Experimental Study on Stabilisation of Clayey Soil Using Cement and Bagasse Ash

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Abstract. In order for the foundation of building to be strong, the soil around it plays a critical role. So, researcher or engineer should have thorough knowledge about the factors affecting behaviour of soil which can be altered by the process of soil stabilisation. This study aims to investigate the applicability of SCBA (Sugarcane Bagasse Ash) to stabilize the clayey soil. Sugar factories produce waste after extraction of sugarcane gets brunt and the ash, hence produced is known as bagasse ash. Soil is treated with partial replacement of cement (3%, 6%, 9% and 12%) and with bagasse ash (2%, 4%, 6% and 8%). A total of 45 specimens were prepared in this study. Later those test specimens were evaluated for compaction properties. The results found after thorough study was that there was increase in the compaction properties with percentage increase in Sugarcane Bagasse Ash up to certain limit.

Keywords: Clayey soil, optimum moisture content, bagasse ash, standard proctor test, maximum dry density.

1. Introduction

In order for the foundation of building to be strong, the soil around it plays a critical role. So, researcher or engineer should have thorough knowledge about the factors affecting behaviour of soil which can be altered by the process of soil stabilisation [1–4]. In recent time there has been a great change in technology. There are many Stabilisation techniques available to improve soil properties like addition of bitumen, cement, lime etc. [5–7] conducted the study on using agricultural wastes i.e. sugar cane bagasse ash, groundnut shell and rice husk ash on the CBR value of the subgrade soil. In this investigation, soil was treated with all the three wastes separately from 0% till 15% in steps of 3% increment. All these mixes were subjected to grain size analysis, compaction and California Bearing Ratio (CBR) tests. [8–12] examined the use of bagasse ash in the expansive clayey soil through series of laboratory tests. The bagasse ash was replaced with soil in 0%, 3%, 5%, 7% and 10% by weight of dry soil. Those blends were subjected to tests like Liquid Limit by Casagrande’s apparatus, Plastic Limit, Plasticity Index, Shrinkage Limit, Free Swell Index and Swelling Pressure. It was also found that wet soils are dried due to presence of bagasse ash and rapid strength increment in initial stage due presence of silica in it which is favorable for construction in wet areas. This paper presents the systematic investigation on the effects of the addition of Sugarcane Bagasse Ash in soft soil on their compaction properties. The practical application
of this study is that the disposal of wastes is today’s major concern and the addition of sugarcane bagasse ash for stabilisation of soil is a fruitful way of utilizing it and hence reducing disposal problem.

2. Materials Used

2.1 Clay Soil

The soil sample for this study was obtained from a village Gharuan, Punjab as shown in figure 1. The engineering properties of the soil sample are listed in table 1.

![Figure 1. Sample](image)

Table 1. Engineering Properties of Soil Sample

| Parameters                        | Values obtained |
|-----------------------------------|-----------------|
| Liquid Limit                      | 22 %            |
| Plastic Limit                     | 15.44%          |
| Natural Moisture Content (%)      | 10.03           |
| Optimum Moisture Content (%)      | 14 %            |
| Plasticity Index                  | 41.74%          |
| Specific gravity                  | 2.07            |
| UCS (Kg/cm²)                      | 0.94            |
| Maximum Dry Density (g/cc)        | 1.85            |
| Soil Type                         | CI              |

2.2 Sugarcane Bagasse Ash

In this study, the Sugarcane Bagasse ash was collected from Morinda Co-operative Sugar Mills Ltd., Morinda, Punjab. It was of grayish black colour and comes in fibrous form as shown in figure 2. The chemical properties of Bagasse ash after X-Ray fluorescence test is presented in table 2.
2.3 Ordinary Portland Cement (OPC) 53 grade

The OPC (Ordinary Portland Cement) used in this investigation was Ultratech OPC-53 grade cement bought from the market. Under this study [13,14], OPC is used as a stabilizing material along with bagasse ash because of its better pozzolanic characteristics [15–18]. The properties of OPC-53 grade obtained from supplier are shown in table 3.

Table 3. Chemical Composition of OPC-53 used in this study

| Chemical element | % by weight |
|------------------|-------------|
| Silica (SiO2)    | 64.27       |
| Fe₂O₃            | 5.76        |
| Al₂O₃            | 5.53        |
| LOI              | 4.97        |
| K₂O              | 2.96        |
| CaO              | 3.73        |
| SO₃              | 1.84        |
| Mn               | 0.35        |
| Zinc             | 0.46        |
| Cu               | 0.18        |
3. Methodology

The experimental work consisted of the following steps:

- Particle size distribution by sieve analysis
- Determination of specific gravity and natural moisture content of soil
- Determination of soil index properties (Atterberg’s Limits)
- Determination of the compaction properties of the soil by Proctor compaction test.

The type of tests performed and composition of the sample is shown in table 4.

| Sample No. | Sample Design | Tests Performed |
|------------|---------------|-----------------|
|            | Soil (%)      | Bagasse Ash (%) | Cement (%)  | MDD | OMC |
| US         | 100           | 0               | 0            | √   | √   |
| C 3        | 97            | 0               | 3            | √   | √   |
| C 6        | 94            | 0               | 6            | √   | √   |

Table 4. Tests performed and sample design in the study.

| Constituents          | %age |
|-----------------------|------|
| Silica (SiO₂)         | 18.23|
| Calcium Oxide (CaO)   | 69.84|
| Alumina (Al₂O₃)       | 4.72 |
| Sodium Oxide (Na₂O)   | 0.56 |
| Iron oxide (Fe₂O₃)    | 1.37 |
| Sulphur Trioxide (SO₃)| 2.34 |
| Magnesium Oxide (MgO) | 1.62 |
| Other Oxides          | 1.32 |
The Clayey soil was replaced with as 3%, 6%, 9% and 12% replacement and with Bagasse Ash i.e. 2% to 8% by weight of soil. The different samples were labeled as US, C3, C6, C9, C12, CBA2, CBA4, CBA6 and CBA8 representing Unstabilized Soil, Soil with different percentages of Cement and Bagasse ash as shown in table 4. The stabilized soil samples were tested for Standard Proctor Test as per IS: 2720(Part 7)-1980.

4. Results & Discussion

4.1 Unstabilized Soil

Before adding Bagasse Ash to the soil, firstly the laboratory tests on unstabilized soil were performed. The results of the same are presented in this section as shown in figure 3, table 5, table 6, table 7, table 8 and table 9.

4.1.1 Particle Size Distribution by Sieve Analysis

| Sieve Size (mm) | Weight (gm) Retained | %age retained | Cumulative %age | %age finer |
|-----------------|----------------------|---------------|-----------------|------------|
| 4.75            | 0                    | 0             | 0               | 100        |
| 2.36            | 40.20                | 8             | 8               | 92         |
| 1.18            | 84.60                | 16.85         | 24.85           | 75.15      |
| 0.6             | 90.20                | 17.96         | 42.81           | 57.19      |
| 0.3             | 106.40               | 21.19         | 64.00           | 36.00      |
| 0.15            | 108.80               | 21.66         | 85.66           | 14.34      |
| 0.075           | 59.40                | 11.83         | 97.49           | 2.51       |
4.1.2 Natural Moisture Content

Table 6. Natural moisture content of the given soil sample

| Sample No. | Sample 1 | Sample 2 | Sample 3 |
|------------|----------|----------|----------|
| Wt. of container (gm) | 47 | 47 | 47 |
| Wt. of container + wet soil (gm) | 150 | 154 | 158 |
| Wt. of container + dry soil (gm) | 140 | 144 | 146 |
| Wt. of water (gm) | 10 | 10 | 12 |
| Moisture content (%) | 10.7 | 10.3 | 9.1 |

The natural moisture content of soil sample calculated from table 6 is 10.03 %

4.1.3 Specific Gravity of the Soil

Table 7. Specific Gravity by Pycnometer Method

| Sample No. | Sample 1 | Sample 2 | Sample 3 |
|------------|----------|----------|----------|

Figure 3. Particle Size Distribution
Empty pycnometer (M1) 633gm 633gm 633gm

Pycnometer with dry soil (M2) 828gm 828gm 828gm

Pycnometer filled with water (M4) 1405gm 1402gm 1406gm

Pycnometer with soil and water (M3) 1506gm 1502gm 1508gm

Specific gravity 2.07 2.05 2.09

Average value of Specific gravity (G) calculated from table 7 = **2.07**

### 4.1.4 Liquid Limit of the Soil

#### Table 8. Liquid Limit by Casagrande’s Apparatus

| Sample No.          | Sample 1 | Sample 2 | Sample 3 |
|---------------------|----------|----------|----------|
| Wt. of container (gm) | 44.9     | 46       | 44.6     |
| Wt. of container + wet soil (gm) | 78.3     | 81.3     | 76.8     |
| Wt. of container + dry soil (gm) | 70       | 75.30    | 74.10    |
| Wt. of water (gm)    | 8.3      | 6        | 2.7      |
| Moisture content (%) | 33.07    | 20.30    | 10       |
| No. of blows         | 17       | 26       | 34       |
Figure 4. Water Content v/s No. of Blows

From figure 4, At 25 Number of blows[19], Moisture content is 22%
Therefore Liquid Limit is equal to 22%

4.1.5 Light Compaction Tests

Table 9. Proctor compaction test for unstabilized soil

| Water Content taken initially | 6%   | 10%   | 14%   | 18%   | 22%   |
|-------------------------------|------|-------|-------|-------|-------|
| Weight of empty mould (g)     | 3673 | 3673  | 3673  | 3673  | 3673  |
| Volume of mould(cm3)          | 1000 | 1000  | 1000  | 1000  | 1000  |
| Weight of soil passing through 4.75mm sieve | 2816 | 2816  | 2816  | 2816  | 2816  |
| Weight of soil + mould (g)    | 5572 | 5670  | 5785  | 5833  | 5764  |
| Weight of compacted soil      | 1899 | 1997  | 2112  | 2160  | 2091  |
| Density (g/cc)                | 1.899| 1.997 | 2.112 | 2.160 | 2.091 |
| Dry unit weight (g/cc)        | 1.79 | 1.81  | **1.85** | 1.83 | 1.71 |
Figure 5 shows that Maximum Dry Density of Unstabilized soil is 1.85 g/cc at optimum moisture content of 14%[20]. Further the effect of addition of cement on the MDD and OMC of the soil is observed and results are shown in table 10 and figure 6.

| Moisture content | Dry density of cement stabilized soil at different cement content |
|------------------|---------------------------------------------------------------|
|                  | 3%   | 6%   | 9%   | 12%  |
| 6%               | 1.68 | 1.68 | 1.63 | 1.60 |
| 11%              | 1.87 | 1.90 | 1.69 | 1.68 |
| 16%              | 1.82 | 1.75 | 1.74 | 1.67 |
| 21%              | 1.71 | 1.70 | 1.75 | 1.62 |
| 26%              | 1.69 | 1.68 | 1.71 | 1.60 |
| 31%              | 1.65 | 1.66 | 1.63 | 1.57 |

Unstabilized Soil

Figure 5. Variation in dry density with moisture content for Unstabilized soil
On replacing the cement with soil at different percentages from 3% to 12%, we get the maximum value of dry density as 1.90 g/cc when 6% of soil is replaced with cement and corresponding OMC comes out to be 11% as shown in figure 6. So, taking an optimum value of 6% Cement, further proctor compaction test was performed on 6% cement and varied percentages of Bagasse Ash from 2% to 8% replacement with soil. The results of the same are presented in table 11.

**Figure 6.** Variation in dry density with moisture content for cement stabilised soil at different cement contents

| Water content | Dry density for 6% cement and varied percentage of bagasse ash |
|---------------|---------------------------------------------------------------|
|               | 2%     | 4%     | 6%     | 8%     |
| 6%            | 1.58   | 1.48   | 1.51   | 1.58   |
| 11%           | 1.81   | 1.52   | 1.66   | 1.62   |
| 16%           | 1.76   | 1.65   | 1.67   | 1.64   |
| 21%           | 1.64   | 1.68   | 1.57   | 1.52   |
| 26%           | 1.60   | 1.49   | 1.49   | 1.45   |

**Table 11.** Proctor compaction test for 6% Cement and varied percentage of bagasse ash stabilized soil
Figure 7. Variation in dry density with moisture content for 6% cement stabilised soil at different bagasse ash contents

Figure 7 show that maximum dry density achieves its peak value at 6% cement and 2% bagasse ash replacement with soil. The MDD comes out to be 1.81 g/cc at an optimum moisture content of 11%.

5. Conclusion

This study examines the effect of Cement and Bagasse Ash on the compaction properties of clay soil. The following interpretations are:

1. The MDD of soil increased from 1.85 g/cc for unstabilized soil to 1.90 g/cc for 6% cement stabilized soil. However, further replacement of soil leads to MDD decrement.
2. The OMC of soil firstly increases from 14 % for untreated soil up to 21 % for soil replaced with 9% cement and then it starts decreasing further replacement.
3. The maximum value of MDD on replacement of soil with 6% cement and varied percentage of bagasse ash is achieved at 2% bagasse ash which comes out to be 1.81 g/cc at an OMC of 11%.
4. Thus an optimal mixture of 92% Soil / 6% Cement / 2% Bagasse Ash is advisable for utilization in soil stabilization.

6. Limitations and Future Scope for studies

1. In this experimentation, Bagasse ash content of only up to 8% was taken, so the effect of bagasse ash beyond 8% can also be studied.
2. The effect of bagasse ash on Durability and Shear strength (consolidation characteristics) can also be tested in future.

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