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Sustainable soil stabilization using plastic waste

I. Varshik Manikanta
varshikmanikanta8055@gmail.com
Sree Dattha Institute of Engineering and Technology, Hyderabad, Telangana

Soma Shiva
somashiva583@gmail.com
Sree Dattha Institute of Engineering and Technology, Hyderabad, Telangana

Ch. Sathish
challasathish6969@gmail.com
Sree Dattha Institute of Engineering and Technology, Hyderabad, Telangana

K. Srija
saibhoomi1329@gmail.com
Sree Dattha Institute of Engineering and Technology, Hyderabad, Telangana

Shaik Roheed Ali
aliroheed@gmail.com
Sree Dattha Institute of Engineering and Technology, Hyderabad, Telangana

P. Sanjay Chandra
sanjaychandra1992@gmail.com
Sree Dattha Institute of Engineering and Technology, Hyderabad, Telangana

ABSTRACT

Soil stabilization is the process of improving the physical and engineering properties of the soil such as shear strength and bearing capacity, soil stabilization is also involving in decreasing the permeability and settlements as the soil is a loose unconsolidated material which is obtained by weathering of rocks and decomposition of organic matter. Which leads to the formation of different types of soils among different types of soils, the black cotton soil is the highly expansive soil which will be showing more swelling and shrinkage and settlement problems. In order to overcome this situation, the soil properties need to be improved by a process known as soil stabilization. This can be done by adding some external agents to it like coal, flyash, bagasse and plastic. Some experiments such as-as liquid limit, plastic limit, California bearing ratio (CBR) is conducted for the stabilized soil which will be showing the improved results in the engineering properties.

Keywords: *Soil stabilization permeability, Organic matter, Expansive soil swelling, Shrinkage, CBR.*

1. INTRODUCTION

The word soil is derived from the Latin word "solium" means the upper layer of the earth that may be dug (or) plowed, specifically. The loose surface material of the earth in which plants grow as per definition point of view soil is a loose unconsolidated material. Which is obtained by weathering of rocks, it may be physical weathering (or) chemical weathering and decomposition oforganic matter which leads to the formation of organic (or) cumulose soil.

Any kind of the civil structure which is constructed on the earth surface should ultimately transfer their loads to the soil. So in order to withstandto that loads the soil should process some engineering properties such as shear strength and bearing capacity. Shear strength is the term used in soil mechanics, to describe the magnitude of the shear stress that a soil can sustain. The shear resistance of soil is resulted from the friction between particles, interlocking of particles, and possibly cementation (or) bonding at particle contacts and bearing strength can be geotechnically be defined as the capacity of the soil to support the bads applied to the ground without causing failure. Thus bearing capacity of the soil is the maximum average contact pressure between the foundation and the soil which should not procedure shear failure in the soil.

Apart from this engineering properties also involve in the decreasing of permeability and settlements. A material is porous if it contains interstices are interconnected or continuous. A liquid can flow througha permeable material electron photomicrographs of even very fine clays indicates that the interstices are interconnected. However, the size, cross-section, and orientation of the interstices in different soils are highly variable. In general, all the soils are permeable. The property of a soil which permits flow of water (or any other liquid) through it, a soil is highly pervious when water can flow through it easily. In an impervious soil, the permeability is very low and water cannot easily flow through it. A completely impervious soil doesnotpermit the water to flow through it. However such completely impervious soils donot exist in nature, as all the soils are previous to some degree. A soil is termed impervious when the permeability is extremely low.

Permeability is a very important engineering property of soils. A knowledge ofpermeability is essential in a number of soil engineering problems such as settlements of buildings, the yield of wells, seepage through and below the earth structure. It controls the hydraulic stability of soil masses. The permeability of soils is also required in the design of fillers to percent piping in hydraulic structures.

Plastic is a synthetic material made from a wide range of organic polymers such as polyethylene, PVC (poly vinyl chloride), nylon, etc. That can be molded into shape while soft, and then set into a rigid or slightly elastic form. Increased use of plastics in day-to-day consumer applications has resulted in the municipal solid waste, an ever-growing fraction of plastic materials which were used for a short time and then discarded. The linear consumption patterns of plastic bags involving single usage and then disposal has led to environmental challenges such as diminishing landfill space, marine,and urban littering. There is, therefore a growing need to find alternative uses of reclaimed plastic bag waste to lengthen the usage time of the plastic material and thereby save the degrading environment.

2. SCOPE AND OBJECTIVE

- To improve the engineering properties of the soil such as shear strength and bearing capacity
- To provide the alternative solution for the disposal of plastic waste
- Decreasing cost of soil stabilization by using cheaper material
- Making the waste materials and environmental hazardous material into the useful material
- Decreasing the plasticity index and increasing the California bearing ratio (CBR) values.

3. METHODOLOGY

The experiments which are conducted for the soil stabilization are as follows:-

- Liquid limit test
- Plastic limit test
- CBR test

a. LIQUID LIMIT TEST

If the soil is organic or fine-grained containing no plus No. 40 (0.425 mm) material, and is in its natural state, proceed without adding water. Chopping, stirring and kneading may be necessary to attain a uniform consistency. Then proceed as described in Sections 6.3 through 6.9 below. The soil sample prepared under 4.3 shall be placed in an evaporating dish, covered, and cured, and then thoroughly mixed with the addition of distilled, demineralized or tap water by alternately and repeatedly stirring, cutting and kneading with a spatula. If needed, further additions of water shall be made in increments of 1 to 3 mL; each increment of water shall be thoroughly mixed with the soil. The cup of EB 15-025 Page 7 of 16 the liquid limit device should not be used for mixing soil and water. Add sufficient water to produce a consistency that will require 25 to 35 drops of the cup to cause closure. Allow ample time for mixing and curing since variations can cause erroneous test results. Some soils are slow to absorb water. Therefore it is possible to add the increments of water so fast that a false liquid limit value is obtained. This is particularly true when the liquid limit of a clay soil is obtained from one determination as in the one-point method. A sufficient quantity of the soil mixture obtained under 6.1 or 6.2 shall be placed in the cup above the spot where the cup rests on the base and shall then be squeezed and spread into the position with a few strokes of the spatula as possible. Care should be taken to prevent the entrapment of air bubbles within the mass. With the spatula, level the soil and at the same time trim it to a depth of 0.3937 in. (10 mm) at the point of maximum thickness. Return the excess soil to the evaporating dish. The soil in the cup shall be divided equally by a firm stroke of the grooving tool along the diameter through the centerline of the cam follower so that a clean, sharp groove of the proper dimensions will be formed. To avoid tearing of the sides of the groove or slipping of the soil cake on the cup, up to six strokes, from front to back, or from back to front counting as one stroke, shall be permitted. The depth of the groove should be increased with each stroke and only the last stroke should scrape the bottom of the cup. 6.4 Lift and drop the cup by turning the crank, F, at the rate of 2 rps, until the two halves of the sample flow together and come in contact at the bottom of the groove along a distance of ½ in. (12.7 mm). Record the number of drops (blows) required to close the groove this distance. A valid test is one in which 15 to 35 blows are required to close the groove.

b. PLASTIC LIMIT TEST

The laboratory standard used to measure the wP throughout the world including Norsk Standard NS 8003-1982, Geotechnical testing Laboratory methods Plastic limit, still adopts the method suggested by Casagrande (1958). This procedure is not a mechanical process, and wP is evaluated by determining the water content of the soil when a thread, made by hand-rolling the soil specimen on a glass plate, breaks up at a nominal diameter of approximately 3 mm. The reliability of the wP result relies heavily on the expertise of the operator performing the test. The drawbacks of the test are well documented and include its highly subjective nature, its over-reliance on operator judgment, and variations in the amount of pressure applied during rolling, the speed of the rolling technique used, and the geometry of the thread. The vagueness of the guidelines on the test procedure, friction between hand, soil and glass, and the risk of contaminating the soil sample all contribute to devaluing the standard thread-rolling method. This method has been described by (Belviso et al. 1985) as ‘a rather crude procedure’, and has long been criticised by others, such as (Houlsby 1982), (Whyte 1982) and (Brown & Downing 2001). Various methods of measuring the Plastic Limits have been developed over the past three decades (Sivakumar 2009). This proposed method is based on the principles and procedures of fall cone method to measure the wL of fine-grained soils. The test is repeated for various water contents, at least three times around the wP of the sample, and the relationship between penetration and water content is established. The newly proposed methods for measuring wP main considerations were to design a device that is more accurate and generally repeatable when performed under similar conditions. The proposed approach is based on the energy that isdissipated as the cone penetrates into the soil. The wL of the soil is taken as the water content at which an 80 g cone with a 300 cone angle penetrates the soil by 20mm (BS 1377: Part 2: 1990). When this cone penetrates into the soil, the energy released by the falling cone will be dissipated within the soil. Figure 3-1 shows the position of the cone before and after penetration into the soil prepared at the WL. The energy released by the cone is the potential energy difference of thecone before and after penetration. The undrained shear strength of the clay at the WP is approximately 100 times higher than that of the strength at the WL. If a similar cone (with thesame cone angle of 30 degrees) is allowed to penetrate the soil prepared at the wP to a depth of 20 mm and it is assumed that the soil strains in a similar manner to that of a soil prepared at the wL (i.e for a similar deformation pattern), the work is done in the soil will be 100 times more than that of the work done when the soil is prepared at the WL. Therefore the required energy to penetrate into the clay prepared at the wP by a distance h (= 20 mm) is 100 x mgh on the existing cone used in the wL test. A thin metal disk is located just above the cone and it is held in position by a magnet attached to the frame. A digital dial gauge is attached to a tie rod which is held in position by a wing-nut so that it can be moved away during cone penetration and brought back into position when taking penetration readings. The magnet is operated using a two-way switch such that when the polarity is changed the magnetic field changes from North to South or South to North. The option of turning off the power to release the magnet was not selected since it may leave the 0.727kg mass with some residual magnetic flux and the cone may not depart from the magnet immediately when the power is turned off.

c. CBR TEST

California bearing ratio (CBR) is an empirical test and widely applied in the design of flexible pavement over the world. This method was developed during 1928-29 by the California Highway Department. Use of CBR test results for the design of roads, introduced in the USA during 2nd World War and subsequently adopted as a standard method of design in other parts of the world, is recently being discouraged in some advanced countries because of the imperialness of the method (Brown, 1996).

The California bearing ratio (CBR) test is frequently used in the assessment of granular materials in base, subbase and subgrade layers of road and airfield pavements. The CBR test was originally developed by the California State Highway Department and was thereafter incorporated by the Army Corps of Engineers for the design of flexible pavements. It has become so globally popular that it is incorporated in many international standards ASTM 2000. The significance of the CBR test emerged from the following two facts, for almost all pavement design charts, unbound materials are basically characterized in terms of their CBR values when they are compacted in pavement layers and the CBR value has been correlated with some fundamental properties of soils, such as plasticity indices, grainsize distribution, bearing capacity, modulus of subgrade reaction, modulus of resilience, shear strength, density, and molding moisture content Doshi and Guirguis 1983 Because these correlations are currently readily available to the practicing engineers who have gained wide experience with them, the CBR test remains a popular one. Most of the Indian highways system consists of flexible pavement; there are different methods of design of flexible pavement. The California Bearing Ratio (CBR) test is an empirical method of design of flexible pavement design.

It is a load test applied to the surface and used in soil investigations as an aid to the design of pavements. The design for new construction should be based on the strength of the samples prepared at optimum moisture content (OMC) corresponding to the Proctor Compaction and soaked in water for a period of four days before testing. In case of existing road requiring strengthening, the soil should be molded at the field moisture content and soaked for four days before testing. It has been reported that soaking for four days may be very severe and may be discarded in some cases, Bindra 1991. This test method is used to evaluate the potential strength of subgrade, subbase, and base course material for use in road and airfield pavements. Bindra 1991 reported that design curves (based on the curve evolved by Road Research Laboratory, U.K) are adopted by Indian Road Congress (IRC: 37-1970). As per IRC, CBR test should be performed on the remoulded soil in the laboratory. In-situ tests are not recommended for design purpose Bindra, 1991.

The design of the pavement layers to be laid over subgrade soil starts off with the estimation of subgrade strength and the volume of traffic to be carried. The Indian Road Congress (IRC) encodes the exact design strategies of the pavement layers based on the subgrade strength which is most commonly expressed in terms of the California Bearing Ratio (CBR). For the design of pavement, CBR value is invariably considered as one of the important parameters. With the CBR value of the soil known, the appropriate thickness of construction required above the soil for different traffic conditions is determined using the design charts, proposed by IRC. CBR value can be measured directly in the laboratory test in accordance with IS:2720 (Part-XVI) on soil sample procured from the work site. Laboratory test takes at least 4 days to measure the CBR value for each soil sample under soaked condition. In addition, the test requires a large quantity of the soil sample and the test requires skill and experience without which the results may be inaccurate and misleading.

4. RESULTS AND DISCUSSIONS

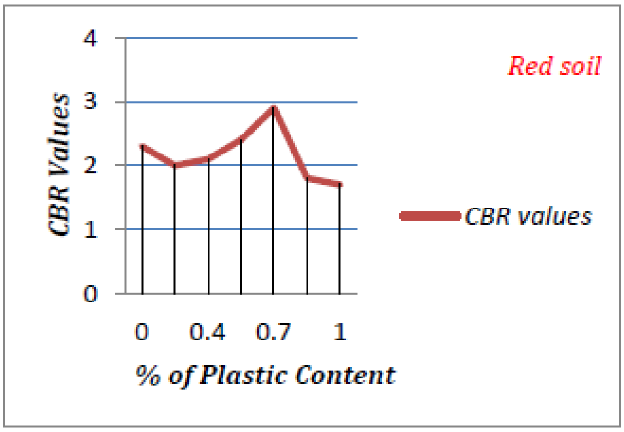
The values of Atterberg limits mentioned in the below table:-

Samples	Liquid limit (w_l)	Plastic limit (w_p)	I_P=W_L=W_P plasticity index
1) Normal soil (S_1) sample	212.2 %	58.27%	153.93%
2)Soil Sample + Coal + Flyash + Baggasse (S_2)	146.48%	63.09%	83.39%
3) Soil sample + plastic strips (S_3)	130.14%	65.99%	64.157%

As the plasticity index is going to increase the settlements in the soil is going to decrease because of the settlements themoments are created in the structure which leads to the failure of the structure. So such difficulties can be overcome by using plastic as a soil stabilizing agent.

Table of values for red soil

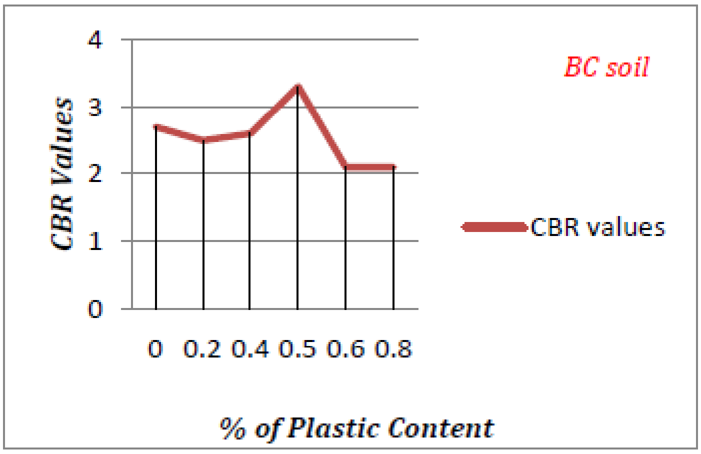
Percentage of Plastic Content	CBR value
0.0	2.5
0.2	2.1
0.4	2.2
0.6	2.4
0.7	2.95
0.8	1.9
1.0	1.68



CBR values varying with the different percentage of plastic for red soil

Table of values for black cotton soil

Percentage of Plastic Content	CBR value
0.0	2.85
0.2	2.51
0.4	2.5
0.5	3.31
0.6	2.2
0.8	2.1



CBR values varying with the different percentage of plastic for black cotton soil

5. CONCLUSION

- The project is mainly focused on the performance of plastic waste as a soil stabilization material. The engineering properties of the soil can be improved to a very large extent by proper mixing of the plastic strips with soil in required proportions
- Using waste polyethylene material for soil stabilization can be considered as eco-friendly
- The plastic introduction in the soil can improve the strength and bearing capacity of the soil
- By using 0.6% to 0.7% of plastic strips in the soil is decreasing the liquid limit and increasing the plastic limit, as a result of this the plasticity index is decreasing which will be decreasing the settlements in soil
- The improved CBR values of the soil are due to the addition of plastic strips
- If the plastic mixing percentage is exceeding 1% the CBR values are getting reduced
- All these increasing engineering properties of the soil is because of decreasing the voids with the addition of the plastic which leads to effective compaction and also increasing the cohesion
- The main advantage of the using plastic is proven to be economical as it is a non-useful waste and free of cost

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