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An Experimental Work into the Effect of Soil Saturation on the Bearing Capacity of Under-reamed Piles

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Abstract

This study examines the behavior and load-bearing capacity of under-reamed piles embedded in cohesive soil at different degrees of saturation (100%, 80%, 60%, and 40%). The major objective is to examine the impact of matric suction (MS), cohesion (Cu), and saturation ratio (Sr) on the axial response of both conventional and under-reamed foundations under unsaturated conditions. Three different pile configurations were tested in laboratory models: a single under-reamed pile (SURP), a double under-reamed pile (DURP), and a straight pile without under-reaming (NP). The ultimate bearing capacity and settlement behavior were evaluated using load-displacement curves and axial compression tests conducted inside a steel soil chamber. The results show that decreasing the degree of saturation significantly increases matric suction, thereby improving the bearing capacity of all pile configurations. For the straight pile (L/D = 22.5), the load capacity increased by 259%, 348%, and 48% at saturation rates of 80%, 60%, and 40%, respectively. The increases observed for the single under-reamed pile were 260%, 346%, and 64%, respectively. Under the same conditions, the double under-reamed pile showed increases of 210.5%, 238%, and 24%. When comparing the different types of piles, it was found that the single under-reamed pile achieved capacity improvements of 42-57% compared to the straight pile. On the other hand, the double under-reamed pile provided even more significant improvements, which ranged from 58% to 109% depending on the degree of saturation. The study highlights the strong interaction between saturation, suction, and pile geometry, offering useful insights for foundation design in partially saturated cohesive soils.

Keywords: Under-reamed Piles, Ultimate bearing capacity, Bulb Geometry, Compressive load, clayey soil, saturation, partially saturated.

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1. Introduction

Under-reamed piles are used in different structures such as machine foundations, tower foundations, bridges, and water-storage tanks. Under-reamed piles with single or multiple bulbs, as per Indian Standard IS 2911 (Part III) [1], are described and detailed in the literature, while other codes do not include them. Under-ream bulb diameters can be 2–3 times the shaft diameter or more, and the maximum distance between the under-reams (S) is dependent on pile dimensions in plan and soil properties (2:2.5). The best spacing between bulbs is 1.0 to 1.5 times the diameter of the bulb, irrespective of soil type. The code also includes formulas for bearing and uplift loads, but can be enhanced by installing multiple bulbs at the base.

Under-reamed piles consist of in-situ concrete piles with bulb additions to their stems to increase the

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pile's bearing surface and compressive capacity [2]. Withstanding uplift forces, such as those from anchors, these piles also improve their tensile bearing capacity. Thus, their tensile load-carrying capacity makes them suitable for supporting the foundations of centrifuges, piers, and transmission lines. The bulb-shaped enlargements in under-reamed piles provide additional resistance to both vertical compression and uplift, helping reduce negative skin friction while enhancing tip resistance and shaft friction along the pile [3]. Fig. 1 displays a full-bulb under-reamed pile.

Fig. 1 Model of an under-reamed pile with a single full bulb [2].

The under-reamed piles are generally employed in weak clayey and sandy soils as well, where vibration and noise restrictions hinder the application of driven piles [4]. They also do well to decrease negative skin friction as well as increase tip resistance and shaft friction [5]. These cast-in-place concrete piles include one or more bulbs along the stem to enhance load capacity under compression, tension, and lateral forces [6–12]. Previous investigations on single and multiple under-reamed piles with varying bulb diameters and lengths have demonstrated significant performance improvements [13]. Numerical analysis further showed that cone-shaped bulbs are more effective than other geometric forms in minimizing vertical displacement [14].

The influence of friction, bearing surfaces, and pile capacity on the behavior under compressive load of under-reamed piles was illustrated by [15]; this is why these types of piles are widely used in engineering buildings for a machine or electric transmission tower foundation. The compressive and tensile strength of the piles were greatly influenced by the numbers, dimensions, geometries, layout, and locations of bulbs [16].

Analysis of the compressive performance of under-reamed piles in a sandy soil was carried out with laboratory tests on key geometric parameters, including pile length, bulb size, configuration, and spacing. The results showed that an appreciable performance improvement could be achieved by under-reaming: a 25 mm-diameter pile had its capacity increased by 305 per cent. The position of the bulb influenced it, and increased spacing of the bulb away from the pile base led to a 57.1% decrease in capacity. Furthermore, increasing the distance between the two bulbs to 150 mm resulted in an 82.6% enhancement in resistance, and raising the number of bulbs from one to three led to a further 127% improvement in the ultimate compressive strength [17].

An investigation into the influence that geometrical characteristics of a SURP have on its final capacity [18] using the Ansys software program. These factors included bulb diameter, length, and bucket length measures. The research presented in [19] developed a load-capacity equation for under-reamed piles using finite element analysis and showed that soil type strongly governs pile performance. Dense sand and stiff clay provided higher capacities due to their greater stiffness and shear strength, while soft clay, loose sand, and silt yielded lower capacities because of their higher compressibility and decreased resistance. These results demonstrate the crucial role of soil

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classification in predicting the compressive behavior of under-reamed piles.

A study investigated the pullout performance of SURP and DURP embedded in dense sand, examining factors including pile pullout behavior, soil response, and soil–pile interface interaction, while also proposing a theoretical approach [20]. Investigated the uplift bearing capacity of an under-reamed pile. Since the impact of various ream angles needed to be assessed, a range of dry sands with varying relative densities was used in the 1-g testing, and thorough 3-D models were created. The angle underreamed is, rather surprisingly, influenced by the surrounding sand density [21].

The research conducted by [22] examined how deeply buried foundation piles are pulled out of both heavy and loose sand. It was shown that the pullout capacity decreased with increasing stem diameter, regardless of embedment depth or base angle, provided the base diameter remained constant. An elastic-plastic analytical model was examined to determine the ultimate pullout capacity of an under-reamed pile. The results of the developed solutions were then compared to the theoretical calculations. In conclusion, the elastic-plastic analytical methods were found to be reasonably consistent with the field test results [23].

Conducted research [24] on under-reamed piles in dry, loose sand, focusing on the placement of bulbs. The study found that adding bulbs to URP does not necessarily enhance its pullout capacity. When placed at the tip of the pile, pullout capacity increased by up to 60%, while placing the bulb at 67% of the pile's length decreased it by about 4%. An experimental study was conducted on individual piles and groups of URPs placed in dense sand, where both tensile and compressive loading conditions were applied. The performance of the two pile systems was examined at the same time. Square pile spacings of 1.5Du, 2.5Du, and 3.5Du were used in the investigation. The results showed that the behavior of the pile group improved as the spacing increased, with group efficiency in the square layout ranging between 0.50 and 0.77 [25].

In a separate study, the researchers in [26] carried out six field experiments in which both compressive and uplift loads were applied to three traditional concrete piles, DURP, and an additional set of three concrete piles. The main focus of this work was to study the load–load-displacement response and to evaluate how the concrete type affects the uniformity, long-term durability, and dimensional stability of the piles. Additionally, the authors of [27] examined the behavior of URPs with different numbers of bulbs and compared them with conventional piles by altering the L/D ratio and the spacing between bulbs. According to the results, an increase in both the L/D ratio and the friction angle caused the tensile capacity to rise. The bulbs played a role in boosting the load-enhancement factor, improving DURP behavior. The uplift capacity was highest at S/Du = 1.5, and then it decreased beyond this spacing.

A study on the optimal spacing ratio of URP groups on expansive soil revealed that increasing the distance between piles initially increased uplift loads, but eventually decreased. The ideal spacing ratios for triangular, square, pentagonal, and hexagonal designs are 9, 10, 5, and 9, respectively [28]. Vali et al. [29] used Plaxis 3D to compare the bearing capacity of under-reamed and tapered piles in cohesive soil under compression and displacement loading. The results clearly show that under-reamed piles exhibit a lower capacity than tapered piles.

Ground occurs naturally in three states: dried, wet, and saturated. The majority of soil mechanics hypotheses have been developed for dry or saturated soils, with little consideration provided for unsaturated soils. Nevertheless, substantial advancements have been made in simulating unsaturated soil behavior over the past two decades. The resistance of piles in partially saturated soil is approximately (3-5) times that of the same soil in saturated conditions [30]. The relationship between sediment and water has been the subject of numerous studies. Unsaturated soil behaves differently from arid or saturated soil, with liquid separating from soil particles or remaining continuous. The degree of saturation (Sr) characterizes unsaturated soil. Unsaturated soils are considered very dry, dry of optimum, at optimum, wet of optimum, and very wet (Sr > 95%) based on moisture content [31-33]. The vacuum system consists of the matrix and the

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osmotic. In the soil-water system, suction was defined as the water potential [34].

The potential for deformation and strength of unsaturated soils explains the soil's reluctance to move and the movement of soil-water, in addition to the soil's water retention capacity within the system [35]. There is a strong relationship between the initial moisture content of fine-grained soil and its structure. Thus, soil relative strength or weakness is influenced by factors such as moisture content, soil structure under varying moisture conditions, and other characteristics such as plasticity, texture, mineralogy, and preparation [36].

Studied pull-out tests. They found that ultimate skin resistance increases nonlinearly with increased initial matric suction and decreased initial saturation, with a 49% increase when initial saturation is reduced. The adhesion factor also increases with reduced initial matric suction and unconsolidated cohesion [37]. The ratio of ultimate shaft capacity to ultimate pile capacity in expansive soil was investigated. They discovered that the ratio decreased as saturation decreased. However, comprehensive experimental studies on under-reamed piles are lacking, limiting understanding of interaction and failure mechanisms [38].

Therefore, this study intends to analyze the behavior of under-reamed piles by evaluating the load–load-displacement response for single and double under-reamed setups and by comparing their behavior with straight piles placed in cohesive soil. The work concentrates on how saturation level, matric suction, and soil cohesion affect the axial compressive capacity at saturation levels of 100%, 80%, 60%, and 40%. The study also looks at the role of under-ream geometry, specifically SURP and DURP, in contributing to capacity improvement under different moisture conditions.

2. Materials and Methods

The specifications of the test materials are divided into three categories:

2.1 Soil Used

A brown clayey soil sample was obtained from the Al-Ekhwa residential complex project, located north of Baghdad. Using a mechanical shovel, a trial pit was excavated to a depth of 2–3 m below the natural ground level, and disturbed samples were taken. The samples were collected and set in airtight plastic bags at the excavation site and transferred to the soil laboratory, where standard tests were performed to determine their physical properties in accordance with established procedures. The information is provided in Table 1 and Fig. 2. In this study, the soil was classified as clay (CL), as shown in the plasticity chart in Fig. 3.

After remolding the samples at different saturation levels (100%, 80%, 60%, and 40%), the undrained shear strength (Cu) was determined using the unconfined compression test. The results show that Cu increases as the degree of saturation (S) decreases, leading to a rise in the unconfined compressive strength (qu). Table 2 presents the measured values of qu.

Table 1: Physical properties of clay soil.

Test Name	Standard	Soil Property	Value
Specific Gravity	ASTM D-854	Specific Gravity (Gs)	Clay 2.76
Atterberg Limits	(ASTM D-4318)	Liquid limit (L.L),	45
		Plastic Limit (P.L), %	26
		Plasticity Index (P.I), %	19
Grain size	(ASTM D-422)	Clay	68.3
		Silt	31.7
		Gravel	0
		Unified Soil Classification System (USCS)	CL
Standard Compaction	ASTM D-1557)	Maximum Dry Unit Weight, (kN/m3)	16.25
		Optimum Moisture Content (O.M.C), %	19
		Initial void ratio(e0)	0.666

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Table 2: Variation of Unconfined Compressive Strength (qu) with Degree of Saturation

Degree of saturation Sr.	Unconfined compression strength (qu) kN/m2	Undrained Cohesion (Cu) KPa	Standard
100%	90	45	
90%	130	65	
80%	208	104	
60%	304	152	

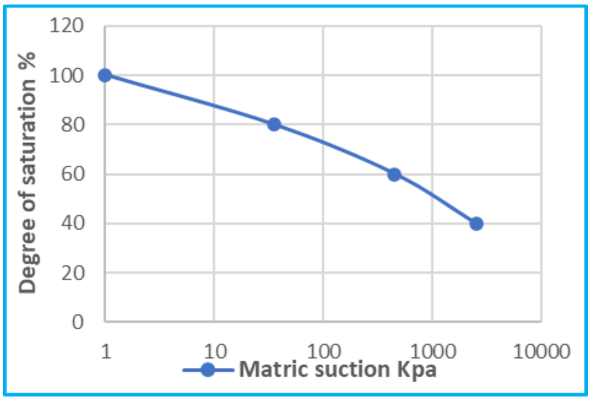

Fig. 2 Soil-Water Characteristic Curve Relating Saturation Degree to Matric Suction via the Whatman 42 Filter Paper Method

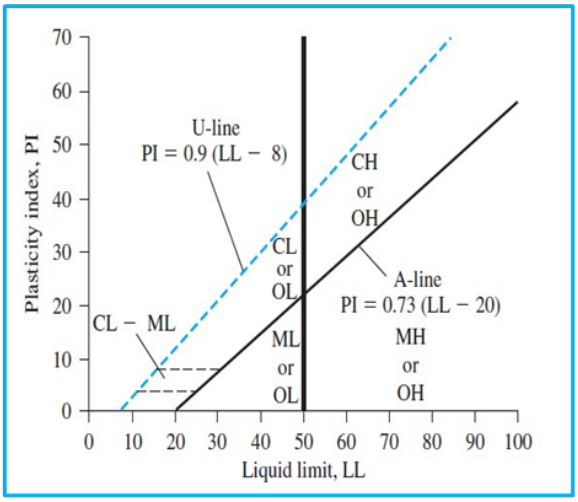

Fig. 3 Plasticity chart for the natural soils [39].

2.2 Piles Used and Under-Reams Model

This study utilized three small-scale aluminum pile models, each measuring 450 mm in length, with a bulb diameter of 50 mm and an overall pile diameter of 20 mm. The length of the pile divided by its diameter (L/D) is 22.5. This examination used three pile configurations: straight piles and under-reamed piles (single bulb and double bulb) with varying vertical distances between the bulbs. The design of the under-reamed pile and under reams was carefully selected according to the Indian Code of Practice (IS 2911) [18]. Table 3 presents the characteristics of the pile model used in the study, and Fig. 4 shows its configuration.

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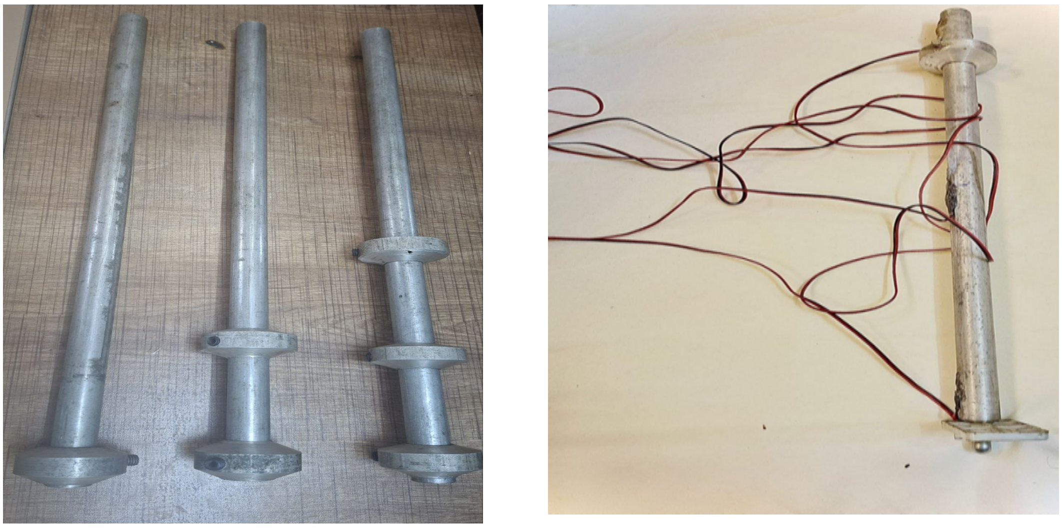

Fig. 4 The Under-Reams piles used in the study.

Table 3: Details of the Model Piles Employed in the Study

Description	Notation	Dimension(mm)
Pile length, mm	L	450
Pile diameter, mm	D	20
Under-reams diameter, mm	Du=2.5 D	50
Bulb spacing c-c	positions of bulb in (D.U.P) at L/2	225
Upper angle of the under-ream pile	degree Ø1	45
Lower angle of under-ream pile	degree Ø2	45

2.3 Laboratory Model Box Steel Container

Based on previous studies, a steel container model was fabricated with dimensions of 600 mm × 600 mm × 600 mm and a thickness of 6 mm. [40, 41] A steel box with internal dimensions introduces inherent scale and boundary effects that may influence stress distribution during model pile testing. As stated by [39, 40], restricted laboratory containers can restrict lateral deformation and provide artificial stiffness, thereby enhancing the measured bearing capacity. Although the chosen box size gives acceptable clearance around the under-reamed piles, some confinement is unavoidable and may restrict the natural development of shear zones. However, the selected dimensions remain compatible with the way small-scale geotechnical modelling is usually done and give an appropriate setting for controlled parametric testing.

The container consists of five single pieces: four for the sides and the fifth for the base. Bolts of 10 mm diameter connect these pieces along the edges of one piece, and with a distance of 10 cm between one bolt and another. One of the container faces contains a glass measuring 60 × 40 mm to monitor soil saturation, as shown in Fig.5. To prevent the sides and bottom of the box from falling outside the stress bulb's influence zone due to pile loading during the tests, the box is designed to be sufficiently large. As shown in Fig.6, a hydraulic jack piston with a maximum capacity of two tons is attached to the frame. The container is based on a steel structure. The container is surrounded by a steel structure that rests on a base and rises 1500 mm from the sides. At its upper end, two steel rests support the download system inside.

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Fig. 5 A steel box with dimensions of 600 mm × 600 mm × 600 mm used in the study.

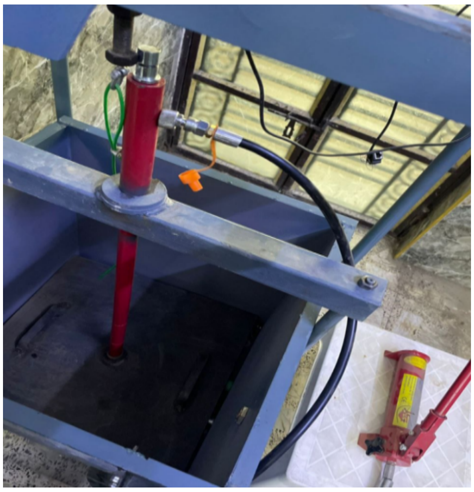

Fig. 6 Hydraulic jack frame.

2.4 Soil Preparation

The initial water content is measured, the soil is dried to 105°, and it is pulverized to a fine consistency, all of which are steps in the process. Experiments were conducted to investigate the load-settling Behaviour of a pile. The dry unit weight of the pile was 16.25 kN/m3, and it was subjected to a range of initial degrees of saturation. The soil was mixed with additional water to achieve the required consistency and saturation level. Utilizing the specific gravity of the soil, the void ratio, dry unit weight, and water content were calculated. This procedure was repeated until the model container was filled with an adequate amount of soil. To maintain water distribution and consistent moisture content, the soil was stored in sealed polythene sacks for at least 72 hours after mixing. Samples were taken from each container to assess the water content. The pre-calculated quantity was distributed to achieve a soil depth of 100 mm in the modeled box, resulting in a soil density of 16.25 kN/m³. Subsequently, it was compacted to the required dry unit weight using a specialized compaction device.

2.5 Suction Measurement

Soil suction can be determined through two principal approaches, direct methods and indirect methods. The negative pore water pressure was measured using matrix potential sensors (the TEROS 21 sensor and the Em50 Data recorder) in this research, as shown in Fig. 7. An indirect method was employed. This enables the measurement of soil mechanical suction. In unsaturated conditions, four sensors were installed at varying depths below the soil surface to quantify suction in the unsaturated clay. Using a porous ceramic disc, the sensor determines the amount of moisture present in the soil and then translates that information into soil matric suction values. It has a high degree of accuracy and operates over a temperature range of -40 to 60 degrees Celsius. In addition, it is equipped with an integrated thermistor that measures soil temperature with a precision of ±1 degree Celsius. The Em50 data acquisition system, manufactured by METER, USA, is used in this study.

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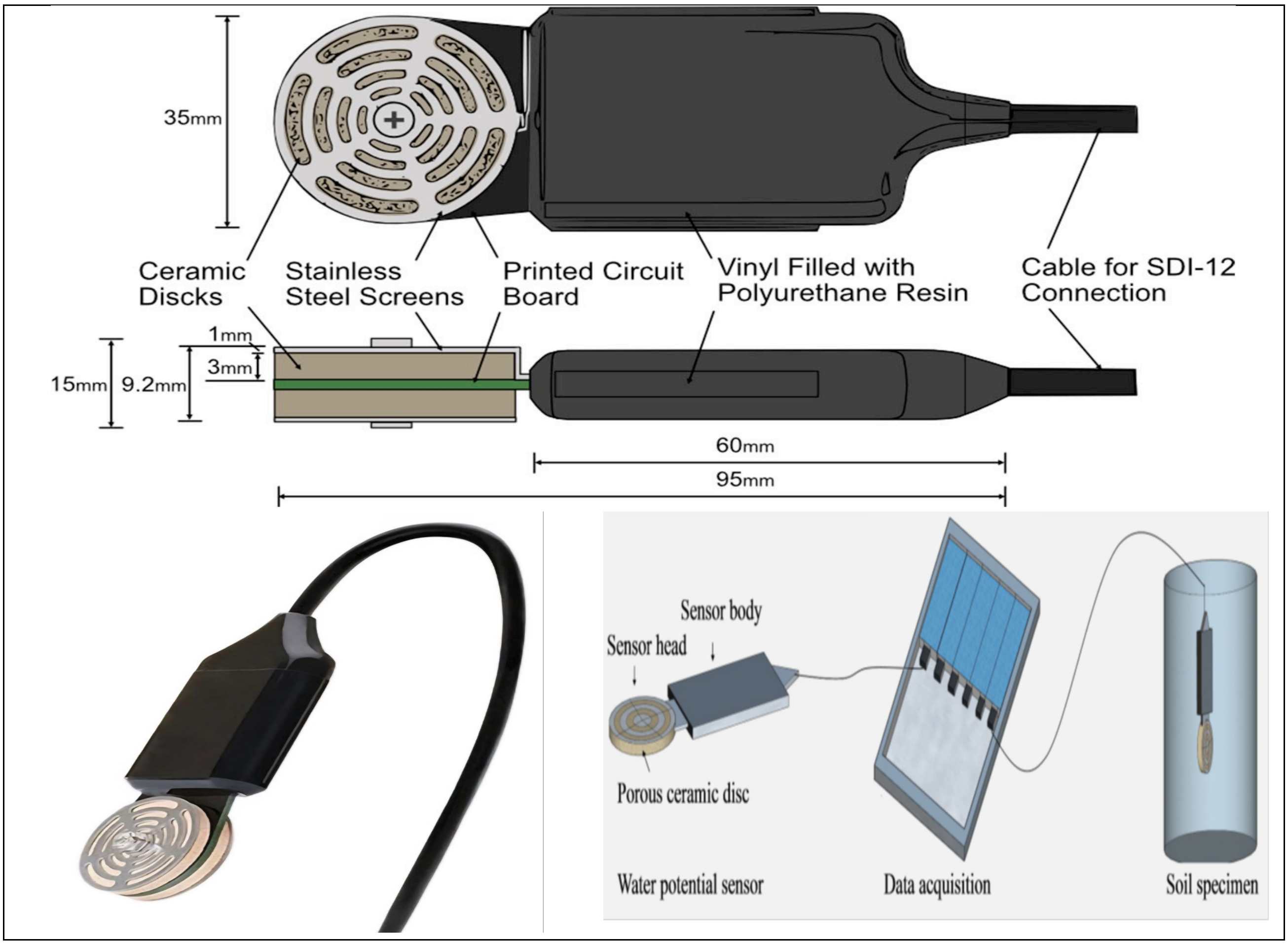

Fig. 7 Schematic view of the TEROS 21: measuring the matric suction of soil [42], and [44].

2.6 Installation of Model Piles

The installation procedure used in this research follows the undisturbed, or no-displacement, technique, in which the under-reamed pile cavity is excavated, and the pile is cast in place using concrete. This method was selected because it accurately represents real field installation practices within a controlled laboratory setting. The model pile was oriented vertically at the center of the testing box, and its alignment was verified using a water-level instrument. The slope of the pile cap was also assessed using the same device. Subsequently, clayey soil was meticulously applied around the pile to achieve the desired saturation levels and create a uniform clay layer. Preparation of the soil bed involved estimating the soil quantity for each lift, densifying it to the required thickness, and placing the layers in order, making sure no layer exceeded 10 cm. Once the soil bed is prepared to the specified level, a force sensor can be installed, with connecting wires extended horizontally to the soil container wall and vertically to the data logger.

3. Test piles under axial compressive load

After four days of installation, the piles are left to allow the soil to regain its thixotropy. The vertical (compression) test is done by applying a load on the pile using a load cell (S-shape). The insertion rate was 1 mm/min, as per ASTM D1143 (2018) [17]. The failure criteria employed in this study to assess ultimate pile resistance were established based on the specific breakpoint, which indicates the maximum ultimate bearing load before failure.

4. Results and Discussion

4.1Effect straight shaft piles, Length 450 mm (L/D=22.5)

The analysis presented in Fig.8 highlights the relationship between the ultimate pile capacity of a standard pile with a length-to-diameter ratio (L/D) of 22.5 and varying degrees of soil saturation (Sr). The ultimate pile capacity is 612.5 N when the soil is fully saturated (Sr = 100%). As the degree of saturation decreases to 80%, the capacity rises markedly to 2200 N, and increases further to 2750 N when saturation drops to 60%. However, this behavior shifts once the saturation level reaches 40%, at which point the capacity falls to 907.5 N.

This pattern shows clearly that the degree of saturation has a substantial impact on the pile capacity. The load-bearing capability of the pile is increased when the saturation level is reduced from 100 %to 80 %. If the pile is able to maintain a consistent reduction to 60 %, it will be able to withstand an even greater load. On the other hand, if the saturation level falls to approximately 40 %, the pile's capacity is reduced due to a notable decline in adhesion between the pile surface and the surrounding soil. The adhesion factor (α) and the undrained shear strength (Cu) are both variables that determine the efficacy of the pile's shaft friction. The amount of water contained has undergone a significant reduction by the time the saturation has reached 40 percent, which in turn has a direct impact on the diminished pile capacity. The same pattern may be noticed in the compression tests conducted on piles that have the same L/D ratio, as shown in Figs. 8 and 9. According to the investigation results, as the degree of saturation decreases, the pile capacity increases until it reaches 60%, at which point it starts to decrease as the degree of saturation continues to drop to 40%. This emphasizes the significant impact that the amount of water present in the soil has on the stability and performance of piles. Fig. 9 shows the relationship between the degree of saturation and matric suction using the TEROS 21 sensor for a straight shaft pile.

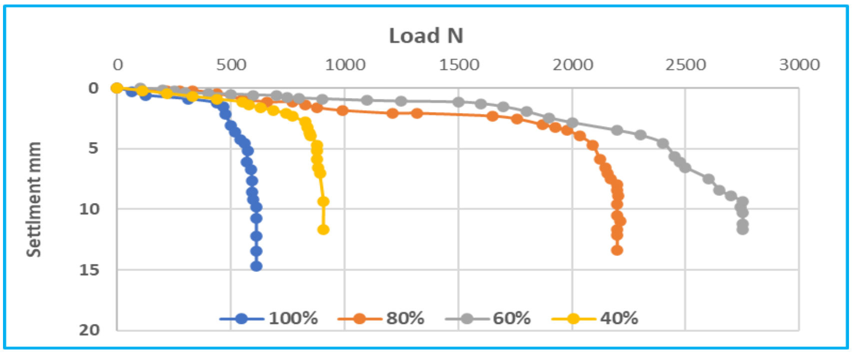

Fig. 8 Load settlement curve for compression for a normal pile of L/D (22.5) in different Sr.%.

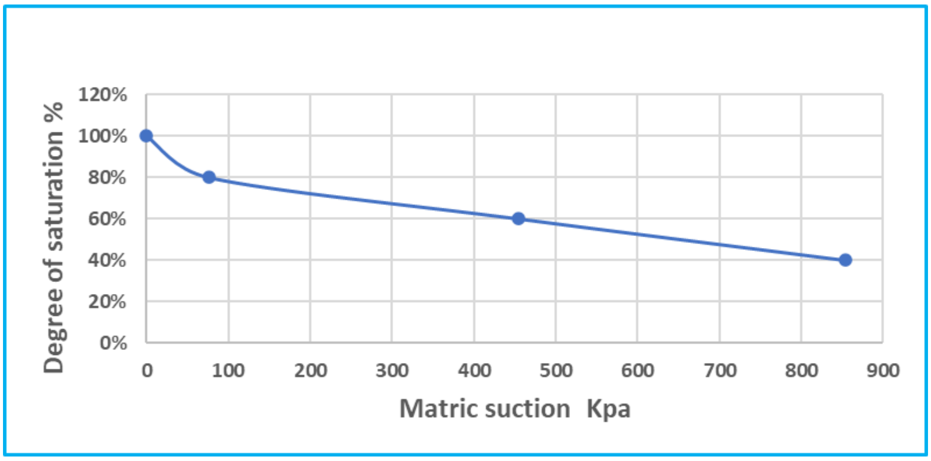

Fig. 9 shows the SWCC straight shaft pile obtained using the TEROS 21 sensor.

4.2 Effect of a single under-reamed pile Length 450 mm (L/D=22.5)

Fig. 10 illustrates the bearing capacity of a single under-reamed pile with a length-to-diameter ratio (L/D) = 22.5 under varying degrees of saturation (Sr). When soil is fully saturated with water (Sr.=100%), the pressure is 868.75 N and increases to 3135 N at 80% saturation, then to 3875 N at 60% saturation. However, when saturation decreases to 40%, the capacity drops to 1425 N. This indicates that the

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bearing capacity significantly improved as the soil's saturation degree decreased from full saturation to 80%. This enhancement is attributed to the physical bonds formed between soil particles by water surface tension, which increases the soil's shear strength and consequently elevates pile capacity. Furthermore, reducing the saturation degree to 60% yields the maximum pile resistance, indicating that the soil's shear strength is highest at this saturation level. Fig. 11. The relationship between matric suction and degree of saturation using the TEROS 21 sensor for a single under-reamed pile.

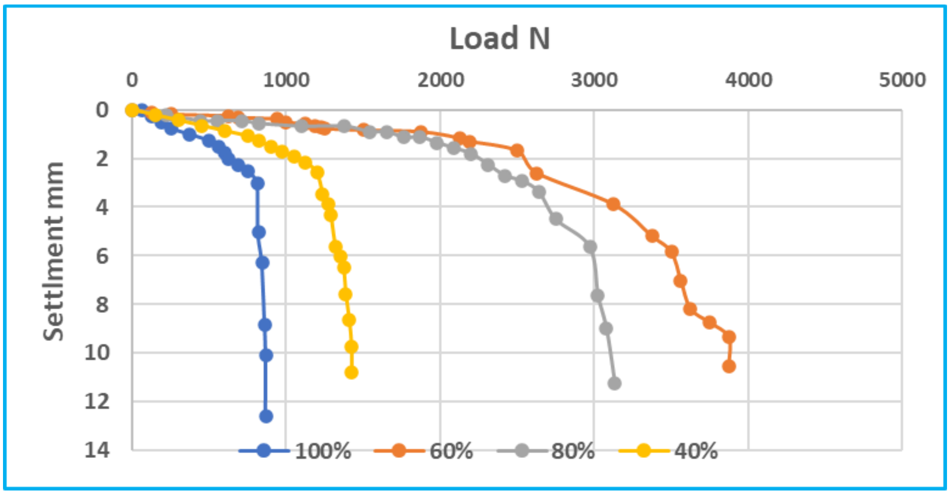

Fig. 10 Load settlement curve for compression for a single under-reamed pile of L/D=22.5 in different Sr.%

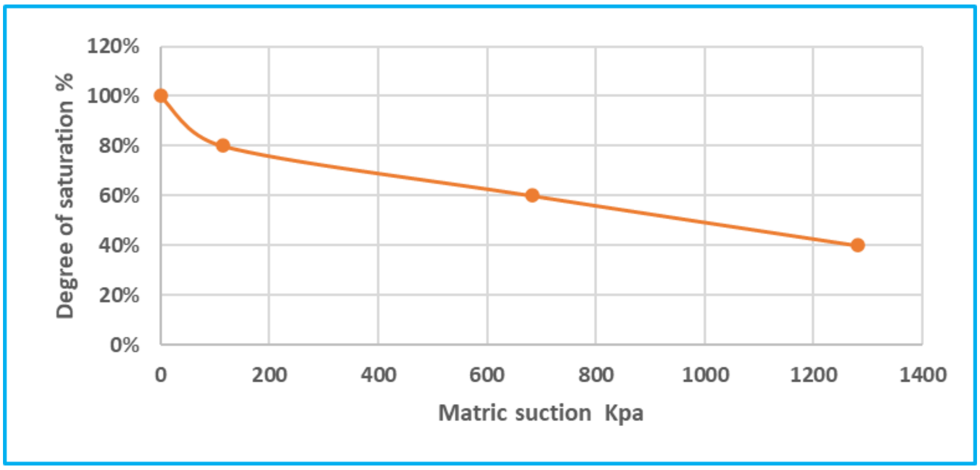

Fig. 11 shows the SWCC for a single under-reamed pile obtained using the TEROS 21 sensor.

4.3 Effect double under-reamed pile Length 450 mm (L/D=22.5)

Fig. 12 illustrates the relationship between pile ultimate resistance and the level of soil saturation for a double under-reamed pile (DURP) that has a length-to-diameter ratio (L/D) of 22.5. When the soil is fully saturated (Sr. = 100%), the pile's ultimate resistance is measured at 1275 N. As the saturation level decreases to 80%, the resistance significantly increases to 3960 N. A further reduction in saturation to 60% results in an increased resistance of 4320 N; however, at 40% saturation, the resistance declines to 1575 N. In the analysis of pile capacity relative to saturation levels, it is observed that as saturation decreases from 100% to 80%, capacity increases significantly. The most pronounced increase occurs at a saturation level of 60%, where the pile capacity notably surpasses that of higher or lower saturation levels. Conversely, at 40% saturation, the change in capacity is minimal. Fig. 13 The relationship between degree of saturation and matric suction using the TEROS 21 sensor for a single under-reamed pile. The findings of this study reveal that pile capacity increases under partially saturated conditions, aligning with the observations of [5], who attributed this behavior to the contribution of matric suction in enhancing soil shear strength. Similar improvements were reported by [7], confirming the positive role of suction in strengthening soil–pile interaction. However, unlike these studies, which focused on straight piles, the present work highlights the enhanced response of single and double under-reamed piles, where enlarged bulbs provide greater soil interlock under suction. This combined effect of partial saturation and under-reamed geometry represents a notable extension to existing research. Overall, the results support previous findings while offering a new understanding of suction influence on piles with L/D = 22.5

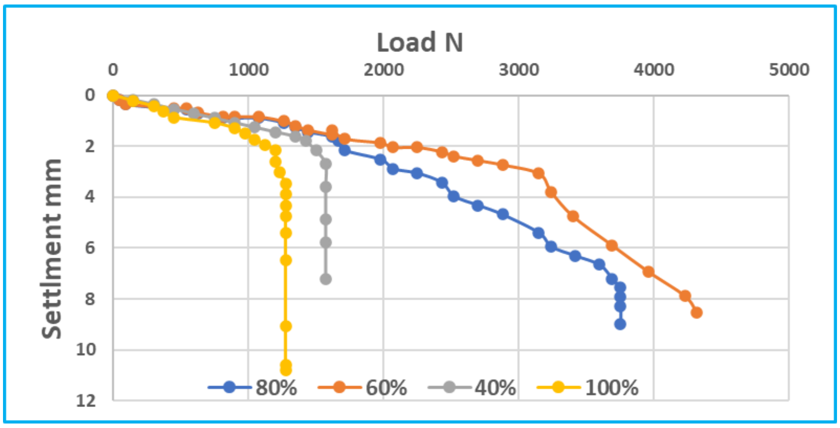

Fig. 12 Load settlement curve for compression of a double under-reamed pile with L/D = 22.5 at different Sr%.

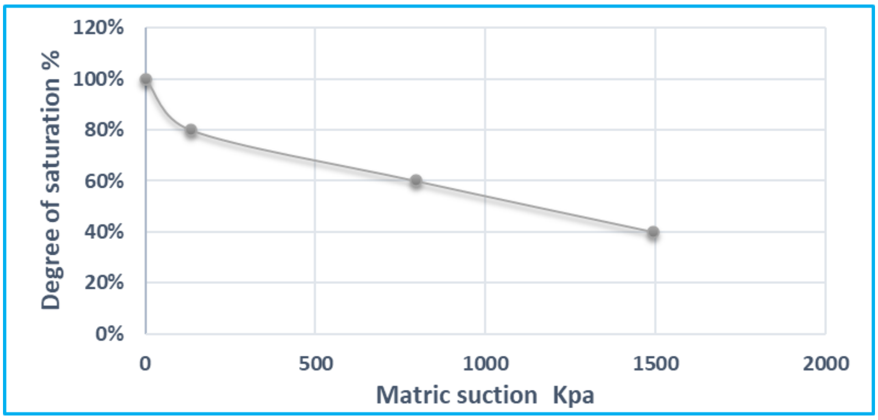

Fig. 13 shows the SWCC for a double under-reamed pile obtained using the TEROS 21 sensor.

4.4 Variation of pile capacity with changes in degrees of saturation.

Fig.14 shows the significant effect of the under-reamed design on pile ultimate capacity at varying saturation degrees. It is clear that adding under-reamed bulbs significantly improves the final bearing capacity compared to straight piles. The DURP shows the most improvement, followed by the SURP. The SP has the least capacity. At intermediate saturation levels (60% and 80%), the ultimate bearing capacity is higher because the clay matrix is partially suctioned. Moreover, the degree of saturation plays a crucial role in pile performance. On the other hand, the capacity tends to go down when the saturation is full (100%) or low (40%). It demonstrates that the ultimate bearing resistance of the pile in clayey soil is affected by both the existence of under-ream bulbs and the degree of saturation.

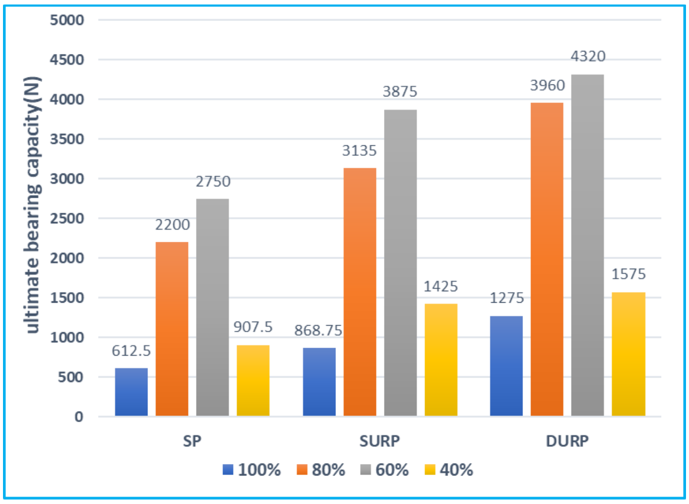

Fig. 14 Ultimate pile resistance versus under-reamed piles for different degrees of saturation Sr%.

Conclusions

According to the experimental tests conducted in this study, the main conclusions can be summarized as follows:

1. The bulb diameter significantly impacts the bearing load of the under-reamed pile, with an increase in bulb diameter directly increasing the bearing load. Reducing initial saturation and increasing initial matric suction leads to a nonlinear increase in the pile's ultimate capacity. An increase in the initial matric suction accompanies this increase.
2. The degree of saturation has a significant impact on the capacity of all the piles that were tested. As saturation decreases from 100% to 60%, the pile capacity increases due to the positive effects of matric suction and improved particle bonding in partially saturated soil. When the soil is fully saturated, the loss of surface tension reduces its shear strength, making the pile less able to withstand weight. Even though capacity drops again to 40% saturation, it is still higher than when conditions are fully saturated.
3. The use of URP instead of straight shaft piles for the same L/D ratio=22.5 during the load-settlement tests, increases the ultimate bearing capacity of the (SURP) by (42%,43%,41%,57%) for soil state at different initial degrees of saturation Sr. (100,80,60,40%) respectively, and about (109%,80%,58%, 74%) for DURP. There is a clear increase in the presence of bulbs in the under-reamed pile compared to normal piles.
4. When Sr. decreased from 100 % to (80, 60, 40%) the piles capacity increased (259%, 348%, 48%) respectively in straight shaft piles with L/D (22.5), the increase was (260%, 346%, 64%) respectively in SURP with L/D (22.5) and (210.5%, 238%, 24%) respectively in DURP with L/D (22.5).

Conflict of interest

A conflict of interest statement must be placed at the manuscript as below: "The authors declare that there are no conflicts of interest regarding the publication of this manuscript".

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