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EFFECTS OF AGRICULTURAL SOLID WASTE BAGASSE ASH ON THE PROPERTIES OF EXPANSIVE SOILS

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Abstract: Expansive soils may be defined as the soils that expand in volume with the ingress of water and shrink when the soils get devoid of water. The variation of volume depends upon the moisture content, also many researchers have shown swelling and shrinkage follow two different mechanisms and generally shrinkage limit does not relate to the swelling characteristics of the soil. As a result of this volume change in soil, significant distress in the soil occurs, causing severe damage to the overlying structure. On the onset of the rainy season, these soils swell and lose their capacity to bear water and generally become softer.

1.0 Introduction

1.1 General

For construction of any structure, it is duty of a responsible engineer to assess and evaluate the properties of the soil in order to know its geotechnical and engineering characteristics. After the evaluation, the properties can be modified suitably with various methods. In this work, an attempt has been made to modify the properties of expansive soil using industrial solid waste Bagasse Ash.

1.2 Expansive Soil

In the seasons which are relatively dry, these soils shrink due to evaporation of water and become harder. The resulting volume change can be the reason of cracking of the structures built upon it. The code of IS-1498 has given a basic idea about the classification of various expansive soil and their expansion characteristics based on their liquid limit and plasticity index values. Expansive soils are problematic in nature and are generally encountered by geotechnical engineers in the process of designing structures like highways, retaining walls, buildings, backfills etc. Expansive soils are normally abundant in semi-arid regions. The cause may be due to the difference in evaporation and precipitation. Various attempts at stabilization of expansive soil have been performed by a plethora of researchers using admixtures like lime, bitumen or cement. Although the stabilization with these admixtures is effective; it is not very much compatible from an economic view point.
Attempts have been made to stabilize expansive soil with various locally available materials which are cheap and abundantly available in that very region where the problematic soil is present. Various wastes, whose disposal becomes a problem, are tried as admixtures to modify the property of soils.

1.3 Bagasse Ash

When it comes to sugar producing countries, India is ranked second in the production of sugar in the whole world. India has one-fifth of the total sugar industries of the world and accounts for almost one-seventh of the global production. In the process of sugar production, Bagasse is one of the major solid wastes produced. After the juice is extracted from the sugar cane, a fibrous matter remains which is generally termed as Bagasse. Indian sugar industries produce Bagasse up to an amount of 100MT per year. The deposition of Bagasse is uneven, random and is done in an unscientific manner which causes problems like valuable space reduction of the industrial area and other geo-environmental problems. If the solid waste is utilized in a proper manner to stabilize the expansive soil such problems can be avoided and the valuable space of the above said industry may be saved. When the Bagasse is burned Bagasse Ash is formed which is used in this particular study. The Bagasse ash is used as a replacement at various percentages; the properties of the virgin soil and the mixes are compared and the result is analyzed in a graphical manner to find out the major changes in the properties of soil.

2.0 Literature Review

2.1 Previous Work

A limited number of studies have been done on the utilization of Bagasse Ash as an admixture to modify the properties of expansive soil. Few of the researches also include other waste materials along with the use of Bagasse Ash as admixtures to improve the properties of expansive soil.

Akshaya Kumar Sabat (2012) has investigated and reported that the addition of Bagasse Ash as an admixture to the expansive soil causes decrease in the MDD and causes increase in the value of OMC. The study has also reported that Bagasse Ash and lime sludge can be used for increasing the strength of flexible pavements in an economically suitable manner.

K. S. Gandhi (2012) has investigated the effects of Bagasse Ash on the properties of expansive soil and has reported a decrease in the value of plasticity index and free swell index of the expansive soil using Bagasse Ash in the proportions of 3 to 10%. The study has also shown that Bagasse Ash reduces the moisture content of wet soils in an effective manner and augments initial strength which is a necessary property for constructions in unstable and excessively moist ground conditions.

Moses, G and Osinubi, K. J. (2013) studied the impact of compactive effort on expansive soil samples which were treated with up to 8%

Ordinary Portland cement (OPC) mixed with up to 8% Bagasse Ash (BA) by the dry weight of soil and were compacted by

Standard Proctor (SP). The study reported an optimal blend of 8% OPC/ 4% BA as the suitable mixture.

Prakash Chavan and Dr.M.S.Nagakumar (2014) have reported the decreasing of plasticity index of expansive soil using Bagasse Ash. The study has also shown that up to an addition of 9% Bagasse Ash, MDD increases and OMC decreases. The study also has reported the increase in UCS values of the same soil at 9% Bagasse Ash content.

C. Rajakumar, T. Meenambal, and P. D. Arumairaj (2014) have reported the increasing of UCC strength with the addition of Coal ash + Bagasse ash, Coal Ash + Groundnut shell ash, and Bagasse ash + Groundnut shell ash with proportions which are uniform.

Amit S. Kharade, Vishal V. Suryavanshi, Bhikaji S. Gujar, and Rohankit R. Deshmukh (2014) have reported that at an effective replacement of 6% Bagasse Ash, the maximum dry density increased by 5.8% and have also suggested that the effective replacement of 6% Bagasse Ash is the optimum blend for an economic approach.

2.2 Properties of Soil

2.2.1 Specific Gravity

Specific Gravity may be termed as the ratio between the mass of any substance of a certain volume to the mass of the same volume of water. It basically tells us how heavier is the soil compared to water.

2.2.2 Particle Size Distribution

Soil is composed of particles of a plethora of shapes and sizes; the range of particle size of soil varies from microns to centimetres depending on various parameters like the place of origin soil, physical weathering and chemical weathering. The physical properties of soil like, density, permeability and strength are determined and affected fully or partially by the size and gradation of particles present in the soil mass. There are various methods like, dry sieve analysis, wet sieve analysis and other methods to determine the particle size of the concerned soil sample. Generally the data is plotted on a graph paper, which is semi-log in nature and whose ordinate is the percentage finer and whose abscissa is the particle diameter which is defined by the sieve size.
The abscissa is generally plotted on a logarithmic scale. The soil is termed as well graded if all the sizes of particle are abundant in a uniform manner. The soil is termed as poorly or uniformly graded if the particles of different size are available either excessively or are deficient.

2.2.3 Atterberg Limits

2.2.3.1 Liquid Limit

Liquid limit may be termed as that moisture content at which the soil behavior changes from plastic to liquid. Indian standard code has provided information regarding the measure of expansive soil relating to its liquid limit.

2.2.3.2 Plastic Limit

The difference between liquid limit and plastic limit is termed as the plasticity index and it is also a deciding factor for any construction.

2.2.3.3 Shrinkage Limit

It is that moisture content after which any moisture reduction in the soil does not cause any volume change.

2.2.4 Free Swell Index

The expansivity of the soil can also be predicted from the FSI value which is the differential increase in volume of soil when it comes under the influence of water or moisture content.

2.2.5 Unconfined Compression Test (UCS Test)

UCS or Unconfined Compression Test is just a specialized phenomenon of tri axial test in which the applied horizontal forces are zero. The sample is not confined horizontally and is only subjected to vertical loading until the failure occurs under shear.

Various samples are tested with different periods of curing to obtain and compare the strength of soil under the effect of various admixtures.

3.0 Experimental Investigations

3.1 Materials

Expansive soil: The expansive soil was collected from Nagpur, India. The sample was collected at a depth of 150 mm below the ground. Manual labour was employed to collect the sample. The soil was packed and transported to the place of study via train.

Bagasse: The Bagasse was collected from Bolangir, India. The Bagasse was collected from the field where the Bagasse Ash was dumped in layers. The Bagasse was collected and packed and brought to the place of study via roadways.

3.2 Preparation of Samples

Expansive Soil: The sample was first left out to dry in contact with direct sunlight and the clods present were broken to achieve uniformity of the sample. The sample was made devoid of small debris and other organic wastes. The sample was then oven-dried for 24 hours at 105 C.

The image of a sample of the expansive soil is given next.

Bagasse Ash: The Bagasse collected was dried in the sun and the lumps were broken. The Bagasse was burnt in the Muffle Furnace at 600 degree Celsius for 24 hours to devoid it of any organic matter present and thus to prepare the Bagasse Ash. The Bagasse ash was then cooled for 6 hours and was mixed with expansive soil to form various mixes.

Figure 1 Sample Of The Expansive Soil

Figure 2 Sample Of The Bagasse Ash

The image of a sample of the Bagasse Ash is given next.

4.0 Results

Different tests were done on Virgin Expansive Soil and various mixes described in section 3.1. The test results are arranged below in the order of replacement of percentage of Bagasse Ash by the dry weight of soil.

4.1 Virgin Expansive Soil

4.1.1 Specific Gravity

The specific gravity of the Virgin Expansive Soil was found out to be 2.61.

4.1.2 Free Swelling Index

The free swelling index of the soil was found out to be 33.33%.

4.1.3 Grain size distribution

Dry sieve analysis was done with sieves of sizes 4.75mm, 2mm, 1mm,0.6mm, 0.425mm,,0.3mm, 0.212mm, 0.15mm, 0.075mm, respectively.

After that sedimentation analysis was done with particles finer than 0.075 mm sieves. The hydrometer reading was taken at 12 time instances. The values obtained are plotted in the semi-log graph below. Where the y-axis represents the % finer and the x-axis represents particle size on a logarithmic scale The following data are obtained from the grain size distribution curve.

D60 = Soil particles finer than 60% of the total mass of the soil sample.
D60 = 0.416 mm
D30 = Soil particles finer than 30% of the total mass of the soil sample.
D30 = 0.197mm
D10 = Soil particles finer than 10% of the total mass of the soil sample.
D10 = 0.071mm
Cu= Coefficient of Uniformity = 5.86
Cc= Coefficient of Curvature = 1.314

4.1.4 Liquid Limit

The liquid limit of the Virgin Expansive Soil was found out to be 45.22%.

4.1.5 Plastic Limit

The plastic limit of the Virgin Expansive Soil was found out to be 27.17%.

4.1.6 Shrinkage Limit

The shrinkage limit of the Virgin Expansive Soil was found out to be 12.78%.

4.1.7 Standard Proctor Compaction Test

The maximum dry density was found out to be 1.78 g/cc. The optimum moisture content was found out to be 17.96%.

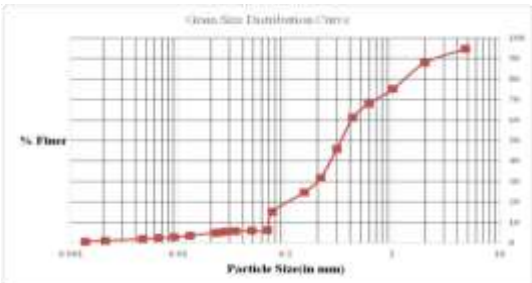

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Figure 3 Grain Size Distribution Curve

4.1.8 Unconfined Compressive Strength Test

The Unconfined Compressive Strength Test value of the Virgin Expansive Soil was found out to be:
7 DAY Unconfined Compressive Strength: 0.415 MPa.

4.2 Virgin Expansive Soil + 4% Bagasse Ash

4.2.1 Free Swelling Index

The free swelling index of the Virgin Expansive Soil + 4% Bagasse Ash was found out to be 26.67%.

4.2.2 Liquid Limit

The liquid limit of the Virgin Expansive Soil + 4% Bagasse Ash was found out to be 43.13%.

4.2.3 Plastic Limit

The plastic limit of the Virgin Expansive Soil + 4% Bagasse Ash was found out to be 27.85%.

4.2.4 Shrinkage Limit

The shrinkage limit of the Virgin Expansive Soil + 4% Bagasse Ash was found out to be 14.37%.

4.2.5 Standard Proctor Compaction Test

The maximum dry density was found out to be 1.73 g/cc. The optimum moisture content was found out to be 19.03%.

4.2.6 Unconfined Compressive Strength Test

The Unconfined Compressive Strength Test value of the Virgin Expansive Soil + 4% Bagasse Ash was found out to be:
7 DAY Unconfined Compressive Strength: 0.425 MPa.

4.3 Virgin Expansive Soil + 8% Bagasse Ash

4.3.1 Free Swelling Index

The free swelling index of the Virgin Expansive Soil + 8% Bagasse Ash was found out to be 30%.

4.3.2 Liquid Limit

The liquid limit of the Virgin Expansive Soil + 8% Bagasse Ash was found out to be 41.03%.

4.3.3 Plastic Limit

The plastic limit of the Virgin Expansive Soil + 8% Bagasse Ash was found out to be 28.61%.

4.3.4 Shrinkage Limit

The shrinkage limit of the Virgin Expansive Soil + 8% Bagasse Ash was found out to be 15.18%.

4.3.5 Standard Proctor Compaction Test

The maximum dry density was found out to be 1.63 g/cc. The optimum moisture content was found out to be 20.8%.

4.3.6 Unconfined Compressive Strength Test

The Unconfined Compressive Strength test value of the Virgin Expansive Soil + 8% Bagasse Ash was found out to be:
7 DAY Unconfined Compressive Strength: 0.461 MPa

4.4 Virgin Expansive Soil + 12% Bagasse Ash

4.4.1 Free Swelling Index

The free swelling index of the Virgin Expansive Soil + 12% Bagasse Ash was found out to be 30%.

4.4.2 Liquid Limit

The liquid limit of the Virgin Expansive Soil + 12% Bagasse Ash was found out to be 42.03%.

4.4.3 Plastic Limit

The plastic limit of the Virgin Expansive Soil + 12% Bagasse Ash was found out to be 28.97%.

4.4.4 Shrinkage Limit

The shrinkage limit of the Virgin Expansive Soil + 12% Bagasse Ash was found out to be 16.41%.

4.4.5 Standard Proctor Compaction Test

The maximum dry density was found out to be 1.57 g/cc. The optimum moisture content was found out to be 22.51%.

4.4.6 Unconfined Compressive Strength Test

The Unconfined Compressive Strength Test value of the Virgin Expansive Soil + 12% Bagasse Ash was found out to be: 7 DAY Unconfined Compressive Strength: 0.388 MPa

4.5 Virgin Expansive Soil + 16% Bagasse Ash

4.5.1 Free Swelling Index

The free swelling index of the Virgin Expansive Soil + 16% Bagasse Ash was found out to be 33.33%.

4.5.2 Liquid Limit

The liquid limit of the Virgin Expansive Soil + 16% Bagasse Ash was found out to be 41.65%.

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4.5.3 Plastic Limit
The plastic limit of the Virgin Expansive Soil + 16% Bagasse Ash was found out to be 29.55%.

4.5.4 Shrinkage Limit
The shrinkage limit of the Virgin Expansive Soil + 16% Bagasse Ash was found out to be 13.38%.

4.5.5 Standard Proctor Compaction Test
The maximum dry density was found out to be 1.53g/cc. The optimum moisture content was found out to be 26.02%.

4.5.6 Unconfined Compressive Strength Test
The Unconfined Compressive Strength Test value of the Virgin Expansive Soil + 16% Bagasse Ash was found out to be: 7 DAY Unconfined Compressive Strength: 0.329 MPa

5.1 Comparison and Discussion

5.1 COMPARISON

5.1.1 Comparison of Liquid Limit Values

The liquid limit of the Virgin Expansive Soil is determined. The Virgin Expansive Soil is mixed with 4%, 8%, 12%, and 16% of Bagasse Ash respectively. The liquid limit values of these mixes are determined and the values are compared in the table given below.

Table 5.1 Effect of Bagasse Ash on Liquid Limit Value

% OF BAGASSE ASH	LIQUID LIMIT (%)
0	45.22
4	43.13
8	41.03
12	42.03
16	41.65

The graph of the above table is plotted next. Where the x-axis represents the percentages of Bagasse Ash added to the virgin soil and the y-axis represents the liquid limit values of the respective mixes.

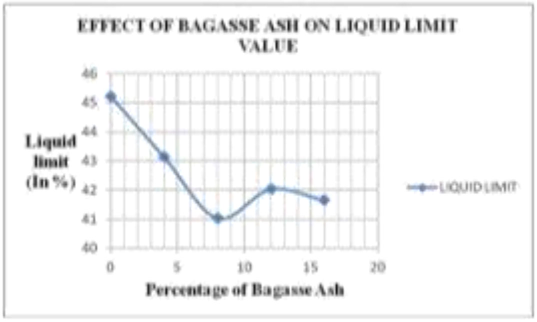

Figure 5.1 Effect Of Bagasse Ash On Liquid Limit Value

5.1.2 Comparison of Plastic Limit Values

The plastic limit of the Virgin Expansive Soil is determined. The Virgin Expansive Soil is mixed with 4%, 8%, 12%, and 16% of Bagasse Ash respectively. The plastic limit values of these mixes are determined and the values are compared in the table given below.

Table 5.2 Effect Of Bagasse Ash On Plastic Limit Value

% OF BAGASSE ASH	PLASTIC LIMIT (%)
0	27.17
4	27.85
8	28.61
12	28.97
16	29.55

The graph of the above table is plotted below. Where the x-axis represents the percentages of Bagasse Ash added to the virgin soil and the y-axis represents the plastic limit values of the respective mixes.

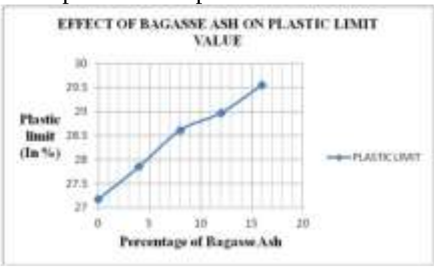

Figure 5.2 Effect of Bagasse Ash On Plastic Limit Value

5.1.3 Comparison of Shrinkage Limit Values

The plastic limit of the Virgin Expansive Soil is determined. The Virgin Expansive Soil is mixed with 4%, 8%, 12%, and 16% of Bagasse Ash respectively. The plastic limit values of these mixes are determined and the values are compared in the table given next.

Table 5.3 Effect Of Bagasse Ash On Shrinkage Limit Value

% OF BAGASSE ASH	SHRINKAGE LIMIT (%)
0	12.78
4	14.37
8	15.18
12	16.41
16	13.38

The graph of the above table is plotted below. Where the x-axis represents the percentages of Bagasse Ash added to the virgin soil and the y-axis represents the shrinkage limit values of the respective mixes.

Figure 5.3 Effect Of Bagasse Ash On Shrinkage Limit Value

5.2 Discussion

- The Free Swell index of the soil is found to be decreasing up to the addition of 4% Bagasse Ash and is equal to the soil mix consisting of soil and 8% Bagasse Ash. The value increases at the addition of 12% Bagasse Ash, yet is less than that of virgin soil and the value increases at the addition of 16% Bagasse Ash and becomes equal to Free Swell Index of the Virgin Expansive Soil.
- The liquid limit value decreases up to 8% addition of Bagasse Ash and increases up to 16% addition of Bagasse Ash. The liquid limit values at 12% and 16% addition of Bagasse Ash are less than that of Virgin Expansive Soil.
- The plastic limit value increases up to 16% replacement of Bagasse Ash.
- The shrinkage limit value increases up to 12% replacement of Bagasse and decreases at 16% replacement of Bagasse Ash.
- The plasticity index decreases up to 8%, increases at 12% and decrease at 16% replacement of Bagasse Ash.
- The MDD decreases constantly up to 16% replacement of Bagasse Ash.
- The OMC decreases constantly up to 16% replacement of Bagasse Ash.
- The MBD decreases constantly up to 12% replacement of Bagasse Ash and increases slightly at 16% replacement of Bagasse Ash.
- The 7 Day UCS value increases up to 8% replacement of Bagasse Ash and decreases up to 16% replacements of Bagasse Ash.

6.0 Conclusion

The addition of Bagasse Ash with Expansive Soil at various replacements, namely, 4%, 8%, 12% and 16% was studied for various changes in properties like, Atterberg limits, plasticity index and UCS values.

On the basis of the present study, the following conclusions were drawn.

- The addition of Bagasse Ash with the expansive soil reduced its plasticity and the minimum plasticity index was obtained at a replacement of 16% Bagasse Ash.
- The minimum liquid limit value was obtained at a replacement of 8% Bagasse Ash.
- The maximum plastic limit value was obtained at a replacement of 16% Bagasse Ash.
- The MDD value decreases with the addition of Bagasse Ash as replacement.
- The OMC value increases with the addition of Bagasse Ash as replacement.
- The UCS value was found to be increasing up to 8% replacement of Bagasse ash and was found to be decreasing after that.

On a broader sense of view, if the Bagasse Ash is used on expansive soils as a replacement; it can solve the various geo-environmental problems rising due to its deposition and can also save the valuable space of the sugar industry and the expansive soil can also be suitably modified.

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