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Improvement of Sub-grade Soil using Natural Jute Fiber Sheet at Various Layers

تحسين خصائص الطبقه النهائيه للتربه باستخدام الياف الجوت الطبيعيه عند طبقات مختلفه

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Abstract

The improvement of sub-grade has always been significant aspect in highway and geotechnical engineering fields. To strengthen the subgrade soil, the use of natural Jute fiber is advantageous because they are cheap, locally available, and biodegradable. In this paper the soil sample was compacted at its maximum dry density corresponding to its optimum moisture content in the Laboratory California Bearing Ratio (CBR) mould with and without natural Jute fiber. Natural Jute fiber sheets equal to the plan of CBR mould diameter were placed at various layers (second, fourth and fifth of soil's layers) to investigate its behaviour on CBR value. The experimental investigations were also involved natural Jute fiber coated with bitumen material to study the effect of bitumen material on the CBR value. The CBR values of soil and soil reinforced with Jute fiber were investigated in the geotechnical engineering laboratory. The results of experimental investigation showed that the inclusion of Jute fiber sheet into the soil increases the CBR value of soil. It is also observed that the placing of Jute fiber at the second layer is more effective than placing it anywhere else in the soil sample; where the CBR value increased by 80% compared with unreinforced soil. The coating of Jute fiber has not shown significant improvement in CBR value; however, it can improve the Jute fiber longevity.
Key Words: *Jute Fiber, Sub-grade Soil, CBR Test, Bitumen.*

الخلاصة:

ان تحسين خواص الطبقه النهائيه لتربة الطرق لها جانب هام في مجالات هندسة الطرق وهندسة تقنيات التربه وان استخدام الياف الجوت الطبيعيه في تقوية التربه مفيد بسبب رخص هذه الماده وتوفرها في الاسواق المحليه فضلا عن قابليتها للتحلل. في هذا البحث تم حدل عينة التربه الى اقصى كثافه جافه باعتماد المحتوى الرطوبي الامثل وتم تهيئة نماذج التربه باستخدام الياف الجوت لفحص نسبة التحمل الكاليفوريني. تم تهيئة الياف الجوت الطبيعية وقصها بقطر مساوي لقطر قالب نسبة التحمل الكاليفوريني ووضعت الياف الجوت في قوالب نسبة التحمل الكاليفوريني فوق الطبقة الثانية والرابعة والخامسة لمعرفه تاثير الجوت على قيم نسبة التحمل الكاليفوريني. وكذلك تم استخدام الجوت المغطى بالاسفلت لدراسة تاثيره على نفس الخاصيه. تم ايجاد نسبة التحمل الكاليفوريني للتربه المسلحه بالجوت وغير المسلحه وكذلك للتربه المسلحه بالجوت المغطى بالاسفلت. بينت الدراسه ان استخدام الجوت يزيد من قيم نسبة التحمل الكاليفوريني بشكل واضح وان استخدام الجوت فوق الطبقه الثانيه هو اكثر فعاليه من اي مكان اخر تم دراسته ويزيد من قيم نسبة التحمل الكاليفوريني بنسبة 80% تقريبا. كذلك تم ملاحظة ان الجوت المغطى بالاسفلت ليس له تاثير واضح على قيم نسبة التحمل الكاليفوريني مقارنة مع الجوت الغير مغطى بالاسفلت ولكنه يزيد من ديمومة الياف الجوت.

Introduction

Soil improvement is of major concern in the construction activities due to rapid growth of urbanization and industrialisation. The term soil improvement is used for the techniques which improve the index properties and other engineering characteristic of weak and soft soils. The stabilization of these soils has been performed since many past centuries to improve engineering

properties of soil. The main method of stabilization includes mixing the soil with soil of higher strength or binding materials like limestone / cement /calcium or reinforcing with suitable element / fiber.Soil reinforcement increases soil strength, bearing capacity, ductility and inhibits deformations. Soil can be reinforcement by inclusion of high strength metal strips / wire and relatively low modulus natural and/or synthetic fibers. During last few decades, much work has been done to improve the engineering properties of soil and it has been established that addition of fiber is an efficient way to enhance the overall engineering performance of soil. Fiber reinforced soil is effective in all types of soils (i.e. sand, silt and clay). The concept of reinforcing soil with natural fibers is ancient one. Natural fibers are locally available, can make composites with cement / lime,cheaper, biodegradable and environmental friendly.There are many fiber e.g. Coconut(coir), Sisal,palm,Jute,rice husk,barley straw etc.,are in use for soil stabilization.In most area of Iraq, soil is composed of silt and clay fraction. The soil has high value of liquid limit and small value of CBR.

Many studies have been conducted relating to the behaviour of soil reinforced with different types of fiber. Gray and Ohashi, (1983) carried out a series of direct shear tests on dry sand reinforced with different synthetic, natural and metallic fiber to investigate the effects of parameters such as fiber orientation, fiber content, fiber area ratios, and fiber stiffness on contribution to shear strength. Based on the test results, they found that an increase in shear strength is directly proportional to the fiber area ratios and shear strength envelopes for fiber-reinforced sand clearly shows the existence of a threshold confining stress below which the fiber tries to slip or pull out. Aggarwal and Sharma (2010) studied the application of Jute fiber in the improvement of subgrade characteristics. They concluded that Jute fiber reinforcement reduces the maximum dry density and increases the optimum moisture content of the subgrade soil. Singh and Yachang (2012) used the Jute sheets to improve the CBR value of fly ash. According to their experimental results the stress-strain behaviour of soil which was improved by inclusion of coir-fiber into the soil and Jute sheets improved the California Bearing Ratio (CBR) value of fly ash significantly. They further concluded that the deviator stress at failure was increased up to 3.5 times over the plain soil. They also observed that stiffness modulus of reinforced soil increases considerably which can reduce the immediate settlement of soil significantly. Singh and Bagra (2013) also conducted a laboratory CBR tests of soil reinforced with Jute fiber having varying lengths and diameters of fiber. Their results showed a significant increase (200 %) in CBR value of soil due to Jute fiber. In the present investigation, the influence of natural Jute fiber sheet and its location on the CBR value of the soil were studied. A number of CBR value tests have been conducted on soil, and soil reinforced with Jute fiber sheet at different location. Also, the tests were carried out on the natural Jute fiber coated with bitumen material to study the effect of bitumen material on the CBR value.

Materials Used

Soil

Soil sample obtained locally is used for the current experimental investigations.The sample used in this research was collected from the site of Al-Mastafawyah in Al-Nassiriyah city, Iraq.The various index properties and compaction properties(maximum dry density and optimum moisture content)of soil were determined in the laboratory as shown in Table 1.The grain size distribution curve of soil is shown in Figure 1. The liquid limit and plastic limit of soil sample were performed in accordance to(ASTM-D4318).The Modified Proctor compaction was carried out to in accordance to (ASTM-D1557) to determine the optimum moisture content and maximum dry density of the sample as per. Summary of the geotechnical properties of the soil used are given in Table 1.

Table 1: Mechanical Properties of Soil

Property	Value
Specific gravity, (Gs)	2.68
Liquid Limit, (w_l)	25.4
Plastic Limit, (w_p)	11.6
Max. dry density, (γ_d)	17.8
Optimum Moisture Content (O.M.C)	14.4
Sand %	32.5
Silt %	53.9
Clay %	13.6

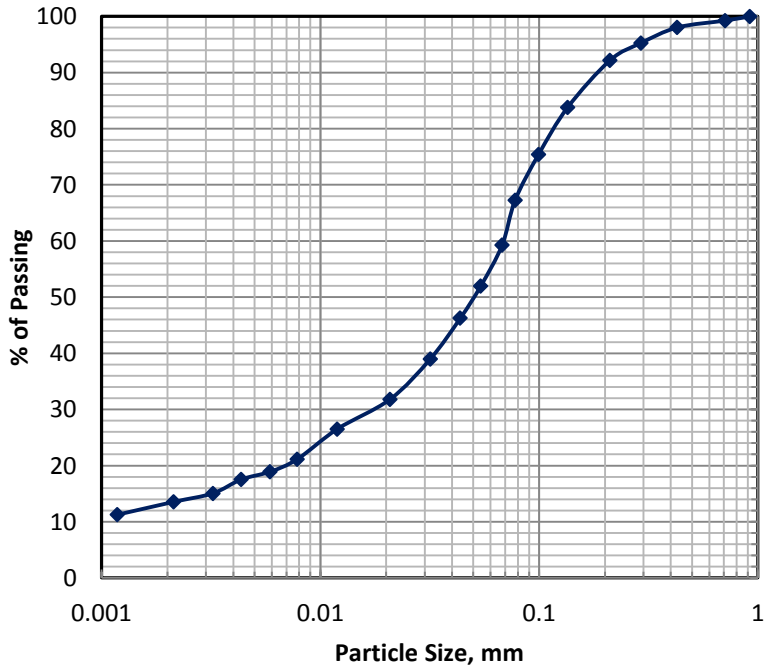


Figure 1: Grain Size Distribution of Soil

Jute Fiber Sheet

The Jute fiber sheets (woven type) taken from the Jute bag, were procured from the local market. The average thickness of the sheet was 2.0 mm. Figure 2 shows a view photograph of the Jute fiber sheet.

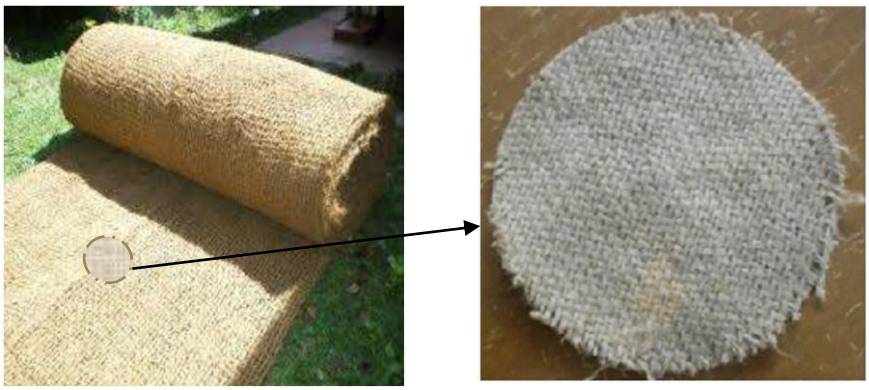


Figure 2: A view Photograph of the Jute fiber sheet used in this study

Bitumen

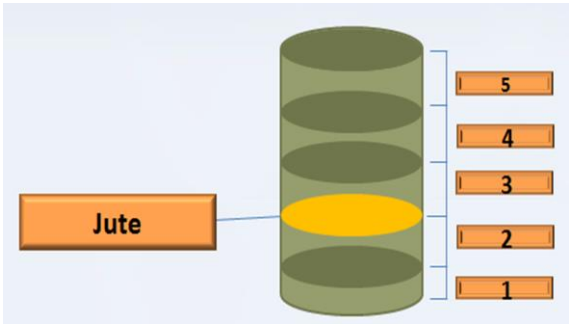
Bitumen was used for coating the Jute fiber to protect them from microbial attack & degradation. Bitumen coating was done in the hot state at a temperature of 145 ^{o}C. Grade and some of the other properties of bitumen are tabulated in Table 2.

Table 2: Properties of Bitumen

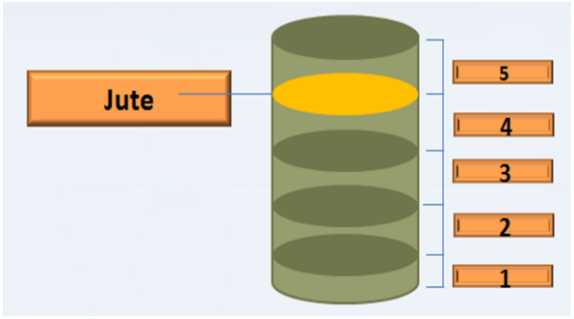
Property	Value
Grade	85-100
Softening Point (^{o}C)	42
Flash Point (^{o}C)	245
Fire Point (^{o}C)	260
Specific gravity, (G_B)	1.011

Experimental Program

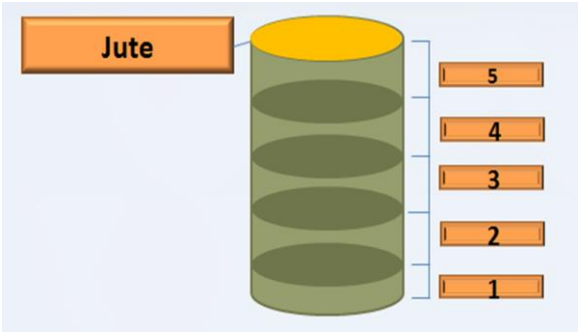
The soil samples of unreinforced and reinforced soil with Jute fiber were prepared in a standard cylindrical mould and placed above various layers (second, fourth and fifth of soil's layers) as shown in Figure 3. All specimens were prepared at maximum dry density for proctor compaction tests, and California Bearing Ratio (CBR) test were prepared as per standard procedure (ASTM-D1883). The desired amount of oven dried (100-105 ^{0}C) soil was taken and mixed thoroughly with water corresponding to its optimum moisture content (OMC) in the CBR mould having 150 mm diameter and 175 mm high with detachable perforated base plate. The soil was then compacted to its maximum dry density obtained by laboratory standard Proctor test.



b- Jute Fiber sheet above second layer



a- Jute Fiber sheet above fourth layer



c- Jute Fiber sheet above fifth layer

Figure 3: Jute fiber sheet placed at different positions

For the preparation of some soil samples of reinforced soil, the natural Jute fiber was coated with bitumen material to investigate the effect of bitumen material on the CBR value as shown in Figure 4.

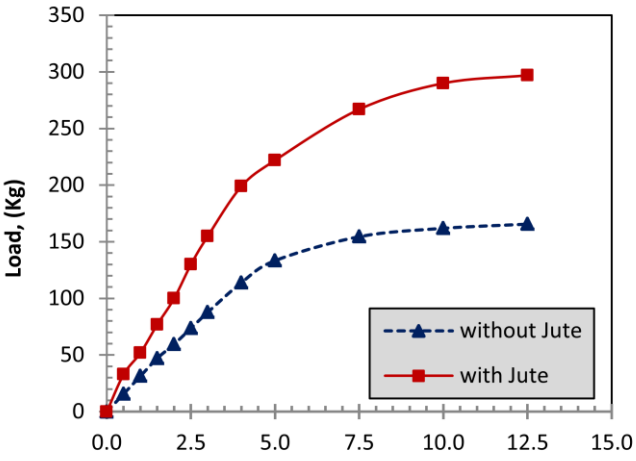
Figure 4: Bitumen coated Jute fiber sheet

Then, the soil sample was compacted to same Proctor density as per ASTM D 1557. The top surface of the specimen in the CBR mould was made level and a filter paper and a perforated metallic disc were placed over the specimen. With spacer disc placed inside the mould, the effective height remains only 127.3 mm and the net capacity is 2250 cm^3. The CBR mould along with compacted soil and surcharge load of 5 kg was then transferred to a tank containing water for soaking of the sample. After 4 days (i.e. 96 hours) of soaking, the mould assembly was taken out from water and the top surface of sample was left exposed to air for half an hour. CBR mould along with soaked soil sample was brought to a motorized loading frame for testing. A strain rate of 1.20 mm/min was used for all the tests, and all the specimens were tested in a similar manner.

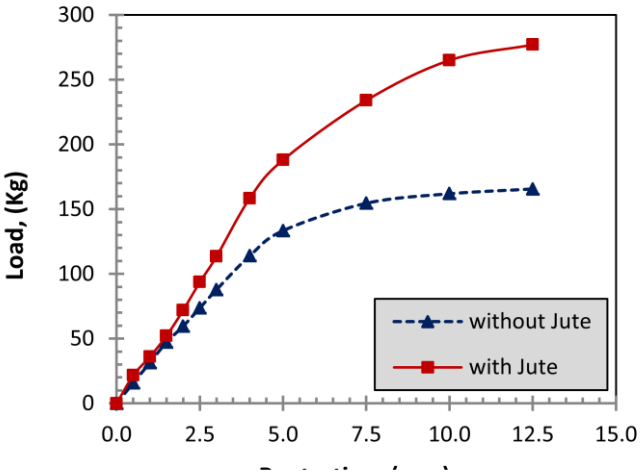
Results and Discussion:

1- Effect of Jute fiber sheet

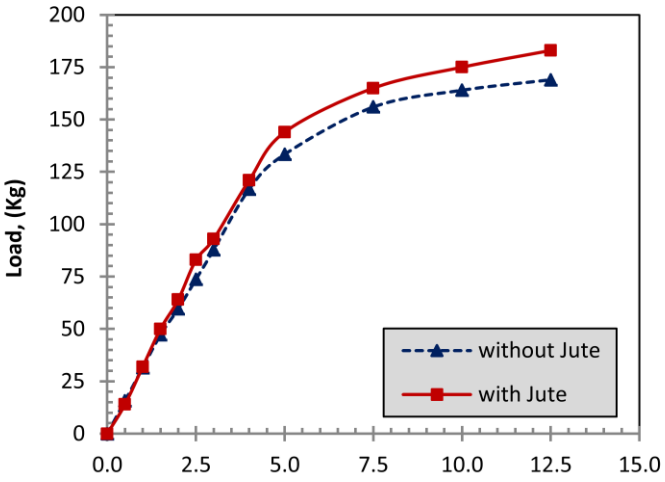
Penetration tests using California Bearing Ratio (CBR) apparatus were conducted to investigate the effect of Jute fiber reinforcement on sub-grade soil. The results obtained from CBR tests performed on unreinforced and reinforced soil with Jute sheet specimens placed at different positions as illustrated in the load-penetration curves in Figure 5. These results for both the unreinforced soil and reinforced soil were plotted on the same graph to facilitate comparisons. The result showed that the Jute fiber sheet placed between soil layers can significantly increase the bearing capacity of soil samples. The increasing of CBR values for all soil samples after inclusion of Jute fiber sheet in it, is due to the fact that Jute fiber sheet interact with soil grains mechanically through surface friction and by interlocking. The function of the interlock or bond is to transfer the stress from the soil to the reinforcing elements by mobilising the tensile strength of reinforcing elements of Jute fiber which result in improvement of load carrying capacity of reinforced soil. The effect of Jute fiber can be interpreted considering mobilized resistance of the soil sample. Therefore, it can be concluded that addition of fiber sheet in soil improves its load carrying capacity and reduce the value of penetration. These results agree with the observation of [(Naeini and Mirzakhanlari, 2008) and (Allahbakhshi and Sadeghi, 2014)].



b- unreinforced and reinforced soil with Jute sheet placed above fourth layer



a- unreinforced and reinforced soil with Jute sheet placed above second layer



c- unreinforced and reinforced soil with Jute sheet placed above fifth layer

Figure 5: CBR value with for unreinforced and reinforced soil samples at different positions

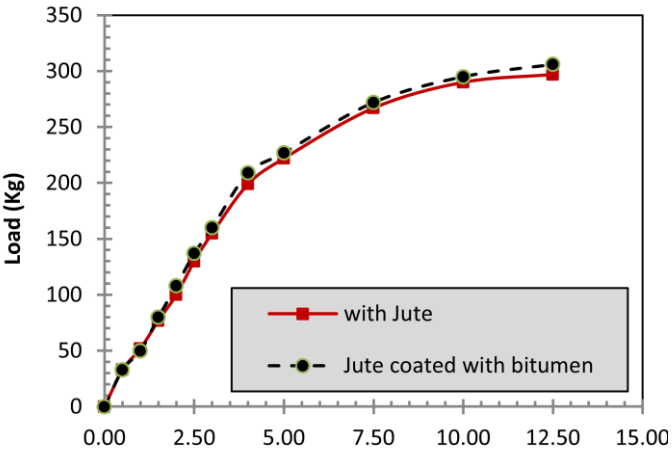
2- Effect of Jute fiber sheet position

The Jute fiber sheets were placed at various layers on soil sample (second, fourth and fifth of soil layers) to investigate the effect of Jute sheet position on CBR value as shown in Figure 5. As mentioned above, the curves responses indicate that the CBR soil is improved by incorporating Jute fibers which placed at any position. It was observed that the improvement of the soil strength of CBR reinforced with Jute fiber sheet depends on its placing position. The soil samples reinforced with sheet layer at various layers (fourth, second and fifth) improved the performance of CBR by about (80%, 67% and 9%) respectively compared to unreinforced soil. It can be concluded that placing Jute fiber sheet above fourth layer is more effective than placing it anywhere else in the soil sample. This is because of the improved redistribution of load provided by the Jute fiber sheet reinforcement when placed at this layer, and due to the mechanical interaction and interlocking provided by Jute fiber sheet interact. While, placing Jute fiber sheet above fifth layer has not shown

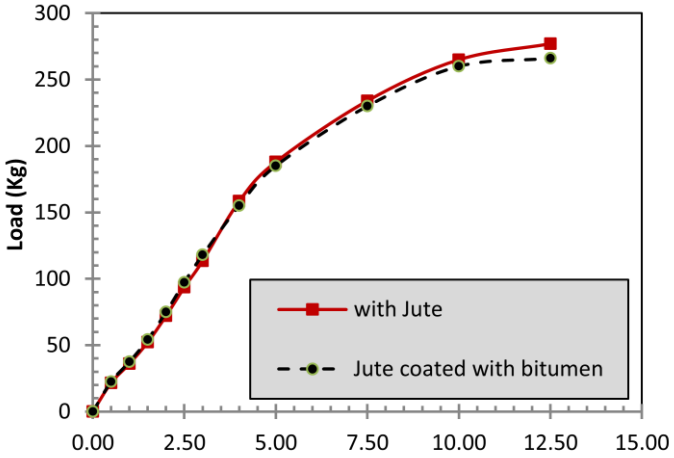
a significant improvement because of missing the advantage of the mechanical interaction and interlocking provided by Jute fiber sheet.

3- Effect of Bitumen Material

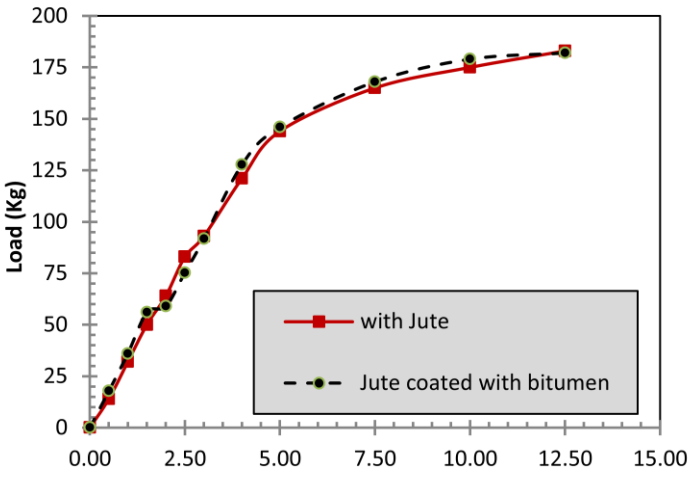
A series of California Bearing Ratio (CBR) tests were performed on the soil reinforced with bitumen coated Jute fiber. Figure 6 shows the comparison CBR results between the soil reinforced with Jute fiber and soil reinforced with bitumen coated Jute fiber placed at various layers (second, fourth and fifth of soil layers). It can be seen from these responses that the coating of Jute fiber sheets with bitumen has insignificant effect on load-penetration values compared with that of soil reinforced with uncoated jute fiber. However, the bitumen is expected to protect the Jute fiber from microbial attack and degradation. Figure 6 presents a summary results of CBR values for unreinforced soil and reinforced (with Jute fiber and soil reinforced with bitumen coated Jute fiber) placed at various layers (second, fourth and fifth of soil layers).



a- Reinforced with Jute fiber and soil reinforced with bitumen coated Jute fiber



b- Reinforced with Jute fiber and soil reinforced with bitumen coated Jute fiber



c- Reinforced with Jute fiber and soil reinforced with bitumen coated Jute fiber placed fifth layer

Figure 5: CBR value with for soil reinforced with Jute fiber and soil reinforced with bitumen coated Jute fiber placed at different positions

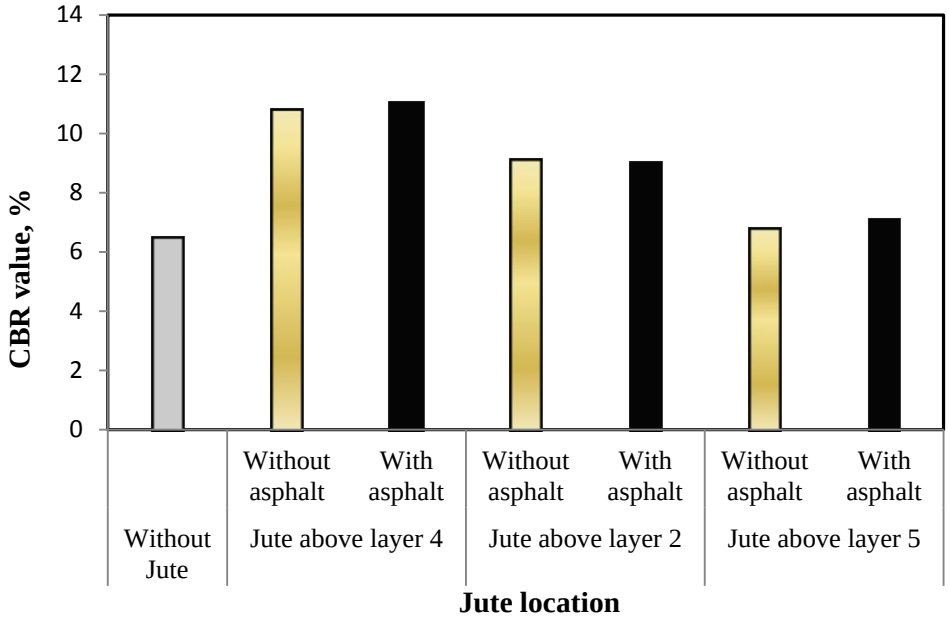


Figure 6: Summary results of CBR values

Conclusions

This investigation was conducted to assess the behaviour of Jute fiber sheet on the performance of subgrade soil. The behaviour of unreinforced soil, and soil reinforced with Jute fiber and soil reinforced Jute fiber coated with bitumen were investigated in terms of CBR values. Based on the results obtained from this investigation, the following conclusions could be drawn:-

1- The placing of Jute fiber sheet between soil layers can significantly increase the bearing capacity of soil samples. CBR tests showed that the placing of layer of Jute fiber at the second, fourth and fifth of the soil sample were observed to be greater than that of unreinforced soil. The CBR values for soil reinforced with Jute fiber were improved by about (80%, 67% and 9%) when Jute fiber layer placed above fourth, second and fifth layer respectively compared with unreinforced soil. Jute fiber makes the soil a composite material whose CBR strength value is greater than that of unreinforced soil.
2- The tests results showed that placing the Jute fiber sheet above the fourth layer of the soil sample gave the most effective results.
3- Although the use of bitumen as coating for Jute fiber has insignificant effect on the CBR values for reinforced but it is expected to protect the Jute fiber from microbial attack and degradation.

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