Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 13 Issue 07, July-2024

A Study on the Effect of Micropiles on Foundation

Arathy M T
Civil Engineering
St Thomas Institute for Science & Technology,
Thiruvananthapuram, Kerala, India

Abstract — **Micropiles are smaller diameter piles which are used around the foundation to reduce the settlement and to increase the bearing capacity of the foundation. Micropiles have high strength casing made up of steel, rebars and grout which transfer loads from the foundation to the soil through soil layers. Micropile applications include underpinning for existing foundations, in-situ soil reinforcement, seismic retrofitting and as foundations for new constructions. In the present study, the effect of micropiles on the settlement of footing resting on locally available clayey soil is studied. Plate load tests were carried out on a model square and circular footing of dimensions 150x150x10mm and 150 mm diameter;10 mm thickness respectively; resting on clayey soil with and without micropiles. The load tests were repeated for both the footings on micropiles of varying length of 10, 20 and 30 times the diameter and spacing 5, 4 and 3 times the diameter of micropiles. The load – settlement behaviour of each case is compared. The optimum length and spacing for the micropiles were determined. It is observed that the increase in the length and spacing of micropiles reduces the settlement considerably. As the installation of micropile is easy and it involves no alteration in the foundation, it can also be used for existing footing as retrofitting measures.**

***Keywords*—Micropiles**

INTRODUCTION

GENERAL

People started to design and build structures for different usages and environments, foundation systems to support such structures had to be developed in order to match the architectural and structural needs. Higher and slender structures subjected to wind and seismic loads need foundations which are capable to support compression, uplift and lateral forces. It is not always possible to find good supporting ground instead of large, mass concrete foundations, which require large areas and mass excavations. Smaller and deeper drilled shaft or pile foundations became more economical, in which steel reinforcing systems embedded in concrete and cement grout are the major component. Micro Piles belong in this category of foundation elements. Micropiles are very simple but unique in design and construction are becoming more and more popular. Micropiles were conceived in Italy in the early 1950's in response to the demand for innovative techniques for underpinning historic buildings and monuments that have sustained damage with time. The micropile systems used today are an evolution from the basic small diameter, cost in place pile developed by Dr.fernando lizzi called "pallo radice ". A typical micropiles construction involves drilling the pile shaft to the required depth placing the steel reinforcement, initial grouting by termie and placing additional grout under pressure where applicable a typical construction sequence. Micropiles are small diameter drilled piles typically between 5-12 inches in diameter which can have a depth of 200 feet and can achieve a working load of 200 tons. They are highly performing and have high capacity drilled deep foundations. Micropiles have a high strength casing made of steel, rebars and grout. They transfer the loads from the foundation to competent soils through soil layers. The loads from the foundation will be dissipated to the soil or rock through the steel and micropile grout. Micropiles are generally used when there are difficult ground conditions, such as natural or man-made obstructions, sensitive ground with adjacent structures, limited access/low headroom and/or karstic geology. Micropiles are divided into two general types – displacement piles and replacement piles. Displacement piles are members that are driven or vibrated into the ground, thereby displacing the surrounding soil laterally during installation. Replacement piles are placed or constructed within a previously drilled borehole, thus replacing the excavated ground. Micropiles can withstand axial and/or lateral loads, and may be considered a substitute for conventional piles or as one component in a composite soil/pile mass, depending upon the design concept employed. These micropiles are used when deteriorating foundation systems, renovation of buildings, to support structures from adjacent construction, to support buildings situated in earthquake prone areas or from landslides stabilization. Nowadays, hollow core bars are widely used in the construction of micropiles. The main advantages of these bars are faster installation and ground improvement. Micropile is an effective solution for conventional piles and carry heavier loads. Micropile applications include underpinning for existing foundations, in-situ soil reinforcement, seismic retrofitting and as foundations for new constructions.

1. OBJECTIVES OF THE STUDY

2. The objectives are as follows :

3. · To evaluate the settlement of footing resting on soil without micropiles and with micropiles of different length and spacing.

4. · To find the optimum length and spacing of the micropiles.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 13 Issue 07, July-2024

SCOPE

- Micropiles are becoming popular as it is a cost effective alternative to improve the load bearing capacity of the footing.
- To reduce the settlement of footing.
- As an improvement technique in strengthening existing foundations, in-situ soil reinforcement, seismic retrofitting and as foundations for new constructions.

LITERATURE REVIEW

5. Irfan Ahmad Shah et.al. (2021) a numerical study on unreinforced and reinforced soil model was carried out to evaluate the effect of various parameters of micropile such as length, spacing and lateral extent of reinforcing elements. Analysis was carried out to study the influence of length of the reinforcement, spacing between the reinforcing bars and their lateral extent beyond the footing edge on the bearing capacity and settlement of the foundation system. The analysis shows that the bearing capacity increases and the settlement decreases with a decrease in the spacing between the reinforcing bars and increase in their lateral extent beyond the footing edge. The maximum improvement in the bearing capacity of the reinforced fly ash was obtained as 340% with a corresponding decrease in the settlement of 86%. For all spacing and lateral extent values, the bearing capacity increases by increasing the length of the reinforcement bars.

6. S. Lekshmi et.al. (2020) studied the effect of micropile on foundation settlement using simple load tests. Two samples were prepared clayey soil with and without micropiles. A tank of dimensions 300x300mm and height 600mm is filled with soil and a steel plate of dimensions 80x80mm is used as footing. Settlement is noted using dial gauges. Another sample tank without micropiles around the footing is also tested. The settlement values are compared. This will be an economical solution in challenging sites like Kuttanad, Ernakulam etc.

7. J. Jagadeeshwar et.al. (2019) describes the bearing capacity of the foundation of the soil is improved using micropiles. Non-linear finite element analysis is carried out to examine the applicability and level of improvement obtained in the field.

Zakir Hussain et.al. (2019) investigate the response of micropile groups subjected to lateral load installed in loose sand (relative density 30%), in medium dense sand (relative density 50%) and in dense sand (relative density 80%). The group behaviour is found to be a function of the state of the sand, spacing of the micropile groups and length-to-diameter (L/D) ratio. Ultimate lateral resistances of micropile groups are maximum at 2D spacing in loose sand and in medium dense sand. In dense sand, maximum lateral resistance is observed in 6D spacing. Overall, it was observed that groups with higher L/D ratio had positive group effects. Modes of failure of the micropile groups are found to be a function of the length-to diameter ratio and relative density of the sand.

Tae- Hyun Hwang et.al. (2017) study investigates the support characteristics of a micropiled raft through model tests and a numerical analysis. The support behaviour of the micropiled raft is evaluated for various conditions, such as soil type, pile length, and installation angle. It is found that the micropiles modify the failure behaviour of the ground considerably, and that the bearing resistance can be enhanced by considering the appropriate failure mode, installation angle, and pile length.

S.A.Naeini & M. Hamidzadeh (2017) examined the improvement of Anzali's saturated loose silty sand using 192 micropiles with a length of 8 meters and diameter of 75 mm. bandar-e Anzali is one of Iran's coastal populated cities which are located in a highseismicity region. The effects of the insertion of micropiles on prevention of liquefaction and improvement of subsidence were examined through comparison of the results of Standard Penetration Test (SPT) and Plate Load Test (PLT) before and after the implementation of the micropiles. The results shows that the SPT values and the ultimate bearing capacity of silty sand increased after the implementation of micropiles. Therefore, the installation of micropiles increases the strength of silty sand improving the resistance of soil against liquefaction.

Nirmali Borthakur & Ashim Kanti Dey (2017) discusses the experimental observations on the behaviour of micropile groups under static axial vertical compressive load. The micropiles were constructed in the clayey soil of very soft consistency in a test pit of size 2.0m×4.0m×3.0m. Load-settlement behaviours of two different sets of micropile groups were studied. In one set, micropile caps were rested on the ground surface and in another set, they were constructed sufficiently above the ground surface. The variables involved in this study were diameter, length, number and spacing of micropiles in a group. The ultimate load carrying capacity of a micropile group and the group settlement under the safe load were determined from experimental observations. The group efficiency and the resistance offered by the micropile cap alone were also determined from the present study. It is observed that the load carrying capacity of a micropile group increases with the increase in diameter, length, number, and spacing of micropiles. A nonlinear equation is established from the experimental data to determine the ultimate load carrying capacity of a micropile group.

B. Vani &P.D Arumairaj (2015) studied the effect of micropiles on the load carrying capacity of footing resting on sand is studied. The parameters involved in this study include pile length and pile spacing. Load test was carried out on a model footing resting on sand with and without micropiles. Load test trial is repeated for footing on micropiles with varying lengths of 10, 20 and 30 times the diameter and spacing 5, 4, 3, 2 times the diameter. Optimum length and optimum spacing for the micropiles are determined. It is observed that the effect of micropiles in the peripheral of footing resists lateral displacement of soil underneath the footing. The micropiles beyond significant depth becomes redundant.

Mostafa Molaali et.al. (2014) the effects of micropiles on improvement of bearing capacity and subgrade modulus of a mat foundation placed on a thin weak soil layer of 4.5m thickness are investigated. Different elastic modulus of weak soil layer (100, 200 and 375 kg/cm2) with two micropile grid spacing of 1.5×1.5m2 and 1.75×1.75m2 are considered. The study is based on finite element analyses using PLAXIS 2D code in which both allowable bearing capacity and subgrade modulus are determined using the pressure-settlement curve obtained from the numerical results. The results indicates that though the micropile technique is capable to enhance the design

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 13 Issue 07, July-2024

parameters of foundation located on very weak soil layers, it is not an effective approach for foundations placed on medium density soil layers.

A.Bhattacharjee et.al. (2011) presents the results of laboratory model tests on the behaviour of a square footing supported on micropiles. The parameters varied in the study include micropile diameter, length, spacing between the micropiles and distance of micropile from the edge of the footing. Bearing capacity of unreinforced and reinforced footings is determined and bearing capacity improvement factor and settlement reduction factors are evaluated. The results are then analysed to study the effect of each parameter. The improvement of bearing capacity is noticed when the diameter and length of micropile increases and spacing between the micropiles and distance of micropile from edge of footing decreases.

G.L. Sivakumar Babu et.al. (2004) deals with a case study in which micropiles of 100 mm diameter and 4 m long have been used to improve the bearing capacity of foundation soil and in the rehabilitation of the total building foundation system. The micropiles were inserted around the individual footings at inclination of 700 with the horizontal. The technique was successful and the structure did not show any signs of distress later. Detailed finite element analysis conducted validated the suggested treatment. The paper describes the case study, the method of treatment adopted in the field and the results of numerical analysis.

MATERIALS AND METHODOLOGY
LOCALLY AVAILABLE CLAYEY SOIL

The clayey soil for the study were collected from Chenkal, Thiruvananthapuram, Kerala. The soil sample was collected in sacs and air dried. The clay collected were contains a greater water content hence behaved heavily sticky with a higher plasticity.

Sl No	Property	Result
1	Specific gravity,G	2.12
2	Water content	31.29
3	Liquid Limit	74%
4	Plastic Limit	25%
5	Soil Classification	CH
6	Percentage of clay	63%
7	Percentage of silt	32%
8	Unconfined Compressive Strength	1 kg/cm^2
9	Maximum dry density	14.12 kN/m^3
10	Optimum moisture content	26%

MICROPILES

Plain mild steel rod having diameter 6 mm and varying lengths of 180 mm, 120mm and 60 mm was used as the micropiles. The spacing of the installation of micropiles were chosen as 5D, 4D and 3D where D is the diameter of micropiles.

ODEL FOOTING

A mild steel square and circular plate of dimensions 150mm x 150mm x 10mm; 150 mm diameter and 10 mm thickness were used as square and circular footing respectively.

Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 13 Issue 07, July-2024

STEEL TANK

A tank is constructed in the laboratory in order to conduct the plate load test. The dimensions of the tank were 800 x 800 x 500 mm.

EXPERIMENTAL PROGRAM

The soil sample of required quantity is filled in the tank as three layers. Each layer is provided with 25 tamping and the soil is compacted and levelled. Micropiles of varying length were inserted into the soil perpendicularly in required spacings.

PLATE LOAD TEST ON FOOTINGS

The plate load test apparatus consisted of a proving ring of 50 kN capacity, hydraulic jack and eccentrically opposite placed dial gauges to find the settlement. Initially, Plate load tests were conducted on square and circular footing without placing the micropiles and the corresponding settlement were noted. Then the micropiles of three different lengths were inserted in three varying spacings and square footing were placed, then plate load tests were done. The settlement with the corresponding load was taken. After each trial, the soil was recompacted. The procedure is repeated for circular footing and the settlements were noted.

RESULTS AND DISCUSSIONS

After the soil gets filled in the tank square footing were placed inside without micropiles and the plate load test were conducted. The settlements were noted and the load - settlement curve were evaluated.

Load (kN)	Settlement (mm)
0	0
0.82	10.77
1.02	13.11
1.22	16.93
1.42	20.27
1.62	24.18

Settlement of square footing without micropiles

The procedure is repeated for circular footing without micropiles and the corresponding settlement were noted and the load – settlement curve were drawn.

Load (kN)	Settlement (mm)
0	0
0.82	14.75
1.02	19.6
1.22	21.85
1.42	24.68

Settlement of circular footing without micropiles

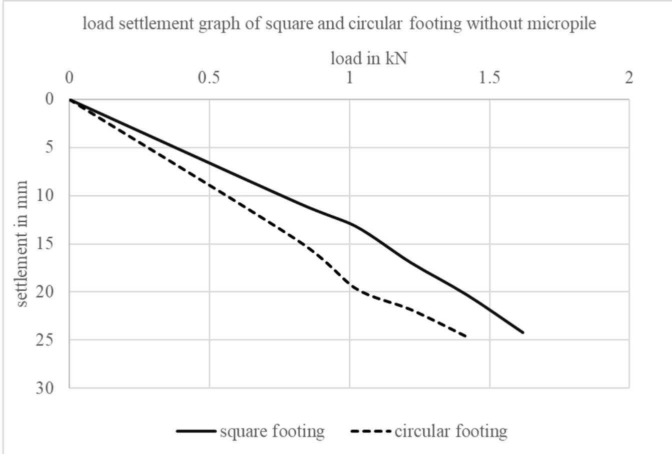


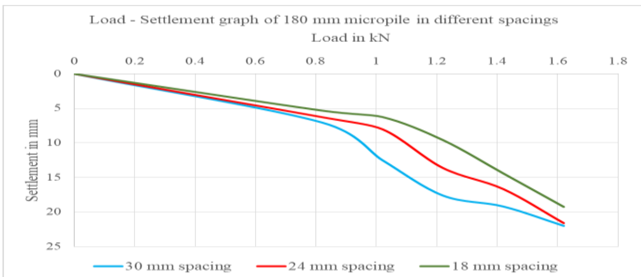
PLATE LOAD TEST ON SQUARE FOOTING WITH 180 MM MICROPILE

Load (kN)	Settlement (mm)		
	30 mm spacing	24 mm spacing	18 mm spacing
0	0	0	0
0.82	7.05	6.27	5.32
1.02	12.5	8.02	6.25
1.22	17.61	13.62	9.58
1.42	19.2	16.68	14.41
1.62	22	21.6	19.25

Settlement of square footing on 180 mm micropile for different spacing

load – settlement variation of 180 mm micropile in different spacings for square footing.

Plate load test were conducted on circular footing similar to square footing. Initially, the 180 mm micropile were tested on Similarly the study were conducted for the remaining lengths and spacings in the square footings and the load settlement curves were evaluatedthe footing and the settlement behaviour were studied.

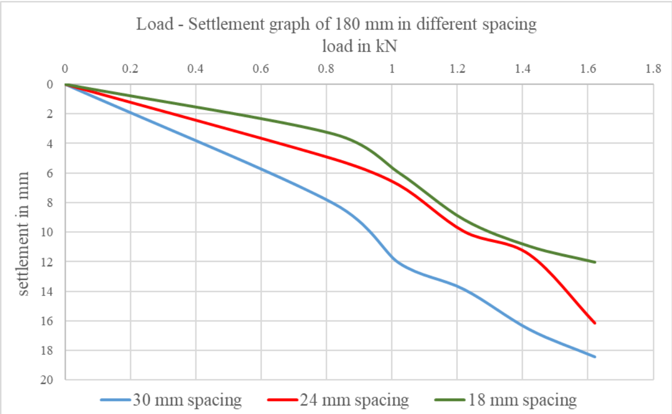


Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 13 Issue 07, July-2024

PLATE LOAD TEST ON CIRCULAR FOOTING WITH 180 MM MICROPILE

Load (kN)	Settlement (mm)		
	30 mm spacing	24 mm spacing	18 mm spacing
0	0	0	0
0.82	8.05	5.05	3.36
1.02	12.07	6.80	5.98
1.22	13.87	9.96	9.16
1.42	16.58	11.52	10.96
1.62	18.43	16.16	12.04



The circular footing resting on 180 mm showing the minimum settlement on 18 mm spacing.

1 PLATE LOAD TEST ON SQUARE FOOTING WITH 120 MM MICROPILE

Soil is removed and filled again and compacted after the first trial. 120 mm micropile were inserted after removing 180 mm micropile and then the test is repeated for the corresponding length for three different spacings.

Settlement of square footing on 120 mm micropile for different spacing

Load (kN)	Settlement (mm)		
	30 mm spacing	24 mm spacing	18 mm spacing
0	0	0	0
0.82	5.67	4.66	3.21
1.02	11.58	10.62	5.6
1.22	16.32	13.45	8.39
1.42	18.31	18.14	13.64
1.62	21.6	19.76	16.67

Load – settlement variation of 120 mm micropile in different spacings for square footing.

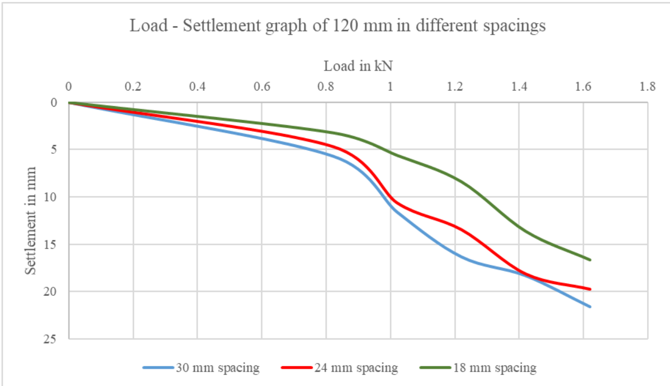


Fig shows the variation in the settlement of 120 mm micropile for three different spacings. The curve shows that the minimum settlement is shown in 18 mm spacing for the 120 mm micropile.

PLATE LOAD TEST ON CIRCULAR FOOTING WITH 120 MM MICROPILE

Settlement of circular footing on 120 mm micropile for different spacing

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 13 Issue 07, July-2024

Load (kN)	Settlement (mm)		
	30 mm spacing	24 mm spacing	18 mm spacing
0	0	0	0
0.82	5.03	4.02	3.14
1.02	7.82	6.17	4.87
1.22	13.09	9.31	8.73
1.42	15.96	11.16	10.64
1.62	18.01	14.31	11.64

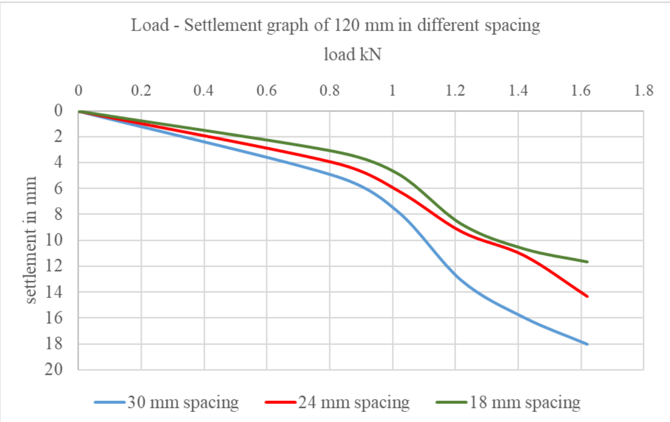


PLATE LOAD TEST ON SQUARE FOOTING WITH 60 MM MICROPILE

Plate load test is repeated for 60 mm micropile on 30, 24 and 18 mm spacings and the settlement is noted.

Settlement of square footing on 60 mm micropile for different spacing

Load (kN)	Settlement (mm)		
	30 mm spacing	24 mm spacing	18 mm spacing
0	0	0	0
0.82	8.84	7.96	7.3
1.02	16.56	13.3	9.64
1.22	17.51	16.45	14.33
1.42	20.26	18.5	15.52
1.62	23.33	20.88	17.81

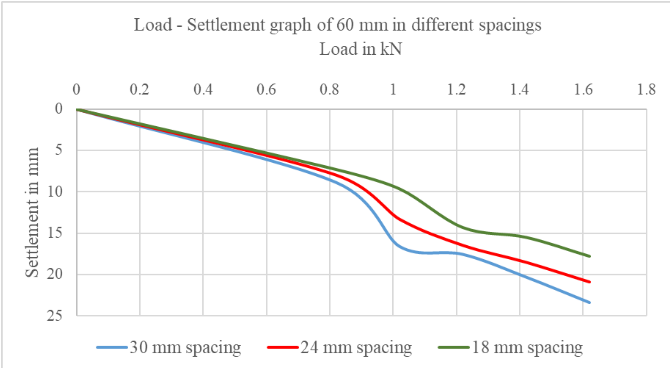
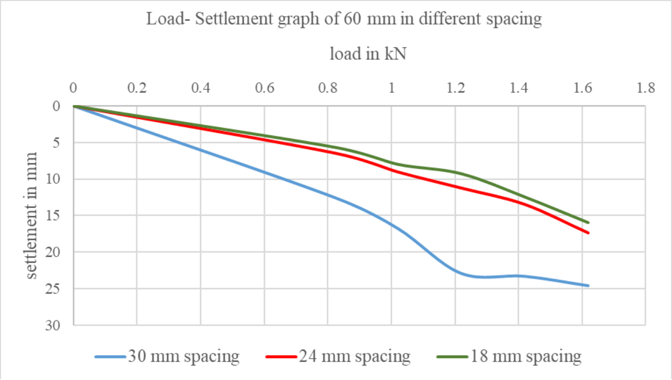


PLATE LOAD TEST ON CIRCULAR FOOTING WITH 60 MM MICROPILE

Settlement of circular footing on 60 mm micropile for different spacing

Load (kN)	Settlement (mm)		
	30 mm spacing	24 mm spacing	18 mm spacing
0	0	0	0
0.82	12.5	6.42	5.62
1.02	16.74	9.01	7.96
1.22	22.9	11.21	9.24
1.42	23.3	13.45	12.41
1.62	24.59	17.35	15.92



The minimum settlement on 18 mm spacing in 60 mm micropile

CONCLUSIONS

Experimental study of micropiles on foundation settlement on clayey samples with and without micropiles were carried out.

- Plate load test were conducted on square and circular footings by varying the length and spacing of the micropiles.
- Settlement of soil bed is more when load is applied on the plate directly before placing the micropile.
- It is studied that with an increase in the length of micropiles the settlement reduces considerably.
- Also by reducing the spacing between micropiles, the settlement of the footing gets reduced.
- The optimum length and spacing of micropiles on both the footings were determined.
- Micropiles shows more effect on circular footing rather than square footing.

REFERENCES

[1] A Bhattacharjee et al. (2011) "Bearing Capacity Improvement Of Square Footing By Micropiles", International Journal of Geotechnical Engineering 1(5): 113- 118.

[2] B Vani and P. D. Arumairaj (2015) "Evaluation of Settlement and Load Carrying Capacity of Footing with Micropiles on Sand", International Journal of Scientific Research 4(6):44 -46.

[3] G L Sivakumar Babu et al. (2004) "Bearing Capacity Improvement using Micropiles: A case study", Geotechnical Special Publication 5(3): 1-8.

[4] Irfan Ahmad Shah et al. (2021) "A Numerical Study on the Bearing Capacity of Fly-Ash Reinforced with Fine Micropiles", International Journal of Geosynthetics and Ground Engineering 7(3): 2-14.

[5] J Jagadeeshwar et al. (2019) "Ground Improvement by Using Micropiles as Foundation", International Journal of Information and Computer Science 6(6):303-310.

[6] Mostafa Molaali et al. (2014) "Soil Improvement Using Micropiles", Conference paper 8(3): 5-10.

[7] Nirmali Borthakur and Ashim Kanti Dey (2017) "Experimental Investigation on Load Carrying Capacity of Micropiles in Soft Clay", Arab J Sci Eng 7(5): 24-37.

[8] S A Naeini and M hamidzadeh (2017) "Using Micropiles to Improve the Anzali's Saturated Loose Silty Sand", International Journal of Geotechnical and Geological Engineering 11(7): 674-681.

[9] S Lekshmi et al. (2020) "Effect of Micropile on Foundation Settlement", International Research Journal of Engineering and Technology 7(5): 7375-7378.

[10] Tae - Hyun Hwang et al. (2016) "Effective Installation of micropiles to Enhance Bearing Capacity of Micropiled Raft", Japanese Geotechnical Society 57(3): 36-49.

Zakir Hussain et al. (2016) "Micropile group behaviour subjected to lateral loading", Innovative Infrastructure Solutions 4(1): 1-9.