Improvement of Black Cotton Soil Using Waste Plastic Bottle Strips

Barnali Ghosh [1]

Abstract

Stabilization of soil can be done in various ways such as mechanical stabilization, chemical stabilization, and by using other improvement techniques. Use and throw plastic becomes a serious issue as it develops man made hazards. One example is that of Mumbai city floods and waste products. The other issue is that plastic lasts in the environment for hundreds of years, hence pollution remains a problem.

Therefore, in the present study, stabilization of soil is done by using locally available plastic waste bottles. These are used in the form of strips by cutting the bottles into strips of six of dimensions 5 mm X 7 mm. Soil samples were collected from Dharwad, Karnataka and their engineering and indexed properties were tested. The soil type used in this project is black cotton soil and it is also known as expansive soil. Testing was done with different plastic waste contents like 0% (without plastic), 2%, 3%, and 5% of weight of dry soil. The main objective of this study was improving properties of soil in an economical way, reducing environmental pollution, and minimizing the problems of plastic waste disposal.

Keywords : **Black cotton soil, plastic waste, shear strength, stabilization**

I. INTRODUCTION

The word plastic has become a part of our day to day life. It is produced throughout the world and its production is more than 150 million tonnes per year worldwide [1]. These days usage of single use plastic and its disposal has raised concerns that single use plastic should be reduced and recycled. According to an American agency, plastic is taking around 20% of total landfill area by volume [2].We can understand that plastic can be reused again and again so that new plastic production can be reduced drastically [3]. Stabilization of soil is done to improve the properties of soil. We have been using traditional materials like cement and lime for soil stabilization for many years. Literature has shown us that waste plastic can be used as a soil stabilizer and as an alternate of traditional materials [1][3] [4]. So, if plastic is used as a stabilizing material for weak soils, we can improve its strength and along with this, recycling plastic can be used in a meaningful, efficient, and cost effective way. In this process, we have used Polyethylene Terephthalate (PET) plastic bottle strips . Investigation has been done to find the effect of plastic bottle strips on Black Cotton soil for which a series of compaction, direct shear, and Unconfined Compression tests have been conducted with different percentages of plastic strips.

II. MATERIALS

A. Black Cotton Soil

It is one of the major soil deposits of India which covers an area of approximately 3,00,500 sq. km. Black cotton soil is clayey in nature and the colour is greyish black. It contains expensive clay mineral such as montmorillonite and exhibits high rate of swelling and shrinkage when in

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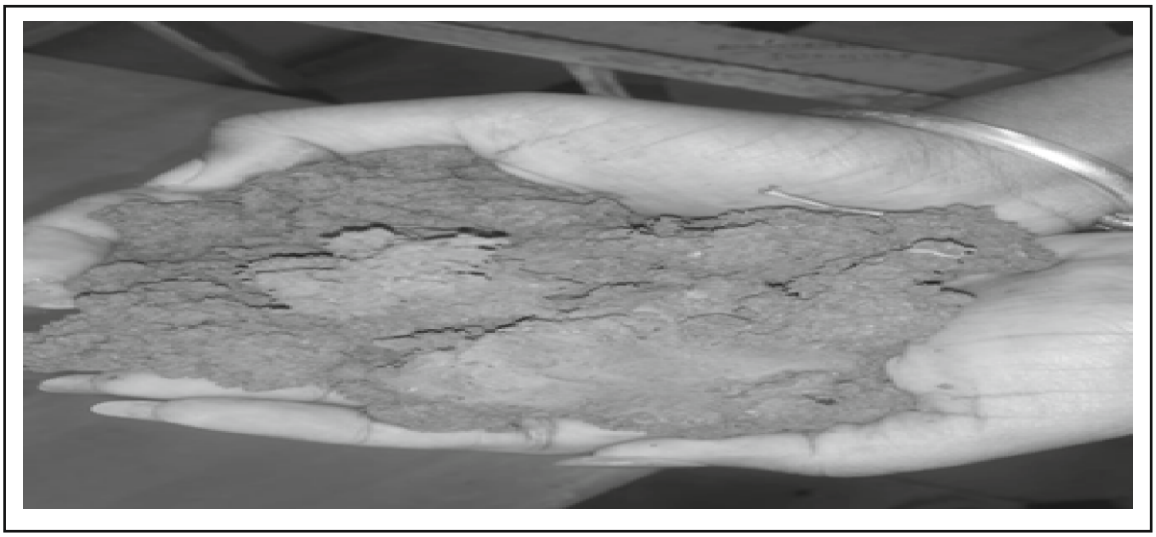

Fig. 1. Black Cotton Soil Collected from Dharwad

contact with water [5]. Due to its unique characteristics, black cotton soil needs stabilization and for the same we have chosen this soil for our analysis. Soil samples are collected from Dharwad and their geotechnical properties and strength characteristics are tested.

B. Plastic Water Bottles

The word plastic describes a huge range of synthetic or semi-synthetic materials that have a wide range of applications. Plastic waste generally includes Polyethylene.

Terephthalate (PET), High Density Polyethylene (HDPE), Low Density Polyethylene (LDPE), Poly Vinyl Chloride (PVC), Poly Propylene (PP), and Polystyrene (PS) [1]. As already mentioned in this study, PET plastic bottle strips are used to improve the engineering properties of soil. Plastic cannot be easily recycled, it can survive for hundreds of years. As plastic has excellent wearing resistance and it has low frictional coefficient, it is considered a better material for stabilization of soil for improvement of the engineering properties of soil. The chemical formula for PET is $(C_{10}H_8O_4)_n$ [1]. In this study, strips of size 5 mm x 7 mm were used.

III. EXPERIMENTAL PROCEDURE

A series of tests with and without plastics were conducted.

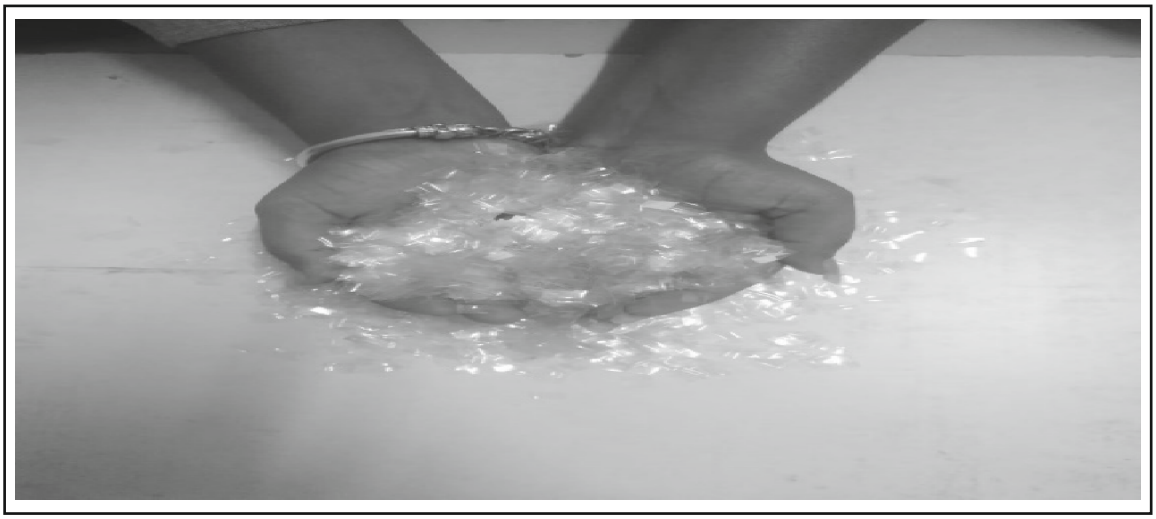

Fig. 2. PET Plastic Bottle Strips

Atterburg limits and sieve analysis were done only for Black cotton soil without plastic as these tests would be difficult with plastic strips. Along with this, standard proctor Compaction Test and Direct shear tests were also conducted with different combination of plastic percentage and without plastic.

A. Specific Gravity and Sieve Analysis

Specific gravity is the ratio of the density of an object and the reference material. Here, calculation for specific gravity was conducted for black cotton soil as per [6] without plastic, black cotton soil with 2%, 3%, and 5% plastic and the results for different plastic proportion were compared.

Sieve analysis is a procedure used to assess the particle size distribution of a material by allowing the material to pass through a series of sieves and weighing the amount of material that is retained on each sieve as a fraction of the whole mass. Sieve analysis is conducted as per [7]only for virgin soil.

B. Atterberg Limits

Atterberg limits are the primary measure of the nature of fine grained soil. Depending on the water content of the soil, it possesses four states, namely solid, semi solid, plastic, and liquid. In each state, the consistency and behavior of a soil is different and also its engineering properties. Liquid limit and plastic limit is conducted as per [8] only for virgin soil without plastic as with plastic strips it is difficult to conduct these tests. It would have been possible only if plastic powder had been mixed with soil. Plasticity index can be found out from liquid limit and plastic limits. Plasticity index has lot of effect on swelling potenti of soil. As Black cotton soil is well known for its swelling characteristics, it is better to get an idea about the swelling potential of the same. Table I shows the relationship between Plasticity Index and Swelling Potential.

TABLE I.

RELATION BETWEEN SWELLING POTENTIAL WITH PLASTICITY INDEX

Plasticity index (PI)	Swelling potential (%)
0–15	Low
10–35	Medium
20–55	High
35 and above	Very High

Source: [9]

C. Standard Proctor Compaction Test

Water content – dry density relation can be obtained from Proctor Compaction Test. Here, a series of tests are done for virgin Black Cotton Soil without plastic, soil reinforced with plastic strips of 2%, 3%, and 5% plastic, and the results for different plastic proportion are compared. Tests are conducted as per [10]. Type of soil tells a lot of things about its maximum dry density and compaction properties. As we know, clays provide greater resistance against compaction and coarse grained soils are generally easy for compaction and achieve higher densities compared to clay.

D. Direct Shear test

Shear strength of soil is the resistance offered by the soil to deformation by shear displacement. There are generally two components known as Cohesion (c) and angle of internal friction (ø) which mostly determine the shear strength of soil. Direct shear tests are conducted as per [11]. In the beginning 2%, 3%, and 5% plastic was taken and mixed properly with the soil till the mixture is homogeneous and then compacted in shear box. The tests were conducted on the samples compacted at optimum moisture content and maximum dry density which we have got from Standard Proctor Compaction Test.

IV. RESULTS AND DISCUSSION

Here, we will be discussing the results of the series of tests we have conducted with virgin Black Cotton soil (without plastic) and soil mixed with different percentage of plastic strips. The results for properties of natural soil obtained from Specific Gravity Test, Standard Proctor Compaction Test, and Direct Shear tTest results are shown in Table II. From the table it is seen that clay particles are more than 55% and classified as silty clay as per IS 1498-1970 soil classification system. Table III shows us the test results with soil mixed with plastic strips (5 mm X 7 mm). Plastic strips are mixed with soil with 2%, 3%, and 5% of weight of dry soil.

According to the values we have got from Table III, it

TABLE II.

PROPERTIES OF BLACK COTTON SOIL WITHOUT PLASTIC STRIPS

S. No.	Property of natural soil		Value
1	Specific Gravity		2.20
2	Particle Size distribution	Gravel (20 – 4.75mm)	0%
		Sand (4.75 – 0.075 mm)	21.5%
		Silt (0.075 – 0.002mm)	33%
		Clay (< 0.002 mm)	55.5%
3	Atterburg Limits	Liquid Limit (LL)	68.6%
		Plastic Limit (PL)	43.2%
		Plasticity Index (PI)	25.4%
4	Compaction Properties	Maximum dry unit weight (MDU)	15.7 KN/m^3
		Optimum moisture content (OMC)	13%
5	Shear strength parameters	Cohesion (C)	21 KN/m^2
		Angle of internal friction (Ø)	18^0

TABLE III.

TEST RESULTS WITH SOIL MIXED WITH PLASTIC STRIPS (5 mm X 7 mm)

S. No.	Plastic content percentage for strip size (5mm X 7mm).	Compaction Parameters		Shear strength parameters	
		OMC (%)	MDD (KN/m^3)	C (KN/m^2)	Ø (^{0})
1	0% (natural soil)	16.2	15.7	21	18
2	2%	15.8	16.1	23.5	25
	* Percentage of increment (%)	–2.47**	2.55	11.90	38.88
3	3%	15.1	16.87	28	28
	*Percentage of increment (%)	–6.79**	7.45	33.33	55.55
4	5%	14	16.3	23.2	31
	*Percentage of increment (%)	–13.58**	3.82	10.48	72.22

*Percentage of increment in the values for different plastic content is compared with that of natural soil

**Negative sign indicates decrement in values

is seen that MDD for soil without plastic is 15.7 KN/m^3. It is increased to 16.1 KN/m^3 with 2% of plastic addition and with 3% of plastic it is increased to 16.87 KN/m^3. With 5% of the plastic it decreased to 16.3 KN/m^3. It is seen that if the plastic content further increases, the MDD decreases. So, it can be said that there is a significant increase in the maximum dry density upto 3% plastic content and after that there is a decrease in MDD, whereas optimum moisture content decreases with the addition of plastic strips. Therefore, we can consider 3% of plastic content as the optimum value. For calculation of the moisture content of soil mixed with plastic, we removed the plastic from the soil before keeping the soil into oven and after this, only dry weight was calculated. So, the soil was kept without plastic strips in the oven. We can understand that there was a decrease of MDD of soil with the increase of plastic strips as proper bonding of soil and plastic was not there.

Direct Shear Test was conducted as per [12] for the soil without plastic and with different percentage of plastic strips. From the results shown in Table III, it is seen that angle of internal friction increases with the increase in percentage of plastic strips. For cohesion till 3% of the plastic content, it increases and after this we can see a reduction in cohesion. So, 3% of the plastic content can be considered as optimum. Shear stress increases as the

plastic pieces are distributed in all the directions. Increase in angle of internal friction may be due to the interlocking between the soil particles and plastic strips. It may be due to the type of the plastic added to the soil also [12]. So, we can conclude that for best results, the soil can be reinforced with plastic strips of prescribed size and it is recommended to use 3% plastic content. Last, when plastic strips are found from from waste plastic and these are used for stabilization of weak soil instead, it is a much expensive conventional material. We can reduce the total cost of soil stabilization and with this, we can get a solution for disposal of harmful plastic waste.

V. SCOPE FOR FUTURE STUDY

The tests were conducted with locally available Black cotton soil, so we cannot comment on the results with other types of soil. Similar tests can be conducted with different types of soil like silty sand etc.

We have used the PET (Polyethylene Terephthalate) type of plastic. Further experiments can be conducted with different types of plastics as well.

The size of the plastic chosen in this paper was 5 mm X 7 mm. Comparison can be done for different sizes of plastic strips.

Further calculation can be done to check cost reduction due to use of waste plastic bottle strips for improvement of soil.

Plastic is generally hydrophobic in nature. This results in poor wettability. Therefore, in future study plastic can be chemically treated and its effect on strength can be found [13].

AUTHOR'S CONTRIBUTION

Barnali Ghosh is the sole author and has performed the entire work described in the paper. She herself has conducted the tests and analyzed the results

CONFLICT OF INTEREST

There is no conflict of interest regarding any involvement of any person and organization.

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