Evaluation of Laterite Soil Stabilized using Polymer Sack Fibers

Jeeja Menon, M.S. Ravikumar

Abstract*: *Utilization of fibers for soil stabilization is one of the effective and economical methods to enhance the engineering properties of soil. This paper aims to evaluate the potential capability of stabilizing locally available laterite soil with waste polymer sack fibers thereby making it more suitable for the manufacture of compressed stabilized earth block (CSEB). Tests were conducted with Polypropylene (PP) sack fibers of lengths 1cm, 1.5cm, 2cm each of 2mm width in constant fiber - soil ratio of 0.15. The experimental analysis suggests that the optimal aspect ratio is 7.5 and the sack fibers with 1.5cm length and 2mm width were selected as the constituent for developing CSEB. This study also contributes to sustainable construction techniques by utilizing plastic waste for producing building material thereby addressing the current environmental crisis as well.

Index Terms*: *Compressed Stabilized Earth Blocks (CSEB), Polypropylene (PP), Sack Fibers, Aspect ratio.

I. INTRODUCTION

Earthen building materials like compressed stabilized earth blocks (CSEB) are experiencing a renaissance in their applications due to the availability of local soil, cost-effectiveness, low embodied energy and their insulating properties.[11,10]. However, the soil has to be stabilized to enhance its engineering properties before it is utilized to make building materials. Soil stabilization using natural fibers like coconut, sisal and palm has been used from ancient times due to its cost-effectiveness, easy availability and adaptability. However, these fibers proved to be less durable due to their degradability, low tenacity, low strength and resistance to water absorption [21, 10]. Hence the potential of utilizing polymer fibers which possess the properties of high durability, strength, non-degradability and non-corrosiveness are being researched vastly as a stabilizing material in the past few years [2, 10].

Laterite soil which is spread in tropical areas of India and Srilanka possess a unique beautiful color and is widely used to make compressed earth blocks. It normally contains high clay content along with inert particles of silt and sand [1,10]. Due to its high clay content, it has to be stabilized before it is used to make compressed earth blocks. Commonly used stabilizer in CSEB is cement which is an energy intensive as well as greenhouse gas generating material. Hence researches are being conducted to replace cement with less energy intensive and environmental friendly stabilizing material. PET fibers extracted from wastewater bottles and Polypropylene fibers extracted from sacks are less energy intensive materials and researches were conducted to investigate their potential to stabilize laterite soil [10]. It has been found that sack fibers are better stabilizers when compared to bottle stabilizers and the optimum content of sack fibers was determined as 0.15%.[10]. This paper aims to investigate the aspect ratio of sack fibers keeping the content constant at 0.15%. It also investigates the effect of plastic fibers on the O.M.C and M.D.D of laterite soil. Moreover, the use of plastic waste in developing engineering materials will reduce the disposal of this non- biodegradable waste and will also contribute to the solid waste management which is the current environmental crisis throughout the world.

II. LITERATURE REVIEW

A comprehensive review of the past literature reveals that there is a growing interest in the research of soil stabilization techniques for developing stabilized earthen building materials like CSEB. Usage of natural fibers for soil stabilization has been recognized as an effective soil stabilization technique since early civilization [14, 10]. However, in spite of the ecological matrices in favor of natural fibers, researchers are now concentrating on polymer fiber based soil stabilization due to the lower strength and durability of natural fibers. The mostly researched polymer fibers used for soil stabilization are fibers of Polyethylene Terephthalate (PET), Polyvinyl chloride (PVC) and Polypropylene (PP) which can be extracted from waste sacks and water bottles [10]. Consequently, this method will also contribute to the solid waste management which is the current environmental crisis of the world.

Research studies have been reported on the effect of plastic fibers on compressive strength, crack reduction, CBR values, split tensile strength, flexural strength, and permeability of the soil. The studies indicate that incorporation of plastic fibers significantly improves U.C.C and ductility of the soil (10,21,19). U.C.C values are found to increase with an increase in fiber length [6]. Moreover, polymer fibers are effective in regulating plastic shrinkage cracking which is widely evident in members having thick and large areas of exposure [15]. The fibers incorporation can inhibit crack propagation thus avoiding the potential of the rapid deterioration of members [32]. Fiber addition reduced plasticity index of almost all soils indicating the increase in strength of soils. [4, 10]. The Shrinkage limits of the soil increased with the incorporation of fibers indicating the decrease in volume changes [30]. Whereas changes in liquid limit and plastic limit values differ in different

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kind of soils.

From the extensive literature review, it can be concluded that reinforcing soil with waste polymer fibers can replace expensive techniques like geosynthetic soil stabilization which are more popular today. Moreover, this will also contribute to the solution of disposal of non -biodegradable waste and thereby help to conserve the environment which is the need of the day.

III. METHOD AND MATERIALS

A. Method

The virgin soil properties of the locally available laterite soil is determined by conducting various tests like Grain Size Distribution, Atterberg`s Limits, Specific Gravity, Standard Proctor Test, Unconfined Compressive Strength Test. Then the soil is separately mixed with Polypropylene (PP) sack fibers in three lengths 1cm, 1.5cm and 2cm each of 2mm width keeping the fiber content constant as 0.15% of dry soil and various tests are conducted on the stabilized soil. The tests conducted to evaluate the performance of fiber-soil composition are Proctor Compaction Test, Atterberg's Limits, and Unconfined Compressive Strength Test. The optimum aspect ratio of the fibers is determined based on the unconfined compressive strength of the fiber-soil composition and is suggested for the preparation of CSEB.

B. Materials

PP (Sack) Fiber

In this work, the polypropylene (PP) fibers extracted from the sacks of leading cement manufacturer 'Ramco' is used. The surface of the sack was made rough to provide more frictional resistance to fibers. The sack is cut into pieces and is roughened using the machine before it is sliced into lengths of 1cm, 1.5cm, 2cm and each of width.

Fig 1: (a) Cutting machine

Fig 1: (b) Roughening sack Fibers

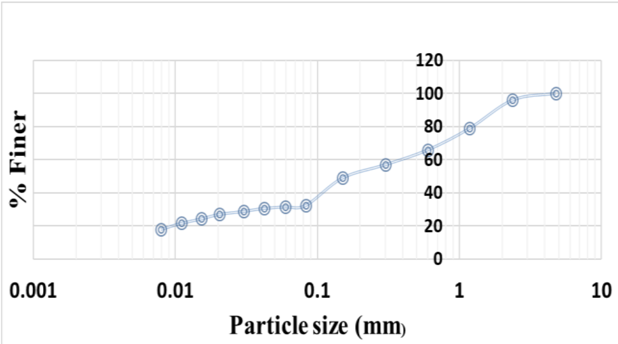
Laterite Soil

In this experiment laterite soil which is classified as clayey silt collected from Perinthalmanna, Kerala, India is used. The soil properties determined are mentioned in Table 1.

Table-1

Natural Water Content (%)	20.4
Specific Gravity	2.56
Optimum Moisture Content (%)	24.02
Maximum Dry Density (g/cc)	1.552
Liquid Limit (%)	57.63
Plastic Limit (%)	38.72
Plasticity Index (%)	18.91
Shrinkage Limit (%)	28.03
Unconfined Compressive Strength (kg/cm2)	0.24
Soil classification	High plasticity
Particle size distribution • Clay (%) • Silt (%)	19.78 28.22

Combined Wet sieve analysis and Hydrometer analysis is used to assess the particle size distribution of soil and is conducted as per [IS 2720 (Part 4) – 1985. The particle size distribution is one of the key factors which decides the performance of soil.



Graph 1: Combined Wet Sieve and Hydrometer graph

The soil was identified as Clayey silt which contains 28.22 % of silt and 19.88% of clay.

IV. TESTING OF FIBER SOIL COMPOSITION

A. Atterberg' s Limits

Atterberg's limits are important to describe the consistency of fine grained soils. The soil consistency is a practical and economical way to distinguish between silty, clayey and sandy soil. Liquid limit and plastic limit is determined by the cone penetration test as per [IS: 2720 (Part 5) -1985]. As the length of sack fiber increases, there is a decrease in the liquid limit & increase in plastic limit up to a fiber length of 1.5cm after which liquid limit increases and P.L decreases. The plasticity index is minimum for soil reinforced with 1.5cm fiber length which implies the strength is maximum at 1.5cm fiber length. Shrinkage limit is conducted as per (IS-2720-PART-1972) (Reaffirmed-2001) and it is an indicator of the tendency of the soil to decrease in volume as water content decreases. As shrinkage limit increases shrinkage decreases. It is

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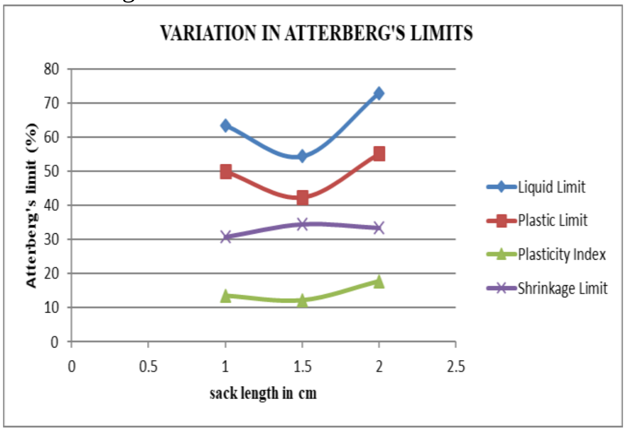
found that shrinkage limit is maximum at a fiber length of 1.5 cm which indicates that shrinkage of the soil is minimum at this fiber length.



Graph 2: Variation in Atterberg's limits

B. Unconfined Compressive Strength Test

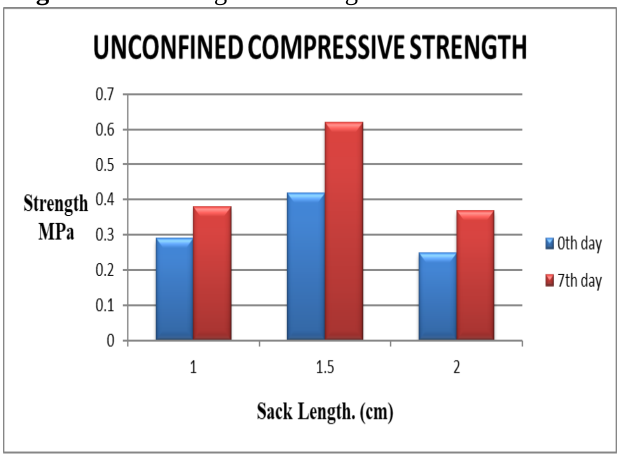
Unconfined compressive strength test is used to measure shear strength of the soil and is conducted as per IS 2710 Part 10. The samples are enveloped in a zip cover and the cover is immersed in water contained in a bucket to prevent the loss of moisture from the sample so that constant temperature and humidity is maintained. The samples are tested at 0^{th} day and 7^{th} day.

Stage 1

Stage 2

Stage 3

Fig 2 Different Stages of Curing

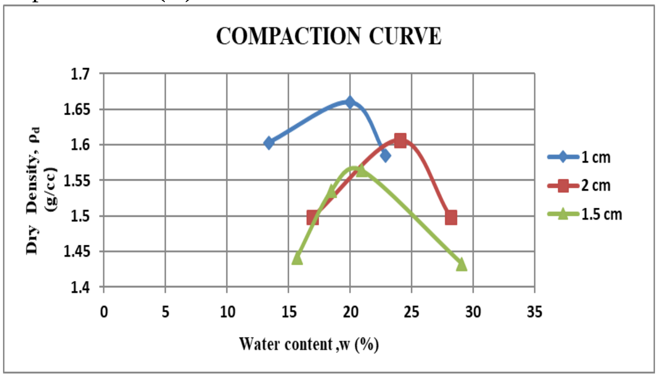


Graph 3: Variation in UCS

The experimental study has provided a good insight into the unconfined strength characteristics of fiber reinforced lateritic soil. The UCS value of fiber reinforced soil has significantly improved and the maximum value was obtained for a fiber length of 1.5 cm which indicates that optimum fiber length is 1.5 cm. The test results also prove that U.C.S value increases as curing days increases.

C. Light Compaction Test

The light compaction test is carried out to determine the optimum moisture content of the fiber soil composition at which it will attain its maximum dry density and is conducted as per IS 2720(X):1991



Graph 4: Variation in OMC & MDD

The variation in OMC is negligible. The optimum moisture content of the soil slightly increases as we increase the sack fiber length, whereas maximum dry density first decreases and then increases.

V. CONCLUSION

The usage of plastic fibers for the stabilization of soil is a recently developed technique which needs research evaluation. This paper reports the strength enhancement of locally available laterite soil using Polypropylene Sack fibers as a stabilizer. Based on the previous studies it was found that the soil stabilized with 0.15% Polypropylene Sack fibers provided better performance. The results obtained in this study provide important insights into the influence of fiber length on Atterberg's limit, unconfined compressive strength and max dry density of fiber reinforced soil. Based on the present investigation, the following findings can be drawn:

- The UCS value of fiber reinforced soil has significantly improved & the UCS value depends on the fiber length
- Max UCS value is for AR 7.5 for both 0^{th} day and 7^{th} day.
- Optimum Moisture Content does not vary much with the addition of plastic fibers and also the effect of fiber length in OMC is negligible.
- The MDD is found to be the min for AR 7.5
- Liquid limit increases with an increase in AR but shows a decrease for AR 7.5
- Plastic Limit also increases with an increase in AR, but there is a sudden decrease for the AR 7.5

- Plasticity Index is minimum for AR 7.5 which implies an increase in strength.

From the above observations, we can conclude that the Optimum Aspect Ratio of polypropylene sack fibers is 7.5. A soil reinforced with fibers of length 1.5 cm and width 2 mm possessed highest unconfined compressive strength and lowest plasticity index which are the indicators of the better performance of reinforced soil and can be used for the preparation of CSEB.

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