

Experimental Study on Load Settlement Behaviour of Granular Pile in Black Cotton Soil

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ABSTRACT: Due to strength and volume stability issues, construction on black cotton soil is either avoided or the soil is removed and replaced with good soil or is improved by adopting soil improvement techniques. The technique of granular pile, usually employed in improving soft marine clays (i.e. soft soils), can also be applied to improve the behaviour of black cotton soil. This thesis represents the results of model study conducted on granular piles constructed in black cotton soil. The granular pile of diameter 30mm and 50mm are constructed at the centre of soil bed using pile material. The effect of different diameter on granular pile is studied with a different granular material i.e. stone chips, sand and silty soil. The load test was conducted on granular pile. The length to diameter ratio (L/D ratio) of the pile was varied as 4, 6, 8 and 10 to study the effect of pile length on load carrying capacity. The load was also performed on pile in saturated soil condition i.e. (soil is saturated for four days).

KEYWORDS: Granular Pile, crushed stone chips, sand, silty soil, load carrying capacity, critical length

I. INTRODUCTION

Sufficient infrastructure of buildings, roads, tunnels, bridges and other civil engineering works is the prime requirement for development of any country. Therefore, the construction is carried out in the sites having very weak or bad ground conditions like soft clays, which cover a vast area. Black cotton soils occur in all the continents. In India about 20% of the total area is covered by Black cotton soil. Since it is in black colour and good for growing cotton, it is commonly referred as Black cotton soil. The soil becomes very soft under wet/saturated condition and hard during summer season. It loses strength and gives rise to many problems to the structure resting on such soils. The problem of damage to structure in black cotton soil is worldwide. The damage to structures is mainly by differential heaving of the dried-up soils. Climatic environment is the most important for the swelling and shrinkage behaviour of these soils. Hence this soil is avoided by replacing it with good soil and adopting soil improvement technique. The behaviour of Black cotton soil can be improved by adopting the concept of granular pile. This technique has been used in many regions to reduce the settlement of superstructure by increasing the load carrying capacity of poor soils. Granular pile behaves like a composite material and is stiffer and stronger than original soil. Different aspects of soft soil improvement using granular piles have been reported in the literature. Rakesh kumar and kumar Jain et al., (2012) found that a circular footing on a granular pile in soft expansive clay of unconfined compressive strength of 50kpa takes 2.5 times more load than the footing is placed on the clay alone. Performed test on granular piles when the surrounding expansive soil was wet and soft by assuming the worst condition Kameshwar Rao Tallapragada, et al., (2011) worked on modification of proposed existing stone column and behaviour has been studied with respect to vertical reinforcement to improve the load carrying capacity of soft clays. The modification was made by a mixture of stone dust/sand and lime to the conventional stone column in addition to the encasement. Surendra Dehariya and P.K. Jain et al., (2012) carried out test on a granular pile made in black cotton soil, the load settlement characteristics of the soil were determined for the different diameter of the granular pile. Granular piles with Geo-grid encasement were also installed in the soil. It has been observed that significant improvement in load carrying capacity is obtained more for encased granular pile compared to granular pile without encasement. Murugesan S, Rajagopal et al., (2012) investigated the both qualitative

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and quantitative improvement of load capacity of individual encased granular pile through laboratory model tests. The load tests indicated that the improvement in the load carrying capacity of the granular pile is due to encasement. Encasement with geosynthetics having higher modulus resulted in stiffer response. The improvement in the performance of stone column was found to be significant, even with partial encasement. Uttam Kumar (2013): The given paper states that the effect of different diameter and types of geosynthetics which is used as encasement for granular pile. The results showed that the larger diameter column has more efficiency than the smaller column and the lateral bulging is minimized by the encased Geosynthetic granular pile. Priebe (1995) estimated the settlement of foundation resting on the infinite grid of stone columns based on unit cell concept. In this concept, the soil around a granular pile for area represented by a single pile depending on pile spacing is considered for the analysis. As all the piles are simultaneously loaded, it is assumed that a lateral deformation in soil at the boundary of unit cell is zero.

II. SCOPE OF RESEARCH

The purpose of this research is to investigate the performance of granular pile with different granular material, which is a new concept and to study the strength characteristics of black cotton soil when used as a foundation material. In this project work, tests have been conducted on two types of pile diameters 30mm and 50mm. By varying parameters like different granular materials, saturated condition and embedment to diameter ratio, the load settlement behavior of black cotton soil is evaluated

III. MATERIALS

A. BLACK COTTON SOIL

Black cotton soil used in the present work was collected from Hiriyuru taluk, Chitradurga district. The sample was collected at a depth of 1.0m eliminating the top soil. The soil is oven dried and used after sieving through IS 4.75mm sieve. The following tests have been conducted to determine the various properties of Black cotton soil as per IS2720 and tabulated below

Table 1. Geotechnical properties of Black cotton soil

SL No.	Properties	Results
1	Natural moisture content (%)	16.1
2	Field density (kN/m^3)	13.49
3	Specific gravity	2.71
4	Liquid limit (%)	55
5	Plastic limit (%)	28
6	Plasticity index (%)	27
7	Clay and Silt (%)	72
8	Maximum dry density (kN/m^3)	15.99
9	Optimum moisture content (%)	20
10	Unconfined compressive strength (kN/m^2)	58.86
11	Cohesion (kN/m^2)	0.3
12	Angle of internal friction	15°

The soil classified according to Plasticity chart, the soil belongs to 'CH' group i.e. inorganic clay with high compressibility.

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B. Sand as Granular material



Fig 1. Sand

The locally available sand is used in this experimental investigation and it is sieved through 2.36 mm sieve and is used for the present work. The various properties of sand are summarized in the Table

Table 2 Properties of Sand

SL No	Properties	Results
1	Specific gravity	2.57
2	Coefficient of uniformity	3.9
3	Coefficient of curvature	1.6
4	Cohesion (kN/m^3)	0.03
5	Angle of internal friction	33

C. Stone chips as granular material



Fig 2. Stone Chips

The locally available sand is used in this experimental investigation and of size 5mm is used for present work. The specific gravity of stone chips is found to be 2.52

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D. Silty Soil chips as Granular material



Fig 3. Silty Soil

The silty soil sieved through 4.75mm sieve is used for the present work. The various properties of silty soil are summarized in the Table

Table 3 Properties of Silty Soil

SL No	Properties	Results
1	Specific gravity	2.55
2	Liquid limit (%)	43
3	Plastic limit (%)	28.07
4	Plasticity index (%)	14.93
5	Cohesion Kg/cm ³	0.25
6	Angle of internal friction	27°
7	Safe bearing capacity (kN/m ³)	190

IV. METHODOLOGY

The experiments were carried out on a 30mm and 50 mm diameter granular pile surrounded by black cotton soil in cylindrical mould of 300 mm diameter and 300 mm height. The soil bed was prepared at a dry density of 15.99kN/m³ and 20% water content. Care was taken to ensure that no significant air voids were left out in the soil bed. The granular pile was constructed at the centre of the soil bed by making hole with thin open ended mild steel pipes of 30mm and 50mm diameters and wall thickness 2mm were used in the present case. The casing pipe was pushed into soil up to the bottom of the tank for making granular pile. Granular material (i.e. Sand, Silty soil, mixture of Stone Chips and Sand) is charged into the hole in layers in measured quantities and compacted to achieve required density. Test on model piles were conducted in a steel tank which was large enough to take care of the pile due to loading (to be in range of 2.5D, where D is the diameter of pile, as per IS 2911 part 4). The project work emphasis the study of the effect of different pile diameter, different granular material, embedment length to diameter ratio and saturation

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conditions on the bearing capacity of piles in Black cotton soil. The length of embedment (L) of 30mm diameter (D) pile in Black Cotton soil was 300mm and 240mm resulting in L/D ratio as 10 and 8 respectively. The embedment length of 50mm diameter pile was 600mm and 200mm resulting in L/D ratio as 6 and 4 respectively. The ultimate loads have been estimated from load-settlement diagrams. Test on model piles were conducted in the laboratory to understand their bearing capacity behavior, the ultimate load was taken corresponding to a settlement equal to 10% diameter of the footing. Four Series of laboratory model tests were performed. First series of test were performed on the clay bed without any granular pile in both saturated and unsaturated condition. Second series of test were performed on 30mm granular pile with different granular materials and varying L/d ratio. Third series of test were performed on 50mm granular pile with different granular materials and varying L/D ratio. Fourth series of test were performed on 50mm pile in saturated conditions for different granular materials. The test has been continued till the settlements up to 25mm and is recorded. For achieving the saturated soil condition the mould was submerged in water for four days prior to conduction of the load test.

V. RESULTS AND DISCUSSION

The load-settlement graphs were plotted for all the granular piles. It can be observed from the experiment, the load-settlement response is linearly increasing and load carrying capacity is significantly affected by the state of the soil. From the load-settlement response, ultimate load is taken corresponding to settlement equal to 10% of diameter of footing. Various load-settlement responses for different conditions of the pile are discussed.

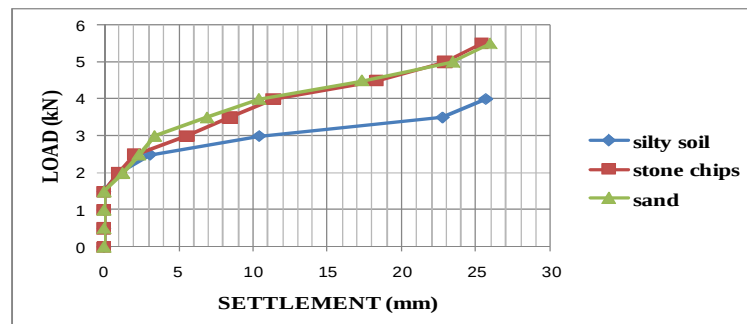


Fig 4. Comparison between Granular materials, 30mm pile, L/D=10

It can be observed from above fig, that in the case of 30mm diameter pile with L/D=10, the ultimate load of silty soil is 2.85kN. For stone chips the ultimate load is 3.05kN. For sand, the ultimate load is 3.4kN. It can be observed that Sand act as an effective granular material compared to other granular materials (i.e. silty soil and stone chips).

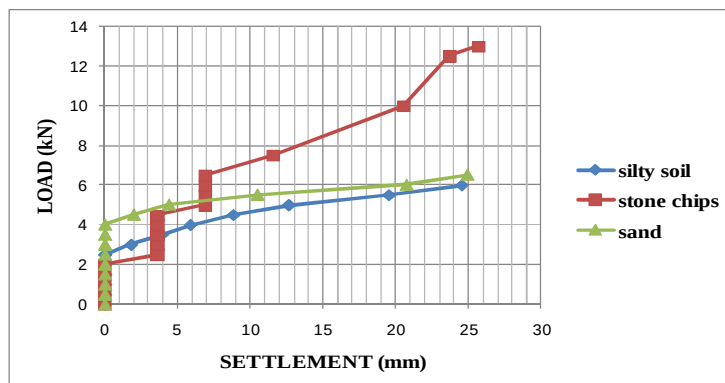


Fig 5. Comparison between Granular materials, 30mm pile, L/D=8

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It can be observed that from above fig that in the case of 30mm diameter pile with $L/D=8$, the ultimate load of silty soil is 2.79kN. For stone chips the ultimate load is 2.95kN. For sand, the ultimate load is 3.2kN. It can be observed that Sand act as an effective granular material compared to other granular materials (i.e. Silty Soil and Stone Chips).

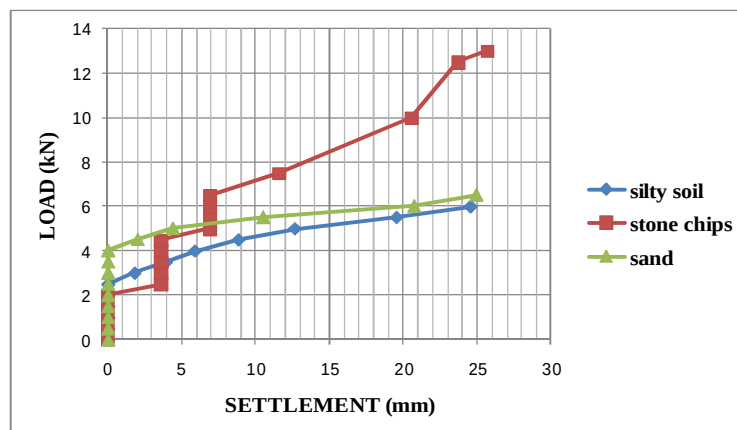


Fig 6. Comparison between Granular materials, 50mm pile, $L/D=6$

It can be observed that from above fig that in the case of 50mm diameter pile with $L/D=6$, the ultimate load of silty soil is 4.05kN. For stone chips the ultimate load is 4.6kN. For sand, the ultimate load is 5.3kN. It can be observed that Sand act as an effective granular material compared to other granular materials (i.e. silty soil and stone chips).

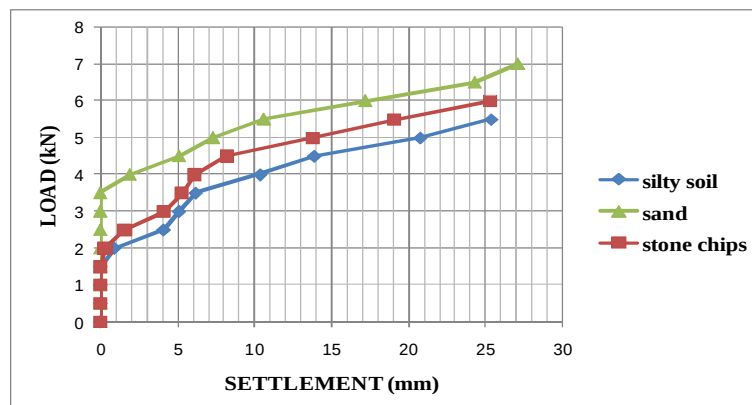


Fig 7. Comparison between Granular materials, 50mm pile, $L/D=4$

It can be observed that from above fig that in the case of 50mm diameter pile with $L/D=4$, the ultimate load of silty soil is 3.3kN. For stone chips the ultimate load is 3.86kN. For sand, the ultimate load is 4.8kN. It can be observed that Sand act as an effective granular material compared to other granular materials (i.e. silty soil and stone chips).

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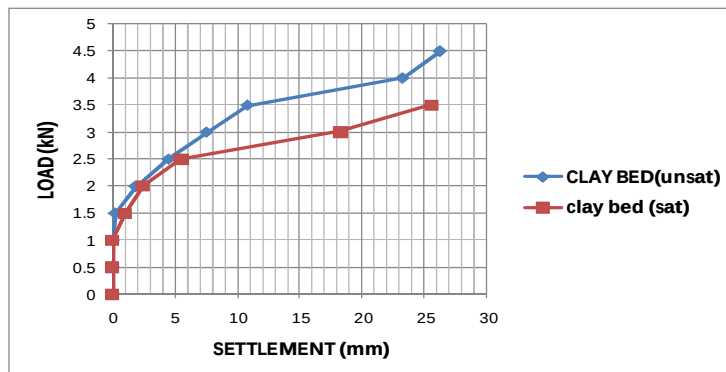


Fig 8. Comparison between Clay bed in Saturated and Unsaturated condition

It can be observed that from above fig, that in the case of clay bed without pile in unsaturated condition, the ultimate load is 2.75kN and in saturated condition, the ultimate load is 2.55kN

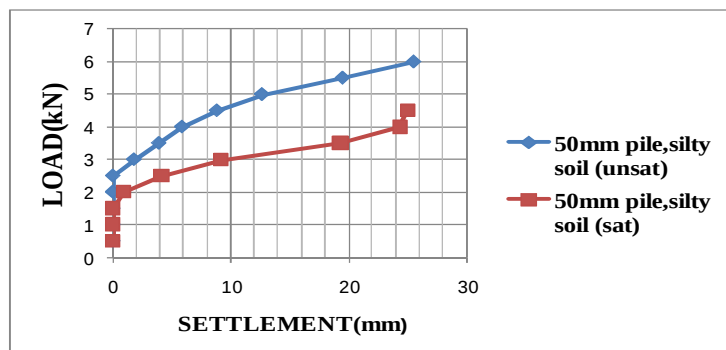


Fig 9. Comparison between Granular Pile in Saturated and Unsaturated condition Silty Soil, 50mm pile

fig 9 shows that in the case of 50mm pile diameter with silty soil as a granular material in unsaturated condition, the ultimate load is 4.05kN and in saturated condition, the ultimate load is 2.62kN

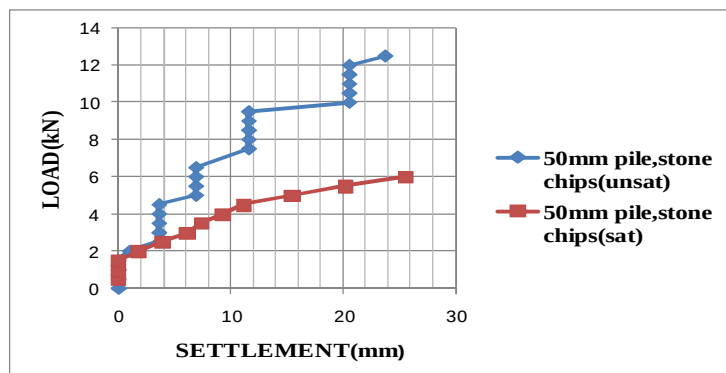


Fig 10. Comparison between Granular pile in Saturated and Unsaturated condition, Stone Chips, 50mm pile

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In the case fig 10 it shows that the stone chips as a granular material in unsaturated condition, the ultimate load is 4.6kN and in saturated condition, the ultimate load is 2.93kN

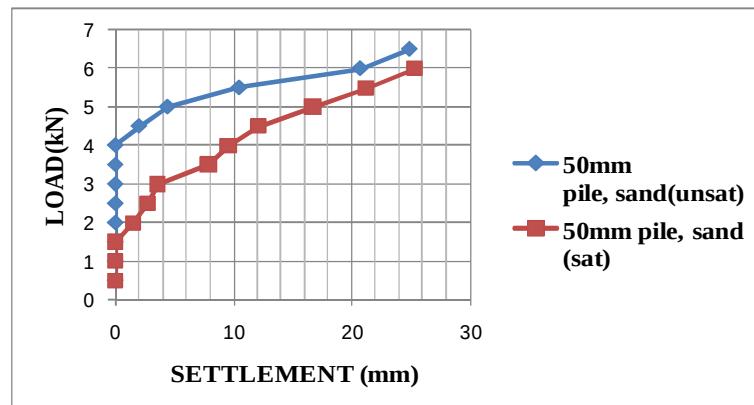


Fig 11. Comparisons between Granular Pile in Saturated and Unsaturated condition, Sand, 50mm pile

Similarly in the fig11 it shows that sand as a granular material in unsaturated condition, the ultimate load is 5.3kN and in saturated condition, the ultimate load is 3.1kN.

VI. CONCLUSION

The use of granular pile technique of soil reinforcement is frequently used in soft and weak soils and has been successfully used to support the isolated footings and embankments. Their use in soft clays has been found to increase in load carrying capacity and significant reduction in settlement. Based on above results following conclusions were drawn

- The results of test conducted on model granular piles showed that the granular pile increases the load carrying capacity and decreases the settlement of black cotton soil.
- The load carrying capacity also varied with pile diameter. Piles with larger diameter were found to be more resistant to compression load since the self-weight of larger diameters were also longer.
- The load-settlement responses and load carrying capacity under axial load depends on embedment length to diameter ratio (L/D). Larger the L/D ratio, higher is the ultimate load carrying capacity.
- The ultimate load carrying capacity is also found to depend on type of granular material. Sand as a granular material is found to have higher resistance against compression load compared to other granular materials (i.e. stone chips and silty soil) used in the investigation.
- The results clearly shown that the granular piles lose strength on saturation. The submergence of test bed reduces strength of both Black cotton soil and pile material. In saturation condition, it also has been found that the sand, as a pile material has higher resistance against compression load compared to other pile materials

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