Improving the Bearing capacity of foundations using micropiles

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Abstract

This paper explores the effect of micropiles on the bearing capacity of foundations. PLAXIS as a finite element code capable of analyzing soil-structure interaction has been utilized and appropriate material properties and boundary conditions have been defined. The analyses aim to conclude the optimum configuration of micropile in the soil to achieve the maximum bearing capacity. For this purpose, four parameters namely, diameter, distance, length and direction of piles in the soil have been considered and sensitivity analyses have been done on different range to determine the effect of each parameter. The results of analyses show that the correct selection of the micropile parameters can increase the capacity of foundation for loading. It is concluded that the slope of micropile is the most influential factor among other parameters that have been studied.

KeyWords:*Micropile, Bearing Capacity, PLAXIS, Finite Element Method*

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1. INTRODUCTION

The design of foundation is a challenging process for most structures. It should be strong enough to withstand the loads from upper structures and able to transfer loads to the foundation uniformly and avoid any stress concentration [1], [2],[3].

The behaviour of pile has been an interesting topics for decades in geotechnical engineering. Different aspects of the issue have been explored. For example, Zhang et al [4], considered the effects of scour-hole dimensions and soil history on the behaviour of laterally loaded piles in soft clay under scour conditions.

Numerical modelling is also popular among researchers. For instance, Horabik et al [5] employed three dimensional Discrete Element Method (DEM) to study the force distribution in a pile. However, Finite Element Method (FEM) is the most popular method and most studies have been done using this technique.

Recently, there have been sophisticated three dimensional models to analyze the dynamics of pile especially in case of liquefaction and earthquake [6], [7] and [8].

In recent years, Micropiles are vastly used as foundation support of buildings. The successful experience of using micropiles expanded the research on different parameters and conditions and optimizing them in foundations [9]. Micropiles have been used for different loading conditions such as dynamic loading [10] and buckling [11].

Soil-micropile interaction is the subject of many researches to determine the mechanism of micropile behavior. Ghorbani et al [12] using a three dimensional finite element analysis investigated the seismic performance of soil–micropile-structure interaction. They considered the peak amplitude of earthquake, number of micropiles, slenderness ratio and mass of superstructure in their analysis. The same analysis conducted by Sadek and Isam on inclined micropiles. They concluded that inclined micropiles allows a better mobilization of axial stiffness and consequently decreases forces applied on micropiles [13]. The performance of micropile in different conditions is another important issue that have been addressed recently. Elsaied [14] considered micropiles adjacent to slopes. Prat [15] conducted a numerical investigations to find the different failure modes of a micropile retaining wall and Veludo et al [16] delve into compressive strength of micropile-to-grout connections.

This paper investigate other parameters of micropiles including length, slope, diameter and spacing. Using finite element model developed by PLAXIS, the effect of each parameter is explored and recommendation will be made to maximize the performance of micropiles.

2. Methodology

Numerical modelling of the structures is an effect way to predict their response to complicated loading conditions[17], [18]. To find the response of micropiles to applied loads numerical modelling has been used in this paper.

Figure 2.1 shows the plan view of the footing and micropiles. As the figure depicts the foundation is a square 2.5*2 meter concrete footing and micropiles are installed in four sides of it. The diameter and thickness of micropiles are selected to be 100 mm and 60 mm respectively. The material properties of micropiles is presented in Table 2.1. The soil is considered to be two layered and material model of micropiles' behaviour is linear elastic while soil material is modelled by Mohr-Coloumbplasticity.

In order to model the problem and analyse the micropiles in different condition the finite element code, PLAXIS, has been utilized. This code is able to model soil and structural elements and considers soil-structure interaction in analysis. It is also capable of doing static and dynamic analysis such as pile driving. In the modelling of the micropiles the following steps have been taken into account:

- Modeling of the problem's geometry: it includes determining the boundaries of the model and defining different layers of soil for the model. This model contains foundation and piles, therefore, structural element, PLATE, needs to be used.
- Applying the boundary conditions: since in this model no dynamic loads have been applied, the standard boundary conditions defined by the code or standard fixities can successfully simulate the model's boundaries. In order to avoid the undesirable effect of boundaries on pile's response, the model has been extended more than six times of the foundation width from the both sides [19].
- Meshing of the model: the meshing of the problem should be fine enough to give precise results and at the same time should not be too fine to make the problem very time-consuming. As a results, to get the best results, the area around the foundation and micropiles are meshed very fine while keeping the mesh around boundary course. Figure 2.2 shows the meshing of the model in the area around foundation and micropiles.
- Determing output points: five points on foundation and in different depth in soil have been determined as output points to monitor the response of foundation, piles and soil layers. Figure 2.2 shows the location of the points in the model.

Table 2.1. Model and material properties [20]

Material	Model	Cohesion (KPa)	Friction angle (degrees)	Young modulus (MPa)	Poisson Ratio	Density (KN/m^3)
Loose sand	**Mohr-Coloumb**	**1**	**25**	**13**	**0.30**	**18**
Dense sand	**Mohr-Coloumb**	**1**	**35**	**30**	**0.30**	**20**
Micropile	**Elastic**	**-**	**-**	**2.1×10^5**	**0.25**	**78.5**

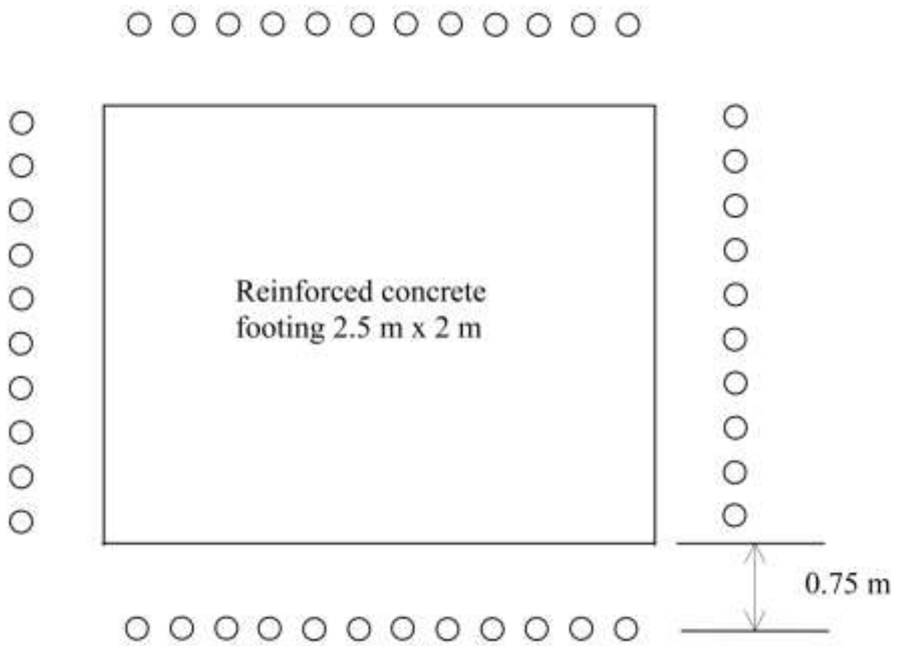

Figure 2.1. Plan view of the foundation and micropiles[20]

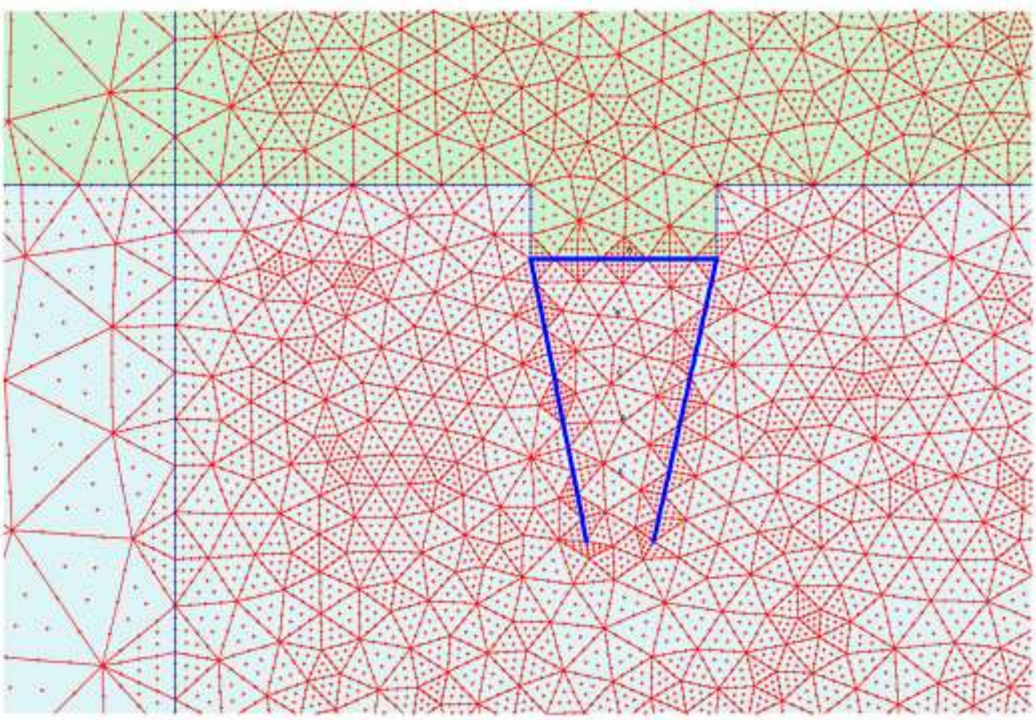

Figure 2.2. Meshing of the area around foundation and micropiles

3. The results of analyses

Many factors affects the bearing capacity of micropiles and this paper performs sensitivity analyses on theses factor to optimize the characteristics of the piles for different conditions. In this paper, the diameter, length, spacing and the slop of micropiles have been considered

3.1. Diameters of micropiles

In order to find out the importance of micropile's diameters and their effect on bearing capacity of foundation, this parameter has been changed in the range of 5 to 20 centimeters. Figure 3.1 demonstrate the bearing capacity of foundation for micropiles with diameters 5 and 20 cm. It is clear that with increasing the diameter of piles, the subsoil capacity increases. The figure also shows that the rate of increase in bearing capacity increases as more settlement occurs in the foundation. Figure depicts the maximum bearing capacity equivalent to the 0.2 meter settlement of the foundation for different diameters of micropiles. It is evident that maximum rate of changes happens in the range of 5 to 10 cm and after that the impact of diameter decreases. For example, the difference between bearing capacity of the foundation with 5 and 10 cm diameter micropiles is about 50 KN/m^2 while the difference for 15 and 20 cm diameter micropiles is only 12 KN/m^2.

3.2. Length of micropiles

Pile length is an important parameter that causes more capacity of loading for both subsoil and foundation. The friction between soil and the pile and also reaching soil layers with higher stiffness or even the rock bed are the benefits of using longer piles. For showing the effect of micropile's length on the foundation and supporting soil this parameters has been changed in the range of 3 to 5 meters. The values considered are 3, 3.5, 3.9 and 5 m. Figure shows the results for two cases of 3 and 5 meter long micropiles. As it is expected with increasing the pile's length, higher capacity can be achieved. The maximum difference that can be observed is about 11% which is in case of 5 cm foundation settlement.

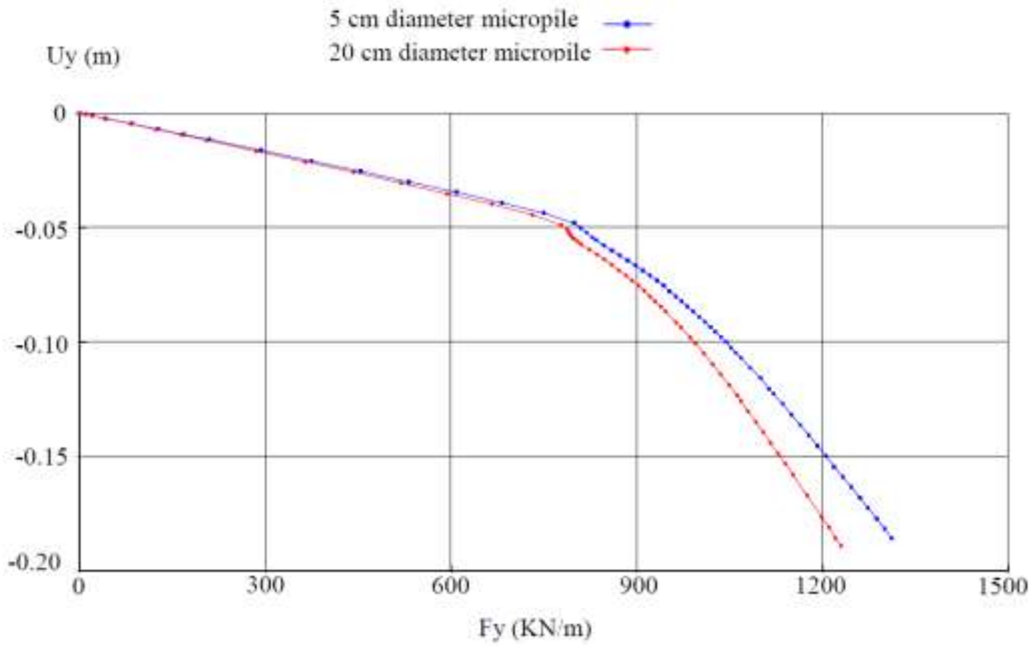

Figure 3.1. The effcet of micropile's diameter on bearing capacity of foundation

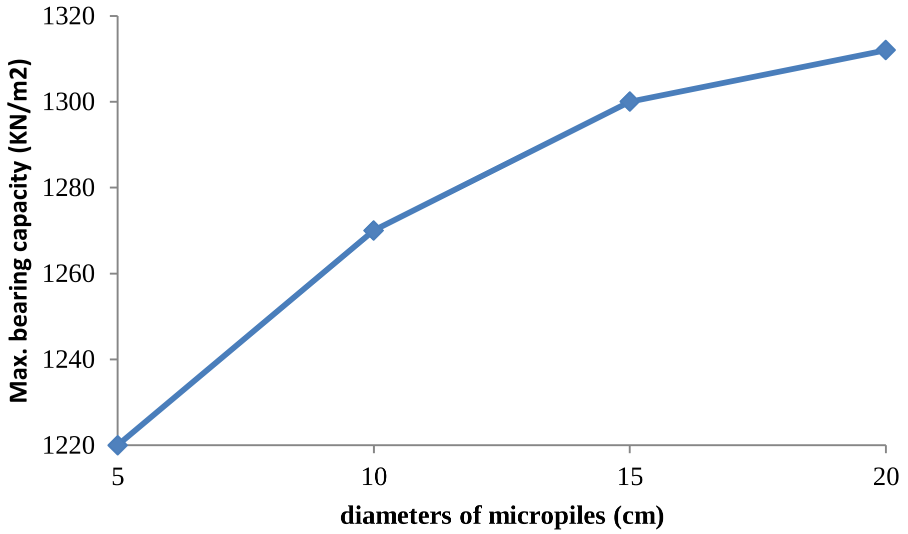

Figure 3.2. The effcet of micropile's diameter on maximum bearing capacity of foundation

It should be noted that for the all the analyses, the other parameters have been kept constant and the studied parameter changes. Figure shows the maximum bearing capacity for various lengths of micropile. According to the figure, increasing the micropile's length causes more bearing capacity. However, this figure suggests that this difference is not considerable.

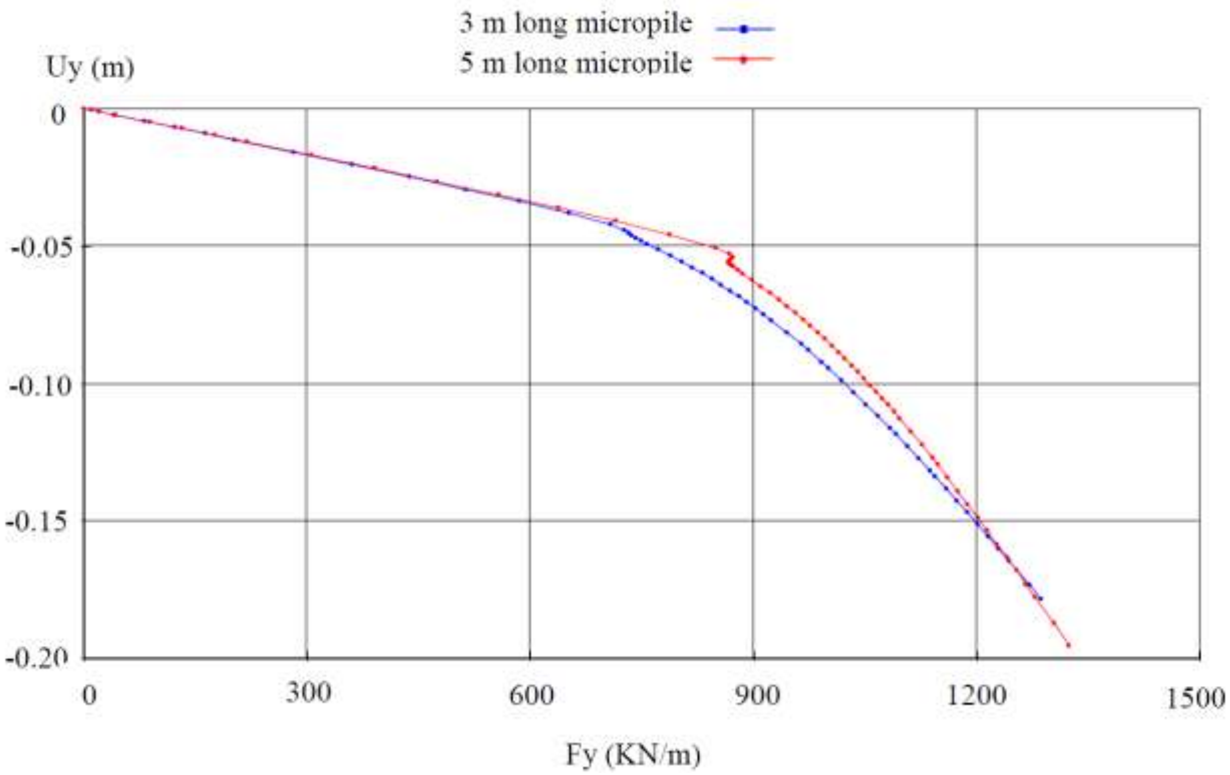

Figure 3.3. The effect of the length of micropiles on the bearing capacity of foundation

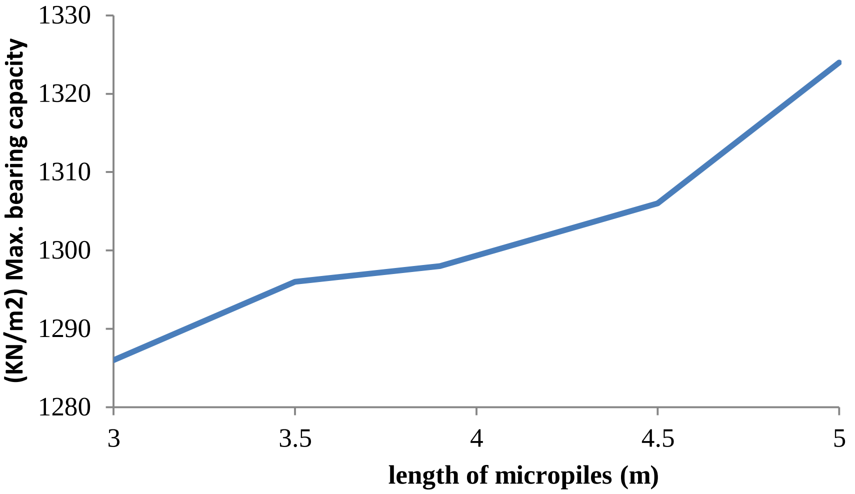

Figure 3.4. The effect of the length of micropiles on the maximum bearing capacity of foundation

3.3. The distance between the micropiles

This section discusses the effect of distance between micropiles on the bearing capacity of foundation. For this reason, the spacing of piles has been selected 0.1 to 0.5 m and separate analyses have been conducted to investigate this parameters. The distance between the micropiles is a function of the diameters of the piles, soil type and load distribution. Based on the results, increasing the spacing adversely affect the bearing capacity of the foundation. However, as it is show in Figure , the influence of micropile spacing has little effect for spacing more than 20 cm and the maximum changes in bearing capacity is limited to 4%. In addition, it is observed that maximum changes occurs in the range of 0.1 and 0.2 meters.

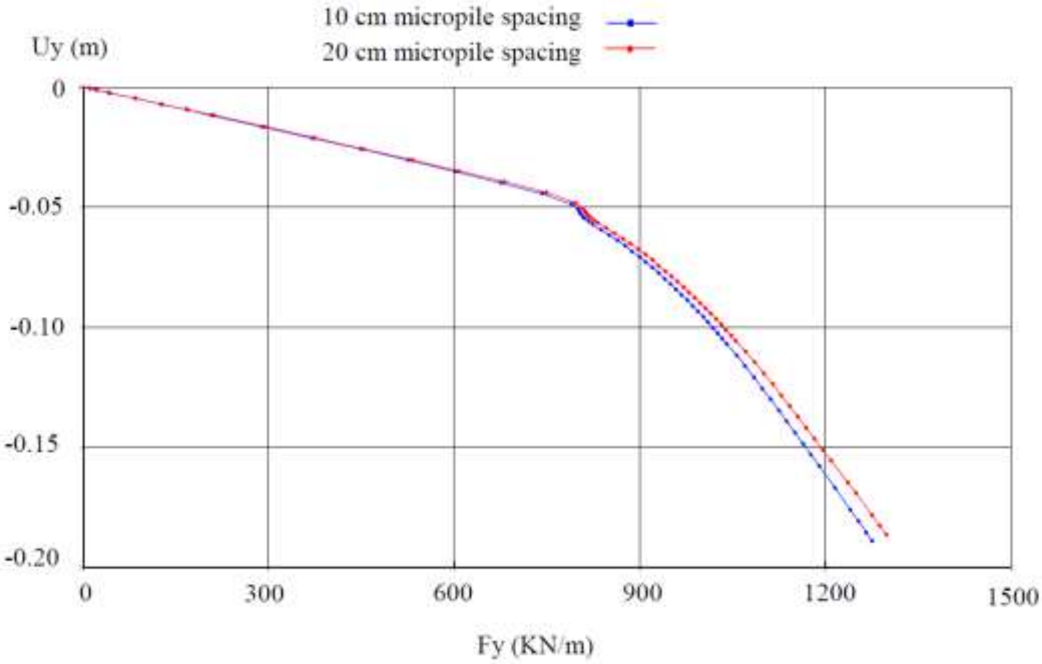

Figure 3.5. The effect of micropiles spacing on bearing capacity of foundation

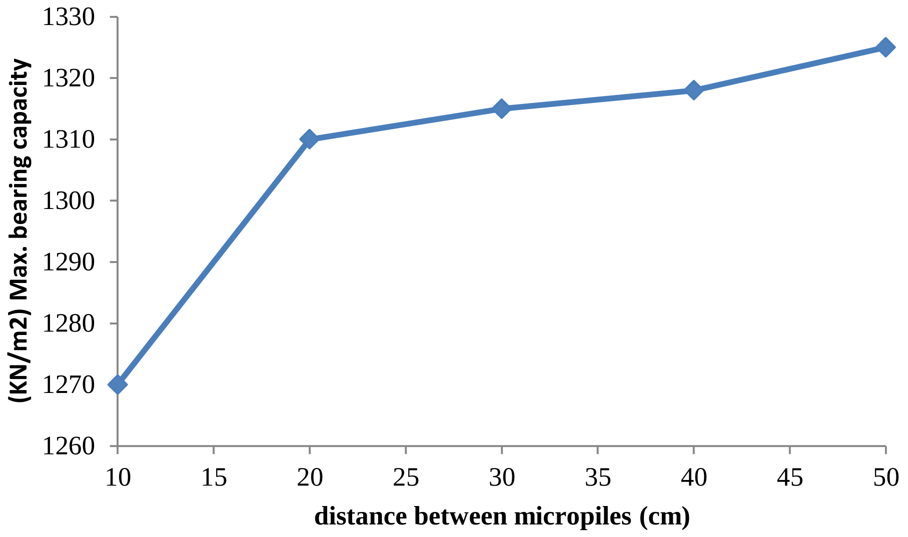

Figure 3.6. The effect of micropiles spacing on maximum bearing capacity of foundation

3.4. The slope of micropiles

One the most important factors that should be considered in pile driving is the direction of pile in soil or the slope of piles which determines the foundation capacity. To take into account this parameter, analyses have been done for micropiles placed at different slopes from 72 to 85 degrees. As suggests, the slope of pile has a great influence on the bearing capacity of foundation and about 20% difference can be seen by changing the slope in the defined range. It is also evident that the maximum changes happen for foundation settlement more than 0.05 m.

Figure also shows the maximum bearing capacity and the slopes of the micropiles. There are two parts can be detected in the figure. The first part, for slops less than 77 degrees which changes of bearing capacity is not considerable and the second part, for slopes more than 77 degrees where significant changes in bearing capacity occurs by increasing the slope of micropiles in soil.

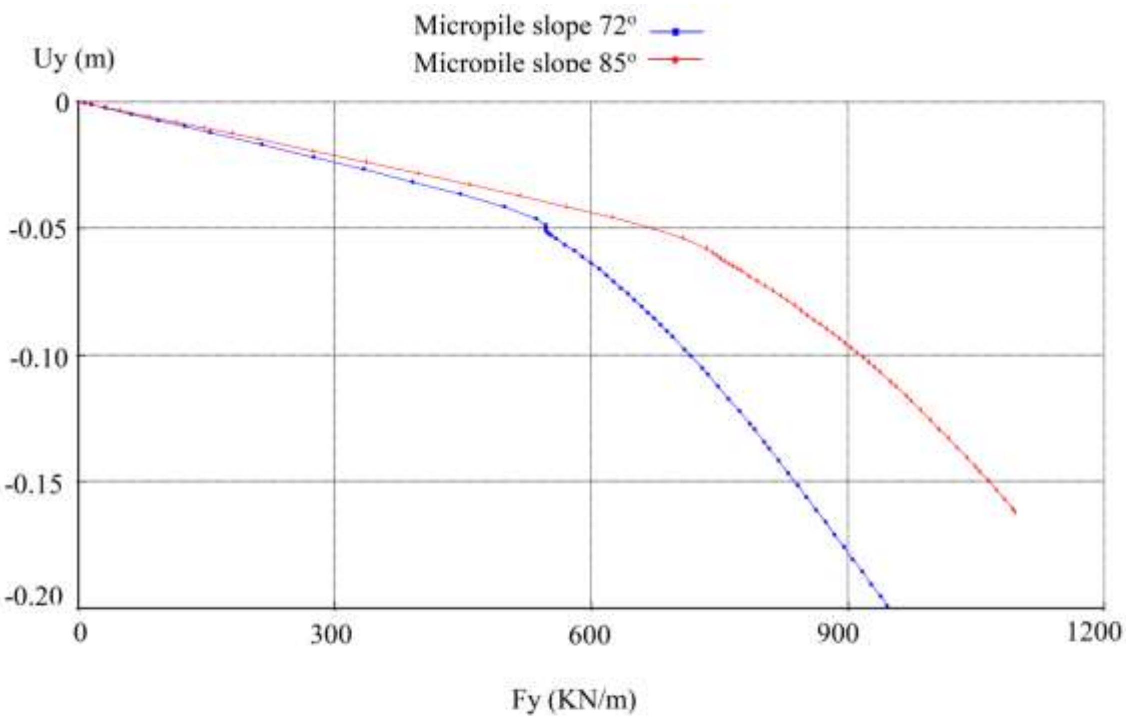

Figure 3.7. The effect of direction of micropiles in soil on bearing capacity of foundation

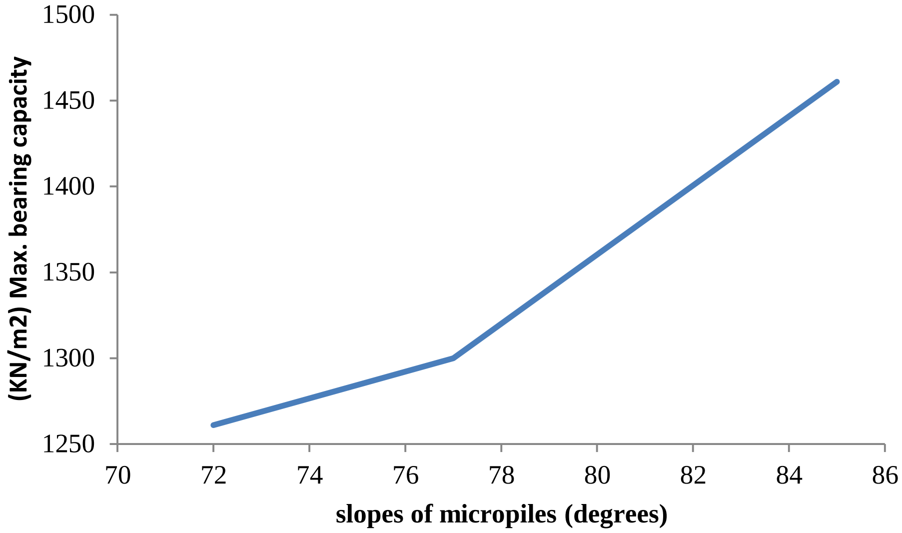

Figure 3.8. The effect of direction of micropiles in soil on the maximum bearing capacity of foundation

4. Conclusion

This paper investigates the effect of micropile parameters as an important issue in geotechnical engineering. The purpose is to find the optimum configuration of micropiles so that the maximum bearing capacity of foundations can be achieved. Four factors have been selected for sensitivity analysis; diameter, length, distance and slopes of micropiles. Based on the results, it can be concluded that diameter of piles has little effect on the bearing capacity of foundation. The same results can be seen for the length of micropiles. This is especially valid for the lengths between 3.5 and 4.5 meters. The distance between piles is important if the spacing is less than 20 cm and for the distances more than 20 cm the spacing has almost no effect. The slope of micropiles in the soil has the most important effect and 20% increase in bearing capacity can be seen by increasing the slope from 72 to 85 degrees.

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5. References

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