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RESEARCH ARTICLE OPEN ACCESS

Quantifying Settlement Characteristics in Granular Pile Anchor Foundation with Diverse Footing Shapes

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Abstract:

Expansive soils challenge the stability of several civil engineering structures. Due to the presence of Montmorillonite clay mineral, they have inherent property of swelling and shrinking up on wetting and drying. Settlement occurs when expansive soil swells or shrinks, causing severe damage to foundations, buildings, roadways, and retaining structures. In such soils, it is necessary to construct a foundation that avoids the adverse effects of settlement. The use of granular pile is one of the effective and efficient methods of ground improvement because of its ability in improving the bearing capacity and reducing the settlement of different soft soils. The clayey soil chosen for this study is from Punchakkari and granular soil used is obtained locally, which are used in this project. Steel rods & Anchor piles of lengths 10, 20, 30 and 40 cm were used respectively. To find the settlement, plate load test were conducted on circular and square footing with pile and GPA of varying lengths. From the results, optimum length of pile & GPA is obtained as 30 cm. Percentage of settlement decreased after conducting the test with pile for circular & square footing is obtained as 37.75% & 22.28% respectively. Percentage of settlement decreased after conducting the test with GPA for circular & square footing is 45.41% & 44.8% respectively. While comparing the results, GPA with circular footing is more effective in reducing settlement than square footing.

Keywords —***Granular anchor pile, settlement, optimum length***

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I. INTRODUCTION

Soils that expand when they become wet and contract when they get dry are known as expansive soils. Geotechnical engineers frequently deal with heave and shrink while building a foundation over these soils. Variations in moisture content can lead to volume changes in expansive soils, which can sometimes seriously harm lightweight structures built on top of them, including pipelines, sidewalks, airport pavement, and residential buildings. In 1973, the projected annual damage attributed to the expanding soil was approximately 2.3 billion dollars. By 2009, that amount had risen to 13 billion dollars in the United States, surpassing the cost of damages resulting from floods, hurricanes, tornadoes, and earthquakes.

Geotechnical construction is an important method to improve certain properties of the soil and prevent structural settlement and includes Granular Pile Anchor (GPA) foundations and pile foundations. It includes materials like sand and gravel which are responsible for load transfer to deeper layers of soil with better bearing capacity. Piles consist of a traditional pile made out of the materials such as concrete or steel, but it carries out a similar function but in a different way regarding transfer of load and settlement.

The shape of the footings will have a significant impact on the performance of the foundations. Two of these types of the footings are circular and square footings which fall under two categories regarding the nature of the soil footing pile interaction and the effect of settlement. Curved footings also transmit loads more equally and hence at a more predictable rate as compared to square footings. Square bases also have high stress concentration on the corners and differential settlement causing unequal loadings.

This project aims to to demonstrate the variation in settlement between granular pile anchor and conventional pile for circular and square footings. It will contrast the loads on the foundations, stress concentrations of the foundations, settlements on these foundation types and shapes of the footings. It is therefore very important to compare foundation design, Structural stability, Differential settlement while constructing a house. These differences help engineers to make better decisions when selecting the appropriate foundation type and the shape of the footing since the kind of foundation design to adopt depends on geotechnical conditions and structural requirements.

II. OBJECTIVE

The objective of this work is to study the settlement of pile and GPA in various lengths. The main objectives are to study the following:

- To analyze the settlement behavior of pile foundation with varying lengths.
- To analyze the settlement behavior of granular pile foundation with varying lengths.
- To find out the optimum length of pile.
- To compare the settlement of soil with pile and granular anchor pile foundation.

III. MATERIALS AND METHODOLOGY

The materials used for the study were clayey soil, sand, circular and square footings, steel plate, model pile, anchor pile of varying lengths, and also modelcircular test tank. The clayey soil for the study were collected from Punchakkari, Thiruvananthapuram, Kerala. Sandy soil used in this project is locally available sand which is used for the construction purposes and was collected from Karipur, Nedumangad in Trivandrum. The footings, piles, anchor pilesof required dimensions were purchased. A model circular test tank is constructed in the laboratory inorder to make the soil bed.The details of the materials, methodology andexperimental setup are explained in the following sections.

A. Materials

The various materials required for the study are listed below:

1) ***Clayey Soil:*** *The clayey soil for the study were collected from Punchakkari, Thiruvananthapuram, Kerala. The soil sample was collected in sacs and air dried. The engineering properties of the soil were determined by conducting basic geotechnical procedures specified by relevant IS codes of practice. While using for the plate load test optimum moisture is added to achieve the field condition.*

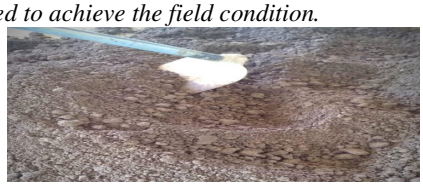

Fig. 1 Clayey Soil

TABLE I
PROPERTIES OF SOIL

Properties	Result
Specific gravity	2.009
Liquid Limit	74.7%
Plastic Limit	38.50%
Plasticity Index	36.5
Unconfined Compressive Strength	23.23kN/m^2
Optimum moisture content	25%
Maximum dry density	1.36 gm/cc
Percentage of clay	31.24%
Percentage of silt	39.6%
Percentage of sand	29.10%

2) ***Sandy Soil:*** *Sandy soil used in this project is locally available sand which is used for the construction purposes and was collected from Karipur, Nedumangad in Trivandrum. Sandy soil was collected in sacs and it is air dried to conduct the tests to find basic properties. While using for the plate load test optimum moisture is added to achieve the field condition.*

Fig. 2 Sandy Soil

TABLE II
PROPERTIESOF SANDY SOIL

Properties	Result
Specific gravity	2.616
Percentage of sand	98.98%
Percentage of gravel	0.7%
Percentage of silt and clay	0.32%
Uniformity co-efficient, Cu	3.35
Co-efficient of Curvature, Cc	1.11
Watercontent	3.59%
Percentage of bulking	12.36%
Optimum moisture content	8%
Dry density	1.36 g/cc
Percentage of voids	25.19%
bulk density(loose state)	1.96 g/cc
bulk density(dense state)	2.137 g/cc
Cohesion	0.03 Kg/cm^2
Angle of internal friction	27^0

3) ***Model Circular Footing:****Model steel circular footing of 25 cm diameter is used for the study. The size provided was decided considering the size of the tank used for conducting plate load test*

Fig. 3 Circular Footing

4) ***Model Square Footing:*** *Model square footing of 25 x 25 cm dimension is used for the study. The size provided was decided considering the size of the tank used for conducting plate load test.*

Fig. 4 Square Footing

5) ***Circular Tank:*** *A tank is constructed in the laboratory in order to perform the plate load test according to IS 1888 : 1982. The circular tank having diameter 600 mm and height 700 mm*

Fig. 5Circular Tank

6) ***Model Piles:*** *Steel rods of diameter 10 mm with varying lengths of 100 mm, 200 mm, 300 mm and 400 mm were used as model pile in this study.*

Fig. 6 Model Piles

7) ***Model Anchor Piles :*** *Model anchor piles of diameter 10 mm with varying lengths of 100 mm, 200 mm, 300 mm and 400 mm were used in this study.*

Fig. 7 Model Anchor Piles

8) ***Steel Plate:*** *Steel plate of 5 cm diameter is placed at the bottom of anchor pile to enhance the pile's performance by reducing settlement*

Fig. 8 Steel Plate

B. Methodology

The soil is being mixed with water at OMC thoroughly and it is then filled in the circular tank. It is being filled in layers where it is being compacted and levelled.Plate load test were conducted on piles and GPA of varying lengths with different footing shapes.According to IS 1888: 1983, Plate Load Test was conducted and the results were obtained. The flow chart of methodology is given below:

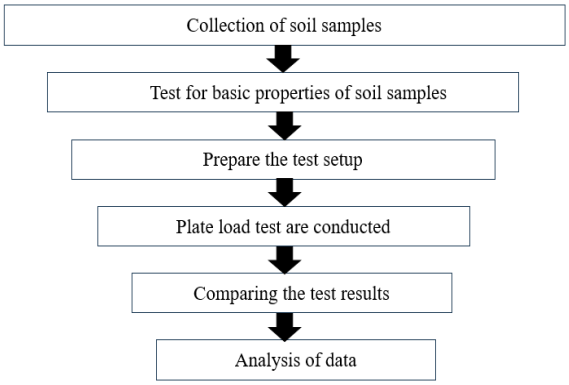

Fig. 9 FlowChartofMethodology

C. Experimental Setup

Plate load tests were conducted on pile and GPA of varying lengths (10, 20, 30 and 40 cm) to determine the settlement on both circular and square footings. A mild steel circular plate of dimension 25 x 1 cm were used as circular footing and mild steel square plate of 25 x 25 x 1 cm were used as square footing. The loads are applied using hand operated-mechanical jacks of capacity 50kN. The applied loads are measured using load dial gauge of capacity 50kN. The settlements are measured using two dial gauges each of 0.01mm sensitivity kept diametrically opposite to each other. The load is applied in equal increments to the model footings & settlements are recorded simultaneously from both the dial gauges. From both square & circular footings, a set of optimum conditions were obtained.

Intially, tests were performed on soil without a pile using circular and square footings. After that plate load test were conducted on pile of varying lengths. Following this, tests were carried out on granular anchor piles of varying lengths with circular and square footings. After these tests, the settlement for each scenario was computed.

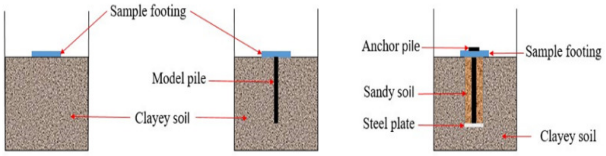

Fig. 10 SchematicDiagramofLoadingSetup

IV. Results And Discussion

A. *Test on Circular Footing andSquare Footing with Pile Foundation*

After the soil gets filled in the tank, circular footing was placed inside without piles and the plate load test was conducted. The settlements were noted and the load - settlement curve was evaluated.The load – settlement curves for without piles on square footing and circular footing were studied.

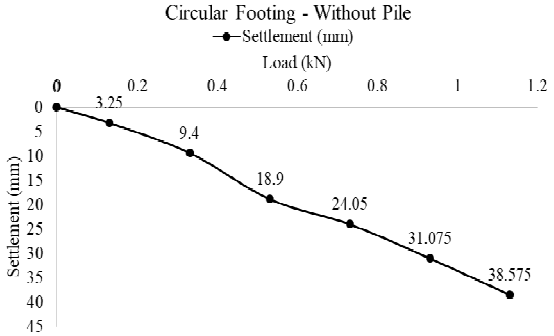

Fig. 11Circular Footing without Piles

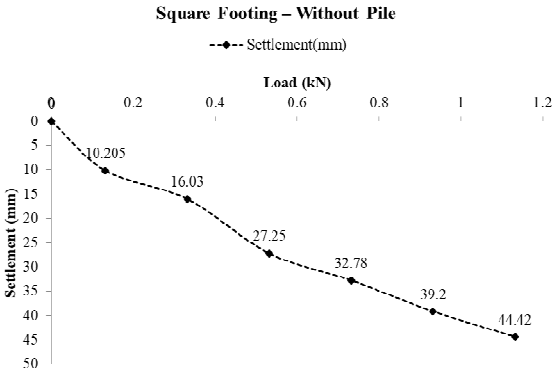

Fig. 12 Square Footing without Piles

The load – settlement curves for piles with varying lengths on circular and square footings were studied. Optimum length on circular footing and square footingwere studied.

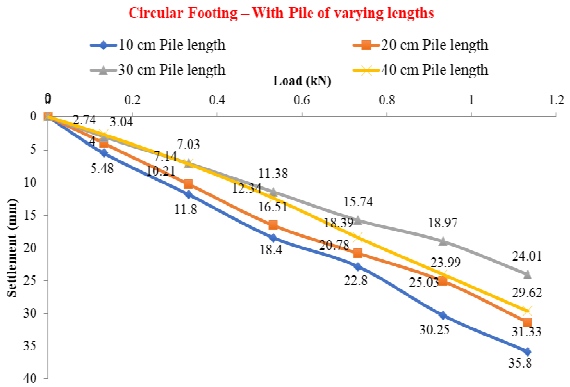

Fig. 13Settlement Variation of Circular Footing with Varying Pile Lengths

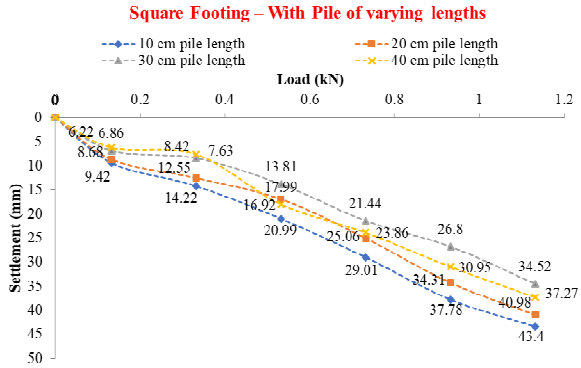

Fig. 14 Settlement Variation of Square Footing with Varying Pile Lengths

B. *Test on Circular Footing and Square Footing with GPA Foundation*

Plate load test were conducted with GPA foundation for different footing shapes to analyze the settlement. The settlements were noted and the load – settlement curve was evaluated. The load – settlement curves for GPA on square footing and circular footing were studied.

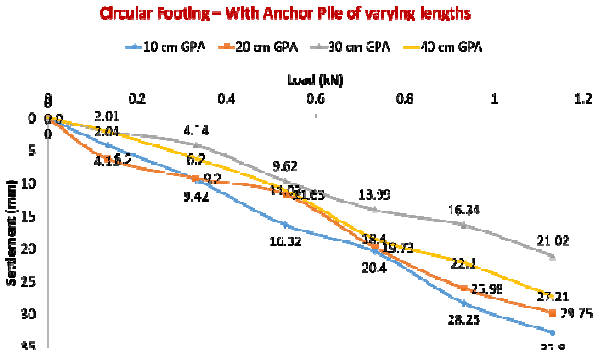

Fig. 15 Settlement Variation of Circular Footing with Varying GPA Lengths

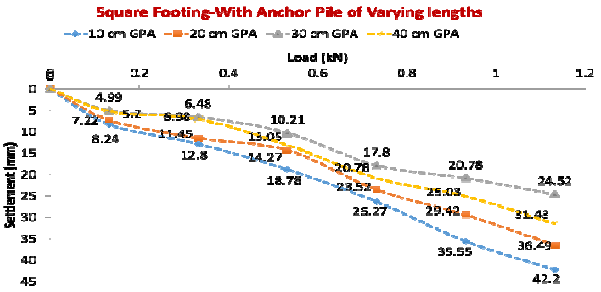

Fig. 16 Settlement Variation of Circular Footing with Varying GPA Lengths

C. *Comparison Study*

After conducting tests on both circular footing and square footing, a comparison study was done for both without pile, with optimum pile and with optimum GPA conducted on both model footings. A comparison of final settlement on both circular footing and square footing were studied.

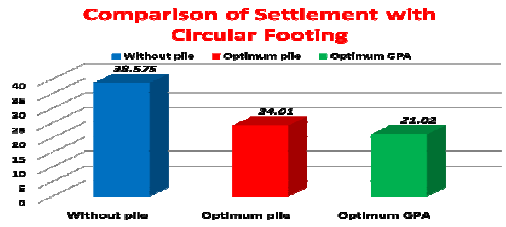

Fig. 17 Comparison of Settlements with Circular Footing

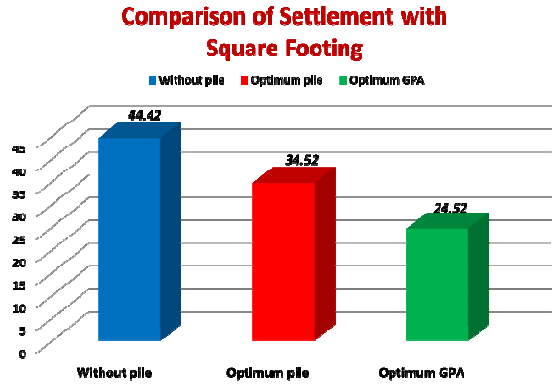

Fig. 18Comparison of Settlements with Square Footing

V. CONCLUSIONS

This paper deals with the study of settlement on the soil collected from Punchakkari, Thiruvananthapuram. Plate load test were conducted on the circular and square footing embedded in the soil for varying pile and granular anchor pile lengths and following results were obtained:

- Plate load test on circular & square footing with pile and GPA were conducted on 10, 20, 30 and 40 cm lengths respectively.
- Percentage of settlement decreased after conducting the test with pile foundation for circular & square footings is 37.75% & 22.28% respectively.
- Percentage of settlement decreased after conducting the test with GPA for circular & square footing is 45.41% & 44.8% respectively.
- Optimum length of pile and GPA for circular & square footing is obtained as 30 cm.
- Settlement decreases as the length of pile increases upto a certain length and then increases.
- This is because a longer pile typically distributes the load over a larger area, reducing the pressure on the soil beneath.
- While comparing the results, GPA with circular footing is more effective in reducing settlement than pile foundation.

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