SOIL STABILIZATION USING WASTE FIBER MATERIALS

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ABSTRACT

The main objective of this study is to investigate the use of waste fiber materials in geotechnical applications and to evaluate the effects of waste polypropylene fibers on shear strength of unsaturated soil by carrying out direct shear tests and unconfined compression tests on two different soil samples. The results obtained are compared for the two samples and inferences are drawn towards the usability and effectiveness of fiber reinforcement as a replacement for deep foundation or raft foundation, as a cost effective approach. So it can be used for the alternative method where its important will be counted and stabilization of soil is the best place where this material can be used up. Therefore, the quantity of waste plastic fiber that is being currently reused or recycled is only a fraction of the total volume produced every year. A treated or stronger sub grade soils shall require relatively thinner section of a flexible pavement as compared to that of an untreated and weaker sub-grade resulting in significant cost advantage. However; in certain cases; especially for low cost embankment/road construction, their cost becomes a prohibitive factor for their wide spread use.

Key words; soil stabilization, plastic fibers, methods of stabilization

INTRODUCTION

With the growth of cities and industrial areas, the availability of land for construction with sufficient bearing capacity and settlement within permissible limit becomes depleted. The geotechnical engineers have been forced to construct at given site with given soil condition. Most developed and developing countries all over the world have huge resources of waste materials such as waste plastic. The growing interest in utilizing waste materials in civil engineering applications has opened the possibility of constructing reinforced soil structure with unconventional backfills, such as waste plastics fibres. Many highway agencies, private organizations and researchers are doing extensive studies on waste materials and research projects concerning the feasibility and environmental suitability. Commonly, gravel is considered to be suitable for road construction. However, in the latest MORTH specifications, several types of gravel are found to be unsuitable for road construction in view of higher finer fraction and excessive plasticity properties. In recent years applications of nontraditional materials either natural or waste products have been tried in road construction in many developing countries. Preliminary experiments show that addition of plastic waste fibres lead to an improvement in strength response and there is a need to do detailed studies in this direction. Randomly reinforcing the soil by using waste plastic fibres obtained from waste plastic bottles and polymer fibre may provide an easy and an economical means to improve the engineering performance of existing soil. Therefore, in the present investigation an attempt has been made to demonstrate the potential of waste plastic fibres as soil reinforcement for improving the subgrade soils. It is the fact that we can reuse the plastic and make it usable for number of times so that its wastage will be reduced remarkably.

For any land-based structure, the foundation is very important and has to be strong to support the entire structure. In order for the foundation to be strong, the soil around it plays a very critical role. So, to work with soils, we need to have proper knowledge about their properties and factors which affect their behavior. The process of soil stabilization helps to achieve the required properties in a soil needed for the construction work.

From the beginning of construction work, the necessity of enhancing soil properties has come to the light. Ancient civilizations of the Chinese, Romans and Incas utilized various methods to improve soil strength etc., some of these methods were so effective that their buildings and roads still exist.

he initial stage of the experimental programme includes the study of the effect of plastic fibre (as reinforcement material) on maximum dry density (MDD) and optimum moisture content (OMC) with different sizes and contents. In this experimental study, raw plastic bottle fibres has been used in three different aspect ratios (AR), i.e. 2 (size=10mm X 5 mm), 4 (size=10mm X 2.5mm) and 8 (size=10 mm X 1.25 mm). These different sizes of plastic strips have been mixed with local sandy-silt soil with clay (Fine Sand = 40.15%, Silt = 30.90%, and Clay = 28.95%) in four different percentages 0.00, 0.25, 0.50 and 1.00% by dry weight of the soil. From the experimental study on remolded fibre reinforced soils, it has found that, compression index (Cc) and coefficient of volume change (mv) values decreases with the increase of fibres in soil from upto 0.50%, but values increases with further increase of plastic fibres upto 1.00% in soil. 90% of total compression takes place within 96 seconds for 800 kN/m2 load with the inclusion of the plastic fibres in soil with aspect ratio 8 and fibre content of 1.00%.

LITERATURE REVIEW

Soil stabilization is the process of altering some soil properties by different methods, mechanical or chemical in order to produce an improved soil material which has all the desired engineering properties.

Soils are generally stabilized to increase their strength and durability or to prevent erosion and dust formation in soils. The main aim is the creation of a soil material or system that will hold under the design use conditions and for the designed life of the engineering project. The properties of soil vary a great deal at different places or in certain cases even at one place; the success of soil stabilization depends on soil testing. Various methods are employed to stabilize soil and the method should be verified in the lab with the soil material before applying it on the field.

Principles of Soil Stabilization:

- Evaluating the soil properties of the area under consideration.
- Deciding the property of soil which needs to be altered to get the design value and choose the effective and economical method for stabilization.
- Designing the Stabilized soil mix sample and testing it in the lab for intended stability and durability values.

2.1.2 Needs & Advantages

Soil properties vary a great deal and construction of structures depends a lot on the bearing capacity of the soil, hence, we need to stabilize the soil which makes it easier to predict the load bearing capacity of the soil and even improve the load bearing capacity. The gradation of the soil is also a very important property to keep in mind while working with soils. The soils may be well-graded which is desirable as it has less number of voids or uniformly graded which though sounds stable but has more voids. Thus, it is better to mix different types of soils together to improve the soil strength properties. It is very expensive to replace the inferior soil entirely soil and hence, soil stabilization is the thing to look for in these cases. [9]

- It improves the strength of the soil, thus, increasing the soil bearing capacity.
- It is more economical both in terms of cost and energy to increase the bearing capacity of the soil rather than going for deep foundation or raft foundation.
- It is also used to provide more stability to the soil in slopes or other such places.
- Sometimes soil stabilization is also used to prevent soil erosion or formation of dust, which is very useful especially in dry and arid weather.
- Stabilization is also done for soil water-proofing; this prevents water from entering into the soil and hence helps the soil from losing its strength.
- It helps in reducing the soil volume change due to change in temperature or moisture content.
- Stabilization improves the workability and the durability of the soil.

Soil properties

1) Shrinkage Limit:

This limit is achieved when further loss of water from the soil does not reduce the volume of the soil. It can be more accurately defined as the lowest water content at which the soil can still be completely saturated. It is denoted by *wS*.

2) Plastic Limit:

This limit lies between the plastic and semi-solid state of the soil. It is determined by rolling out a thread of the soil on a flat surface which is non-porous. It is the minimum water content at which the soil just begins to crumble while rolling into a thread of approximately 3mm diameter. Plastic limit is denoted by *wP*.

3) Liquid Limit:

It is the water content of the soil between the liquid state and plastic state of the soil. It can be defined as the minimum water content at which the soil, though in liquid state, shows small shearing strength against flowing. It is measured by the Casagrande's apparatus and is denoted by *wL*.

EXPERIMENTAL INVESTIGATIONS

The experimental work consists of the following steps:

1. Specific gravity of soil
2. Determination of soil index properties (Atterberg Limits)
   i) Liquid limit by Casagrande's apparatus
   ii) Plastic limit
3. Particle size distribution by sieve analysis
4. Determination of the maximum dry density (MDD) and the corresponding optimum moisture content (OMC) of the soil by Proctor compaction test
5. Preparation of reinforced soil samples.
6. Determination of the shear strength by:
   i) Direct shear test (DST)
   ii) Unconfined compression test (UCS).

Index and strength parameters of PP-fiber

Behavior parameters	Values
Fiber type	Single fiber
Unit weight	0.91 g/cm^3
Average diameter	0.034 mm
Average length	12 mm
Breaking tensile strength	350 MPa
Modulus of elasticity	3500 MPa
Fusion point	165 °C
Burning point	590 °C
Acid and alkali resistance	Very good
Dispersibility	Excellent

Preparation of samples

Following steps are carried out while mixing the fiber to the soil-

- All the soil samples are compacted at their respective maximum dry density (MDD) and optimum moisture content (OMC), corresponding to the standard proctor compaction tests
- Content of fiber in the soils is herein decided by the following equation:

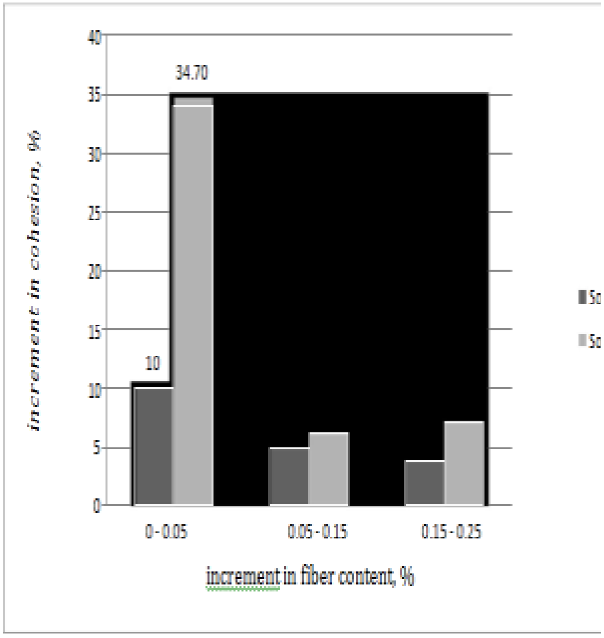
$$\rho_f = \frac{W_f}{W}$$

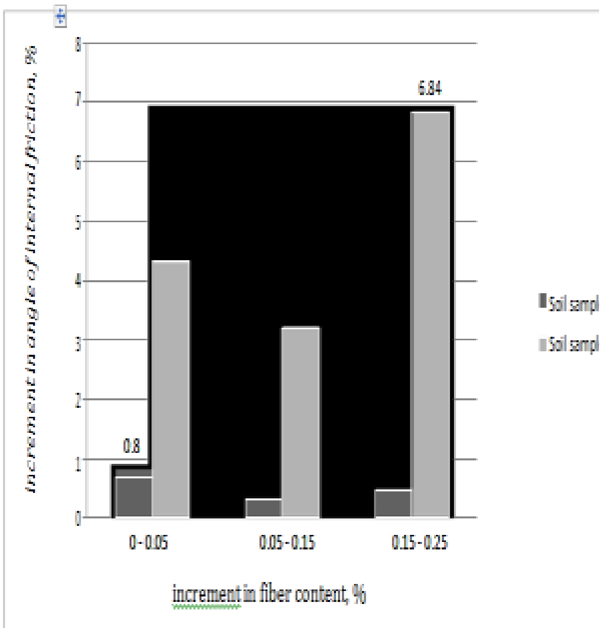
Where, ρf= ratio of fiber content
Wf = weight of the fiber
W = weight of the air-dried soil

- The different values adopted in the present study for the percentage of fiber reinforcement are 0, 0.05, 0.15, and 0.25.
- In the preparation of samples, if fiber is not used then, the air-dried soil was mixed with an amount of water that depends on the OMC of the soil.
- If fiber reinforcement was used, the adopted content of fibers was first mixed into the air-dried soil in small increments by hand, making sure that all the fibers were mixed thoroughly, so that a fairly homogenous mixture is obtained, and then the required water was added.

RESULTS & DISCUSSIONS

Comparison of shear parameters between soil sample- 1 and soil sample- 2





4.7.2 Inferences from Unconfined Compression Test

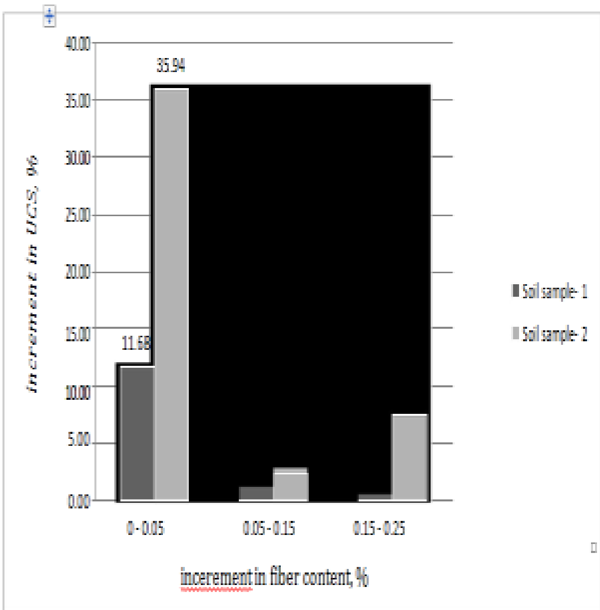
Soil sample- 1

- UCS value increases from 0.0643 MPa to 0.0562 MPa, a net **14.4%**
- The slope of increment graph is continuously decreasing with an initially steep slope

Soil sample- 2

- UCS value increases from 0.0692 MPa to 0.1037 MPa, a net **49.8%**
- The slope of the increment graph varies with alternate rise and fall

Comparison between soil sample-1 and soil sample- 2 for UCS



CONCLUSIONS

On the basis of present experimental study, the following conclusions are drawn:

1. Based on direct shear test on soil sample- 1, with fiber reinforcement of 0.05%, 0.15% and 0.25%, the increase in cohesion was found to be 10%, 4.8% and 3.73% respectively (illustrated in figure-25). The increase in the internal angle of friction (φ) was found to be 0.8%, 0.31% and 0. 47% respectively (illustrated in figure-27). Since the net increase in the values of c and φ were observed to be 19.6%, from 0.325 kg/cm2 to 0.3887 kg/cm2 and 1.59%, from 47.72 to 48.483 degrees respectively, for such a soil, randomly distributed

polypropylene fiber reinforcement is not recommended.

2. The results from the UCS test for soil sample- 1 are also similar, for reinforcements of 0.05%, 0.15% and 0.25%, the increase in unconfined compressive strength from the initial value are 11.68%, 1.26% and 0.62% respectively (illustrated in figure-29). This increment is not substantial and applying it for soils similar to soil sample-1 is not effective.
3. The shear strength parameters of soil sample- 2 were determined by direct shear test. Figure- 26 illustrates that the increase in the value of cohesion for fiber reinforcement of 0.05%, 0.15% and 0.25% are 34.7%, 6.09% and 7.07% respectively. Figure 27 illustrates that the increase in the internal angle of friction (φ) was found to be 0.8%, 0.31% and 0. 47% respectively. Thus, a net increase in the values of c and φ were observed to be 53%, from 0.3513 kg/cm^2 to 0.5375 kg/cm^2 and 15.02%, from 27.82 to 32 degrees. Therefore, the use of polypropylene fiber as reinforcement for soils like soil sample- 2 is recommended.
4. On comparing the results from UCS test of soil sample- 2, it is found that the values of unconfined compressive strength shows a net increment of 49.8% from 0.0692 MPa to 0.1037 MPa (illustrated in figure- 30). This also supports the previous conclusion that use of polypropylene fibers for reinforcing soils like soil sample- 2 is recommended.
5. Overall it can be concluded that fiber reinforced soil can be considered to be good ground improvement technique specially in engineering projects on weak soils where it can act as a substitute to deep/raft foundations, reducing the cost as well as energy.

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