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Pull-out Response of Granular Anchor Piles Embedded in Cohesive Soil

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Abstract
Granular anchor pile foundation (GAPF) is one of the recent innovative foundation technique conceived for eradicating the problems imposed by clayey soils due to its less resistance against uplift loads. In GAPF system, the foundation is being anchored at the bottom of granular pile with the mild steel tie rod which makes it tension resistant and enables it to offer resistance to the uplift loads which results in improving the overall engineering behavior of the cohesive soils. This paper presents the results of a laboratory-scale test program conducted to study the pullout response of GAPF embedded in clayey soils. Pullout load tests were conducted on GAPF by varying different parameters *viz*. length of pile (250 mm, 350 mm and 450 mm), L/D ratio (7.5, 10 and 12.5), size of the granular material, angle of inclination of load with vertical and encasing of pile with geosynthetic material. The tests on group of granular anchor pile consisting of two piles were also conducted to understand the group action of GAP. This paper presents the effect of all the parameters on pull out loads. The test results indicate that the pull-out capacity decreases with the increase in L/D ratio from 7.5 to 12.5. There was an increase in the pull-out load resistance, when the diameter of the pile and angle of load inclination increases. Moreover, pullout load capacity increases when size of the granular fill increased. Furthermore, the uplift capacity increases with the encasing of geotextile on the periphery of GAPF thus resulting in mobilizing higher shear resistance on the pile-soil interface.

Keywords: Granular Anchor Pile Foundation (GAPF), Pullout Load, Encased Pile, Clayey Soil

1. Introduction

One of the most important aspects of a civil engineering project is its foundation system. Designing the foundation system properly lead to a safe, efficient and economic project overall. Geotechnical engineers face several challenges when designing structures over weak subsoil conditions *viz*. soft/loose /expansive soils etc. The structures are subjected to compressive vertical load, uplift loads (tension forces), lateral loads or a combination of all these to make resultant load oblique. Granular piles (GP) were developed initially to resist compressive loads through predominantly pile action. Granular piles, also known as stone columns, have been extensively used in soft clays and loose sands to rectify their geotechnical properties [1, 2]. However, the capacity of single or small groups of GPs was restricted due to bulging near the upper end of pile. Granular pile is also used to improve liquefaction resistance of loose sands and minimize settlements following a seismic event. Granular piles increase the unit weight by replacement, drain rapidly the excess pore pressures generated, act as strong and stiff elements and carry higher shear stresses [3]. It can be installed in wide variety of soils, ranging from loose to medium sands, soft to medium clays and organic soils but is deficient in taking uplift loads. The failure mechanism of GP under uplift loads demonstrates the granular material displacing out from the sides of the pile-soil interface. Hence, any pressure bulb is not formed, thus restricting its uplift capacity near the bottom of the pile.This deficiency of granular pile may be improved by providing an anchor plate at the base of the granular pile with a rod attached to the bottom of foundation to resist pullout loads [4 - 7]. The Granular Anchor Pile (GAP) is much superior to that of solid piles as the load is directly transferred to the tip where the bulging capacity is the highest [3]. Considerable research work has been carried out in past to develop procedures for practicing engineers to design different types of piles under axial compression, axial pullout or lateral loads but understanding the behavior of GAP is very restricted.

However, most of the studies on GAP are focused on expansive soil to counteract the effect of vertical uplift loads due to swelling pressure, as the soil expands. There are many structures such as television and transmission towers, tall chimneys, tension cable for suspension bridges and marine structures such as floating platforms, bridge abutments, retaining walls, bulkheads, avalanche control structures (snow nets, umbrella system), tall buildings etc., whose foundations are subjected to large uplift forces. The conventional shallow foundation in cohesive soil may not be sufficient to withstand the uplift forces, such cases required deep foundations such as concrete pile, under reamed piles foundations, belled pier foundations. Therefore, the behavior of GAP is required to be studied in the case of non- expansive clayey soil also. Mostly, all the studies were made taking vertical uplift loads, but in practical generally uplift forces in conjunction with lateral forces becomes inclined. Therefore, response of GAP under inclined forces is also required to be studied. The geogrid reinforced granular anchor pile foundation in expansive soils led to improvement in the uplift capacity with increase in the number of geogrids [14, 15].The pullout capacity of GAP in cohesion less soil was also studied [16].The literature above indicates the resistance capacity of GAP against vertical uplift loads using experimentally in sand and expansive both. But in the actual field condition the uplift forces acts as oblique, which has not been explored. Also, some another research gaps are there that need to be investigated such as effect of encasing of GAP with geogrids, geonets and geotextile, influence of size of the granular fill. Therefore, for a thorough understanding of pile-soil interaction, it is necessary to study the behavior of a granular anchor pile foundation by varying different parameters subjected to pullout loads embedded in cohesive soil. In this paper, extensive experimental tests were conducted on laboratory -scale GAP installed in clayey soils under uplift and oblique pull-out loads by varying different pile parameters.

2. Concept of Granular Anchor Pile

Granular Anchor Piles (GAP) is a widely used technique for improving the settlement and strength characteristics of cohesive and non- cohesive soils for shallow foundation. A granular anchor pile is one in which the foundation is anchored at the bottom of the granular pile to a mild steel plate through a central mild steel rod (Fig.1). This serves to hold the particulate granular medium and prevents the granular pile from being sheared away and is thus instrumental in mobilizing the frictional resistance to the uplift force on the foundation.

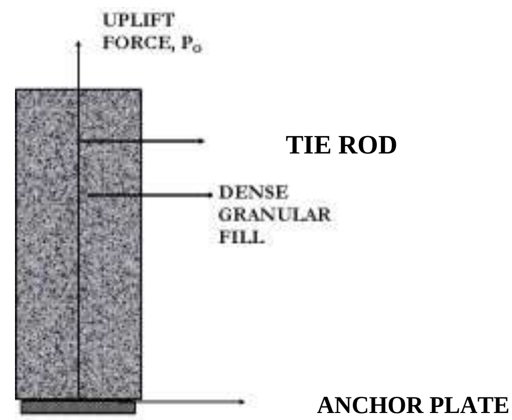

Fig. 1. Concept of Granular Pile Anchor

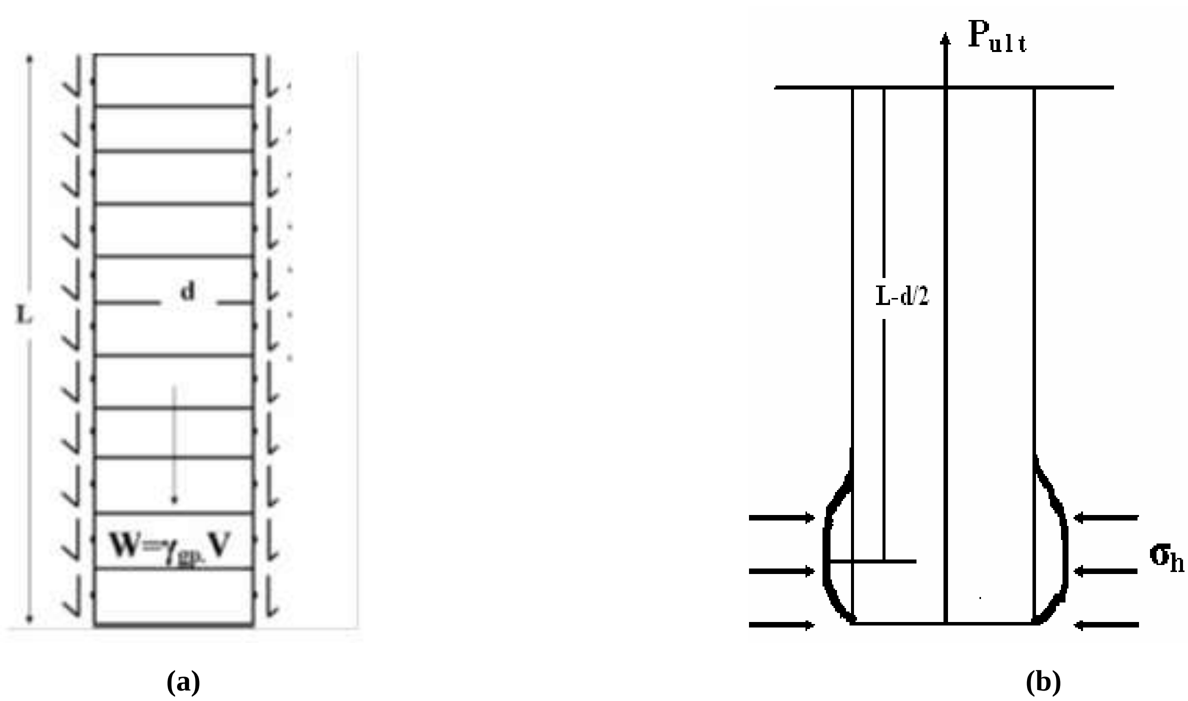

Fig. 2 (a) Pullout (b) Bulging Failures of GAP

The uplift force caused on the foundation under shallow foundation is therefore resisted by (*i*) the weight of the granular pile, and (*ii*) the frictional resistance along the pile–soil interface. The ultimate uplift load, P_{ult}, of the GAP is the summation of the shear resistance mobilized along the circumference of the pile along the depth and the weight of the pile material given as

$$P_{ult} = л.d.L.c_u + (л.d^2/4).L.\gamma_{gp} \quad (1)$$

and for bulging mechanism

$$P_{ult} = \pi.d^{2/}/4.\ N_{\Phi}\ \{c_u.\ N_c^{*}+\sigma_{ho}\} \quad (2)$$

Where,

d	=	diameter of pile
L	=	length of pile
c_u	=	cohesion of soil
P_{ult}	=	ultimate pullout load
γ_{gp}	=	unit weight of the granular pile material
N_c^{*}	=	Bearing Capacity Factor by Vesic
σ_{ho}	=	horizontal stress
$N\phi$	=	Bearing Capacity Factor by Vesic $(1-\sin\phi_{gp})/(1+\sin\phi_{gp})$

Equations (1) and (2) are applicable for a single GAP, and can be amend according to the number of GAP. Furthermore, construction of GAP is simple and economical, therefore has an potential to be used in the field condition.

3. Materials

3.1 Soil

The soil used in pull-out tests was collected from Village Sarsod, District Hisar, Haryana (India). Table 1. shows the index properties of the soil. Based on the index properties, the soil was classified as CI as per IS 1498:1970 [17]. The soil had a maximum dry unit weight of 15.1 kN/ m^3 at optimum moisture content (OMC) of 18% as determined from the standard Proctor compaction test IS:2720-PART 7 [18]. The grain size distribution curve is shown in Fig. 3 and Proctor compaction curve of the soil is shown in Fig. 4.

Table 1. Index Properties of the Soil

Specific gravity	2.71 IS:2720-PART 3 [19]
Sand (%)	3
Silt (%)	67
Clay (%)	30
Liquid limit (%)	46 IS: 2720-PART 5 [20]
Plastic limit (%)	23 IS: 2720-PART 5 [20]
Plasticity index (%)	23
Free swell index, FSI (%)	22.7 IS: 2720 PART 40 [21]
USCS classification	CI

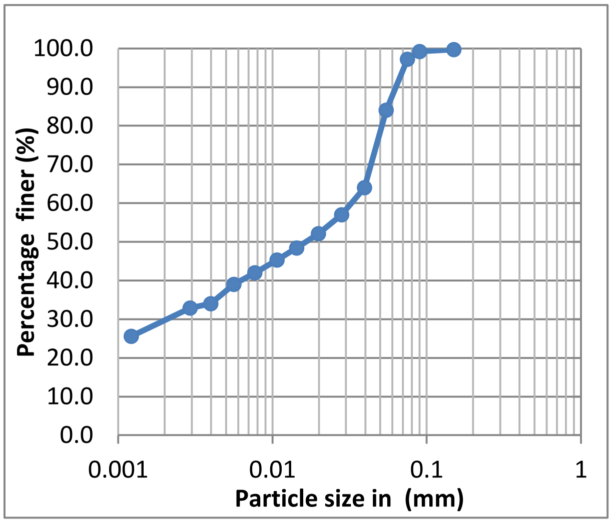

Fig. 3. Grain Size Distribution Curve of soil

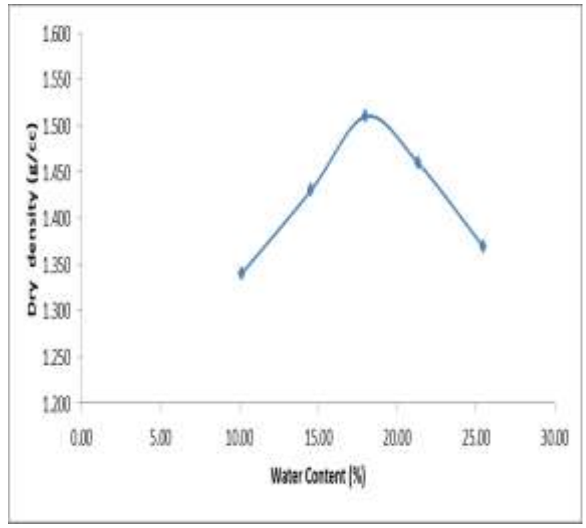

Fig. 4. Standard Proctor compaction curve of soil

3.1.1 Mineralogy analysis using X-ray diffraction (XRD) test

Prepared samples were run on Cu-Kα (λ = 1.5406 Å) source, Diffractometer (45 kV potential difference and 40 mA current) at scan speed 1°/min, step size of 0.017° and 2θ in the range of 10°–90°. The XRD raw data, after removal of unwanted noise and spikes was studied. The XRD micrograph is shown in Fig. 5. From the XRD results, it was found that this material predominantly consists of Muscovite, quartz and albite. It was evident from the results that the soil does not contain any expansive clay minerals. However, from differential free swell test also, its expansiveness was categorized as moderate.

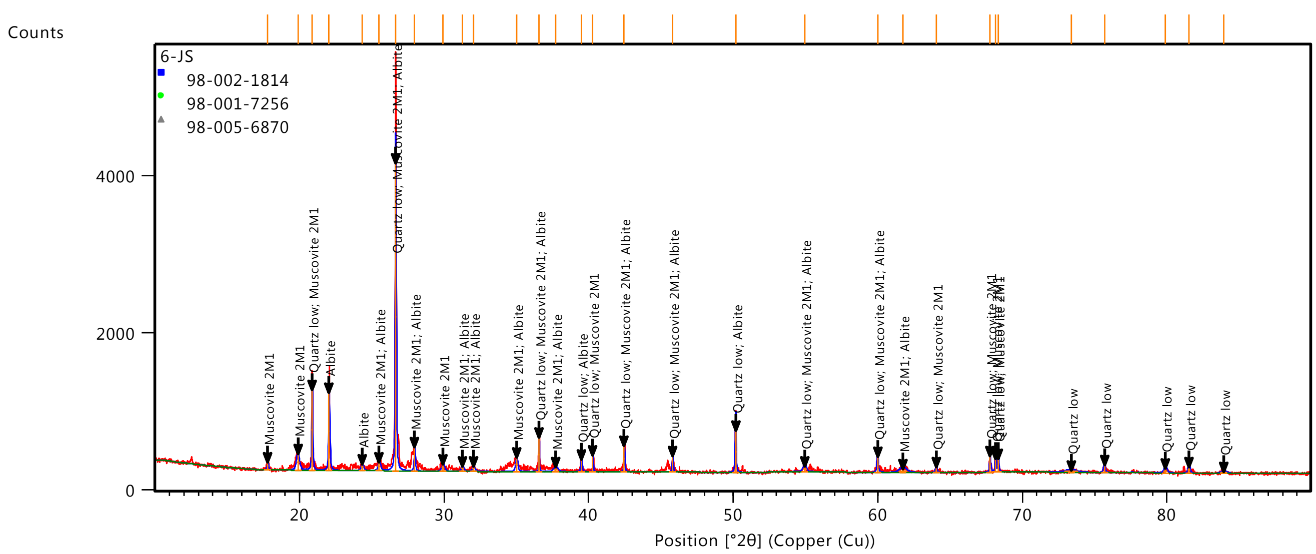

Fig. 5. X-ray diffraction (XRD) of soil

3.1.2 Morphological Characteristics

The nature of particles such as shape and surface of clay sample was carried out using Scanning electron microscope (SEM) technique. The result of SEM at X2000 magnification is shown in Fig.6. It can be noticed that clay particles are composed of irregular particles with complex pore structure. It also contains the sand and silt particles. This can be attributed to the result that due to these irregular shape particles, there is more inter-particle bonding and hence resulted in more friction while uplifting the pile.

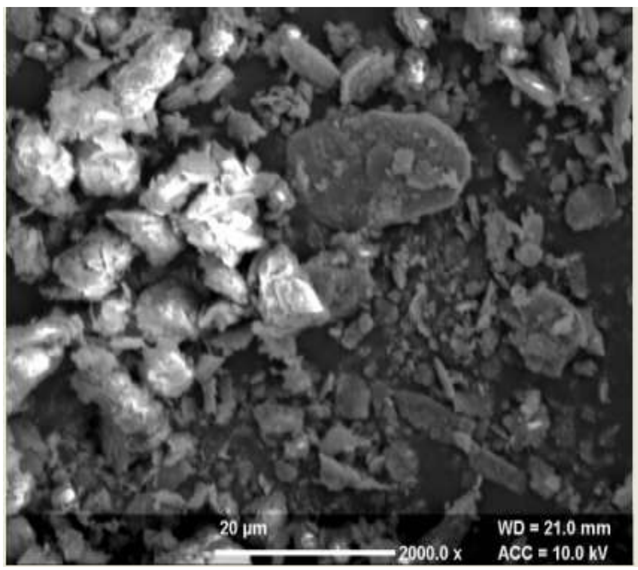

Fig. 6. SEM micrograph of Soil at X2000 magnification

3.2 Granular pile Material

Granular anchor piles were installed in the soil beds using a granular material that was a mixture of particle size of coarse aggregates varies between 3 mm to 6 mm and 8 mm to 10 mm. All the granular anchor piles studied in this laboratory -test program were compacted by ramming the granular material into equal parts up to the required height. The maximum and minimum density of the granular material from relative density test IS 2720- Part 14 (1983) is 20.1 kN/m^3 and 14.1 kN/m^3 respectively. Granular material was filled in the pile at 60% relative density i.e 17 kN/m^3.

3.3 Geosynthetic Material

The geosynthetic material is used in the test for the encasing of granular material and estimation of pull-out capacity of granular anchor pile foundation was carried out by encasing the geotextile and geonet on the periphery of GAP. The Geotextile and geonet used in the test has following properties as listed in Table 2.

Table 2. Properties of geotextile and geonet material

	Geotextile (Non-Woven)	Geonet
Thickness (mm)	1.8	6
Mass per unit area (gms)	250	500
Ultimate max. Tensile strength (kN/m)	8	90
Elongation (%)	55	15
Apparent opening size (mm)	0.15	10

3.4 Piles

In order to study the effect of pull-out loads on granular anchor pile foundation (GAPF), the steel piles were fabricated as shown in Fig.7.The circular anchor plate of diameter equal to diameter of pile has been welded to the bottom of the tie rod, thus making a rigid bond for embedded lengths as 250 mm, 350 mm and 450 mm for L/D ratio 7.5, 10 and 12.5. The hook was made at the top of the pile to connect the loading wire and apply the uplift load on the granular anchor pile.

Fig. 7: Piles used in laboratory Tests

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4. Proposed Methodology

4.1 Experiment program

The laboratory tests were performed on soil to study the uplift capacity of a GAPF system. The aim of the study was to investigate the behavior of the granular anchor pile foundation system as a new foundation technique used in improvement of cohesive soils. Various tests have been conducted by varying different pile parameters to understand the behavior of granular anchor pile foundation. The parameters such as pile length, pile diameter, L/D ratio, load inclination, group pile, encasing of pile periphery with geotextile and geonet, spacing of piles has been studied.

4.1.1 Model test setup

The rectangular tank of size 900 mm (L) x 900 mm (B) x 600 mm (H) was fabricated to perform model laboratory test. The wall thickness of the metal tank was kept 5 mm. The experimental setup is shown in Fig.8. The soil was filled in the tank at MDD i.e 15.1 kN/m^3 and weight of the soil required to fill the tank was calculated. The tank was divided into convenient number of equal parts, each part having to be compacted for desired unit weight so as to achieve the required density. A total of 9 no. GAP piles were casted simultaneously at c/c distance of 225 mm. A steel tie rod with a circular plate of diameter equal to that of GAP was welded and placed vertically at the bottom of the test tank at the required position with c/c spacing of 225 mm distance from each pile w.r.t tank dimensions. This spacing was adopted by considering the uplift load influence on the pile surface. The anchor rod and pile casing were held in position with the help of the steel bars placed on the top of the tank, tied with the binding wires as shown in Fig. 8.

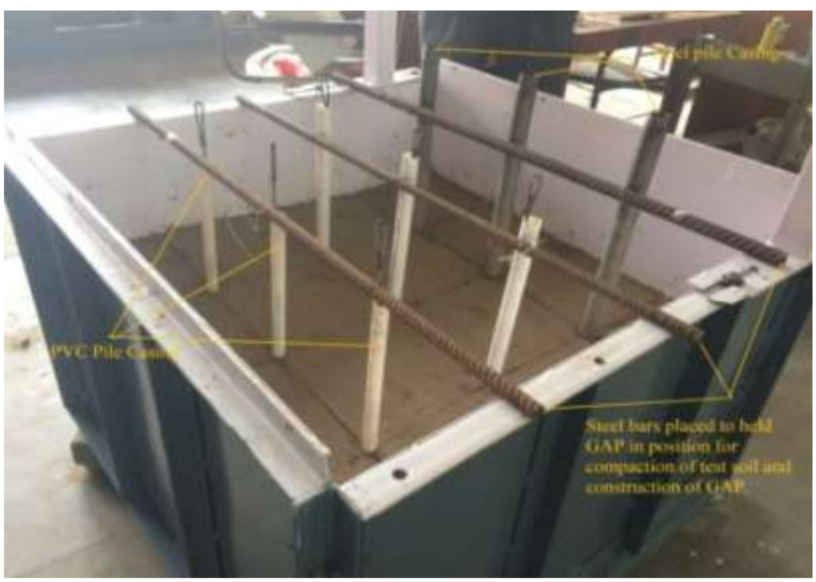

Fig. 8.Preparation of test bed and construction of GAP

The soil was filled in layers of 50-mm thickness in the tank. Each part of the soil was carefully placed in the tank such that it abstains from entering the casing pipe and thus compacting with the rammer up to the required height of the test tank The amount of the granular pile material required to be filled at uniform density, was filled in layers of equal thickness with simultaneous removal of casing pipe. After the test bed and construction of GAP was ready, the top end of the MS anchor rod was connected to the loading arrangement with the help of a specially designed and fabricated attachment provided at the top to transfer the uplift force to the GAP system. After compaction, the loading frame was placed over the granular anchor pile centrally, the side frame was fastened with the nut-bolt with the test tank to resist the upward thrust on the loading frame. The pull out load was applied at the center of the pile axis with the properly designed load arrangement, which consists of the steel frame, a flexible steel wire rope (10 mm dia), and 3 nos. of frictionless pulleys, a loading platform and dead weights. A special fabricated 6 mm dia steel hook was made to attach the loading setup with the granular anchor pile from which the pull-out load was transferred to the GAP. On the other hand, a steel wire was connected with the U- shaped hook fastened with nut bolt to make its connection with the loading platform. The pullout dead loads were applied with respect to axis of granular pile, by taking steel wire rope through pulleys and placing loading setup at accurate position from the granular pile. In each case, this was achieved by placing the loading setup at calculated position, attaching wire rope with granular anchor pile and putting 8 kg weight on the loading platform for straightening of the wire rope. The tank was fabricated for load carrying capacity of 650 kg. Incremental loading was provided in 10–15 increments by putting known dead weights in the loading platform, till granular anchor pile completely pulled out of the clay bed. For measuring the upward displacements in vertical direction a L-shape steel plate was welded with the steel hook attachment from which the pull out load was applied, two dial gauges were placed on the steel plate to measure the upward movements. The average displacement found from the two dial gauges was considered to be the final uplift movement. For oblique pull-out loads, the pulley was fastened to the side frame and inclination angles have been marked with the inclinometer to apply pull-out loads on the GAP system. The markings were marked at desired angles and the load was applied at different load inclination *viz.* 15^o, 30^o and 45^o with a provision of movable pulley as shown in Fig.9. Different tests were carried out on GAPs by varying different parameters of pile.

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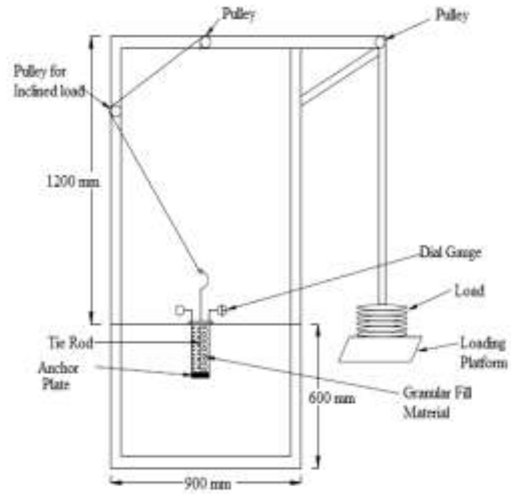
9(a) Laboratory Setup



9 (b) Schematic Diagram

Fig. 9 Model of experimental setup for inclined loading

5 Variables Studied

All the tests were performed on clayey soils that were compacted at MDD i.e 15.1 kN/m^3. The thickness of clay beds was kept constant as 600 mm. Pullout load tests were conducted on GAP by varying different pile parameters *viz*. length of pile, diameter of pile, L/D ratio, size of the granular material, angle of inclination of load and encasing of geotextile and geonet on periphery of pile, spacing of the piles as mentioned in table.3. By using all these variables in different combination, a series of tests were conducted and load- displacement response were examined.

Table 3. Variables in respect to granular pile

Length (*L*) mm	L/D	Load inclination with vertical	Encased GAP	Size of the granular fill material	*c/c* spacing for group of two piles
250	7.5,10,12.5	0^0,15^o, 30^o, 45^o		3 to 6 mm	2 D ,2.5 D, 3D
350	7.5,10,12.5	0^0,15^o, 30^o, 45^o	Geonet &Geotextile	3 to 6 mm & 8 to 10 mm	2 D ,2.5 D, 3D
450	7.5,10,12.5	0^0,15^o, 30^o, 45^o		3 to 6 mm	-

5.1 Effect of L/D ratio

To understand the effect of L/D on granular anchor pile foundation under pull out loads, tests were performed by varying L/D Ratio as 7.5, 10 and 12.5 for lengths 250 mm, 350 mm and 450 mm of piles. The graph were plotted to analyze the results of uplift capacity of GAP system.

5.1.2 Load Obliquity

To understand the effect of load obliquity on granular anchor pile foundation under pull out loads, test were performed by varying load inclination as 0^0,15^o, 30^o and 45^o for lengths 250 mm, 350 mm and 450 mm at L/D ratio 7.5, 10 and 12.5.

5.1.3 Encased pile

The granular anchor pile was encased with geosynthetic (geotextile and geonet), a total 9 no. tests were performed on length as 350 mm and L/D ratio as 7.5, 10, 12.5 to analyze the pullout load responses. The influence for geosynthetic (geotextile and geonet) encased GAP has been studied to compare the results with and without encasing GAP and ascertain their efficiency for the same.

5.1.4 Size of granular material

The size of the granular material used in the construction of granular anchor piles majorly governs the efficacy of GAPF system. In granular anchor pile, the resistance to uplift is developed mainly due to the weight of the granular pile material and Uplift resistance due to friction mobilized along the pile soil interface, so size of the granular fill was varied as 3 mm to 6 mm and 8 mm to 10 mm for length 350 mm at L/D ratio as 7.5, 10 and 12.5 and results for the same were compared.

5.1.5 Group and Spacing between two group GAP

To find out the effect of spacing on the uplift capacity of GAPF system, tests were performed on different pile spacing as 2 D, 2.5 D and 3 D for group of two piles on different pile parameters and thus, to analyze their pullout load responses.

6. Results and discussions

The results of pullout test on single GAP, group GAP, encased GAP (by varying different parameters such as length of piles, diameter of piles, L/D ratio, load inclination, size of granular fill) are discussed in terms of pullout load- uplift displacement behavior. To study the effect of pull-out load, the graphical representation of results are presented showing the applied uplift load (kg) on x-axis and the corresponding upward displacement (mm) on y-axis. Ultimate pull-out has been considered as the load at which the pile was physically pulled out.

6.1 Effect of length and diameter on Granular Anchors pile foundation

Figs.10 through 12 shows the effect of vertical pullout load-upward displacement curve for single GAP of different length and diameters with L/D ratio 7.5, 10 and 12.5 respectively. The curves indicates that, at all stages of loading, the upward load required to be applied on the GAP to cause a given upward movement increased with increase in length of GAP. However, it may be observed that, up to an applied uplift load of 15 kg, there was no significant upward movement in the GAP. This is because of the weight of the GAP and the shear resistance mobilized in the downward direction along the cylindrical pile-soil interface because of the anchorage. In Fig.13 pullout behavior of the curve reflects the effect of diameter of GAP on pullout behavior. The applied upward load was observed to increase with increasing diameter of the GAP at all stages of the test as the resistance to uplift increased with increasing surface area of the pile-soil interface. It has also been observed from the results that as the L//D ratio of GAP increases, the pullout load decreases. Therefore, the uplift resistance depends upon the frictional characteristics and the surface area of the interface. The higher the surface area of the interface, the greater the uplift resistance. Increasing the diameter increases the surface area and pile anchor weight and consequently uplift resistance and results in increased failure pullout load.

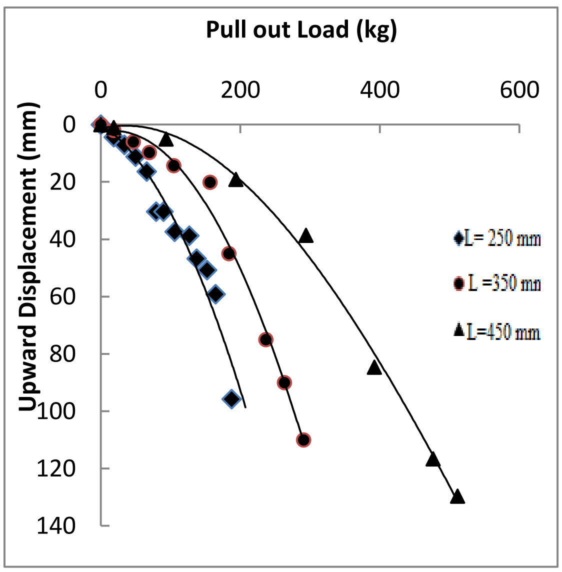


Fig. 10. Pullout deformation curves for L/D=7.5

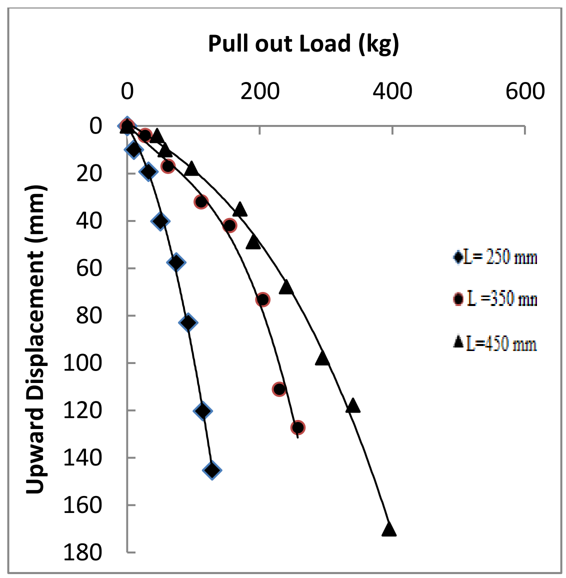


Fig.11. Pullout deformation curves for L/D=10

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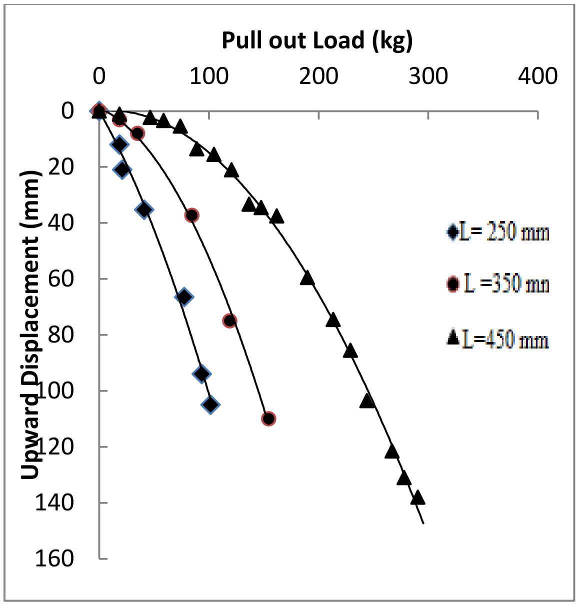

Fig. 12. Pullout deformation curves for L/D=12.5

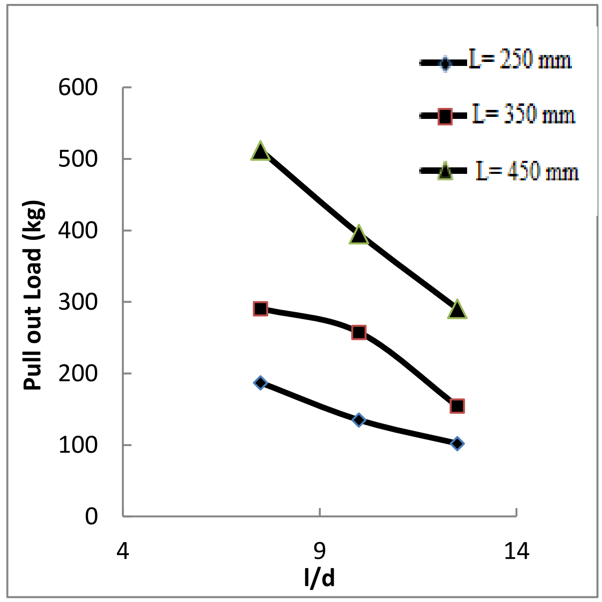

Fig. 13.Pullout deformation curve of L/D versus Pull-out load

6.2 Group and Spacing Effect on Pullout Behavior of Granular Anchor pile

A group of two GAP at the spacing of 2 D, 2.5 D AND 3 D were tested and length of the pile was kept as 250 and 350 mm for L/D ratio 7.5, 10 and 12.5. The comparison of pullout behavior of the GAP, when tested single and when tested under group effect for L/D= 7.5 is shown in Fig.14. It was observed that the GAP under group effect resulted in increased uplift load for a given upward movement in comparison to that of a single GAP tested. This may be due to arching action between the GAP, which offers more resistance to uplift. As a result, the pile-soil interface friction for the group would be much more than in the case of the single GAP. Thus, the uplift capacity of the clay bed was increased significantly on the installation of group GAP. Also, the effect of spacing on pullout capacity was observed keeping the spacing between piles as 2D, 2.5 D and 3D. The values of pullout load for GAP for L=250 mm with L/D=7.5, 10 and 12.5 and spacing 2D, 2.5D and 3D is shown in Table 4. As the spacing between pile increases from 2D to 2.5D, the pullout load increases and then decreases with increase in spacing from 2.5 D to 3D. Fig.15 shows pullout curve for the c/c pile spacing effect on the mechanism of granular anchor pile foundation for L=250 mm at L/D ratio 7.5. It has been observed from the curve that the group pile shows maximum pullout load for spacing 2.5D. This may be due to interaction effect of zone of skin friction between the two adjacent pile, which is significant up to 2.5 D. As the distance between the adjacent pile increases beyond 2.5D, the pile acts as independent having less interaction effect. This is similar to the conventional friction pile in which the optimum spacing is considered to be 3D as per IS 2911 (IS:2911-Part 1)

Table. 4 Pull-out results of GAP for L=250 mm and spacing 2D, 2.5D and 3D

Length (mm)	L/D	Pull Out Load of Single Pile (kg)	Pull Out Load For Group Of Pile	
			Spacing	Load (kg)
250	7.5	183	2D	370
			2.5D	448
			3D	442
	10	143	2D	292
			2.5D	353
			3D	349
	12.5	102	2D	235
			2.5D	256
			3D	253

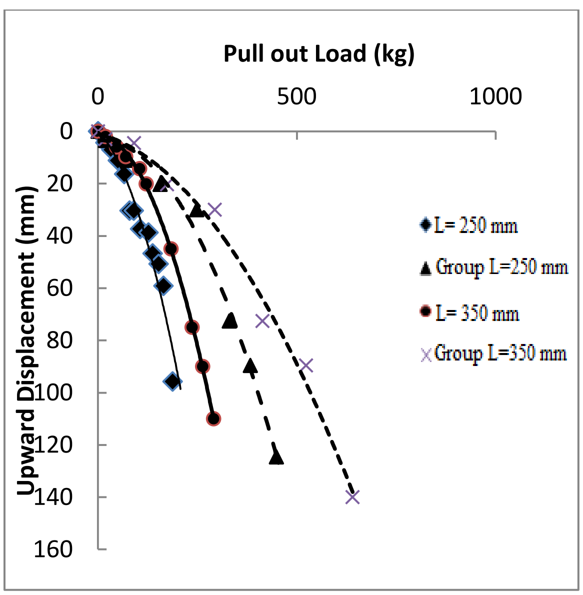

Fig. 14 Pullout deformation curves for single pile and group piles for L/D= 7.5 and spacing between piles as 2.5D

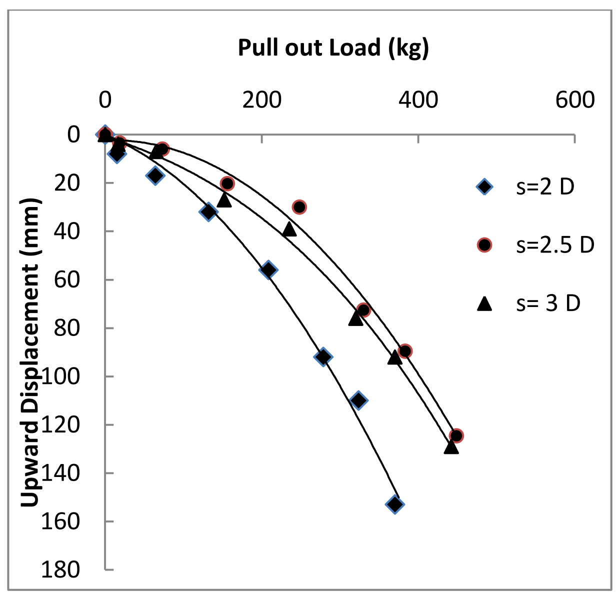

Fig. 15. Pullout deformation for spacing curves for L=250 mm and D= 33.33 mm

6.3 Effect of load inclination on Pullout Behavior of Granular Anchor pile

To know the influence of load inclination on ultimate oblique pullout capacity of granular anchor pile, a comparison graph has been prepared between ultimate pullout capacities versus inclinations of pullout load as shown in Fig. 16. The pullout load was varied for different angles *viz* 0^0,15^o, 30^o and 45^o w.r.t vertical axis. With increase in load inclination the uplift capacity decreases as shown in Table 5. This may be due to the fact that with increase in load inclination the pile-soil interaction offers less resistance to uplift load thus failing in making adequate pressure bulb which results in decrease of uplift capacity. Since, there is not any direct available literature on the pull-out behavior of GAP under inclined loading. Therefore, it may be compared with conventional pile under oblique pull-out loads.

Table 5. Pull-out results of GAP for load inclination

Length (mm)	L/D	Inclination Angle	Pull Out Load (kg)
	7.5	0^o	183
	7.5	15^O	170
250	7.5	30^O	144
	7.5	45^O	123
	10	0^o	143
	10	15^O	119
250	10	30^O	101
	10	45^O	91
	12.5	0^o	102
250	12.5	15^O	96
	12.5	30^O	75
	12.5	45^O	65

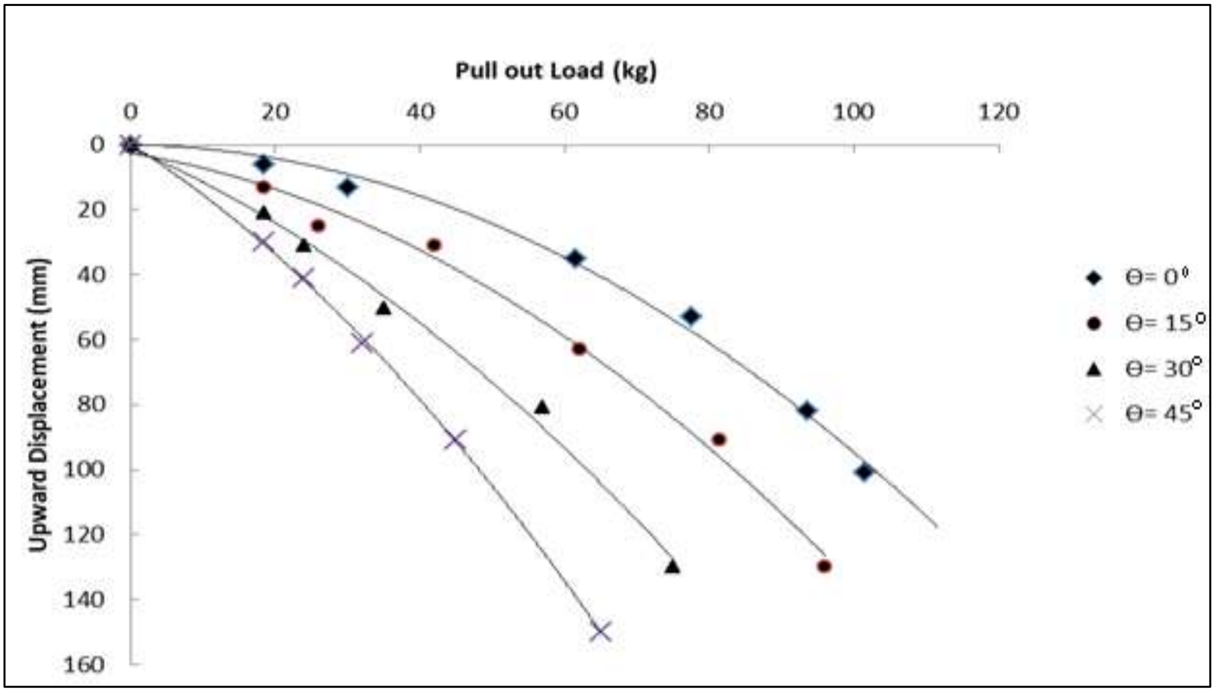

Fig. 16. Pullout deformation curves for load inclination for L=250 mm and L/D=12.5

6.4 Effect of encasing of Granular Anchor pile with geotextile and geonet

To know the influence of encasing on the ultimate pullout capacity of granular anchor pile, a comparison graph has been prepared between ultimate pullout capacities and upward displacement as shown in Fig. 17. The granular anchor pile encased with geotextile offers more resistance as compared to geonet encased and without encased Granular Anchor Pile. This is because of the increased friction mobilized between pile and soil interface. The casing with non- woven geotextile prevents the aggregates to move into the soil in comparison to geonet, therefore the uplift capacity in non-woven geotextile was observed to be more in comparison to that of geonet.

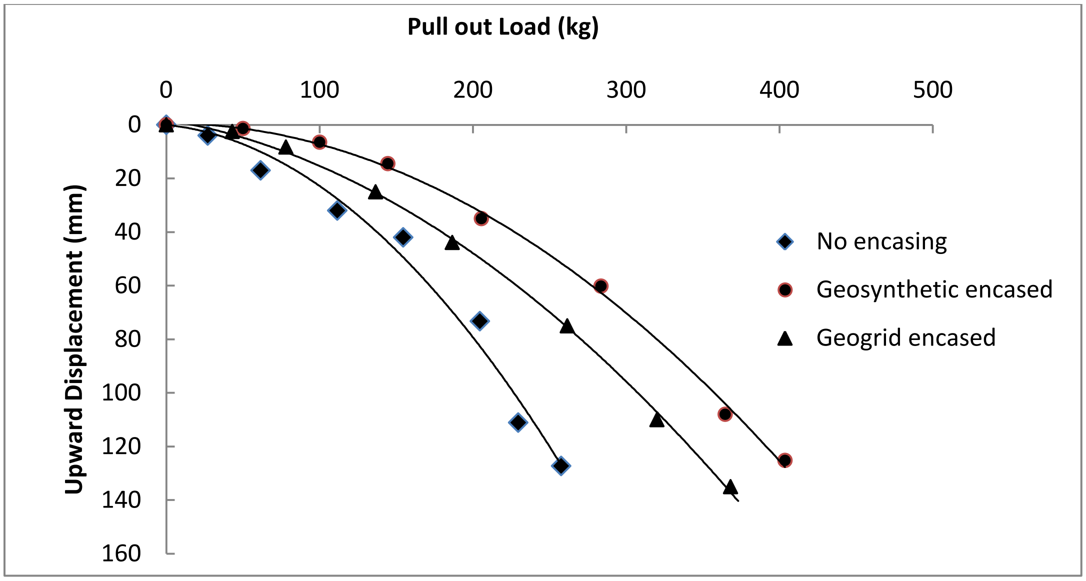

Fig. 17. Pullout deformation curves for encased piles for L= 350 mm and D =35mm

6.5 Effect of size of the granular material fill on pullout load capacity

Fig. 18 show the influence of size of granular material on ultimate pullout capacity of granular anchor pile. With increase in the size of the aggregates the movement of aggregate in soil is restricted thus making large pressure bulb in comparison to smaller aggregates. Also, with the increase in size of the granular fill, the weight of the granular anchor pile increases, thus results in resistance to uplift load due to self-weight of the pile.

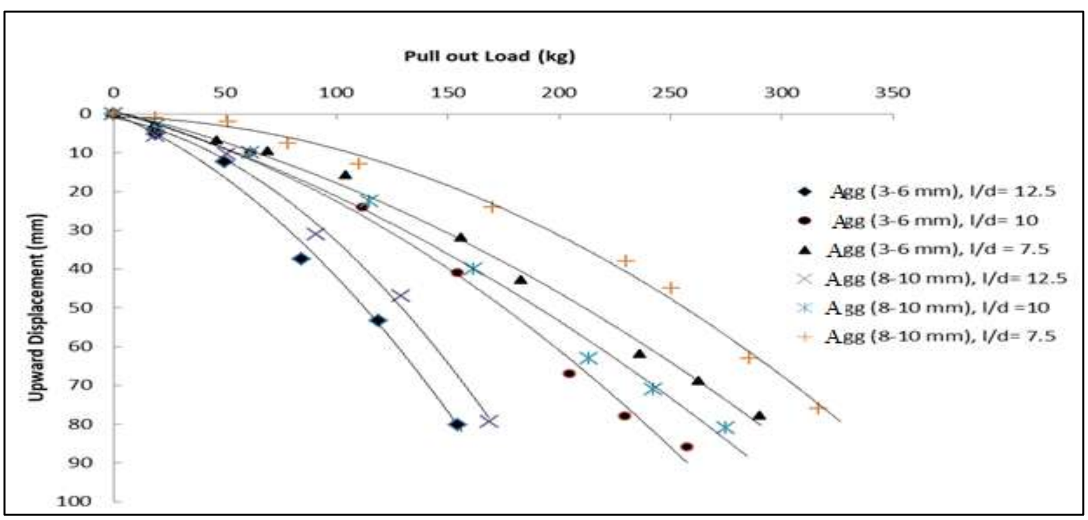

Fig.18. Pullout deformation curves for size in granular material

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7. Conclusions

A comprehensive laboratory-test program was performed to study the pullout load response of GAP embedded in non- expansive clayey soil. The test program studied pullout load-upward movement behavior of GAP embedded in soil with varying parameters. Following conclusions can be drawn from the present study.

1. The uplift load increases with the increase in diameter of the GAP. The resistance to uplift force increases with increasing surface area of the pile-soil interface consequent upon increase in the diameter.
2. For a given L/D ratio, the failure pullout load increased with increasing length of the GAP. Similarly, for a given length of the GAP, the failure pullout load increased with decreasing L/D ratio. Increasing diameter increases the surface area and consequently the uplift resistance and results in increased failure pullout load.
3. It was found that the ultimate pullout capacity decreases when load inclination increases with the axis of the pile.
4. The granular anchor pile encased with geotextile offers more resistance as compared to geonet encased and without encased Granular Anchor Pile.
5. With the increase in size of the granular material, resistance to uplift load increases.

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