Elastoplastic Finite Element Analysis Of Pile Supported Circular Footing On Cohesionless Soil Using PLAXIS 2D

Prof. K.N. Sheth[0000-1111-2222-3333] and Rahul Chhatrala2[1111-2222-3333-4444]

[1] Professor, Head, Department of Civil Engineering, Dharmsinh Desai University, Nadiad
[2] Teaching Assistant, Department of Civil Engineering, Adani Institute of Infrastructure Engineering, Ahmedabad.
rahulchhatrala62@gmail.com

Abstract. In traditional foundation design, it is customary to consider first the use of shallow foundation. If it is not adequate, deep foundation such as a pile foundation is used instead. Unlike the conventional pile foundation design in which the piles are designed to carry the majority of the load, the design of a Piled Footing allows the load to be shared between the footing and pile as well increase in capacity due to confinement below footing. Hence, it is necessary to take the complex soil-structure interaction effects into account. The present work is an attempt to determine the increase in capacity of piled footing due to the increase in skin friction of the pile beneath the shallow footing due to the confinement offered to the sand by the shallow footing. A parametric study is carried out only for cohesionless soil. The foundation type is circular footing over the circular pile of uniform cross-section. For this, different geometrical data viz. diameter of footing and diameter & length of pile has been chosen after review of different researches carried out in this area. To handle such type of soil-structure interaction problem, numerical simulation is done with the help of FEM software, Plaxis 2D. While using Plaxis 2D, the axisymmetric condition for modelling the pile, 15 nodded triangular elements and Mohr-Coulomb model for the soil properties are used. After analyzing sets of problems in PLAXIS, it is concluded that Piled Footing proves to be advantageous for footing resting on loose sand rather than dense sand due to enhancement of skin friction beneath footing. The skin friction is increased even in dense sand, but at the cost of losing the capacity of shallow footing.

Keywords: Piled Footing, Skin Friction, PLAXIS 2D, Confinement effect

1 Introduction

Foundations are structural components that enable loads to be transferred into the subsoil. The type of foundations required depends on number of factors including soil type, load magnitude ground conditions etc. Foundations are generally categorized as Shallow and Deep Foundations.

As per the traditional design methodology, it is customary to adopt shallow foundation first. If the structural loads are relatively higher and/or subsoil conditions are not favorable, then we adopt Pile foundation. Pile is a columnar structure which is used for transferring structural loads at higher depth, using tip bearing and skin friction.

But in last few decades, an alternative solution has been obtained, in which pile is provided beneath the raft or shallow footing. This is known as piled raft foundation system. The analysis of piled raft is very popular since few decades. But in most of the cases, pile group is adopted for the construction of the piled raft foundation. It is not conventional to use piled raft foundation for single pile i.e. Piled Footing.

Structural Design Philosophy and implementation to Codes of Practice has transformed from conventional Working Stress Method to soil structure interaction problem handled with Finite Element Analysis Method. Hence an analytical study is carried out to find the bearing capacity of circular Piled footing in cohesionless soil.

The elasto-plastic analysis of circular Shallow footing (individual), circular Pile foundation (individual) and circular Piled footing (combined of shallow and pile) is carried out for determination of bearing capacity using Mohr-Coulomb soil model. The main objective of this study is how much bearing capacity of pile supported footing is enhanced due to increased confinement below shallow footing due to increased skin friction.

The main objective of this study is to determine, how much bearing capacity of Pile Supported footing is enhanced due to increased confinement beneath shallow footing and hence increase in skin friction. This analysis is done on cohesionless soil without water-table. This assessment has been carried out using FEM software PLAXIS 2D using Mohr-Coulomb soil model. This analysis is carried out in cohesionless soil for different φ (PHI) Values and different dimensions of Shallow and Pile foundation geometry.

In fig. shows a single bored pile of uniform diameter d (Circular) and length L driven into homogeneous mass of soil of known physical properties. A static vertical load is applied on the top. It is required to determine the ultimate bearing capacity Qu of the pile.

When ultimate load applied on the top of the pile is Qu, a part of the load is transmitted to the soil along the length of the pile and balance is transmitted to the pile base. The load transmitted to the soil along the length of the pile is called the Ultimate Friction Load or Skin Friction Qf and that transmitted to base is called base or Point resistance Qb.

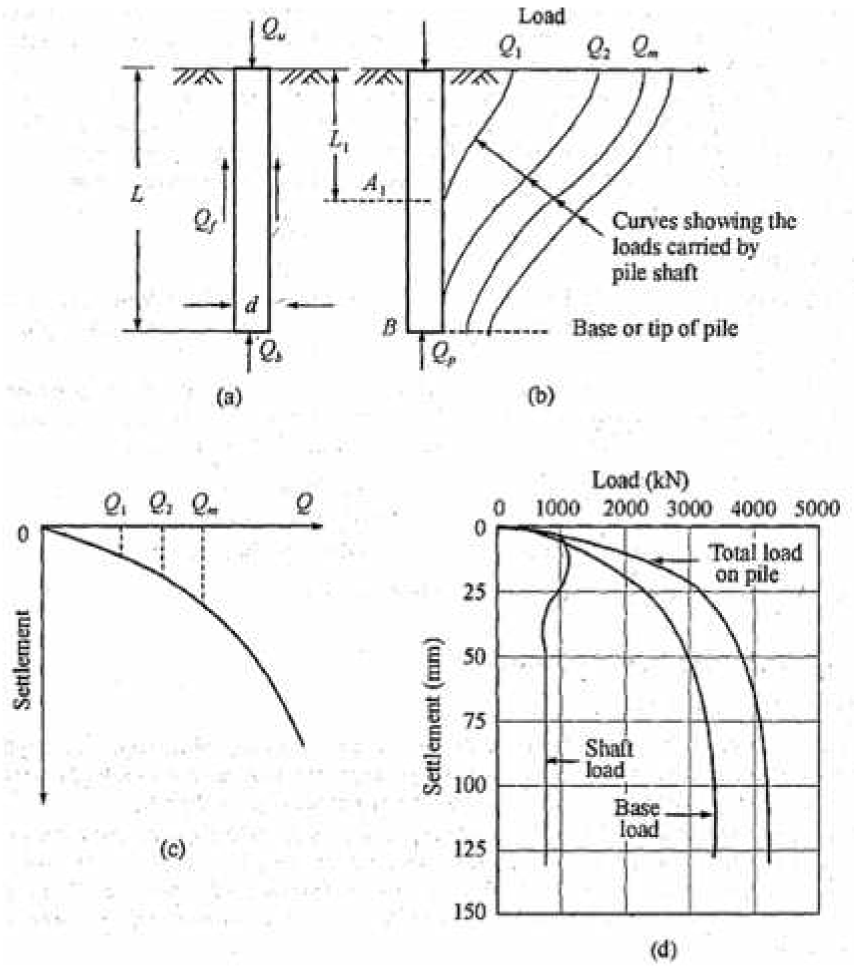

Fig.1 Load Transfer Mechanism: (a) Single pile, (b) Load Transfer curves, (c) Load settlement curve, (d) Load settlement relationships for large diameter bored and cast-in-place piles (after Tomlinsion, 1986)

2 Numerical Modelling

FEM is a method of solving continuous problems governed by differential equations by dividing the continuum into a finite number of elements, which are specified by a finite number of parameters. A problem is solved by dividing the larger geometry into small elements, which are interconnected with nodes.

To handle such type of soil-structure interaction problem, numerical simulation is done with the help of FE software. While using Plaxis 2D, the axisymmetric condition for modelling the shallow footing and pile foundation and 15 nodded triangular elements are used. For modelling of soil properties Mohr-Coulomb model is used.

Linear Elastic model is used for modelling shallow footing and pile foundation. The properties of soil are chosen empirically as shown in table. Although, a parametric study is carried out only for cohesionless soil for varying angle of friction from 26° to 36° at the increment of 2°. The interface angle of friction is considered as 0.75 x Angle of friction.

Dimensions of the geometry of the foundations are adopted using different geometrical ratios, i.e. Dia of pile to width of footing (D/B) and Length of pile to Width of footing (L/B). Pile diameter is adopted as 300mm, 450mm, 600mm and 750mm.

ϕ (PHI)	SPT - N	Unit Weight γ, kN/m^3	Modulus of Elasticity E, kN/m^2
26	4	12.70	9500
28	7	14.00	11000
30	10	16.00	12500
32	16	18.05	15400
34	23	20.60	18800
36	30	22.00	22500

3 Load Transfer Mechanism

The combined system of Shallow footing and Pile foundation incorporates very complex soil structure interaction when subjected to load. When load is applied on the Piled footing, initially small amount of load is taken only by shallow footing. As the load increases, the load is simultaneously being shared between shallow and Pile foundation.

Due to this simultaneous load sharing, when this combined system reached to the shear failure of the shallow footing, the whole capacity of the shallow footing is not utilized. However, due to confinement offered by shallow footing, increase in the skin friction of the pile is observed.

Hence, in the combined system, capacity of the pile increases at the cost of losing the capacity of the shallow footing. Still there are some of the geometrical ratios in which shallow footing has utilized its full capacity in the combined system at the shear failure. Those ratios are mentioned in the conclusion.

4 Conclusion

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1. After analyzing problems for shear criteria and settlement criteria, it is observed that Piled footing is not providing any effective benefits in capacity for settlement criteria, since this type of combined system requires higher settlement for utilizing full capacity of individual elements. Hence, piled footing is not recommended to be used for the working loads of the structure.

2. In shear criteria, piled footing provides effective increase in capacity for all geometrical parameters for loose sand (i.e. $\varphi = 26$ & 28). Hence, smaller diameter pile with minimum L/B ratio = 2.0 (Length of pile to width of footing ratio) can increase the capacity up to 18 percent for loose sand.

3. When piled footing is to be used for medium to dense sand, geometrical parameters D/B = 0.2 (diameter of pile to width of footing ratio) and L/B = 3.0 to 3.5 (Length of pile to width of footing ratio) is recommended since it is observed that shallow footing is utilizing its full capacity up to shear failure of combined system and hence advantage of increase in skin friction is achieved beneath shallow footing. Besides, larger length of pile provides advantage of confinement due to overburden near tip of the piled footing.

4. For D/B ratio as 0.10 and 0.15, % increase in ultimate capacity decreases with the increase in angle of friction for same L/B ratio. Whereas for D/B as 0.20, the change in % increase in ultimate capacity remains negligible.

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