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# Soil Stabilization of Expansive Black Cotton Clay Using Alum as a Stabilizing Agent

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**ABSTRACT :**

Black cotton soil that is large is known for its high shrink-swell behavior, low bearing capacity, and poor engineering performance. This means that it can't be built on without proper stabilization. This study investigates alum (aluminum sulfate) as a chemical stabilizing agent to improve the geotechnical properties of black cotton clay. We mixed different amounts of alum with the soil and tested it for Atterberg limits, compaction properties, California Bearing Ratio (CBR), and unconfined compressive strength (UCS). The plasticity index went down a lot and the maximum dry density went up when alum was added to the experiment. The CBR and UCS values also went up a lot, which means that the soil that was treated is stronger and more stable. These results show that alum can be used to stabilize black cotton soil that expands, making it a cheap and eco-friendly option for building roads and other geotechnical uses.

Keywords: Black cotton soil, soil stabilization, alum, expansive clay, geotechnical properties, strength improvement.

## Introduction

Soil is the main material used to build all civil engineering structures, and how it acts has a big effect on how stable and long-lasting they are. Because it spreads out so much, black cotton soil is one of the most difficult types of soil. Most of this soil is made up of montmorillonite minerals. When it rains, these minerals make the soil swell too much, and when it doesn't rain, they make it shrink too much. Black cotton soil foundations, pavements, and road subgrades can crack, settle unevenly, and fail structurally because of these changes in volume. Because of this, stabilizing black cotton soil has become a very important field of study in geotechnical engineering.

Many people have used lime, cement, and fly ash to make soils that are too big stronger. But these stabilizers usually cost more, hurt the environment, or are hard to find. People are looking for other options, and alum (aluminum sulfate) has become a popular choice for a possible chemical stabilizer. Alum is cheap and easy to find. It can change the structure of the soil by making it less plastic and less likely to shrink and swell. By chemically interacting with clay particles, it can improve bonding, compaction, and the ability to hold weight.

This study looks at how treating black cotton soil with alum affects its geotechnical properties. Different tests are done in the lab to find out how much stronger and more stable the soil has become. These tests include the Atterberg limits, the compaction test, the unconfined compressive strength (UCS), and the California Bearing Ratio (CBR). The goal is to find the right amount of alum that will work best and to show that alum is a cheap, long-lasting, and useful way to stabilize construction work in areas with expansive soil.

### *Soil Stabilization*

Soil stabilization makes soil stronger, more durable, and better able to hold weight. This lets it be used in building things like roads, foundations, and embankments. It helps with issues like too much swelling, too much shrinking, low shear strength, and poor drainage.

Soil stabilization's main goal is to make weak soil more stable and better for engineering use in a range of environmental and loading situations.

## LITERATURE REVIEW

### *INTRODUCTION*

This chapter centers on a literature review of Black Cotton Soil, analyzing several field and laboratory studies previously conducted to assess the efficacy of sand combined with alum in stabilization. During the literature review, numerous studies in this domain utilizing diverse materials were discerned.

**Efficiency of cement and lime in stabilizing the black cotton soil**
Studies on soil stabilization have shown that black cotton soil needs effective stabilizing agents to improve its engineering properties because it tends to swell and shrink a lot. Cement and lime are two of the most common stabilizers because they make things much stronger, less plastic, and less likely to change size. Earlier studies have shown that cement makes things stronger and last longer at first, while lime makes things less likely to swell and easier to work with. These stabilizers change the soil's microstructure by making calcium silicate hydrates and calcium aluminate hydrates, which are cementitious compounds. These chemicals fill in the spaces and keep the particles together. Different experiments have shown that cement and lime are good for building roads and other geotechnical uses on bad soils because they make the soil more compact, stronger when not confined, and have higher California Bearing Ratio (CBR) values.

**Groundnut shell ash stabilization of black cotton soil (2010)**
Black Cotton Soil (BCS) is known for having bad engineering properties, like being weak and swelling and shrinking a lot. Researchers have looked into using agricultural waste materials like Groundnut Shell Ash (GSA) as a stabilizing agent to make it work better. Studies show that GSA, which has a lot of silica, alumina, and lime, interacts with soil in a pozzolanic way, which makes its properties better, like unconfined compressive strength (UCS), California Bearing Ratio (CBR), and shear strength. Adding GSA also lowers the plasticity index and makes BCS better at holding weight. Not only does GSA improve the soil, but it also encourages recycling waste and building in a way that is good for the environment. In general, earlier studies show that GSA is a good way to stabilize soil that is both cheap and good for the environment.

**Study on strength and volume change behavior of stabilized black cotton soil with different pH of soil-lime mixes for pavement subgrade(2021)It is hard to work with Black Cotton Soil** (BCS) when building things because it can get bigger and smaller a lot and is not very strong. People know that lime stabilization makes BCS stronger and less likely to change size. Many studies show that the pH level of soil-lime mixtures is very important for stabilization because it changes chemical reactions, such as cation exchange and pozzolanic reactions, that make the soil better. Research indicates that optimal pH levels enhance the unconfined compressive strength (UCS) of BCS, decrease its plasticity, and mitigate its swelling and shrinkage. These changes make stabilized BCS a better material for building roads. Literature also says that controlling the pH of soil-lime mixtures makes stabilization work better, which leads to long-lasting and eco-friendly pavement foundations. **.**

**Experimental study on addition of lime and fly ash for the soil stabilization**
Many studies have shown that adding lime and fly ash to weak soils makes them much better for engineering. When lime comes into contact with clay minerals in soil, it creates cementitious compounds through pozzolanic reactions. This makes the soil more stable, stronger, and less flexible. Fly ash, which comes from burning coal, is a pozzolanic material that makes soil more compact, stronger, and able to hold more weight when mixed with lime. Researchers found that the best mix of lime and fly ash depends on the kind of soil. Using both materials together works better than using just one, especially on clayey or expansive soils. Improvements include a higher California Bearing Ratio (CBR), less swelling, and better stability when under load.

## At Present Study

### *Objectives-*

1. To study the basic engineering properties (Atterberg limits, compaction characteristics, swelling index, and shear strength) of untreated black cotton soil.
2. To investigate the effect of alum treatment on the geotechnical properties of black cotton soil at varying percentages of alum.
3. To evaluate the improvement in load-bearing capacity and reduction in swelling and shrinkage potential of black cotton soil after alum stabilization.
4. To determine the optimum alum content that provides maximum improvement in strength and stability.
5. To compare the performance of alum-stabilized soil with untreated soil through laboratory tests such as CBR, UCS, and permeability tests.
6. To assess the suitability of alum as a cost-effective stabilizing agent for black cotton soil in road construction, foundations, and other geotechnical applications.

### *Experimental Study*

**Materials-**
**Black Cotton Clay Soil Sample Collect-**We got a sample of black cotton clay soil from Bhim Nagar, a village near Gwarighat in Jabalpur, Madhya Pradesh. The site is located at 23.1111678 degrees north and 79.9267115 degrees west. Once all the plants have been removed, soil is taken from the area

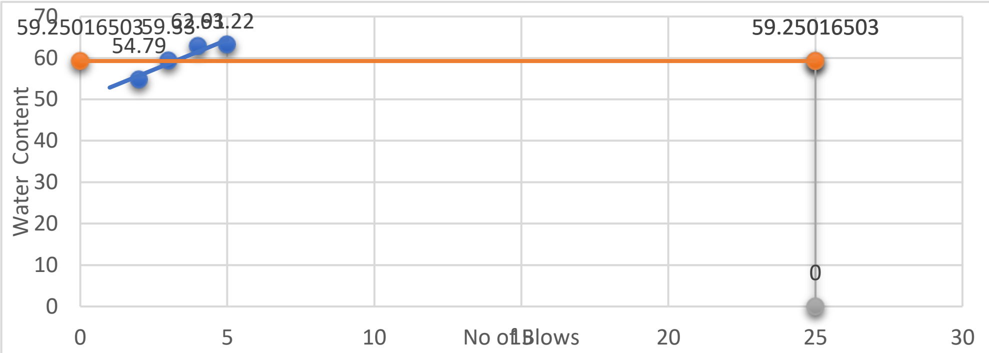
at a depth of about 1 to 2 meters below the surface. It was first dried in an oven at 110°C, then broken into small pieces, and finally sieved in the lab to make samples. .

**Alum-** Alum is a hydrated double salt that contains aluminum sulfate and another sulfate of a monovalent metal, such as potassium, ammonium, or sodium. This is $MAl(SO_4)_2 \cdot 12H_2O$, where M stands for a single cation, such as $K^+$, $Na^+$, or $NH_4^+$. Alum is a solid that looks like crystals and is either colorless or white. It dissolves easily in water. People use it a lot because it can bind, thicken, and tighten things. Adding alum (aluminum sulfate) to black cotton clay soil makes it less plastic, swell, and shrink. This makes it stronger, more stable, and able to hold more weight.

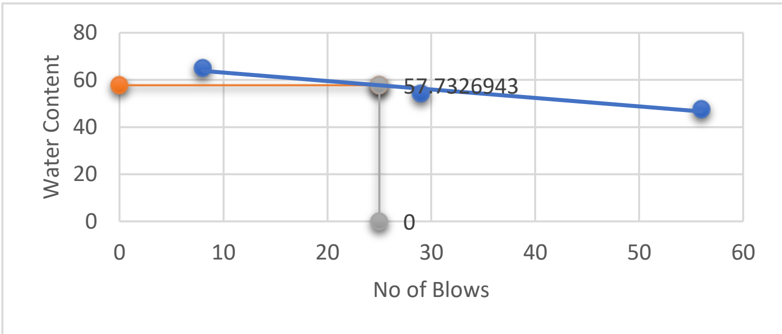
## Testing Methodology

***LIQUID LIMIT TEST***

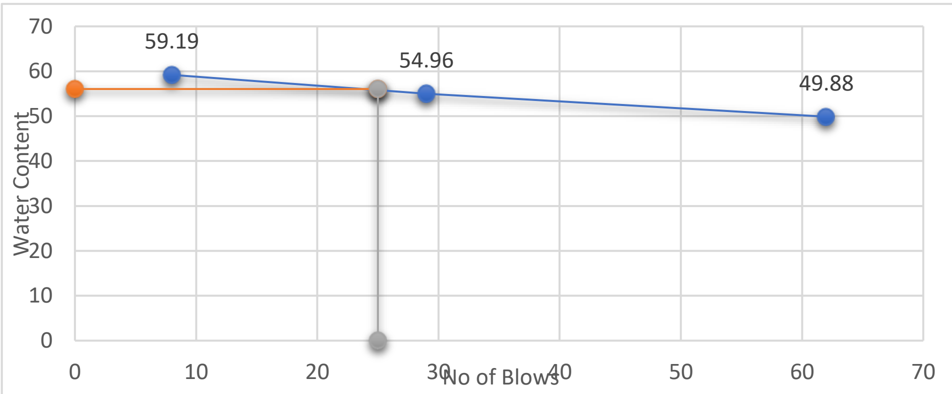
**For Plain Black Cotton Clay Soil.**



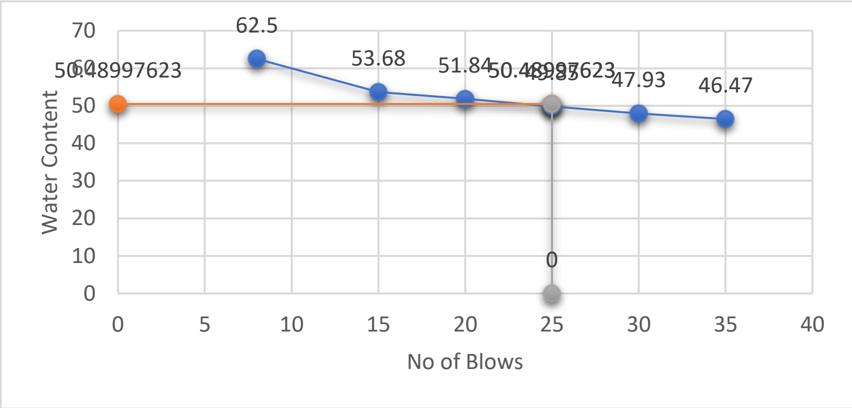

**For Black Cotton Clay Soil Added 5% Alum**




**For Black Cotton Clay Soil Added 10% Alum**



**For Black Cotton Clay Soil Added 15% Alum**




| Content | Liquid Limit at 25 blows |
|---|---|
| Plain Black Cotton Soil | 59.25% |
| Black Cotton Soil+ 5% Alum | 57.73 |
| Black Cotton Soil+ 10% Alum | 56.04 |
| Black Cotton Soil +15% Alum | 50.48 |

**PLASTIC LIMIT TEST**

| BCS | BCS+5%ALUM | BCS+10%ALUM | BCS+15%ALUM |
|---|---|---|---|
| 27.48 | 29.54 | 30.2 | 32.43 |

**PLASTICITY INDEX (PI)**

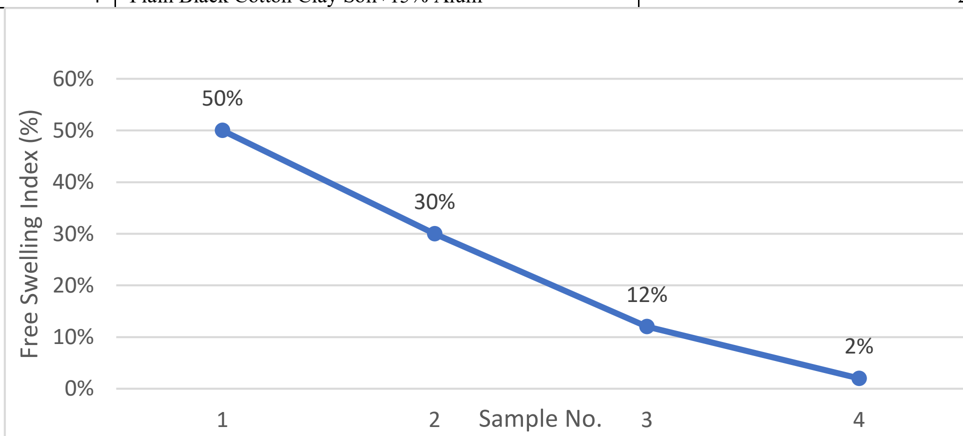
| Content | Liquid Limit | Plastic Limit | Plasticity Index |
|---|---|---|---|
| Plain Black Cotton Soil | 59.25% | 27.48 | 31.77 |
| Black Cotton Soil+ 5% Alum | 57.73 | 29.54 | 28.19 |
| Black Cotton Soil+ 10% Alum | 56.04 | 30.2 | 25.84 |
| Black Cotton Soil +15% Alum | 50.48 | 32.43 | 18.05 |

**SHRINKAGE LIMIT**

| BCS | BCS+5%ALUM | BCS+10%ALUM | BCS+15%ALUM |
|---|---|---|---|
| 8% | 11% | 12% | 15% |

**DIFFERTIAL FREE SWELL TEST**

| S.NO | Samples | Free Swelling Index (%) |
|---|---|---|
| 1 | Plain Black Cotton Clay Soil | 50% |
| 2 | Plain Black Cotton Clay Soil+5% Alum | 30% |
| 3 | Plain Black Cotton Clay Soil+10% Alum | 12% |
| 4 | Plain Black Cotton Clay Soil+15% Alum | 2% |

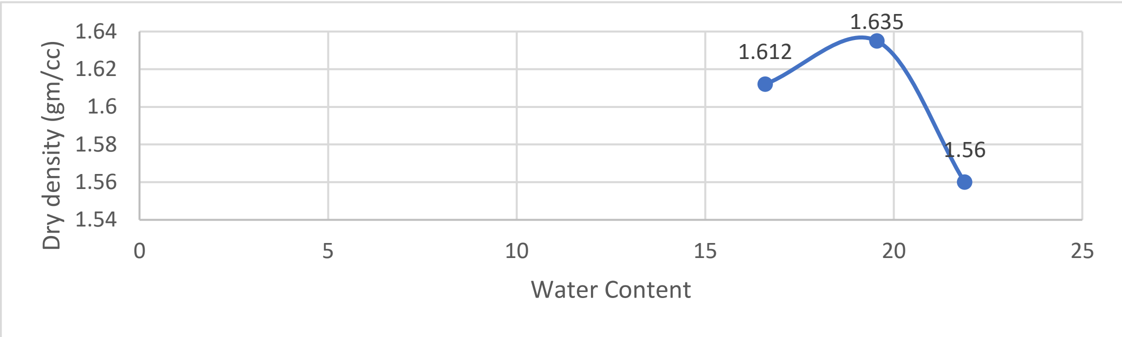


**Unconfined Compressive Strength Test**

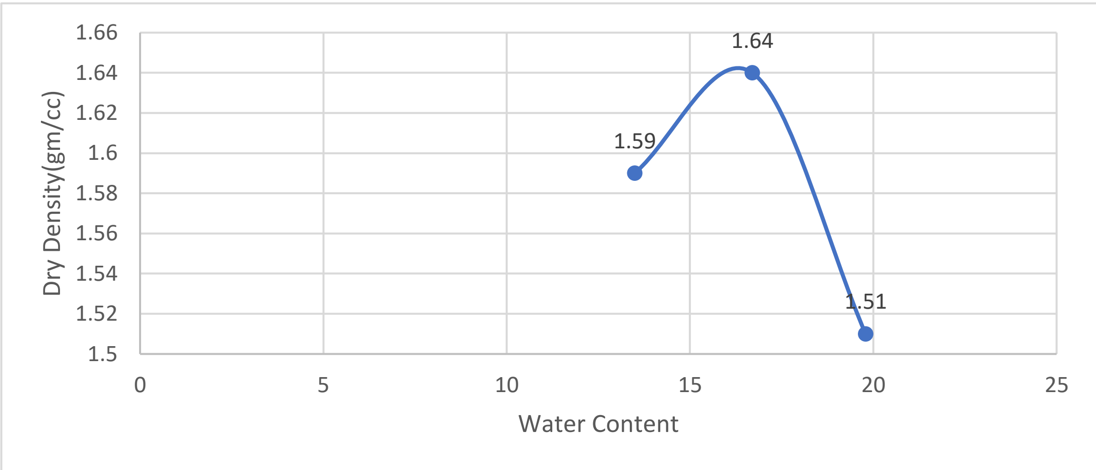
| S.NO | Samples | U.C.S (KN/m2) |
|---|---|---|
| 1 | Plain Black Cotton Clay Soil | 104 KN/m² |
| 2 | Plain Black Cotton Clay Soil+5% Alum | 111.3 KN/m² |
| 3 | Plain Black Cotton Clay Soil+10% Alum | 158 KN/m² |
| 4 | Plain Black Cotton Clay Soil+15% Alum | 176 KN/m² |

***MDD and OMC TEST***

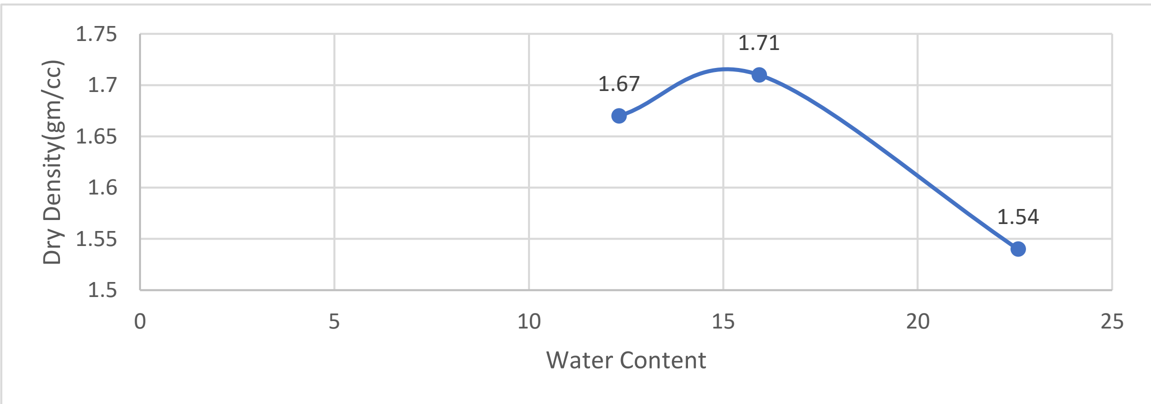
**For Plain Black Cotton Clay Soil**



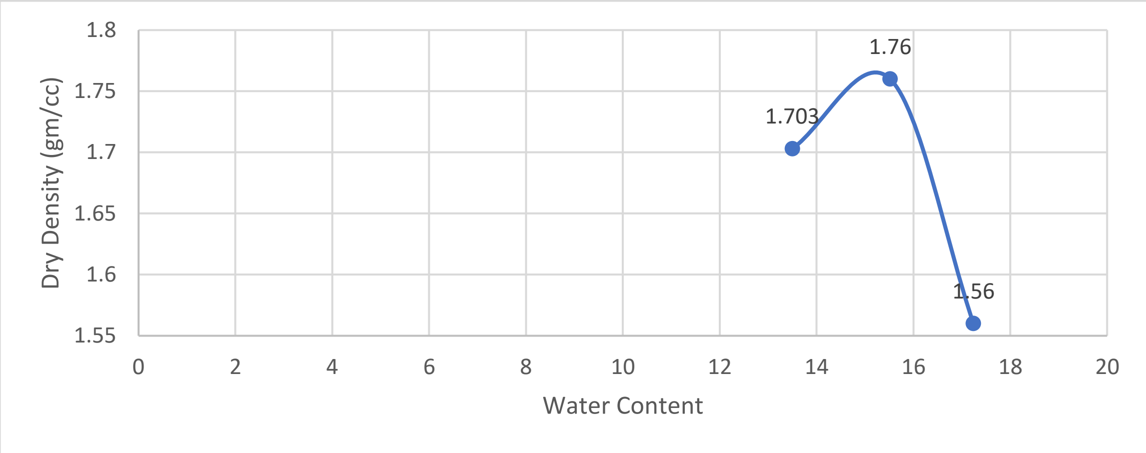

**For Black Cotton Clay Soil Added 5% Alum**




**For Black Cotton Clay Soil Added 10% Alum**



**For Black Cotton Clay Soil Added 15% Alum**



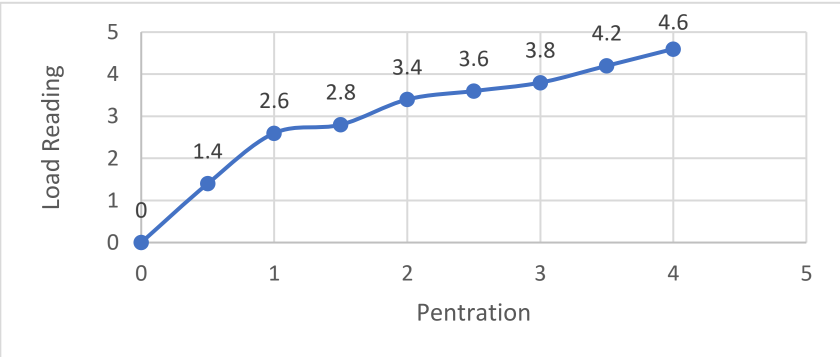

**California Bearing Ratio (CBR) TEST**

**For Plain Black Cotton Clay Soil**

CBR VALUE at 2.5= $\frac{Load}{Standard\,(1370\ kg)} \times 100$

$= \frac{36.72}{1370} \times 100$

= 2.68%

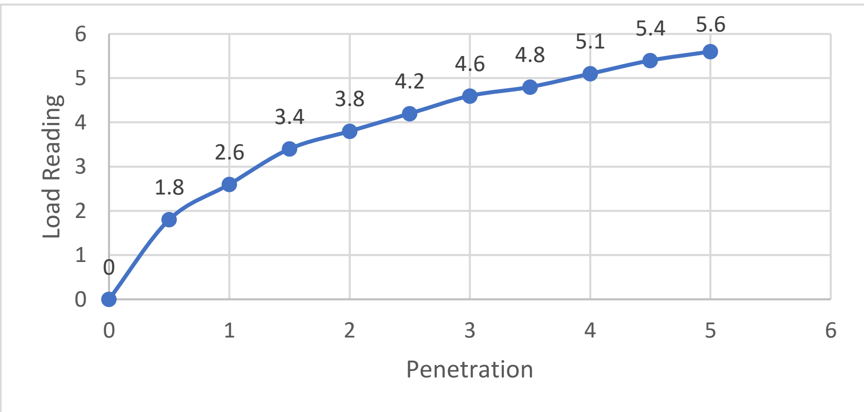



**For Black Cotton Clay Soil Added 5% Alum**

CBR VALUE at 2.5= $\frac{Load}{Standard\,(1370\ kg)} \times 100$

$= \frac{38.76}{1370} \times 100$

= 2.82%

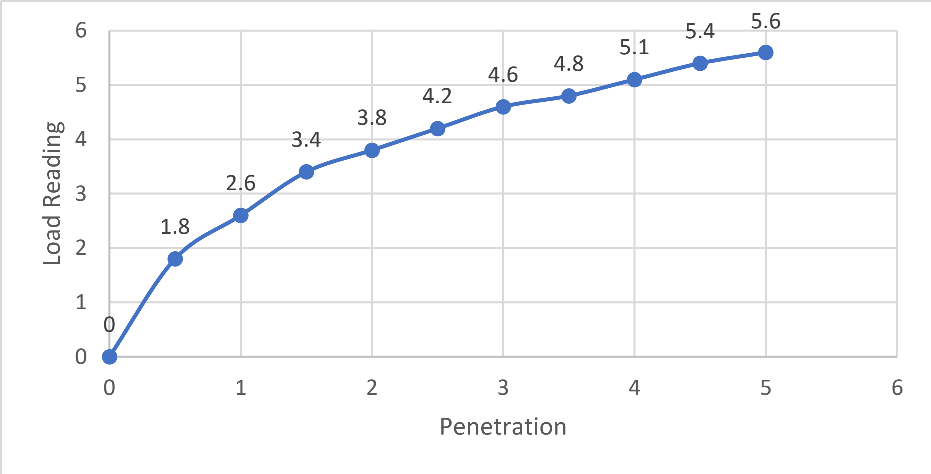



**For Black Cotton Clay Soil Added 10% Alum**

CBR VALUE at 2.5= $\frac{Load}{Standard\,(1370\;kg)}\times 100$

$= \frac{42.84}{1370}\times 100$

= 3.12%

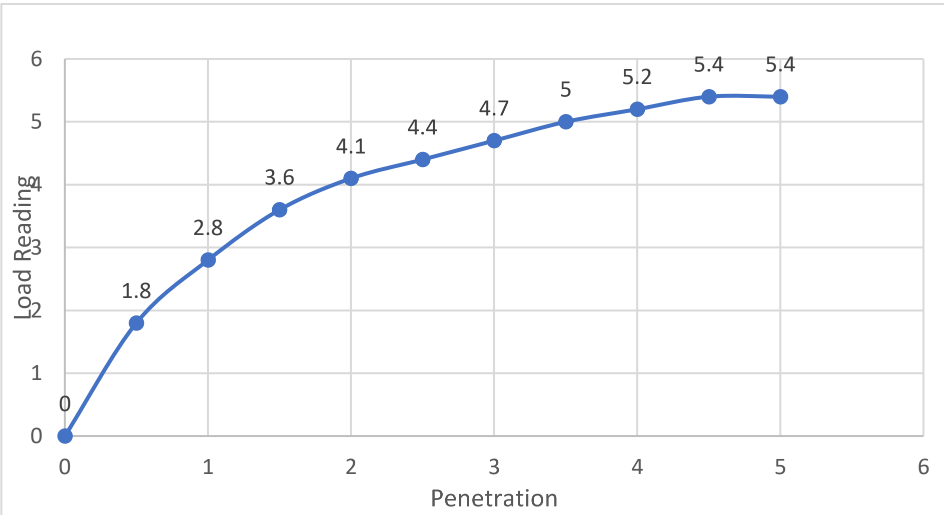



**For Black Cotton Clay Soil Added 15% Alum**

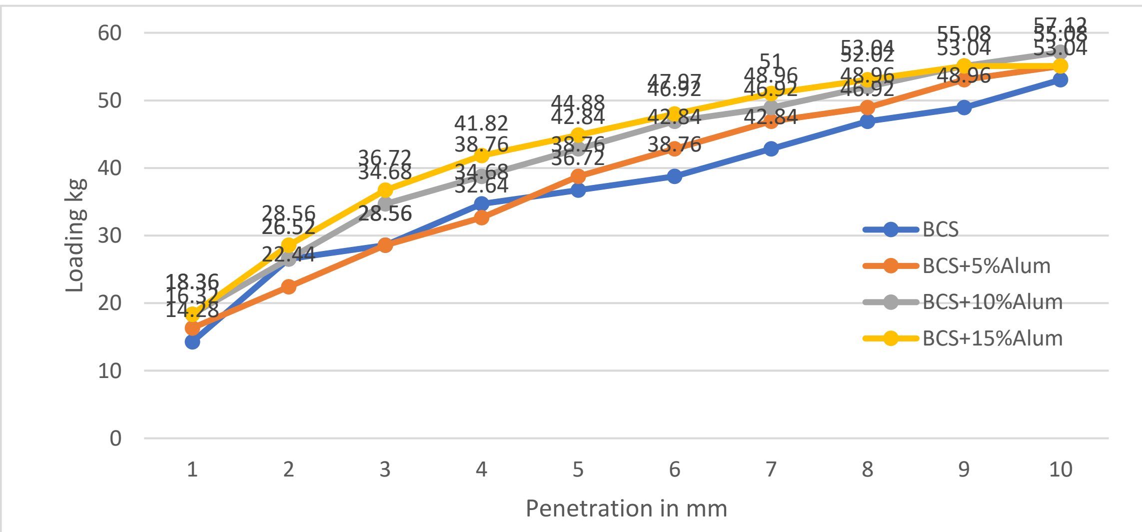
CBR VALUE at 2.5= $\frac{Load}{Standard\,(1370\;kg)}\times 100$

$= \frac{44.88}{1370}\times 100$

= 3.27%




**CBR Test using various composition**



## Summary of the Test Results

| S.NO | TESTS | BCS | BCS+5%ALUM | BCS+10%ALUM | BCS+15%ALUM |
|---|---|---|---|---|---|
| 1. | Liquid Limit | 59.25 | 57.73 | 56.04 | 50.48 |
| 2. | Plastic Limit | 27.48 | 29.54 | 30.2 | 32.43 |
| 3. | Shrinkage Limit | 8% | 11% | 12% | 15% |
| 4. | Plasticity Index | 31.77 | 28.19 | 25.84 | 18.05 |
| 5. | Free Swelling Index | 50% | 30% | 12% | 2% |
| 6. | O.M.C (%) | 19.55% | 16.70% | 15.92% | 15.52% |
| 7. | M.D.D (gm/cc) | 1.635gm/cc | 1.64gm/cc | 1.71gm/cc | 1.76gm/cc |
| 8. | U.C.S (KN/m2) | 104 KN/m² | 111.3 KN/m² | 158 KN/m² | 176 KN/m² |
| 9. | C.B.R 2.5 (%) | 2.68% | 2.82% | 3.12% | 3.27% |



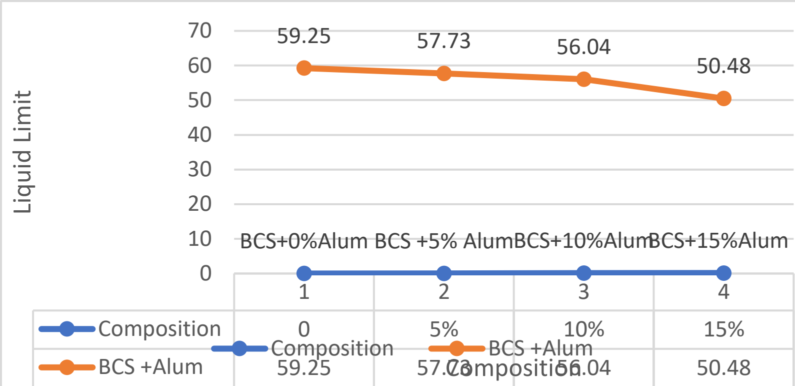


## Result and Discussion

**(a) Index Properties**

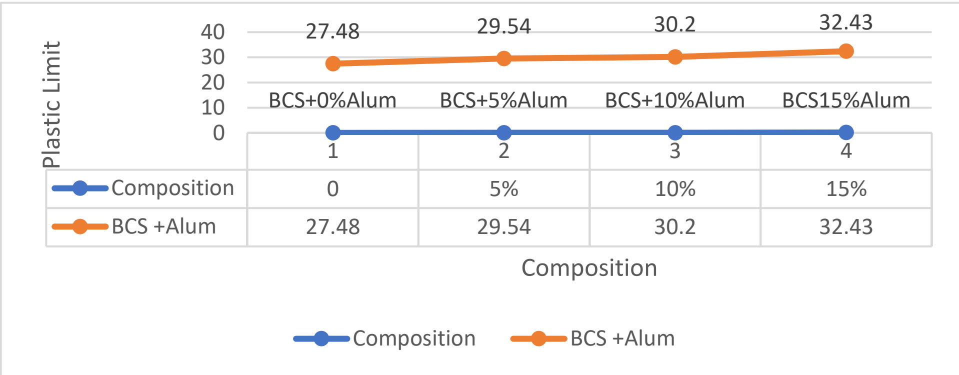
**Liquid Limit**

Liquid limit is decreased from 59.25% to 50.48% with the increase of Alum content from 0% to 15% in Black Cotton Clay Soil.



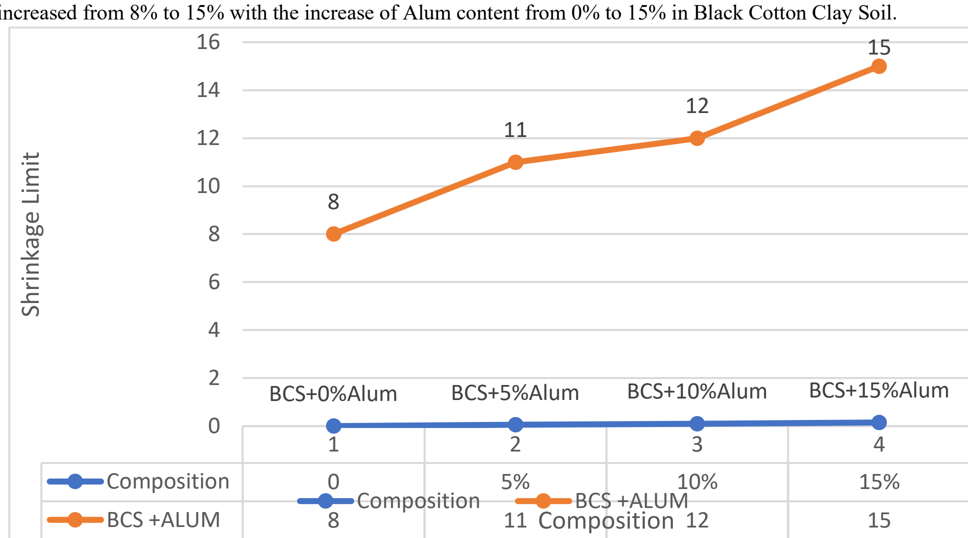

**Plastic Limit**

Plastic limit is increased from 27.48 to 32.43 with the increase of Alum content from 0% to 15% in Black Cotton Clay Soil.



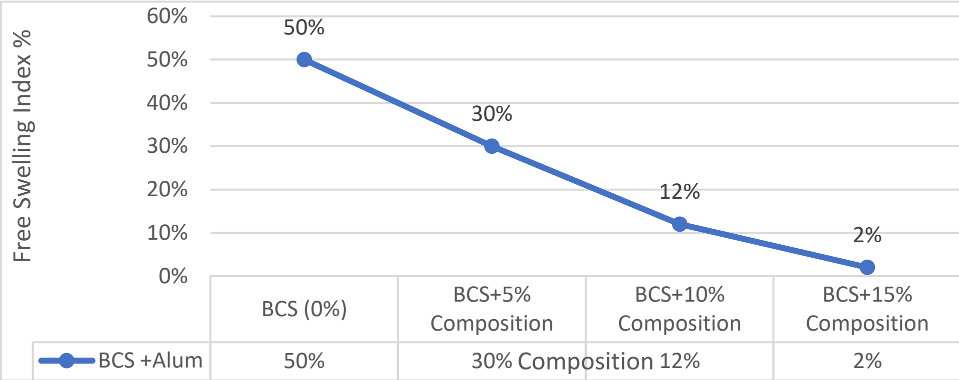

**Shrinkage Limit**

Shrinkage limit is increased from 8% to 15% with the increase of Alum content from 0% to 15% in Black Cotton Clay Soil.




**Differential Free Swell Index**

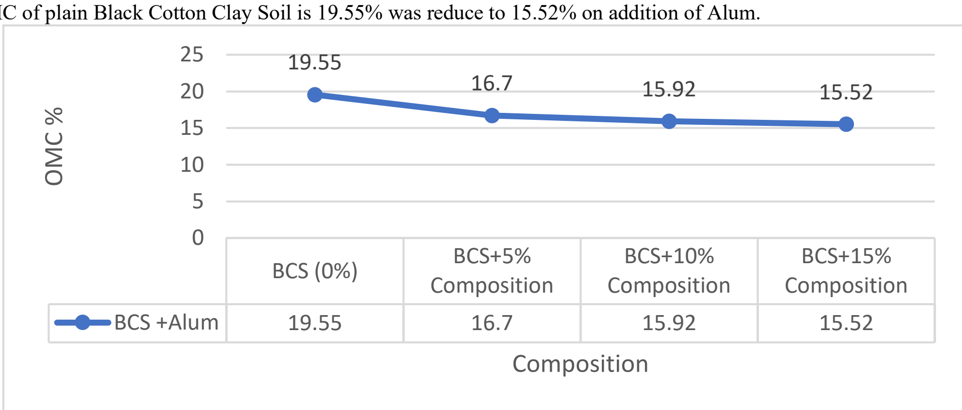
The Differential Free Swell value of soil reduced consider by Alum is mixed to soil, further, is value decreased from 50% to 2% with the increase of Alum content from 0% to 15% in Black Cotton Clay Soil.




**(b) Engineering Properties**

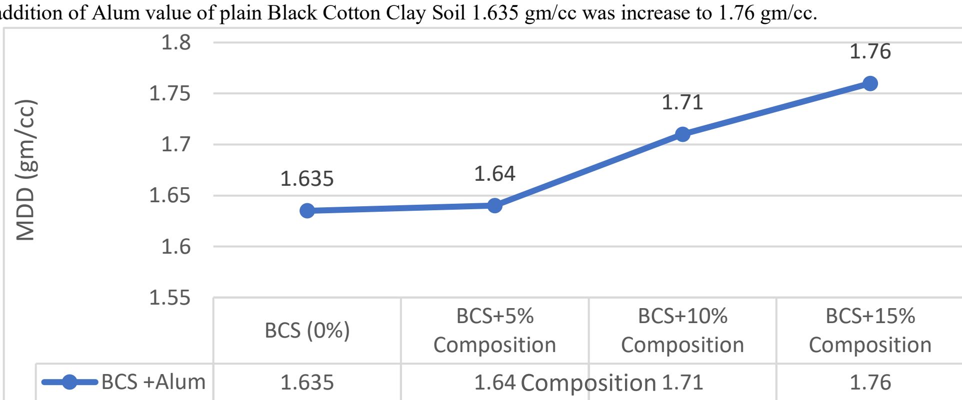
**Optimum Moisture Content**

The OMC of plain Black Cotton Clay Soil is 19.55% was reduce to 15.52% on addition of Alum.



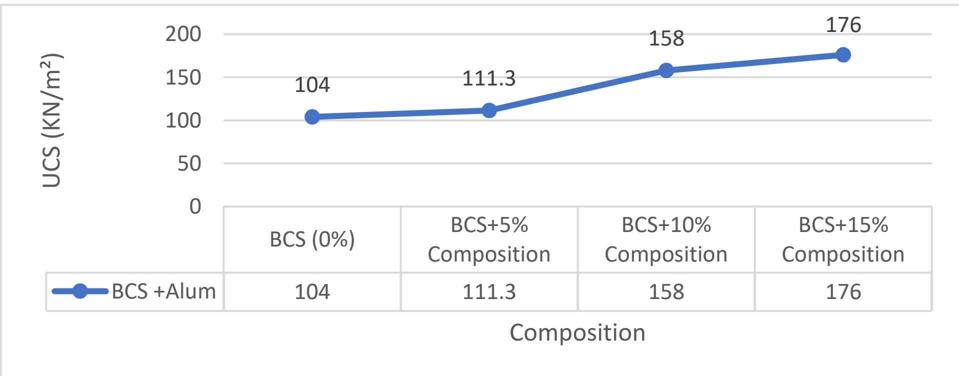

**Maximum Dry Density (MDD)**

Due to addition of Alum value of plain Black Cotton Clay Soil 1.635 gm/cc was increase to 1.76 gm/cc.



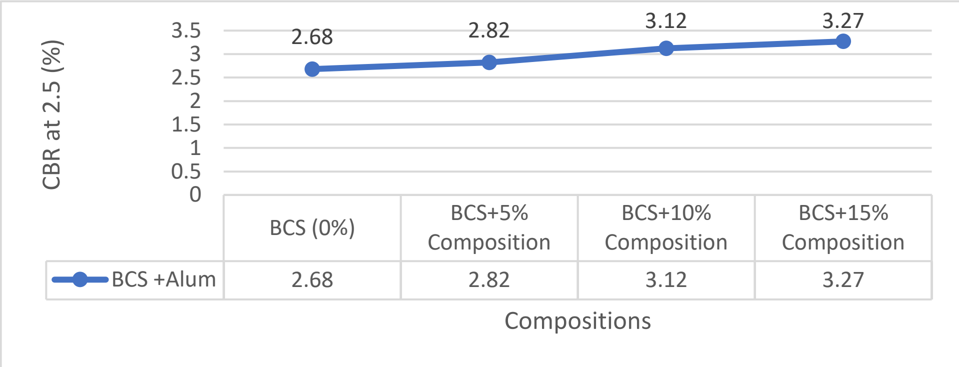

**Unconfined Compressive Strength**

The UCS of Black Cotton Clay Soil 104 KN/m² was increased to 176 KN/m² on addition of Alum.



**California Bearing Ratio (CBR)**

The CBR value of Black Cotton Clay Soil is 2.68% was increased to 3.27% on addition of Alum.




## Conclusion

The study concludes that the addition of alum as a stabilizing agent significantly improves the strength and stability properties of expansive black cotton soil. Laboratory test results such as Atterberg limits, compaction characteristics, CBR, and UCS indicate that alum reduces the soil's plasticity, increases dry density, and enhances load-bearing capacity. Alum effectively minimizes swelling-shrinkage behavior, thereby overcoming the limitations of black cotton soil in construction works.

Hence, the treatment of expansive soils with alum can be considered a cost-effective, easily available, and environmentally sustainable method for soil stabilization, especially in road construction and foundation engineering.

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