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Experimental Studies on Use of Polypropylene Material (Emptied Cement Bags) in Soils - An Alternative to Geosynthetics

Md. Shakeel Abid and M. Andal
Department of Civil Engineering, Kakatiya Institute of Technology and Science, Warangal, Telangana State, India

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ABSTRACT

On many situations, industrial and infrastructural projects are constructed on soft and weak soil of low bearing capacity. Under these circumstances, the geotechnical engineers normally opt for a suitable ground improvement technique, to improve bearing capacity and reduce settlements. In these situations, reinforced soil has become a viable and cost-effective technique and use of geosynthetics has been proven to be another alternative. But, the use of geosynthetics is not cost effective. Geosynthetics improves the tensile strength of the soil and as a replacement to it, low cost emptied cement bags (made out of polymeric materials) can be used. Improved bearing capacity can be expected when emptied cement bags are used as the reinforcement to the soils. In this paper deteriorated emptied cement bag fibres are used as a stabilizing material to improve the soil characteristics of the cohesive and cohesionless soils. An experimental programme is presented to explore the beneficial aspects of emptied cement bags which is used for stabilizing soils. It is found that this stabilizing technique has improved the cohesion and angle of internal friction in case of cohesionless soils and increased the unconfined compressive strength to a noticeable extent in case of cohesive soils.

INTRODUCTION

Randomly distributed fibre reinforcement technique has been successfully used in a variety of applications such as soil reinforcement and soil stabilization. This is a relatively simple technique for ground improvement and has tremendous potential as a cost effective solution to many geotechnical problems. The main objective of this study is to investigate the use of waste fibre materials in geotechnical applications and to evaluate the effects of waste polypropylene fibres on shear strength parameters of cohesionless soils by conducting direct shear test and CBR tests and for cohesive soils by conducting direct shear test and unconfined compression test.

Emptied cement bags are used for reinforcing the soil material. It is observed that the load carrying capacity of the soil is increased when emptied cement bags are used. The present technical investigation aims to quantify the characteristics of the soil when stabilized with emptied cement bags as reinforcing material.

One major constraint with the use of geosynthetic material is increase in cost of construction. Narasimha & Neerja (2012) described the influence of geofabrics in the construction of pavements of expansive clayey subgrades. Islam & Ahmed (2012) had studied the application of jute bags for soil and impacts of jute on environment. The enhanced strength and stiffness properties of soil reinforced with jute geotextile sheets were studied by Singh (2013). Md. Shakeel Abid & Nitesh (2015) had performed various tests on embankments reinforced with geotextile and reported that the effective position to place a geosynthetic material in a soil structure for reinforcement is at a distance of H/3 from the top of the embankment. Deb et al. (2011) have performed a series of laboratory tests to investigate the effect of reinforcement on sand bed resting on stone columns. Alexiew et al. (2005) found an increase in load carrying capacity of stone column when encased with geotextile. Black et al. (2007) conducted laboratory tests for the performance of reinforced columns in weak deposits. Murugesan & Rajagopal (2007) studied various parameters by conducting various tests on geosynthetic encased stone columns.

EXPERIMENTAL PROGRAM

The experimental program was developed by focusing the application of emptied cement bag which is used as an alternative to the geosynthetic material, for reinforcing and stabilizing different types of soils. With this aim, various laboratory tests were conducted on soil, finding out its properties with and without using emptied cement bags. Finally, the results are compared.

Properties of Materials

Cohesionless and cohesive soils: As the emptied cement

Table 1: Properties of cohesionless soil.

Parameters	Value
Cohesion	0
Angle of friction	ϕ =36°
Optimum moisture content	6.41%
Maximum dry density	16.9 kN/m^3
CBR value at 2.5 mm penetration	22.46%
CBR value at 5 mm penetration	27.85%

Table 2: Properties of cohesive soil.

Parameters	Value
Differential free swell	14.28%
Liquid limit	42%
Plastic limit	26.9%
Maximum dry density	2.0 kN/m^3
Optimum moisture content	14%
Cohesion	49 kPa
Unconfined compressive strength	117 kPa
Undrained shear strength	58 kPa

Table 3: Properties of an emptied cement bag.

Parameters	Value
Yarn material	Polypropylene
Thickness	0.7 mm
Tensile strength	58 kN/m

Table 4: Outline of tests for reinforcement of soil.

Soil	Test	Property	Emptied cement bag
Sand	Direct shear test	Shear strength parameters	At the centre
Sand	CBR Test	CBR value	At a distance of H/2 from the top
Sand	CBR Test	CBR value	At a distance of H/3 from the top

bag which is made of polypropylene material is tested for reinforcing and stabilizing the soil, two different soils were used for this purpose. Although, the emptied cement bags are used as a layer for reinforcing and stabilizing the soil, the emptied cement bags are transformed to small particles and mixed in it at different proportions.

To check whether the emptied cement bag can be used for reinforcement of soil, a cohesionless soil, whose properties are depicted in Table 1, is chosen and tests were performed to enhance its engineering properties. While, a cohesive soil, whose properties are depicted in Table 2, is chosen to enhance its engineering properties by stabilization process.

Table 5: Outline of tests for stabilization of soil.

Soil	Test	Property	Emptied cement bag content
BC soil	Unconfined compressive strength test	Compressive strength	2%
BC soil	Unconfined compressive strength test	Compressive strength	4%
BC soil	Unconfined compressive strength test	Compressive strength	6%
BC soil	Unconfined compressive strength test	Compressive strength	8%
BC soil	Direct shear test	Shear strength parameters	6%

Polypropylene Material

The selection of polypropylene material is important in laboratory tests from scale view point. Any geosynthetic polypropylene material gives good results when tested for various conditions, but usage of a geosynthetic material is uneconomical. An alternative for the geosynthetic material would reduce the cost of the project. An emptied cement bag which is generally made of polypropylene material has a good amount of tensile strength. Due to its tensile properties it is chosen as an alternative for geosynthetic materials in this work. The properties of an emptied cement bag are depicted in Table 3.

TEST PROGRAM

Reinforcement of soil using polypropylene material (emptied cement bags): As the soil is weak in tension, emptied cement bags are used to increase the tensile strength and the shear strength properties of the soil and the soil gets reinforced. Reinforcing the soil with polypropylene fibre increases the tensile strength and shear strength parameters of the soil. Therefore, laboratory tests were conducted to study the effects of polypropylene fibre on various characteristics of soils. The test program adopted to enhance soil properties by reinforcement using emptied cement bag as a replacement to geosynthetic material is given in Table 4.

Stabilization of soil using polypropylene material (deteriorated emptied cement bag fibres): Cohesive soils have less density, load bearing capacity and the settlements are more. Stabilizing these cohesive soils with polypropylene fibre decreases swelling characteristics of soil. Therefore, laboratory tests (Table 5) were conducted to study the effects of polypropylene fibre on the engineering properties and swelling characteristics of expansive soil. The use of polypropylene material for stabilization of soil is completely different compared to that of reinforcement. Here, the deteriorated fibres of emptied cement bag is mixed in cohesive soil with different percentage contents. These fibres of emptied cement bags, when added to the soil, the engineering properties of the soil are enhanced.

TEST PROCEDURE

The test procedure involves determination of engineering properties of soil with and without using the emptied cement bags. After determining the basic soil properties, to reinforce the soil (sand) an emptied cement bag has to be sandwiched in between soil and again tested to determine its engineering properties like shear strength and CBR value. While determining the CBR value of soil reinforced with emptied cement bag, it is very important to place the polypropylene material at an optimum position. For this purpose, two trials have been made. In the first trial the emptied cement bag is placed at a distance of H/2 from the top of the soil. In the second trial the emptied cement bag is placed at a distance of H/3 from the top of the soil and then both the cases are compared. The polypropylene material has to be placed, where the intensity of stress is maximum, such that the load carrying capacity of the soil is increased to maximum extent and the tensile strength of the polypropylene material is effectively used.

In the second stage, stabilization of cohesive soil is done by adding the deteriorated polypropylene fibres of an emptied cement bag in various contents of 2%, 4%, 6% and 8%. After adding the deteriorated emptied cement bag fibres in soil, it is tested for its engineering properties like compressive strength and shear strength.

RESULTS AND DISCUSSION

Enhancement in engineering properties of cohesionless soil: Figs. 1- 4 show the results of the tests done. After completion of tests on the cohesionless soil, it was observed that the engineering properties of soil have been enhanced when an emptied cement bag is used for the reinforcement of soil. Table 6 shows the variation in the engineering properties of soil when it is tested with and without placing an emptied cement bag for reinforcement. The optimum position to place polypropylene material can be determined by the obtained results. It is very important that the soil does not fail before the failure of the polypropylene material. If the soil fails before the failure of the reinforcing material, it indicates that the tensile strength of the reinforcing material is not effectively utilized. The load carrying capacity of the soil will be maximum if the tensile strength of the reinforcing material is utilized to the maximum extent.

The CBR value of soil reinforced with emptied cement bag is higher when compared with the CBR value of soil alone. After the test, the cement bag placed in the test was removed and it was observed that there was no sign of any damage to the material. This generally indicates that the soil has failed before the failure of the polypropylene material. Hence, placing of polypropylene material at a distance of H/2 from top surface of soil is not optimum. Then the polypropylene material is placed at a distance of H/3 from top of the soil, so that the tensile strength of the polypropylene material is effectively utilised by the soil for the loads coming upon it (Fig. 5).

From Table 6 and Fig. 6, it can be observed that the CBR value increases when an emptied cement bag is placed at a distance of H/2. It further increases when it is placed at a distance of H/3. As the depth of the soil increases, the intensity of stress due to the load on the soil decreases. Therefore, it is better to place the reinforcing material towards the top surface of the soil, where the stress intensity is maximum, and by which the tensile strength of the emptied cement bag can be effectively utilized. Hence, it can be said that the load carrying capacity of soil will be increased when emptied cement bag is used as an alternative to geosynthetic material for soil reinforcement.

It is expected that the load carrying capacity of the soil further increases if the polypropylene material is placed in two layers along the depth of the soil, one at a distance of H/2 and the other at a distance of H/3 from the top surface of

Table 6: Comparison of engineering properties of soil when reinforced with an emptied cement bag.

Property of soil without reinforcement	Value	Property of soil with reinforcement	Value
Angle of friction	36°	Angle of friction, when emptied cement bag placed at centre	42°
Shear strength	71 kPa	Shear strength, when emptied cement bag placed at centre	88 kPa
CBR value @ 2.5 mm and 5 mm	22.4%	CBR value @ 2.5 mm and 5 mm	44.3%
Penetration	27.8%	Penetration, when emptied cement bag placed at a distance of H/2 from top	56.7%
		CBR value @ 2.5 mm and 5 mm	48.2%
		Penetration, when emptied cement bag placed at a distance of H/3 from top	63.7%

Fig. 1: Placing emptied cement bag for reinforcement of soil.

Fig. 2: Addition of deteriorated emptied cement bag fibres in a definite content for soil stabilization.

Fig. 3: Soil stabilized with deteriorated emptied cement bag fibres tested for compressive strength.

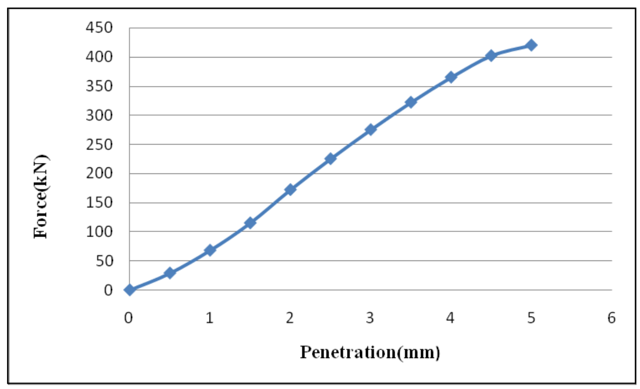

Fig. 4: CBR test curve when cement bag is placed at a distance of H/2 from top.

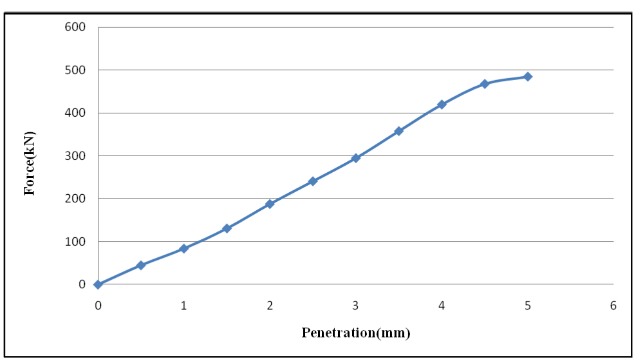

Fig. 5: CBR test curve when cement bag is placed at a distance of H/3 from top.

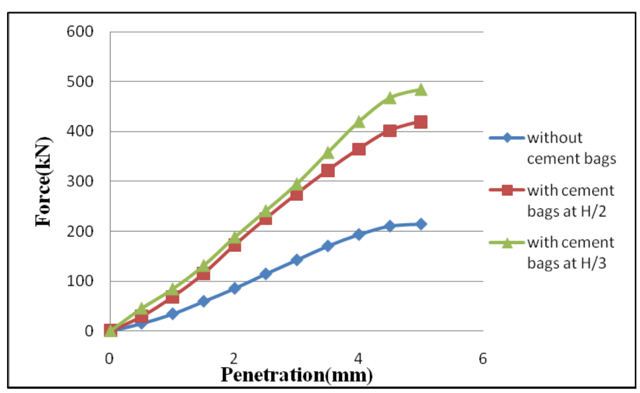

Fig. 6: Comparison of CBR test results with and without cement bags.

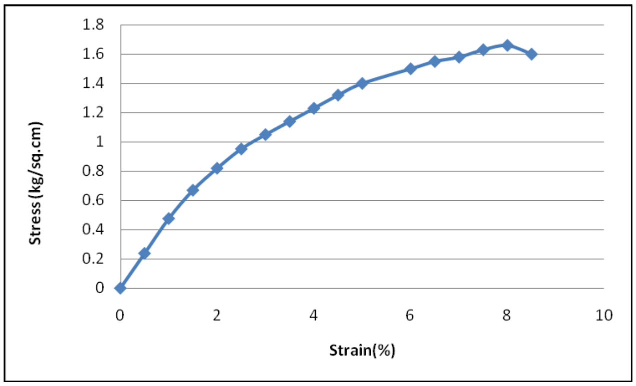

Fig. 7: Stress strain curve for the soil stabilized with 2% of cement bag fibres.

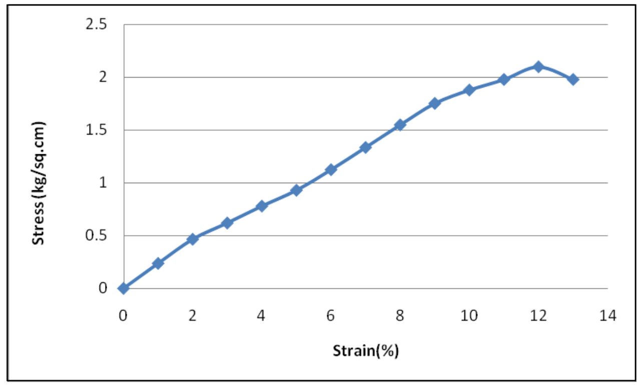

Fig. 8: Stress strain curve for the soil stabilized with 4% of cement bag fibres.

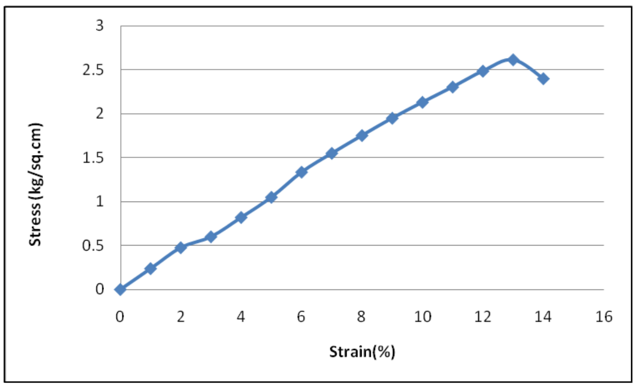

Fig. 9: Stress strain curve for the soil stabilized with 6% of cement bag fibres.

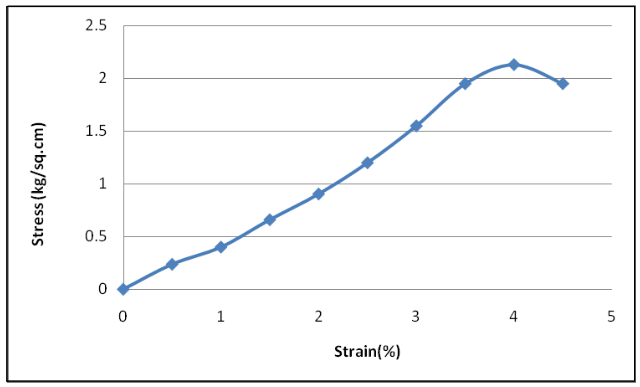

Fig. 10: Stress strain curve for the soil stabilized with 8% of cement bag fibres.

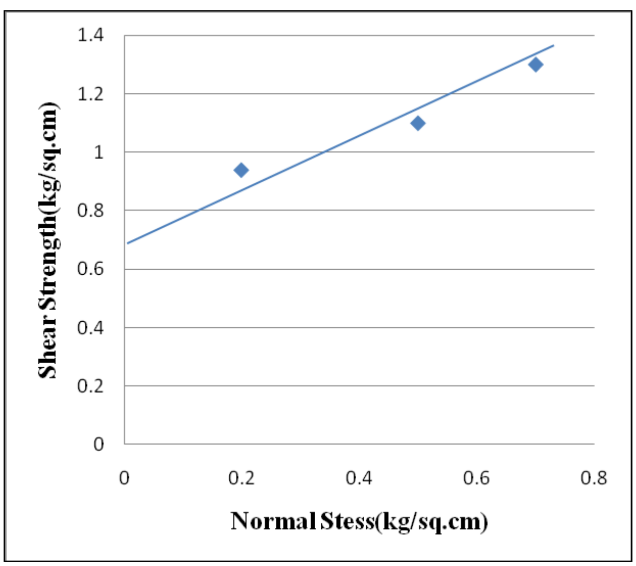

Fig. 11: Failure envelope of soil stabilized with cement bag fibres of 6%.

the soil. Placing the polypropylene material below a distance of H/2 from the top of the soil would not be effective as the intensity of stress at that depth is very low.

Enhancement in engineering properties of cohesive soil: After determining the properties of cohesive soil, various laboratory tests were conducted on cohesive soil by adding the deteriorated emptied cement bag fibres in it, in various percentage contents (2%, 4%, 6% , 8%). The shear strength and unconfined compressive strength of the cohesive soil are compared, when the deteriorated emptied cement bag fibres are added in it at various percentage contents and the optimum percentage content added in soil for stabilization is determined.

Figs. 7-10 show the stress strain characteristics of the soil when stabilized with deteriorated emptied cement bag fibres.

From the figures, it is clear that as the amount of deteriorated emptied cement bag fibres mixed in the soil increases, the compressive strength of the soil also increases. The

Table 7: Results of tests conducted on soil using emptied cement bag.

Percentage of deteriorated emptied cement bag	Property of the soil	Value
2%	Unconfined compressive strength	162.6 kPa
4%	Unconfined compressive strength	205.8 kPa
6%	Unconfined compressive strength	254.8 kPa
8%	Unconfined compressive strength	206.4 kPa

compressive strength of the soil continuously increased when cement bag fibres are added up to 6% of the total soil content. On further addition of cement bag fibres i.e., 8% of the total soil content, the compressive strength of the soil is decreased. This is because of reduction in content of soil. To verify this, a direct shear test is conducted on the same soil by adding 6% emptied cement bag fibres of the total content of soil.

Fig. 11 clearly shows that there in an enhancement in shear strength parameters of the soil when it is stabilized with cement bag fibres.

Table 7 shows the compressive strength and undrained shear strength of the soil, when stabilized with deteriorated emptied cement bag fibres adding in various percentage contents in the soil.

As the fibre content increased, the unconfined compressive strength was also increased. Therefore, the results indicate that stabilization of expansive soils with emptied cement bag fibres is an effective method.

CONCLUSION

As the geosynthetics are not economical, emptied cement bags can be used as an alternative for reinforcement and stabilization of the soil. Various tests were conducted on cohesionless soils using emptied cement bags as a reinforcing material and the load bearing capacity of the soil is found to be increased. CBR test is conducted using emptied cement bag at a distance of H/2 and H/3. At a distance of H/3 the strength is found to be maximum. So, the effective position of placing emptied cement bag is at a distance of H/3 from the top. It is found that the engineering properties of the soil are enhanced when an emptied cement bags are used.

A deteriorated emptied cement bag fibre is used for stabilization of cohesive soil. It is found that the engineering properties of the cohesive soil are increased when an emptied cement bag is used as a stabilizing material. As the fibre content was increased up to 6% of content of soil, the unconfined compressive strength was increased. On further increase of cement bag fibre content, the strength of soil has been decreased. Hence, the optimum content that can be added for stabilization of soil is 6% of its mass. This proves that emptied cement bags can be used both for reinforcement and stabilization of different soils.

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