

Effect of the Degree of Saturation on the Behavior of a Single Sand Column in Clay

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Abstract

Researchers have extensively studied the Use of granular piles (sand columns) as a ground improvement technique under fully saturated conditions, but have paid limited attention to the influence of the unsaturated zone, which reflects soil conditions in arid and semi-arid regions. However, their behavior in partially saturated soils remains critical due to the complex interaction between soil suction and structural stiffness. The objective of this research is to assess the behavior of a single sand column in partially saturated soil by studying the effect of increasing the L/D ratio and the area replacement ratio on column efficiency. The study used 32 mm diameter columns with varying slenderness ratios ($L/D = 8, 10, 12$, and 15) at varying degrees of Saturation (60%, 80%, and 100%). Clay soil layers were placed in a $60 \times 40 \times 60$ cm steel box, and a hydraulic jack applied axial load using square foundations of 9×9 cm and 6×6 cm, representing area ratios (a_s) of 0.09 and 0.22. Electrical matric potential sensors measured matric suction. The results show that column capacity varies significantly with Saturation, matric suction, and slenderness ratio. When Saturation decreased from 100% to 80% and 60%, the bearing capacity of the composite soil increased for all L/D ratios used. Further increases in the L/D ratio beyond a certain limit do not substantially enhance capacity at ($S_r=100\%$) and ($S_r=80\%$), where increases range from 1% to 6%. However, this percentage increases significantly at ($S_r=60\%$) up to 18% for the same ($a_s=0.09$), and becomes higher when (a_s) increases to (0.22). Additionally, increasing the area ratio from 0.09 to 0.22 significantly improves the bearing capacity.

Keywords: Matric suction, Shear strength, and Bearing capacity

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1. Introduction

The vadose zone, situated above the groundwater level and typically characterized by unsaturated soils, is the typical location for building geotechnical infrastructure. The distribution of matric suction within the soil volume is closely related to how soil behaves in the unsaturated zone, producing distinct features compared with fully saturated or dry conditions [1]. Approximately one-third of the earth's surface is thought to be arid or semi-arid, where water evaporation exceeds infiltration each year, leaving soils in an unsaturated state [2]. The Use of stone/sand columns, sometimes referred to as granular piles or columns, for both stiff and flexible structures is increasing [3] and [11].

Furthermore, for improving the ground's mechanical characteristics (such as increasing its shear strength and decreasing its settlement), stone columns have also been shown to be useful in reducing the liquefaction potential and accelerating the radial consolidation [13]. Numerous researchers have conducted in-depth experimental and computational investigations regarding the column behavior in a wide range of soil types, from loose sand [14] and [15] to soft compressible clays [16] and [20].

The function of unsaturated soil conditions in the enhancement of soil layers with stone columns is a subject that has not been thoroughly examined. A large percentage of deformation in a sand column is

anticipated to occur at the ground surface, which is generally unsaturated.

It is predicted that 40% of the global population resides in arid regions [21]. Using stone columns can be an economical approach to soil improvement. These investigations are based on conventional soil mechanics theory, which assumes the groundwater table is at the natural ground surface. However, differences in saturation degree are expected to significantly alter the shear strength and shear-induced volume-change response of soils, which in turn affects the interaction between the soil layer and the stone column. For this reason, a sturdy, economical, and effective stone-column design requires a deep understanding of the effects of saturated and unsaturated conditions.

The primary source of a stone column's strength and stiffness is the soil's ability to provide lateral confining support. The surrounding soil's lateral confining support primarily depends on its shear strength, which is influenced by the degree of Saturation and the matric suction that occurs along with it ($u_a - u_w$) [22]. Additional interparticle forces are developed in the unsaturated soil as a result of the action of matric suction ($u_a - u_w$). The bonds formed by these forces help to increase the shear strength, as illustrated in Fig. 1. A soil-water characteristic curve is the relation between soil suction and soil gravimetric water content, volumetric water content, or saturation degree [23]. It is expected to exhibit a typical non-linear change in shear strength. k

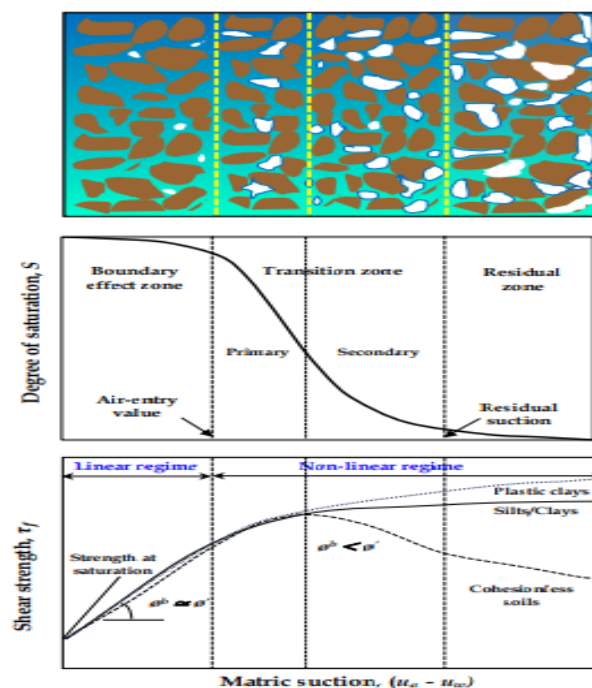


Fig. 1 Soil water characteristic curves (SWCCs) for various soil types and the fluctuation of shear strength in relation to matric suction in various zones [23].

2. Experimental work

2.1 Soil Used

To investigate the soil's physical characteristics, standard tests were carried out. Tables 1 and 2 show the soil and sand properties. According to USCS, the soil classification is (CL). Fig. 2 shows the grain size distribution of the soil.

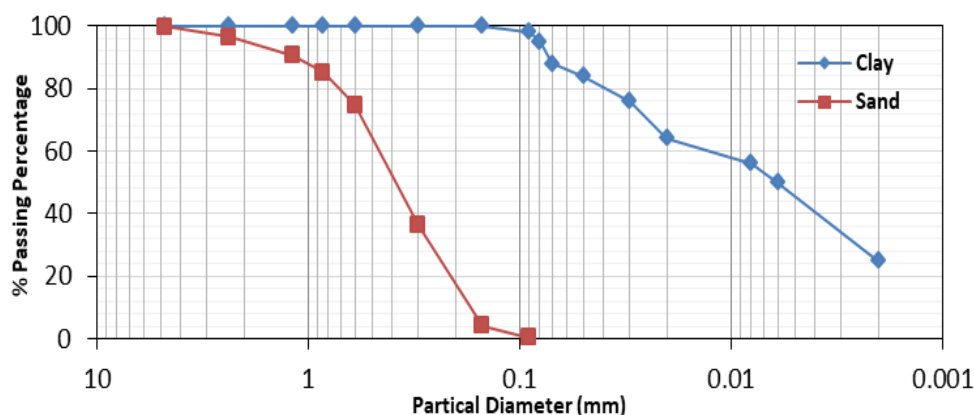


Fig. 2 Grain size distribution of clay soil and sand column.

Table 1: The physical characteristics of the used clay

Soil Property	Value	Specification
Liquid limit, LL	33	ASTM D 4318
Plastic limit, PP	19	ASTM D 4318
Plasticity index, PI	14	ASTM D 4318
Clay %	54	ASTM D 422
Silt %	41	ASTM D 422
Sand %	5	ASTM D 422
Classification (USCS)	CL	ASTM D 2487
Activity	0.35	-
Specific gravity (Gs)	2.7	ASTM D 854
Maximum dry unit weight, kN/m ³	16.5	ASTM D 698
Optimum moisture content	17	ASTM D 698

Table 2: The properties of the used sand column

Property	Value	Property	Value
Minimum dry unit weight, kN/m ³	14.5	D10 mm	0.17
Maximum dry unit weight, kN/m ³	18	Coefficient of uniformity, Cu	2.62
Used dry unit weight, kN/m ³	16.6	Coefficient of curvature, Cc	1.15
Relative density, %	65	Specific gravity, Gs	2.65
D60 mm	0.46	Angle of internal friction ²	39°
D30 mm	0.32	Cohesion (c) kN/m ²	0

2.2 Soil preparation

The 400 kg of air-dried soil was split into 20 kg groups for soil preparation, and each group was mixed separately with enough water to reach the desired consistency. The approved Eq. degree of Saturation: ($S_r * e = G_s * w\%$) was used to estimate moisture content through the relationship involving specific gravity, void ratio, and degree of Saturation." A big mixer was used to carry out the mixing process. Various water ratios were introduced into the soil to reach the three specified saturation levels of 60%, 80%, and 100%.

To achieve a consistent moisture content, the damp soil put it in plastic sheet from 2-4 days for balance water distribution after it had been well mixed, the soil was arranged in ten layers each layer of soil was compacted in a rectangular tank that sized 600 mm in height, 600 mm in length, and 400 mm in width, and thickness 4mm, using an electrical compactor with a steel 10*10 cm compaction base and square steel as show in Fig.3. To regain its

strength the prepared soil was left for five days. For each test carried out at different water contents, the same placing technique was applied.

2.3 Installing the Sand column

A displacement method was used in this work by inserting a closed-ended tube with an inner diameter of 32 mm and a wall thickness of 0.2 mm perpendicular to the center of the soil bed using the hydraulic jack to reach the predetermined depth, as shown in Fig. 4. Four tubes were used to achieve different L/D (8,10,12 and 15) and area replacement ratio (portion of the soil that sand column has replaced) that equald (0.09 and 0.22). The equation can be written as follows:

$$a_s = \frac{A_s}{A_s + A_c} \quad (1)$$

Where A_s is the area of the sand column cross-section, and A_c is the area of clay soil surrounding the sand column. The tube was then gradually pulled out of the soil. Sand was added to the column using a funnel. It was layered into the hole and carefully densified with a 20 mm diameter tamping rod.



A) Soil compaction



B) Soil preparation complete

Fig. 3 Soil preparation.



A) Construction sand column



B) The tube used at work



C) Filling the hole with sand



D) Completing the sand compaction process

Fig. 4 Installation of sand columns.



A) Experimental setup of the hydraulic jack and container



B) Details of the loading cell system with LVDT

Fig. 5 A view of the hydraulic jack and container.

2.4 Application of the Load

A single sand column with a 32mm diameter was subjected to the load using a (9*9 and 6*6) cm, 15 mm thick square steel plate, after being placed at the geometric of the column, based on Bossiness's stress distribution theory (i.e., $q/q_0 \approx 0.05$ at 1.5B horizontally and 3.2B depth) [24], the chosen container dimensions (60×40×60 cm) are deemed adequate for the (9*9 and 6*6) cm footing. The lateral and vertical extents of stress, which influence 1.5B and 3.2B, respectively, are well accommodated within the container, minimizing boundary effects and ensuring reliable test results. The load was applied for up to 18mm settlement at a penetration rate of 0.25 to 1.25) mm/min based on [25]. For axial compression testing of cohesive soil, the load was applied using a loading jack in the form of load increments, as illustrated in Fig. 5. The frame is 2 m high and 1m wide. It is locally designed and made from steel channels.

A 1-ton hydraulic jack piston is fastened to the frame. In addition to the sand column, the surrounding soil also helped to support the placed load. The load was applied to the single column incrementally until settlement exceeded the failure limit for all models, where the failure criterion used in this research was defined as the load corresponding to 10% of the model footing width, according to [26]. The footing settlement due to static loading was measured using an LVDT. The

results were recorded in the LabVIEW program installed on the laptop.

3. Determination of the SWCC of the soil

Soil can be measured in two ways: directly and indirectly. The indirect approach used in this study detects the negative porewater pressure using matric potential sensors (the Em50 data logger and the Mp6 sensor). The ECH2O system linked the sensors to the Em50 logger. The ECH2O system comprises data loggers, sensors, telemetry, and software, and it supports accurate measurement of soil moisture and other environmental factors. In the experimental models and specimens used in this study, the sensor measured soil suction; four sensors were positioned at varying depths beneath the soil surface.

After a day, the equilibrium conditions were attained, as shown in Fig. 6. Table 3 shows the manufacturer's specifications. The sensor can monitor a wide range of high suction magnitudes (almost 10,000 kPa or greater) under particular conditions over a few hours [27]. Fig. 7 shows the matric suction results for four degrees of Saturation.

Table 3. Specifications of matric potential sensors (Decagon Devices, Inc.)

Parameter	Value
Range	-9 kPa to 100000 kPa (Pf 2.00 to pF 9.01)
Resolution	0.1 kPa
Measurement duration	150 ms
Range of operating temperature	-40 to 60 C0

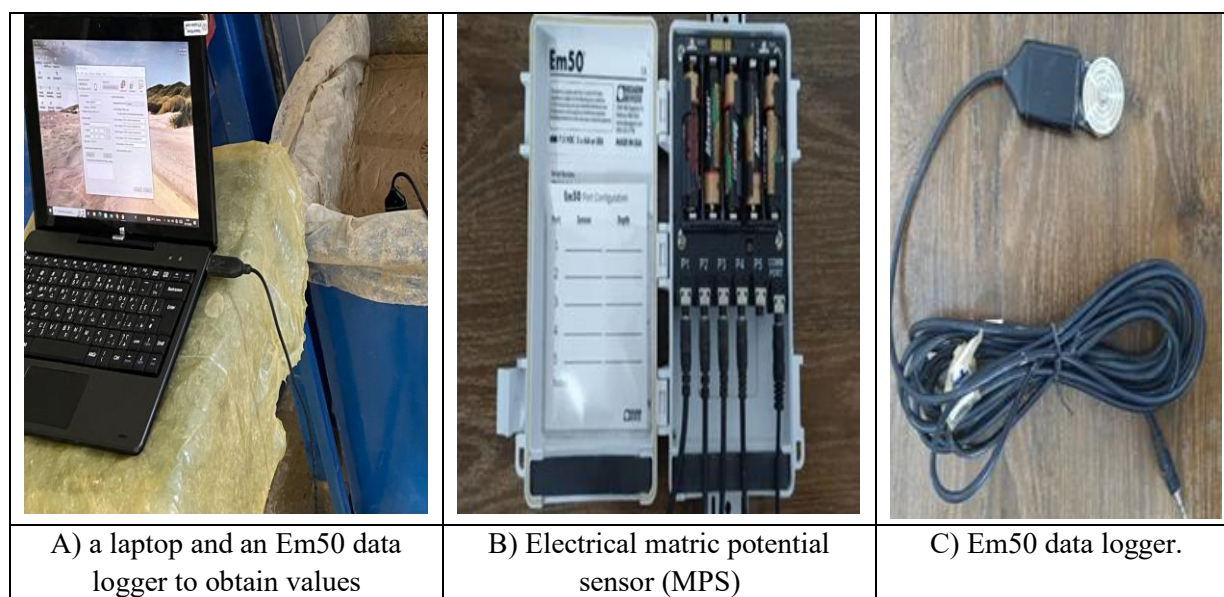


Fig. 6 Soil Suction Measurement

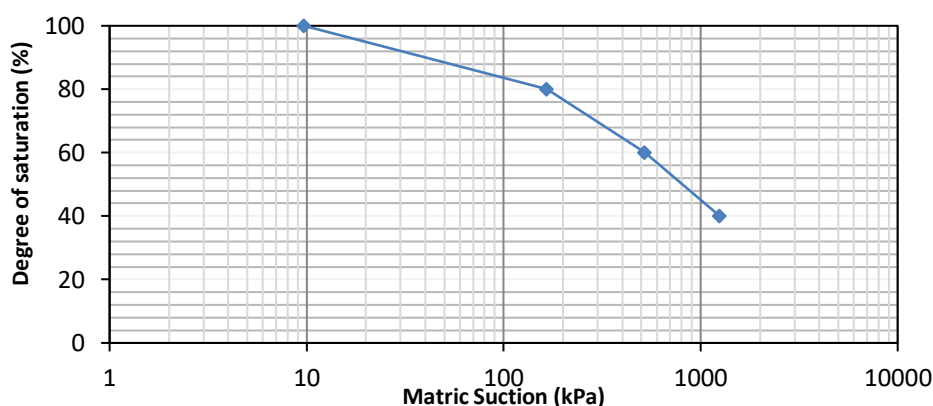


Fig. 7 Relationship between degree of Saturation and matric suction.

4. Result and Discussion

4.1 Effect of slenderness ratio and area ratio at various degrees of Saturation

All figs. are presented, where the bearing capacity is plotted versus the settlement ratio (S/B), where S/B refers to footing settlement to its width for different degrees of Saturation (Sr.=100%,80%,60%) combined with different area ratios (as=0.09,0.22) and different L/D ratios (L/D=8,10,12,15). Fig. 8 shows the bearing capacity curve for a sand column with various L/D ratios at (Sr.=100%) with (as=0.09%) for all L/D. The strength of the sand column increased as L/D increased. When L/D increased from 8 to 10, the ultimate capacity increased from 59 kPa to 60 kPa, an increase of 1%. When L/D became 12, the capacity became (63 kPa). When L/D became 15,

the capacity increased to (65 kPa), which means an increase of 3% over the capacity at L/D 12 and 8% over L/D 10, and an increase of 9% over L/D 8.

Fig. 9 represents the bearing capacity curve for (as=0.22) with various L/D ratios. As shown, when L/D increased from 8 to 10, the column strength increased from 73.6 kPa to 75 kPa, an increase of 2%. When L/D becomes 12, the strength becomes (77.3 kPa), which is 2% higher than L/D=10 and 5% higher than L/D=8. When L/D becomes 15, the sand strength becomes (78 kPa), which is 1% higher than the column capacity at L/D 12 and 4% and 6% higher than L/D 10 and 8, respectively.

Fig. 10 shows the bearing capacity curve for a sand column with various L/D ratios at (Sr.=80%) with (as=0.09) for all L/D. The strength of the

sand column increased as L/D increased. When L/D increased from 8 to 10, the ultimate capacity increased from 140.5 kPa to 147 kPa, an increase of 6%. When L/D became 12, capacity increased to 148 kPa (3% increase); at L/D 15, capacity increased to 162 kPa (3% higher than at L/D 12), 4% higher than at L/D 10, and 8% higher than at L/D 8.

Fig. 11 represents the bearing capacity curve for ($a_s=0.22$) with various L/D ratios. As shown, when L/D increased from 8 to 10, the column strength increased from 185 kPa to 202 kPa, an increase of 7%. When L/D becomes 12, the strength becomes (215.6 kPa), which is 6% than $L/D=10$ and increasing 13% than $L/D=8$. When L/D becomes 15, the strength becomes (225 kPa), which is 4.5% higher than the column capacity at L/D 12 and 11%, 18% than L/D 10, and 8%, respectively. Fig. 12 represents different L/D ratios ($a_s=0.09$). The bearing capacity of composite soil increases with increasing L/D ratio. At the increasing of L/D ratio from 8 to 10 ultimate soil capacity increased from (190 kPa to 225 kPa) which means increased 18% and when L/D become 12 the capacity will increasing to (266 kPa) which means increased 18% than L/D 10 and increased 40% than L/D 8, and when L/D become 15 the bearing capacity of composite soil will reached to (288 kPa) which means 10% than L/D 12 and 29% greater than L/D 10 and 52% greater than L/D 8.

Fig. 13 clearly shows the increase in bearing capacity of composite soil at ($a_s=0.22$). When increasing in L/D from 8 to 10 the bearing capacity will increased from (238 kPa to 286 kPa) which means increased 21% and when L/D become 12 the capacity increasing to (310 kPa) which means increasing 11% and 30% than ($L/D=8$), and when L/D increased to 15 the capacity increasing to (357 kPa) which means increasing 15% than L/D 12 and 24% than L/D 10 and 50% than L/D 8.

Fig. 14 clearly shows the effect of increasing L/D on the column's strength at various area replacement ratios. Increasing L/D ratios does not affect the improvement ratio at any area replacement ratio. Fig. 15 clearly shows the effect

of increasing L/D on column strength. It can be noted there is no effect of increasing L/D ratios or the effect is negligible of L/D on bearing capacity of composite soil for all area replacement ratio at $S_r.80\%$ for all area replacement ratios and that. On the other hand, increasing the area replacement ratio will increase the bearing improvement ratio. Fig. 16 shows the results for different L/D ratios at $S_r. = 60\%$. It can be noticed that the effect of increasing L/D appears at a degree of Saturation of 60% much more than at $S_r. (80\% \text{ and } 100\%)$, because the soil confinement strength at $S_r.=60\%$ is higher than at 80% and 100%.

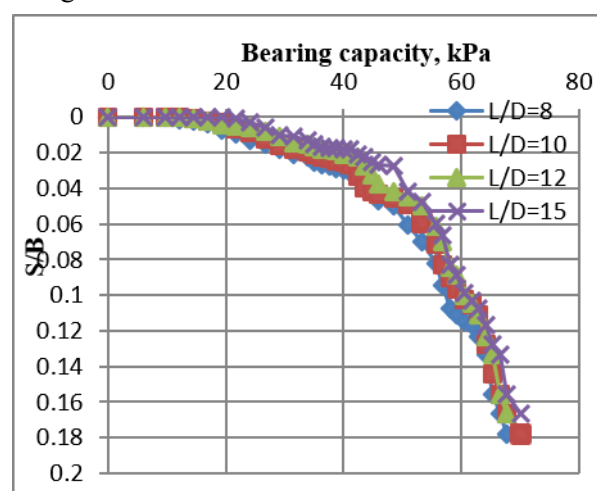


Fig. 8 Bearing Capacity curve for ($S_r.=100\%$) at area ratio 0.09

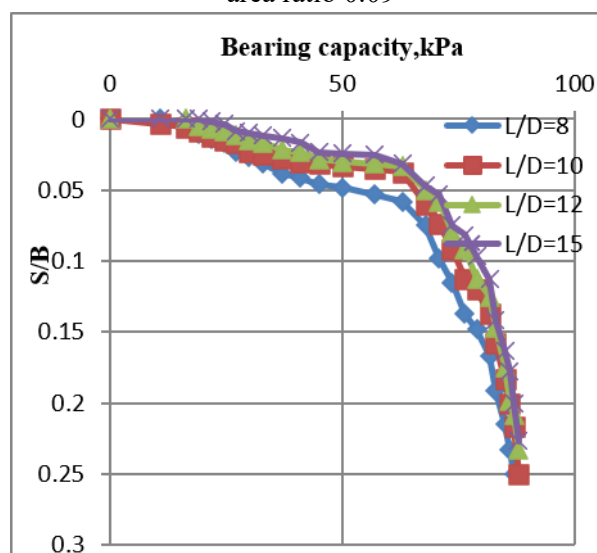


Fig. 9 Bearing Capacity curve for ($S_r.=100\%$) at area ratio 0.22

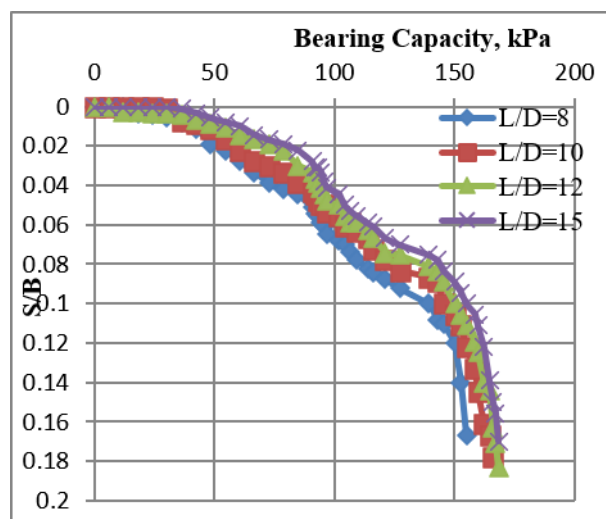


Fig. 10 Bearing Capacity curve for (Sr.=80%) at area ratio 0.09

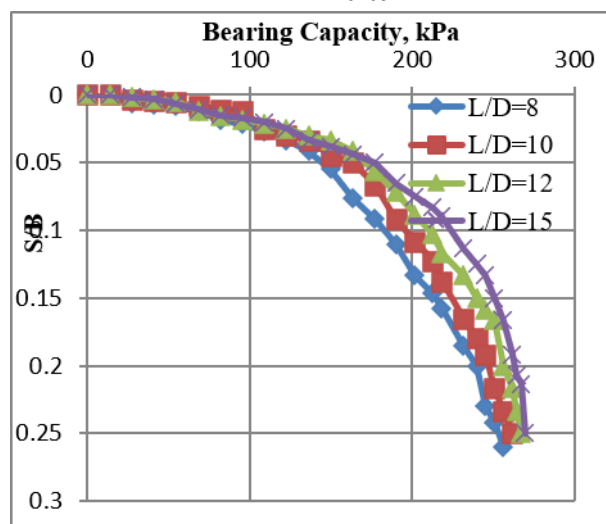


Fig. 11 Bearing Capacity curve for (Sr.=80%) at area ratio 0.22

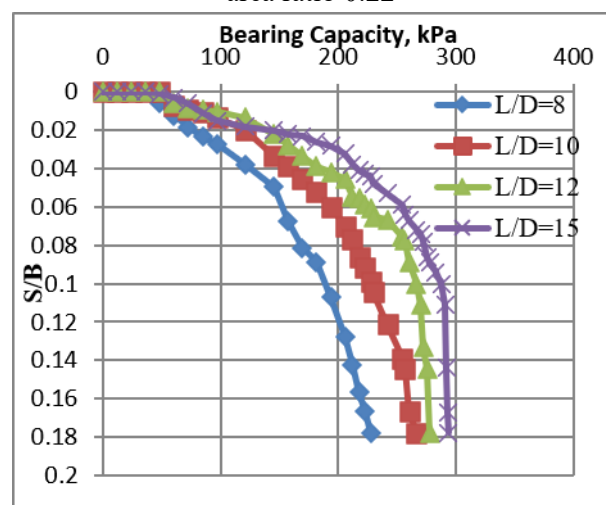


Fig. 12 Bearing Capacity curve for (Sr.=60%) at area ratio 0.09.

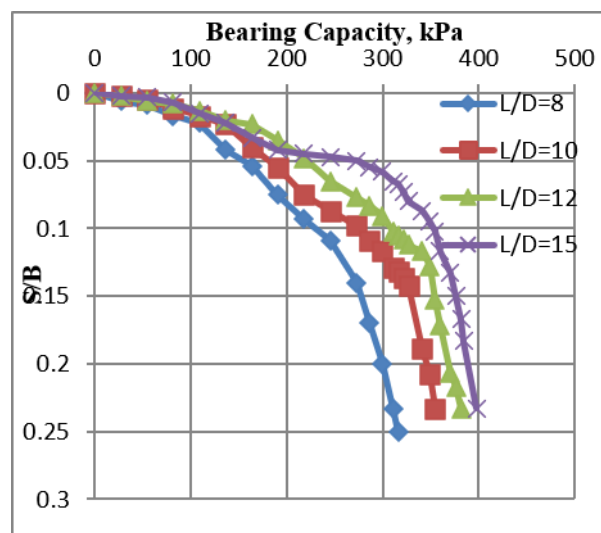


Fig. 13 Bearing Capacity curve for (Sr.=60%) at area ratio 0.22

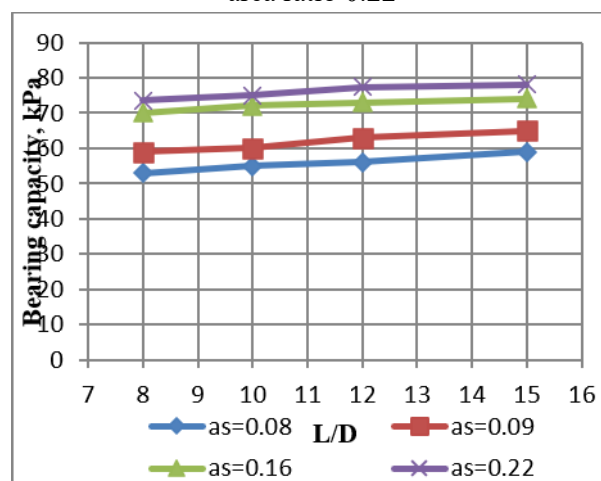


Fig. 14 Ultimate bearing capacity versus L/D for different as at (Sr.=100%)

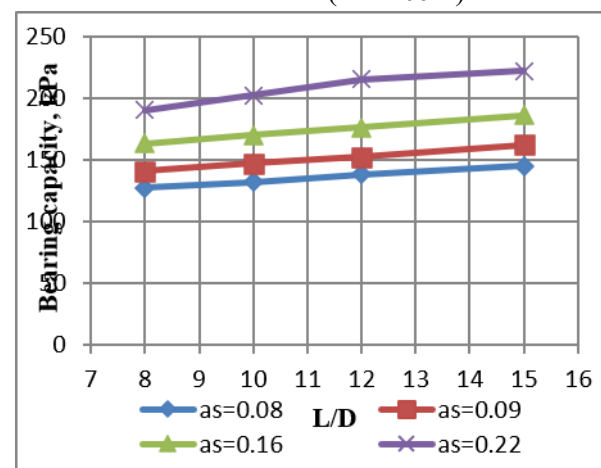


Fig. 15 Ultimate bearing capacity versus L/D for different as at (Sr.=80%)

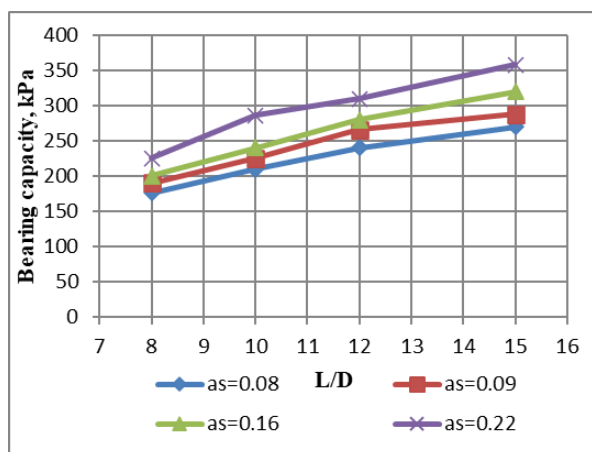


Fig. 16 Ultimate bearing capacity versus L/D for different as at (Sr.=60%).

4.2 Effect of degree of Saturation on behavior of the sand column

Fig. 17 display relationship between bearing capacity with S/B for three degree of Saturation (Sr.=100%, 80%, 60%), it show that ultimate capacity for single sand column of ($L/D=8$) at ($as=0.09$), it indicate that the Saturation high impact on resistance of column and increased when reducing the Saturation from fully saturation cases (Sr.=100%) to unsaturation cases (Sr.=80%), by reduction the degree of Saturation to (Sr.=60%), the capacity can be substantially increased which is obvious. The bearing capacity of composite soil with a single column ($L/D=8$) at ($as=0.09$) in full Saturation (Sr.=100%) is (59 kPa). This increases when the saturation level is (Sr.80%) to (140 kPa), which is a 131% increase over the saturated case. Following that, it increased to (190 kPa) at (Sr.60%), which means an increase of 42% over (Sr.80%) and 223% over the fully conditioned case.

Fig. 18 represented bearing capacity curve with normalized settlement, S/B, for three degrees of Saturation at ($as=0.09$), which shows that the ultimate capacity for a composite soil with single column of $L/D=10$ is (60 kPa) when the soil is fully saturated (Sr.=100%) and increased to (147 kPa) when Sr. reduced to 80%, indicating that the capacity increased by 145%, then increased to (225 kPa) when Sr.=60%, which implies the capacity increased by 54% more than the Sr.80% case and 275% than saturated state Sr.100%. Fig. 19 displays the bearing capacity curve of $L/D=12$

at ($as=0.09$), as it shows that when decreasing the degree of Saturation from Sr.100% to Sr.800%, the capacity increases from (63 kPa to 148 kPa) which indicate increasing 134%, after that when Sr. become 60% the capacity become (266 kPa) that means increasing 80% than Sr.80% and 322% than Sr.100%.

Fig. 20 display bearing capacity with S/B for $L/D=15$ at different Saturation in ($as=0.09$), it can be noticed that when degree of Saturation decreased from (100% to 80%), the capacity of composite soil will increasing from (65 kPa to 162 kPa) which means increasing 145%, and when Sr. decreasing to become 60% the capacity increasing to be (288 kPa) which means increasing 79% than Sr.80% and 339% than Sr.100%.

A comparable behavior is noticed in ($as=0.22$) as show in Fig. 21 relation between bearing capacity and normalized, S/B at three degree of saturations, when Sr. decreased from 100% to 80% the capacity increasing from (73 kPa to 177 kPa) that means increasing 191%, and when Sr. become 60% the capacity increasing from (177 kPa 238 kPa) that means 36% than Sr.80% and 230% than Sr.100%.

Fig. 22 illustrate the bearing capacity with S/B for ($L/D=10$) in three degrees of Saturation at ($as=0.22$), it indicated that the ultimate capacity for a composite soil is (76 kPa) when the soil is fully saturated (Sr.=100%) and increased to (202 kPa) when Sr. reduced to 80%, it indicating that the capacity increased by 166% than Sr.100%, then increased to (286 kPa) when Sr.=60%, which implies the capacity increased by 43% compared to the Sr.80% case and 276% than saturated state Sr.100%. Fig. 23 showed baring capacity with S/B for $L/d=12$ at three degree of Saturation in ($as=0.22$), it can be noticed that when Sr. decrease from (100 to 80) ultimate column capacity increase from (77 kPa) to (215 kPa) which means capacity increase 162% and when Sr. becomes 60% the column capacity increase to (310 kPa) which means 70% than Sr.80% and 348% than Sr.100%.

When $S_r = 60\%$, since the soil is unsaturated at this point, there is a significant "matric suction" holding the soil particles together, which is the main cause of the unsaturated soil's increased soil improvement. Tension surface forces in the air-water pores serve as extra "physical bonds" between soil particles at low saturation levels. The effective confining tension (σ_3) that the surrounding soil applies to the sand column wall is increased by this suction. Because lateral confinement is the only source of strength for a concrete column, surface tension acts as an "invisible shell" that keeps the column from bulging and allows it to sustain much larger vertical loads, gradually increasing the improvement ratio. Because of this stress, the soil around the column becomes more rigid, improving lateral confinement and preventing lateral bulging from causing column failure. At ($S_r=100\%$), values drop to less than 0.7. At complete Saturation, the soil loses much of its shear strength due to the absence of matric suction. This weakens the "confinement ring" surrounding the column, allowing lateral expansion and reducing its effectiveness.

A similar observation was proposed by (28): as the degree of Saturation Increases, bearing capacity decreases. The minimum bearing capacity of unsaturated silty sand soil treated with stone columns was observed, the results show lowest bearing capacity occurs at (90-100%) saturation where the bearing capacity appears to be around (210 kPa) at 90% saturation and its (340 kPa) at Saturation 60% and that is because the matric suction value, where it decreases with increased Saturation, and the greater the strength of soil which high lateral confinement, the bulging of column will reduce which provide. This means unsaturated soil shear strength significantly impacts the stone column's behavior.

Fig. 24 show bearing capacity with S/B of $L/D=15$ at different saturation degrees in ($a_s=0.22$), it indicates that the saturation high impact on resistance of column and increased when reducing the Saturation from fully saturation cases ($S_r=100\%$) to unsaturation cases ($S_r=80\%$), by reduction the degree of Saturation to

($S_r=60\%$), the capacity can be substantially increased, which is obvious. The bearing capacity of composite soil with a single column ($L/D=15$) at ($a_s=0.22$) in full Saturation ($S_r=100\%$) is (78 kPa). This increases from ($S_r=80\%$) to (225 kPa), an increase of 188% over the saturation case. Next, it increased to (357 kPa) at ($S_r=60\%$), which is 60% higher than ($S_r=80\%$) and 357% higher than the fully conditioned case.

On the other hand, when increasing the area ratio from (0.09 to 0.22) for the same $L/D=8$, Fig. 17 and Fig. 20, the bearing capacity will increase at all saturation degrees, in case of fully Saturation ($S_r=100\%$), the bearing capacity will increasing from (59kPa to 73kPa), that means $a_s=0.09$ increasing 23%. The same thing happens when ($S_r\%$) is reduced to be ($S_r=80\%$), the percent of bearing capacity increasing 27% when increasing a_s from (0.09 to 0.22) for the same $L/D=8$. Furthermore, when $S_r=60\%$, the capacity increasing 26% when increasing from (0.09 to 0.22) because the area ratio (a_s) serves as a primary determinant for the Improvement Ratio. As a_s increases, a larger volume of soil is replaced by high-stiffness granular material, leading to a significant increase in the composite elastic modulus of the treated ground. This shift promotes the stress concentration effect, where the columns intercept a greater portion of the vertical loads, thereby shielding the surrounding weak soil. Consequently, the overall bearing capacity is enhanced, and the settlement is minimized, resulting in a higher Improvement Ratio as observed in the experimental results.

Similarly, increasing L/D to ($L/D=10$), this mechanism allows for a more effective transfer of vertical loads to deeper, more stable soil layers. Consequently, the overall settlement is further reduced, reinforcing the system's efficiency in a manner analogous to increasing the area replacement ratio. Increasing a_s from ($a_s=0.09$) Fig. 18 to ($a_s=0.22$) fig. 21, for ($L/D=10$) and ($S_r=100\%$), bearing capacity increasing 27%, and when degree of Saturation reduces to be ($S_r=80\%$), the ratio of improvement increasing to be 37%, and increasing where ($S_r=60\%$) to become 27%.

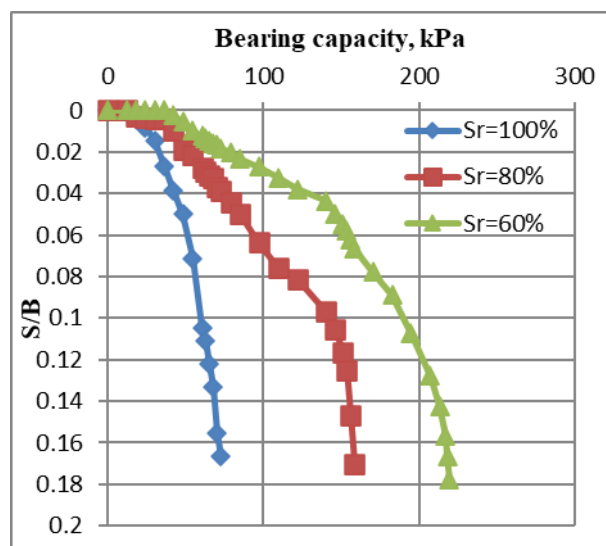


Fig. 17 Bearing capacity curve for sand column with $L/D=8$ for different degrees of Saturation at $as=0.09$

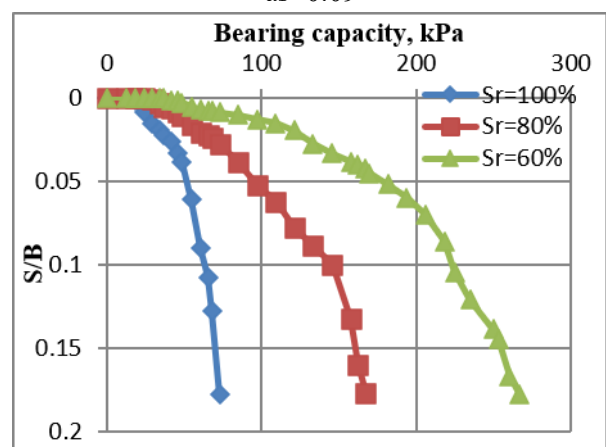


Fig. 18 Bearing capacity curve for sand column with $L/D=10$ for different degrees of Saturation at $as=0.09$

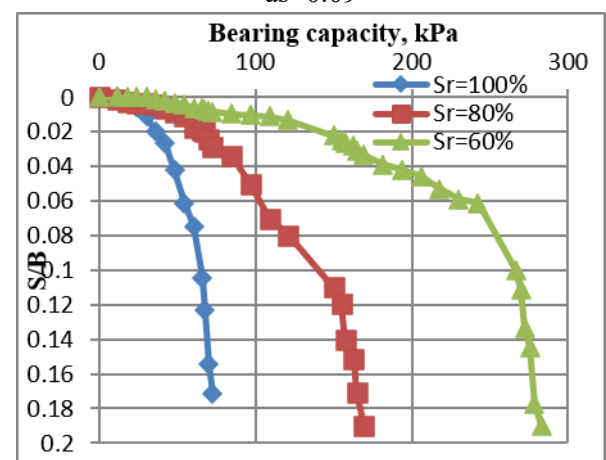


Fig. 19 Bearing capacity curve for sand column with $L/D=12$ for different degrees of Saturation at $as=0.09$

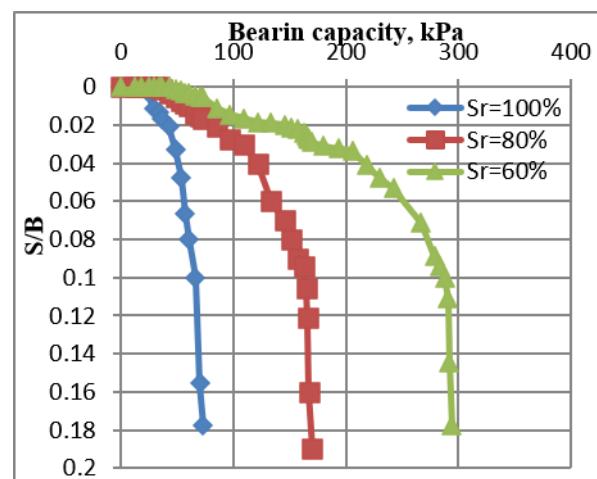


Fig. 20 Bearing capacity curve for sand column with $L/D=15$ for different degrees of Saturation at $as=0.09$

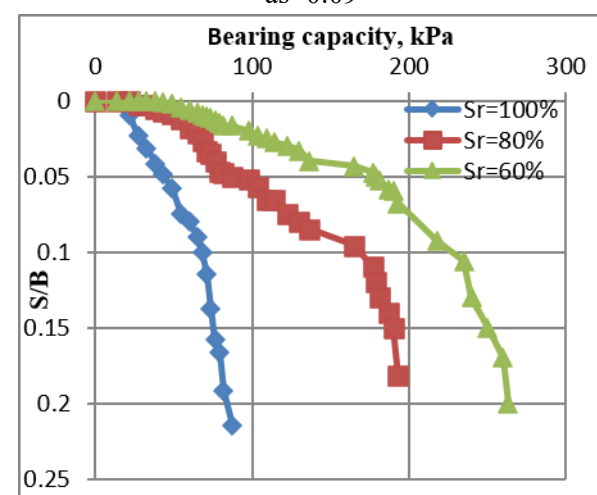


Fig. 21 Bearing capacity curve for sand column with $L/D=8$ for different degrees of Saturation at $as=0.22$

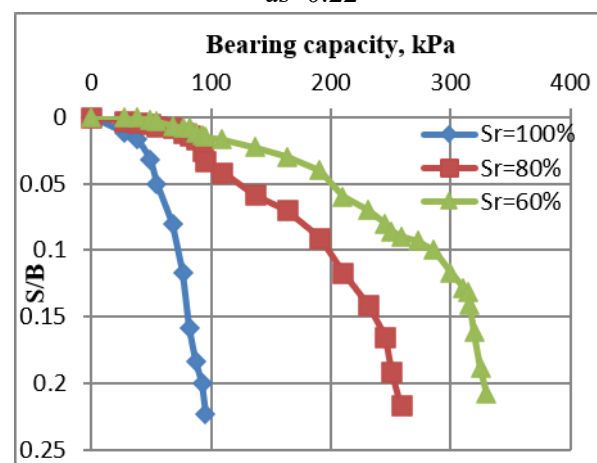


Fig. 22 Bearing capacity curve for sand column with $L/D=10$ for different degrees of Saturation at $as=0.22$

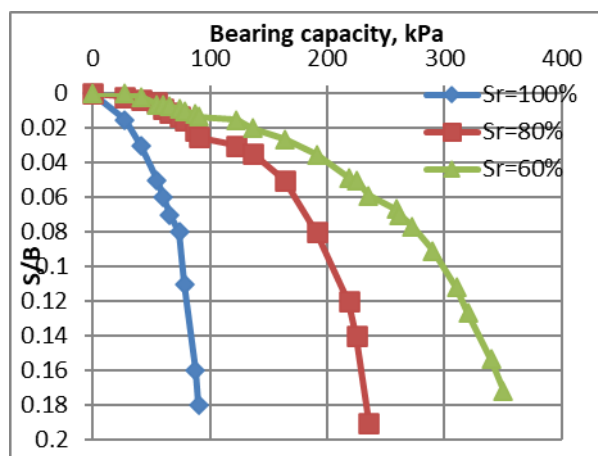


Fig. 23 Bearing capacity curve for sand column with $L/D=12$ for different degrees of Saturation at $a_s=0.22$

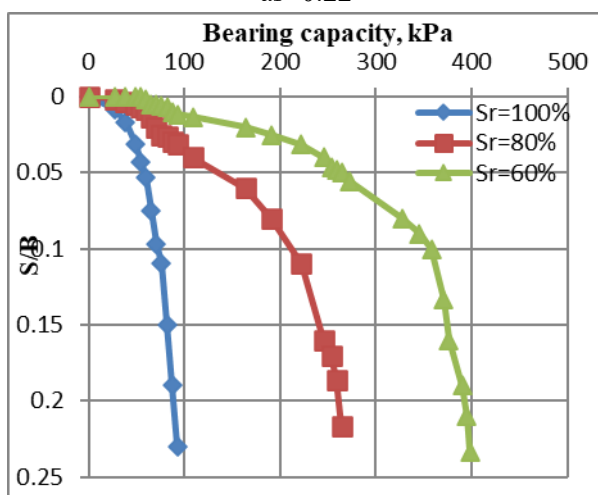


Fig. 24 Bearing capacity curve for sand column with $L/D=15$ for different degrees of Saturation at $a_s=0.22$

5. Conclusions

The degree of Saturation has a significant impact on the effectiveness of the sand column for all area replacement ratios, where, with S_r reduction, the effectiveness of the single column increases, subsequently increasing bearing capacity, where the maximum bearing capacity of composite soil is at ($S_r=60\%$), and the minimum value is at ($S_r=100\%$). It can be noted that the increasing L/D ratio of sand column give increasing in capacity of composite soil but this increasing it was negligible at $S_r=100\%$ for all area replacement ratio, whereas at a low saturation degree ($S_r=80\%$), it resulted in a noticeable increase in capacity and that increasing also small effect, and when degree become ($S_r=60\%$), the capacity will significant increasing

and it play an important role in the possibility of increasing L/D ratio. It was observed that when the area ratio increased from (0.09 to 0.22), it led to an increase in the effective column for all degrees of Saturation and for all (L/D).

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Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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