Finite Element Analysis of Pull-out Behaviour of Granular Pile-Anchors in Expansive clay Beds

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ABSTRACT

Expansive Soil (ES) usually referred to as Black cotton soil is found within the central a part of India and covers around 20 % of mainland area. Expansive soils are soils that have large volume modification associated with changes in water contents. The fact that expansive soils are a major engineering downside makes their study a very important research aspect due to the accruing cost concerned in terms of economic loss once construction is undertaken Granular pile anchors GPA are one among the recent innovative foundation techniques devised for mitigating the issues expose by swelling clay beds. This analysis of pull-out behaviour of granular pile anchor (GPA) in expansive clay bed is with two cases. First case is to test single pile of different lengths and diameters to check the pull-out behaviour and in second case 5 piles are arranged in group in such a way to check the pull-out behaviour of only central pile while other four piles are not tested for pull-out. In both the cases we are pulling out on single pile but the difference is in both the cases is that we are checking the behaviour of single pile with no surrounding piles but in second case piles are arranged in group in such a way that four surrounded piles are spaced at a centre to centre spacing of 2D (D=dia of pile) in square pattern while checking the pull-out behaviour of centre pile. The pull-out behaviour of piles in every case is compared with experimental results as already done in experimentation. This analysis is done by using PLAXIS 3D software.

Keywords*: - Expansive Soil, Granular pile anchor (GPA), Plaxis 3D, Swell, Shrinkage.*

INTRODUCTION

Expansive soils are exceedingly hazardous soils and cause harm to structures established in 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. As a result of the substitute swelling and shrinkage of these soils, structural building structures, for example, establishments, holding dividers, asphalts, waterway beds and linings established in these soils get seriously split, bringing about a colossal money related misfortune. A huge number of dollars in

USA, a large number of pounds in Kingdom and crores of rupees in India are gone through consistently to address the harm brought about by these soils. The perils brought about by these soils everywhere throughout the world have been recorded. In India they are called black cotton soils and are prevalent in the conditions of Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra and in parts of Tamil Nadu and Uttar Pradesh.

The first to have explored the problems associated with expansive soils was the U.S. Bureau of Reclamation (USBR) in 1938. From that point forward, broad research has been completed everywhere throughout the world to recognize expansive soil to decide their swelling attributes, to advance techniques for distinguishing the issues related with them, and to create answers for these issues.

An expansive soil can be distinguished by different methods, for example, by the mineralogical piece, relationship of swelling qualities with record properties and direct estimation of swelling attributes. The most dependable of these procedures is the immediate estimation of swelling qualities. Montmorillonites, kaolinites and illites are the three noteworthy kinds of earth minerals. Of these three kinds of minerals, montmorillonite contributes most to the volume change conduct of expansive mud. Among the more typical systems utilized for the assurance of the mineralogical organization are Differential Thermal Analysis (DTA), compound investigation, X-Ray Diffraction (XRD) and Electron Microscope Resolution (EMR) (EMR) which, nonetheless, are exceptionally refined. A less complex technique for recognizing expansive clay is by utilizing its index properties. Endeavours have been made to anticipate the swelling conduct of expansive clays by building up different connections with their index properties. Clay content, liquid limit, shrinkage limit, plasticity index, shrinkage index and action are among the index properties utilized for the connections. It is seen that structures established in expansive soils grow unattractive breaks because of exchange swelling and shrinkage. The issue is increasingly serious with delicately stacked structures as the heaviness of the superstructure isn't adequate to oppose the swelling weight of the fundamental expansive soil and, subsequently, heave occurs during amid rainstorm. This is later trailed by shrinkage of the soil in summer. A definitive outcome would be unattractive and risky cracking of structures. The substitute swelling and shrinkage in interchange stormy and summer seasons result in the misery of basic components like grade beams, columns, flooring and walls.

CONCEPT OF GAP SYSTEM

The GAP structure is a cost-effective and operational technique developed for refining the shear-strength assets of the soil and enhancing the uplift capacity soils. The uplift resistance of the GAP system is mainly derived from friction mobilized along the pile–soil interface and the self-weight of the pile-footing assembly. This friction is mainly generated because of the anchor system, and it provides resistance to the upward movement of the foundation. In the construction of GAP, a borehole is drilled in the expansive soil (figure 1) and then a casing pipe is inserted to that borehole to prevent lateral movement of surrounding soil. After inserting the casing pipe, an anchored rod of suitable thickness which is further connected to an anchor plate at one end, is then inserted into the borehole. After this, the borehole is filled with required quantity of backfill by compacting it in layers of same thickness so that required density can be ensured. The other end of anchor rod is connected to footing plate which is placed at top of granular pile. This arrangement is helpful in resisting the uplift forces.

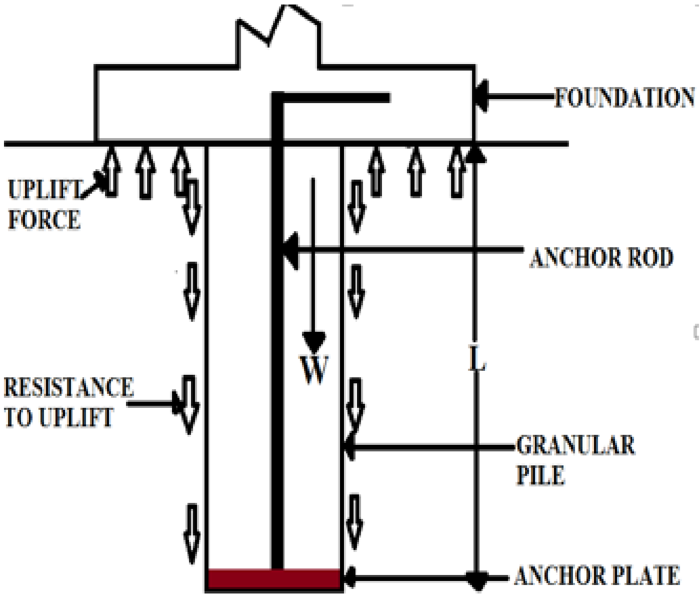

Figure 1: Granular anchor pile and forces acting on it.

FINITE ELEMENT METHOD

The finite element method (FEM), is a numerical methodology for resolution issues of engineering and mathematical physics. Typical drawback areas of interest embrace structural analysis, heat transfer, fluid flow, mass transport, and electromagnetic potential. The analytical resolution of these issues usually needs the answer to boundary price issues for partial differential equations. The finite part methodology formulation of the problem ends up in a system of algebraical equations. the tactic approximates the unknown operate over the domain.to unravel the matter, it subdivides an oversized system into smaller, less complicated elements that are referred to as finite elements. the easy equations that model these finite elements are then assembled into a bigger system of equations that models the whole problem. FEM then uses variational ways from calculus of variations to approximate Associate in Nursing by minimizing an associated error function.

PULL-OUT BEHAVIOUR OF GRANULAR PILE ANCHOR MODELLING AND ANALYSIS

A prototype model of granular anchor pile of various lengths and diameters was modelled in PLAXIS 3D software for analysing uplift capability. The soil round the outer boundary of GAP was thought-about as expansive soil that extends to a depth of 1000 millimetre below the bottom surface. A soil layer was modelled using borehole choice in PLAXIS 3D by taking appropriate set up dimensions. The set-up dimensions of soil layer were taken as 1000mm x 1000mm and depth was kept as 1000mm. Single granular pile was modelled in PLAXIS 3D software by exploitation poly-curve and extrudes choices. The modelling of anchor plate and footing was finished the plate components. The node to node part was wont to model the anchor rod of the GAP system to tie the anchor plate, footing plate and GAP along. For plate elements and node to node anchor, a linear elastic model was thought-about. Mohr-Coulomb criterion was used for outlining the connection between granular pile and clay. The modelling of volume components was done using ten-node tetrahedral components and therefore the plate components were modelled exploitation six-nodded triangular components. Generation of mesh plays an awfully important role within the calculation of correct values just in case of finite part methodology and thus, coarse global finite element mesh was used for the analysis of modelling. For the single pile, a circular footing equal to that of the diameter of anchor plate was thought-about at the top. The modulus of elasticity of pile was kept constant throughout the analysis. The modulus of physical property of soil was varied from 4MPa to 10MPa. The effect of water table was kept constant throughout. To analyse the uplift behaviour of the GAP system, the results were plotted graphically taking upward movement (mm) on X-axis and the corresponding uplift capacity (N) on Y-axis. An upward displacement of 10% of pile diameter at the top at the centre of GAP was applied in all the cases and corresponding uplift was measured.

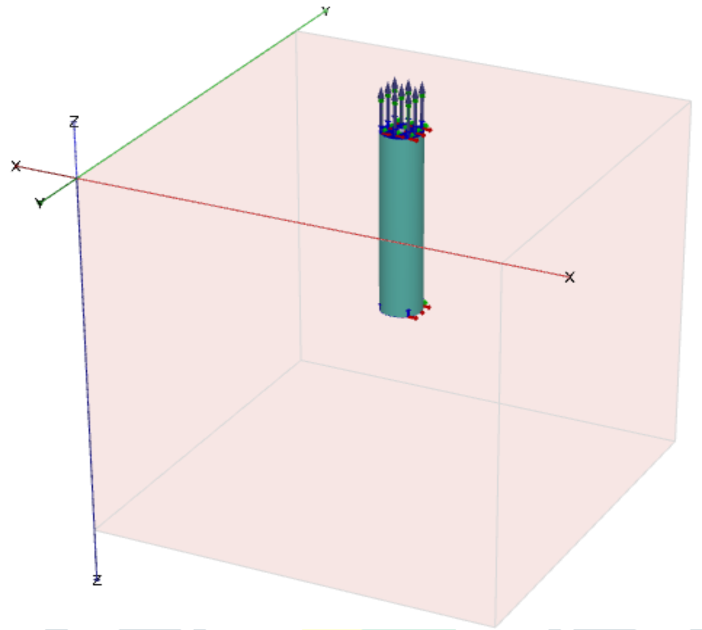

Figure 2: Modelling of single GAP

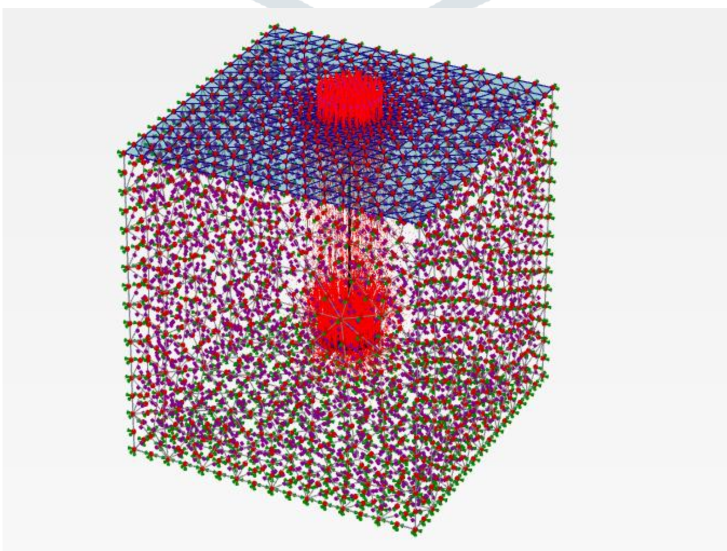

Figure 3: Arrow Diagram of deformation

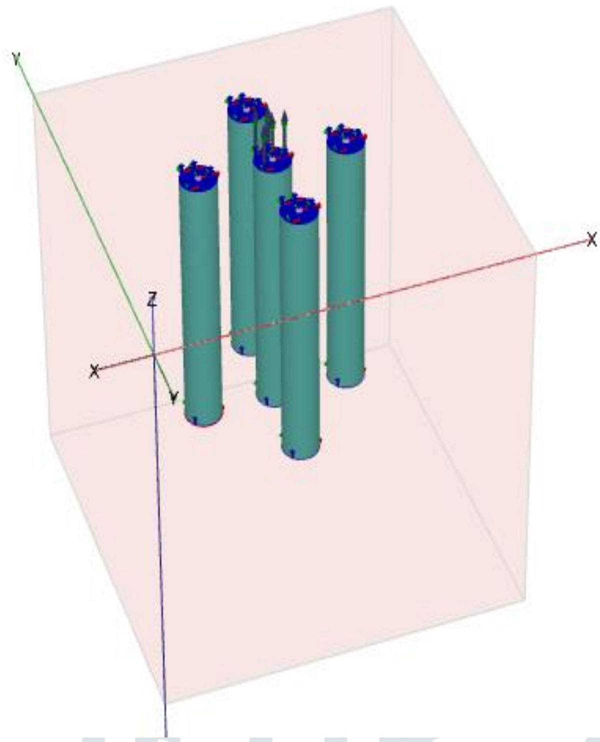

Fig.4 Modelling of Group Piles l/d Ratio=6.66

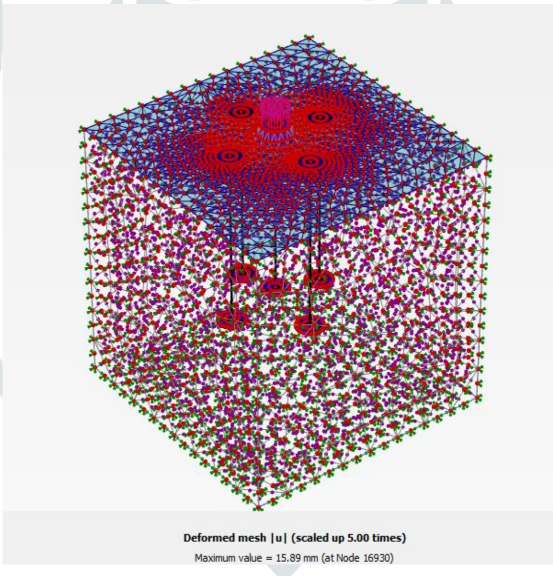

Fig 5. Deformed mesh of group of piles

MATERIAL USED

The material properties of soil, GAP and structural components and parameters of GAP, footing utilized in the numerical study has been tabulated in table 1 and table 2, severally, as below:

Table 1: Properties of soil, GAP and structural element

Material and its Properties	Clay	GAP	Anchor Plate	Footing Plate
$\gamma_{unsat,}$ kN/m^3	17	22	-	-
$\gamma_{sat,}$ kN/m^3	19	24	-	-
Cohesion (c), kN/m^2	25	0	-	-
Angle of shearing resistance (Ø)	0	36	-	-
Poisson Ratio (μ)	0.40	0.30	0.15	0.15
Modulus of Elasticity (E), MPa	4,6,8,10	11	2 x 10^5	2 x 10^5

L/D Ratio of GPA'S

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**

RESULTS AND DISCUSSIONS

The results of pull-out tests on single GPAs and a group of six GPAs ar mentioned in terms of fallback load-upward movement behaviour. to review the pull-out behaviour, the results ar premeditated graphically by showing the applied uplift load kN on the y axis and the corresponding upward movement mm on the x axis. Fig. shows the pull-out load-upward movement curves for single GPAs of a homogenous diameter of 200 mm with lengths varied as 500, 750, and 1000 millimetre. The curves indicate the influence of length of the GPAs. All the GPAs were tested up to failure. The curves conferred within the figure show that the failure pull-out load increased with increasing length of the gpa. The curves conjointly indicate that, in any respect stages of loading, the upward load needed to be applied on the gpa to cause a given upward movement magnified with increasing length of gpa. However, it may be determined that, up to an applied uplift load of four kN, there was no significant upward movement within the GPAs. this can be as a result of the weight of the gpa about 0.8 kN and also the shear resistance mobilized within the downward direction on the cylindrical pile-soil interface about 6 kN because of the anchorage

The uplift load needed to cause associate upward movement of 25 mm within the gpa was 9, 12, and 14 kN for GPAs of lengths 500, 750, and 1000 mm severally. This shows that, once the length of the gpa was exaggerated from 500 mm to 750 mm and 1000 mm, the share increase within the uplift load needed for associate upward movement of 25 mm was 37.3% and 59.5% respectively.

Fig. 7 shows the pull-out behaviour of GPAs of 1000 mm length but of diameters variable as 100, 150, and 200 mm. The curves in the figure replicate the result of diameter of GPAs. All the curves in the figure show that the failure fallback load raised with the increasing diameter and weight of the gpa. The applied upward load was determined to extend with increasing diameter of the GPA in any respect stages of the test because the resistance to uplift raised with increasing surface area of the pile-soil interface. Fig. 8 shows the variation of failure pul-out load kN with the l/d ratio of the gpa. The curves present the information for various lengths of the GPAs. For a given l/d ratio, the failure retreat load increased with increasing length of the gpa. this is attributed to the increase within the fallback resistance with increasing extent of the GPA. Similarly, for a given length of the gpa, the failure pull-out load raised with increasing diameter or decreasing l/d ratio. Increasing the diameter will increase the surface area and pile anchor weight and consequently uplifts resistance and ends up in increased failure pull-out load

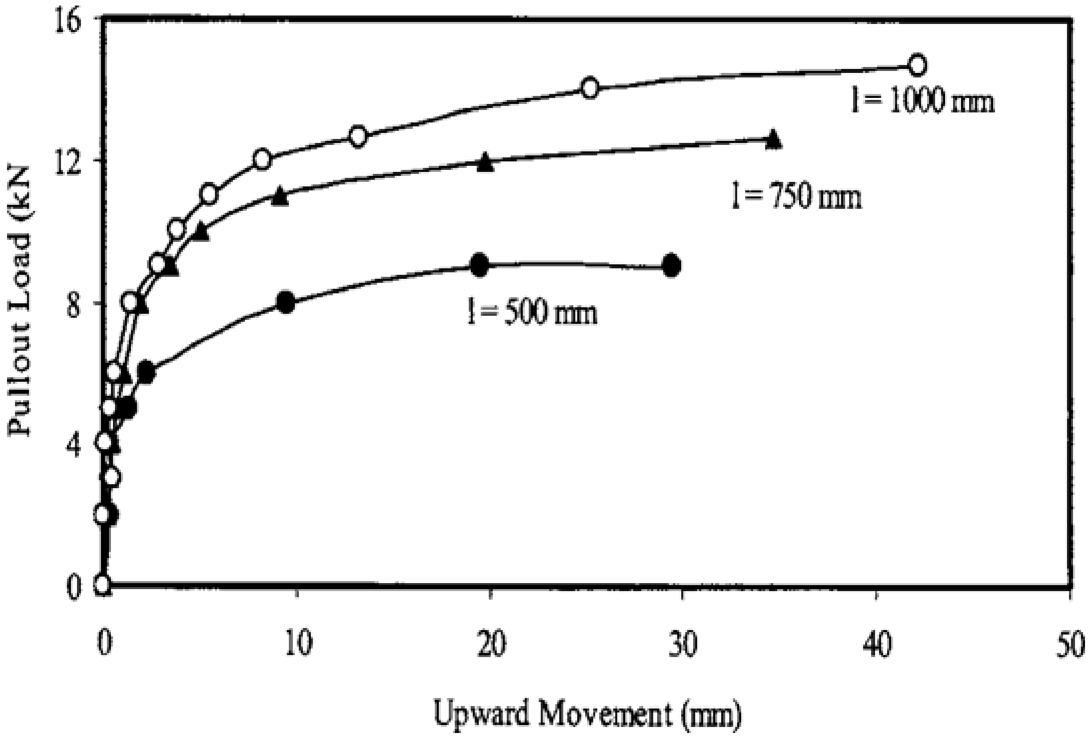

Fig. 1. Pull-out behaviour of gpa of diameter 200 mm

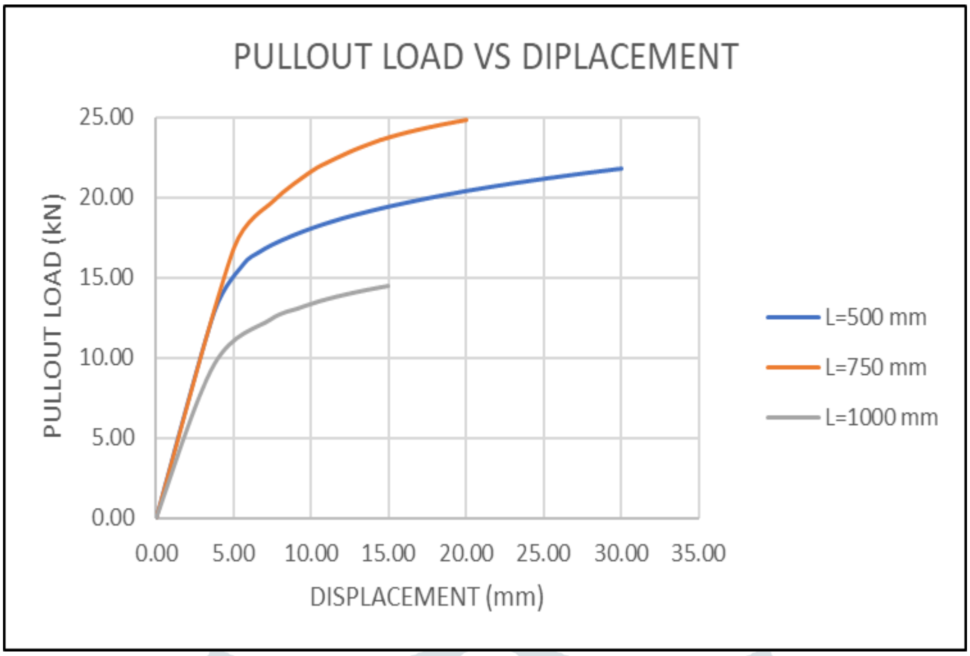

Fig 2. Pull-out behaviour of GPA of 1000 mm length

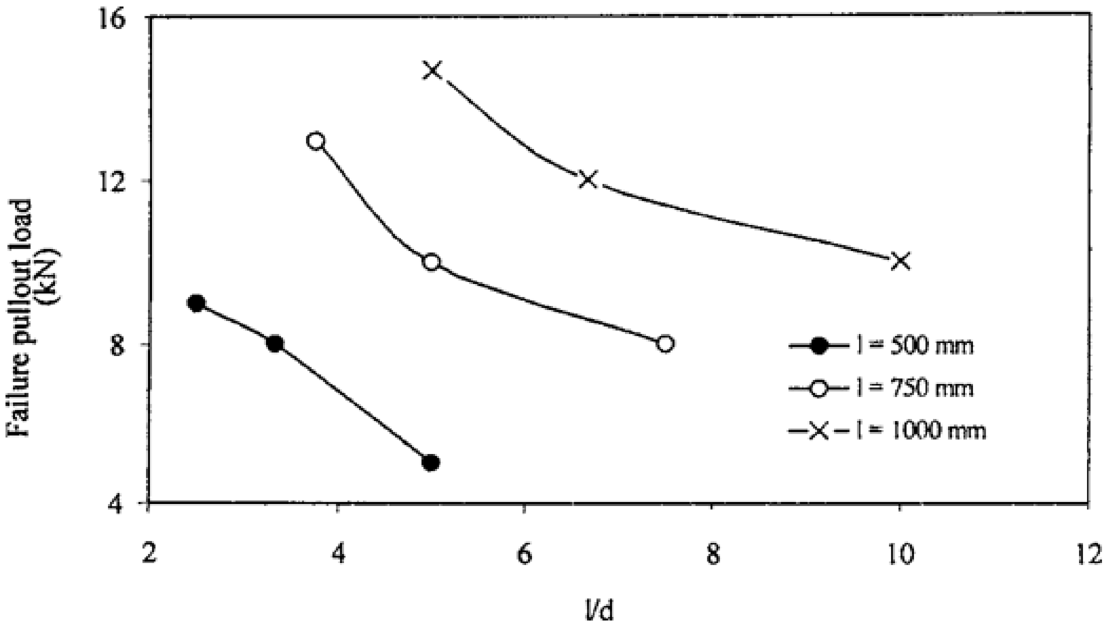

Fig 3. Variation of failure pull-out load with *l*/*d* ratio of granular pile anchor

GRANULAR PILE ANCHOR PULLOUT BEHAVIOUR IN GROUP

A gpa of length 1000 millimetre and diameter 150 millimetre was tested under pull-out load when single and once under group result. The group gpa test was delineated within the previous sections. Fig.4 shows, by comparison, the pull-out behaviour of the gpa once tested single and once tested below group result. The gpa below group result resulted in magnified uplift load for a given upward movement compared to it of one gpa tested. this can be due to the influence of the GPAs within the group on the test GPA. As heave of the expansive clay bed was reduced considerably on the installation of group of GPAs, that conjointly act as tension members, there wasn't abundant reduction within the dry unit weight of the expansive clay bed. As a result, the pile-soil interface friction for the group would be way more than within the case of the single gpa. This conjointly resulted during a higher lateral swelling pressure confining the test gpa radially than within the case of a single GPA. there's an arching action between the GPAs, which offers additional resistance to uplift. The uplift load needed to be applied on the gpa to cause associate upward movement of 25 millimetre was 14.7 kN once tested below group effect as against an uplift load of 12.25 kN for a similar quantity of upward movement of twenty-five millimetre when tested single. This indicated a share increase of 25.22% within the applied uplift load once the standard was tested below group result. The failure pull-out load of the gpa once tested under group was 20 kN as against a failure pull-out load of 14kN for the gpa once

tested single, indicating associate improvement of 55% within the failure pull-out load.

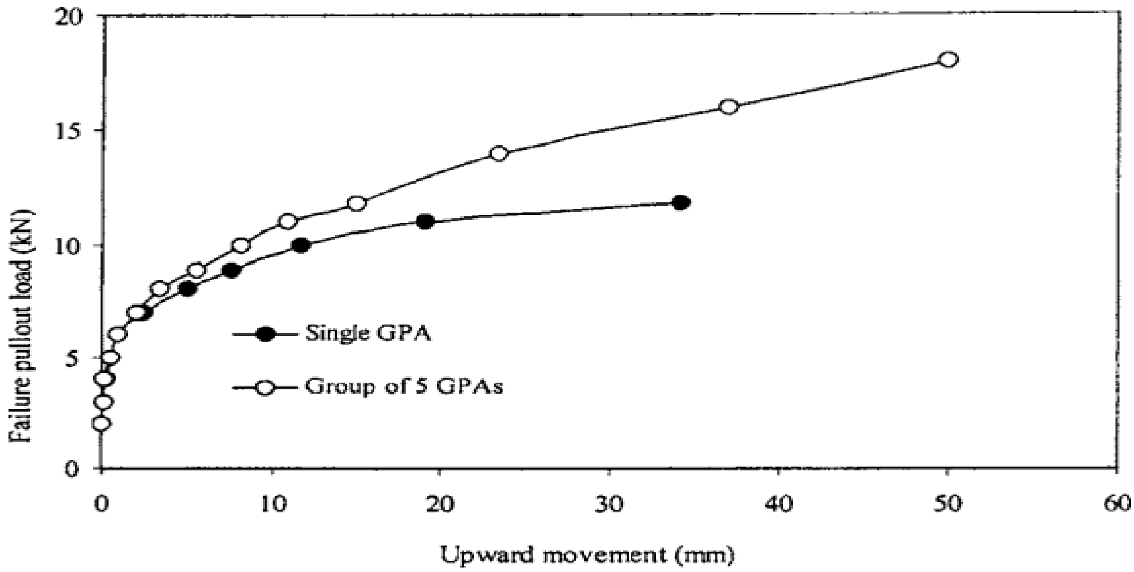

Fig. Pull-out behaviour of single granular pile anchor and group of granular pile anchors diameter150 mm and length1000 mm

EFFECT OF CHANGE IN VALUE OF INTEREFRENCE (R)

PLAXIS usually takes the value of interference as rigid while setting it manually we can change this value from constant to lesser or higher values. After changing the values from 0.5 to 1 result in higher pull out load respectively for the two cases. Fig 5 shows the effect of change in value of R.

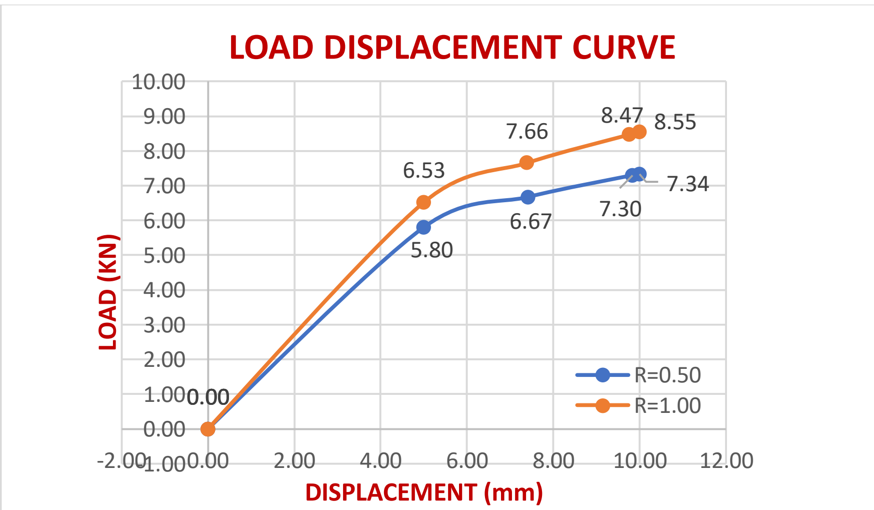

Fig 5. Effect of change in value of R from 0.5 to 1.0 for gpa of l/d ratio =5

CONCLUSIONS

PLAXIS 3D, FEA was performed exploitation to review the performance of the GAP system in expansive soil. the results of key parameters, like elastic modulus of the expansive soil, change in the value of interference (R), position of water table on the uplift capability of GAP were examined. The load-displacement response and ultimate pull-out capability of the GAP were additionally analysed. Supported to the current study, the subsequent conclusions are made

The upward load needed to be applied on the gpa to cause a given upward movement magnified with increasing length of GPA. For GPAS of length 500, 750, and 1000 mm, the uplift load needed to cause an upward movement of 25 mm in the gpa was nine, 12, and 14 kN, severally. When the length of the gpa was magnified from five hundred to 750 and 1000 mm, the percentage increase within the uplift load needed for an upward movement of 25 mm was 33.3 and 55.5%, respectively. The uplift load magnified with increasing surface of area of the gpa.

With increasing extent of the pile-soil interface resulting upon increase within the diameter the uplift load or failure retreat load magnified.

For a given l/d quantitative relation, the failure retreat load magnified with increasing length of the gpa. The failure pull-out load for GPAs of l/d quantitative relation of 5 was severally 5, 11, and 15 kN, when length of measure modified as five h, 750,500 and100 mm. Similarly, for a given length of the measure, the failure retreat load magnified with decreasing l/d quantitative relation. Increasing diameter increases the surface area and consequently the uplift resistance and ends up in magnified failure pull-out load. The failure pull-out load of gpa of length 1000 mm was 11, 13, and 15 kN where the l/d ratio was ten, 6.67, and 5, severally or diameters a hundred, 150, and 200 mm. once the length or diameter of the measure will increase, the pull-out load of the measure additionally.

The granular pile anchor underneath the impact of a group of 4 GPAs resulted in hyperbolic uplift load for a given upward movement as compared to that of the gpa once tested as a single pile anchor. The failure pull-out load of the gpa once tested underneath group was 19.5 kN as against a failure pull-out load of 14 kN for the gpa when tested single, indicating a 50% improvement within the failure pull-out load.

For l/d ratio of 5After changing the values of interferences from 0.5 to 1 it resulted in higher pull out load respectively for the two cases.

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