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IMPROVEMENT OF SHEAR STRENGTH IN RED SOIL USING PET BOTTLE STRIPS

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Abstract— **The amount of waste produced has increased year after year, making disposal a major issue. Particularly, the recycling ratio of plastic wastes in life and industry is low, and many of them are reclaimed for the reason that they are unsuitable for incineration. This study demonstrates a simple method of recycling plastic waste as reinforcing material in the field of engineering. Reinforced soil construction is an effective and dependable method for increasing soil strength and stability. The method is used in a wide range of applications, from retaining structures and embankments to subgrade stabilization beneath footings and pavements. This paper describes an experiment in which plastic waste pieces were mixed with two types of soil (clayey soil and sandy soil) at different mixing ratios (0,2,4,6,8) percent by its poundage. The direct shear test was used to investigate the shear strength parameters (cohesion value and angle in inner friction) of reinforced and unreinforced samples for the two types of soils. In addition, a series of compaction tests on red soil mixed with varying percentages of waste pieces were carried out. It was discovered that an increase in internal friction results in a significant improvement in soil strength. It was also discovered that the plastic pieces reduce the maximum dry density of the soil due to their low specific gravity and decreases the optimum moisture content.**

Keywords— **Plastic, PET Bottles, Recycled Aggregates, Bearing Limit, CBR test, Red soil, Shear strength**

I. INTRODUCTION

Nowadays, engineers are forced to use local lands due to a lack of accessibility to lands with adequate bearing capacity for construction. In such cases, soil improvement techniques such as soil reinforcement and soil stabilization performed admirably under a variety of conditions. Soil reinforcement has been accomplished using a variety of methods and materials, including various types of geosynthetics and fibers. Using randomly distributed fiber as reinforcement has at least two advantages. To begin, the discrete fibers are simply added and mixed randomly with soil, much like cement, lime, or other additives.

Second, randomly distributed fibers limit the development of potential planes of weakness parallel to oriented reinforcement. Due to environmental and economic concerns, there is a growing trend toward the use of alternative materials that may meet design specifications. One way to reuse these wastes is to convert them into materials for soil reinforcement and construction applications such as highway base material and retaining wall backfill. The soil that has been reinforced with a waste 4 plastic strip is frequently used in embankment/road construction, resulting in significant cost savings as well as safe disposal of waste materials in an environmentally friendly manner. As a result, many researchers have concentrated on developing suitable methods for reusing waste materials. Plastic wastes are typically high-strength materials with low reactivity to acids and alkalis. Because these wastes are not biodegradable, they remain unchanged for years and pollute the environment. The use of plastic waste, such as tire shreds, to improve the mechanical properties of soil dates back to the 1990s. Many researchers have investigated the engineering properties of plastic waste reinforced soils. Benson and Khire were the first to propose incorporating other plastic wastes into soil. As reinforcing material, they used translucent HDPE milk jugs that were dig strips. Samples were subjected to direct shear tests, and the results revealed that incorporating these wastes into the soil increased the friction angle and shear strength of the sand. Consoli et al. carried out an experiment Uncemented and artificially cemented soil reinforced with polyethylene fibers derived from plastic wastes were studied.

A. *Soil Stabilization*

Soil stabilization is the process of changing some soil properties using mechanical or chemical methods to create an improved soil material with all of the desired engineering properties. Soils are generally stabilized to increase their strength and durability, or to prevent soil erosion and dust formation. The main goal is to create a soil material or system that will hold under the design use conditions and for the engineering projects designed life. Soil properties vary greatly between locations, and in some cases even within the same location; soil testing is critical to the success of soil stabilization. Various techniques are used to stabilize soil and before using it in the field, the method should be tested in the lab with soil material.

Principles of Soil Stabilization:

1) Assessing the soil properties of the area in question.
2) Determining the soil property that needs to be changed in order to obtain the design value and selecting the most effective and cost-effective method of stabilization.
3) Designing the Stabilized soil mix sample and testing it in the lab for intended stability and durability values.

B. Needs and Advantages

Soil properties vary greatly, and structure construction is heavily reliant on the bearing capacity of the soil; thus, we must stabilize the soil to make it easier to predict and even improve the load bearing capacity. When working with soils, it is also critical to consider the gradation of the soil. The soils can be well-graded, which is preferable because it has fewer voids, or uniformly graded, which sounds stable but has more voids. As a result, it is preferable to combine different types of soils to improve soil strength properties. It is prohibitively expensive to replace the inferior soil entirely, and thus, soil properties of strength It is very expensive to completely replace the inferior soil, so soil stabilization is the thing to look for in these cases.

1) It improves soil strength, thereby increasing soil bearing capacity.
2) It is more cost and energy efficient to increase the bearing capacity of the soil rather than use a deep foundation or raft foundation.
3) It is also used to improve soil stability in slopes or other such places.
4) Soil stabilization is sometimes used to prevent soil erosion or dust formation, which is especially useful in dry and arid weather.
5) Soil water-proofing is also accomplished through stabilization; this prevents water from entering the soil and thus aids in the preservation of the soil's strength.
6) It aids in reducing the change in soil volume caused by changes in temperature or moisture content.
7) Stabilization improves the soil's workability and durability.

II. Methods

Surface stabilization refers to the process of improving a situation where the influence zone is less than 1m (roads, for example). In our research, we have focused on two major types of methods.

A. Mechanical Stabilization: Soils of varying gradations are mixed together in this procedure to achieve the desired property in the soil. This can be done on-site or somewhere else where it can be easily transported. The final mixture is then compacted using standard methods to achieve the desired density. The mechanical stability of mixed soil is determined by the following factors.

1) *Mechanical Strength of the Aggregate* — — If the aggregates used are of high strength, the mixed soil is stable. However, if the mixture is properly designed and compacted, even low-strength aggregates can provide good mechanical stability.

2) *Mineral Composition*— The mechanical stability of the mixed soil is determined by the mineral composition. The minerals should be resistant to weather.

3) *Gradation*— To achieve a high density, the gradation of the mixed soil should be such that the voids of the coarser particles are filled with finer particles.

4) *Plasticity Characteristics*— Highly plastic soils are used as binders in the surfacing of mud roads. They have greater cohesion, moisture retention capacity, and provide a seal against surface water movement downward. Soils with low plasticity should be used for base courses to avoid excessive water accumulation and the resulting loss of strength. The soil on-site is unlikely to meet both requirements. To achieve the desired mix, soils from various sources must be mixed.

B. Additive method of stabilization It refers to the incorporation of manufactured products into the soil, which, when done correctly, improves the soil's quality. Chemical additives include materials such as cement, lime, bitumen, fly ash, and others. Different fibers are sometimes used as soil reinforcements. There are two methods for incorporating these fibers. The adding to the fibers takes action by various methods.

1) *Oriented fiber reinforcement* - The fibers are arranged in some order, and all of them are oriented in the same direction. In this orientation, the fibers are laid down layer by layer. In this type of arrangement, continuous fibers in the form of sheets, strips, or bars, for example, are used systematically.

2) *Random fiber reinforcement*- In this arrangement, discrete fibers are distributed randomly throughout the soil mass. The soil and reinforcement are mixed until they form a more or less homogeneous mixture. The materials used in this type of reinforcement are typically made of paper, nylon, metals, or other materials with varying physical properties. Randomly distributed fibers have some advantages over systematically distributed fibers. In some ways, this method of reinforcement is similar to the addition of admixtures such as cement, lime, and so on. This method, in addition to being simple

to add and mix, provides strength isotropy, reduces the likelihood of potential weak planes that occur in the other case, and provides ductility to the soil.

III. Soil Properties Analysis and Methods

A. *Specific gravity:* This test was carried out in accordance with the IS code: 2720 (part 3, section 1) – 1980. As shown in the figure, a density bottle is used to conduct a specific gravity test. Using a density bottle, the following formula is used to calculate the specific gravity of fine-grained soil.

B. *Seive Analysis:* In accordance with IS 2720 (Part 4)-1975 A sieve analysis (or gradation test) is a practice or procedure used in civil engineering and chemical engineering to assess the particle size distribution (also known as particle size distribution analysis gradation) Allowing a granular material to pass through a series of sieves with progressively smaller mesh sizes and weighing the amount of material stopped by each sieve as a fraction of the total mass.

C. *Moisture Content:* The soil's Optimum Water Content is the water content at which a maximum dry unit weight can be obtained after a given amount of compaction effort. There would be no voids in the soil with a maximum dry unit weight. If you're trying to compact a hard dry soil to make it more dense, you should wet it first. The OPT is the amount of water in the soil that allows you to compact it the most. If there is too much water, the pore water pressure would be too high during compression to allow it to compact any further. If there is insufficient water, the soil will naturally resist compaction through shear strength, friction, and effective stress.

D. *Atterberg's Limit:* The Atterberg limits are a basic measure of a fine-grained soil's critical water content: its plastic limit and liquid limit. The water content at which soils transition from one state to another is referred to as the consistency limit or Atterberg's limit.

1) *Shrinkage Limit:* This limit is reached when additional water loss from the soil does not reduce the volume of the soil. It is more precisely defined as the lowest water content at which the soil remains completely saturated. It is denoted by the symbol wS.

2) *Plastic Limit:* This limit is located between the soil's plastic and semi-solid states. It is determined by rolling out a thread of soil on a non-porous flat surface. It is the lowest water content at which the soil begins to crumble while rolling into a thread about 3mm in diameter. wP denotes the plastic limit.

3) *Liquid Limit:* It is the amount of water in the soil that exists between the liquid and plastic states. It is defined as the minimum water content at which the soil, while still liquid, exhibits low shear strength against flowing. It is measured using the Casagrande apparatus and is denoted by the symbol wL.

E. *Compaction Test:* Compaction testing is performed in accordance with IS code: 10074 (1982) using the mini compaction apparatus depicted in the figure. Compaction is defined as the rearrangement of soil particles caused by the application of mechanical energy to soil in order to reduce the void ratio of soil. Highway Compaction testing is critical during the construction of an earthen dam. Using this test, the OMC and MDD of the Red soil without any additives are calculated, and the optimum plastic content of the Red soil with addition of different PET Bottles strips percentages such as 0 percent, 0.25 percent, 0.5 percent, 0.75 percent, and 1.0 percent is determined.

F. *CBR Test:* : As per IS code: Part 16 of 2720 (1979) The California bearing ratio test is a penetration test used to assess the subgrade strength of roads and pavements. The CBR test is performed in a CBR mould with penetrations in the soil specimen. The CBR value is determined by the load corresponding to 2.5mm and 5mm penetration.

IV. Reinforcing Material

1) *Plastic Waste:* Plastics are now ubiquitous in our daily lives. Plastics are used in almost every aspect of manufacturing. Tons of plastic products are molded every day, despite the fact that waste continues to accumulate. Plastic is frequently used as a primary component in everything from water bottles to credit cards to car dashboards. Because most plastics are not biodegradable, an enormous amount of plastic waste continues to accumulate worldwide, with industrialized nations contributing the most plastic waste. Aside from containers, more plastic waste is generated by durable products like furniture and nondurable products like plastic bags. Obviously, the goal is to reduce the overall amount of plastic waste generated. In an ideal world, all plastic produced would be reused, degraded, or reincarnated into another product. We must find a way to reduce the amount of plastic waste produced by either using less plastic in the first place or finding more efficient ways of recycling and reusing plastic products.

2) *Plastic Granules:* Stationery is made from plastic granules. Our organization employs granules that are both long-lasting and cost-effective, and they are used in the production of a variety of stationary items used by ordinary people in their daily lives.

III. LITERATURE REVIEW

A. ***Mercy Joseph Poweth et al*** In 2013, research was conducted on the safe and productive disposal of quarry dust, tyre waste, and wastes-plastic by using them in the subgrade of pavements. In their paper, they conducted a series of CBR and SPT tests to determine the optimal percentages of waste plastics and quarry dust in soil samples. Only quarry dust should be mixed with the soil plastic mix to increase its maximum dry density and suitability for pavement sub grade, according to the results. Tyres alone are insufficient for subgrade. They concluded that mixing soil plastic with quarry dust keeps the CBR value within the required range. The CBR value of a soil tyre mixed with quarry dust is lower than that of a soil plastic quarry dust mix, but it can be used for pavement sub grade.

B. ***Choudhary et al. (2010)*** To improve the engineering performance of sub-grade soil, a new type of plastic strip called reclaimed High Density Polyethylene (HDPE) is introduced and reinforced to locally available sandy soil. Randomly added to the sandy soil are different concentrations of HDPE strips (0.25,0.5, 0.75, 1, 2, and 4%), as well as different lengths and proportions. They also discovered that as the HDPE strip content and size increased, so did the CBR values, resulting in a significant reduction in sub-grade thickness.

C. ***Dr. A.I. Dhatrak et al in 2015*** After reviewing the performance of plastic waste mixed soil as a geotechnical material, it was discovered that using waste plastic bottle chips for the construction of flexible pavement to improve the sub grade soil of the pavement is an alternative method. In his paper, he conducts a series of experiments on soil mixed with various percentages of plastic (0.5 percent, 1 percent, 1.5 percent, 2 percent, and 2.5 percent) to calculate CBR. Based on the results of the experiments, he concludes that using plastic waste strips will improve soil strength and can be used as subgrade. Because there is a scarcity of good quality soil for embankments and fills, it is a cost-effective and environmentally friendly method of disposing of waste plastic.

D. ***Jha and Gill et al in 2010*** HDPE has been shown to have the potential to be used as soil reinforcement by improving the engineering properties of subgrade soil. A series of CBR tests on reinforced soil were carried out using varying percentages of HDPE strips length and proportions obtained from waste plastic and mixed randomly with the soil. The results of CBR tests show that using a strip cut from reclaimed HDPE as soil reinforcement in a highway application is beneficial.

E. ***Rajkumar Nagle et al in 2014*** CBR studies were carried out in order to improve the engineering performance of subgrade soil. As reinforcement, they mixed polyethylene, bottles, food packaging, and shopping bags, among other things, with red, yellow, and sandy soil. According to their findings, the value of MDD and CBR increases as plastic waste increases. The load bearing capacity and settlement characteristics of a selected soil material are also enhanced.

F. ***Achmad Fauzi et al in 2016*** The engineering properties of waste plastic High Density Polyethylene (HDPE) and waste crushed glass as reinforcement for subgrade improvement were calculated. Integrated Electron Microscopy and Energy-Dispersive XRay Spectroscopy were used to investigate the chemical element (SEM-EDS). When the waste HDPE and Glass content was increased, the engineering properties PI, C, OMC values decreased and, MDD, CBR values increased.

G. ***Hatem Nsaif et al in 2013*** By combining plastic waste pieces with two types of soil (clayey soil and sandy soil) at different mixing ratios (0,2,4,6,8) percent by weight, it was discovered that there is a significant improvement in soil strength due to increased internal friction. The percentage increase in angle of internal friction for sandy soil is slightly higher than for clayey soil, but there is no significant difference in cohesion between the two types of soils. It was also determined that the soil's MDD and OMC decreased as a result of the low specific gravity of the plastic pieces.

H. ***Chebet et al in 2014*** carried out laboratory tests to determine the increase in shear strength and bearing capacity of locally available sand caused by random mixing of HDPE (high density polyethylene) material from plastic shopping bags. The improve Strength for the reinforced soil due to tensile stresses mobilised in the reinforcements, according to a visual inspection of the plastic material following tests and analysis. Plastic properties (concentration, length, and width of the strips) and soil properties were identified as factors influencing reinforcement material efficiency (gradation, particle size, shape).

I. ***Tarun Kumar, Suryaketan*** "Behavior of Soil Through Plastic Strip Mixing", International Research Journal Of Engineering & Technology e-ISSN: 2395-0056. This study is being conducted on the development of roadways, which is very important and must be strong enough to support various loads. To meet these challenges, plastic waste is used in the form of strips of varying sizes to identify the required percentage amount of plastic strips and to provide an alternative method of disposing of plastic wastes. To investigate the reinforcing effect of mixed plastic strips in soil, a series of standard proctor and unsoaked strips were used.*CBR tests have been performed, and it has been determined that* the maximum dry density of plastic mix soil decreases with increase of percentage of plastic strips, and for CBR increases with increase of percentage of PET strips within a certain threshold.

J. ***Kiran kumar Patil, Shruti Neeralagi*** "Soil Stabilization Using Plastic Waste," ISSN 2348-7550, Vol. 5, Issue No. 07, July 2017. Soil stabilization is an effective method for improving soil properties. The primary goal of any stabilization technique is to increase the strength and stiffness of the soil, as well as its workability and constructability. Plastic, such as shopping bags, is used to reinforce the soil and improve its various properties. Applications of soil stabilization include increasing soil shear strength, foundation bearing capacity, and improving natural soil subgrade for highway and airport construction. For stabilization, they used plastic bottle strips and plastic bag strips. The study concluded that there is an increase in the CBR value of a soil and that the maximum CBR is achieved when 0.75 percent of plastic bottle strips are added to the soil; further addition of the strips results in a decrease in the CBR value. In the case of plastic bag strips, it was discovered that 2% of the total weight of the soil is the optimum proportion of the strips. We can also conclude from this study that strips cut from plastic bottles are a better option than strips from soil bags for increasing the CBR value of the soil.

K. ***Sharan Veer Singh, Mahabir Dixit***, "Stabilization of Soil Using Waste Plastic Material: A Review," ISSN(Online) 2319-8753, Vol. 6, Issue 2, February 2017. Infrastructure is a significant sector that drives the overall development of the Indian economy. The foundation is the most important part of any structure, and a strong foundation is essential. Expansive soils, such as red soil, cause foundation problems, necessitating soil stabilization. This paper focuses on soil stabilization through the use of plastic waste products. The plastic inclusion can increase the strength of the soil, thereby increasing its soil bearing capacity. The use of plastic waste as reinforcement reduces the waste disposal problem. In India, studies have been conducted to The use of plastic waste as reinforcement reduces the waste disposal problem. In India, studies have been conducted to determine whether these waste materials are suitable for Indian roads Based on these findings, additional research is needed to determine the optimal percentage of plastic waste content.

IV. Materials and Methodology

A. Soil Properties and methodology:

The study was conducted on locally available medium-grained red soil in the Bengaluru region. It had a specific gravity of 2.73 and a maximum particle size of CL-ML was assigned to the soil.

Table I shows the general properties of the collected material, which is red soil.

TABLE I
RED SOIL GENERAL PROPERTIES

Soil Properties	Property values
Area	Bengaluru Urban
Depth	2m
Grain Size Analysis	
Gravel	1%
Sand	28%
Fines (silt + clay)	71%
Index Properties	
Liquid limit	56%
Plastic limit	33.33%
Plasticity index	22.67%
Specific Gravity	2.73
Free Swell index	40
Soil Classification	CH
Engineering Properties	
Optimum Moisture Content (OMC)	13.4%
Maximum Dry Density (MDD)	1.67 kg/m3

B. Reinforcing Materials: PET Plastic Strips

The reinforcement was made up of two kinds of plastic waste. The first (designated as Type I) employed plastic carry bags of LDPE with a mass per unit area of 30gsm and a thickness of 0.05 mm. Strips 12 mm wide were cut from these. These strips were then cut into 24 mm and 12 mm pieces. Strips measuring 24 mm x 12 mm are designated as Type I A, while strips measuring 12 mm x 12 mm are designated as Type I B.

V. RESULT ANALYSIS

A. Specific gravity: The Specific Gravity test values of soil sample are given in the table 5.1

TABLE 5.1
SPECIFIC GRAVITY VALUES

Sample number	Mass of empty bottle (M1) in gm.	Mass of bottle+ dry soil (M2) in gm.	Mass of bottle + dry soil + water (M3) in gm.	Mass of bottle + water (M4) in gm.	specific gravity
1	660	860	1544	1417	2.73
2	660	861	1542	1417	2.75
3	660	860	1539	1416	2.71
Avg. specific gravity					2.73

B. *Seive Analysis:* The Seive Analysis test values of sample are given in Table 5.2 and Fig 1 shows the grain size distribution graph

TABLE 5.2
SEIVE ANALYSIS VALUES

Clay	Slit	Sand	Gravel
37%	26%	37%	0

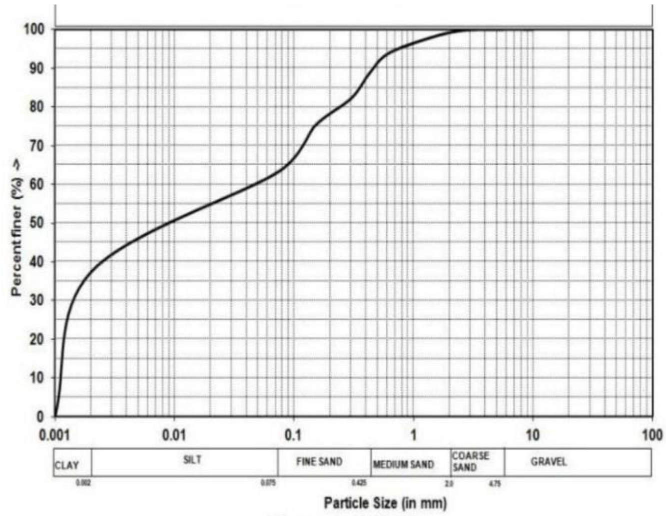


Fig. 1 Grain size distribution graph

C. *Moisture Content:* The Moisture Content test values of soil sample are given in the table 5.3 and Fig 2 shows OMC and MDD graph

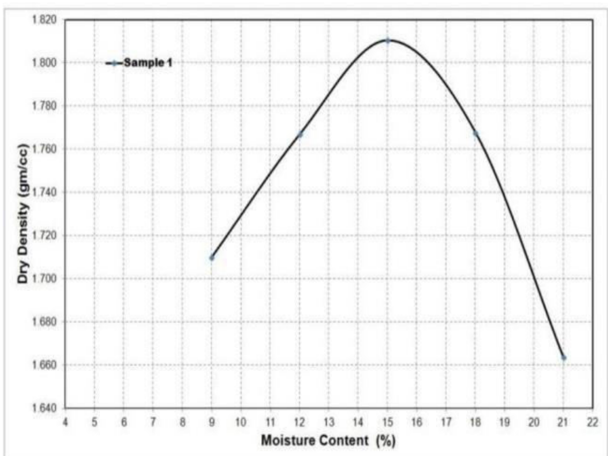


Fig. 2 OMC and MDD graph

D. *Atterberg's Limit:* The result of Atterberg's Limit Analysis is given in Table 5.4

TABLE 5.4
ATTERBERG'S LIMIT VALUES

Parameter	Sample
Plastic Limit	25.5 %
Liquid limit	40 %
Plasticity Index	14.50 %

E. *Compaction Test:* The graphical representation of compaction test with addition of 0% (shown in Fig 3), 0.25% (shown in Fig 4), 0.5% (shown in Fig5), 0.75% (shown in Fig 6), 1.0% (shown in Fig 7) of waste plastic is given in following figures:

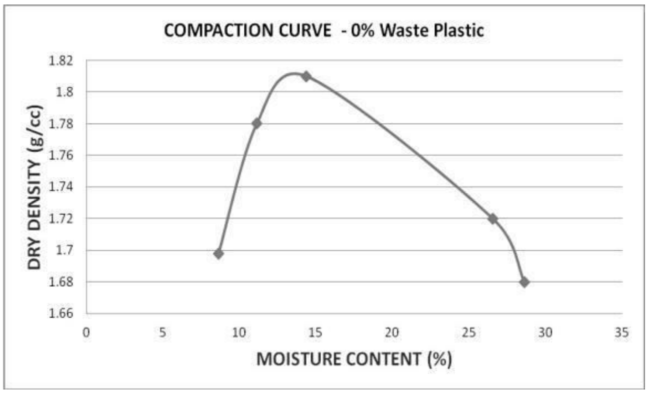


Fig. 3 Compaction curve for soil with 0% plastic

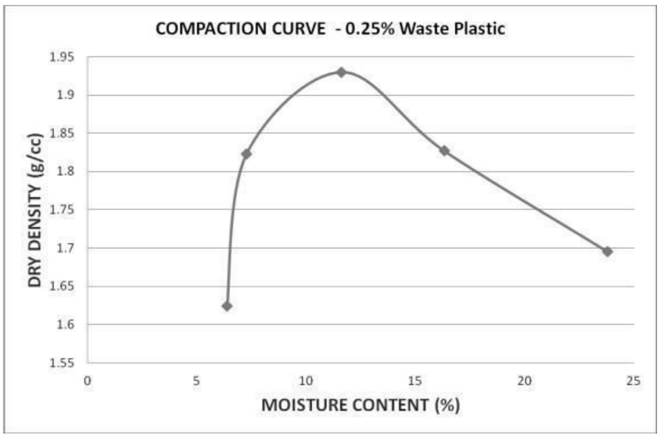
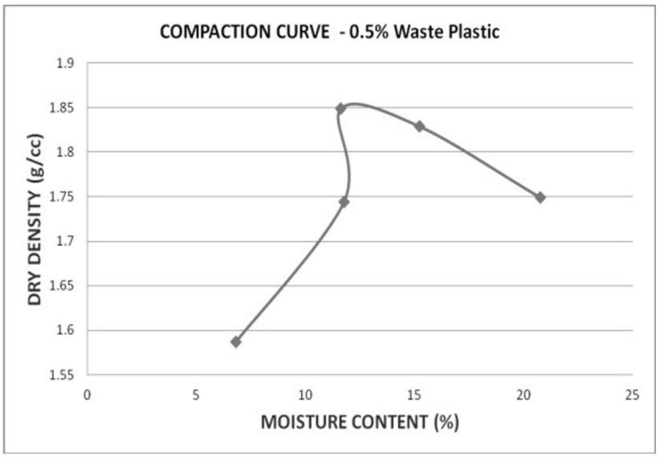


Fig. 4 Compaction curve for 0.25% Waste Plastic



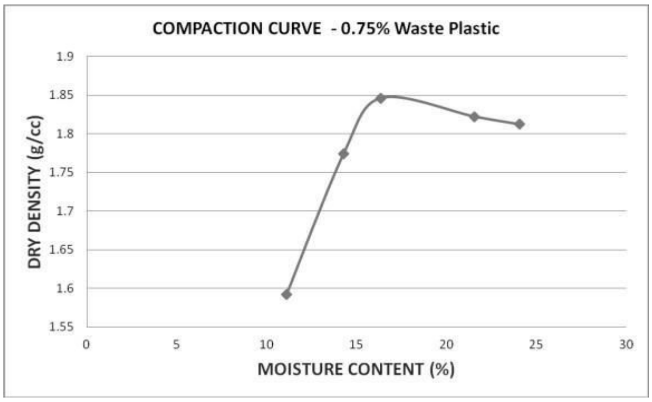


Fig. 5 Compaction curve for 0.5% Waste Plastic

Fig. 6 Compaction curve for 0.75% Waste Plastic

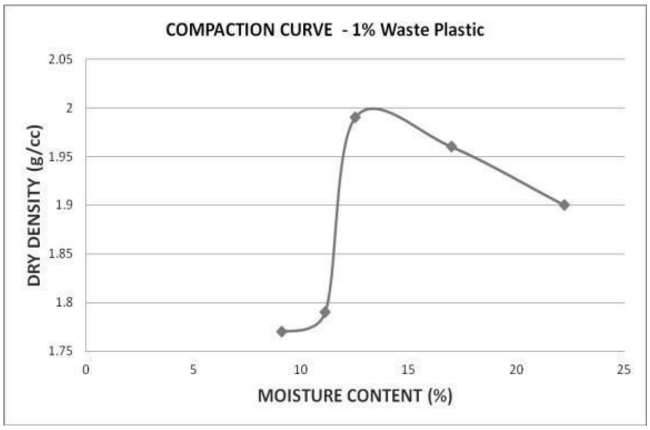


Fig. 7 Compaction curve for 1.0% Waste Plastic

F. *CBR Test:* The graphical representation of CBR test with addition of 0% (shown in fig 8), 0.25% (shown in fig 9), 0.5% (shown in fig 10), 0.75% (shown in fig 11), 1.0% (shown in fig 12) of waste plastic is given in following figures

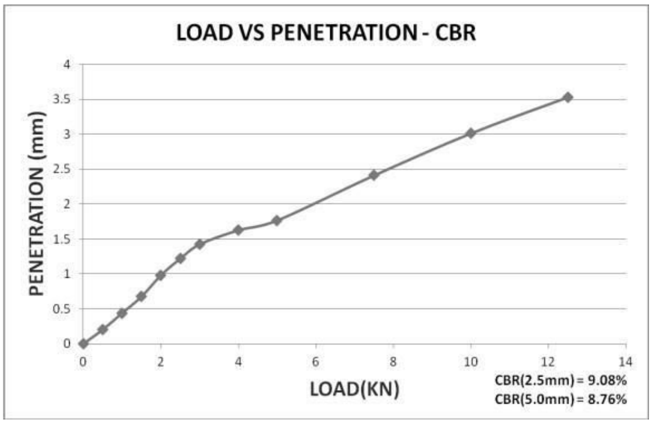


Fig. 8 CBR Test on soil mix with 0 % Waste Plastic

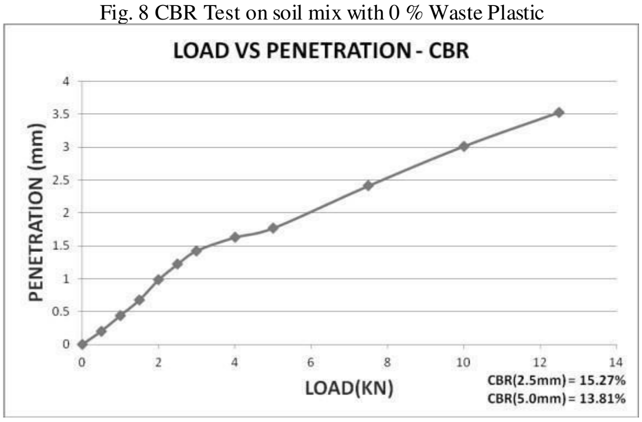


Fig. 9 CBR Test on soil mix with 0.25 % Waste Plastic

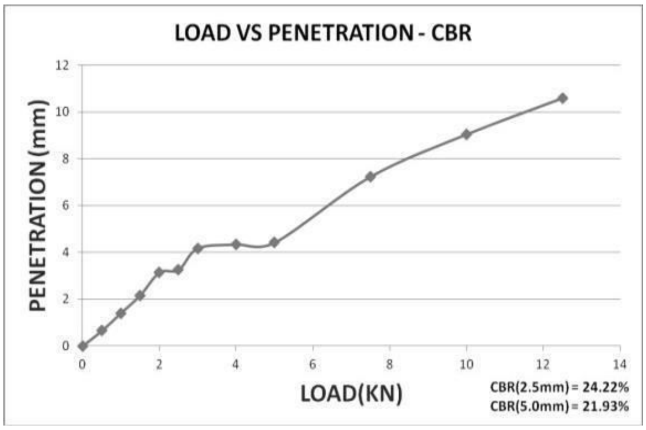


Fig. 10 CBR Test on soil mix with 0.5 % Waste Plastic

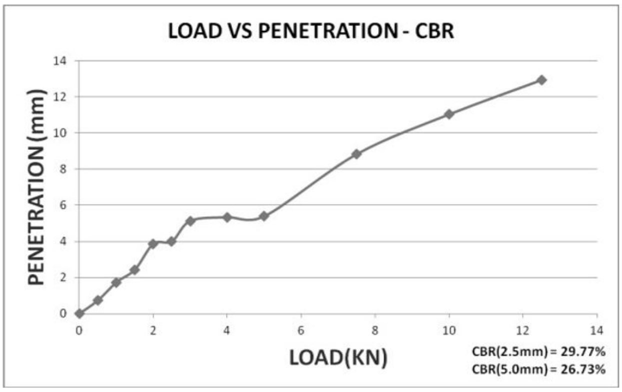


Fig. 11 CBR Test on soil mix with 0.75 % Waste Plastic

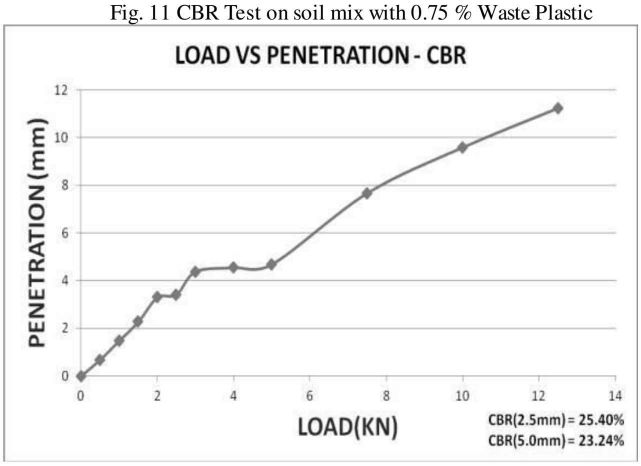


Fig. 12 CBR Test on soil mix with 1.0% Waste Plastic

The CBR value of the soil with 0% waste plastic corresponding to 2.5mm and 5.0mm penetration were found to be 9.08% and 8.75 %, were raised to 15.26% and 13.71 % respectively when waste plastic content was increased with 0.25% waste plastics.The CBR Value for 2.5mm and 5.0mm penetration further increase with the increase of waste plastic content with 0.5%(24.22 %, 21.93 %), 0.75% (29.77 %, 26.73 %). The CBR Value was maximum when the waste plastic content was 0.75%, further increase in waste plastic reduced the CBR value. The CBR values for 2.5mm and 5.0mm for 1% and 1.25% are 1%(25.40 %, 23.24 %) & 1.25%(23.61 %, 21.64 %).

VI. Conclusions

A. General

Use of plastic products such as polythene bags, bottles, containers and packing strips etc. is getting bigger day by day. The throwaway of the plastic waste without being the reason for any hazards to the environment has become a real challenge to the present society. Thus using PET bottles for improving strength is an economical and gainful utilization since there is scarcity of good quality soil for embankments and fills. Thus this project is to meets the challenges of society to reduce the quantities of plastic disposed, producing useful material from non-useful waste materials that lead to the starter of livable place.

1) standard proctor test that the increase in maximum dry density occurs at 0.5% of adding plastic waste and plastic granules.
2) Results by CBR test concludes that the bearing capacity of the soil is increased at 1% of adding plastic waste and plastic granules.
3) Results by UCS test concludes that the Compression strength of the soil is increased at 0.5% of adding plastic waste and plastic granules.

B. Future Scope

1) In future study test can be carried on black cotton soil or on different types of soil.
2) The plastic waste can be replaced by cement, marble polish waste, Fly ash, sand and quarry dust. Plastic granules can be replaced by waste plastic powder, polythene covers.
3) From the above materials, different proportions and combinations can be made which can be used for construction of subgrade and pavements.

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[6] Kumar, M. A., Prasad, D. S. V. and Prasadaraju, G. V. R. Utilization of industrial waste in flexible pavement construction. Electronic Journal ofGeotechnical Engineering, Vol. 13, 2009.Table 1Gravity AnalysisS. No.PropertiesValues1Specific gravity2.662Grain-size Analysis (%)GravelSandSiltClay7.6% 78.6% 10.4%4.5%3Liquid Limit (%)414Plastic Limit (%)195dry density (g/cm4)1.626Moisture content (%)14.00

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