



Behaviour of Granular Anchor Pile (Gap) and Group Piles In Different Type of Soils under Vertical Pullout Loads

Jaswant Singh, Anupam Mital, V.K. Arora

Abstract: In the present study, the load displacement behaviour of Granular Anchor Pile (GAP) and Group piles under vertical pullout loads in two different type of cohesionless soils have been investigated. The main objective of the study is to investigate the effect of embedment length, diameter and spacing varying (L/D and S/D ratio) on Pullout Capacity of Granular Anchor Pile system in different type of soils. GAP pile is innovative and effective in resisting the uplift pressure exerted on the foundation. Based on the laboratory study on single and group of 2 and 4 GAP systems, it is found that the ultimate Pullout Capacity of single GAP system increases with the increase in length (L) to diameter (D) ratio in both type of soils. The rate of increase of ultimate pullout capacity of single GAP systems having 50 mm diameter and 100 mm diameter was significant up to increase in L/D ratio of 39%. Thus, it was inferred that for single GAP system, there is maximum advantage upto L/D ratio 10.50 for 50 mm and 7.00 for 100 mm. In case of medium dense soil with higher relative density, the increase in pullout capacity is more as compared to loose soil with lower relative density. It was further confirmed that ultimate pullout capacity is a function of diameter of GAP and soil characteristics. The ultimate pullout capacity of group of 2 and 4 GAP systems with 100 mm diameter was found to increase with S/D ratio upto 3.00 and 2.75 respectively only in both the soils.

Keywords:- Cohesion less soils, Ultimate pullout capacity, Settlement, GAP System, Vertical pullout Load, Pile Material.

I. INTRODUCTION

Pile foundations are suitable to transfer loads to a stable stratum at deeper depths where top soil layers are weak and do not provide adequate bearing capacity. Granular piles (GP) are comparatively recent development through which in addition to achieving the desired load carrying capacity, excessive settlement may be significantly reduced.

But GP cannot be accepted in traditional form to act as tension members to offer resistances to pullout forces generated in case of tall and submerged structures due to their inherent nature. Hence, the effectiveness of granular piles will be better if these are combined with other soil improvement techniques. So, the granular pile is modified by reinforcing with steel tie rod protruding above the pile head and the lower end of the steel rod is fixed with a mild steel anchor plate. The assembly is termed as Granular Anchor Pile (GAP). The uplift capacity of Granular anchor pile determines the behaviour of foundation of structure connected to it. In the present study, laboratory investigations were carried out in different soils (loose to medium dense cohesionless) having different relative densities for computation of pullout capacity of single and group GAP system by varying the length, diameter and spacing of the GAP. Schematic diagram of 2 GAP system is shown in Fig.1.

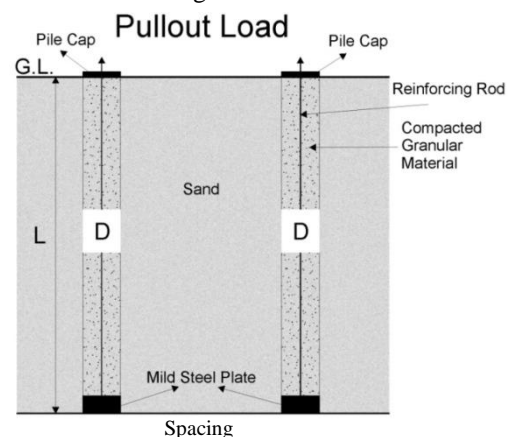


Fig .1.Group of Two Granular Anchor Piles

II. BRIEF REVIEW OF LITERATURE

Numerous researchers have suggested to determine the pullout capacities of Granular Pile and modified Granular Pile in cohesive and cohesionless soil by considering the various parameters of pile and soil characteristics. Alamgir [1] has shown that granular piles either reinforced by or enveloped by gro-membrane performed better. The effectiveness of granular piles will be better if these are combined with other soil improvement techniques. Braja and Seeley [2] concluded from the pullout tests on model single and group pile sand box that the efficiency of a group increases with increase in spacing between the piles. Chattopadhyay and Pise [3] proposed an analytical method to predict the ultimate uplift capacity of piles embedded in sand with assumed curved failure surface through the soil.

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Dash and Pise [4] conducted the test on model piles to study the effect of compressive load on uplift capacity of model piles and their experimental results indicated that the compressive load on the pile decreases the net uplift capacity of a pile and this decrease depends upon the magnitude of the compressive load. Ghaly and Hanna [5] carried out test on vertical screw anchor installed in sand under pullout load. Models were developed employing the limit equilibrium method of analysis to predict the uplift capacity of anchors installed at shallow, medium and deep depths. Meyerhof and Adams [6] has proposed a general theory of uplift resistance for a strip footing in soil and found that soil mass having approximately truncated pyramidal shape is lifted up and reaches to the ground surface. Ranjan and Kumar [7] suggested the foundation technique with a limited scope to control heave and resist uplift loads. Foundation technique suggested by Sharma, Kumar and Nagendra [8] have observed that the resistance to uplift can be increased by placing a base geo synthetic above the anchor plate. Subba and Kumar [9] assumed a log spiral failure surface to develop a theory for vertical uplift capacity of shallow horizontal strip anchors in a general C- ϕ Soil. Kumar and Kumar [10] proposed granular pile system is a variable means for ground improvement. Vidyaranya and Kumar [11] analyzed the displacements in granular piles in groups of two, three or four presented based on Poulos and Davis (1980) for rigid piles. Kumar (2002) [12] reported the laboratory and field study of GAP system under axial pullout loads. Vani [13] carried out evaluation of settlement and load carrying capacity of footing with micropiles on sand. The research work till date on granular anchor piles indicates that its application to pullout loads has not attracted desired attention. Thus, in order to bridge the knowledge gap, the authors have modified the granular pile to the proposed GAP system.

III. LABORATORY SOIL TESTING

In the present study, a test assembly was accordingly developed to study the behavior of GAP system embedded in loose to medium dense cohesionless soil deposit and subjected to vertical pullout loads. Two types of sand viz. local tibba sand and Yamuna sand have been used in the experimental works. The Local Tibba sand was obtained from village chaudhriwas on Rajgarh Road Hisar (at a distance of 10 Km from Hisar) whereas Yamuna sand locally available was used. These sands were found to be standard poorly graded sand as per Indian Standard. The other properties of sands as determined in the laboratory are presented in Table-I

Table - I: Properties of Test Soil Sand

Sr. No.	Characteristics	Local Tibba Sand	Yamuna Sand
1	Unit Weight of Sand - γ_d	16.29 kN/m ³	16.12 kN/m ³
2	Maximum Void Ratio - e_{max}	0.90	0.95
3	Minimum Void Ratio - e_{min}	0.50	0.48
4	Specific Gravity - G_s	2.65	2.63
5	Relative Density - I_D	65.65%	64.38%
6	Effective size - D_{10}	0.12 mm	0.20 mm
7	Uniformity Coefficient - C_u	1.75	2.25
8	Coefficient of Curvature, - C_c	0.59	0.75
9	Angle of Internal Friction - Φ	36.5°	34.5°

The GAP having the best composition of pile material having the maximum density on compaction i.e. 18.19 kN/m³ has been taken and accepted for the whole process in construction of GAP systems. Table-II indicates that the best possible composition or grading of granular material that has been found as crushed stone aggregate having size as 5 mm = 40%, 2 mm to 5 mm = 40% and sand = 20% provide a density as 18.19 kN/m³. Same installation & testing procedure was adopted for all other cases. The sieve analysis has been used to select the crushed stone aggregates of different grading. The pile material was poured (by volume) in each layer followed by compacting blows spread equally in the middle layer and on the last portion respectively so that the entire material within a specific layer is compacted constantly.

Table - II: Properties of Granular Material

Sr. No	Compacted Pile Material	Length of Pile (L) (mm)	Diameter of Pile (D) (mm)	Ratio of Length to Diameter (L/D)	Density (kN/m ³)
1.	Mixed granular material in equal quantities (0.2 m – 10 mm)	425	100	4.25	17.98
2.	2 mm – 5 mm (40%), 5 mm (40%), Sand (20%)	425	100	4.25	18.19
3.	2 mm – 5 mm (50%), 5 mm (25%), 10 mm (25%)	425	100	4.25	17.85
4.	2 mm – 5 mm (40%), 5 mm (20%), 10 mm (40%)	425	100	4.25	18.00

IV. LABORATORY TEST SET-UP AND TESTING

A square steel test tank of plan dimension 1250 mm x 1250 mm and depth 1000 mm was fabricated & utilized for construction & testing of GAP system. The experimental test assembly with the testing of single GAP is shown in Fig-2. The dimensions of the tank used for deposition of sand have been selected carefully so that the behaviour of tank should not get changed. A suitable steel pullout loading frame was fabricated for the laboratory tests.

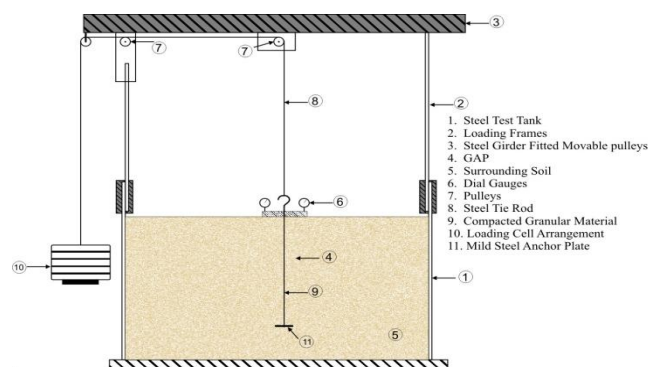


Fig.2. Experimental Test Assembly

The rainfall technique has been used for deposition of sand in the tank. For this purpose, a strainer having size 1.10 m x 1.10 m in plan having 3 mm circular holes at 10 mm spacing from each other was used for the deposition of sand.

The strainer could be hanged at any desired height using steel chains.

Sand was filled in layers of 100 mm each by keeping the same height of fall as 0.65 m for all the layers. An initial layer of sand at the bottom of tank for each test has been laid before depositing the subsequent layers of sand. A casing / hollow pipe diameter 50 mm or 100 mm was placed with steel anchor plate having the diameter slightly less than the diameter of bore hole / casing pipe allowing the steel tie rod having diameter 10 mm to pass through exactly at the middle of the pipe. The thickness of steel plate is kept as 6 mm in case of 50 mm diameter and 8 mm in case of 100 mm diameter. The subsequent layers of sand were also deposited in the tank attaining the same height of fall up to desired length of soil and the lid of casing pipe removed. Designed quantity of crushed stone aggregate sand mixture was poured into the casing pipe and compacted through the fixed number of blows to each layer. The above procedure was then repeated till the full length GAP was installed and casing pipe was pulled out. After installation of GAP system, the pile cap was placed at the top of the GAP. Flexible G.I. wire was attached to the pile top & then pullout

load was applied gradually through the loading cell arrangement. The displacements of GAP were recorded by dial gauges fixed at the top of pile cap. The same procedure was adopted for both types of sand.

V. LABORATORY TEST RESULTS

- The proposed GAP system (S) individually and on its groups installed in varying soils for 50 mm and 100 mm diameter anchor pile have been conducted to arrive at ultimate pullout capacities. The experimental investigations were carried out with varying L/D ratios as 7.00, 8.50, 9.50, 10.50 & 11.50 for 50 mm diameter and L/D ratios as 4.25, 5.75, 6.50, 7.00 and 7.25 for 100 mm diameter in Single GAP System as shown in Table - III.
- For 2 GAP & 4 GAP system, having the 100 mm diameter and keeping the same L/D ratio as 4.25 in all the tests with varying the spacing as 1.50, 1.75, 2.25, 2.75 & 3.25, the tests have also been performed in both the soils as shown in Table IV & V.
- The values of ultimate pullout capacities of various tests conducted on single and group of 2 & 4 GAP system are also presented for Local Tibba sand and for Yamuna sand of Table IV.

Table-III Summary of Laboratory Test Results – Single GAP System

S. N.	Configuration of Pile	Length (L) (mm)	Diameter (D) (mm)	L/D Ratio	Ultimate Pullout Capacity	
					Local Tibba sand (kN)	Yamuna sand (kN)
	2	3	4	5	6	7
1	Single	350	50	7.00	0.18	0.16
2	Single	425	50	8.50	0.19	0.17
3	Single	475	50	9.50	0.202	0.179
4	Single	525	50	10.50	0.207	0.18
5	Single	575	50	11.50	0.21	0.184
6	Single	425	100	4.25	0.29	0.26
7	Single	575	100	5.75	0.32	0.286
8	Single	650	100	6.50	0.33	0.29
9	Single	700	100	7.00	0.335	0.297
10	Single	725	100	7.25	0.34	0.30

Table-IV Summary of Laboratory Test Results – 2 GAP and 4 GAP System

Sr. No	Configuration of Pile	Length (L) (mm)	Diameter (D) (mm)	L/D Ratio	Spacing (S) (mm)	S/D Ratio	Ultimate Pullout Capacity	
							Local Tibba sand (kN)	Yamuna sand (kN)
1	2	3	4	5	6	7	8	9
1	2 GAP	425	100	4.25	150	1.50	0.42	0.39
2	2 GAP	425	100	4.25	175	1.75	0.48	0.45
3	2 GAP	425	100	4.25	225	2.25	0.57	0.51
4	2 GAP	425	100	4.25	275	2.75	0.59	0.54
5	2 GAP	425	100	4.25	325	3.25	0.60	0.55
6	4 GAP	425	100	4.25	150	1.50	0.76	0.74
7	4 GAP	425	100	4.25	175	1.75	0.88	0.86

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8	4 GAP	425	100	4.25	225	2.25	0.99	0.97
9	4 GAP	425	100	4.25	275	2.75	1.05	1.03
10	4 GAP	425	100	4.25	325	3.25	1.05	1.03

VI. RESULTS AND DISCUSSION:

The ultimate pullout capacities have been determined from the pullout load versus displacement curves as shown in Fig. 3, 4, 5 & 6 for all the tests. Values given in Table III listed at Sr. No. 1 to 5 represent the single GAP system having diameter 'D' equal to 50 mm with different L/D ratios of 7.00, 8.50, 9.50, 10.50 & 11.50. These values indicate that on increasing L/D ratio upto 39%, the rate of increase of ultimate pullout capacity of single GAP system having diameter equal to 50 mm was upto 14% and further increase in L/D ratio, the increase in pullout capacity was observed insignificant.

Similarly, values given in Table-III listed at sr. no. 6 to 10 show the magnitude of pullout capacity for single GAP system having diameter equal to 100 mm with L/D ratio of 4.25, 5.75, 6.50, 7.00 & 7.75 respectively. For increase in L/D ratio up to 39%, trend of increase of pullout capacity was found similar to 50 mm diameter. Thus, it is observed from the above that the pullout load displacement behavior of single GAP system is a function of diameter and L/D ratio.

Table -IV indicates the magnitude of pullout capacity for 2 GAP & 4 GAP system for both the soils. It is evident from Table-IV that with the increase of spacing, pullout capacity also increases. For 100 mm diameter 2 GAP system, the ultimate pullout capacity does not increase significantly beyond S/D ratio of 3 and 4 GAP system having the same diameter 100 mm, the ultimate pullout capacity does not increase significantly beyond S/D ratio 2.75.

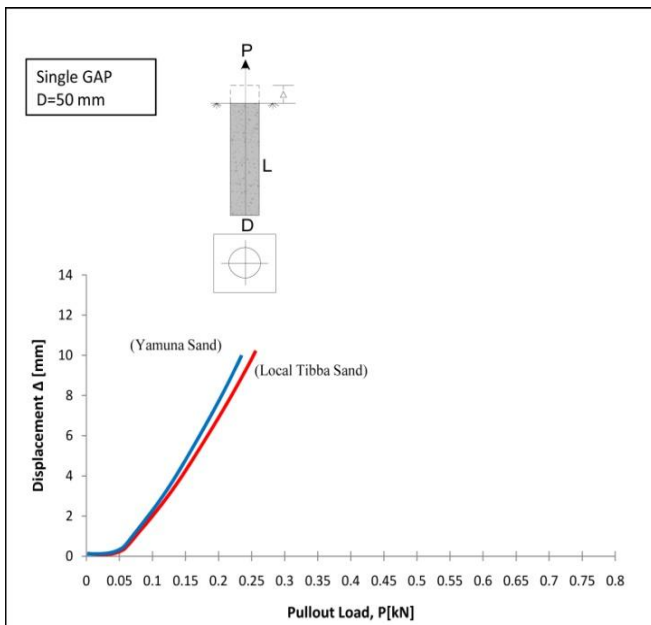


Fig. 3 Pullout Load - Displacement Curve of Single GAP Diameter 50 mm

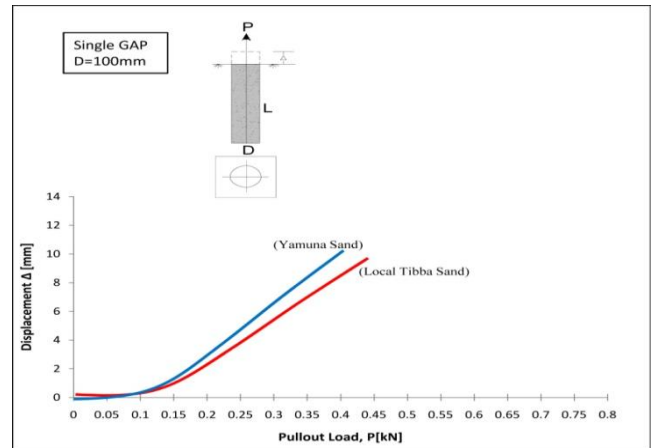


Fig. 4 Pullout Load - Displacement Curve of Single GAP Diameter 100 mm

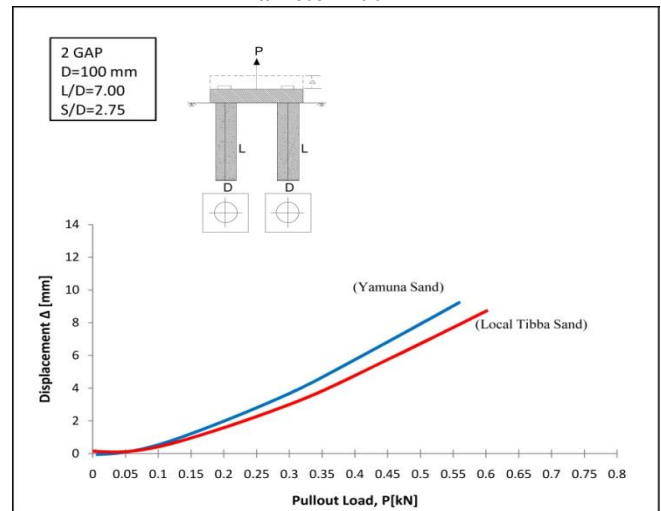


Fig. 5. Pullout Load - Displacement Curve of 2 GAP Diameter 100 mm

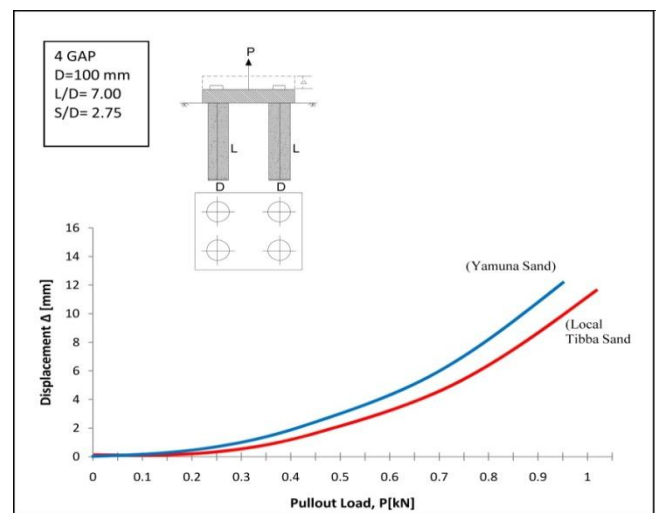


Fig. 6. Pullout Load - Displacement Curve of 4 GAP Diameter 100 mm

VII. CONCLUSIONS

The major conclusions are:-

1. For increase in L/D ratio upto 39%, the ultimate pullout capacity of single GAP system increases to the extent of 14% for 50 mm diameter and 100 mm diameter. Further, increase in pullout capacity was insignificant for increase in L/D ratio beyond 39%.
2. The pullout load displacement behaviour of single GAP is influenced by the diameter & L/D ratio. However, the effect on ultimate pullout capacity is considerably less for greater L/D ratio.
3. For 2 GAP & 4 GAP systems of 100 diameters, the ultimate pullout capacity does not increase significantly beyond S/D ratio of 3.00 and 2.75 respectively, so spacing of 2.75 to 3.00 D is recommended.
4. The ultimate pullout capacity was more in case of Local Tibba sand than Yamuna sand on account of higher relative density for all the cases (Single, 2 & 4 GAP system).

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