Performance Evaluation of Granular Pile Anchors In Clayey Soil

Hanna T N[1], Manoj C M[2]

[1]PG Student, Geomechanics and Structures, Department of Civil Engineering, Saintgits College of Engineering, Kottayam, Kerala, India
[2]Assistant Professor, Department of Civil Engineering, Saintgits College of Engineering, Kottayam, Kerala, India

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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. Granular Pile Anchor (GPA) is one of the recent ground improvement technique 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. This paper presents a study on the behavior of GPA in clays. The data presents model tests of clay beds reinforced with varying number of GPAs. The laboratory model tests using GPA system revealed that the pull-out capacity 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 percent for 40mm diameter pile. For a given l /d ratio, the failure pullout load increased with increasing number GPA. Initial pile load test showed that group action has more effect than single GPA also, safe load can be determined from initial pile load test.*

Keywords: **Granular Pile Anchor, Granular Materials, Clays, Pull-Out Resistance, Piles, Anchors**

1. INTRODUCTION

Clays are considered highly problematic, because of its inherent tendency to undergo volumetric changes corresponding to the changes in moisture regime (Chen 1988). Because of this, civil engineering structures such as residential building, pavements, canal linings and lightly loaded structures, constructed on these soils, are severely damaged. Various innovative foundation practices adopted in marine soils are replacement of clayey soils by dense soils, physical stabilizations, like sand-clay and gravel-clay mixes, chemical stabilization using cement, lime, calcium chloride and fly ash. Further, some special foundation techniques such as drilled piers, belled piers and under-reamed piles have also been suggested as an alternate foundation practices in clays.

Granular anchors are a relatively new and promising foundation solution, particularly suited for lightly loaded structures (Rao, Phanikumar, and Suresh 2008). In addition to the improvement provided to the surrounding ground, granular anchors can resist both pullout or uplift forces and compression forces. In a granular pile anchor foundation system, the foundation is anchored to a base plate at the bottom of the granular pile through an anchor rod.

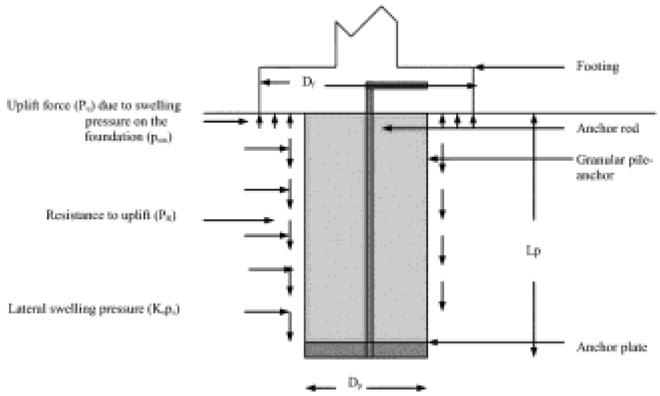

Fig-1 : Schematic Diagram of Granular Pile Anchor

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 behavior of foundation connected to it.

1.1 Scope

The Experimental evaluation of Granular Pile Anchors in clay by preparation of clay bed with single and multiple GPA to check whether pile foundation can be replaced by granular pile anchors and also suggest its suitability in clayey soil through initial pile load test and pull out test.

1.2 Materials Used

The test material involves uniformly graded soil clayey soil. Major portion of the foundation medium involves clay. The pile material consist of mixture of 20% metal chips with particle size ranging from 6 mm to 10 mm and 80% coarse sand with particle size ranging from 2.4 mm to 4.8 mm. It was observed from the pilot studies that, at this proportion, the granular material could be compacted over a wide range of relative density values.

For the present study, the GPAs were compacted at a relative density (*Dr*) of 70%.

Fig-2 : Clay sample and Composition of pile material.

The soil sample was collected from pandarakulam, Alappuzha district. The sample was black colored clay with a glowing texture. The sample was collected from a construction site from a depth of around 1.5m below ground level. An air tight container was taken and the sample was stored in it to determine the initial moisture content. The soil sample was collected and stored near the laboratory premises.

1.3 Experimental Setup

The experimental setup consists of cylindrical tanks of size 600 mm diameter and 450 mm height were used for conducting the experiments. A clay layer of 60 mm thick was laid at the bottom of the test tank and leveled using a rammer.

Fig-3 : Clay bed reinforced with single GPA

A casing pipe of diameter equal to that of the GPAs was held vertically into the bottom layer exactly at the centre of the tank. A steel rod with a circular plate of diameter equal to that of the GPAs fastened to it was inserted into the casing pipe such that the plate is on the top of the sand layer.Similarly, for preparing the clay bed reinforced with single GPA (N = 1), the weight of the granular pile material required for the relative density of 60% was also divided into five equal parts, each part to be compacted to the required height of 60 mm, ensuring uniform relative density. The pipe was carefully withdrawn as the process of compaction progressed.

The process of compacting the clay bed and the GPA was continued till the clay bed and the GPA were compacted until desired height is reached. When the compaction was over, the casing pipe used for installing the GPA was withdrawn completely and the footing was attached to the top end of the anchor rod.

A dial gauge was fixed on the top of the footing. A similar compaction procedure was adopted for soils reinforced with two GPAs (N = 2) also. Figure shows the experimental setup of clay bed reinforced two GPAs (N = 2).

Fig-4 : Clay bed reinforced with two GPA

A dial gauge with its spindle resting on the foundation plate was fixed to the tank with the help of a magnetic base.

2. TEST DESCRIPTION

Tests conducted include basic soil properties, plate load test, pull out load test. Following are the steps involved in the experiment, collecting the soil samples performing different tests to determine the basic soil properties of clay, propose the suitability of GPA foundation, conducting plate load test, conducting pull out test on GPA

Table -1: Index Properties of Soil

SL NO	ENGINEERING PROPERTIES	TEST RESULT
1	Specific gravity	2.59
2	Water content	114%
3	Liquid limit	110%
4	Plasticity Index	59%
5	Shrinkage limit	26%
6	Classification of soil	CH
7	Maximum dry density	1.16g/cc
8	Optimum moisture content	44%
9	Percentage of clay particles	74%
10	Percentage of sit particles	16%
11	Percentage of sand	10%

The following tests were conducted to determine the Engineering properties of the soil sample namely initial moisture content, Specific gravity test, Atterberg's limit, hydrometer analysis and compaction.

2.1. Initial Pile Load Test On Scaled GPA Model

This test was performed to confirm the design load calculations and to provide guidelines for setting up the limits of acceptance for routine tests. It also gives an idea of the suitability of the piling system. Initial Test on piles is to be carried out at one or more locations depending on the number of piles required.

Fig-5 : Experimental setup for initial pile load test

Load applied for the initial load test is 2.5 times the safe carrying capacity of the pile. Loading for Initial Tests was conducted as per Appendix 'A' Clause 6.3 of IS-2911 Part IV.The loads were applied in increments of 10% of ultimate value, corresponding settlement were recorded. Safe load is 2/3rd of the final load at which the total displacement attains a value of 12 mm or 50% of the final load at which the total displacement equals 10% of the pile diameter

2.2 Pullout Load Test:

Experiments on pullout response of granular pile anchors (GPA) are conducted in a tank of 600 mm diameter and 400 mm height. The test tank was made of galvanized Iron . The experimental setup is shown in Fig-6.

Fig-6 : Experimental setup for pull out test.

The height of the soil bed was 300mm and the height of granular pile anchor was the same 200mm) in all the tests. A casing pipe of diameter equal to that of the granular pile was placed at the center of the tank.

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 40 mm. Relative ensities (Dr) of granular fill material was varied as 50, 60, and 70% for 40mm granular pile anchor. The comparison of pullout behavior using different fill materials is presented here.

3. RESULTS AND DISCUSSION

3.1 Effect of Change in Relative Density of GPA 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 40mm diameter. The load displacement response of 40mm anchor pile with relative densities of 50%, 60% and 70% is shown in Chart 1.

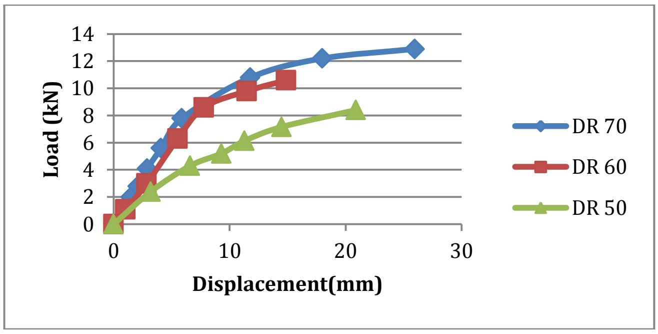

Chart-1 : Load displacement graph of 40mm anchor pile.

There was an increase of 35% in the ultimate load when relative density was increased from 50% to 70% for 40mm diameter pile. For the present study, the GPAs were compacted at a relative density of 70%.

3.2 Group Effect on Pullout Behavior of Granular Pile Anchor

A GPA of length 200 mm and diameter 40 mm was tested under pullout load when single and when under group effect and comparison is shown in figure 4.5, the pullout behavior of the GPA when tested single and when tested under group effect.

The GPA under group effect resulted in increased uplift load for a given upward movement in comparison to that of a single GPA tested.

For a given l /d ratio, the failure pullout load increased with increasing number GPA, failure pullout load for l /d ratio 5 was respectively 13,19 kN. Displacements up to 340mm were required to mobilize ultimate pullout capacity of anchors for negligible ground heave i.e. <2 mm was measured at 0.3m from the centerline for 2GPA.This suggested that these anchors failed in localized bulging near base of gravel columns.

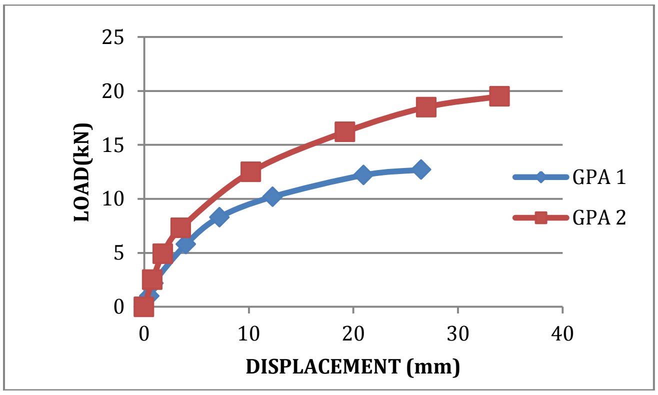

Chart-2 : Group effect on pullout behavior of GPA

The uplift load required to be applied on the GPA to cause an upward movement of 25 mm was 17.5 kN when tested under group effect as against an uplift load of 13 kN for the same amount of upward movement of 25 mm when tested single

3.3 Group Effect on Initial Pile Load Test on GPA

Load bearing capacity increased from 425 N to 542 N when 2 GPA's were installed instead of single GPA. This shows that group action has more effect than single GPA.

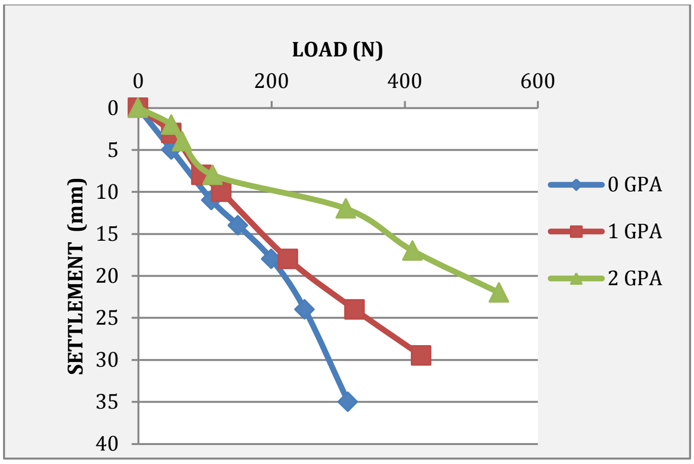

Chart-3 : Granular Pile Effect Of Single GPA &Group GPA

Safe load for single GPA determined as 283N &362N for 2 GPA from the ultimate value obtained.

4. CONCLUSIONS

(1)Pull-out capacity of granular pile anchor increased with increasing relative density of the granular material. There was a maximum increase of 35% in ultimate load capacity when the relative density was increased from 50 to 70% for 40mm diameter pile.

(2)For a given l /d ratio, the failure pullout load increased with increasing number GPA, failure pullout load for l /d ratio 5 was respectively 13kN and 19 kN.

(3)The uplift load required to be applied on the GPA to cause same upward movement of 25 mm was 17.5kN for 2 GPA and that for single GPA is13kN. Displacements upto 340mm were required to mobilize ultimate pullout capacity of anchors for negligible ground heave i.e. <2 mm was measured at 0.3m from the centerline for 2GPA. This suggested that these anchors failed in localized bulging near base of gravel columns.

(4)Load bearing capacity increased from 425 N to 542 N when 2 GPA's were used instead of single GPA. This shows that group action has more effect than single GPA.

(5)Safe load for single GPA was determined as 283N and 362N for 2 GPA from the ultimate value obtained.

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