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EXPERIMENTAL STUDY GRANULAR PILE ANCHOR FOUNDATION

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Abstract:* Mostly the lightly loaded structures founded in expansive soils develop cracks owing to alternate shrinkage and swelling as the weight of the super structure cannot counteract the swelling pressure. Hence the cost of foundation to be laid in these soils must be in suitable proportions to the low cost of the super structure. Therefore in this thesis, it is attempted to study the efficacy of the Granular pile anchors in reducing heave of foundations, as natural stone is used for their installation ,granular piles may be quite cost-effective. The foundation has been anchored to a granular pile through a mild steel rod fastened to a mild steel plate of diameter equal to that of the pile at the bottom of the pile. This is called granular pile anchor. When the soil swells and lifts the foundation, heave is reduced because of the shearing resistance developed between the soil and pile along the cylindrical surface of the pile. Heave tests are conducted to measure the reduction in heave due to installation of granular piles. Simultaneously pull-out tests are conducted to measure the frictional resistance offered by the granular pile. The study i have made is just an attempt but, still there is a lot of scope to conduct research in this area in a full scale study in the field.

***Keywords:* Soil, Granular, swell potential, swelling pressure, heave tests, pullout tests**

I. INTRODUCTION

Expansive soils swell on inhibition of water during the monsoon, reduce in density, and become slushy. But, in dry seasons, they shrink because of evaporation of water, and become hard due to increase in density. This trend of the soils tends to decrease with depth (Katti, 1978). The volumetric deformation in these soils is attributed to seasonal variations in the ground water profile resulting in changes in the moisture content (Rees and Thomas, 1993). During summer polygonal shrinkage cracks appear near the surface , extending to a deep of about 2m,indicating a high potential for expansion and contraction (Mon , 977). The depth of cracking indicates the depth of active zone in which significant volume changes occur, which is defined as the thickness of the soil in which moisture deficiency exists (Snethen, 1980). The entire stratum of expansive soil in the field may not be active. As most soils do not respond quickly to climatic changes, the depth of active zone is greater than the depth of seasonal moisture fluctuation (Jennings, 1965; Snethen, 1980). Katti (1978) observed that, in Indian expansive soils, the depth of active zone is confined only to the top 1.0 to 1.2 m, and that there will not be any change in dry density corresponding to changes in moisture content. According to Mohan (1977), however, significant ground movement occurs even up to a depth of 3.5 below ground level. Ramaswamy (1990) observed that, in certain areas, the depth of active zone might extend beyond 3.5m also.

II. MATERIALS AND METHODS

MATERIALS USED

In this section, the details pertaining to soil, granular used in this investigation are given.

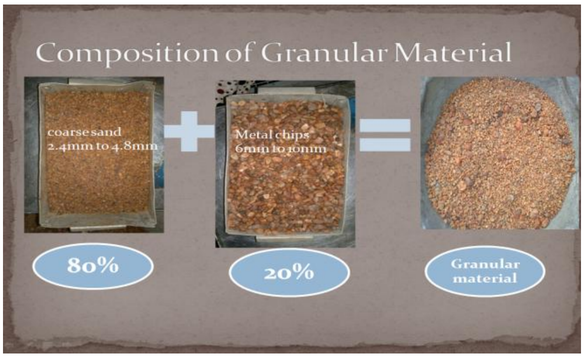
Soil

Expansive soil sample have been collected from Punadhipadu near Kankipadu in Krishna district of Andhra Pradesh. All the samples have been collected from an average depth of 1.5m to 2.0m.Only remolded soil samples have been tested, as it would be possible to control the initial conditions like the dry density and moisture content in that case. The soil sample has been air-dried, powdered and passed through 4.75mm sieve. The soil fraction passing 4075mm sieve has been kept in a hot – air oven at a temperature of 1050c to 1100 c for 24 hours. It has been then allowed to cool down to room temperature and compacted in a consolidation ring. Initial water content, W (%): 20,Initial dry unit weight, d : 15KN/m3. The index properties of the soil are given in the Table. The 'soil' is classified as 'CH' as per I.S. classification (I.S. 1498:1970) indicating that it is high plastic clay.

Index properties of soil

Specific Gravity	2.73
Grain size distribution:	
Gravel (%)	0
Sand (%)	0
Silt (%)	28
Clay (%)	72
Consistency limits:	
Liquid limit	65
Plastic limit	20
Shrinkage limit	10
Plasticity index	45
I.S.Classification	CH
Free swell index(FSI)	64
Degree of expansion based on FSI (I.S.:1498-1970;Revised Edition, 1982)	High

GRANULAR PILE The granular material that has been used for the installation of the piles is mixture of 20% metal chips whose particle size ranges between 6mm and 10mm and 80% coarse sand with size varying between 2.4mm and4.8mm. It has been found from pilot studies that, at this proportion gave the largest difference between maximum and minimum void ratios



PHYSICAL PROPERTIES OF THE GRANULAR PILE MATERIAL

Specific gravity: the specific gravity (G) of the granular pile material has been determined using a pycnometer (I.S.2720, part III-section 1, 1980).

Natural void ratio: the maximum and minimum void ratios of the granular pile material have been first determined. The natural void ratio (e o) of the granular pile material has been calculated by fixing the relative density (D r) at which the granular pile is to be compacted, from the equation,

$$D_r = (e_{max} - e_o)/(e_{max} - e_{min})$$

Where E max' and E o are the maximum, minimum and natural void ratios of the granular pile material respectively.

III. METHODOLOGY

COMPACTION OF THE SOIL AND INSTALLATION OF GRANULAR PILE

For the proposed tests, metal test tank of size 300mm * 300mm *600 mm have been used.

The various variables studied are as under:

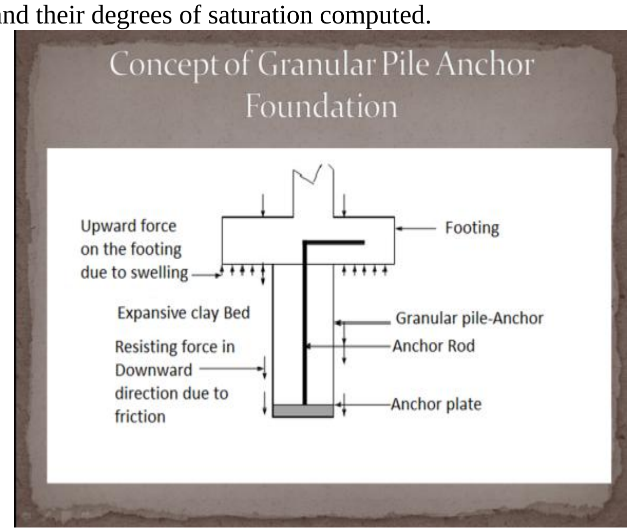
Placement conditions of the expansive soil: the water content, W, of the soil has been kept constant at 20%, & the dry unit weight, $\gamma_{d,}$ as 15 KN/m^3, has been chosen because it has been found to be the minimum water content at which swelling would be fairly high and, at the same time, the soil could be compacted with ease. Installation of granular pile: the following are the variables studied in respect of granular piles in this investigation:

Length, Lp (mm) : 300

Diameter, D p (mm): 30, 40 and 50

Surface footing: in all the tests, a square mild steel plate of size 100mm * 100mm has been used as the surface footing.

Method of compaction of soil and granular pile: As shown in fig 3.7 & fig 3.8 a sand layer, 250mm thick, has been laid at the bottom of the test tank and leveled with a rammer .mild steel box have been pushed into it for a depth of about 30 to 40mm so as to form a square box at a uniform distance of 10mm from the sides of the tank .this gap of 10mm all round has been filled with sand to from vertical sand packing for saturating the soil quickly. A casing pipe of diameter equal to that of the granular pile has been pushed vertically in to the bottom sand layer exactly at the centre. A mild steel rod of 8mm diameter, with a mild steel circular plate of diameter equal to that of the granular pile fastened to it has been inserted vertically into the casing pipe so that the plate would be on the top of the bottom sand layer. The weight of the expansive soil required has been divided into a convenient number of equal parts, each part having to be compacted to the required height ensuring that the desired unit weight has been attained. Each part of the soil has been carefully poured in the tank such that it does not enter the casing pipe, and compacted with a rammer. The height of the compacted layer has been checked. Similarly, the weight of the granular pile material required for the particular relative density has also been divided into equal parts, each part having to be compacted with a rod to the required height ensuring uniform relative density. For instance, after compacting the expansive soil surrounding the casing pipe to a height of 100 mm, a part of the pile has been slowly withdrawn to a certain height, less than that of the compacted soil layer. The pile material has been compacted with a rod. This ensures the development of full friction between the soil and the pile. The mild steel box used to form the all round vertical sand packing have also been withdrawn to a certain height. Sand has been poured in to the 400mm gap and poked with a rod to maintain continuity of sand packing. The process of compacting the soil and the pile and of installing sand packing has been continued till the soil and the pile have been compacted to the desired unit weights and reaches the same height at the end. When the compaction is over, the metal sheets and the casing pipe have been withdrawn completely. A sand layer, 25mm thick, has been laid over the surface of the compacted to the top end of the mild steel rod with the help of nuts. A dial gauge with its spindle resting on the foundation plate has been fixed to the tank with dial gauge reading to zero, water has been added continuously from the top till complete heave has occurred on saturation of the expansive soil. The point of saturation is understood to have reached. When there has been no further increase in the dial gauge reading. For this purpose, a dial gauge reading – time plot has been made each time, and equilibrium has been assumed to have reached when the curve becomes nearly flat of horizontal, and the heave has been determined. After complete heave has occurred, the water content of the soil samples collected from various depths has been determined, and their degrees of saturation computed.



Pull-out capacity of granular pile

The swelling soil causes an uplift force on the foundation when foundations are anchored to granular piles, the uplift force is resisted by the friction offered by the granular pile, and width is measured by conducting pull – out tests on granular piles embedded in expansive soil.

For this test, the surface footing has not been provided. A pulley has been fixed to a horizontal bar at the top of the test tank as shown in fig3.15 the top end of the anchor rod of the granular pile has been made fastened to the hook is passed over the pulley . The other end of the wire has been fastened to a loading hanger. A dial gauge has been fixed to read the upward movement of the pile. The loads have been applied on the hanger in the increments of 10% of the ultimate value and the corresponding dial gauge reading has been recorded. The test has been continued till failure has occurred.

EFFECT OF SPACING OF GRANULAR PILE ANCHORS

To study the effect of spacing of granular pile anchors, two granular pile anchors have been installed at different spacings in expansive soil and the heave measured and compared with that measured when only single pile is installed. in this test , compaction has been done as already explained, but with two granular piles. The initial dry unit weight and water content of the soil are 15 KN/m3 and 20% respectively. The diameter and length of the piles have been 30mm and 300mm respectively. The spacing has been varied in terms of the diameter, D p of the pile as 2Dp and 2.5Dp. After compaction, two individual footing plates have been saturated and heave measured at different radial distances from the centers of the piles

IV. RESULTS

Heave test

Only expansive soil

Time (Hrs)	Centre		Edge		Swell Potential (%)
	Div	Mm	Div	mm	
0.5	144	1.44	51	0.51	0.48
1	204	2.04	73	0.73	0.68
2	307	3.07	120	1.20	1.02
3	352	3.52	173	1.73	1.17
19	598	5.98	288	2.88	1.99
20	600	6.00	290	2.90	2.00
21	602	6.02	295	2.95	2.006
22	604	6.04	297	2.97	2.013
23	604	6.04	299	2.99	2.013
24	604	6.04	300	3.00	2.013
40	630	6.30	315	3.15	2.1

40mm Dia granular pile

Time (Hrs)	Centre		Edge		Swell Potential (%)
	Div	mm	Div	mm	
0.5	19	0.19	22	0.22	0.063
1	90	0.90	43	0.43	0.3
2	95	0.95	178	1.78	0.316
3	100	1.00	180.5	1.805	0.33
17	250	2.50	183	1.83	0.833
18	273	2.73	186	1.86	0.91
19	278	2.78	191	1.91	0.926
20	293	2.93	194.5	1.945	0.976
21	323	3.23	197	1.97	1.076
22	375	3.75	322	3.22	1.25
23	428	4.28	322	3.22	1.43
24	453	4.53	325	3.25	1.51

50mm Dia granular pile

Time (Hrs)	Centre		Edge		Swell Potential (%)
	Div	Mm	Div	mm	
0.5	24	0.24	22	0.22	0.08
1	39	0.39	43	0.43	0.13
17	173	1.73	178	1.78	0.57
18	178	1.78	180.5	1.805	0.59
19	178.5	1.785	183	1.83	0.595
20	179	1.79	186	1.86	0.597
21	182	1.82	191	1.91	0.636
22	183.5	1.835	194.5	1.945	0.65
23	187	1.87	197	1.97	0.657
24	215	2.15	322	3.22	1.07
38	215	2.15	322	3.22	1.07
39	215	2.15	325	3.25	1.08

Granular pile of 60mm Dia

Time (Hrs)	Centre		Edge		Swell Potential (%)
	Div	mm	Div	mm	
0.5	81	0.81	67	0.67	0.27
1	99	0.99	101	1.01	0.33
2	155	1.55	135	1.35	0.52
20	176	1.76	140	1.40	0.58
21	180	1.80	143	1.43	0.6
22	183	1.83	145	1.45	0.61
23	186	1.86	150	1.50	0.62
24	195	1.95	160	1.60	0.65
40	200	2.00	170	1.70	0.67

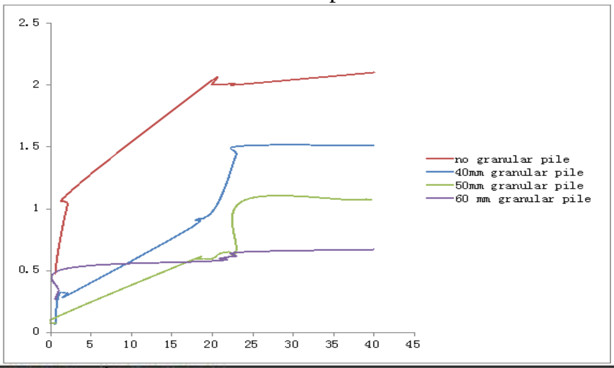
Heave reduction factor

Test	Swell Potential	Heave Redution Factor
Only Expansive Soil	2.1%	-
40mm granular pile	1.51%	28%
50mm granular pile	1.08%	48.57%
60mm granular pile	0.67%	68.09%

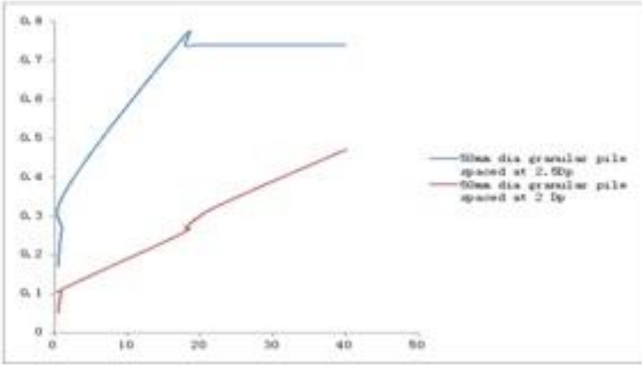
Pull out capacity

Tests	Pull out capacity
Only Expansive Soil	7.5Kg
40mm granular pile	28 Kg
50mm granular pile	32 Kg
60mm granular pile	37 Kg

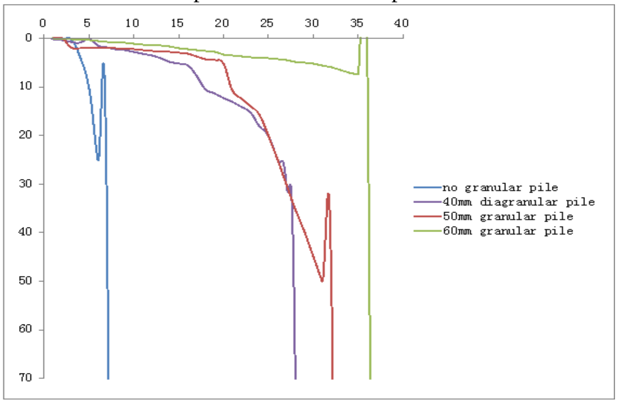
Graph 1: Variation of swell potential with time for untreated soil and soil treated with various pile diameters



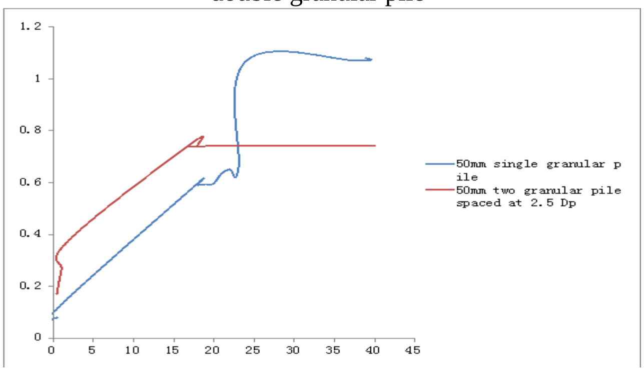
Load (Kg)	Displacement							
	Without Granular Pile		40mm Granular Pile		50mm Granular Pile		60mm Granular Pile	
	Div	Mm	Div	mm	Div	mm	Div	Mm
1	2	0.02	15	0.15	0	0	3	0.03
2	10	0.1	40	0.40	0	0	10	0.10
3	24	0.24	63	0.63	190	1.9	23	0.23
4	345	3.45	91	0.91	195	1.95	33	0.33
5	1035	10.35	120	1.20	200	2	43	0.43
6	2500	25	146	1.46	209	2.09	56	0.56
7	3000	30	180	1.80	210	2.1	72	0.72
8	Failure	300	216	2.16	212	2.12	85	0.85
9			244	2.44	218	2.18	97	0.97
10			275	2.75	225	2.25	110	1.10
11			312	3.12	234	2.34	125	1.25
12			356	3.56	250	2.5	140	1.40
13			412	4.12	273	2.73	150	1.50
14			477	4.77	278	2.78	170	1.70
15			524	5.24	293	2.93	195	1.95
16			562	5.62	323	3.23	218	2.18
17			772	7.72	375	3.75	236	2.36
18			1050	10.50	428	4.28	251	2.51
19			1140	11.40	453	4.53	271	2.71
20			1235	12.35	522	5.22	328	3.28
21			1310	13.10	1062	10.62	350	3.50
22			1410	14.10	1250	12.5	369	3.69
23			1520	15.20	1400	14	396	3.96
24			1800	18.00	1570	15.7	408	4.08
25			2000	20.00	1970	19.7	416	4.16
26			2500	25.00	2500	25	428	4.28
27			3000	30.00	3000	30	452	4.52
28			6500	65.00	3500	35	476	4.76
29			failure	failure	4000	40	498	4.98
30					4500	45	524	5.24
31					5000	50	550	5.50
32					6500	65	600	6.00
33					failure	failure	650	6.50
34							700	7.00
35							749	7.49
36							790	7.90
37							Failure	Failure



Load-displacement curve for pull-out test



Comparison of swell potential for single granular pile to the double granular pile



V. CONCLUSIONS

The following are the conclusions that can be drawn from the study of the efficacy of granular pile anchors as foundation alternatives in expansive clays

- Heave of expansive clays can be reduced significantly by the installation of granular pile anchors. This can be attributed to the frictional resistance offered by the granular piles.
- The swell potential of an expansive soil bed decreases with increase in the surface area of the pile. For a given surface area, the increase of the pile diameter results in greater reduction of swell potential than increase in the pile length of the bulging of the granular pile increases with increase in the diameter of the granular pile .
- Expansive soils improved with granular pile anchors adjust quickly to changes in the moisture content because of the higher permeability of the

granular pile.

- When 2 or more granular pile anchors are installed in an expansive soil, heave of the ground will be reduced more than when a single granular pile anchor is installed. The heave decreases with the decrease in spacing between the piles. When the spacing is equal to 2 times the diameter, the heave is reduced to an insignificant value.
- The load carrying capacity of expansive soil is increased with the improvement of ground by installation of granular pile anchors

VI. FUTURE SCOPE OF GRANULAR PILE ANCHOR FOUNDATION

In this project an attempt is made to study the efficacy of granular pile anchors by conducting experiments in the laboratory i.e., through experimental study. The experimental study conducted and the results obtained were clearly discussed in the previous chapters in chapter 2 and 4.m It was clear that the pull-out capacity increases for the expansive clay installed with granular pile when compared to that of the untreated soil i.e., soil with no granular pile. And from heave tests, heave significantly reduces with the installation of granular pile. Swell potential decreases with increase in surface area of granular pile. Swell potential decreases when two or more granular piles are installed at a spacing inn between 2 to 3 times the diameters of the pile.

From the results obtained it was experimentally proved that the granular pile anchors are efficient in reducing heave and in increasing the pull-out capacity. The study we have conducted is just an attempt but, still there is a lot of scope to conduct research in this area if full scale study is conducted in the field. Full scale study can be conducted in the field by laying 2 or 3 footings side by side under which granular pile anchors are installed. By conducting a load test similar to the pull-out test conducted in laboratory the efficiency of the granular pile anchors can be completely studied. The granular pile anchors were proved to be very cost effective. So these granular pile anchors can be used as an effective foundation technique for lightly loaded structures if a full scale study is conducted.

