Anchor Piled Footings – An Alternative Foundation Technique in Expansive Soils

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***Abstract*—A search for alternative foundation systems in expansive soils has been continued since their problems were recognized all over the world. Despite the availability of a good number of remedial techniques, their adoptability and effectiveness under varied geographical and climatic conditions have remained questionable. The present paper discusses the field investigations on the recently promulgated technique of anchor piled footings in expansive soils. These studies have revealed that the granular anchor piles exhibit promising pullout capacity even under fully wet condition compared to conventional concrete piles. The heave of model footings provided with granular anchor piles decreased by about 73-93% while for footings provided with conventional concrete piles the heave value is decreased by 40 - 75%. It is felt from this study that the above technique of anchor piled footings can be an effective alternative to conventional pile foundations in expansive soils.**

***Index Terms*— Expansive soil, Granular anchor piles, Concrete anchor piles, Heave measurements, Pullout capacity.**

I. INTRODUCTION

Foundations resting on expansive soils are subjected to cyclic swell-shrink movements due to alternate wetting and drying [1, 2, 3]. These foundation movements cause severe distress to the structures resting on these soils, especially the lightly loaded ones like single storied dwellings, pavements, canal linings, pipe lines, retaining walls etc. [4, 5, 6]. The annual cost of damage caused by these soils to the civil engineering structures amounts to billions of dollars all over the world [7, 8, 9]. To counter the heave of footings resting on these soils, several foundation techniques were put forth by the engineering community like sand cushion, CNS layer, chemical stabilization, moisture control, pile foundations and under-reamed pile foundation. Most of these techniques are being practiced with varied degree of success over a wide a range of climatic variation and soil properties.

Under-reamed pile foundation gained prominence all over the world, which is based on the principle that it anchors down the structures in a stable zone of soil bed [10].

Though this foundation technique has become popular in India, it is considered to be cost prohibitive, especially for low cost structures, where the cost of the structure itself is low [11, 12]. Some researchers [13, 14] have reported the difficulty in bulb formation and instead, suggested an increase in pile length into the stable zone. Small diameter piles popularly known as micropiles have been increasingly used for various geotechnical applications like underpinning of foundations and to resist tensile loads. It has been felt by researchers that these piles can be tried as a potential alternative to under-reamed piles [15, 16]. Similarly, some investigators [9, 17, 18] felt that the granular piles could be used to counteract the damage potential of footings resting on expansive soils, although they were originally developed to deal with the soft ground problems. However, a conventional granular pile cannot resist any uplift load coming on to it due to its discrete particulate behaviour. Hence, the discrete particles are unified by providing a central anchorage member connected to the foundation footing and is named as granular anchor pile.

In the present investigation, an attempt is made in the field to study the effectiveness of granular anchor piles in reducing the heave of footings resting on them and compared with those of conventional concrete piles. The footings with the connected tension piles are designated as "Anchor Piled footings". Pullout load tests were carried out to understand their pullout capacity upon which their effectiveness to control heave of footings depends. Tests were carried out both in unsaturated and in fully wet conditions of soil mass to estimate the loss of pullout load capacity upon wetting of soil mass.

II. EXPERIMENTAL PROGRAMME

A. Heave Studies

In order to study the relative influence of concrete and granular anchor piles on heave of shallow footings, different lengths and diameters of the respective piles were connected to 1.5 m x 1.5 m size of footings cast at 0.6 m depth in the outside campus of NIT.-Warangal, (Fig. 1). The range of soil properties at this site are: Liquid limit = 70 - 110%, Plastic limit = 26 - 30 %, Shrinkage limit = 15 %, Clay content = 35-48 %, Swell potential = 12 - 28 % and Swell pressure = 200 – 440 kPa. The degree of expansion of soil bed is increasing with depth at this site [19].

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Fig. 1: Location of footings

The following systems of piled footings are used for heave study.

(i) Granular Anchor Piled Footings

For this system of footings, the required size of boreholes were made in the footing pits and the precast concrete pedestals with designed reinforcement were placed in the boreholes (Fig.2) and the annular space between the pedestal and borehole walls was filled with granular material (2 parts of aggregate : 1 part of sand) in lifts. Each lift of material was thoroughly rammed using a 30 kg annular hammer devised for the purpose till negligible set per blow was recorded. After forming the pile, the pedestal reinforcement was connected to the footing reinforcement to unify the discrete granular material in resisting the uplift loads. Subsequently, the footings were cast using M 15 grade concrete

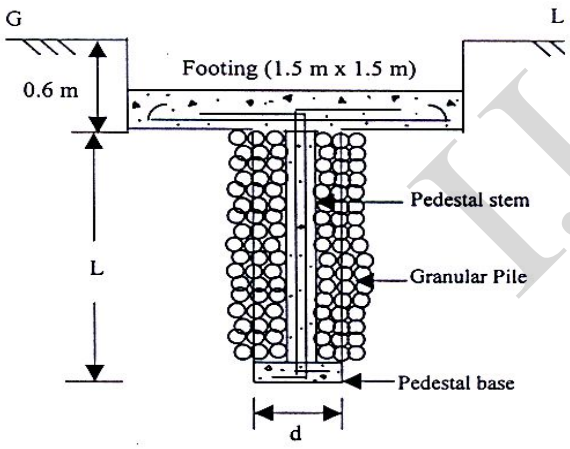


Fig.2: Granular Anchor Piled Footing

(ii) Concrete Piled Footings

The concrete piles were cast by making the required length and diameter of boreholes in the footing pits. The reinforcement was provided as per the estimated uplift load on the footing. The piles and footings were cast using M 15 grade concrete after connecting the pile reinforcement to that of footing (Fig.3).

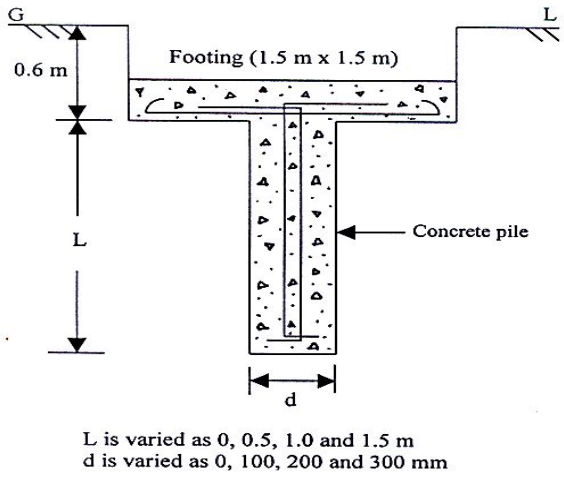


Fig.3. Concrete Piled Footing

B. Pull out Load Studies

The systems of granular anchor and concrete piles used for this study are shown in figures 4 and 5 respectively. 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.

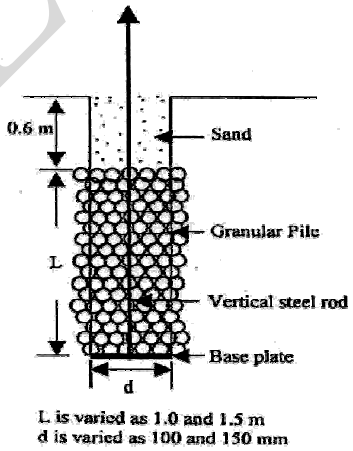


Fig.4: System of Granular anchor piles

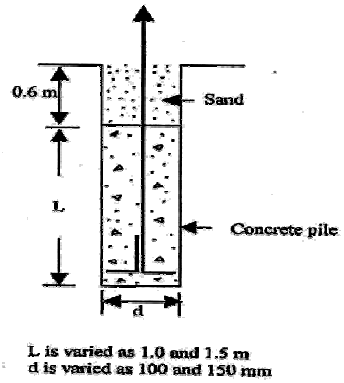


Fig.5: System of Concrete piles

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The pull-out loads were applied using a specially devised rectangular frame for the purpose (Fig.6). As can be seen from this figure that the central steel rod of the pile was tightly connected to one of the shorter legs of the rectangular frame by bolts and a steel beam passing through the frame was supported at the ends. A hydraulic jack of the required capacity was placed centrally on the steel beam which in turn is connected to a proving ring tied to the frame. When load is applied by hydraulic jack, the frame is lifted-up rising the pile connected to it. The piles are pulled-out at the rate of 0.75 mm/min and the load is recorded. Testing is continued till maximum load is obtained.

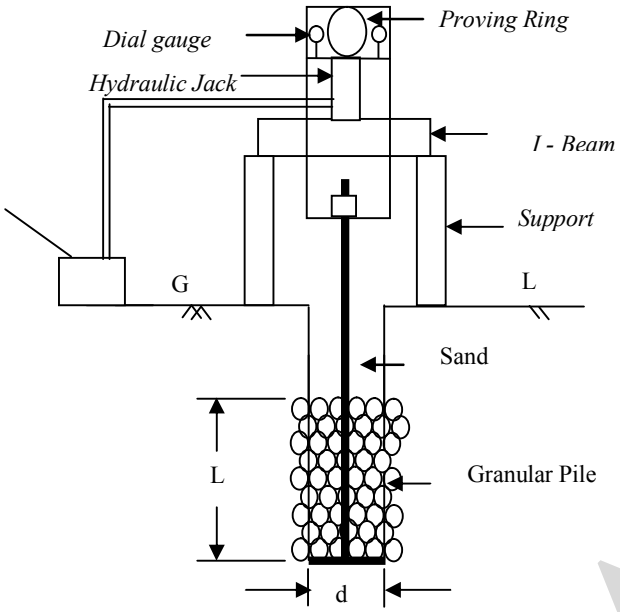


Fig.6: Details of Field Pull-out Tests

The location where the pull out studies were carried out is shown in fig. 7.



Fig. 7: Location of Piles for Pullout Tests

III. RESULTS AND DISCUSSIONS

A. *Heave studies*

The heave-time plots for footings with concrete tension piles are shown in Figs. 8 and 9. It can be seen from these plots that the heave of footings increased with time and attained maximum values at about 40 to 60 days. Fig. 8 indicates that the heave of footings decreases with increasing length of tension pile. Similarly, heave reduction is also observed with increasing diameter of tension piles (Fig.9). It can further be observed that the heave of piled footings beyond 40 days is nominal whereas the untreated footing required about 60 days to attain maximum heave. The heave of piled footings is cut down by 40 - 75% compared to the footing without any pile.

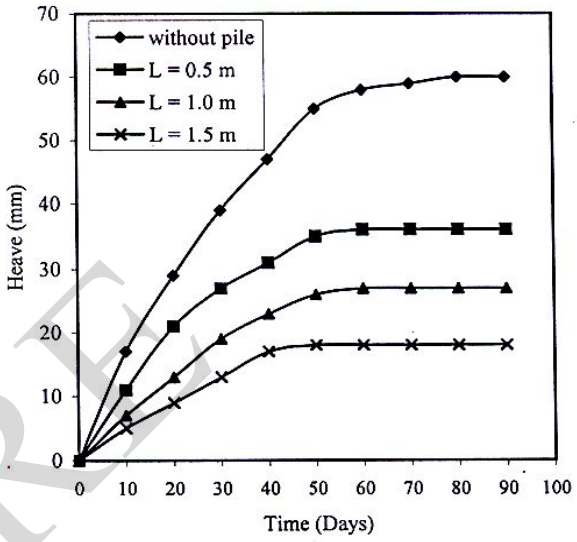


Fig.8: Heave-Time Plots for 1.5 m x 1.5 m Size of Footing Provided with Different Lengths of 200 mm Diameter Concrete Piles

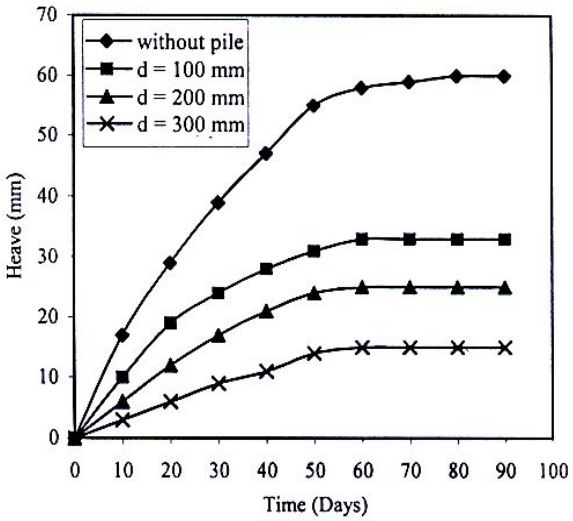


Fig.9: Heave-Time Plots for 1.5 m x 1.5 m Size of Footing Provided with Different Diameters of 1.0 m Long Concrete Piles

Figs. 10 and 11 show the heave-time plots for footings connected to granular anchor piles. It can be seen from these figures that the heave of footings is cut down by 73% – 93%

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due to provision of granular anchor piles. The heave of footings is decreasing either with increasing length of pile or its diameter. The maximum heave of granular anchor piled footings is obtained within 30 to 40 days as against 60 days for unpiled footing. The substantial reduction in heave of piled footings could be attributed to the partial restraint provided by these micropiles to the initial heave that enable the soil to develop self stabilising cohesive bonds with controlled heave.

Among the two types of piles, granular anchor piles are found to be superior to concrete piles in controlling heave. This could be supported by the fact that the granular fill of these piles is thoroughly rammed which enable the particles to interact and interlock with the sides of borehole, whereas in concrete piles, the concrete is filled and compacted by simple rodding.

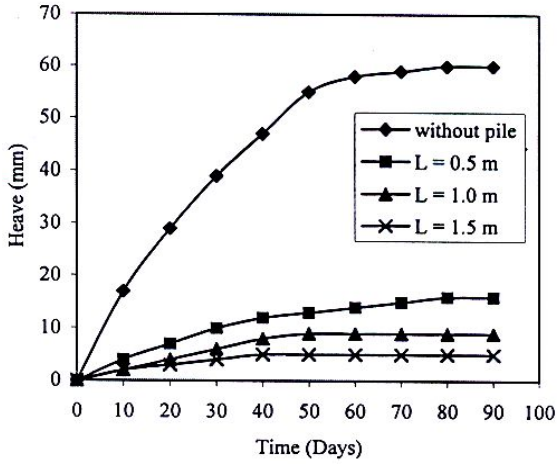


Fig.10: Heave-Time Plots for 1.5 m x 1.5 m Size of Footing Provided with different lengths of 200mm diameter Granular anchor piles

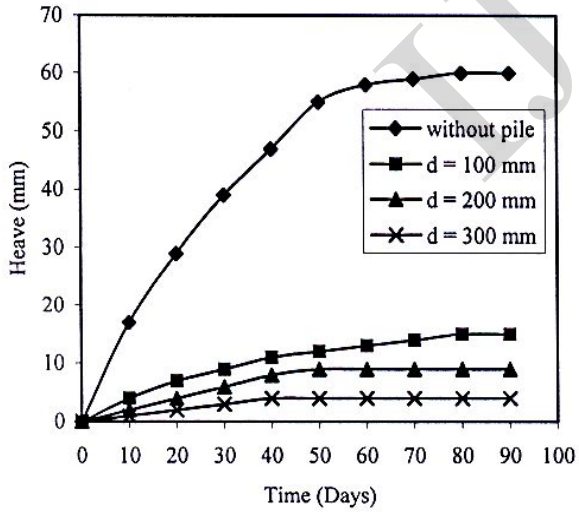


Fig.11: Heave-Time Plots for 1.5 m x 1.5 m Size of Footing Provided with Different Diameters of 1.0 m Long Granular Anchor Piles

B. Pull out Load Studies

Figs. 12 and 13 show the pull-out resistance versus deformation plots for different sizes of concrete and granular anchor piles. The pull-out resistance of concrete piles in unsaturated state is ranging from 70 – 95 kPa whereas for granular anchor piles, it is about 200 - 220 kPa.

The pull-out resistance of concrete and granular anchor piles is decreased by about 30% and 25 % respectively upon saturation. The pull-out resistance of granular anchor piles is more than twice the value for concrete piles both in saturated and unsaturated states. The high value of pull-out resistance for granular anchor piles could be attributed to thorough packing and lateral displacement of granular fill due to ramming. Such lateral displacement of granular fill develops close interaction and interlocking with the sides of borehole; which is questionable in case of concrete piles. Though a marginal variation in pull-out resistance of different sizes of concrete piles is recorded in unsaturated state, the size effect is negligible in saturated state for both the types of piles

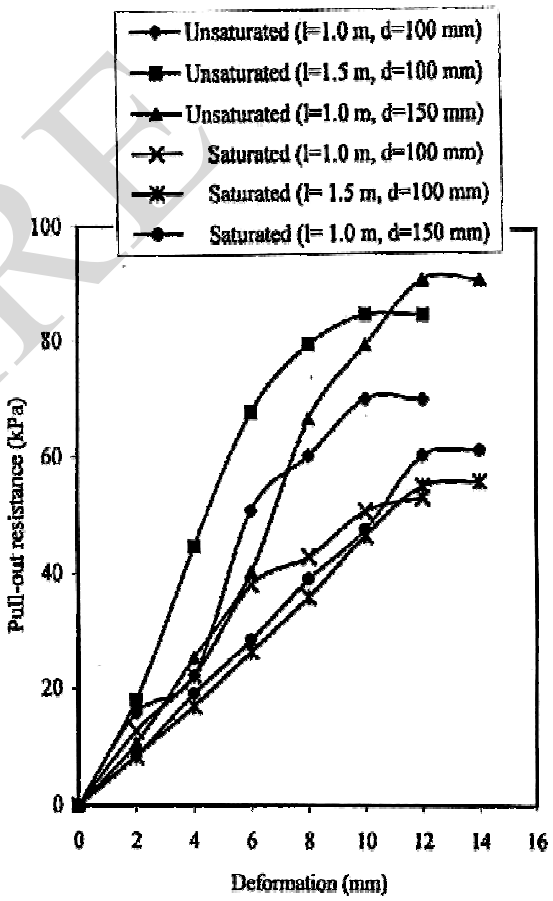


Fig. 12: Pull-out Resistance Vs Deformation Plots for Different Sizes of Concrete Tension Piles

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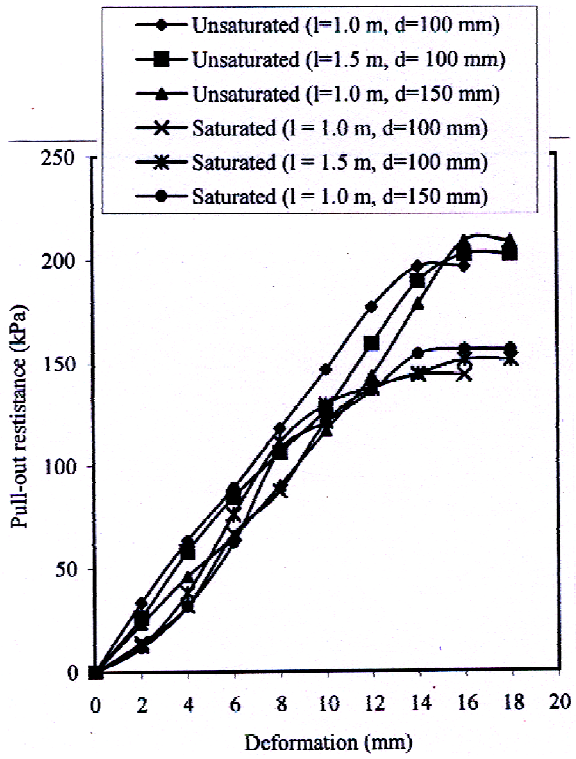


Fig. 13: Pull-out Resistance Vs Deformation Plots of Different Sizes of Granular Anchor Piles

IV. CONCLUSIONS

The following conclusions are drawn based on the test results and observations made during this study.

1. The maximum heave of piled footings is reached in a shorter time period than unpiled footing.
2. The maximum heave of footings provided with concrete piles is cut down by 40 to 75% whereas for the footings provided with granular anchor piles, it is decreased by 73 – 93%.
3. The pullout resistance of concrete and granular anchor piles in saturated state is about 60 and 170 kPa respectively.
4. The anchor piled footings could be promising alternative foundation system in expansive soils in view of the simplicity in construction and their effectiveness.

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