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Soil Stabilization by Using Plastic Waste Granules Materials

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Abstract: *Soil stabilization can be explained as the alteration of the soil properties by chemical or physical means in order to enhance the engineering quality of the soil. The main objectives of the soil stabilization are to increase the bearing capacity of the soil, its resistance to weathering process and soil permeability. which can be done by use of controlled compaction or addition of suitable admixtures like cement, lime and waste materials like fly ash, phosphor gypsum etc. This new technique of soil stabilization can be effectively used to meet the challenges of society, to reduce the quantities of waste, producing useful material from non-useful waste materials. Plastic waste such as bottles and plastic granules is used to as a reinforcement to perform the maximum dry density, CBR, UCS studies while mixing with soil for improving engineering performance of sub grade soil. Plastic waste and plastic granules were mixed randomly with the soil. A series of Standard proctor test, California Bearing Ratio (CBR) tests and Unconfined compression test were carried out on randomly reinforced soil by varying percentage of plastic waste and plastic granules with different sizes and proportions. Results of tests demonstrated that inclusion of waste plastic and plastic granules in soil with appropriate amounts improved strength and deformation behavior of sub grade soils substantially.*

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I. Introduction

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 the behaviour. The process of soil stabilization helps to achieve there quired 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.

In India, the modern era of soil stabilization began in early 1970's, with a general shortage of petroleum and aggregates, it became necessary for the engineers to look at means to improve soil other than replacing the poor soil at the building site. Soil stabilization was used but due to the use of obsolete methods and also due to the absence of proper technique, soil stabilization lost favor. In recent times, with the increase in the demand for infrastructure, raw materials and fuel, soil stabilization has started to take a new shape. With the availability of better research, materials and equipment, it is emerging as a popular and cost-effective method for soil improvement.

Here, in this work, soil stabilization has been done with the help of randomly distributed plastic waste and plastic granules material to improve the shear strength parameters, compaction effect and bearing strength of black cotton soil.

1.1 Soil Stabilization

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.

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.

- 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.

1.3 Methods

Mechanical method of Stabilization

In this procedure, soils of different gradations are mixed together to obtain the desired property in the soil. This may be done at the site or at some other place from where it can be transported easily. The final mixture is then compacted by the usual methods to get the required density.

Additive method of stabilization

It refers to the addition of manufactured products into the soil, which in proper quantities enhances the quality of the soil. Materials such as cement, lime, bitumen, fly ash etc. are used as chemical additives. Sometimes different fibers are also used as reinforcements in the soil. The addition of these fibers takes place by two methods. **Oriented fiber reinforcement**

The fibers are arranged in some order and all the fibers are placed in the same orientation. The fibers are laid layer by layer in this type of orientation. Continuous fibers in the form of sheets, strips or bars etc. are used systematically in this type of arrangement.

(a) Random fiber reinforcement

This arrangement has discrete fibers distributed randomly in the soil mass. The mixing is done until the soil and the reinforcement form a more or less homogeneous mixture. Materials used in this type of reinforcements are generally derived from paper, nylon, metals or other materials having varied physical properties.

Randomly distributed fibers have some advantages over the systematically distributed fibers. Somehow this way of reinforcement is similar to addition of admixtures such as cement, lime etc. Besides being easy to add and mix, this method also offers strength isotropy, decreases chance of potential weak planes which occur in the other case and provides ductility to the soil.

1.4 Soil properties

Atterberg Limits

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 w_P.

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.

1.5 Particle Size Distribution

Soil at any place is composed of particles of a variety of sizes and shapes, sizes ranging from a few microns to a few centimeters are present sometimes in the same soil sample. The distribution of particles of different sizes determines many physical properties of the soil such as its strength, permeability, density etc.

Particle size distribution is found out by two methods, first is sieve analysis which is done for coarse grained soils only and the other method is sedimentation analysis used for fine grained soil sample. Both are followed by plotting the results on a semi-log graph. The percentage finer N as the ordinate and the particle diameter i.e. sieve size as the abscissa on a logarithmic scale. The curve generated from the result gives us an idea of the type and gradation of the soil. If the curve is higher up or is more towards the left, it means that the soil has more representation from the finer particles; if it is towards the right, we can deduce that the soil has more of the coarse grained particles.

The soil may be of two types- well graded or poorly graded (uniformly graded). Well graded soils have particles from all the size ranges in a good amount. On the other hand, it is said to be poorly or uniformly graded if it has particles of some sizes in excess and deficiency of particles of other sizes. Sometimes the curve has a flat portion also which means there is an absence of particles of intermediate size, these soils are also known as gap graded or skip graded.

For analysis of the particle distribution, we sometimes use D10, D30, and D60 etc. terms which represents a size in mm such that 10%, 30% and 60% of particles respectively are finer than that size. The size of D10 also called the effective size or diameter is a very useful data. There is a term called uniformity coefficient Cu which comes from the ratio of D60 and D10, it gives a measure of the range of the particle size of the soil sample.

1.6 Specific gravity

Specific gravity of a substance denotes the number of times that substance is heavier than water. In simpler words we can define it as the ratio between the mass of any substance of a definite volume divided by mass of equal volume of water. In case of soils, specific gravity is the number of times the soil solids are heavier than equal volume of water. Different types of soil have different specific gravities.

1.7 Shear strength

Shearing stresses are induced in a loaded soil and when these stresses reach their limiting value, deformation starts in the soil which leads to failure of the soil mass. The shear strength of a soil is its resistance to the deformation caused by the shear stresses acting on the loaded soil. The shear strength of a soil is one of the most important characteristics. There are several experiments which are used to determine shear strength such as DST or UCS etc.

The shear resistance offered is made up of three parts:

i) The structural resistance to the soil displacement caused due to the soil particles getting interlocked.

ii) The frictional resistance at the contact point of various particles.

iii) Cohesion or adhesion between the surface of the particles.

In case of cohesion less soils, the shear strength is entirely dependent upon the frictional resistance, while in others it comes from the internal friction as well as the cohesion.

Methods for measuring shear strength:

1.8 Direct Shear Test (DST)

This is the most common test used to determine the shear strength of the soil. In this experiment the soil is put inside a shear box closed from all sides and force is applied from one side until the soil fails. The shear stress is calculated by dividing this force with the area of the soil mass. This test can be performed in three conditions- undrained, drained and consolidated undrained depending upon the setup of the experiment.

1.9 Unconfined Compression Test (UCS test)

This test is a specific case of triaxial test where the horizontal forces acting are zero. There is no confining pressure in this test and the soil sample tested is subjected to vertical loading only. The specimen used is cylindrical and is loaded till it fail.

1.10 Reinforcing Materials

1.10.1 Plastic Waste

Plastics currently play a massive role in our daily lives. Plastics are utilized in virtually all areas of manufacturing. Tons and tons of plastic products are molded on a daily basis, even as the waste continues to build up. From water bottles, to credit cards, to the dashboard of a car, plastic is often a primary component. Due to the fact that most plastics are not biodegradable, an enormous sum of plastic waste continues to build up worldwide, with industrialized nations contributing the largest amount of plastic waste.

More specifically, the majority of plastic waste comes from packaging and containers (e.g. shipping materials, shampoo bottles, beverage bottles etc.). Once we've consumed whatever was contained in that plastic, it becomes "waste." As we continue to utilize plastic products, we continue to generate more plastic waste. Our increasing dependence on petroleum products creates a vicious cycle of waste creation, and environmental degradation. In addition to containers, more plastic waste is generated
from durable products, such as furniture, and nondurable products, such as plastic bags. Obviously, the goal is to lower the overall amount of generated plastic waste. In a perfect world, 100% of the plastic generated would simply be reused, degraded, or reincarnated into another product. We must find a way to reduce the amount of plastic waste generated by initially using less, or finding more efficient ways of recycling and reusing plastic products.

1.10.2 **Plastic Granules**

Plastic Granules Used For Stationery. Our organization use granules which are durable and cost effective and used for manufacturing various stationary items used by common people in their daily life.

II. Literature Review

Choudhary, Jha and Gill et al in (2010) demonstrated the potential of HDPE to convert as soil reinforcement by improving engineering properties of sub grade soil. From waste plastic HDPE strips are obtained and mixed randomly with the soil and by varying percentage of HDPE strips length and proportions a series of CBR tests were carried out on reinforced soil. There results of CBR tests proves that inclusion of strip cut from reclaimed HDPE is useful as soil reinforcement in highway application.

Anas Ashraf et al in (2011) studied on the possible use of plastic bottles for soil stabilization. The analysis was done by conducting plate load tests on soil reinforced with layers of plastic bottles filled with sand. The bottles cut to halves placed at middle and one third position of tank. The test results showed that cut bottles placed at middle position were the most efficient in increasing strength of soil.

Hatem Nsaif et al in (2013) concluded by mixing plastic waste pieces with two types of soil (clayey soil and sandy soil) at different mixing ratios (0,2,4,6,8)% by weight respectively that, there is significant improvement in the strength of soils because of increase in internal friction. The percentage of increase in the angle of internal friction for sandy soil is slightly more than that in clayey soil, but there is no significant increase in cohesion for the two types of soils. Also, it was concluded that due to low specific gravity of plastic pieces there is decreases in MDD and OMC of the soil.

Mercy Joseph Poweth et al in (2013) investigated on safe and productive disposal of quarry dust, tyre waste and wastes-plastic by using them in the pavements sub grade. In their paper a series of CBR and SPT test were carried out for finding the optimum percentages of waste plastics, and quarry dust in soil sample. The results shows only quarry dust should be mixed with the soil plastic mix, to increase its maximum dry density and is suitable for pavement sub grade. Tyres alone are not suitable for sub grade. They concluded that Soil plastic mixed with quarry dust maintains the CBR value within the required limit.

S.W. Thakare and S. K. Sonule, et al (2013) carried out various laboratory tests to investigate the effect of reinforcement of sandy soil with model plastic water bottle through model plate load tests. The study showed that the ultimate bearing capacity of footing increases with increasing the layer of plastic bottles as reinforcement. The increase in bearing capacity may be due to the additional confinement to the soil in the vicinity of footing similar to that in case of Geocell. The bearing capacity increases with the increase in width of reinforcement and number of layers. Thus, the use of plastic bottles as reinforcement was recommended to reduce the quantity of plastic waste which creates the disposal problems.

Bala Ramudu Paramkusam et al in (2013) performed an experimental study to investigate the stabilization effect of waste plastic on dry density and CBR behavior of red mud, fly ash and red mud, fly ash mixed with different percentage of waste plastic content. Based on light compaction tests, authors concluded that MDD value of the red mud, fly ash mixed with plastic increases as the waste plastic increases till 2%, further increase in plastic waste reduces the MDD value. OMC value remains same in each case. A marked increase in CBR value was also observed on adding 0.5%, 1.0%, 2.0%, of waste plastic and was found to be decreased after inclusion of 3% and 4%. Increase of CBR value indicates that the thickness of pavement can be reduced by addition of waste plastic content up to 2%.

Chebet et al in (2014) did laboratory investigations to determine the increase in shear strength and bearing capacity of locally available sand due to random mixing of strips of HDPE (high density polyethylene) material from plastic shopping bags. A visual inspection of the plastic material after tests and analysis indicates that the increased strength for the reinforced soil is due to tensile stresses mobilized in the reinforcements. The factors identified to have an influence on the efficiency of reinforcement material were the plastic properties (concentration, length, width of the strips) and the soil properties (gradation, particle size, shape).

Akshat Malhotra and Hadi Ghasemain et al in (2014) studied the effect of HDPE plastic waste on the UCS of soil. In a proportion of 1.5%, 3%, 4.5% and 6% of the weight of dry soil, HDPE plastic (40 micron) waste was added. They concluded that the UCS of black cotton soil increased on addition of plastic waste. When 4.5 % plastic waste mixed with soil strength obtained was 287.32KN/m2 which is maximum because for natural soil it was 71.35KN/m^2.

Rajkumar Nagle et al in (2014) performed CBR studies for improving engineering performance of sub grade soil. They mixed Polyethylene, Bottles, Food packaging and shopping bags etc as reinforcement with black cotton soil, yellow soil and sandy soil. Their study showed that MDD and CBR value increases with increase in plastic waste. Load bearing capacity and settlement characteristics of selected soil material are also improved.

Dr. A.I. Dhatrak et al in (2015) after reviewing performance of plastic waste mixed soil as a geotechnical material, it was observed that for construction of flexible pavement to improve the sub grade soil of pavement using waste plastic bottles chips is an alternative method. In his paper a series of experiments are done on soil mixed with different percentage of plastic (0.5%, 1%, 1.5%, 2 % & 2.5%) to calculate CBR. on the basis of experiments that he concluded using plastic waste strips will improve the soil strength and can be used as sub grade . It is economical and eco-friendly method to dispose waste plastic because there is scarcity of good quality soil for embankments and fills.

Subhash, K. et al in (2016) conducted experimental study on soil stabilization using glass and plastic granules mixed with varying percentage. Modified Proctor tests were carried out to study OMC and CBR. They concluded that there is a decrease in MDD on addition of glass and plastic in varying percentages. The MDD of 1.53 gm/cc was obtained at 6% of glass and plastic. The maximum OMC was obtained as 22.6% at 6% mixing of additive. Further, an increase in the OMC was observed, maximum value of OMC was obtained as 22.6% at 6 % glass and plastic additive with the soil. An increase in the UCS from 0.609 Kg/cm2 to 3.023 Kg/cm2 which is about 5 times as that of virgin soil. Maximum CBR value was 7.14 %, which is 2 times of CBR of virgin soil.

III. Methodology

3.1 Introduction

Laboratory investigations were conducted on the soil specimens in order to study the properties of soil and soil mixed with varying percentage of fiber. The tests were conducted according to Indian standards IS: 2720.

3.2 Soil Properties

The soil is obtained from Rajahmundry, East Godavari district, Different tests were conducted in laboratory on the soil sample obtained to estimate various properties of the soil sample and the properties obtained from the tests conducted can be classified into two categories as follows

- Index Properties
- Engineering Properties

3.3 Index properties

Soil index properties are the properties of soil that indicate the type and conditions of the soil and provide a relationship to structural properties and are used extensively by engineers to discriminate between the different kinds of soil within a broad category.

For example clay will exhibit a wide range of engineering properties depending upon its composition.

Classification tests to determine index properties will provide engineers with valuable information when the results are compared against empirical data relative to the index properties determined. The below are the different index properties of the soil and the respective tests to be done find out their properties. The tests were conducted according to Indian standards **IS: 2720.**

IV. Material Collection

4.1 Soil

The soil used for current study has been taken from Rajahmundry of East Godavari district. It is collected from a depth of 2m. Tests are conducted to determine the index properties, engineering properties as per Indian standards (IS 2720). The soil properties are given in table 4.1

Table 4.1 Soil properties

Area	Ramannapallem
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/m^3

4.2 Reinforcing Materials

The materials used for the present study are plastic waste and plastic granules materials.

4.2.1 Plastic Waste

Table 4.2 Plastic Waste Properties

Material Type	Plastic Waste (bottles)
Size	4.75mm (passing)
Colour	White
Specific Gravity	1.8

4.2 Plastic Granules

Table 4.3 Plastic Granules Properties

Material type	Plastic granules
Size	4.75mm (passing)
Colour	black
Specific gravity	2

Figure-4.1 Plastic Granules

V. Results And Analysis

5.1 Specific Gravity test

The Specific Gravity test values of soil sample are given in the table 5.1

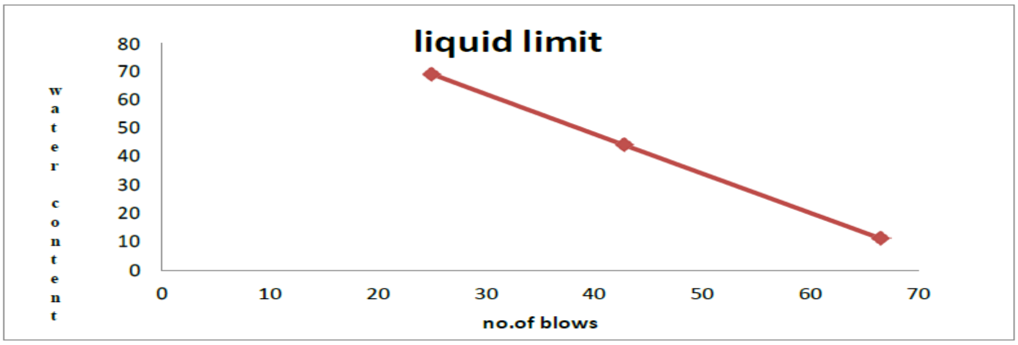
Table-5.1 Specific Gravity values

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

5.2 Liquid Limit test

Table-5.2 Liquid Limit test values

Sample No.	1	2	3
Mass of empty can	36	32	36
Mass of can + wet soil in gm.	46	42	46
Mass of can + dry soil in gm.	44	39	42
Mass of soil solids	8	7	6
Mass of pore water	2	3	4
Water content (%)	25	42.85	66.66
No. of blows	69	44	11



Graph-5.1 liquid limit

- Liquid limit as obtained from graph = **56%**

5.3**Plastic Limit**

Table 5.3 Plastic Limits Valves

Sample No.	**1**
Mass of empty can	36
Mass of (can+ wet soil) in gm.	40
Mass of (can + dry soil) in gm.	39
Mass of soil solids	1
Mass of pore water	3
Water content (%)	33.33

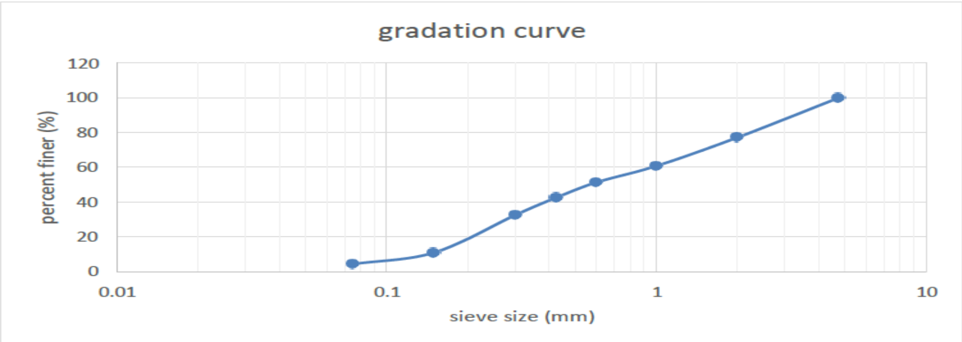
- Plastic limit = **33.33% Plasticity Index**

Ip = WL – WP = 56-33.33 = 22.67%

5.4 Particle Size Distribution

Table-5.4 Particle size distribution

Sieve size	**Retained (g)**	**Retained (%)**	**Cumulative retained (%)**	**Cumulative finer (%)**
4.75mm	0	0	0	100
2mm	114	22.8	22.8	77.2
1mm	82	16.4	39.2	60.8
600microns	47	9.4	48.6	51.4
425microns	44	8.8	57.4	42.6
300microns	50	10	67.4	32.6
150microns	108	21.6	89	11
75microns	33	6.6	95.6	4.4
pan	22	4.4	100	0



Graph-5.2 Particle size distribution

From graph

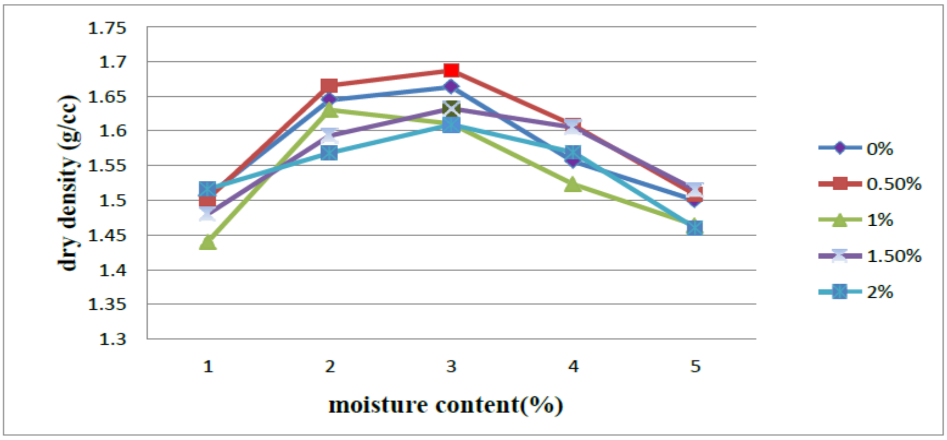
- Coefficient of curvature(cc) = 6.92
- Coefficient of uniformity(cu) = 0.6

5.5 Standard Proctor Compaction Test

Standard Proctor Compaction Test results variation at different Percentage of adding plastic waste and plastic granules.

Table 5.5 Standard Proctor Compaction Test results variation

Test	Dry density	OMC
Soil without adding plastic	1.67g/cm^2	13.4%
Soil adding 0.5% plastic waste	1.73g/cm^2	12.8%
Soil adding 1% plastic waste	1.7 g/cm^2	13%
Soil adding 1.5% plastic waste	1.65 g/cm^2	17.64%
Soil adding 2% plastic waste	1.609 g/cm^2	17.9%



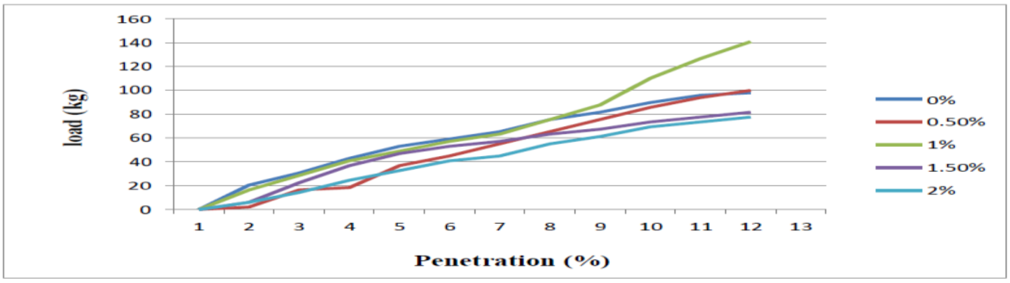
Graph-5.5 Comparison graph between standard proctor test results

5.6 California bearing ratio test (CBR) values

California bearing ratio test (CBR) results variation at different Percentage of adding plastic waste and plastic granules

Table-5.6 California bearing ratio test (CBR) results variation

Test	CBR 2.5mm	CBR 5mm
Soil without adding plastic	4.39	4.04
Soil adding 0.5% plastic waste	3.27	3.67
Soil adding 1% plastic waste	**4.94**	**4.23**
Soil adding 1.5% plastic waste	3.869	3.27
Soil adding 2% plastic waste	2.97	2.97



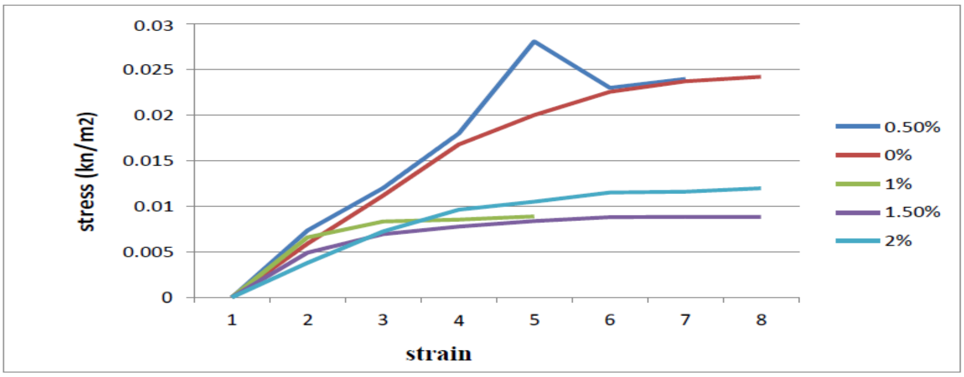
Graph-5.6 California bearing ratio test (CBR) results variation

5.7 Unconfined Compressive Strength of Cohesive Soil

Unconfined Compressive Strength Test results variation at different Percentage of adding plastic waste and plastic granules

Table 5.7 UCS results variation

Test	Compressive stress q_u	Shear strength S
Soil without adding plastic	25.6 kn/m^2	12.18 kn/m^2
Soil adding 0.5% plastic waste	**28.1 kn/m^2**	**14 kn/m^2**
Soil adding 1% plastic waste	8.8 kn/m^2	4.4 kn/m^2
Soil adding 1.5% plastic waste	8.8 kn/m^2	4.4 kn/m^2
Soil adding 2% plastic waste	11.9 kn/m^2	5.95 kn/m^2



Graph -5.7 comparison graph between UCS test Results

VI. Conclusions

6.1 General

Use of plastic products such as polythene bags, bottles, containers and packing strips etc. is increasing day by day. The disposal of the plastic wastes without causing any ecological hazards has become a real challenge to the present society. Thus using plastic bottles as a soil stabilizer 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 waste, producing useful material from non-useful waste materials that lead to the foundation of sustainable society.

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

6.2 FUTURE SCOPE

- In future study test can be carried on black cotton soil or on different types of soil.
- 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.
- 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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