

Eureka Journal of Civil, Architecture and Urban Studies (EJCAUS)

ISSN 2760-4977 (Online) Volume 2, Issue 5, May 2026



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MICROPILE TECHNIQUES FOR SOIL TREATMENT AND FOUNDATION ENHANCEMENT IN EXISTING STRUCTURES

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Abstract

Micropiles are an effective means of improving the ground. It is also used for the support of foundations. Micropiles are widely used in geotechnical engineering. It is used for strengthening weak soils. Moreover, it is also used for the rehabilitation of existing structures. The paper shows a specialized study for Micropiles systems as an engineering process used for soil treatment within Princesses Residential Complex 2 in Najaf Governorate. The engineering of these structures is such that all of them are residential buildings each two-story built of brick with mat foundation of thickness 30 cm. Observed cracking in walls & foundation along with severe subsidence in soil. The method involves site investigation which includes the drilling of 3 wells of 15m depth. Soils were found to be sandy (SP) and had very high SO₃ (10.491), TSS (25.591), OM(0.135), GYPSUM (22.453), The soil is weak up to 6 meters depth (SPT = 15 blows), and after 6 meters depth it increases to more than 50 blows, Where the groundwater level is 13 meters deep, The failure is due to the breaks of drainage pipes and constant irrigation of the gardens which dissolve salts, organic materials and gypsum, leaving voids behind which cause massive subsidence of the soil. Results show improvement in load-bearing capacity, reduction in settlement, and stability. The study demonstrates the effectiveness of Micropiles in complex soil conditions and limited construction spaces.

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Keywords: Micropiles; Soil Treatment; Ground Improvement; mat Foundation Engineering; Settlement Control.

1. Introduction

The performance of buildings is mostly dependent on the character of the supporting soil. In many situations soils like soft clays loose sands or variable deposits do not have the capacity and stability to carry structures or their loads safely. Micropiles also known as mini-piles or root piles are small diameter (generally 100-300mm) deep foundation elements drilled and grouted in the ground that is reinforced with a steel bar or casing that is capable of taking load to deeper competent soil. These micropiles are widely used for soil treatment, underpinning of foundations and repairing and strengthening of structural members. Due to micropiles' less site requirement and easy installation they are greatly in demand in the urban areas where there are many existing structures. In the paper micropiles engineering application has been reviewed for soil improvement in constructed buildings with special reference to design methodology, field applications and performance evaluation.

2. Methodology

2.1 Site Investigation

A thorough geotechnical investigation is carried out to assess subsurface conditions. Soil samples taken from boreholes help determine some of the physical and mechanical properties of soil. For example, grain size, consistency and shear strength and compressibility. Sampling can be divided into:

- Disturbed samples, which can be used for classification tests but cannot retain natural soil structure.
- Undisturbed samples retain the in-situ conditions of soil and are used for advanced laboratory tests, more so cohesive soil.

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Commonly used sampling tools consist of split- spoon samplers and piston samplers. Correct sample handling and storage are essential for the integrity of the sample and the test results (Braja M. Das, 2019).

A. Borehole drilling , sampling and SPT

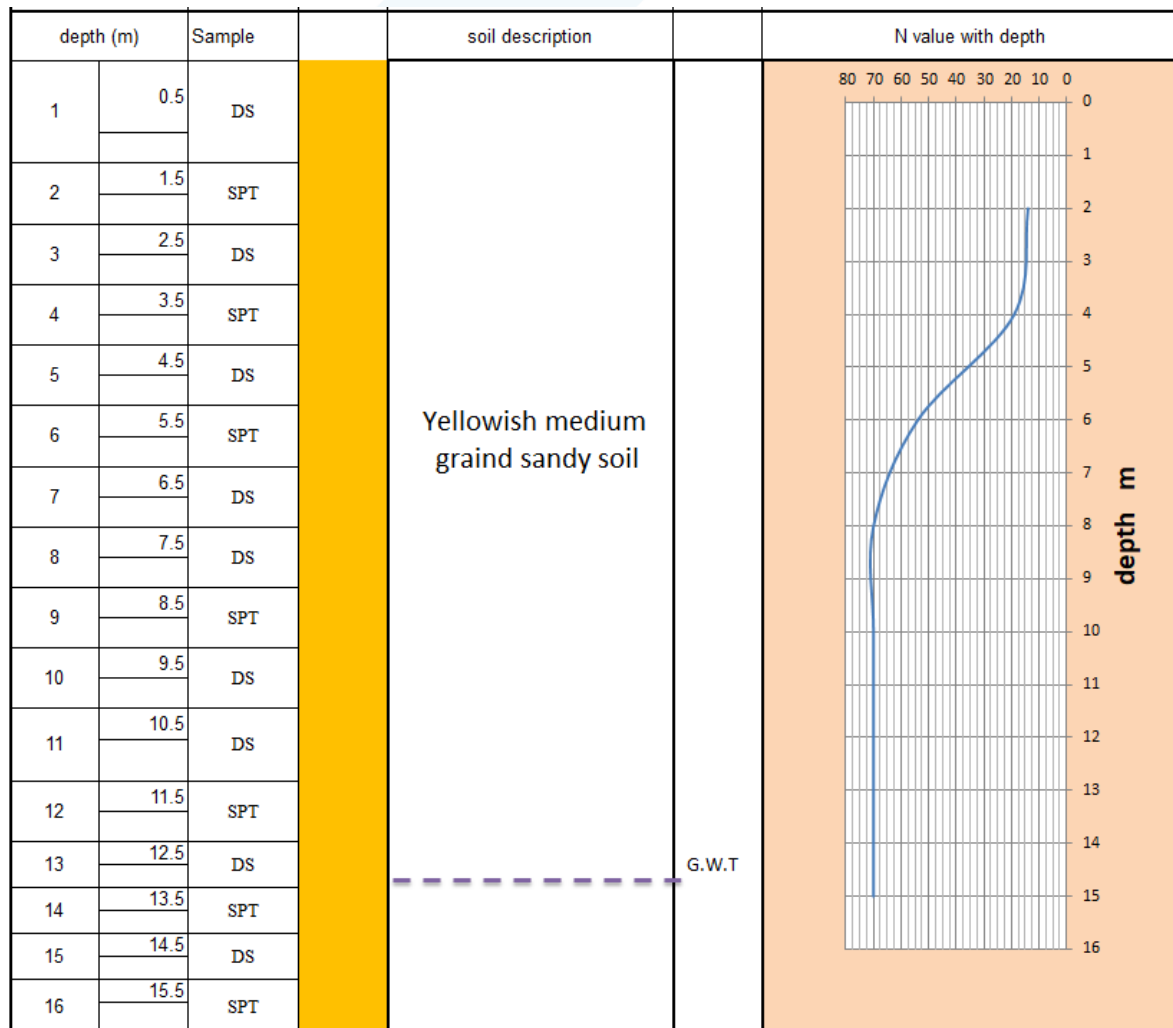


Figure 1: soil profile with depth and SPT.

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B. Laboratory testing (shear strength, permeability and chemical analysis)

Table 1. Soil classification according to USCS and physical properties

depth (m)	soil classification				Gradation		soil classification	M.C %	Density g/cm ³	Gs
	clay %	silt %	sand %	gravel %	Cu	Cc				
0-2	5	7	85	3	3.7	0.57	poorly graded sand, SP	2.3	1.61	2.55
3-5	3	4	87	6	4.2	0.63		1.8	1.7	
6-8	0	3	95	2	4	0.63		3.2	1.92	2.58
9-11	0	4	85	11	3.8	0.59		7.2	1.97	
12-14	0	1	91	8	4.3	0.64		13	2.01	2.61
15-16	0	5	78	17	3.9	0.59		12	2.1	2.6

C. Direct shear test result

Table 2. Direct shear test result

depth (m)	Direct shear test	
	C (kN/m ²)	Φ (deg.)
0-2	13	37
3.0-5.0	0	42
6.0-8.0	0	44
9.0-11.0	0	43
12.0-14.0	0	45
15-16	0	44

D. Chemical analysis

Table 3. Chemical analysis results

depth (m)	SO ₃ %	T.T.S %	OM %	Gypsum %
0-2	5.9	14.4	0.15	12.6
3.0-5.0	4.8	15.0	0.1	13.0
6.0-8.0	4.5	8.7	0.1	3.8
9.0-11.0	1.8	0.9	0.2	1.9
12.0-14.0	2.2	1.1	0.1	2.4
15-16	2.2	1.1	0.15	2.4

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2.2 Micropile Design

The design of micropiles encompasses a combination of structural and geotechnical considerations that help to ensure safe and efficient load transfer to competent ground layers. The design is mainly controlled by the structural load requirements, site soil conditions, grout-ground interaction and the type of reinforcement adopted.

The diameter, length, spacing and quantity of micropiles is based mainly on structural load requirements. Depending on how the structure allows, axial compression, tension, and lateral forces may be present. The FHWA (2005) stated the design of micropiles with appropriate load factors of safety will successfully resist these loads in ultimate and serviceability limits.

Also, micropile behavior is greatly affected by soil layering and strength. There must be detailed site investigations to ascertain the soil strata, engineering properties of soil and depth of competent strata. Load transfer mechanisms such as end bearing and skin friction depend on the nature of soil conditions and dictate the required embedment depth of micropile (Braja M. Das, 2019).

The bond strength of the grout with the soil/rock material – this has to be studied. This bond controls the micropile shaft resistance, which is the main load-carrying mechanism in most cases. Several factors affect bond strength, which include soil type, grouting technique, construction quality, and more. Greater bond strength leads to better load transfer, and may reduce the pile length needed (Deep Foundations Institute 2015).

Micropile reinforced with steel bars or steel casings, affects structural capacity and durability of micropile. Steel bars are generally used for axial loading basically, while casings may be needed in conditions with high bending stresses, poor ground stability or aggressive conditions. According to the American Society of Civil Engineers (2018), the choice of reinforcement must guarantee sufficient strength, stiffness and resistance to corrosion over the design life of the structure.

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2.3 Types of Micropiles

Micropiles are most commonly classified according to their grouting method which has a direct influence on their load transfer mechanism, bond strength and capacity. The four types (A, B, C and D) represent succeeding levels of grouting pressure and complexity with different performances respectively.

Gravity Grouted Micropiles are installed under gravity by placing grouts without the application of external pressure. This is the simplest method which is mostly adopted in stable ground situation where very little improvement of bond strength required. (Federal Highway Administration, 2005)

A type B micropile is one where grout pressure and volume are controlled and injected under low pressure and in a controlled manner as the drill casing is withdrawn. This process enhances the interaction between grout and the surrounding soil, resulting in improved bond strength compared to gravity grouting. Institute: (Deep Foundations Institute 2015)

Type C: Single-Stage Grouted Micropiles refers to the application of grout at a high pressure within a single stage after the drilling process is completed. The shaft resistance and load-bearing capacity get increased by improved grout penetration into the ground. According to American Society of Civil Engineers (2018) Type D: Multiple-Stage Grouted Micropiles (High Capacity), also referred to as multi-stage or post-grouted micropiles, entail additional premium grouting at high pressures along with specially installed tubes provided with valves (Tube-à-Manchette system). The bond strength between grout and soil is increased significantly due to this staged grouting process and thus has the highest load capacity of all micropile types. According to the Federal Highway Administration, 2005.

2.4 Installation Procedure

For the micropiling work, installation of ten piles, drilling of foundation hole, and laying of reinforcing steel was done up to 10 metres. Removal and infusion of needles from mounds.

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- A. Hole with a 300 mm diameter and a depth of 10 meters.
- B. Supporting measure: The preparation and placing of three longitudinal bars of 16 mm diameter. Every 20 cm, transverse bars with a 6 mm diameter were prepared and tied.
- C. The mortar is injected, which is a mixture of cement and water with water cement ratio equal 0.5. This continues till complete filling of the pit and expulsion of scum.

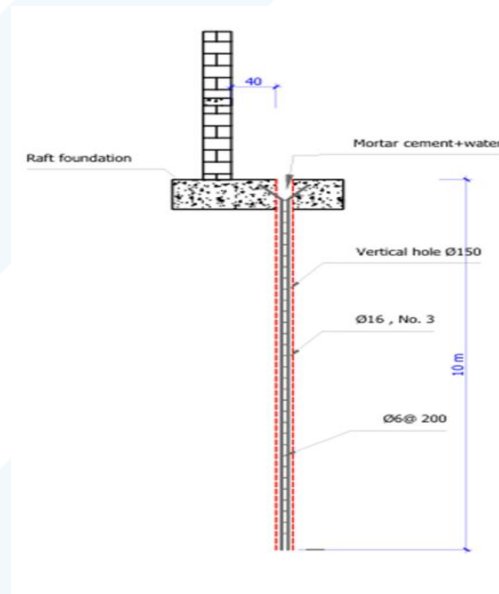


Figure 2 : section in Micropile

3. Results and Discussion

3.1 Improvement in Soil and Foundation Performance

Table 4. Comparison of raft Foundation With and Without Micropiles

Parameter	raft foundation without micropiles	raft foundation With Micropiles
Bearing Capacity	Low	High
Settlement	High	Significantly Reduced
Load Transfer	Weak	Efficient
Stability	Poor	Improved

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Figure 3: stage of drilling Micropile

3.2 Load Capacity Enhancement

Micropiles efficiently enhance load-bearing capacity through transfer of loads to deep soils. Tests indicate load. The capacity has improved 5 to 8 times compared to shallow foundations. They have a strong resistance to both compression.

3.3 Settlement Reduction

Micropiles can be effective in reducing any total and differential settlement, among other advantages. Using technique to bypass weak upper soil layers. Providing strong load-bearing elements. This helps especially in existing buildings where control of settlement is critical.

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3.4 Performance in Difficult Conditions and Engineering Evaluation

Micropiles demonstrate excellent performance under challenging site conditions and loads, making them a successful solution in modern geotechnical engineering. They are particularly effective in locations with limited access where large conventional piling equipment cannot operate efficiently, as well as in densely populated urban environments where space constraints and sensitivity to disturbances are critical considerations. Their installation process produces minimal vibration and noise, which is important and beneficial in areas close to existing structures or infrastructure. They are also well-suited to weak or multi-layered soils, where conventional foundation systems may struggle to achieve consistent and reliable performance. From an engineering perspective, micropiles require minimal installation space, produce low vibration during construction, and offer high load-bearing capacity despite their relatively small diameter. While their cost is generally moderate to high compared to some conventional alternatives, their exceptional flexibility, adaptability, and reliability in complex soil conditions often justify their selection in public works projects.

4. Conclusion

According to comparison, the overall performance of the foundation increases with the inclusion of micropiles. The original mat foundation has a low bearing capacity, high settlement, weak load transfer, or poor stability. With the inclusion of the micropiles, all the parameters are significantly improved. To be more specific, this means that the bearing capacity increases, the settlement reduces tremendously, load transfer is more efficient, and the overall stability improves.

As a result, micropile-supported mat foundations are more effective, especially in cases of inadequate soil properties for safe load-bearing.

Assessment of micropiles on key issues shows that they are an advanced versatile foundation solution particularly in difficult site conditions. Due to their need for minimal installation space and low vibration, they are particularly advantageous

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in confined or sensitive environments, such as urban or refurbishment projects. Even though they are moderately or highly priced, micropiles have high load-bearing capabilities and flexibility and adapt well to soil conditions – as well as structural demands. In summary, micropiles are a good foundation solution, where performance, adaptability, and buildability are given higher priority than initial costs.

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