ESTIMATION OF SETTLEMENT OF STEPPED PILE IN GRANULAR SOIL

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Abstract

Pile foundation is a mostly used type of deep foundation to transfer superstructure load into the subsoil and bearing layers. However, accurate prediction of the elastic settlement of pile is difficult concerning complicated pile-soil interaction phenomenon. Present paper deals with the analysis of single and double-stepped pile and proposed evaluation are conducted with the aid of finite element software PLAXIS 2D. In this analysis, load-settlement behaviour of a single conventional, single stepped and double-stepped pile is evaluated in granular soil. For the single conventional pile, single stepped and double-stepped pile, the parameters like the total volume of the pile, the total length of pile, the deformation properties of surrounding soil and pile kept constant for all the cases to study the variation in behaviour. In the double-stepped pile, the diameter of the pile for upper, middle and lower portion has been varied to study the effect on the load-settlement response for regular and inverted manner. The results obtained from the analysis of the single conventional pile, single stepped pile, and double-stepped pile were compared with the experimental results of F. Kirzhner, and G. Rosenhousewhich were performed in 1982 in Ashkelon South power station in Israel. Results show the better performance behaviour of the regular double-stepped pile as compared to the inverted double-stepped pile; single stepped and single conventional pile.

Keywords Single conventional pile; Single stepped pile; Double-stepped pile; Load-settlement; granular soil.

1 Introduction

Available settlement analysis either assumes that the soil resistance can be represented by a series of disjointed spring (the string stiffness is determined through theoretical, experimental or empirical means) or that of the soil is a continuum. In FEM, a continuum is divided into a number of elements. Every element consists of multiple nodes, and each node has a number of degrees of freedom which correspond to discrete values of unknowns in the boundary value problem to be solved. Many researchers have worked on settlement analysis of pile by using various approaches and methods such as analytical, finite element methods. [1] proposed a new empirical method for simulating the non-linear point resistance response of single piles in cohesionless soil. Also, the shear resistance responses along the pile shaft were found by using the concept of the t-z curve.[3] presented the response of non-homogeneous floating granular pile in homogeneous soil medium based on elastic continuum approach. [7] studied the termination criteria of bored pile socketed in the rock layer subjected to axial loading by numerical analysis. For numerical analysis, PLAXIS 3D foundation 1.1 were used. Also, numerical results were compared with the field test results. [9] analyzed numerically the top settlement of single pile by using PLAXIS 3D foundation and validates with field results, which were performed in Brazil, during a full-scale field test, presented by [5].
[2, 6, 8, 10], studied the response of rigid and compressible single piles embedded in multilayered soil. [4] Provided the guideline for the analysis of the ultimate bearing capacity of single pile in granular soil. [5] presented soil behaviour of a perfectly plastic elastic model (Mohar Coulomb) and an elastoplastic model with strain hardening (Nova 1982) in terms of load settlement and force distribution long pile surface. Also, numerical results were compared with experimental results.
Many researchers have worked on settlement analysis of single conventional pile foundation, but very few researchers have accomplished on settlement analysis of single pile by varying its shape and size, and it indicates there is scope for research work. In the present study, the analysis is performed for the single conventional pile, single stepped pile, and double-stepped by varying its diameter of an upper and lower portion of the pile for load-settlement behaviour.

2 Methods of Analysis and Materials

The experimental results of the loading test, which were performed in Ashkelon South power station in Israel in 1982, were taken for estimation of the ultimate bearing capacity of single pile in sand. The diameter and length of the pile were considered as 0.9m, and 20m respectively. The piles were monitored using extensometer and load cells to getting accurate results. For deformable piles, the load was applied at the top

of the pile.Iit is well known that under slow cyclic loading, engineering materials degrade and become softer and weaker. In present analysis IS 2911 (part I section II 1979) has been used. The following assumptions are used as follow,

- The soil medium is continuous, isotropic and non-homogeneous.
- An axisymmetric configuration was implemented, with the axis of symmetry aligned with the axis of the pile.
- No-slip or yield at the pile-soil interface.
- The sides of the Pile are perfectly rough and rigid.
- The analysis is performed for the no-tension condition in the soil as well.

2.1 Geometry model

In the present analysis, the soil domain is considered as 100% of pile length for a horizontal plane from the central vertical axis of the pile and for depth 200% of pile length (Ref). The point load of 9000 KN is applied to the centre of the pile for the analysis of settlement behaviour of the pile. The embedded pile is considered cast in situ in multilayered granular soil as shown in fig 1.

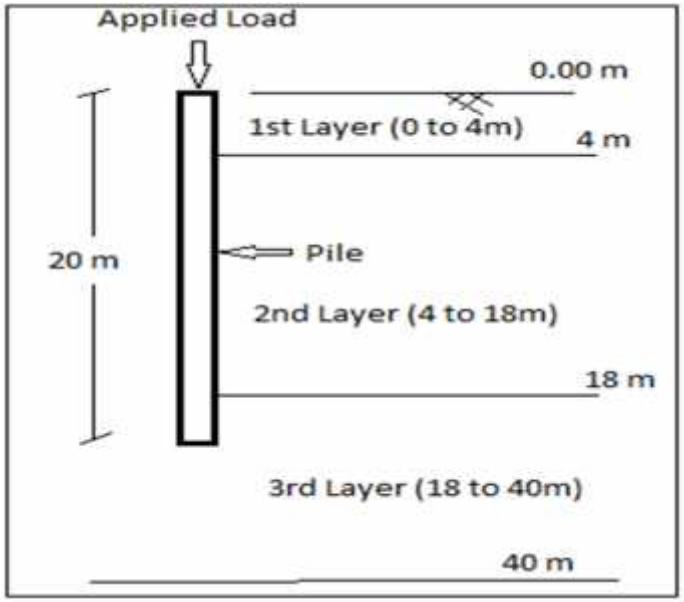

Fig 1. The geometry of the pile-soil system

2.2 Properties of surrounding soil and pile

In the present study, the properties of soils are used the same for every case. In this consist 3 soil layers such as thickness of the first layer is 4m (0-4) of density 1.74 ton/cubic m, youngs modulus 700- 4600 Mpa, Poisson ratio 0.3, thickness of second layer 14m (4-18) of density 1.84 ton/cubic m, youngs modulus 900-9300 Mpa, Pois-

son ratio 0.3 and for third soil layer 22m (18-40) of density 2 ton/cubic m, youngs modulus 900-9300, Poisson ratio 0.3. The angle of friction and cohesion of soil is taken as 30-32 degrees and zero, respectively. For each layer of soil Mohr- Columb and the drained condition are used. In the case of a pile, the linear elastic and nonporous condition is used.

3 Result and discussion

The results of the present study validate with the experimental results of loading test, Asklon and numerical solution FLAC 1 provided by F. Kirzhner and G. Rosehouse (2001) on Analysis of the ultimate bearing capacity of a single pile in granular soils. For the same diameter of pile 0.9m and length of pile, 20m is considered. The present study results are very closely matched with F. Kirzhner and G. Rosehouse (2001), as shown in fig 2.

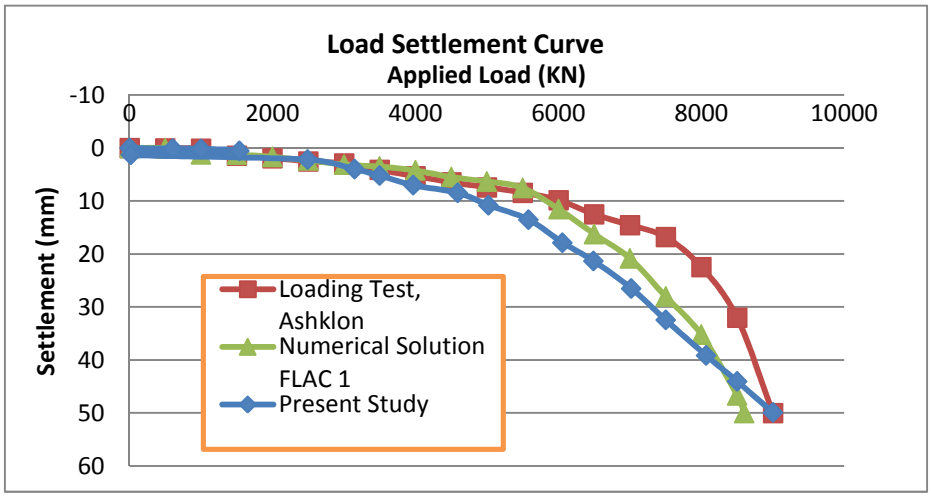

Fig 2. Validation of load settlement curve

3.1 The effect of Stepped shape on the settlement of Pile

In this study, the effect of the stepped shape of the pile on the settlement of pile is analyzed numerically by using Plaxis 2D. For the same, the length and diameter of the pile is considered as 20m and 1m, respectively. In this analysis total length and volume of the pile is kept constant for single conventional, regular single stepped, inverted single stepped, regular double-stepped and inverted double-stepped pile by varying its step length and diameter as shown in fig 3.

3.1.1 The effect of a single stepped pile on settlement

From fig 4. It is observed that the top settlement of regular single stepped and inverted single stepped pile decreases as compared to the conventional pile of same length and volume. The top settlement of regular single stepped pile is more efficient as compared to the single stepped inverted and conventional pile. Because at the bottom surface of a regular single stepped pile getting more surface area as compared to others and due to that more amount of stress is generated.

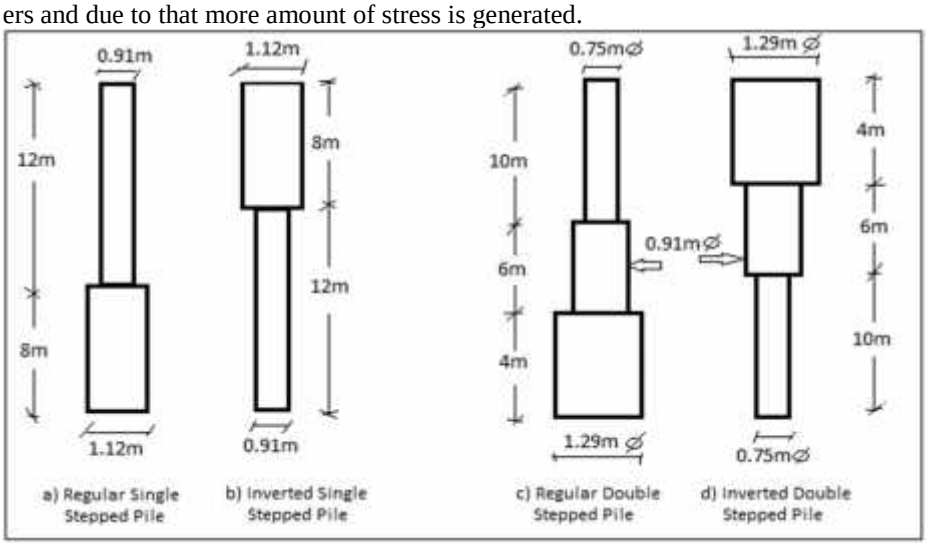

Fig 3. Geometry of stepped pile

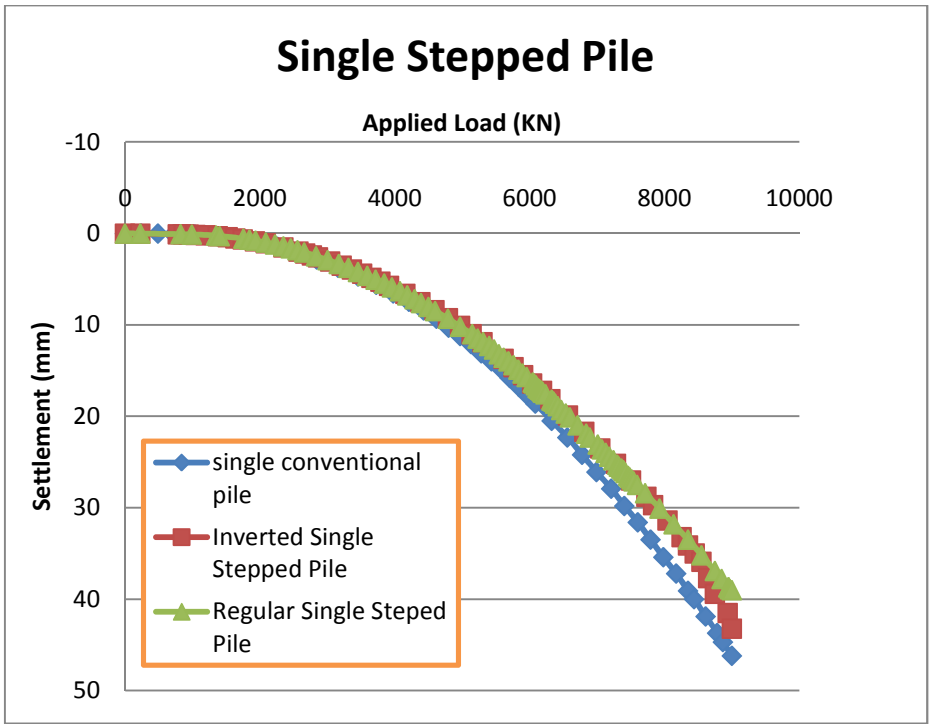

Fig 4. Load settlement curve of the single stepped pile

3.1.2 The effect of Double stepped pile on settlement

From fig 5. It indicates that the regular double-stepped pile perform better in terms of settlement and load-carrying capacity as compared to the single conventional and inverted double-stepped pile. As we increases the number of steps to the pile, whose base area goes increase and settlement will get reduces. But at the same time, the upper area gets reduces and due to that, there is a possibility of failure of the pile at the upper portion.

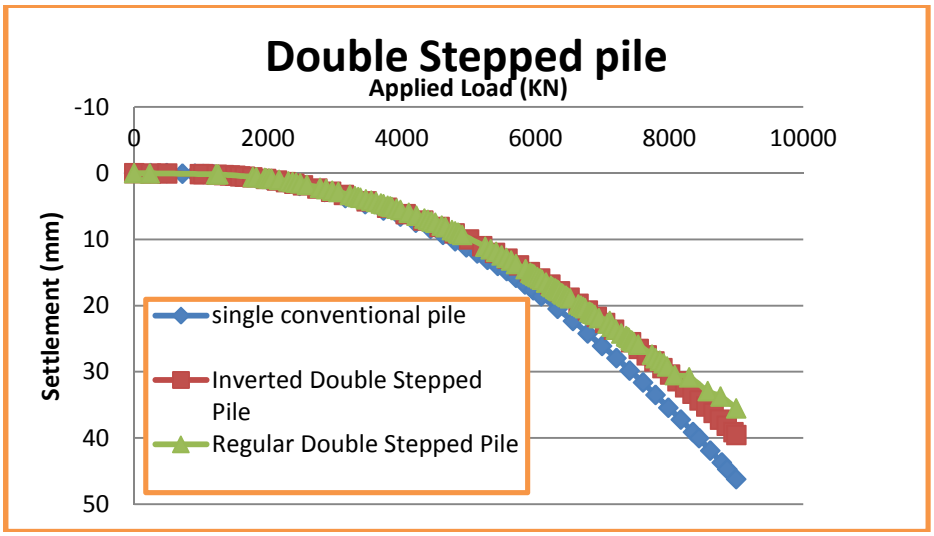

Fig 5. Load settlement curve of the double-stepped pile

Table 1. percentage reduction in settlement compare to single conventional pile

Sr. No.	Shape of Pile	Applied load (KN)	Top settlement (mm)	Percentage reduction in settlement
1	Single conventional		46.2	0%
2	Regular Single Stepped		39	15.58%
3	Inverted Single Stepped	9000	43.2	6.5%
4	Regular Double Stepped		34.4	25.55%
5	Inverted Double Stepped		39.5	14.51%

3.1.2 Percentage reduction in settlement

In this study, also analyzed the percentage reduction in the settlement on the same amount of applied load for all cases. Here, the ideal case is considered as single conventional pile and results of other cases are compared with it as mentioned in table no. 1.

Table.1. Indicates, settlement of regular double-stepped is 25.55%, inverted double-stepped 14.51%, regular single stepped 15.58%, and inverted single stepped pile 6.5% less as compared to the single conventional pile.

4 Conclusion

Based on the finite element analysis in the present study, the regular stepped pile performs better in terms of the settlement as compared to the conventional circular pile of the same material, volume, and length. Because of at the lower end of the pile getting the larger cross-sectional area as compared to the regular pile and hence more frictional resistance develops on outer and bottom surfaces of the pile and its result reduces the settlement of pile. The number of steps we can provide up to a certain limit due to practical reason. In case of regular stepped pile, if the number of steps is increased then the lower base of pile getting increased but the upper portion of pile getting decreases and due to that the pile will get fail at an upper portion. So, it is advisable to provide the optimum number of steps to the pile. In case of the inverted stepped pile, the lower base portion of pile getting less and due to that it tries to penetrate more like a regular stepped pile.

In the present analysis, settlement of regular double-stepped pile reduces by approximately 25.55%, inverted double-stepped pile 14.51%, regular single stepped pile 15.58%, Inverted Single Stepped 6.5% as compared to the conventional pile.

It is noted that the regular double-stepped pile perform better as compared to the other cases discussed in the present study.

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