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Investigate the Properties of the Granular Materials Incorporated Cotton Fiber

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Absrtact: Cotton fibers are founded in many countries of the world in different sizes and colors. The presence of PP cotton fibers in soils gives an important change in the behavior and convert the properties of these types of soils. This research introduces a method to upgrade the performance of the granular materials which are normally used in subbase courses. The research program aims to investigate the benefit of using PP cotton fiber as reinforcing material on CBR (California Bearing Ratio) for subbase which is adopted as an indication for treatment. A laboratory tests were made on a granular soil (named commonly as subbase) samples to study the difference between cotton fiber and cement use. CBR value of 34.9 affirmed as a guide value to make the comparisons. In addition, five percentages, i.e., 0.5, 1, 2, 4 and 6% are used for each material to study their effect on CBR values. With cement, the CBR increases with all percentages used. The study show that the use of cement reinforcement increase the CBR value more than the use of cotton fiber. While for cotton fiber the maximum percentage is 1% by total mass of soil with more than 45% increase in comparison with the virgin subbase material which corresponding to almost 1.5% of OPC addition.

Key words: Subbase, CBR test, cotton fiber, cement, OPC addition, Iraq

INTRODUCTION

In all construction projects the main goal of engineers is to construct a structures, highways, roads, etc., able to resist the applied loads and environment conditions. If the soil under structure cannot able to resist the applied load it must be treat this soil to improving its performance and give it the required strength. One of the guides to measure the soil strength to bear applied loads is CBR (California Bearing Ratio) which is defined as a penetration test calculation of the mechanical strength of natural ground, subgrades and base courses under new carriageways construction. It was developed by the California Department of Transportation before World War II.

Because of the problems which are occur in sub-base layer in roads and buildings in Iraq, many ways to improve strength and durability of sub-base material must be investigated. This study investigates adding cement and PP cotton fiber to the sub-base material and study CBR with and without them.

Attom and Al-Tamimi (2010) used two types of polypropylene fibers to study their effect on shear strength parameters of sand. The first type of fiber is highly flexi-ble with flat profile and the second with relatively high stiffness and crimpled profile. The results showed that, the shear strength of the sand increased with increasing the flexible flat profile fibers content. The results showed also that by increasing the aspect ratio of the flexible flat profile the angle of internal friction and the shear strength increases and the crimpled profile fiber increase the shear strength with high nor-mal load and has small or no effect on shear strength at low aspect ratio with low normal load.

Al Adili *et al*. (2012) chose a papyrus fiber to reinforce a clayey silt samples. The used percentages of fiber were 5, 10, 15 and 25% by volume of sample. Consolidation, direct shear and displacement tests were performed to study the strength behavior of reinforced soil. The results showed a significant improvement in shear strength parameters c and ϕ at 10% fiber and the displacement was reduced.

Singh and Bagra (2013) prepared samples of soil at a maximum dry density and optimum moisture content to study the effect of Jute fiber with percentages of 0.25, 0.5, 0.75 and 1% on CBR. The used fiber was taken as 30, 60 and 90 mm in length and the diameter was 1 and 2 mm for each length. The effect of lengths and diameters of fiber on CBR were investigated. The results conducted that the CBR increases when fiber content increases and the increasing in length and diameter of fiber increase the

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CBR value of reinforced soil and this increase is substantial at 1% fiber for 90 mm fiber length having diameter 2 mm, thus, the increasing CBR value will substantially reduce the thickness of pavement subgrade.

Butt *et al.* (2014) studied the effect of human hair fiber (natural fiber) on the strength of cohesive soil. The strength was represented by CBR value which is investigated for 0.5, 1, 1.5, 2 and 2.5% of fiber is compared with soil without fiber. The results showed that, the CBR value at 0.5% fiber is less than unreinforced soil but after increasing the fiber percentage CBR value increases up to 2%, then starts decreasing at 2.5%. Also, the researchers concluded that the fiber prevent cracks in samples.

Sonthwal and Sahni (2015) studied the improvement CBR of locally available soil using 0.25, 0.5, 0.75 and 1% of jute fiber. The length of jute fiber was taken as 10 mm and 25 mm and diameter was 4 mm and 8 mm for each length. The results conducted that the CBR value of reinforced soil with Jute fiber coated with bitumen increases up to 131.81%. They included also that, the optimum moisture content increases and maximum dry density decreases.

Das *et al.* (2016) investigated the shear strength parameters of sand variation using brown coconut fiber as reinforcing material. The length of fiber pieces is 15 mm. the direct shear test was performed to estimate the shear strength parameters. The results for using 0, 1, 2 and 3% fiber showed that the optimum improvement is given at 2.1% fiber which is gives an improvement in shear strength parameters reaches to 21.7%.

Lime, fly ash and Ordinary Portland Cement (OPC) are the principle materials which are used for cementitious stabilization and modification of base, subbase and subgrade layers of soil and highway pavement. Lime and OPC are manufactured products while fly ash is a by-product material of coal combustion at electric power generating stations (Little *et al.*, 2001).

Scope of study: This study introduces a practical study to investigate the performance of granular materials which are represent the sub-base course in geotechnical projects and highways pavements by using Fiber. Also, conducting comparisons with the performance by using cement as an additive to granular materials. The mechanical properties have been evaluated by conduction the CBR test at the maximum dry density and optimum moisture content for the two adopted improvement method.

MATERIALS AND METHODS

Granular soil: The sub-base used in this study was brought from a quarry placed in the sea region which is located in Al-Najaf, Iraq. In the laboratory, the required experimental testing was conducted to recognize physical, chemical and engineering properties of the selected soil. The grain size distribution of the granular material is shown in Fig. 1. According to the Standard Commission for Roads and Bridges (SCRB) in Iraq (Anonymous, 2010). The granular material can be classified as Class C. Table 1 presents the physical and chemical properties of the collected sample with the corresponding testing method.

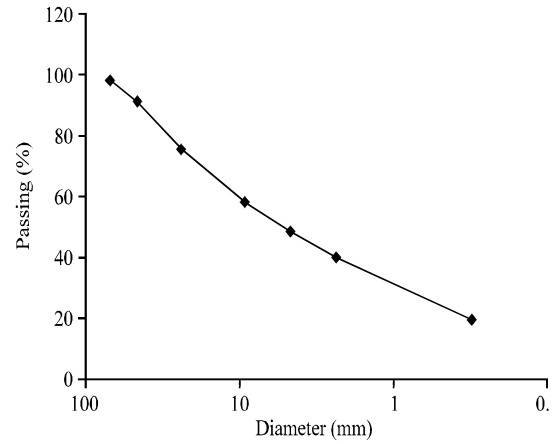

Fig. 1: The grain size distribution of the collected granular materilas

Table 1: Physical and chemical properties of the granular material

Property	Test methods	Results
Liquid limit (%)	ASTM D423	34.8
Plasticity index (%)	AASHTO T90	12.0
Organic materials (%)	BS 1377, No. 8	1.2
SO_3 salts (%)	BS 1377, No. 9	0.8
Optimum Moisture Content (OMC) (%)	AASHTO T180	7.1
Maximum Dry Density (MDD) kN/m^3	AASHTO T180	21.1
CBR	AASHTO T193	34.9

Table 2: Chemical properties of used cement

Physical properties	Test result	Limit of Iraqi specification IQS No.5/1984
Setting Time (mIn.)		
Initial	150	≥45 min
Final	275	≤600 min
Fineness (Blain method) In cm^2/g	2810	≥2500
Compressive strength		
In MPa at 3 days	18.3	≥15
7 days	28.3	≥23

Cement material: In this study, the used cement is collected from a local Kerbala Cement Plant. The type of cement is sulfuric salts resisting. The samples of used cement were tested in the Laboratory of Engineering Consulting Bureau, Faculty of Engineering, University of Kufa. The chemical and physical properties of cement are presented in Table 2 and 3, respectively.

Table 3: Physical properties of used cement

Oxide	Content (%)	Limits according to IQS No.5/1984
SiO_2	21.42	-
CaO	63.75	-
MgO	1.78	≤5%
Fe_2O_3	5.90	-
Al_2O_3	3.04	-
SO_3	2.15	≤2.5%
Free lime	1.52	≤4%
Loss of Ignition	1.21	≤4%
Insoluble Residue	1.30	≤1.5%
L.S.F	0.90	0.66-1.02
Main (compounds (Bogue's equation)	% by wt. of cement	
C_3S		55.55
C_2S		19.50
C_3A		0
C_4AF		17.95

Table 4: Quick details of PP cotton fiber

Materials	100% polyester
Style	Hollow conjugated
Color	Raw white
Fineness	1.5-20D
Fiber length	32-102 mm
Application	Soft toys
Grade	Virgin
Usage	Filling safa toys pillow quilt

Fig. 2: PP cotton fiber materilas

Fiber material: The fiber material which is used inthis study is called (PP cotton fiber) as shown in Fig. 2. Table 4 shows a quick detail of this PP cotton fiber is used mainly as a filling material, it is resist the abrasion, pilling, distortion and heat.

Experimental work: The experimental research divided into two stages, first is testing five samples of granular material (sub-base) with 0.5, 1, 2, 4, 6% of cement of granular material weight as an additive and compare the CBR values with those of sub-base without cement. Second stage is testing another five samples of sub-base with 0.5, 1, 2, 4, 6% of fiber material of granular material weight as an additive and compare CBR of sub-base without and with fiber. California Bearing Ratio (CBR) is conducted in accordance to AASHTO T193. CBR test is a laboratory penetration test used to calculate base, subbase and subgrade layer hardness for pavements and roads. The CBR was developed in the 1950's by the California Department of Transportation and since, then it has been used extensively for pavement design purposes. Initially it was intended to describe granular aggregates with sizes ranging between 4.75 and 20 mm. More recently it has been used for soil materials (Anonymous, 2004).

Sample preparation: Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) of the collected sub-base have been indicated in accordance to AASHTO 180 which were 7.1% and 21.1 kN/m^3, respectively as shown in Table 1. Then the material retained on 19 mm sieve has been replaced by an equal mass of material passing the 19 mm sieve and retained on No. 4 sieve obtained by separation from portions of the same not used for testing, the samples have been prepared with addition of OMC, i.e., 7.1%.

At first, the CBR test was performed at OMC for the sample of sub-base without additives as a control sample. Then, five samples were tested by adding cement and other five samples by adding fiber with different percentages.

CBR testing method: CBR test has been used as a respected type testing to visualized the mechanical properties of the samples with and without additives. CBR test was carried out in accordance to AASHTO T193 with and without additives. Five percentages of additives which were used, i.e., 0.5, 1, 2, 4, 6%. It is worthy to say that the procedure of this test was depending on conducting dry density in accordance with AASHTO T180 and CBR test in accordance with AASHTO T193 for each design sample with three different compaction effort, i.e., 10, 30 and 65 blows for each layer. Then the CBR value has been calculated for the 95% of the maximum dry density which is normally adopted in the field. The design samples will be nominated as control. CBR testing machine is shown in Fig. 3 while the electric compactor shown in Fig. 4 which has been used to prepare dry density and CBR test samples.

Fig. 3: CBR test machine

Fig. 4: Compactor apparatus, CBR mold and density mold

RESULTS AND DISCUSSION

Compaction test and CBR test of control sample: The compaction test is one of the useful tests that should be carried out to conduct the maximum dry density and optimum moisture content for different types of soil which are identified as compaction parameters and listed

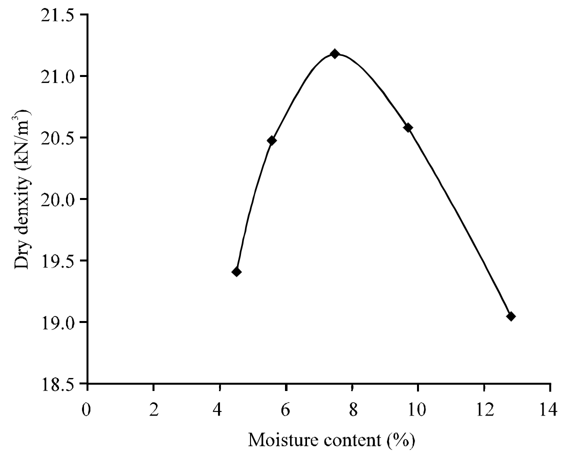

Fig. 5: Dry density and moisture content relationship of control sample

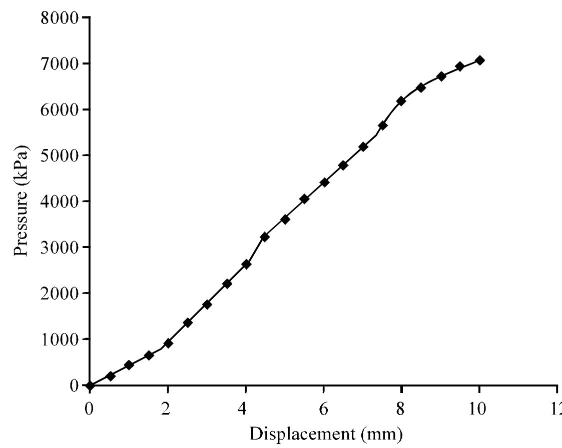

Fig. 6: Displacement and pressure relationship of CBR test for control sample

in Table 1. These parameters vary dependent mainly on soil type. The preparation of the specimens for the experiments to find the other geotechnical properties such as CBR, density, porosity and triaxial test are dependent primarily on the values of OMC and MDD which are obtained from compaction test.

In this study, modified proctor compaction tests and CBR test were performed on the sub-base sample without cement and fiber as a control sample. Figure 5 shows the dry density and moisture content relationship for a control sample from Fig. 5, it can be seen that the Maximum Dry Density (MDD) is 21.1 kN/m^3 and Optimum Moisture Content (OMC) is 7.1%.

CBR test was conducted for control sample, the relationship between displacement and pressure is shown in Fig. 6. The pressure corresponding to the higher value of 2.5mm and 5 mm displacement divided by mold area gives CBR value of 34.9 as listed in Table 1.

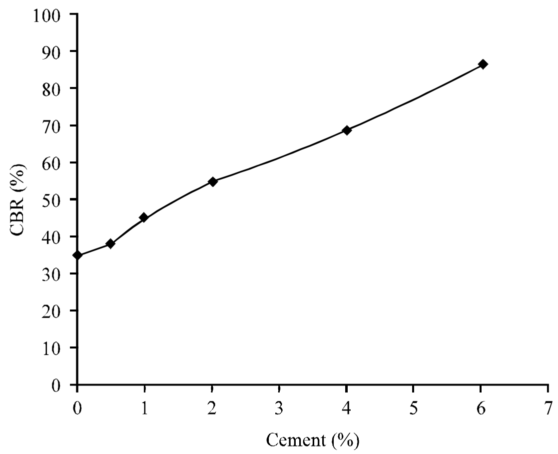

Fig. 7: Relationship between cement percentage and CBR

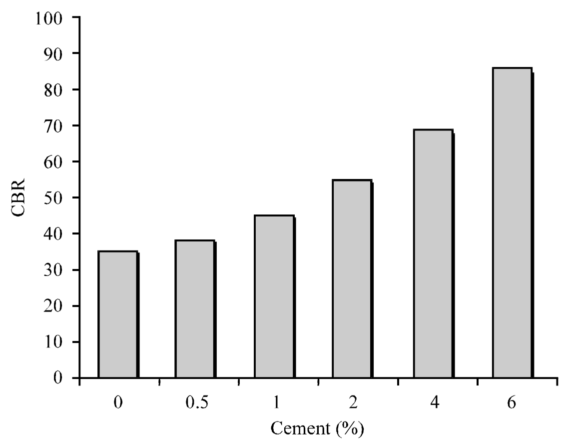

Fig. 8: CBR value for different cement percentages

CBR test using cement: CBR test was performed using 0.5, 1, 2, 4, 6 % cement of the weight of sample as additive to study its effect on CBR value at OMC. The same procedure as for a control sample was adopted to calculate CBR value. Figure 7 shows the relationship between cement percent and CBR for samples without and with cement, from this figure it can be seen that the CBR increase with increase cement percentage with a large amount from 0.5-4% and with a little increment from 4-6% as shown in in Fig. 7 and 8.

CBR test using cotton fiber To study the effect of PP cotton fiber on CBR value at OMC, the test was performed also using fiber for the same percentages, i.e., 0.5, 1, 2, 4, 6% of the weight of sub-base sample. The relationship between fiber percent and CBR is shown in Fig. 9 and 10. From Fig. 9-11, it can be seen that CBR decrease at 0.5% fiber and increase at 1% fiber, then CBR decrease for 2, 4, 6% fiber, that means 1% fiber is an ideal percentage to improve CBR of sub-base at OMC.0

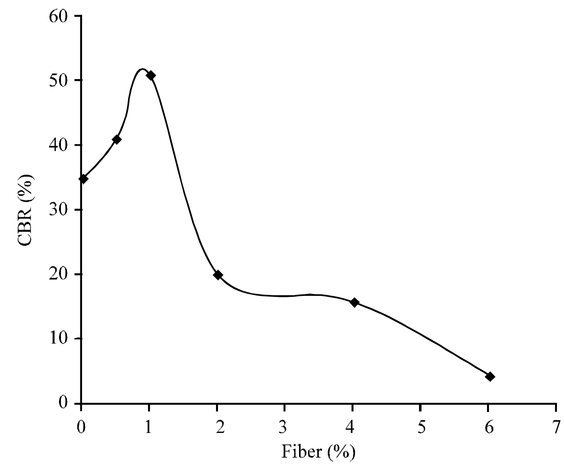

Fig. 9: Relationship between fiber percentage and CBR

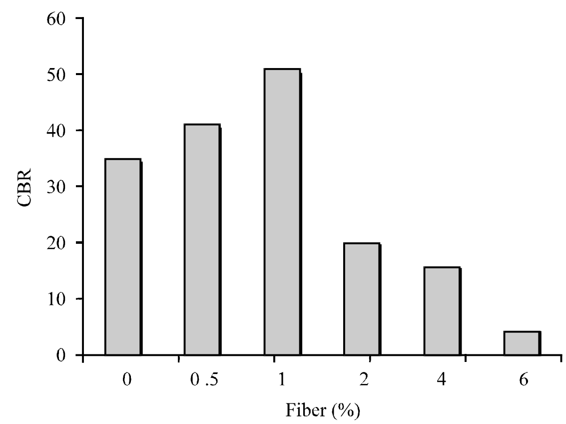

Fig. 10: CBR value for different fiber percentages

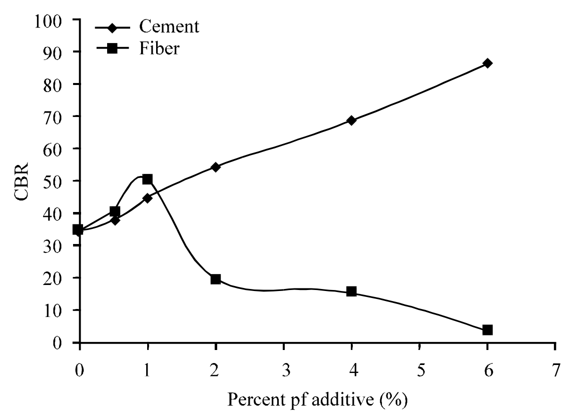

Fig. 11: Relationship between cement and fiber percentages and CBR

Results analysis: From the laboratory results, it can be concluded that there is a significant increase in the CBR value when using cement with sub-base in the construction of roads and structures. From Fig. 11, it can be concluded that the use of cement increasing CBR about 147% for 6% cement, this improvement in CBR is considered as an excellent modification to sub-base layer in resisting the loads and give more durability. The improvement at 2% cement reaches to 56% which is considered as a good percentage of improvement if the required CBR within the acceptable specifications limits and the saving in cement cost is favorite. The results introduce that the use of 1% fiber gives maximum improvement in CBR. From Fig. 11, it can be seen that the corresponding CBR to 1% fiber is 50.8 and for sub-base alone is 34.9, this means that the maximum improvement reaches to 45.7% at 1% fiber.

The maximum improvement of using fiber is of 1% which is give 50.8 CBR with more than 45% increase in comparison with the virgin material while for using cement the percentage which gives 50.8 CBR about 1.6%. For example for the 100 ton of sub-base it is needed 1.6 ton of cement and 1 ton of fiber.

CONCLUSION

This study investigated use of cement and PP cotton fiber to improve CBR of sub-base. The experimental research performed to evaluate CBR of samples using 0.5, 1, 2, 4, 6% for each cement and fiber and compared with the CBR of sub-base without additives. Many conclusions can be drawn from the experimental results as: The use of cement up to 6% increase the value of CBR about 147% in comparison with the virgin granular material. The optimum percentage of fiber is 1% by mass of aggregate with which the CBR increased more than 45% in comparison with the virgin material. The optimum fiber content corresponding to the CBR value with 1.6% of cement.

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