SUBGRADE SOIL STABILIZATION BY USING DEMOLISHED CONCRETE WASTE AND RECYCLED PLASTIC POLYMERS

submitted in partial fulfillment of the requirements

for the degree of

Bachelor of Engineering

by

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Anjuman-I-Islam's Kalsekar Technical Campus

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CERTIFICATE

This is to certify that the project entitled "**Subgrade Soil Stabilization by Using Demolished Concrete Waste and Recycled Plastic Polymers**" is a bonafide work of **Khan Suhail Muqueem (16DCE71), Devekar Shweta Dhanaji (16DCE62), Hodekar Arbaz Alauddin (16DCE63), Patel Najeeb Mabud (16DCE78)** submitted to the University of Mumbai in partial fulfillment of the requirement for the award of the degree of "Undergraduate" in "Civil Engineering"

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This dissertation report entitled "**Subgrade Soil Stabilization by Using Demolished Concrete Waste and Recycled Plastic Polymers**" by **Khan Suhail Muqueem (16DCE71), Devekar Shweta Dhanaji (16DCE62), Hodekar Arbaz Alauddin (16DCE63)** and **Patel Najeeb Mabud (16DCE78)** is approved for the degree of "Civil Engineering"

Examiners

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Supervisors:

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Date:

Place: Panvel

Declaration

We declare that this written submission represents our ideas in our own words and where others ideas or words have been included, we have adequately cited and referenced the original sources. We also declare that, we have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in our submission. We understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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ABSTRACT

Long term performance of pavements depends upon the stability of its underlying soil. There are various methods of stabilizing subgrade soil which are both expensive and labour intensive. However, based on literature review, it was found that using demolished concrete waste and recycled plastic polymer beads in order to enhance the properties of the weak soil and making it suitable for engineering purpose can be a low cost and effective alternative for soil stabilization. Also, the current annual rate of generation of construction waste is 1183 million tonnes worldwide in which 11.4 to 14.69 million tonnes per annum is generated in India. Therefore, reusing demolished concrete waste and recycled plastic polymer beads as subgrade stabilizer proves to be environment friendly too. So there is a need to transform ineffective waste materials into effective subgrade materials. In this study, the initial properties of unstabilized soil sample (such as maximum dry density, optimum moisture content, CBR value and unconfined compressive strength) and the initial properties of waste concrete aggregates (such as specific gravity, moisture content, bulk density, aggregate impact value and aggregate crushing value) are determined. Then the unstabilized soil is mixed with varying proportions of waste concrete aggregates and recycled plastic polymer beads and its CBR values, maximum dry density, optimum moisture content and unconfined compressive strength is determined and compared with that of unstabilized soil, based on which the optimum dosage of stabilizer is suggested.

Keywords: soil stabilization, demolished construction waste, waste concrete aggregates, recycled plastic polymers beads, environment friendly

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATION NOTATION AND NOMENCLATURE

RP	Recycled Plastic
CBR	California Bearing Ratio
UCS	Unconfined Compressive Strength
MDD	Maximum Dry Density
OMC	Optimum Moisture Content
C&D	Construction and Demolition
BKD	Brick Kiln Dust

Chapter 1

Introduction

1.1 General

Soil stabilization is the ground improvement technique to enhance natural properties of subgrade soil to meet engineering purpose. Stabilizing local weak soil enables reduction in construction cost and improves performance of pavement. When the subgrade soil and the overlying layers provide adequate support for the traffic loads, the pavement gives satisfactory service in the design period. Its increases ultimate strength in terms of California Bearing Ratio (CBR), ductility, toughness, energy absorption capacity of soil and unconfined compressive strength. Various methods and materials are used for stabilizing the soil. Some of the renewable technologies are: enzymes, surfactants, biopolymers, synthetic polymers, co-polymer based products, cross-linking styrene acrylic polymers, tree resins, ionic stabilizers, fiber reinforcement, calcium chloride, calcite, sodium chloride, magnesium chloride and more. Some of these new stabilizing techniques create hydrophobic surfaces that prevent road failure from water penetration or heavy frosts by inhibiting the ingress of water into the treated layer.

However, recent technology has increased the number of traditional additives used for soil stabilization purposes. Such non-traditional stabilizers include: polymer based products (e.g. cross-linking water-based styrene acrylic polymers that significantly improves the load-bearing capacity and tensile strength of treated soils), copolymer based products, fiber reinforcement, calcium chloride and sodium chloride. Soil can also be stabilized mechanically, for example, using geogrids or geocells, which are a 3D mechanical soil stabilization technique. Other stabilization techniques include using on-site materials including sub-soils, sands, mining waste and crushed construction waste to provide stable, dust free local roads for complete dust control and soil stabilization.

Utilizing new soil stabilization technology, a process of cross-linking within the polymeric formulation can replace traditional road/house construction methods in an environmentally friendly and effective way.

In other words soil stabilization means "soil stabilization is a process of treating a soil in such a manner as to maintain, alter or improve the performance of the soil as road constructing material. The changes in the soil properties are brought about either by incorporation of the additives or by mechanical blending of different soil types.

1.2 Problem Statement

Poor subgrade soil condition can result in inadequate pavement support and reduce pavement life. Alligator cracks will appear on the surface of the pavement due to weak subgrade. Poor subgrade results in corrugation at surface and increase in unevenness. Due to moisture variation, swelling and shrinkage of weak subgrade will occur. If the subgrade is too weak to support the wheel loads, the pavement will flex excessively which ultimately causes the pavement to fail. If soil is poor, there is excessive variation in volume and stability with the variation in water content. Poor soil behaves as non-plastic soil also the soil become friable in nature and it becomes easy to pulverize the lumps.

1.3 Proposed Solution

Stabilizing the weak soil with suitable waste material as stabilizer could be an effective and economic method. According to 11th year plan, construction industry in India is the second largest economic activity after agriculture. The quantity of waste materials generated per annum from construction and demolition activities vary from 11.5 to 14.69 million tons in India. Due to the rapid growth in the construction industry, it will be appropriate to link construction and demolition waste generation with the Indian economic growth. Therefore, suitable practices are needed to handle construction and demolition (C & D) waste in order to propose a sustainable approach. Stabilization of weak subgrades using construction and demolition wastes would ultimately lower carbon footprints in contrast to using traditional quarried materials. Hence construction and demolition wastes could be shifted from "Waste Material" category to "Resource Material" category.

Figure 1.1 Construction and Demolition Waste

Waste plastic is one such, which is commonly used for shopping bags, storage and marketing for various purposes due to its most advantage character of less volume and weight. Most of these plastic are specifically made for spot use, having short life span and are being discarded immediately after use. Though, at many places waste plastics are being collected for recycling or reuse, however; the secondary markets for reclaimed plastics have not developed as recycling program. Therefore, the quantity of plastics that is being currently reused or recycled is only a fraction of the total volume produced every year. The estimated municipal solid waste production in India up to the year 2017 was of the order of 54 million tons per year. From this plastics constitute around 4 % of the total waste. Plastic has become a major problem these days as this product is non-biodegradable so disposing it efficiently is a difficult challenge. With the few reasons cited above, it is very important that we find ways to re-utilize these plastic wastes. Therefore, the investigation and attempt has been made to demonstrate the potential of reclaimed plastic wastes as soil reinforcement for improving the sub grade soils. Soil mixed with plastic have advantages over other reinforcing materials. It improves the ductility, toughness, strength, stiffness and durability of soil as plastic is non-biodegradable. It reduces the compressibility of soil and improves soil piping resistance. Moreover, it is cheap as compared to other materials being used for reinforcing soils.

Figure 1.2 Recycled Plastic Polymers

1.4 Objectives

Objectives of our study are:

1. To determine the initial properties of unstabilized soil sample such as maximum dry density, optimum moisture content, CBR value and unconfined compressive strength.
2. To determine the initial properties of aggregates such as specific gravity, moisture content, bulk density, aggregate impact value and aggregate crushing value of demolished aggregate.
3. To determine CBR values, maximum dry density, optimum moisture content, unconfined compressive strength of stabilized soil with different dosage of stabilizer.
4. To compare the above properties of stabilized and unstabilized soil.
5. To suggest optimum dosage of stabilizer for soil improvement levels.

Chapter 2

Literature Review

2.1 General

During the literature review for this work, we have referred quite a few text and reference books on geotechnical engineering; and research papers from various national and international journals. This part summarizes on the literature of improvement of soil using demolished concrete waste and recycled plastic polymer.

2.2 Review of Literature

Depa (2013) had conducted tests on clayey soil with stabilizer as Brick Kiln Dust(BKD). The proportion of stabilizer taken by her was (clay soil: BKD) 80:20, 50:50, 50:60. She concluded that the optimum proportion of stabilizer was 50:50 and CBR value increased from 0.6% to 6.0% and further decreased.

Tawgirimania *et al.* (2014) had conducted tests on silty sand soil with stabilizer as demolished concrete and Lime. The quantities of stabilizer was taken by him were 0%, 2%, 4%, 6%, 8%, 10%. He concluded that the optimum quantity of stabilizer was 6% for lime and 8% for demolished waste and CBR value of unsoak soil increased from 9.18% to 20.83% and that of soak soil increased from 4.95% to 14.19% by demolished waste and CBR value of unsoak soil increased from 9.18% to 18.18% and that of soak soil increased from 4.94% to 13.2% by lime and further decreased.

Missal SS. And Vasatkar A.R (2016) had conducted tests on Weak red soil with stabilizer as Construction waste and Plastic waste. The quantities of stabilizer were taken by them for construction waste and plastic waste were 3%, 5%, 7% and 9%.They concluded that the optimum quantity of stabilizer for construction waste and plastic waste was 7% and CBR value increased from 2.73% to 8.54% by plastic waste and 2.73% to 7.39% by construction waste and further decreased.

Rawat P. and Kumar A. (2016) had conducted tests on river side soil which was of CL-ML type of soil. HDPE (High Density Polyethylene) was cut into strips by them, 5mm wide in aspect ratio (l/b) of 1, 2 and 3.They had performed number of tests on soil to determine its initial properties and also they were having general properties of HDPE plastic. Soil sample were mixed with 0.5,1, 1.5 & 2 % of HDPE strips with three aspect ratios as 1, 2, and 3 by the authors and then standard proctor test was conducted to find their MDD (maximum dry density) for soaked and unsoaked soil. They concluded that OMC shows little change as the Aspect Ratio (AR) and percentage of HDPE strips changes & MDD of soil decreases with the increase in percentage of AR of HDPE maximum value of CBR is obtained when soil was mixed with 1.5% HDPE strips of AR. The CBR of such a reinforced soil is found 4 times more than unreinforced soil.

Paul and Cyrus (2016) had conducted tests on the Kaolinitic soil with stabilizer as demolition concrete aggregate. The quantities of stabilizer taken by them were 0%, 20%, 40% and 60%. They concluded that the optimum quantity was 40% and CBR value increased from 3.4% to 11.2% and further CBR decreased with 40% addition of aggregates, which was 3.2 times increase in the CBR value and there was 25cm decrease in the pavement thickness which accounts to be 45% of the original thickness.

Lovedeep *et al.* (2017) had conducted test on subgrade soil which was collected from then Guru Nanak Dev Engineering College campus. Waste concrete fines was collected by from their Concrete Testing laboratory. They had performed various tests on unstabilized soil to determine initial properties. They crushed & sieved the collected concrete waste and then sample passing through 1.76mm IS sieve was used. The dosage of concrete fines was 10%, 20%, 30% & 40% and their CBR value increased from 6.56 to 6.93, 10.94, 21.89 &29.19 resp.

Neeladharan *et al* (2017) had conducted tests on clayey soil with stabilizer as Tiles waste and Sodium Hydroxide. The quantities of stabilizer were taken by them for tiles waste 0%, 5%, 10% to 40% and for NaOH 0%, 2.5%, 5% to 20%. They concluded that the optimum quantity of stabilizer for tiles waste was 35% and NaOH 7.5% and CBR value increased from 1.93% to 16.19% and further decreased.

Dixit M.S and Patil K.A (2017) collected the soil sample from J. K Road Bhopal region it was black cotton soil. First they conducted all initial tests like standard proctor test for finding MDD(maximum dry density) and OMC(optimum moisture content), Atterbergs limit, plasticity index, Unconfined compressive strength and CBR on soil sample and found its all initial value. Then they mixed black cotton soil with varying percentage of stone dust and polypropylene fibers with dosage of 5%, 10%, 15% and 20% and 0.5- 1.5% and conducted all the tests with stabilizers. And from the performed tests finally they concluded that the CBR value of soil sample from 1.59 is increased upto 5.29 at 10 % stone dust and 1% of polypropylene fibers and recommended that percentage as optimum dosage of stabilizer because further increase in percentage of stabilizer there was reduction in CBR value of soil sample.

Vajiwade *et al.* (2018) had conducted tests on the black cotton soil with stabilizers as stone dust and plastic glass strip. The quantities of stabilizers taken by them for stone dust was 5%, 10%, 15% and 20% and for plastic glass 0.5%, 1.0%, 1.5%, 2.0%. Stone dust which was used in soil was passing through 90 micron IS sieve and the glass were cut into 1cm x 1.5cm by them. They concluded that the optimum quantity of stone dust was 15% and plastic glass 1.5% and the CBR value increased from 4.32% to 9.25 and further decreased.

Vivek *et al.* (2018) had conducted tests on the black cotton soil with stabilizers as construction and demolition (comprised block work, cement plastering, brick work and concrete work). The quantities of stabilizers taken by them were for 2%, 4%, 6% till 14%. They concluded that the optimum quantity of stabilizer was 10% and the MDD value increased from 1411 KN/m^3 to 2148 KN/m^3 and further decreased.

Chapter 3

Materials and Methodology

3.1 General

This study demonstrates the use of demolished concrete aggregate and recycled waste polymers as a stabilizing material in soil in which, an experimental work has been carried out to find the California Bearing Ratio of soil before and after stabilization. The results generated by testing of soil with different proportion of C and D waste and RPP will help to find optimum dosage of stabilizer in soil with similar properties. The graph will helps to understand the effect of stabilizer by proportion of its weight.

3.2 Materials

3.2.1 Soil

The main material used for this study is soil. The soil has been collected from a field located at Uran Road owned by Jawaharlal Nehru Port Trust (JNPT). The soil properties is been tested with different experiments to find its characteristics properties such as classification of soil, liquid limit, plastic limit, CBR value, maximum dry density and optimum moisture content. Random sampling was done to get the representative sample. It was taken from the depth range from 5m to 10m. It was brownish clayey soil.

Figure 3.1 Collected soil sample

3.2.2 Demolished Concrete

Demolished concrete waste was obtained from Concrete Technology laboratory of Anjuman-I-Islam's Kalsekar Technical Campus (AIKTC).It involves crushing, sorting, sieving and removal of contamination. The obtained material was hand crushed using hammer to get the representative sample containing aggregate wastes of size ranging from 4.75mm to 20mm. The properties of demolished aggregate are given below:

Table 3.1 Properties of Demolished Concrete

Property	Values
Crushing value	13.78%
Impact value	9.475%
Bulk density	1666.03 Kg/m^3
Abrasion value	20.16%
Water absorption	1.4%
Specific gravity	2.67

These properties of aggregate represents the quality as it is used for stabilization of soil.

Figure 3.2 Crushing of Aggregate

3.3 Methodology

Procurement of the materials was the important phase of the study. Soil was collected from JNPT Uran. The RP polymers were obtained from Aegis Polymers, Mulund and C & D waste was collected from Concrete Technology laboratory of AIKTC. By studying various literature which was published earlier tests to be performed and the proportion of inclusion of RP polymers is decided as 0.5%, 1.0%, 1.5%, and 2% and demolished aggregates of proportion 5%, 10%, 15% and 20%.

3.3.1 Tests

Following are the tests which we have performed on soil and on aggregate to show the initial behaviour of sample.

3.3.1.1 Tests on soil

All tests that were performed were according to their respective Indian Standard code. The test was performed in laboratory. Tests are as follows:

1. Determination of California Bearing Ratio

This test has been performed in accordance to IS: 2720:1987 (Part-16).

<u>Apparatus:</u>

Cylindrical mould, Spacer disc, Surcharge weights, Penetration plunger, loading machine of capacity 5000 kg, Compaction rammer of 2.6 kg with a drop of 310 mm, proving ring, dial gauges, balance, filter papers, mixing tools, tray to contain soil sample and measuring cylinder, Sieve of size 20 mm and 4.75 mm.

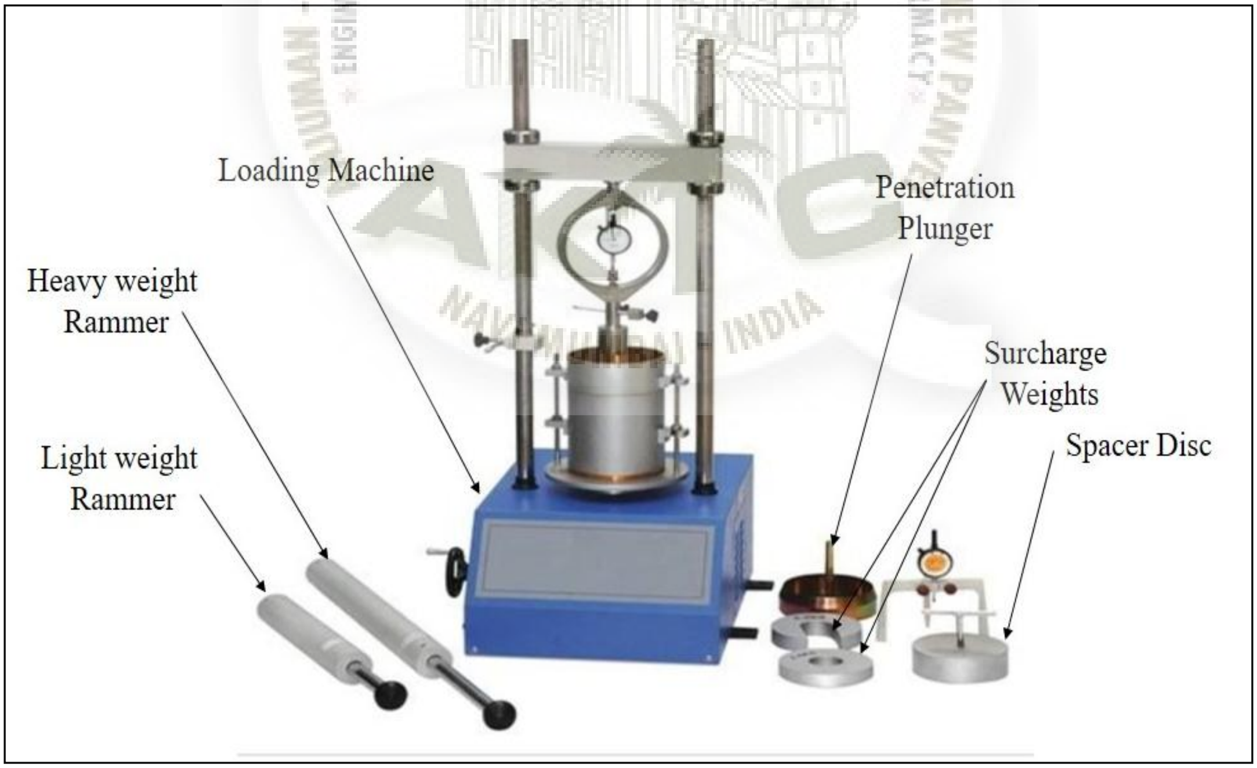

Figure 3.3 Experimental set up for CBR Test

Test Procedures:

A. Preparation of (dynamically compacted) Test Specimen (by light compaction):

1. First the mould was assembled and then spacer disc were placed with threaded hole facing bottom side at the bottom of base plate and filter paper was placed at the top of it.
2. Lubricating oil was applied to the inner side of the mould to prevent the stickiness of soil to the mould.
3. Then mould was fixed over base plate and spacer disc and also collar and clamps were tightened.
4. Now, about 5 kg of soil passing 20 mm sieve and retained on 4.75 mm sieve was taken and mixed with a predetermined quantity of water such that the water content of the soil is either equal to the OMC and mixed thoroughly.
5. Then the soil was transferred into the mould and filled into 3 compacting layers.
6. Now each layer was compacted by giving 56 numbers of blows to each layer which should be uniformly spread throughout the area.
7. Similarly, remaining two layers were compacted by giving 56 no. Of blows.
8. After compaction of the top layer, the collar was removed.
9. After removing the filter paper, the weight of the mould filled with soil was noted.
10. The spacer disc along with the filter paper was removed and another filter paper at the bottom was placed.
11. The mould was placed such that compacted surface is at the bottom and annular weight of mass 2.5 kg was placed.
12. Then the whole assembly was placed on loading machine, the proving ring and dial gauges were attached in position.

B. Penetration Test:

1. The plunger was fixed, the plunger was kept in contact with the soil surface and seating load of 4 kg was applied so that full contact is established between soil and plunger.
2. Then another 2.5 kg slotted weight was added at the top.
3. The plunger was allowed to penetrate at a rate of 1.25 mm/min.
4. The load readings were recorded at penetration of 0, 0.5, 1, 1.5, 2, 2.5, 3, 4, 5, 7.5, 10 and 12.5.
5. The maximum load and penetration was recorded.
6. The load penetration curve was plotted.

Figure 3.4 Performed Set up for CBR Test

2. Modified Standard Proctor Test

This test has been performed in accordance to IS 2720 (Part 8:1983).

Apparatus:

Cylindrical mould and accessories (volume1000cm3), Rammer 4.9 kg, Balance (accuracy) , Sieves (19mm) , Mixing tray, Trowel, Graduated cylinder (500 ml capacity), Metal container.

Figure 3.5 Instruments of Standard Proctor Test

Test Procedures:

1. 5 Kg of soil was taken and the water is added to it to bring its moisture content to about 4% in coarse grained soils and 8% in case of fine grained soils with the help of graduated cylinder.
2. The mould with base plate attached was weighed to the nearest 1 gm. The extension collar was attached with the mould.
3. Then the moist soil in the mould was compacted in three equal layers, each layer being given 25 blows from the 4.9Kg rammer dropped from a height of 450 mm. above the soil.
4. The extension is removed and the compacted soil is leveled off carefully to the top of the mould by means of a straight edge.
5. Then the mould and soil was weighed to the nearest 1 gm.
6. The soil was removed from the mould and a representative soil sample was obtained for water content determination.
7. Steps 3 to 6 are repeated after adding suitable amount of water to the soil in an increasing order.

Figure 3.6 Performed Setup of Standard Proctor Test

3. Unconfined Compressive Strength

This test has been performed in accordance to IS 2720 (Part 10:1991).

Apparatus:

Unconfined compressive test apparatus (proving ring type), Proving ring, capacity 1 KN, accuracy 1 N, Dial gauge, accuracy 0.01 mm, Weighing balance, Oven, Stopwatch, Sampling tube, Split mould, 38mm diameter, 76mm long, Sample extractor, Knife, Vernier calipers, Large mould.

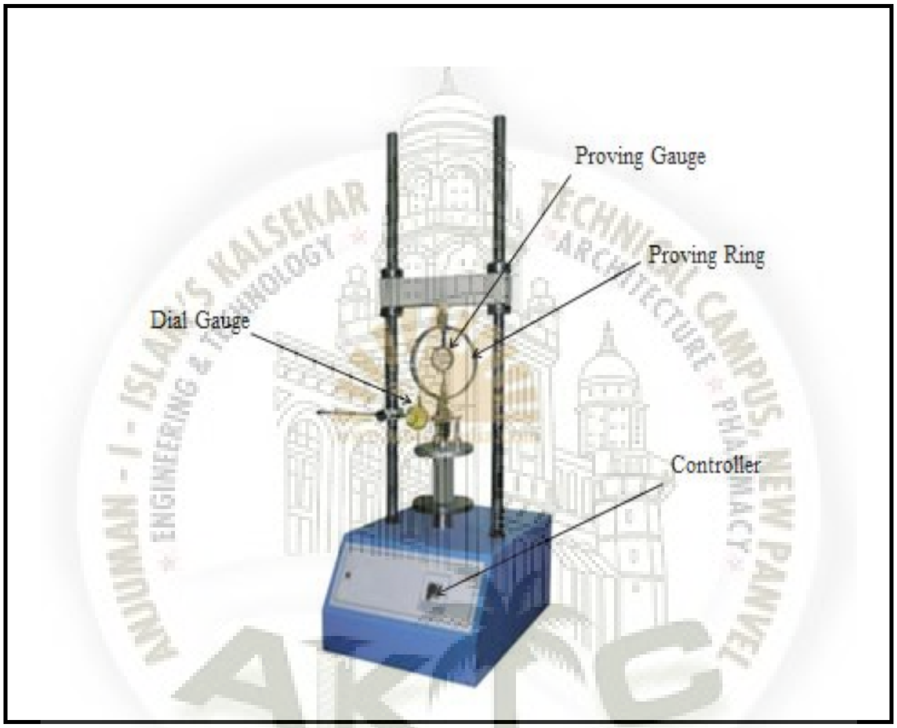

Figure 3.7 Experimental Setup of UCS Test

Test Procedure:

1. Soil which is to be tested was mixed with water. This sample was than filled in the mould which was oiled in advance. The mould is having the same internal diameter as that of specimen which is to be tested.
2. The mould was opened carefully and sample is taken out.
3. The initial length and diameter of specimen were measured.
4. The specimen was placed on the bottom of loading device. The upper plate was adjusted to make contact with the specimen and the dial gauge reading was kept (compression) at zero. The dial gauge readings provide the deformation in the sample and in turn strain.
5. The specimen compressed until cracks were developed or strain curve is well past its peak or until a vertical deformation of 20% is reached.

6. The dial gauge reading was taken approximately at every 1mm deformation of the specimen.
7. The proving ring readings provide the corresponding load in turn axial stress on the sample.
8. Test was repeated with different dosage of specimen.
9. Water content of each sample was determined.

Figure 3.8 Performed Setup of UCS Test

4. Grain Size Analysis

This test has been performed in accordance to IS 2720 (Part 4):1985.

Apparatus:

Set of fine sieves, 4.75mm, 2.36mm, 1.18mm, 600micron, 425, 300, 150, and 75 microns, weighing balance with accuracy of 0.1% of the mass of the sample, Oven, Mechanical shaker.

Figure 3.9 Mechanical shaker

Test Procedure:

Soil passing 4.75mm I.S. Sieve and retained on 75micron I.S. Sieve contains no fines. Those soils can be directly dry sieved rather than wet sieving.

1. 2000gm of the soil sample was taken.
2. Sieve analysis using a set of standard sieves as given in the data sheet was conducted.
3. The sieving was done by mechanical sieve shaker for 10 minutes.
4. Weight of the material retained on each sieve was noted.
5. The percentage retained on each sieve is calculated on the basis of the total weight of the soil sample taken.
6. From these results the percentage passing through each of the sieves is calculated.
7. The grain size curve for the soil in the semi-logarithmic graph is drawn.

5. Liquid Limit Test

This test has been performed in accordance to IS 2720 (Part 5) – 1985.

Apparatus:

Casagrande's liquid limit device, Grooving tools of standard types, Oven, Evaporating dish, Spatula, IS Sieve of size 425 µm, Weighing balance, with 0.01g accuracy.

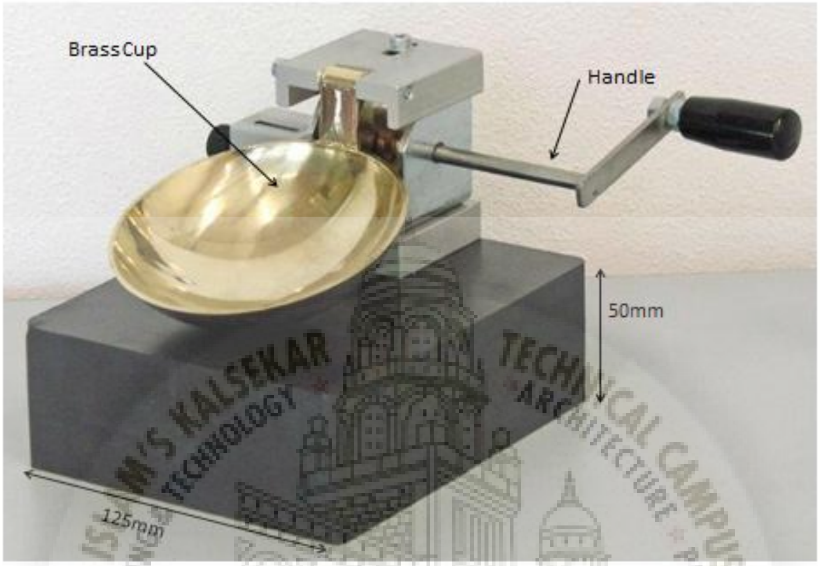

Figure 3.10 Casagrande's liquid limit device

Test Procedure:

1. A portion of the paste is placed in the cup of the liquid limit device.
2. Level the mix so as to have a maximum depth of 1cm.
3. The grooving tool was drawn through the sample along the symmetrical axis of the cup, holding the tool perpendicular to the cup.
4. For normal fine-grained soil: The Casagrande's tool is used to cut a groove 2mm wide at the bottom, 11mm wide at the top and 8mm deep.
5. After the soil pat has been cut by a proper grooving tool, the handle is rotated at the rate of about 2 revolutions per second and the no. of blows counted, till the two parts of the soil sample come into contact for about 10mm length.
7. About 10g of soil near the closed groove is taken and its water content is determined.
8. The soil of the cup is transferred to the dish containing the soil paste and mixed thoroughly after adding a little more water. The test was then repeated for 3 more times.

9. By altering the water content of the soil and repeating the foregoing operations, 4 readings were obtained in the range of 15 to 35 blows.
10. Liquid limit is determined by plotting a 'flow curve' on a semi-log graph, with no. of blows as abscissa (log scale) and the water content as ordinate and drawing the best straight line through the plotted points.

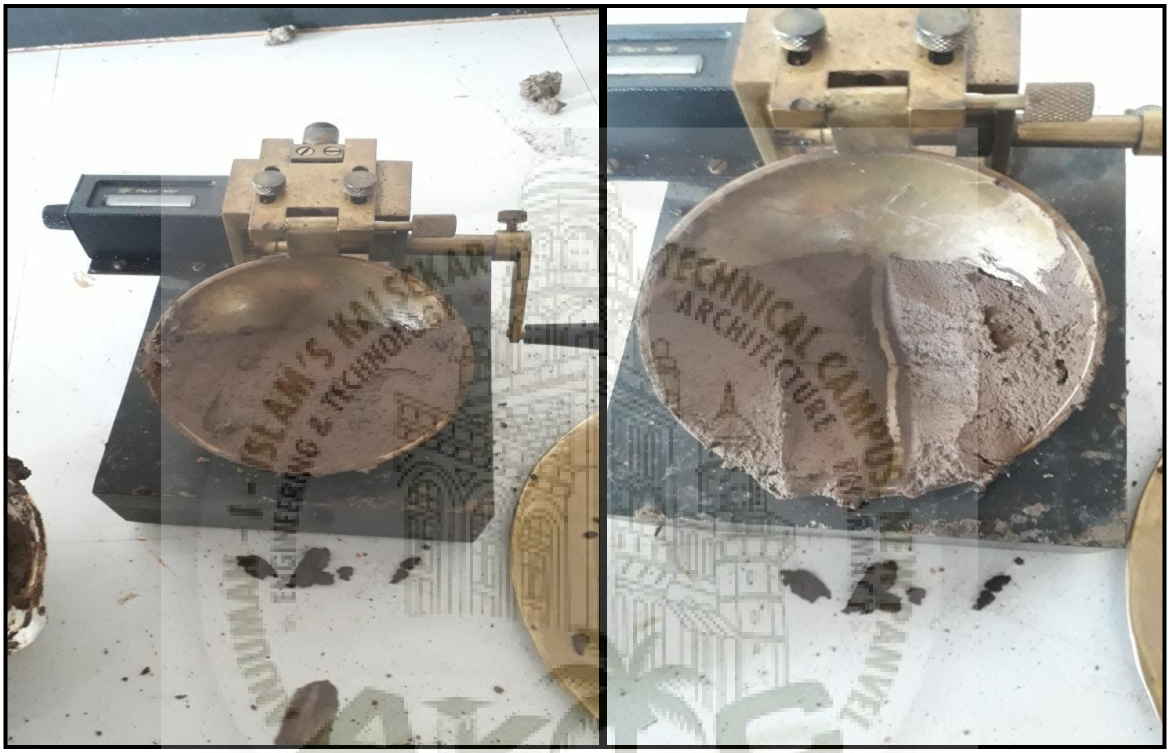

Figure 3.11 Performed Casagrande's liquid limit

6. Plastic Limit Test

This test has been performed in accordance to IS 2720 (Part 5) – 1985.

Apparatus:

Porcelain evaporating dish about 120mm diameter, Spatula, Container to determine moisture content, Container to determine moisture content, Oven, Ground glass plate – 20cm x 15cm, Rod – 3mm dia. and about 10cm long.

Figure 3.12 Plastic limit apparatus

Test Procedure:

1. 10g of the soil was taken and rolled it with fingers on a glass plate. The rate of rolling was in between 80 to 90 strokes per minute to form a 3mm dia.
2. If the dia. of the threads can be reduced to less than 3mm, without any cracks appearing, it means that the water content is more than its plastic limit. Knead the soil to reduce the water content and roll it into a thread again.
3. Repeated the process of alternate rolling and kneading until the thread crumbles.
4. The pieces of crumbled soil thread is collected and kept in the container used to determine the moisture content.

Figure 3.13 Rolled Soil Sample

Figure 3.14 Samples for Determination of Water Content

3.3.1.2 Tests on Aggregate

1. Determination of Crushing Value

This test has been performed in accordance to IS 2386 (Part IV) -1963.

Apparatus:

A steel cylinder, plunger and base plate, A straight metal tamping rod, A balance machine, IS sieves of sizes 12.5mm, 10mm and 2.36mm, Compression testing machine, Cylindrical metal measure.

Test Procedure:

1. Aggregate passing through 12.5 mm sieve and retained on 10 mm sieve was taken. About 6.5 kg of surface dry aggregate was filled in the standard cylinder in 3 layers, each layer was tamped 25 times by a standard tamping rod. It was leveled off. Its weight was found out (A).

2. The plunger was placed on the aggregate.

3. The assembly was then kept under compression testing machine and total load of 40 tones was applied uniformly within 10 minutes.

4. The load was released; the aggregate was taken out and sieved on 2.36 mm sieve. The fraction passing through was weighed (B).

5. Then The aggregate crushing value can be calculated by,

   Aggregate crushing value= (B/A) X 100 percent.

2. Determination of Impact Value

This test has been performed in accordance to IS 2386 (Part IV) -1963

Apparatus:

A testing machine weighing 45 to 60 kg with a metal base, cylindrical steel cup, metal hammer weighing 13.5 to 14.0 kg the lower end being cylindrical in shape, 50 mm long, 100.0 mm in diameter, with a 2 mm chamfer at the lower edge and case hardened. The hammer should slide freely between vertical guides and be concentric with the cup. Free fall of hammer should be within 380±5.

Test Procedure:

1. 1The test sample of aggregate passing through 125 mm IS sieve and retained on 10 mm IS sieve was taken and the aggregate was oven dried at 110 C for 4 hours.

2. The aggregate was filled in the cup (W1). By lifting the handle, hammer is allowed to fall freely as it was released by the tripping mechanism, on to the aggregate in the cup.

3. 15 such blows were given and then the aggregate was taken out and sieved on 2.36 mm sieve.

4. The fraction passing through was weighed (W2).

5. The aggregate impact value is given by,

   a. Aggregate impact value = (W2/ W1) x 100.

3. Bulk Density of Aggregate

This test has been performed in accordance to IS 2386 (Part III)-1963.

Apparatus:

Sieve, Tray, Weighing machine, Container of known volume, tamping rod.

Test Procedure:

1. The weight of empty container (W1) was taken of volume (V).
2. The cylindrical container was filled about one-third with the aggregate and each layer was tamped 25 times using tamping rod.
3. The final layer was filled till top, tamped 25 times and surplus aggregate was removed and considering weight the cylinder completely filled with aggregate(W2).
4. Bulk density of the aggregate can be calculated as follows:

   Bulk Density=(W2-W1)/V (Kg/m3).

4. Determination of Abrasion Value

This test has been performed in accordance to IS 2386 (Part IV) – 1963.

Apparatus:

Los Angeles machines, Sieve, Cylindrical metal measure, Tamping Rod, Balance (0-10kg), Oven.

Test Procedure:

1. This test gives the relative resistance of aggregate to wearing.
2. The specified weight 10 kg, depending on the size of the aggregate was taken and it was placed in the cylinder of the LA machine along with the abrasive charge.
3. The abrasive charge consists of a specific number of steel balls.
4. The cylinder was rotated at 20 to 33 r.p.m. for 1000 revolutions, depending on the grading of the aggregate. The aggregate was removed from the cylinder and sieved on 1.7 mm sieve.
5. The fraction passing through 1.7 mm sieve was expressed as percentage of original weight gives the aggregate abrasion value.

5. Determination of Specific Gravity and Water Absorption

This test has been performed in accordance to IS 2386 (part-III) 1963.

Apparatus:

Weighing balance, oven, glass vessel referred as pycnometer, jar about 1.25litercapacity, try and 1 kg of aggregate and water.

Test Procedure:

1. A sample of about 1kg was placed in try and covered with distill water at a temperature of 22-32°c soon after immersion air entrapped in or bubbles on the surface of aggregate

was removed by gentle agitation with rod sample was remained immersed for 24hours.

2. The water was then be carefully drained from the sample. The saturated and surface and dry sample was weighted as (W1).
3. The aggregate was then placed in pycnometer which is filled with distilled water. The pycnometer was topped up with distilled water weighted as (W2).
4. The contents of aggregate pycnometer was emptied, care was taken that all aggregate is transferred then the pycnometer was refilled with distilled water to same level as before and weighted as (W3).
5. Then the water was carefully drained from the sample and sample was placed in oven in try at 100°c to 110°c for 24hours, then it was cooled in air tight container and weighted as (W4).
6. Then find the specific gravity of aggregate,
   Specific gravity=W4/{W1-[W2-W3]}
   Water absorption= {100-(W1-W4)}/W4.

Chapter 4

Results and Discussion

4.1 General

Experimental determination of various soil properties has been carried out in accordance with their respective Indian Standard code. For every experiment of soil properties determination no. of samples were tested and their average value has been taken. For standard proctor test the soil sample is prepared with different proportion of plastic polymer beads and demolished concrete aggregates such as 0.5%-5%, 0.5%-10%, 0.5%-15%, 0.5%-20% where 0.5% is of polymer beads and 5.10,15,20% aggregates and so on is prepared. Plain soil is also prepared for comparison of reinforced and plain sample. Samples for each proportion is prepared and tested. Readings were noted and calculation is done and results are interpreted.

4.2 Results of tests on soil

Following are the test results which were performed on soil without stabilizer and with stabilizer which shows the effectiveness of the stabilizers.

4.2.1 Initial Properties of soil

These results shows the properties of soil such as UCS, MDD, OMC, LL etc. of the soil which afterward will compare with stabilized soil.

4.2.1.1 Atterberg's Limit:

1. Liquid Limit:

In accordance with IS 2720 (Part 5) – 1985
Three samples were tested using casagrande's liquid limit devices. The water content varies in each sample and number of blows given to soil sample is using apparatus is noted down. Graph is plotted using water content and number of blows.

Table 4.1 Readings of Liquid Limit

Determination No.	1	2	3
1. Number of blows	15	10	35
2. Container number	4	28	23
3. Mass of container + wet soil (g)	39.47	37.51	46.17
4. Mass of container +dry soil (g)	32.36	29.04	35.14
5. Mass of water (g)	7.11	8.47	11.03
6. Mass of container (g)	13.16	15	15
7. Mass of oven dry soil(g)	19.2	14.04	20.14
8. Water content (%)	37.03	37.62	35.38

From graph-for 25 blows,

Liquid Limit (LL) = 35.98%

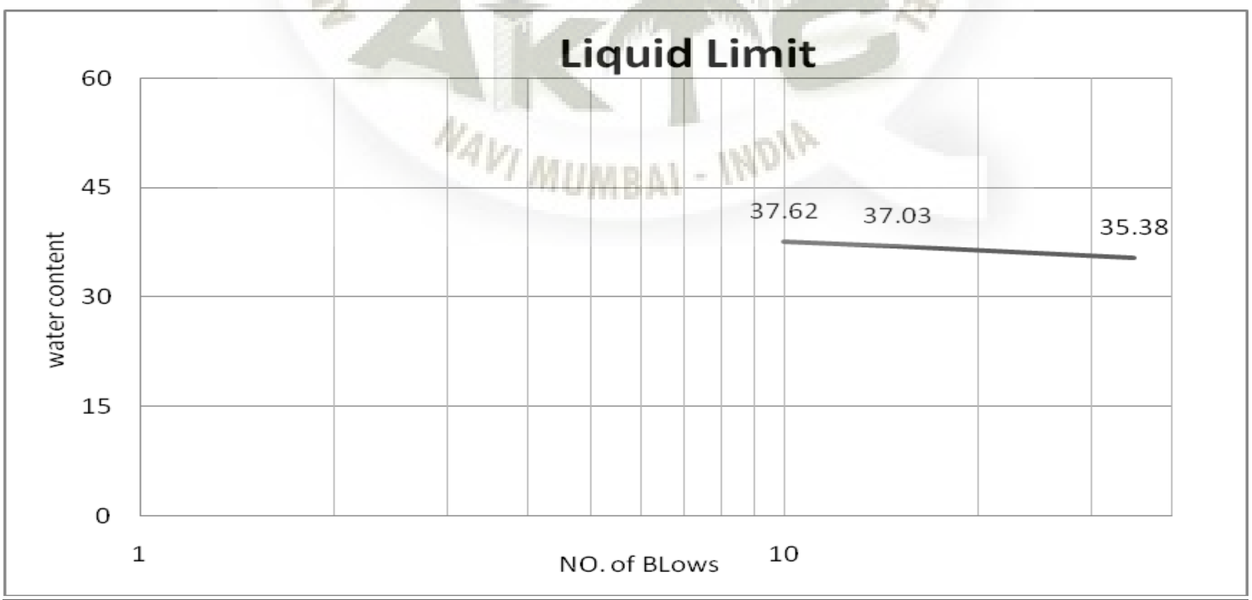

Figure 4.1 Liquid Limit Graph

2. Plastic Limit:

In accordance with IS 2720 (Part 5) – 1985

Three samples are tested using Plastic limit device in accordance with IS 2720 (Part 5) – 1985.

Table 4.2 Readings of Plastic Limit

Determination no.	1	2	3
1. Container no.	B1	C32	21
2. Mass of container + wet soil (g)	22.68	29.18	24.71
3. Mass of container + dry soil(g)	21.23	26.41	22.61
4. Mass of water(g)	1.45	2.77	2.1
5. Mass of container(g)	15.06	13.63	13.19
6. Mass of dry soil(g)	6.17	12.78	9.42
7. Water content (%)	23.5	21.67	22.29

Plastic Limit = 22.49%

4.2.1.2 Grain Size Analysis:

In this system, soils are arranged according to the grain size. Terms such as gravel, sand, silt and clay are used to indicate grain sizes. These terms are used only as designation of particles size, and do not signify the naturally occurring soil types, which are mixtures of particles of different sizes and exhibit definite characteristics.

Table 4.3 Grain Size Analysis

IS Sieve	Particle size D(mm)	Mass retained (gm)	Percentage Retained	Cumulative % retained	Cumulative % finer
100	100	0	0	0	100
63	63	0	0	0	100
20	20	0	0	0	100
10	10	0	0	0	100
4.75	4.75	20	2	2	98
2.36	2.36	18	1.8	3.8	96.2
1.18	1.18	24	2.4	6.2	93.8
600	0.6	32	3.2	9.4	90.6
425	0.425	53	5.3	14.7	85.3
300	0.3	89	8.9	23.6	76.4
150	0.15	118	11.8	35.4	64.6
75	0.075	124	12.4	47.8	52.2
Pan		522	52.2	100	0

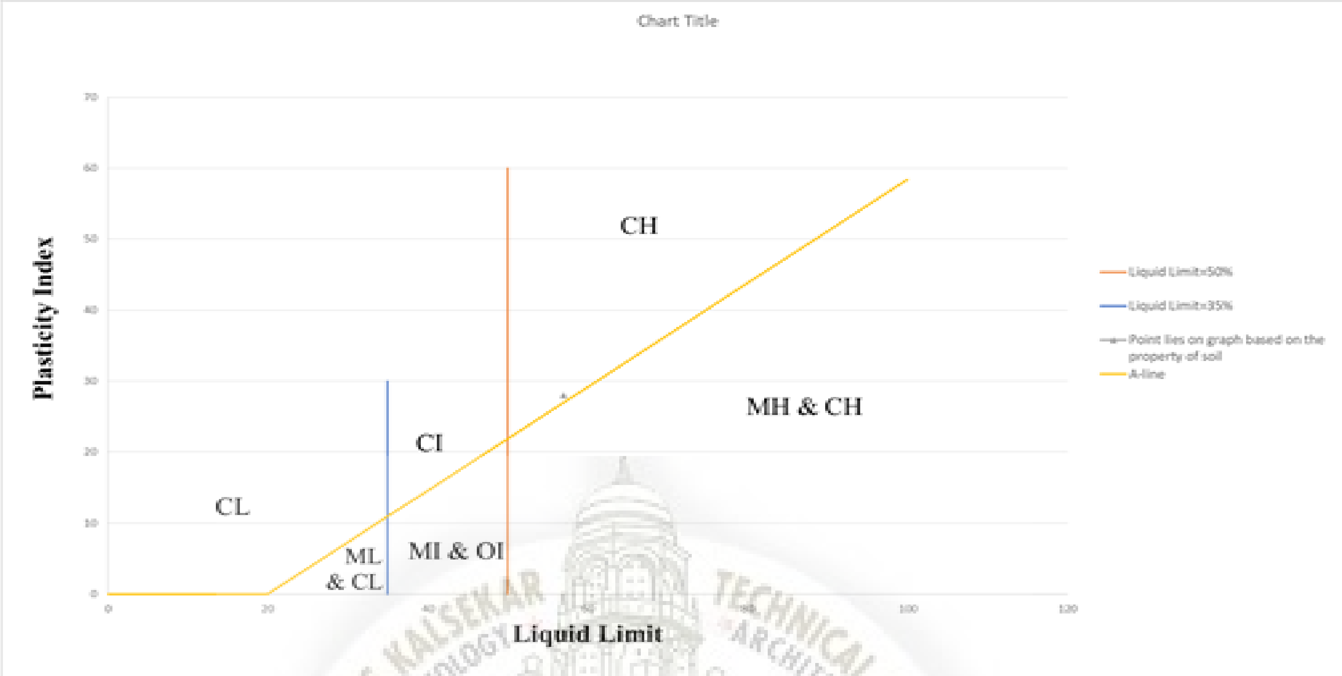

Figure 4.2 Plasticity Chart (IS Soil Classification)

Result:

As half the material by mass is smaller than 75 micron IS sieve, therefore it is fine grained soils. Laboratory classification of fined grained soil is done with the help of plasticity chart.

Plasticity Index (Ip) is given by,

Ip=LL-PL

Ip=35.98-22.49=13.49%

After plotting the point for Ip=13.49% and LL=35.98% on the plasticity chart, group symbol for soil will be CI, that is inorganic clays, gravelly clays, sandy clays, silty clays, lean clays of medium plasticity.

4.2.1.3 Modified Standard Proctor Test on Soil:

This test describes the compaction property of the soil without stabilizer by plotting the graph between dry densities and water content.

Table 4.4 Modified Proctor Test on Soil

Description	Readings		
A)Density			
1. Mass of mould + compacted soil (Kg)	7.61	7.465	7.655
2. Mass of mould (Kg)	5.57	5.57	5.57
3. Mass of compacted soil (Kg)	2.04	1.895	2.085
4. Bulk density (gm/cc)	2.04	1.895	2.085
5. Dry density (gm/cc)	1.81	1.75	1.89
B) Water content			
1. Mass of container + wet soil (gm)	71.64	37.3	70.51
2. Mass of container + dry soil (gm)	65.3	35.55	65.35
3. Mass of water (gm)	6.34	1.75	5.16
4.Mass of container (gm)	15	15.1	15.25
5. Mass of dry soil (gm)	50.3	20.45	50.1
6. Water content (%)	12.60	8.56	10.30

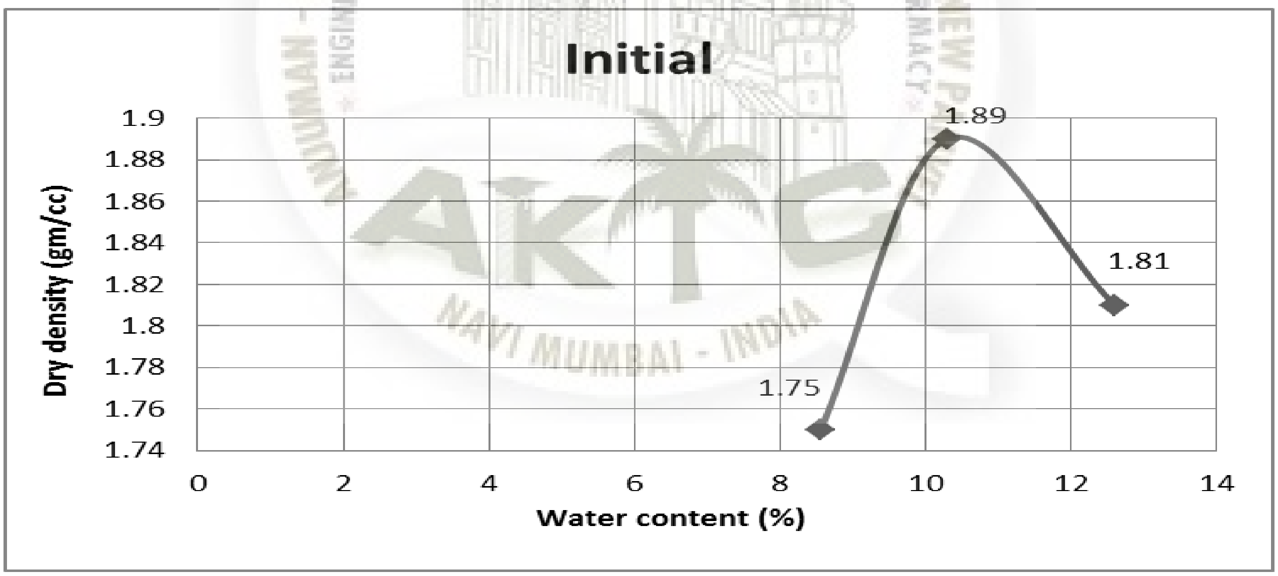

Figure 4.3 Modified Std. Proctor Graph

From graph,
Optimum Moisture Content (OMC) =10.3%

Maximum Dry Density (MDD) =1.89 gm/cc

4.2.1.4 Unconfined Compression Test:

The unconfined compressive strength of a soil is defined as the ratio of axial failure load to cross sectional area of the soil sample when it is not subjected to lateral pressure. The test is performed on cylindrical sample. Sample is subjected to direct compression until it fails.

This is the simplest and quickest test for determining the cohesion and the shear strength of the cohesive soils. These values are used for checking the short term stability of foundations and slopes.

Observations:

1. Internal diameter of specimen =3.8cm
2. Initial length =7.6cm
3. Dial gauge constant (G) =0.01mm
4. Proving ring constant (Cf) =0.23Kg

Observation Table:

Table 4.5 Readings of Unconfined Compression Test

Sample no.	DGR	PRR	Deformation=DGR× (G/10)	Load=PRR×CF	Strain	Corrected area	Compressive stress P/A
1.	50	4.2	0.05	0.966	0.007	11.415	0.085
	100	11.6	0.1	2.668	0.013	11.491	0.232
	150	26.6	0.15	6.118	0.020	11.568	0.529
	200	31.4	0.2	7.222	0.026	11.646	0.620
	250	35.2	0.25	8.096	0.033	11.726	0.690
	300	38	0.3	8.74	0.039	11.806	0.740
	350	40	0.35	9.2	0.046	11.887	0.774
	400	41.2	0.4	9.476	0.053	11.970	0.792
	450	40.8	0.45	9.384	0.059	12.054	0.779
	500	37	0.5	8.51	0.066	12.139	0.701

Result:

1. The Unconfined Compressive Strength =0.779 Kg/cm^2
2. Shear strength of the soil =0.779/2=0.3895 Kg/cm^2

4.2.1.5 California Bearing Ratio Test:

The California Bearing Ratio test is penetration test meant for the evaluation of subgrade strength of roads and pavements. The results obtained by these tests are used with the empirical curves to determine the thickness of pavement and its component layers. This is the most widely used method for the design of flexible pavement.

The CBR values are usually calculated for penetration of 2.5 mm and 5 mm. Generally the CBR value at 2.5 mm will be greater that at 5 mm and in such a case / the former shall be taken as CBR for design purpose. If CBR for 5 mm exceeds that for 2.5 mm, the test should be repeated. If identical results follow, the CBR corresponding to 5 mm penetration should be taken for design. This method is applicable to flexible pavements only.

The stronger the subgrade (the higher the CBR reading) the less thick it is necessary to design and construct the road pavement, this gives a considerable cost saving. Conversely if CBR testing indicates the subgrade is weak (a low CBR reading) we must construct a suitable thicker road pavement to spread the wheel load over a greater area of the weak Subgrade in order that the weak subgrade material is not deformed, causing the road pavement to fail.

Observations:

1. Weight of Mould =3.78 kg
2. Weight of Mould + Compacted Soil =7.845 kg
3. Weight of Container + Wet Soil =80.38 gm
4. Weight of Container + Dry Soil = 74.58 gm
5. Weight of Container = 14.9 gm
6. Weight of water =5.8 gm
7. Weight of dry soil = 59.68 gm
8. Water content = 9.718%
9. Dial gauge constant (G) = 0.01 mm
10. Proving ring constant (CF) =5.24 Kg
11. Height of mould =175mm
12. Diameter of Mould =150mm
13. Volume of specimen =3092.5 cm3
14. Bulk density = 1.31gm/cc

15. Dry density = 1.19 gm/cc

Observation table:

Table 4.6 Readings of California Bearing Ratio Test

DGR	PRR	Penetration in (mm)	Load (Kg)
0	0	0	0
50	2.6	0.5	13.624
100	4	1	20.96
150	6.6	1.5	34.584
200	7.4	2	38.776
250	10.6	2.5	55.544
300	11.4	3	59.736
350	12	3.5	62.88
400	13.2	4	69.168
450	14.8	4.5	77.552
500	15.4	5	80.696
550	16.6	5.5	86.984
600	17.8	6	93.272
650	18.6	6.5	97.464
700	19.2	7	100.608
750	20.2	7.5	105.848
800	21	8	110.04
850	21.8	8.5	114.232
900	22.4	9	117.376
950	23.2	9.5	121.568
1000	23.8	10	124.712
1050	24.4	10.5	127.856
1100	25	11	131
1150	25.6	11.5	134.144
1200	26.2	12	137.288
1250	26.8	12.5	140.432

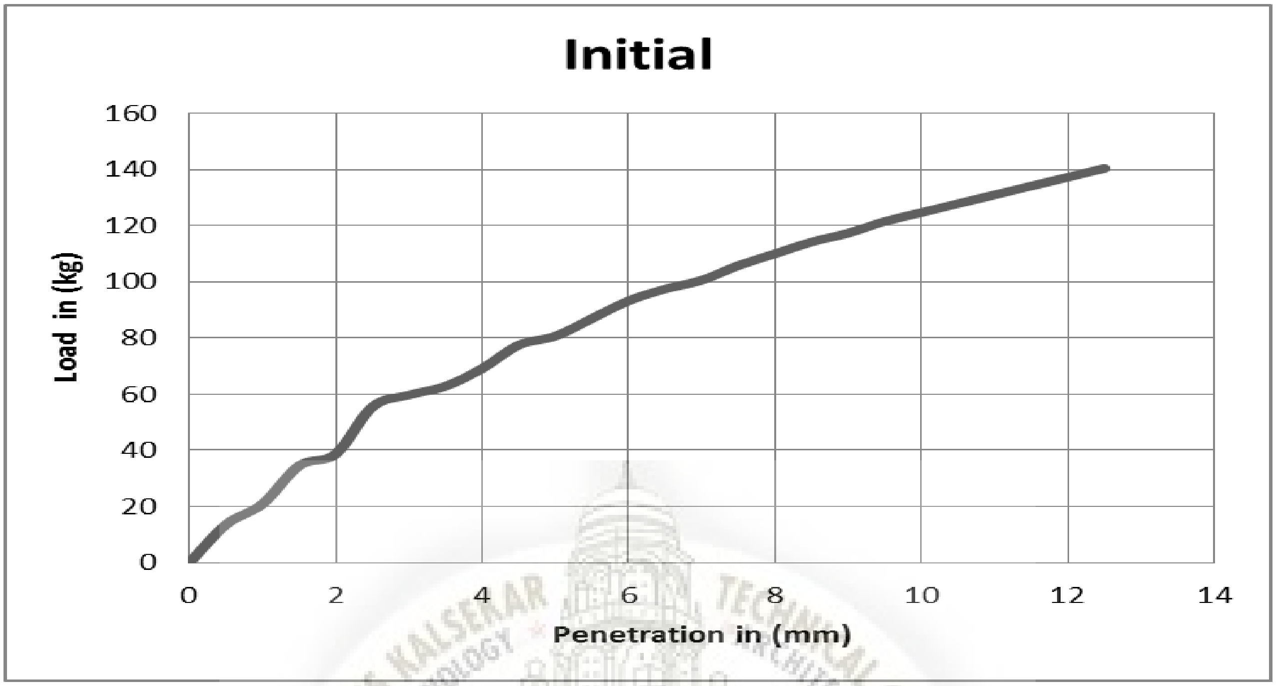

Figure 4.4 California Bearing Ratio Graph

Calculations:

CBR is the ratio of force per unit area required to penetrate a soil mass with standard circular piston at the rate of 1.25 mm/min. to that required for the corresponding penetration of a standard material.

C.B.R. = Test load/Standard load×100

The following table gives the standard loads adopted for different penetrations for the standard material with a C.B.R value of 100 %.

Table 4.7 Standard loads for different penetrations

Penetration of plunger (mm)	Standard load ((Kg)
2.5	1370
5.0	2055
7.5	2630
10.0	3180
12.5	3600

Result:

CBR value of the soil sample =55.544/1370×100 = 4.054

4.2.2 Stabilized Properties of soil:

Normal soil is mixed with different proportions of stabilizers and tested in college laboratory.

Different dosages of stabilizers mixed with the soil are:

1. 0.5% of RPP with 5%, 10%, 15% and 20% of demolished concrete aggregate.
2. 1% of RPP with 5%, 10%, 15% and 20% of demolished concrete aggregate.
3. 1.5% of RPP with 5%, 10%, 15% and 20% of demolished concrete aggregate.
4. 2% of RPP with 5%, 10%, 15% and 20% of demolished concrete aggregate.

Test results of above mentioned dosage are given below:

4.2.2.1 Modified Proctor Test:

1. <u>0.5% of Recycled Plastic Polymers:</u>

A. <u>0.5% of RPP with 5% of Demolished Concrete Aggregates:</u>

Table 4.8 Readings of Modified Standard proctor Test (0.5% & 5%)

Quantity of stabilizer	**0.5% & 5%**			
A) Density				
1. Mass of mould + compacted soil (Kg)	7.6	7.55	7.15	7.095
2. Mass of mould (Kg)	5.575	5.57	5.075	5
3. Mass of compacted soil (Kg)	2.025	1.98	2.075	2.095
4. Bulk density (gm/cc)	2.025	1.98	2.075	2.095
5. Dry density (gm/cc)	1.82	1.80	1.81	1.79
B) Water content				
1. Mass of container + wet soil (gm)	82	60.24	51.89	62.35
2. Mass of container + dry soil (gm)	75.28	56.08	46.9	55.36
3. Mass of water (gm)	6.72	4.16	4.99	6.99
4.Mass of container (gm)	15	15	13.43	15.09
5. Mass of dry soil (gm)	60.26	41.08	33.41	40.27
6. Water content (%)	11.15	10.13	14.94	17.36

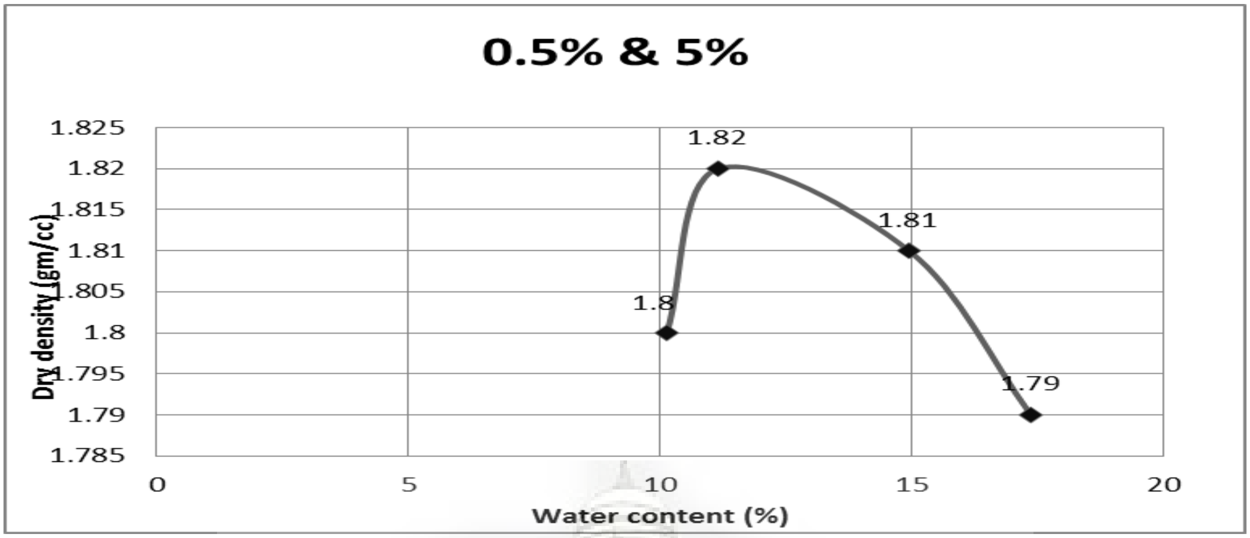

Figure 4.5 Modified proctor Graph (0.5% & 5%)

From graph,

Optimum Moisture Content (OMC) =11.15%

Maximum Dry Density (MDD) =1.82 gm/cc.

B. <u>0.5% of RPP with 10% of Demolished Concrete Aggregates:</u>

Table 4.9 Readings of Modified Standard proctor Test (0.5% & 10%)

Quantity of stabilizer	**0.5% & 10%**		
A)Density			
1. Mass of mould + compacted soil (Kg)	7.525	7.635	7.635
2. Mass of mould (Kg)	5.565	5.55	5.545
3. Mass of compacted soil (Kg)	1.96	2.085	2.09
4. Bulk density (gm/cc)	1.96	2.085	2.09
5. Dry density (gm/cc)	1.81	1.87	1.84
B) Water content			
1. Mass of container + wet soil (gm)	70.73	75.4	52.61
2. Mass of container + dry soil (gm)	66.61	69.16	47.6
3. Mass of water (gm)	4.12	6.24	5.01
4.Mass of container (gm)	15.45	15.55	10.53
5. Mass of dry soil (gm)	51.16	53.61	37.07
6. Water content (%)	8.05	11.64	13.51

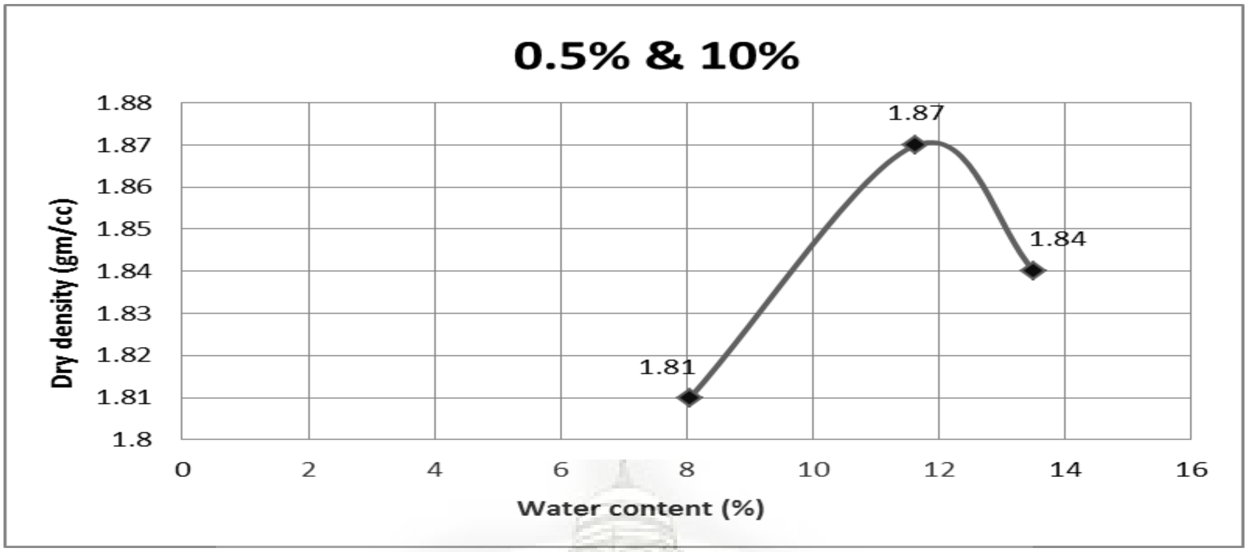

Figure 4.6 Modified proctor Graph (0.5% & 10%)

From graph,

Optimum Moisture Content (OMC) =11.64%

Maximum Dry Density (MDD) =1.87 gm/cc.

C. <u>0.5% of RPP with 15% of Demolished Concrete Aggregates:</u>

Table 4.10 Readings of Modified Standard proctor Test (0.5% & 15%)

Quantity of stabilizer	**0.5% & 15%**		
A)Density			
1. Mass of mould + compacted soil (Kg)	7.525	7.575	7.62
2. Mass of mould (Kg)	5.565	5.545	5.55
3. Mass of compacted soil (Kg)	1.96	2.03	2.07
4. Bulk density (gm/cc)	1.96	2.03	2.07
5. Dry density (gm/cc)	1.82	1.84	1.82
B) Water content			
1. Mass of container + wet soil (gm)	43.24	52.09	62.51
2. Mass of container + dry soil (gm)	40.74	48.44	56.88
3. Mass of water (gm)	2.5	3.65	5.63
4.Mass of container (gm)	7.86	13.28	15.55
5. Mass of dry soil (gm)	32.88	35.16	41.33
6. Water content (%)	7.60	10.38	13.62

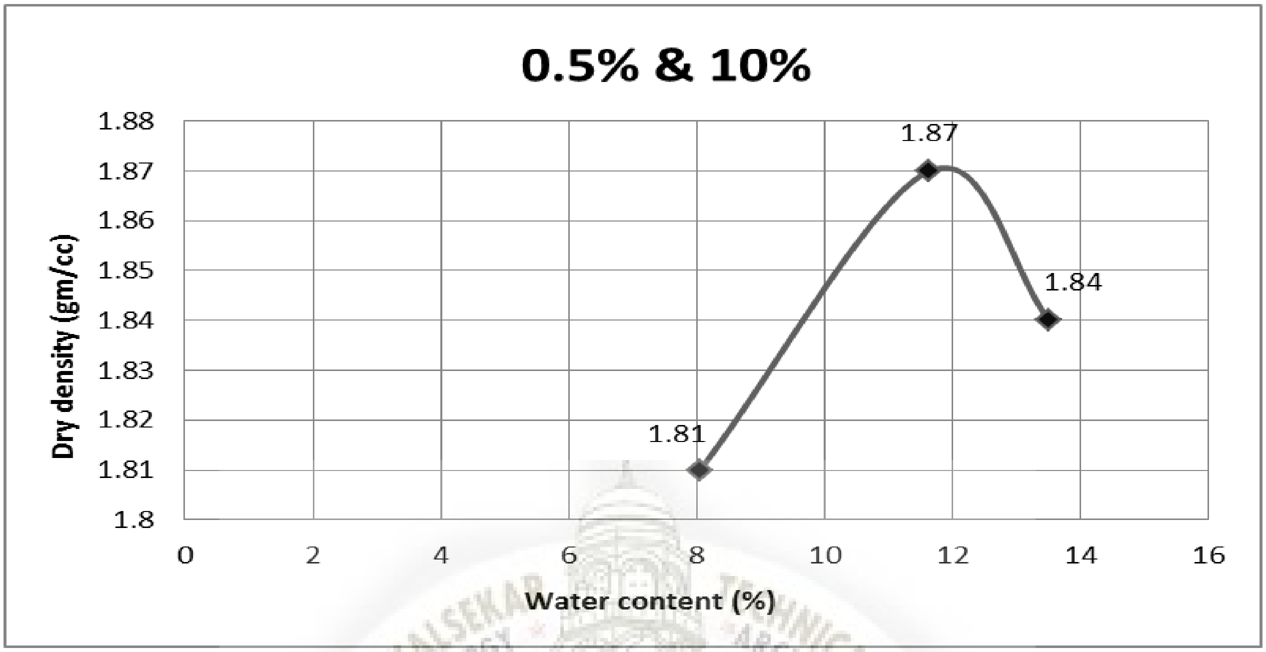

Figure 4.7 Modified proctor Graph (0.5% & 15%)

From graph,

Optimum Moisture Content (OMC) =10.38%

Maximum Dry Density (MDD) =1.84 gm/cc.

Result:

Table 4.11 Values of OMC and MDD of 0.5% RPP with different dosage of CD waste

Dosages	**OMC (%)**	**MDD (gm/cc)**
0.5% & 5%	11.15	1.82
0.5% & 10%	**11.64**	**1.87**
0.5% & 15%	10.38	1.84

From the above table, no need to perform the test with dose of 0.5% and 2% as further increment of CD waste decreases the MDD. It also gives the maximum value of MDD amongst 0.5% dosage of RPP with other dosage of CD waste.

2. <u>1.0% of Recycled Plastic Polymers:</u>

A. <u>1.0% of RPP with 5% of Demolished Concrete Aggregates:</u>

Table 4.12 Readings of Modified Standard proctor Test (1% & 5%)

Quantity of stabilizer	**1.0% & 5%**		
A)Density			
1. Mass of mould + compacted soil (Kg)	7.645	7.625	7.495
2. Mass of mould (Kg)	5.565	5.545	5.57
3. Mass of compacted soil (Kg)	2.08	2.08	1.925
4. Bulk density (gm/cc)	2.08	2.08	1.925
5. Dry density (gm/cc)	1.93	1.89	1.81
B) Water content			
1. Mass of container + wet soil (gm)	112.36	61.33	47.15
2. Mass of container + dry soil (gm)	105.22	57.047	45.08
3. Mass of water (gm)	7.14	4.283	2.07
4.Mass of container (gm)	15.54	1547	13.24
5. Mass of dry soil (gm)	89.68	41.577	31.84
6. Water content (%)	7.96	10.30	6.50

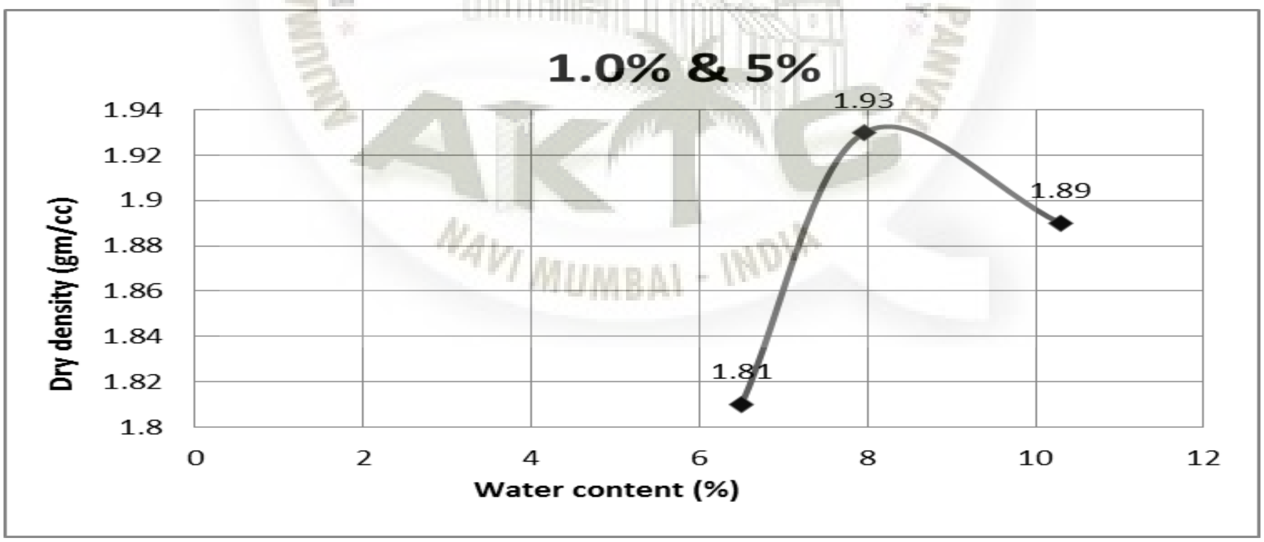

Figure 4.8 Modified proctor Graph (1.0% & 5%)

From graph,

Optimum Moisture Content (OMC) =7.96%

Maximum Dry Density (MDD) =1.93 gm/cc.

B. 1.0% of RPP with 10% of Demolished Concrete Aggregates:

Table 4.13 Readings of Modified Standard proctor Test (1.0% & 10%)

Quantity of stabilizer	1.0% & 10%			
A)Density				
1. Mass of mould + compacted soil (Kg)	7.5	7.61	7.74	7.595
2. Mass of mould (Kg)	5.55	5.52	5.52	5.6
3. Mass of compacted soil (Kg)	1.95	2.09	2.22	1.995
4. Bulk density (gm/cc)	1.95	2.09	2.22	1.995
5. Dry density (gm/cc)	1.8	1.79	1.93	1.68
B) Water content				
1. Mass of container + wet soil (gm)	82.71	43.54	49.7	58.69
2. Mass of container + dry soil (gm)	77.66	39.19	44.92	51.3
3. Mass of water (gm)	5.05	4.35	4.78	7.39
4.Mass of container (gm)	15.1	13.15	13.67	11.69
5. Mass of dry soil (gm)	62.56	26.04	31.25	39.61
6. Water content (%)	8.07	16.71	15.3	18.66

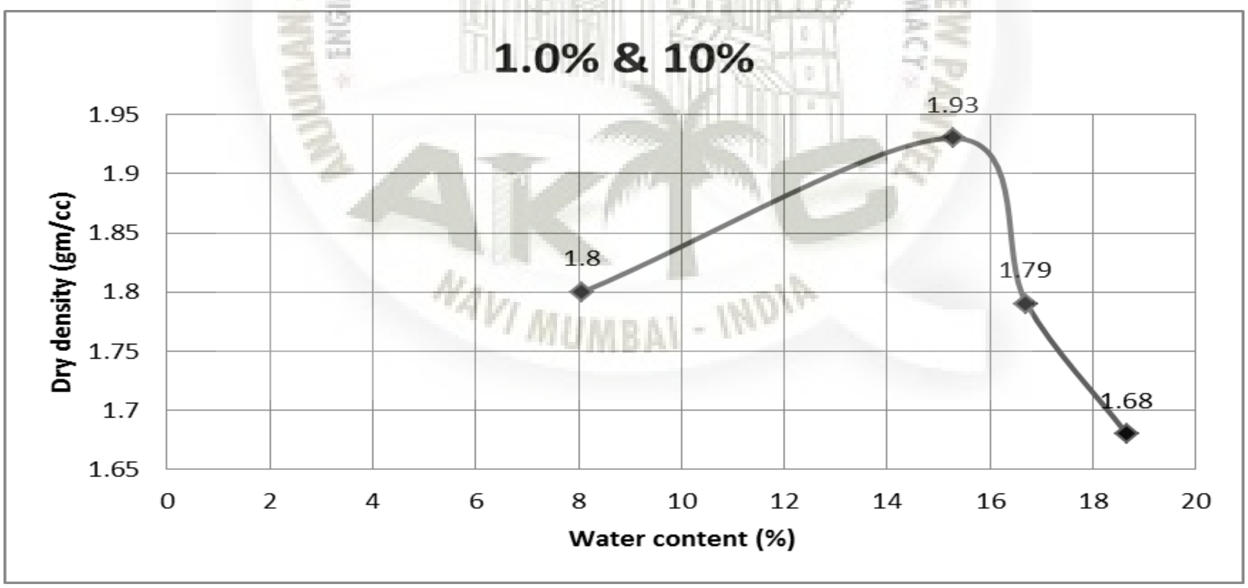

Figure 4.9 Modified proctor Graph (1.0% & 10%)

From graph,

Optimum Moisture Content (OMC) =15.3%

Maximum Dry Density (MDD) =1.93 gm/cc.

C. <u>1.0% of RPP with 15% of Demolished Concrete Aggregates:</u>

Table 4.14 Readings of Modified Standard proctor Test (1.0% & 15%)

Quantity of stabilizer	1.0% & 15%			
A)Density				
1. Mass of mould + compacted soil (Kg)	7.519	7.55	7.655	7.63
2. Mass of mould (Kg)	5.575	5.55	5.575	5.55
3. Mass of compacted soil (Kg)	1.944	2	2.08	2.08
4. Bulk density (gm/cc)	1.944	2	2.08	2.08
5. Dry density (gm/cc)	1.78	1.81	1.84	1.80
B) Water content				
1. Mass of container + wet soil (gm)	71.3	65.4	50.53	49.95
2. Mass of container + dry soil (gm)	66.58	60.47	46.32	44.77
3. Mass of water (gm)	4.72	4.93	4.21	5.18
4.Mass of container (gm)	15.5	14.3	14.5	11.69
5. Mass of dry soil (gm)	51.08	46.17	31.82	33.08
6. Water content (%)	9.24	10.68	13.23	15.66

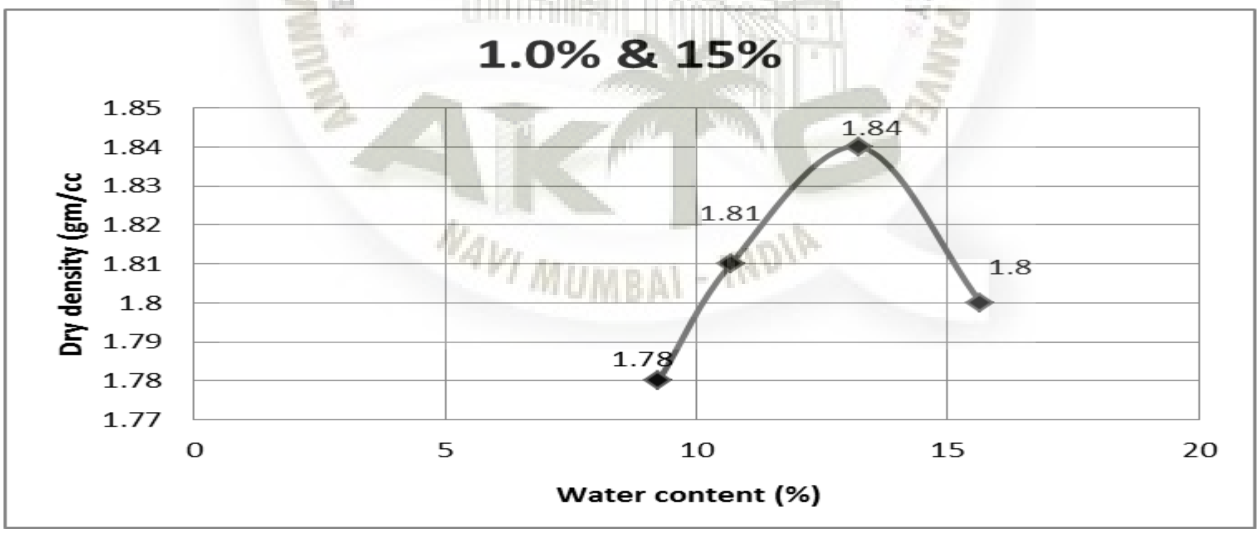

Figure 4.10 Modified proctor Graph (1.0% & 15%)

From graph,

Optimum Moisture Content (OMC) =13.23%

Maximum Dry Density (MDD) =1.84 gm/cc.

Result:

Table 4.15 Values of OMC and MDD of 1.0% RPP with different dosage of CD waste

Dosages	**OMC (%)**	**MDD (gm/cc)**
1.0% & 5%	**7.96**	**1.93**
1.0% & 10%	15.3	1.93
1.0% & 15%	13.23	1.84

From the above table, no need to perform the test with dose of 1.0% and 2% as further increment of CD waste decreases the MDD. It also gives the maximum value of MDD amongst 1.0% dosage of RPP with other dosage of CD waste.

3. 1.5% of Recycled Plastic Polymers:

A. 1.5% of RPP with 5% of Demolished Concrete Aggregates:

Table 4.16 Readings of Modified Standard proctor Test (1.5% & 5%)

Quantity of stabilizer	**1.5% & 5%**		
A)Density			
1. Mass of mould + compacted soil (Kg)	7.45	7.59	7.6
2. Mass of mould (Kg)	5.575	5.575	5.565
3. Mass of compacted soil (Kg)	1.875	2.015	2.035
4. Bulk density (gm/cc)	1.875	2.015	2.035
5. Dry density (gm/cc)	1.74	1.83	1.80
B) Water content			
1. Mass of container + wet soil (gm)	71.36	58.63	74.11
2. Mass of container + dry soil (gm)	67.21	54.6	67.14
3. Mass of water (gm)	4.15	4.03	6.97
4.Mass of container (gm)	14.88	13.7	14.86
5. Mass of dry soil (gm)	52.33	40.9	52.28
6. Water content (%)	7.93	9.85	13.33

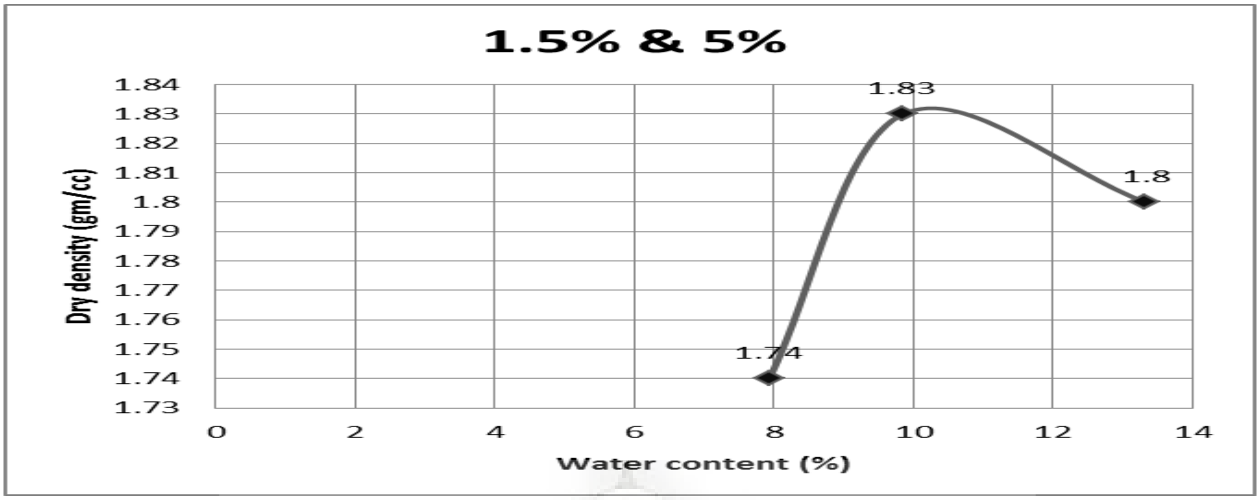

Figure 4.11 Modified proctor Graph (1.5% & 5%)

From graph,

Optimum Moisture Content (OMC) =9.85%

Maximum Dry Density (MDD) =1.83 gm/cc.

B. <u>1.5% of RPP with 10% of Demolished Concrete Aggregates:</u>

Table 4.17 Readings of Modified Standard proctor Test (1.5% & 10%)

Quantity of stabilizer	**1.5% & 10%**			
A)Density				
1. Mass of mould + compacted soil (Kg)	7.475	7.55	7.63	7.62
2. Mass of mould (Kg)	5.55	5.56	5.55	5.56
3. Mass of compacted soil (Kg)	1.925	1.99	2.08	2.06
4. Bulk density (gm/cc)	1.925	1.99	2.08	2.06
5. Dry density (gm/cc)	1.78	1.81	1.85	1.80
B) Water content				
1. Mass of container + wet soil (gm)	75.46	66.82	73.78	74.32
2. Mass of container + dry soil (gm)	71.08	62.09	67.33	66.76
3. Mass of water (gm)	4.38	4.73	6.45	7.56
4.Mass of container (gm)	15.53	13.7	14.95	15.45
5. Mass of dry soil (gm)	55.55	48.39	52.38	51.31
6. Water content (%)	7.88	9.77	12.31	14.73

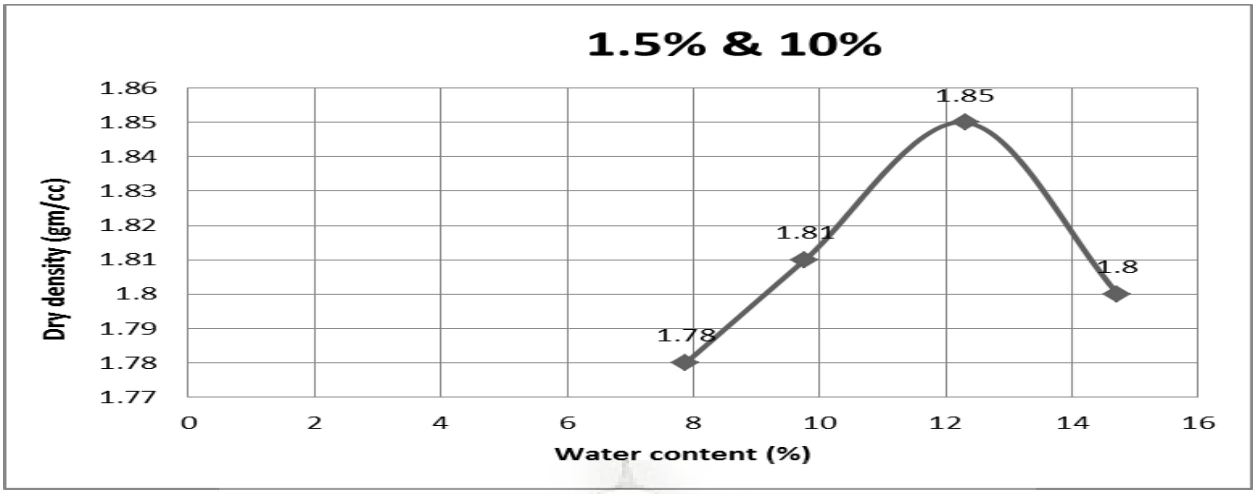

Figure 4.12 Modified proctor Graph (1.5% & 10%)

From graph,

Optimum Moisture Content (OMC) =12.31%

Maximum Dry Density (MDD) =1.85 gm/cc.

C. 1.5% of RPP with 15% of Demolished Concrete Aggregates:

Table 4.18 Readings of Modified Standard proctor Test (1.5% & 15%)

Quantity of stabilizer	**1.5% & 15%**			
A)Density				
1. Mass of mould + compacted soil (Kg)	7.625	7.565	7.565	7.69
2. Mass of mould (Kg)	5.63	5.55	5.52	5.6
3. Mass of compacted soil (Kg)	1.995	2.015	2.045	2.09
4. Bulk density (gm/cc)	1.995	2.015	2.045	2.09
5. Dry density (gm/cc)	1.82	1.83	1.80	1.82
B) Water content				
1. Mass of container + wet soil (gm)	96.36	72.33	73.24	65.19
2. Mass of container + dry soil (gm)	89.27	66.89	65.84	58.55
3. Mass of water (gm)	7.09	5.44	7.4	6.64
4.Mass of container (gm)	15.45	13.14	11.69	13.6
5. Mass of dry soil (gm)	73.82	53.75	54.15	45.49
6. Water content (%)	9.60	10.12	13.67	14.60

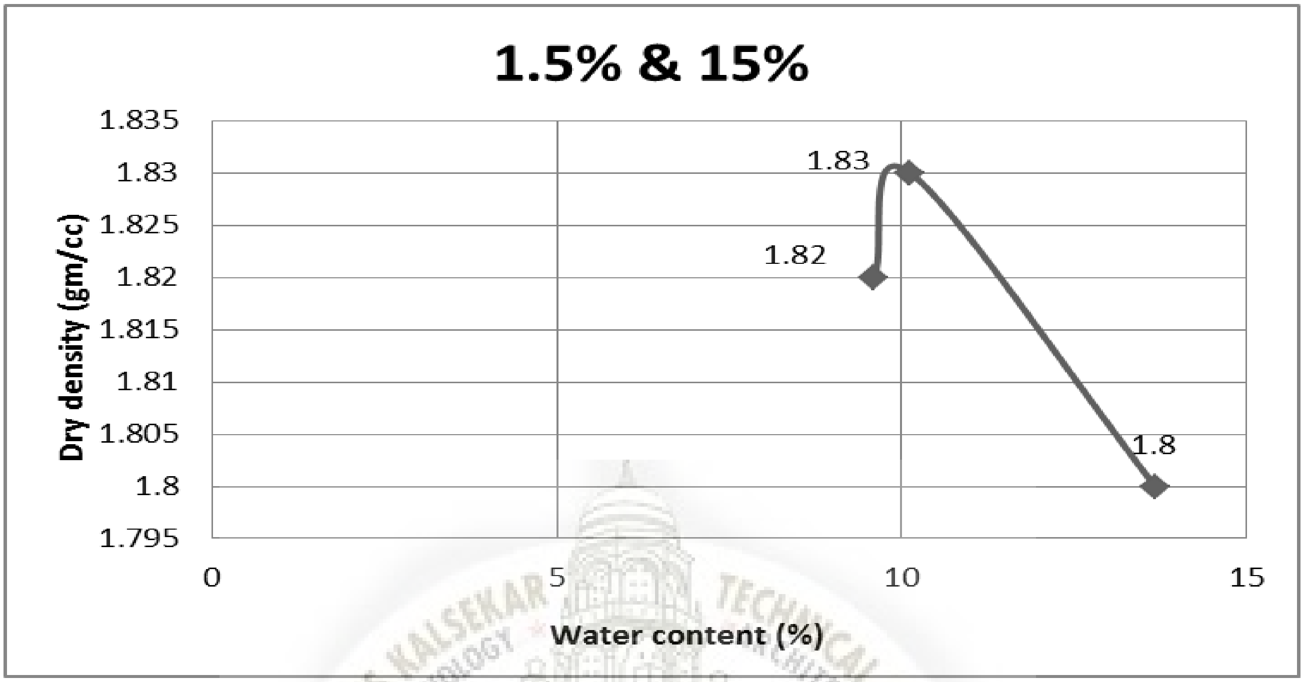

Figure 4.13 Modified proctor Graph (1.5% & 15%)

From graph,

Optimum Moisture Content (OMC) =10.12%

Maximum Dry Density (MDD) =1.83 gm/cc.

Result:

Table 4.19 Values of OMC and MDD of 1.0% RPP with different dosage of CD waste

Dosages	**OMC (%)**	**MDD (gm/cc)**
1.5% & 5%	9.85	1.83
1.5% & 10%	**12.31**	**1.85**
1.5% & 15%	10.12	1.83

From the above table, no need to perform the test with dose of 1.5% and 2% as further increment of CD waste decreases the MDD. It also gives the maximum value of MDD amongst 1.5% dosage of RPP with other dosage of CD waste.

4. <u>2% of Recycled Plastic Polymers:</u>

A. <u>2% of RPP with 20% of Demolished Concrete Aggregates:</u>

Table 4.20 Readings of Modified Standard proctor Test (2% & 20%)

Quantity of stabilzer	**2% & 20%**			
A)Density				
1. Mass of mould + compacted soil (Kg)	7.49	7.55	7.655	7.715
2. Mass of mould (Kg)	5.55	5.565	5.55	5.57
3. Mass of compacted soil (Kg)	1.94	1.985	2.105	2.145
4. Bulk density (gm/cc)	1.94	1.985	2.105	2.145
5. Dry density (gm/cc)	1.82	1.83	1.89	1.86
B) Water content				
1. Mass of container + wet soil (gm)	89.9	64.49	61.6	76.59
2. Mass of container + dry soil (gm)	85.23	60.39	56.7	68.32
3. Mass of water (gm)	4.67	4.1	4.9	8.27
4.Mass of container (gm)	15.45	13.44	13.14	13.28
5. Mass of dry soil (gm)	69.78	46.95	43.56	55.04
6. Water content (%)	6.69	8.73	11.25	15.03

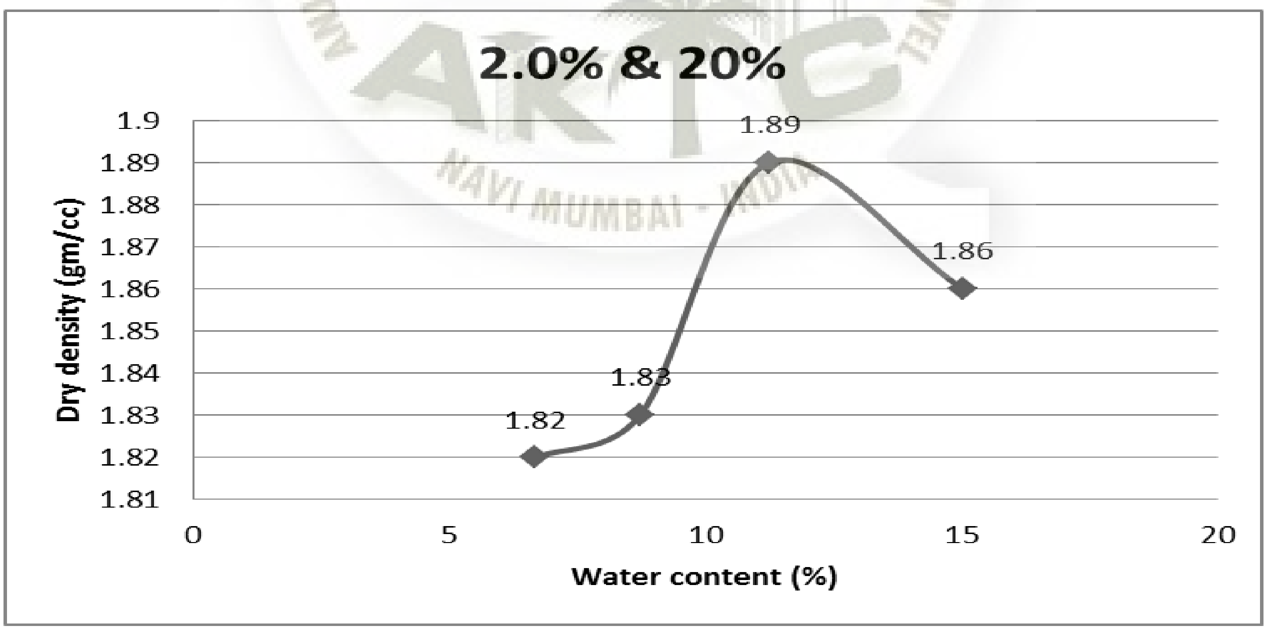

Figure 4.14 Modified proctor Graph (2.0% & 20%)

From graph,

Optimum Moisture Content (OMC) =11.25%

Maximum Dry Density (MDD) =1.89 gm/cc.

4.2.2.2 California Bearing Ratio (CBR) Test:

1. **<u>0.5% of Recycled Plastic Polymers:</u>**

   A. <u>0.5% of RPP with 5% of Demolished Concrete Aggregates:</u>

<u>Observations:</u>

1. Weight of Mould =3.77 kg
2. Weight of Mould + Compacted Soil =7.815 kg
3. Weight of Container + Wet Soil =68.24 gm
4. Weight of Container + Dry Soil = 61.71 gm
5. Weight of Container = 13.43 gm
6. Weight of water =6.53 gm
7. Weight of dry soil = 48.28 gm
8. Water content = 13.52%
9. Dial gauge constant (G) = 0.01 mm
10. Proving ring constant (CF) =5.24 Kg
11. Height of mould =175mm
12. Diameter of Mould =150mm
13. Volume of specimen =3092.5 cm3
14. Bulk density = 1.308 gm/cc
15. Dry density = 1.15 gm/cc

Observation Table:

Table 4.21 Readings of California Bearing Ratio Test (0.5% & 5%)

DGR	PRR	Penetration in (mm)	Load (Kg)
0	0	0	0
50	1.2	0.5	6.288
100	2.4	1	12.576
150	3.8	1.5	19.912
200	5.4	2	28.296
250	6.8	2.5	35.632
300	8.6	3	45.064
350	10.2	3.5	53.448
400	11.4	4	59.736
450	12.4	4.5	64.976
500	13.4	5	70.216
550	14.2	5.5	74.408
600	15	6	78.6
650	15.6	6.5	81.744
700	16	7	83.84
750	16.6	7.5	86.984
800	17.2	8	90.128
850	17.8	8.5	93.272
900	18.2	9	95.368
950	18.8	9.5	98.512
1000	19.2	10	100.608
1050	19.6	10.5	102.704
1100	20	11	104.8
1150	20.4	11.5	106.896
1200	20.8	12	108.992
1250	21.2	12.5	111.088

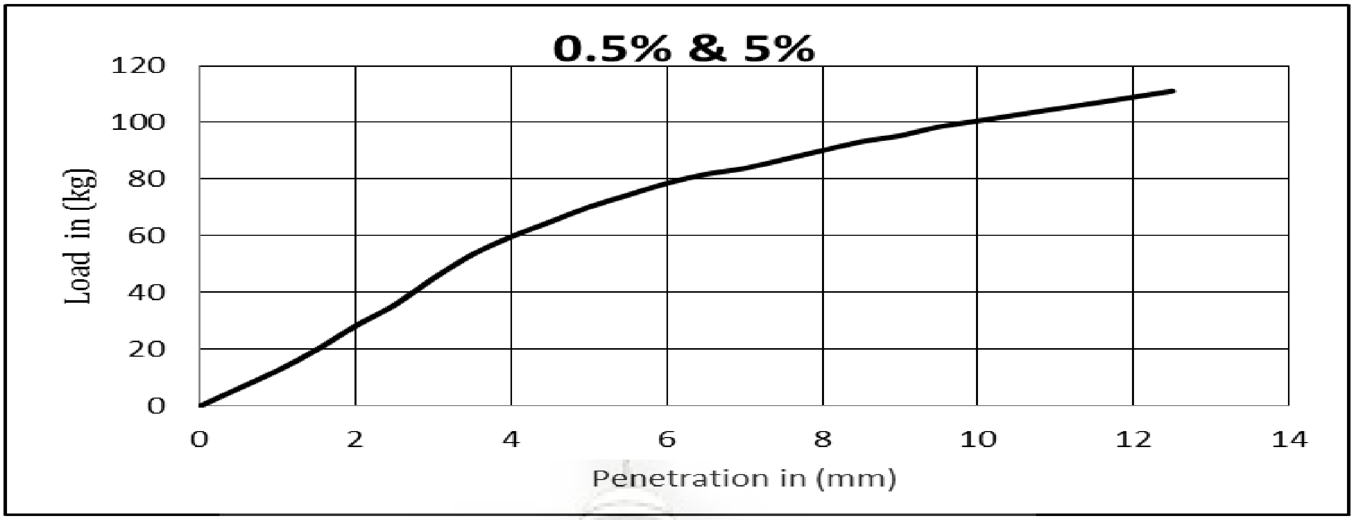

Figure 4.15 California Bearing Ratio Graph (0.5% & 5%)

Result:

CBR value of the soil sample =70.216/2055×100 = 3.42

B. 0.5% of RPP with 10% of Demolished Concrete Aggregates:

Observations:

1. Weight of Mould =3.77 kg
2. Weight of Mould + Compacted Soil =8.075 kg
3. Weight of Container + Wet Soil =62.83 gm
4. Weight of Container + Dry Soil = 57.64 gm
5. Weight of Container = 13.74 gm
6. Weight of water =5.19 gm
7. Weight of dry soil = 43.9 gm
8. Water content = 11.82%
9. Dial gauge constant (G) = 0.01 mm
10. Proving ring constant (CF) =5.24 Kg
11. Height of mould =175mm
12. Diameter of Mould =150mm
13. Volume of specimen =3092.5 cm3

14. Bulk density = 1.39 gm/cc
15. Dry density = 1.243 gm/cc

Observation Table:

Table 4.22 Readings of California Bearing Ratio Test (0.5% & 10%)

DGR	PRR	Penetration in (mm)	Load (Kg)
0	0	0	0
50	1.8	0.5	9.432
100	3.6	1	18.864
150	5.2	1.5	27.248
200	6.8	2	35.632
250	8.8	2.5	46.112
300	10.6	3	55.544
350	12.4	3.5	64.976
400	13.8	4	72.312
450	14.8	4.5	77.552
500	16.1	5	84.364
550	17.4	5.5	91.176
600	18.3	6	95.892
650	19.2	6.5	100.61
700	20	7	104.8
750	20.9	7.5	109.52
800	21.6	8	113.18
850	21.8	8.5	114.23
900	22.8	9	119.47
950	23.2	9.5	121.57
1000	23.6	10	123.66
1050	23.9	10.5	125.24
1100	24.4	11	127.86
1150	24.8	11.5	129.95
1200	24.9	12	130.48
1250	25.5	12.5	133.62

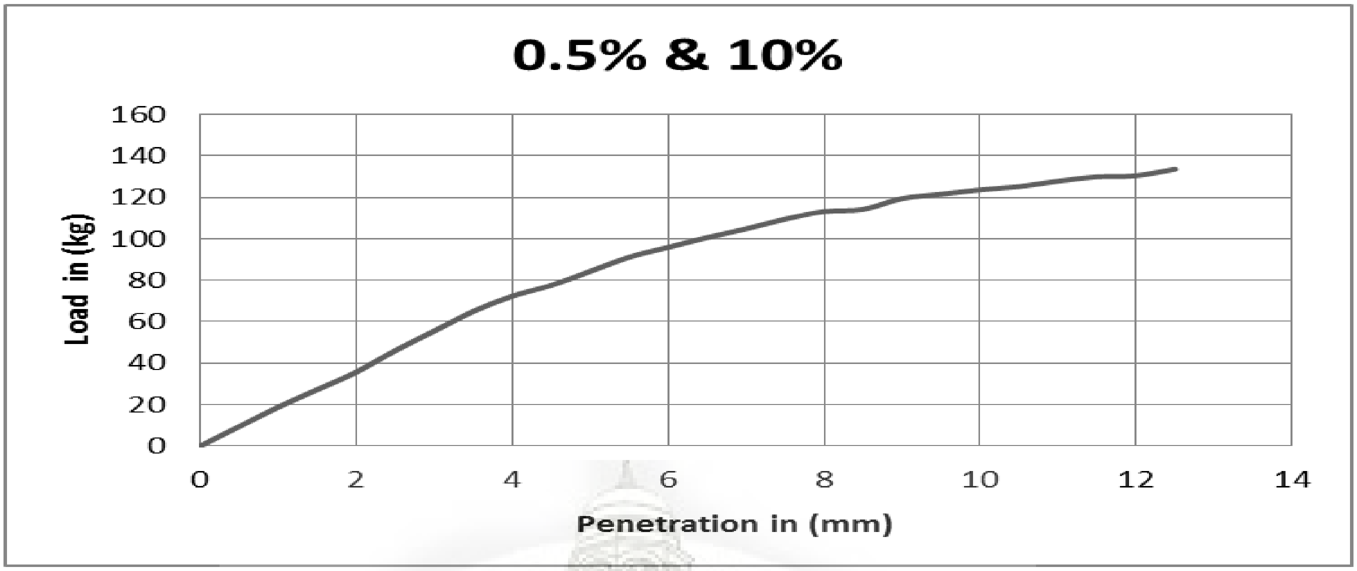

Figure 4.16 California Bearing Ratio Graph (0.5% & 10%)

Result:

CBR value of the soil sample =84.364/2055×100 = 4.1

2. 1.0% of Recycled Plastic Polymers:

A. 1.0% of RPP with 5% of Demolished Concrete Aggregates:

Observations:

1. Weight of Mould =3.77 kg
2. Weight of Mould + Compacted Soil =7.775 kg
3. Weight of Container + Wet Soil =83.13 gm
4. Weight of Container + Dry Soil = 77.93 gm
5. Weight of Container = 15.86 gm
6. Weight of water =5.2 gm
7. Weight of dry soil = 62.07 gm
8. Water content = 8.37%
9. Dial gauge constant (G) = 0.01 mm
10. Proving ring constant (CF) =5.24 Kg

11. Height of mould =175mm
12. Diameter of Mould =150mm
13. Volume of specimen =3092.5 cm3
14. Bulk density = 1.295 gm/cc
15. Dry density = 1.194 gm/cc

Observation Table:

Table 4.23 Readings of California Bearing Ratio Test (1% & 5%)

DGR	PRR	Penetration in (mm)	Load (Kg)
0	0	0	0
50	1.2	0.5	6.288
100	3	1	15.72
150	5	1.5	26.2
200	6.8	2	35.632
250	8.6	2.5	45.064
300	10.4	3	54.496
350	12.3	3.5	64.452
400	13.8	4	72.312
450	14.9	4.5	78.076
500	16	5	83.84
550	17	5.5	89.08
600	18	6	94.32
650	18.6	6.5	97.464
700	19.6	7	102.7
750	20.2	7.5	105.85
800	20.9	8	109.52
850	21.5	8.5	112.66
900	22.2	9	116.33
950	22.7	9.5	118.95
1000	23.2	10	121.57
1050	23.8	10.5	124.71
1100	24.3	11	127.33
1150	24.7	11.5	129.43
1200	25	12	131
1250	25.5	12.5	133.62

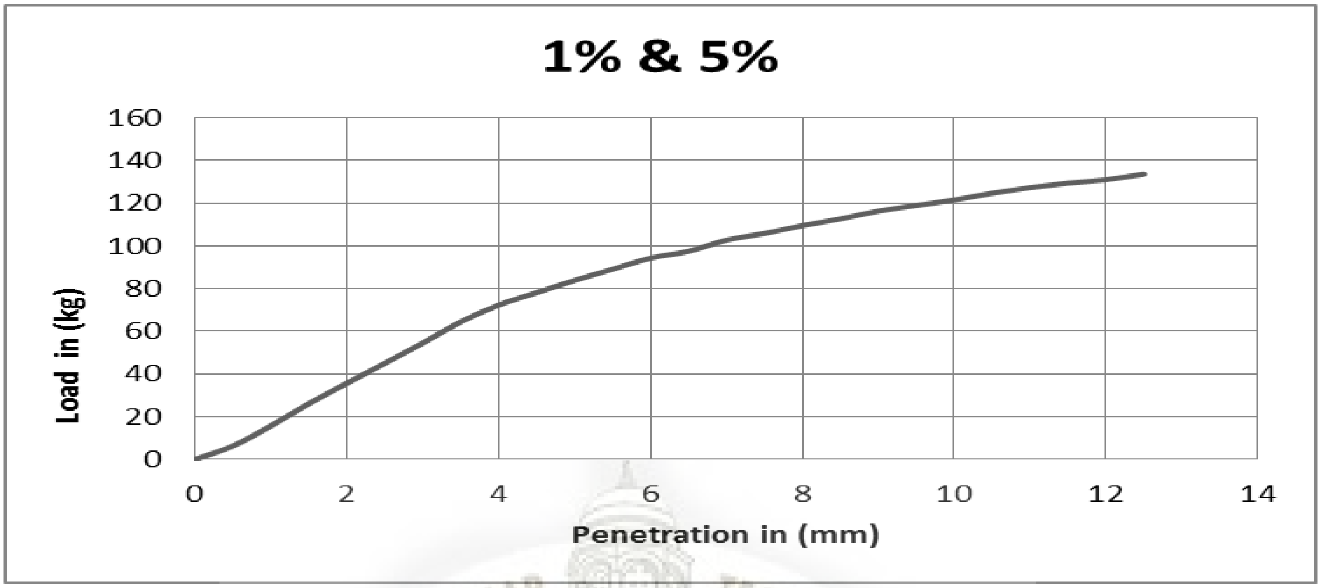

Figure 4.17 California Bearing Ratio Graph (1.0% & 5%)

Result:

CBR value of the soil sample =83.84/2055×100 = 4.079

B. 1.0% of RPP with 10% of Demolished Concrete Aggregates:

Observations:

1. Weight of Mould =3.78 kg
2. Weight of Mould + Compacted Soil =7.845 kg
3. Weight of Container + Wet Soil =80.38 gm
4. Weight of Container + Dry Soil = 74.58 gm
5. Weight of Container = 14.9 gm
6. Weight of water =5.8 gm
7. Weight of dry soil = 59.68 gm
8. Water content = 9.71%
9. Dial gauge constant (G) = 0.01 mm
10. Proving ring constant (CF) =5.24 Kg
11. Height of mould =175mm
12. Diameter of Mould =150mm

13. Volume of specimen =3092.5 cm3
14. Bulk density = 1.314 gm/cc
15. Dry density = 1.197 gm/cc

Observation table:

Table 4.24 Readings of California Bearing Ratio Test (1% & 10%)

DGR	PRR	Penetration in (mm)	Load (Kg)
0	0	0	0
50	3	0.5	15.72
100	5.4	1	28.296
150	7.4	1.5	38.776
200	9.4	2	49.256
250	11.4	2.5	59.736
300	13.5	3	70.74
350	15.4	3.5	80.696
400	17.2	4	90.128
450	19.2	4.5	100.61
500	20.6	5	107.94
550	22.2	5.5	116.33
600	23.6	6	123.66
650	24.8	6.5	129.95
700	26	7	136.24
750	27.4	7.5	143.58
800	28.4	8	148.82
850	29.4	8.5	154.06
900	30.6	9	160.34
950	31.6	9.5	165.58
1000	32.4	10	169.78
1050	33.2	10.5	173.97
1100	34.2	11	179.21
1150	35	11.5	183.4
1200	35.7	12	187.07
1250	36.4	12.5	190.74

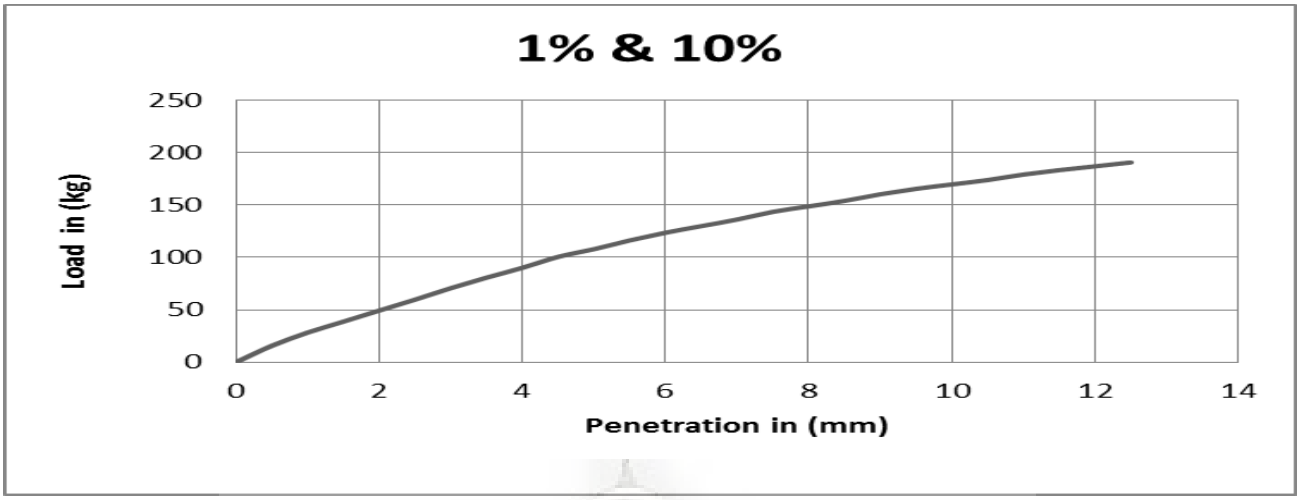

Figure 4.18 California Bearing Ratio Graph (1% & 10%)

Result: CBR value of the soil sample =107.94/2055×100 = 5.25

3. 1.5% of Recycled Plastic Polymers:

A. 1.5% of RPP with 10% of Demolished Concrete Aggregates:

Observations:

1. Weight of Mould =3.77 kg
2. Weight of Mould + Compacted Soil =8.04 kg
3. Weight of Container + Wet Soil =62.6gm
4. Weight of Container + Dry Soil = 56.23 gm
5. Weight of Container = 11.3 gm
6. Weight of water =6.37 gm
7. Weight of dry soil = 44.93 gm
8. Water content = 14.17%
9. Dial gauge constant (G) = 0.01 mm
10. Proving ring constant (CF) =5.24 Kg
11. Height of mould =175mm
12. Diameter of Mould =150mm
13. Volume of specimen =3092.5 cm3
14. Bulk density = 1.38 gm/cc
15. Dry density = 1.208 gm/cc

Observation table:

Table 4.25 Readings of California Bearing Ratio Test (1.5% & 10%)

DGR	PRR	Penetration in (mm)	Load
0	0	0	0
50	1.7	0.5	8.908
100	3.3	1	17.292
150	5.1	1.5	26.724
200	6.8	2	35.632
250	8.4	2.5	44.016
300	9.6	3	50.304
350	11	3.5	57.64
400	12.3	4	64.452
450	13.3	4.5	69.692
500	14.4	5	75.456
550	15.2	5.5	79.648
600	15.9	6	83.316
650	16.7	6.5	87.508
700	17.1	7	89.604
750	18	7.5	94.32
800	18.5	8	96.94
850	19.1	8.5	100.08
900	19.6	9	102.7
950	20.2	9.5	105.85
1000	20.5	10	107.42
1050	20.9	10.5	109.52
1100	21	11	110.04
1150	21.7	11.5	113.71
1200	22.1	12	115.8
1250	23	12.5	120.52

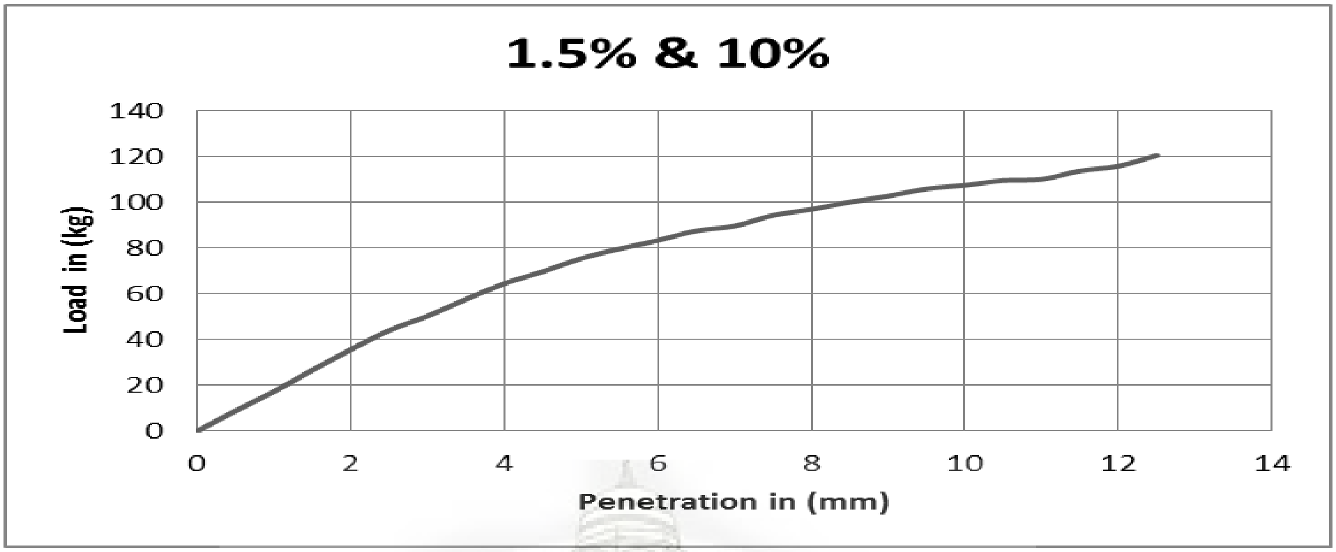

Figure 4.19 California Bearing Ratio Graph (1.5% & 10%)

Result: CBR value of the soil sample =75.456/2055×100 = 3.67

B. 1.5% of RPP with 15% of Demolished Concrete Aggregates:

Observations:

1. Weight of Mould =3.77 kg
2. Weight of Mould + Compacted Soil =7.65 kg
3. Weight of Container + Wet Soil =52.79 gm
4. Weight of Container + Dry Soil = 48.22 gm
5. Weight of Container = 12.74 gm
6. Weight of water =4.57 gm
7. Weight of dry soil = 35.48 gm
8. Water content = 12.9%
9. Dial gauge constant (G) = 0.01 mm
10. Proving ring constant (CF) =5.24 Kg
11. Height of mould =175mm
12. Diameter of Mould =150mm
13. Volume of specimen =3092.5 cm3
14. Bulk density = 1.254 gm/cc

15. Dry density = 1.11 gm/cc

Observation table:

Table 4.26 Readings of California Bearing Ratio Test (1.5% & 15%)

DGR	PRR	Penetration in (mm)	load
0	0	0	0
50	3.6	0.5	18.864
100	6.8	1	35.632
150	9.4	1.5	49.256
200	11.6	2	60.784
250	13.6	2.5	71.264
300	15.4	3	80.696
350	17	3.5	89.08
400	18.4	4	96.416
450	19.8	4.5	103.75
500	20.3	5	106.372
550	21.8	5.5	114.23
600	22.8	6	119.47
650	23.6	6.5	123.66
700	24.2	7	126.81
750	25	7.5	131
800	25.4	8	133.1
850	25.8	8.5	135.19
900	26.2	9	137.29
950	26.4	9.5	138.34
1000	26.6	10	139.38
1050	26.9	10.5	140.96
1100	27.1	11	142
1150	27.3	11.5	143.05
1200	27.6	12	144.62
1250	27.9	12.5	146.2

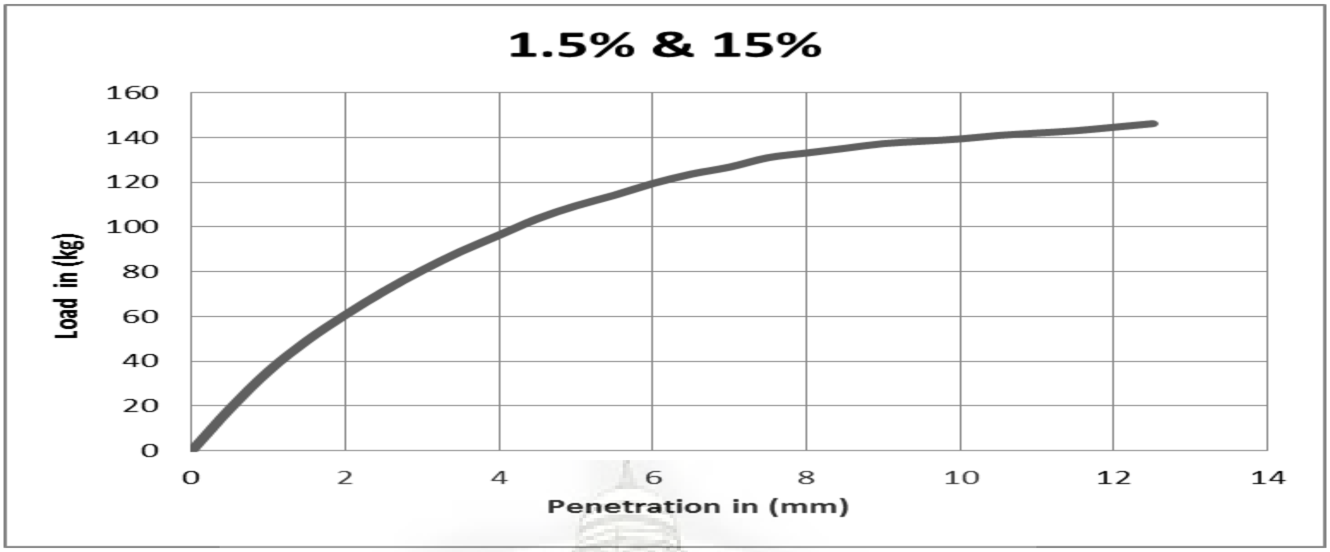

Figure 4.20 California Bearing Ratio Graph (1.5% & 15%)

Result:

CBR value of the soil sample =71.264/1370×100 = 5.2

4. 2% of Recycled Plastic Polymers:

A. 2% of RPP with 20% of Demolished Concrete Aggregates:

Observations:

1. Weight of Mould =3.775 kg
2. Weight of Mould + Compacted Soil =7.555 kg
3. Weight of Container + Wet Soil =49.01 gm
4. Weight of Container + Dry Soil = 45.57 gm
5. Weight of Container = 13.65 gm
6. Weight of water =3.44 gm
7. Weight of dry soil = 31.92 gm
8. Water content = 10.77%
9. Dial gauge constant (G) = 0.01 mm
10. Proving ring constant (CF) =5.24 Kg
11. Height of mould =175mm
12. Diameter of Mould =150mm

13. Volume of specimen =3092.5 cm3
14. Bulk density = 1.222 gm/cc
15. Dry density = 1.101 gm/cc

Observation table:

Table 4.27 Readings of California Bearing Ratio Test (2.0% & 20%)

DGR	PRR	Penetration in (mm)	Load (Kg)
0	0	0	0
50	3.4	0.5	17.816
100	6.8	1	35.632
150	9.4	1.5	49.256
200	11.4	2	59.736
250	13	2.5	68.12
300	14.4	3	75.456
350	15.5	3.5	81.22
400	16.4	4	85.936
450	17.4	4.5	91.176
500	18.2	5	95.368
550	19.2	5.5	100.608
600	20.1	6	105.324
650	20.8	6.5	108.992
700	21.6	7	113.184
750	22.2	7.5	116.328
800	22.9	8	119.996
850	23.5	8.5	123.14
900	24	9	125.76
950	24.5	9.5	128.38
1000	25	10	131
1050	25.4	10.5	133.096
1100	25.8	11	135.192
1150	26.2	11.5	137.288
1200	26.9	12	140.956
1250	27.1	12.5	142.004

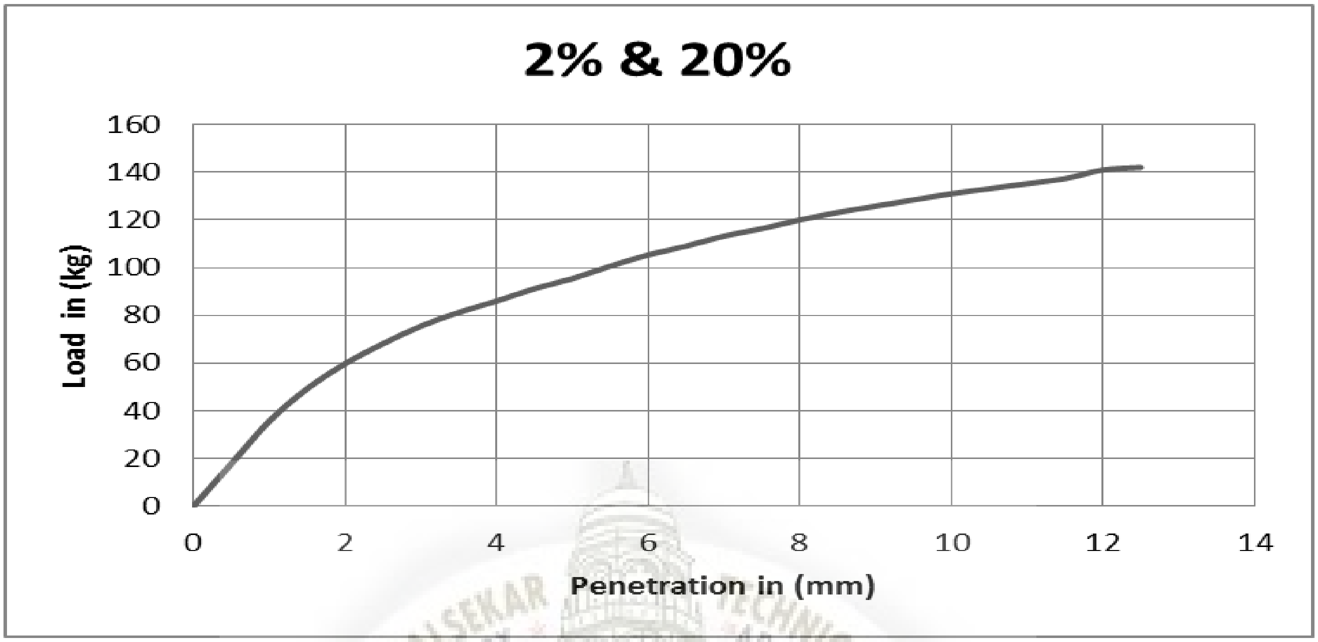

Figure 4.21 California Bearing Ratio Graph (2% & 20%)

Result:

CBR value of the soil sample =68.12/1370×100 = 4.97

4.2.2.3 Unconfined Compression Test:

A. 0.5% of RPP with 5% of Demolished Concrete Aggregates:

Observations:

1. Internal diameter of specimen =3.8cm
2. Initial length =7.6cm
3. Dial gauge constant (G) =0.01mm
4. Proving ring constant (Cf) =0.23Kg

Observation Table:

Table 4.28 Readings of Unconfined Compression Test

Sample no.	DGR	PRR	Deformation (mm)	Load (Kg)	Strain	Corrected area (mm2)	Compressive stress (P/A) (Kg/cm2)
1	50	2	0.05	0.46	0.0066	11.415	0.040
	100	7	0.1	1.61	0.0132	11.491	0.140
	150	11.2	0.15	2.576	0.0197	11.568	0.223
	200	15.4	0.2	3.542	0.0263	11.646	0.304
	250	19	0.25	4.37	0.0329	11.726	0.373
	300	22	0.3	5.06	0.0395	11.806	0.429
	350	22.4	0.35	5.152	0.0461	11.887	0.433
	400	25.8	0.4	5.934	0.0526	11.970	0.496
	450	26.9	0.45	6.187	0.0592	12.054	0.513
	500	27	0.5	6.21	0.0658	12.139	0.512
	550	24.8	0.55	5.704	0.0724	12.225	0.467
	600	20	0.6	4.6	0.0789	12.312	0.374

Result:

1. The Unconfined Compressive Strength =0.513 Kg/cm^2
2. However for this type of the stabilizer, UCS test is not suitable because the size of the polymers is larger than size of soil particles required for performing the test.
3. When sample was tested in UCS machine and axial load is applied on it, due to larger size of the polymers a define plane of failure is created which fails the sample from that critical plane at lower axial load than axial load at which normal soil was failed.

Figure 4.22 Failure of stabilized UCS sample

Chapter 5

Conclusion

The feasibility of using clayey soil stabilized with demolition concrete aggregate and recycled plastic polymers, as a subgrade material has been investigated. The stabilizing agents used were crushed demolition concrete aggregates. The conclusions drawn from the results obtained from various laboratory tests are given below.

When clayey soil was mixed with crushed demolition concrete aggregates and recycled plastic polymers,

- The value of MDD amongst 0.5% dosage of RPP is maximum when it is mixed with 10% of C&D waste and value is 1.87gm/cc at OMC of 11.64% and corresponding CBR value is 4.1.
- The value of MDD amongst 1.0% dosage of RPP is maximum when it is mixed with 5% and 10% of C&D waste and value is 1.93gm/cc at OMC of 7.96% and 15.3% respectively and CBR value corresponding to the dosage of C&D waste is 4.079 and 5.25 respectively.
- The value of MDD amongst 1.5% dosage of RPP is maximum when it is mixed with 10% of C&D waste and value is 1.85gm/cc at OMC of 12.31% and corresponding CBR value is 3.67.

- The value of OMC and MDD at 2.0% of RPP and 20% of C&D waste is 11.25% and 1.89% respectively and corresponding CBR value is 4.97.
- The value of MDD goes on decreasing with further increase in dosage of stabilizer, therefore no need to test soil with increase dosage of stabilizer.
- Based on the test results, the value of MDD and OMC is maximum at 1.0% and 5% but with less CBR value than 1.0% and 10% with same MDD.
- Therefore the optimum dosage of RPP and C&D waste at which the maximum properties of the soil is achieved is 1.0% and 10% respectively.
- The value of MDD and OMC increased from 1.89 gm/cc and 10.3% to 1.93 gm/cc and 15.3% with 10% addition of aggregates.
- CBR value increased from 4.054 to 5.25 which help to reduce the thickness of pavement.
- As seen before for this type of the stabilizer, UCS test is not suitable because the size of the polymers is larger than size of soil particles required for performing the test.

Stabilization of weak subgrades using demolition concrete waste will ultimately lower carbon footprints in contrast to using traditional quarried materials. Hence demolished concrete wastes could be shifted from “Waste Material” category to “Resource Material” category.

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