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Ground Improvement Using Granular Pile Anchor Foundation

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Abstract

The use of granular pile is one of the effective and efficient methods of ground improvement because of its ability in improving the bearing capacity and reducing the settlement of different soft soils. Conventional granular piles cannot be used as tension members to offer resistance under pull out loads. Granular Pile Anchor (GPA) is one of the recent ground improvement technique in devised for resisting pull out forces. In a granular pile anchor, the footing is anchored to a mild steel plate placed at the bottom of the granular pile through a reinforcing rod or a cable.

The main objective of the present study is to investigate the effect of relative density of fill material, granular pile diameter on the pull capacity of the granular pile anchor and the comparison of encased and non-encased granular pile has been done. The laboratory model tests using GPAF system revealed that the pull-out capacity of the granular pile anchor increased with increasing relative density of the granular material. There was a maximum percentage increase of 35% in the ultimate load when the relative density was increased from 50 to 70% for 50mm diameter pile. It was also revealed that the pull-out capacity of the granular pile anchor increased with increasing diameter of the granular pile anchor. The increase of 35% was also obtained when the diameter was increased from 30mm to 50mm at a relative density of 70%. For the encased pile, maximum increase in the percentage ultimate pullout load was obtained for pile diameter of 30mm and it was about of 13.2%.

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1. Introduction

Stone columns/granular piles are effective and efficient over various other methods of ground improvement because of their ability to improve the performance of different soils varying from soft, loose sand deposits to waste fill sites. Granular piles in conventional form cannot be used as tension members to offer resistance to pullout or uplift forces generated under tall structures like transmission towers, overhead tanks or other similar structures and also for the footings resting on expansive soil. The inherent nature of the granular pile is modified by placing a metallic plate at the bottom of the granular pile and connecting the same to the footing with a cable or a rod.

The pullout or tensile forces generated are transmitted to the base of the granular pile with the modification at the base of the granular pile. The uplift resistance depends on (i) the weight of the granular pile and (ii) the shearing resistance along the soil-granular pile interface. The force in the pile anchor is transmitted to pile-soil interface by virtue of a base plate that is rigidly connected to the anchor. The uplift capacity of pile anchor determines the behaviour of foundation connected to it.

2. Experimental study

2.1 Materials used

Soil used for the study was black cotton soil collected from Coimbatore, Tamil Nadu at a depth of 1m from the ground level and it was blackish in colour. The soil was initially air dried in open atmosphere prior to the testing. The soil passing through 4.75mm sieve was used for the entire study. The properties were determined and are listed in Table 1.

Table 1.Properties of soil

Properties	Values
Specific gravity	2.5
Liquid limit(%)	62
Plastic limit(%)	31
Plasticity index(%)	31
Shrinkage limit(%)	14
Clay(%)	11
Silt(%)	54
Sand(%)	35
Maximum dry density(kN/m^3	17
Optimum moisture content(%)	18
Free swell index	30

The granular materials that were used for the installation of the granular piles was sand and copper slag. Fill material which passes through 4.75 mm and retained on 2mm sieve was used as the column fill material. The properties of sand and copper slag were given in table 2 and 3 respectivelySection headings

Table 2. Properties of sand

Properties	Values
Specific gravity	2.7

Maximum density, $\Upsilon_{d\ max}$ (kN/m^3)	18.1
Minimum density, $\Upsilon_{d\ min}$ (kN/m^3)	14.5
IS classification	Poorly graded

Table 3. Properties of copperslag

Properties	Values
Specific gravity	2.7
Maximum density, $\Upsilon_{d\ max}$ (kN/m^3)	26.4
Minimum density, $\Upsilon_{d\ min}$ (kN/m^3)	20.4
IS classification	Poorly graded

2.2Test description

Experiments on pullout response of granular pile anchors (GPA) are conducted in a tank of dimensions 500x500x700mm. The test tank was made of Galvanised Iron sheets. The experimental setup is shown in Fig. 3. The initial dry unit weight of soil was 14kN/m^3 in all the tests. The height of the soil bed was 300mm and the height of granular pile anchor was the same (300mm) in all the tests. A casing pipe of diameter equal to that of the granular pile was placed at the center of the tank. The weight of the soil required was divided into a convenient number of equal parts, each part having to be filled to the predetermined height, so that we can ensure the unit weight.. Each part of the soil was carefully placed in the tank such that it did not enter the casing pipe. The soil bed was filled in layers of 100mm thickness.

The assembly of mild steel plate and anchor rod was placed vertically in the casing pipe. The amount of the granular pile material required for the particular relative density was taken and divided into three convenient numbers of equal parts. Each part was compacted to the required height that ensured uniform relative density. During the process of compaction, the casing pipe used was withdrawn gradually. Pullout loads were applied through pulley system fastened to the tank. Pullout force was transferred to the base of the granular pile using a wire rope. One end of the wire rope is connected to the anchor plate while the other end is connected to a hook of a load hanger. The loads were applied in increments of 10% of the ultimate value, and the corresponding upward movement was recorded. The tests were continued until failure. The ultimate pullout capacity of the granular pile anchor is the load at which the GPA is pulled out of soil.

The diameter of the anchor plate was varied as 30mm and 50 mm. Relative densities (Dr) of granular fill material was varied as 50, 60, and 70% for 30mm and 50mm granular pile anchor. Also, the comparison of pullout behaviour using different fill materials is presented here.

3. Results and discussions

3.1 Effect of Change in Relative Density of Fill Material

Pullout tests were conducted to study the effect of change in relative density of fill material on the pullout capacity. The relative density of sand was varied as 50%, 60%, and 70%. The pullout test is conducted for 30mm and 50mm diameter anchor pile at a water content of 40% for surrounding clay bed. Fig. 4 shows the load-displacement response of 30mm anchor pile at a water content of 40% with relative densities of 50%, 60% and 70%. Fig. 5 shows the load- displacement response of 50mm anchor pile at a water content of 40% with relative densities of 50%, 60% and 70%.

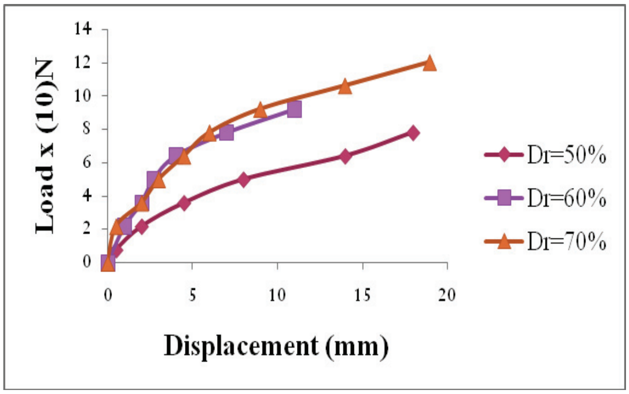

Fig. 3. Load- displacement graph of 30mm anchor pile at w=40%

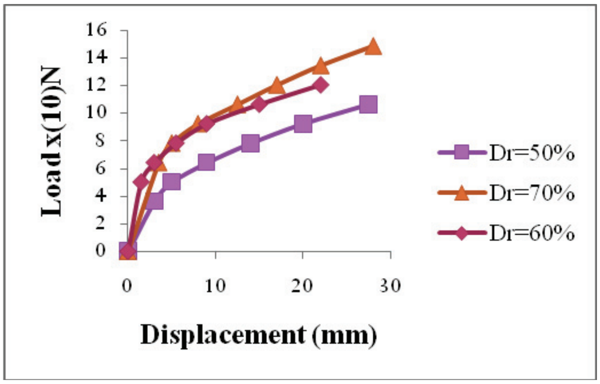

Fig. 4. Load- displacement graph of 50mm anchor pile at w=40%

Fig. 4 and Fig. 5 show that the ultimate pullout load increases with increase in the relative density of the fill material. For 30mm anchor pile the ultimate load increases from 92.6N to 106.7N and 120.8N. It shows a percentage increase of 15% and 29% when the relative density was increased from 50 to 60% and 70% respectively. For 50mm anchor pile the ultimate load increases from 120.8N to 134.9N and 163.1N. It shows a percentage increase of 11.6% and 35% when the relative density increases from 50 to 60% and 70% respectively. With increase in the relative density the fill material will become denser and hence the weight of the granular pile will increase resulting in more pullout capacity. The pullout failure is sharp, i.e., once the limit load is attained the GPA gets pulled out of the soil as is the case for piles in tension. The displacement increased sharply during the last load increment i.e., ultimate load in all the pullout tests.

3.2 Effect of Change in Diameter of Pile

The pullout test was conducted to study the effect of change in the diameter of anchor pile on the pullout behaviour. The pullout behaviour was studied by keeping the water content of clay bed and relative density fill material as constant parameters and the diameter of anchor pile was varied as 30mm and 50mm. Also, the effect of change in diameter of pile was studied for different relative densities. Fig. 6 shows the load-displacement graph of anchor piles at water content 40% and relative density 50% with different diameter 30mm and 50mm. Fig. 7 shows the load-displacement graph of anchor piles at water content 40% and relative density 60% with different diameter 30mm and 50mm. Fig. 8 shows the load-displacement graph of anchor piles at water content 40% and relative density 70% with different diameter 30mm and 50mm.

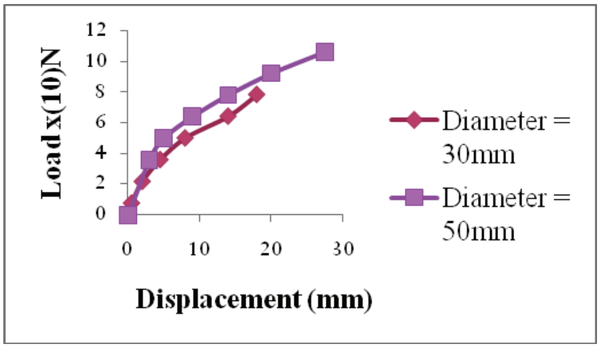

Fig. 5. Load- displacement graph of anchor pile at w=40% and Dr=50% with different diameter

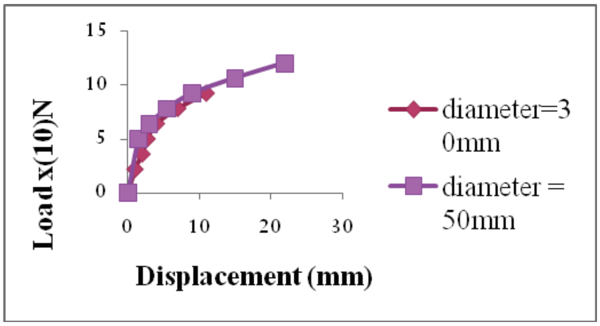

Fig. 6. Load- displacement graph of anchor pile at w=40% and Dr=60% with different diameter

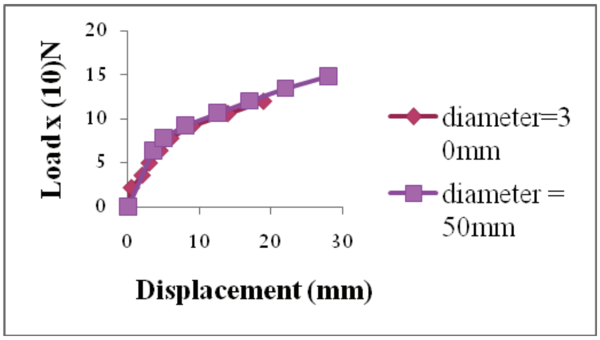

Fig. 7. Load- displacement graph of anchor pile at w=40% and Dr=70% with different diameter

Fig. 6, Fig. 7 and Fig. 8 show that the ultimate pullout load increases with increase in the diameter of the granular pile anchor. For relative density of 50% there is a percentage increase of 30% when the diameter was increased from 30mm to 50mm. For relative density of 60% there is a percentage increase of 26% when the diameter was increased from 30mm to 50mm. For relative density of 70% there is a percentage increase of 35% when the diameter was increased from 30mm to 50mm. As the diameter increases the surface area of the granular pile increases. Hence the weight of the granular pile and area for the interface friction will increase.

3.3 Comparison of encased and non-encased granular pile

The pullout tests were carried out on granular pile encased with non-woven geotextile. The tests were carrried out for 30 mm and 50 mm granular pile. The obtained results were compared with results of non-encased granular pile having diameter 30 mm and 50 mm. The tests were performed at a water content of 40% and relative density 60%.

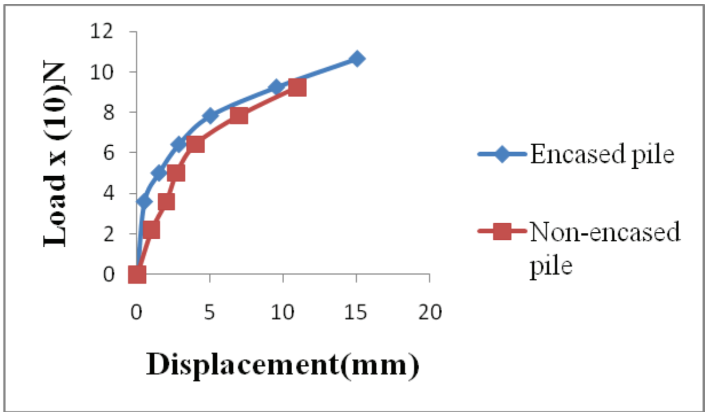

Fig: 8.Load- displacement graph of 30mm granular pile for encased and non-encased pile

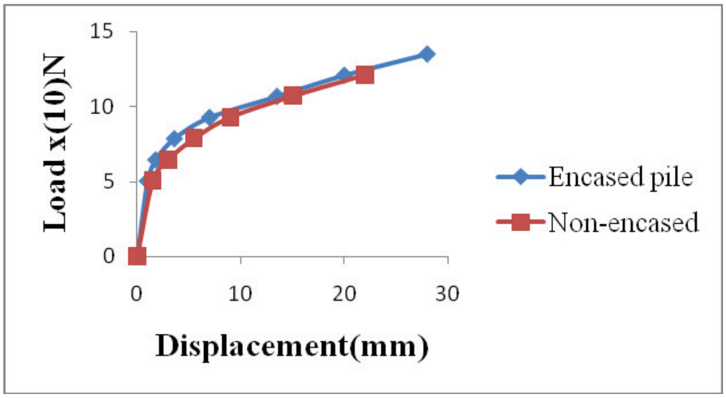

Fig: 9. Load- displacement graph of 50mm granular pile for encased and non-encased pile

The ultimate pullout load for the encased pile is greater when compared to that of the non-encased pile. The ultimate pullout load for the encased pile is 121N and for the non-encased pile is 106.7N. It shows an increase of about 13.4% in the ultimate pullout load value. The ultimate pullout load for the encased pile is greater when compared to that of the non-encased pile. The ultimate pullout load for the encased pile is 149N and for the non-encased pile is 135N. It shows an increase of about 10.4% in the ultimate pullout load value. It is due to the greater interface friction between the non-woven geotextile and sand compared to that of soil and sand.

4. Conclusions

The following conclusions were made from this study:

- For a pile diameter of 30 mm the percentage increase in ultimate pullout load was 15% and 29% when the relative density was increased from 50 to 60% and 70% respectively.
- For a pile diameter of 50 mm the percentage increase in ultimate pullout load was 11.6% and 35% when the relative density was increased from 50 to 60% and 70% respectively
- At a relative density of 70% the percentage increase in ultimate pullout load was 35% when the diameter was increased from 30 to 50mm
- The ultimate pullout load for the encased pile is greater when compared to that of the non-encased pile
- It indicated a percentage increase of 13.2% when encased granular pile anchor was used

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