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Sandy soil improvement by using sustainable material

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ABSTRACT

Sandy soils cover large spaces in Iraq, and it is dry and weak. Building on these soils is risky since they are unstable, and the soil may collapse after loads are placed on it. To build on these soils, the soil must be improved and strengthened or reinforced. One of the most common soil improvement methods is the use of additives, but the use of chemical additives such as oil derivatives, plastics, and others are considered to be harmful to the environment. This research aims to enhance the engineering properties of sandy soils in Karbala, Iraq, such as shear strength and bearing capacity. by using jute fibers, which are environmentally friendly and recycled materials derived from plant fiber remnants, and it is also considered to be low-cost additives. Laboratory tests on reinforced and unreinforced soil were conducted. The variables examined in this study are the dimensions and thickness of footing, the dimension of jute fiber sheet, the depth of first layer of jute sheet and vertical spacing between reinforced layers. The results demonstrated that adding jute fibers to the soil improved its engineering properties significantly. The study also showed the possibility of using environmentally friendly materials such as jute fibers to improve and strengthen sandy soils in Iraq, particularly at shallow depths, as well as how plant fibers can be reused for engineering purposes.

Keywords: soil improvement, jute sheet, sandy soil.

1. *Introduction*

Sand may be regarded as weak, and it is classified as cohesion-less soil or frictional due to the lack of adhesion between soil particles. these soils have low shear resistance, low bearing capacity, no moisture retention, and no plasticity, with negligible or non-existent shear strain between their particles.[1] [2] sandy soils are common in Iraq, engineers frequently face sandy soils as a result of urban expansion and development in the country, especially in the southern and western parts of the country, one of the issues that geotechnical engineers frequently face is soils' failure to resist loading; as a result, It is required to improve the soil because it is frequently in a loose state and might not be able to support the proposed infrastructure. It's required to look for alternatives for improving engineering properties, particularly shearing strength and bearing capacity [3]. In general, soil improvement is a process that is carried out to improve the geotechnical qualities (and engineering response) of soil at a site [4] Stabilization techniques, particularly chemical and mechanical techniques, are related to major environmental concerns such as climate change due to enormous carbon-dioxide emissions, high expenses, pollution of the environment (air, land, and water), loss of nonrenewable resources, and the increasing prevalence of heavy and toxic substances concerning the geo-environmental [5]. since the demand for environmentally friendly solutions is increasing, Different types of reinforcement fibers are employed to improve the characteristics of soil as a recycled and eco-friendly material. The use of natural fibers as reinforced material considers to be successful method for improving soil and ground in a sustainable way. [6] [7] [8] Jute fiber is preferred due to its increased tensile strength, resistance to rotting and heat, and porous texture, which improves its drainage and filtering abilities. Jute is additionally inexpensive, readily available regionally, eco-friendly, and recyclable [9]

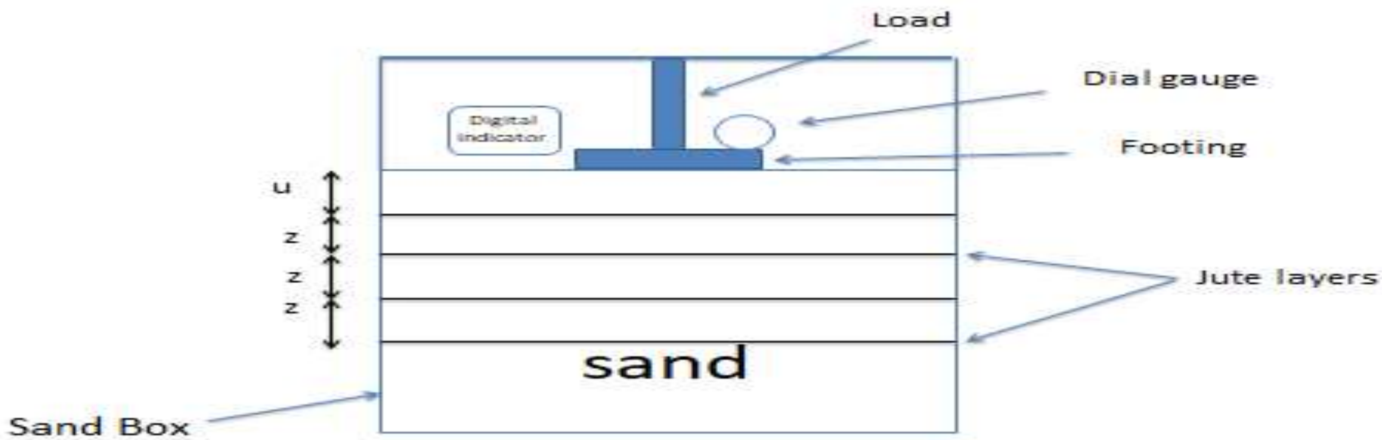
Lal, studied the possibility of using jute fiber as sheets to reinforce expansive soil. the result showed that using two layers of jute fiber sheet is more effective than using three layers of fiber sheet since the cohesion was 153.52 Kpa with two layers and 54.96 Kpa with three layers. Other researchers [10]–[13] have studied the ability of using jute fiber as a reinforced material to improve soil properties. by cutting the fiber into pieces with different lengths and mixing it with the soil, the percentages of jute add vary from (0.25 to 50) % and with length varying from (30mm to 90mm). Singla, 2020, investigated the optimum cement-jute mixture and the effect of this mixture on strengthening the mountainous clay soil subgrade. The pycnometer test, Casagrande's test, plastic limit test, stander, and modified proctor tests were performed. The jute fiber used was 6 mm in diameter and added in different percentages (0.4,0.7,1,2,4) % and for the cement, the percentages were 1,3,5 and 7% of the sample weight. [14]The result showed that the optimum jute cement mixture value was 5% for cement and 0.4% for jute. For CBR it was found that the cement-jute mixture increased CBR by 0.88 times, however, the addition of cement has been approved to reduce MDD.

Therefore, recycling these wastes and using it again will reduce environmental pollution. The study attempts to improve Iraq's sandy soils using eco-friendly and recyclable additives.

The variables that were studied in this experimental study are as follows:

1- The influence of footing width on the bearing capacity, where B is the width of the steel footing.

2- The influence of thickness change of footing (T) over the capacity.



Properties	value
Specific gravity, *Gs*	2.67
Void ratio	$e_{max} = 0.83$, $e_{min} = 0.57, e_{used} = 0.73$
Dry unit weight	$\gamma_{max} = 17.97, \gamma_{min} = 15.41$, $\gamma_{used} = 15.4$
Relative density	Dr= 31%
The angle of internal friction	$\emptyset = 28$

3- The influence of changing the depth of first layer. In which (u/B) is the depth of reinforced layer under the footing as percentage to footing width.

4- The influence of vertical-spacing between two reinforced layers (z/B) on the bearing-capacity of sand when the footing (B) is at the optimum-value and optimum thickness (T). Therefore, The vertical spacing between layers is (z/B).

5- Layering effect (N), by using from 1 to 4 layers of jute sheets.

2. *Laboratory Work*

Figure 1 illustrates the model testing configuration. The following paragraphs will explain each of the five sections of the testing method: soil parameters, measuring devices, soil containers and steel footings used, reinforced layer, and testing program.

Figure 1: model testing configuration.

2.1 *Soil Properties*

In this study, sandy soil from southern region of Iraq was used. The parameters of the soil used in the study are shown in Table 1 according to the laboratory testing.

2.2 *Measurement Devices*

The instruments used to collect testing data described below:

a- A digital indictor SI460 with capacity of

15 ton (147 KN) used in order to measure the applied axial load on footing.

b- Dial gages were used to measure the vertical settlement that are fixed in the middle and edge of the footing.

Table 1: soil properties

2.3 Soil box and steel Footing.

The soil box and steel footing used in the testing program ars.

2.4 Reinforced **Material.**

Jute fiber sheet was used in this research as a reinforcement material, the fibers were obtained from a local shop in Baghdad, the properties of jute fiber are listed in Table 2.

Table 2: Reinforced material properties.

Physical and chemical property	value
Color	Yellow brown
Moister regain	12 - 14%
Cellulose	55 – 63%
Heating action	Not degrade
Oxidizing agents	Not affected
Conductivity	Very good
Tensile strength	300-700 Mp

2-5 ***Testing*** **Program.**

The sequence and details of the seven tests paradigms and the amount of change in the value of the variables used in the research tests are listed in table 3.

Table 3: Testing program.

Model	B (mm)	Footing Thickness	Br/b	Depth Ratio u/B	Vertical spacing ratio z/B	Number of Layers
1	80 100 120 140	(mm) 5				
2	*140	5 10 15				
3	*140	*15	1.2	0.25 0.5 0.1		1
4	*140	*15	1.2 1.5 2	*0.5		1
5	*140	*15	*2	*0.5		1
6	*140	*15	*2	*0.5	0.25 0.5 0.75 0.1	2
7	*140	*15	*2	*0.5	*0.5	1 2 3

						4
8	*140	*15	*2	*0.5	*0.5	*4

3. *Results* and *Discussion*

***The effect of footing width*:** Soil was added to the sandbox by raining technique to achieve the desired density, figure 2 shows the effect of using footing with different dimensions and a thickness of 5 mm on the bearing capacity of the soil and its settlement. From the figure it can be noticed that the increases in footing width from (80, 100, 120, to 140) mm, led to decrease in settlement and increases in the Bearing capacity from 10 Kpa to 18 Kpa. It can be seen that footing with width of B=140mm can carry more load.

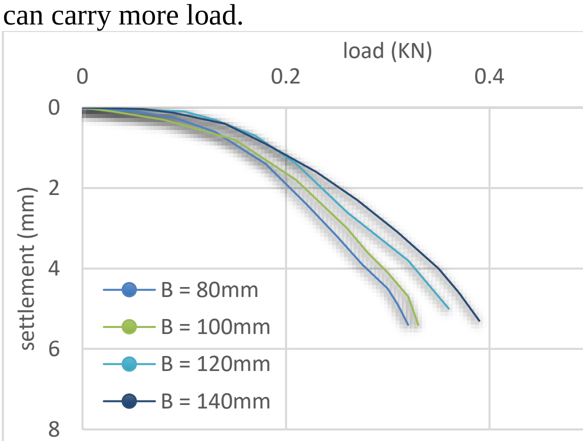


Figure 3: load-settlement curves with different footing widths.

***The effect* of footing thickness:** the effect of the thickness change of the footing over the load-settlement shown in **Figure 4,** It is noticeable that increasing the thickness from (5, 10 to 15 mm) causes the Bearing capacity to improve from (22 to 24.5 kPa), it was obseved that increases in the footing thickness led to increase in the performance of footing.

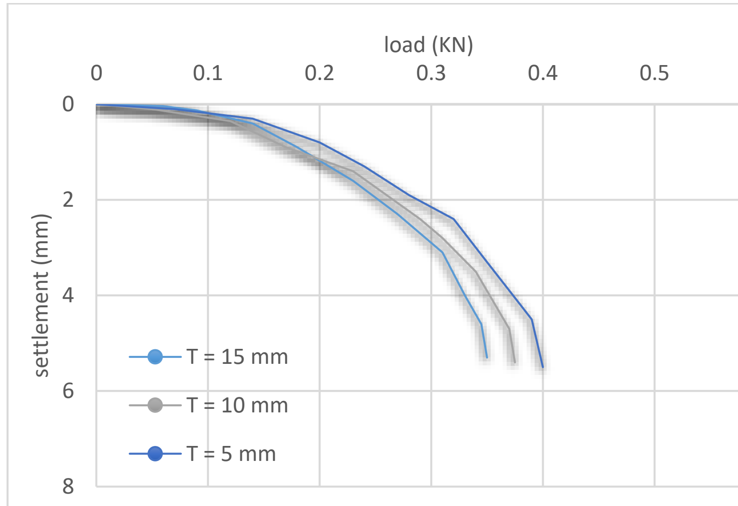


Figure 4: load-settlement curves with different footing thickness.

Depth of the first reinforced layer (u), Figure 5 shows the effect of placement the first reinforced layer of jute fiber in sand soil under the footing on the bearing-capacity. The depth of first jute layer which suggested a percentage based on the footing's width, varies from (u/B= unreinforced, 0.25, 0.5, and 1.0). The results illustrated that for a depth ratio equals 1 (u = B), the Load and settlement are equal to unreinforced state. Increasing the depth ratio above 1 does not lead to a change in the properties of the sand above the reinforced layer. The change in depth ratio (u/B) from unreinforced state to (u/B= 0.25, 0.5) causes reduction in settlement and increasing in load carrying. The optimum reduction in settlement and increasing in load carrying when the depth ratio u/B = 0.5.

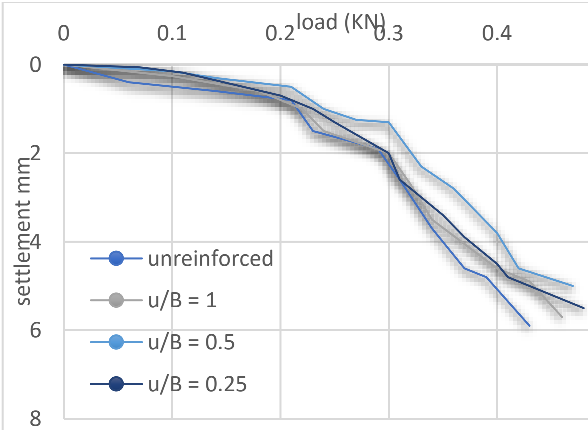


Figure 5: load- settlement curves with different depth percentage for one layer of reinforced jute.

It can be seen that the general behavior of the settlement reduction percentage decreases with increase in load. Figure 6 shows the effect of using jute sheets with different widths. The results confirm that increasing the reinforcement area under footing increases the soil's carrying capacity, therefore decreasing soil settlement.

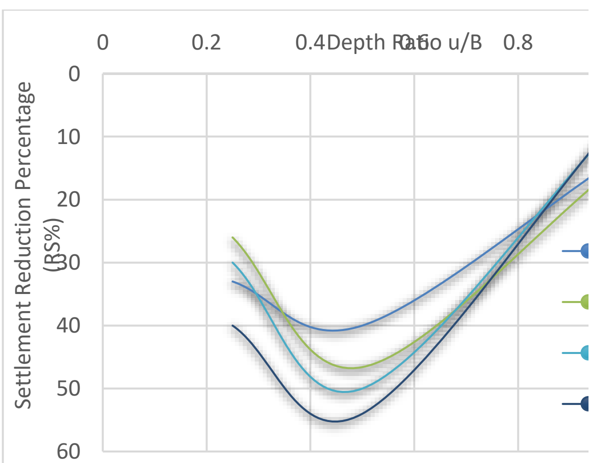


Figure 6: Settlement Reduction Percentage Versus Depth Ratio at Load =0.1kN.

Effect of Vertical Spacing Between Reinforced Layers: The effect of vertical spacing ratio between reinforced layers (z/B) where (z= vertical spacing between jute layers and B= footing width), on the load carrying of footing was investigated as shown in Figure 7, result indicate that the load carrying decreases and settlement increases with increasing vertical spacing values. The maximum load carrying is at z/B=0.5, for width ratio values of Br/B = 2.

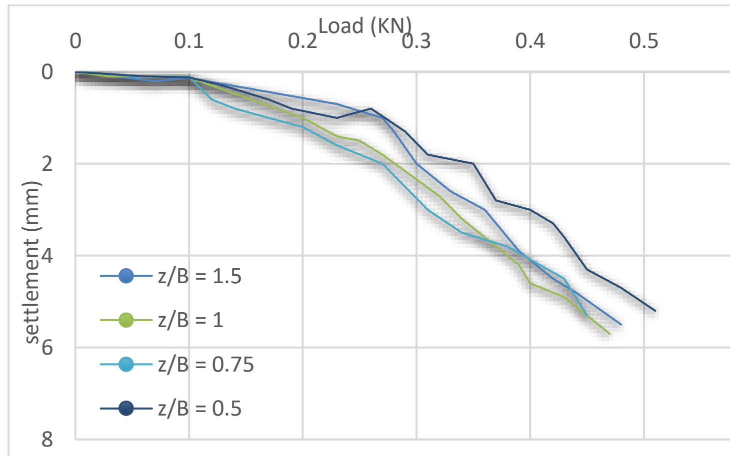


Figure 7: load-settlement curve for different space ratio.

Effect of using more than two layers of reinforcement material: The bearing value changes more drastically with the number of the reinforcement layer (N) than other parameters. It can be noticed on figure 8 that using more than two layers of jute fiber sheet increases soil strength, The bearing capacity increased with the increasing the number of reinforcement layers from (23 for unreinforced soil to 44 reinforced soils with four layers of jute) Kpa, due to the soil become more rigidly of soil with increasing number of layers.

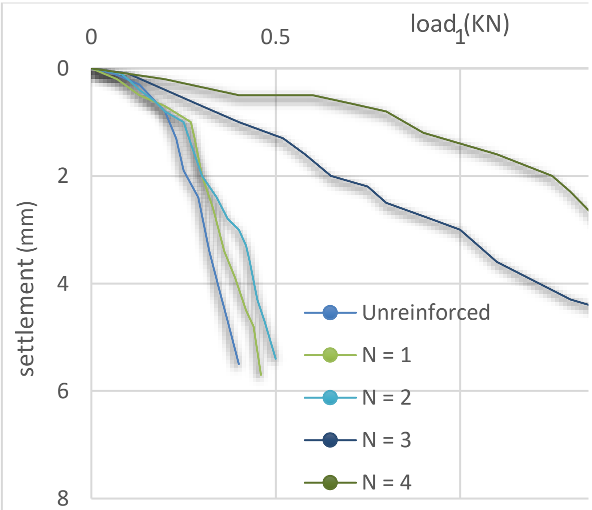


Figure 8: load-settlement curve with more than one layer.

4. *Conclusion*

The current study consists of testing performance of jute fiber sheet in sand reinforcement. The parameters that investigated in this research are the effect of footing width, thickness of footing, the position of first jute sheet layer and vertical spacing between jute layers. six models of footing were tested. The following finds provide an overview of the study project's conclusions based on test results.:

- The increases in footing width (B) causes an increase in footing bearing capacity.
- The increases in the footing thickness led to increase in the performance of footing and increases in the footing capacity.
- The optimum percentage of (u/B) the depth of first layer of jute sheet to footing width found to be u/B= 0.5.
- Increasing u/B over the optimum value doesn't lead to an increment in the bearing capacity of sand.
- The results demonstrated that increasing the reinforcement area beneath the footing improves the soil bearing capacity, which decreases soil settlement.
- Increasing vertical spacing (z/B) values led to reduction in soil bearing capacity.
- The optimum vertical spacing between jute sheets layers z/B= 0.5.
- The use of more than one layer of jute fibers led to an increase in the bearing capacity of soil.
- The use of 4 layers of jute fibers leads to a significant increase in the bearing capacity of the soil, as it doubled the bearing capacity of the soil
- However, the use of more than 4 layers of jute fibers does not lead to a noticeable increase in the bearing capacity of sandy soil and can be considered a financial loss.

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