacity of soft soils were conducted in C.B.R mould. The mould was a rigid metal cylinder with inside diameter 15cm and a height of 23cm along with collar. An electrically operated machine equipped with a movable base that traveled at a strain rate of 1.25mm/min and a calibrated load indicating device(proving ring) was used to force the penetration of plate into the soft soil. The loads were carefully recorded as a function of settlement up to a value of 20mm to observe the post-failure behavior as well.

Preparation of Clay Bed

The clay was pulverized, mixed with the predetermined amount of water of about 45% and for moisture equilibrium, it was kept for a week in a large test tank for a degree of saturation as 100%. The test bed was prepared in lifts of 0.05M thickness. For each layer, the amount of soil required to produce the desired bulk density of 19KN/m^2 was weighted, mixed with water in a bucket and placed in a large tank, leveled and compacted. Compaction was done with a wooden board to maintain the desired consistency similar to field condition. The average shear strength in the test beds was found 6kpa.

Details of Experiments

The details of experiments that were planned to understand the load carrying were given in Table6. All the experiments were divided into 5 series based on curing period due to an addition of cementing agents in granular piles installed in soft clays.The percentage of addition of cementing agents was fixed based on the literature. KoteswaraRao(2012) concluded that 4% lime with 15% sawdust was found to be an optimum dosage in a stabilization of soil. Kenneth Andromalos(2001) showed 12% cement was found optimum for soil mixing technique for stabilization for the typical type of soft soil. Rajasekaranand NarasimhaRao (1997) showed that to prevent a formation of ettringite, an expansive mineral calcium sulfate is required for stabilizing soft marine clays. So keeping this mind 4% of cementing agents were fixed to add individually and in combined form to study its effect. This was done to study the influence of particular parameter on the overall behavior of the bearing capacity. Test series 1 is performed with out curing periods. Test series 2 and 4 has curing periods of 8 days and where as test series 3 and 5 have 28 days.In these test, series efforts were made to know the influence of combined effect of cementing agents which were compared with individual cases.

Load Tests on Untreated and Treated Soft Soil

Soil bed was formed in a C.B.R mould in layers and each layer is tamped to maintain desired bulk density. A 2cm sand layer is placed over clay bed to have uniform load distribution, over which a 7cm diameter plate is kept. The load is applied with plunger assembly over this plate. All tests were strain controlled at 1.25mm/min. It is one of the field conditions expected as in this case the angle of internal friction tends to zero leading to the large reduction in bearing capacity. The load was applied until settlement reached 2cm.

Installation of Granular Pile

The granular piles with different pile materials were installed by a displacement method. An open Stainless steel pipe of 5cm diameter, smeared with petroleum jelly (to reduce friction), with a closed bottom (to arrest soil entering the pipe from bottom) was inserted into the soft clay up to a depth equal to a length of the granular pile. Stones aggregates were charged in and compacted with a hammer to maintain uniformity diameter of a granular pile. Now the pipe was slowly raised, simultaneously aggregate is charged ensuring outside clay not intruding in. This was continued till granular pile is formed. This set-up was kept for one day with seating pressure. The following day plate load test was conducted.

Geo-Synthetic Encased Granular Pile

The procedure used for this granular pile is similar to the previous one. The entire soil bed was formed in the C.B.R mould in layers as per the required water content. A diameter of 5cm is maintained properly by stitching woven geotextile using high tensile thread along the shaft and also at the bottom. The stainless steel pipe is covered with geotextile and the assembly was inserted into the soft ground. Stones aggregates were charged in and compacted in heights. Now the pipe was slowly raised, simultaneously aggregate is charged ensuring uniformity of the column diameter. This was continued till geosynthetic encased granular pile is formed. This set-up was kept for one day with seating pressure. The following day plate load test was conducted.

Figures

A]Test Setup using C.B.R Mould.

B] clay bed prepared and stored in a tank




C] Geosynthetic encased granularpile D] prepared soil specimen E] granular pile installed insoftclay

TABLE V: LIST OF TEST CONDUCTED

S. No	***Types of tests conducted***
Test series 1 (without curing)	1.Test on normally consolidated unreinforced soft soil 2.Test on soft soil + natural aggregate granular pile 3.Test on soft soil + recycled aggregate granular pile 4.Test on soft soil + geosynthetic encased granular pile 5.Test on soft soil + Rammed Earth material as pile
Test series 2 (8 days curing)	1.Test on soft soil + 4% cement in recycled aggregate granular pile 2. Test on soft soil + 4% lime in recycled aggregate granular pile
Test series 3 (8 days curing)	1.Test on soft soil + (4% cement+4% lime+4%gypsum) +50% marble dust + 38% soft soil. 2.Test on soft soil + (4% cement+4% lime+4%gypsum) + 25% re-cycle aggregates + 25% marbler dust + 38% soft soilmixed. 3.Test on soft soil + (4% cement+4% lime+4%gypsum) + 50% re-cycle aggregates + 38% soft soil mixed.
Test series 4 (28 days curing)	1.Test on soft soil + 4% cement in a recycled aggregate granular pile. 2.Test on soft soil + 4% lime in a recycled aggregate granular pile.
Test series 5 (8 days curing)	1.Test on soft soil + (4% cement+4% lime+4%gypsum) +50% marbledust + 38% soft soil mixed. 2.Test on soft soil + (4% cement+4% lime+4%gypsum) + 25% re-cycle aggregates + 25% marble floor dust + 38% soft soil mixed. 3.Test on soft soil + (4% cement+4% lime+4%gypsum) + 50% re-cycle aggregates + 38% soft soil mixed.

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Results

TABLE VI: Test Results For Cycle-1

Materials	*Soft soil*	*Soft soil provided with granular pile*	*Soft soil provided with a granular pile made of re-cycled Aggregates*	*Geosyntheticencased granular pile*	*Rammed earth material as granular pile*
Bearing Pressure intensity (kpa)	10.4	97.5	89.23	175.5	40.3

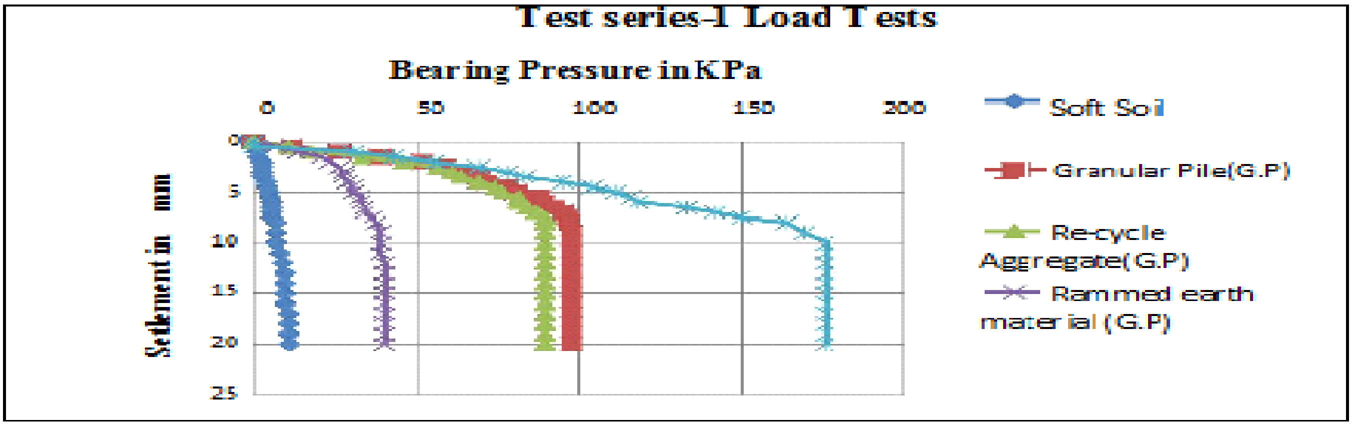


TABLE VII : Test Results For Cycle 2 And 4 (Pressure Intensities In Kpa)

Materials	*4% lime + 50% re-cycle aggregate mixed with soil*	*4% cement + 50% re-cycle aggregate mixed with soil*
8 days	104.59	119.89
28 days	114.8	140.3

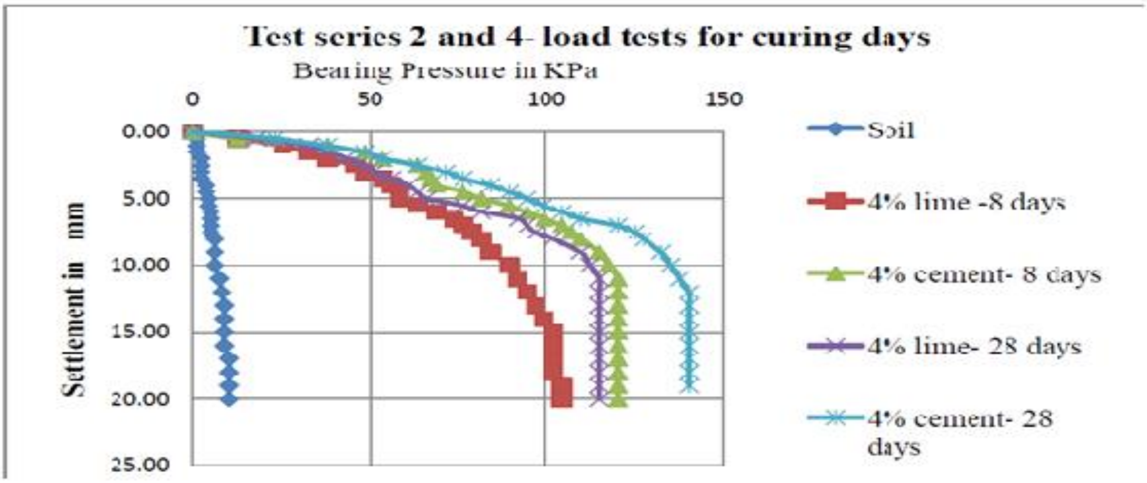
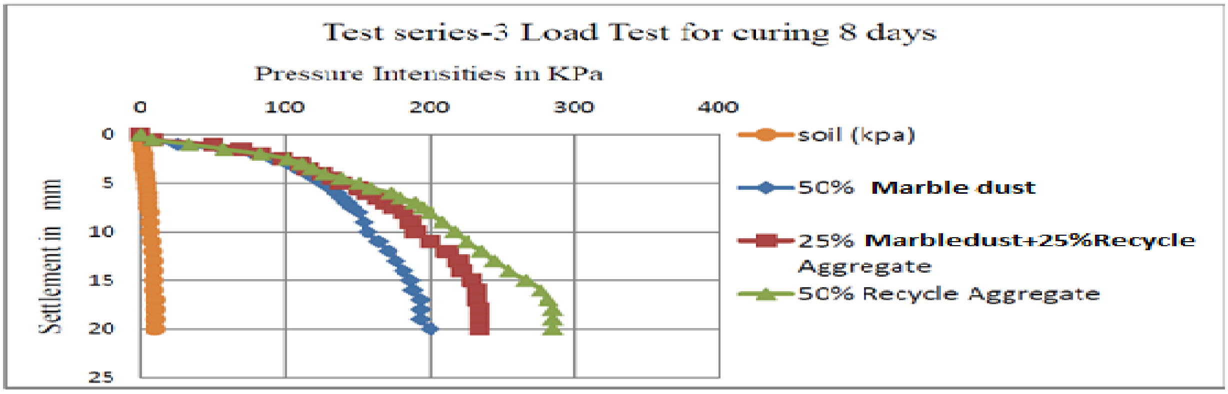


TABLE VIII : shows Pressure Intensities In (Kpa)Of Granular Piles With Combined Effect Of Cementing Agents With Curing Periods.

Materials	*12% cementing agents + 50% rock dust as a granular pile mixed with soil*	*12% cementing agents + 25% rock dust + 25% re-cycle aggregate as granular pile mixed with soil*	*12% cementing agents + 50% re-cycle aggregate granular pile mixed with soil*
8 days curing	148.2	178.4	218.4
28 days curing	286	315.9	409.5



Conclusions

Based on the results, the following are drawn:

1. The load carrying capacity of soil increased by 10 times when it is provided with granular pile whereas it is increased by 16 times when it is provided with geosynthetic encased granular pile.
2. The load carrying capacity of the granular pile formed with re-cycled aggregate is almost equal to that of the pile formed with natural aggregate. The variation in the value between both of them is only 8%.
3. The addition of cementing agents increased the load carrying capacity considerably. With the addition of 4% cement (or), lime independently increased the value by 15 times that of a normal granular pile.
4. When the cementing agents like cement and lime along with gypsum are mixed to a soil, the increase in the capacity is as high as 40 times when compared to that of a normal granular pile.

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