**Predicting axial pile load capacity**

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**Abstract:** The latest strides in the domain of construction have led to major changes in the nature of the methods and material used in construction. This is especially noticeable in urbanized area in which the price of land is a governing factor. Therefore, shallow foundations are often found to be incapable of supporting the heavy structural loads and the use of deep foundations becomes essential. In this research work, centrifuge modeling is used to simulate piles embedded in difficult soils. The study treats combinations of soil strata that are known to be having a complex and probably hardly known behavior under different loading conditions. The widely used theoretical models such as Mohr-Coulomb, Tresca, Von Mises, Drucker-Prager, etc. can't give an accurate representation of peat for example. In this study, actual soil materials are used. Their physical and mechanical properties are pre-determined before testing. Soil-pile interaction is studied especially with regards to the phenomenon of negative skin friction. Finally, the physical model results were calibrated with the behavior of 1 g model in an area having a lethological section analogous to one of the centrifuge tests.
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**Keywords:** domain; construction; urbanized area; lethological section

## 1. Introduction

High-rise buildings are the signs of the renaissance construction in Egypt. A high concentration of population in Egypt occurs in the Delta region that the dominated top soil geological composition is soft clay. The shallow foundation fails to carry the load produced from high buildings and even those of moderate heights. Thus, the use of pile foundation becomes a need. The extension of piles in soft clay may create negative skin friction forces (Zeevaert 1959; Zeevaert 1973; Bozuzuk 1981; Fellenius 1972 and Meyerhof 1976). The methods of evaluating the values of these forces are still not clearly agreed upon by different researches (Burland 1973; Shen et. al. 2006; Chan 2006 and Leung et. al. 2004).

However, Pile Load Test is one of the most practical and efficient techniques in Egypt that determine the resultant axial pile load capacity. Therefore, it is intended to use its results to calibrate the centrifuge models that treat such problem.

## 2. Calibration Model

An actual in-situ full scale pile load model is used to calibrate of the centrifuge testing results. The tested site exists in City of El-Mahalla El-Kobra, an important industrial city in Nile Delta, Egypt. The site layout and sketch of soil stratification are illustrated in Figure 1.

According to soil profile, it is clear that a thin layer of fill occupies, at the most, the top first meter of the soil. The fill is followed by soft clay until a depth of about 16.000m. Medium dense sand starts from about 16m below ground level to the end of borings.

The tested pile is of a pre-cast type and was driven through the soil by a steam hammer. The pile has the following dimensions: Diameter = 0.60 m, Length = 18.00 m from 0.00 level. The pile has a 10 φ 16mm /m' Reinforcement at the top 7.80 m of its length, while 8 mm stirrups with 15 cm pitch are used.

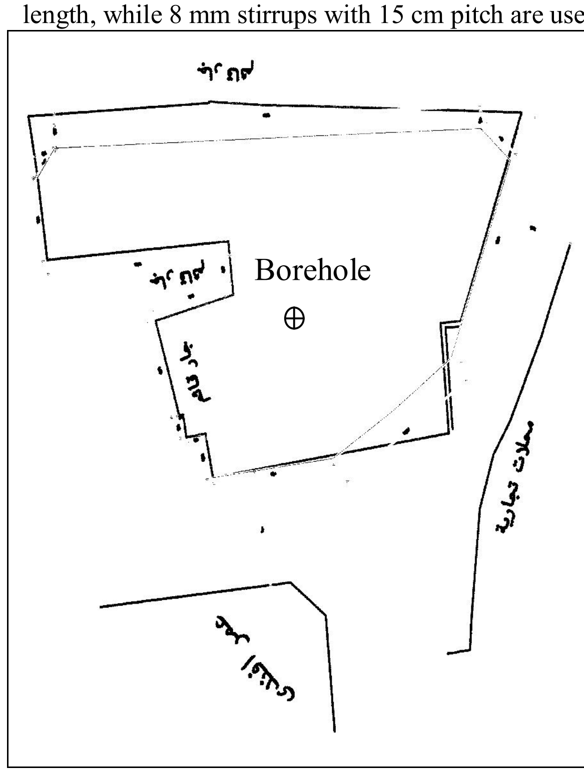


**Figure 1.** Site Layout and Soil Profile

The Pile Load Test was performed according to Egyptian Code for Soil Mechanics and Foundations

"Second Edition - Version 2001" (E.C. 2001). The pile was loaded using a hydraulic Jack with a starting applied load equals 22.5 tons which represents 25% of the design load according to EC. The settlement was measured after reaching the steady condition after 15 minutes. The applied load was increased gradually with 22.50 t increments and the settlement was measured after reaching the steady state condition after each increment. The final load was 135t. Table (1) shows the applied load as percentage of design load and the load residence time. Figure (1) shows site layout and soil profile.

Figure (2) includes the relationship between applied load and pile settlement during the processes of loading and unloading. It is found that the maximum settlement is 6.703 mm at 135 ton. According to E.C. there are two methods for results analysis. The first one is Modified Chin Method (Chin, F.K.1970), while the second method is Brinch Hansan Method (Brinch Hansan1963). Figures (3-a) and (3-b) contain the representation of the results of using both methods respectively

Table 1. The applied load as percentage of design load and the load residence time.

| Applied load as percentage of design load | Load residence Time |
|---|---|
| 00.00 | 4.00 hrs. |
| 25.00 % | 15.00 min. |
| 50.00 % | 15.00 min. |
| 75.00 % | 15.00 min. |
| 100.00 % | 15.00 min. |
| 125.00 % | 15.00 min. |
| 150.00 % | 12.00 hrs. |

The allowable pile load is 90.00 ton according to (E.C. 2001). The ultimate pile load for different analysis methods is found in Table 2. It's noticed that the factor of safety is high which may mean that the design of this pile is non-economic.

Table 2. Ultimate Pile Load of Pile Load Test

| Method of Analysis | Ultimate Pile Load | Factor of Safety | Allowable Pile Load |
|---|---|---|---|
| Modified Chin-Kondner Method | 173 ton | 1.92 | 90 ton |
| Brinch Hansen Method | 184 ton | 2.04 | 90 ton |

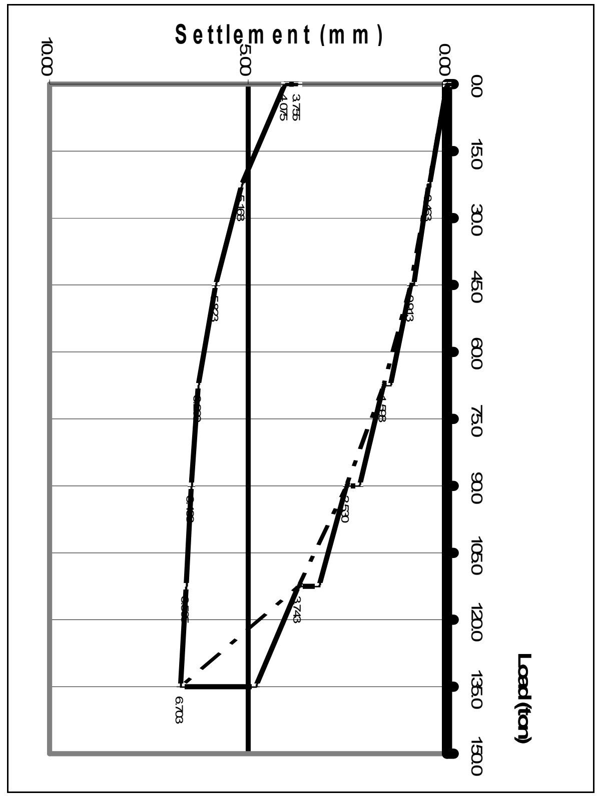

Figure 2. Load – Settlement Curve

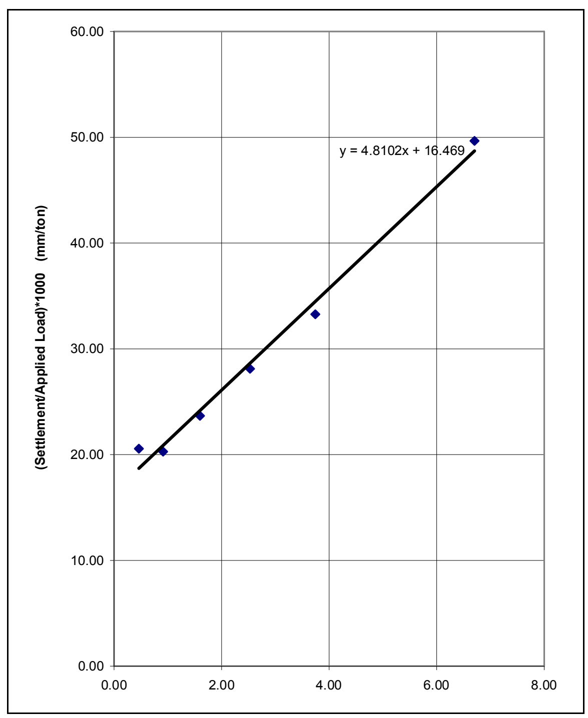

Figure 3-a. Modified Chin Criterion.

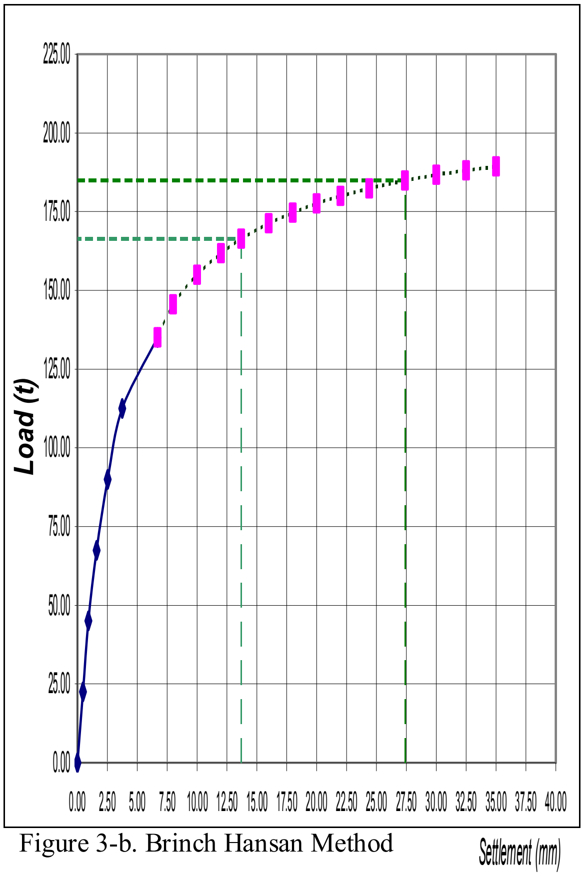


Figure 3-b. Brinch Hansan Method

**Centrifuge Modeling**

The Centrifuge modeling has proved a great success in the field of geotechnical studies. This type of modeling has helped to clarify the vagueness of some types of geotechnical problems that was almost impossible to reach with other types of treatment (Ng 2006, Stewart 1991 and Lam 2009) Soil behavior is stress-strain dependent. A proper modeling of the prototype stress level is crucial in any small-scale-physical test. By using a geotechnical centrifuge (schofield1980), a prototype stress field can be created by applying a centrifugal acceleration that *N* times the Earth's gravitational (g). For the tests reported in this work *N* is 50. This means that scaling factors, *N* and $1/N^2$, should be applied to convert linear dimensions and applied forces from model to prototype scales, respectively.

All the tests described in this work were carried out at the Centrifuge Laboratory of the Mansoura Faculty of Engineering. Figure (4) shows the setup of the model and dynamic actuator as tested in the 130g-ton geotechnical centrifuge. All tests were performed in a container with dimensions of 700 mm length, 470 mm width and 500 mm in height.

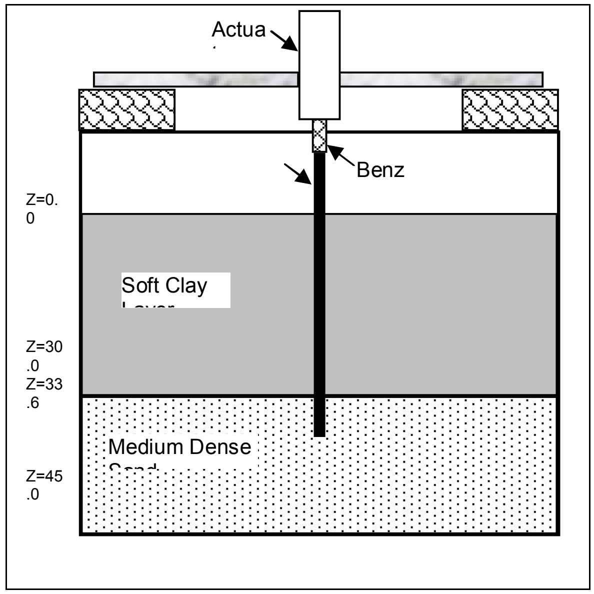


Figure 4. Loading Setup

Figure 5. Tested Pile in Container

For sand layer, $\varphi=33^0$, while for soft clay L.L=74.80, P.L.=23.10, P.I.=51.70, C.I.=0.38 and W.C.= 55.15.

Thus, the tests were designed to study the behavior of single pile passing through soft clay and is resting on medium sand and penetrate a depth equal 3 D of this layer ;D is pile diameter (E.C. 2001). The average centrifuge results are recorded in Table (3)

The pile in test is driven pile and is constructed before running the test. The soil in the test is simulated to the in-situ soil properties. The soft clay is saturated. The pile is 12 mm in diameter and 300 mm in length.

The loading procedure is that to apply 0.1 N and measure the cross bonding settlement until the rate of settlement equal zero then apply another 0.1 N.

Table (3): Centrifuge Test 1 Results

| *50 g* model | | Equivalent to *1 g* | |
|---|---|---|---|
| Applied Load (KN) | Settlement (mm) | Applied Load (ton) | Settlement (mm) |
| 0.09 | 0.004 | 22.50 | 0.20 |
| 0.18 | 0.014 | 45.00 | 0.70 |
| 0.27 | 0.043 | 67.50 | 2.15 |
| 0.36 | 0.064 | 90.00 | 3.20 |
| 0.45 | 0.097 | 112.50 | 4.80 |
| 0.54 | 0.140 | 135.00 | 7.00 |
| 0.63 | 0.200 | 157.50 | 10.00 |
| 0.72 | 0.264 | 180.00 | 13.20 |
| 0.81 | 0.356 | 202.50 | 17.80 |
| 0.90 | 0.520 | 225.00 | 26.00 |
| 0.99 | 0.760 | 247.50 | 38.00 |

According to (E.C. 2001) the allowable settlement is 2 % D in additional to Elastic Compression of pile. In case of steel pile the elastic settlement is neglected. Figure (6-a) and (6-b) show the Modified Chin Method and Brinch Hansan Method to determine the ultimate pile load.

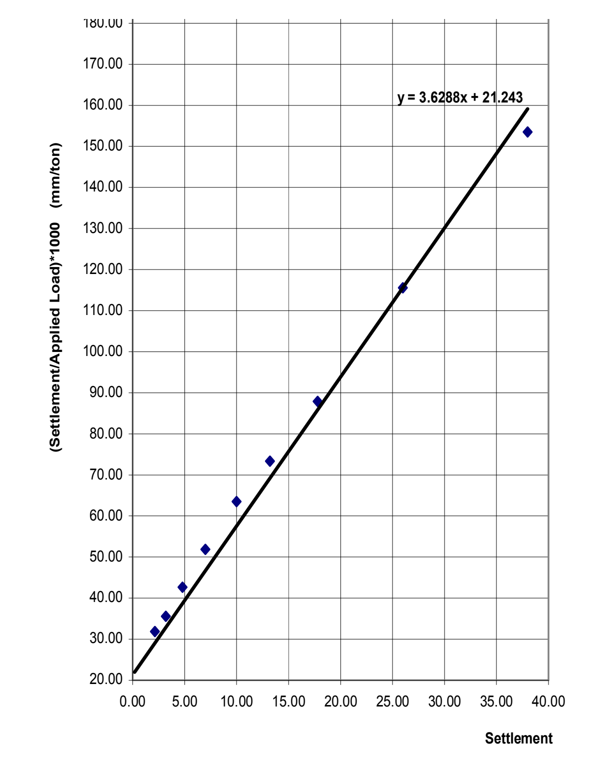


Figure 6-a. Modified Chin-Kondner Method.

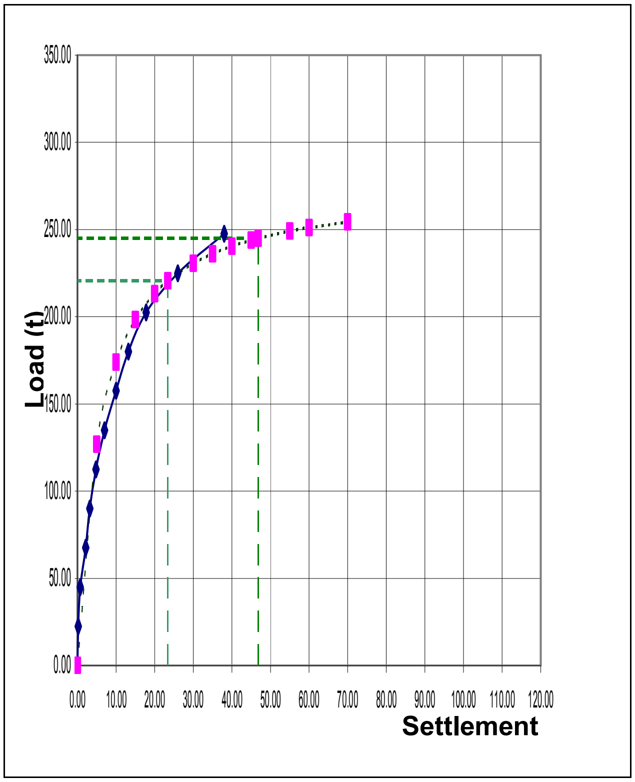


Figure 6-b. Brinch Hansan Method

Table (4) shows the ultimate pile load of centrifuge modeling. It's noticed that the factor of safety is very high (2.56 and 2.77) so that the allowable pile load can be increased to 150 ton. In case of allowable pile load is 150 ton the factor of safety will be 1.53 and 1.66 according to Modified Chin-Kondner Method and Brinch Hansen Method.

Table 4. Ultimate Pile Load of Centrifuge Modeling

| Method of Analysis | Ultimate Pile Load | Factor of Safety | Allowable Pile Load |
|---|---|---|---|
| Modified Chin-Kondner Method | 230 | 2.56 | 90 ton |
| Brinch Hansen Method | 249 | 2.77 | 90 ton |

It is clear that the centrifuge results are very close, though slightly higher than those obtained from the in-situ testing. This is because of the use of steel piles which sustain less negative friction than concrete piles which presents another indication of the existence of negative skin friction.

**Conclusions:**

In the last decade, the pile foundation is widespread in Egypt. Initially there was a problem, namely the construction of the piles, but this problem quickly faded with the emergence of a large number of pile foundation companies. Another problem emerged, which is the high cost of pile foundations especially when compared to other foundation Types. When the pile foundation becomes a need an economic design is indispensable.

Based on practical experience in the construction and design of piles, it was noticed that there is a gap between designed load capacity and actual load capacity for piles. Mostly, the actual pile load capacity is greater than the designed.

The fact that the test of the steel pile lead to a higher pile loading capacity indicates that negative skin friction does exist or otherwise, the concrete pile should have lead at least to a value equal to or higher than that of the steel pile.

In this work, the opportunity to use both centrifuge modeling and full scale pile load test results are used to confirm the validity of their notice. It was proved that the pile capacity inferred from Pile centrifuge test is higher than design load by over 50 %. However, the obtained results are only applicable for the cases of piles buried in soft clay layer and bearing on medium dense sand.

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