

To Improve the Strength of Black Cotton Soil Using SILO STAB Chemical Stabilizer

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ABSTRACT

Soil stabilization is a crucial method in geotechnical engineering for improving soil properties and making them more suitable for construction purposes. One of the most used methods is chemically adding materials such as lime, cement, fly ash, bitumen, and other industrial waste products to stabilize unproductive soils. The use of these materials enhances the soil's capacity to bear weight, as well as its strength and durability. Several chemical processes, including cementation, pozzolanic reactions, and cation exchange, modify soil properties during this stage, resulting in an increase in compressive strength, a decrease in permeability, and a decrease in plasticity. When applied to challenging soils like expanding clays and loose sands, chemical stabilization provides an affordable and long-term solution for subgrades, embankments, and pavement foundations. This page details the research on chemically stabilized B C Soil's Atterberg limits and UCS.

Keywords: Black Cotton Soil, Soil Stabilization, Silo

I. INTRODUCTION

1.1 Properties of B C Soil

The color of black cotton soil is dark brown or completely black. They have a high compressibility and are found to be between 0.50 and 10 meters deep.

Table No. 1: Properties of Soil

Sl. No.	Property	Value
1.	Dry density (kg/m ³)	1300-1800
2.	Liquid limit	40-120%
3.	Plastic limit	20-60%
4.	Specific gravity	2.60 - 2.75
5.	Maximum dry density	20-35%
6.	Compression index	0.2-0.5
7.	Proctor Density (kg/m ³)	1350-1600
8.	Free Swell index	40-180%
9.	Swelling pressure (kN/m ²)	50-800
10.	C.B.R (soaked)	1.2-4.0
11.	Fines (<75 microns)	70-100%
12.	Soil classification	CH or MH

Table No. 2: Chemical Composition of Soil

Sl. No.	Mineral	Value
1.	Alumina	10%
2.	Iron oxide	9-10%
3.	Lime and magnesium carbonates	6-8%
4.	Potash	<0.5%
5.	Phosphate, nitrogen, humus	low
6.	PH value	>7(Alkaline)
7.	Organic Content	0.4-204%
8.	CaCO ₃	1-15%
9.	SiO ₂	50-55%

10.	SiO ₂ , Al ₂ O ₃	3-5%
11.	Montmorillonite mineral	30-50%

1.2 CLAY MINEROLOGY

Clay contains phyllosilicates with two-dimensional sheet structures. Cation substitutions in these sheets create layer charges, which affect how the minerals interact with water and organic compounds. These minerals have a high area of surface and high cation exchange capacity. Kalin, smectite, illite, and chlorite are the four primary categories of clay minerals. Different physical and chemical characteristics are shown by each category.

Clay minerals are very fine-grained, usually smaller than 4 micrometers. They make up about 16% of the Earth's surface materials by volume. Clays are commonly found in soils, sedimentary rocks, low-grade metamorphic rocks, and hydrothermal zones. Clay mineralogy is the study of these minerals, including their structure, composition, classification, and natural distribution.

1.4 TYPES OF CLAY MINERALS

1) SILICATE CLAYS (CRYSTALLINE)

1. Kaolinite
2. Montmorillonite
3. Illite
4. Mixed layer clays

II. LITERATURE REVIEW

Piyush V. Kolhe and others made this statement. The soil of British Columbia is unstable when subjected to heavy loads because it has a limited carrying capacity and shearing strength. This makes the soil difficult to work with. Consequently, it is essential to either fortify or stabilize the soil in British Columbia to meet the requirements. Within the scope of this study, the engineering and index properties of soil in British Columbia are investigated in relation to the effects of rubber tire shred, with the percentages ranging from 0 to 10 percent. To explore the impact that rubber tires have on the soil, the shred of rubber tires was incorporated into the soil at a percentage of two percent, six percent, eight percent, and ten percent by the weight of the soil. The CBR values climbed in tandem with the quantity of rubber tires that were shredded, and they eventually reached their greatest point of 8% respectively. Because of this, due to the higher CBR value, it has the potential to be exploited in an efficient manner in the construction of roadways.

The authors Anush Thomas et al. More recently, a chemical called Terrasil has been used as a soil stabilizer. Silane is the component that makes up Terrasil. It may be dissolved in water and is resistant to sunlight and heat. It is a reactive soil modification that is utilized for the purpose of waterproofing stone bases and soil subgrade. There have been a variety of dosages of terrasil utilized, and the effects on OMC, MDD, plasticity index, and unconfined compressive strength have been calculated and evaluated. After a time of curing, the UCS of soil that had been treated with terrasil rose. Terasil dosages that were raised resulted with an increase in MDD and a decrease in the optimal moisture content. The dosages of terrasil that result in increases in dry density can reach up to 0.5%. When the liquid limit drops and the plastic limit increases, the plasticity index lowers. This decrease in plasticity index leads to the swelling potential of the soil diminishing, which in turn causes the liquid limit to decrease.

The authors Anil Pandey et al. When compared to the various modes of transportation that are available, roads have consistently been the most widely used. It is imperative that additional precautions be taken throughout the construction phase to ensure that highly loaded vehicles that are running on roadways can support their full weight. Using cement soil stabilization, geotechnical attributes such as plasticity, compaction, and unconfined compressive strength can be improved. Both before and after the soil stabilization process, these qualities were reviewed and evaluated. The UCS of the soil was found to rise with both the quantity of cement that was added to it and the length of time that it was allowed to cure. Because of the strength and durability, it gives, it is an excellent choice for use as a basis or subbase material since it provides remarkable value. The weight is distributed more evenly, which is beneficial to the pavement.

2016 publication by Paliwal. An investigation on the use of foundry sand waste to enhance the strength of soil is being carried out. By executing all the tests, he decided that employing 10% of foundry waste can lower the OMC.

Panchal et al. In this article, the approaches that can be utilized to improve the ground through the utilization of bio-enzyme are explained. The application of terrazyme, which is a bio-enzyme, is what leads to the improvement of the soil. This natural and non-toxic liquid enzyme is called Terrazyme. Terrazyme is a liquid. The primary components consist of the fermentation of plants, extracts of herbs and vegetables, and extracts of fruits. Additionally, Terrazyme can be utilized as a soil stabilizer, and it also has the additional benefit of boosting the CBR value throughout the process of road construction. Before the soil sample is analyzed, it is subjected to terrazyme treatment at doses of 500, 700, 900, and 1000 milliliters per cubic meter. The strength, dry density, consistency limit, and CBR value of soil samples that were treated with varying concentrations of terrazyme for varying amounts of time showed suitable improvements according to the specifications.

III. OBJECTIVES & SCOPE

3.1 OBJECTIVES

Employing silo stab as a stabilization technique aims to prolong soil durability, while soil improvement endeavors to augment the stability of soil masses or boost their engineering properties through alternative means. The behavior of black cotton soil was analyzed in this experiment with and without stabilization. The stabilizer was a compound known as Silo stab. Cement also serves as a stabilizer. This research investigated the stabilizing mechanism and strength of soil using varied dosages. This was performed to determine the soil's resilience.

3.2 SCOPE OF WORK

1. Procurement of black cotton soil from Kalaburagi, Karnataka
2. Procurement of Silo stab from Muzaffarnagar, Uttar Pradesh

IV. METHODOLOGY

4.1 GENERAL

It includes theoretical of the geotechnical tests performed to determine results. This chapter also enlists and describes the materials and methodology used for the experiment work. In this chapter the list of tests and theory to determine which property of soil.

4.2 Soil Particle Size Distribution by Hydrometer Method IS Code: IS 2720 (PART 4) 1985

The particle size distribution of fine-grained soils that pass through a 75 μ sieve may be found using the hydrometer technique. With the help of hydrometer's central specific gravity of a soil suspension is checked. A material's specific gravity is proportional to its mass, which is a function of its particle size.

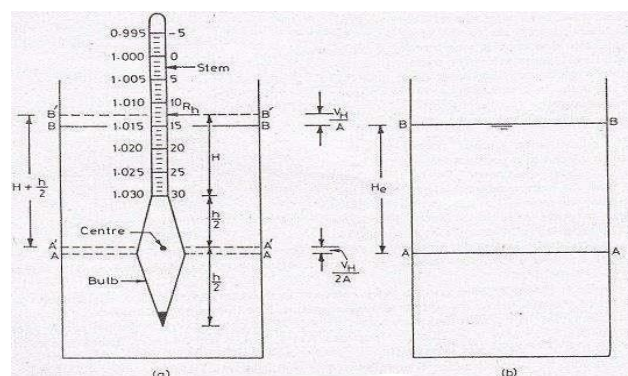


Figure No. 1: Hydrometer Method

4.3 FREE SWELL INDEX (IS: 2720 (Part XL) –1977)

Free swell index, differential free swell, or simply free swell is the volume expansion of soil under water when

no external restriction is applied.

4.4 Determine Liquid Limit of Soil Specimen by Casagrande Method IS Code: IS 2720 (PART 05) 1985

Soil exhibiting low shear strength behaves nearly like a liquid at its liquid limit, which is determined by the water content. Employing Casagrande's liquid limit apparatus, the flow adequately seals the groove in about 25 blows.

Given the difficulty of achieving exactly 25 blows in a single test, we should conduct three or four tests and separately determine the number of blows (N) required in each test. Log N and w, the water content, are thereafter represented in a semi-logarithmic format. The figure indicates that the water content at N=25 represents the liquid limit.

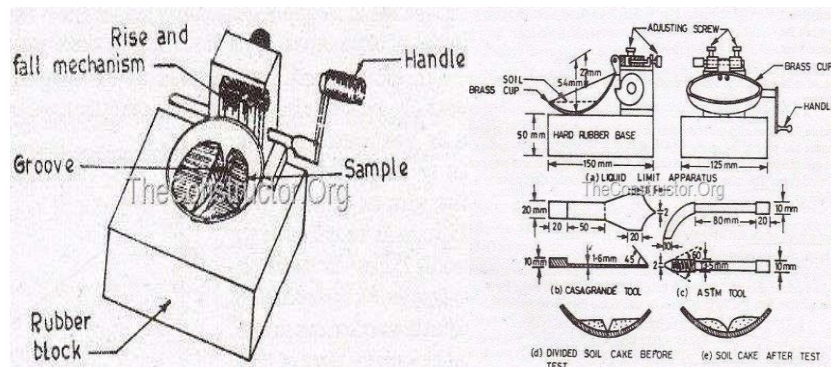


Figure No. 2: Casagrande's Apparatus Details and Tools



Figure No. 3: Liquid limit test

4.5 Determination of Plastic Limit of Soil (IS Code: IS 2720 (PART 05) 1985)

Soil starts to act like a plastic substance at a certain moisture concentration, which is called its plastic limit. Soil spun into threads of 3.2 mm (1/8 inch) diameter will collapse at this water concentration, also known as the plastic limit.

This article will provide the test procedures required to determine the soil plastic limit according to ASTM D4 -148.



Figure No. 4: *Plastic Limit Test*

4.5 Determination of Shrinkage Limit (IS :2720 Part 6-1972)

The idea behind shrinkage limit is that when soil dries out, the amount of saturated clay soil will decrease because the soil will lose moisture.

As the material dries, there comes a point when additional drying will only reduce the moisture content, not the volume.

Calculation:

Following formula should be used to determine the shrinkage limit.

Shrinkage Limit

$$(W_s) = \left\{ w - \left(\frac{v-v}{w} \right) \right\} \times 100$$

Where, W = Moisture content of wet soil part

4.5.1 SWELL PRESSURE (IS 2720-1977 PART 41)

Swell Pressure Test by Consolidate



Figure No. 5: *Swell Pressure Test by Consolidometer*

4.5.2 Swell Pressure Test by Constant Volume Method



Figure No. 6: Swell Pressure Test by Volume Method

4.6 CALCULATIONS

The volume and the moisture changes and the soil cement losses of the specimen should be calculated as in 5.1.1 and 5.1.4.

For specimen No 1 and 2 the difference between the volumes of specimens at the time of molding and subsequent volumes as a percentage of the original volume should be calculated.

The moisture content of specimens No. 1 and 2 at the time of molding and subsequent moisture contents should be calculated as a percentage of the original oven-dry weight of the specimen.

The oven-dry weight of specimens No. 3 and 4 as obtained in 4.6 shall be corrected for water which was responded with the cement and soil during the test and is retained in the specimen at 110°C, as follows:

$$\text{Corrected oven-dry weight} = \left\{ \frac{W_d}{(W+100)} \right\} \times 100$$

W = oven-dry weight after drying at 110°C

w = percentage of water retained in specimen.

The percentage of water retained in specimens No.3 and 4 after drying at 110°C for use in the above formula may be assumed to be equal to the average percentage of water retained in specimens No.1 and 2.

The soil cement loss of specimens No. 3 and 4 shall be calculated as a percentage of the original oven-dry weight of the specimen as follows:

$$\text{Soil cement loss, \%} = \frac{A}{B} \times 100$$

Where,

A = original calculated oven-dry weight - final corrected oven-dry weight,

B = original calculated oven-dry weight

V. RESULTS AND DISCUSSION

5.1 Method of Treatment of Natural Black Cotton Soil

In this investigation we performed tests like Hydrometer, Liquid limit, Plastic limit, Shrinkage limit, Swell pressure for natural Black Cotton soil without nano material SILO STAB.

Table No. 3: Characteristics of Black Cotton Soil without SILO STAB.

Sl. No.	Tests	Kalaburagi Black Cotton Soil
Hydrometer test		
1.	Gravel	7%
2.	Sand	9%
3.	Silt	40%
4.	clay	44%
5.	Liquid limit	69%
6.	Plastic limit	24%
7.	Shrinkage limit	10%
8.	Free swell	85%
9.	Swell pressure gm/cm ²	0.16

5.2 Method of Treatment of B C Soil with SILO STAB

- In this investigation we performed tests like Hydrometer, Liquid limit, Plastic limit, Shrinkage limit, Swell pressure, with or without nano material SILO STAB.
- Silo stab soluble material, thus mix silo stab with the water at 1:3 (Silo stab: water) ratio.
- For treated 100 gm soil to mix with 100 gm water solution ratio after mixing this put this soil in oven until it becomes dry. The dried soil is used for a test as treated soil.

Table No. 4: Characteristics of Black Cotton Soil with SILO STAB

Sl. No.	TESTS	Kalaburagi Black Cotton Soil
Hydrometer test		
1.	Gravel	5%
2.	Sand	12%
3.	Silt	38%
4.	clay	45%
5.	Liquid limit	48%
6.	Plastic limit	25%
7.	Shrinkage limit	8%
8.	Free swell	50%
9.	Swell pressure	0.11 gm/cm ²

5.3 Compaction Test for Black Cotton Soil with Cement

Standard Proctor's compaction test as per IS 2720 (Part 7) was conducted on Black cotton with at varying cement content of 4 to 6 percent by weight of the material.

Table No. 5: Standard Proctor Test with cement

Sample	Cement Content, (%)	OMC (%)	MDD (gm/cm ³)
Soil 1	-	14.0	1.65
Soil 2	4	14.3	1.68
Soil 3	5	14.5	1.75
Soil 4	6	14.8	1.88

5.4 Compaction Test for Black Cotton Soil with Cement and SILO STAB

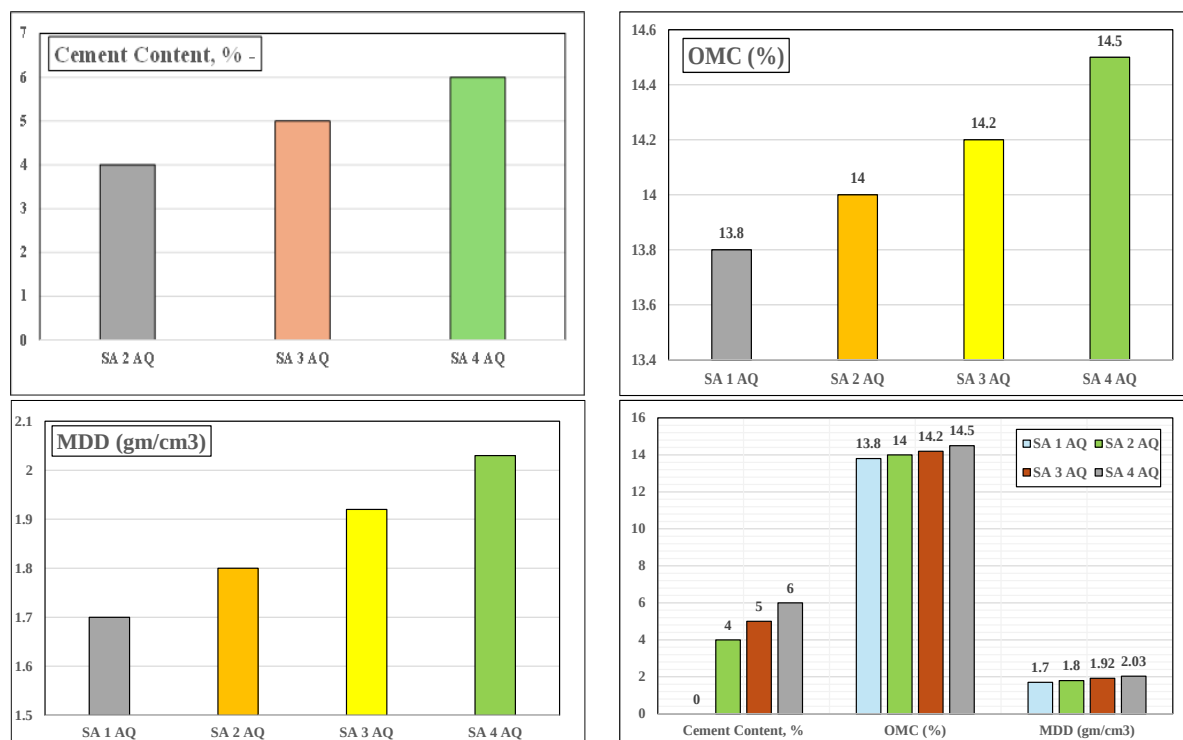
In accordance with IS 2720 (Part 7), a standard Proctor's compaction test was performed on FDR material containing "SILOSTAB-AQ" mixed at a rate of 1.0 k/m³ of Black Cotton soil material. The cement concentration

ranged from 4 to 6 percent by weight of the sample.

See Figure 2 for the compaction curve of the B C Soil. For Black Cotton Soil, cement and SILOSTAB-AQ produced comparable curves. To prepare the specimen for testing its unconfined compressive strength (UCS) at various cement concentrations, these curves were used to determine the mix's Optimal Moisture Content (OMC) and Maximum Dry Density (MDD). Table 2 displays the outcomes of Proctor's exams. To get the required moisture and density in the soil mix, it is essential to determine the correct quantity of cement and water for the black cotton soil.

Table No. 6: Standard Proctor Test with cement and SILO STAB

Sl. No.	Sample	Cement Content, %	OMC (%)	MDD (gm/cm ³)
1.	SA 1 AQ	-	13.8	1.70
2.	SA 2 AQ	4	14.0	1.80
3.	SA 3 AQ	5	14.2	1.92
4.	SA 4 AQ	6	14.5	2.03



Graph No. 1: Cement content, OMC (%), MDD (gm/cc) and over all graphs



Figure No.7: Standard Proctor Test Set Up

5.5 Unconfined Compressive Strength

Based on the OMC test results of the cement/CCS treated soil sample, specimens are prepared at each cement content of 4, 5 and 6 percent for unconfined compressive strength testing. IRC SP 89, 2018 (Part II) has discussed the requirements of commercial chemical stabilizer (CCS) for use in the stabilization of soil—aggregate mixture. The code suggests that the CCS can be used to stabilize all types of aggregates, including marginal aggregates, reclaimed asphalt pavement material, and reclaimed concrete pavement material. So here the 70:30 ratio is taken for UCS. 70% of soil and 30% 40mm down aggregate. This ratio is determined by the chemical manufacturer.

Two criteria are specified in the IRC code.

- The Unconfined Compressive Strength (UCS).
- Percent loss in weight after 12 cycles of wetting and drying of the specimens.

The UCS is measured on a cylindrical specimen compacted to the density corresponding to OMC and MDD. It is suggested that the UCS value of the base course layer should be 4.5 to 7.0 MPa.

IRC SP 89, 2010 suggests that UCS of a stabilized mix can be determined on 150 mm cubic specimen when dealing with coarse-grained material. Compressive strength results on identical materials from strength tests on cubical specimens would be more than obtained from cylindrical specimens. Therefore, cube strength should be corrected to get the corresponding cylindrical strength. For the relatively low strengths encountered in stabilized mixes, this correction factor, however, is suggested as 1.0 only. Therefore, 150 mm cube strength is UCS in the present study.

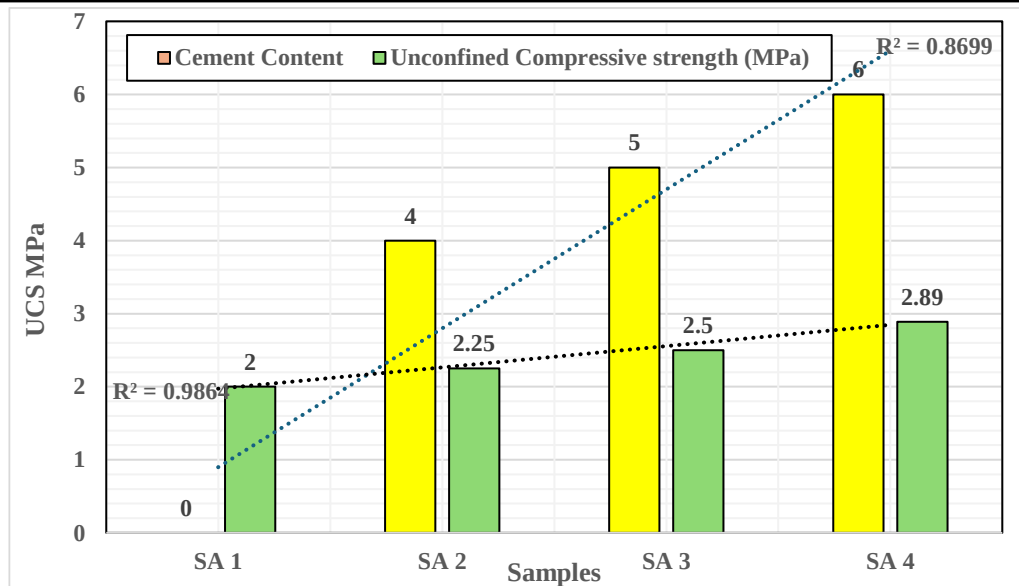
5.6 Results of Unconfined Compressive Strength (as measured on 150 mm cube specimens) are given in

Table No. 7: Results of Unconfined Compressive Strength (as measured on 150 mm cube specimens)

Sl. No.	Sample	Cement Content	Unconfined Compressive strength (MPa)
1.	SA 1	-	2.00
2.	SA 2	4	2.25
3.	SA 3	5	2.50
4.	SA 4	6	2.89



Figure No. 8: Unconfined Compressive Strength Testing

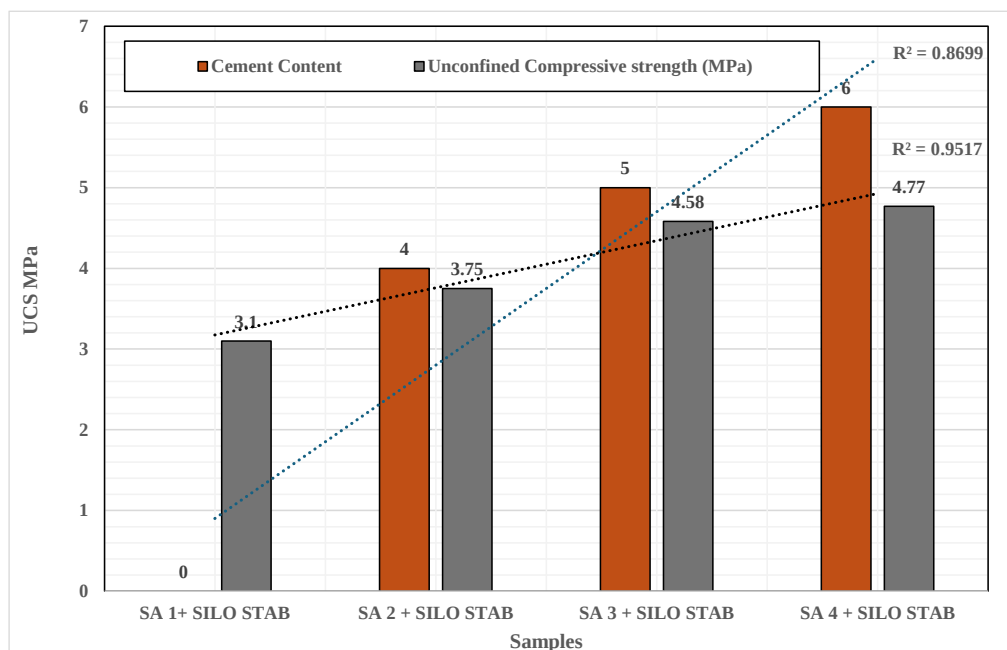


Graph No. 2: Unconfined Compressive Strength Testing

The value of UCS (as measured on 150 mm cube specimens) are observed in

Table No. 8: Results of Unconfined Compressive Strength (as measured on 150 mm cube specimens) with SILO STAB

Sl. No.	Sample	Cement Content	Unconfined Compressive strength (MPa)
1.	SA 1+ SILO STAB	-	3.10
2.	SA 2 + SILO STAB	4	3.75
3.	SA 3 + SILO STAB	5	4.58
4.	SA 4 + SILO STAB	6	4.77



Graph No. 2: Unconfined Compressive Strength Testing

The stabilizer SILOSTAB AQ in the present study was added to the B C Soil material, at the rate of 1.0 kg/m³. The 7 days UCS value after the addition of the chemical was obtained as 3.75, 4.58, and 4.77 MPa at 4 %, 5%, and 6% cement content, respectively. IRC SP 89 (Part II), 2018 suggests that the UCS value of the stabilized base course layer should be 4.5 to 7 MPa.

The value of UCS (as measured on 150 mm cube specimens) are observed in

VI. CONCLUSIONS

- a) Liquid Limit: Decreased by 20%, indicating a reduction in the soil's water-holding capacity and plasticity.
- b) Plastic Limit: Increased by 1%, suggesting a slight improvement in the soil's workability and reduction in plasticity index.
- c) Shrinkage Limit: Decreased by 2%, pointing to a minor reduction in volumetric changes upon drying.
- d) Free Swell Index: Decreased by 25%, reflecting a significant improvement in the soil's expansive behavior.
- e) Swell Pressure: Decreased by 5%, indicating a reduction in the pressure exerted by soil upon wetting, enhancing stability.
- f) Unconfined Compressive Strength (UCS): Achieved a minimum of 4.5 MPa, meeting the requirements specified in IRC: SP 89 (Part 2) for stabilized subbase/base applications.

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