

Behaviour of Square Footing on Clay Soil Reinforced with Two Type of Geotextile

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ABSTRACT

The behaviour of foundations on clay soil reinforced with geo-textile using laboratory model footing tests was investigated. The square model footing was made of a steel plate with dimensions of 150 mm × 150 mm. The parameters investigated in this study included the top layer spacing, the length of reinforcement layers, and the type of geotextile. The test results showed that the inclusion of reinforcement could significantly improve the soil's bearing capacity and reduce the footing settlement. The increase in BCR values varied depending on the type of geo-textile and how it dealt with the soil. BCR increases as u/B increases until it reaches a certain point where it decreases. The maximum improvement is achieved at $u/B=0.3$ for both types, this value varying depending on the length of the geotextile. The values of L/B that achieve a higher BCR are 3 and 8 for woven and nonwoven, respectively. The results show that woven geotextile has superior BCR values; however, in practice, nonwoven can achieve excellent performance with less reinforcement than woven.

Keywords: Woven Geotextile, Nonwoven Geotextile, Square Footing, Parametric Study, Bearing Capacity Ratio

INTRODUCTION

Since soil is the main element in geotechnical engineering, developing it in the same direction as other materials is difficult, construction equipment developments have facilitated the use of compaction and other soil improvement techniques. Soil reinforcement is probably the best example of a parallel development between material and construction application, similar to reinforced concrete, steel and polymeric materials provide tensile resistance and stability to soils with low to no tensile strength [1]. The concept of reinforced soil has been used since Babylonian times, it was used to build ziggurat temples before 3500 years ago, as well as the Great Wall of China with natural materials.

Recently, the concept of reinforced soil was introduced in the 1960's using flat metal reinforcing bars, and in 1970s metallic grids were used as reinforced elements, but with the corrosion problem and development of geosynthetic materials led to make the reinforced soil one of the best methods to improvement soil with polymeric materials. in compare with other traditional methods of improvement soils, geosynthetic reinforcement considered as a feasible treatment alternative and one of the cost-effective techniques to avoid construction of costly deep foundations or piles, in many cases, using a geosynthetic can significantly increase safety factor, improve performance, and lower costs. Many studies have been conducted to develop a practical model in terms of cost and efficiency using geosynthetic reinforcement for increase the load-bearing capacity of foundation, these studies have been conducted some for surface footing conditions and other for embedded footing using different type, number of layer of geosynthetic and some parameters that may effect on the ultimate bearing capacity [2-12]. The authors Chakraborty and Kumar [13] conducted an experimental study to specify the optimum diameter and critical position of reinforcement layer that yield maximum bearing capacity, other parameter can also effect on the bearing capacity. Useche-Infante et al. [14] studied the possibility of increase

the improvement of bearing capacity of circular foundation on geogrid reinforced sand by parameters: the depth of the first geogrid layer u , vertical separation between layers of geogrid h , diameter of the geogrid D , number of reinforcement layers N , deep of the foundation D_f , relative density of the sand D_r , type of geogrid and the effect of wraparound end of reinforced layer, the results compared with analytical and multiple layer of geotextile to reinforced sand with wraparound end improved the load bearing capacity and modulus of subgrade reaction more than using reinforcement layer without wraparound end, with increase depth of embedded footing up to depth equal to B , and in other study, Kazi et al. [11] investigated the optimum embedded depth of strip footing and the number of reinforcement layer that achieved maximum bearing capacity and compared these results with numerical results based on finite element analysis.

Altalhe et al. [15, 16] evaluated the impact of one, two, and three reinforcing layers on the bearing capacity ratio (BCR) of strip footings. Reinforcement significantly influences sand's load-bearing ability in soils with lower relative density compared to those with higher relative density. The perfect amount is two reinforcements. Moreover, the optimal distance between the two reinforcing layers is $0.3 B$. The positioning of the footing relative to the slope face influences the enhancement in bearing capacity, along with the geotextile arrangement. Altalhe et al. [17] reported a study on experimental model testing regarding the performance of a strip footing that relies on a line of soil nails and a single geotextile layer on a sandy slope. The findings indicate that the bearing capacity of strip footings is significantly enhanced when an earth slope is stabilized with a single layer of geotextile or a series of soil nails, and this enhancement becomes more pronounced as the spacing between soil nails decreases. Stabilizing an earth slope using a single layer of geotextile instead of multiple soil nails offers significantly greater overall benefits.

The main goal of this research is to determine whether there is a way to improve the behavior of square footings on clay soil. The experimental study will investigate different parameters that increase soil bearing capacity as well as its ability to withstand higher loads on weak soil (silty clay soil) using two different types of geotextiles. The model tests take into account the following parameters: top layer depth (u), layer length (L), and geotextile type.

MATERIAL PROPERTIES

Clay

The soil used for this study was collected from Shahat-libya to depth 0.7m, the soil sample was dried under room temperature for month (air dried $25^{\circ}\text{C} \pm 5$), after that, the important physical and mechanical properties that describe and classified the soil were conducted according to American Society of Testing Materials (ASTM)

LABORATORY TESTS

Test Setup

Table 1: Most Important Mechanical and Physical Properties of Used Soil.

Soil Property		Value
Consistency Limits	LL (%)	32.947
	PL (%)	19.036
	PI (%)	13.911
Specific Gravity Gs		2.553
Compaction	Max. Dry Density Yd (g/cm ³)	1.825
	O.W.C (%)	14.831
Hydrometer Analysis	Silt (%)	77.3
	Clay (%)	29.5

Table 2: Engineering Properties of Geotextiles.

Property		Nonwoven Textile	Woven Textile
Tensile Strength (N)	FabricWeight (g/m ²)	400	250
	Thickness (mm)	3.8	-
	Grab Tensile Strength (M.D) (N)	1000	1068
	Grab Tensile Strength (C.D) (N)	1750	
	Permeability (Cm/S)	0.25	0.04

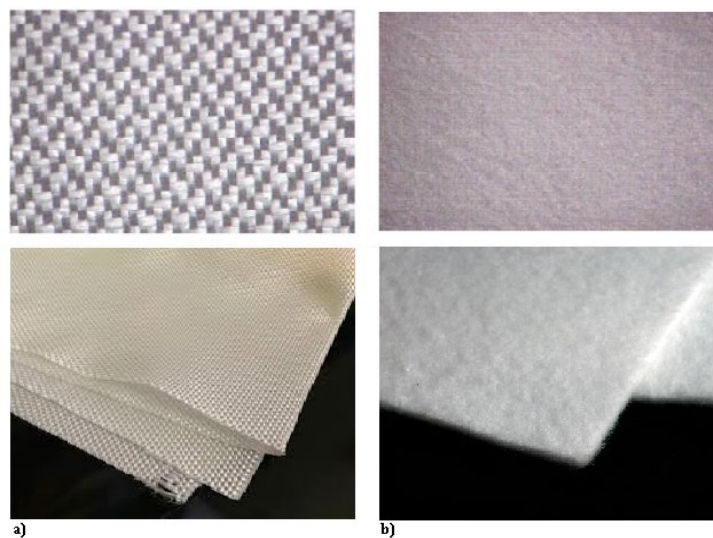


Figure 1: Geotextile Used in this Study, a) Woven Geotextile, b) Non-Woven Geotextile.

The laboratory apparatus consisted primarily of a tank, a rectangular steel footing, and a loading device. According to Chummar [18] the soil failure surface extends around 2B on each side

specification. These properties are indicated in Table 1. After drying, the soil was aggregated to larger particles, so it had to be washed in sieves no.4 and 200 to calculate the retaining percentage of soil. The R₄ and R₂₀₀ were found to be 8.94% and 32.114%, respectively. The ASTM D-2487 uniform classification of fine grained inorganic soil was used to classify soil, with soft soil classified as CL (group symbol)-Sandy lean clay (group name).

Geotextile

In this study two types of geotextiles will use: woven and nonwoven textile as shown in Fig 1. A nonwoven geotextile was used with thickness 3.8mm under 2KN/m² and its grab elongation >100%. The physical and mechanical properties of the reinforcement were obtained from the data sheet of manufacturer, which are shown in Table 2. The axial stiffness EA, for woven and nonwoven are 2135.2 and 2000 KN/m respectively.

from the edge of footing and its depth is about 1.1B from the base of foundation, Mandal and Sah [19] the width and depth of the steel tank are more than four times the width of the model footing. So, to ensure

the failure surface develop freely and to minimum the effects of ends, the box was made of steel tank with $1.5 \times 1 \times 0.5$ m and 0.5 m in depth, one of the test tank walls was made of Polycarbonate glass 5 mm in thickness, supported directly on two steel columns and was marked at 10 mm intervals to facilitate preparation of the soil. To avoid lateral deformation, the tank walls were braced with steel column on the outer sides, the inside walls of box were polished to reduce friction with the ends of foundation. The glass side allowed for visual inspection of the sample during preparation and observation of soil particle deformation during testing, and the tank box was designed to be rigid enough to maintain plane strain conditions. The model footing used for the test was a square footing composed of 15×15 cm steel plates with 25 mm thickness, on a center of footing surface a hole was created and a rod of diameter similar to the diameter of the bearing rod was

installed for applying load. A hydraulic jack welded against a reaction frame was used to apply the load to the footing, a dial gauge with 20KN capacity was used to measure the applied load, where the load increments were applied and maintained until the rate of settlement s/B was achieved 16%. Two dial gauge placed on the footing sided were used to measure the settlement, the model footing setup is shown in Fig 2 and 3.

Reinforcement Layout

The problem being studied in the laboratory is the bearing capacity of square footing, with width of which is (B) , it is located on clay soil with a specific density γ , reinforced with type of geotextiles, the first layer from the bottom of the foundation (U) , and the length of each layer is (L) as shown in Fig 4.

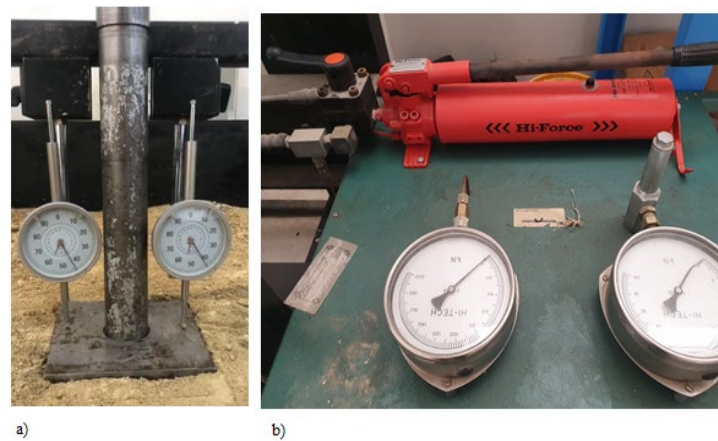


FIGURE 2: Experimental Apparatus: a) Schematic View of Footing Apparatus, b) Hydraulic Jack.

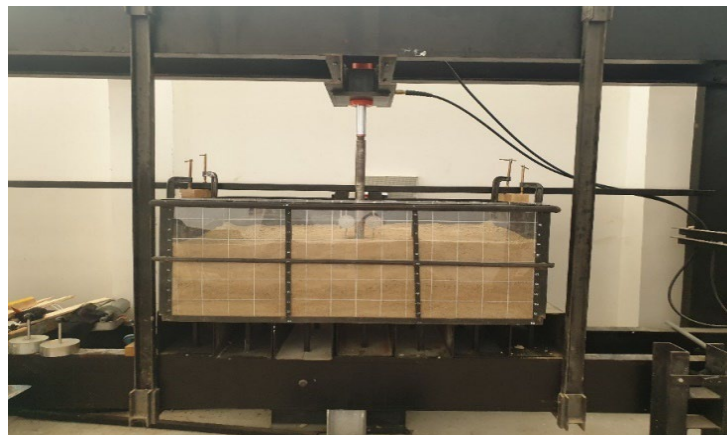


FIGURE 3: Model Footing Load Test Arrangement in the Laboratory.

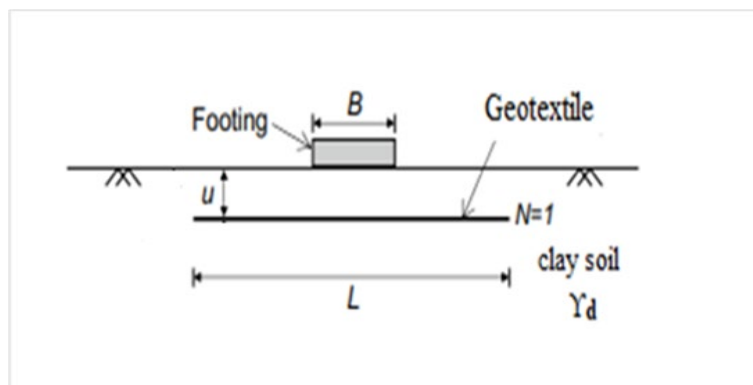


FIGURE 4: Parameters of the Study

Test Procedure and Program

All laboratory experiments were conducted in the Soil Mechanics and Foundations Laboratory in the College of Civil Engineering at Omar Almukhtar University. A series of laboratory model test were conducted according to Table 3. The soil was passed on a 9.5mm sieve for soil homogeneity. Then the water was added according to the program of test and mixed by hand, the box was filled with soil in four layer each layer was approximately 100-150 mm thick, the quantity of soil required for each layer was first determined, then leveling and compacting using a 15 mm diameter steel plate with a weight of 8 kg under a number of blows which given a desired density (varied from 25 to 50 times depending on the thickness of layer and the position of a geotextile layer). This procedure is carried out for each layer until

the soil reaches the desired depth of 400mm then covered for at least 24 hours for uniform moisture distribution.

After the final layer was completed, the surface was leveled, and the foundation was perfectly centered on the loading jack to prevent eccentric loading. The footing had been loaded by a hydraulic jack supported against a reaction frame. The load transmitted to the footing was measured using a load gauge. The load was applied in small increments. In each experiment, after preparing the soil with the desired density, it was checked using small metal cylinders in various places in the box, the dry density was $1.23 \pm 0.05 \text{ g/cm}^3$ that achieve 68 % from the maximum dry density of soil with water content of the soil were calculated as $8.24 \pm 0.5\%$. the ratio of depth of the soil to the width of footing is 2.6

Table 3: Experimental Test Program for Reinforced Soil.

No. of Test	Reinforcement Type	U/B	L/B	No. of Test	Reinforcement Type	U/B	L/B
Ur1	Without	-	-	-	-	-	-
Wr1-15	Woven Geotextile	0.25	3	Nr1-15	Non-Woven Geotextile	0.25	3
Wr2-15	Woven Geotextile	0.25	6.67	Nr2-15	Non-Woven Geotextile	0.25	6.67
Wr3-15	Woven Geotextile	0.25	8	Nr3-15	Non-Woven Geotextile	0.25	8
Wr4-15	Woven Geotextile	0.3	3	Nr4-15	Non-Woven Geotextile	0.3	3
Wr5-15	Woven Geotextile	0.3	6.67	Nr5-15	Non-Woven Geotextile	0.3	6.67
Wr6-15	Woven Geotextile	0.3	8	Nr6-15	Non-Woven Geotextile	0.3	8
Wr7-15	Woven Geotextile	0.67	3	Nr7-15	Non-Woven Geotextile	0.67	3
Wr8-15	Woven Geotextile	0.67	6.67	Nr8-15	Non-Woven Geotextile	0.67	6.67
Wr9-15	Woven Geotextile	0.67	8	Nr9-15	Non-Woven Geotextile	0.67	8
Wr10-15	Woven Geotextile	1	3	Nr10-15	Non-Woven Geotextile	1	3
Wr11-15	Woven Geotextile	1	6.67	Nr11-15	Non-Woven Geotextile	1	6.67
Wr12-15	Woven Geotextile	1	8	Nr12-15	Non-Woven Geotextile	1	8

Table 4: Summary of Model Tests Results

Test No.	Geotextile Type	u mm	L mm	s/B=5%		s/B=10%		s/B=16%	
				q	BCR	q	BCR	q	BCR
				KN/m ²		KN/m ²		KN/m ²	
Ur1-15	-	-	-	220.96	-	357.12	-	491.06	-
Wr1-15	Woven	37.5	450	177.78	0.80	444.44	1.24	800	1.63
Wr2-15	Woven	37.5	1000	148.35	0.67	393.33	1.10	768.40	1.56
Wr3-15	Woven	37.5	1200	266.67	1.21	659.19	1.85	1104.66	2.25
Wr4-15	Woven	45	450	201.71	0.91	373.33	1.04	610.76	1.24
Wr5-15	Woven	45	1000	167.35	0.76	380.29	1.06	552.11	1.21
Wr6-15	Woven	45	1200	422.38	1.91	870.61	2.31	1211.45	2.39
Wr7-15	Woven	100	450	197.53	0.89	444.44	1.24	800	1.63
Wr8-15	Woven	100	1000	351.07	1.59	572.97	1.60	803.95	1.64
Wr9-15	Woven	100	1200	223.75	1.01	533.33	1.50	758.62	1.54
Wr10-15	Woven	150	450	272.45	1.23	478.71	1.34	680.96	1.39
Wr11-15	Woven	150	1000	226.35	1.02	372.56	1.04	537.54	1.09
Wr12-15	Woven	150	1200	244.62	1.11	382.22	1.08	551.11	1.13
Nr1-15	Non-Woven	37.5	450	266.67	1.21	711.11	1.99	956.26	1.95
Nr2-15	Non-Woven	37.5	1000	131.67	0.60	355.56	0.99	660.22	1.34
Nr3-15	Non-Woven	37.5	1200	148.09	0.67	329.46	0.92	572.07	1.16
Nr4-15	Non-Woven	45	450	251.71	1.14	444.48	1.25	702.22	1.39
Nr5-15	Non-Woven	45	1000	187.59	0.85	446.51	1.25	766.67	1.56
Nr6-15	Non-Woven	45	1200	137.17	0.62	240	0.78	421.62	0.86
Nr7-15	Non-Woven	100	450	225.23	1.02	481	1.35	800	1.63
Nr8-15	Non-Woven	100	1000	227.64	1.03	427.76	1.2	674.05	1.37
Nr9-15	Non-Woven	100	1200	355.56	1.61	537.66	1.51	858.67	1.75
Nr10-15	Non-Woven	150	450	225.20	1.02	449.99	1.26	763.48	1.55
Nr11-15	Non-Woven	150	1000	195.53	0.88	373.37	1.05	552.27	1.12
Nr12-15	Non-woven	150	1200	146.11	0.66	258.97	0.73	387.22	0.79

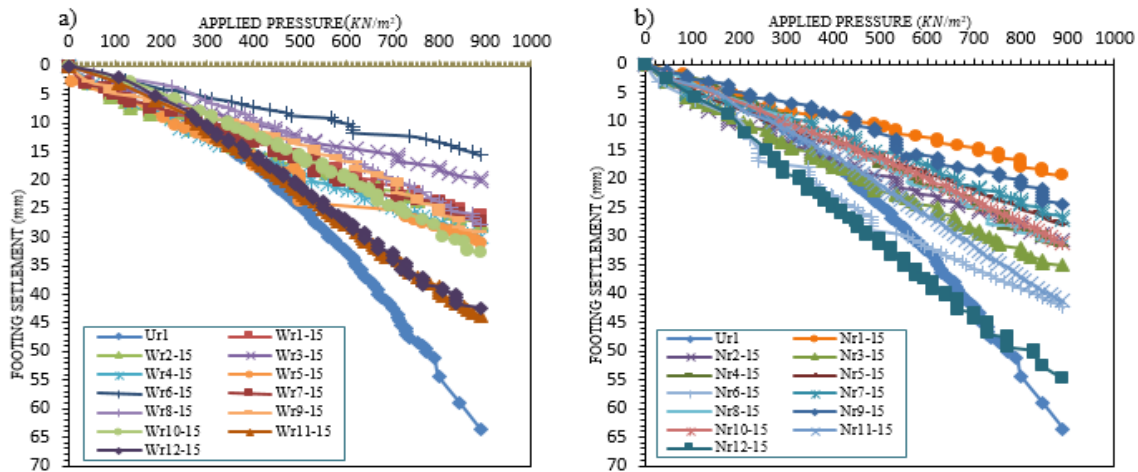


Figure 5: Pressure–Settlement Curves for 150 mm Model Footing Tests, a) Woven Geotextile Reinforced Soil, b) Non-Woven Geotextile Reinforced Soil.

Results and Discussion

In this study, we use BCR parameter to evaluated the improving of soil by two type of geotextile, woven and non- woven geotextile, the bearing capacity ratio BCR that is equal to the bearing capacity of reinforced soil to bearing capacity of unreinforced soil at the same settlement, this non-dimensional factor has been used to assist in expressing and comparing the test results, this determined at specific settlement/width ratio to canceled the effect of width footing on results.

Load-Settlement Response

A series of tests have been conducted as mentioned in Table 3, the results of these laboratory model tests are summarized in Table 4. In these tables the BCRs obtained at settlement ratios $s/B = 5\%$, 10% , 16% are presented. The results of the model footing tests are shown graphically in Fig 5 for woven and nonwoven geotextile. Figure 5 shows the pressure-settlement curves measured for 150 mm footing model tests for different values of u and L with two types of geotextile.

We can see from these curves that the pressure increases as the settlement increases for both reinforced and unreinforced soil. Cerato [20] describes this pressure-settlement behavior pattern as resembling a typical punching-shear failure. Mandal and Sah [19] found the same thing for a square footing on geogrid-clay soil. Because the failure point is undefined; the bearing capacity is deter-mined at various settlement ratios and used to find the BCRs.

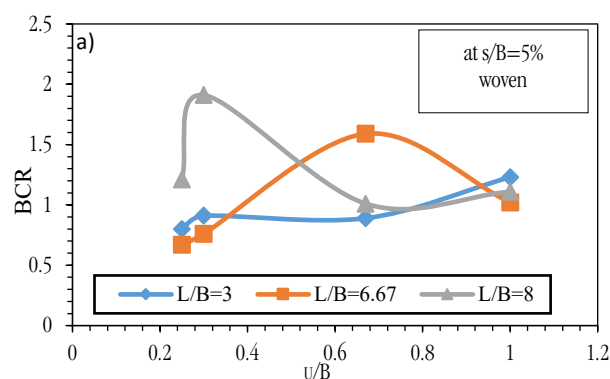
Effect of Top Spacing of Reinforcement

The optimal location of the reinforcement layer was investigated using two types of geotextile, concurrently with testing of the optimum

length of geotextile, to demonstrate how it varies with the other parameters of study. For the three levels of settlement, the increase in bearing capacity caused by the use of geotextile at different u/B ratios increases with footing settlement.

For Woven Geotextiles

BCRs increase as u/B increases until a certain value is reached, at which point they decrease. Fig 6 shows that as the length of the woven geotextile increases, the value of u/B that achieves the highest BCR decreases. With short length, the maximum value of u/B increases to $u/B=1$ and decreases as L values increase; as shown in Figure 6, the maximum improvement achieved with u/B is 0.3 with $L/B=8$. It can be explained that when the depth of the first layer is small, the initial sliding of the woven geotextile in the soil-geotextile layer occurs at a low bearing pressure. This is due to the low friction force between the geotextile and the soil. As a result, for shallow depths, the effect of geotextiles on the bearing capacity of square footing is minimal if length is small and increases with length, The need for longer length decreases with deeper depth because the bearing capacity decreases downward. for $L/B=8$, the maximum improvement is achieved with $u/B=0.3$ and then decreases; this state has the highest BCR value of up to 2.5. this finding is similar to that reported by Skati and Das [21] indicated that the optimum u location of one geotextile layer with $10B$ length is about $0.33B$. Mandal and Sah [19] investigated a lengthy layer of geogrid to investigate the effect of u/B on bearing capacity and found that the maximum improvement was achieved at $u/B=0.25-0.3$. Shin and Das [22] discovered that the maximum improvement in BCR occurred for sand soil reinforced with geogrid with $u/B= 0.35$ and $L/B=6$. Other researchers have reported similar u/B and L/B values with planer reinforcement layers.



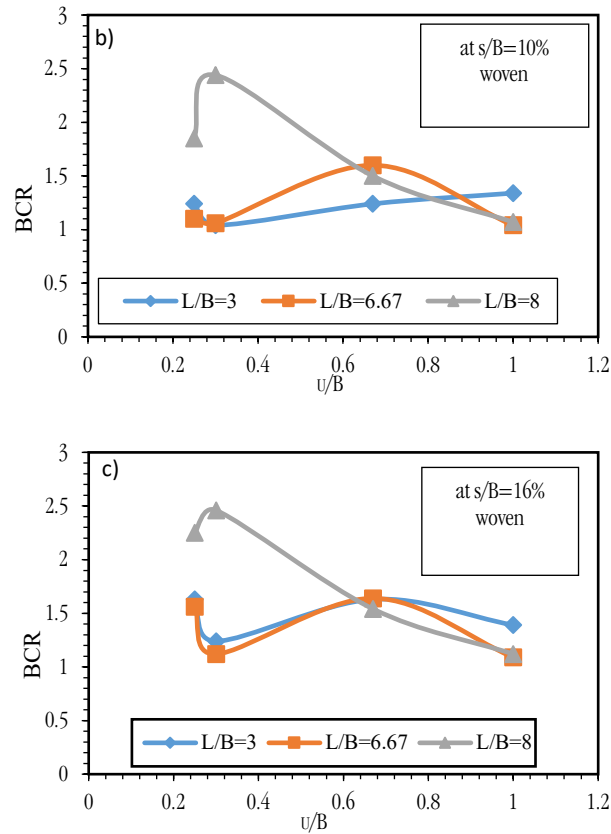


Figure 6: BCR Versus u/B at Different Length Ratio L/B for Woven Geotextile. For Settlement Ratio a) $s/B=5\%$, b) $s/B=10\%$, c) $s/B=16\%$.

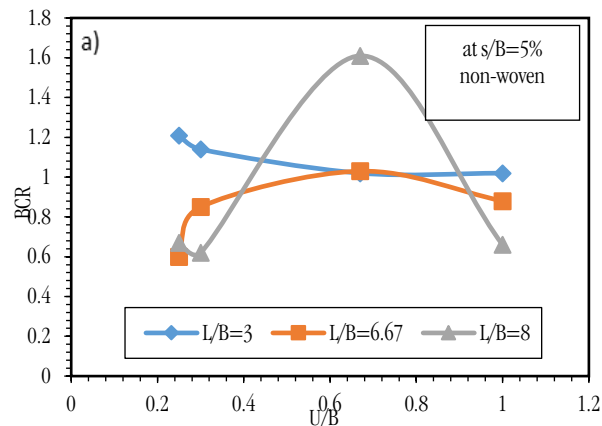
The behavior of sand soil reinforced with geogrid was studied by Das and Omar [23], who discovered that the ideal values of u and L were, respectively, $0.33B$ and $8B$. According to Khing et al. [24], $u=0.375B$ and $L=8B$ were the ideal values for improving the sand-geogrid bed. The results of this section can be used to determine the mechanics of the woven geotextile.

Because we used one type of reinforcement in this study and its working mechanics vary depending on the type of surrounding soil and the applied loads, this portion of the test was conducted with woven geotextile with a fairly smooth surface. However, because it is woven, it comes into contact with the soil, causing the lateral restraint effect. This effect restricts the movement of soil particles along the reinforcement under the foundation load, activating the friction force at the reinforcement-soil interface. This effect reduces horizontal movement, improving the lateral confining pressure and compressive

strength of the soil beneath the footing. As a result, the ultimate bearing capacity of the foundation improves. The mesh may play an important role in the soil-reinforcement interaction for woven geotextiles, but pull-out failure may occur with short lengths of woven geotextile, which explains the results of the experiment.

For Non-Woven Geotextile

The behavior in this series of tests differed from the woven geotextile used in the current study. We can see from Fig 7 that as u/B increases, the length required to obtain the maximum BCR increases. With a smaller depth ratio u/B , the maximum BCR occurs at a short length, and a greater length is required as U/B increases. For non-woven geotextile, the maximum improvement is achieved at $u/B=0.25$ and $L/B=3$. For $L=3B$, the bearing capacity of soil decreases as u increases. This.



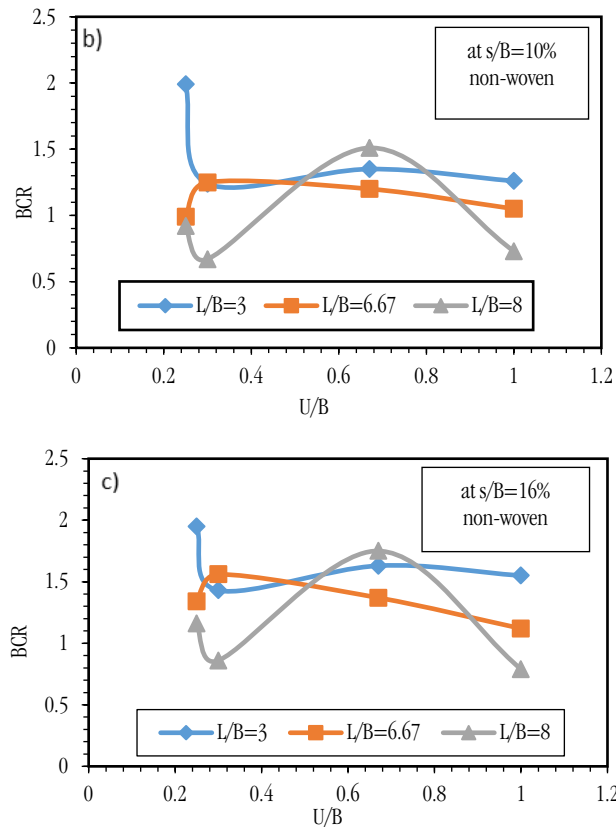


Figure 7: BCR Versus u/B at Different Length Ratio L/B for Non-Woven Geotextile. For Settlement Ratio a) $s/B=5\%$, b) $s/B=10\%$, c) $s/B=16\%$.

may occur because when the depth of geotextile is too great, failure may occur between the base of foundation and the layer of geotextile, resulting in the tensile force of geotextile not being developed. This finding is similar to that of Useche-Infante et al. [14] who studied the role of geogrid in improving sand soil under circular footing and observed that the optimal depth and length of geogrid to achieve maximum BCR were 0.25-0.4 and 3-5, respectively. Also, Thamer and Shaia [25] found that the optimum increase in bearing capacity occurs at $u/B=0.25-0.5$ and $L=4B$ for geotextile-reinforced sand. Mandal and Sah [19] conducted a study on geogrid reinforced clay under square footings and realised a BCR of 1.36 at $u/B=0.25$. Guido et al. [26, 27], Singh [28] suggested that the optimum L/B was approximately 2 for square footing on geogrid reinforced sand. similar u/B and L/B values with planer reinforcement layers. Ghazavi and Mirzaeifar [29] investigated the improvement in Geogrid-Sand bed and reported the most effective values of u and L as $0.3B$ and $3B$ respectively. Yetimoglu et al. [30] studied the Bearing capacity of rectangular footings on geogrid-reinforced sand and found that the optimum values of u and L were $0.25B$ and $4.5B$, respectively. Nonwoven geotextiles, unlike woven geotextiles, have a high elongation and an almost rough surface; laboratory observation show that they interact heavily with the soil. As a result, samples in which the length of the nonwoven geotextile crossed the stress influence zone had higher bearing capacity improvements. As depth increases, the load spreads out in the soil at a steeper angle, requiring more length to cross this zone. So, when u/B is higher, and because nonwoven has a high resistance to pull out failure, the tensioned member effect develops, so that as the geotextile moves downward caused by footing settlement in the reinforced zone due to load, which is higher beneath footing and decreases deeper, the curved geotextile develops upward

force that counters the applied load, thereby increasing bearing capacity.

Effect of Length of Reinforcement

In the previous two sections, we examined the effect of length with varying depth and type of reinforcement layer on bearing capacity. In contrast to previous research in the literature, length was not investigated with a specific value of u/B . In comparison with the results of optimal depth values, which were almost identical for both types and similar to the results of many previous studies, the effect of length was different. This effect is determined by a variety of factors, including the depth of the reinforcement u , the type of reinforcement, its resistance to pulling forces, and the distribution of stresses within the soil. A number of previous studies differed on the optimal length value, with results ranging from $3B$ to $8B$. In this study, the optimal length value for the woven geotextile type was 3, while the non-woven geotextile type was 8 as shown in Fig 8 and 9 for the woven and nonwoven respectively. Although the effective parameter in both type of geotextile to improving BCR is layer depth u , because it is directly related to the soil stresses. however, length has an effect to increase this improvement differ by interact it with model components, as known in properties of geotextile, woven has higher tensile strength with low elongation and nonwoven have elongation up to 100%. The term of optimum length of reinforcement refers to the truth that just the part of strengthening location inside the shear zone under the footing will have its tensile strength crowded effectively with extra length outside shear zone to give pulling resistance to reinforcement, as a result, the optimal reinforcement width equals the sum of the shear zone and anchoring zone widths on both sides. For woven geotextile, as known, has elongation between 5% and 25%, so the resistant to pull out test not much higher. So, in short length with small depth layer, the

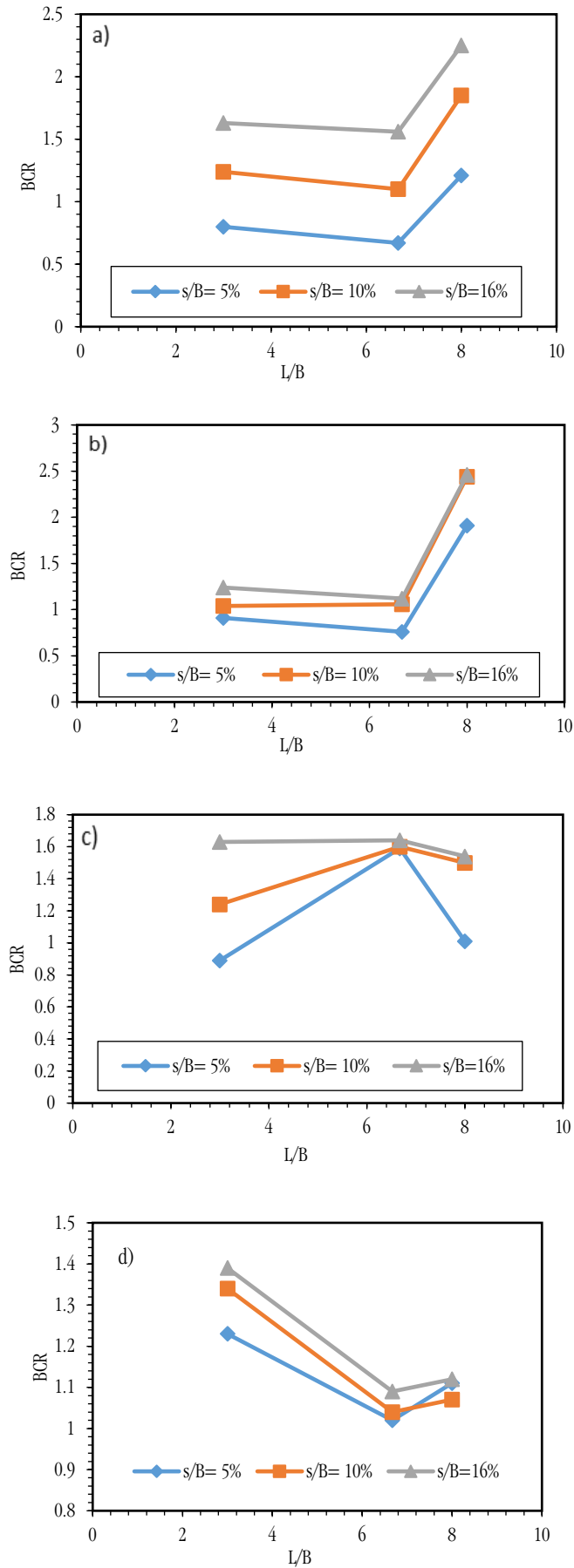


Figure 8: BCR Versus L/B for Woven Geotextile at Different Settlement Ratio (s/B): a) $u/B=0.25$, b) $u/B=0.3$, c) $u/B=0.67$, d) $u/B=1$.

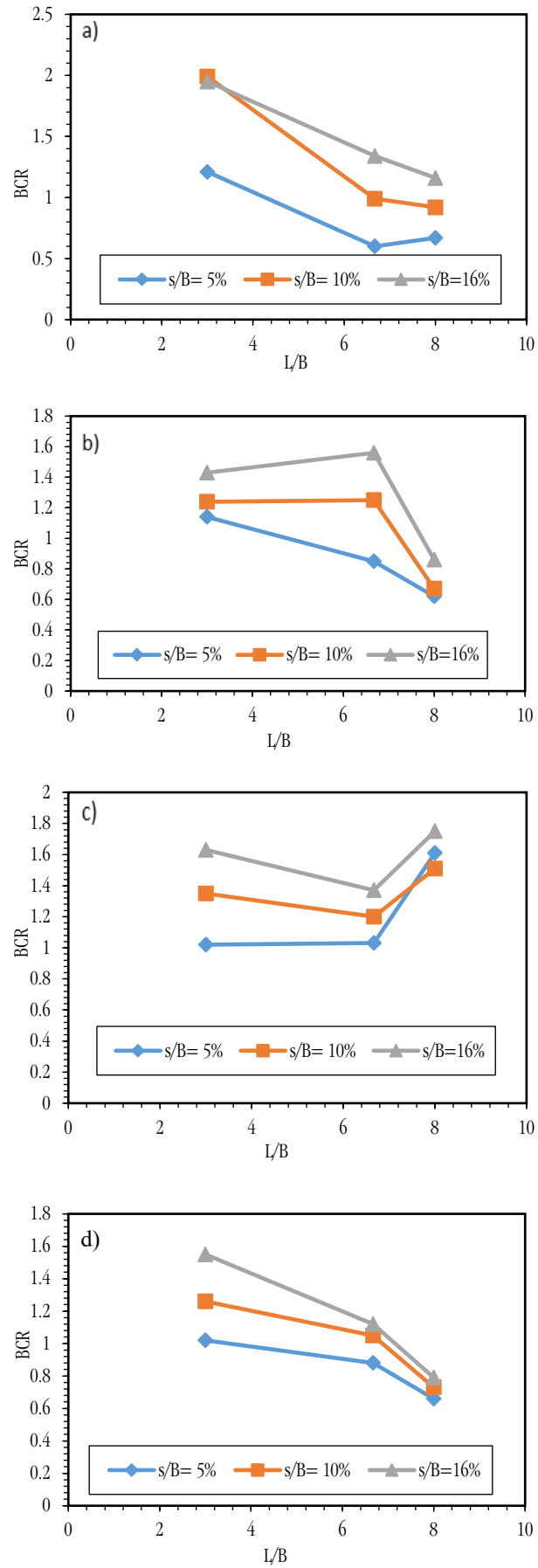


FIGURE 9: BCR Versus L/B for Non-woven at Different Settlement Ratio (s/B): a) $u/B=0.25$, b) $u/B=0.3$, c) $u/B=0.67$, d) $u/B=1$.

maximum stresses in the shear zone will be higher, the vertical and horizontal movement of particles are greater under the footing, so woven mobilized tensile strength will be stronger, the mobilized lateral resistance by passive resistance, interlocking and friction in the stable mass of soil is less than the transferred horizontal shear stresses and the geotextile layer will move down with the soil movement underneath the footing, pull out failure occur. Needed to longer woven, this need decrease as u increase as the stresses in shear zone decrease deeply. The reinforcing mechanism of woven in this case

follow the lateral restraint effect, Fig (10-a), Chen and Abu-Farsakh [31] this effect due to interaction between geotextile and soil that restrict the horizontal displacement of soil, so increasing the lateral confining pressure and compressive strength of soil under footing, therefore, increase in bearing capacity of foundation. For woven, its grid plays a vital role in soil-reinforcement interaction for fine particles, so further enhance the constraint to the soil. We can see by physical observation, Fig 11, damage to the ends of shorter woven geotextile after test due to pulling forces.

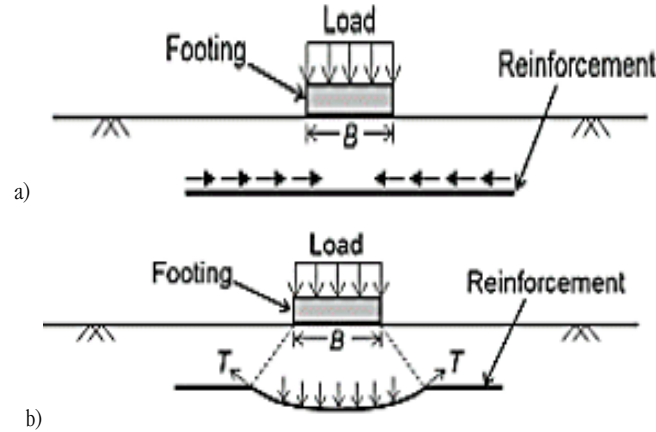


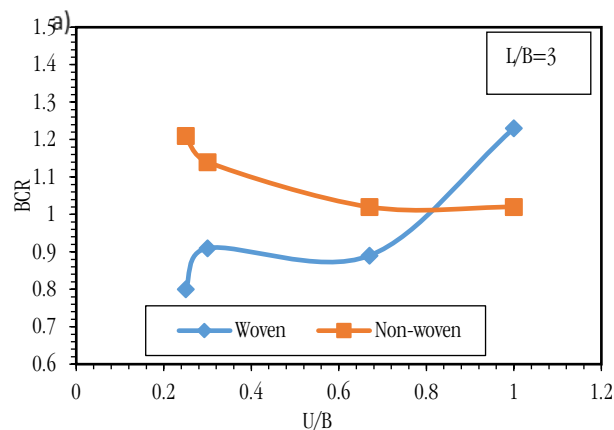
FIGURE 20: Mechanism of Reinforcement: a) Lateral Restraint Effect, b) Tensioned Membrane Effect.



FIGURE 31: Damaged Ends of Shorter Woven Geotextile Compare to Longer One.

On the contrary, Non-woven geotextile have a high elongation up to 100% that resistant pull out test so with small depth, short length serves as longer lengths of woven ones as the interaction between soil and reinforcement mobilized. In higher depth ratios, the need of longer lengths to get maximum BCRs increases. The mechanism of reinforcement in this case follow the tension membrane effect Fig (10-

b) [31], this effect occurs when loads applied, the soil and geotextile move downward due to footing settlement, the bended geotextile will generate upward force to counter the applied footing loads, resulting improve bearing capacity. So, as the stress influence zone the loads spread in steeper angle, needed higher lengths to generate counter upward nonwoven forces.



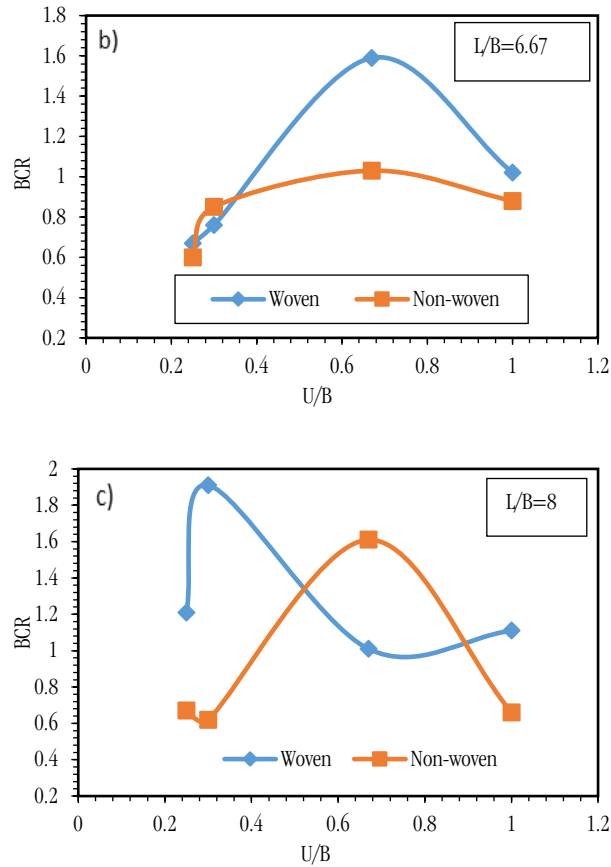


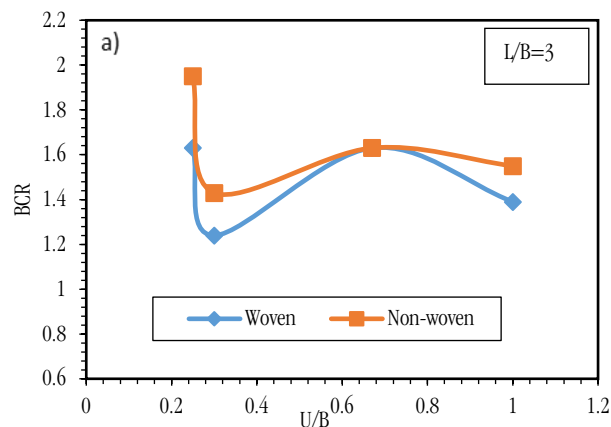
Figure 42: Different Between Woven and Nonwoven at $s/B = 5\%$. a) $L/B=3$, b) $L/B=6.67$, c) $L/B= 8$.

Different in Behavior Between Woven and Nonwoven Geotextile

Fig 12 and Fig 13 depict the differences in reinforcement behavior between woven and non-woven geotextile at two stages of settlement $s/B = 5\%$ and 16% . in the case of $s/B = 5\%$, the applied loading increment at in the beginning, so the tensile strength of geotextile is not induced and the interaction forces is not mobilized in most cases of tests, so for low elongation, we can see for woven geotextile at $L/B=3$ with small depth ratio, the BCR was small and increases as U/B increase, as the overlying load increase that may mobilized the interaction forces. on contrast of woven, non-woven geotextile has a higher elongation so it improves the BCR at shorter length with small depths since it has a high resistant to pull out forces. it reduces the outward shear stresses transmitted from the overlying soil and with own membrane effect, provide a vertical support to the overlying. this

improving decreases as u/B increases due to increase in overlying loading.

In long length $L/B=8$, woven geotextile outperforms on non-woven geotextile. as for large L/B ratio, the pull out resistant improve, and with its higher tensile strength the maximum BCR achieves. We can note in some cases the BCR was less than 1, that is because, at apply loads and before induced the improving forces by geotextile, the soil was separated and act like a soil bed with small depth that weak the foundation until the interaction forces active. In the case of $s/B = 16\%$, the bearing capacity was higher and the tensile geotextile forces and interaction forces were mobilized, so the different in behavior decreases. so we almost see the superiority of woven behavior in soil reinforcement. in all cases of test at $u/B = 1$, the BCRs for woven were higher than non-woven.



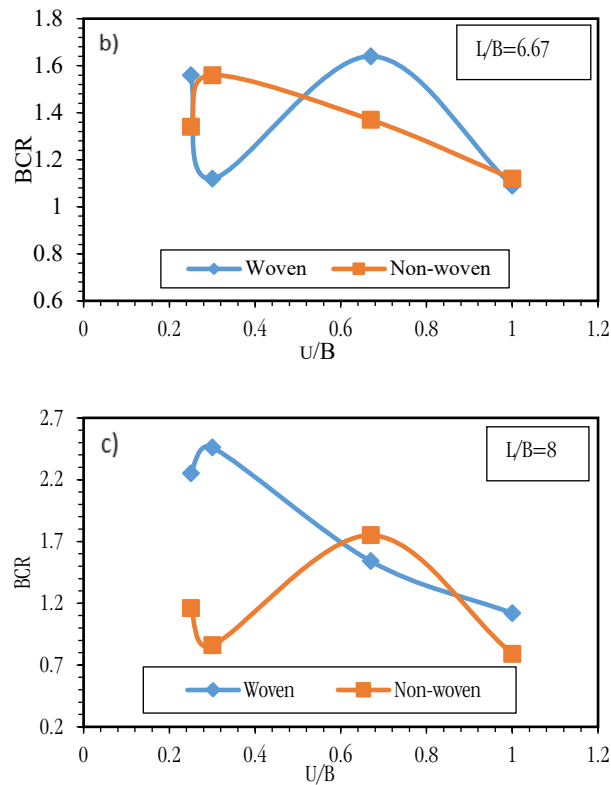


Figure 53: Different between Woven and Nonwoven at $s/B = 16\%$. a) $L/B=3$, b) $L/B=6.67$, c) $L/B=8$.

Conclusion

In the current study, a number of laboratory tests were carried out to ascertain the bearing capacity behavior of square footing placed on clay soil reinforced with geotextile, with varying values of the layer's length and depth, and how the behavior varies with type. It is possible to draw the following conclusion:

1. The application of geotextile at various u/B and L/B ratios increased the bearing capacity of the soil.
2. BCRs increase as u/B increases up to a certain value, after which they decrease. The length and location of the geotextile layer within the soil determined this point.
3. The optimal u/B value for woven and nonwoven geotextiles was 0.25-0.3, resulting in up to 200% increase in bearing capacity.

4. The most effective L/B values for higher BCR values are 8 and 3 for woven and nonwoven geotextile, respectively.

5. The effect of length is contingent upon several factors, such as the soil's stress distribution, the type of reinforcement, the depth of the geotextile, and its resistance to pull-out forces.

6. Because woven geotextiles have a higher strength and lower elongation ratio than nonwoven ones, the resistance to pullout test will be much higher for the latter. In fact, woven materials even had higher BCR values. A viable solution could be to use nonwoven fabric with less reinforcement.

Laboratory observations reveal that nonwoven geotextiles interact significantly with the soil due to their high elongation and nearly rough surface compared to woven geotextiles. Consequently, samples with greater bearing capacity improvements were those whose nonwoven geotextile length extended beyond the stress influence zone.

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