STRENGTH PARAMETERS OF UNTANNED LEATHER ASH MIXED EXPANSIVE SOIL

A

PROJECT REPORT

Submitted in partial fulfillment of the requirements for the award of the degree

of

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision

of

Mr. Niraj Singh Parihar

Asst. Professor

By

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to

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

WAKNAGHAT, SOLAN – 173234

HIMACHAL PRADESH, INDIA

MAY,2019

STUDENT'S DECLARATION

I hereby declare that the work presented in the Project report entitled **"Strength Parameters of Untanned Leather Ash Mixed Expansive Soil"** submitted for partial fulfilment of the requirements for the degree of Bachelor of Technology in Civil Engineering at **Jaypee University of Information Technology, Waknaghat** is an authentic record of my work carried out under the supervision of **Mr. Niraj Singh Parihar**. This work has not been submitted elsewhere for the reward of any another degree/diploma. I am fully responsible for the contents of my project report.

Signature of Student

Bhupinder Singh Verma (151668)

Aditya Dhiman (14663)

Department of Civil Engineering

Jaypee University of Information Technology, Waknaghat, India

Date: ……………………

CERTIFICATE

This is to certify that the work which is being presented in the project report titled **"Strength Parameters of Untanned Leather Ash Mixed Expansive Soil"** in partial fulfilment of the requirements for the award of the degree of Bachelor of
Technology in Civil Engineering submitted to the Department of Civil Engineering, **Jaypee University of Information Technology, Waknaghat** is an authentic record of work carried out by **Bhupinder Singh Verma (151668) and Aditya Dhiman (141663)** during a period from August, 2018 to May, 2019 under the supervision of **Mr. Niraj Singh Parihar** Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

The above statements made is correct to the best of our knowledge.

Date: 8-04-2019

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Abstract

Black cotton soil (Expansive soil) is very weak in bearing capacity and does not have sufficient stability for any type of construction work to be done on it. So, improving its engineering properties is very essential. It swells and shrinks excessively with change of water content. So, stabilization of black cotton soil has been done using untanned leather waste ash in the present study. To know the optimum quantity of untanned leather ash to enhance the strength and decrease swelling and shrinkage property, leather waste ash was added to the black cotton soil by weight in the percentage concentration of 2%, 4%, 6%, 8%, and 10%.

The leather waste used in this present study contains lime in good proportion though major part of the waste is directly dumped into landfills. Black cotton soil having high cation exchange properties can be stabilized using this lime content. The present study is based upon use of the lime containing leather waste ash for enhancement of the expansive soil strength.

Content

List of Abbreviations

Serial no.	Abbreviation used	Description
1.	BCS	Black cotton soil
2.	CBR	California Bearing Ratio
3.	IS	Indian Standard
4.	MDD	Maximum Dry Density
5.	OMC	Optimum Moisture Content

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Chapter 1: Introduction

1.1 General introduction

Black Cotton soil (BCS) is formed under circumstance of bad drainage from basic rocks like lime stone under swift change in climate. Due to cultivation of cotton as an important crop grown on this soil it is known as black cotton soil. Black cotton soil is most unsuitable for construction work because it is an expansive clay and has a tendency of shrinking and swelling excessively with change in water content. Which lead to differential settlement of structures. This is because of the rate of Montmorillonite is more in BCS then illite and kaolinite.

Main attribute of Black Cotton soil are:

a. Color black to brown.
b. High proportion of expansive clay mineral called Montmorillonite.
c. It has low strength property.

Leather industries are causing soil pollution, atmospheric pollution, water and air pollution. Heavy metals like chromium are considered toxic for nature which are present in leather waste. The process of tanning animal skin converts the protein of the skin, which make it more resistant and less susceptible for decaying.

For stabilizing BCS various stabilizers like lime, cement, rice husk, fly ash, etc. are used due to rising cost of stabilizer and toxic waste dumping directly into landfills which is effecting environment. Leather waste having heavy metals present can be used as stabilizer for Black Cotton soil having high cation exchange property.

2.1 Literature review conclusions:

1. **“Experimental Investigation on Stabilization of Black Cotton Soil by using Lime and Fly Ash”**

   R.MahaDevi ;2017

   They used lime and fly ash in 5%, 10%, 15%, and 10%, 20%, 30%, respectively.

   Addition of 15% lime and 30% fly ash gives maximum strength and minimum swelling.

2. **“Studies on Stabilization of Black Cotton Soil Using Lime”**

   Harish G. R ;2017

   In this stabilization of black cotton soil has been carries out using lime. The test results has been shown that there is an improvement in strength properties of soil and also decrease in plasticity index and substantial increase in CBR value has been also observed.

3. **“Experimental Investigation For Stabilization Of Black Cotton Soil By Using Lime And Brick dust Waste”**

   Dr. D.S.V. Prasad ;2017

   The brick powder effectively utilized with black cotton soil in improving the soil CBR values.

   use of brick dust is found to be economical for local area.

4. **“Stabilization of black cotton soil by using cement, lime and rice husk”**

   Sajja Satish ;2018

   In this it was seen that with increase in the content of cement and lime, the strength increases. Also, it was seen that rising the percentage of rice husk, strength increases up to 7% and then it cut down to 10%. Therefore, rice husk not used for stabilization purpose of soil.

5. **“Stabilization of Black Cotton Soil using Lime”**

   Sailendra Singh ;2015

   They found that properties of black cotton soil get effectively modified by varying proportions of lime.

   They used lime in 4% and 6% and found that swelling decreases 40% to 80%.

6. **“Experimental Study on Stabilization of Black Cotton Soil With Stone Dust And Fibers”**

   K. Suresh;2009

   Study effect of stone dust and fibers to improve strength properties and got combination of optimum percentage at 3% for stone dust and 0.6% for fibers to mix with BCS for stabilization.

7. **“Stabilization of Black Cotton Soil Using Groundnut Shell Ash”**

   A.Parvathy Karthika; 2018

   Use ground nut shell ash from 2% to 12% find index properties bring in this material and got optimum percentage at the mix of 6%.

8. "Stabilization of black cotton soil by using Sisal fiber"

Sandyarani; 2018

Use fiber in various percentage of 0.2%to 1.25% in ratio of 0.3 only calculated strength parameter that is UCS and CBR (unsoaked) and found OMC and MDD at 0.5% and maximum strength 0.5%.

9. "Use of Lime & Concrete Waste Material for Stabilization of Black Cotton Soil"

Mehul M. Chavda;2017

Use lime and concrete waste as a stabilizer to check CBR as a material for a sub grade and found maximum MDD at a mixture of 5% lime 12% waste of concrete and strengthen the properties of BCS.

10. "Stabilization of Black Cotton Soil Using Coir Pith"

Arthi priya.D; 2017

Use coir pith in extent of percentage in a gap of 0.5 starting from 2% till 4% calculate OMC and UCS and achieve results in increase as they increase the proportion of coir pith added to the soil.

2.1.1 Summary

- The stabilization of black cotton soil is carried out in above experimental studies.

- In all the materials used in above cases found that all were increasing the attribute of BCS.

- When additives like lime, cement, fly ash, brick dust is added to black cotton soil they cause improvement in strength properties of soil.

- Some of the materials like fibers, ground nut shell ash, stone dust is used only to increase strength of BCS (expensive soil) and they found upright results.

2.1.2 Objectives

- To determine the difference in strength of plain black cotton soil and leather ash mixed black cotton soil.

- To get the optimum percentage of leather waste ash for mixing with black cotton soil.

3.1 Black Cotton Soil

3.1.1 Introduction

The black soil formed by cooling of lava after a volcanic eruption. The texture and composition of soil formed by lava and the breakdown of igneous rocks after volcanic action. This soil fertile and inorganic in nature and best for cultivation of cotton. Due to this reason this soil is known as black cotton soil. The colour of black cotton soil is black because it has titanium dioxide in small concentration which gives it black colour.

It is generally found in central parts of India like Deccan Plateau in Maharashtra, Madhya Pradesh, Gujrat and in parts of Karnataka and Tamil Nadu also.

3.1.2 Procurement

Black cotton soil is collected from Sri. Gomata Gayatri Organics Pvt. Ltd. Visakhapatnam, Andhra Pradesh, India.

Fig.1: Sample of plain black cotton soil

3.2 Leather waste

3.2.1 Introduction

The leather waste ash we have used is of untanned leather waste. This waste rich in calcium concentration. So, in this leather waste ash will be used as stabilizer to enhance the features of Black Cotton Soil and reduce its shrinkage and swelling.

3.2.2 Procurement

Leather waste is collected from a tannery in Jalandhar, Punjab.

3.2.3 Preparation of Untanned Leather Waste ash for use

- Firstly, the obtained leather waste air dried so dampness present be removed and then Oven dried to completely reduce moisture content.
- After that waste was openly burnet at the source then grinded and converted into fine powdered form.
- This obtained ash was then preceded through 450micron sieve and kept in air tight vessel.

(a) (b)

Figure2: Sample of (a) Untanned Leather Waste Ash, (b) Untanned Leather Waste.

4.1 Testing Methodology

4.1.1 Dry Sieve Analysis

The test is performed to get particle size distribution of soil particles. The testing is done according IS: 2720(part 4)-1985-Method of testing of soil (part 4- Grain size analysis).

Procedure

The test was done using sieves of size: 4.75mm,2.00mm,1.00mm, .25µm, 212 µm,150 µm,75 µm and sieve shaker and digital weighing machine. Taken 200 gm soil soaked in water. Sieving of taken soil is done from 75-micron sieve and washed with high flow of water pressure. Retaining material oven dried and weighed in a digital weighing machine and then the material is sieved with help of mechanical sieve shaker till the period of ten minutes. Material retained in each sieve was weighed. After that the particle size distribution curve is drawn in semi-log graph paper.

Figure 3: Sieve set for dry sieve analysis.

4.1.2 Liquid Limit

This test is performed to get the moisture content at which the soil changes its form from plastic to liquid. The testing is then done according to IS: 2720(part 4)-1985

Procedure

Apparatus used for this test are Casagrande apparatus, China dish, Grooving tool, Spatula, Digital Weight machine and a sieve of 425 microns. Soil sample course through 425micron sieve then taken. The sample is mixed with distilled water in evaporating dish. The good thick paste is made uniform and then kept in the cup. The layer is taken maximum 10 mm thick. Grooving tool is used make a cut in soil. The speed of rotation of handle is 2 revolutions per sec. The counted number of blows in which separated soil just joined till length of 13mm was noted. Soil sample is then taken near closed groove. A graph giving relation in between the number of blows and water content is then made. Liquid limit is obtained from the graph then that will be proportional to 25 blows.

Figure: 4 Liquid limit sample.

4.1.3 Plastic Limit

This test is performed to get the moisture content of soil when the soil starts behave like plastic material. The testing done according IS: 2720(part 5)-1985- Method of testing of soil.

Procedure

Apparatus required for this experiment are China dish, Weighing Machine, Spatula, 425micron sieve. Taken a sample of soil course through 425micron sieve. Place the soil in the china dish, pour water in it and mix with the help of spatula. Take a mould of sample weighing around 8 gm, form ball of taken soil using palms. Then form thread of a uniform diameter (around 3mm) using the taken ball of soil.

Thread should then reach the specified dia. the procedure then should be repeated until rolling thread starts to crumbles. Then take sample from broken thread keep it in a oven for drying of sample. The same procedure should be then repeated at slightly different water content to get the average of a particular value.

Figure 5: Plastic limit sample.

4.1.4 Shrinkage Limit

This test is performed to get the maximum moisture content in which reduction of water content do not make any significant difference in the volume. The testing done according IS: 2720(part 6)-1978.

Procedure

Apparatus used in this experiment are China dish, Weighing machine, Spatula, 425 microns sieve, Shrinkage dishes, Mercury. Taken sample of a soil course through 425micron sieve. Mass of shrinkage dish is taken after cleaning dish properly. volume of empty shrinkage dish is taken by flowing mercury in dish. Shrinkage dish is greased followed by filling of the soil sample in . The shrinkage dish is then weighed and placed in oven. Then complete drying of the volume oven dry pat is taken by passing mercury in to the dish. Then amount of mercury that displaced is weighed. Volume of dry soil pat is obtained.

(a) (b) (c)

Figure 6: Sample of shrinkage limit (a) Mercury, (b) Soil Sample, (c) Mercury Displaced.

4.1.5 Standard Proctor Test

This test is performed to get the maximum dry density and optimum moisture content of soil. The testing done according IS: 2720(Part 8)-1983.

Procedure

Apparatus used for this experiment are Standard proctor mould 944 cc of capacity, Weighing machine, Ramer weighing 2.5 kg, Dry weight of soil is taken 5 kg is mixed with proper amount of water. Proctor is then weighed without taking base plate collar is taken. Then the fixing collar and the base plate to soil is filled with three layers provider with 25 blows in every layer**.** The surface top soil is then made smooth after removing the collar of proctor. Bulk density of soil is calculated. Sample is taken from mould for the water content. Water content of soil is then to be increased by adding a some amount of water in each repetition. The whole procedure is then to be repeated until weight of a sample starts decreasing or shows constant value.

Fig 7 sample of standard proctor test.

4.1.6 Unconfined Compression Test

U.C.S is performed to find the unconfined compressive strength of soil.

Procedure:

Equipments used in this experiment is Standard proctor mould, Unconfined compressive strength testing machine, Weighing Machine, Hammer. Soil is compacted in same manner as in standard proctor method. U.C.S sampler oiled then it is inserted to compacted soil weight. U.C.S sampler is then removed which containing soil specimen. The specimen length of 8cm to be cut i.e. Length is measured of 76mm and diameter measured of 38. Then the specimen is to be placed in unconfined compression test machine. The measurement of load and displacement is done when the load decreases which represents the failure of soil specimen. Unconfined compressive strength is calculated.

Figure 8: Sample failure of UCS.

4.1.7 California Bearing Ratio

CBR test is performed using IS: 2720 (part 16) 1973 for plain and mixed expansive soil.

Procedure

The mould placed with surcharge weight on penetration test machine. Set the piston on sample for full contact of it in center. Set reading gauges of stress, strain on zero. Then load applied on at penetration rate about 1.25mm/min. take readings at penetration of 0.5, 1, 1.5, 2, 2.5, 3, 4, 5 and record it. Take maximum load that noted and accord with penetration value.

5.1 Tests performed on B.C.S

5.1.1 Specific gravity

To get the specific gravity of Black Cotton soil, using pycnometer.

The formula used is as follows:

Specific gravity = (wt. of dry soil + pycnometer) – (wt. of dry pycnometer)

[(wt. dry soil+ pycnometer) – (wt. dry pycnometer)] – [(wt. water+ soil+ pycnometer)- (wt. water+ pycnometer)]

The Specific gravity of soil is **2.65.**

Figure 9: Pycnometer sample for specific gravity.

5.1.2Dry Sieve Analysis

The weight of soil that has been taken for sieve analysis is 1kg (Annexure 1.1).

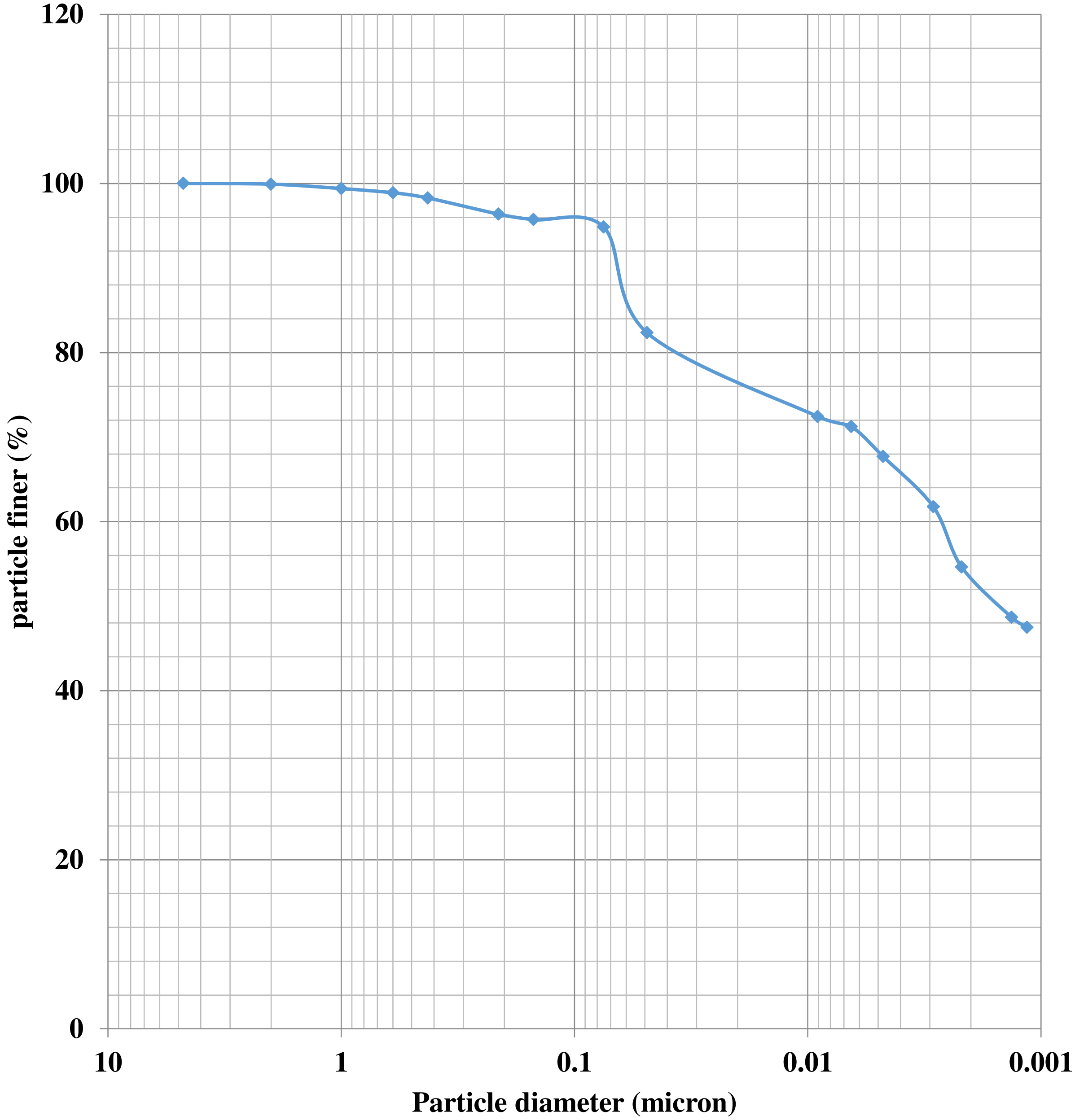

Figure 10: Particle size distribution curve.

5.1.3 Liquid limit

Liquid limit that moisture content at which soil starts to behave like liquid (Annexure 1.2).

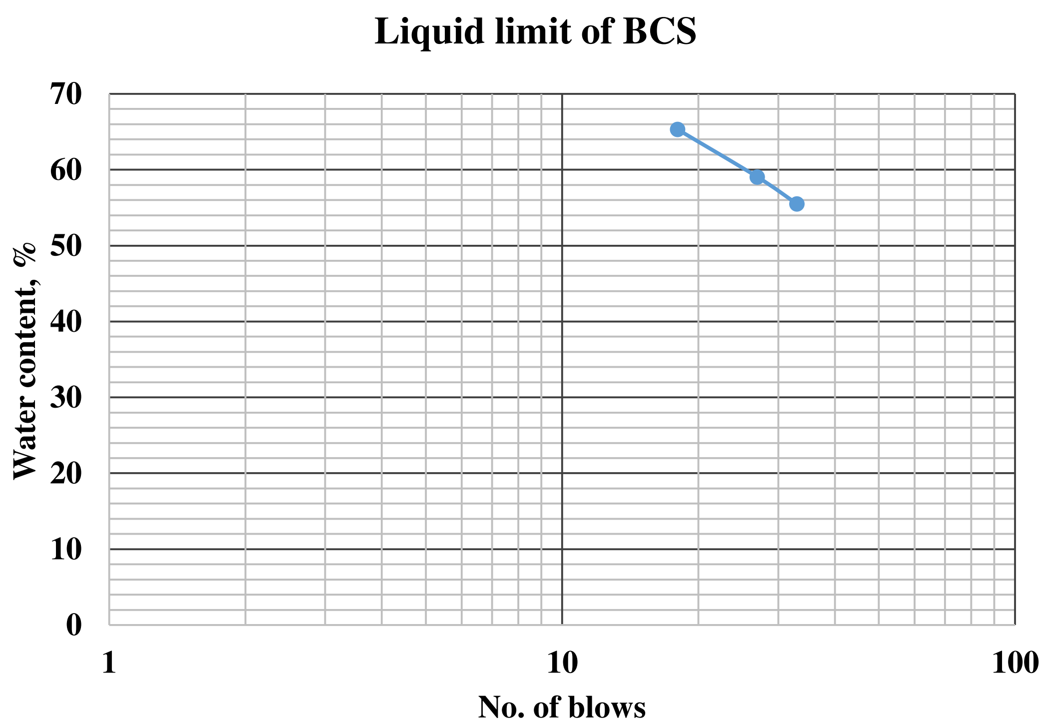

Figure 11: Flow curve for BCS.

Liquid limit calculated corresponding to 25 blows and found to be **63.4%.**

5.1.4 Plastic limit

That moisture content at which soil can be moulded into threads of 3mm without crack formation or failure.

The plastic limit of BCS was calculated and found to be **34.6%.**

Plasticity Index (Ip) = liquid limit – plastic limit.

63.4 – 34.6 = **21.95.**

Variation in plasticity index

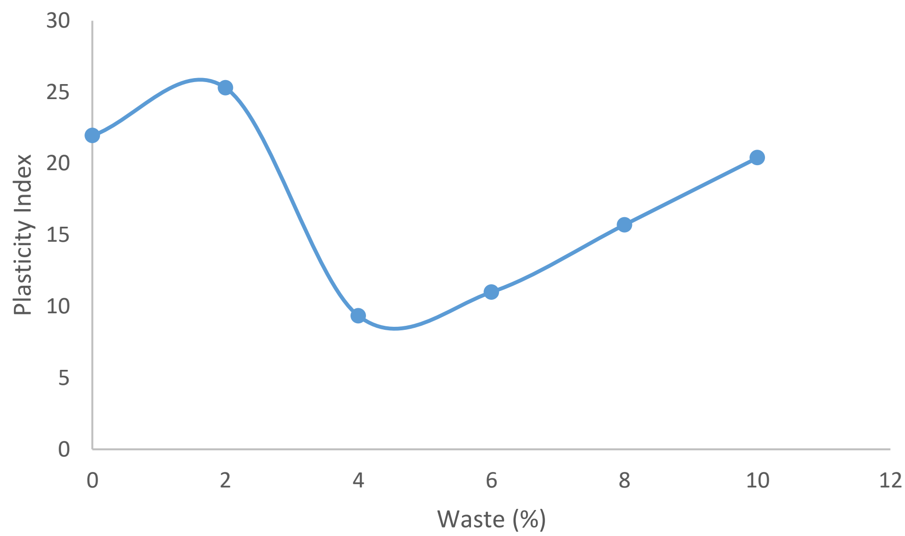

Figure 12: Variation in plasticity index with waste ash

5.1.5 Shrinkage limit

The average shrinkage limit of BCS is **13.1%** (Annexure1.3).

5.1.6 Free Swell Index

This test is used to check swelling property of soil (Annexure 1.4).

The Free Swell Index of BCS = 63.64 %.

5.1.7 To determine OMC and MDD of BCS

O.M.C is determined using standard proctor test (Annexure 1.5).

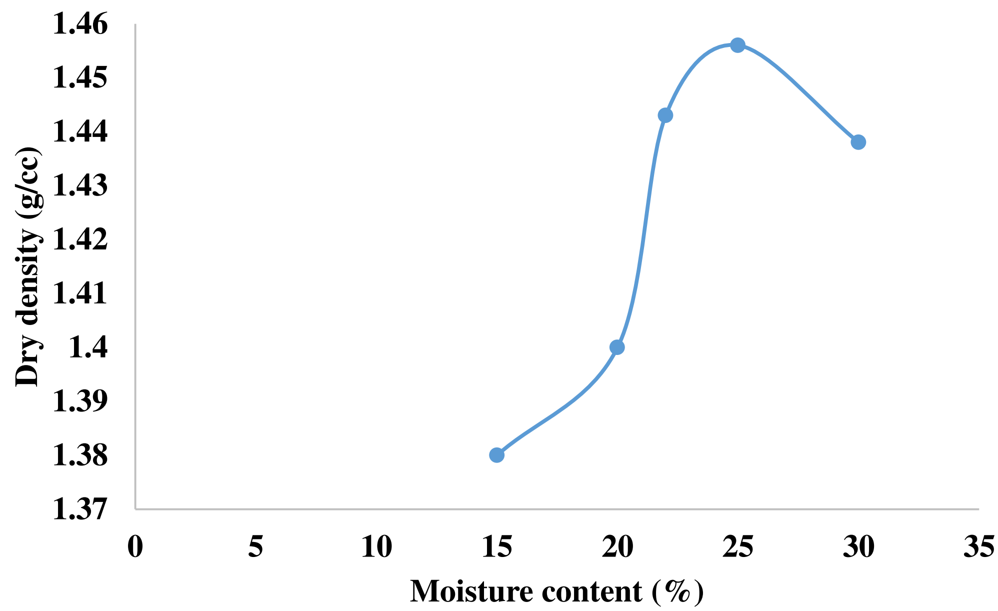

Figure 13: Compaction Curve of BCS.

From the curve MDD is **1.458** corresponding to OMC of **24%.**

5.1.8 Unconfined compression test

U.C.S is done to measure the compressive strength of soil.

After calculating the UCS was found to be **112KN/m^2.**

5.1.9California Bearing Ratio Test

CBR measure of bearing capacity of the soil. Here load is taken for penetration of 2.5mm and 5mm is measured. (Annexure1.6)

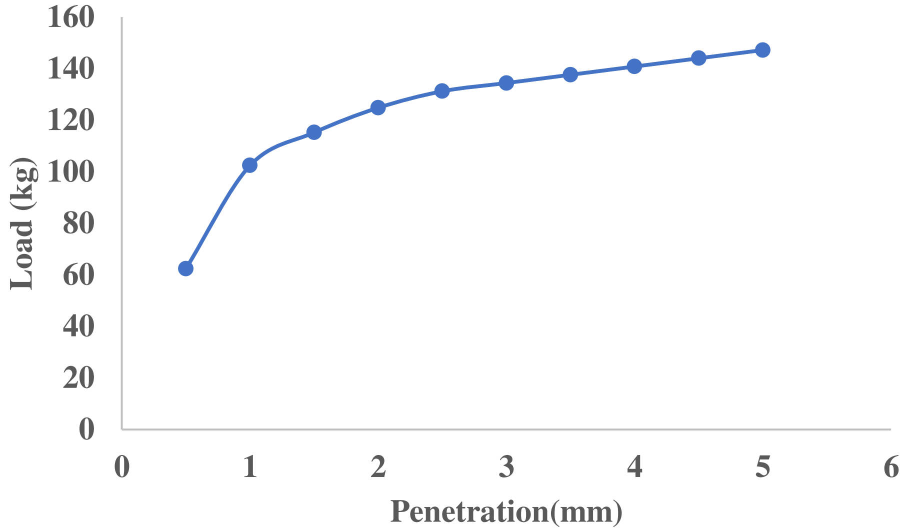

Figure 14: CBR Load penetration curve

C.B.R. value at 2.5mm = (131.2/1370) *100 = **9.57**

C.B.R. value at 5mm = (147.2/2050) *100 = **7.18**

5.2 Test done on B.C.S + untanned leather waste ash

5.2.1 Plastic limit

To determine the plastic limit untanned leather waste ash is added to BCS in proportion of 2%, 4%, 6%, 8%, 10% by its weight (Annexure 1.7).

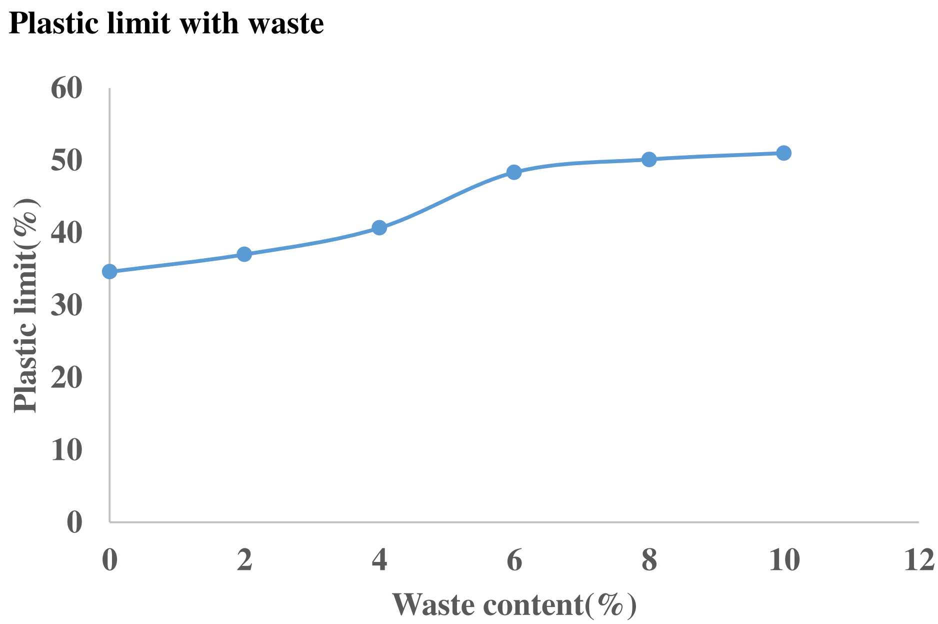

Figure 15: Plastic limit variation with leather waste ash

With rise in waste percentage the plastic limit start increasing and maximum value is **38%** at **6%** waste.

5.2.2 Liquid Limit

B.C.S. is mixed with waste ash in 2%, 4%, 6%, 8%, 10% added by its weight. (Annexure1.8)

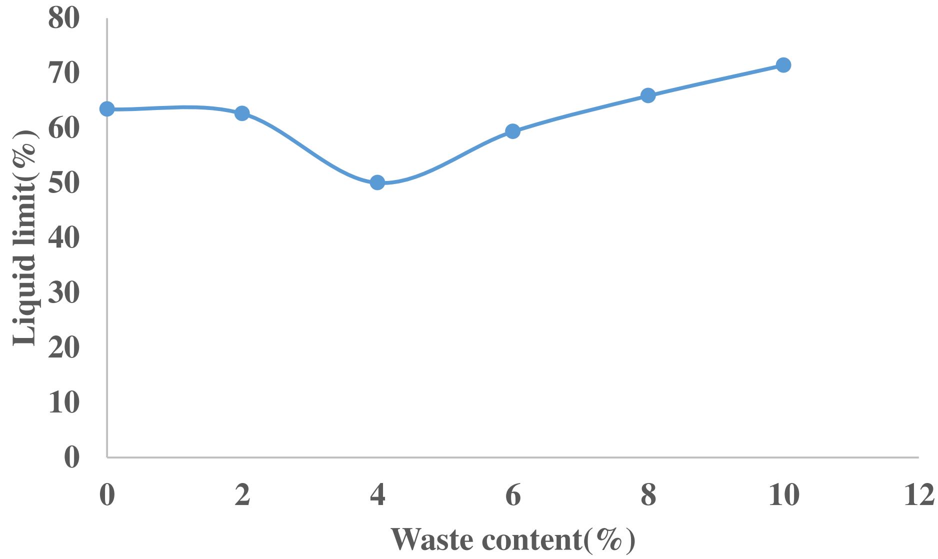

Figure 16: Liquid Limit variation with leather waste ash

5.2.3 Shrinkage Limit

B.C.S. is mixed in waste ash in 2%, 4%, 6%, 8%, 10% added by its weight. (Annexure1.9)

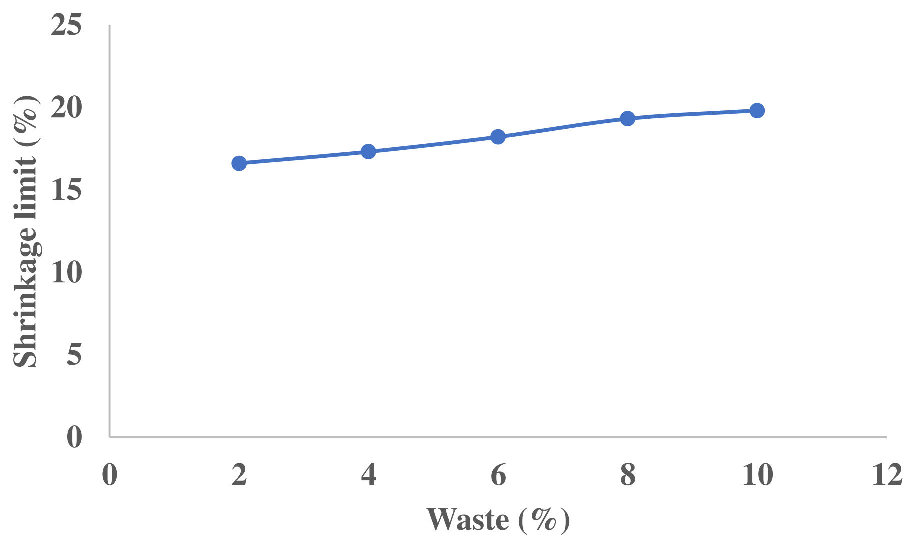

Figure 17: Shrinkage Limit variation at different untanned leather waste ash

5.2.4 Optimum Moisture Content

Here B.C.S mixed with 2%, 4%, 6%, 8%, 10% of untanned leather ash and using standard proctor test O.M.C and M.D.D was calculated.

<u>BCS + 2% untanned leather waste ash</u>

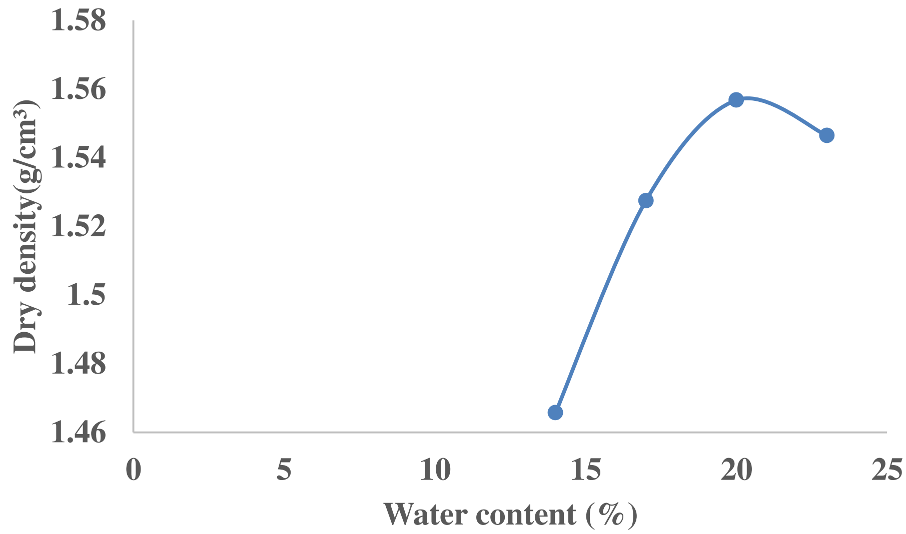

Figure 18: Standard compaction curve BCS+ untanned leather

OMC found to be **21%** and the MDD is **1.556g/cm³.** (Annexure1.10.1)

B.C.S +4% Untanned leather waste ash

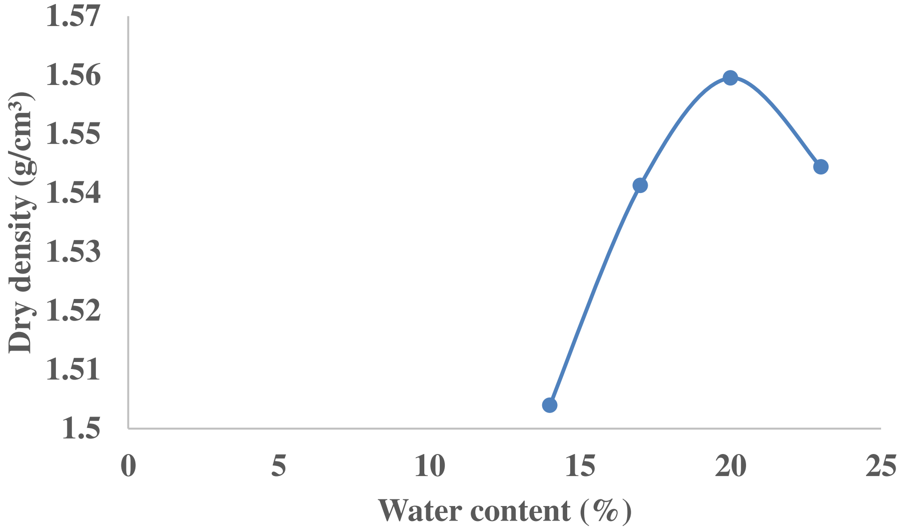

Figure 19: Standard compaction curve BCS+ untanned leather

OMC found to be **20%** and the MDD is **1.559g/cm³.** (Annexure1.10.2)

B.C.S +6% Untanned leather waste ash

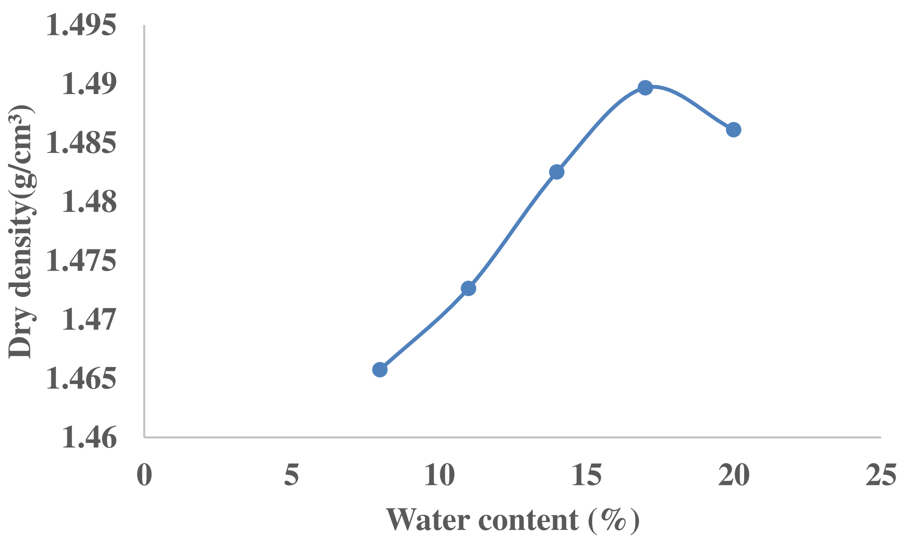

Figure 20: Standard compaction curve BCS+ untanned leather

OMC found to be **17%** and the MDD is **1.489g/cm³.** (Annexure1.10.3)

B.C.S +8% Untanned leather waste ash

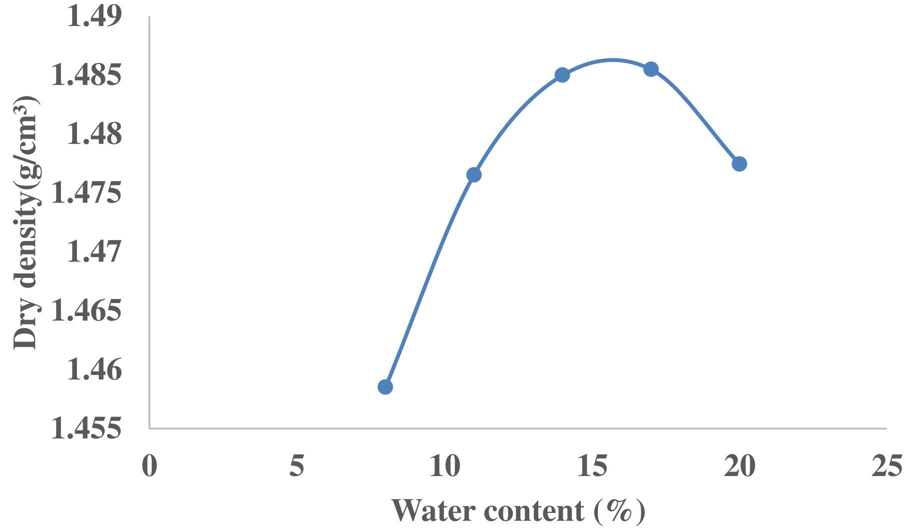

Figure 21: Standard compaction curve BCS+ untanned leather

OMC found to be **16.3%** and the MDD is **1.486g/cm³.** (Annexure1.10.4)

B.C.S +10% Untanned leather waste ash

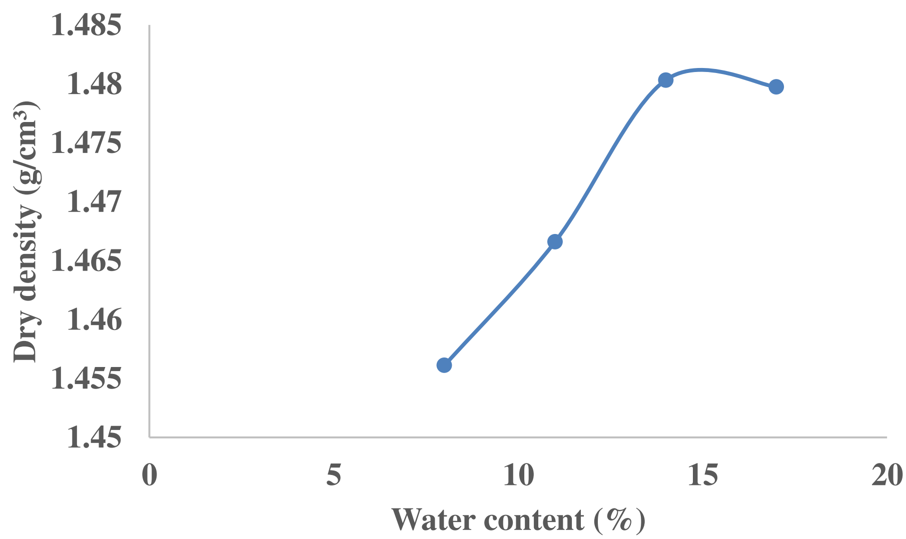

Figure 22: Standard compaction curve BCS+ untanned leather

OMC found to be **14.5%** and the MDD is **1.483g/cm³.** (Annexure1.10.5)

5.2.4.1Variation of MDD with untanned leather waste ash

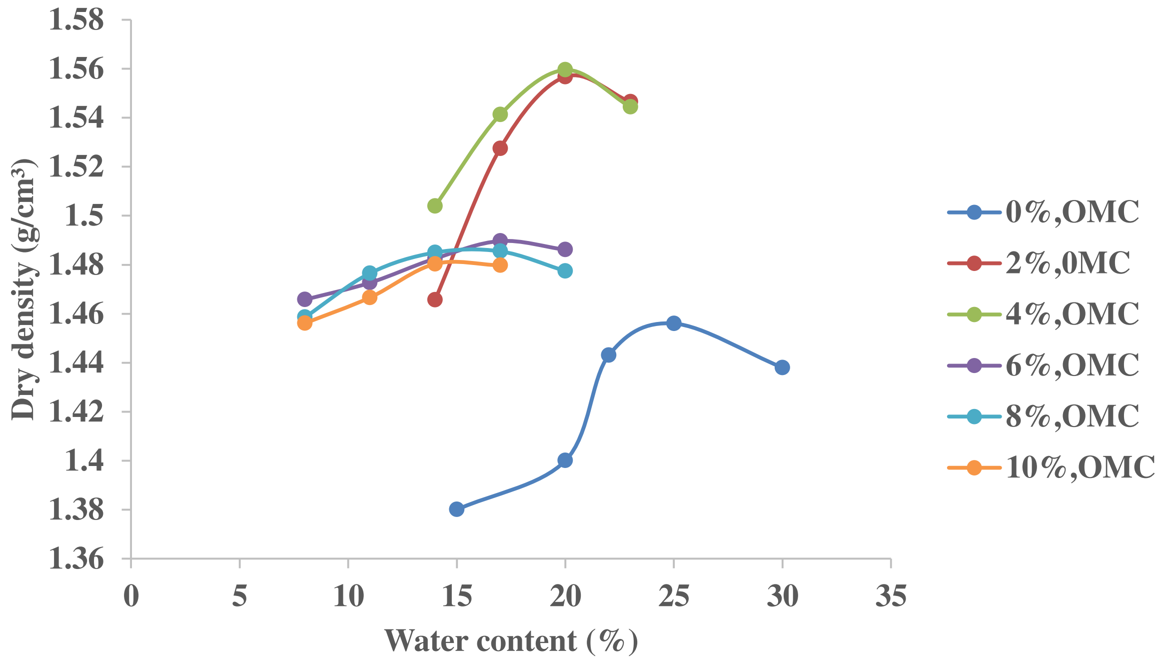

Figure 23: Variation of MDD

Graph 13 shows that with rising proportion in untanned leather waste ash the value of MDD increases till 4% addition of untanned leather ash and the MDD at 4% is 1.559g/cm³. Then with rise in content of leather ash there is decrease in MDD.

5.2.5 Unconfined Compressive Strength

Here B.C.S mixed with 2%, 4%, 6%, 8%, 10% of untanned leather ash and Unconfined Compression Strength was calculated.

B.C.S. +2% Untanned leather waste ash

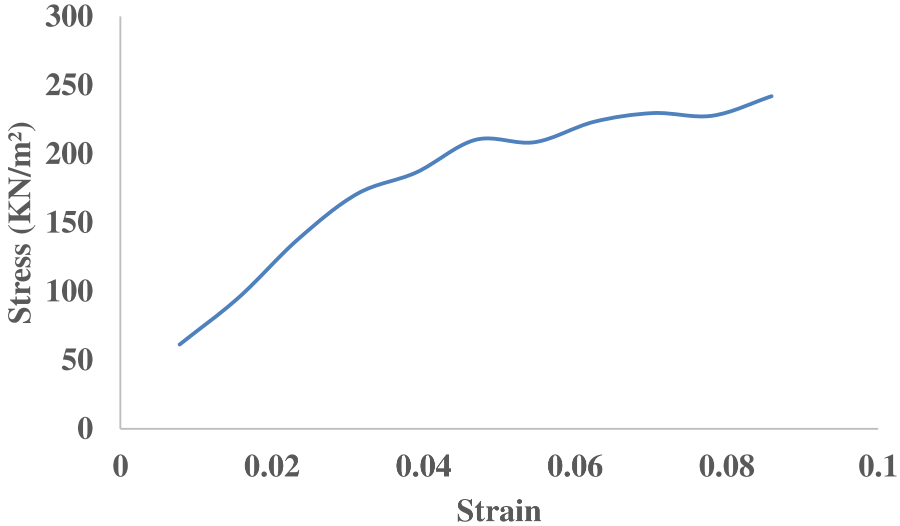

Figure 24: Stress Strain curve B.C.S +untanned leather waste ash

Here the UCS is calculated and is **120.9.** (Annexure 1.11.1)

B.C.S. +4% Untanned leather waste ash

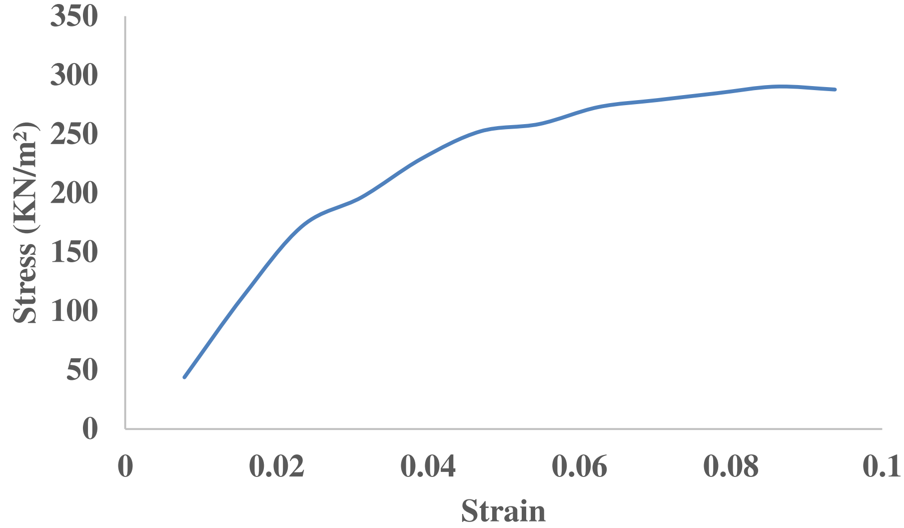

Figure 25: Stress Strain curve B.C.S +untanned leather waste ash

Here the UCS is calculated and is **145.14.** (Annexure 1.11.2)

B.C.S. +6% Untanned leather waste ash

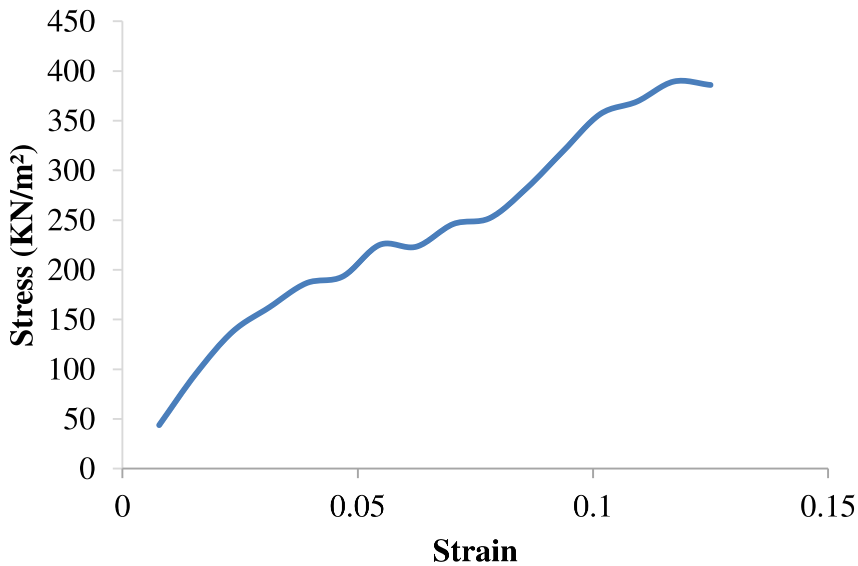

Figure 26: Stress Strain curve B.C.S +untanned leather waste ash

Here the UCS is calculated and is **194.7.** (Annexure 1.11.3)

B.C.S. +8%Untanned leather waste ash

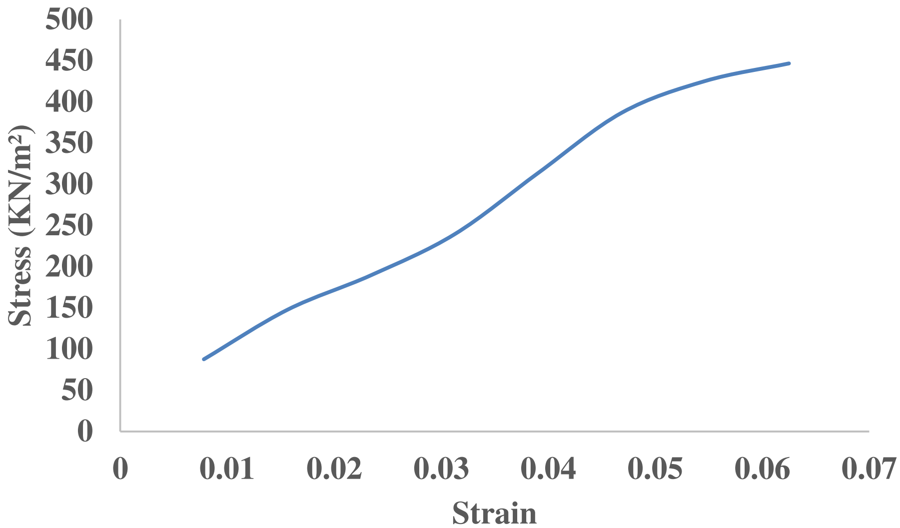

Figure 27: Stress Strain curve B.C.S +untanned leather waste ash

Here the UCS is calculated and is **223.3.** (Annexure 1.11.4)

B.C.S. +10% Untanned leather waste ash

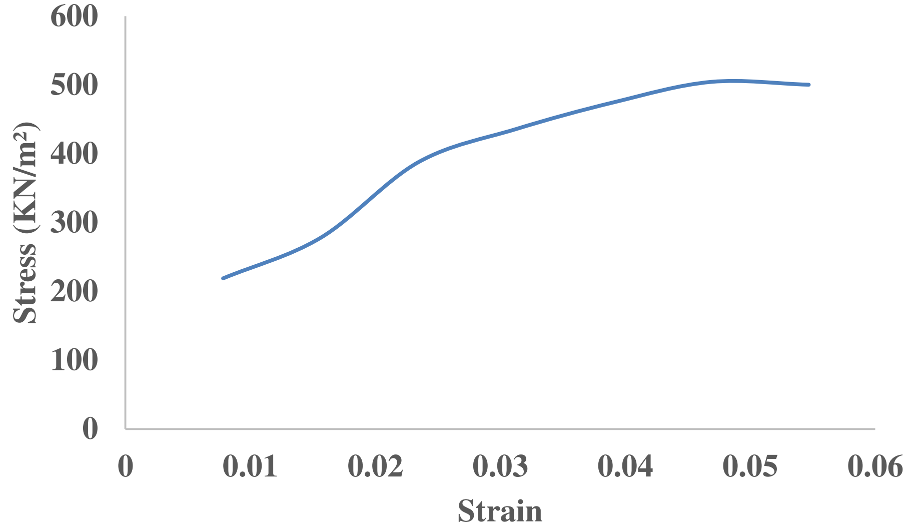

Figure 28: Stress Strain curve B.C.S +untanned leather waste ash

Here the UCS is calculated and is **252.2.** (Annexure 1.11.5)

5.2.5.1 Variation in UCS

Variation in Unconfined Compression Strength of B.C.S with addition of untanned leather waste ash in 2%, 4%, 6%, 8%, 10%.

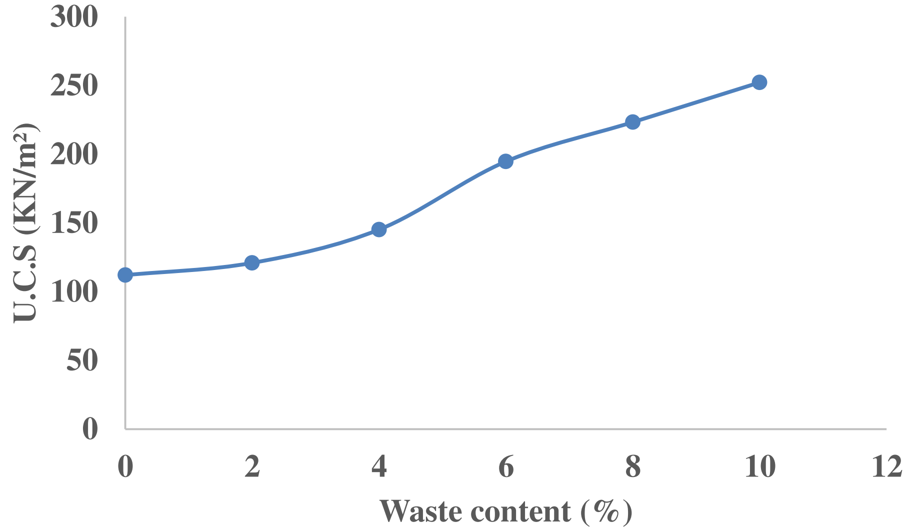

Figure 29: Variation in UCS

So, here in graph 19 we can see that with rise in Unconfined Compression Strength of BCS as there is increase in untanned leather waste ash. (Annexure 1.11.6)

5.2.6 California Bearing Ratio

CBR is done on BCS added untanned leather waste ash in variation of 2%, 4%, 6%, 8%, 10%.

By calculating CBR we can also know that if the material can be used for subgrade in pavement.

<u>B.C.S +2%Untanned leather waste ash</u>

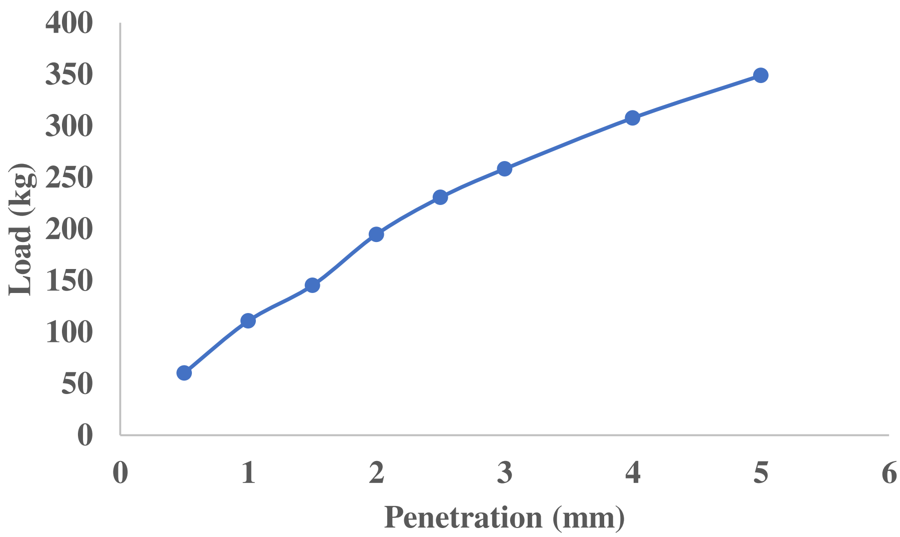

Figure 30: CBR for BCS +untanned leather ash

The CBR value calculated is **16.8%** at penetration of **2.5mm.** (Annexure 1.12.1)

B.C.S +4% Untanned leather waste ash

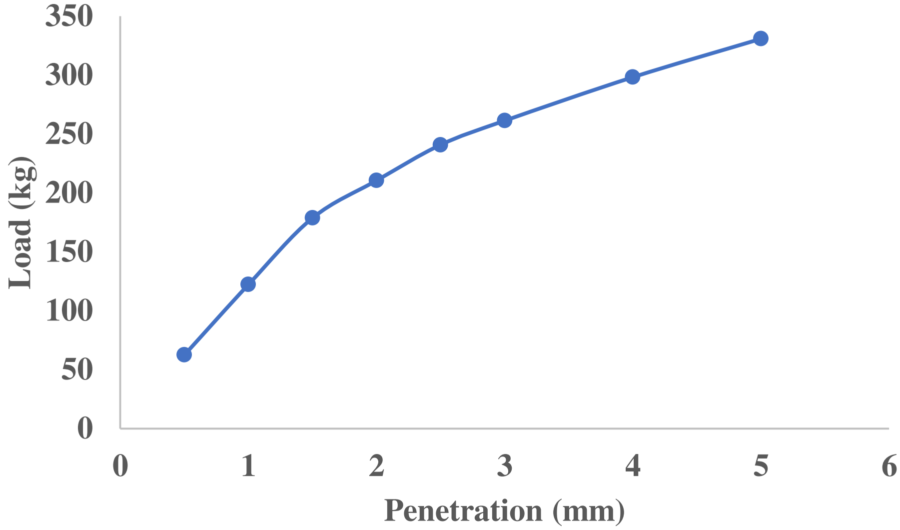

Figure 31: CBR for BCS +untanned leather ash

The CBR value calculated is **17.5%** at penetration of **2.5mm.** (Annexure 1.12.2)

B.C.S +6% Untanned leather waste ash

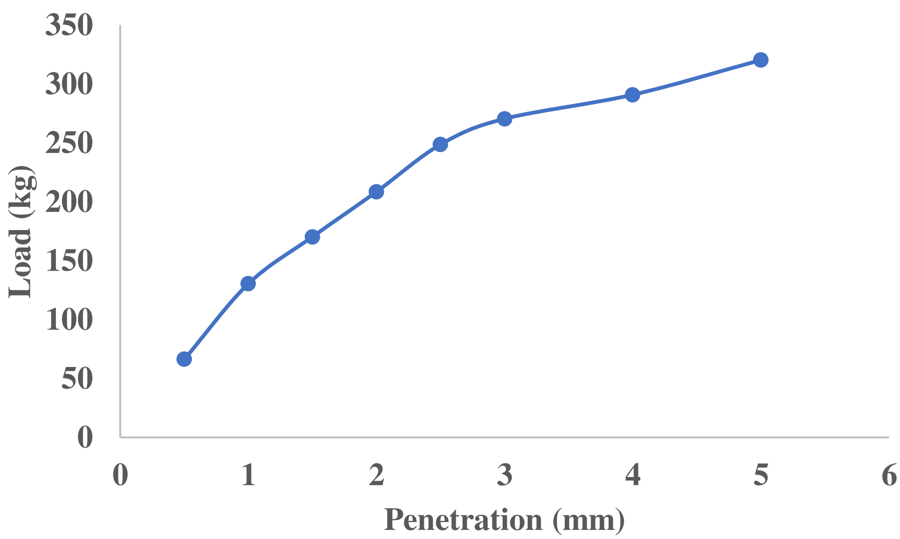

Figure 32: CBR for BCS +untanned leather ash

The CBR value calculated is **18.1%** at penetration of **2.5mm.** (Annexure 1.12.3)

B.C.S +8%Untanned leather waste ash

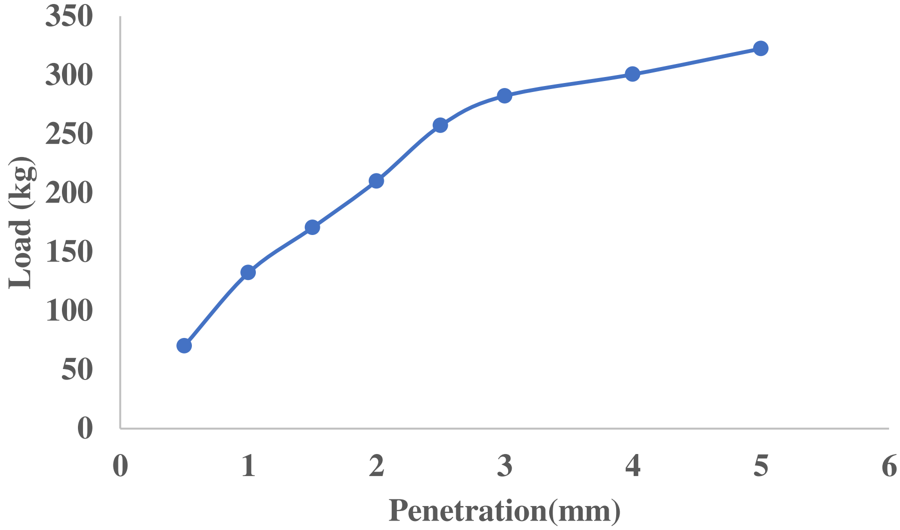

Figure 33: CBR for BCS +untanned leather ash

The CBR value calculated is **18.7%** at penetration of **2.5mm.** (Annexure 1.12.4)

B.C.S +10%Untanned leather waste ash

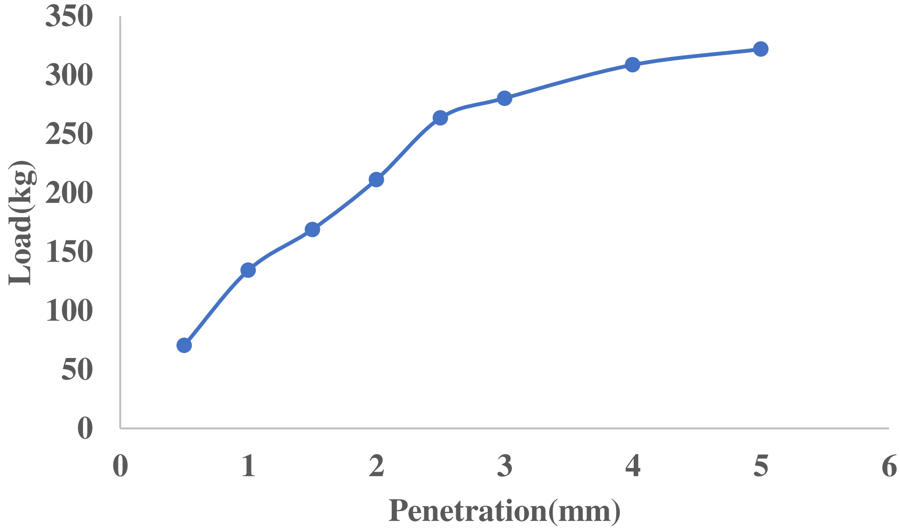

Figure 34: CBR for BCS +untanned leather ash

The CBR value calculated is **19.2%** at penetration of **2.5mm.** (Annexure 1.12.5)

5.2.6.1 Variation in CBR

Variation in California Bearing Ratio of B.C.S added with untanned leather waste ash in 2%, 4%, 6%, 8%, 10%.

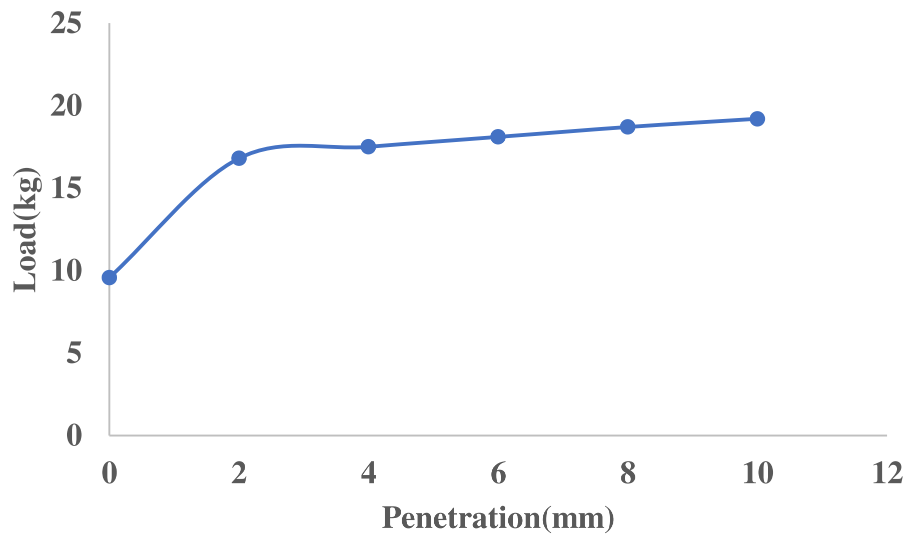

Figure 35: Variation in UCS

In graph 25 we can see that there is increase in CBR values of BCS as there is increase in untanned leather waste ash. (Annexure 1.11.6)

CHAPTER 6: Conclusion

From the results acquired above it can be concluded that:

- After performing test on plain soil it was found that it is showing a properties of black cotton soil. As per IS classification the soil is fine grained soil as clay particles present is 52%.
- The result of MDD increase was high when untanned leather ash was mixed MDD value 1.559 was highest at 4%.
- In case of UCS value increase as there was rise in proportion of waste ash. The maximum UCS is 252.2 at 10% waste ash content.
- Equivalently there was increase in values of CBR with rise in proportion of waste ash. The maximum CBR is 19.2 at 10% waste ash content.

Future Scope

It is concluded that untanned leather waste ash can be used for stabilizing from experimental results. As there is increase in strength of BCS as there is rise in proportion of untanned leather ash.

- In the present study the untanned leather waste was burnt openly in no temperature control. So, in controlled heat temperature there can be distinct results.
- Untanned leather waste ash can be used to examine the swelling and shrinkage property of expensive soil.

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ANNEXURE

Annexure1.1

Table 1 Dry sieve analysis of B.C.S

IS sieve (mm)	Weight of soil retained (gram)	Percentage Weight retained (%)	Cumulative percentage retained (%)	Percentage finer (%)
1	0	0	0	100
0.6	4.8	7.6	7.6	92.4
0.425	7.2	11.4	19	81
0.212	10.3	16.3	35.3	64.7
0.150	17.2	27.2	62.5	37.5
0.075	14.8	23.4	85.9	14.1
pan	8.8	13.9	99.8	0.2

Table 2 Hydrometer analysis of soil

Time (min)	Hydrometer reading (Rh)	percent finer in suspension (%)	Corrected length (mm)	Temperature (C)	k	Diameter (mm)	Percent finer (%)
0.5	62	117.8	6.1	16	0.014	0.0489	11.78
1	62	117.8	6.1	16	0.014	0.034577	11.78
2	62	117.8	6.1	16	0.014	0.02445	11.78
4	62	117.8	6.1	16	0.014	0.017289	11.78
8	62	117.8	6.1	16	0.014	0.012225	11.78
15	61	115.9	6.3	16	0.014	0.009073	11.59
30	60	114	6.5	16	0.014	0.006517	11.4
60	57	108.3	7	17	0.0139	0.004748	10.83
180	52	98.8	7.8	17	0.0139	0.002894	9.88
360	46	87.4	8.8	16	0.014	0.002189	8.74
1080	41	77.9	9.6	15	0.0142	0.001339	7.79
1440	40	76	9.7	16	0.014	0.001149	7.6

Annxure1.2

Table 3 Liquid limit of BCS

Number of blows	Weight of container	Weight of container +wet soil	Weight of container + oven dry soil	Moisture content
33	19.6	25.2	23.2	55.5
27	19.3	26.3	23.7	59.04
18	21.0	29.6	26.2	65.3

Annexure1.3

Table 4 Shrinkage limit of soil

Empty wt. of dish (gm)	Wt. of dish + wet soil (gm)	Wt. of dish + dry soil (gm)	Wt. of dry soil (gm)	Wt. of mercury (gm)	Volume of dry soil (gm)	Wt. of wet soil (gm)	Moisture content (%)	Shrinkage limit
36.2	69.9	55.5	19.3	141.2	10.412	14.4	74.6	14.36
24.3	59.5	44.7	20.4	131.7	9.712	14.8	72.54	12.11

Annexure 1.4

Table 5 Free swell index of soil

Observations	Lapse time (hours)	Volume of soil in cylinder containing kerosene (V_1) (cc)	Volume of soil in cylinder containing distilled water (V_2) (cc)
1	0	11	15
2	24	11	18

Annexure 1.5

Table 6 MDD of BCS

Wt. Mould + Base plate (gm)	Moisture content (%)	Wt. of compacted soil	Bulk density (g/cc)	Dry density (g/cc)
3686	15	1584.6	1.58	1.38
3686	20	1678.4	1.68	1.4
3686	22	1765.3	1.72	1.443
3686	25	1821.6	1.82	1.456
3686	30	1809.2	1.78	1.438

Annexure1.6

Table 7 CBR test readings

Penetration (mm)	Load (kg)
0.5	62.4
1	102.4
1.5	115.2
2	124.8
2.5	131.2
3	134.4
3.5	137.6
4	140.8
4.5	144
5	147.2

Annexure1.7

Table 8 Plastic Limit variation of untanned waste ash with BCS

waste	plastic limit
2	37
4	40.66
6	48.33
8	50.12
10	51

Annexure1.8

Table 9 Liquid Limit variation of untanned waste ash with BCS

Waste (%)	Liquid Limit (%)
2	62.6
4	50
6	59.33
8	65.83
10	71.4

Annexure 1.9

Table 10 Shrinkage limit variation at different untanned leather waste ash

Waste (%)	Shrinkage limit (%)
2	16.6
4	17.3
6	18.2
8	19.3
10	19.8

Annexure 1.10

Annexure 1.10.1

Table 11 Standard compaction test BCS+ 2%untanned leather

Weight of mould + base plate (gm)	Weight of mould + base plate + compacted soil (gm)	Weight of compacted soil (gm)	Bulk density (g/cm³)	Moisture content (%)	Dry density (g/cm³)
3661.7	5331.4	1669.7	1.670861	14	1.465668
3661.7	5447.6	1785.9	1.787142	17	1.527472
3661.7	5528.5	1866.8	1.868098	20	1.556749
3661.7	5562.5	1900.8	1.902122	23	1.546441

Annexure 1.10.2

Table 12 Standard compaction test BCS+ 4%untanned leather

Weight of mould + base plate (gm)	Weight of mould + base plate + compacted soil (gm)	Weight of compacted soil (gm)	Bulk density (g/cm³)	Moisture content (%)	Dry density (g/cm³)
3657.9	5371.2	1713.3	1.714492	14	1.50394
3657.9	5459.9	1802	1.803253	17	1.541242
3657.9	5528	1870.1	1.871401	20	1.559501
3657.9	5556.2	1898.3	1.89962	23	1.544407

Annexure 1.10.3

Table 13 Standard compaction test BCS+ 6%untanned leather

Weight of mould + base plate (gm)	Weight of mould + base plate + compacted soil (gm)	Weight of compacted soil (gm)	Bulk density (g/cm³)	Moisture content (%)	Dry density (g/cm³)
3659.3	5241.2	1581.9	1.583	8	1.465741
3659.3	5292.8	1633.5	1.634636	11	1.472645
3659.3	5348.2	1688.9	1.690075	14	1.482522
3659.3	5401	1741.7	1.742911	17	1.489668
3659.3	5441.4	1782.1	1.783339	20	1.486116

Annexure 1.10.4

Table 14 Standard compaction test BCS+ 8%untanned leather

Weight of mould + base plate (gm)	Weight of mould + base plate + compacted soil (gm)	Weight of compacted soil (gm)	Bulk density (g/cm³)	Moisture content (%)	Dry density (g/cm³)
3660.5	5234.6	1574.1	1.575195	8	1.458514
3660.5	5298.3	1637.8	1.638939	11	1.476522
3660.5	5352.2	1691.7	1.692877	14	1.484979
3660.5	5397.3	1736.8	1.738008	17	1.485477
3660.5	5432.2	1771.7	1.772932	20	1.477443

Annexure 1.10.5

Table 15 Standard compaction test BCS+ 10%untanned leather

Weight of mould + base plate (gm)	Weight of mould + base plate + compacted soil (gm)	Weight of compacted soil (gm)	Bulk density (g/cm³)	Moisture content (%)	Dry density (g/c³)
3663.9	5235.4	1571.5	1.572593	8	1.456105
3663.9	5290.7	1626.8	1.627931	11	1.466605
3663.9	5350.3	1686.4	1.687573	14	1.480327
3660.5	5390.6	1730.1	1.731303	17	1.479746

Annexure 1.11

Annexure 1.11.1

Table 16 UCS of BCS +2%leather ash

Deformation	Strain	Corrected Area	Load	Stress
0.5	0.007813	11.42466	0.07	61.270996
1	0.015625	11.51533	0.11	95.52486
1.5	0.023438	11.60745	0.16	137.84251
2	0.03125	11.70106	0.2	170.92471
2.5	0.039063	11.79619	0.22	186.50092
3	0.046875	11.89288	0.25	210.20983
3.5	0.054688	11.99117	0.25	208.4868
4	0.0625	12.09109	0.27	223.30487
4.5	0.070313	12.1927	0.28	229.64562
5	0.078125	12.29603	0.28	227.71583
5.5	0.085938	12.40112	0.3	241.91361

Annexure 1.11.2

Table 17 UCS of BCS +4%leather ash

Deformation	**Strain**	**Corrected Area**	**Load**	**Stress**
0.5	0.007813	11.42466	0.05	43.765
1	0.015625	11.51533	0.13	112.893
1.5	0.023438	11.60745	0.2	172.3031
2	0.03125	11.70106	0.23	196.5634
2.5	0.039063	11.79619	0.27	228.8875
3	0.046875	11.89288	0.3	252.2518
3.5	0.054688	11.99117	0.31	258.5236
4	0.0625	12.09109	0.33	272.9282
4.5	0.070313	12.1927	0.34	278.8554
5	0.078125	12.29603	0.35	284.6448
5.5	0.085938	12.40112	0.36	290.2963
6	0.09375	12.50803	0.36	287.8152

Annexure 1.11.3

Table 18 UCS of BCS +6%leather ash

Deformation	Strain	Corrected Area	Load	Stress
0.5	0.007813	11.42466	0.05	43.765
1	0.015625	11.51533	0.11	95.52486
1.5	0.023438	11.60745	0.16	137.8425
2	0.03125	11.70106	0.19	162.3785
2.5	0.039063	11.79619	0.22	186.5009
3	0.046875	11.89288	0.23	193.393
3.5	0.054688	11.99117	0.27	225.1657
4	0.0625	12.09109	0.27	223.3049
4.5	0.070313	12.1927	0.3	246.0489
5	0.078125	12.29603	0.31	252.114
5.5	0.085938	12.40112	0.35	282.2325
6	0.09375	12.50803	0.4	319.7946
6.5	0.101563	12.61679	0.45	356.6675
7	0.109375	12.72747	0.47	369.2801
7.5	0.117188	12.8401	0.5	389.4051
8	0.125	12.95474	0.5	385.959

Annexure 1.11.4

Table 19 UCS of BCS +8%leather ash

Deformation	Strain	Corrected Area	Load	Stress
0.5	0.007813	11.42466	0.1	87.529995
1	0.015625	11.51533	0.17	147.62933
1.5	0.023438	11.60745	0.22	189.53345
2	0.03125	11.70106	0.28	239.2946
2.5	0.039063	11.79619	0.37	313.66063
3	0.046875	11.89288	0.46	386.78609
3.5	0.054688	11.99117	0.51	425.31307
4	0.0625	12.09109	0.54	446.60974

Annexure 1.11.5

Table 20 UCS of BCS +10% leather waste

Deformation	Strain	Corrected Area	Load	Compressive Stress
0.5	0.007813	11.42466	0.25	218.825
1	0.015625	11.51533	0.32	277.8905
1.5	0.023438	11.60745	0.45	387.6821
2	0.03125	11.70106	0.51	435.858
2.5	0.039063	11.79619	0.56	474.7296
3	0.046875	11.89288	0.6	504.5036
3.5	0.054688	11.99117	0.6	500.3683

Annexure 1.11.6

Table 21 Variation in UCS

Waste (%)	**UCS (KN/m²)**
0	112
2	120.9
4	145.14
6	194.7
8	223.3
10	252.2

Annexure 1.12

Annexure 1.12.1

Table 22 CRB of BCS +2%leather waste

Deformation (mm)	Load (N)
0.5	60.4
1	110.8
1.5	145.2
2	194.8
2.5	230.6
3	258.2
4	307.6
5	348.8

Annexure 1.12.2

Table 23 CRB of BCS +4%leather waste

Deformation (mm)	Load (N)
0.5	62.4
1	122.2
1.5	178.7
2	210.5
2.5	240.8
3	261.3
4	298.2
5	330.8

Annexure 1.12.3

Table 24 CRB of BCS +6%leather waste

Deformation (mm)	Load (N)
0.5	66.2
1	130.4
1.5	170.2
2	208.5
2.5	248.6
3	270.4
4	290.8
5	320.2

Annexure 1.12.4

Table 25 CRB of BCS +8%leather waste

Deformation (mm)	Load (N)
0.5	70.2
1	132.2
1.5	170.5
2	210.1
2.5	257.2
3	282.3
4	300.6
5	322.4

Annexure 1.12.5

Table 26 CRB of BCS +10%leather waste

Deformation (mm)	**Load (N)**
0.5	70.5
1	134.2
1.5	168.8
2	211.2
2.5	263.4
3	280.2
4	308.5
5	321.8

Annexure 1.12.6

Table 27 Variation in CBR

Waste (%)	**CBR**
0	9.57
2	16.8
4	17.5
6	18.1
8	18.7
10	19.2

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