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EVALUATION BEARING CAPACITY OF RING FOOTINGS ON REINFORCED LOOSE SAND

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Ring footing represents a significant structural member in different applications such as fuel or water storage tanks in addition to other structures. The advantage of this type of footing is related to the ability to reduce the weakness of some soils that may affect the safety of structures. An experimental testing program was conducted by using a small-scale model in the laboratory of the college of engineering at the university of Al-Mustansiriyah which consists of twelve ring footing models resting on loose sand reinforced by geogrid layers. The parameters that studied in this research are the diameter of ring footing, thickness of ring, the position placed of one reinforced layer and vertical spacing between two reinforced layers. The findings of this research shown that the optimum percentage of diameter ratio of ring footing is (0.25) and when the depth-ratio increases, the bearing-capacity of ring footing begin decreases. In general, the increase in ring thickness causes the bearing-capacity and the rigidity of ring foundation to increase. The optimum of the depth-ratio of the first reinforced layer is (0.25) and the optimum value of vertical-spacing bounded by layers is around (0.25) which produces a maximum value of the bearing-capacity. Its noticed that when these percentages exceeded value 0.25, the bearing-capacity of the ring foundation drops eventually.

Keywords: experimental setup, ring footing, reinforced layers, loose sand

1 INTRODUCTION

In many cases, the geotechnical engineers face a problematic soil with a weak characteristic such as soft clay and loose sand. To overcome this problem, several geotechnical engineers recommend an improvement technique such as (reinforced soil) to enhance the bearing-capacity of the weak soil. Moreover, the implementing of the ring footing is another option that adopted by some experts in geotechnical field to overcome the soil weakness. Several researchers such as [5, 7, 8, 13, 16, 17] were studied the bearing-capacity of ring foundation constructed in different type of soils. Hataf and Baziar [11] noticed an increase, after using a square foundation in the bearing -capacities of the reinforced soils and then obtained the optimum values of (u/B) and (z/B) where the u and z represent the first-layer depth and the vertical spacing between reinforced-layers, respectively. Jawad [12] studied the influence of the first layer depth and the vertical-spacing bounded by layers for sandy soil that reinforced with geogrid materials on the foundation bearing capacity under the effect of eccentric loading. Boushehrian and Hataf [3] investigated several factors such as the number used of reinforcing layers, the depth to the first reinforced layer, and vertical-distances among layers. Also, the study includes the effect of the reinforcement optimum depth and the stiffness of the reinforcements on the increase of the bearing-capacity percentage.

On the other hand, Jitesh [5] proposed an equation for the maximum bearing capacity that used for the ring foundation and the study approved that the bearing-capacity of the ring foundation depends on the factor of bearing-capacity ($N\gamma$). Chandrawanshi et. al. [4] perform or used small model of footing with and without ring on medium to dense sand. It was found that the capacity increases when the sand soil confining by skirts and this attributed to the confinement which applied by the skirt that prevents the lateral-displacement of the sand soil. El-Sawwaf and Nazir [10] investigated the behavior of small-scale ring footing loaded eccentrically and standing on a reinforced sand. Sharma and Kumar [18] are studied the ring footing behavior depending on a dimensionless factor known reduction-factor (RF.). Badakhshan and Noorzad [9], studied an eccentrically-loaded circular footing, setting on a sand soil reinforced with a geogrid, is performed, the depth influences of the first and second geogrid-layers and the number of reinforcement-layers (1– 4) on the variation of the settlement vs load and the foundation tilting under various load-eccentricities (0.0 cm, 0.750 cm, 1.50 cm, 2.250 cm and 3.0 cm) are studied. The obtained results show that reinforced condition is revealed increase in ultimate bearing-capacity in comparison with the unreinforced state. Moreover, the observed results shown that when placing the reinforcements at the optimum-embedment depth (u/D =0.420 and h/D = 0.420), the bearing-capacity percentage (BCR.) increases with increasing load-eccentricity to the core-boundary of the foundation, and with further increase of load-eccentricity, the BCR. is decreases.

Al-Tirkity and Al-Taay [2] studied the behavior of strip footings on reinforced soil, the results show the optimum-values of (u/B) of the first geogrid-layer vary from (0.350 to 0.450) according to the value of load-eccentricity. Many researchers [3, 14, 15] have shown by testing circular and square foundations with optimum depth of the first reinforcement-layer and the vertical-spacing between reinforcement layers that provide the maximum BCR. vary from (0.20 to 0.50) for (u/D or u/B) and from (0.30 to 0.60) for (h/D or h/B), respectively. Sona and Soumya [19] conducted small scale model of ring footings with size 100 mm outer diameter and inner diameters 20 mm, 40 mm and 60 mm were made of steel was installed on a steel test box size 500 mm x 500 mm x 600 mm. The testing program included unreinforced and geotextile reinforced bed to obtain optimum top layer spacing and optimum number of geotextile layers. Load versus settlement behaviour of rings state that the optimum top layer spacing is 0.3 times the outer diameter of ring and optimum number of reinforcement layer is 3. Dhatrak and Poonam [1], were evaluated the ultimate bearing-capacity of shallow foundation, supported by geogrid-reinforced sand and subjected to a centric-load. Both ultimate load-capacity of a circular and ring foundation standing on surface dense sand bed has been investigated.

In this research, experimental work has been prepared and the parameters that studied are as follows:

1. The effect of percentage($\frac{Din}{Dout}$) for ring footing on the bearing capacity, where D_{out} and D_{in}, is the external and internal diameter of ring footing, respectively.
2. The influence of thickness change of ring foundation (Tr) over the capacity.
3. The influence of changing the position placed one reinforced layer ($\frac{u}{Dout}$) on the bearing -capacity of the ring footing at optimum value of ($\frac{Din}{Dout}$) and thickness of ring footing. In which, ($\frac{u}{Dout}$) is depth of reinforced layer under ring footing as percentage to external diameter of ring.
4. The influence of changing the vertical-spacing bounded by two reinforced layers ($\frac{z}{Dout}$) on the bearing-capacity at the optimum-value of ($\frac{Din}{Dout}$) and the thickness of ring footing. So that, ($\frac{z}{Dout}$) is the vertical-spacing between layers as a percentage to external diameter of ring.

2 EXPERIMENTAL WORK

The model testing setup is shown in Figure 1. The testing methodology are divided into five sections: soil properties, measurement devices, soil container and aluminum footing used, reinforced layer, and testing program which are explained in the next paragraphs.

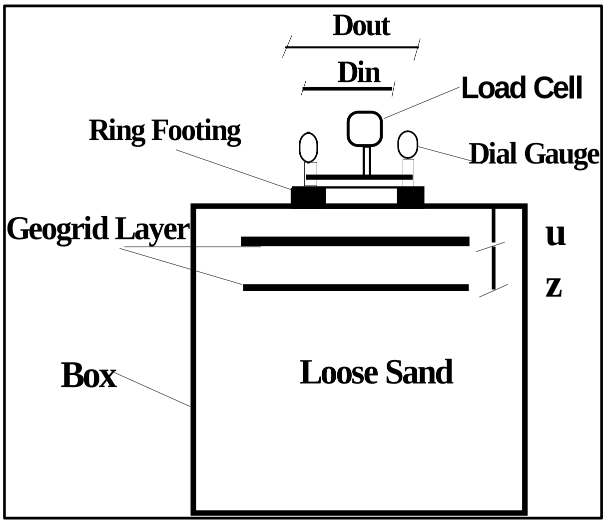

Figure 1: Schematic of model testing setup.

2.1 Soil Properties

The type of soil that used in this research is loose sand. Table 1 illustrates the properties of the soil that placed in the testing model and after completing the preparation of loose sand samples.

2.2 Measurement Devices

The devices that used to measure the testing data are consisting as follow:

a) Load measurement device which is used load cell compression load cell with load capacity 300 kg/500 kg/2 ton/10 tons to 30 ton to measure the applied load.
b) Dial gages were used to measure the vertical settlement that are fixed in the middle and edge of the footing.

Tabel 1. Sand used in model testing.

Item	Property	Value	Standard of the Test
1	Loose state relative density, Dr, %	28	
2	Angle of internal friction in degree , ϕ	21˚	ASTM D 3080
3	Specific gravity	2.67	ASTM D 854
4	Density used, kN/m^3	15.6	
5	USCS- soil type	SP	ASTM D2487

2.3 Soil Container and Aluminum Footing.

The soil container and aluminum footing that used in testing methodology are:

a) Rigid steel tank with dimension of (0.9m x 0.9 m x 0.9m).
b) Nine models of aluminum ring footing.

2.4 Reinforced Layer

The type of reinforcement that used in this research is geogrid to reinforce loose sand. The properties of geogrids is listed in Table 2.

Table 2. Specification of reinforced layer

Reinforcement Type	Property	unit	value
Geogrids	Polymer	---	PVC - Polymer
	Form	---	Sheet layer
	Color	---	black
	Aperture size	mm	25 x 25
	Tensile strength	N	2675

2.5 Testing Program

The detail of the twelve testing models and the change amount in the value of parameters that used in the testing program of current research are listed in Table 2.

3 RESULTS AND DISCUSSION

The effect of the optimum diameter ratio of ring footing $\frac{Din}{Dout}$, as mentioned in the beginning about the testing details, the soil used in this research is prepared by using retaining technique to control the relative density and the density of sand. Figure 2 shows the bearing capacity value versus the change of percentage of diameter ratio $\frac{Din}{Dout}$ at thickness of ring footing equal to (5 mm). The observed of this figure illustrates that the increases in $\frac{Din}{Dout}$ from (0.25, 0.5 to 0.75) led to increase in the bearing capacity from (18, 30 to 40) kPa, respectively. Which means that the increases in $\frac{Din}{Dout}$ is around three times and caused the bearing-capacity of the foundation to increase about two times. Figure 3 reveals the optimum percentage of diameter ratio $\frac{Din}{Dout}$ which produces a maximum value of the bearing-capacity around (0.25) and when the depth ratio beyond the value of 0.25, the bearing-capacity of the ring foundation will begin to decline.

Thickness of Ring Footing at Optimum Diameter Ratio $\frac{Din}{Dout}$, the influence of the thickness change of the ring foundation over the bearing-capacity is shown in Figure 4. It can be seen that increases in the ring thickness from (5, 10 to 15 mm) causes increase in the bearing capacity from (40, 50 to 60 kPa), respectivelly. Morever, it was obseved that increases in the ring thickness led to increase in the rigidity of footing, then increases in the footing capacity.

Tabel 2. Detail of testing program

Model	Dout, mm	Din, mm	R=Dout - Din	Thickness of Ring Tr, mm	$\frac{Din}{Dout}$	U, mm	$\frac{u}{Dout}$	Z, mm	$\frac{z}{Dout}$
1		150	50		0.75				
2		100	100	5	0.5				
3		50	150		0.25				
4									
5				10					
6				15					
7	200					150	0.75		
8						100	0.5		
9		Din*=50	R*=150			50	0.25		
10				Tr*=15	$(\frac{Din}{Dout})$			150	0.75
11					*=0.2	U*=50	u/Dout*	100	0.5
12					5		=0.25	50	0.25

Note: remark * is represented the optimum value which produces the high value of the bearing capacity.

Depth of first reinforced layer (u), Figure 5 illustrates the effect of installation of first reinforced layer in loose sand under the ring foundation on the bearing-capacity. The depth of first reinforced layer which proposed as a percentage from the outside diameter of the ring foundation varies from (0.25, 0.50 and 0.75). The results revealed that the increase in the depth percentage the first reinforced layer causes a drop in the ring footing bearing-capacity. It is well known that using one-layer of reinforcement can cause a rise in the bearing-capacity in comparison to the non-reinforced soils. Furthermore, changing the depth of the layer ($\frac{u}{Dout}$) from (0.25, 0.50 and 0.75) produces a decrease in the bearing capacity from (100, 70 to 60 kPa), that means increases the depth of the first reinforced layer around three times from (0.25 to 0.75) causes the bearing-capacity to decrease about (40%).

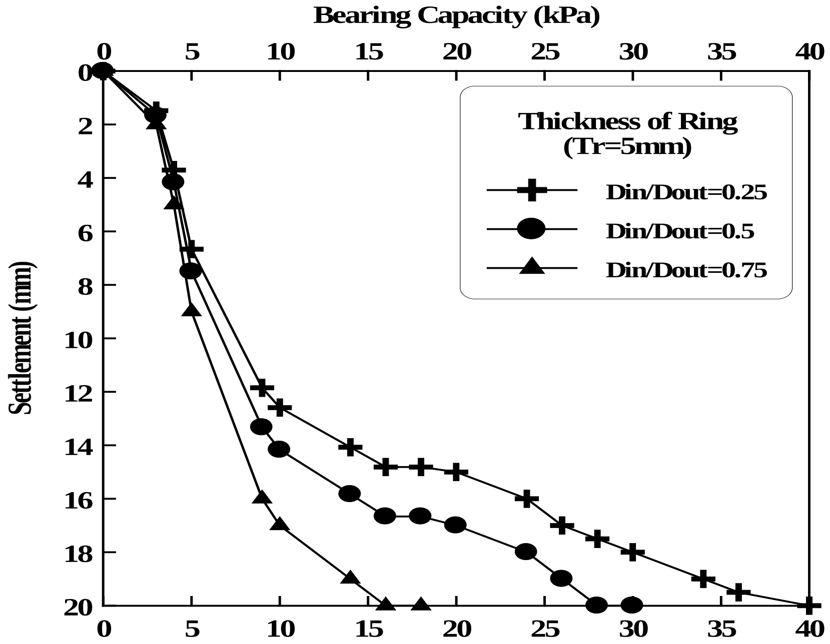

Figure 2: Bearing capacity versus settlement at different diameter ration of ring footing.

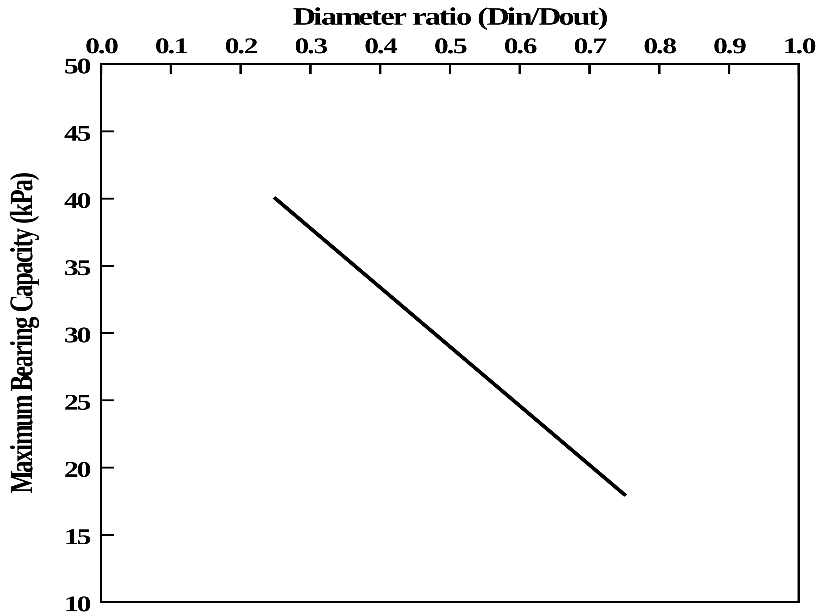

Figure 3. Maximum bearing capacity versus diameter ratio.

Figure 7 shows the value of the optimum depth-ratio of first reinforced layer is (0.250) which produces a maximum value of the bearing capacity for one-layer of geogrid and when the value of ($\frac{u}{Dout}$) beyond the (0.250), the bearing capacity of the ring footing will decrease eventually.

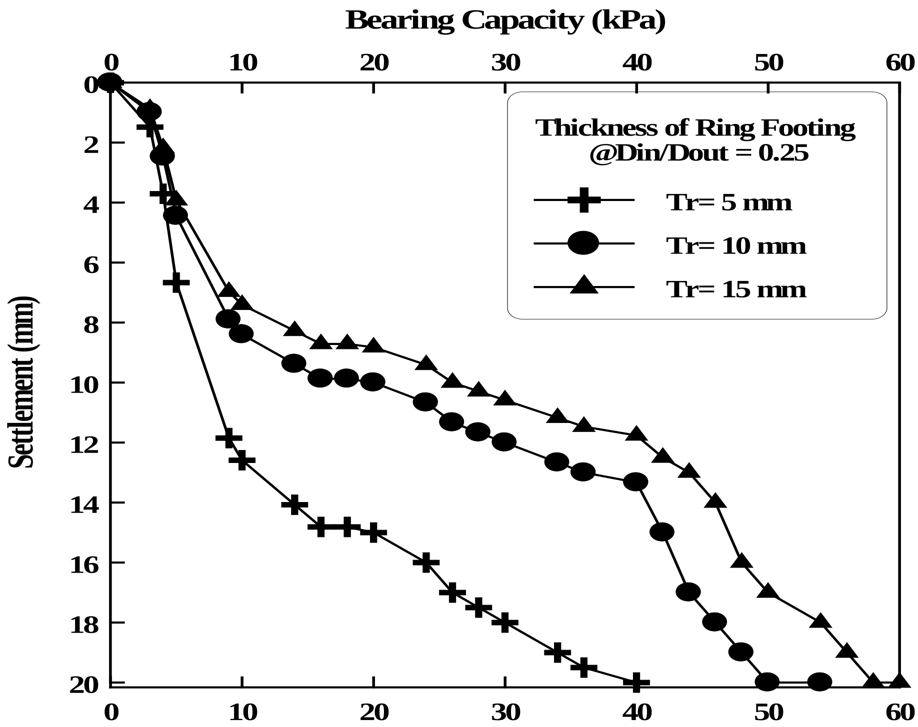

Figure 4. Bearing Capacity versus Settlement at different thickness of ring footing.

Vertical Spacing between Reinforced Layers (z/Dout), changing the value of vertical spacing between two-layer installations under the ring footing as percentage to outside diameter of the ring foundation from (0.25, 0.5 and 0.75) has effect on the bearing capacity of ring footing that changed from (190, 150 to 105), respectively, as shown in Figure 6. This trend reveal that increases ($\frac{z}{Dout}$) about three times can cause a drop in the bearing-capacity of the ring foundation around two times. Figure 7 shows that the optimum vertical-spacing between two-layers is around ($\frac{z}{Dout}$= 0.25) which produces a high value of the bearing capacity and when the value of ($\frac{z}{Dout}$) increases up to o.25, the ring foundation bearing-capacity will begin to decline.

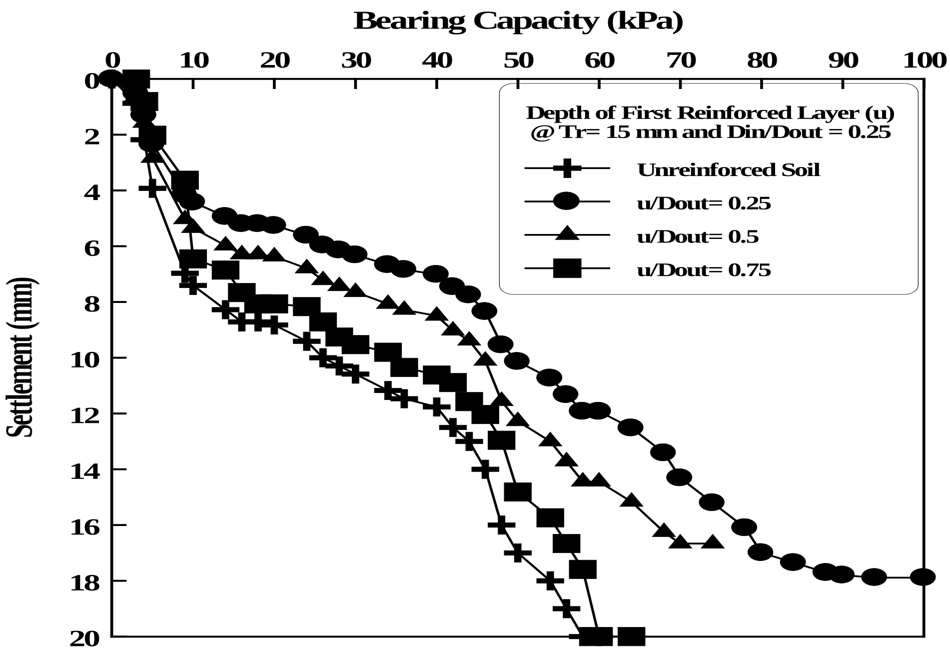

Figure 5. Bearing capacity versus settlement after installation of the first reinforced layer.

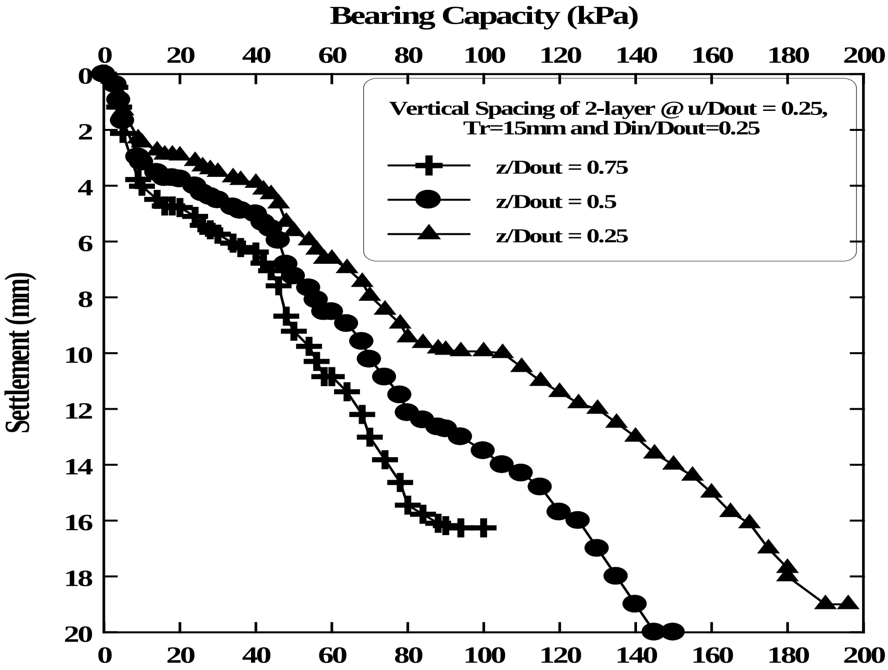

Figure 6. Bearing capacity versus settlement at different value of vertical spacing of two reinforced layers.

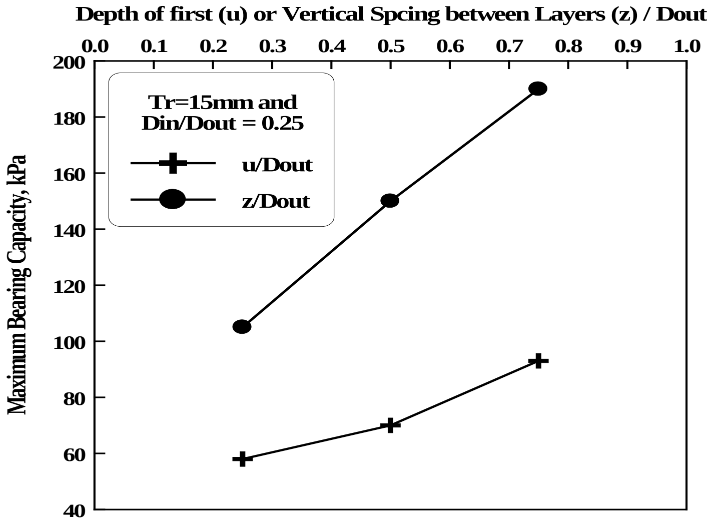

Figure 7. Maximum bearing capacity versus depth or vertical-spacing between geogrid layers.

4 CONCLUSIONS

The current research project consists of testing twelve small-scale ring foundation models resting on loose sand soil-reinforced with geogrid layers. The parameters that investigated in this research are the effect of diameter of ring footing, thickness of ring, the position placed of 1- reinforced layer and vertical spacing between 2- reinforced layer. nine small models of ring footing resting. The findings of this research project that concluded from testing data can summary in the following statements:

- The increases in diameter percentage of the ring footing $\left(\frac{Din}{Dout}\right)$ about 3 times causes an increase in the footing bearing capacity around two times.
- the aims of this study is found that the value of ($\frac{Din}{Dout}$) should not less than 0.25 in design of ring footing to give high bearing capacity.
- The optimum percentage of diameter ratio ($\frac{Din}{Dout}$) which produces the high value of the bearing capacity is found (0.25)
- In general, the increases in the ring thickness led to increases in the rigidity of footing and increases in its capacity.
- The increases in the value of depth-ratio ($\frac{u}{Dout}$) of the first reinforced layer causes decrease in the footing bearing-capacity.
- The research found that the optimum depth-ratio of the first reinforced layer around ($\frac{u}{Dout}$=0.25).

- The optimum vertical-spacing between two layers is found ($\frac{z}{Dout}$= 0.25)
- The increases in ($\frac{z}{Dout}$) beyond 0.25 produces a decrease in the footing bearing capacity.

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