Stabilization of black cotton soil using untanned leather industry solid waste

A PROJECT

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
Assistant professor

By

Abhishek Sharma
(141653)

Ribhu Gupta

(141654)

to

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

WAKNAGHAT, SOLAN – 173 234

HIMACHAL PRADESH, INDIA

CERTIFICATE

This is to certify that the work which is being presented in the project report titled **"STABILIZATION OF BLACK COTTON SOIL USING UNTANNED LEATHER INDUSTRY SOLID WASTE"** in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Civil Engineering and submitted to the Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by by **ABHISHEK SHARMA (141653)** and **RIBHU GUPTA(141654)** during a period from July 2017 to May 2018 under the supervision of **Mr. NIRAJ SINGH PARIHAR** Assistant Professor, Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

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

Date: - ....

Dr. Ashok Kumar Gupta	Mr.Niraj Singh Parihar	External Examiner Professor
& Head of Department	Assistant Professor	
Civil Engineering Department	Civil Engineering Department	
JUIT Waknaghat	JUIT Waknaghat	

ACKNOWLEDGEMENT

In performing our project, we had to take the help and guidelines of some respected persons, who deserve our greatest gratitude. The completion of this project report gives us much pleasure. We would like to show our gratitude **to Mr. Niraj Singh Parihar , Assistant Professor** for giving us the guideline for project throughout numerous consultations. We would like to extent our deepest gratitude to all those who have directly and indirectly guided us in writing this report.

We also thank **Dr. Ashok Kumar Gupta, Professor and Head of Department**, Department of Civil Engineering, Jaypee University of Information Technology, for consent to include copyrighted pictures as a part of our report. We also thank **Mr. Amar Kumar, Mr. Jaswinder Deswal, Mr. Itesh Singh**, Technical and laboratory , Department of Civil Engineering, Jaypee University of Information Technology, for providing us with all the facilities, necessary components and excellent working conditions required to complete the project. We thank all the people for their help directly and indirectly to complete our project.

Abhishek Sharma(141653)

Ribhu Gupta(141654)

Abstract

Improvement of soil properties is one of the biggest challenges in front of a geotechnical engineer when working on problematic soils. For any construction project its quality and long term performance depends upon soundness of underlying soil. In India a large proportion of land is covered by black cotton soil generally called as an engineer's nightmare due to its unsoundness.

Reuse of any by-product in stabilization of soil is of both environmental and engineering favour. The need to bring down the cost of waste disposal and growing cost of soil stabilizers has urged an investigation into the stabilizing potential of leather industry waste in black cotton soil (expansive clay) .For any construction project its quality and long term performance depends upon soundness of underlying soil.

In this project samples of solid waste from manufacturing of leather (pre-fleshing) have been used. Many heavy metals from this waste are directly dumped into landfills which makes the land toxic and barren, thus black cotton soil having high cation exchange properties can be stabilized using these heavy metals.

Contents

List of Abbreviations

Serial No.	Abbreviation Used	Description
1	LWA	Leather waste ash
2	n.d.	Not detected
3	MDD	Maximum Dry Density
4	OMC	Optimum Moisture Content
5	GSA	Groundnut shell ash
6	IS	Indian Standard
7	CBR	California Bearing Ratio

List of Figures

List of Tables

Chapter 1

Introduction

1.1 General introduction

Black cotton soil covers about 16.6% geotechnical area of our country. Black cotton soil has been referred as civil engineer's nightmare because of its tendency to swell when moisture content is increased and shrink when dry thus applying swell pressure and leading to differential settlement of structures and also lowering bearing capacity of soil . Shrinking soil is not suitable for construction works because it leads to cracking. The concentration of montmorillonite is more in black cotton soil.

The main characteristics of black cotton soils are:

I. Black or darkish grey to brown colour .
II. High content of expansive clay mineral montmorillonite.
III. Tendency to shrink and swell with change in moisture condition.

Fig 1 Cracking in black cotton soil

Leather industry has been associated with high pollution due to bad smell, organic wastes and high water consumption. Heavy metals like chromium (III) and chromium (VI) have been considered toxic in nature and are abundant ineffluent from waste.

Tannery waste is characterized in 3 categories:

I. Wastes from untanned skins (trimming ,fleshing wastes)
II. Wastes from tanned leather (Shaving waste, buffing dust)
III. Wastes from dyed and finished leather (trimmings from leather)

Fig 2 Dumping site of solid leather waste in Jalandhar, Punjab

The black cotton soil is an undesirable foundation material. With growing cost of soil stabilizers such as cement and lime and the need to protect the environment from degradation by dumping the toxic waste directly into landfills the need to use these heavy metals for both engineering and environmental favour has emerged. These heavy metals can be used with high cation exchange properties of black cotton soil and stabilize the same.

Thus, the need for economical and eco- friendly way of soil stabilization emerged and was the main motivation for this project.

Chapter 2

Literature Review

2.1 Literature review conclusions:

- **Stabilization of expansive soil with lime and brick dust**

  Ajay Kumar, Ashok Kumar, Ved Prakash, September 2016

  The maximum dry density of black cotton soil increased upto addition of 6% lime and 25% of brick dust because of frictional resistance from brick dust in addition to cohesion from black cotton soil and lime gives binding property to soil. Liquid limit of black cotton soil decreased by the addition of lime and brick dust. This is because quick lime chemically combines with water and this reaction dries up the soil.

- **Soil amended with admixture as stabilizing agent to retain heavy metals**

  Sayeed Mohammad,Arif Ali Baig, July 2014

  Black cotton soil can be used as a filter material to separate heavy metals such as copper and chromium in an industrial landfill.

- **Groundnut shell ash (GSA) stabilization for black cotton soil**

  Oriola Folagbade, George Moses, May 2010

  GSA showed progressive strength development with longer curing periods. Increase in the dosage of GSA upto 4% increases the maximum dry density due to flocculation and agglomeration leading to volumetric decrease in density. Above 4% GSA decrease in maximum dry density due to void within the coarse aggregate being filled with GSA.

- **Characterization of Leather Industry Wastes**,

  H. Ozgunay, S. Colak, M.M. Mutlu, F. Akyuz, (2007)

  Chemical analysis was done on various collected samples. Tests includes B.O.D, C.O.D., pH and heavy metals tests. The results of this study have revealed that the leather industry generates waste with different characteristics according to the process step at which it is generated. The most appropriate method for reusing and disposing of these wastes requires the information regarding the steps followed in the process.

- **Solid waste generation in leather industry**

  J. Kangaraj, K.C. Velappan, April 2006

  Collagen (a protein) is mainly present in animal skin. It can join easily with amino acids and helps in tanning process. Fleshing waste can be converted into glue. Buffing dust is used as feed in poultry farms

- **Impact of tannery and textile industry on soil**

  P.K.Chonkar, S.P.Dutta, H.C.Joshi June 2000

  Total porosity of soil decreases. Phosphorous and pottasium content increases in soil. Growth of seedlings reduced due to the presence of Cr^{3+}

- **Pollutants in tannery effluents**

  M. Bosnic, J. Buljan and R. P. Daniels, August 2000

  Tests for B.O.D. and C.O.D were done. Tests for heavy metals like Cr^{3+}, Cr^{6+}, Cl^{-} and Na^{+} were also conducted.

2.2 Summary of literature review:

- Tests were performed on leather industry waste but not on soil stabilization using the same.
- Black cotton soil with lime and textile + leather industry waste can be used as a filter material in industrial landfill to adsorb selected heavy wastes like chromium and copper but no mentions on stability of soil with same were given
- Black cotton soil having high cation exchange properties can be stabilized using heavy metals like Chromium(III) (Cr^{3+}) and chromium(VI) (Cr^{6+}) which is present in leather industry waste.

Chapter 3

Objectives

- To find the change in strength of black cotton soil using leather industry waste
- To the check the changes in shrinkage and swelling of black cotton soil
- To find the optimum percentage of leather industry waste useful for soil stabilization

In order to achieve the above objectives, tests such as liquid limit, plastic limit, shrinkage limit, free swell index, unconfined compressive strength, proctor, California bearing ratio (unsoaked) were performed firstly on black cotton soil and then by mixing 2%,4%,6%,8% and 10% of waste by weight of soil.

Their compaction behavior and variation of swell, shrinkage, strength were analyzed and changes with addition of waste were studied.

Chapter 4

Materials

4.1 Black cotton soil

4.1.1 General characteristics

Black soil is very suitable for growing crops like cotton and is thus referred to as black cotton soil. Black cotton soil has a tendency to shrink when moisture decreases and swell when the same increases. Montmorillonite the major mineral present in soil is formed under alkaline conditions. This soil is generally black in colour and is formed by weathering of basalt rock. This soil is an organic clay of high to medium compressibility and forms a major soil group in India covering nearly 16.6% of the total land area.

4.1.2 Procurement

In India black cotton soil is mainly found in the states of Madhya Pradesh, Maharashtra, Gujrat, Andhra Pradesh and some parts of Rajasthan.

The black cotton soil for this project has been obtained from Guna, Madhya Pradesh.

Fig 3 Sample of black cotton soil obtained

4.2 Leather Industry Waste

The leather waste consists of these five basic solid wastes.

- Pre-fleshing waste
- Lime fleshing waste
- Shaving waste
- Buffing waste
- Trimming waste

These waste are rich in organic content , chromium and calcium concentrations.

The waste obtained for this project is pre fleshing and lime fleshing waste from Jalandhar, Punjab.

The waste was then burnt openly by at nearly 1000°C and then was grinded into fine powder. The powdered waste was then passed through 425μ sieve and stored in an air tight container.

Fig 4 Sample leather waste before burning

Fig 5 Sample leather waste ash

4.2.1 Characterization of leather industry waste

The chemical analysis of Leather Industry waste was done at Himachal Pradesh University, Shimla and Punjab University, Chandigarh.

The composition of leather industry waste was determined through atomic spectroscopy which yielded the chemical composition of constituents such as Chromium(Cr), Iron(Fe), Sodium(Na), Calcium(Ca), Nitrogen(N), Sulphur(SO_2) as shown in table1.

Water Content (%)	pH	Nitrogen (%)	Sulphur (ppm)	Chromium (ppm)	Iron (ppm)	Sodium (ppm)	Calcium (ppm)
44.53	7.35	7.8	n.d.	n.d.	750	7536	17212

Table 1 Characterization of leather industry waste

The waste was found to contain high amounts of calcium , sodium and iron concentrations however the presence of chromium remained undetected due to waste being pre fleshing (type II) category of waste. [H.Ozgunay, (2007)]

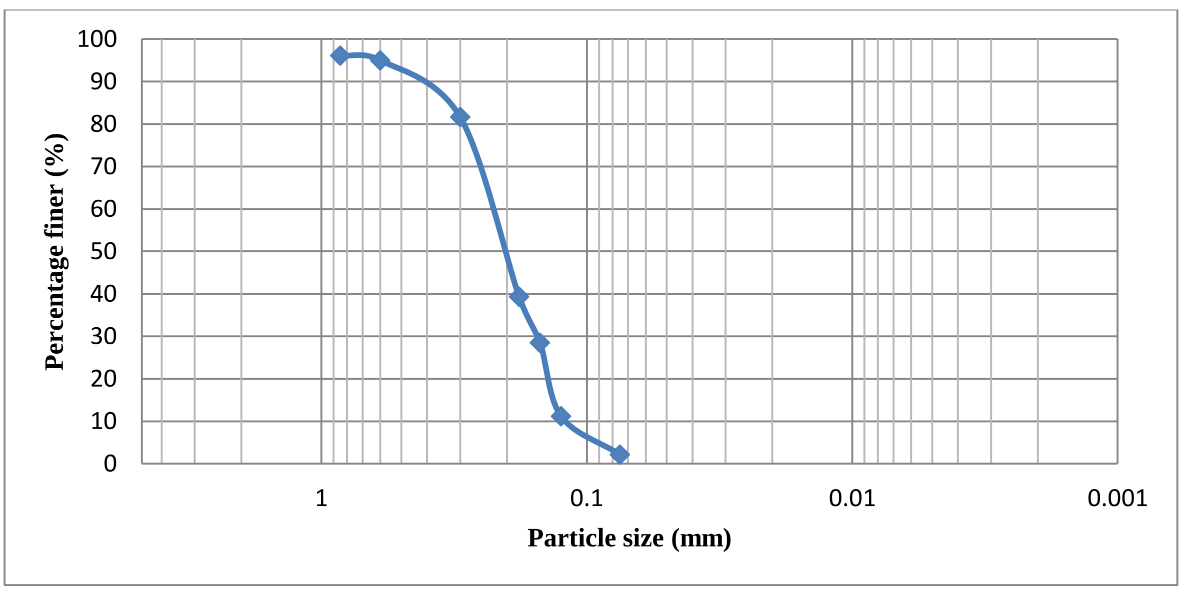

Fig 6 Particle size distribution curve for leather waste

Chapter 5

Testing methodology

5.1 Dry Sieve Analysis

The dry sieve analysis have been performed as per IS : 2720(part 4)-1985- Method of test for soil (part 4- Grain size analysis).

Procedure

- 200 gm of soil was taken and was soaked in the water.
- The soil specimen was then sieved through 75 micron sieve and washed with water under tap of high pressure.
- The material was washed until the clean water passed through the soil.
- The material retained on the sieve was dried in oven and weighed.
- It was then sieved through the mechanical sieve shaker for about ten minutes and retained material on each sieve was collected and weighed.
- The material which was retained on the pan was equal to the total mass of soil minus the sum of all the masses of material retained on all sieves.
- The curve for the soil was drawn in the semi-log graph and particle size distribution curve was obtained.

5.2 Liquid Limit

The liquid limit tests have been performed as per IS : 2720(part 5)-1985- Method of test for soil .

Procedure

- Soil sample was passed through 425 micron sieve.
- About 120 gm of soil sample passing through 425 microns sieve was taken and mixed thoroughly with distilled water in the evaporating dish.
- After the formation of uniform paste a portion of paste was placed in the cup and was leveled so as to have maximum depth of 10 mm.
- A groove cut was made in the soil in the cup using grooving tool.
- The handle was rotated at the rate of 2 revolutions per second and number of blows necessary to close the groove for a distance of 13 mm noted.
- 10gm of soil near the closed groove was taken to determine its water content.

- A graph was plotted between number of blows(N) on a logarithmic scale and water content (W) on the natural scale.
- From the graph the liquid limit was determined by reading the water content corresponding to 25 blows on the flow curve.

5.3 Shrinkage limit

The shrinkage limit tests have been performed according to IS : 2720(part 6)-1978-Method of test for soil .

Procedure

- About 30g of soil sample was taken in a large evaporating dish. It was mixed with distilled water to make a paste .
- Shrinkage dish was cleaned and mass was determined.
- The mercury was filled in the shrinkage dish and excess mercury was removed by pressing the glass plate over the top of the shrinkage dish. And no air was allowed to entrap.
- Inside portion of the shrinkage dish was coated with a thin layer of silicon grease.
- The soil specimen was placed in the center of the shrinkage dish.
- The dish was filled with soil and weighed as shown in fig 7.
- Then the dish was placed in the oven for 24 hours at 110C.
- The dish with the dry soil was weighed.
- Volume of dry soil pat was determined by placing the soil pat in glass cup full of mercury.
- On placing the soil pat in the glass of full of mercury and forcing the pat under the mercury by means of glass plate, the mercury was displaced.
- The displaced mercury was weighed and its volume was determined.
- The obtained volume was the volume of the dry soil pat.

Fig 7 samples for shrinkage limit test

5.4 Standard Proctor test

The consolidation tests have been performed using light compaction as per
IS:2720 (part 8)- 1983.

Procedure

- An oven dried soil of about 5 kg was taken and was thoroughly mixed with sufficient amount of water to dampen it with approximate water content.
- The proctor mould was weighed without base plate and collar. The collar and base plate was then fixed. The soil was then filled in three layers giving 25 blows after each layer. The blows should be uniformly distributed over the surface.
- Collar was removed and then trimmed to make the surface level using straight edge as shown in fig 8
- Then weighed using a sensitive electronic balance.
- The weight of the compacted soil was divided by the volume to get the bulk density.
- The sample was removed thoroughly and a small sample was taken for water content calculations.
- The remaining soil is thoroughly beaked and was passed through no. 4 sieve.
- The water is then added to increase the water content.

Fig 8 consolidated sample of proctor test

5.5 Unconfined Compression Test

The unconfined compression tests have been performed using ASTM D2166- 06 Standard Test Method for Unconfined Compressive Strength of Cohesive Soil.

Procedure

- The sample of UCS test were derived after performing standard proctor compaction at OMC to maintain a uniform level of compaction energy for all testing samples. The initial length and diameter of the specimen was measured.
- Both the end of the samples was trimmed carefully as shown in fig 8.
- Sample was placed on the loading plate of unconfined compression test machine as shown in fig 9.
- The load was initially applied by raising the lower plate.
- The load and displacement was measured on the screen as shown in fig 10.
- The sample was compressed until its loading becomes constant or started decreasing.

Fig 9 Extraction of UCS sample from Standard proctor

Fig 10 UCS samples

Fig 11 Setup for UCS

5.6 California Bearing Ratio Test

The CBR tests have been performed using the reference standard IS: 2720 (part 16) 1973 Methods for Test of soil.

Procedure

- The mould was placed with the surcharge weights on the penetration test machine.
- For the full contact of the piston on the sample the penetration piston was seated at the centre of the specimen with the smallest possible load.
- The stress and strain load gauge was set to zero.
- The load was applied on the piston at the penetration rate of about 1.25mm/min.
- The load readings at penetration of 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0 mm were recorded.
- The maximum load and corresponding penetration (for <5 mm) were noted

5.7 Hydrometer Analysis

- About 50g of soil was taken.
- 100 ml of sodium hexametaphosphate solution was added and was warmed for 10 minutes and was then slurry was transferred to the cup of the mechanical mixer as shown in fig12.
- The soil suspension was stirred for about 15 minutes.
- The suspension was transferred to the Hydrometer jar and the cylinder was filled upto 1 litre mark by adding distilled water.
- After this another Hydrometer jar was filled with 1 litre distilled water to store the hydrometer in between consecutive readings of the soil suspension to be recorded.
- The soil suspension was mixed roughly, by placing the palm of the right hand over the open end and holding the bottom of the jar with the left hand and by turning the jar upside down and back.
- The Hydrometer jar was placed on the table and the stopwatch was started. The Hydrometer was inserted into the suspension and Hydrometer readings were recorded at the total elapsed times of ¼, ½, 1 and 2 minutes.
- After 2 minutes reading, the Hydrometer was removed and was transferred to the distilled water jar and step no-8 was repeated.
- The hydrometer readings were recorded at interval of 1, 2, 4, 8, 16, 30, 60, 120 minutes and every one hour thereafter.

Fig 12 Preparation of sample for hydrometer analysis

Fig 13 Mechanical stirrer

Fig 14 Dried sample for hydrometer analysis

Chapter 6

Results and discussions

6.1 Tests on soil

6.1.1 Sieve analysis

Total weight of soil taken for sieve analysis was 600g (Annexure 1.1.1)

Percentage of weight of soil retained on 75micron sieve = 37.51%
Percentage of soil passing through 75micron sieve = **62.49%**

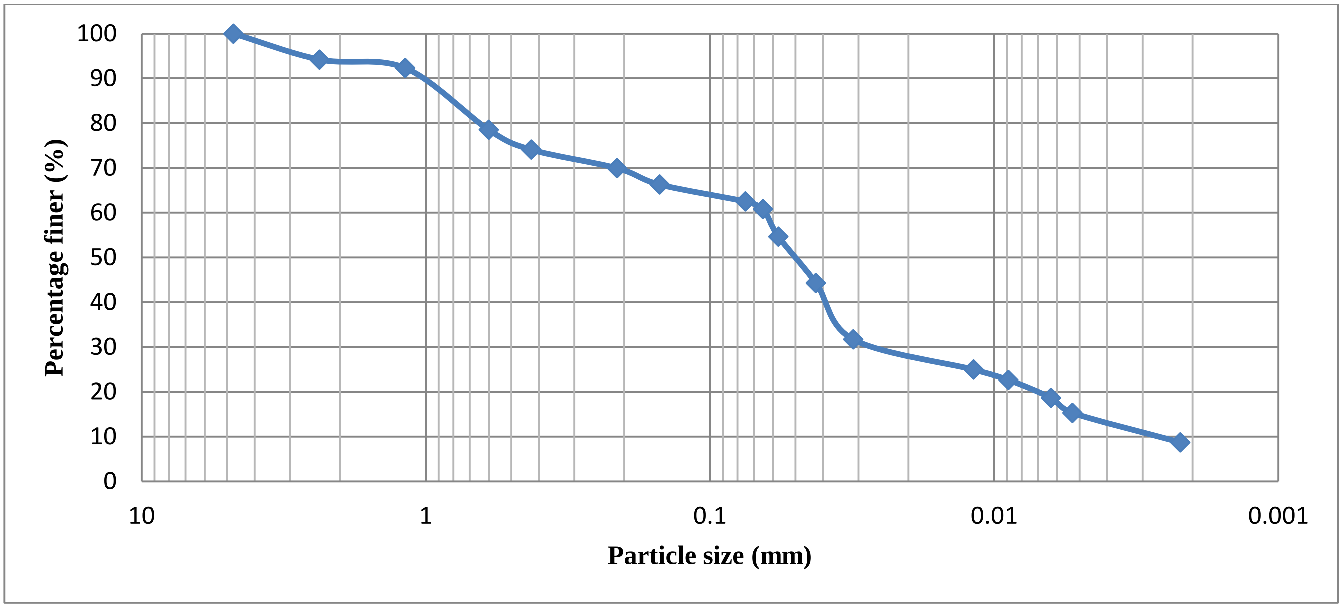

Fig 15 Particle size distribution curve for soil

Since the percentage of passing through the75micron sieve i greater than 50% it is a classified as a fine soil according to IS:1498-1970.

Result **:**

D_{60} =0.065mm

D_{30}= 0.028mm

D_{10}= 0.0029mm

C_u= 0.065/0.0029 = 22.41

C_c= $(0.028)^2$/ (0.065*0.0029) = 4.16

6.1.2 Liquid limit

The Casagrande's apparatus was used to calculate the liquid limit. For different moisture contents the no. of blows were noted and plotted on semi-log graph.

6.1.2.1 Liquid limit black cotton soil :

The variation of no. of blows with water content for black cotton soil has been shown in fig 16

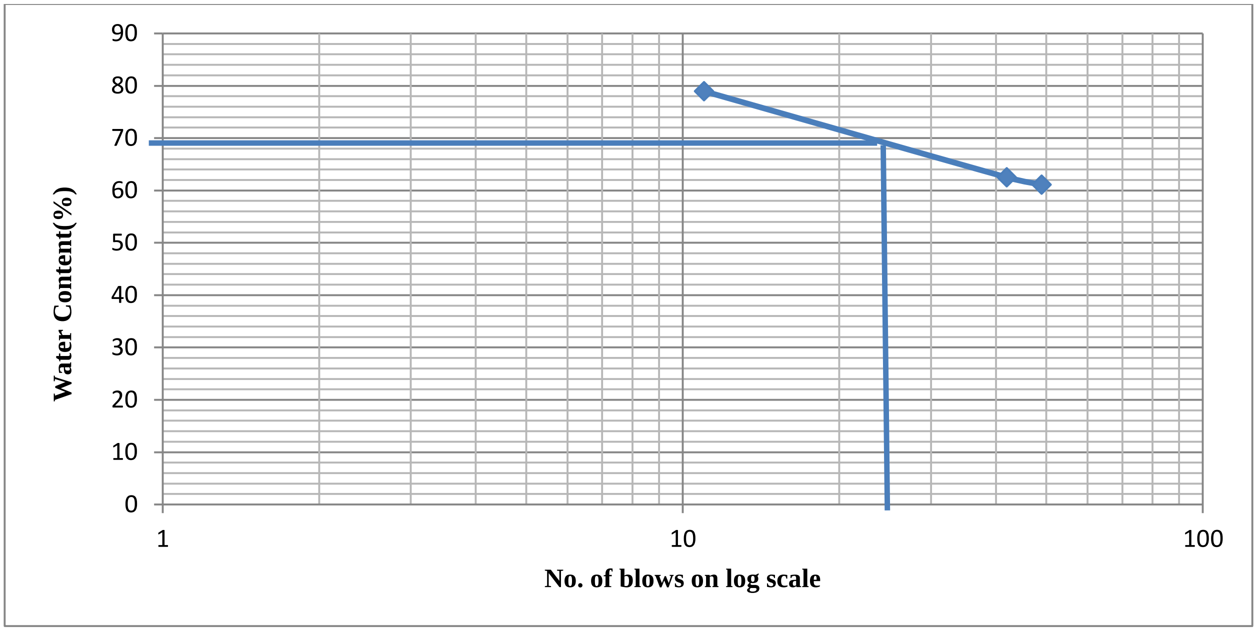

Fig 16 Flow curve for black cotton soil

The liquid limit(w_l) for this soil sample was 69% co corresponding to 25 blows on the flow curve (Annexure 1.2.1)

6.1.3 Plastic limit and plasticity index of soil sample

At regular intervals of rolling the soil sample, the diameter of thread was brought down to 3mm, the cracks on surface of thread were noted. The plastic limit of soil sample was found out to be 40.13%.

PLASTICITY INDEX = LIQUID LIMIT - PLASTIC LIMIT

= 69-40.13 = 28.87 %

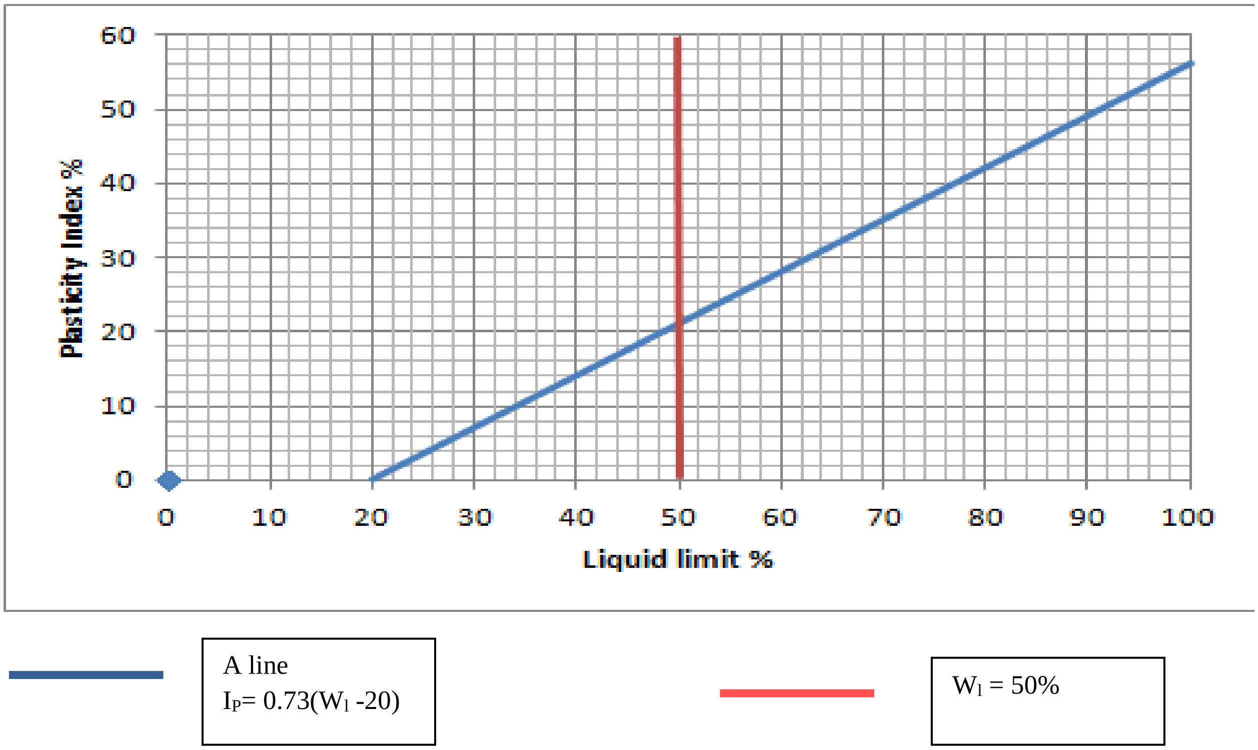

Fig 17 Plasticity Chart

Swelling Potential	Plasticity index percentage
Low	0-10
Medium	10-20
High	20-35
Very high	35 and above

Table 2 Relationship between plastic index and swelling potential

- As per the plasticity chart it has been obtained that soil has high swelling charcterstics and lies below A -line.
- Thus according to IS classification black cotton soil with W_l = 69% and I_P = 28.87%. We get MH or OH category of soils i.e. inorganic silts of high plasticity or organic clays of high plasticity as shown in fig 17.
- Using the oven drying method we differentiated between organic and inorganic soil. The liquid limit of soil if decreased by less than 30%, it is classified as inorganic or otherwise organic. So after oven drying liquid limit decreased from 69% to 37%.
- Soil is thus classified as **organic clay of high plasticity (OH) .**

6.1.4 Standard Proctor

The standard proctor test was performed on black cotton soil and the compaction curve was plotted between dry density and water content.

6.1.4.1 Standard proctor black cotton soil :

The variation of dry density with water content for black cotton soil has been shown in fig .18

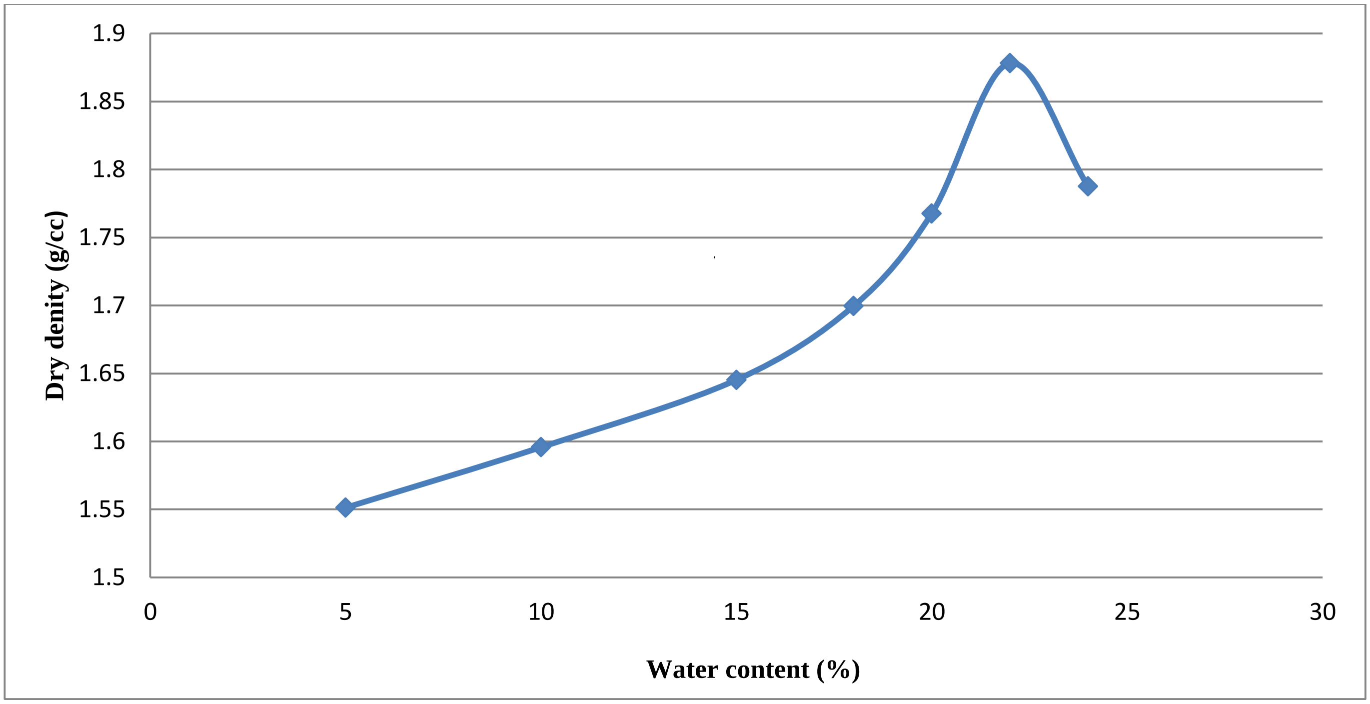

Fig 18 Compaction curve of black cotton soil

The **M.D.D.** of soil calculate from graph is **1.87g/cc** at **O.M.C.** of **21.78%** (Annexure 1.3.1)

6.1.5 California Bearing Ratio Test

The values for CBR was calculated at 2.5mm and 5mm penetration under unsoaked conditions were obtained.

6.1.5.1 C.B.R of soil

The variation of penetration with load for black cotton soil has been shown in fig .19

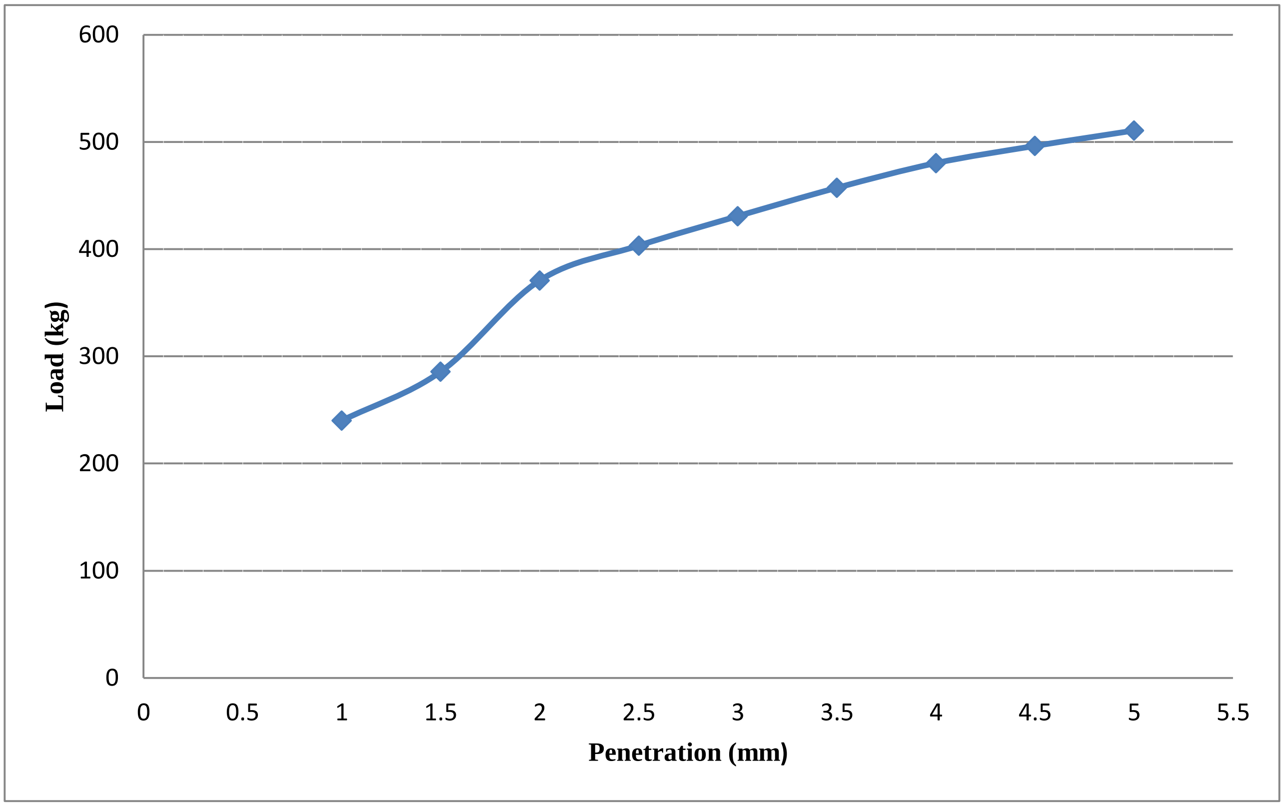

Fig 19 Load penetration curve for soil

CBR at 2.5mm = (403.3/1370)*100 = 29.43%

CBR at 5.0mm = (510.66/2055)*100 = 24.8%

The CBR value for black cotton soil was 29.43. (Annexure)

6.2 Tests on soil and leather waste ash

6.2.1 Liquid limit

The liquid limit of soil was 69% and varied from 78.83% to 74.1% after the waste was added.

6.2.1.1 Liquid limit (soil + 2% waste)

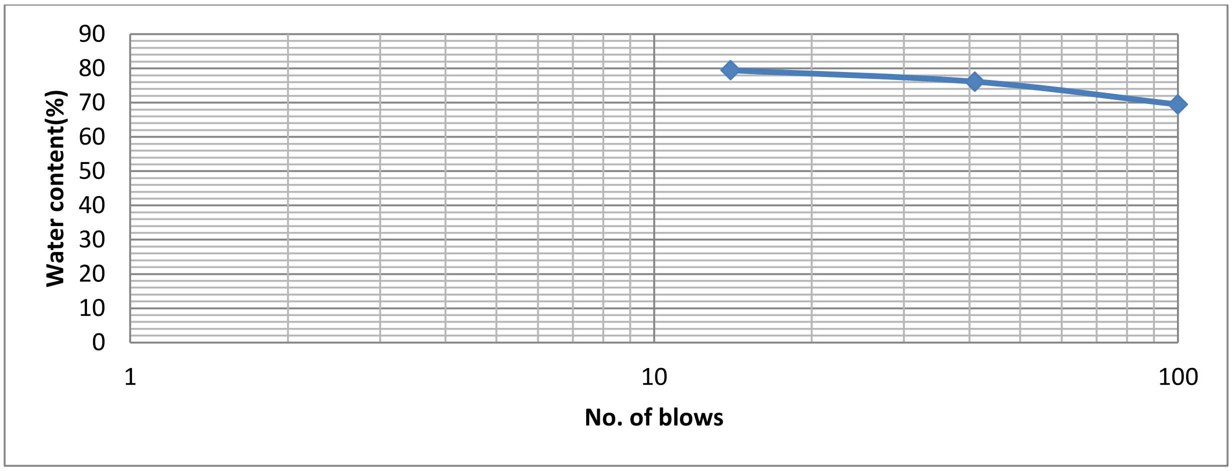

Fig 20 flow curve with 2%(w/w) waste

The liquid limit (w_l) for this soil sample was 78.83% (Annexure 1.2.2)

6.2.1.2 Liquid limit (soil + 4% waste)

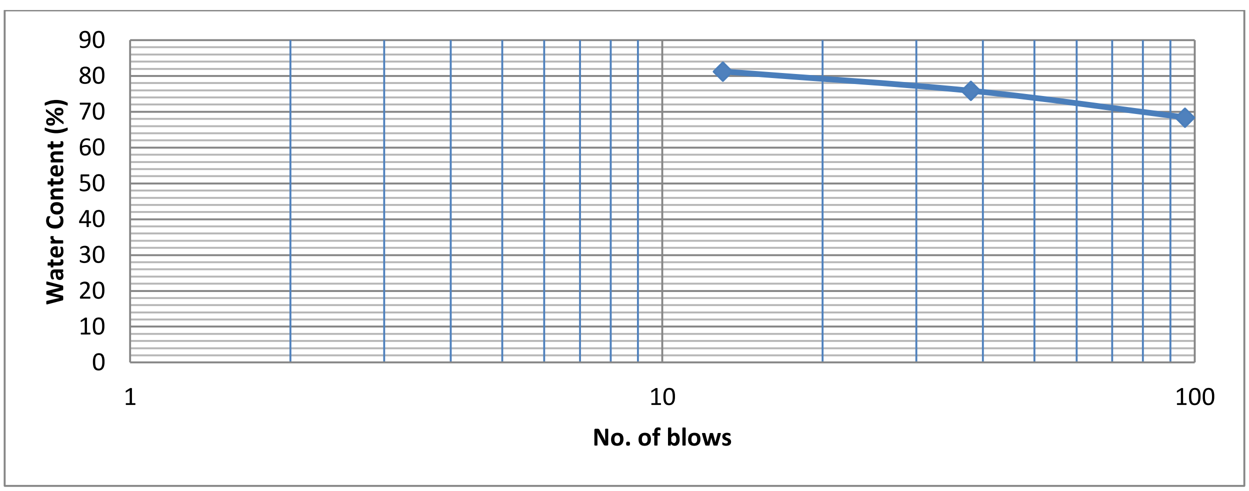

Fig 21 flow curve with 4%(w/w) waste

The liquid limit (w_l) for this soil sample was 77.05% (Annexure 1.2.3)

6.2.1.3 Liquid limit (soil + 6% waste)

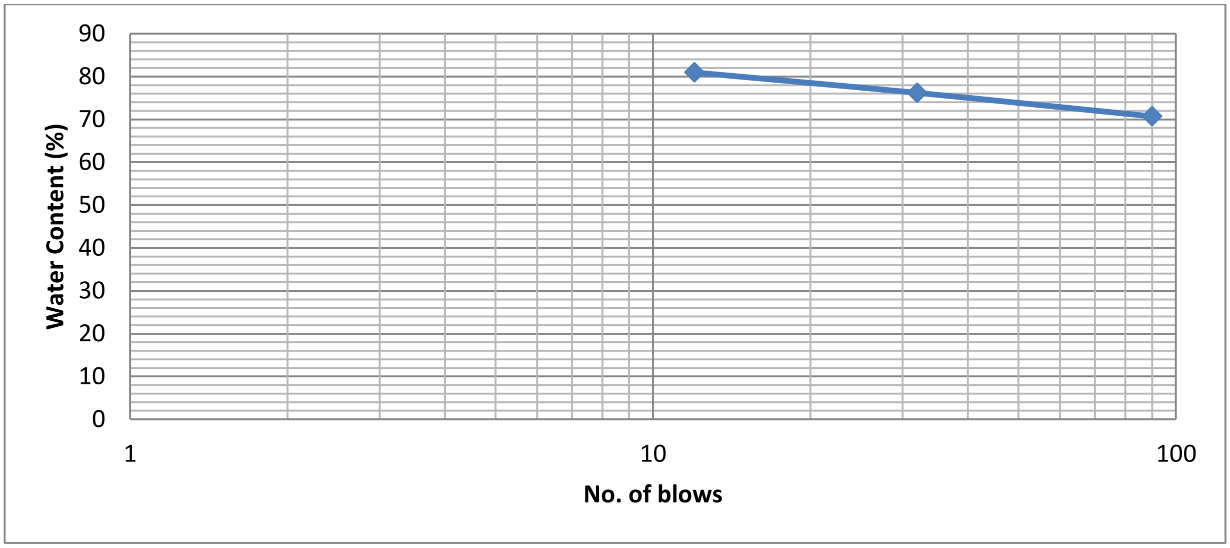

Fig 22 flow curve with 6%(w/w) waste

The liquid limit (w_l) for this soil sample was 75.91% (Annexure 1.2.4)

6.2.1.4 Liquid limit (soil + 8% waste)

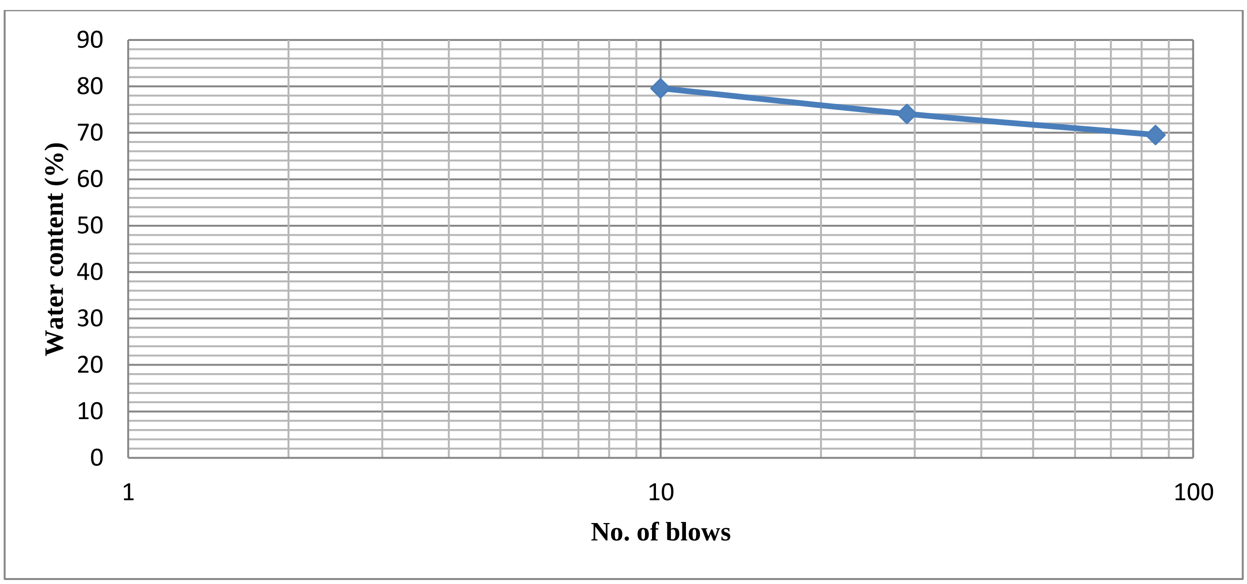

Fig 23 flow curve with 8%(w/w) waste

The liquid limit (w_l) for this soil sample was 74.1% (Annexure 1.2.5)

6.2.1.5 Variation of liquid limit with waste content

Waste variation % (w/w)	Liquid limit
0	69%
2	78.83%
4	77.05%
6	75.91%
8	74.1%

Table 3 Liquid limit of black cotton soil with waste content

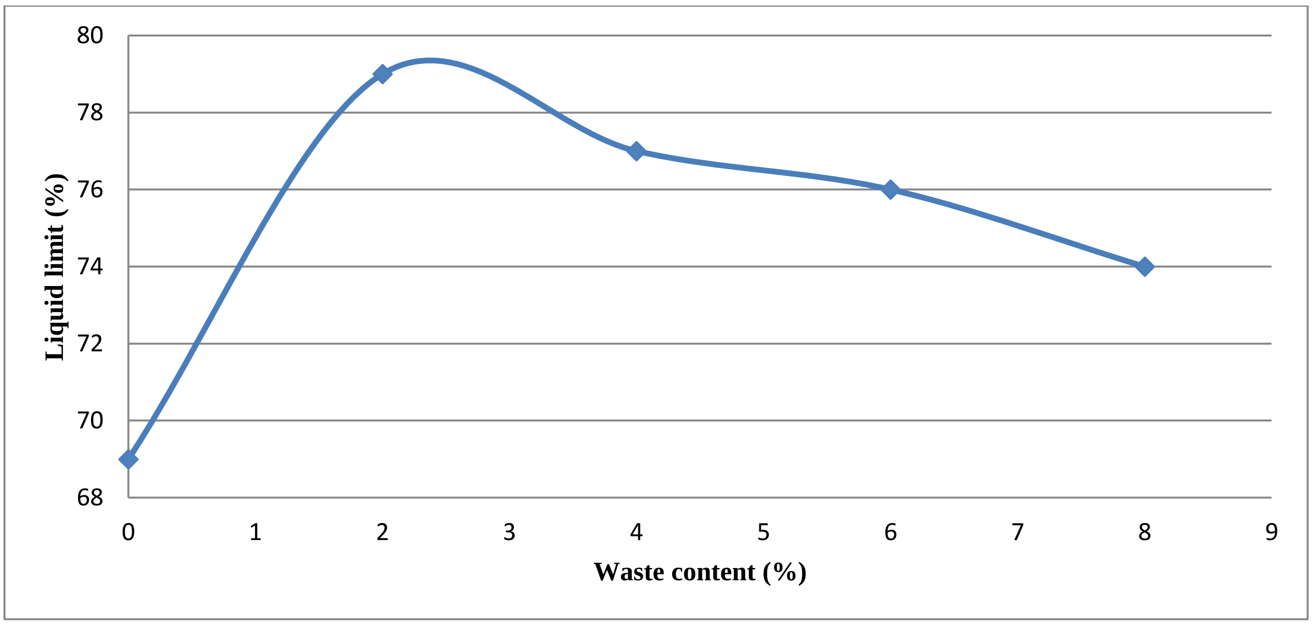

Fig 24 Variation of liquid limit with leather waste ash

With the addition of waste increase in liquid limit is possibly due to fact that water might have been absorbed due to the porous nature of leather waste ash. The decrease in the liquid limit thereafter is because the liquid limit of black cotton soil is controlled by thickness of double diffused layer. When the waste content is increased there is reduction in double diffused layer thickness , thus leading to decrease in liquid limit thereafter.

6.2.2 Shrinkage Limit :

6.2.2.1 Variation of shrinkage limit with waste content

Table 5 shows the waste variation with leather waste ash variation (Annexure 1.6)

Waste variation % (w/w)	Shrinkage limit (%)
0	9.377
2	11.05
4	12.60
6	14.96
8	15.33

Table 4 Variation of shrinkage limit of soil with waste ash content

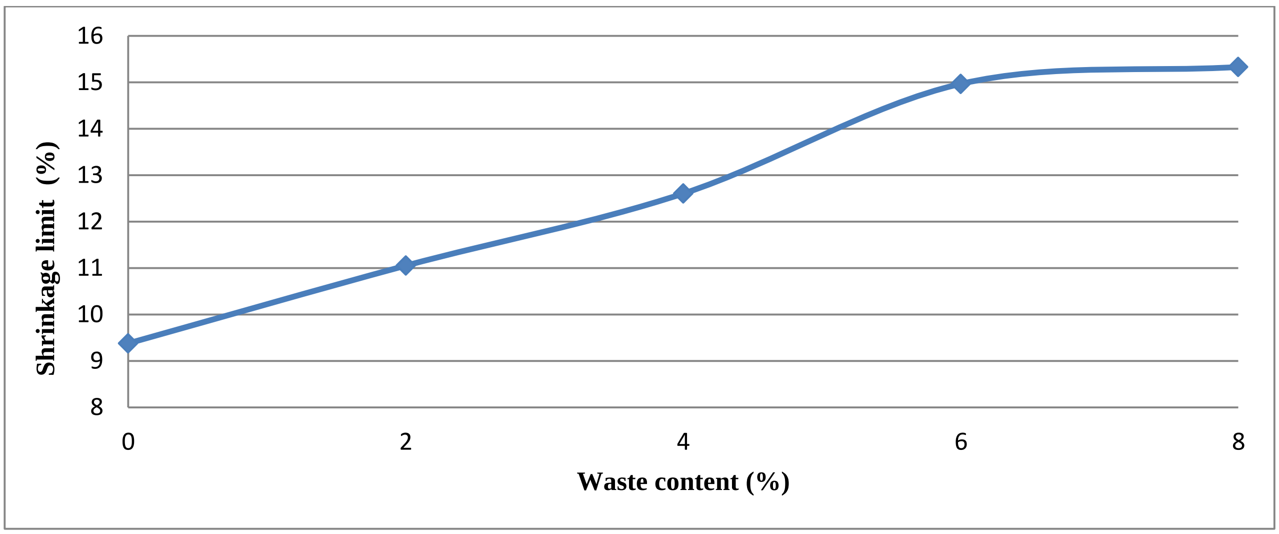

Fig 25 U.C.S. vs waste content

The shrinkage limit of soil increases with the increase in waste content thus decreasing the shrinkage of soil. This is mainly due to addition of inert material which doesn't let the soil to shrink once it starts loosing water. Addition of inert waste thus decreases the cracking in soil making it more stable in high temperatures and high moisture fluctuation. Also lesser the thickness of double diffused layer, lesser loss of water on shrinkage and hence an increase in the shrinkage limit.

6.2.3 Standard proctor Test

The standard proctor tests were performed on soil and soil + waste (2%, 4%, 6%, 8%). The results for the same are plotted on graph between dry density and water content.

6.2.3.1 OMC and MDD of soil + 2%waste(w/w)

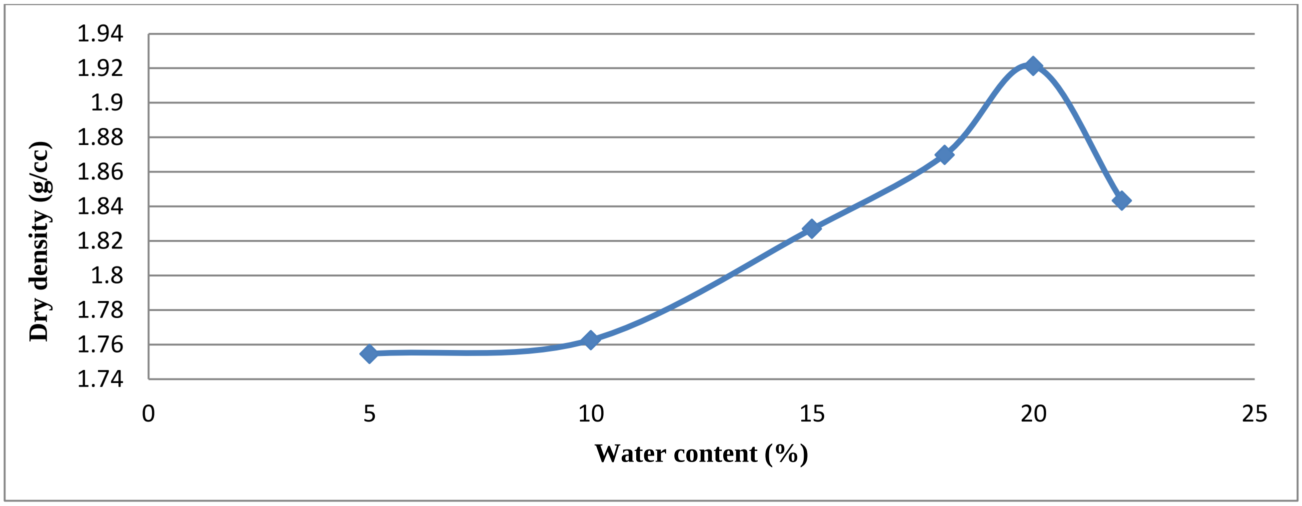

Fig 26 Compaction curve of soil + 2% waste(w/w)

The **M.D.D.** of soil calculate from graph is **1.92g/cc** at **O.M.C.** of **20.75%**. (Annexure 1.3.2)

6.2.3.2 OMC and MDD of soil + 4%waste(w/w)

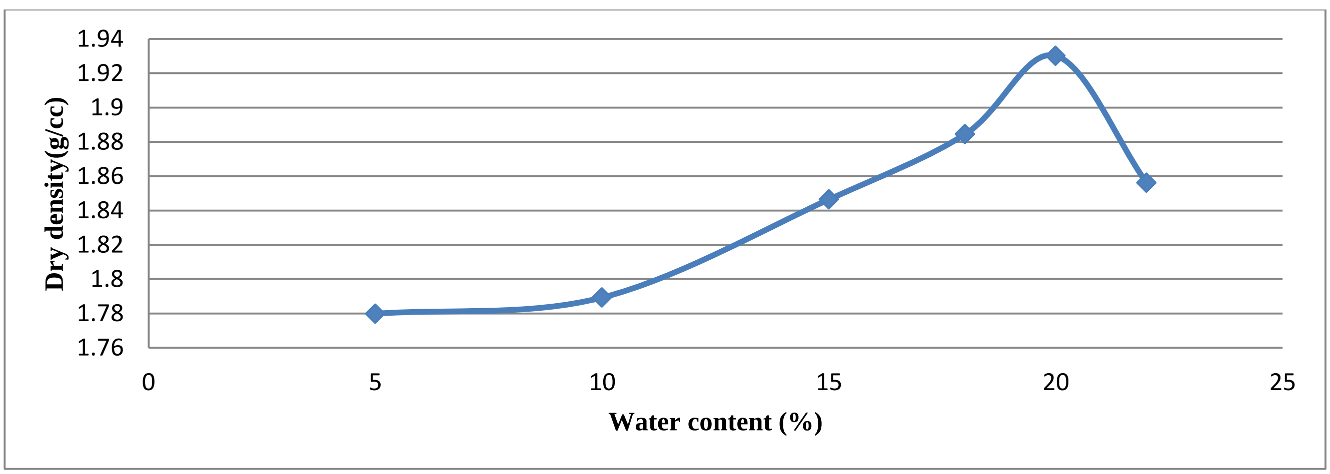

Fig 27 Compaction curve of soil + 4% waste(w/w)

The **M.D.D.** of soil calculate from graph is **1.93g/cc** at **O.M.C.** of **20.65%**. (Annexure 1.3.3)

6.2.3.3 OMC and MDD of soil + 6%waste(w/w)

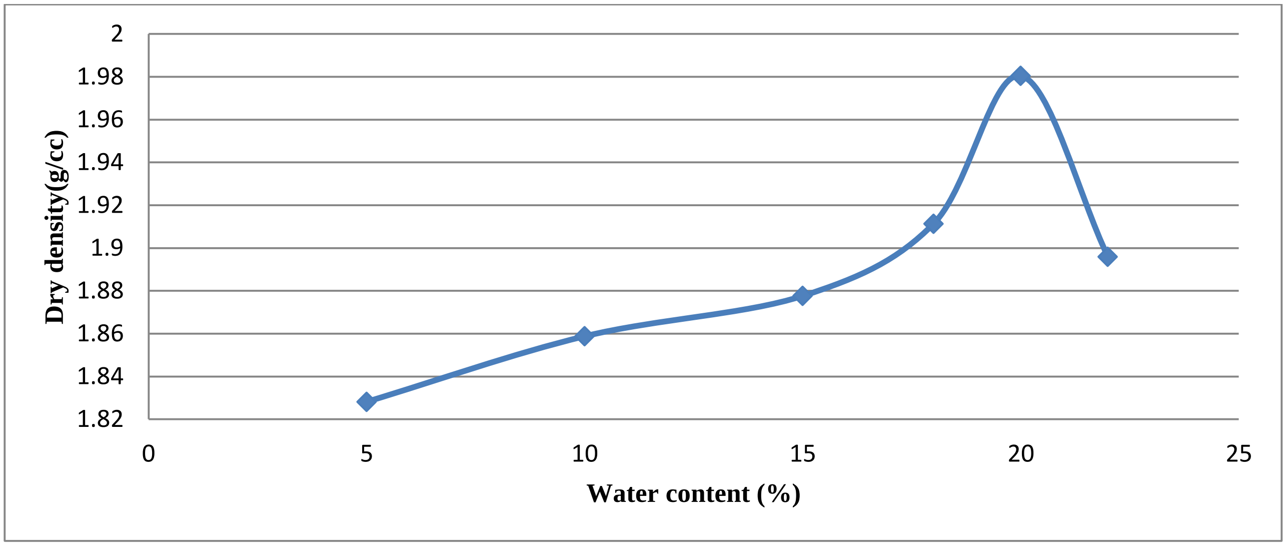

Fig 28 Compaction curve soil + 6%waste(w/w)

The **M.D.D.** of soil calculate from graph is **1.98g/cc** at **O.M.C.** of **20.40%**. (Annexure 1.3.4)

6.2.3.4 OMC and MDD of soil + 8%waste(w/w)

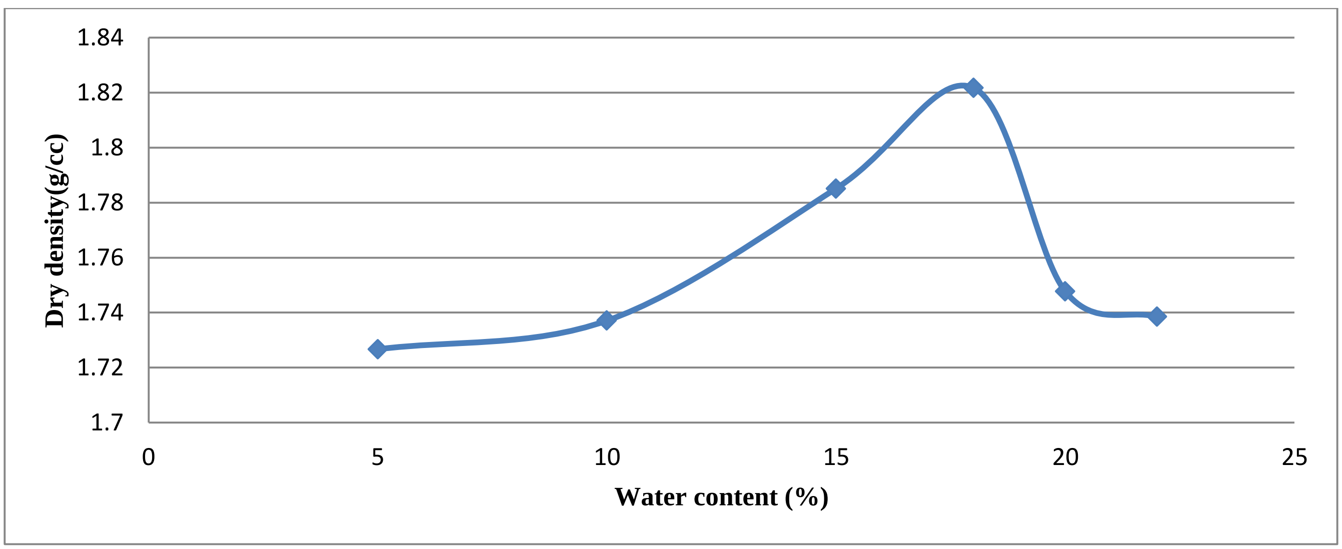

Fig 29 Compaction curve of soil + 8% waste(w/w)

The **M.D.D.** of soil calculate from graph is **1.83g/cc** at **O.M.C.** of **18.92%**. (Annexure 1.3.5)

6.2.3.5 OMC and MDD of soil + 10%waste(w/w)

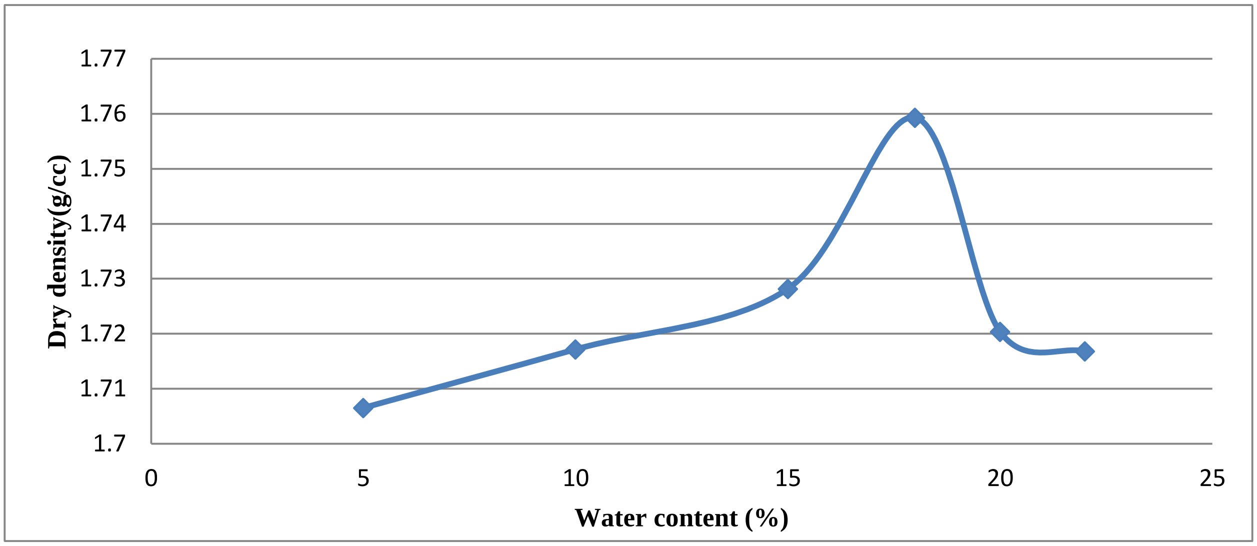

Fig 30 Compaction curve of soil +10% waste(w/w)

The **M.D.D.** of soil calculate from graph is **1.76g/cc** at **O.M.C.** of **18.78%**. (Annexure 1.3.6)

6.2.3.6 Variation of O.M.C with waste content

Waste variation % (w/w)	Optimum Moisture Content (%)
0	21.78
2	20.75
4	20.65
6	20.40
8	18.92
10	18.78

Table 5 Variation of O.M.C of soil with waste content

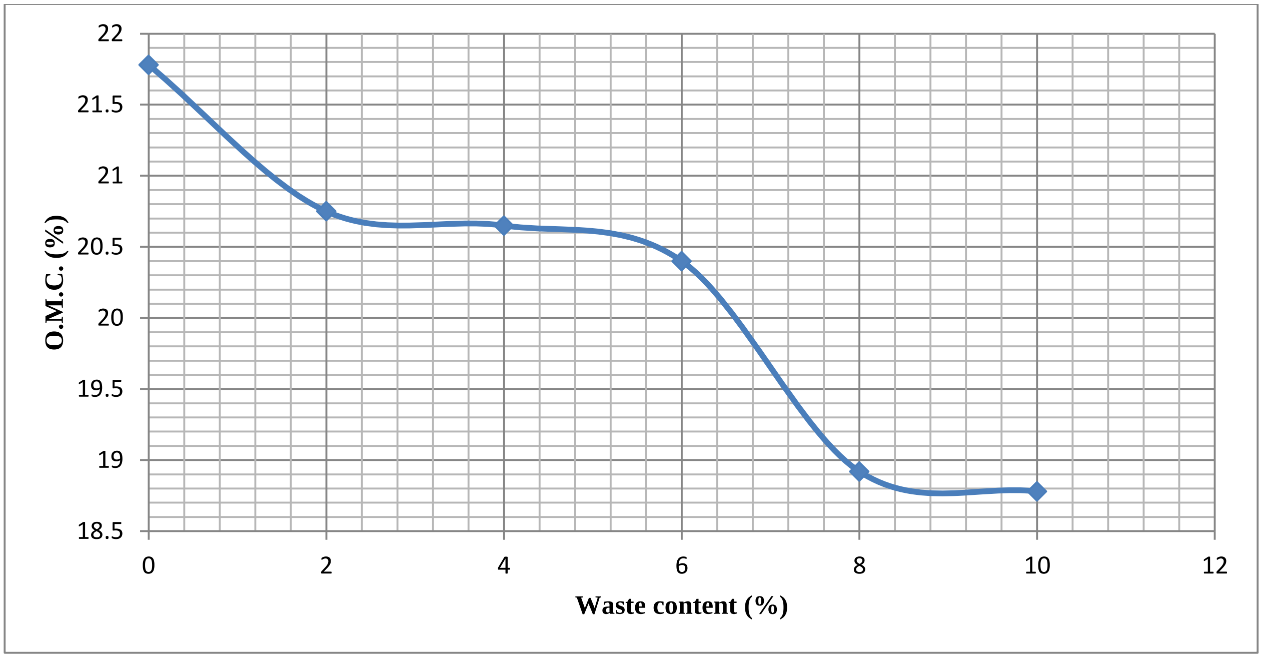

Fig 31 O.M.C. vs waste content

With the increase in waste percentage the O.M.C. of soil decreases.

6.2.3.7 Variation of M.D.D with waste content

Waste variation % (w/w)	Maximum Dry Density (g/cc)
0	1.87
2	1.92
4	1.93
6	1.98
8	1.83
10	1.76

Table 6 Variation of M.D.D. of soil with waste content

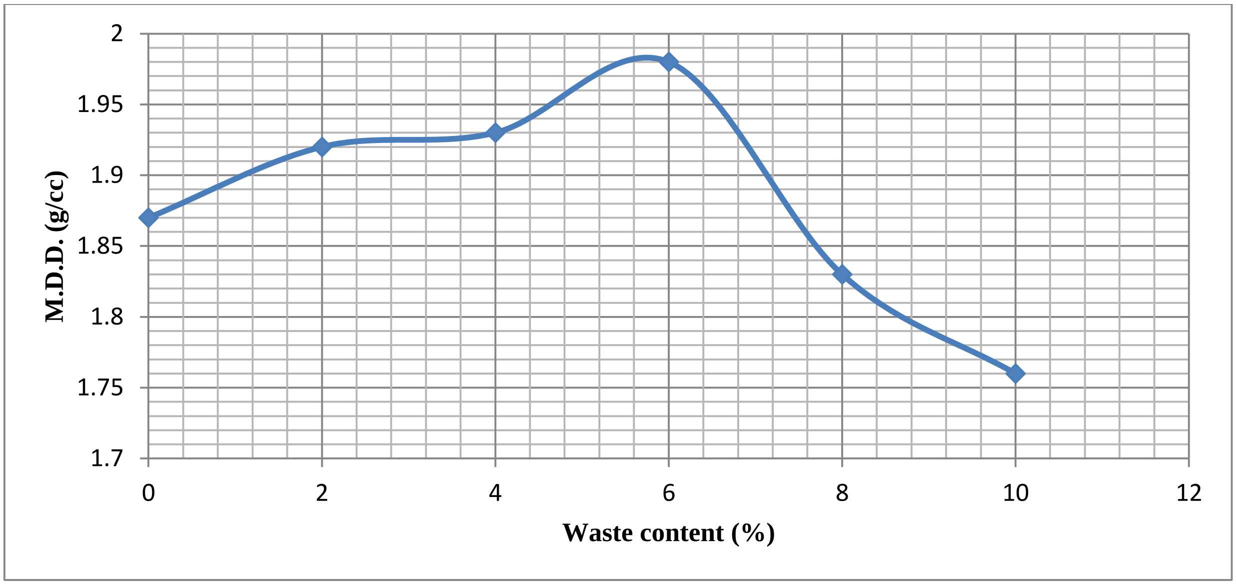

Fig 32 M.D.D. vs waste content

With the increase in percentage of waste the M.D.D. firstly increases upto 6% and then starts to decrease.

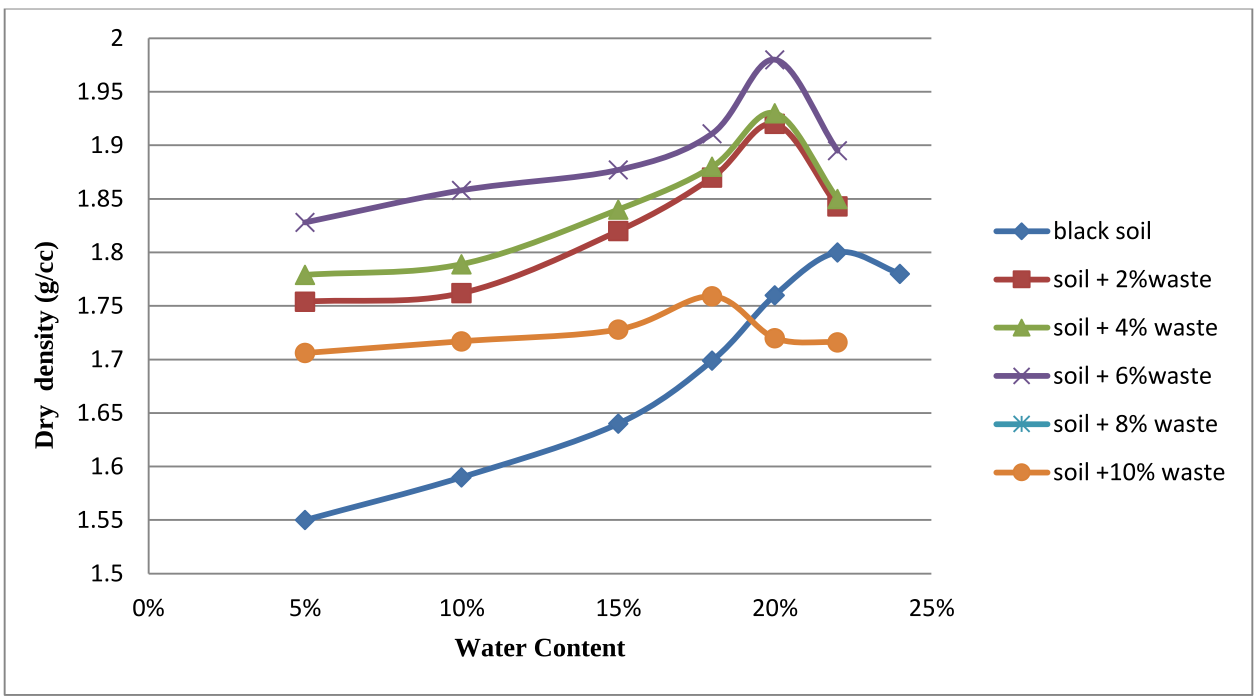

Fig 33 M.D.D vs Water Content

The standard proctor compaction shows increase in M.D.D. with increase in dosage of leather waste upto 6% of waste. This is possibly due to agglomeration and flocculation leading to volumetric decrease thus leading to higher density. The maximum dry density observed was 1.98g/cc at a waste content of 6% (w/w).

Above 6% of waste content there is a decrease in M.D.D. and can be due to excessive contact of ash having lesser density as compared to that of soil thus decreasing the M.D.D. of soil.

6.2.4 Unconfined Compression Test

6.2.4.1 UCS of soil + 2% waste(w/w)

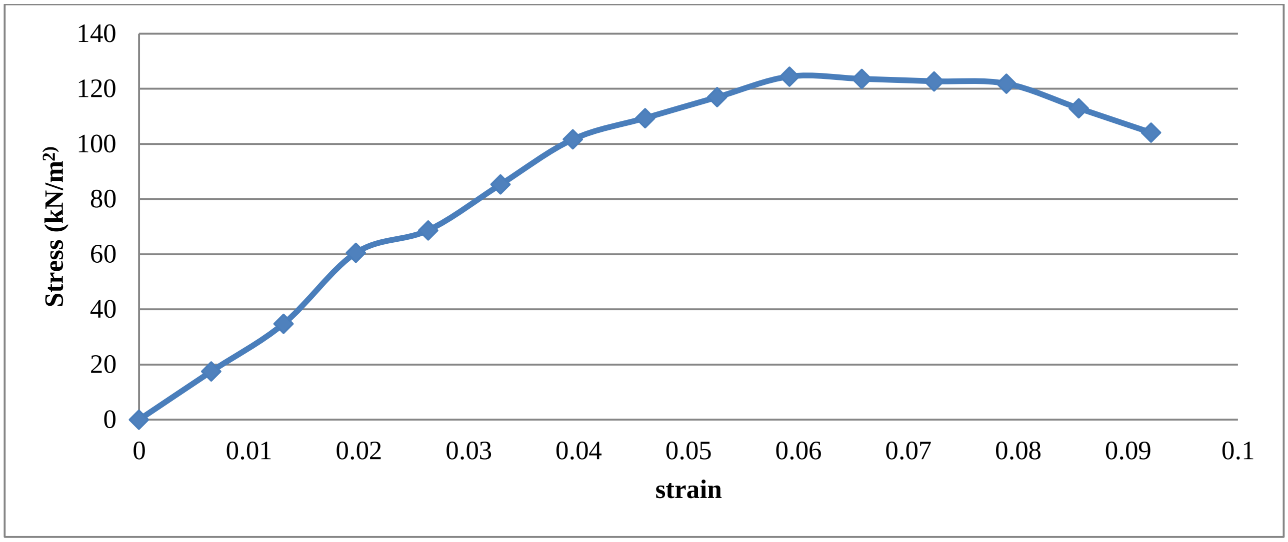

Fig 34 Unconfined Compressive Strength curve of soil + 2% waste(w/w)

The unconfined compressive strength of soil + 2%waste (w/w) =124.49 kN/m^2 (Annexure 1.4.1)

6.2.4.2 UCS of soil + 4% waste (w/w)

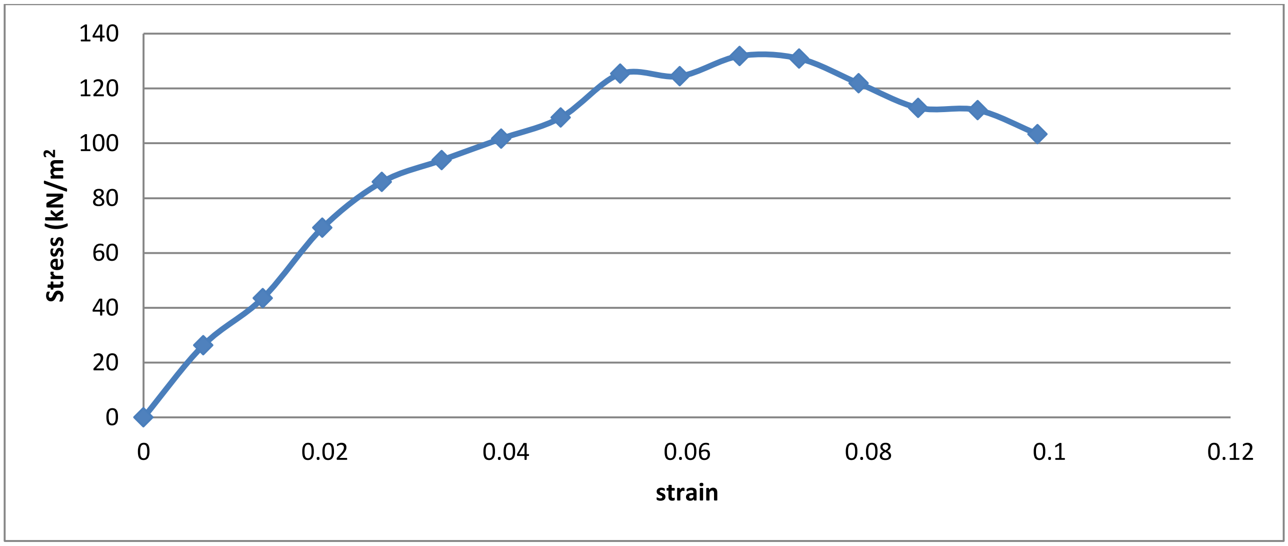

Fig 35 Unconfined Compressive Strength curve of soil + 4% waste(w/w)

The unconfined compressive strength of soil + 4%waste (w/w) =131.86 kN/m^2 (Annexure 1.4.2)

6.2.4.3 UCS of black cotton soil + 6% waste (w/w)

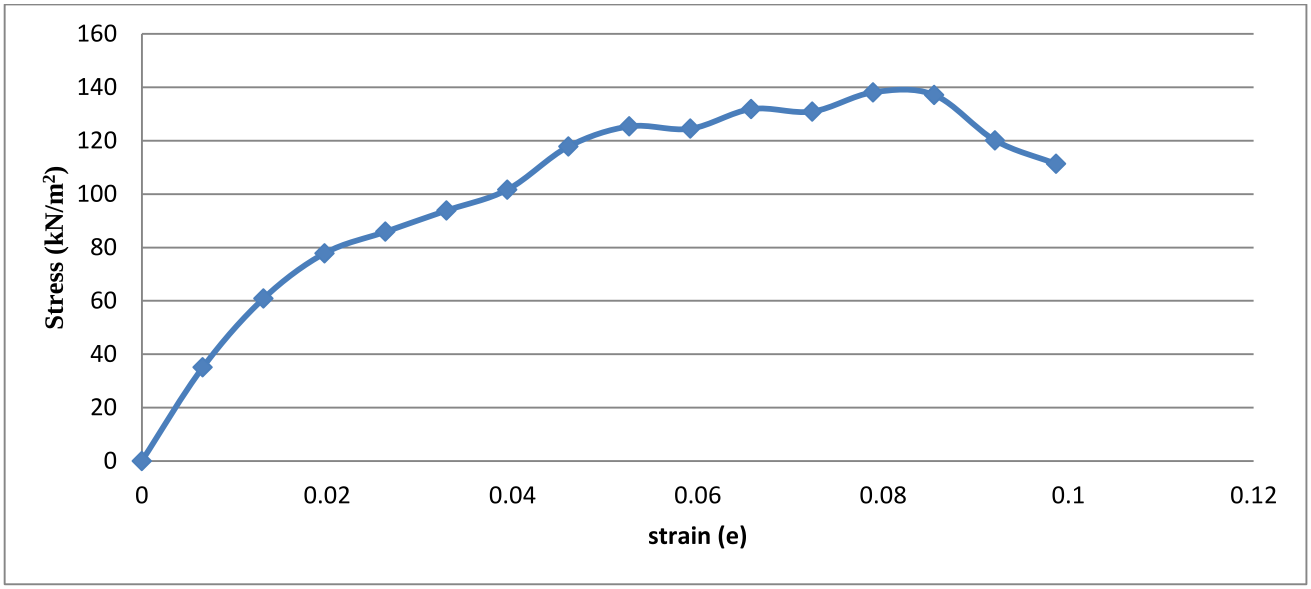

Fig 36 Unconfined Compressive Strength curve of soil + 6% waste(w/w)

The unconfined compressive strength of soil + 6%waste (w/w) =138.13 kN/m^2 (Annexure 1.4.3)

6.2.4.5 UCS of soil + 8%waste(w/w)

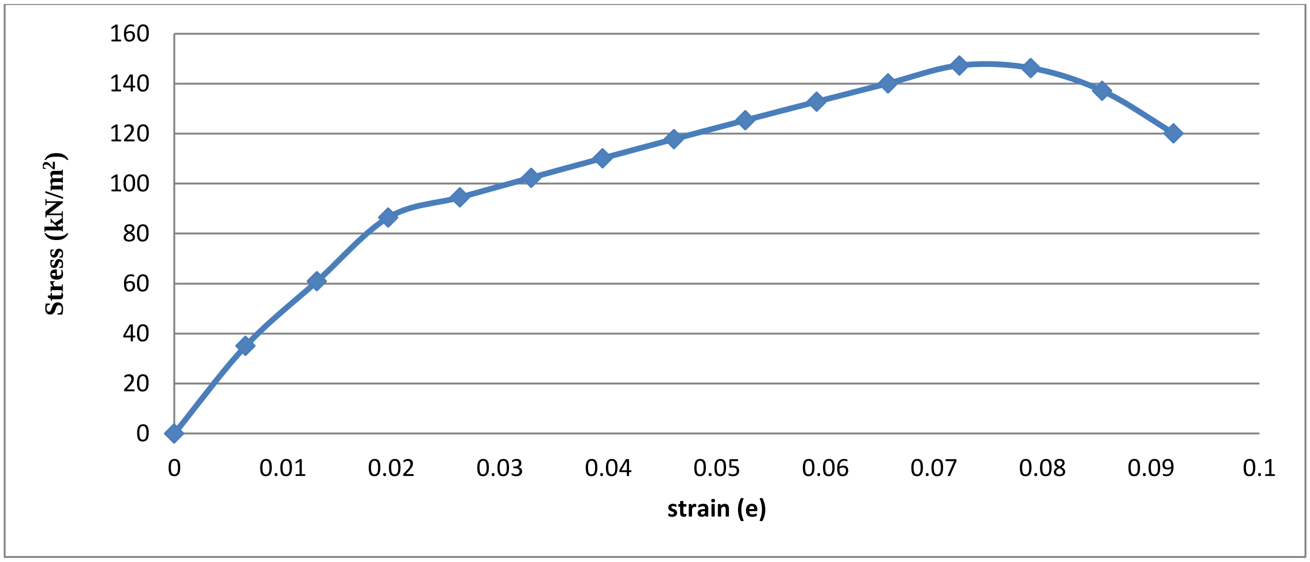

Fig 37 Unconfined Compressive Strength curve of soil + 8% waste(w/w)

The unconfined compressive strength of soil + 8%waste (w/w) =147.30 kN/m^2 (Annexure 1.4.4)

6.2.4.6 Variation of U.C.S. with waste content

Waste variation % (w/w)	Unconfined Compression Strength (kN/m^2)
0	114
2	124.49
4	131.86
6	138.13
8	147.30

Table 7 Variation of U.C.S of soil with waste content

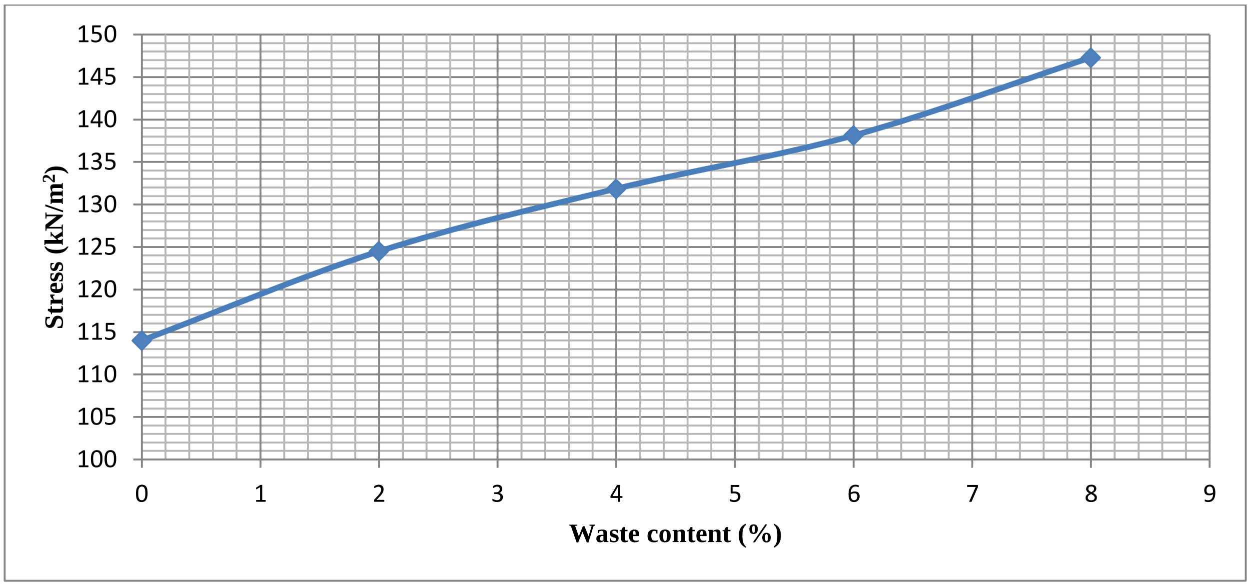

Fig 38 U.C.S. vs waste content-

The unconfined compressive strength of black cotton soil can be increased by as much as 29.21 % by just adding 8% (w/w) of leather industry waste. This is due to impact of compaction parameters on soil and waste mixtures as they are compacted to optimum conditions. Thus to increases the unconfined compressive strength of soil 8% of waste is the optimum percentage to be added.

6.2.5 California Bearing Ratio Test

6.2.5.1 C.B.R of soil + 2%waste (w/w)

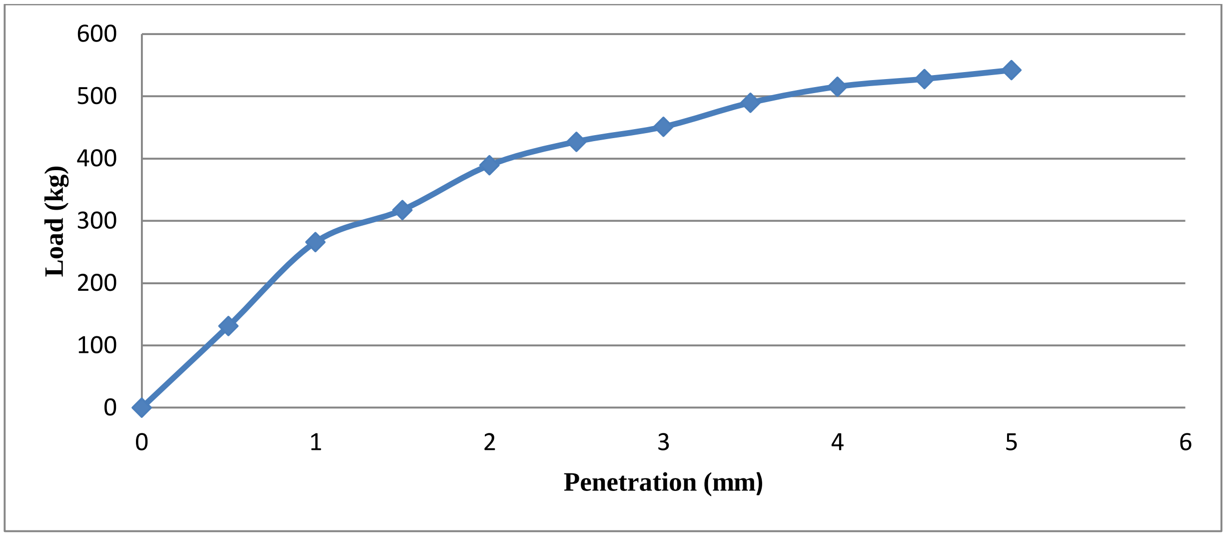

Fig 39 Load penetration curve for soil +2% waste(w/w)

CBR value for soil + 2%waste (w/w) at 2.5 mm = 31.18 % (Annexure 1.5.2)

6.2.5.2 C.B.R of soil + 4%waste (w/w)

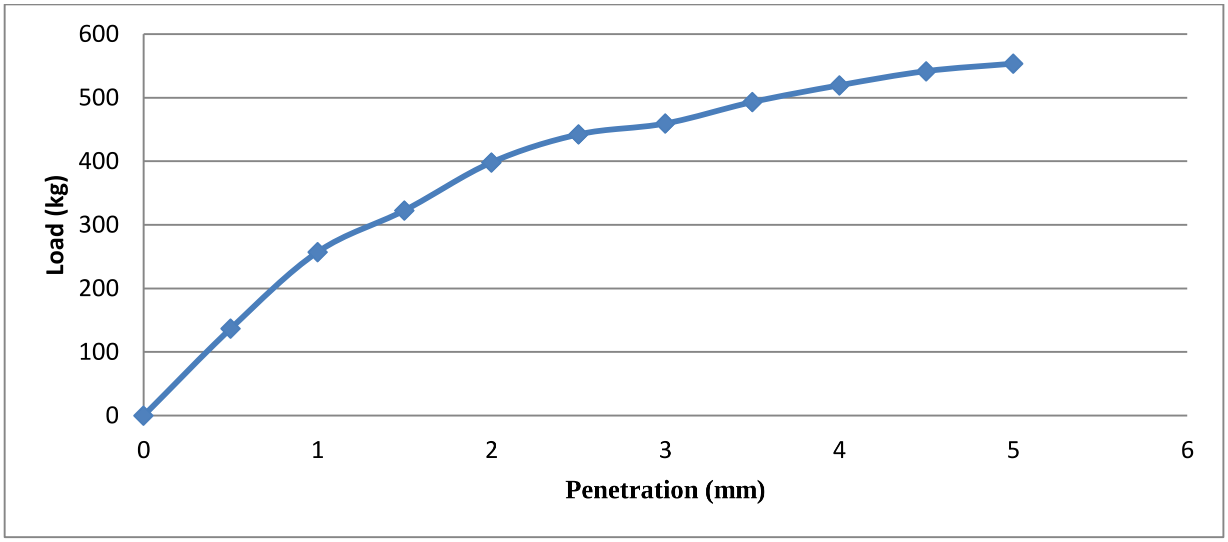

Fig 40 Load penetration curve for soil +4% waste(w/w)

CBR value for soil + 4%waste (w/w) at 2.5 mm = 32.27 % (Annexure 1.5.3)

6.2.5.3 C.B.R of soil + 6%waste (w/w)

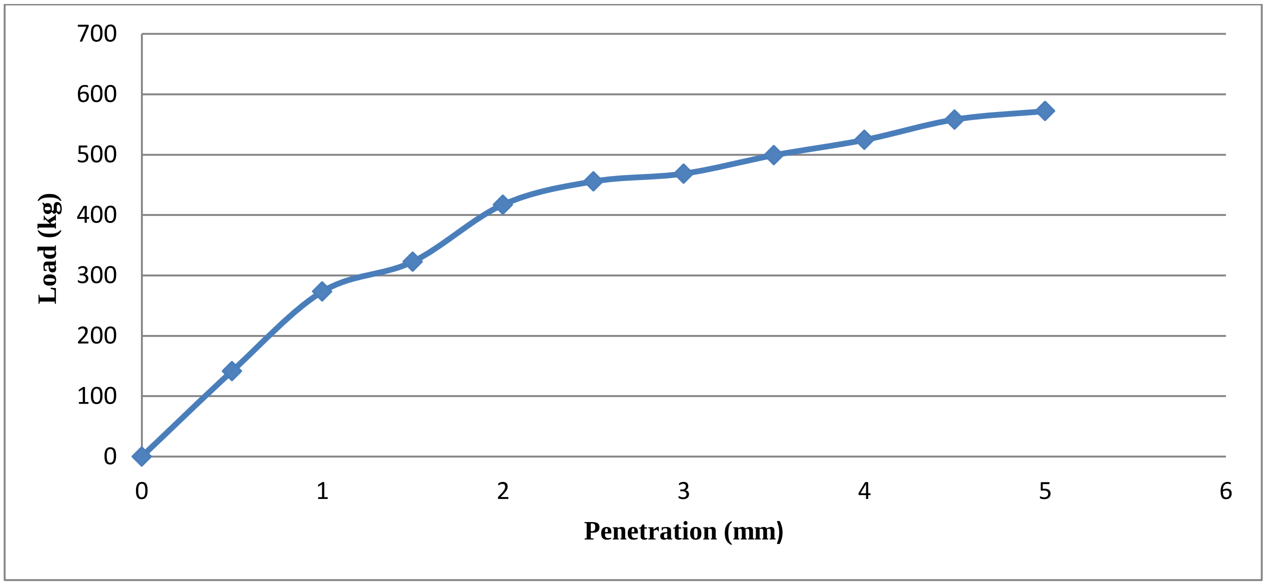

Fig 41 Load penetration curve for soil +6% waste(w/w)

CBR value for soil + 6%waste (w/w) at 2.5 mm = 33.26 % (Annexure 1.5.4)

6.2.5.4 C.B.R of soil + 8%waste (w/w)

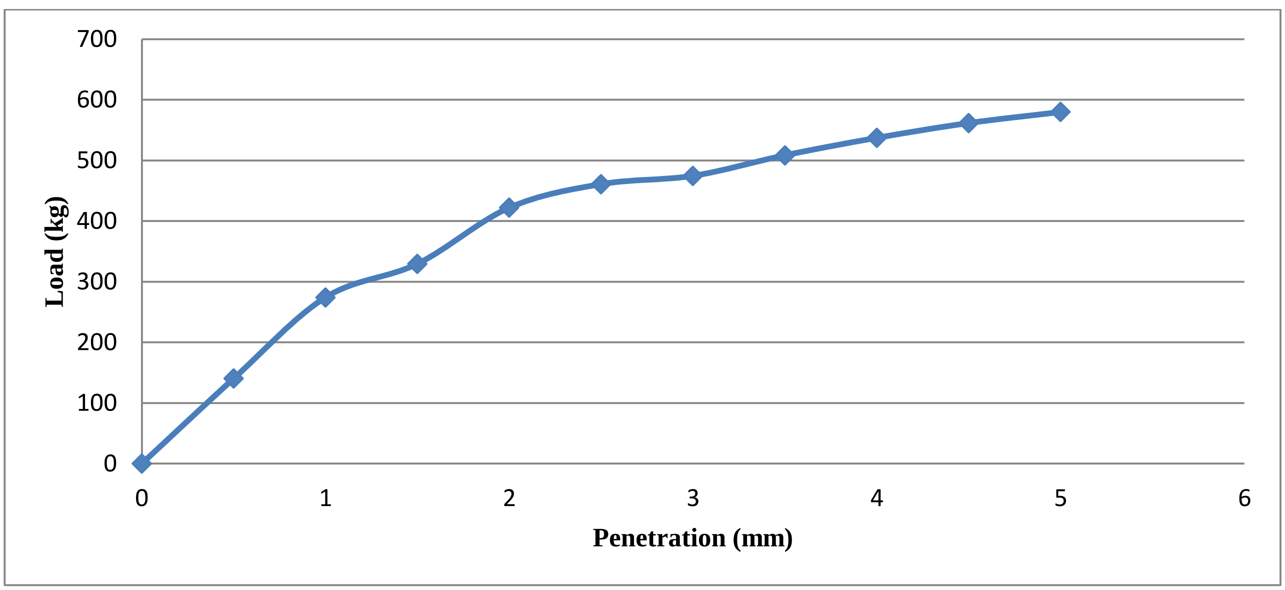

Fig 42 Load penetration curve for soil +8% waste(w/w)

CBR value for soil + 8%waste (w/w) at 2.5 mm = 33.64 % (Annexure 1.5.5)

6.2.5.5 Variation of C.B.R. with waste content

Waste variation % (w/w)	California Bearing Ratio (%)
0	29.43
2	31.18
4	32.27
6	33.26
8	33.64

Table 8 Variation of C.B.R of soil with waste content

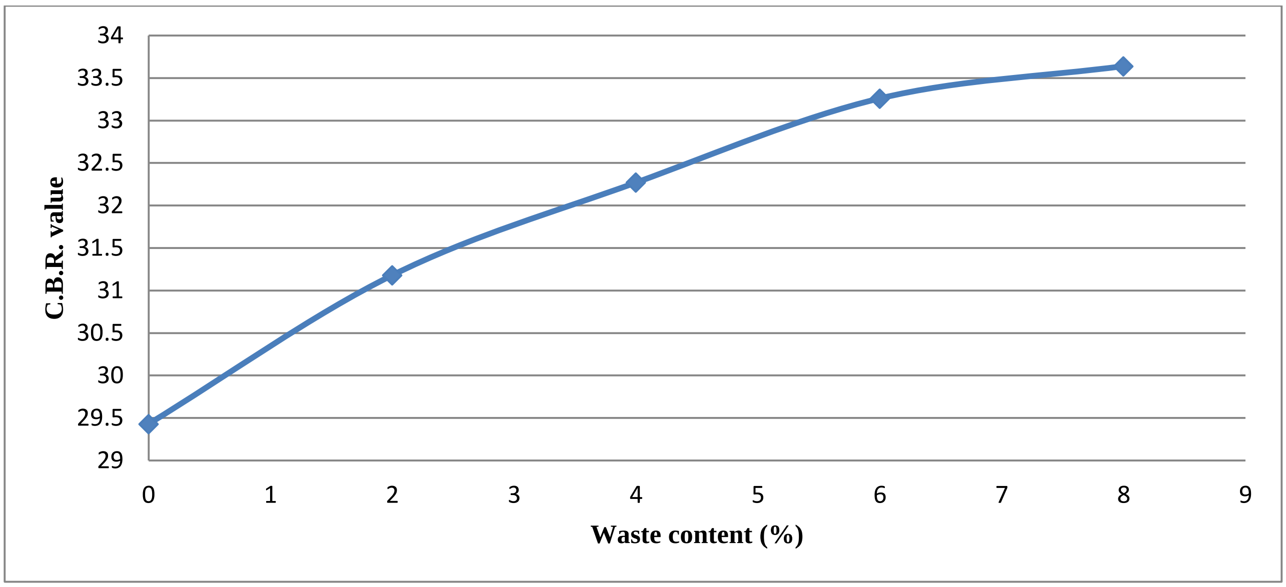

Fig 43 U.C.S. vs waste content

With the addition of leather industry waste the C.B.R. value of black cotton soil increases by 14.30% . Black cotton soil has a low C.B.R. value and is therefore not suitable for laying of pavements and thus some modification needs to be done. Leather industry waste can provide us with a means of black cotton soil stabilization as well as an eco-friendly way of hazardous waste disposal.

Chapter 7
Conclusion

- The tests performed on leather industry waste concluded the presence of high amount of calcium and ferrous ions chromium however remained undetected due to pre fleshing waste.
- According to IS classification the soil is of **OH** category i.e. organic clay of high plasticity.
- With the addition of leather industry waste the maximum dry density of soil increased upto 6% of the initial M.D.D.
- The increase of strength from UCS with addition of waste is primarily due to effect of compaction parameters of soil with fine waste at their respective optimum conditions. The increase in strength was as much as 29.21%.
- The increase in the C.B.R. value was 14.30% as compared to that of black cotton soil .
- The shrinkage limit of soil also increased by 6% which concluded that leather industry waste can minimize the shrinkage of black cotton soil.
- All these showed excellent results at percentage of 6-8%(w/w). Thus the **optimum percentage for addition of leather industry waste in black cotton soil is 6-8%.**

Future Scope

From the above literature review and experimental data , it can be concluded that soil stabilization using leather industry waste is an economical as well as eco-friendly method. This experimentation enhances almost all the desired properties of soil but still many research gaps do prevail which can be exploited in future for effective and efficient usage :

- Wastes rich of chromium can be used as chromium being a heavy metal can be used to stabilize the soil
- Waste in our experimentation was incinerated at uncontrolled temperature. This can be done at a controlled temperature in a furnace.
- Leather industry waste having high amounts of calcium can show even more enhanced properties of U.C.S. after 3 to 7 days of curing.
- The effect on water table of using soil and waste mixture in sub base needs to be determined , might be a possibility that with water running to water table the waste releases toxic ions thus making the underground water toxic for consumption.

References

1. Bosnic M, Buljan J , Daniels R.P. (2000), “Pollutants in tannery effluents” , US/RAS/92/120

2. Chonkar P.K., Dutta S.P. ,Joshi H.C. (2000), “Impact of tannery and textile industry on soil” , Journal of Scientific and Industrial Research , Volume 59, pp 446-454

3. Folagbade Oriola, Moses George (2010) “Groundnut shell ash stabilization for black cotton soil”, Electronic Journal of Geotechnical Engineering (EGJE), Volume 15 Bund.E

4. Kanagraj J , Vellapan K.C. , Chandra Babu N.K. , Sadulla S (2006) “Solid waste generated in leather industry and its utilization for a cleaner environment ” , Journal of Scientific and Industrial Reserach ,Volume 65 , pp.541-548

5. Kumar Ajay, Kumar Ashok , Prakash Ved (2016) “Stabilization of expansive soil with lime and brick dust”, International Journal of All Research Education and Scientific Methods (IJARESM), ISSN:2455-6211 , Volume -4 , Issue 9, pp 448-451

6. Maier F., Kolozomik K., Sukop S., Mladek M.(1999) “ Products of Enzymatic Decomposition of Chrome-Tanned Leather Waste”. JSLTC 83, pp 512-521

7. Mohammad Sayeed , Baig Ali Arif (2014), ”Soil amended with admixture as stabilizing agent to retain heavy metals”, Geo Congress Technical Paper, GSP 234

8. Ozgunay H ,Colak S, Mutlu M.M. (2007) “Characterization of leather industry waste", Polish Journal of Environmental Study , Volume 16 , No. 6 , 867-873

9. Rutland FH, Prentiss WS (1991) “Environmental compatibility of chromium containing tannery and other leather product wastes at land disposal sites” J A Leather Chem Association,86,364-374.

10. Sempere J.F., Martinez M.L.B., Montesinos R.F.,Lillo M.C(1997) “Characterization of Tannery Wastes” Journal of Hazardous Materials.54.

11. Lollar R M , Brown E M(1991), “Potential use of tannery effluents” Journal of leather chemical association,75.

12. I.S: 2720 (Part VII)-1980: “Indian standard for determination of water content- Dry density relationship using light compaction”, Bureau of Indian Standards Publications, New Delhi.

13. I.S: 2720 (Part XVI)-1965 : “Indian standard for laboratory determination of CBR”, Bureau of Indian Standards Publications, New Delhi

14. IS: 2720 (Part V)-Indian Standard Methods of tests for soils:Determination of Liquid limit., 1985

15. IS: 2720 (Part V)-Indian Standard Methods of tests for soils:Determination of Plastic limit., 1985

16. I.S. code 2720 (Part viii)-1965, determination of maximum dry density and optimum water content.

ANNEXURE

Annexure 1.1

Annexure 1.1.1

IS sieve (mm)	Wt. of soil retained (g)	Percentage wt. retained (%)	Cumulative percentage retained (%)	Percentage finer (%)
4.75	0	0	0	100
2.36	34.85	5.81	5.81	94.79
1.18	11.32	1.89	7.70	92.31
0.6	82.86	13.81	21.51	78.50
0.425	26.58	4.43	25.94	74.07
0.212	24.83	4.14	30.07	69.93
0.15	21.96	3.66	33.73	66.27
0.075	22.68	3.78	37.51	62.49

Table 9 Percentage finer in dry sieve analysis of soil

Annexure 1.1.2

Sieve size (mm)	Percentage finer (%)
0.065	60.8
0.0574	54.67
0.0423	44.26
0.0313	31.69
0.0118	24.97
0.0089	22.64
0.0063	18.61
0.0053	15.28
0.00221	8.69

Table 10 Hydrometer analysis for percentage finer of soil

Annexure 1.1.3

IS sieve (mm)	Wt. of soil retained (g)	Percentage wt. retained (%)	Cumulative percentage retained (%)	Percentage finer (%)
4.75	0	0	0	100
0.850	11.6	3.83	3.83	96.13
0.600	3.4	1.133	5.00	95.00
0.300	40.1	13.366	18.36	81.63
0.180	126.8	42.266	60.63	39.36
0.150	32.6	10.866	71.50	28.50
0.125	52	17.33	88.883	11.16
0.075	27	9	97.83	2.166
Pan	3.2	1.0667	98.90	1.1

Table 11 Percentage finer in dry sieve analysis of LWA

Annexure 1.2

Annexure 1.2.1

Weight of empty container (g)	Wt. of container + sample (g)	Wt. of container + oven dried sample (g)	Moisture content (%)	No. of blows (n)
19.1	22.5	21	78.94	11
19.3	23.2	21.7	62.50	42
18.6	18.6	20.4	61.11	49

Table 12 Liquid limit of soil

Annexure 1.2.2

Weight of empty container (g)	Wt. of container + sample (g)	Wt. of container + oven dried sample (g)	Moisture content (%)	No. of blows (n)
19.1	22.32	21	69.473	100
19.4	22.94	21.41	76.119	41
18.7	23.24	21.23	79.446	14

Table 13 Liquid limit of soil + 2%waste(w/w)

Annexure 1.2.3

Weight of empty container (g)	Wt. of container + sample (g)	Wt. of container + oven dried sample (g)	Moisture content (%)	No. of blows (n)
19.1	25.5	22.9	68.42	96
19.9	25	22.8	75.862	38
20.9	23.8	22.5	81.250	13

Table 14 Liquid limit of soil + 4%waste(w/w)

Annexure 1.2.4

Weight of empty container (g)	Wt. of container + sample (g)	Wt. of container + oven dried sample (g)	Moisture content (%)	No. of blows (n)
19.7	23.8	21.68	70.70	90
20.7	24.4	22.8	76.19	32
20.3	24.1	22.4	80.95	12

Table 15 Liquid limit of soil + 6%waste(w/w)

Annexure 1.2.5

Weight of empty container (g)	Wt. of container + sample (g)	Wt. of container + oven dried sample (g)	Moisture content (%)	No. of blows (n)
19.7	23.6	22	69.56	85
19.9	29.3	25.3	74.07	29
18.6	22.91	22.91	79.58	10

Table 16 Liquid limit of soil + 8%waste(w/w)

Annexure 1.3

Annexure 1.3.1

Wt. of empty mould (g)	Wt. of mould +compacted soil (g)	Wt. of compacted soil (g)	Water Content (%)	Bulk Density (g/cc)	Dry Density (g/cc)
3708	5247.3	1539.3	4.93	1.628	1.551
3708	5366.8	1658.8	9.87	1.755	1.595
3708	5496	1788.0	14.96	1.892	1.645
3708	5603.2	1895.2	17.52	2.005	1.699
3708	5712.5	2004.5	19.96	2.121	1.767
3708	5873.3	2165.3	21.78	2.291	1.878
3708	5802.7	2094.7	23.84	2.216	1.787

Table 17 Standard proctor for soil

Annexure 1.3.2

Wt. of empty mould (g)	Wt. of mould +compacted soil (g)	Wt. of compacted soil (g)	Water Content (%)	Bulk Density (g/cc)	Dry Density (g/cc)
3708	5449.1	1741.1	4.87	1.842	1.754
3708	5540.3	1832.3	9.21	1.938	1.762
3708	5693.5	1985.5	14.38	2.101	1.827
3708	5793.2	2085.2	18.53	2.206	1.869
3708	5886.9	2178.9	20.75	2.305	1.921
3708	5833.3	2125.3	22.3	2.248	1.843

Table 18 Standard proctor for soil + 2%waste (w/w)

Annexure 1.3.3

Wt. of empty mould (g)	Wt. of mould +compacted soil (g)	Wt. of compacted soil (g)	Water Content (%)	Bulk Density (g/cc)	Dry Density (g/cc)
3708	5474	1766	4.91	1.868	1.779
3708	5567.9	1859.9	9.47	1.968	1.789
3708	5714.6	2006.6	14.90	2.123	1.846
3708	5809.3	2101.3	18.57	2.224	1.884
3708	5896.8	2188.8	20.65	2.316	1.930
3708	5848	2140	22.1	2.264	1.856

Table 19 Standard proctor for soil + 4%waste(w/w)

Annexure 1.3.4

Wt. of empty mould (g)	Wt. of mould +compacted soil (g)	Wt. of compacted soil (g)	Water Content (%)	Bulk Density (g/cc)	Dry Density (g/cc)
3708	5522	1814	4.67	1.919	1.828
3708	5640.2	1932.2	9.83	2.044	1.858
3708	5748.5	2040.5	14.87	2.159	1.877
3708	5839.3	2131.3	18.36	2.255	1.911
3708	5953.8	2245.8	20.40	2.376	1.980
3708	5893.8	2185.8	22.17	2.313	1.895

Table 20 Standard proctor for soil + 6%waste (w/w)

Annexure 1.3.5

Wt. of empty mould (g)	Wt. of mould +compacted soil (g)	Wt. of compacted soil (g)	Water Content (%)	Bulk Density (g/cc)	Dry Density (g/cc)
3708	5421.3	1713.3	4.97	1.813	1.726
3708	5513.7	1805.7	9.65	1.910	1.737
3708	5648	1940	14.32	2.052	1.785
3708	5739.4	2031.4	18.92	2.149	1.821
3708	5689.9	1981.9	20.13	2.097	1.747

Table 21 Standard proctor for soil + 8%waste (w/w)

Annexure 1.3.6

Wt. of empty mould (g)	Wt. of mould +compacted soil (g)	Wt. of compacted soil (g)	Water Content (%)	Bulk Density (g/cc)	Dry Density (g/cc)
3708	5401.3	1693.3	4.55	1.791	1.706
3708	5493	1785	9.69	1.888	1.717
3708	5586.1	1878.1	15.64	1.987	1.728
3708	5669.8	1961.8	18.78	2.075	1.759
3708	5658.9	1950.9	20.78	2.064	1.720

Table 22 Standard proctor for soil + 10%waste (w/w)

Annexure 1.4

Annexure 1.4.1

Deformation	Load	Corrected Area	Strain	Stress
0	0	-	0	0
0.5	0.02	1141.046887	0.006578947	17.52776351
1	0.04	1148.653867	0.013157895	34.82337122
1.5	0.07	1156.362953	0.019736842	60.53462697
2	0.08	1164.176216	0.026315789	68.7181192
2.5	0.1	1172.095782	0.032894737	85.31725948
3	0.12	1180.123836	0.039473684	101.684244
3.5	0.13	1188.262621	0.046052632	109.4034246
4	0.14	1196.514444	0.052631579	117.0065273
4.5	0.15	1204.881678	0.059210526	124.4935521
5	0.15	1213.366761	0.065789474	123.6229678
5.5	0.15	1221.972199	0.072368421	122.7523835
6	0.15	1230.700571	0.078947368	121.8817993
6.5	0.14	1239.554532	0.085526316	112.9438007
7	0.13	1248.536812	0.092105263	104.1218799

Table 23 U.C.S. for soil + 2% waste (w/w)

Annexure 1.4.2

Deformation	Load	Corrected Area	Strain	Stress
0	0	-	0	0
0.5	0.03	1141.046887	0.006578947	26.29164527
1	0.05	1148.653867	0.013157895	43.52921402
1.5	0.08	1156.362953	0.019736842	69.18243082
2	0.1	1164.176216	0.026315789	85.897649
2.5	0.11	1172.095782	0.032894737	93.84898543
3	0.12	1180.123836	0.039473684	101.684244
3.5	0.13	1188.262621	0.046052632	109.4034246
4	0.15	1196.514444	0.052631579	125.3641364
4.5	0.15	1204.881678	0.059210526	124.4935521
5	0.16	1213.366761	0.065789474	131.864499
5.5	0.16	1221.972199	0.072368421	130.9358758
6	0.15	1230.700571	0.078947368	121.8817993
6.5	0.14	1239.554532	0.085526316	112.9438007
7	0.14	1248.536812	0.092105263	112.1312553
7.5	0.13	1257.650219	0.098684211	103.3673736

Table 24 U.C.S. for soil + 4% waste (w/w)

Annexure 1.4.3

Deformation	Load	Corrected Area	Strain	Stress
0	0	-	0	0
0.5	0.04	1141.046887	0.006578947	35.05552703
1	0.07	1148.653867	0.013157895	60.94089963
1.5	0.09	1156.362953	0.019736842	77.83023467
2	0.1	1164.176216	0.026315789	85.897649
2.5	0.11	1172.095782	0.032894737	93.84895843
3	0.12	1180.123836	0.039473684	101.684244
3.5	0.14	1188.262621	0.046052632	117.8190726
4	0.15	1196.514444	0.052631579	125.3641364
4.5	0.15	1204.881678	0.059210526	124.4935521
5	0.16	1213.366761	0.065789474	131.864499
5.5	0.16	1221.972199	0.072368421	130.9358758
6	0.17	1230.700571	0.078947368	138.1327058
6.5	0.17	1239.554532	0.085526316	137.1460436
7	0.15	1248.536812	0.092105263	120.1406307
7.5	0.14	1257.650219	0.098684211	111.31871

Table 25 U.C.S. for soil + 6% waste (w/w)

Annexure 1.4.4

Deformation	Load	Corrected Area	Strain	Stress
0	0	-	0	0
0.5	0.04	1141.046887	0.006578947	35.05552703
1	0.07	1148.653867	0.013157895	60.94089963
1.5	0.1	1156.362953	0.019736842	86.47809852
2	0.11	1164.176216	0.026315789	94.48741391
2.5	0.12	1172.095782	0.032894737	102.3807114
3	0.13	1180.123836	0.039473684	110.157931
3.5	0.14	1188.262621	0.046052632	117.8190726
4	0.15	1196.514444	0.052631579	125.3641364
4.5	0.16	1204.881678	0.059210526	132.7931222
5	0.17	1213.366761	0.065789474	140.1060302
5.5	0.18	1221.972199	0.072368421	147.3028603
6	0.18	1230.700571	0.078947368	146.2581591
6.5	0.17	1239.554532	0.085526316	137.1460436
7	0.15	1248.536812	0.092105263	120.1406307

Table 26 U.C.S. for soil + 8% waste (w/w)

Annexure 1.5

Annexure 1.5.1

Load (kg)	Deformation (mm)
0	0
1	240.00
1.5	285.74
2	370.85
2.5	403.30
3	430.82
3.5	457.23
4	480.31
4.5	496.33
5	510.66

Table 27 C.B.R. for black cotton soil

Annexure 1.5.2

Load (kg)	Deformation (mm)
0.5	131.5
1	266.1
1.5	317.8
2	389.5
2.5	427.3
3	451.1
3.5	489.8
4	515.6
4.5	527.9
5	542.1

Table 28 C.B.R. for soil + 2% waste (w/w)

Annexure 1.5.3

Load (kg)	Deformation (mm)
0	0
0.5	136.8
1	257.3
1.5	322.8
2	398.3
2.5	442.2
3	459.4
3.5	493.2
4	519.5
4.5	541.8
5	553.6

Table 29 C.B.R. for soil + 4% waste (w/w)

Annexure 1.5.4

Load (kg)	Deformation (mm)
0	0
0.5	141.6
1	273.4
1.5	322.8
2	417.4
2.5	455.7
3	468.6
3.5	499.2
4	524.5
4.5	558.3
5	572.2

Table 30 C.B.R. for soil + 6% waste (w/w)

Annexure 1.5.5

Load (kg)	Deformation (mm)
0	0
0.5	140.3
1	274.2
1.5	329.5
2	422.1
2.5	460.9
3	474.6
3.5	508.5
4	537.2
4.5	561.6
5	579.8

Table 31 C.B.R. for soil + 8% waste (w/w)

Annexure 1.6

	Empty weight of dish	Weight of dish with wet soil	Weight of dry soil pat and dish	Wt.of dry soil pat	Wt. Of mercury	Vol. of dry soil	Wt. Of wet soil pat	Water content	Shrikage limit	Mean
	W1(g)	W2(g)	W3(g)	Wd(g)	(g)	Vd	W wet	w		
BCS	31.1	68.2	54.6	23.5	168.5	12.3897	37.1	57.872	9.1477	9.377
	30.8	69.7	56.3	25.5	175.3	12.8897	38.9	52.549	9.6067	
2%	24.5	63.2	48.2	23.7	156.7	11.5221	38.7	63.291	11.317	11.05
	36.2	72.7	58.3	22.1	160.8	11.8235	36.5	65.158	10.785	
4%	34.5	71.6	57.5	23	172.1	12.6544	37.1	61.304	12.671	12.61
	31.9	67.2	53.7	21.8	177.8	13.0735	35.3	61.927	12.539	
6%	24.3	61.9	48.4	24.1	190	13.9706	37.6	56.017	15.065	14.97
	24.5	63.8	49.8	25.3	185	13.6029	39.3	55.336	14.873	
8%	24.4	59.9	46.4	22	187.3	13.7721	35.5	61.364	15.6	15.33
	34.5	71.8	57.4	22.9	175.3	12.8897	37.3	62.882	15.064	

Table 32 Shrinkage limit