# STUDY OF EFFECT OF USED ENGINE OIL AND PET STRIPS ON GEO TECHNICAL PROPERTIES OF SOIL

Sudhir kumar[1], Sajjan Kumar Paswan[2]
Mtech.Scholar[1],Associate Professor[2],
Department of Civil Engineering[1,2]
National Institute of Technology, Jamshedpur, India

*Abstract* — It is noticed in some research that the use of waste materials such as plastic bamboo, etc., is very helpful in stabilization of soil. There is a lack of good soil now-a-days that makes it difficult to create the process. Therefore, to enhance the properties of the soil so that it can be used for various buildings, the requisite admixture in the soil needs to be added. In this study, plastic bottles are used as a mixture. The waste plastic bottles are cut into small strips and 0.5 percent, 1.0 percent, 1.5 percent and 2.0 percent of the dry weight of the soil is added to the soil in different quantities, Similarly waste engine oil is mixed with soil as a contamination with different percentage i.e. 2%, 3%, 4%, 6% and 8% with different tests to analyze behaviour of soil. The results of this study favourably show that the inclusion of this material in clayey soil would be useful for ground improvement in geotechnical engineering.

Keywords — Clayey soil, plastic bottles strips, waste engine oil, soil stabilization, wet sieve analysis, proctor compaction test, CBR, Unconfined compression test, Atterbergs limit.

## I INTRODUCTION

Soil stabilization is a process in which, suitable materials such as lime, cement, fly ash, bitumen etc. are added which helps in increasing the shear strength and bearing capacity of soil, which leads to the improvement of the properties of soil. It controls the shrink as well as swell properties, increases shear and bearing strength of soil. Plastic is a non-biodegradable material and the disposal of waste plastic bottles causes environmental pollution. Plastic can be recycled or reused i.e. reprocessing these plastic wastes and make some useful products. Waste of plastics can be used as admixtures in stabilizing soil. Waste plastic materials can be reused because it can be recycled many times thus reducing the wastage. Use of the plastic waste for the enhancement of the properties of soil is an effective and economical way of stabilization.

**METHODS OF SOIL STABILIZATION**

There are different materials available from which soil stabilization can be achieved. Depending on the different internal factor which describes the bonding between the soil and the stabilizer used, the methods of soil stabilization are majorly categorised into two types, they are:

**1.1.1) Mechanical Stabilization –** In this method of soil stabilization friction plays a key role. In this method the friction between soil and admixture helps in increasing the properties of soil.

**1.1.2) Chemical Stabilization –** In this method of soil stabilization, chemical reactions occurs between the minerals in soil and the different admixtures added to the soil.

**OBJECTIVE OF THIS STUDY:**

The general objectives of the project is to study stabilization of clayey soils with PET plastic bottles strips wastes.

The specific objectives of the study are:

- To compare the maximum dry density and optimum moisture content values of the unreinforced soil with the values gained after reinforcement with PET plastic strips.
- To investigate the effect of including PET plastic strips on the strength and compressibility of the soil based on the values of compaction, liquid limit, plastic limit plasticity index and CBR values.
- To investigate the effect of including waste engine oil on the strength and compressibility of the soil based on the values of compaction, liquid limit, plastic limit plasticity index and CBR values.

**SIGNIFICANCE OF THE STUDY:**

With the rising cost of industrial stabilizing chemicals (agents) and costly mechanical methods of stabilization of weak soils, it is becoming very expensive to manage and conduct construction works which require improvement of existing soils on site. Also due to improper application of industrial stabilizing agents to minimize construction costs, accidents and disasters happen during and after construction all over the world including India. Tunnel landslide, slope failure, rutting in roads and cracks in buildings occur mostly due to poor application of stabilization on expansive and collapsible type of soils. To tackle these kinds of construction problems using affordable and simply available material such as plastic is a perfect alternative.

**MATERIALS AND METODOLOGY**

**Materials used:**

- Soil
- Plastic fibres
- Waste engine oil

**Soil:**

Clayey soils are inorganic clays of medium to high compressibility and from a major soil group in India. They are characterized by high shrinkage and swelling properties. Because of its high swelling and shrinkage characteristics, the clayey soil has been a challenge to the civil engineers.

**As per Indian standards (IS 2720),**

**Table- 1, Basic properties of soil**

| Properties | Value |
|---|---|
| Sieve analysis: | |
| Sand | 1.74% |
| Fines (silt + clay) | 98.26% |
| Optimum moisture content (%) | 7.78 |
| Maximum dry density (g/cc) | 1.946 |
| Liquid limit (%) | 50.20 |
| Plastic limit (%) | 27.78 |
| Plasticity index (%) | 22.42 |
| Shrinkage limit (%) | 23.309 |

**Plastic bottles strips-**The waste plastic were collected from nearby disposal sites and made into strips of different Aspect Ratios. The bottles were cleaned properly after collection and cut into three different sized strips manually using scissors.

**Table 2. Properties of PET plastic.**

| Behaviour parameters | Values |
|---|---|
| Fibre Type | PET |
| Tensile Strength | 350 MPa |
| Modulus of elasticity | 1800N/mm2 |
| Density | 1.0 g/cc |
| Melting point | 590 $^{0}$C |
| Resistance to acidic and alkali actions | Very good |

**Source: ASTM D638, 2007**

**Table 3. Strips sizes**

| Strip | Width (mm) | Length (mm) |
|---|---|---|
| 1 | 5 | 7.5 |
| 2 | 10 | 15 |
| 3 | 15 | 20 |

**Table 4: properties of engine oil [IS 13656 (2002)]**

| Properties of waste engine oil | |
|---|---|
| **Colour** | **Black** |
| **Physical state** | **liquid only** |
| **Melting point** | **-34.4 deg celcius** |
| **boiling point** | **360 deg celcius** |

The waste engine oil is collected from vehicle maintenance workshop,

Engine lubricant is any one of numerous substances that consist of base oils enhanced with numerous additives, in particular antiwear additives, detergents, dispersants, and, for multi-grade oils, viscosity index improvers. Motor oil is used for lubrication of internal combustion engines. The fundamental feature of motor oil is to lessen friction and wear on moving components and to clean the engine from sludge (one of the functions of dispersants) and polish (detergents). It also neutralizes acids that originate from gas and from oxidation of the lubricant (detergents), improves sealing of piston rings, and cools the engine by using carrying warmth faraway from moving parts.

**METHODOLOGY:**

Particle size distribution, Atterberg limit and basic gravity of soil tests were included in characterizing the soil sample taken for this analysis. In order to filter out any more impurities and unwanted particles, the soil sample taken was sieved. It was prepared for testing then. The following tests were performed: limit of plastic, limit of liquid, index of plasticity. On the other hand, PET fibres are distinguished by size (length and width), texture of the surface, shape and colour.

**Wet sieve Analysis: [IS 2720 (Part 4) -1985] 1) General:**

The grain size distribution is found by mechanical analysis. If the percentage fines are more there is a need to conduct wet sieve analysis.

**Apparatus Required:**

The different apparatus used for test were, sieves confirming to IS: 460 (Part 1) -1978.

4.75mm, 2mm, 1mm, 600µ, 425µ, 300µ, 212µ, 150µ, 75µ. Oven to maintain temperature between 105 $^0$C to 110 $^0$C, trays and buckets, bushes.

**Procedure:**

Suitable quantity of soil about 200 g passing through 4.75mm sieve is taken in 75µ sieve and is washed thoroughly using clean water until clear water appears and retained portion of soil is kept for oven drying. Retained sample is sieved using either mechanical sieve shaker or manually sieved. Set of IS sieves as 4.75mm, 2mm, 1mm, 600µ, 425µ, 300µ, 212µ, 150µ, 75µ were used. Soil was washed manually for 10 to 15 minutes. Materials retained on each sieve were weighed. Percentage of soil passing 75 is considered as combination of silt and clay, soil retained above 75 is coarse grained soil. Particles retained above 2mm sieve are considered as gravel portion of soil under investigation.

**Liquid Limit Test [IS 2720 (Part 5) – 1985] 1) General:**

In order to study the liquid limit of soil Casagrande test was conducted. Liquid limit is generally determined by the mechanical method using Casagrande's apparatus. As per this method the liquid limit is defined as the moisture content at which 25 blows will just close a groove of standardized dimensions cut in the sample by the grooving tool by a specified amount.

**Apparatus Required:**

- Casagrande's apparatus
- Grooving tool
- Spatula
- Evaporating dish
- Moisture containers
- Balance of capacity 200 gm
- Oven to maintain 105 $^0$C to 110 $^0$C

**Procedure:**

Around 150 gm of dry soil sample is weighed and thoroughly mixed with distilled water in the evaporating dish to form a uniform thick paste passing through 425 IS sieves. In the case of clay soil, for a requested time of up to 24 hours, the paste should be held in a watertight container to ensure the uniform distribution of moisture in the soil paste. The device of the liquid limit is modified to have a free falls through precisely 10 mm to the cup. The cup and the instruments for grooving are washed well. The paste should have a fairly rigid consistency in such a way that 30-35 blows are required in the trial run to close the standard groove to the bottom for a specified length of 12 mm. The soil paste is remixed and a part of the paste is put above the lowest spot in the cup of the system and pressed down to have a horizontal surface with the spatula. Strong strokes of the spatula trim the soil paste in such a way that the full depth of the soil sample in the cup is 10 mm. The soil sample in the cup is split through the middle line of the cam along the diameter, followed by strong strokes. At the rate of 2 revolutions per second, the crank is rotated so that the test cup is raised and lowered as defined. This continues until the two halves of the soil cake slowly flow under the blows and come into contact for a length of 12 mm at the bottom of the groove and the number of blows given is registered.

In the next experiment, an additional small amount of water is applied to the soil paste in the dish, mixed well with a spatula and the appropriate amount of paste in the test cup, and the operations are repeated to determine the number of blows needed to close the decreases in the groove. The procedure is repeated every time for 3 or more trials with slightly increased water content, noting the number of blows so that there are at least 4 to 6 uniformly distributed readings of number of blows between 15 and 35.

**Plastic Limit Test [IS2720 (Part 5) -1985] 1) General:**

In order to study the Atterberg's limit it is important to conduct plastic limit test. Plastic limit (PL) is the water content at which the soil rolled into thread of smallest diameter possible starts crumbling and has a diameter of 3mm.

**2) Apparatus Required:**

- Evaporating dish of about 120mm diameter
- spatula
- Ground glass plate
- Moisture containers
- Rod of 3mm diameter
- Oven controlled at temperature 105 $^0$C to 110 $^0$C.

**3) Procedure:**

About 30 g of dry soil sample passing through 425µ IS sieve is weighed out. The soil is mixed thoroughly with distilled water in the evaporating dish till the soil paste is plastic enough to be easily moulded with fingers. A small ball of about 8 gm weight is formed with the fingers and this is rolled between the fingers and the ground glass plate to a thread throughout its length. The pressure just sufficient to roll into a thread of uniform diameter should be used. The rate of rolling should be between 80 to 90 strokes per minute counting a stroke as one complete motion of hand forward and back to the starting position again. The rolling is done till the diameter of the thread is 3mm. Then the soil is kneaded together to a ball and rolled again to form thread. During this process the alternate rolling and kneading there will be loss in water content in the soil sample and it gradually become stiffer. The process of kneading and rolling into thread is continued until the thread starts crumbling under the same pressure required for rolling, when the thread just reaches a diameter of 3 mm and the soil sample can no longer be rolled into thread of smaller diameter.

If the crumbling start at diameter less than 3mm, then water content is more than plastic limit and if the diameter is greater while crumbling starts, the moisture content is lower. By trial, the thread which starts crumbling at 3 mm diameter under normal rolling pressure should be obtained and the pieces of the crumbled thread of soil sample should be immediately transferred to an air tight moisture container, lid tightly placed quickly and weighed to find the wet weight of the thread. Any delay in transferring the sample of thread to the container or closing with the lid tightly could result in considerable loss in the moisture due to rapid evaporation. The container with the soil sample is kept in the oven for about a day and dry weight is found. The water content of the soil thread is determined which is plastic limit of the soil. The above process is repeated three to four, more times so as to get at least three consistent values of plastic limit.

**Shrinkage Limit Test: [IS 2720 (Part -6) 1972] 1) General:**

Shrinkage limit (SL) in a remoulded soil sample is the maximum water content, expressed as a percentage of oven dry weight, at which any further reduction in water content will not cause decrease in volume or shrinkage of the soil sample.

**2) Apparatus Required:**

- IS sieve 425µ
- Oven
- Balance
- Mercury
- Desiccator

**3) Procedure:**

100 gm of soil sample from a thoroughly mixed portion of the material passing through 425µ IS sieve is taken. About 30 gm of above soil sample is placed in the evaporating dish and thoroughly mixed with distilled water to make a paste. The weight of clean empty shrinkage dish is determined and recorded. The dish is filled in three layers by placing approximately 1/3rd of the amount of wet soil with the help of spatula. Then the dish with wet soil is weighted and recorded immediately. The wet soil cake is air dried until the colour of the pat turns from dark to light. Then it is oven dried at a temperature of 105 $^0$C to 110 $^0$C for 12 to 16 hours. The weight of the dish with dry sample is determined and recorded. Then the weight of oven dried soil is calculated ($w_o$). The shrinkage dish is placed in the evaporating dish and the dish is filled with mercury, till it overflows slightly. Then it is pressed with the plain glass plate firmly on its top to remove excess mercury. The mercury from the shrinkage dish is poured into a measuring jar and the volume of the shrinkage dish is calculated. This volume is recorded as the volume of the wet soil pat (v). A glass cup is placed in a suitable large container and the glass cup removed by covering the cup with glass plate with pongs and pressing it. The outside of the glass cup is wiped to remove the adhering mercury. Then it is placed in the evaporating dish which is cleaned and empty. Then the oven dried soil pat is placed on the surface of the mercury in the cup and pressed by means of the glass plate with prongs, the displaced mercury being collected in the evaporating dish. The mercury so displaced by the dry soil pat is weighed and its volume ($v_0$) is calculated by dividing this weight by unit weight of mercury.

**3.2.5) Compaction Test: [IS 2720(Part 7) – 1980] 1) General:**

The standard proctor test is conducted to study the density of soil and its corresponding optimum moisture content. Compaction of soil is a mechanical process by which the soil particles are constrained to be packed more closely together by reducing the air voids. Soil compaction causes decrease in air voids and consequently an increase in dry density. This may result in increase in shearing strength.

**Apparatus:**

- Mould of capacity 1000cm$^3$, diameter of 100mm and height 127.3mm.
- Metal rammer of 50mm diameter, wt. of rammer 2.6 kg with a free drop of 310mm
- IS sieve 4.75mm
- Trowel
- Balance of capacity 10 kg
- Oven

**Procedure:**

About 3 kg of air dried soil sample passing through 4.75 mm IS sieve is taken. Required amount of water is added to it that is about 4% of the soil sample taken. Mass of the empty and clean cylindrical mould along with the base plate fixed to it is measured. Then, collar is attached and grease is applied inside the mould and collar. The soil sample is mixed thoroughly and filled in 1000 cc mould.

The moist soil is compacted in three equal layers and each layer is given 25 blows from the rammer weighing 2.6 kg with a drop of 310mm. Each layer of the compacted soil should be scratched with the spatula before putting the soil for next layer. The amount of soil should be just sufficient to fill the mould leaving about 5mm to be struck off when the collar is removed.

Collar is removed and the excess soil is trimmed using a straight edge. The mould is cleaned from the outside and mass of the mould with base plate and compacted soil is taken. A representative sample for water content determination is taken and rest of the soil is taken out of the mould. The above procedure is repeated for 5 to 6 times till the mass of the soil starts decreasing.

**3.2.6) California Bearing Ratio Test: [IS 2720 (Part 16) - 1987] 1) General:**

The CBR test denotes a measure of resistance to penetration of soil or flexible pavement material, of standard plunger under controlled test conditions.

**2) Apparatus Required:**

- CBR test equipment consists of a motorised loading machine fitted with the plunger which penetrates at the specified rate into the test specimen placed in CBR mould.
- Hollow cylinder mould of inner diameter 150mm and height 175mm
- Spacer disc
- Compaction rammer of 4.89 kg with a drop of 450mm
- Metal weighs i.e. two discs weighing 2.5 kg each
- IS sieve 19mm
- Tray
- Mixing bowl
- Filter paper
- Weighing balance
- Straight edge
- Measuring jar

**3) Procedure:**

5 kg of dry soil sample passing through 19mm IS sieve is taken. Optimum amount of water is added to it and mixed thoroughly. Grease is applied in the inner surface of the CBR mould then the spacer disc is placed at the bottom of the mould. The filter paper is kept over the spacer disc and the soil sample is filled into the mould in five layers with each layer being tamped for 55 blows using 4.89 kg rammer with a free fall of 450mm, to obtain the required density. The surcharge weight of 5 kg i.e. two disc weighing 2.5 kg each is kept. The mould is then immersed in clean water and it is allowed for soaking for minimum four days. After four days the assembly is removed and test is done for CBR using motorised loading machine.

The mould with the specimen is clamped over the base plate and the same number of surcharge weights are placed on the specimen centrally such that the penetration test could be conducted. The mould with base plate is placed under the penetration plunger of the loading machine. The penetration plunger is seated at the centre of the specimen and is brought in contact with top surface of the soil sample by applying a seating load of 4 kg. The dial gauge for measuring the penetration values of the plunger is fitted in position and the penetration dial gauge is set to zero.

The dial gauge of the proving ring for load readings or the load cell readings is also set to zero, not considering the seating load.

The load is applied through the penetration plunger of the motorised loading machine at a uniform rate of 1.25 mm per minute. The load readings are recorded at penetration readings of 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 7.5, 10, and 12.5 mm. In case the load readings start decreasing before 12.5 mm penetration, the maximum loading value and the corresponding penetration value are recorded. After the final reading, the load is released and the mould is removed from the loading machine. If the load values are given by the proving ring assembly, calibration factor of the proving ring is noted so that the load dial values can be converted into load in kg.

**Unconfined Compression Test: [IS 2720(Part 10): 1991] 1) General:**

The shear strength of the soil is determined by conducting unconfined compression test. Unconfined compression tests are carried out on cohesive soil specimen. The test may be considered as a special case of triaxial compression test when the lateral confining pressure $\sigma_3$ is equal to 0. Therefore, the cylindrical test specimen may be directly placed in a compression testing machine and the compressive load applied.

**Apparatus Required:**

- Strained controlled compression testing machine with proving ring assembly to measure load applied
- Dial gauge to measure deformation
- Moulds and tools to prepare test specimen.

| Sl. No. | IS sieve size | Particle size (D) mm | Mass of soil retained ($M_1$) g | % Mass of retained, ($M_1$/M) * 100 | Cumulative % retained, c | Cumulative % fine N= 100- C |
|---|---|---|---|---|---|---|
| 1 | 2 mm | 2.000 | 0 | 0.00 | 0.00 | 100 |
| 2 | 1mm | 1.000 | 06 | 05.22 | 5.22 | 94.78 |
| 3 | 600µ | 0.600 | 37 | 32.17 | 37.39 | 62.61 |
| 4 | 425µ | 0.425 | 09 | 07.83 | 45.22 | 54.78 |
| 5 | 300µ | 0.300 | 15 | 13.04 | 58.26 | 41.74 |
| 6 | 212µ | 0.212 | 17 | 14.78 | 73.04 | 26.96 |
| 7 | 150µ | 0.150 | 00 | 0.00 | 73.04 | 26.96 |
| 8 | 75µ | 0.075 | 29 | 25.22 | 98.26 | 01.74 |
| 9 | pan | 0 | 0 | 0.00 | 98.26 | 01.74 |

**Procedure:**

Soil sample of 150 g is taken, passing through 425 micron IS sieve. Optimum water is to be added and mixed thoroughly. The specimen of required size is obtained using sampling tube. The initial length and diameter of the specimen is measured. The specimen is put on the bottom plate and it is raised to make contact with the upper plate. Compression dial gauge and load dial gauge is adjusted to zero. The specimen is compressed to produce an axial strain rate of 0.5 – 0.2% per minute. Both the dial gauge readings are recorded at suitable time intervals or at least at every 1 mm deformation of the specimen. The specimen is compressed till the cracks are definitely developed or stress strain curve is well past its peak or 20% of vertical deformation is reached whichever occurs earlier. Sketch the failure pattern and measure failure angle with horizontal, if possible, and if specimen is homogeneous and partially saturated.

**RESULTS AND DISCUSSION**

**Wet sieve Analysis:**

Wet sieve analysis of clayey soil was carried out in order classify the soil. The following observations were made:

Sample taken [passing 4.75 mm sieve before washing] =200gm Sample retained on 0.075mm sieve after washing and drying =115 gm Sample passed through 0.075mm sieve after washing =85 gm, 42.5%.

**Table 4: sieve analysis of clayey soil.**

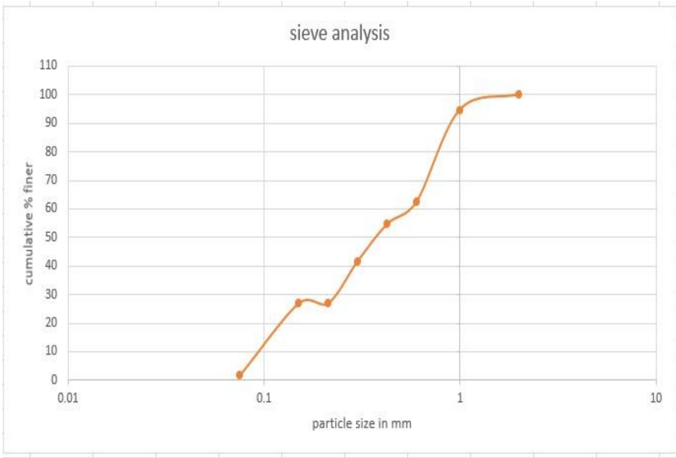


**Fig. 1.4 grain size distribution curve of clayey soil.**

From the analysis we could find that:

Silt and clay = 98.26%

Sand = 1.74%.

We can conclude that the soil sample is clayey soil [CH].

**Liquid Limit test.**

The consistency of the soil and strips mixture is measured by conducting Atterberg's Limit Test. Results of liquid limit test for every specimen are given in the following figures. Whereas the results of plastic limit tests are summarized in Table 15. Sample taken passing through 425µ sieve =150 gm.

**Liquid limit 0% PET strips.**

| Determination number | 1 | 2 | 3 |
|---|---|---|---|
| Number of drops, N | 33 | 28 | 23 |
| Soil moisture container no. | 07 | 08 | 09 |
| Mass of container + moist soil (g) | 20.4 | 23.2 | 26.3 |
| Mass of container + dry soil (g) | 14.7 | 16.2 | 17.9 |
| Mass of dry soil (g) | 13 | 14.4 | 16.2 |
| Mass of container (g) | 1.7 | 1.8 | 1.7 |
| Mass of water (g) | 5.7 | 7 | 8.4 |
| Moisture content | 43.8461 | 48.6111 | 51.85 |

**Table 5. Liquid limit data for clayey soil.**

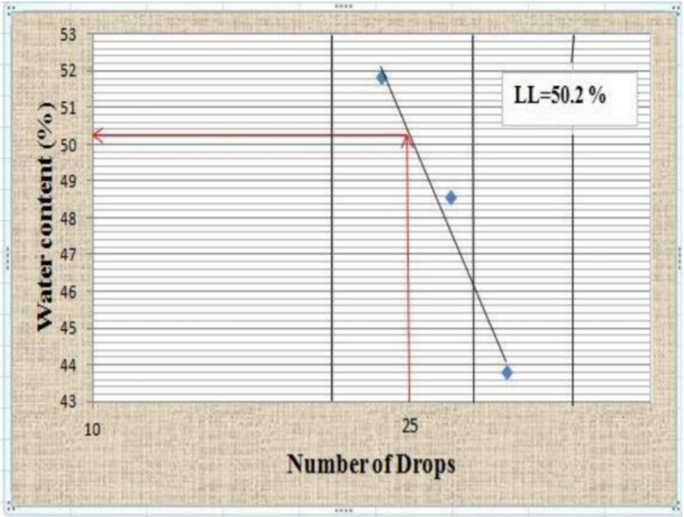


**Fig. 1 LL of soil with 0.0% PET strips.**

The above figure shows results for liquid limit for a pure soil sample that is free from any inclusion of plastic fibres. Based on the graph, it can be seen that 50.2% of liquid limit is attained by plotting the corresponding water content percentage to the twenty five blows of the cassagrande apparatus on a semi log graph. This value of 50.2 percentage of liquid limit puts the soil sample to be categorised under highly compressible silt and organic clay because the value is greater than 50%. Liquid limit 0% PET strips.

Liquid limit 0.5% PET strips.

| Determination number | 1 | 2 | 3 |
|---|---|---|---|
| Number of drops, N | 31 | 27 | 22 |
| Soil moisture container no. | 11 | 12 | 13 |
| Mass of container + moist soil | 21.1 | 23.9 | 27 |
| (g) + 0.5% PET | | | |
| Mass of container + dry soil (g) + 0.5% PET | 15.6 | 17 | 18.6 |
| Mass of dry soil (g) + 0.5% PET | 13.013 | 14.414 | 16.216 |
| Mass of container (g) | 2.587 | 2.5856 | 2.3838 |
| Mass of water (g) | 5.5 | 6.9 | 8.4 |
| Moisture content | 42.2654 | 47.8688 | 51.8000 |

**Table 6. Liquid limit data for clayey soil with 0.5% plastic strips.**

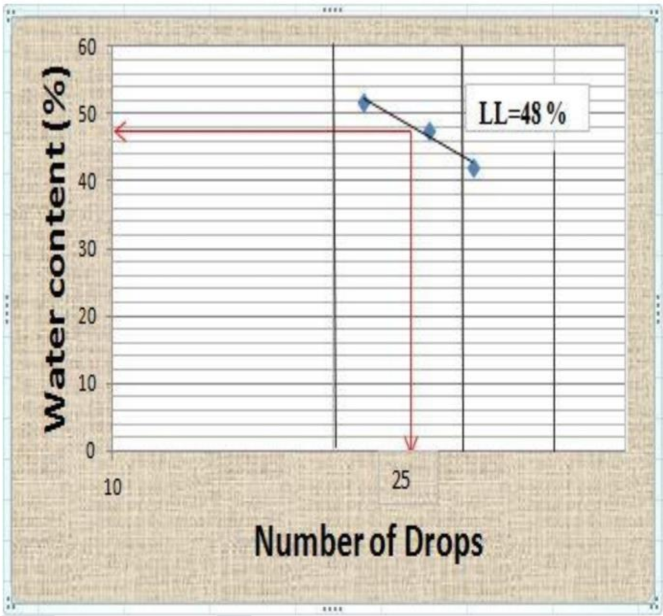


**Figure 2. LL of soil with 0.5% PET strips.**

A value of 48% in liquid limit is recorded for 0.5% PET plastic fibre strips inclusion in the soil sample. It shows a decrease in Liquid Limit values when compared with the previous sample which has no PET fibre strips addition.

**Liquid limit 1.0% PET strips.**

| Determination number | 1 | 2 | 3 |
|---|---|---|---|
| Number of drops, N | 26 | 23 | 20 |
| Soil moisture container no. | 07 | 08 | 09 |
| Mass of container + moist soil (g) + 1.0% PET | 21.1422 | 23.9478 | 27.054 |
| Mass of container + dry soil (g) + 1.0% PET | 15.6312 | 17.034 | 18.6372 |
| Mass of dry soil (g) + 1.0% PET | 13.0 | 14.4 | 16.2 |
| Mass of container (g) | 2.6312 | 2.634 | 2.4372 |
| Mass of water (g) | 5.511 | 6.9138 | 8.4168 |
| Moisture content | 42.39231 | 48.0125 | 51.9555 |

**Table 7. Liquid limit data for clayey soil with 1.0% plastic strips.**

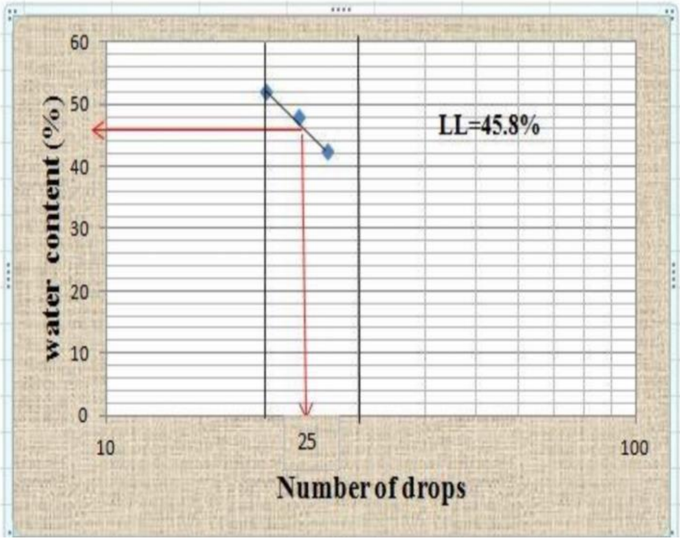


**Figure 3 LL of soil with 1.0 % PET strips.**

The above figure gives 45.8 % of liquid limit values which again is a much lower value than the homogenous specimen.

**Liquid limit 1.5% PET strips.**

| Determination number | 1 | 2 | 3 |
|---|---|---|---|
| Number of drops, N | 27 | 23 | 21 |
| Soil moisture container no. | 07 | 08 | 09 |
| Mass of container + moist soil (g) + 1.5% PET | 21.7764 | 24.6662 | 27.8656 |
| Mass of container + dry soil (g) + 1.5% PET | 17.2 | 17.8 | 18.5 |
| Mass of dry soil (g) + 1.5% PET | 13.0 | 14.4 | 16.2 |
| Mass of container (g) | 4.2 | 3.4 | 2.3 |
| | | | |
| Mass of water (g) | 4.5764 | 6.8662 | 9.3656 |
| Moisture content | 35.2035 | 47.68218 | 57.8124 |

**Table 8. Liquid limit data for clayey soil with 1.5% plastic strips.**

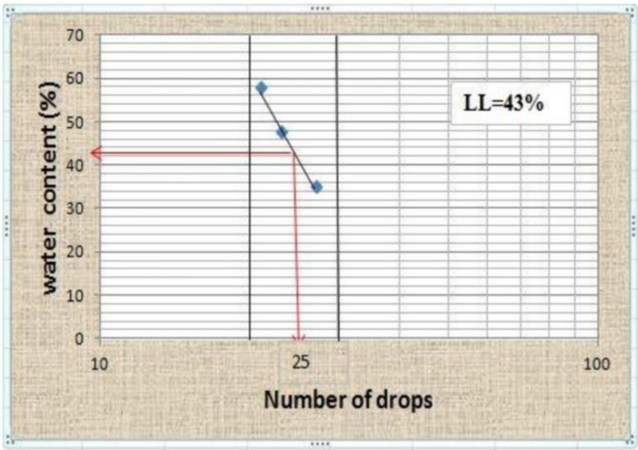


**Figure 4 LL of soil with 1.5% PET strips.**

The sample which contains 1.5% PET plastic fibre strips showed to have the maximum der density in the previous test and for the liquid limit test it was found to have 43% value, which is a decreasing amount than 50.2 % for the pure soil sample.

**Liquid limit 2.0% PET strips.**

| Determination number | 1 | 2 | 3 |
|---|---|---|---|
| Number of drops, N | 29 | 25 | 23 |
| Soil moisture container no. | 07 | 08 | 09 |
| Mass of container + moist soil (g) + 2.0% PET | 21.7851 | 24.6761 | 27.8767 |
| Mass of container + dry soil (g) + 2.0% PET | 15.876 | 17.496 | 19.332 |
| Mass of dry soil (g) + 2.0% PET | 15.2 | 15.8 | 18.32 |
| Mass of container (g) | 0.676 | 1.696 | 1.012 |
| Mass of water (g) | 5.9091 | 7.1801 | 8.5447 |
| Moisture content | 38.8761 | 45.4436 | 46.6417 |

**Table 9. Liquid limit data for clayey soil with 2.0% plastic strips.**

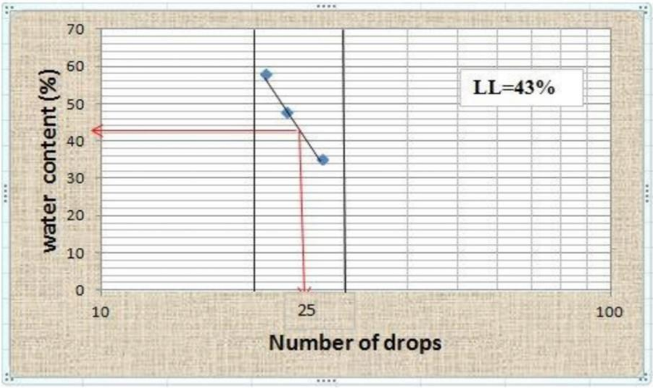


**Figure 5 LL of soil with 2.0% PET strips.**

The final specimen for the liquid limit test was done on the 2.0%% PET plastic fibre strips inclusion to the soil. The values of LL remain the same as the 1.5% inclusion sample which is 43%.

### 4.3 Plastic Limit Test.

Results of plastic limit of soil sample unreinforced with PET fibres and soil samples reinforced with PET fibres are shown in table 4.2 below. And also, the PI is calculated from both the liquid limit and plastic limit values. Values for PI, which is the difference between LL and PL are given below in table.

. **Table 10. Plastic limit data for 0% PET strips.**

| | |
|---|---|
| Container no. | 05 |
| Mass of container + moist soil | 6.3 |
| (gm) | |
| Mass of container + dry soil (gm) | 5.3 |
| Mass of container (gm) | 1.7 |
| Mass of dry soil (gm) | 3.6 |
| Mass of water (gm) | 1 |
| Moisture content (%) | 27.7777 |

**Table 11. Plastic limit data for 0.5% plastic strips.**

| | |
|---|---|
| Container no. | 06 |
| Mass of container + moist soil (gm) + 0.5% PET strips | 6.5 |
| Mass of container + dry soil (gm) + 0.5% PET strips | 5.51 |
| Mass of container (gm) | 1.8 |
| Mass of dry soil (gm) + 0.5% PET strips | 3.71 |
| Mass of water (gm) | 0.99 |
| Moisture content (%) | 26.6846 |

**Table 12. Plastic limit data for 1.0% PET strips.**

| | |
|---|---|
| Container no. | 07 |
| Mass of container + moist soil (gm) + 1.0% PET strips | 5.8 |
| Mass of container + dry soil (gm) + 1.0% PET strips | 4.9 |
| Mass of container (gm) | 1.3 |
| Mass of dry soil (gm) + 1.0% PET strips | 3.6 |
| Mass of water (gm) | 0.9 |
| Moisture content (%) | 25 |

**Table 13. Plastic limit data for 1.5% PET strips.**

| | |
|---|---|
| Container no. | 08 |
| Mass of container + moist soil (gm) + 1.5% PET strips | 4.8 |
| Mass of container + dry soil (gm) + 1.5% PET strips | 4.15 |
| Mass of container (gm) | 1.3 |
| Mass of dry soil (gm) + 1.5% PET strips | 2.85 |
| Mass of water (gm) | 0.65 |
| Moisture content (%) | 22.8070 |

**Table 14. Plastic limit data for 2.0% PET strips.**

| | |
|---|---|
| Container no. | 09 |
| Mass of container + moist soil (gm) + 1.5% PET strips | 4.82 |
| Mass of container + dry soil (gm) + 1.5% PET strips | 4.1 |
| Mass of container (gm) | 1.3 |
| Mass of dry soil (gm) + 1.5% PET strips | 2.8 |
| Mass of water (gm) | 0.72 |

| | |
|---|---|
| Moisture content (%) | 25.7142 |

| Soil sample | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| PET fibre in percentage | 0 | 0.5 | 1.0 | 1.5 | 2.0 |
| Plastic limit | 27.78 | 26.68 | 25.00 | 22.81 | 25.71 |

**Table 15. Plastic limit result of soil samples.**

**Plasticity index Result**

| PET (%) | 0 | 0.5% | 1.0 | 1.5 | 2.0 |
|---|---|---|---|---|---|
| PL (%) | 27.78 | 26.68 | 25 | 22.81 | 25.71 |
| LL (%) | 50.2 | 48 | 45.8 | 43 | 43 |
| **PI (%)** | **22.42** | **21.32** | **20.80** | **20.19** | **17.29** |

**Table 16. PI value for samples.**

**Plasticity Index (PI) =Liquid Limit (LL) – Plastic Limit (PL)**

**4.4 Shrinkage Limit.**

**Volume of wet soil pat (V) cc.**

| Sl. no. | | |
|---|---|---|
| 1 | Shrinkage dish no. | 01 |
| 2 | Fibre added, % | 0 |
| 3 | Mass of empty porcelain weighing dish, $M_1$ gm | 166 |
| 4 | Mass of mercury weighing dish + mercury filling the shrinkage dish, $M_2$ gm | 460 |
| 5 | Mass of mercury filling the dish $M_3 = (M_2 M_1)$ gm | 294 |
| 6 | Volume of wet soil pat, V= $(M_3/13.6)$ cc | 21.618 |

**Mass of dry soil pat and its water content.**

| **Sl. No.** | | |
|---|---|---|
| 1 | Mass of empty shrinkage dish, $M_4$ gm | 37 |
| 2 | Mass of shrinkage dish + wet soil, $M_5$ gm | 71 |
| 3 | Mass of shrinkage dish + dry soil $M_6$ gm | 57 |
| 4 | Mass of water $M_W = (M_5 - M_6)$ gm | 14 |
| 5 | Mass of dry soil, $M_d = (M_6 - M_4)$ gm | 20 |
| 6 | Water content, W = $(M_w/M_d)$ | 0.70 |

**Volume of dry soil pat ($V_d$) cc.**

| | | |
|---|---|---|
| 1 | Mass of mercury weighing dish + mercury displacement by dry soil, $M_7$ gm | 333 |
| 2 | Mass of mercury displaced by dry soil pat, $M_8$ = (M- M) gm | 167 |
| 3 | Volume of dry soil pat, Vd = (M /13.6) cc | 12.279 |
| | **d) Calculation** | |
| 4 | Shrinkage Limit (%) Ws = (w-{V-Vd/Md}*100 | 23.309 |

**Table 17. Shrinkage limit test on Clayey soil.**

Solar heater is the most economical and efficient solar technologies, which is widely used due to their easiness in space heating, removing the moisture from timber, used for drying the industrial products, vegetables and fruits. They may be also used in combination with photovoltaic solar absorber panels which is used to manufacture photovoltaic thermal hybrid solar energy collectors (hybrid PV/T systems or PVT) to produce heating effect or to generate electricity. The basic advantages of solar power collectors are: the fluid which is flowing inside the collectors does not get freeze or boil, they cannot create noise during flowing, the operating of solar panel system is very safe and the operating cost is also very less, system cannot produce any kind of harmful wastes and the running life of solar system is also long enough life cycle (Abdullah and Bassiouny, 2014).[5] but solar power collectors have some following drawbacks: low density, the thermal absorption capacity of solar panel is low and the thermal conductivity of air is also low which lead to low thermal efficiency, high cost system installation and non-uniform rate of heat generation

**Procedure for the Atterberg limits test**

Liquid limit test was done using Casagrande method while plastic limit test was done by hand rolling of soil (BS 1377:1990). In order to perform the liquid limit test for a particular soil, appropriate amounts of water were added to the contaminated soils and thoroughly mixed. Appropriate amount of soil was placed in a Casagrande cup, a groove cut through the soil; then, the crank handle of equipment turned at two revolutions per second. The cup lifts and drops, and groove closed along a distance of 13mm, with two parts of soil in contact at the bottom of the groove. The number of bumps was recorded. The number of bumps at which the groove closed varied as the soil was mixed with more water.

This was performed for number of bumps within 10 and 50, by remixing the soil taken out from the Casagrande cup with wet soil on glass plate and remixing with more water. Two bump counts were on each side of 25 bumps. Wet soil was taken from the zone where the two portions of soil divided by cutting of the groove had flowed together, via a spatula. The wet soil was placed in a container and water contents were measured by oven drying of soils. The water content for the plastic limit test was determined by oven drying soil that crumbled at 3mm diameter, via the hand rolling method.

The fall cone test is the preferred test for liquid limit tests; however, it is unreliable for use with clays that possess expansive properties.

**The water contents of the contaminated and uncontaminated soils defined the Atterberg limits of the soils. The formulae used for calculating the water contents in the uncontaminated and contaminated soils are**

**Uncontaminated soil**

$w_u = M_w / M_d \times 100$

where $w_u$ = water content of uncontaminated soil (%); $M_w$ = mass of loss of water (g);

$M_d$ = Mass of dry soil (g).

**Oil contaminated soil**

$\mathbf{w_o = [(M_t - M_r) - M_v])/(M_s + M_{or}) \times 100}$

$\mathbf{= [(M_t - M_r) - M_v] / M_r \times 100}$

where $w_o$ = water content of oil contaminated soil (%); $M_t$ = mass of wet contaminated soil (g); $M_r = M_s + M_{or}$ = mass of dried contaminated soil (g); $M_v$ = mass of loss of oil (g); $M_s$ = mass of dried soil without oil and water (g); $M_{or}$ = mass of oil residue (g). The loss of oil ($M_v$) was considered insignificant for this study, hence, water content (%) of oil contaminated soil will be:

$\mathbf{= (M_t - M_r) / M_r \times 100}$

Typical variation of water content with the number of bumps is shown in Figure below. The liquid limit is the water content corresponding to 25 number of bumps. The liquid limit of the soil in Figure below is 48%.

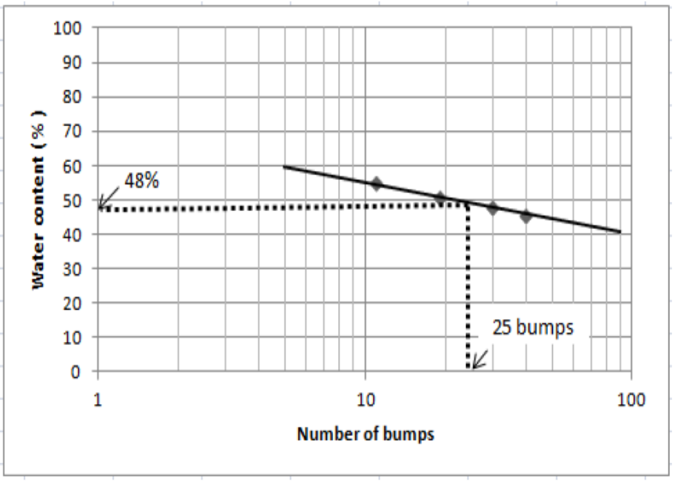


**Figure 6: Liquid limit of uncontaminated soil**

| Test number | 1 | 2 |
|---|---|---|
| Mass of wet soil (g) | 7.90 | 14.38 |
| Mass of dry soil (g) | 7.00 | 12.74 |
| Water loss (g) | 0.90 | 1.64 |
| Water content (%) | 12.85 | 12.87 |
| Plastic limit (average) | 12.86 | |
| Plastic limit | 13 | |

When the soil was contaminated with oil, the sum of the oil content and liquid limit or plastic limit was the total fluid content at Atterberg limits while the sum of oil content and plasticity index was the total fluid content at plasticity index.

**Procedure for the compaction test**

Compaction was done following the British Standard light compaction test as outlined in BS 1377:1990, using 2500g rammer with 50mm diameter of face at a drop of 300mm. The compaction mould had a diameter of 105mm and length of 115.5mm, with volume of 1000cm$^3$ . Appropriate amount of soil was taken from the soil mixture prepared for the test as stated in section 3.3.3 and compacted in three layers in a mould with extension collar for one compaction test; each layer received 27 blows. The soil was compacted in three layers for thorough densification, however, soils compacted in more than three layers have more densification. The extension collar was removed at the end of the compaction procedure and the soil was trimmed to the top level of the mould. The soil, mould and base were weighed. Bulk density (ρ) from each compaction test was calculated as:

$\mathbf{\rho = (M_{SMB} - M_{MB})/V}$

**Where, $M_{SMB}$ = mass of the soil, mould and base; $M_{MB}$ = mass of the mould and base; V= volume of the mould.**

The soil was removed from the mould using an extruder, then broken and remixed manually with the remainder of the prepared sample. Known increment of water was added manually to the remixed soil and the above mentioned compaction procedure was repeated. The procedure was repeated until five compactions were carried out. The ratio of the sum of mass of water increment added and the mass of water in the soil to the mass of soil was the water content for a compaction.

The formulae used in calculating the dry density for the uncontaminated and contaminated soils are shown below:

**Uncontaminated soil**

$M = M_{sl} + M_{wt}$

$\rho = M/V = (M_{sl} + M_{wt})/V$

$M_{wt} = wM_{sl}$

**where M = total mass of compaction mould content; $M_{sl}$ = Mass of solids;**

**$M_{wt}$ = mass of water; ρ = bulk density; w = water content.**

**Substituting $M_{wt} = wM_{sl}$ into equation**

$\rho = (M_{sl} + wM_{sl})/V$

$\rho = M_{sl}(1 + w)/V$

However, $M_{sl}/V = \rho_d$ = dry density

$\rho = \rho_d(1 + w)$

$\rho_d = \rho/(1 + w)$

Oil contaminated soil

$M = M_{sl} + M_{wt} + M_o$

$M = M_{sl} + wM_{sl} + ocM_{sl}$

$M = M_{sl}(1 + w + oc)$

$M_{sl} = M/(1 + w + oc)$

**where $M_o$ = mass of oil; oc = oil content.**

**But,** $\rho_d = M_{sl}/V$

$\rho_d = M/[V(1 + w + oc)]$

$\rho_d = \rho/(1 + w + oc)$

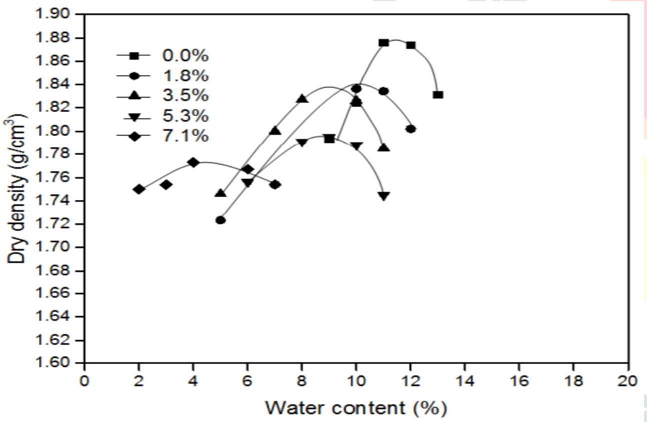


Figure 7 : Compaction curves of uncontaminated and contaminated soil.

Figure 8 – Soil sieve apparatus.

**STANDARD LOAD USED IN CALIFORNIA BEARING RATIO TEST**

| Penetration of the plunger(inch) | Standard load (lb) | Penetration of plunger(mm) | Standard load (kg) | Penetration of the plunger(inch) |
|---|---|---|---|---|
| **0.1** | **3000** | **2.5** | **1370** | **0.1** |
| **0.2** | **4500** | **5.0** | **2055** | **0.2** |
| **0.3** | **5700** | **7.5** | **2630** | **0.3** |
| **0.4** | **6900** | **10.0** | **3180** | **0.4** |
| **0.5** | **7800** | **12.5** | **3600** | **0.5** |

The CBR test is carried out on a compacted soil in a CBR mould 150 mm in diameter and 175 mm in height , provided with detachable collar of 50 mm and a detachable perforated base plate. A displacer disc, 50 mm deep to be kept in the mould during the specimen preparation, enables a specimen of 125 mm deep to be obtained. The moulding dry density and water content should be the same as would be maintained during field compaction. To simulate worst moisture condition of the field, the specimens are kept submerged in water for about 4 days before testing. Generally, CBR values of both soaked as well as unsoaked samples are determined. Both during soaking and penetration test, the specimen is covered with equal surcharge weights to simulate the effect of overlying pavement or the particular layer under construction. Each surcharge slotted weight , 147 mm in diameter with a central hole 53 mm in diameter and weighing 2.5 kg is considered approximately equivalent to 6.5 cm of construction. A minimum of two surcharge weights (i.e. 5kg surcharge load) is placed on the specimen. Load is applied on the penetration piston so that the penetration is approximately 1.25mm/min.

The curve is mainly convex upwards although the initial portion of the curve may be concave upwards due to surface irregularities. A correction is then applied by drawing a tangent to the curve at the point of greatest slope. The corrected origin will be the point where the tangent meets the abscissa.

The CBR values are usually calculated for penetrations of 2.5 mm and 5mm. Generally the CBR values at 2.5mm penetration will be greater than 5mm penetration and in such a case the former is taken as the CBR value for design purposes. If the CBR value corresponding to a penetration of 5mm exceeds that for 2.5mm, the test is repeated. If identical results follow, the bearing ratio corresponding to 5mm penetration is taken for design.

## EXPERIMENTAL PROCEDURE

1. Estimation of proctor density and optimum moisture content for each soil sample.
2. Moulding the soil sample into standard moulds keeping its moisture content and dry density exactly same as its optimum moisture content and proctor density respectively.
3. Determination of CBR strength of the respective soil samples in moulds using the CBR instrument.

Each soil sample is tested for its CBR strength after being soaked in water for 1 day, 2 days, 3 days and 4 days. Unsoaked CBR is also determined for each sample.

**PROCTOR DENSITY AND OPTIMUM MOISTURE CONTENT OF VARIOUS SOIL SAMPLES**

| Sample | MDD(Kg/m3) |
|---|---|
| A | 2270 |
| B | 2186 |
| C | 2354 |
| D | 2220 |
| E | 2232 |
| F | 2080 |
| G | 2272 |
| H | 1874 |
| I | 2168 |

**Observations of CBR test**

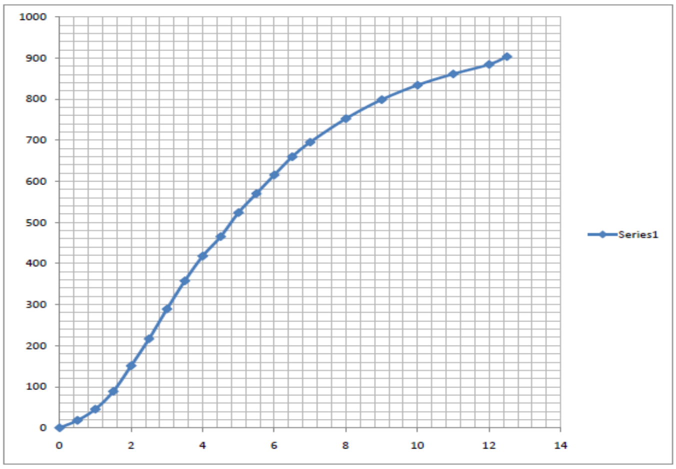


**Figure 9 – un - soaked sample**

**X : penetration(in mm)**
**Y: loading(in kg)**

**CBR2.5=(330/1370)*100%=24%**
**CBR5=(600/2055)*100%=23.7%**

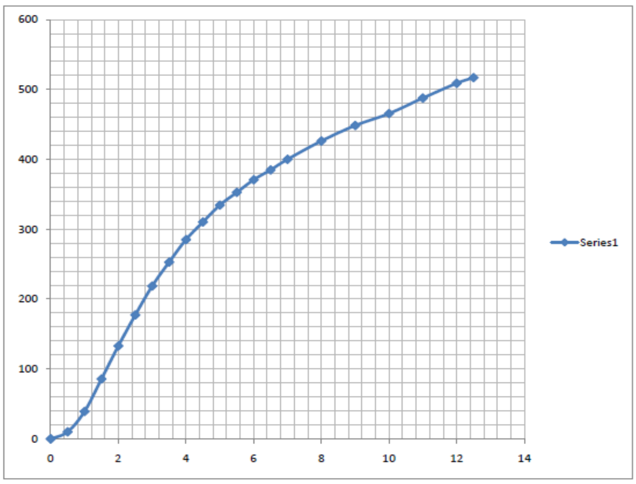


**Figure – 10 day soaked sample**

**X : penetration(in mm)**
**Y: loading(in kg)**

**CBR2.5=(235/1370)*100%=17.4%**
**CBR5=(350/2055)*100%=17%**

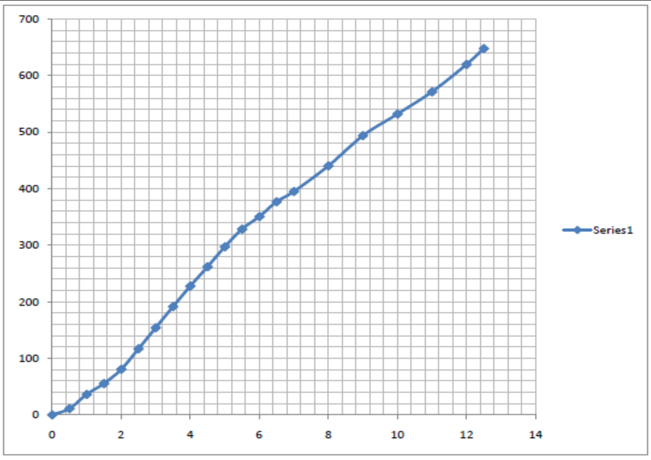


**Figure – 11 day soaked sample**

**X : penetration(in mm)**
**Y: loading(in kg)**

**CBR2.5=(116.85/1370)*100%=8.5%**
**CBR5=(297.16/2055)*100%=14.4%**

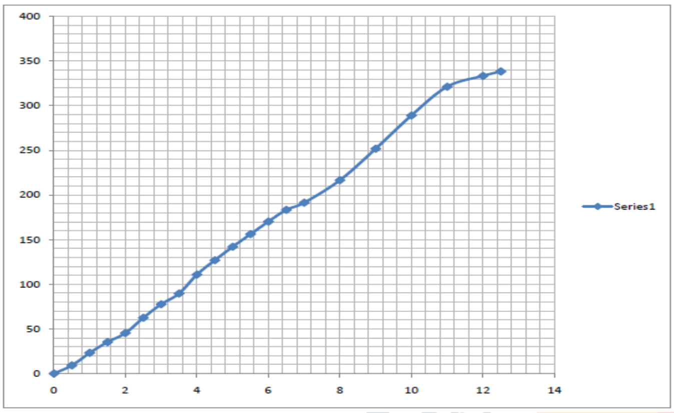


**Figure – 12 day soaked sample**

**X : penetration(in mm)**
**Y: loading(in kg)**

**CBR2.5=(62.45/1370)*100%=4.6%**
**CBR5=(142.03/2055)*100%=6.9%**

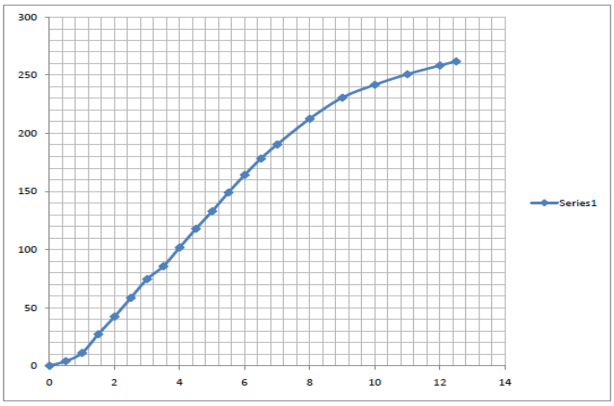


**Figure – 13 day soaked sample**

**X : penetration(in mm)**
**Y: loading(in kg)**

**CBR2.5=(58.42572/1370)*100%=4.26%**
**CBR5=(132.9689/2055)*100%=6.47%**

**Liquid limit.**

- The Liquid Limit of the soil alone was found to be 50.2%.
- The liquid limit of the soil with addition of 0.5%, 1.0%, 1.5% and 2.0% plastic strips by weight of soil is found to be 48%, 45.8%, 43% and 43% respectively.
- The liquid limit of the soil with addition of 0.5%, 1.0%,

1.5%, 2.0%, plastic strips is found to be decreased by 4.38%, 8.76%, 14.34% and 14.34% respectively, when compared to liquid limit of soil alone.

**Plastic Limit.**

- The plastic limit of soil alone was found to be 27.78%.
- The plastic limit of the soil with addition of 0.5%, 1.0%,

1.5% and 2.0% plastic strips by weight of soil is found to be 26.68%, 25%, 22.81% and 25.71% respectively.

- The plastic limit of the soil with addition of 0.5%, 1.0%,

1.5%, 2.0% plastic strips is found to be decreased by 3.95%, 10.0%, 17.89% and 7.47% respectively, when compared to plastic limit of soil alone.

**Plasticity Index.**

- The plasticity index of the soil alone was found to be 22.42 %.
- The plasticity index of the soil with addition of 0.5%, 1.0%, 1.5% and 2.0%, plastic strips by weight of soil is found to be 21.32%, 20.80%, 20.19% and 17.29% respectively.
- The plasticity index of the soil with the addition of 0.5%, 1.0%, 1.5% and 2.0% of plastic strips is found to be decreased by 4.90%, 7.22%, 9.94% and 22.88% respectively.

**Standard Proctor Test.**

- The optimum moisture content (OMC) and maximum dry density (MDD) of soil alone was found to be 7.78% and 1.946 g/cc respectively.
- The MDD of the soil with addition of 0.5%, 1.0%, 1.5% and 2.0% plastic strips by weight of soil is found to be 1.953 g/cc, 1.959 g/cc, 1.972 g/cc and 1.966 g/cc respectively and the corresponding OMC is found to be 7.78% for all.
- The MDD of the soil with addition of 0.5%, 1.0%, 1.5% and

2.0% plastic strips is found to be increased by 0.35%, 0.668%, 1.336% and 1.027% respectively and there is no any significant change in the OMC if the soil.

**California Bearing Ratio Test.**

- The CBR value of the soil alone was found to be 1.82 % for

2.5mm and 1.66% for 5mm

- The CBR value of the soil with addition of 0.5%, 1.0%, 1.5% and 2.0%, plastic strips by weight of soil is found to be 3.59%, 4.06%, 5.73% and 3.92% for 2.5mm penetration. For 5mm penetration the CBR values are as follows 3.15%, 3.85%, 5.12% and 3.89% respectively.
- The CBR values of the soil with addition of 0.5%, 1.0%, 1.5% and 2.0% plastic strips by weight of soil is found to be increased by 97%, 123.07%, 214.83% and 115.38% in case of 2.5mm penetration. In case of 5 mm penetration

values get increased by 89.75%, 131.92%, 208.43% and 134.33% respectively. These increment in percentages are seen also in the literature.

**Unconfined Compression Test.**

- The shear strength of soil alone was found to be 12.18 KN/ $m^2$.
- The shear strength of the soil addition of 0.5%, 1.0%, 1.5% and 2.0%plastic strips by weight of soil is found to be 14 KN/$m^2$, 4.4 KN/$m^2$, 4.4 KN/$m^2$ and 5.95 KN/$m^2$ respectively.
- The shear strength of the soil with the addition of 0.5%, 1.0%, 1.5% and 2.0% of plastic strips is found to be decreased by 14.94%, 68.87%, 68.87% and 51.14% respectively.

## CONCLUSION

This project is to meet the challenges of society to reduce the quantities of plastic waste, producing useful materials from nonuseful waste materials that leads to the foundation of sustainable society.

On the basis of present experimental study, the following conclusions are drawn:

1. Liquid limit of the soil decreases on adding the PET strips which indicates the increase in the shear strength of soil.
2. There is substantial increase in MDD with increase in addition of plastic strips up to 1.5% by weight beyond which it decreased.
3. There is no any significant change in the OMC value on addition of plastic strips.
4. The California Bearing Ratio (CBR) of the soil alone is obtained as 1.82% and its maximum increment value was 214.83% on addition of 1.5% of plastic strips.
5. In unconfined compression test it was observed that the shear strength of the soil has increased with the increase in plastic strips, when compared to that of shear strength of soil tested without strips.
6. On increasing the number of days of soaking, CBR decreases due to higher ingress of water. Dramatic loss of strength is observed when unsoaked soil is soaked for 1day under water and then tested for its CBR strength.
7. Rate of ingress of water decreases with days of soaking because it closes in towards saturation. Most amount of water is soaked on the 1st day and thus accounts for the highest drop in CBR strength of the soil sample.

## References


**[1]** MegnathNeopaney, Ugyen, KezangWangchuk, SherubTenzin,Stabilization of soil by using plastic wastes, International Journal of Emerging trends in Engineering and Development, ISSN2249-6149 Issue 2, vol.2 (March-2012).

**[2]** PragyanBhattarai, A.V. A Bharat Kumar, K. Santosh, T. C.Manikanta& K. Tejeswini, Engineering Behaviour of soil Reinforced with plastic strips, International Journal of Civil, Structural, Environmental and Infrastructure Engineering Research and Development (IJCSEIERD) ISSN 2249-6866 Vol.3, Issue 2, June 2013,83-88.

**[3]** A.K. Choudhary, J.N. Jha and K.S. Gill, A Study on CBRBehaviour of waste plastic strips Reinforced Soil, Emirates Journal For Engineering Research, 15(1), 51-57 (2010).

**[4]** Priti Mishra, JhaAjachi R.B., MohnishSatrawala, Harsh Amin,Experimental Study On Waste Recycled Product (W.R.P.) And Waste Plastic Strips (W.P.S.) As Pavement Sub-Base Material, International Journal Of Scientific & Technology Research, Volume 2, Issue 12, December 2013 ISSN 2277-8616.

**[5]** B.C. Punmia, Jain Ashok, Jain Anil, P (2005). Soil Mechanics andFoundation, 16 edn, p.p. 1-3 ,37-87, 849-855.

**[6]** Consoli, N.C., Montardo, J.P., Prietto, P. D. M., and pasa, G.S.,Engineering Behaviour of sand reinforced with plastic wastes, Journal of Geotechnical and Geo environmental Engineering. Vol. 128 No.6, 2002, pp, 462-472.

**[7]** Rao, G.V. and Dutta, R.K. (2004) "Ground improvement withplastic waste "proceeding, 5th International Conference on Ground improvement technique, Kaulalumpur, Malaysia, 321-328.

**[8]** Arora, K.R. (2004) soil mechanics and foundation Engineering.Standard publishers distributors, New York [citation Time(s):1]

**[9]** Stabilization of soil by using waste plastic materials–sharanveersingh, Mahabir Dixit, Department of soil, central soil and material research station, New Delhi (IJIRSET)February 2017

**[10]** Engineering behaviour of soil reinforced with plastic strips –pragyanbhattarai, K. Tejaswini, K. Santosh, civil Engineering Department, K.L. University, India( Jun 2013)

**[11]** Fauzi, A., Djauhari, Z. And Fauzi, U.J. (2016) soil engineeringproperties improvement by utilization of cut waste plastic bottles and crushed waste glass as additive. International journal of engineering and technology, 8, 15-18

**[12]** Gandhi, K.S.(2012) Expansive soil stabilization using Bagasseash. International Journal of Engineering Research and Technology, 1, 2278.