



## **EXPERIMENTAL STUDY OF RELATIVE DENSITY EFFECT ON BEARING CAPACITY OF SAND REINFORCED WITH GEOGRID**

Noor A. Fagher<sup>1</sup> and Mohammed K. Fakhruddin<sup>2</sup>

<sup>1</sup> MSc. Student, Civil Engineering Department, Faculty of Engineering, University of Kufa, Najaf, Iraq. Email: [noora.alnafakh@student.uokufa.edu.iq](mailto:noora.alnafakh@student.uokufa.edu.iq)

<sup>2</sup> Asst. Prof., Ph.D, Civil Engineering Department, Faculty of Engineering, University of Kufa, Najaf, Iraq. Email: [mohammed.fakhruddin@uokufa.edu.iq](mailto:mohammed.fakhruddin@uokufa.edu.iq)

[HTTP://DX.DOI.ORG/10.30572/2018/KJE/120304](http://dx.doi.org/10.30572/2018/KJE/120304)

### **ABSTRACT**

Reinforced soil technology is considered one of the most important methods of soil improvement due to its simplicity and speed in implementation and saving cost. In this research a strip footing and geogrid (Tensar SS2) were used to reinforced sandy soil and investigated the effect of relative density on bearing pressure and compressibility. The soil was strengthened with four layers of (geogrid Tensar SS2) and used a five relative densities were (30.7%, 49.7%, 56.5%, 64%, and 75.9%) to include cases of loose, medium and dense sand. The results also showed the effect of relative density on the bearing capacity and the settlement as experimental tests indicated that increasing the relative density from 30.9% to 64% gave an improvement in soil bearing capacity, as well as an effective improvement in carrying capacity when increasing the relative density from 64%. The results showed that the bearing capacity when using relative densities of 49.7%, 56.5%, 64%, 75.9% increased by 1.218, 1.287, 1.512, and 2.1799, respectively, of the bearing capacity of reinforced soils with relative density of 30.7%. As for the effect of relative density on the settlement, it was found that the settlement is generally less in the case of soil with higher relative density.

**KEYWORDS:** Geogrid, Relative density, Strip footing, Sandy soil.

## 1. INTRODUCTION

The soil reinforcement gets a long tradition in the previous literature. Earlier mention of reinforcement of soil belong to the Sumerians under King Kurigalzu I, who elevated the Aqar-Quf temple in Mesopotamia at the north of Bagdad city dated back to 3500 years ago. The Sumerians were aware regarding the importance of both soil and brickwork that they had almost no strength in tension and reinforcing elements into their constructions were necessary to enhance the tensile forces for stabilization (Ziegler, M. 2017). The footing standing on weak soil, has decrease bearing capacity shows increase settlement below small loads. One of the important missions of geotechnical engineers is the upgrading in strength features or variables of soil. To accomplish this task, the investigators assessed techniques of ground-upgrading to elevate the bearing capacity of soil (Patil and Rakaraddi, 2015). "The appropriate definition of soil reinforcement is "a construction material consisted of cohesionless free drainage materials, which is strong in compression but weak in tension, and the reinforcing elements, with high tensile strength materialsn (Singhvi, Arora and Veerwal 2017).

## 2. MATERIAL

### 2.1. Sand

The Table 1 summarized the all properties of sand which are used in this studies. While Fig. 1. depicted the grain size distribution of sand and classified as poorly graded (SP) in accordance to the Unified Soil Classification System (USCS).

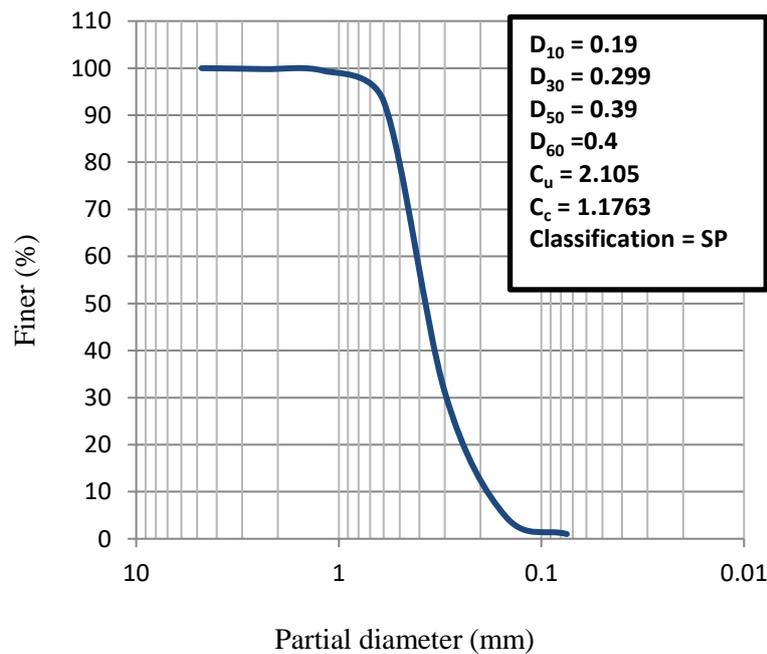


Fig. 1. Grain size distribution curve of the sand.

**Table 1. Physical and Chemical Properties of the sand used.**

Soil property	Results					Specification
Effective size, D10	190 (mic)					ASTM D 422
D30	299 (mic)					
D50	390 (mic)					
D60	400 (mic)					
Coefficient of uniformity ( $C_u$ )	2.105					
Coefficient of curvature ( $C_c$ )	1.176					ASTM D 854
Specific gravity ( $G_s$ )	2.61					
Max. dry unit weight ( $\gamma_{dmax}$ )	17.658 KN/m <sup>3</sup>					
Min. dry unit weight ( $\gamma_{dmin}$ )	14.59 KN/m <sup>3</sup>					
Max. void Ratio, ( $e_{max}$ )	0.754					
Min. Void Ratio, ( $e_{min}$ )	0.45					-
Water content, %	6.56					ASTM D 2216
Relative density ( $D_r$ ) %	30.7	49.3	56.5	64	75.9	
friction Angle ( $\phi$ used)	27.89	31.8°	33°	35°	43°	SATM D 3080
Dry unit weight used, (KN/m <sup>3</sup> )	15.4	15.9	16.2	16.4	16.8	-
Void Ratio, e	0.66	0.603	0.58	0.55	0.523	-
Organic material	1.4					BS.1377(1967)
Gypsum content, %	2.7					
T.D.S., (mg/L)	1150					

## 2.2. Geogrid

Table 2 summarized the properties of the Tensar SS2 used in this study, (Al-Omari and Fekheraldin, 2012).

**Table 2. The properties of geogrid Tensar SS2 (Al-Omari and Fekheraldin, 2012).**

Characteristics	loneliness	Results
Grid type/color	-	Rectangle/black
Aperture size (MD/XMD)	mm	28/40
Mass /unit area	kg/m <sup>2</sup>	0.3
Thickness of Rib	mm	1.2/1.1
Thickness of Junction	mm	3.9
ultimate tensile resistance	kN/m	14.4/28.2
modulus of Elasticity	N/mm <sup>2</sup>	570/990
Tensile strength	N/mm <sup>2</sup>	24/30.7
Percentage elongation at max load	percent	3.5/2.9

### 3. LOADING FRAME

The Fig. 2 illustrated the all details of model of container and strip footing and loading frame.

Strip model footing has been produced from a thick plate with dimensions (490\*135\*40 mm), for length, wide and high respectively, while the thickness (10) mm to represented rigid steel plate. The sand container had been made by (Fakhraldin, 2013) to contain the soil, with dimensions (1000\*500\*700 mm) in length, width and depth respectively.

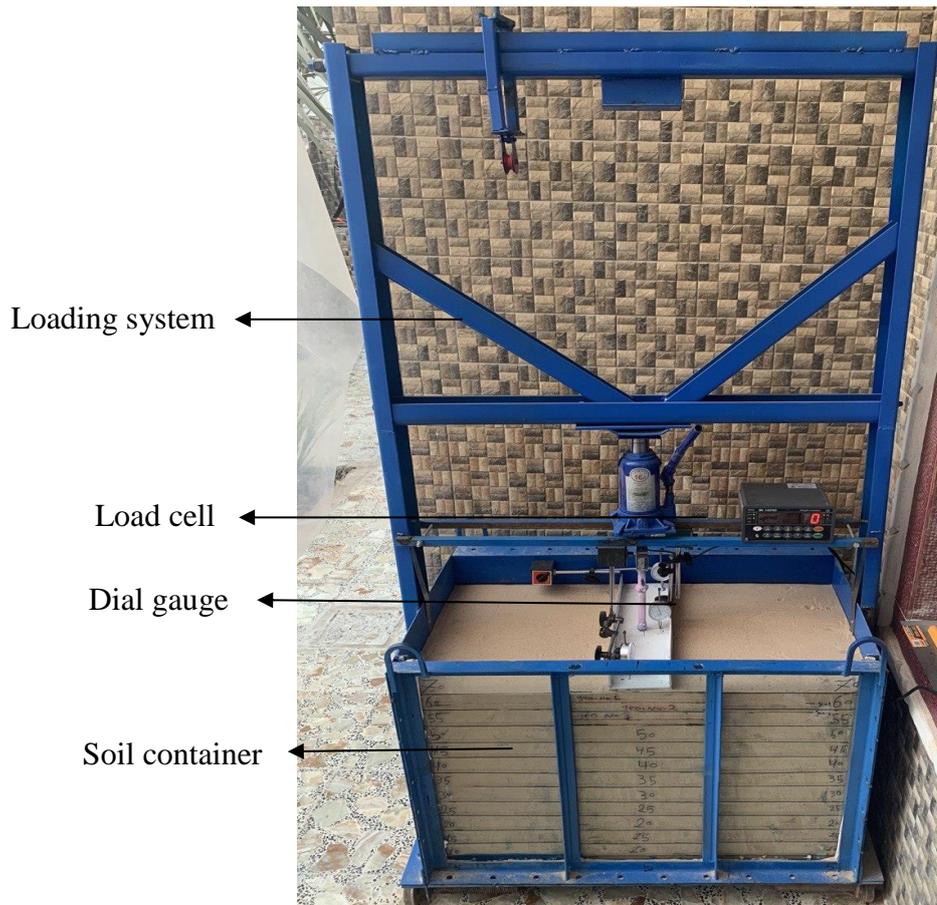
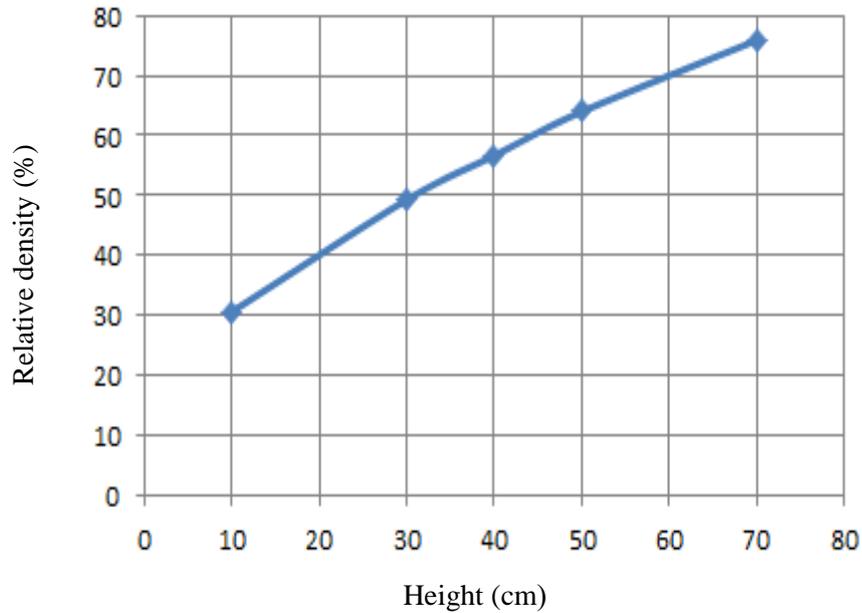


Fig. 2. Loading frame and model.

### 4. SAND PREPARATION

To achieve and represented the all soil state including soft, medium and stiff of sand in container which required device to raining the sand, (Turner and Kulhawy, 1987). Fig. 3 depicted the relative density of 30.7%, 49.35%, 56.5%, 64%, 75.9% will be 10cm, 30cm, 40cm, 50cm, and 70cm respectively. The relative density was choosing at 30.7%, 49.35%, 56.5%, 64%, and 75.9% to covered loose, medium, and dense sand.



**Fig. 3. Relative density controlled.**

## 5. GEOGRID PREPARATION

The distribution geogrid layers in the model are depicted in [Fig. 4](#)

The values of ( $u$ ) equal to ( $B/4$ ) and the distance between reinforcement layers ( $h$ ) considered  $0.1875 B$ , [Fakhruldin \(2013\)](#), while the depth of last reinforced layer was conducted according to the following equation

$$d = u + (N - 1) * h$$

Where

N: layer numbers

In this study used  $u$  equal to  $B/4$ ;  $h = 0.1875B$ ; and (N) equal to 4.

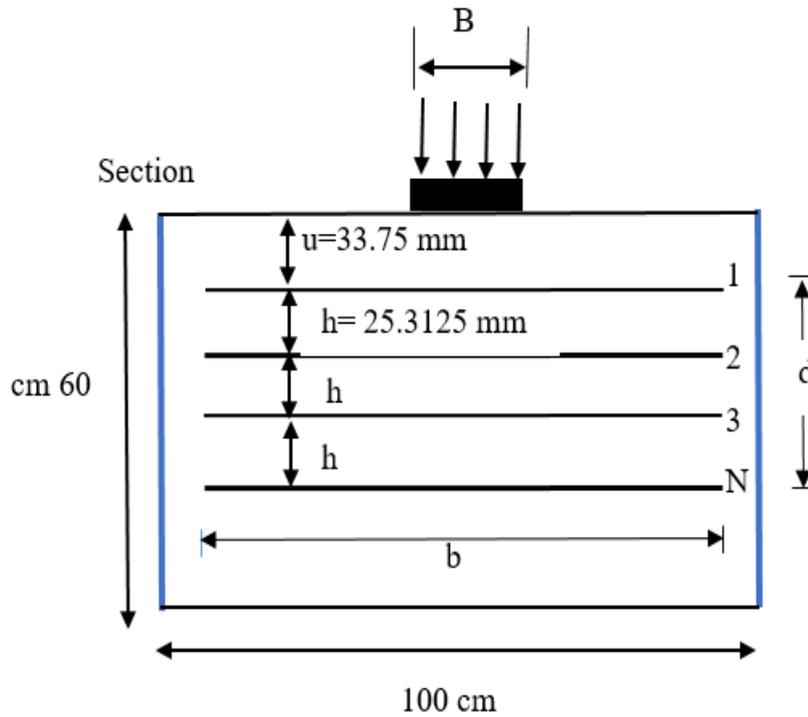


Fig. 4 Distribution of geogrid in the model.

## 6. WORKING STEPS

The steps of this work program were summarized in the following:

Step one: It includes the chemical and physical characteristics of the soil

1. Physical characteristics include: Sieve analysis, minimum and Maximum density, internal friction ( $\phi$ ), Specific gravity, and Water content.
2. Chemical characteristics: the content of Gypsum, (T.D.S), and  $SO_3$  content.

Step two: It include testing the reinforced soil under strip footing. the parametric studies include; five relative densities (30.7%, 49.35%, 56.5%, 64%, and 75.9%), ( $D_f=0$ ),  $u = 0.25B$ ,  $h = 0.1875B$  and  $N=4$ .

## 7. RESULTS AND DISCUSSIONS

The first layer of the reinforcement had been with a depth ( $u$ ), which was being of about  $0.25B$ , the depth of second layers ( $h$ ) was  $0.1875B$  from the first layer, the depth of third layers ( $h$ ) was  $0.1875B$  from the second layer, and the depth of fourth layers was  $0.1875B$  from the third layer, the  $B$  is the footing width. The tests were conducted on the heights of dropping equals to (10, 30, 40, 50, and 70) cm the relative density were 30.7%, 49.35%, 56.5%, 64%, and 75.9%. The bearing pressure and load-settlement relation had been presented in Fig. 5. Similarly, the

ultimate bearing capacity which had been gated from the model tests and the compressibility had been summarized in Table 3. The marked of the point of ultimate bearing capacity on the curve of the load settlement had been performed with easily, where the test was strain-controlled, beside to the clear vision of the peak.

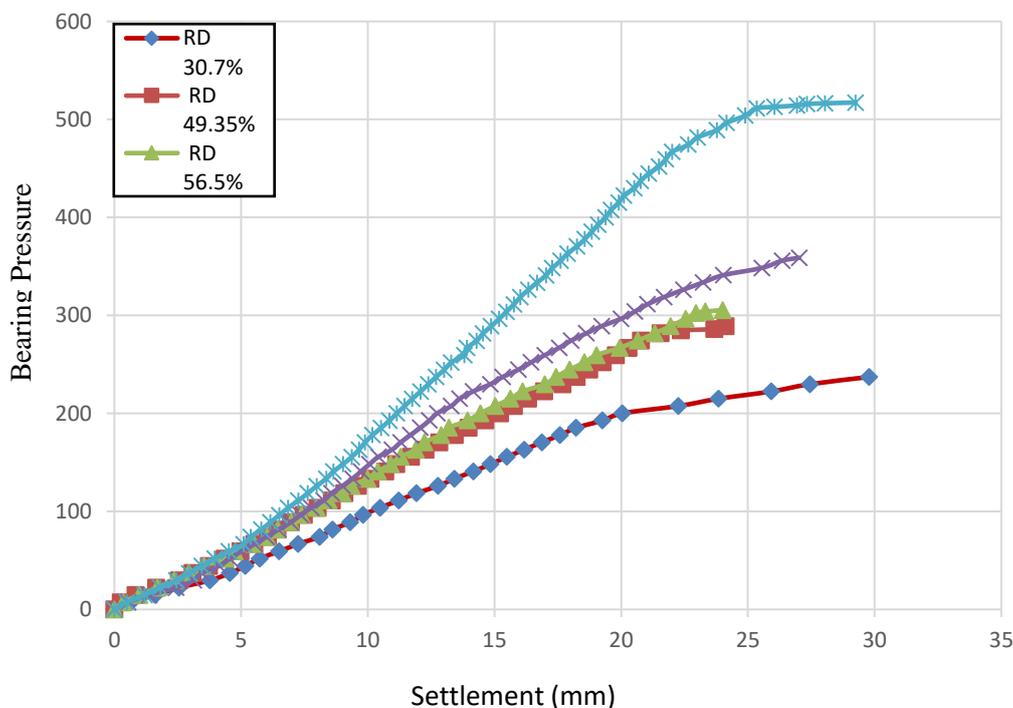


Fig. 5. Bearing pressure versus settlement for fourth layers of geogrid Tensar SS2.

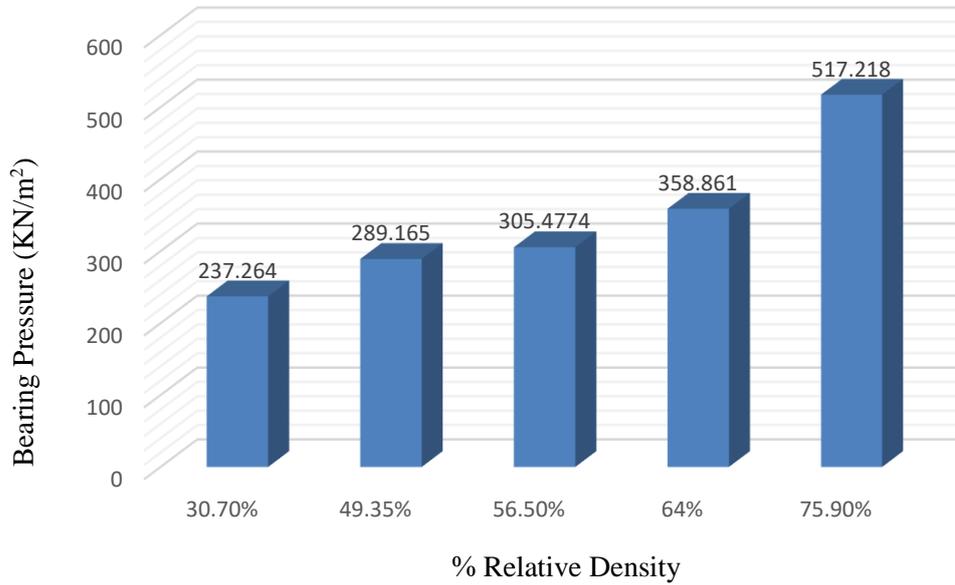
Table 3. Ultimate bearing pressure and compressibility for fourth layers of geogrid.

Test No.	R.D %	(qult)R KPa	Max. settlement(mm)	Improvement in B.C (%)	Decrease in settlement (%)
1	30.7	237.26	29.78	-	-
2	49.35	289.16	24.12	1.2187	1.6326
3	56.5	305.47	24.01	1.287	1.709
4	64	358.86	27.02	1.512	1.943
5	75.9	517.218	29.25	2.1799	2.346

### 7.1. Effective of Relative Density on the Bearing Pressure

The tests that have been carried out in reinforced sand by 4 layers of Tensar SS2 giving rise to the following findings that have been illustrated in Fig 6, findings have been illustrated for relative densities of 30.7%, 49.35%, 56.5%, 64%, and 75.9%. In synchronize with previous literature, it can be showed that increasing the relative density from 30.9% to 64% will lead to

a bigger load capacity at every settlement level. On the other hand, increasing from 64% to 75.9% will lead to an even more striking increment.



**Fig. 6. Effective of relative density on the bearing pressure for four layers of geogrid Tenasr SS2.**

**7.2. Effective of Relative Density on the Settlement**

In Fig. 7 the settlement is reducing when the soil density is increasing. This result, can be attributed to the end anchorage increment from the soil which withstands the downward deflection of the geogrid Tenasr SS2 rank, which caused of incremental effective of the enhancement.

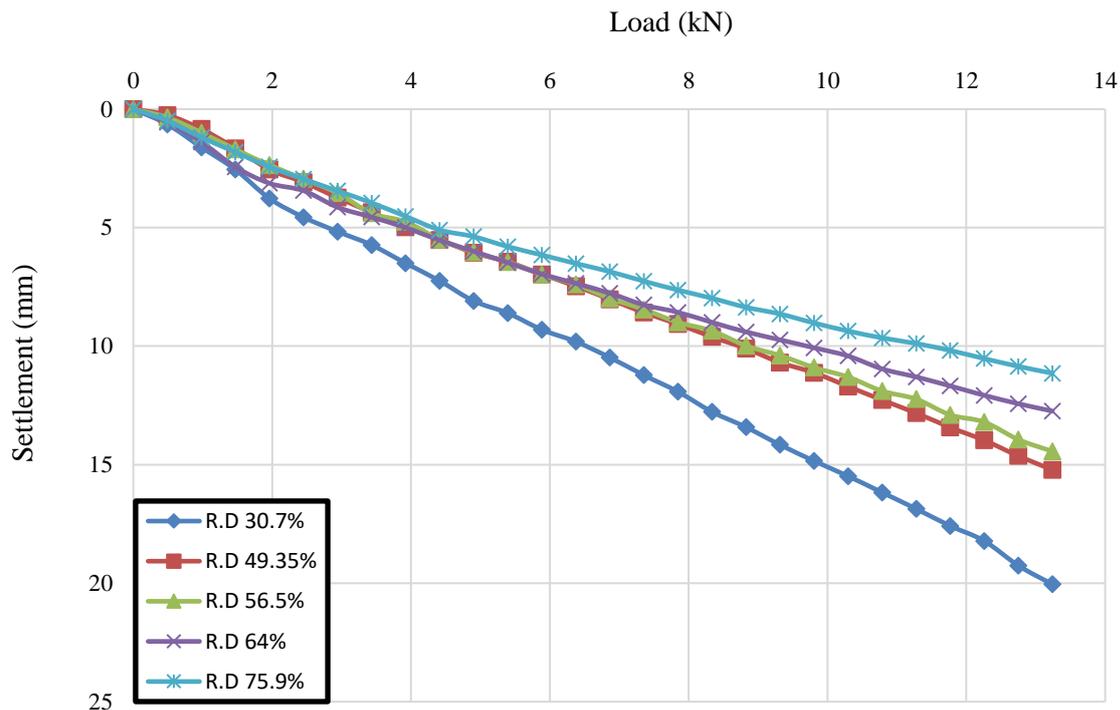


Fig. 7. Load versus settlement for fourth layers of geogrid Tensar SS2.

## 8. CONCLUSION

The following conclusions can be drawn from this study

1. It can be concluded that the increment of the relative density from 30.9% to 64% led to a higher load capacity at each level of settlement, while the increment from 64% to 75.9% caused of an extra dramatic increment. Also, for the effective of relative density on the settlement, it can be concluded that the settlement is generally found to be lower for higher density of soil.
2. The bearing capacity of sand increased about 237.26, 289.16, 305.47, 358.86 and 517.218 kPa after strengthen sand by four layers of geogrid Tensar SS2 with relative densities were 30.7%, 49.35%, 56.5%, 64%, and 75.9% respectively. It is showed that the bearing pressure of sand was increased after increased the relative density about 1.218, 1.287, 1.512, and 2.1799 the reinforced sand's bearing capacity by relative density 30.7%.

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