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A Review on Performance of Granular Plate Anchors in Black Cotton Soil

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ABSTRACT:Expansive soils are exceedingly hazardous soils and cause harm to structures establishedin them due to their capability to respond to changes in dampness routine. They swell when they soak up water and shrink when water vanishes from them. The granular plateanchor pile structure is a cost-effective and operational technique developed for refiningthe shear-strength assets of the soil and enhancing the uplift capacity soils. The upliftresistance of the plate anchor pile system is mainly derived from friction mobilized alongthe anchor plate–soil interface and the self-weight of the pile-footing assembly. Thisfriction is mainly generated because of the anchor plate system, and it provides resistanceto the upward movement of the foundation and also granular plate anchors arecapable of providing pullout resistance in various practical applications.

KEYWORDS: Black Cotton Soil, Plate Anchors, Uplift Displacement Capacity**.**

I. INTRODUCTION

Expansive soils are soils that have large volume modification associated with changes in water content such as small office buildings, highways, air strips and othermajor structures are highly affected by fluctuations in the water content. The foundations of structures embedded in expansive soils are observed to undergo cyclic swell-shrinkmovements due to alternate wetting and drying of these soils causing severe distress tothe structures resting on these soils.The plate anchor structure is a cost-effective and operational techniquedeveloped for refining the shear-strength assets of the soil and enhancing the upliftcapacity soils. The uplift resistance of the plate anchor system is mainly derived fromfriction mobilized along the pile–soil interface and the self-weight of the pile-footingassembly. This friction is mainly generated because of the plate anchor system and it providesresistance to the upward movement of the foundation. Among the various types of deepfoundations used in construction sites to support and stabilize structures, granular plate anchors a notable options.

These alternatives are often utilized when conventionalfoundation techniques, such as deep concrete foundations, are impractical or infeasible.For mitigating the problems due to alternating heave and shrinkage of expansive soils,many innovative deep foundation techniques have been suggested. Granular plate Anchors are thesystem which resist lateral loads with or without beingbraced depending on circumstances and an ordinary or standard house pile is required tocarry a vertical load. They are designed to provide uplift resistance and stability to thestructures.

Fig. 1.shows the helical shapes of double plate anchor. Plate anchor are effective in improving the bearing capacity and reducing the settlement of weaksoils.

Fig. 1: Helical Shape Double Plate Anchors

Mechanism of Plate Anchors

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The behavior of foundation of granular plate anchor depends on the uplift capacity of theanchor plate. The granular plate anchor foundation must be designed such that it resists theupward force in the foundation and does not fail in pullout. The resistance to upwardforce and safety against pullout depend upon the swelling pressure, the surface area of theplate anchor and the relative density of the granular material which is use as a casingmaterial. The concept of a plate anchor and the various forces acting on thefoundation shown in Fig. 2.

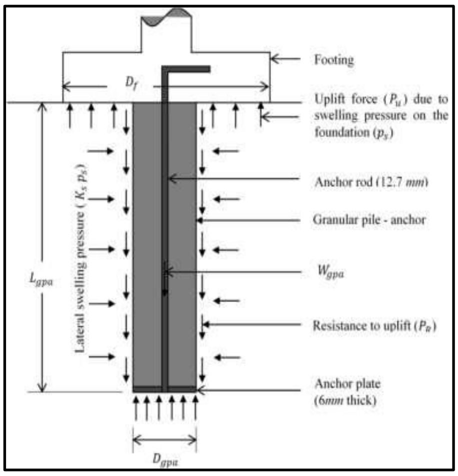

Fig. 2: Mechanism of Plate Anchor

II. LITERATURE REVIEW

[1] M. Muthukumaret.al(2009), investigated the experimental test data on GPA-reinforced expansive clay beds, which were initially inundated with water and later subjected to pullout load as they were allowed to shrink.This paper presents pullout test data on GPA-reinforced expansive clay beds, which were initially inundated with water and later allowed to undergo shrinkage through air-drying. The length and diameter of GPA used were 200 mm and 40 mm respectively. The thickness of theexpansive clay beds was also equal to 200 mm.

Fig.3. shows pullout load deformation curves for GPAs installed in expansive clay beds subjected to varying periods of shrinkage (30 days, 60 days and 90 days) that resulted in respectiveequilibrium water contents of 30%, 20% and 10%. The granular pile anchors were not tested up to failure. The data indicate that pullout load (N) requiredto be applied on the GPAs for agivenupward movement increased with decreasing water content or increasing periods of shrinkage. Thus the pullout load-deformation curves lay up for GPAs subjected to shrinkage of longer periods in comparison to those of GPAs subjected to shrinkage of shorter period.

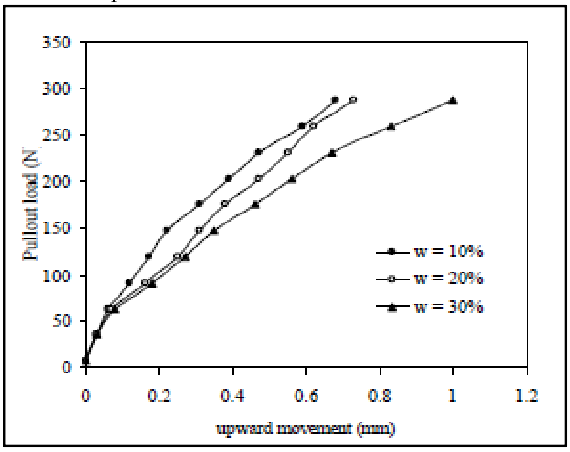

Fig. 3:Pullout Curves

Table1.Test Results

Wi	Cohesion (kPa)	Interface friction angles (Degrees)	Pullout Load (N)
10%	16	29.54	238.18
20%	19	25.33	213.68
30%	21	21.47	186.38

From above investigaton it was concluded that, the Pullout load (N) required to be applied on the GPAs for a given upward movement increased with decreasing water content or increasing periods of shrinkage. friction angle (f') increased and interface cohesion (c') decreased with shrinkage period. Pullout behavior of GPAs subjected to shrinkage depends more on interface friction angle than on interface cohesion.

Dr. P. Hari Krishnaet.al (2013) [2].conductedpull-out capacity of granular anchor piles in expansive soils. From these studies, it was found that the pull-out resistance of granular anchor piles is more than twice the value of concrete piles in both unsaturated and saturated states. The pull-out resistance of concrete and granular anchor piles was decreased by about 32% and 25% respectively upon saturation. The process of preparation of soil bed and granular pile has been continued till the required height was achieved. Asand layerof 200 mm thick was laid over the surface of compacted soil to have the surcharge effect on it. As shown in Fig. 4.shows the top end of the anchored rod was connected to a proving ring, which is attached to loading frame,and dial gauges were attached to the angles on either side of theanchor rod.Tensile load was applied on the pile (with a speed of 0.75 mm/

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min) and the proving ring readings were observed for different dial gauge readings..

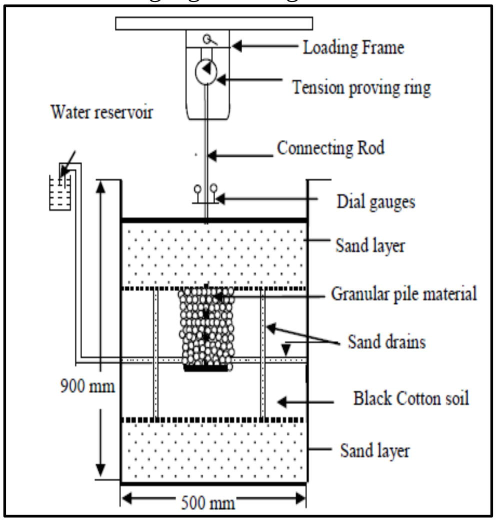

Fig. 4: Details of experimental set-up for

The pull-out tests were carried-out both in saturated and unsaturated states. Fig.5. shows the experimental setup for determining the pullout capacity of granular anchor piles. For the tests in unsaturated state, the respective piles were pulled-out immediately after their formation and the tests in saturated state were conducted after thorough wetting of the ground for about 10 days. The pull-out loads were applied using a specially devised rectangular frame for the purpose.

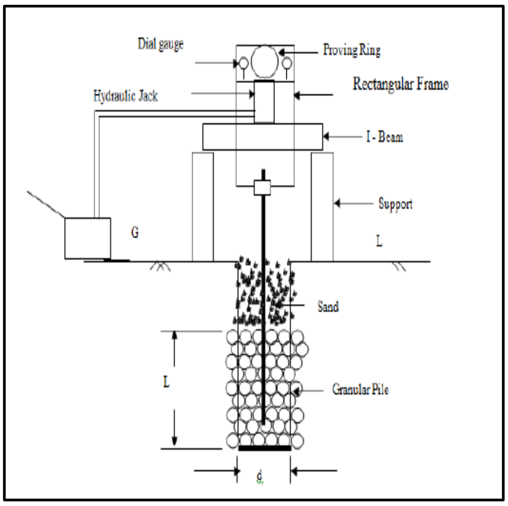

Fig. 5: Experimental Setup for Determining the Pullout Capacity ofGranular Anchor Piles

Table. 2. Pull-out capacity of piles in the laboratory (Diameter of pile = 50 mm, Length of pile = 200 mm)

Sr. No.	Type of Pile	Pull Out Load (N)	Pull Out Resistance (kN/Sq.m)
A) Unsaturated Condition			
1	Concrete Pile (CP)	1900	60.5
2	Granular Anchor Pile (GAP)	6600	210.1
B) Saturated Condition			
1	Concrete Pile (CP)	1700	54.1
2	Granular Anchor Pile (GAP)	5300	168.7

From table2.it can be observed that the pull-out capacity of granular anchor pile both in unsaturated and saturated conditions is about 3 to 4 times more than that of concrete pile.

The load deformation curves for the pull-out tests on concrete pile and granular anchor pile are shown in Fig. 6. From these test results, it can be revealed that the frictional forces generated along the pile soil surface in case of granular anchor piles are high when compared to concrete piles.

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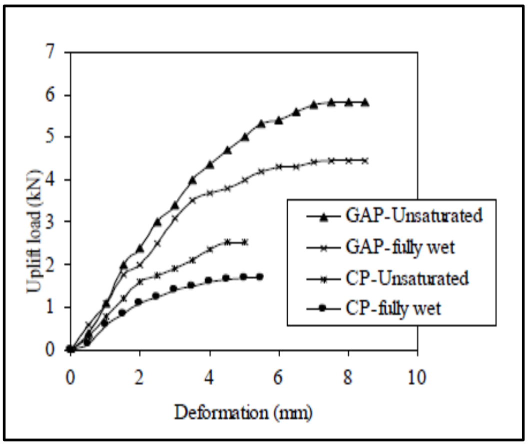

Fig. 6: Variation of uplift load with deformation of different tension piles

From above study it was concluded that the granular anchor pile was found to be a cost effective foundation treatment alternative to the conventional concretepiles for increasing the pull-out carrying capacity of foundations on expansive soil.

The pull out tests both in laboratory and field under both saturated and unsaturated conditions have revealed that the pull-out resistance of the granular anchor piles was around 3 to 4 times that of similar concrete piles.

Vidhya Morriset.al,(2019) [3] investigated the pullout resistance of granualr pile anchors on expansive soil.Expansive soil shows large volume change behavior when subjected to different moisture condition. Uplift of light weight structures occurs due to the swelling of soil. To increase the uplift resistance granular pile, anchors are used with and without reinforcement. Model studies are performed on granular piles anchors to check the pullout resistance. Study include testing of granular pile anchors with and without reinforcement in unsaturated and saturated condition. Black cotton soil was collected from Palakkad district. The initial test on soil was done and it is found that the soil is silty clay. A model test tank of 50cmx50cmx60cm dimensions are made. Pullout test is done to determine the pullout capacity of GPA, pullout test is done with different l/d ratio in unsaturated condition with and without reinforcement. From the result obtained it is seen that, when the l/d ratio increases the pullout resistance also increases and the maximum result obtained is 99.7N for l/d ratio equal to 2.5 without reinforcement and 102.24N for l/d ratio with 2.5 with reinforcement

Here in this study granular pile anchors with different l/d ratio is used and in the order 1.5, 2 and 2.5 with diameter fixed as 8cm and length of 12cm, 16cm, and 20cm. The test is done in both saturated and unsaturated condition with and without reinforcement and the reinforcement used here is woven geotextiles.In this study the expansive clay bed is filled in the maximum dry density and optimum moisture content. The model tank dimension is 60cm x 60cm x 50cm in dimension. By keeping the diameter of pile constant and by changing the length of pile ie with different l/d ratio as 1.5, 2 and 2.5. The diameter of pile is kept constant as 8cm with varying length of 12cm, 16cm and 20cm.The effect of length of pile is studied in the pullout resistance in unsaturated condition. The same effect is studied in the case of pile with reinforcement and the effect of reinforcement is studied in the pullout resistance of pile.

Pullout test on soil is done on specially prepared tank of dimension of 60cm x 60cm x 50cm with special pulley arrangement. Pullout test is done in both saturated and unsaturated condition, with and without reinforcement. The reinforcement used is woven geotextiles. Fig. 7 shows the pullout graph of unsaturatedondition without reinforcement with l/d ratio of 1.5 and the maximum pullout resistance obtained is 49.77N. Fig.8 shows the pullout graph of with an l/d ratio of 2 and the maximum pullout resistance obtained is 66.45N. Fig. 9 shows the pullout graph obtained for an l/d ratio of 2.5 and the maximum pullout resistance obtained is 99.72N.

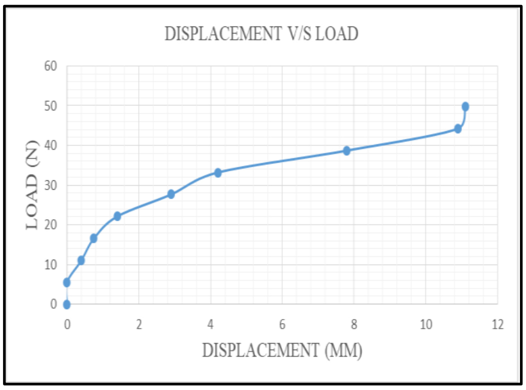

Fig.7:Displacement v/s load graph with l/d ratio 1.5

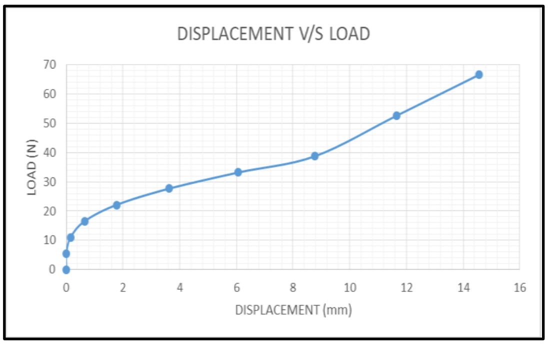

Fig. 8: DisplaceEment v/s load graph with l/d ratio 2

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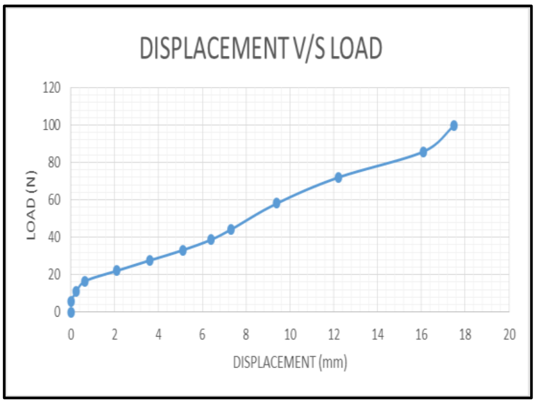

Fig. 9: Displacement v/s load graph with l/d ratio 2.5

pullout test on soil is done on specially prepared tank of dimension of 50cm x 50cm x 60cm with special pulley arrangement. Pullout test is done in both saturated and unsaturated condition, with and without reinforcement. The reinforcement used is woven geotextiles. Fig. 10 shows the pullout graph of unsaturated condition with reinforcement with l/d ratio of 1.5 and the maximum pullout resistance obtained is 63.64N. Fig. 11 shows the pullout graph of with an l/d ratio of 2 and the maximum pullout resistance obtained is 88.5N. Fig. 12 shows the pullout graph obtained for an l/d ratio of 2.5 and the maximum pullout resistance obtained is 102.4N.

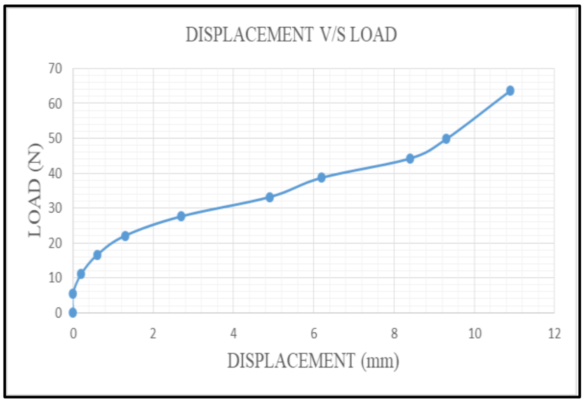

Fig. 10: Displacement v/s load graph with l/d ratio 1.5

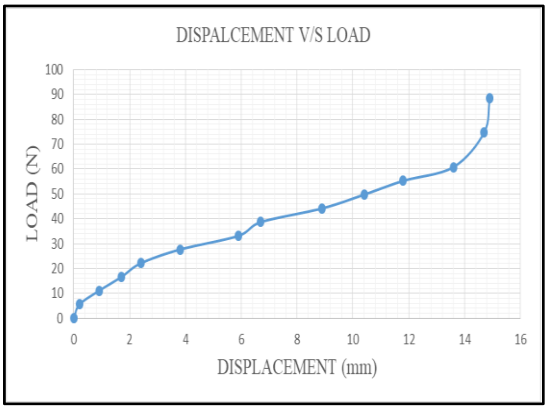

Fig. 11: Displacement v/s load graph with l/d ratio 2

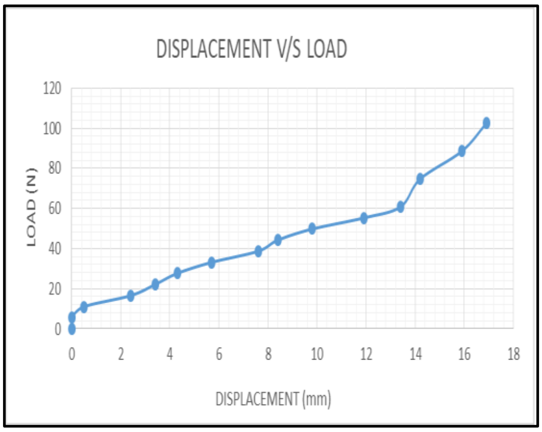

Fig. 12: Displacement v/s load graph with l/d ratio 2.5

From the result obtained on the pullout test done on unsaturated soil with and without reinforcement it is seen that the pile with l/d ratio of 2,5 shows greater pullout resistance in both reinforced and unreinforced condition. The pullout value obtained for l/d ratio 2.5 for unsaturated condition without reinforcement is 99.72N. And the pullout value obtained for with reinforcement is 102.44N. From the result obtained it is seen that the pullout resistance increase with the increase in length of pile.

HeenaMalhotraet.al.(2016),[4].conducted a study on ground improvement by granularanchor pile foundation in cohesive soilunder axial pullout loads.In this paper, the laboratory experiments were conducted to understand thebehavior of axial pullout load of granular anchor pile foundation in cohesive soil.The parameters studied were length of the pile, diameter of the pile, L/D ratio andsize of the granular fill material. The test results indicate that the pullout capacitydecreases with the increase in L/D ratio from 7.5 to 12.5. There was an increase in thepullout load resistance, when the diameter of the pile increases. Moreover, pulloutload capacity

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increases when size of the granular fill increased. Fig. 13 shows a granular pile.

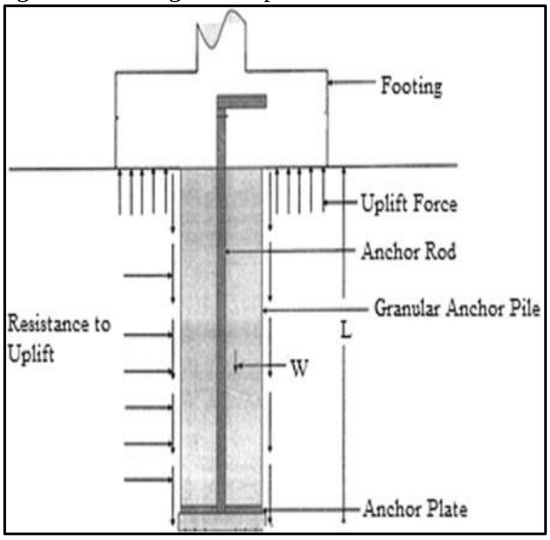

Fig. 13: granularpile anchor

Fig. 14 shows anchor pile used in laboratory tests.

Fig. 14: Anchor piles used inlaboratory tests

The effect of vertical pullout load-upward displacement curve for GAP of differentlength and diameters with L/D ratio 10 is shown in Fig.15. The curves indicatethat at all stages of loading, the upward load required to be applied on the GAPto cause a given upward movement increased with increase in length of GAP. Theultimate capacity of pile is evaluated using the double tangent intersectionmethod.

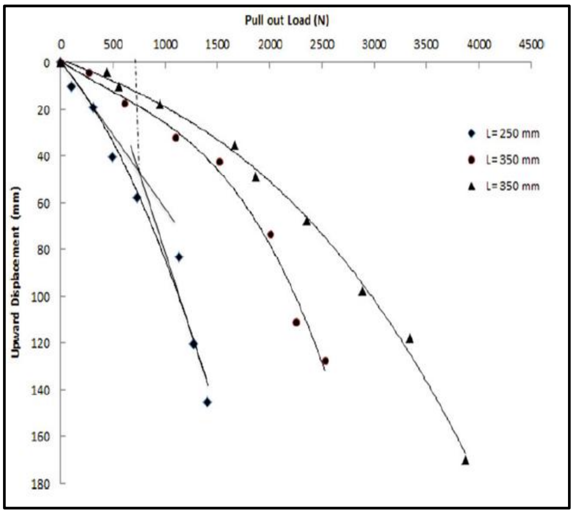

Fig. 15:Pullout deformation curves for L/D = 10

Table 3:Ultimate pullout capacity of single GAP for length 250 mm, 350 mm and 450 mm

Length of pile (mm) L/D Ultimate pullout capacity of clay (N)	Length of pile (mm) L/D Ultimate pullout capacity of clay (N)	Length of pile (mm) L/D Ultimate pullout capacity of clay (N)
250	7.5	7.5
	10	10
	12.5	12.5
350	7.5	7.5
	10	10
	12.5	12.5
450	7.5	7.5
	10	10
	12.5	12.5

From the above study it was studied that 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 upon increase in the diameter.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.

A. SriramaRaoet.al.(2007), [5].investigated a pullout behavior of granular pile-anchors in expansive claybeds in situ. This paper presents the results of a test programconducted to study the pullout response of GPAs embedded in expansive

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clay beds. Pullout load tests were conducted on GPAs of varyinglengths and diameters. It was found from the field pullout load tests that granular pile anchors of larger surface area resulted in higherpullout capacity. Of the various single granular pile anchors with l /d values between 2.5 and 10, the GPA of length 1000 mm and diameter200 mm (l /d=5) showed the best pullout load response when tested alone, resulting in a failure uplift capacity of 14.71 kN. Increase indiameter and length of granular pile anchor increased the uplift capacity. When the length of the GPA was increased from 500 to 750 and1000 mm, the percentage increase in the uplift load required for an upward movement of 25 mm was 33.3 and 55.5% respectively. Thepullout load of the GPA when tested under group was 18 kN as against a 12 kN for the GPA when tested single.Fig. 16.shows the pullout load test setup.

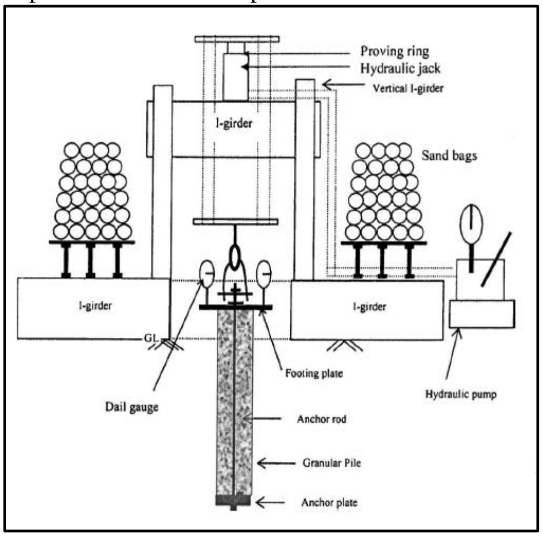

Fig. 16: Pullout load test setup

Table 4.shows the range of the length to diameter ratios (l /d) of the GPA.

Table 4:l /d Ratios of GPAs

Diameter of the GPA (d) (mm)	Length of the GPA (l), mm		
	500	750	1000
100	5	7.5	10
150	3.33	5	6.67
200	2.5	3.75	5

Fig. 17.shows the pullout load-upward movement curves for singleGPAs of a uniform diameter of 200 mm with lengths varying as500, 750, and 1000 mm.

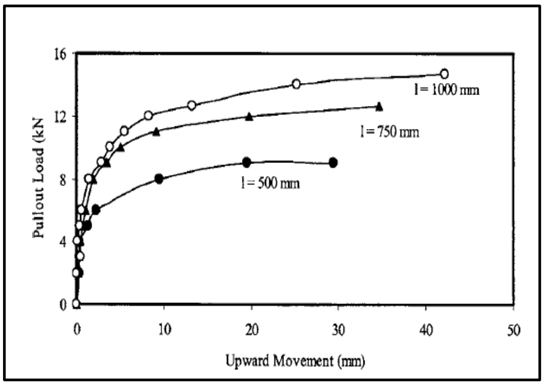

Fig. 17: Pullout behavior of granular pile anchors of diameter 200 mm

Fig. 18.shows the pullout behavior of GPAs of 1000 mm lengthbut of diameters varying as 100, 150, and 200 mm.

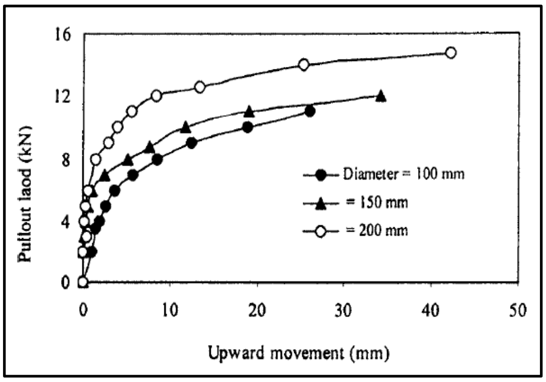

Fig. 18: Pullout behavior of granular pile anchors of 1000 mm length

Fig. 19.shows the variation of failure pullout load (kN) with the l /d ratio of the GPA.

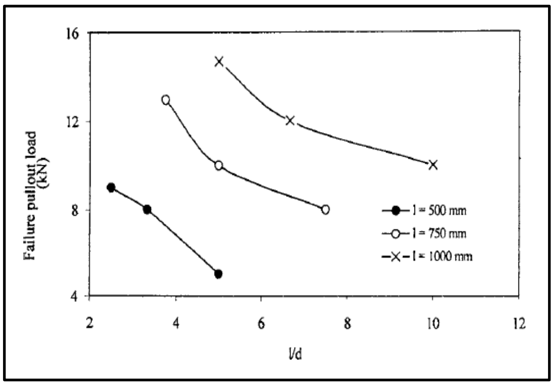

Fig. 19: Variation of failure pullout load with l /d ratio of granular pileanchor

From above investigation it was found that the uplift load or failure pullout load increased with theincreasing diameter of the GPA also. This is because theresistance to uplift increased with increasing surface area ofthe pile-soil interface consequent upon increase in the diameter.The uplift load required to be applied on the GPA (l=1000 mm) for an upward movement of 25 mm was respectively11, 11.5, and 14.2 kN for GPA of diameter 100,150 and 200 mm. This indicates that the percentage increasein the uplift load required for an upward movement of25 mm was 5 and 30% when the diameter or surface area ofthe GPA was increased from 100 to 150 and 200 mm.

III. CONCLUSIONS

Within the framework of the present investigations the following broad conclusions are drawn:

For H/D ratio, the pullout load capacity increases with increase in embedment depth.The resistance to uplift force increases with increase in spacing of anchor plates i.e. increase in Sp/D ratio.The pull-out resistance capacity of double plate anchor pile is much greater than single plate anchor pile.(upto 59%). The pull-out capacity of triple plate anchor pile is much greater than double plate anchor pile.(upto 44%).

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