"STABILISATION OF BLACK COTTON SOIL USING TANNED LEATHER WASTE ASH"

A
PROJECT REPORT

Submitted in partial fulfilment 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-Grade II)

by

Vaibhav Thakur (151641)
Akshay Sharma (151642)

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 **"Stabilisation of Black Cotton Soil using Tanned leather waste ash** "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.

Vaibhav Thakur Akshay Sharma

151641 151642

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 **"STABILISATION OF BLACK COTTON SOIL USING TANNED LEATHER WASTE ASH"** 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 **Vaibhav Thakur (151641) and Akshay Sharma (151642)** 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 statement made is correct to the best of our knowledge.

Date: ....

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

Vaibhav Thakur (151641)

Akshay Sharma (151642)

ABSTRACT

Black cotton soil is clayey soil which is very troublesome for construction purpose due to high swelling and shrinkage properties. It requires Stabilisation for its use in construction purposes.

Tanned leather waste produced by tanneries contains heavy metals such as Chromium. These wastes are usually dumped in the areas near tanneries creating pollution. Heavy metals such as Chromium can help in stabilising Black cotton soil due to Black cotton soil's cation exchange capacity.

This can be a good solution to pollution caused by tanneries as tanned leather waste can be as a stabilising material for Black cotton soil.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVATIONS

Serial No.	Abbreviation Used	Description
1	B.C.S	Black cotton soil
2	IS	Indian Standard
3	C.B.R	California Bearing Ratio
4	M.P	Madhya Pradesh
5	Cr	Chromium
6	Cr-ISW	Chromium loaded initial solid waste
7	P. I	Plasticity Index
8	O.M.C	Optimum moisture content
9	M.D. D	Maximum dry density
10	Wt.	Weight

CHAPTER 1
INTRODUCTION

1.1 General Introduction

Black cotton Soil is one of the most abundant soil found in India. It is an inorganic soil which is very good for agricultural purposes but a nightmare for civil engineering works. It is a highly expansive soil and has the tendency to swell to large volumes when its moisture content gets increased and shrink when its lost. Due to its large volumetric changes it applies a swelling pressure which results in differential settlement and also causes loss in bearing strength of soil. This property of Black cotton soil is due to the presence of montmorillonite clay minerals which are present in abundance in it.

Leather Industry is infamous throughout the world for the pollution caused by it. Different types of wastes are produced by the leather industry during different processes involved in conversion of animal hide to the commercially used leather. As in different processes different chemicals are used so the chemical composition of the waste produced is different in different stages.

Tanning of animal hides is done to permanently alter the protein structure of skin to make it more durable and to prevent its decomposition. Nowadays Chrome tanning is used for tanning animal hides. The wastes produced are in the form of chrome shaving wastes, buffing dust which contains high amount of Cr (III) and Cr (VI) which are very toxic in nature which are dumped in land near tanneries.

For use of Black cotton soil in foundations, it needs to be stabilised with various stabilisers such as lime, rice husk etc... Due to increase in price of stabilisers and dumping of large quantities of tanning wastes in land, we need to find a less expensive and eco-friendly solution to this problem. By taking advantage of cation exchange capacity of Black cotton soil and making use of chromium present in tannery wastes can help in stabilising it.

CHAPTER 2

LITERATURE REVIEW

2.1 Literature review:

- **Incineration of tannery sludge under oxic and anoxic conditions: Study of chromium speciation**
  P.Kavouras,E.Pantazopoulou,S.Varitis,G.Vourlias,K.Chrissafis,G.P.Dimitrakopulos,M.Mitrakas,A.I.Zouboulis,Th.Karakostas,A.Xenidis ; 2015

  Important point:

  Incineration of Cr-ISW at oxic conditions, Crystalline $CaCrO_4$ was formed containing Cr^{+6} chromium state after 5000 C some part was converted into $MgCr_2O_4$ containing Cr^{+3}.

- **Impacts of chromium from tannery effluent and evaluation of alternative treatment options.**

  Alebel Abebe Belay; 2010

  Important point:

  Cr is highly toxic and carcinogenic to human beings and environment. Treatment options were evaluated to prevent consequences but neither of them was able to treat it 100%.

- **Soil amended with admixtures as a stabilising agent to retain heavy metals**

  Important point:

  Syed Abu Sayeed Mohammed and Arif Ali Baig Moghal; 2014

  Soil such as Black cotton soil can be used to absorb heavy metals such as chromium. Black cotton soil + 6% lime caused maximum retention of heavy metals

- **Studies on stabilisation of black cotton soil using lime**

  Harish G R; 2017

  Important point:

The addition of lime resulted in decreasing the plasticity index and free swell index. With increase in percentage of lime, curing period unconfined compressive strength of soil increased for 9% lime.

- **Stabilisation of Black cotton soil with sand and cement as a subgrade for pavement**

  Mrs. Neetu B. Ramteke, Prof.Anilkumar Saxena, Prof.T.R. Arora; 2014

  Important point:

  Engineering Properties of soil can be increased by making use of sand and cement as stabilizers. C.B.R value is increased with increase in the sand content. The Maximum Value of C.B.R is obtained when using 2% cement and 40% lime. There is reduction in free swell index and Atterberg limits with increase in sand content.

- **Soil stabilization using industrial waste (wheat husk and sugarcane straw ash)**

  Maninder singh, Rubel Sharma, Abhishek

  Important point :

  B.C.S was stabilised with help of wheat husk ash and sugarcane straw ash. Sugarcane and rice husk were washed, dried and burned at 600 degree Celsius. C.B.R,U.C.S, O.M.C and atterberg limits were calculated. results showed addition of both waste more beneficial than adding them individually

2.2 Summary

- Tests which were performed were done on the tanned leather waste only not on soil mixed with it.
- Waste generated from tanneries contains heavy metals such as Chromium.
- High cation exchange capacity of B.C.S can be used for trapping heavy metals such as chromium ions which are present in the effluent of tanneries.
- Engineering properties such as swelling, U.C.S , C.B.R of soil can be improved by using lime, sand , wheat husk ash and sugarcane ash as stabilizers.

CHAPTER 3
OBJECTIVES

- To determine the change in strength and swelling behaviour of soil using open burned tanned leather waste ash as an additive.

- To determine the change in swelling behaviour of soil using open burned tanned leather waste ash as an additive.

- To determine the optimum content of tanned leather waste ash for the stabilisation of black cotton soil.

CHAPTER 4
MATERIALS

4.1 Black cotton soil

4.1.1 Introduction

Black cotton soil is one of the soils which are present in India in abundance. It is generally present in central India. This type soil is considered as very good for agricultural purposes as it is very fertile. Crops such as rice, maze, wheat etc. and cotton are grown in this type of soil. It is formed by the weathering of basaltic rocks and is black in colour. This soil is inorganic in nature.

4.1.2 Procurement

The black cotton soil used in this project was acquired from Guna, M.P, India.

Figure 4.1 Oven dried sample of Black cotton soil

4.2 Tanned Leather waste

4.2.1 Introduction

The leather waste used in this project is tanned leather waste in form of chrome trimmings and shavings having high organic and chromium content which are obtained after tanning process. The waste is also called wet blue waste.

4.2.2 Procurement

The leather waste was acquired from a tannery in Jalandhar, Punjab. The waste acquired is the waste generated after the tanning process.

4.2.3 Preparation of leather waste for use

- The leather waste obtained was firstly air dried to remove some moisture content and then oven dried for further reduction in water content.
- The oven dried leather waste was then open burned so as to reduce some organic content and convert it into ash.
- The waste ash obtained was then grinded and passed through 450-micron sieve.
- The amount passing was stored in an air tight container.

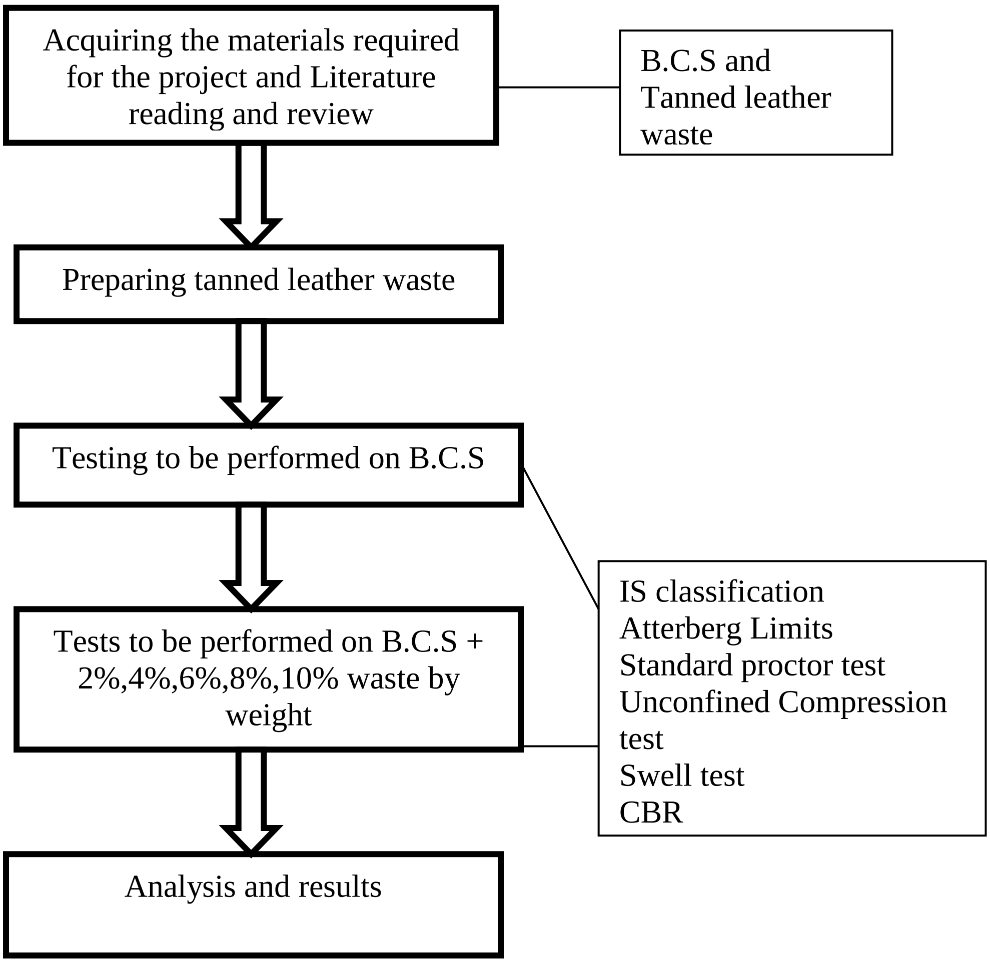
Figure 4.2 Tanned leather waste before burning

Figure 4.3 Tanned leather waste after burning

CHAPTER 5

METHODOLOGY

5.1 Work plan



Various literatures about tanning, B.C.S stabilisation were read and relevant conclusions were drawn. Materials used in the project namely black cotton soil and tanned leather waste were procured The tanned leather waste was incinerated ,grinded and passed through 425-micron sieve to get tanned leather waste ash. Various Tests **(refer to subsection 6.1)** Were performed on tanned leather waste ash to determine its properties. Various tests **(refer to subsection 6.2)** were performed on B.C.S and B.C.S + tanned leather waste ash **(refer to subsection 6.3) and** their results were obtained. Results from all the tests are analyzed and final conclusion is drawn out.

5.2 Testing Methodology

5.2.1 Dry sieve Analysis

This test is done to obtain particle size distribution of various soil particles present in the soil sample. The testing is done according to IS: 2720(part 4)-1985- Method of test for soil (part 4- Grain size analysis).

Equipment required:

- Sieves of sizes :4.75 mm, 2.00mm, 1.00 mm, 4.25μm, 212 μm,150 μm,75 μm
- Sieve shaker.
- Weighing machine

Procedure:

- 200gm of soil was taken and soaked in water.
- Sieving of soil was done through 75-micron sieve and washed with high pressure water.
- Retaining material was oven dried and weighed.
- After this the material was sieved with the help of mechanical sieve shaker for a period of ten minutes.
- Material that retained on each sieve was weighed.
- Material in the pan equals total mass of soil subtract the sum of all masses of materials retained.
- The particle size distribution curve was drawn on semi-log graph paper.

5.2.2 Hydrometer Analysis

This test is done to obtain particle size of soil passing through 75-micron sieve. In this method specific gravity is used to differentiate between different size of soil particles as specific gravity is dependent on the particle sizes.

Equipment required:

- Hydrometer.
- Flocculating agent.
- Weighing machine.
- 75-micron sieve**.**
- Thermometer.

- Two glass jar of 1 litre capacity.

Procedure:

- 50 gm of soil was taken and 150 ml of flocculating agent was added to it.
- Slurry is then added to a mechanical mixer.
- The other glass jar is filled with distilled water to 1 litre mark.
- The mixed soil is then added to the glass jar and distilled water is added to fill it to 1 litre mark and mixed properly.
- Hydrometer is then dipped into the glass jar containing suspension and readings are taken at 15 seconds,30 seconds,1 minute and 2 minutes.
- After 2-minute reading hydrometer is taken out of the suspension and kept in glass jar containing distilled water and cleaned.
- Then again is dipped in suspension and taken reading at 8 minute and then again removed.
- Repeat above steps and take readings at interval of 1, 2, 4, 8, 16, 30, 60, 120 minutes and every one hour thereafter.

5.2.3 Liquid Limit

This test is done to determine the water content at which soil changes its state from plastic to liquid. The testing is done according to IS: 2720(part 4)-1985- Method of test for soil.

Equipment required:

- Casagrande apparatus.
- Grooving tool.
- China dish.
- Spatula.
- Weighing machine.
- 425-micron sieve.
- Empty containers.

Procedure

- Soil sample passing 425-micron sieve was taken.

- The sample was mixed with distilled water in the evaporating dish.
- The paste was made uniform and placed in the cup. The layer was kept maximum 10 mm thick.
- Grooving tool was used to make a cut in the soil.
- The speed of rotation of the handle was 2 revolutions per second
- The number of blows at which separated soil joined till the length of 13mm was noted.
- Soil sample was taken near the closed groove.
- A graph showing relation between number of blows and the water content was made.
- Liquid limit was obtained from the graph corresponding to 25 blows.

5.2.4 Plastic Limit

This test is done to determine that moisture content of soil at which soil starts to behave like a plastic material. The testing is done according to IS: 2720(part 5)-1985- Method of test for soil.

Equipment required:

- China dish.
- Spatula.
- Weighing machine.
- 425-micron sieve.
- Empty containers

Procedure:

- Soil sample passing 425-micron sieve was taken.
- The soil is placed in the china dish, and mix with water through spatula.
- Part of sample nearly 8 gm was taken and a ball was formed out of it.
- After this thread of uniform diameter (around 3 mm) is formed using the soil ball.
- Thread should reach the specified diameter; the procedure was repeated until the rolling thread crumbles.
- A sample from the broken thread was taken and kept it in oven for drying.
- The same procedure was repeated at slightly varying water contents to average to a particular value.

5.2.5 Shrinkage Limit

This test is done to determine the maximum water content at which a reduction in water content does not cause significant change in volume. The testing is done according to IS : 2720(part 6)-1978- Method of test for soil.

Equipment required:

- China dish.
- Spatula.
- Weighing machine.
- 425-micron sieve.
- Mercury
- Shrinkage dishes.

Procedure:

- Soil sample passing 425-micron sieve was taken..
- Weight of shrinkage dish was determined after cleaning it properly.
- The volume of the empty shrinkage dish was determined by pouring mercury in it.
- The shrinkage dish was greased followed by the filling of soil sample in it.
- The shrinkage dish was weighed and kept in the oven.
- After complete drying the volume of dry pat was determined by displacing the mercury in the dish.
- The amount of mercury displaced was weighed.
- Volume of dry soil pat was obtained

5.2.6 Standard proctor test

This test is done to determine the maximum dry density and optimum moisture content of the soil. The testing is done according to IS: 2720(part 8)-1983- Method of test for soil.

Equipment required:

- Standard proctor mould of 944 cc capacity.
- Rammer weighing 2.5kg.
- Weighing machine.

Procedure:

- Dry mass of soil weighing 5 kg was mixed with appropriate amount of water.
- Weight of proctor without base plate and collar was taken.

- After the fixing of collar and the base plate the soil was filled in three layers giving 25 blows for each layer**.**
- The surface of top soil was made smooth after the removal of the collar.
- Bulk density of the soil was calculated.
- Small piece of sample was taken from the mould for water content calculations.
- Water content of the soil was increased by adding a certain amount of water for each further repetition.
- The whole process was repeated until the weight of the sample starts to decrease or becomes constant.

5.2.7 Unconfined Compression Strength Test

U.C.S is used to determine the unconfined compressive strength of soil.

Equipment used

- Standard proctor mould.
- Unconfined compressive strength testing machine
- Hammer and weighing machine.

Procedure:

- The soil was compacted as per standard proctor method at O.M.C.
- U.C.S sampler was oiled and was inserted to the compacted soil mass.
- U.C.S sampler was removed containing the soil specimen.
- The soil specimen length was cut so that it was of the required dimensions i.e. Length of 76mm and diameter of 38 mm.
- The soil specimen was then placed in unconfined compression test machine.
- The load and displacement when the load start to decrease was measured as it represents failure in soil specimen.
- Unconfined compressive strength was calculated and stress-strain curve was drawn.

5.2.8 California Bearing Ratio Test

California bearing ratio is a measure of bearing strength of soil. The C.B.R is calculated at 2.5mm and 5mm displacements. IS: 2720 (part 16)-1973- Methods for Test of soil was followed.

Equipment used

- C.B.R mould having a diameter of 150 mm and height of 175 mm with detachable extension, collar with height of 50 mm and detachable perforated base plate with thickness of 10 mm.
- Spacer disc of diameter of 148 mm and height of 47.7 mm along with handle.
- Metal rammer weighing 2.5 kg and a drop of 310mm.
- Weighing machine.
- C.B.R loading machine.
- Mixing bowel.

Procedure:

- The soil was compacted at O.M.C in C.B.R mould by laying soil in 5 equal layers and proving 55 blows from metal hammer after each layer.
- The C.B.R mould was then placed in C.B.R loading machine.
- The stress and displacement gauge were set to zero.
- Loading was applied and loads and corresponding penetrations were measured.
- C.B.R is calculated at 2.5mm and 5mm displacement.

5.2.9 Swell Test

This test is done to measure swelling and swelling pressure of the expansive soils. The test is done according to IS 2720:41:1977.

Equipment used

- Two porous stones of different diameters.
- Filter paper.
- Standard proctor mould.
- Metal rammer weighing 2.5 kg and a drop of 310 mm.
- Consolidometer.
- Ring sampler.
- Consolidometer cell

Procedure:

- 2.5 - 3 kg of soil was taken and water equal to or just below the shrinkage limit of the soil was added.
- The soil was compacted as per standard proctor method by a hammer of 2.5 kg and 31 cm height of fall.
- Upper collar was removed and soil was trimmed off to level it.
- Outer surface of the ring sampler was oiled.
- Ring sampler was inserted into the compacted soil and sample was taken out.
- Ring sampler was kept in consolidometer cell with porous stone and filter paper on the each face and filled with water.
- Consolidometer cell was placed in the consolidometer and dial gauge readings were set to zero
- Dial gauge readings at different time period till the time when the reading becomes constant were measured.
- When the reading become constant , loads in some interval so as to get dial gauge readings back to zero were applied.

CHAPTER 6

RESULT AND DISCUSSIONS

6.1 Tests performed on tanned leather waste ash

6.1.1 Specific Gravity

Specific gravity helps in determining the weight of a volume of a sample with respect to the weight of water of same volume at 4 degree Celsius. For determination of specific gravity for tanned leather waste, specific gravity bottle is used. The formula used for determination is as follows:

$$\textbf{Specific gravity} = \frac{(\text{weight of waste + bottle}) - (\text{weight of dry bottle})}{[(\text{wt. waste+bottle}) - (\text{wt. dry bottle})] - [(\text{wt. water+soil+bottle}) - (\text{wt. water+bottle})]}$$

The Specific gravity was calculated and found out be **0.53.**

6.1.2 Atomic Absorption Spectroscopy

Atomic absorption spectroscopy was done on the tanned leather waste ash to determine the contents of various compounds present in the tanned leather waste ash. Table 1 gives the result. The test was done at a laboratory in Chandigarh.

Test parameter	Results	Units
Iron (Fe_2O_3)	3280.9	mg/kg
Chromium	37481.3	mg/kg
Nitrogen	6790	mg/kg
Calcium	420000	mg/kg
Sodium (NaO_2)	21000	mg/kg
Carbon Content	21.94	%

Table 1 Atomic Absorption Spectroscopy result.

From the **Table 1** it is evident that the tanned leather waste ash contains high amounts of calcium and chromium .

6.2 Tests performed on B.C.S

6.2.1 Sieve Analysis

For sieve analysis 1 kg of black cotton soil was taken

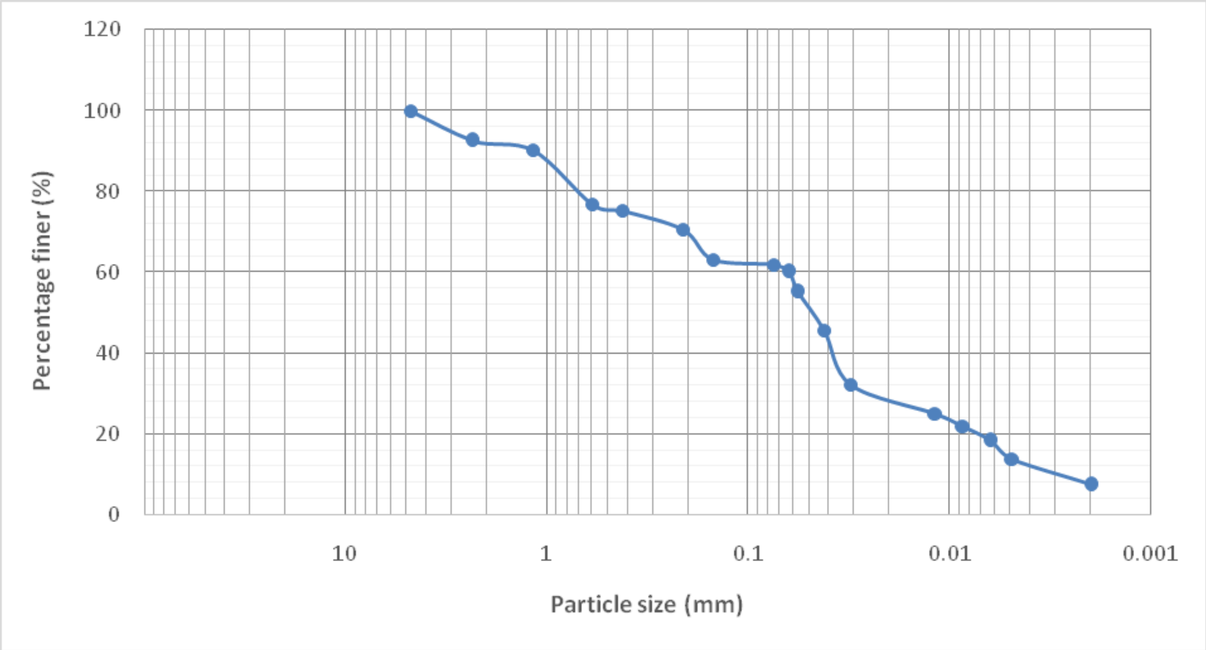


Figure 6.1 Particle size distribution of B.C.S

- The percentage of soil which was retained on 75-micron sieve was = 38.1%. The Soil percentage which passed through 75-micron sieve was 61.9%.
- Percentage of soil which passed through 75-micron sieve is more than 50% so according to IS:1948-1970 the soil is classified as a fine soil**.** As per IS criteria the soil is fine grained soil. Furthermore, plasticity index of the soil lies below the A-line hence it is OH.
- D_{60} , D_{30} and D_{10} were calculated and were found out having values as 0.069 mm, 0.029 mm and 0.0027 mm respectively.
- Similarly C_u and C_c were calculated and were found out having values as 25.1 and 4.51.

6.2.2 Liquid Limit

Liquid limit the water content at which soil starts to behave as liquid. It is the value of moisture content corresponding to 25 blows. Water contents corresponding to different blows are plotted in a semi-log graph.

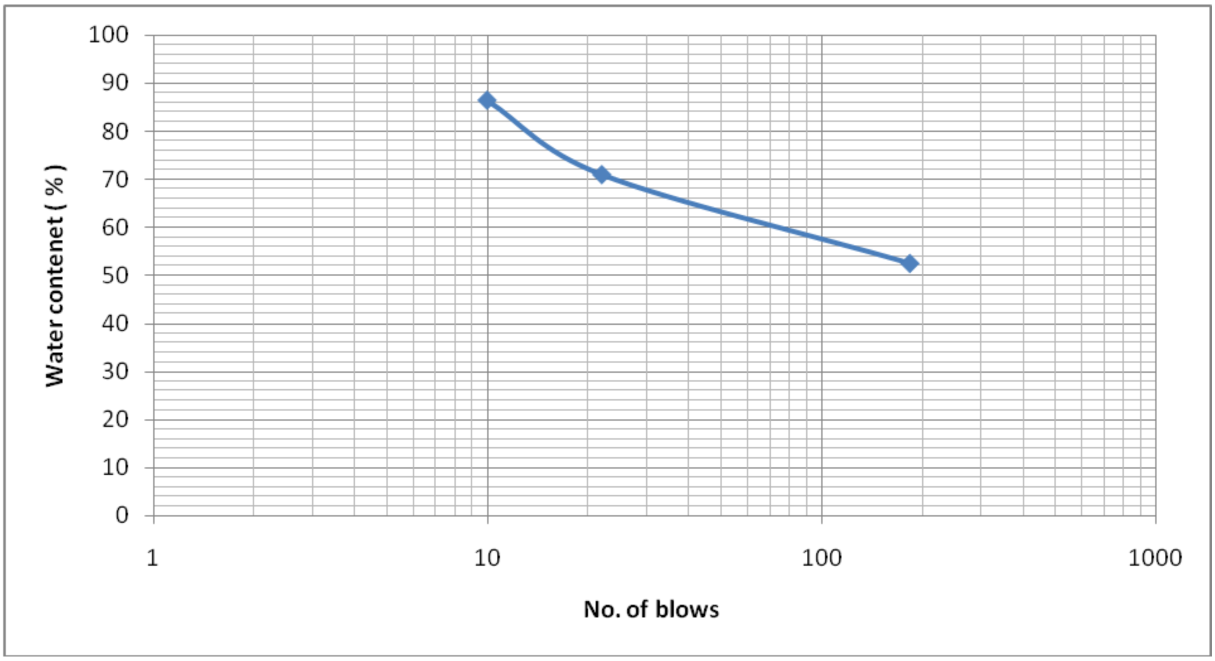


Figure 6.2 Flow curve for black cotton soil

The liquid limit is calculated as the water content corresponding to 25 blows. The liquid limit of Black cotton soil was found out to be **69.3 %. (Annexure 1.1.3)**

6.2.3 Plastic Limit

Plastic limit is the moisture content at which soil starts to behave as a plastic material i.e. soil can be moulded without crack formation.

The plastic limit of the black cotton soil was calculated to be **41.35 %. (Annexure 1.1.5)**

6.2.4 Plasticity Index

Plasticity index defines the range of water contents over which soil remains in plastic state. It is calculated as subtraction of Liquid limit and Plastic limit.

PLASTICITY INDEX (I_p) = LIQUID LIMIT – PLASTIC LIMIT

69.3 – 41.35 = **27.95.**

6.2.5 Shrinkage Limit

Shrinkage limit is the maximum moisture content at which any reduction in moisture content soil will not cause any reduction in volume of soil. It is measured with the help of shrinkage dish. The shrinkage limit was found out to be **8.95%. (Annexure 1.1.4)**

6.2.6 Optimum Moisture Content

Optimum moisture content (O.M.C) is the moisture content at which when soil is compacted, we get the maximum dry density. For achieving maximum strength through soil, we need to compact it at O.M.C. O.M.C is obtained by plotting graph between dry density and moisture content of compacted soil. We have used Standard Proctor Method to determine the O.M.C.

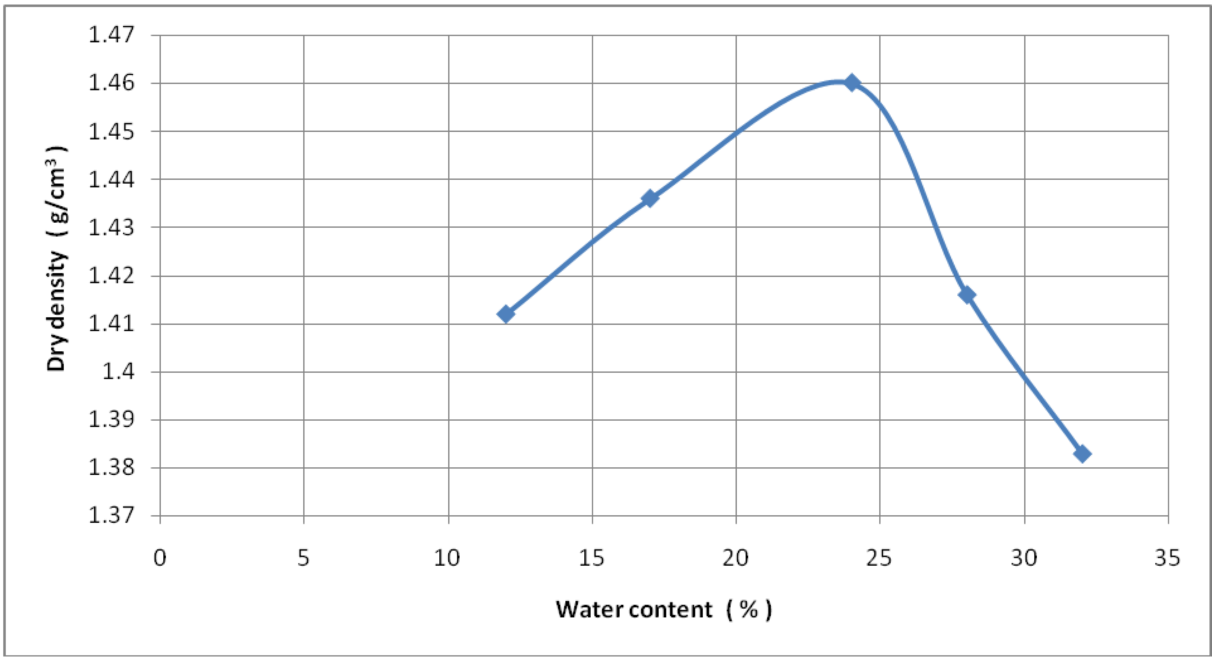


Figure 6.3 Standard proctor compaction curve

Figure 6.3 shows the variation of dry density with moisture content. From the curve it is evident that **M.D.D is 1.462** corresponding to **O.M.C of 23.4 %. (Annexure 1.1.6)**

6.2.7 Unconfined Compressive Strength Test

U.C.S measures the unconfined compressive strength of soil specimen. Unconfined compressive strength is strength of soil in such a condition where there is no lateral pressure acting on the soil.

The load obtained was **0.13 KN** and corresponding displacement was **4.22mm**.After calculating the unconfined compressive strength was found out to be **108.31 KN/m^2.**

6.2.8 California Bearing Ratio Test

California bearing ratio is a measure of the bearing capacity of soil. Load values corresponding to 2.5mm and 5mm are measured.

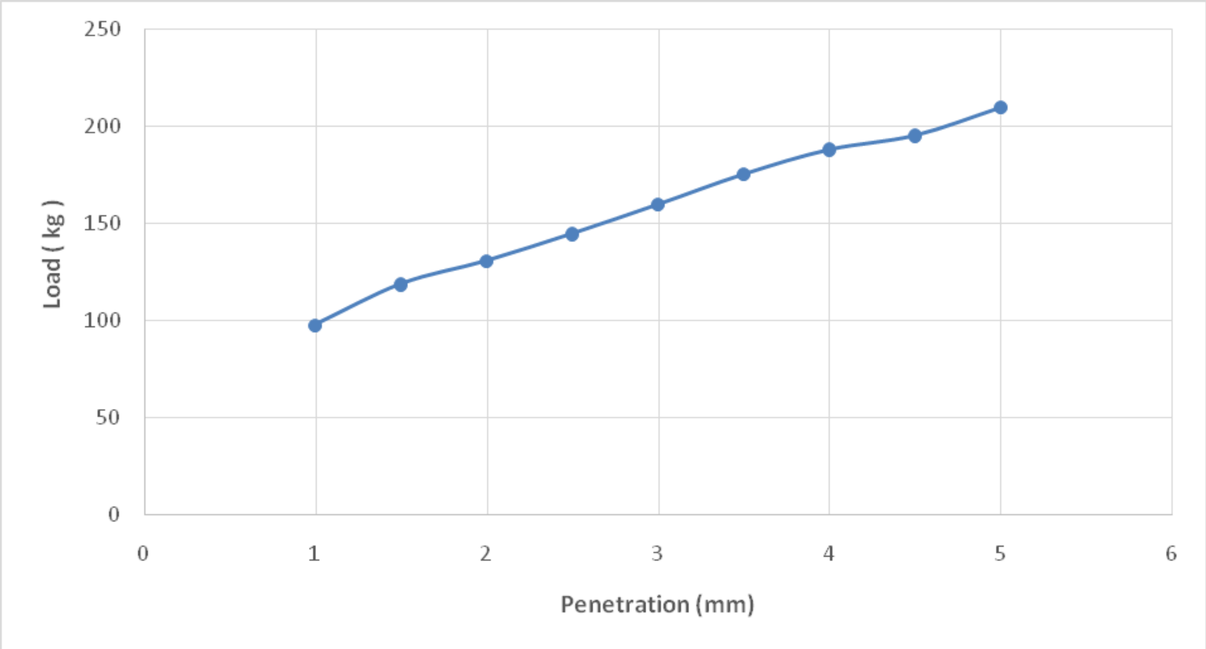


Figure 6.4 C.B.R Load penetration curve

C.B.R at 2.5mm = (145/1370) *100 =**10.51. (Annexure 1.1.7)**

C.B.R at 5mm = (210/2050) *100 = **10.24. (Annexure 1.1.7)**

6.2.9 Swell Test

The swelling and swelling pressure of B.C.S were **16.83 mm** and **4.2 kg/cm^2**.It indicates high swelling characteristics. **(Annexure 1.1.8)**

6.3 Tests performed on B.C.S + tanned leather waste ash

6.3.1 Liquid Limit

B.C.S was mixed with waste in 2%,4%,6%,8% and 10% by weight of soil.

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

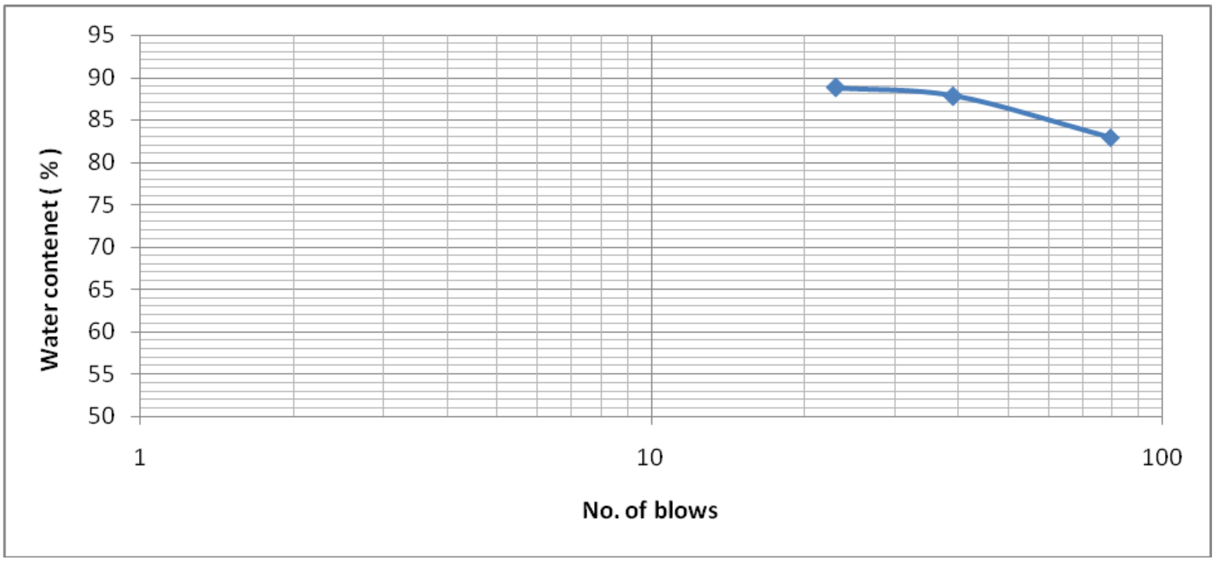


Figure 6.5 Flow curve for B.C.S + 2% tanned leather waste ash

The liquid limit for B.C.S + 2% tanned leather waste = **88.6 %. (Annexure 1.2.1)**

<u>B.C. S + 4% Tanned leather waste</u>

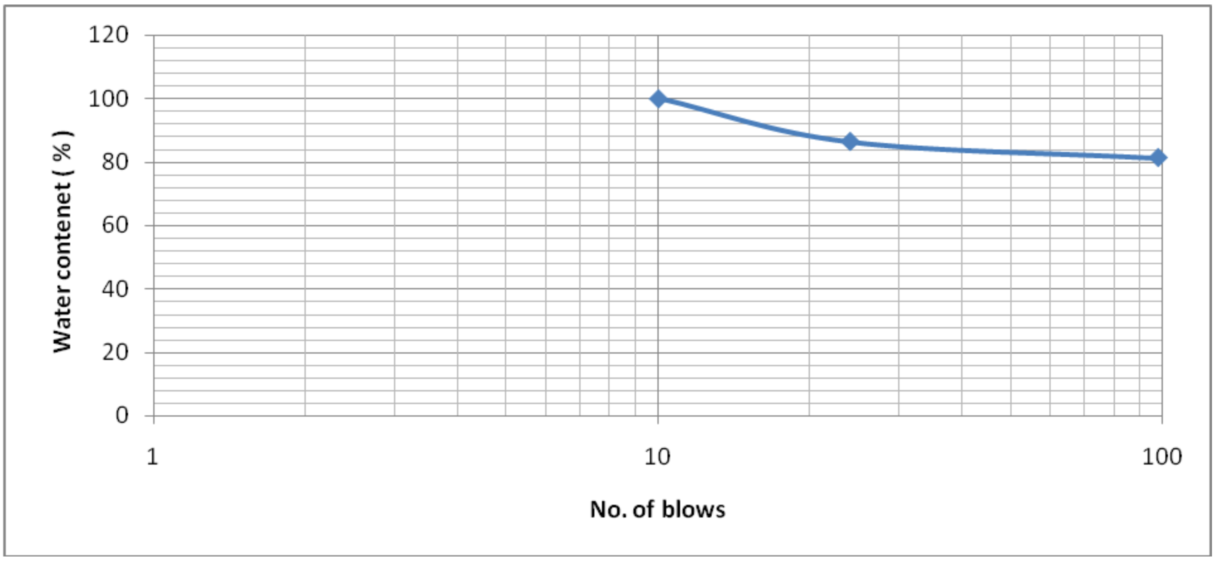


Figure 6.6 Flow curve for B.C.S + 4% tanned leather waste ash

The liquid limit for B.C.S + 4% tanned leather waste = **85.8 %. (Annexure 1.2.2)**

B.C. S + 6% Tanned leather waste .

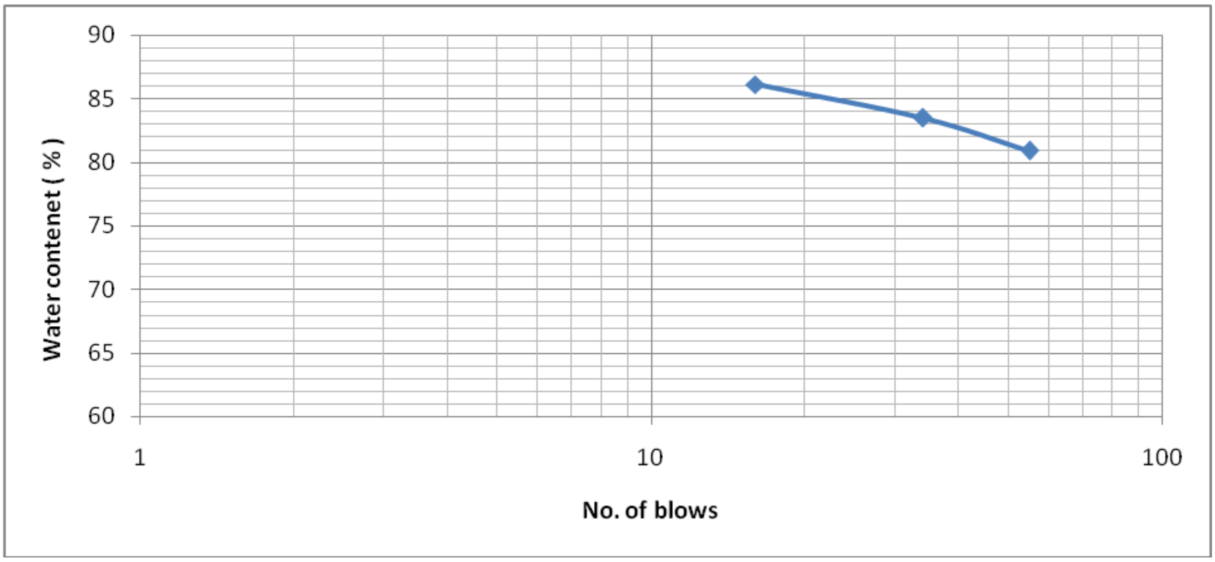


Figure 6.7 Flow curve for B.C.S + 6% tanned leather waste ash

The liquid limit for B.C.S + 6% tanned leather waste = **84.8 %. (Annexure 1.2.3)**

B.C. S + 8% Tanned leather waste

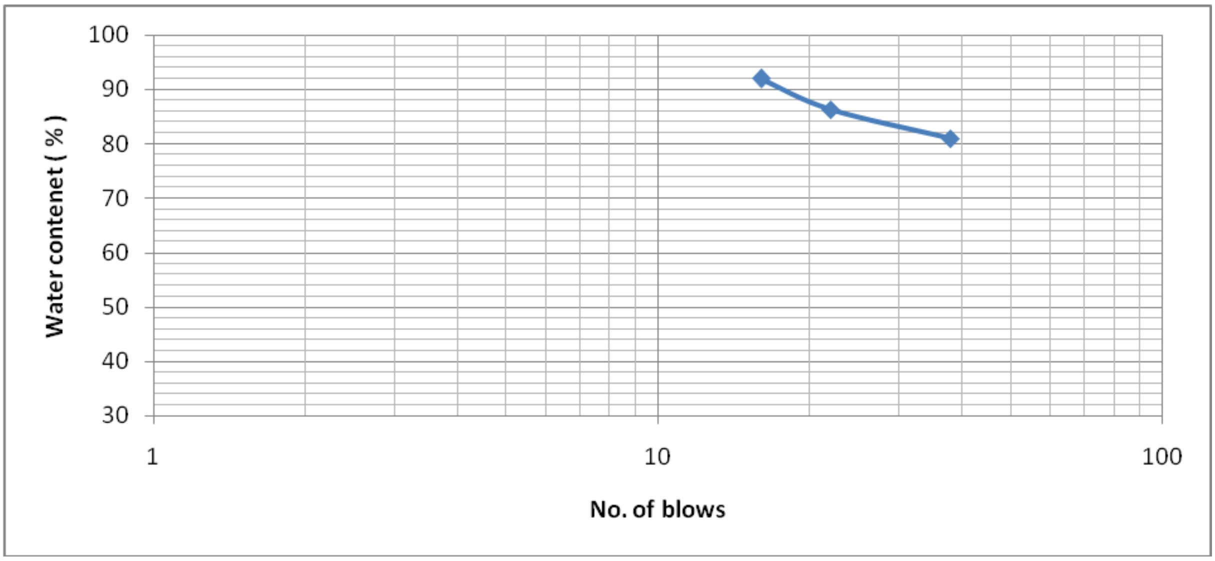


Figure 6.8 Flow curve for B.C.S + 8% tanned leather waste ash

The liquid limit for B.C.S + 8% tanned leather waste = **84.1 %. (Annexure 1.2.4)**

B.C. S + 10% Tanned leather waste

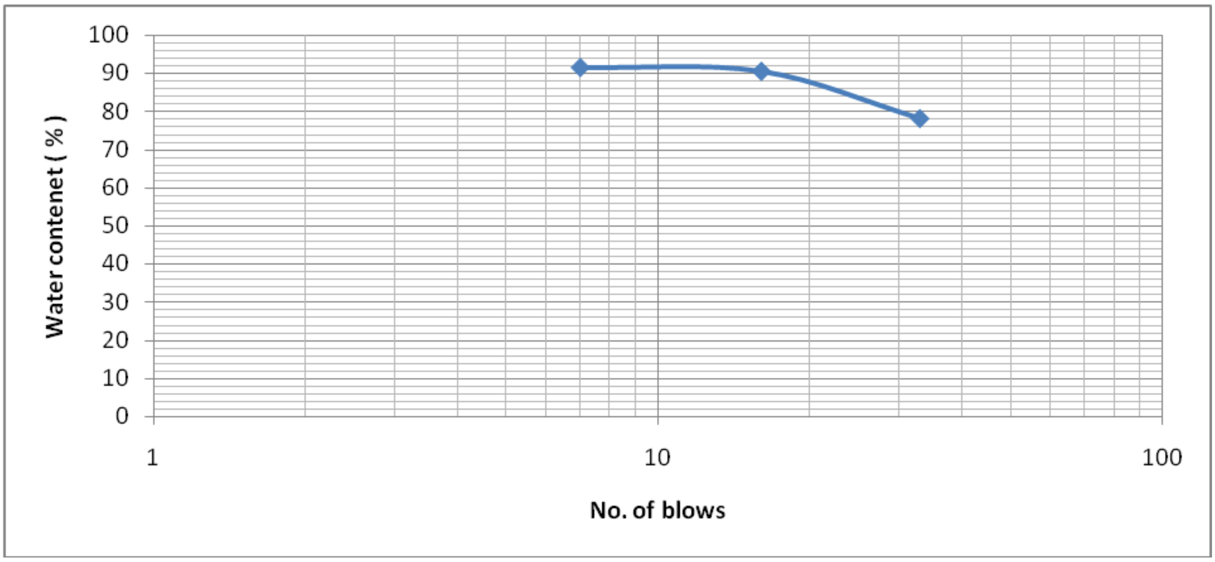


Figure 6.9 Flow curve for B.C.S + 10% tanned leather waste ash

The liquid limit for B.C.S + 10% tanned leather waste = **83.2 %. (Annexure 1.2.5)**

6.3.1.1 Variation of Liquid Limit with different waste contents.

Waste (%)	Liquid limit (%)
0	69.3
2	88.6
4	85.8
6	84.8
8	84.1
10	83.2

Table 2 Variation of Liquid limit with different tanned leather waste ash contents.

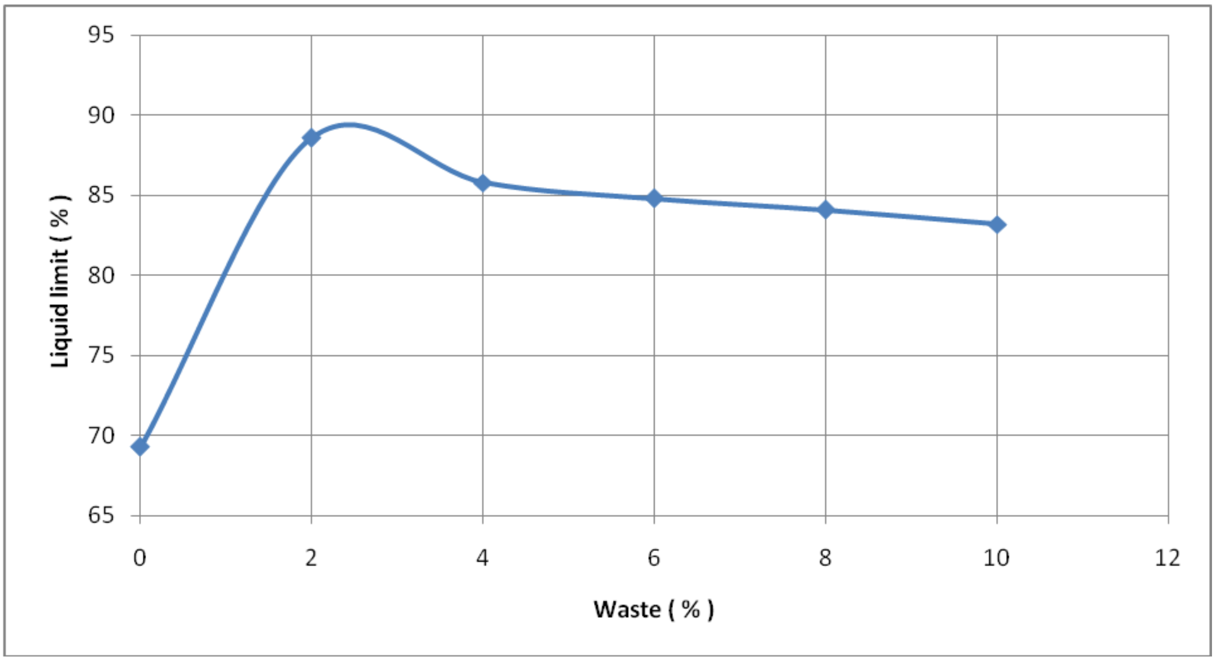


Figure 6.10 Variation of liquid limit with different tanned leather waste ash contents

It is evident from **Figure 6.10** that the liquid of B.C.S + tanned leather waste increases till 2% waste content but as the tanned leather waste content is increased further there is reduction in the liquid limit. The liquid limit decreases and reaches a minimum value of 83.2% corresponding to tanned leather waste content of 10%.

The initial increase in liquid limit, as tanned leather waste is fine and porous it may have absorbed water initially which caused soil to absorb high amount of water thus increasing liquid limit. Further with more tanned leather waste content, the Double diffusible layer thickness decreased due to chromium ions attaching to it instead of water molecules so it resulted in decrease in liquid limit.

6.3.2 Plastic Limit

6.3.2.1 Variation of Plastic Limit with different waste contents

For different percentages of tanned leather waste ash content different Plastic limits were observed. **Table 3** given below shows us the variation. **(Annexure 1.2.6 - 1.2.10)**

Waste (%)	Plastic limit (%)
0	41.35
2	44.32
4	50.68
6	50.87
8	45.33
10	41.12

Table 3 Variation of Plastic limit with different tanned leather waste ash contents.

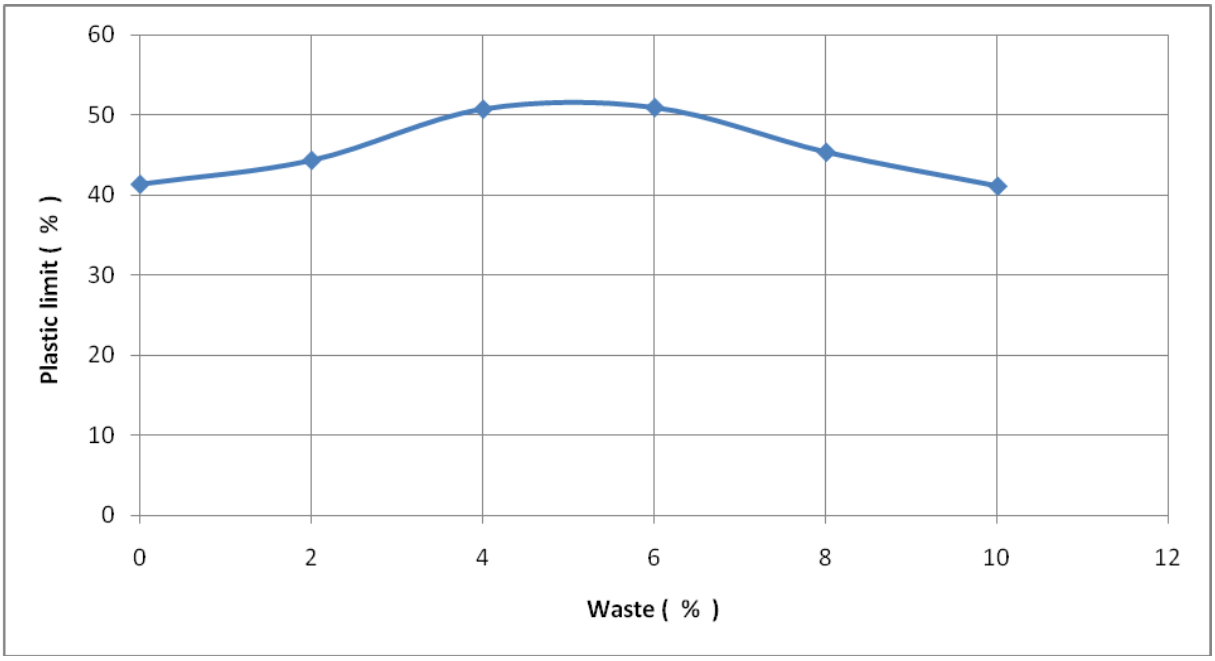


Figure 6.11 Variation of Plastic limit of B.C.S with different tanned leather waste ash contents.

From **Figure 6.11** it can be implied that with increase in tanned leather waste % the plastic limit starts to increase and reaches a max value of **50.87%** at **6%** tanned leather waste content and after that it starts to decrease reaching value of **41.12%** at **10%** tanned leather waste content.

6.3.3 Shrinkage Limit

6.3.3.1 Variation of Shrinkage Limit with different waste contents

For different percentages of tanned leather waste ash content different Shrinkage limits were observed. **Table 4** given below shows us the variation**. (Annexure 1.2.11-1.2.15)**

Waste (%)	Shrinkage limit (%)
0	8.95
2	12.35
4	13.6
6	14.05
8	14.15
10	14.35

Table 4 Variation of Shrinkage limit with different tanned leather waste ash contents.

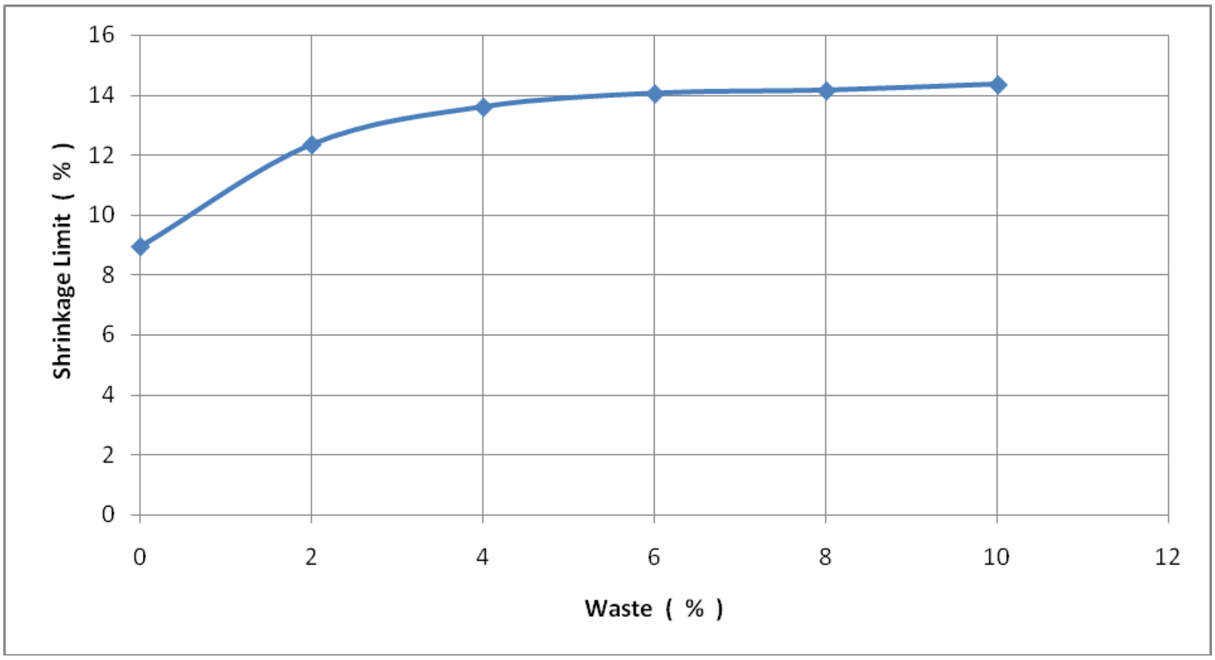


Figure 6.12 Variation of Shrinkage limit of B.C.S with different tanned leather waste ash contents

From the **Figure 6.12** it can be interpreted that there is increase in the shrinkage limit of B.C.S with increase in tanned leather waste ash content. Shrinkage limit reaches the maximum value of 14.35 % corresponding to 10% tanned leather waste ash content. The increase in Shrinkage limit indicates decrease in swelling of the Soil.

6.3.4 Optimum Moisture Content

For B.C.S + 2% ,4% ,6% ,8% and 10 % tanned leather waste ash, By means of standard proctor test optimum moisture content (O.M.C) and corresponding maximum dry density (M.D.D) were calculated.

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

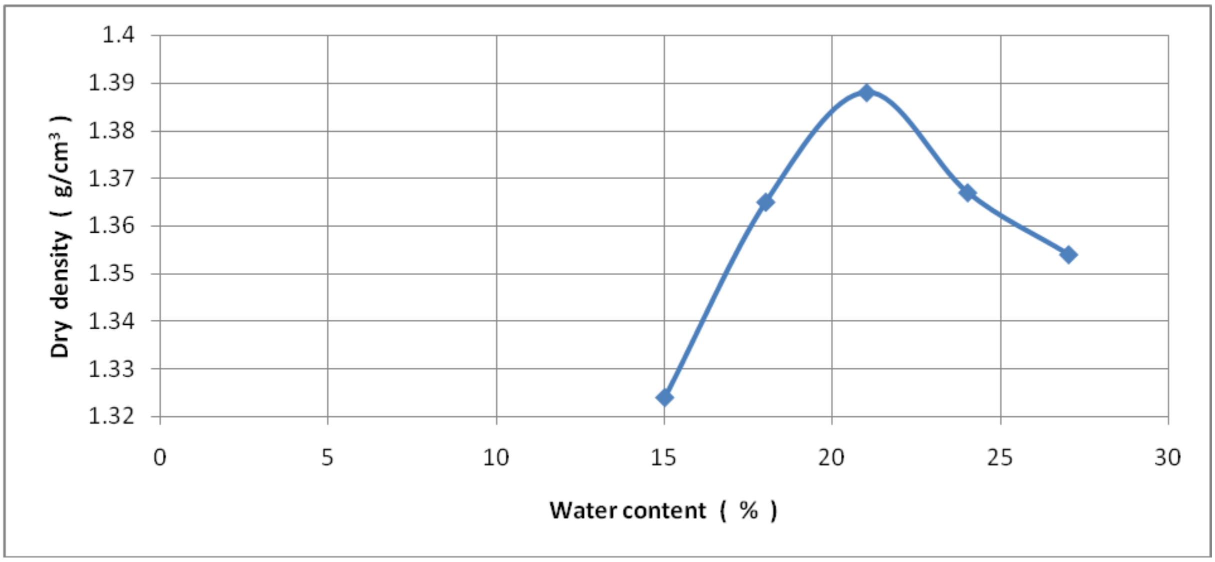


Figure 6.13 Standard proctor compaction curve B.C.S + 2% tanned leather waste ash

The optimum moisture content was found out to be **21.2 %** and the corresponding dry density is **1.38 g/cm^3. (Annexure 1.3.1)**

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

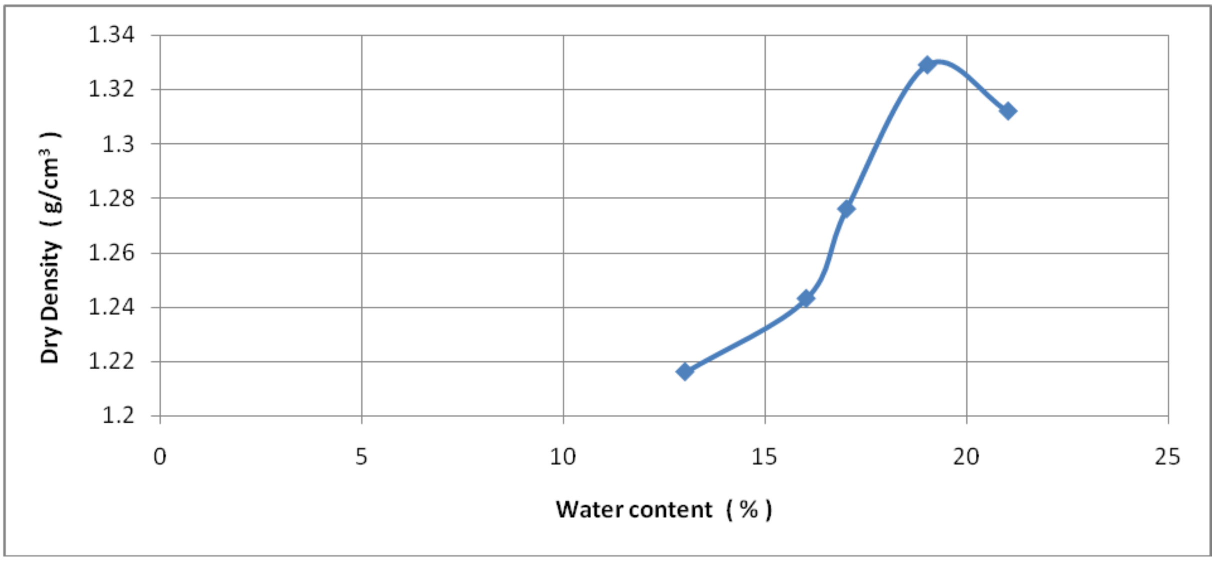


Figure 6.14 Standard proctor compaction curve B.C.S + 4% tanned leather waste ash

The optimum moisture content was found out to be 19 % and the corresponding dry density is 1.329 g/cm^3. **(Annexure 1.3.2)**

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

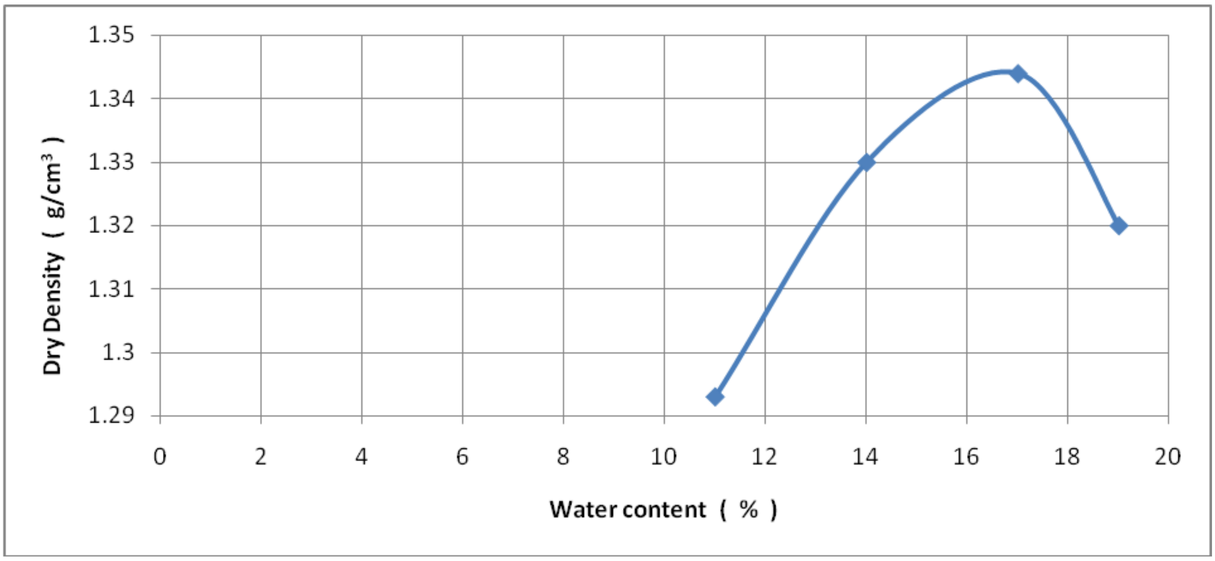


Figure 6.15 Standard proctor compaction curve B.C.S + 6% tanned leather waste ash

The optimum moisture content was found out to be 17.3 % and the corresponding dry density is 1.344 g/cm^3**. (Annexure 1.3.3)**

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

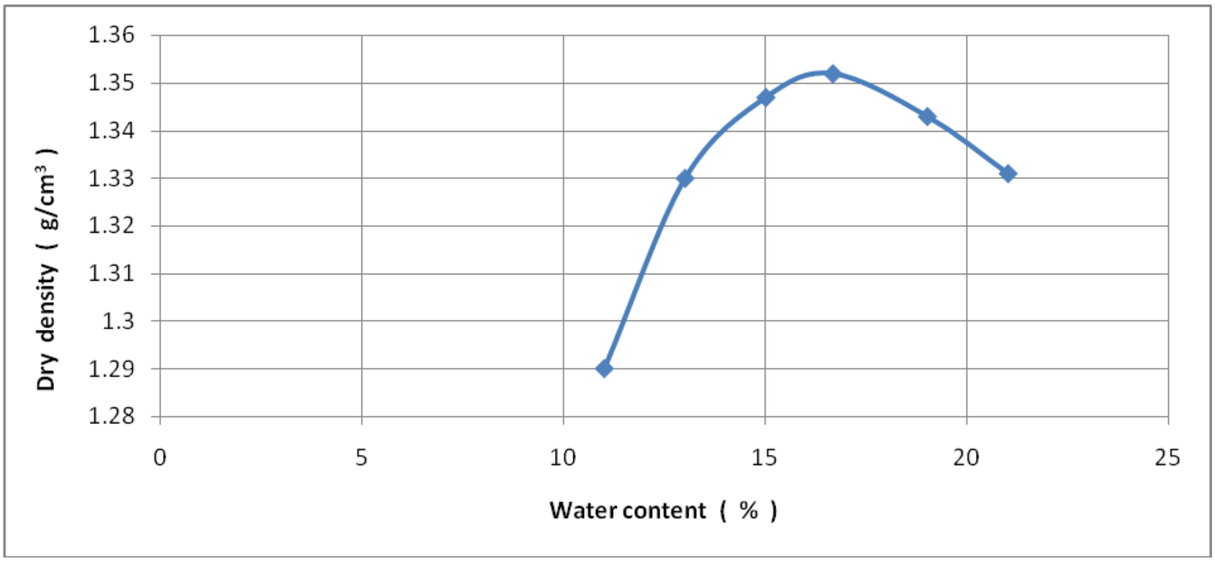


Figure 6.16 Standard proctor compaction curve B.C.S + 8 % tanned leather waste ash

The optimum moisture content was found out to be 16.66 % and the corresponding dry density is 1.352 g/cm^3. **(Annexure 1.3.4)**

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

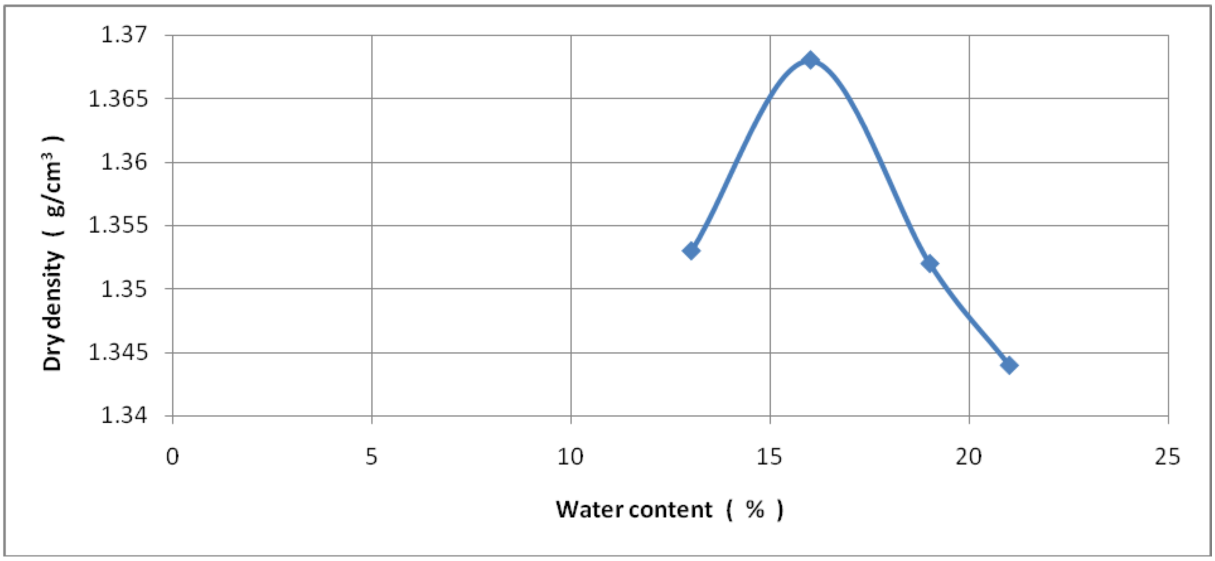


Figure 6.17 Standard proctor compaction curve B.C.S + 10 % tanned leather waste ash

The optimum moisture content was found out to be 15.8 % and the corresponding dry density is 1.368 g/cm^3. **(Annexure 1.3.5)**

6.3.4.1 Variation of O.M.C with tanned leather waste ash content

Waste (%)	**O.M.C (%)**
0	23.4
2	21.2
4	19
6	17.3
8	16.6
10	15.88

Table 5 Variation of O.M.C with different tanned leather waste ash contents.

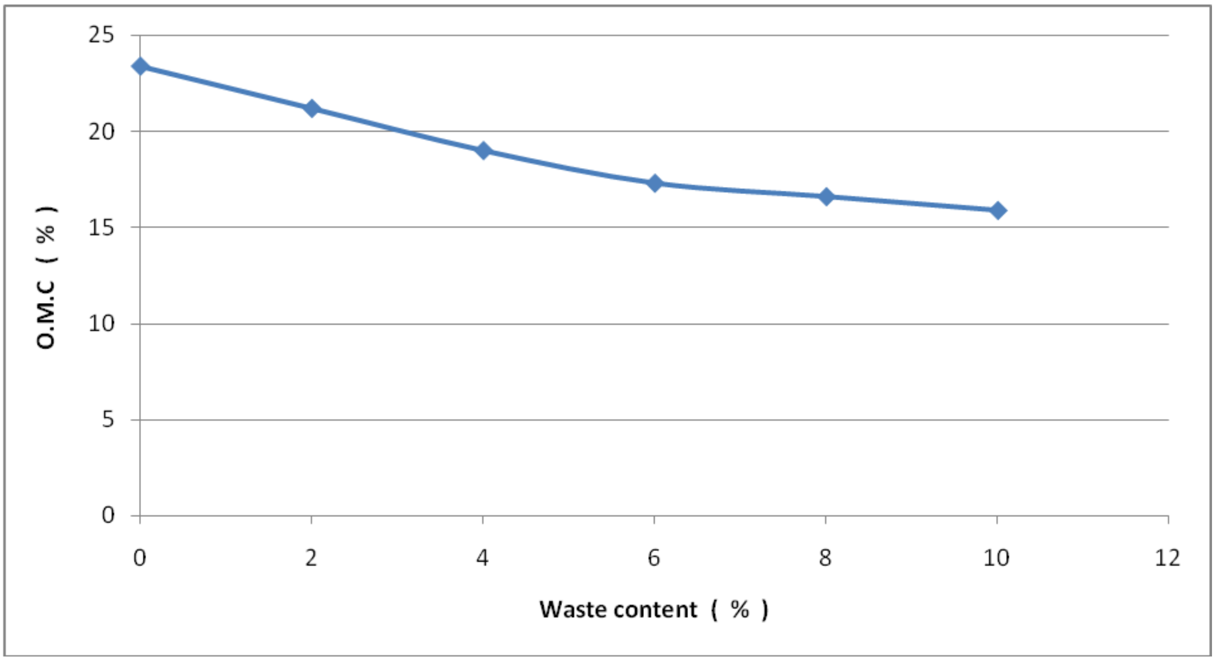


Figure 6.18 Variation of O.M.C with different tanned leather waste ash contents.

From the **Figure 6.18** it can be interpreted that with the addition of tanned leather waste ash there is decrease in the optimum moisture content of the Black cotton soil. This decrease can be explained by the increase in flocculation caused by the tanned leather waste ash

6.3.4.2 Variation of M.D.D with tanned leather waste ash content

Waste (%)	**M.D.D (g/cm^3)**
0	1.465
2	1.388
4	1.329
6	1.344
8	1.352
10	1.368

Table 6 Variation of M.D.D with different tanned leather waste ash contents.

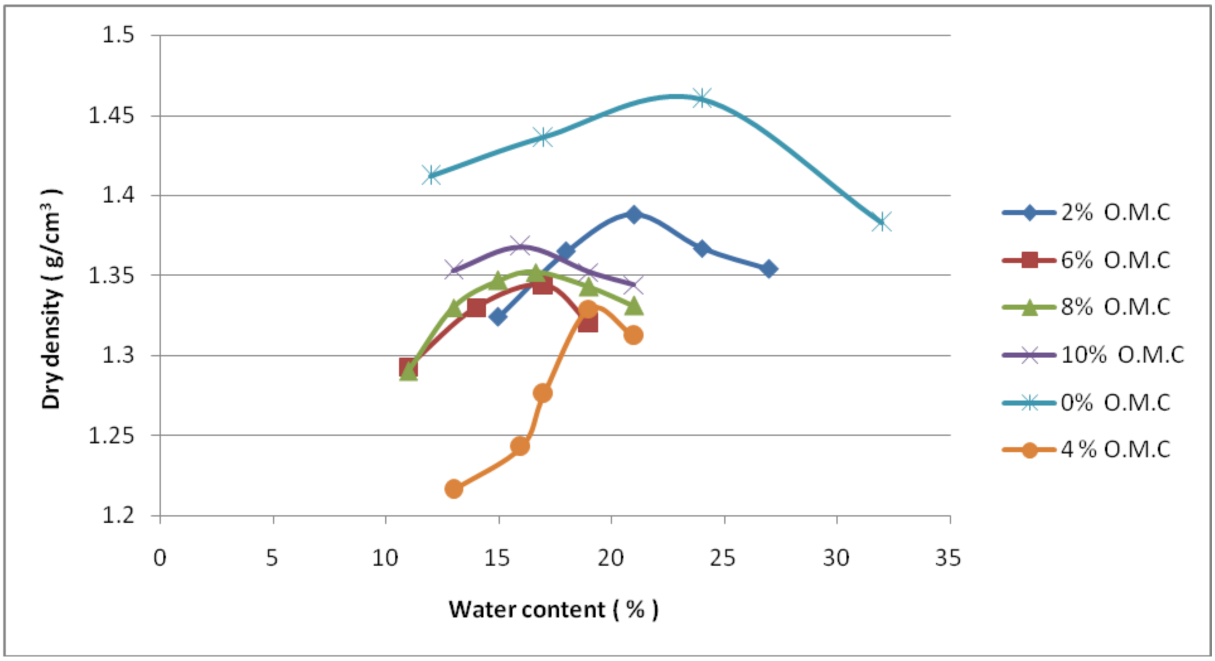


Figure 6.19 Variation of M.D.D with different tanned leather waste ash contents

From **Figure 6.19** it can be seen that with increase in tanned leather waste ash content there is decrease in M.D.D till 4% tanned leather waste ash content and corresponding M.D.D is 1.344 g/cm^3. This can be explained due to the fact that the specific gravity of the tanned leather waste ash is 0.53 and specific gravity of soil will be much more than this .Due to replacement of some part of soil with tanned leather waste ash causes this decrease in dry density.

After tanned leather waste ash content of 4% , there is increase in the M.D.D . M.D.D reaches value of 1.368 g/cm^3 at 10 % tanned leather waste ash content.

6.3.5 Unconfined Compressive Strength

For B.C.S + 2% ,4% ,6% ,8% and 10 % tanned leather waste ash the unconfined compressive strength (U.C.S) was found.

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

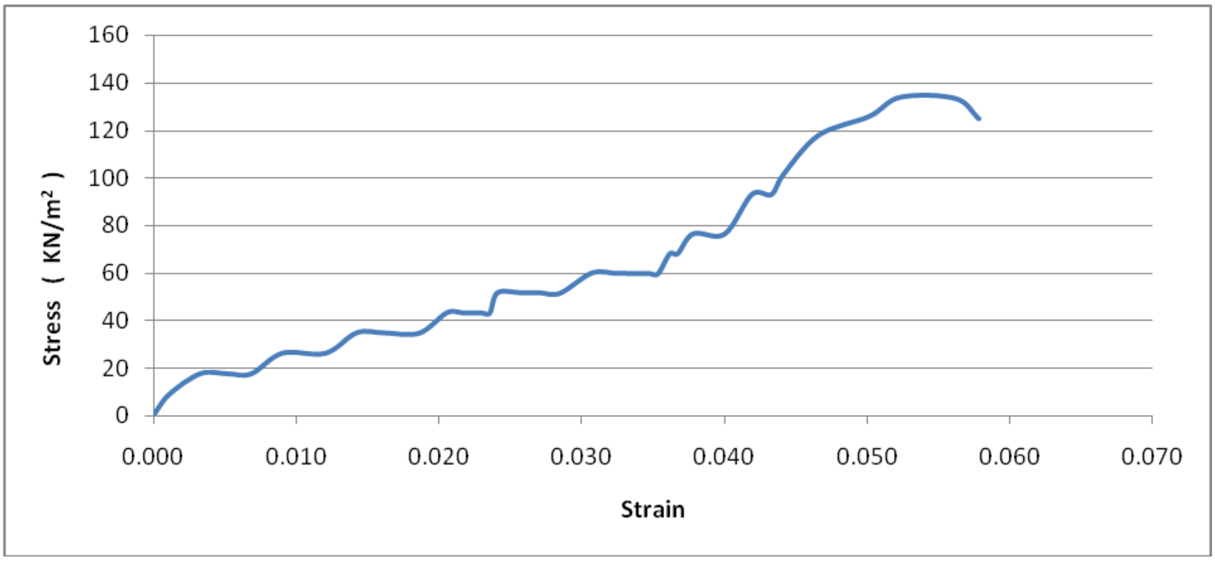


Figure 6.20 Stress - Strain curve B.C.S + 2 % tanned leather waste ash

The Unconfined Compressive strength was found out to be **133.76 . (Annexure 1.4.1)**

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

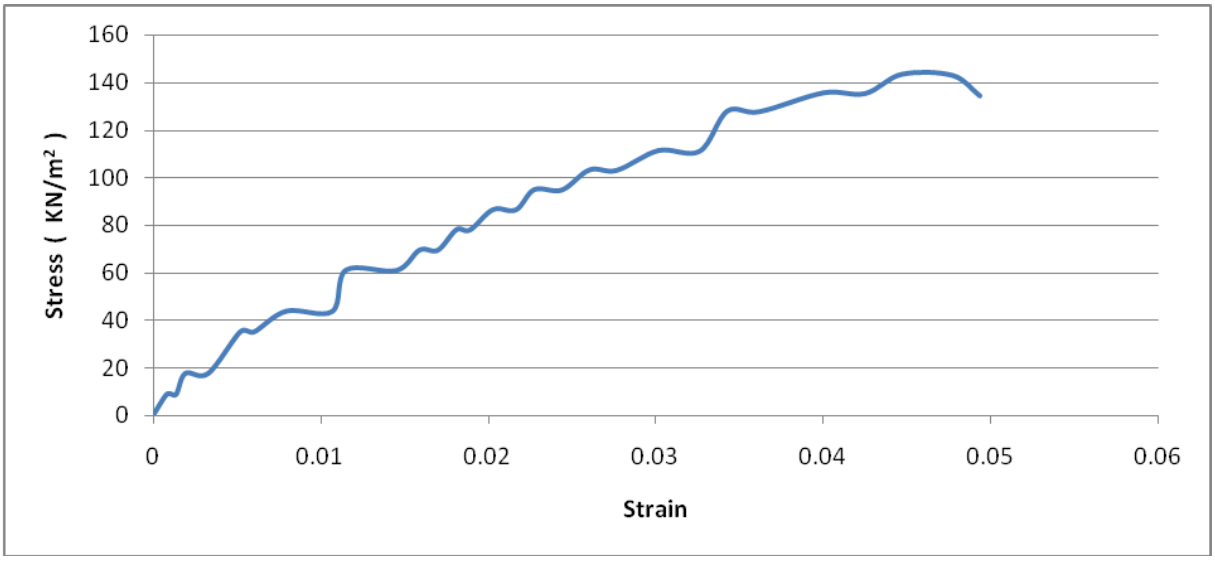


Figure 6.21 Stress - Strain curve B.C.S + 4 % tanned leather waste ash

The Unconfined Compressive strength was found out to be **143.27 . (Annexure 1.4.2)**

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

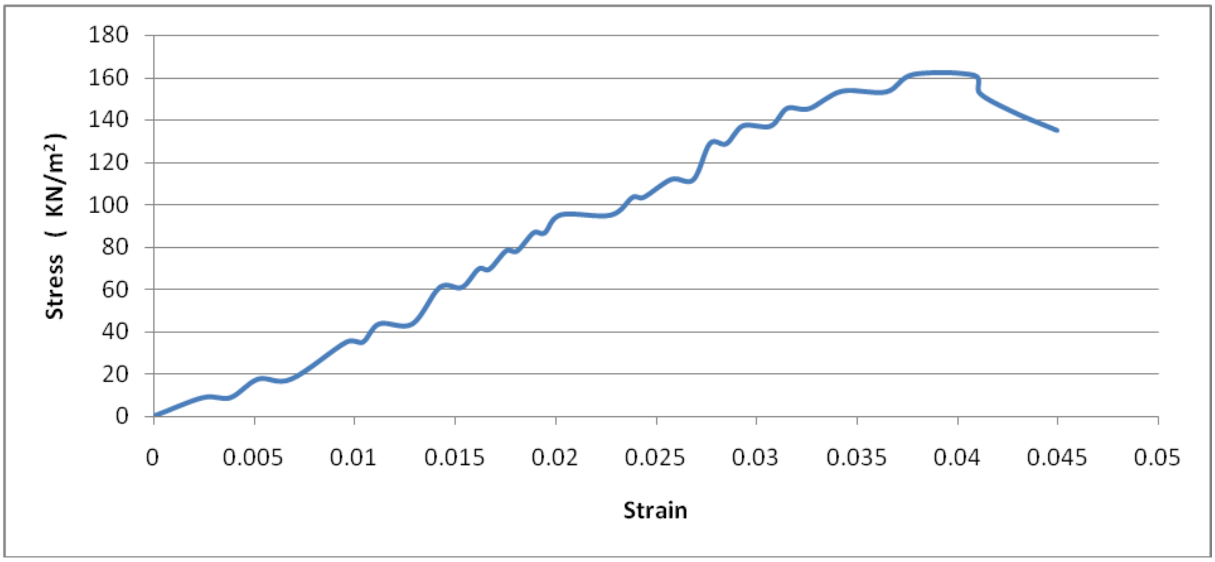


Figure 6.22 Stress - Strain curve B.C.S + 6 % tanned leather waste ash

The Unconfined Compressive strength was found out to be **161.273 . (Annexure 1.4.3)**

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

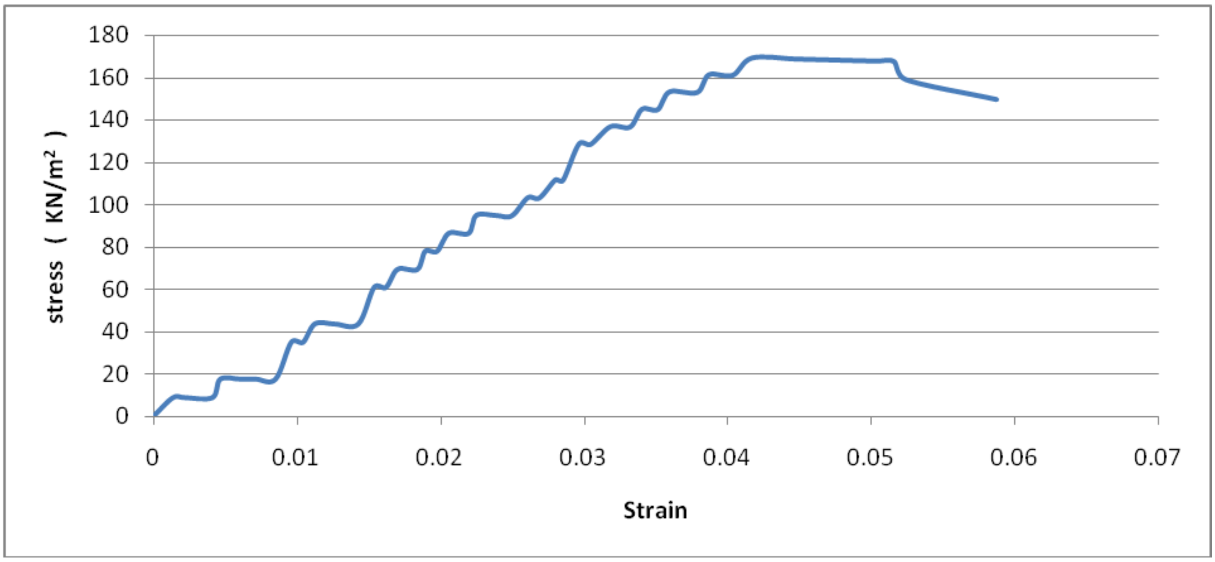


Figure 6.23 Stress - Strain curve B.C.S + 8 % tanned leather waste ash

The Unconfined Compressive strength was found out to be **186.025 . (Annexure 1.4.4)**

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

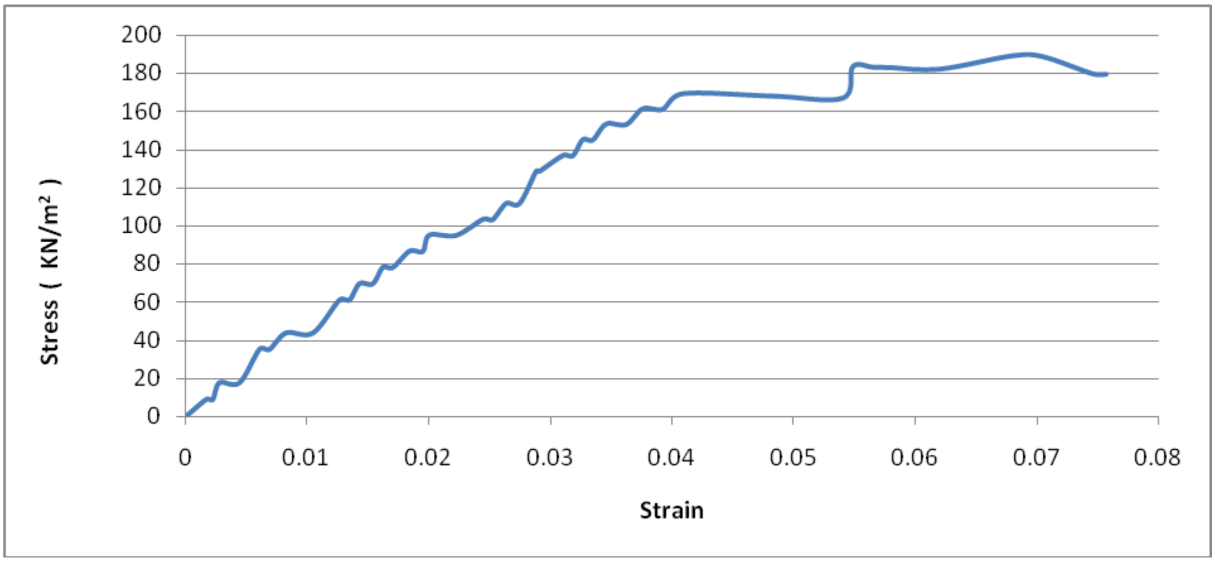


Figure 6.24 Stress - Strain curve B.C.S + 10 % tanned leather waste ash

The Unconfined Compressive strength was found out to be **189.11. (Annexure 1.4.5)**

6.3.5.1 Variation of U.C.S with tanned leather waste ash content.

Table 7 gives the variation of U.C.S with different percentages of tanned leather waste ash added.

Waste (%)	**U.C.S (KN/m^2)**
0	108.31
2	133.76
4	143.27
6	161.27
8	169.086
10	189.11

Table 7 Variation of U.C.S with different tanned leather waste ash contents.

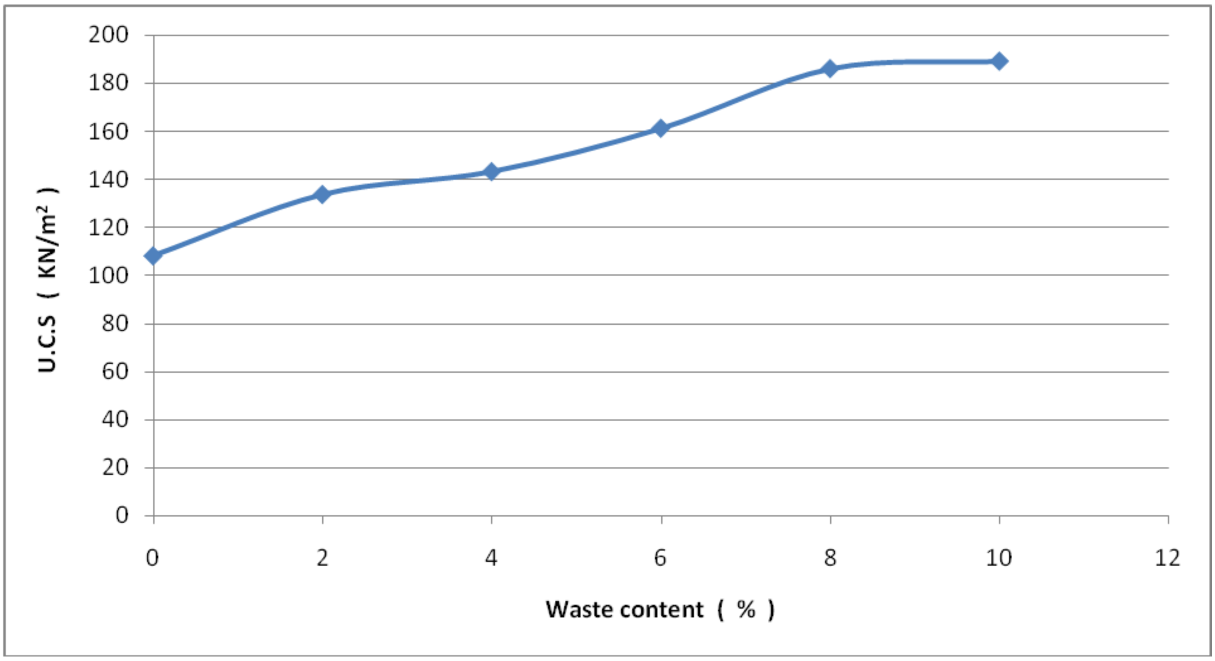


Figure 6.25 Variation of U.C.S with different tanned leather waste ash contents.

From **Figure 6.25** it can be interpreted that there is increase in the Unconfined compressive strength of B.C.S with increase in tanned leather waste ash content. Unconfined compressive strength reaches a maximum value of 189.11 KN/m^2 at 10% tanned leather waste ash content. This increase in Unconfined compressive strength is maybe due to change in the compaction parameters done at O.M.C.

6.3.6 California Bearing Ratio Test

California bearing ratio (C.B.R) tests were performed on both plain B.C.S and B.C.S with addition of tanned leather waste ash in 2%,4%,6%. C.B.R test helps in determining the suitability of a material as a sub grade for pavement.

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

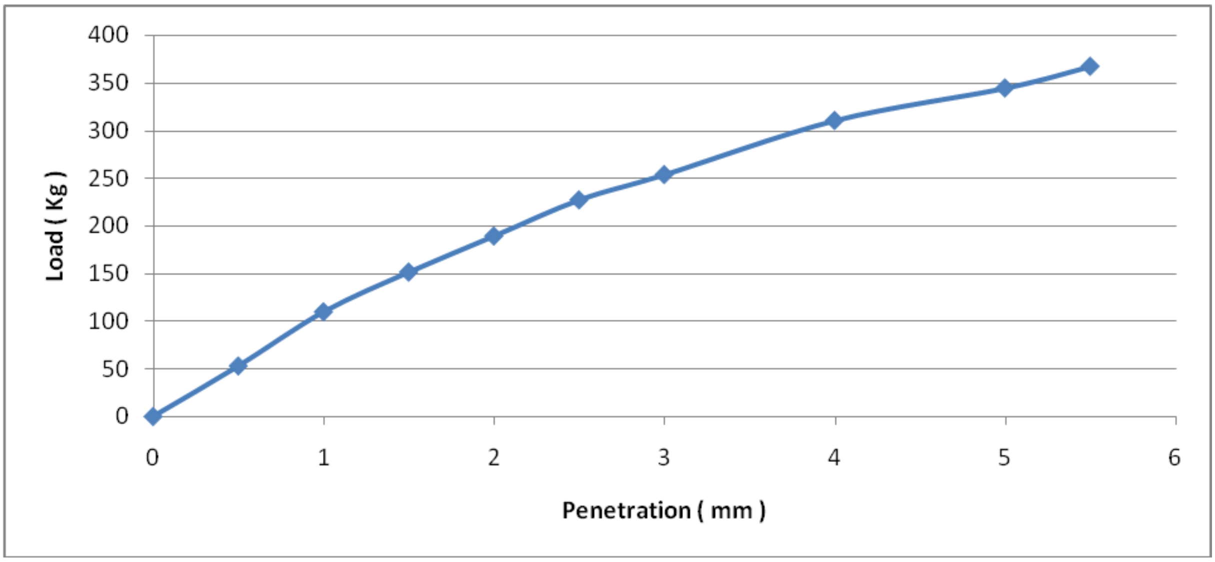


Figure 6.26 C.B.R curve for B.C.S + 2 % tanned leather waste ash

The maximum C.B.R value was found out to be **16.7 %** corresponding to 5 mm. **(Annexure 1.5.1)**

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

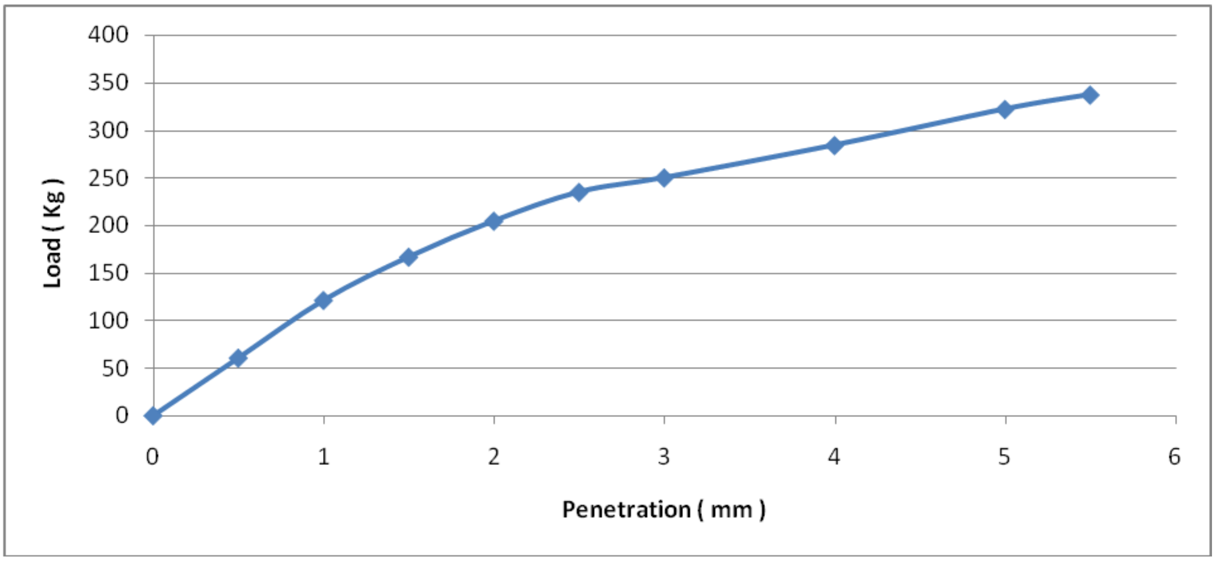


Figure 6.27 C.B.R curve for B.C.S + 4 % tanned leather waste ash

The maximum C.B.R value was found out to be **17.1 %** corresponding to 2.5 mm. **(Annexure 1.5.2)**

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

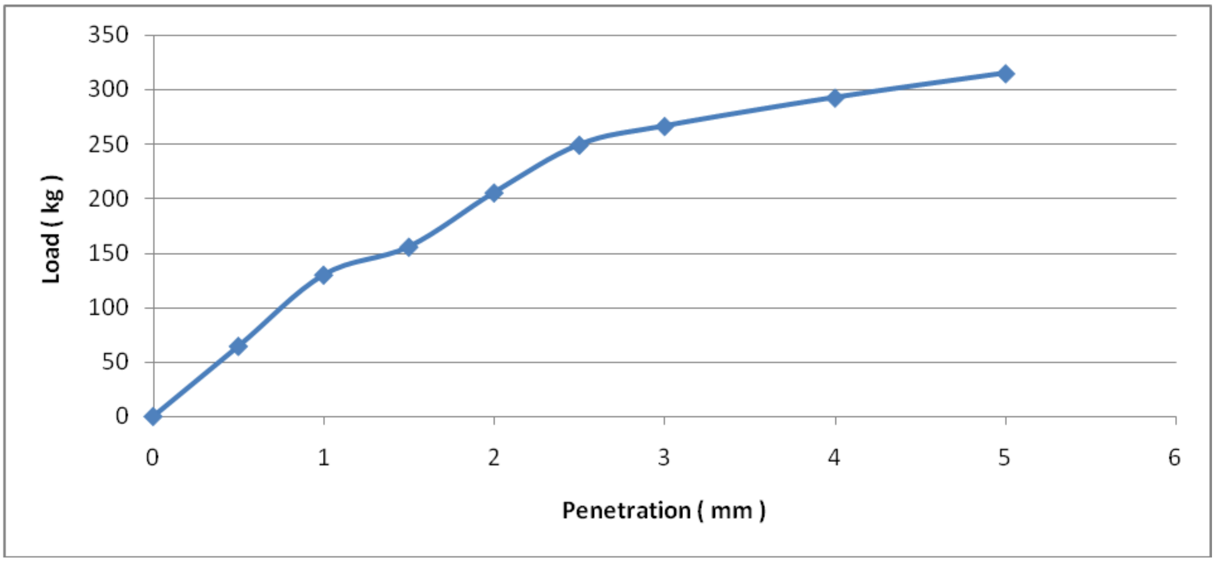


Figure 6.28 C.B.R curve for B.C.S + 6 % tanned leather waste ash

The maximum C.B.R value was found out to be **18.2 %** corresponding to 2.5 mm**. (Annexure 1.5.3)**

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

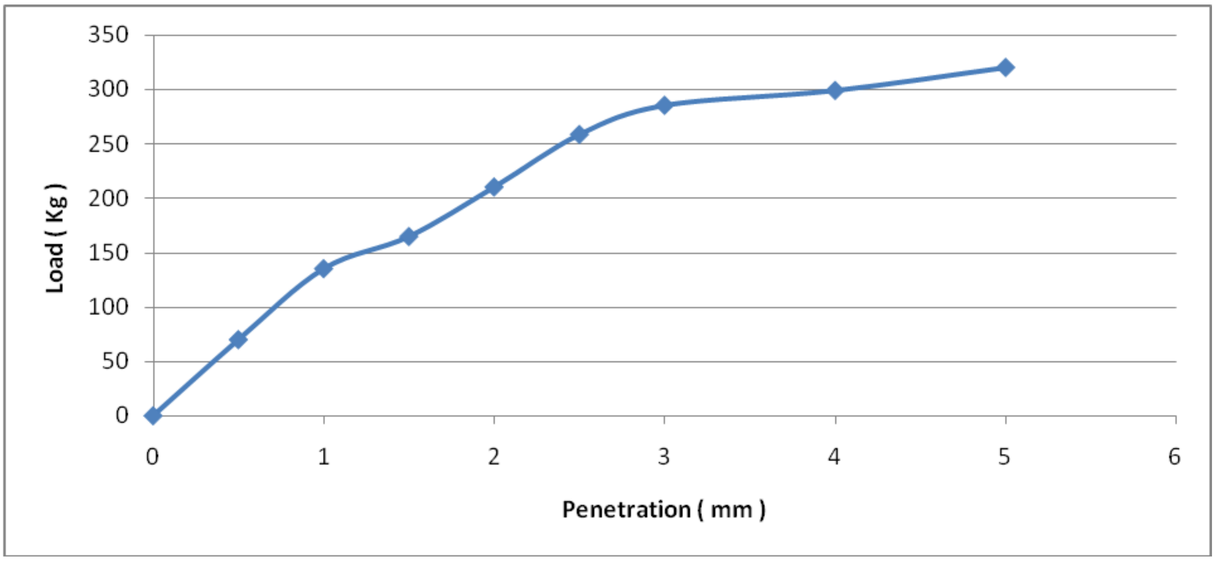


Figure 6.29 C.B.R curve for B.C.S + 8 % tanned leather waste ash

The maximum C.B.R value was found out to be **18.8 %** corresponding to 2.5 mm. **(Annexure 1.5.4)**

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

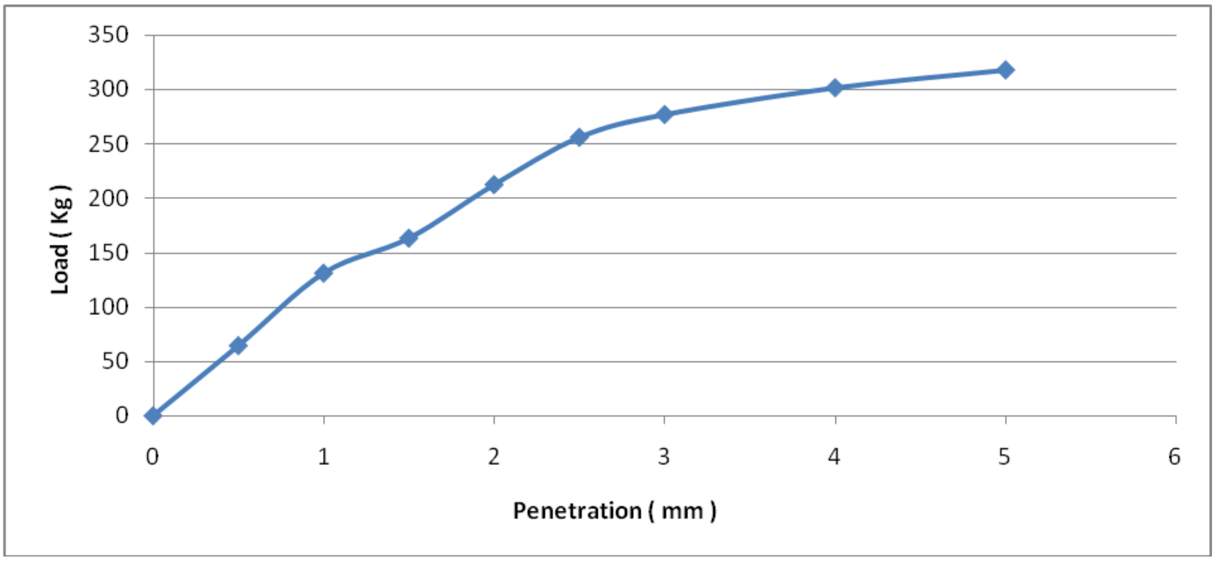


Figure 6.30 C.B.R curve for B.C.S + 10 % tanned leather waste ash

The maximum C.B.R value was found out to be **18.6 %** corresponding to 2.5 mm. **(Annexure 1.5.5)**

6.3.6.1 Variation of C.B.R value with tanned leather waste ash content

Waste (%)	C.B.R
0	10.51
2	16.7
4	17.1
6	18.2
8	18.8
10	18.6

Table 8 Variation of C.B.R Value with different tanned leather waste ash contents.

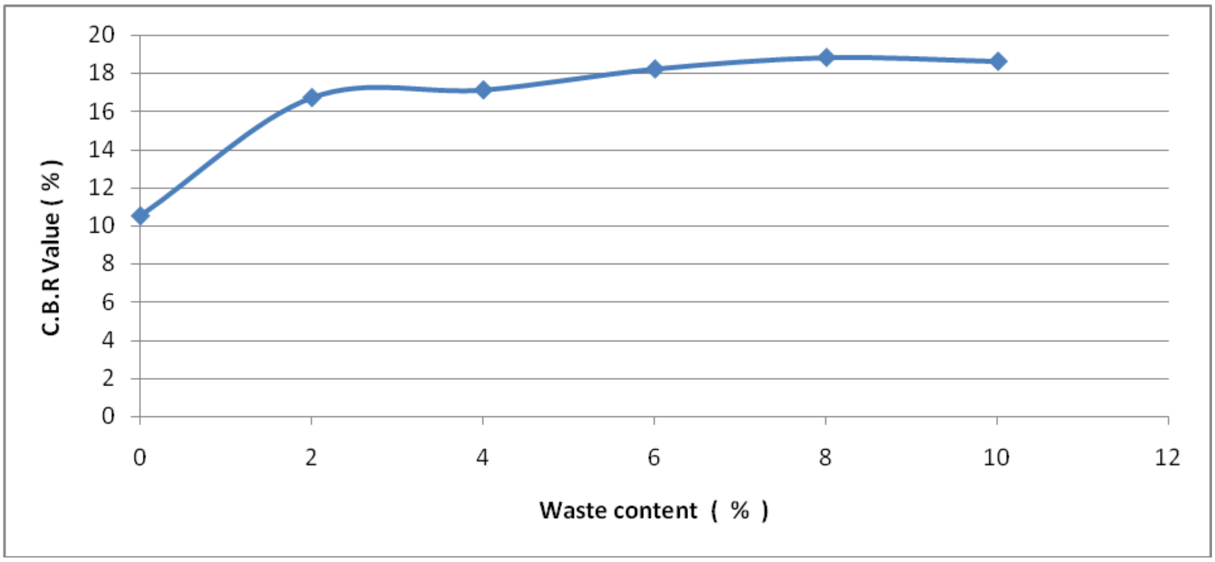


Figure 6.31 Variation of C.B.R Value with different tanned leather waste ash contents.

From **Figure 6.31** it can be interpreted that there is increase in C.B.R value with increase in tanned leather waste ash till 8% tanned leather waste ash content.C.B.R reaches a maximum value of 18.8 at 8 % tanned leather waste ash content. After this there is a slight decrease in C.B.R value . As there is increase in C.B.R value it can be said that the tanned leather waste ash mixed with B.C.S has improved its use as a sub grade material.

6.3.7 Swell Test

6.3.7.1 Variation of Swelling and Swelling pressure at different waste ash contents

In this test the swelling (mm) and swelling pressure (kg/cm^2) of B.C.S with different waste contents were determined. **Table 9** provides us the readings corresponding to B.C.S with different waste contents. **(Annexure 1.6.1 - 1.6.5)**

Waste content (%)	Swelling (mm)	Swelling pressure (kg/cm^2)
0	16.83	4.2
2	13.91	1.8
4	12.5	0.95
6	12.21	0.85
8	13.02	1.7
10	14.06	1.95

Table 9 Variation of Swelling and Swelling Pressure with different tanned leather waste ash contents.

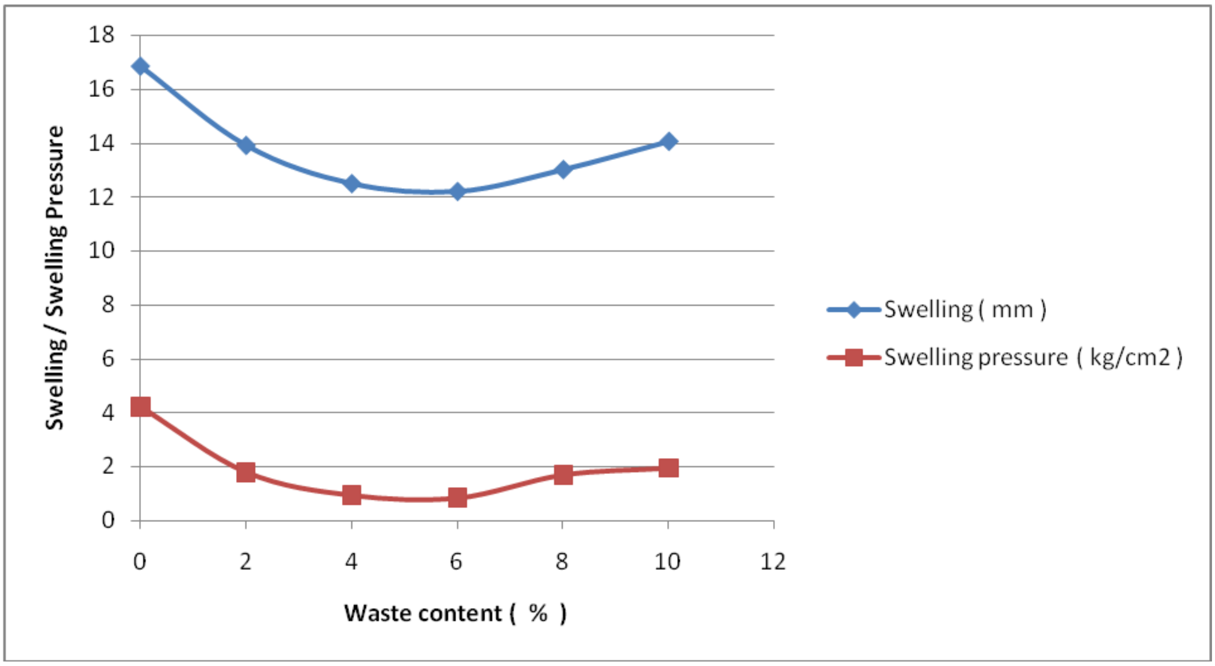


Figure 6.32 Variation of Swelling and Swelling Pressure with different tanned leather waste ash contents.

From the **Figure 6.32** it is evident that Swelling and swelling pressure both decrease with increase in waste content till it reaches a minimum value corresponding to 6% tanned leather waste ash content after which they start to increase. The minimum value of swelling is found out to be 12.21 mm and corresponding swelling pressure is 0.85 kg/cm^2.

The decrease of 27.4 percent in swelling for 6% tanned leather waste ash content is observed. The decrease of 79.4 percent in swelling pressure for 6% tanned leather waste ash content is observed.

CHAPTER 7
CONCLUSION

- The black cotton soil used in this Project has high swelling characteristics as the swelling and swelling pressure are 16 mm and 4.2 Kg/cm^2 respectively.
- Tanned leather waste ash can be used for stabilising the B.C.S as there are improvements in Strength and swelling characteristics.
- The decrease of 27.4 percent in swelling for 6% tanned leather waste ash content is observed.
- The decrease of 79.4 percent in swelling pressure for 6% tanned leather waste ash content is observed.
- The U.C.S value changes from 108.31 KN/m^2 to 189.11 KN/m^2 corresponding to 10 % tanned leather waste ash content .Thus there is 74.6 % increase in the U.C.S.
- C.B.R value increased from 10.51 % for Plain B.C.S to 18.8% for B.C.S with 8% tanned leather waste ash.
- The results shows us good values for both strength and swelling at 6% tanned leather waste ash content. So it is the optimum content of tanned leather waste ash.
- By using Tanned leather waste ash in stabilisation of B.C.S ,it is an eco friendly solution to the pollution related to tanneries and problems faced by engineers on black cotton soil.

Future Scope

Use of tanned leather waste ash as stabiliser can be concluded from the experimental results. With the addition of tanned leather waste ash there is improvement in swelling and strength of the B.C.S.

- In this project tanned leather waste was open burned with no control in temperature. By incinerating tanned leather at controlled temperature may yield different results.
- By products of various industries containing heavy metals can also be used to stabilize the soil.

References

[1] Kavouras, P., Pantazopoulou, E., Varitis, S., Vourlias, G., Chrissafis, K., Dimitrakopulos, G., . . . Xenidis, A. (2015). Incineration of tannery sludge under oxic and anoxic conditions: Study of chromium speciation. *Journal of Hazardous Materials, 283*, 672-679.

[2] Punmia,B.C , Jain,Ashok k.,Jain,Arun K.(2005) "*Soil mechanics and Foundations*." New Delhi: Laxmi Publications (P).

[3] G R,Harish(2017) "Studies on stabilisation of black cotton soil using lime." *International Research Journal Of Engineering And Technology,* volume 4(6).

[4] Fulzele, U.G. et al.(2016)"Study of structures on black cotton soil." *International journal of advances in science, engineering and technology,* volume 4(4)

[5] Belay, A. A. (2010). Impacts of Chromium from Tannery Effluent and Evaluation of Alternative Treatment Options. *Journal of Environmental Protection, 01*(01), 53-58.

[6] Ramteke,Neetu (2014)"Stabilisation of Black cotton soil with sand and cement as a subgrade for pavement" *IJESRT,* volume 3(6)

[7] Singh,P Akhand,Rao,P Devendra (2013)"Assessments Of Tannery Effluent: A Case study Of Kanpur In India" *EBC,*volume 2(7),461-464.

[8] Chhonkar, PK et al. (2000) "Impact of industry effluents on soil health and agriculture: part 2 tannery and textile industry effluents" *Journal of scientific and industrial research*, volume59(2),446-454

[9] Mohammed, S. A., & Moghal, A. A. (2014). Soils Amended with Admixtures as Stabilizing Agent to Retain Heavy Metals. *Geo-Congress 2014 Technical Papers*

[10] Singh, Maninder, Sharma, Rubel and Abhishek (2017)"Soil stabilization using industrial waste (wheat husk ash and sugarcane straw ash)" *International Research Journal Of Engineering And Technology,* volume 4(9).

ANNEXURE

ANNEXURE 1.1

Annexure 1.1.1

IS sieve (mm)	Weight of soil retained (%)	Percentage weight retained (%)	Cumulative Percentage retained (%)	Percentage finer (%)
4.75	0	0	0	100
2	74	7.4	7.4	92.6
1	24	2.4	9.8	90.2
0.6	135	13.5	23.3	76.9
0.425	15	1.5	24.8	75.2
0.212	46	4.6	29.4	70.6
0.15	74	7.4	36.8	63.2
0.075	13	1.3	38.1	61.9

Table 10 Dry sieve analysis of B.C.S

Annexure 1.1.2

Diameter (mm)	Percentage finer (%)
0.063	60.2
0.0569	55.2
0.0422	45.6
0.0312	32.3
0.0118	25.16
0.0086	21.89
0.0063	18.35
0.0049	13.86
0.00199	7.49

Table 11 Hydrometer analysis of B.C.S

Annexure 1.1.3

No of blows	Wt. of container (gm)	Wt. of container + wet soil (gm)	Wt. of container + dry soil (gm)	Moisture content (%)
183	20.4	29.4	26.3	52.5
22	20.6	36.5	29.9	70.96
10	20.4	42.21	32.1	86.41

Table 12 Calculations for B.C.S liquid limit

Annexure 1.1.4

Empty Wt. of dish (gm)	Wt. dish + wet soil (gm)	Wt. dry soil + dish (gm)	Wt. of dry soil (gm)	Wt. of mercury (gm)	Vol. of dry soil (gm)	Wt. of wet soil (gm)	Moisture content (%)	Shrinkage limit (%)
31.5	70.1	56.6	25.1	176.2	13.556	35.6	53.85	8.8
24.5	64.4	50.9	26.4	185.3	14.236	39.9	51.13	9.1

Table 13 Shrinkage limit calculations

Annexure 1.1.5

Wt. of container (gm)	Wt. of wet soil + container (gm)	Wt. of oven dried soil + container (gm)	Moisture content (%)
18.8	25.6	23.7	38.7
20.4	27.6	25.4	44

Table 14 Calculations for plastic limit of B.C.S

Annexure 1.1.6

Wt. Mould + Base plate (gm)	Wt. Mould + Base plate + soil (gm)	Moisture content	Wt. of compacted soil	Bulk density (g/cc)	Dry density (g/cc)
3684	5177.2	12	1493.2	1.581	1.412
3684	5271	17	1587	1.681	1.436
3684	5394	24	1710	1.811	1.460
3684	5364.9	28	1710.9	1.812	1.416
3684	5408	32	1724	1.826	1.383

Table 15 O.M.C and dry density calculation

Annexure 1.1.7

Penetration (mm)	Load (Kg)
1	98
1.5	119
2	131
2.5	145
3	160
3.5	175.6
4	188.3
4.5	195.6
5	210

Table 16 Readings of CBR test

Annexure 1.1.8

Time (hours)	Reading (mm)
0	0

0.12	4.96
0.232	10
2.86	12.04
24.21	13.38
50.45	14.42
75.96	14.86
78.211	15.21
98.258	15.56
119.532	15.72
130.982	15.86
177.923	16.01
206.93	16.21
224.12	16.3
302.894	16.83

Table 17 Readings of Swell test B.C.S

ANNEXURE 1.2

Annexure 1.2.1

No of blows	Wt. of container (gm)	Wt. of container + wet soil (gm)	Wt. of container + dry soil (gm)	Moisture content (%)
79	20.5	29.1	25.2	82.9
39	18.8	26.5	22.9	87.8
23	18.8	27.3	23.3	88.8

Table 18 Calculation for liquid limit B.C.S + 2% tanned waste ash

Annexure 1.2.2

No of blows	Wt. of container (gm)	Wt. of container + wet soil (gm)	Wt. of container + dry soil (gm)	Moisture content (%)
98	19.9	30.6	25.8	81.3
24	19.5	29.3	25.1	86.4
10	19.5	29.5	24.5	100

Table 19 Calculation for liquid limit B.C.S + 4% tanned waste ash

Annexure 1.2.3

No of blows	Wt. of container (gm)	Wt. of container + wet soil (gm)	Wt. of container + dry soil (gm)	Moisture content (%)
55	19.9	30.4	25.7	80.9
34	21.2	28.9	25.4	83.5
16	19.8	27.8	24.1	86.1

Table 20 Calculation for liquid limit B.C.S + 6% tanned waste ash

Annexure 1.2.4

No of blows	Wt. of container (gm)	Wt. of container + wet soil (gm)	Wt. of container + dry soil (gm)	Moisture content (%)
16	20.4	29.6	24.8	92
22	19.5	28.8	24.5	86.3
38	22.2	31.6	26.4	81

Table 21 Calculation for liquid limit B.C.S + 8% tanned waste ash

Annexure 1.2.5

No of blows	Wt. of container (gm)	Wt. of container + wet soil (gm)	Wt. of container + dry soil (gm)	Moisture content (%)
33	19.5	41.4	31.8	78.04
16	20.1	38.2	29.6	90.5
7	19.6	35.2	27.8	91.5

Table 22 Calculation for liquid limit B.C.S + 10% tanned waste ash

Annexure 1.2.6

Wt. of container (gm)	Wt. of wet soil + container (gm)	Wt. of oven dried soil + container (gm)	Moisture content (%)
20.5	27.8	25.6	43.13
18.8	25	23	47.62
18.8	23.1	21.9	38.71
19.7	26.5	24.3	47.82

Table 23 plastic limit B.C.S + 2% tanned leather waste ash

Annexure 1.2.7

Wt. of container (gm)	Wt. of wet soil + container (gm)	Wt. of oven dried soil + container (gm)	Moisture content (%)
19.4	24.2	22.7	45.45
19.6	22.2	21.3	52.94
20.1	22.9	21.9	55.55
19.9	26	24	48.78

Table 24 plastic limit B.C.S + 4% tanned leather waste ash

Annexure 1.2.8

Wt. of container (gm)	Wt. of wet soil + container (gm)	Wt. of oven dried soil + container (gm)	Moisture content (%)
19.3	22.4	21.4	47.61
18.6	21.7	20.6	55
18.8	22.7	21.4	50

Table 25 plastic limit B.C.S + 6% tanned leather waste ash

Annexure 1.2.9

Wt. of container (gm)	Wt. of wet soil + container (gm)	Wt. of oven dried soil + container (gm)	Moisture content (%)
19.6	22.2	21.4	44.4
18.6	20.5	19.9	46.15
18.8	20.4	19.9	45.45

Table 26 plastic limit B.C.S + 8% tanned leather waste ash

Annexure 1.2.10

Wt. of container (gm)	Wt. of wet soil + container (gm)	Wt. of oven dried soil + container (gm)	Moisture content (%)
20.9	27.8	25.7	20.9
18.8	24.7	23	18.8
19.6	26	24.2	19.6

Table 27 plastic limit B.C.S + 10% tanned leather waste ash

Annexure 1.2.11

Wt. shrinkage dish + wet soil (gm)	Wt. shrinkage dish + Dry soil (gm)	Wt shrinkage dish (gm)	Wt Hg displaced by soil sample (gm)	Vol. of soil sample (gm)	Vol. of shrinkage dish (cc)	Shrinkage limit (%)
60.4	43.2	24.5	133.6	9.82	24.3	14.2
65.3	49.2	24.8	127.16	9.35	22.9	10.4

Table 28 Shrinkage limit B.C.S + 2% tanned leather waste ash

Annexure 1.2.12

Wt. shrinkage dish + wet soil (gm)	Wt. shrinkage dish + Dry soil (gm)	Wt shrinkage dish (gm)	Wt Hg displaced by soil sample (gm)	Vol. of soil sample (gm)	Vol. of shrinkage dish (cc)	Shrinkage limit (%)
61.8	49.5	35.5	164.8	12.12	22.5	13
65.2	51.6	36	150.0	11.03	22.4	14.2

Table 29 Shrinkage limit + 4% tanned leather waste ash

Annexure 1.2.13

Wt. shrinkage dish + wet soil (gm)	Wt. shrinkage dish + Dry soil (gm)	Wt shrinkage dish (gm)	Wt Hg displaced by soil sample (gm)	Vol. of soil sample (gm)	Vol. of shrinkage dish (cc)	Shrinkage limit (%)
63.2	48	31.2	126.8	9.32	22.2	13.7
63.2	48	31.3	129.7	953	22.1	14.4

Table 30 Shrinkage limit + 6% tanned leather waste ash

Annexure 1.2.14

Wt. shrinkage dish + wet soil (gm)	Wt. shrinkage dish + Dry soil (gm)	Wt shrinkage dish (gm)	Wt Hg displaced by soil sample (gm)	Vol. of soil sample (gm)	Vol. of shrinkage dish (cc)	Shrinkage limit (%)
66.7	52.5	36.2	143.6	10.56	22.5	13.9
59.8	48.8	35.9	183.1	13.46	22.6	14.4

Table 31 Shrinkage limit + 8% tanned leather waste ash

Annexure 1.2.15

Wt. shrinkage dish + wet soil (gm)	Wt. shrinkage dish + Dry soil(gm)	Wt shrinkage dish(gm)	Wt Hg displaced by soil sample(gm)	Vol. of soil sample (gm)	Vol. of shrinkage dish (cc)	Shrinkage limit (%)
62.4	48.4	31.4	170.5	12.53	23.8	15.8
62.3	48.5	31.7	167.9	12.34	23.9	12.9

Table 32 Shrinkage limit + 10% tanned leather waste ash

ANNEXURE 1.3

Annexure 1.3.1

Wt. of mould (gm)	Wt. mould + soil (gm)	Wt. of soil (gm)	Bulk density (g/cm^3)	Dry density (g/cm^3)	Water content (%)
3675.9	5113.7	1437.8	1.523	1.324	15
3675.9	5196.9	1521	1.611	1.365	18
3675.9	5262.1	1586.2	1.680	1.388	21.3
3675.9	5277	1601.1	1.696	1.367	24
3675.9	5300	1624.1	1.720	1.354	27

Table 33 Standard proctor test B.C.S + 2% tanned leather waste ash

Annexure 1.3.2

Wt. of mould (gm)	Wt. mould + soil (gm)	Wt. of soil (gm)	Bulk density (g/cm^3)	Dry density (g/cm^3)	Water content (%)
3697.8	4994.93	1297.13	1.374	1.216	13
3697.8	5058.93	1361.13	1.441	1.243	16
3697.8	5107.12	1409.32	1.492	1.276	17
3697.8	5190.74	1492.94	1.581	1.329	19
3697.8	5196.42	1498.62	1.587	1.312	21

Table 34 Standard proctor test B.C.S + 4% tanned leather waste ash

Annexure 1.3.3

Wt. of mould (gm)	Wt. mould + soil (gm)	Wt. of soil (gm)	Bulk density (g/cm^3)	Dry density (g/cm^3)	Water content (%)
3700	5055.38	1355.38	1.435	1.293	11

3700	5133.56	1433.55	1.518	1.332	14
3700	5184.42	1484.42	1.572	1.344	17.3
3700	5186.55	1486.54	1.574	1.323	19

Table 35 Standard proctor test B.C.S + 6% tanned leather waste ash

Annexure 1.3.4

Wt. of mould (gm)	**Wt. mould + soil (gm)**	**Wt. of soil (gm)**	**Bulk density (g/cm^3)**	**Dry density (g/cm^3)**	**Water content (%)**
3683.4	5036.9	1353.5	1.433	1.293	11
3683.4	5114.7	1431.3	1.516	1.332	13
3683.4	5147.7	1464.3	1.551	1.347	15
3683.4	5178.3	1494.9	1.583	1.357	16.66
3683.4	5198.3	1514.9	1.604	1.348	19
3683.4	5204	1520.6	1.610	1.331	21

Table 36 Standard proctor test B.C.S + 8% tanned leather waste ash

Annexure 1.3.5

Wt. of mould (gm)	**Wt. mould + soil (gm)**	**Wt. of soil (gm)**	**Bulk density (g/cm^3)**	**Dry density (g/cm^3)**	**Water content (%)**
3659.8	5103.1	1443.3	1.528	1.353	13
3659.8	5158.8	1499	1.587	1.368	15.88
3659.8	5179.1	1519.3	1.609	1.352	19
3659.8	5216.1	1556.3	1.64	1.344	21

Table 37 Standard proctor test B.C.S + 10% tanned leather waste ash

ANNEXURE 1.4

Annexure 1.4.1

Displacement (mm)	**Load (kN)**	**Corrected Area (mm^2)**	**U.C.S (kN/m^2)**	**Strain**
0	0	1133.54	0	0
0.083	0.01	1134.784	8.812	0.001
0.250	0.02	1137.281	17.586	0.003
0.688	0.03	1143.888	26.226	0.009
1.083	0.04	1149.932	34.785	0.014
1.563	0.05	1157.334	43.203	0.021
1.833	0.06	1161.560	51.655	0.024
2.333	0.07	1169.444	59.858	0.031
2.750	0.08	1176.096	68.022	0.036
2.875	0.09	1178.107	76.394	0.038
3.188	0.11	1183.163	92.971	0.042
3.354	0.12	1185.877	101.191	0.044
3.542	0.14	1188.946	117.751	0.047
3.813	0.15	1193.407	125.691	0.050
3.979	0.16	1196.168	133.760	0.050
4.396	0.15	1203.129	124.675	0.058

Table 38 U.C.S test B.C.S + 2% tanned leather waste ash

Annexure 1.4.2

Displacement (mm)	**Load (kN)**	**Corrected Area (mm^2)**	**U.C.S (kN/m^2)**	**Strain**
0	0	1133.54	0	0
0.0625	0.01	1134.472	8.809	0.0013
0.1458	0.02	1135.719	17.609	0.0019
0.3958	0.04	1139.474	35.103	0.0052

0.6041	0.05	1142.623	43.758	0.0079
0.8750	0.07	1146.742	61.042	0.0115
1.2083	0.08	1151.853	69.453	0.0158
1.375	0.09	1154.425	77.960	0.0180
1.5416	0.1	1157.010	86.429	0.0202
1.7291	0.11	1159.930	94.833	0.0227
1.9791	0.12	1163.848	103.106	0.0260
2.2916	0.13	1168.782	111.226	0.0301
2.6041	0.15	1173.759	127.794	0.0342
3.0416	0.16	1180.797	135.501	0.0400
3.3958	0.17	1186.557	143.271	0.0446
3.7500	0.16	1192.374	134.186	0.0493

Table 39 U.C.S test B.C.S + 4% tanned leather waste ash

Annexure 1.4.3

Displacement (mm)	**Load (kN)**	**Corrected Area (mm^2)**	**U.C.S (kN/m^2)**	**Strain**
0	0	1133.54	0	0
0.1875	0.01	1136.343	8.800	0.0024
0.3958	0.02	1139.474	17.551	0.0052
0.7291	0.04	1144.520	34.949	0.0095
0.8541	0.05	1146.424	43.613	0.0112
1.0833	0.07	1149.931	60.873	0.0128
1.2291	0.08	1152.174	69.433	0.0167
1.3333	0.09	1153.781	78.004	0.0175
1.4375	0.1	1155.393	86.550	0.0181
1.5416	0.11	1157.010	95.072	0.0202
1.8125	0.12	1161.233	103.338	0.0238
1.9533	0.13	1163.521	111.729	0.0257
2.1041	0.15	1165.817	128.665	0.0276

2.2291	0.16	1167.792	137.010	0.0293
2.3958	0.17	1170.437	145.244	0.0315
2.6041	0.18	1173.759	153.353	0.0342
2.8750	0.19	1178.106	161.275	0.0378
3.125	0.18	1182.148	152.265	0.0411

Table 40 U.C.S test B.C.S + 6% tanned leather waste ash

Annexure 1.4.4

Displacement (mm)	**Load (kN)**	**Corrected Area (mm^2)**	**U.C.S (kN/m^2)**	**Strain**
0	0	1133.54	0	0
0.1041	0.01	1135.095	8.809	0.0013
0.3541	0.02	1138.847	17.561	0.0046
0.7291	0.04	1144.520	34.949	0.0095
0.8541	0.05	1146.424	43.613	0.0112
1.1666	0.07	1151.212	60.805	0.0153
1.2916	0.08	1153.138	69.375	0.0169
1.4375	0.09	1155.393	77.895	0.0189
1.5625	0.1	1157.333	86.405	0.0205
1.7083	0.11	1159.605	94.589	0.0224
1.9791	0.12	1163.848	103.106	0.0260
2.1250	0.13	1166.146	111.478	0.0279
2.2500	0.15	1168.122	128.411	0.0296
2.4166	0.16	1170.768	136.662	0.0317
2.5833	0.17	1173.426	144.874	0.0339
2.7291	0.18	1175.761	153.092	0.0359
2.9375	0.19	1179.114	161.137	0.0386
3.1666	0.20	1182.824	169.086	0.0416
3.9791	0.19	1196.131	167.345	0.0515

Table 41 U.C.S test B.C.S + 8% tanned leather waste ash

Annexure 1.4.5

Displacement (mm)	Load (kN)	Corrected Area (mm^2)	U.C.S (kN/m^2)	Strain
0	0	1133.54	0	0
0.125	0.01	1135.407	8.807	0.0016
0.2083	0.02	1136.655	17.595	0.0027
0.4583	0.04	1140.417	35.074	0.0060
0.625	0.05	1142.939	43.746	0.0082
0.9583	0.07	1148.016	60.974	0.0126
1.0833	0.08	1149.931	69.569	0.0142
1.2291	0.09	1152.174	78.113	0.0161
1.3958	0.1	1154.748	86.598	0.0183
1.5208	0.11	1156.686	95.099	0.0200
1.8541	0.12	1161.886	103.280	0.0243
2.0000	0.13	1164.176	111.666	0.0263
2.1875	0.15	1167.133	128.520	0.0287
2.3541	0.16	1169.774	136.778	0.0309
2.4791	0.17	1171.763	145.080	0.0326
2.625	0.18	1174.092	153.309	0.0345
2.854	0.19	1177.770	161.321	0.0375
3.104	0.20	1181.816	169.231	0.0408
4.166	0.22	1199.290	183.441	0.0548
5.166	0.23	1216.221	189.110	0.0679
5.666	0.22	1224.867	179.611	0.0745

Table 42 U.C.S test B.C.S + 10% tanned leather waste ash

ANNEXURE 1.5

Annexure 1.5.1

Penetration (mm)	Load (Kg)
0	0
0.5	53.6
1	109.91
1.5	151.6
2	189.5
2.5	227.4
3	253.9
4	310.7
5	344.8

Table 43 Readings of CBR Value for B.C.S + 2 % tanned leather waste ash

Annexure 1.5.2

Penetration (mm)	Load (Kg)
0	0
0.5	60.6
1	121.3
1.5	176.7
2	204.6
2.5	234.9
3	250.2
4	284.2

5	322.1

Table 44 Readings of CBR Value for B.C.S + 4 % tanned leather waste

Annexure 1.5.3

Penetration (mm)	**Load (Kg)**
0	0
0.5	64.4
1	129.9
1.5	155.6
2	205.4
2.5	249.4
3	266.5
4	292.7
5	314.9

Table 45 Readings of CBR Value for B.C.S + 6 % tanned leather waste ash

Annexure 1.5.4

Penetration (mm)	**Load (Kg)**
0	0
0.5	70
1	135.2
1.5	164.8
2	210.3
2.5	258.6
3	285.4

4	299.1
5	320.2

Table 46 Readings of CBR Value for B.C.S + 8 % tanned leather waste ash

Annexure 1.5.5

Penetration (mm)	Load (Kg)
0	0
0.5	64.4
1	131
1.5	163.1
2	212.3
2.5	255.8
3	276.7
4	310.3
5	317.6

Table 47 Readings of CBR Value for B.C.S + 10 % tanned leather waste ash

ANNEXURE 1.6

Annexure 1.6.1

Time (hours)	Reading
0	0
0.25	4.26
1.86	10
1.99	12.04
22.183	12.93
50.443	13.34
72.796	13.46
75.196	13.48
99.196	13.59
124.796	13.66
149.096	13.83
175.696	13.91

Table 48 Readings of Swell test B.C.S + 2 % tanned leather waste ash

Annexure 1.6.2

Time (hours)	Reading
0	0
0.163	6.42
0.256	10
2.523	10.62
20.983	11.21
26.214	11.42
48.316	11.71
68.166	11.97
102.442	12.18
148.325	12.21
176.211	12.29

201.5	12.35
248.512	12.5

Table 49 Readings of Swell test B.C.S + 4 % tanned leather waste ash

Annexure 1.6.3

Time (hours)	**Reading**
0	0
0.1166	7.35
0.1833	9.36
0.2666	10
0.35	10.42
1.433	10.55
18.966	11.05
44.449	1151
47.449	11.56
68.449	11.75
96.649	12
119.983	12.03
134.983	12.13
158.983	12.16
182.983	12.19
206.983	12.21

Table 50 Readings of Swell test B.C.S + 6 % tanned leather waste ash

Annexure 1.6.4

Time (hours)	**Reading**
0	0
0.116	5.16
0.523	10
1.441	11.21

1.921	11.28
25.621	11.48
40.613	11.56
64.21	11.72
96.496	12.08
112.83	12.21
121.112	12.52
148.26	12.81
180.21	12.98
201.938	13.02

Table 51 Readings of Swell test B.C.S + 8 % tanned leather waste ash

Annexure 1.6.5

Time (hours)	**Reading**
0	0
0.033	1.45
0.1833	5.5
0.4166	7.69
0.466	7.86
2.466	8.103
13.466	10.772
20.5	11.98
23.216	12.08
46.516	12.79
101.932	13.52
119.782	13.66
143.015	13.79
167.348	13.87
189.761	14.06

Table 52 Readings of Swell test B.C.S + 10 % tanned leather waste ash