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USAGE OF PLASTIC WASTE FOR THE STABILIZATION OF SOIL

[1]G.S.V. BRAMAJI RAO, [2]Y.DINESH, [3]CH. VINAY CHANDRASEKHAR

*[123]Assistant Professor, Civil Engineering Department, Pragati Engineering College, India.

ABSTRACT

Stabilization of soil is the process which is used to improve the engineering properties of the soil such as its shear strength and bearing capacity. Soil stabilization is also involved in decreasing the permeability and structure base settlement. Sub grade soil consists of mainly native soil which has been compacted so that it can with stand the loads above it. It is required in many structures such as pavements and slabs. When sub grade soil is not adequate to support the necessary loads then it needs stabilization to make the soil suitable for construction. Taking in consideration the harmful effects of plastic on environment and on the climate, usage of it as an additive in soil was suggested in this study. In this way, the plastic waste isused for a better purpose and the quantity of dumped plastic in landfills will get reduced. For this purpose a clay soil sample with medium plasticity was mixed with 0.2%, 0.3% and 0.4% of plastic strips by weight of soil and the experimental results were compared to the control soil sample with 0% plastic. The tests were conducted according to American Society for Testing and Materials (ASTM) and includes Waterberg limits, Standard compaction test, Unconfined compression test (UCS) and California bearing ratio (CBR). The shrinkage behavior of soil has been monitored via several wetting and dry cycles. The obtained results showed that CBR values increases with addition of plastic strips. With respect to unconfined compressive strength, increasing the percentage of plastic strips from 0 to 0.4% resulted in an increase of 145% in the strength of stabilized soil. The shrinkage results also demonstrated that addition of plastic strips results in decreasing the shrinkage in soil. Therefore usage of plastic

***Keywords*:** Polyethylene (bags); Soil stabilization; waste reduction; environment friendly solution

1. INTRODUCTION

1.1. GENERAL

The concept of stabilizing the soil has been ongoing for thousands of years. The need to strengthen the soil arose when it was identified that certain weak regions in the soil which were hindering the movement of man and his belongings could be improved by mixing with certain materials known as stabilizing agents. Soil stabilization is the process of blending and mixing materials to improve engineering properties of soil like increasing shear strength, compressibility, and permeability, thus improving load bearing capacity of a sub-grade to support pavements and foundations.

1.2.3 SOIL STABILIZATION ADVANTAGES

This enhances the engineering characteristics of the soil, thereby improving the soil fertility capacity. Soils in which stabilization has been carried out on are much stronger compared to soils with no stabilization because the properties have been strengthened through the reaction between the soil and the stabilizer. It saves time and cost. Site preparation time is reduced due to the soil already undergoing stabilization as it would not require the tradition 'dig and dump' method. Also, it reduces drying and strengthening of wet soil. This stability can also be utilized in preventing erosion of soil or dust formations, this is important during dry season. It enhances the work abilityand the durability of the soil-aggregate. Stabilization in slope areas can be achieved using this procedure. It also reduces the soil volume change due to a change in temperature or water content.

1.2.4 PROPERTIES OF SOIL STABILIZATION

Soil stabilization (chemical stabilization) involves using stabilizing agents to alter the geotechnical characteristics of a weak soil like the strength, durability, compressibility, strength andpermeability. The components comprise of the soil and a stabilizing agent that is additives.

1.3. OBJECTIVE OF THE STUDY

The objectives of this study can be sum up as:

- To improve the soil engineering properties like shear strength and bearing capacity.
- To provide alternate remedy for plastic waste disposal
- Decreasing cost of soil stabilizationby using cheaper material
- Making the waste materials and environmental Hazardous material into the useful material

1.4. SCOPE OF THE STUDY

The objectives of the present study are to

- To evaluate the effect of percentage of plastic strips ongeotechnical properties of Black cotton soil such as California Bearing Capacity ratio.
- To determine the optimum percentage of plastic strips forsoil stabilization.

2. LITERATURE REVIEW

It has been as certained through several studies that the qualification of plastic waste in regards to its use as a soil stabilizer. Studies include:

Gill et.al, Choudhary, Jha (2010)

Gilletal.andChoudharyin2010 through research conducted, proved the potential possibilities of HDPE (high density polyethylene) to act as a soil rein forcer by enhancing the properties of sub grade soil.

Various percentage of HDPE strips length andproportions were obtained from plastic waste and mixed with the soil, on which a series of CBR tests were conducted on the reinforced soil. The CBR test conducted shows that the addition of HDPE strips in soil to reinforce it is beneficial in highway application.

Nsaif (2013)

Nsaif (2013) through a research to study the manner in which soil strengthened is by plastic waste materials concluded that by mixing pieces of plastic waste with both clayey and sandy soil at varying mixing ratios (0, 2, 4, 6, 8)

% respectively by weight, there was a relevant increment in the cohesion for both soil types. It was also concluded that was a reduction in MDD and OMC of the soil as a result of the low specific gravities of the plastic pieces.

3. MATERIALS ANDMETHADOLOGY

3.1. SOIL

The term soil in soil engineering is defined as an unconsolidated material, composed of soil particles, produced by the disintegration of rocks

3.1.1. TYPES OF SOIL

As per Indian Council of Agricultural Research (ICAR) soil are classified as follows:

1. Alluvial soil
2. Black cotton soil
3. Red & Yellow soil
4. Laterite soil
5. Mountainous or Forest soil
6. Arid or Desert soil
7. Saline and Alkaline soil
8. Peaty and Marshy soil

3.2. BLACK COTTON SOIL

Black cotton soil is a cohesive soil. It possesses the characteristics of swelling during the rainyand shrinking during summer. Due to swelling, the structure has the uplift pressure and generate heave in the foundations, plinth beams, ground floor of the building and canals, road surfaces etc.It swells due to a higher percentage of clay

Due to shrinkage, cracks are created in walls,slabs, plinth protection, floors, etc. The cracks aregenerally in the range of 100mm to 150mm wide and 0.5m to 2m deep. The black cotton soils are highly compressible and have extremely low bearing capacity. The shear strength of soil isincredibly low.

Black cotton soil is also known as expansive soil.A large part of central India and a part of South India covering Madhya Pradesh, Maharashtra, Karnataka, Tamil Nadu, South Gujarat, and Utter Pradesh is covered with Black cotton soil. The covering is approximately 3, 00,000 sq.kms.

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3.2.1. PROPERTIES OF BLACK COTTONSOIL

- Black cotton soils are black in colour and alsorecognized as regur soil. These are prepared of lava discharges.
- It is suitable for the cultivation of cotton and is also known as black soil.
- This soil is formed of incredibly fine clayed material and is well known for its moisture holding capacity.
- They formulate deep cracks during the hotclimate which enables the adequate aeration of the soil.
- These soils are sticky when moist and tough to work on.
- Black cotton soil is fine textured and clay in nature. It has great quantities of lime, iron, magnesium, and mainly low amount of phosphors, nitrogen, and organic matter.
- It has up to 50% clay content and accordingly is highly retentive of moisture. Because of the huge clay content, the soil expands when wet and becomes tough to plow through.
- During the arid season, this soil shrinks and formulates a huge crack which enables thecirculation of air. The soil is incredibly fertile in most of the locations where it is found.

3.2.2. ENGINEERING PROPERTIES OFBLACK COTTON SOIL

Table 3.1 Engineering properties of Blackcotton soil

Properties	Value
Dry density	1300-1800 kg/m^3
Liquid limit	40-120%
Plastic limit	20-60%
Specific Gravity	2.6-2.75%
Maximum Dry Density	20-35%
Compression Index	0.2-0.5%
pH	7.2-8.5

3.4. MATERIAL

3.4.1. BLACK COTTON SOIL

The materials used in this case study were locallyacquired. The soil used was collected from aroundthe university. The soil sample was prepared according to ASTM standards and basic routine tests were carried out in order to classify the soil sample. Figure 3.1 show the material used for this study.

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Figure 3.1 Black cotton soil

3.4.2. PLASTIC WASTE STRIPS

In the process of conducting this study, shoppingbags were collected from the studentsin university Campus. The material has an averagedensity of average 798kg/m^3, with atensile strength range of 14 to 20 MPa, with athickness of 40 micron (Dikkar, 2017). In orderto conduct the experiment a batch of plastic strips of known dimensions and weight were combined to drysoil and then thoroughly mixed. The shoppingbags were cut into strips of width 10mm andlength 15mm and were added to the soil atconcentrations of 0.20%, 0.30%and 0.40% byweight of soil cube casting with different mix design cube of 10%,20% of plastic

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Figure 3.2 Plastic waste strips

4. RESULTS ANDDISCUSSION

This chapter is going to concentrate on the analysis anddiscussion of the experimental laboratory work inorder to achieve the general objectives of the thesis. As such, this chapter is going addressthe following discussion.

1. Atterberg Limits analysis
2. Compaction analysis
3. Unconfined compression test (UCS)
4. California bearing ratio test(CBR)
5. Shrinkage test analysis

4.1. ATTERBERG LIMITS ANALYSIS

The Atterberg limit analysis is the analysis that comprises the comparison of liquid limitand plastic limit test. These are limits which originated from Albert Atterberg, a Swedish soil scientist in 1911 whose aim was to observeand measure the various significant changes in fine

Black cotton soil passed through 75microns sieve

– grained soils based on its water content. Figure 4.1 shows the result of liquid limit which is 49 and Figure 4.2 shows the comparison of Atterberg limits having plastic limit of 32and plasticity index is 17.Seeing the results from liquid limit it can be seen from plasticity chart that the soil has medium plasticity.

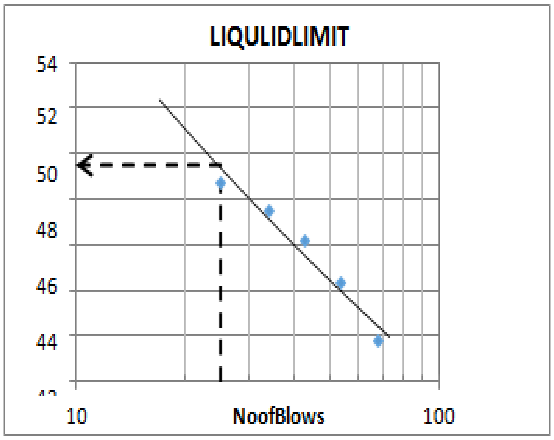
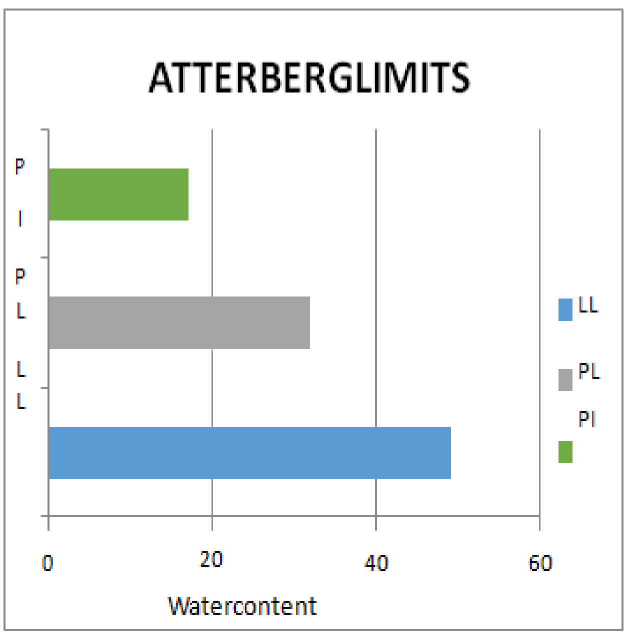


Figure 4.1 LL test with respect to no.ofstrokes and WC %



a number of factors will affect the degree of compaction that can be achieved: Nature and type of soil, i.e.sand or clay, grading, plasticity, water content atthe time of compaction, site conditions, e.g.weather, type of site, layer thickness, compactive effort: weight, vibration, number of passes.

In compaction test firstly, we used 5%, 10%, 15%, 20% and 25% of water content to find the optimum moisture content (OMC) and maximum dry density (MDD).The obtained results show that the OMC can be reached and found at 20.11% and MDD is 1.62 (g/cm^3) (see, Table4.1),this result can be demonstrated with 0%plasticcontent.

Figure 4.2 Atterberg limit comparisonshowing PL, LL, and PI

4.2. COMPACTION TEST ANALYSIS Compaction is a process that brings about an increase in soil density or unit weight, accompanied by a decrease in air volume. There is usually no change in watercontent. The degree of

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4.3.

W (%)	9.8	15	20.11	27.64	30.36
γd(g/cm3)	1.4943	1.5662	1.6152	1.4100	1.3491

Table 4.1 Compaction results for WC% and 0% plastic content

DD with

compaction is measured by dry unit weight and depends on the water content and compactive effort e.g weight of hammer, number of impacts, weight of roller, and number of passes. For a given compaction effort, the maximum dry unit weight occurs at optimum water content. Compaction can be applied to improve the properties of an existing soil or in the process of placing fill. The main objectives are to: increase shear strength and therefore bearing capacity, increase stiffness and therefore reduce future settlement and decrease voids ratio and so permeability, thus reducing potential frost heave. It has been reported that

From the Figure4.3 it can be seen that the water content and dry density have direct relationship between 5%-15% this is to say the higher the moisture content the higher the dry density (DD). But when the percentage water content increased to 20% then the DD decreases with the increases of water content values. Based on the Table 4.1 it can also be observed that, the water content is increasing with the increase in dry density. This is clear that after 15% the DD is reducing even with the increased of water content. Figu re4.3demonstratedthecompaction results showing compaction with 0% plastic contents together with Saturation of100%,90%and 80%

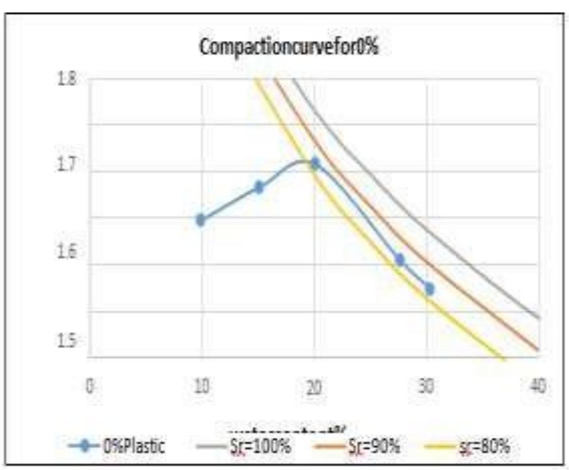

Figure 4.3Compaction forWC%and DDwith 0%plastic

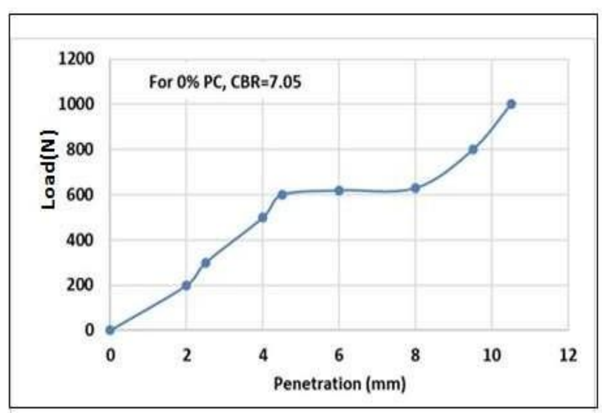

Figure4.8:CBRwithLoad vs.Penetrationfor0%plastic

Secondly the compaction was carried out with0.2% plastic contents by the weight ofthe soil. This were carried out with the same percentage of water contents (5%,10%,15%,20%and 25%).Table 4.2 shows the summary of the obtained WC% and DD. As it can be seen thewater contents were found to be higher than theaimed water contents at the

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end of measurements.It could be related to the internal water around theclay particles. The samples were dried at 60degree centigrade, so their properties will notalter during the drying process. This has resulted in starting with 2% water content.

4.4. CALIFORNIA BEARING RATIO

The California Bearing Ratio (CBR) is the most utilized parameter for dimensioning flexible pavements. The analysis was also carried using the same content of plastic (0, 0.2, 0.3 and 0.4%). The samples were compacted at their previously obtained OWC and MDD in CBR mould, and the test was conducted till 12.9mm penetration. Table 4.5 shows the water content percentage measure dat the end of test with the corresponding plastic values.

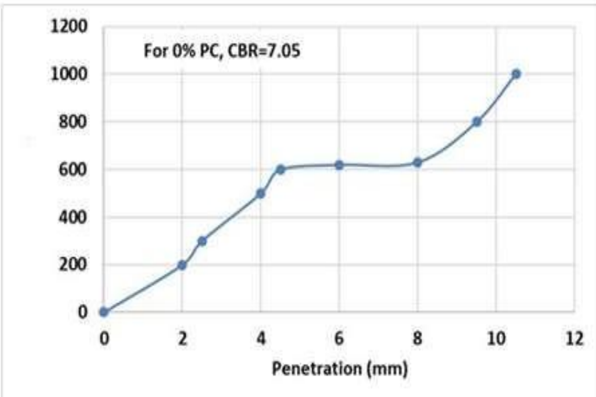
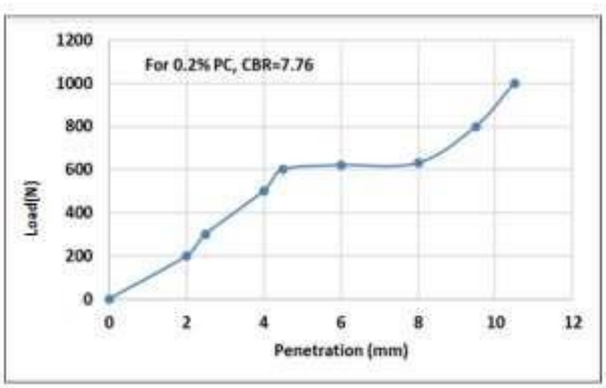


Figure4.8:CBRwithLoad vs.Penetrationfor0%plastic

In figure 4.8 shows CBR load verses penetration.The load was given in ratio of 1.25mm till12.9mmpenetrationwasreached.Figure4.9,4.10 and4.11areshowingresultsfor0.2%,0.3%and 0.4%plasticbagaddition respectively.



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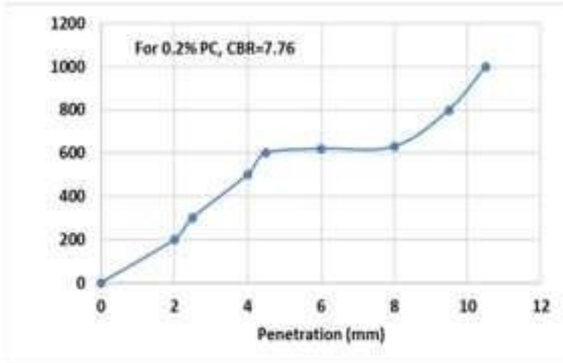
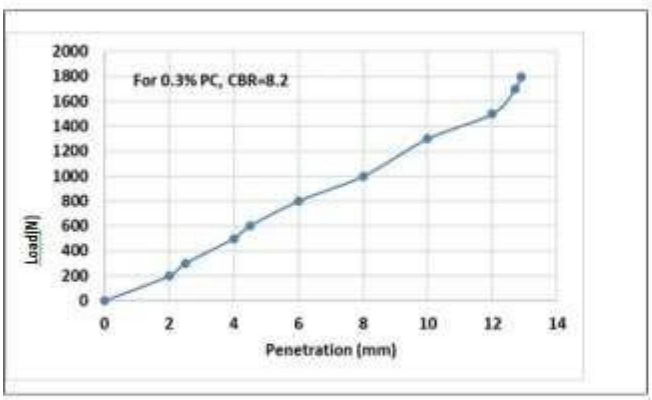


Figure4.9:CBRwithLoad vsPenetrationwith0.2%plastic



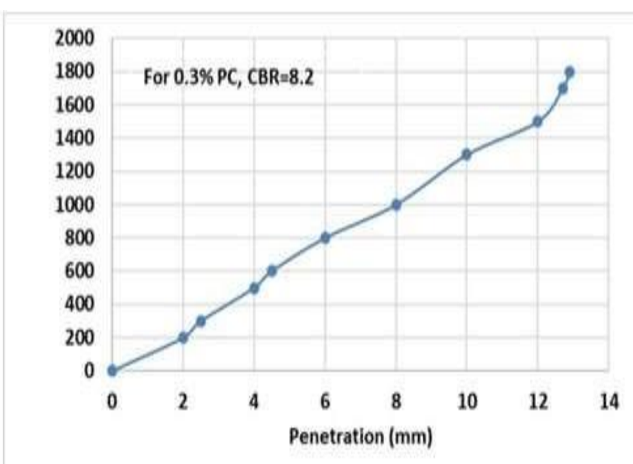


Fig4.10:CBRwithLoadvs.Penetrationwith0.3%plastic

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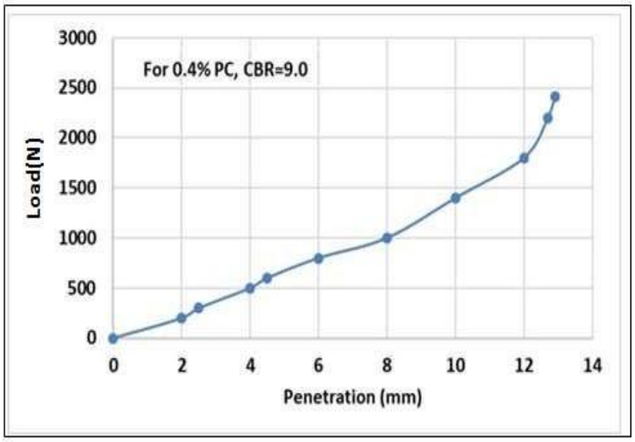

Figure4.11:CBRwithLoadvs.Penetrationwith0.4%plastic

Plasticcontent	CBR%	LOAD(N)
0	7.05	1594
0.2%	7.76	1695
0.3%	8.2	1795
0.4%	9.0	2415

Table4.7:Plastic content with CBR Value and load penetration

As it can be seen from the table 4.7 the increase in resistance to penetration is increased as percentage of plastic is increased which also causes increase in CBR ratio. At 0.4% the sample required more load which is 2.415kn to penetrate the soil specimen. And harder the material the higher will be the CBR value. So CBR is also found to be maximum at 0.4% inclusion of plastic content .The CBR value for clay should be from(3 – 10%) according to (American Association of State Highway and Transportation Officials). As we achieve more CBR at 0.4% plastic content but we are losing maximum dry density. Hence recommended is soil sample with 0.3% plastic content because it has better soilpacking with a good CBR value of8.2%.

4.5. UNCONFINED COMPRESSION TEST

The UCS is done to find compression strength in an unconfined condition of the soil, for this purpose four samples were compacted at their obtained MDD and OWC with 0, 0.2, 0.3 and0.4% of plastic bag addition. The height and diameter of sample were (120.7) mm and(102)mm respectively. The samples are then placed in UCS testing machine and readings were observed until the cracks were observed inthe samples.

After getting the results it is noticed that the strength of soil is increased as plastic bag percentage is increased. Therefore at 0.4% addition of plastic bags unconfined compressive strength was reached. But same is thescenario with UCS as with CBR we loses our maximum dry density at 0.4%. So UCS at 0.3% can be accepted as the optimum amount of stabilizer addition

Plasticcontent	UCS(kPa)	Increasei n UCS	Cohesion
0%plasticcontent	88	----	44
0.2%plasticcontent	154	75%	77
0.3%plasticcontent	195	121%	97.5
0.4%plasticcontent	216	145%	108

0.4%. So UCS at 0.3% can be accepted as the optimum amount of stabilizeraddition

Table4.8:UCS Results with different percentages of plastic/ percentage difference

By addition of 0.4% of plastic bags an increase of 145% is observed in compressive strength of soil sample. As undrained cohesion of clay soil can be measured by equation

$C_u = q_{u/2}$

Where c_u is cohesion

q_u is unconfined compression testSo, it can be concluded that increasing the plastic bags content increases the cohesion of the samples and therefore shear strength increases.

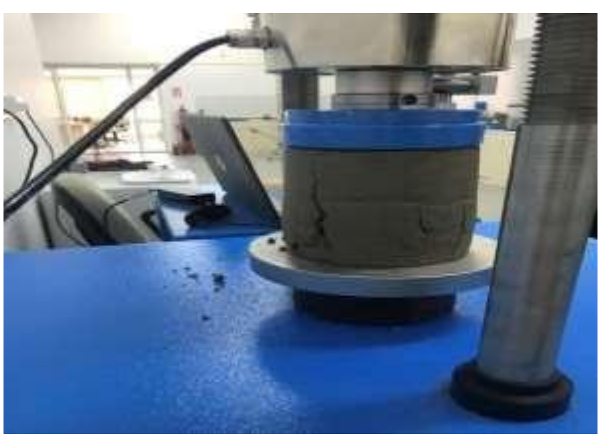

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Figure4.12:UCSresultshowingthe failureunderstressfor0% plasticcontent

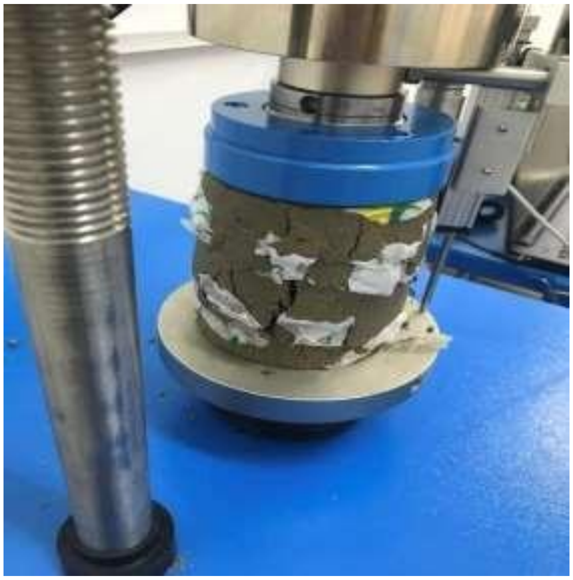

Figure4.13:UCS result showing the failure under stressfor0.2%plasticcontent

With 0% plastic

Figure4.15:UCS result showing the failure under stressfor0.4%plasticcontent

Figure 4.16 shows the UCS comparison of soil samples with 0.2%, 0.3% and 0.4% of plastic bagsstrips stress (kpa) vs Axial stain (%). As it can be seen that all the samples show plastic behaviorwhile failure as it is expected from cohesive samples which means that samples continue to carry some stress even after failure in response to its residual strength.

4.6. SRINKAGE BEHAVIOUR OF SOILANALYSIS

This experiment is conducted according to IS:2720 (Part 6)

– 1972 to ascertain the volume shrinkage behavior of a soil sample. For the purpose of this study, the soil sample has been compacted at his optimum water content with zeroand then with three different percentages of plastic content as 0.2%, 0.3% and

0.4% respectively. With this method, the volume of the soil is measured. After they were put to series of wetting and drying cycles. In each cycle200gram/ml of water was added ineach sample to notice the crack.

With 0% plastic

With 0.2% plastic

With 0.3% plastic

With 0.4% plastic

Plastic %	Days1	Day 2	Day 4	Day 6	Day8	%Difference
	0	24	48	96	144	
0%	2000cm^3	2000cm^3	1000cm^3	725 cm^3	621cm^3	68%
0.2%	2000cm^3	1600cm^3	1450cm^3	1050cm^3	869cm^3	56%
0.3%	2000cm^3	1875cm^3	1772cm^3	1345cm^3	910cm^3	54%
0.4%	2000cm^3	1750cm^3	1654cm^3	1280cm^3	828cm^3	58%

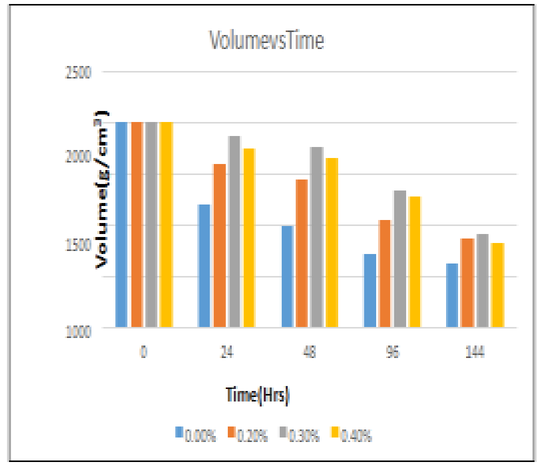

Figure4.18:Showingvolumecomparison of samples

Table4.9: Showing different volumes calculated at different intervals

As it can been seen from the table 4.6 there is significance volume change after adding water to the sample and leaving it toseveral wetting drying cycles. The initial volume notedafter the samples were made was 2000Cm^3 for eachsample and it was left till it totally dried, that normallytook about 24 hours in temperature of 30 to 40 degreecentigrade for one day to dry and the measurement doneafter drying shows that the sample with 0% plasticcontent has shrinked more than sample with 0.4% plastic content because the shrinkage was less as compared to other samples. It canbe explained as plastic bags shreds act as fibers within the soil, keeping the grains together and there fore resisting the shrinkage. After these cond measurement 200 g/ml of water was added in all the sample and the readings were noted after full drying. The sample with 0% plastic shows more shrinkage as compared to the samples containing more amount of plastic content.

The samples were further more left for wetting/Drying cycles by adding 400 g/ml in total on water with 2 days interval of wetting and drying. The results noted after 4 cyclesshows that the sample with higher shrinkage contains no plastic. At 0.4% less cracks were observed as it can be seen in figure 4.18.

Maximum volume change after the fourth cycle was observed in the sample with no plastic content by68%.volume reduction. This volume reduced to 54% inaddition of 0.3% plastic bags shreds.0.2% and 0.4% reduced the volume shrinkage to 56% and

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58% respectively. The starting stage of drying was from OWC but after first drying cycle 200g/ml of water was added to sample with area of 500 (cm^2) resembling 4mm of rain per squaremeter. After second cycle of drying ,400 gram/ml water resembling 8mm of rain was added tothe sample, showing a heavy rain condition 4 to 8mm per hour (USGS.gov).

As Cyprus is considered as a semi arid climate therefore soil is often dry or partly saturated. The test was operated to monitor the behavior of dry soil after a heavy rain and then the shrinkage of it during drying process.

CONCLUSION

The plastic waste is deteriorating ourenvironment and proper care or methods need tobe obtained in order to get rid of plastic pollution and to use it in to something more beneficial. So as geotechnical engineering our major goals is touse this waste material in torecyclable material, therefore this thesis employed the used of plastic waste as the stabilization of the soil.

As stated above the following are the main objective ofthe thesis:

- To improve the engineering characteristics of thesoil such as shear strength and bearing capacity
- To find a good way for dumping of plastic wastes.
- Decreasing cost of soil stabilization by using cheaper material
- Making the waste materials and environmentalhazardous material into the useful material.

For this purpose, the soil from near east university campus has been collected and different test such as compaction, compression, CBR and shrinkage behavior of the soil has been implemented with and without plastic percentage content as the stabilizer. Optimum moisture content and maximum dry density of the soil were found out and then soil with plastic content as 0.2%, 0.3% and 0.4% were considered and it was noted that the optimum was reached and attained at 0.3%.

It was observed that CBR value goes on increasing from 7.05% at 0% to 9.0% at 4.0% plastic bag contents. Major difference has been noted in soil for 0% and 0.4%.

While performing UCS test the percentage difference of samples with no plastic and with0.2%,0.3% and 0.4% were calculated which goes on increasing from 0 to 145% showing that the samples with 0.4% plastic fibers has much compression strength as compared to other samples.

Shrinkage analysis were also done on sampleswith same amount of plastic bags content and results shows that shrinkage was reduced and cracks were visibly improved.

Soil stabilization is a process of increasing different engineering properties of soil such as its strength and its bearing capacity. The main purpose is to make the soil good enough to be used for different construction purposes such as road construction and pavements.

The demand of plastic and its usage is increasing everyday and it is effecting our environment. It is very important to find a good way for its disposal

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instead of dumping which has some harmfuleffects. So using it to stabilize the soil is a cheapand better way. Likemany countries Cyprus has also issues of dumping the waste so this will help to reduce the amount of plasticwaste and will provide us a soil which has betterengineering properties. These plastic wastes havemuch harmful effect even on climate. If wedumped these waste we are having groundpollution. The latchet flowing from these plasticbags percolate into ground and destroying our ground water resources. Burning these wastes causes emission of methane gases which is destroying our ozone layer.Adding plastic to soil will improve its engineering properties. The demand of plastic is increasing and we need to find a cheap and better solution for its disposal. According to this research and comparing it with previous studies done it isobserved that using this waste in soil stabilization give good engineering properties to the soil.Many countries are now focusing on using soil in plastic. India has started it in construction of roadsand pavements.

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