# STABILIZATION OF LOW COMPRESSIBLE CLAYEY SOIL USING GYPSUM & SUGARCANE BAGASSE ASH

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**Abstract -** *Clayey soil has a high concentration of the mineral illite, which changes size when exposed to moisture, that's the reason for structure's fractures, which is based on this kind of soil. Low bearing capacity and high volume change are characteristics of the clayey soil. This research focuses on enhancing the soil's load bearing capacity by adding gypsum and sugarcane bagasse ash(SCBA). The controlled burning of sugarcane straw yields the sugarcane bagasse ash. The soil for this investigation came from a locality in the Punjab region of Ludhiana. Compaction test, California Bearing Ratio (CBR) & Unconfined Compressive Strength (UCS) tests were conducted in this study on materials containing varied percentages of gypsum (3%, 5%, 7%, and 9%) as well as sugarcane bagasse ash (8%,12% and 16% ). Gypsum addition results in an increase in OMC values and decrease in MDD values. But, it also improves the value of UCS & CBR when sugarcane bagasse ash is added at a 12% concentration and 7% gypsum concentration.*

**Key Words: clayey soil, gypsum, SCBA, Compaction test, California Bearing Ratio (CBR) ,Unconfined Compressive Strength (UCS).**

## 1. INTRODUCTION

The strength of the foundation decides whether it will not fail to support the structure of the building constructed over it. Thus, making the bearing capacity of a soil an essential element in infrastructure development, like as road construction. Because all of the loads in the structure will concentrate on the foundation, the soil has to have a high bearing capacity. Clay soils usually have a low bearing capacity so problems with the soil might arise. This can be seen through the CBR (California bearing ratio) values. If the soil's bearing capacity is low, the CBR value will be low as well, and stabilising material can be added to the soil to increase it. This stabilising element may take the form of waste products, chemicals, or other substances that improve the soil's bearing capacity. On the basis of strength, soil is divided into three types: soft soil, medium soil, and hard soil. It is quite challenging to establish a structure on soft soil because, as soon as a load is placed throughout the different phases of construction, the earth begins to compress and settle which causes the structure to begin to move. For this reason, the buildings are built on either hard or medium soil. If there is soft soil present, the site's soil conditions must be improved by taking the appropriate steps. For the majority of building projects, clayey soils are frequently utilized. They have good plastic characteristics and are soft soils, thus as the moisture content rises, so do their shear strength, compressive strength, and volume changes. The use of refuse and industrial effluent and their subsidiary goods as alternatives to building materials may effectively contribute to environmental restoration and minimize their negative effects on environment, especially in light of the millions of tons of waste produced yearly across the nation, which not only causes the problem of disposal but also adds to environmental contamination and health risks.

## 2. MATERIAL USED FOR THIS STUDY

### 2.1 SUGARCANE BAGASSE ASH [SCBA]

Sugarcane bagasse ash is a pozzolanic substance with extremely high levels of silica and aluminium. Calcium-hydroxide silicate, which has certain cementitious qualities, combines with the pozzolanic properties of materials in the presence of water. Bagasse ash is kept in damp environments. The bagasse pile is partially dried by the exothermic process caused by the sugar residue's minor deterioration. Bagasse ash is a very homogenous substance. 1,48,000 hectares are now under cultivation for sugarcane. Moreover, it is predicted that each hectare of sugarcane would produce 100 tonnes of sugar. According to this, 4 to 5 million tonnes of sugarcane are produced annually. Bagasse ash was created from sugarcane in the proportion of 40%.

**Table -1:** Chemical composition of SCBA

| Sr. No. | Chemical composition | Percentage by mass |
|---|---|---|
| 1. | Silica ($SiO_2$) | 61.00 |
| 2. | Potassium Oxide ($K_2O$) | 7.52 |
| 3. | Calcium Oxide (CaO) | 3.10 |
| 4. | Iron oxide ($Fe_2O_3$) | 2.80 |
| 5 | Alumina ($Al_2O_3$) | 1.14 |
| 6 | Magnesium Oxide (MgO) | 1.45 |
| 7 | Phosphorous ( $P_2O_5$) | 2.30 |
| 8 | Titanium Oxide ($TiO_2$) | 0.41 |

| | | |
|---|---|---|
| 9 | Sulphate ($SO_3$) | 1.43 |
| 10 | Chloride (Cl) | 0.33 |
| 11 | Sodium Oxide ($Na_2O$) | 0.04 |
| 12 | Manganese Oxide (MnO) | 0.04 |
| 13 | Loss on Ignition | 18.44 |

### 2.2 GYPSUM

Calcium sulphate dihydrate, or gypsum, is a soft sulphate mineral. Its chemical formula is $CaSO_4.2H_2O$. It is extensively excavated, used as manure, and the primary component of several plaster, pavement or blackboard chalk, and drywall products. Alabaster, a large-scale, fine-grained form of gypsum that is either white or delicately coloured, has been employed for sculpting by a number of civilizations, included Medieval England's Nottingham alabasters, Mesopotamia, Rome, and the Byzantine Empire. Gypsum has retrograde solubility, which means it becomes less soluble at increasing temperatures, unlike the majority of other salts. At 25 °C, gypsum has a moderate water solubility of 2.0–2.5 g/l. Gypsum is composed of layers of calcium (Ca2+) and sulphate (SO24) ions that are closely linked together. When gypsum is subjected to high temperatures, results in water loss and initially transforms into calcium sulphate hemihydrate. Because gypsum is 150 times more soluble than limes and contains 23 % calcium and 18% sulphur, it provides a natural source of plant nutrients.

**Figure -1**: Sugarcane bagasse ash & Gypsum

## 3. METHODOLOGY

Following tests were conducted with proper procedure on the soil sample;

1. Specific gravity test
2. Moisture Content
3. Atterberg's Limits
4. Compaction test
5. California bearing ratio
6. Unconfined compression test

## 4. LITERATURE REVIEW

**M. Carlina et al. (2021)** Waste products in the form of eggshell powder and bagasse ash were used as stabilizing materials in this investigation. The bagasse ash combination employed in this investigation had variations of 7%, 10%, and 13% plus 3% eggshell powder Moisture content, sieve analysis, specific gravity, consistency limitations, compaction testing, and CBR testing are all included. , there is a 92.303 % increase in the CBR value of clay soil using a stabilization mixture

**Kumar Abhimanyu Bhardwaj et al. (2019)** This research paper's goal is to examine the strength characteristics of naturally clayey soil reinforced with varying amounts of gypsum by soil weight and a fixed amount of calcium chloride as a binding agent. On both natural soil and reinforced soil with different amounts of gypsum (2%, 4%, 6%, and 8 %) by weight and a set proportion of calcium chloride (1%), a series of Standard Proctor test, Free swell Index & California Bearing Ratio (CBR) test were conducted.

**B. A. Mir et.al (2016)** To assess the behavior of SCBA admixed cement stabilized soil, Laboratory tests include soil grading, atterberg limits, compaction characteristic, and CBR tests. test specimens were prepared with soil using varying percentages of SBA (0, 7.5%, 15%, and 22.5 %) and cement (0, 3 %, and 6 % by wt of the soil) at 0.95γdmax and optimum moisture content and various tests as per the applicable standard operating procedures. Additionally, it was shown that adding SCBA cement mix at the ideal proportion of 7.5% SCBA and 6.5% cement produced exceptional results.

## 5. RESULTS & DISCUSSION

### 5.1 Mix proportions for experiments with varying percentages of different Stabilizing agent

Mix design aims to determine the ideal ratio of gypsum and sugarcane bagasse ash to stabilize the soil to the required strength. In varying ratios, soil, gypsum, and sugarcane bagasse ash were combined to conduct various tests.

**Table -2:** Mix proportion (soil% + gypsum%)

| SAMPLES | SOIL (%) | GYPSUM (%) | TOTAL (%) |
|---|---|---|---|
| 1 | 100 | 0 | 100 |
| 2 | 97 | 3 | 100 |
| 3 | 95 | 5 | 100 |
| 4 | 93 | 7 | 100 |
| 5 | 91 | 9 | 100 |

The value of the optimized gypsum sample will serve as a fixed proportion for the further calculation of the strength parameters, and the behavior of the clay soil will also be examined with various additions of sugarcane bagasse ash (SCBA).

**Table -3:** Mix proportion (soil & optimum gypsum% + SCBA%)

| SAMPLE | SOIL + OPTIMUM GYPSUM CONTENT (%) | SCBA (%) | TOTAL (%) |
|---|---|---|---|
| 1 | 92 | 8 | 100 |
| 2 | 88 | 12 | 100 |
| 3 | 84 | 16 | 100 |

### 5.2 CLASSIFICATION OF SOIL

According to Indian Standard Classification of Soil, soil is usually divided in categories based on certain index properties. The table below tabulates the grouping. The first letter indicates the soil type, and the second letter denotes the degree of compressibility, for example, the CL group of soil denotes clay and low compressibility.

**Table -4: Index properties of Soil**

| SR.NO | PROPERTIES | VALUE |
|---|---|---|
| 1 | Specific gravity | 2.63 |
| 2 | Liquid limit (LL in %) | 30.20 |
| 3 | Plastic limit (PL in %) | 17.95 |
| 4 | Plasticity index ($I_p$ in %) | 12.25 |
| 5 | Soil group (as per IS: 1498) | CL |

**Figure -2:** Soil samples

### 5.3 OMC & MDD of Soil Samples with gypsum

The value of OMC and corresponding MDD with different percentage of gypsum are summarized in the table below-

**Table -5:** OMC & MDD results with gypsum

| S.No. | Gypsum (%) | MDD ($kN/m^3$) | OMC (%) |
|---|---|---|---|
| 1 | 0 | 17.9 | 12.5 |
| 2 | 3 | 17.6 | 12.9 |
| 3 | 5 | 17.2 | 14.15 |
| 4 | 7 | 17.0 | 14.8 |
| 5 | 9 | 16.6 | 16 |

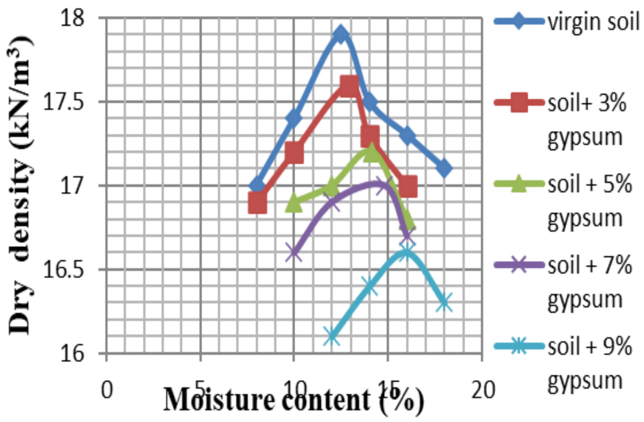


**Chart -1:** Variation in compaction characteristics with gypsum

Gypsum reduces the maximum dry density while increasing the soil's optimum moisture content up to a specified admixture content %. The decrease in dry density is brought on by soil particle flocculation. The soil gets looser and more challenging to compress. While the addition of finer particles likes gypsum increased the soil's surface area, which in turn improved the optimal moisture content. More water is needed to moisten soil particles with greater surface areas.

### 5.4 Unconfined compressive strength (UCS) of soil sample with Gypsum

Results of the UCS test with various gypsum percentages are displayed and summarized in the table below:

**Table -6:** UCS results with gypsum

| S.No | Gypsum (%) | UCS ($kN/m^2$) |
|---|---|---|
| 1 | 0 | 204.76 |
| 2 | 3 | 217.71 |
| 3 | 5 | 232.20 |
| 4 | 7 | 273.93 |
| 5 | 9 | 260.34 |

The percentage increment in UCS values at varying percentages 3%, 5%, 7% & 9% of gypsum are found to be 6.32%, 13.4%,33.78% & 27.14% respectively, more than the virgin soil samples. The maximum value is found at 7% which is 273.93kN/m²

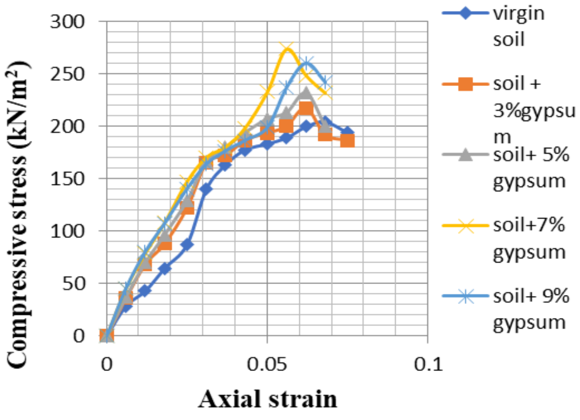


**Chart -2:** Variation in UCS with gypsum

### 5.5 California bearing Ratio (CBR) of soil sample with gypsum

CBR values with different percentages of gypsum is given below

**Table -7:** CBR results with gypsum

| S.No. | Gypsum (%) | CBR (%) |
|---|---|---|
| 1 | 0 | 3.53 |
| 2 | 3 | 4.06 |
| 3 | 5 | 4.33 |
| 4 | 7 | 5.12 |
| 5 | 9 | 4.55 |

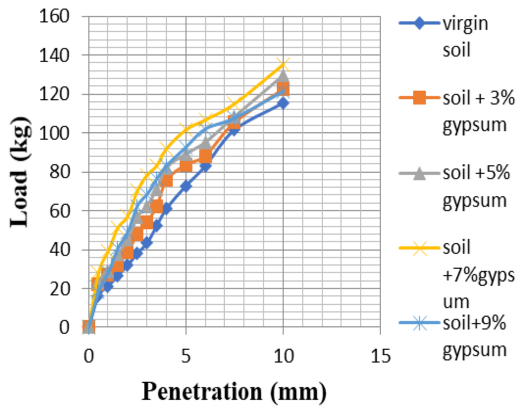


**Chart -3:** California bearing ratio test variations with gypsum

### 5.6 OMC & MDD Of 7% Gypsum With Sugarcane Bagasse Ash

The values of OMC & MDD after adding significant proportion of sugarcane bagasse ash in percentage of 8,12 & 16% with optimum value of gypsum which is taken as 7% is summarized below

**Table -8:** OMC & MDD results with SCBA

| S.No. | SCBA (%) | OMC (%) | MDD (kN/m³) |
|---|---|---|---|
| 1 | 8 | 16 | 16.9 |
| 2 | 12 | 16.8 | 16.7 |
| 3 | 16 | 18 | 16.5 |

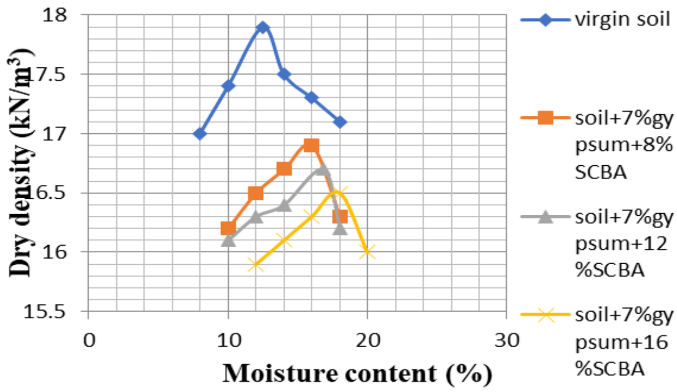


**Chart -4:** Variation in compaction characteristics with gypsum & SCBA

Maximum dry density tends to rise and optimum moisture content gradually decline at admixture content higher than optimal levels. This discrepancy in results is explained by the fact that at greater admixture contents, the soil structure tends to spread, increasing maximum dry density and decreasing optimum moisture content.

### 5.7 UCS of 7% gypsum mixed with sugarcane bagasse ash (SCBA)

The value of UCS with different percentage of SCBA are compiled below

**Table -9:** UCS results with SCBA

| S.No. | SCBA (%) | UCS (kN/m²) |
|---|---|---|
| 1 | 8 | 298.82 |
| 2 | 12 | 331.50 |
| 3 | 16 | 303.85 |

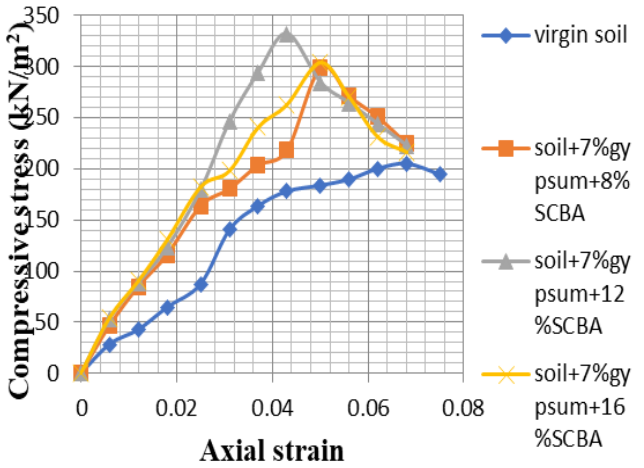


**Chart -5: Variation in UCS with gypsum & SCBA**

With the addition of gypsum and bagasse ash to soil, unconfined compressive strength of the soil has significantly increased. After reaching an appropriate proportion of admixture, unconfined compressive strength starts to decline. This variance is related to the soil's transition from flocculated to the dispersed structure after exceeding an optimum admixture proportion. Additionally, the ideal moisture level is rising as well.

### 5.8 CBR of 7% gypsum with different percentage of SCBA

The CBR values at different percentage with SCBA is shown below

**Table -9:** CBR results with SCBA

| S.No | SCBA (%) | CBR (%) |
|---|---|---|
| 1 | 8 | 6.14 |
| 2 | 12 | 9.42 |
| 3 | 16 | 7.10 |

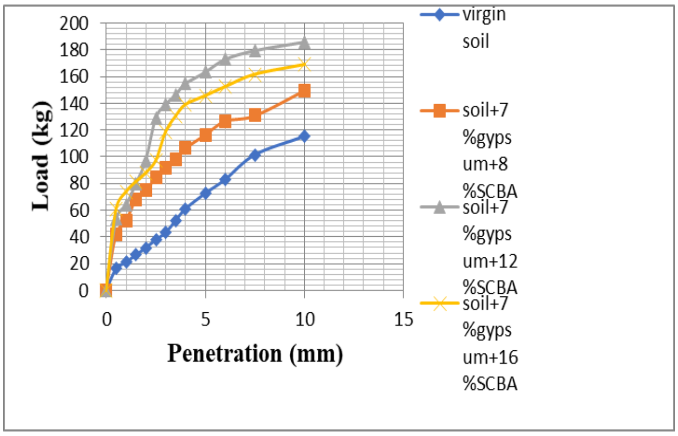


**Chart -6:** California bearing ratio test variations with gypsum & SCBA

The value of CBR indicates a drop with an increase in sugarcane bagasse ash, but a very little decrease with gypsum. The gypsum particle size, which fills the spaces in clayey soil, is to blame for this behavior. While in case of sugarcane bagasse ash, CBR value decreases if more bagasse ash is applied than is optimal. The CBR decreases with higher ash additions, which may be caused by the quantity of ash that doesn't react and form crystals. As a result, you have unreacted ash grains rather than soil grains, which do not increase soil resistance.

## 6. CONCLUSIONS

Following conclusions from tests were drawn during the investigation and experiments

- Addition of gypsum resulted in increase OMC and a decline in compressibility value in terms of the MDD parameter, OMC of virgin soil is 12.5% and MDD 17.9kN/m$^3$, with addition of gypsum and SCBA the value of OMC increases while MDD decreases considerably. The change in soil matrix, which shows a more randomly flocculated structure due to the presence of CaO in SCBA and the addition of gypsum content, may be responsible for the rise in moisture content.

- The UCS is highest at 7% gypsum which is 33.78%. UCS with the combination of gypsum (7%) and sugarcane bagasse ash (12%) shows the peak value that is found as 331.50 kN/m$^2$. The increase of UCS when compared with untreated soil is 61.89%.

- CBR value of virgin soil is found out as 3.53%. The value of CBR of the soil having addition with 7% gypsum is 5.12%, the percentage increment in CBR value when compared to virgin soil is 45.04%. The CBR value of combined soil sample with 7%gypsum & 12% SCBA is 9.42%, which is a 166.85% increase in CBR value over virgin soil.

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## BIOGRAPHIES

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