Experimental Study on Behavior of Micropiles on Sand Resting on Footing

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Abstract— Micro piles have been used in the account of Ground Improvement to enhance the Bearing Capacity and to reduce the settlements of the soil for strengthening the foundation of the structures. The frictional resistance between the pile surface and the associated group/ network effects of Micro piles and the ground soil is considered the feasible mechanism for improvement. The most common reason behind the foundation underpinning is seismic retrofit and prevention of the damaging settlement. Micro piles are generally used for the underpinning, whereby different load transfer structures are implemented between the existing structure and the Micro piles. The classification of Different kinds of load transfer structures was introduced in the present paper. In present years, the pile foundation has not been dependent on the load-bearing piles, that have been used in japan such as friction pile foundation and piled raft foundation. The current authors have been researching the support structures by the friction between the earth soils around the surface of the piles. In this study, the various sizes of pile foundations are used. Micro Piles consist of a small diameter (usually less than 12 inches), driven piles or cast-in-place drilled piles, which are a mixture of the steel reinforcement and grout. It can be adapted over conventional piles, the reason behind that is that they can be drilled under hard subsoil conditions, on the Other Hand Conventional pile foundations cannot be constructed and can be used for strengthening the existed foundations.

Indexed Terms— Micropile, Load Bearing Resistance, Foundation

I. INTRODUCTION

The word" GROUND IMPROVEMENT" can be defined in the simple words "It is the process of the enhancing the qualities of soils and subsoils. "The phrase Ground Improvement is referring to the enhancement and improvement of the ground soil and subsoil layers but in some cases, it also refers to the enhancement of the rock layer ASCE (1997). For Improving the problems related to the poor soil Conditions (Geo-Odyssey, Karstic Limestone 2001) the geotechnical engineers used the ground Improving techniques as a tool for fixing it. Whenever a poor grade of soil is exited on the site, the project builder has been faced the many questions about the poor soil conditions, which can be:

- Is that the poor soil condition can be completely removed and can be replaced with a suitable material?
- Should the poor condition of the ground be ignored by changing the project's location or by the use of the deep foundation on the existed soil surface?
- Should the dimension and designs of the superstructure (height, length, breadth, configuration, etc.) be changed according to the limitation of the ground?

Micro Piles can be explained as small diameter drilled piles consisting of a mixture of grout with the steel reinforcement placed concentrically of the grout for the load (Sun et al, 2013; Bruce and Juran, 1997; Bruce et al,1995). The centrally placed reinforcing is of high strength steel bar or a tube that is inside the grout drilled under with high pressure for strengthening the bonds between the surrounding soil and piles. The Micro Piles can be installed vertically or at an angle at any ground condition for strengthing the adjoining of the superstructure. Micro piles are mostly used in the various ground applications of ground improvement to reduce the settlement of the foundation and to enhance the bearing capacity of the soils. The use of the Micropiles has been continuously increasing over the

past few years. To reduce the risk of landslides and the effects of earthquakes on the structures Micro piles have been used. Evaluating the lateral load acting on the Micro piles was the major concern of the micro piles, which will provide almost every information for the design.

1.1 Classification of GIT's

The method of the soil Improvement that are widely used in the current state of the practice can be divided into 3 different categories:

- Densification
- Consolidation
- Reinforcement of soil

To increase the Shear strength of the soil and to reduce the settlement under the lateral load and to enhance its resistance against the liquefaction(soil having zero shear strength), the concentrically placed high strength steel inside the grout are used.. The one of the following methods are accomplised for Reinforcing the soil are:

Mechanically stabilization
Soils nailing
Soils anchoring
Micro piles
Stone columns
Fiber reinforcement

Now the Micro piles are in use for more than 55 years. They were adopting it as a most innovative solution to help the people in the post-war reconstruction process. For the last 20-25 years, Micro piles techniques have been used very widely and have developed from the concept of low capacity micro piles network to the use of high capacity elements. To counter the problems like supporting high loads and restricted access engineers generally used these types of small elements. Along with it Geotechnical Engineers and Soil researchers also give their attention to Micro piles networks that are technically, logically, and economical solutions to the problems related to soil stabilization, seismic retrofit, and lateral loading. Micro piles consisting of small diameter piles (generally less than 30cm) are injected vertically and are placed closer than the conventional pile foundations and the lateral loads are supported by complex soil-pile structures analogous to high strength steel reinforced concrete. The presence of the stone columns transforms the soil into a composed mass of the granular cylinders with the native soil alone Bruce D.A., Traylor, and Lolcama J (2001). The earliest concept is based on 3-d techniques of earth reinforcement involving the mixing of the continuous Polymer fibers (yarn) with the granular soil to form a composed material having the ability to resist the tensile forces acting on it. Micro piles can be placed in various types of soils such as non-cohesive soils, cohesive plastic clays, and poorly graded granular soils. The Micro piles placed vertically in the rock exhibited the maximum load-carrying capacity.

Like all other materials,The Micro piles also have pros and cons.

Advantages of Micropile

- Micropiles can be easily installed where there is a constraint of low headroom.
- With the help of ground anchors and grouting objects Micropiles can be installed at any angle.
- They cause minimum disturbance to the adjoining structures and have minimal voice and vibrations.
- As a remedy for existing foundations, Micropiles can be installed for new construction.
- With any length Micropiles are installed in threaded sections or making it ideal for low headroom installations.
- Due to being small in size Micropiles rigs are able to get into places where other deep foundations rigs can't.
- Where there is a need for low vibration or noise is prime importance Micropiles are used to underpin the existing.

Disadvantages of Micropile

- It is uneconomical as compared to others.
- There are very high chances of corrosion.
- Hammer used for Micro pilling is noisy and its vibrations may damage adjoining structures.
- During the construction below the surface objects or boulders can block or diverge the pile.

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1.2 Classification of Micropiles

A micropile is a small diameter drilled pile and grouted & placed reinforcement in the center of that. It is developed by the drilling a into the sand or by creating boreholes , then placed reinforcement, and grouting the bore hole. Micro piles are usually classified according to the groutings and design applied . The design application defines the function of the micropile and on the other hand the grouting method explains the grout/grout bond capacity.

In the design application, there are generally 2 types of application. The first type is where the micropile is directly loaded either axially or laterally and the pile reinforcement resists the majority of the applied load. This type of pile is used to transfer structural loads to deeper, more competent, or stable stratum and may be used to restrict the movement of the failure planes in slopes. The loads on the structure are primarily resisted by the highly-resisted steel reinforcement structurally and by the grout/grout bond zone geotechnically.

The second type of design application is where the micro piles reinforce the soil to make a reinforced soil composite that resists the applied load and is known as a reticulated pile network.

The method of grouting is generally the most sensitive construction over grout/grout bond capacity and varies directly with the grouting method.

TYPE A: Type A classification indicated that grout is placed under the head only. Sand-cement mortar, as well as neat cement grouts, can be used because the grout column is not pressurized.

TYPE B: Type B indicated that neat & of specific grade of cement grout is placed into the borehole under the high-pressure as the temporary tensiled steel drill casing is withdrawn. Injection pressures typically range from 0.5 to 1 MPA and are limited to avoid hydro-fracturing the surrounding ground or causing excessive ground takes, and to maintain a seal around the casing during its withdrawal, where possible.

TYPE C: Type C indicates a two-step process of grouting. Primary grout is placed under the pressure of 1 to 2 MPA, causing hydro-fracturing of the surrounding ground. Prior to the hardening of the primary grout, the second grout is injected usually via a tube or a manchette. This method is sometimes referred to as IGU (Injection Globallet Unitaire).

TYPE D: Type D indicates the further two-step process of grouting similar to TYPE C with modification to the secondary grouting. Primary grout is placed under pressure and after hardening of the initially placed grout, additional grout is injected via tube a manchette at a pressure of 2 to 8 MPA. Some other types of micropile are described below:-

1. Displacement piles
2. Bored piles

Displacement piles are drilled piles and can be either precast or cast-in-place. Some companies have developed a cast-in-place rotary displacement pile marketed under the trade-mark which combines enhanced friction capacity with the creation of a thread around the pile casing, that significantly increases pile bore diameter.

Bored piles are made in many different forms:

- Cased piles
- Slurry piles including barrettes
- Continuous Auger piles

Some companies have developed highly-sophisticated machines with excellent products for the construction of piles. The machines carry electronic systems to ensure perfect results every time.

II. EXPERIMENTAL WORK

2.1 Introduction

The protection of natural recourses and sustainable development plays an important role in modern requirements for construction works. Construction materials are very significant in our lives because we spend 90% of our time in buildings or infrastructures (roads, highways, bridges, etc. The micropiles are the main components of soil and for many reasons, there is a need to re-use them. The bearing capacity of the sand subgrade is increased when reinforced uniformly with vertical rods. The aim of this experimental work is to determine the influence of variables on the bearing capacity and extent of improvement. Plate load tests were conducted on a model footing resting on clay reinforced with micro piles. The main idea of performing the model tests was to determine the

bearing capacity and settlement of footings resting on unreinforced/reinforced soil.

2.2 Experimental Procedure

The following steps are used to conduct the laboratory test on the model square footing of size 57x10cm and 10cm thick.

Filling & compaction: - The soil used in filling & compaction was the fine sand. The filling up of the tank is done in 11 layers of sand having 10cm thickness each. And the compaction is done by the rainfall method of compaction. In this method, the soil is filled into the tank from a height of 40 cm, giving a density of 1.4kg/cm^3 which is the required density of the experimental soil. The steel sieve was placed above 40 cm of each layer of sand for simultaneously filling and compaction. The steel sieve was adjustable and it was attached to the angles provided at the top of the tank with the help of chains. For each test, the bottom five layers remain as it is and the upper six layers are extracted every time. The poured sand was leveled with the help of a trowel and beveled edge. The level was checked with the help of a bubble tube.

Fig-1: Filling and Self Compaction Apparatus

Installation of steel piles: - For installation of steel piles center of the tank is determined. After that points were marked where the piles were to be installed. The vertical piles are installed at the center, 0.5B and 1.0B from the center of footing. The length of the piles used was 10cm, 20cm, and 30cm respectively. In this, no piles were installed below the footing, the reason being that it was a case of an existing footing wherein no reinforcement could be provided below the footing, only the side reinforcement could be done to increase the bearing capacity.

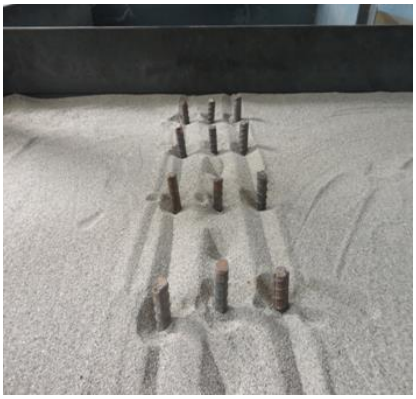

Fig -2: shows different positions of reinforced piles

- Place the tank under the reaction frame and centering of the tank is to be done. Now square footing is to be provided at the center of the tank. A load-bearing ball is provided at the space provided above on the footing. A proving ring fitted with the plunger and a horizontal plate is placed and a load-bearing ball is placed below the mechanical jack and above the proving ring. A complete set up of frame is shown in fig 3.

Fig-3: Hydraulically Operated Jack and Settlement Gauge Assembly

- Fix the dial gauge with the frame at the proper position and adjust it to zero.
- Apply the load through the mechanical jack of the reaction frame by rotating it with the help of a rod. Note the reading of the settlement dial gauge after 11 divisions of dial gauge or applying 0.3 kN load. Take the reading until the soil fails to bear the load.

3 Material Used

The following materials were used to perform the test in the laboratory:

2.1 Sand

Locally available dry sand was used in the model tank for the experimental study. For the test which is performed in a lab, specific gravity and finesses modulus of the sand are 2.69 and 2.66 respectively.

2.2 Steel Rod

The steel rod used in this study was made of mild steel material. The physical properties of mild steel are given in the table.

Table-1: Properties of steel

Limit of Proportionality	280 N/mm^2
Ultimate Stress	415 N/mm^2
Young's Modulus = E	x 10^5 N/mm^2

2.3 Testing Tank

The dimension of the tank was fixed as 57cm (length), 125cm (width) and 120cm (height). The sides and bottom of the tank were made up of a 9mm thick steel sheet, welded to the base framework of steel angles and plates.

Figure-4: Testing Tank

2.4 Footing

Model footing made up of mild steel was used. The footing was machined to correct size in rectangular shape. The size of the footing used was 57cm x 10cm x 10cm thick. A curve is provided at center of footing so that load bearing ball rested and do not slip when load is applied through reaction frame.

2.5 Test Performed

Experimental program consists of the following test.

- Plate load tests on the model footing

2.5.1 PLATE LOAD TESTS

Plate load tests were conducted on a model footing resting on sandy soil reinforced with steel piles on a tank. The detail of the tests performed is presented in

Table 2. Tests were performed after reinforcing the soil by introducing the steel piles of L = 10cm, 20cm, and 30cm at different locations as described below. The arrangement of installation of steel piles is vertical in nature.

Table-2: No of tests performed

L= LENGTH OF PILE	N= NUMBER OF PILES	H/B= LOCATION OF PILE	N= NUMBER OF PILES	
			VERTICAL PILES	
10cm	4	0	4	0
	12	0	4	0
		0.5	8	0
	20	0	4	0
		0.5	8	0
		1	8	0
20cm	4	0	4	0
	12	0	4	0
		0.5	8	0
	20	0	4	0
		0.5	8	0
		1	8	0
30cm	4	0	4	0
	12	0	4	0
		0.5	8	0
	20	0	4	0
		0.5	8	0
		1	8	0
UN-REINFORCED	0	0	0	0
TOTAL TESTS	09			

III. RESULTS AND DISCUSSIONS

Plate load tests were conducted on natural sand to confirm the effect on the bearing capacity and settlement. Two parameters, related to the bearing capacity of reinforced sand were investigated. The parameters included the length of the pile (L), and the number of piles (N).

3.1 Number of Piles

Figure 5 to 13 shows the variation of settlement of reinforced soil. Results indicate that with an increase in length of pile, settlement decreases at the same pressure level, and results also indicate an increase in the bearing capacity of the soil. When the length of the pile increases from 10cm to 20cm, the results also show an increase in the bearing capacity of the soil by 9.09% for N=4, 15.78% for N=12, and 19.04% for N=20. Similarly, when the length of the pile increases from 10cm to 30cm 39.39% for N=4, 44.73% for N=12, and 80.95% for N=20.

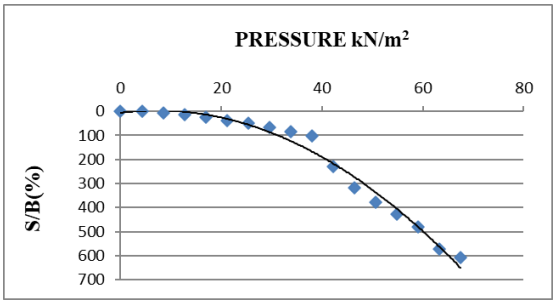

Figure-5: Pressure settlement curve for soil reinforced with micropiles (L/B=1 , N=4)

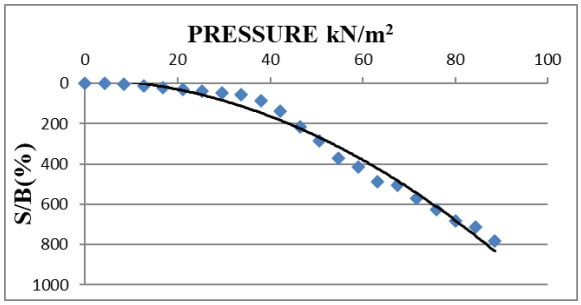

Figure-6: Pressure settlement curve for soil reinforced with micro piles (L/B=1 , N=12)

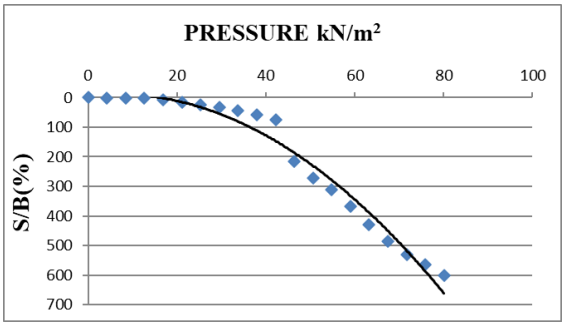

Figure-7: Pressure settlement curve for soil reinforced with micro piles (L/B=1 , N=20)

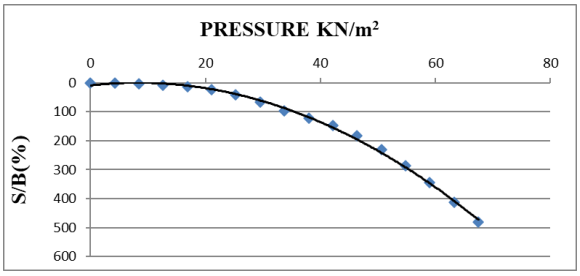

Fig-8 : Pressure settlement curve for soil reinforced with micropiles (L/B = 2 , N=4)

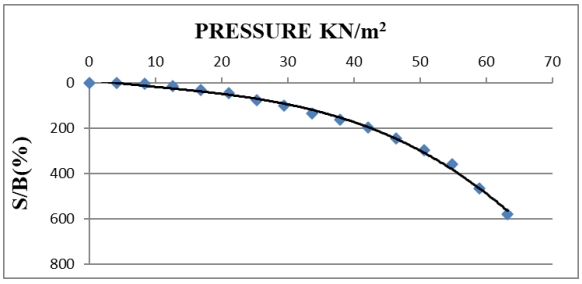

Fig-9 : Pressure settlement curve for soil reinforced with micropiles (L/B = 2 , N=12)

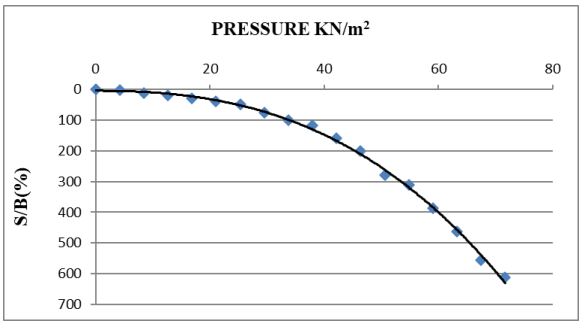

Fig-10 : Pressure settlement curve for soil reinforced with micropiles (L/B = 2 , N=20)

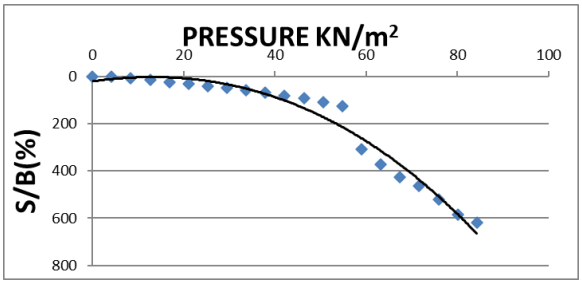

Fig-11 : Pressure settlement curve for soil reinforced with micropiles (L/B=3 , N=4)

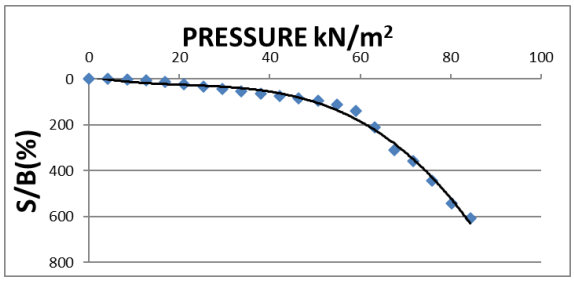

Fig-12 : Pressure settlement curve for soil reinforced with micropiles (L/B=3 , N=12)

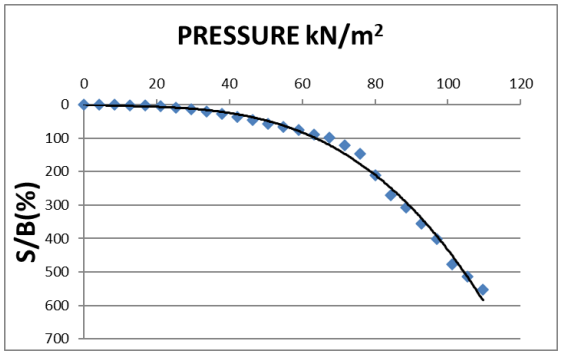

Fig-13: Pressure settlement curve for soil reinforced with micro piles (L/B=3 , N=20)

IV. CONCLUSION

The study shows the advantages of using vertical piles or reinforcing rods on different types of soils such as sand sub grades.

As the number of vertical piles and the length of the piles increase the stiffness of the ground increases which increases the ultimate bearing capacity of the column.

The Results also indicate that with the increase in piles length, soil settlement decreases at the same pressure level.

Micropiles have proved successful at solving problems at a wide range of difficult sites. Installation costs are decreasing while productivity is increasing. Both will encourage the method's wide use. Higher load capacities will further their benefits and enhance their use. Many new applications for this advancement in construction techniques can be expected, both in new projects and for rehabilitation work.

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